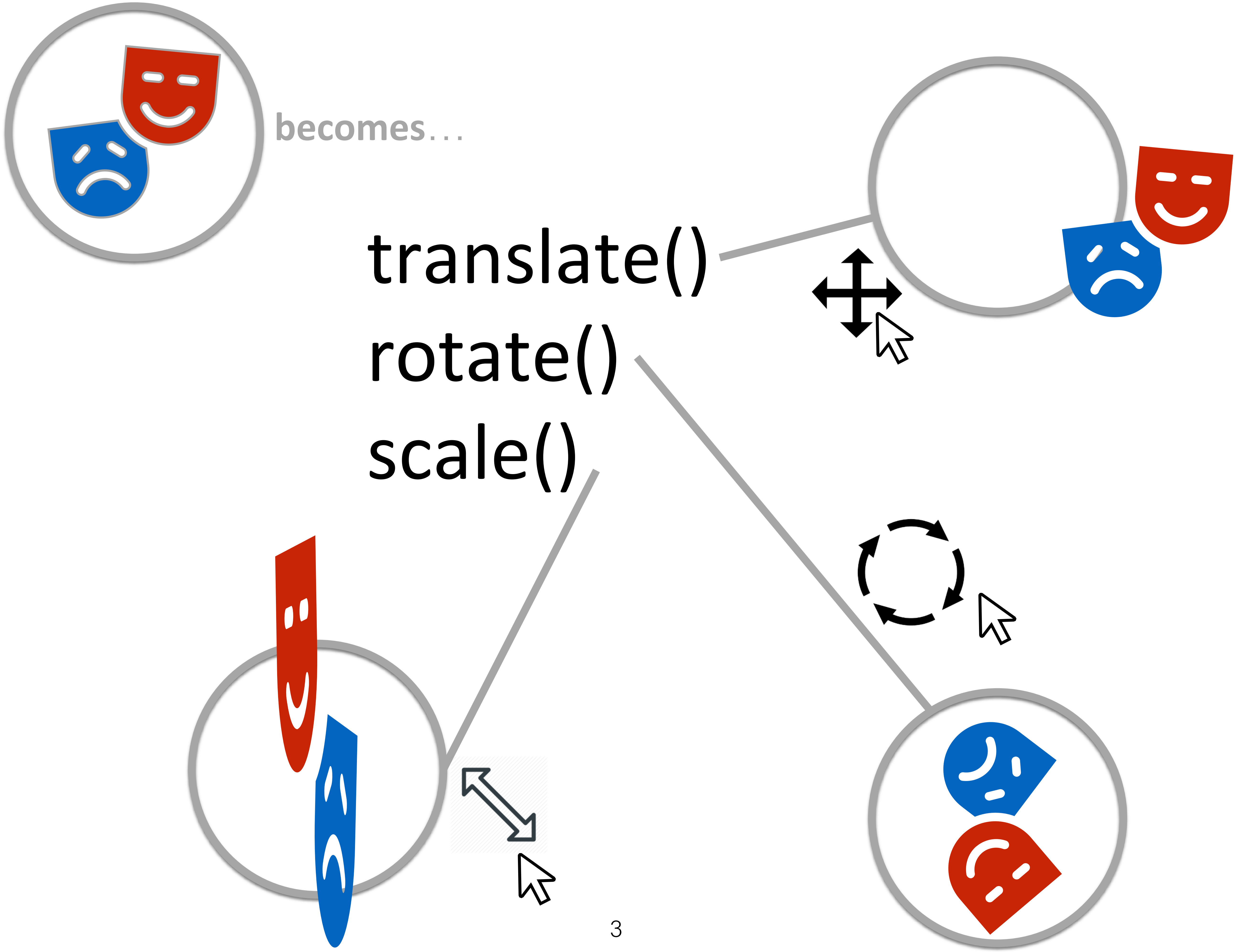
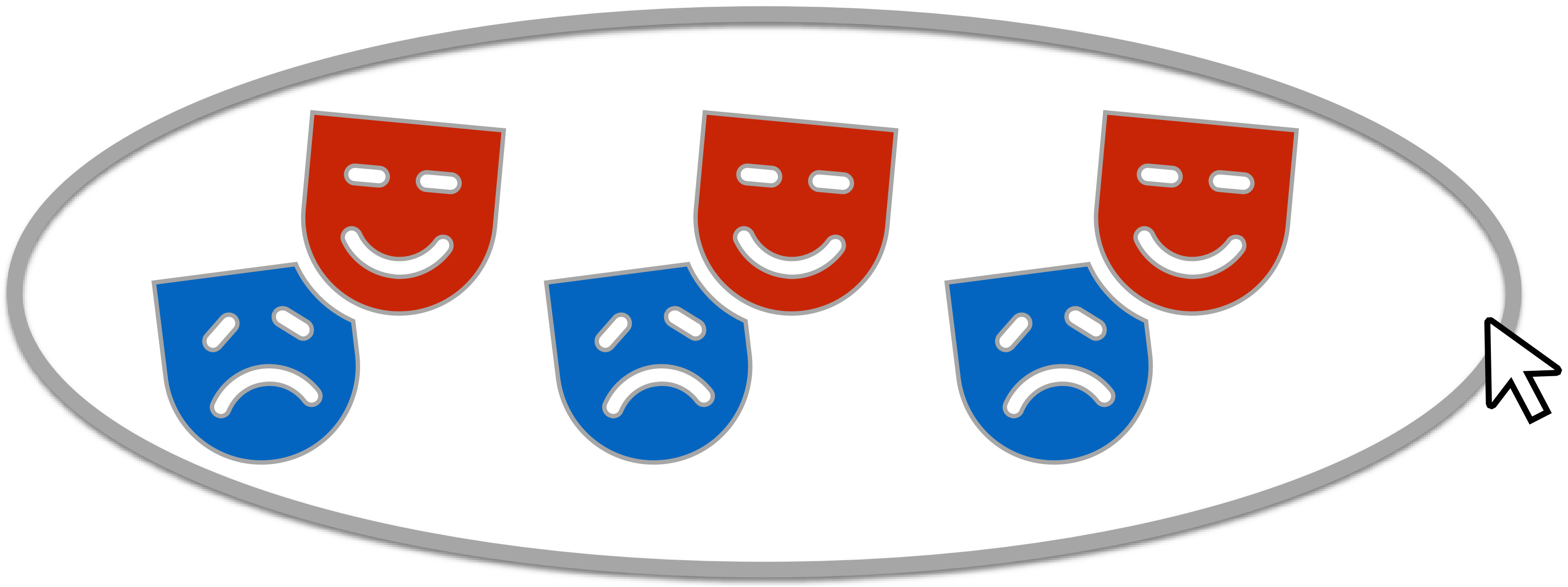
Geometric Context

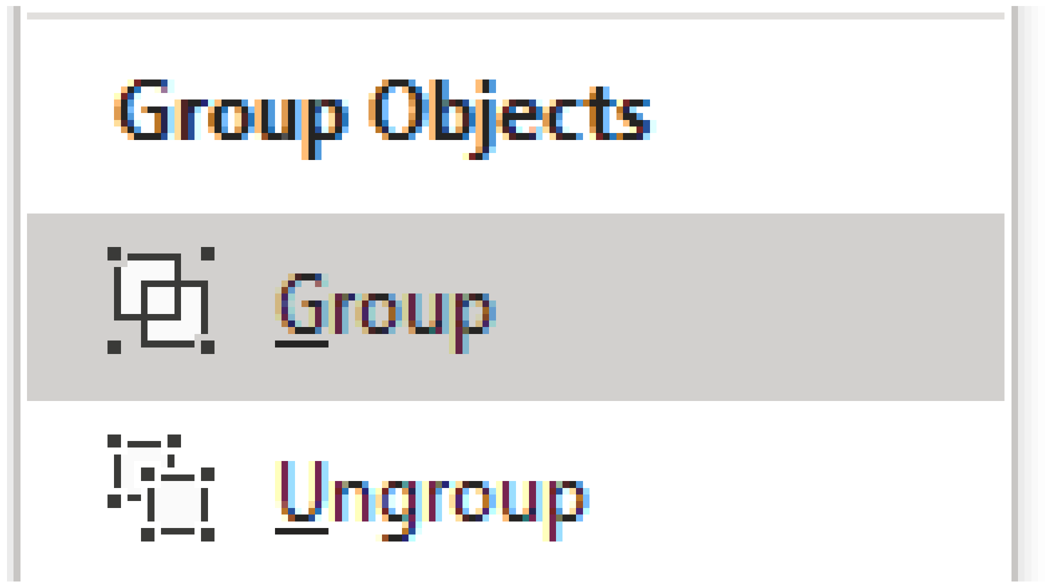
CS 106 Winter 2021

```
translate()
rotate()
scale()

push()
pop()
```



translate()
rotate()
scale()





`push()` → Checkpoint

`pop()` → Restore

Each is simple/familiar enough

```
translate()
rotate()
scale()

push()
&
pop()
```

but...

get them in the right order

Tricky order

```
{
    [illegible]
}
```

Person with a drawing tool:

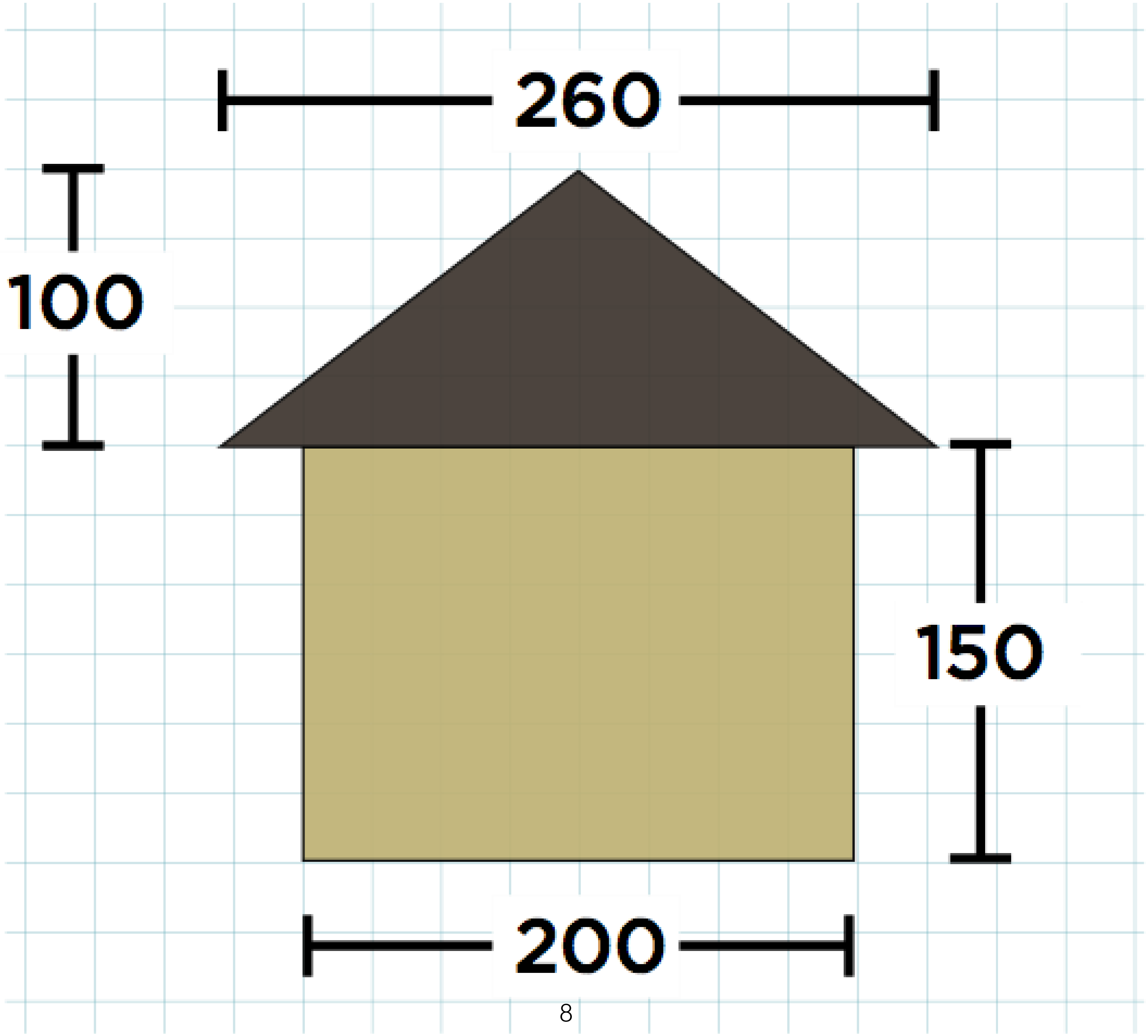
1. Draw it. Who cares where.
2. See it there.
3. Move it where it goes.
4. See it there.

Code in a drawing context:

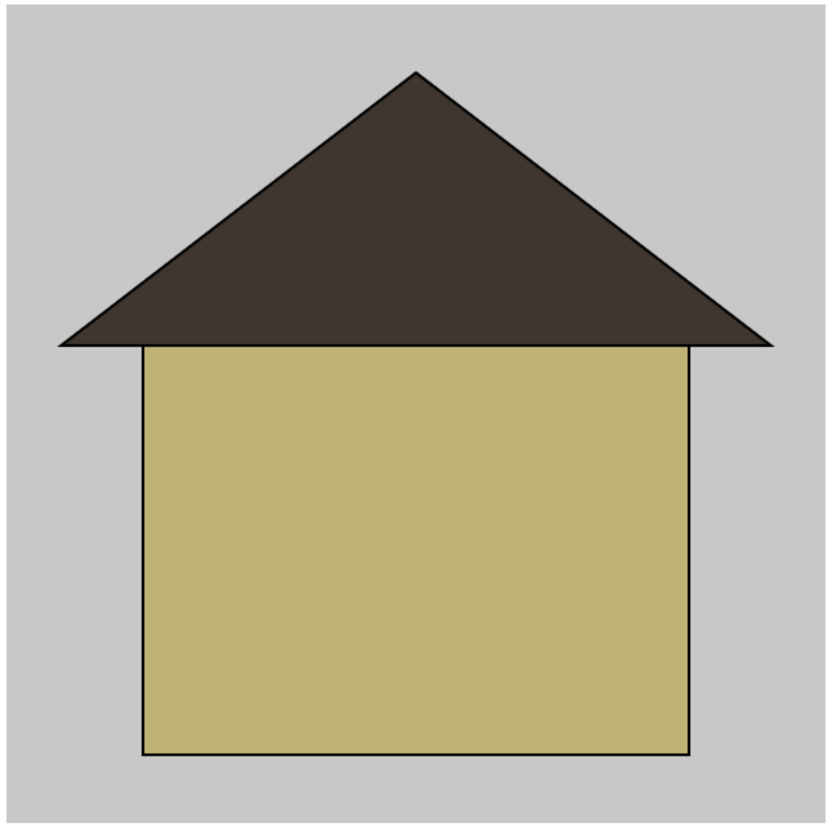
1. Move the context.
2. Draw. (No peeking.)
3. Leave the context.
4. See what you drew.

Understanding Context

with *translate*


260
100
150
200

```
function setup() {

   createCanvas(300, 300);

   background(200);



   fill(191, 179, 117);

   rect(50, 125, 200, 150);

   fill(62, 54, 47);

   triangle(150, 25, 20, 125, 280, 125);

}
```

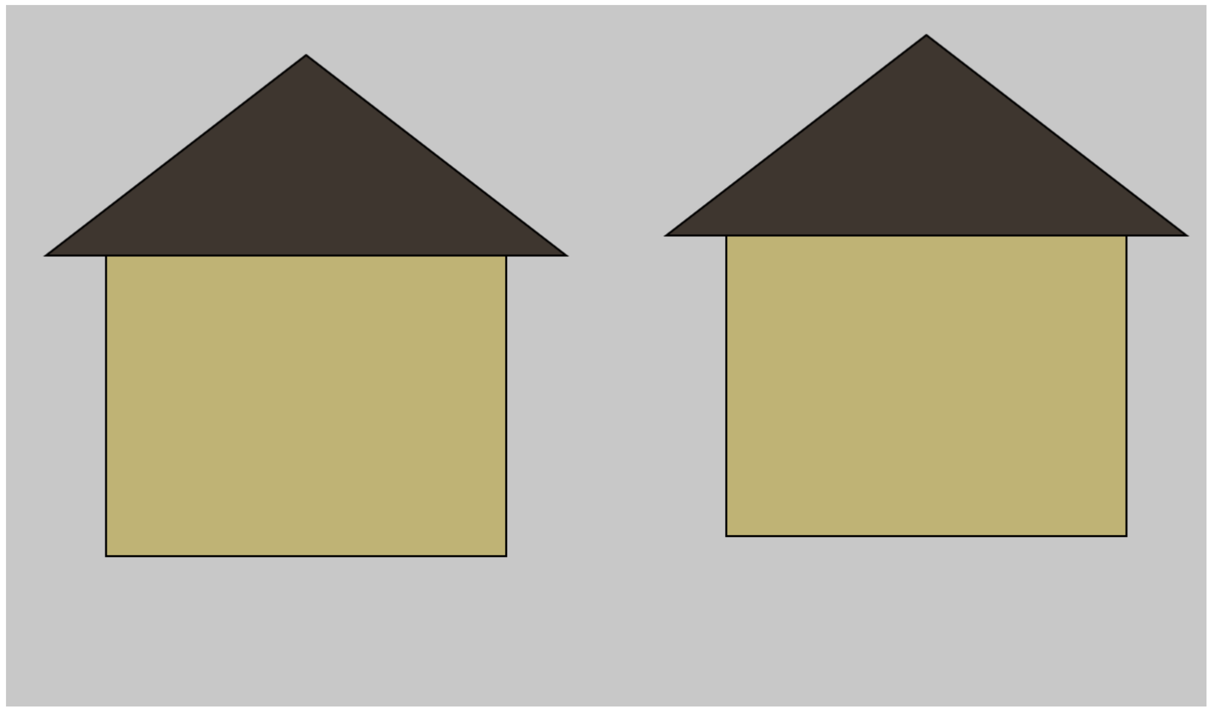


https://openprocessing.org/sketch/1144052

Error Prone to Move 10 Pixels to the Right

```
function setup() {
  createCanvas(300, 300);
  background(200);

  fill(191, 179, 117);
  rect(60, 125, 200, 150);
  fill(62, 54, 47);
  triangle(160, 25, 30, 125, 290, 125);
}
```

Two Houses



```
function setup() {
  createCanvas(600, 350);
  background(200);

  fill(191, 179, 117);
  rect(50, 125, 200, 150);
  fill(62, 54, 47);
  triangle(150, 25, 20, 125, 280, 125);

  fill(191, 179, 117);
  rect(360, 115, 200, 150);
  fill(62, 54, 47);
  triangle(460, 15, 330, 115, 590, 115);
}
```

https://openprocessing.org/sketch/1144057

Less Error Prone

```
function drawHouseAt(x, y) {
  [illegible]
}

function setup() {
  createCanvas(600, 350);
  background(200);

  drawHouseAt(0, 0);
  drawHouseAt(310, -10);
}
```

Less Error Prone

```
function drawHouseAt(x, y) {
   fill(191, 179, 117);
   rect(50 + x, 125 + y, 200, 150);
   fill(62, 54, 47);
   triangle(150 + x, 25 + y, 20 + x,
      125 + y, 280 + x, 125 + y);
}

function setup() {
   createCanvas(600, 350);
   background(255);

   drawHouseAt(0, 0);
   drawHouseAt(310, -10);
}
```

https://openprocessing.org/sketch/1144066

Not Covering This Slide in W21

```
let global_x = 0.0;
let global_y = 0.0;

function myRect(x, y, w, h) {
	rect(x + global_x, y + global_y, w, h);
}

function myTriangle(ax, ay, bx, by, cx, cy) {
	triangle(ax + global_x, ay + global_y,
		bx + global_x, by + global_y,
		cx + global_x, cy + global_y);
}
```

Not Covering This Slide in W21

```
function drawHouse() {
  fill(191, 179, 117);
  myRect(50, 125, 200, 150);
  fill(62, 54, 47);
  myTriangle(150, 25, 20, 125, 280, 125);
}

function setup() {
  createCanvas(600, 350);
  background(255);

  global_x = 0;
  global_y = 0;
  drawHouse();

  global_x = 310;
  global_y = -10;
  drawHouse();
}
```

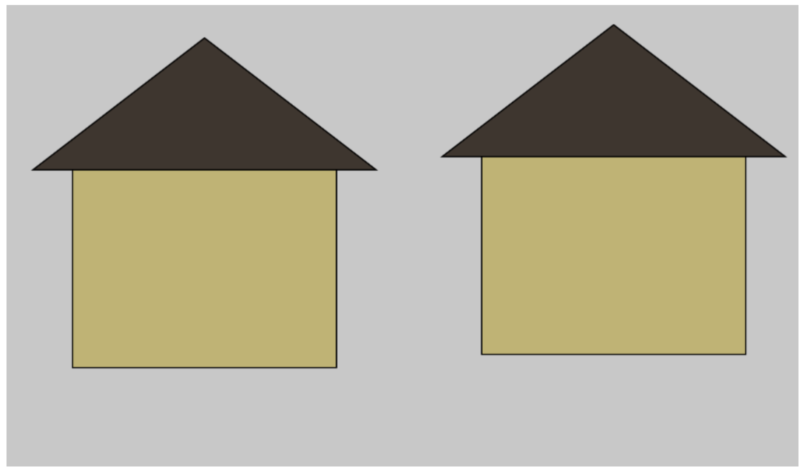
Not Covering This Slide in W21

```
function myTranslate(x, y) {
  global_x += x;
  global_y += y;
}

function setup() {
  createCanvas(600, 350);
  background(255);

  myTranslate(0, 0);
  drawHouse();

  myTranslate(310, -10);
  drawHouse();
}
```

The built-in functions translate(), rect() and triangle() already do the work of our myTranslate(), myRect() and myTriangle().

The global amount of translation is the “geometric context”.

translate()

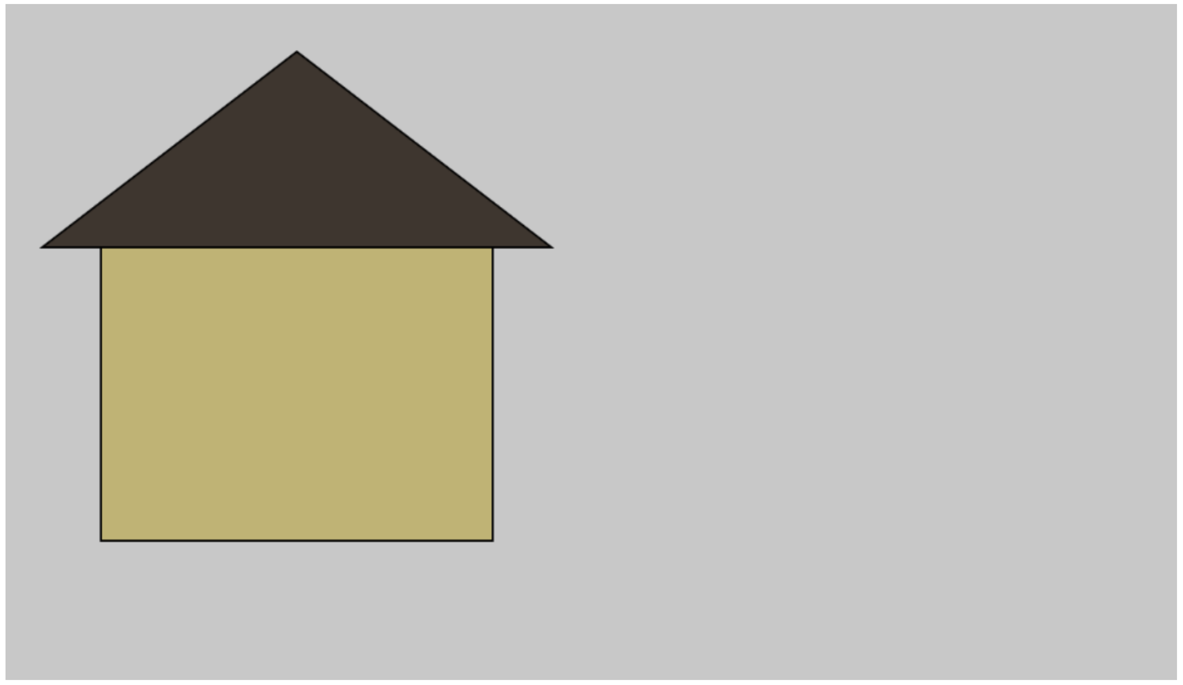


```
function drawHouse() {
   fill(191, 179, 117);
   rect(50, 125, 200, 150);
   fill(62, 54, 47);
   triangle(150, 25, 20, 125, 280, 125);
}

function setup() {
   createCanvas(600, 350);
   background(200);

   drawHouse();

   translate(310, -10);
   drawHouse();
}
```

https://openprocessing.org/sketch/1144085

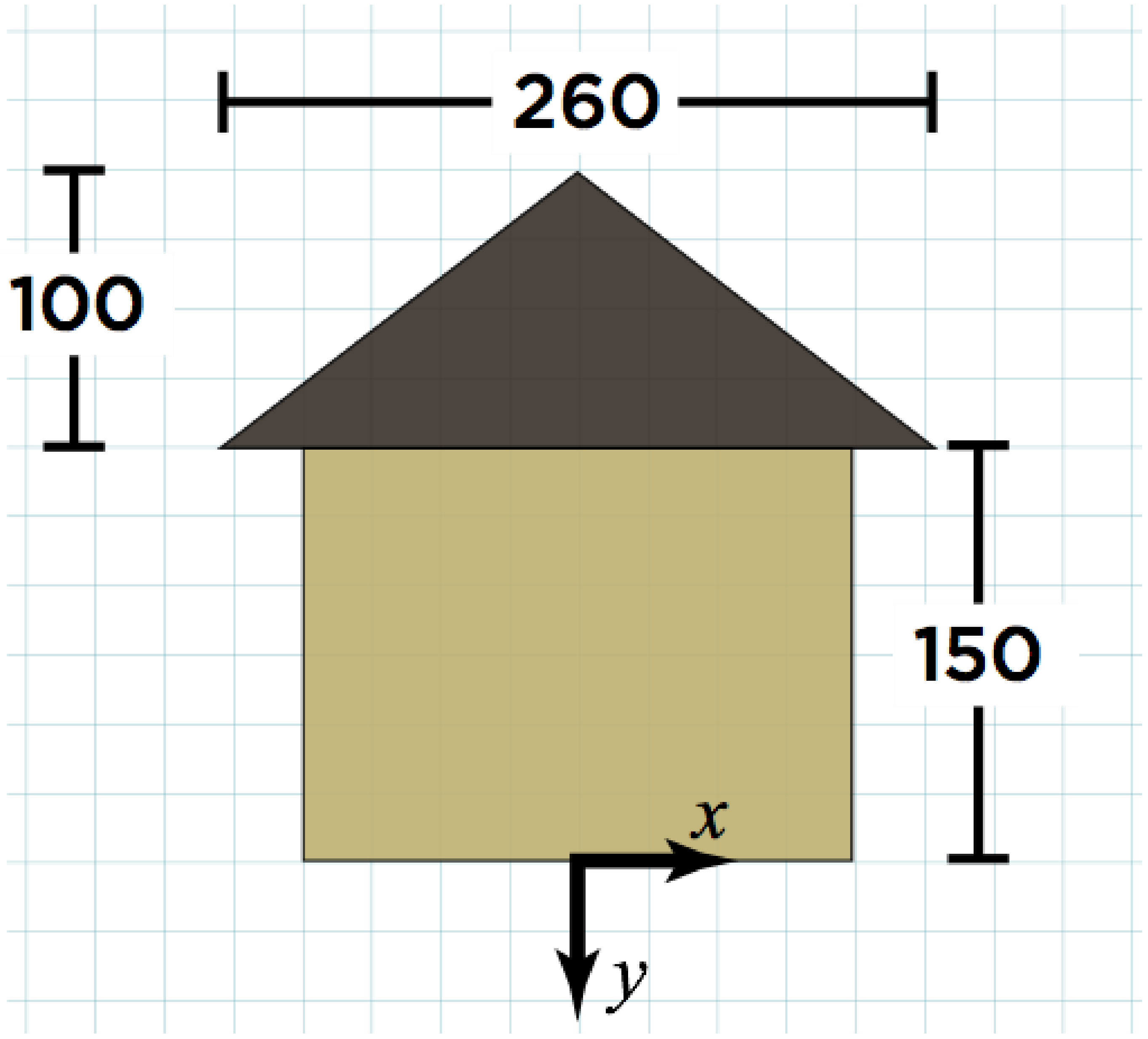
Translate to mouseX and mouseY

```
function drawHouse() {
   fill(191, 179, 117);
   rect(50, 125, 200, 150);
   fill(62, 54, 47);
   triangle(150, 25, 20, 125, 280, 125);
}

function setup() {
   createCanvas(600, 350);
}

function draw() {
   background(200);
   translate(mouseX, mouseY);
   drawHouse();
}
```



https://openprocessing.org/sketch/1144123

Geometric context allows us to draw any object in its “native coordinate system”.



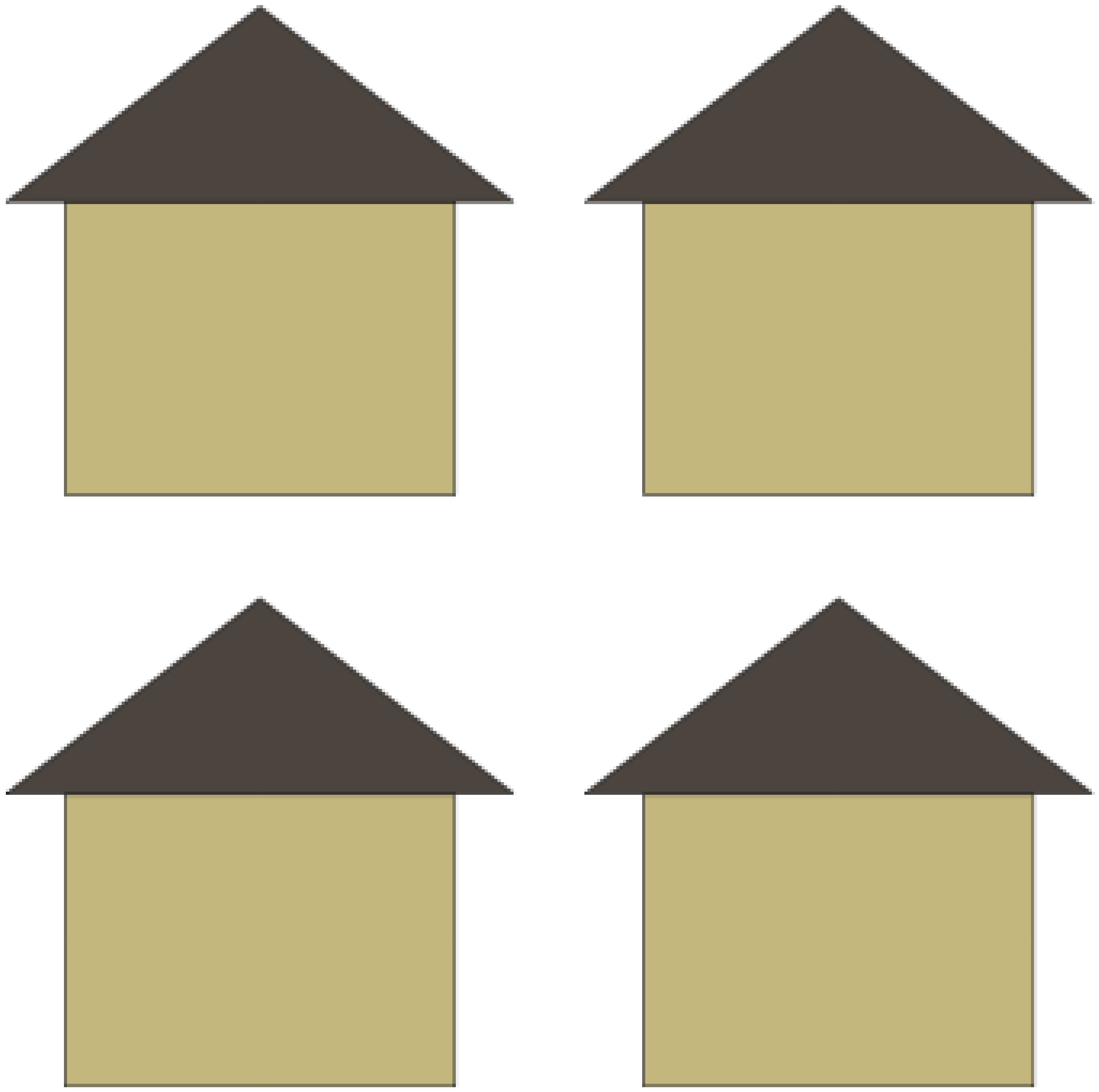
```
function setup() {
   createCanvas(300, 400);
   background(200);
}

function draw() {
   background(200);
   translate(mouseX, mouseY);
   drawHouse();
}

function drawHouse() {
   fill(191, 179, 117);
   rect(-100, -150, 200, 150);
   fill(62, 54, 47);
   triangle(-130, -150, 0, -250, 130, -150);
}
```

https://openprocessing.org/sketch/1144135

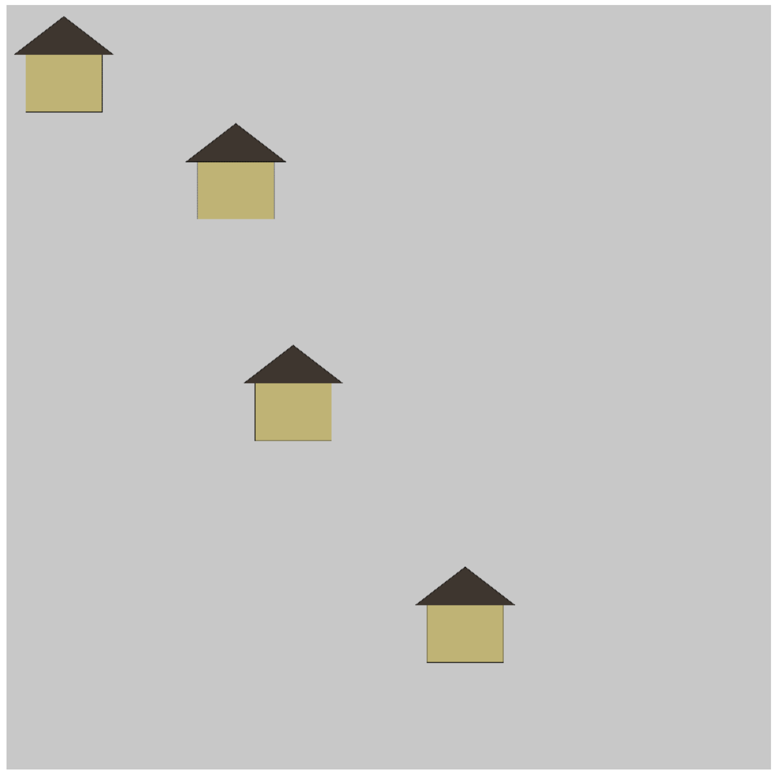
Context Accumulates

so we

take control with *push* and *pop*



```
function setup() {
   createCanvas(2000, 2000);
}

function draw() {
  background(200);
  translate(150, 280);
  drawHouse();
  translate(450, 280);
  drawHouse();
  translate(150, 580);
  drawHouse();
  translate(450, 580);
  drawHouse();
}

function drawHouse() {
   fill(191, 179, 117);
   rect(-100, -150, 200, 150);
   fill(62, 54, 47);
   triangle(-130, -150, 0, -250, 130, -150);
}
```

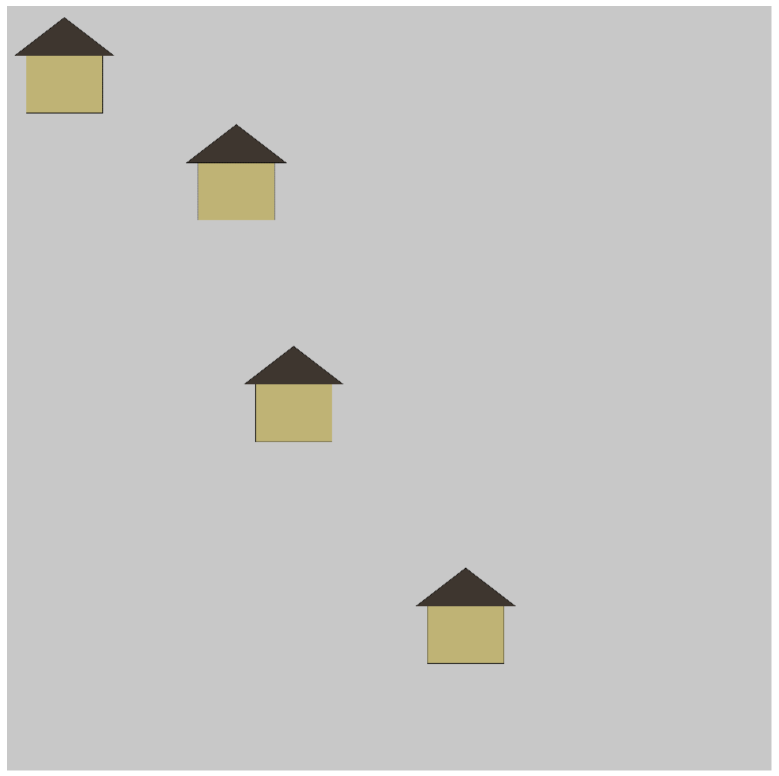


This doesn't work, because transformations *accumulate*.

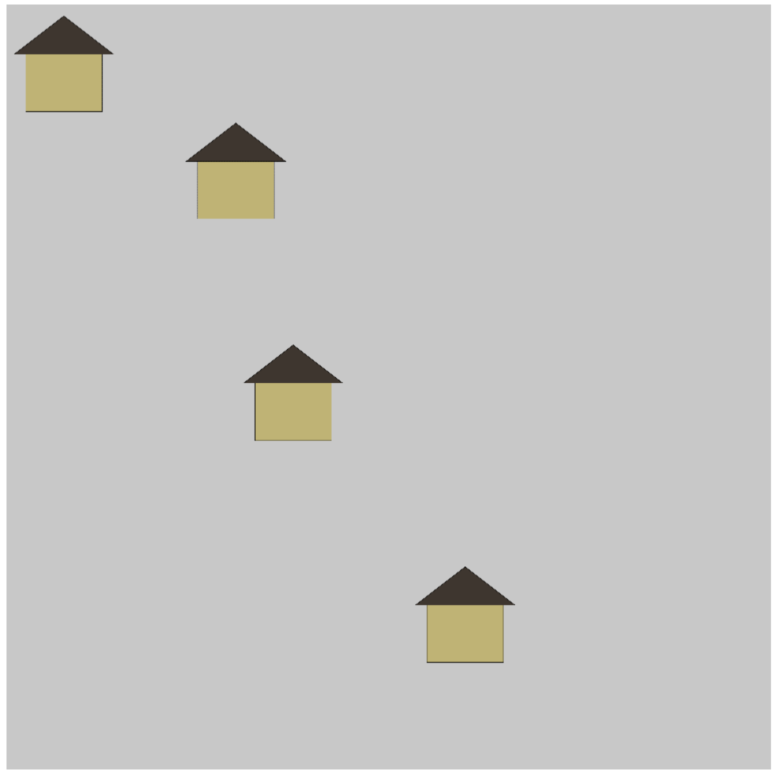
Initial context: translate by 0, 0

```
function draw() {
  background(255);

  translate(150, 280);
  drawHouse();
  translate(450, 280);
  drawHouse();
  translate(150, 580);
  drawHouse();
  translate(450, 580);
  drawHouse();
}
```

```
function draw() {
  background(255);

  translate(150, 280);
  drawHouse();
  translate(450, 280);
  drawHouse();
  translate(150, 580);
  drawHouse();
  translate(450, 580);
  drawHouse();
}
```



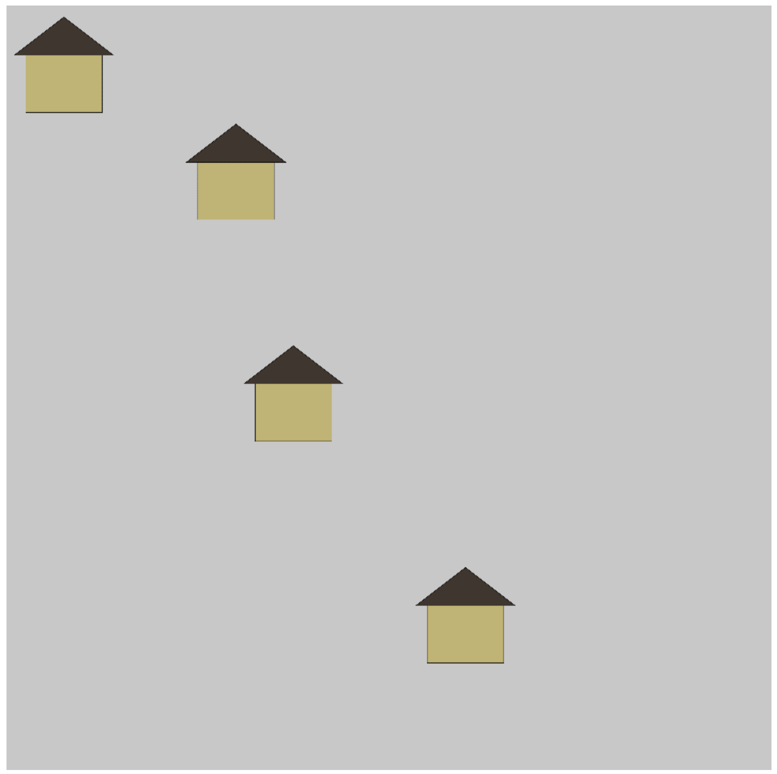
Translated by 150, 280



```
function draw() {
  background(255);

  translate(150, 280);
  drawHouse();
  translate(450, 280);
  drawHouse();
  translate(150, 580);
  drawHouse();
  translate(450, 580);
  drawHouse();
}
```

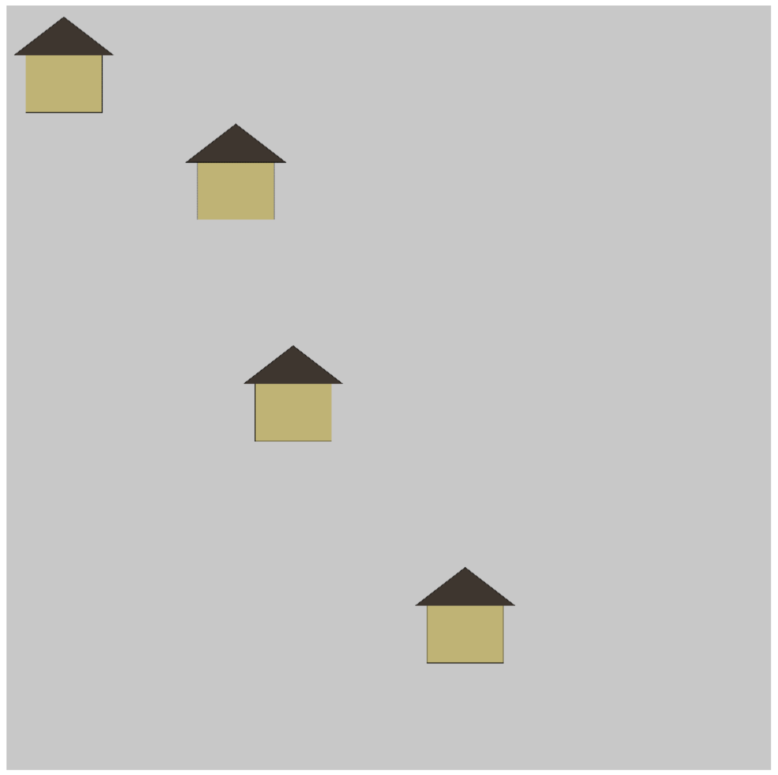
Translated by 150 + 450, 280 + 280

```
   translate( 150, 280 );
   drawHouse();
   translate( 450, 280 );
   drawHouse();
   translate( 150, 580 );
   drawHouse();
   translate( 450, 580 );
   drawHouse();
}
```



Translated by
150 + 450 + 150,
280 + 280 + 580

```
  translate( 150, 280 );
  drawHouse();
  translate( 450, 280 );
  drawHouse();
  translate( 150, 580 );
  drawHouse();
  translate( 450, 580 );
  drawHouse();
}
```



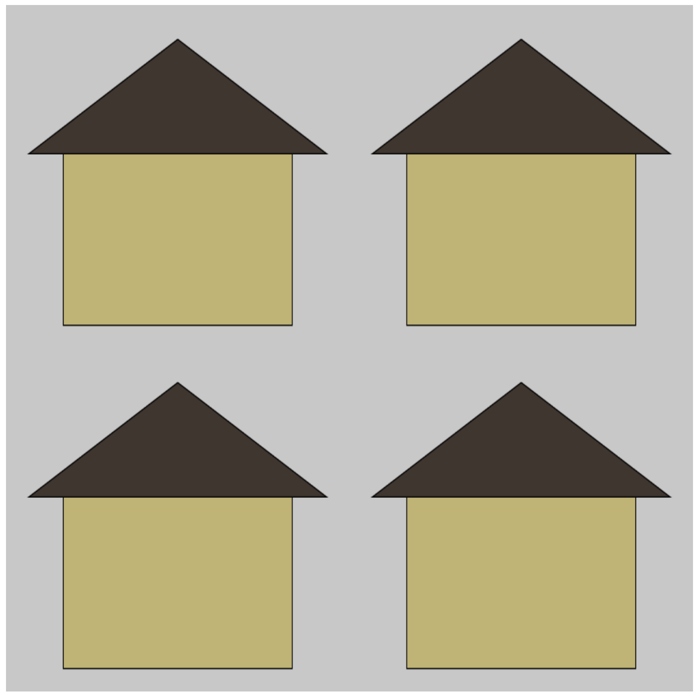
Translated by
150 + 450 + 150 + 450,
280 + 280 + 580 + 580

push(): Set a “checkpoint”, remembering the current geometric context.

pop(): Go back to the context that was saved, before the last push that hadn’t been popped yet

```
function setup() {
   createCanvas(600, 600);
}

function draw() {
  background(200);

  push();
  translate(150, 280);
  drawHouse();
  pop();

  push();
  translate(450, 280);
  drawHouse();
  pop();

  push();
  translate(150, 580);
  drawHouse();
  pop();

  push();
  translate(450, 580);
  drawHouse();
  pop();
}
```

```
function drawHouse() {
   fill(191, 179, 117);
   rect(-100, -150, 200, 150);
   fill(62, 54, 47);
   triangle(-130, -150, 0, -250, 130, -150);
}
```

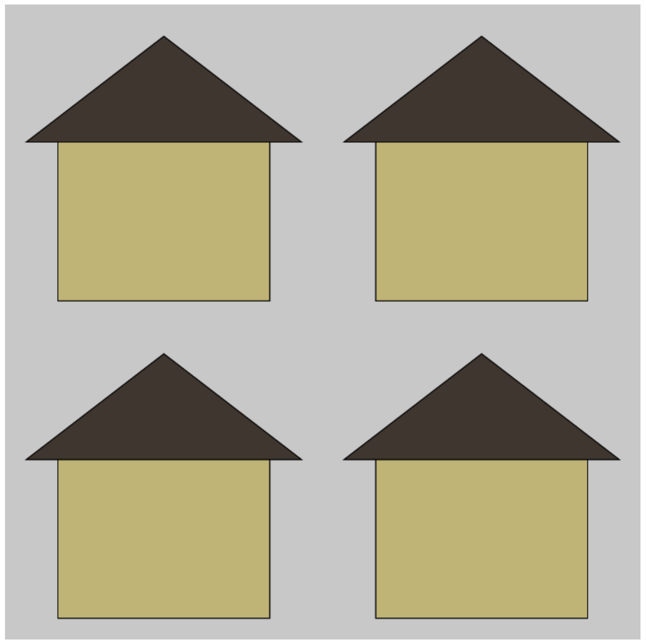


Draw each house within a temporary context, then throw that context away.

https://openprocessing.org/sketch/1145779

Could Put Two Translates in one Push/Pop: (Not encouraged for beginners)

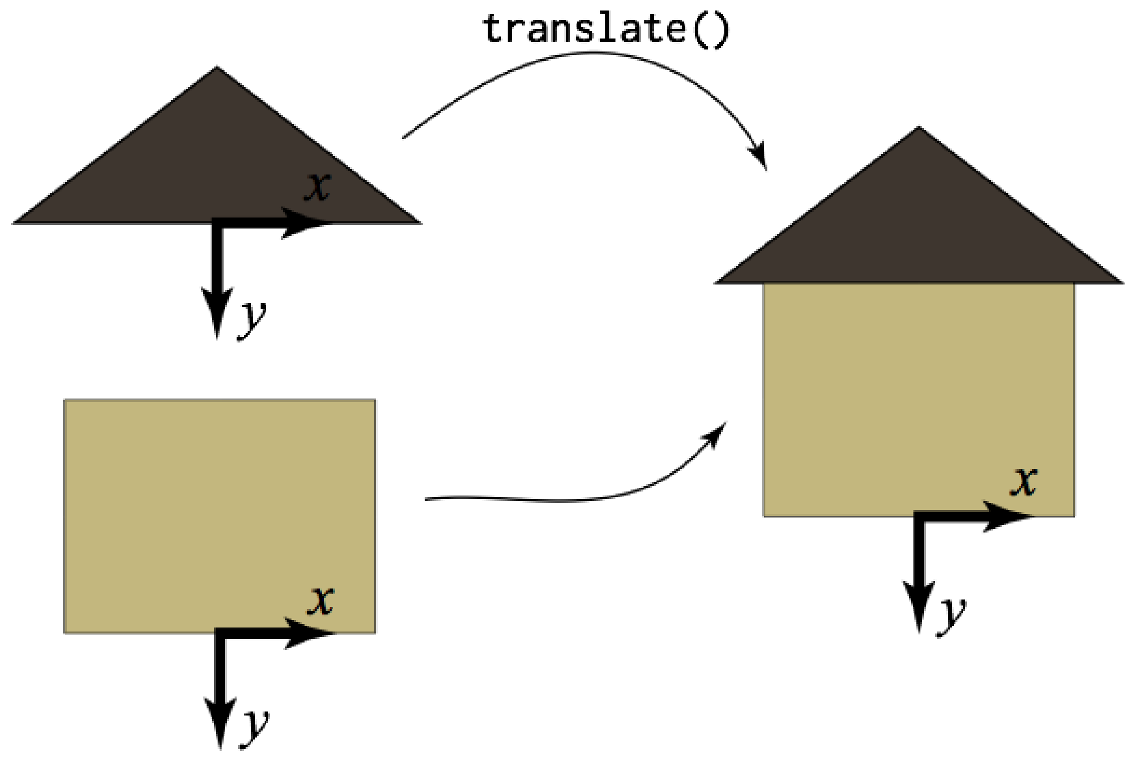
```
function draw() {
   background(200);

   push();
   translate(150, 280);
   drawHouse();
   translate(300, 0);
   drawHouse();
   pop();

   push();
   translate(150, 580);
   drawHouse();
   translate(300, 0);
   drawHouse();
   pop();
}
```



https://openprocessing.org/sketch/1145797

Add a translate() within drawHouse()

```
function setup() {
   createCanvas(600, 600);
}

function draw() {
  background(200);

  push();
  translate(150, 280);
  drawHouse();
  pop();

  push();
  translate(450, 280);
  drawHouse();
  pop();

  push();
  translate(150, 580);
  drawHouse();
  pop();

  push();
  translate(450, 580);
  drawHouse();
  pop();
}
```

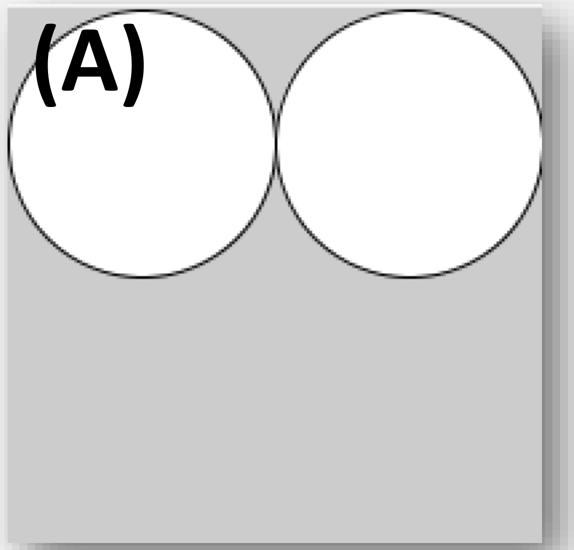


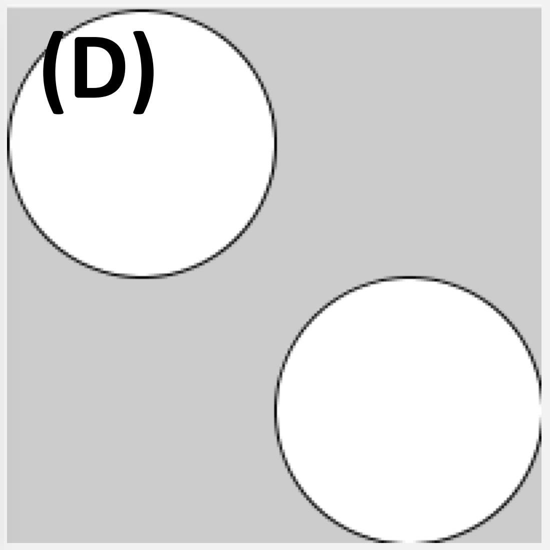
```
function drawHouse() {
   fill(191, 179, 117);
   rect(-100, -150, 200, 150);
   fill(62, 54, 47);

   push();
   translate(0, -150);
   triangle(-130, 0, 0, -100, 130, 0);
   pop();
}
```

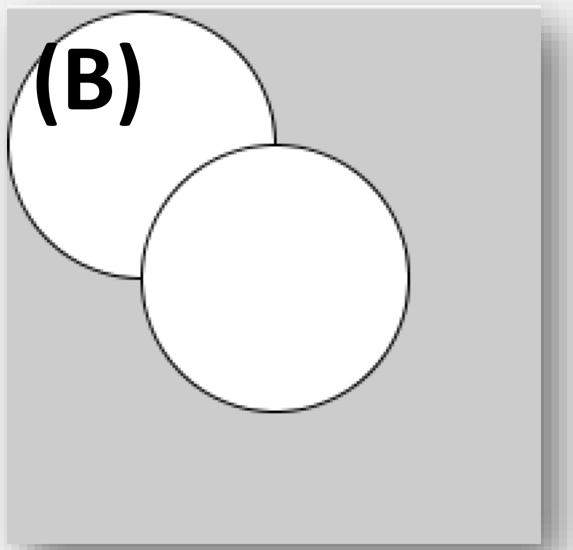
https://openprocessing.org/sketch/1145810

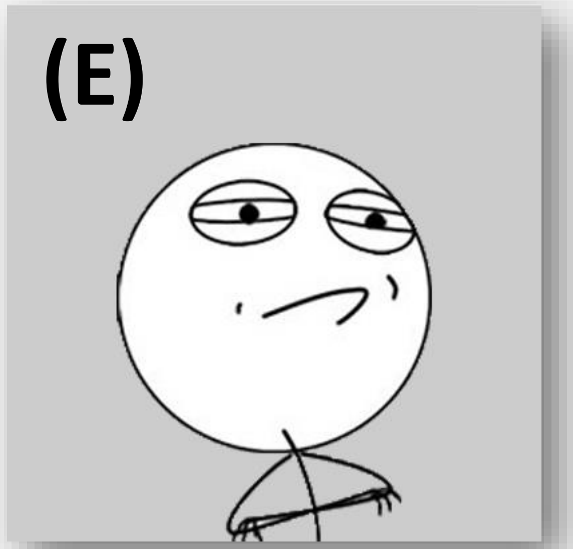
What will the following code draw?

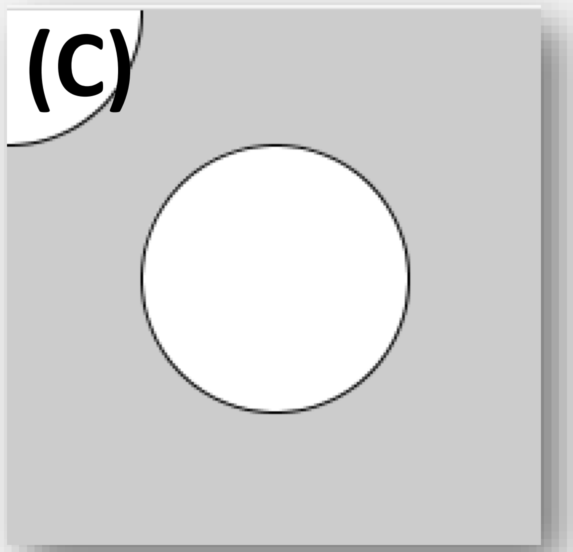
```
function setup() {
  createCanvas(200, 200);
   background(200);

  translate(50, 50);
  ellipse(0, 0, 100, 100);
  translate(100, 100);
  ellipse(0, 0, 100, 100);
}
```

(A)


(D)


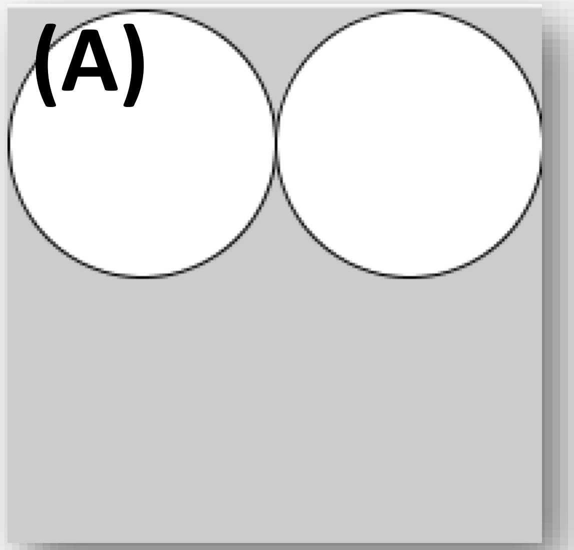
(B)


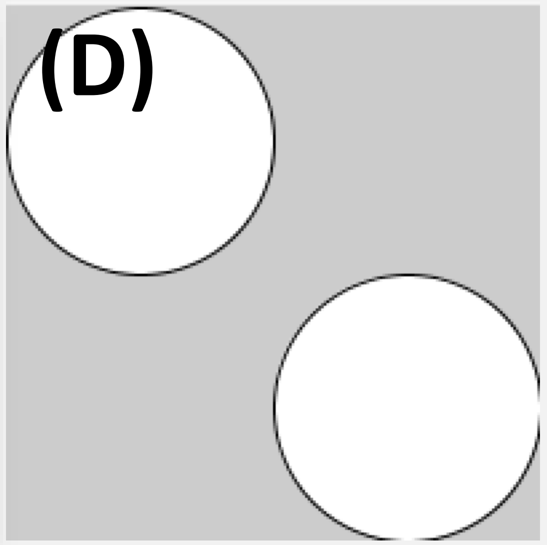
(E)


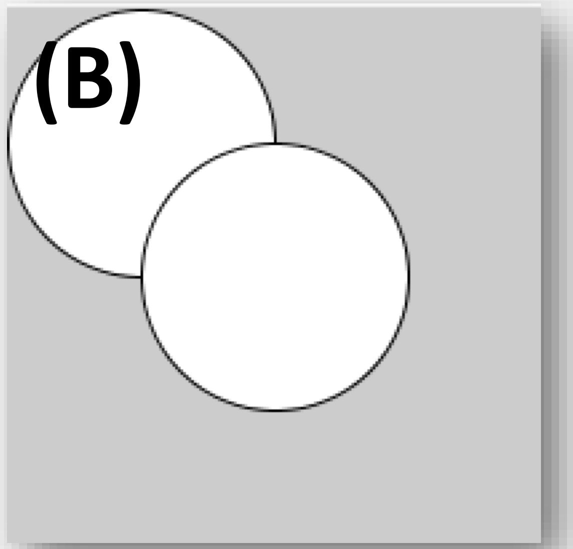
(C)


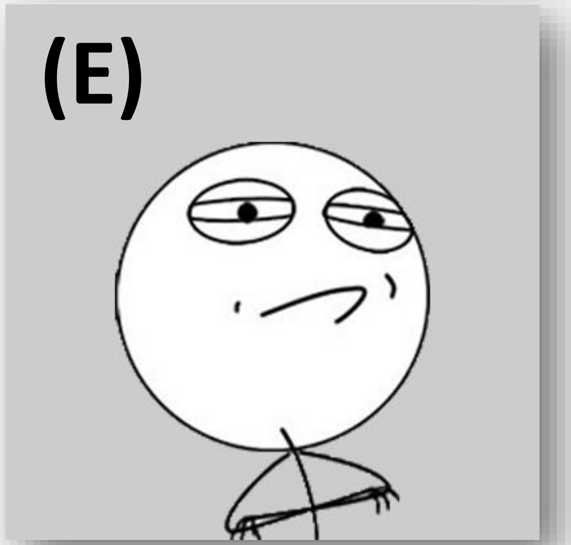
What will the following code draw?

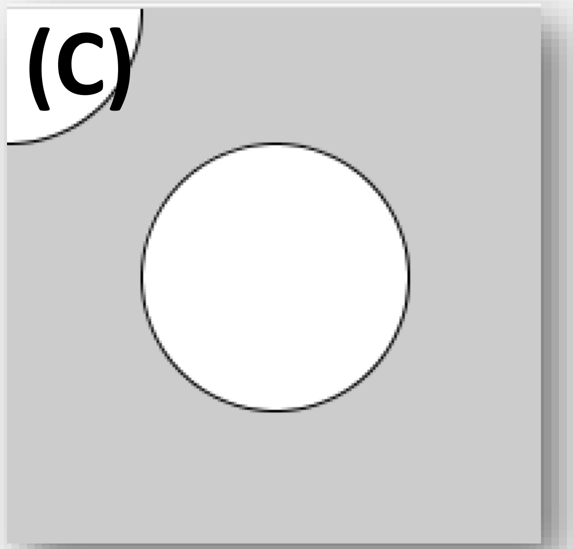
```
function setup() {
   createCanvas(200, 200);
   background(200);

   push();
   translate(50, 50);
   ellipse(0, 0, 100, 100);
   pop();

   translate(100, 100);
   ellipse(0, 0, 100, 100);
```











When order matters

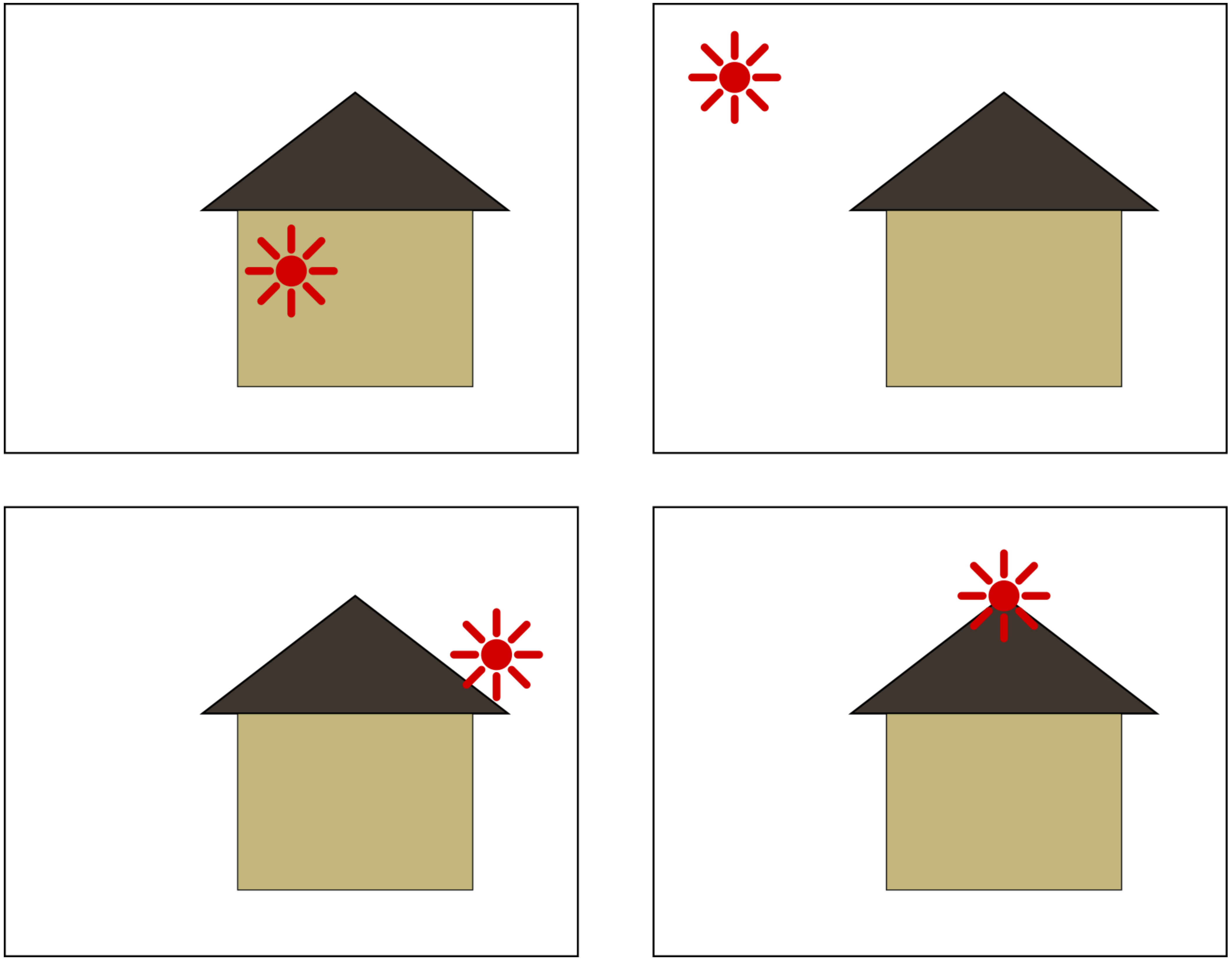
Getting *rotate* and *scale* right

rotate(theta): Rotate the current geometric context by some angle theta (in radians).

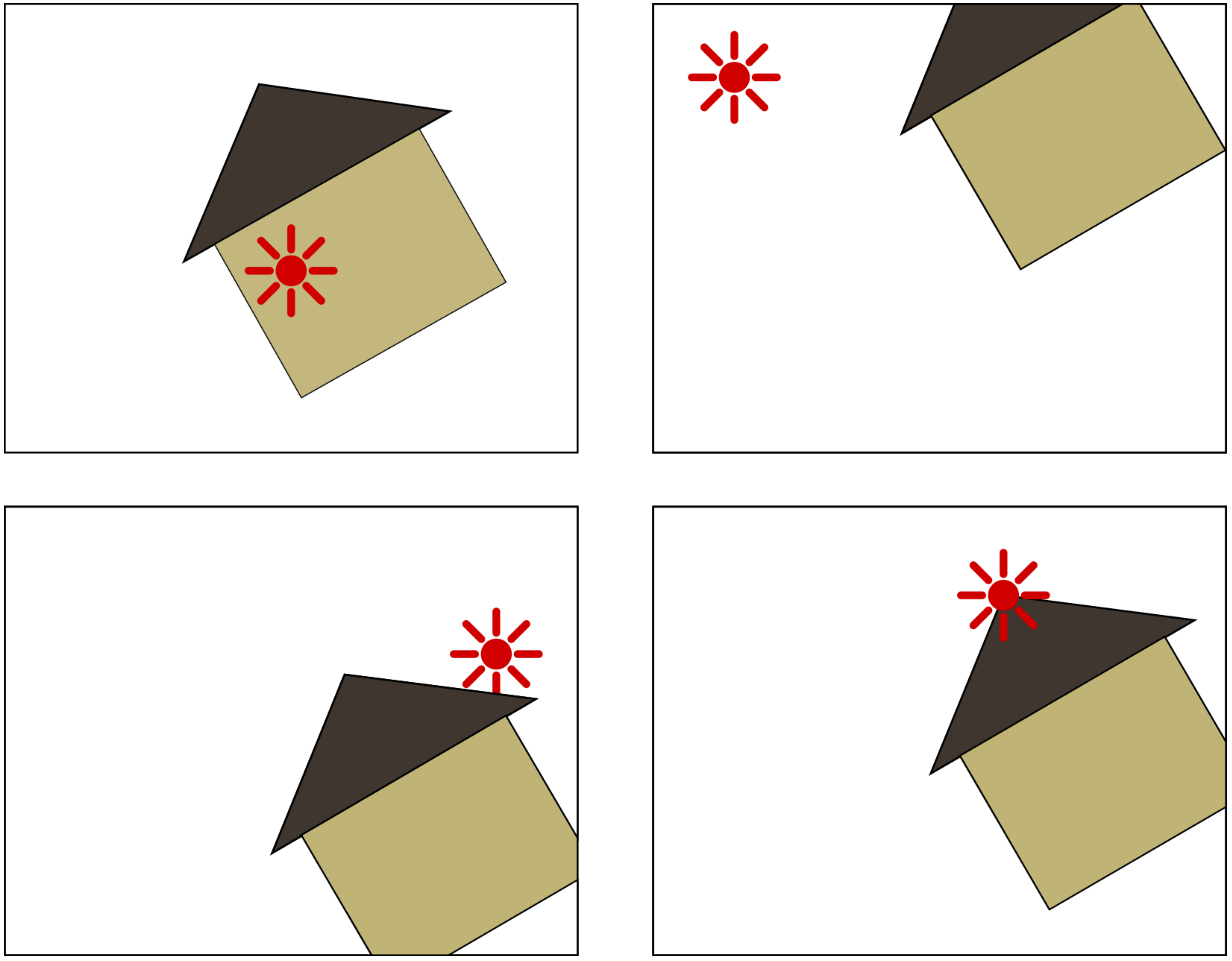
scale(a, b): Scale the current geometric context by ratios a in the x direction and b in the y direction.

scale(a): Equivalent to scale(a, a), i.e., scale uniformly in x and y.

Rotation happens “about a point”.



Rotation happens “about a point”.



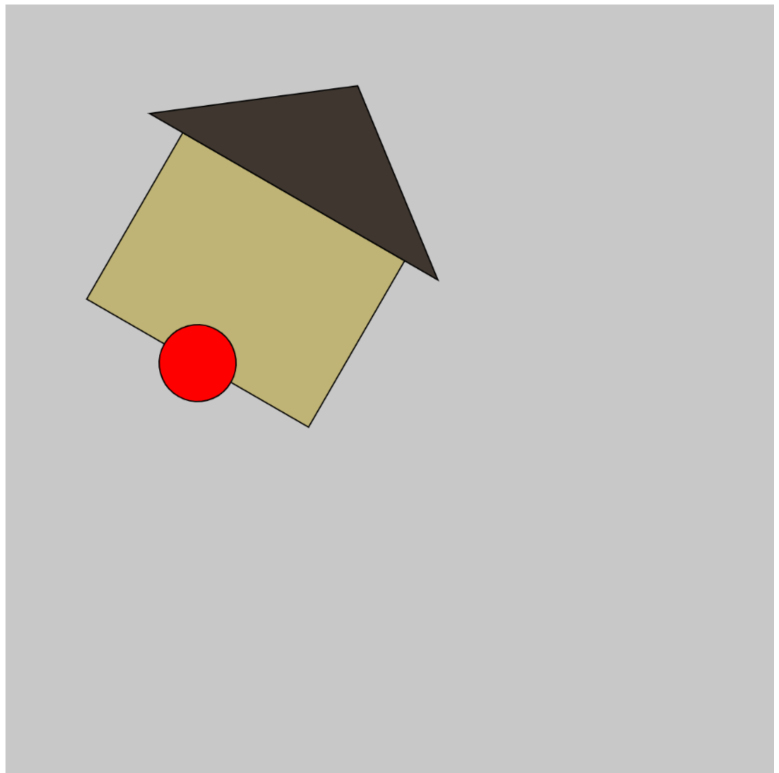
rotate(theta): Rotate the current geometric context by some angle theta (in radians) *about the origin.*

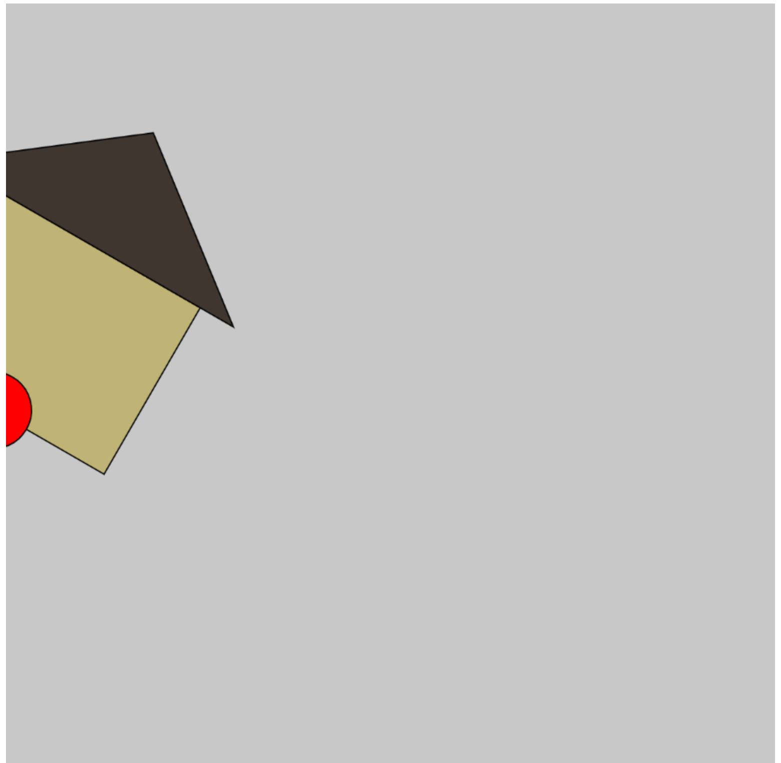
Wherever that is, *right now.*

Order matters!

```
function draw()
{
  background( 255 );

  translate( 150, 280 );
  rotate( radians( 30 ) );
  drawHouse();
}
```

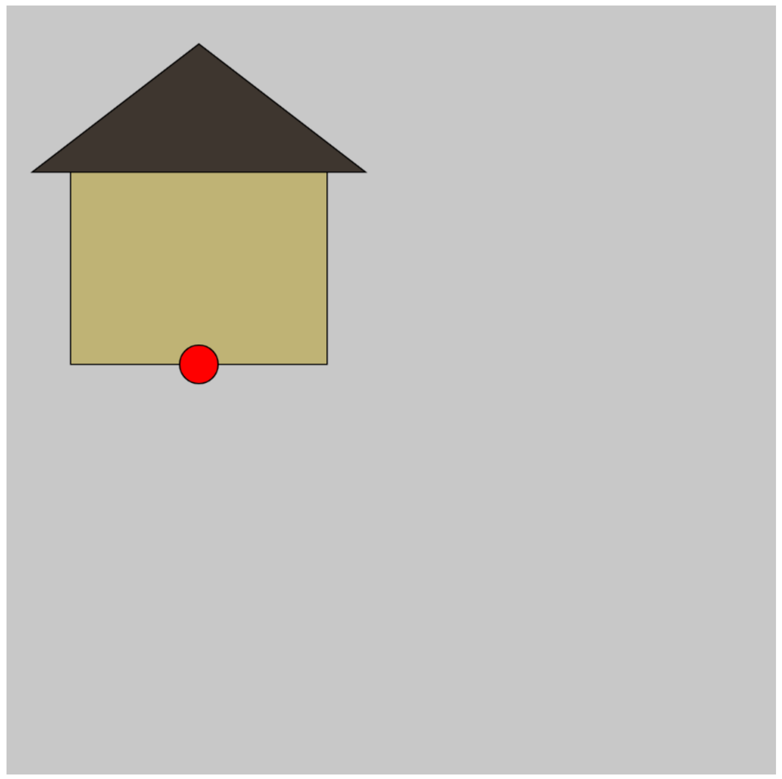
```
function draw()
{
  background( 255 );

  rotate( radians( 30 ) );
  translate( 150, 280 );
  drawHouse();
}
```





Order matters! Translate then rotate

```
function setup() {
   createCanvas(600, 600);
}

function draw() {
   background(200);

   translate(150, 280);
   // rotate(radians(30));
   drawHouse();

   fill(255, 0, 0);
   ellipse(0, 0, 10, 10);
}

function drawHouse() {
   fill(191, 179, 117);
   rect(-100, -150, 200, 150);
   fill(62, 54, 47);
   triangle(-130, -150, 0, -250, 130, -150);
}
```

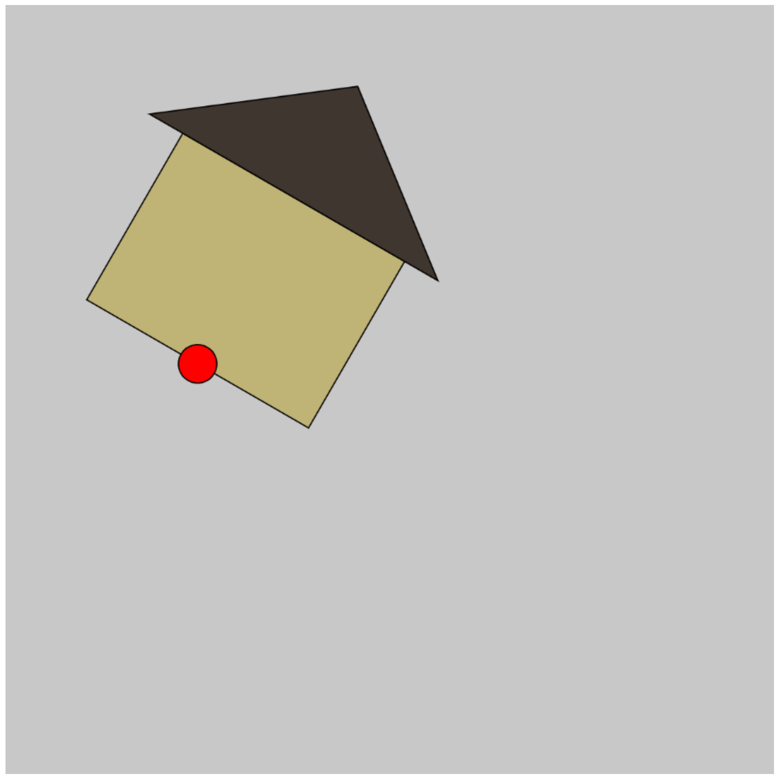


rotate() is commented out.
Red dot shows the origin (i.e. 0,0).

https://openprocessing.org/sketch/1148198

Order matters! Translate then rotate

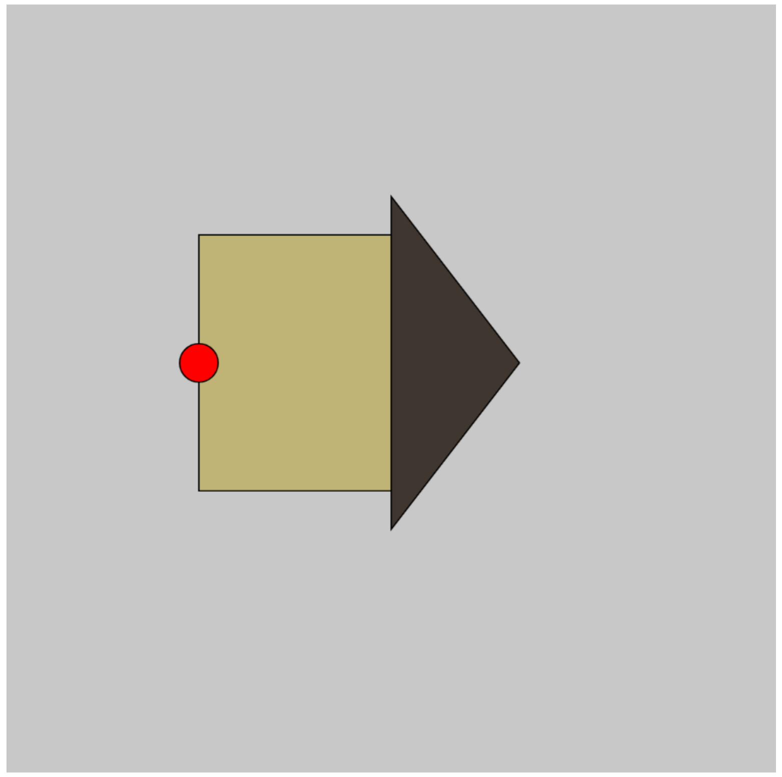
```
function setup() {
   createCanvas(600, 600);
}

function draw() {
   background(200);

   translate(150, 280);
   rotate(radians(30));
   drawHouse();

   fill(255, 0, 0);
   ellipse(0, 0, 10, 10);
}

function drawHouse() {
   fill(191, 179, 117);
   rect(-100, -150, 200, 150);
   fill(62, 54, 47);
   triangle(-130, -150, 0, -250, 130, -150);
}
```



Rotate 30 degrees.
Red dot shows the origin (i.e. 0,0).

Order matters! Translate then rotate

```
function setup() {
   createCanvas(600, 600);
}

function draw() {
   background(200);

   translate(150, 280);
   rotate(radians(90));
   drawHouse();

   fill(255, 0, 0);
   ellipse(0, 0, 10, 10);
}

function drawHouse() {
   fill(191, 179, 117);
   rect(-100, -150, 200, 150);
   fill(62, 54, 47);
   triangle(-130, -150, 0, -250, 130, -150);
}
```

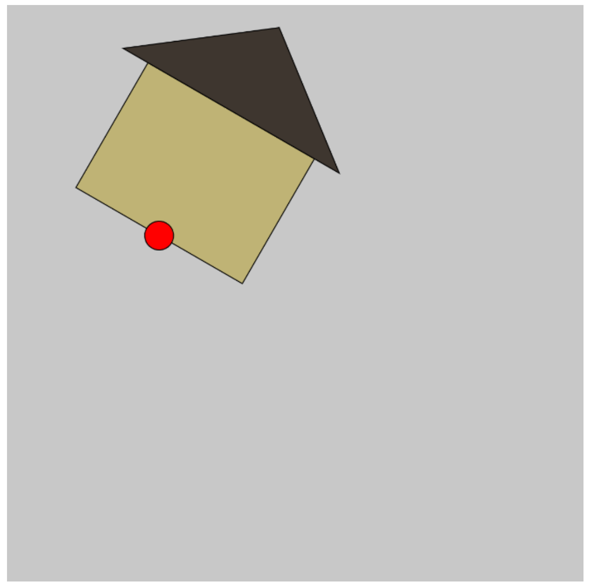


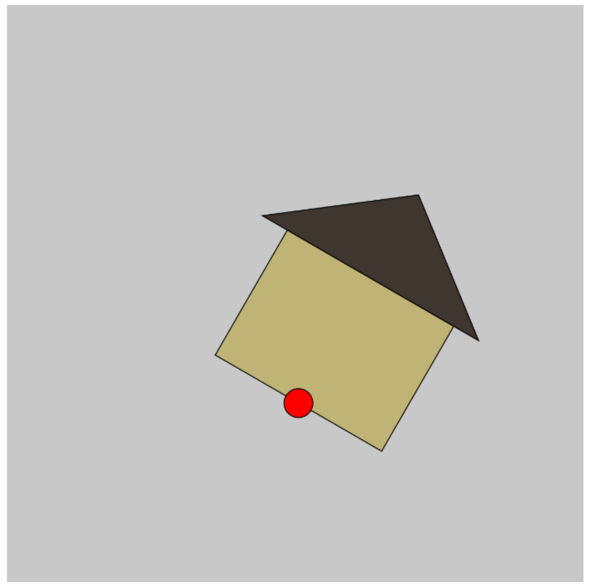
https://openprocessing.org/sketch/1148212

Rotate 90 degrees.
Red dot shows the origin (i.e. 0,0).

Order matters! Translate then rotate

```
function setup() {
   createCanvas(600, 600);
}

function draw() {
   background(200);

   translate(mouseX, mouseY);
   rotate(radians(30));
   drawHouse();

   fill(255, 0, 0);
   ellipse(0, 0, 10, 10);
}

function drawHouse() {
   fill(191, 179, 117);
   rect(-100, -150, 200, 150);
   fill(62, 54, 47);
   triangle(-130, -150, 0, -250, 130, -150);
}
```

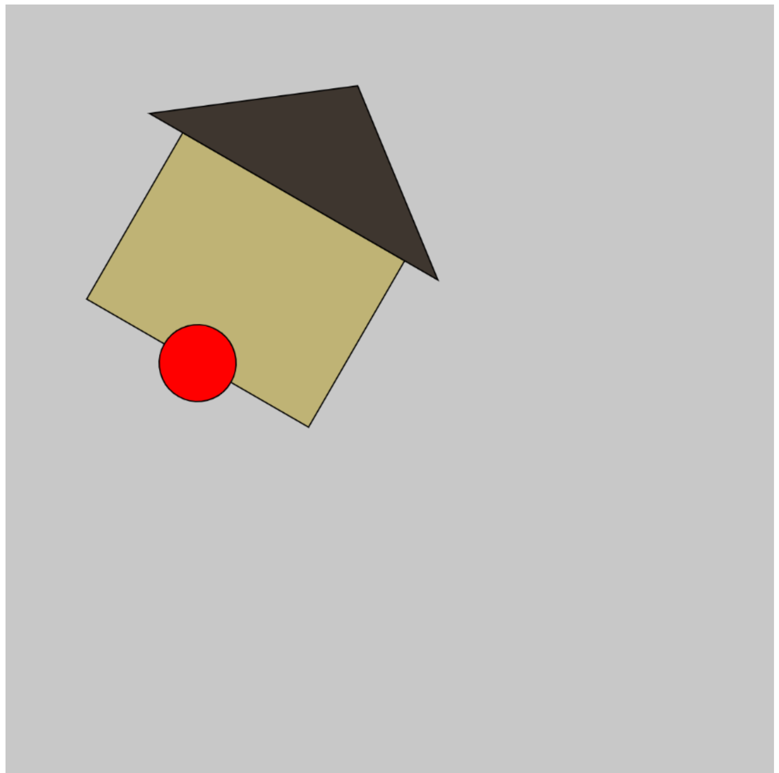




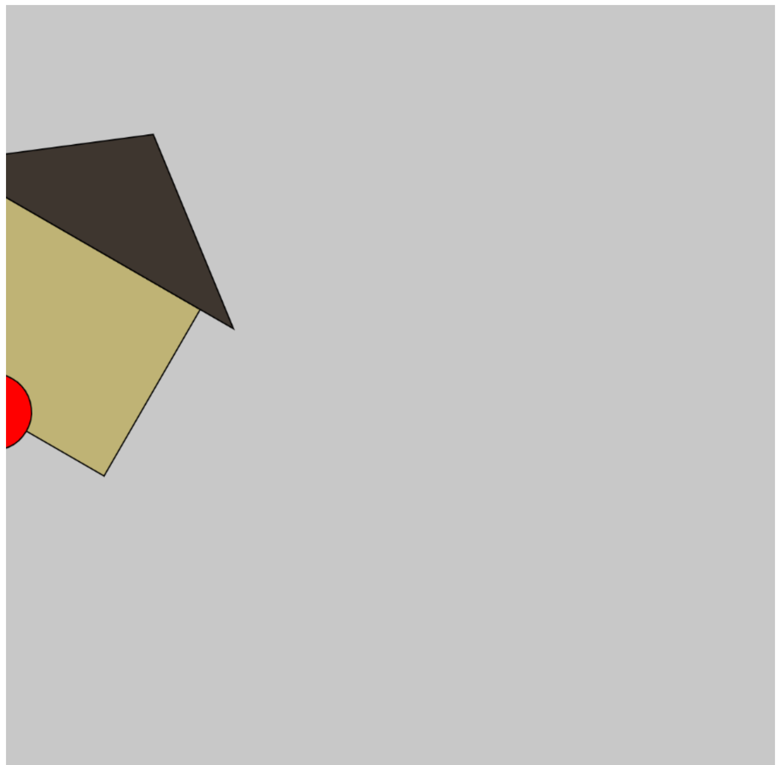
Translate by mouseX and mouseY
Rotate 30 degrees.
Red dot shows the origin (i.e. 0,0).

Order matters!

```
function draw()
{
  background( 255 );

  translate( 150, 280 );
  rotate( radians( 30 ) );
  drawHouse();
}
```

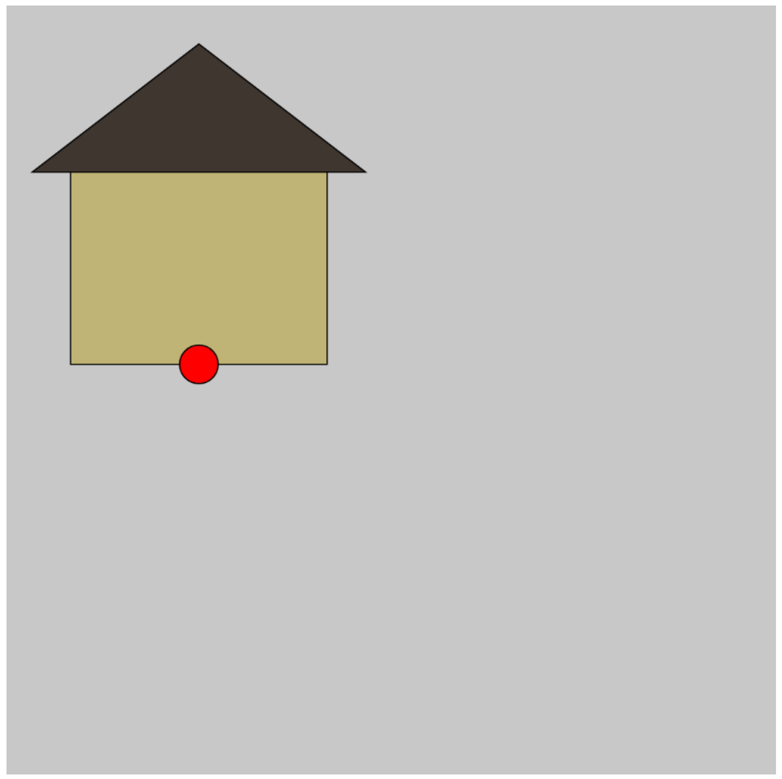


```
function draw()
{
  background( 255 );

  rotate( radians( 30 ) );
  translate( 150, 280 );
  drawHouse();
}
```



Order matters! Rotate then translate

```
function setup() {
   createCanvas(600, 600);
}

function draw() {
   background(200);

   // rotate(radians(30));
   translate(150, 280);
   drawHouse();

   fill(255, 0, 0);
   ellipse(0, 0, 60, 60);
}

function drawHouse() {
   fill(191, 179, 117);
   rect(-100, -150, 200, 150);
   fill(62, 54, 47);
   triangle(-130, -150, 0, -250, 130, -150);
}
```

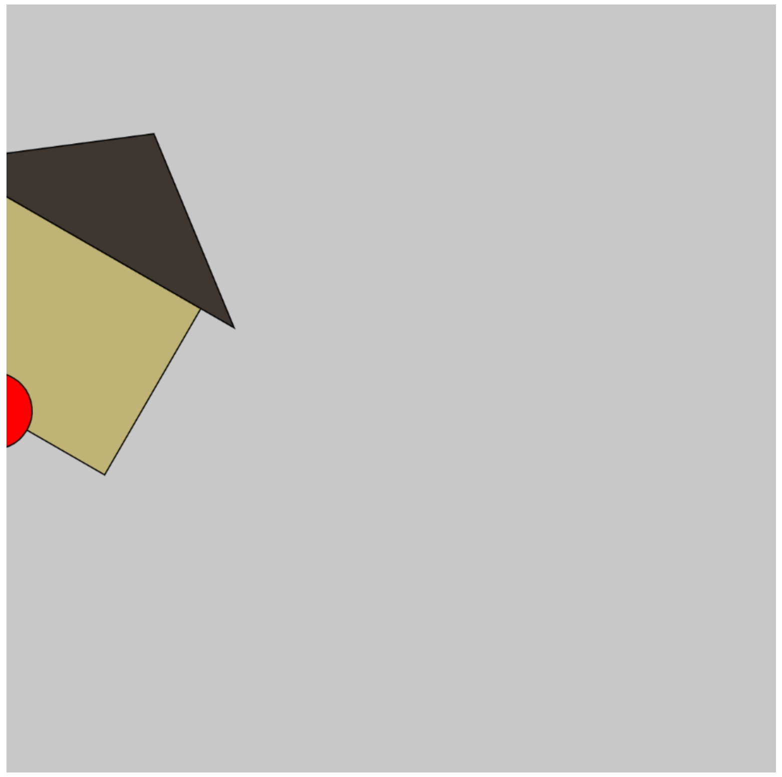


rotate() is commented out.
Red dot shows the origin (i.e. 0,0).

https://openprocessing.org/sketch/1148312

Order matters! Rotate then translate

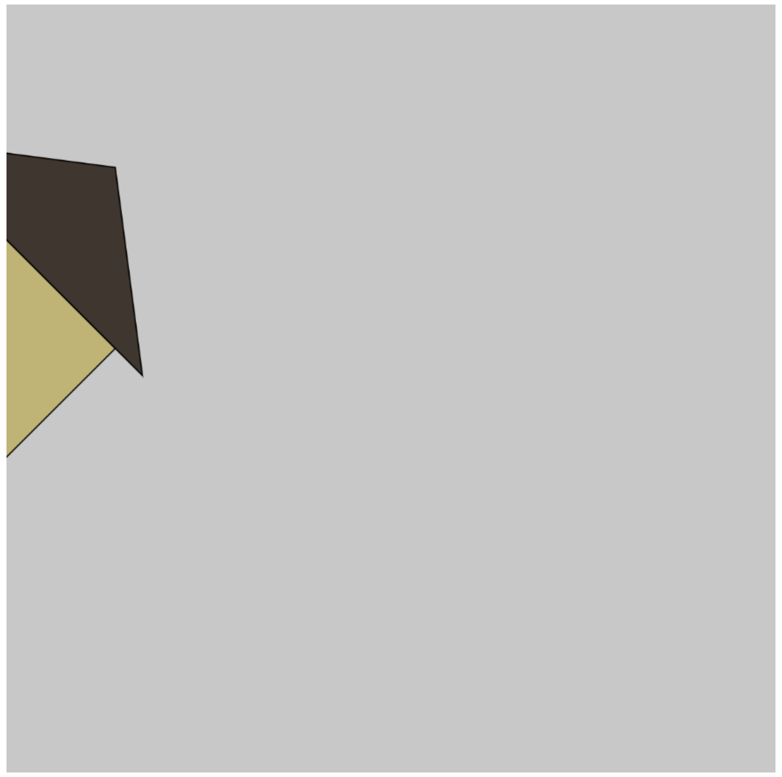
```
function setup() {
   createCanvas(600, 600);
}

function draw() {
   background(200);

   rotate(radians(30));
   translate(150, 280);
   drawHouse();

   fill(255, 0, 0);
   ellipse(0, 0, 60, 60);
}

function drawHouse() {
   fill(191, 179, 117);
   rect(-100, -150, 200, 150);
   fill(62, 54, 47);
   triangle(-130, -150, 0, -250, 130, -150);
}
```



Rotate 30 degrees, then translate.
Red dot shows the origin (i.e. 0,0).

Order matters! Rotate then translate

```
function setup() {
   createCanvas(600, 600);
}

function draw() {
   background(200);

   rotate(radians(45));
   translate(150, 280);
   drawHouse();

   fill(255, 0, 0);
   ellipse(0, 0, 60, 60);
}

function drawHouse() {
   fill(191, 179, 117);
   rect(-100, -150, 200, 150);
   fill(62, 54, 47);
   triangle(-130, -150, 0, -250, 130, -150);
}
```

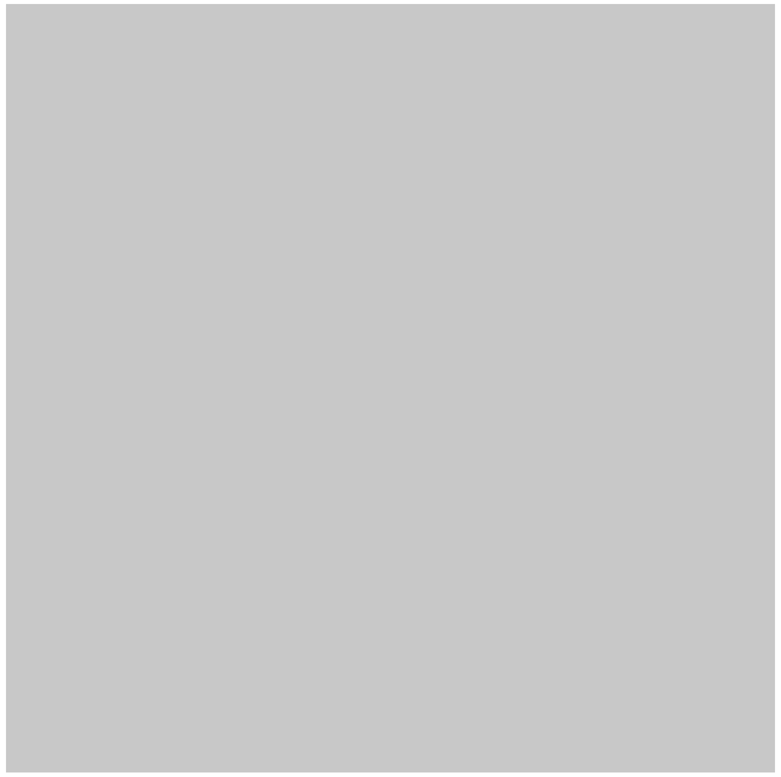


Rotate 45 degrees, then translate.
Red dot shows the origin (i.e. 0,0).

https://openprocessing.org/sketch/1148324

Order matters! Rotate then translate

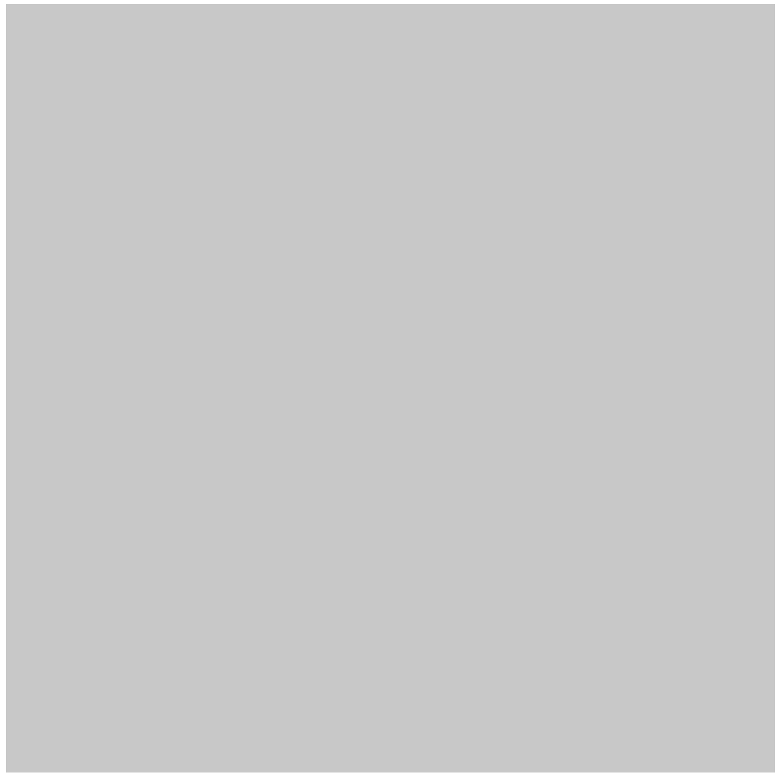
```
function setup() {
   createCanvas(600, 600);
}

function draw() {
   background(200);

   rotate(radians(90));
   translate(150, 280);
   drawHouse();

   fill(255, 0, 0);
   ellipse(0, 0, 60, 60);
}

function drawHouse() {
   fill(191, 179, 117);
   rect(-100, -150, 200, 150);
   fill(62, 54, 47);
   triangle(-130, -150, 0, -250, 130, -150);
}
```



Rotate 90 degrees, then translate.
Red dot shows the origin (i.e. 0,0).

Order matters! Rotate then translate

```
function setup() {
   createCanvas(600, 600);
}

function draw() {
   background(200);

   rotate(radians(90));
   translate(150, 280);
   drawHouse();

   fill(255, 0, 0);
   ellipse(0, 0, 60, 60);
}

function drawHouse() {
   fill(191, 179, 117);
   rect(-100, -150, 200, 150);
   fill(62, 54, 47);
   triangle(-130, -150, 0, -250, 130, -150);
}
```



Rotate 90 degrees, then translate.
Red dot shows the origin (i.e. 0,0).

Understanding order, Version 1

```
function draw()
{
  background( 255 );

  translate( 150, 280 );
  [illegible]
  [illegible]
}
```

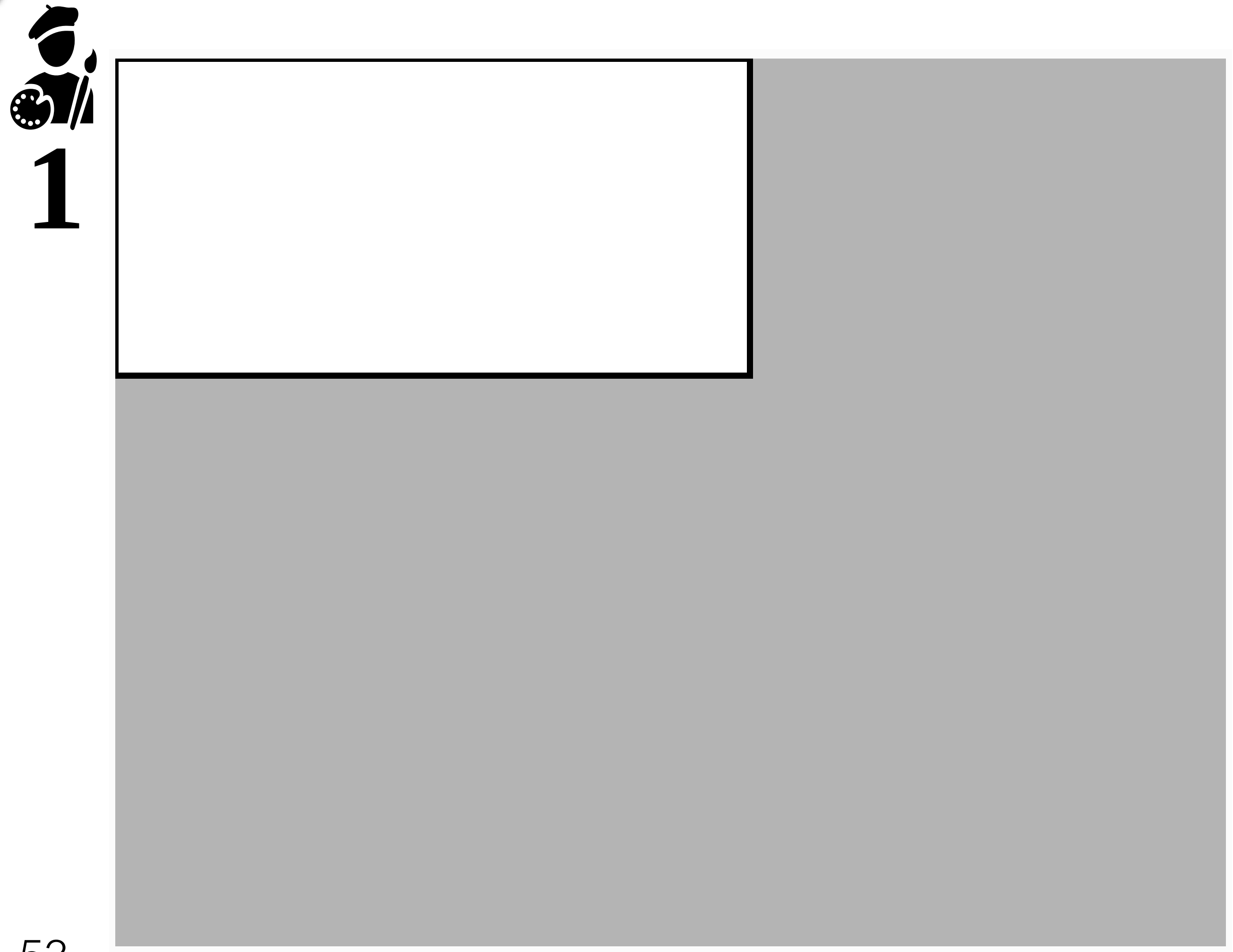
"Whatever happens next, do it in a context that has been translated by (150, 280)."

In this first model, read the drawing command first. Then read the transformations, *backward*, changing your imagined drawing each time.

```
rotate( radians( 30 ) );
translate( 100, 0 );
rect( 0, 0, 200, 100 );
```

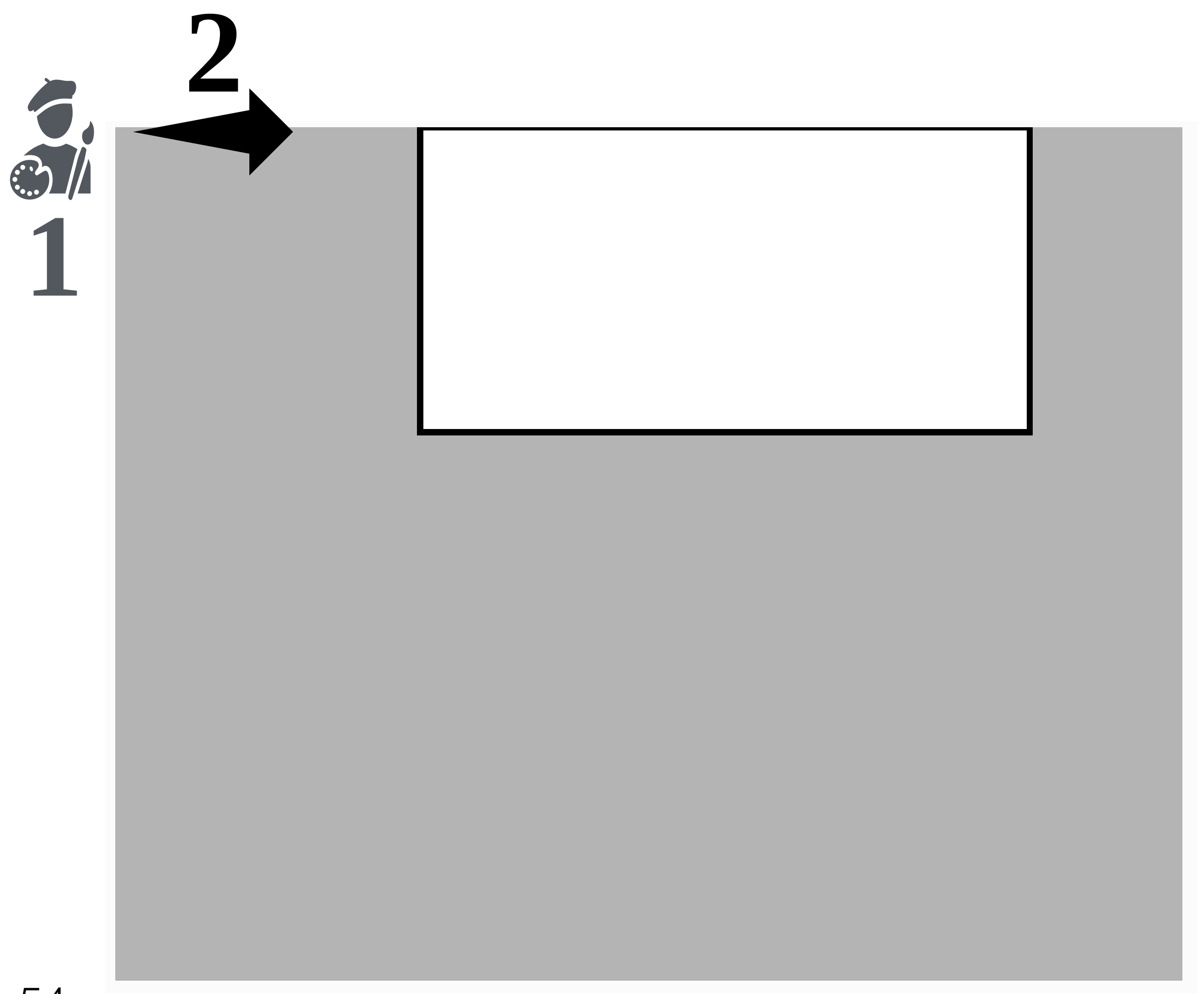
In this first model, read the drawing command first. Then read the transformations, *backward*, changing your imagined drawing each time.

```
//  rotate( radians( 30 ) );
//  translate( 100, 0 );
1.  rect( 0, 0, 200, 100 );
```



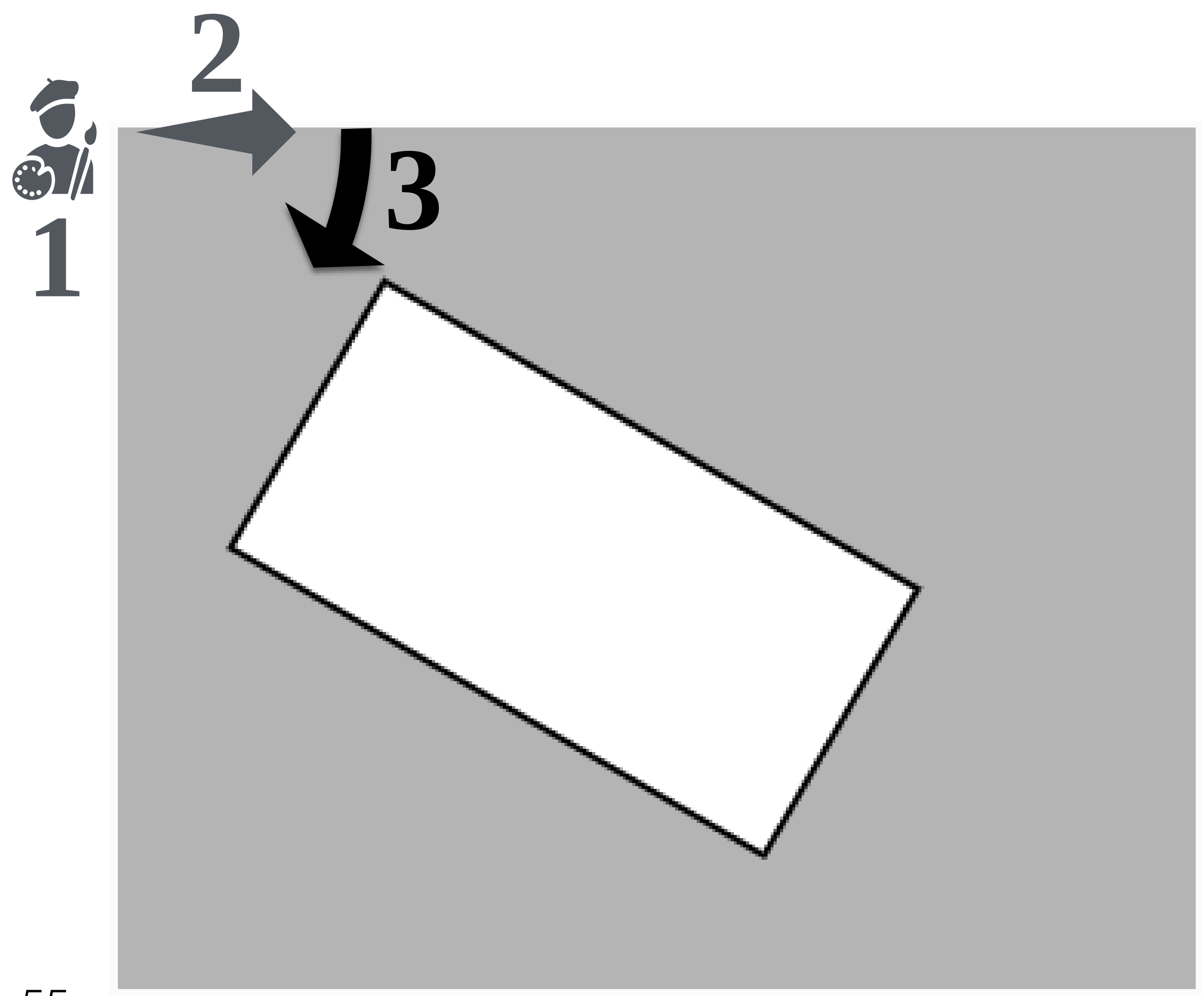
In this first model, read the drawing command first. Then read the transformations, *backward*, changing your imagined drawing each time.

```
//   rotate( radians( 30 ) );
2.   translate( 100, 0 );
1.   rect( 0, 0, 200, 100 );
```



In this first model, read the drawing command first. Then read the transformations, *backward*, doing it to your imagined drawing each time.

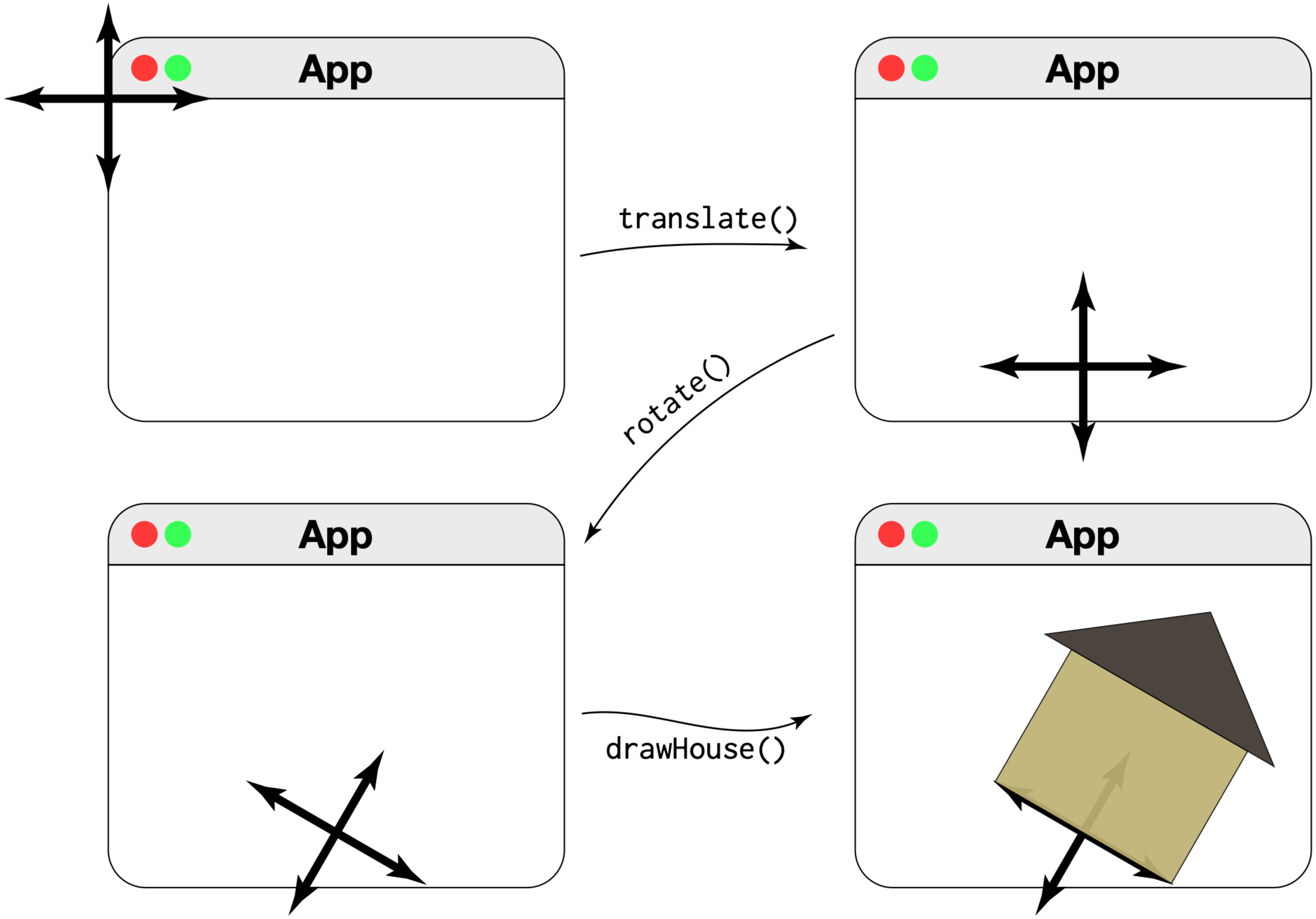
```
3. rotate( radians( 30 ) );
2. translate( 100, 0 );
1. rect( 0, 0, 200, 100 );
```



Understanding order, Version 2

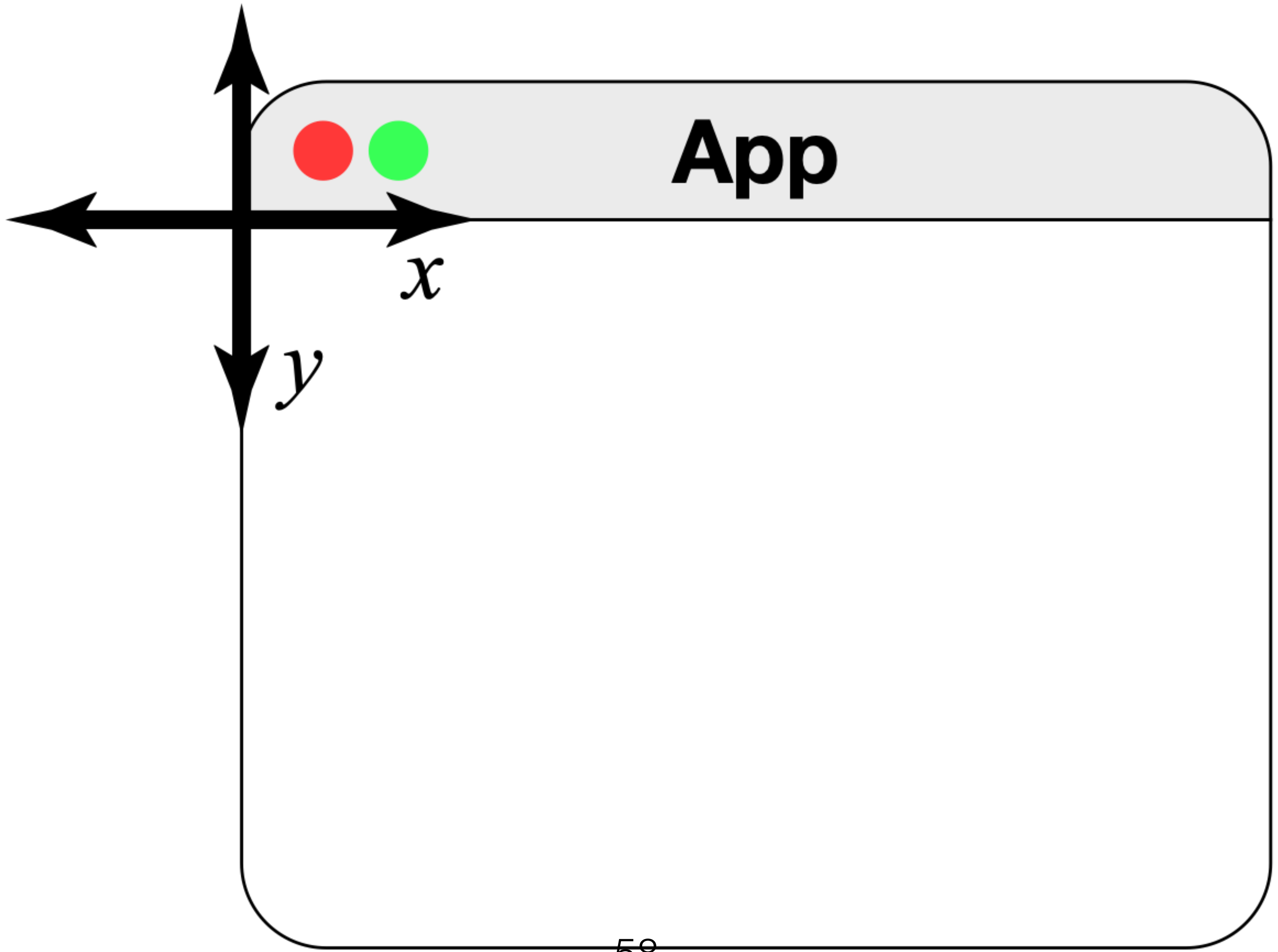
```
function draw()
{
  background( 255 );

  translate( 150, 280 );
  [illegible]
  [illegible]
}
```

“Translate the actual coordinate axes by this much. Later, draw using these transformed axes.”


App
App
translate()
rotate()
App
App
drawHouse()

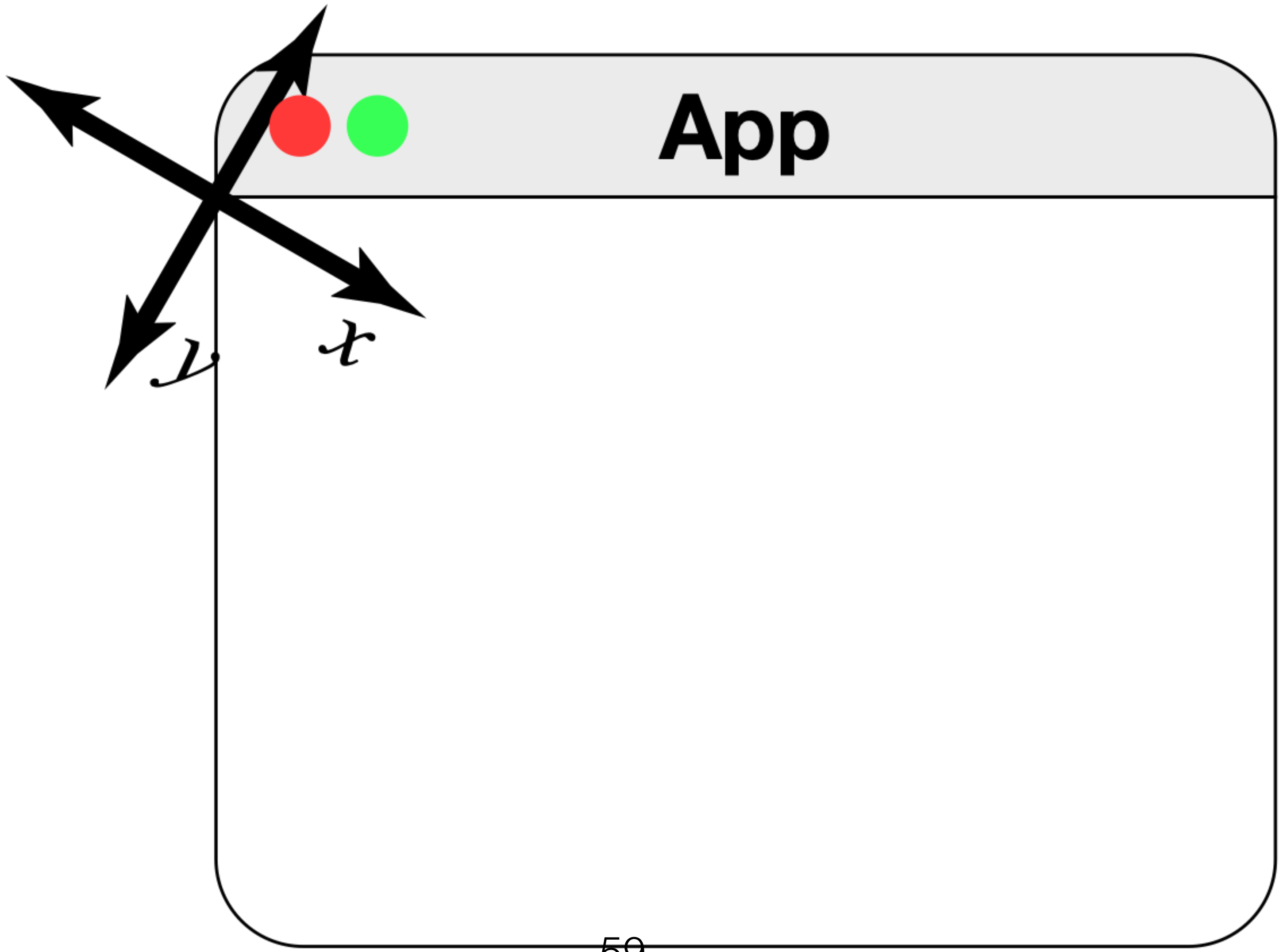
In this second model, each transformation must be applied in the transformed coordinate system that got you there!

```
rotate( radians( 30 ) );
translate( 100, 0 );
rect( 0, 0, 200, 100 );
```



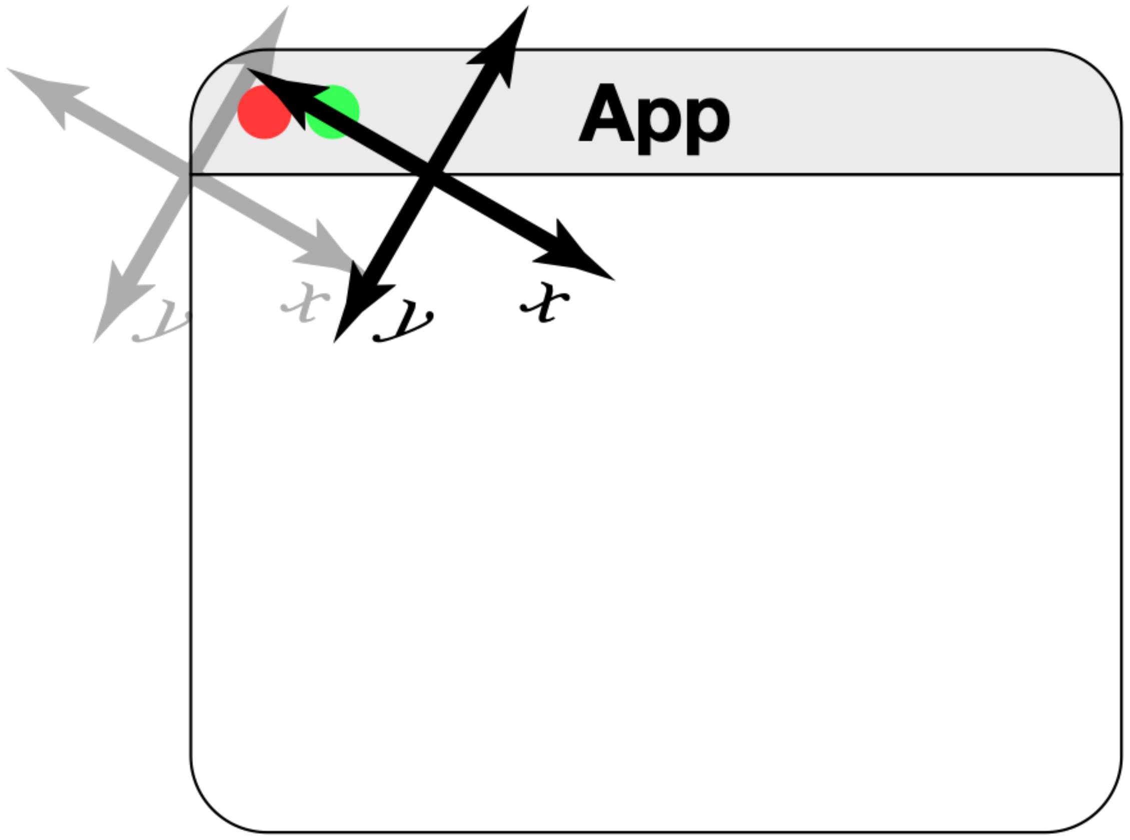
In this second model, each transformation must be applied in the transformed coordinate system that got you there!

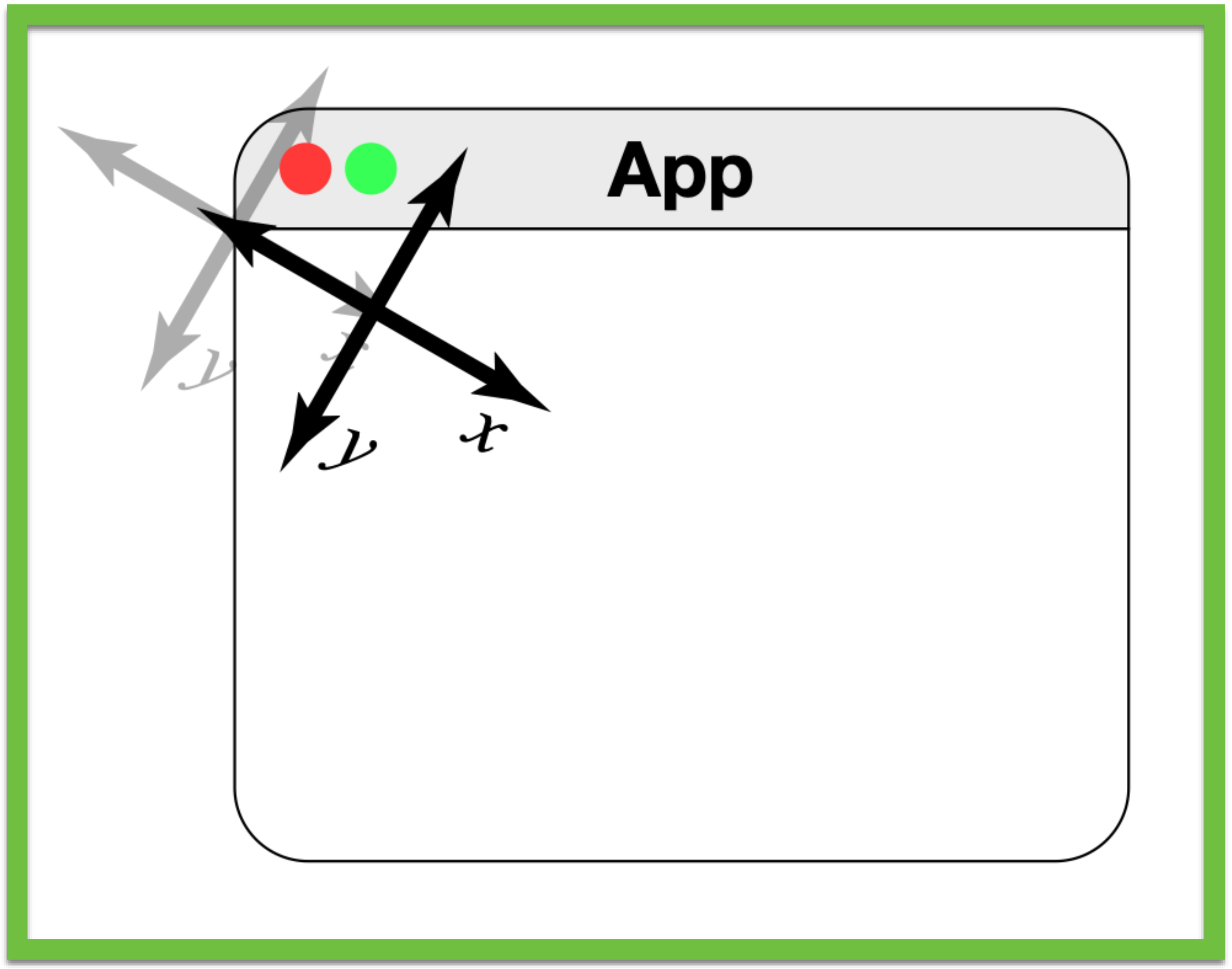
```
rotate( radians( 30 ) );
translate( 100, 0 );
rect( 0, 0, 200, 100 );
```



In this second model, each transformation must be applied **in the transformed coordinate system** that got you there!

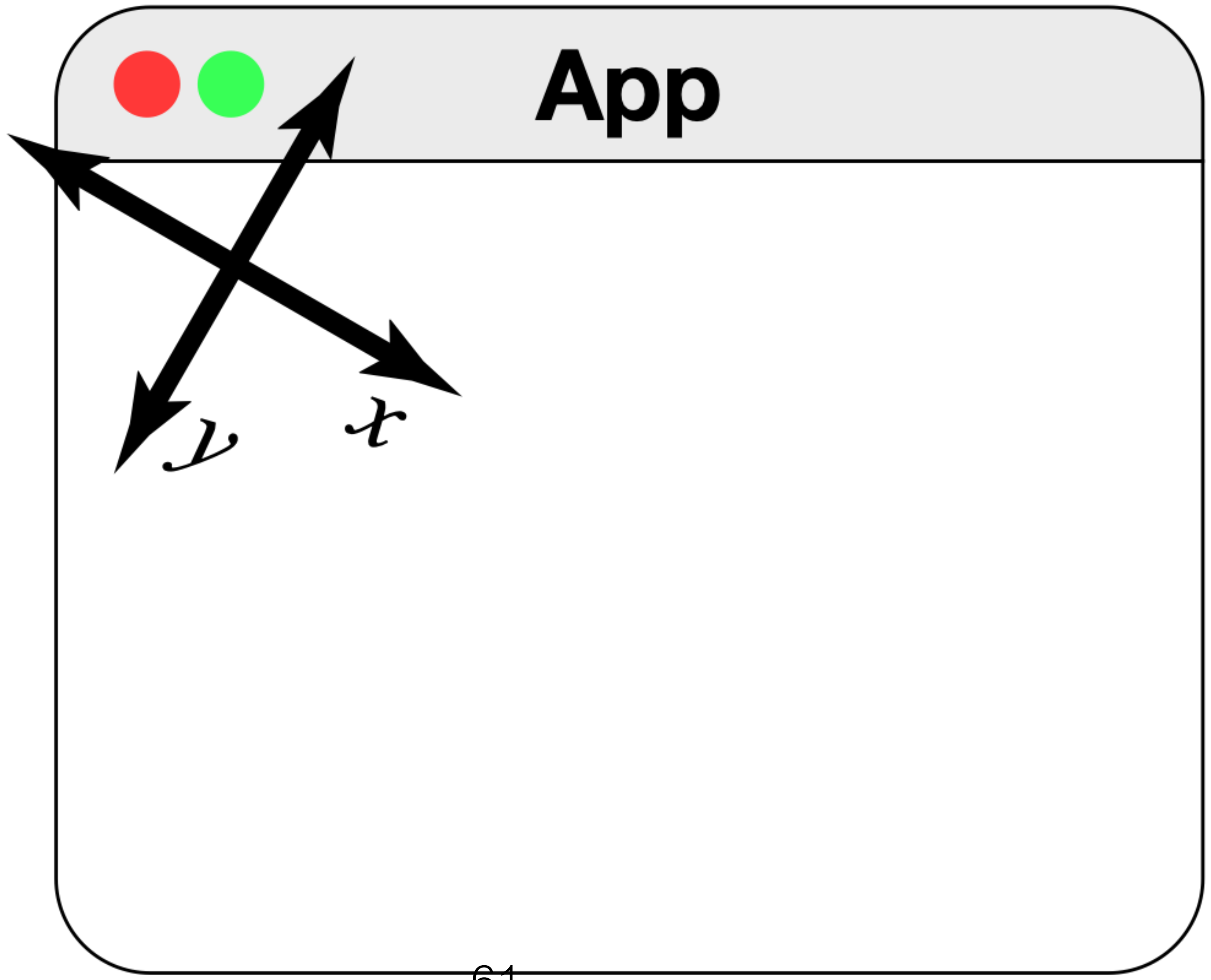
```
rotate( radians( 30 ) );
translate( 100, 0 );
rect( 0, 0, 200, 100 );
```





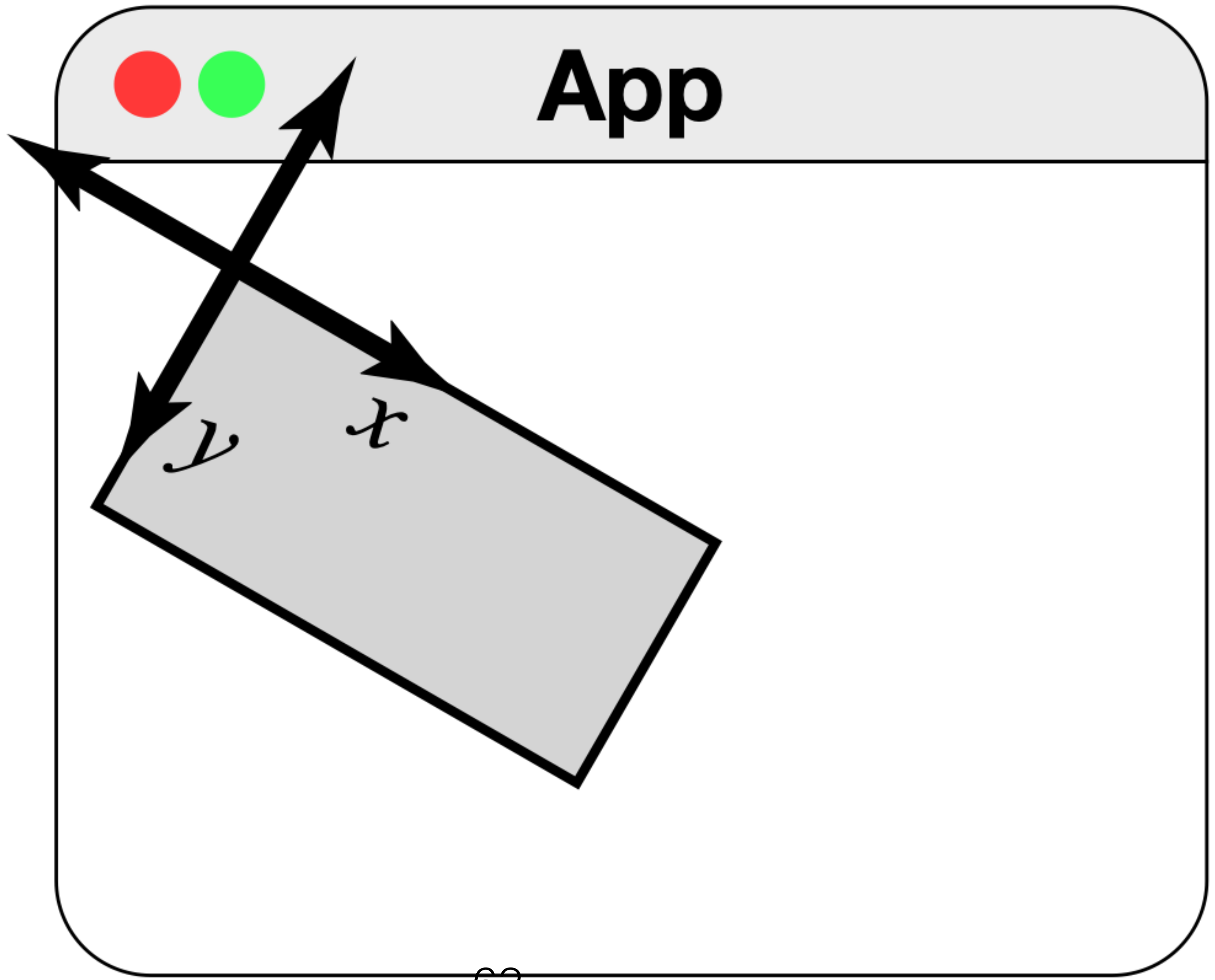
In this second model, each transformation must be applied in the transformed coordinate system that got you there!

```
rotate( radians( 30 ) );
translate( 100, 0 );
rect( 0, 0, 200, 100 );
```



In this second model, each transformation must be applied in the transformed coordinate system that got you there!

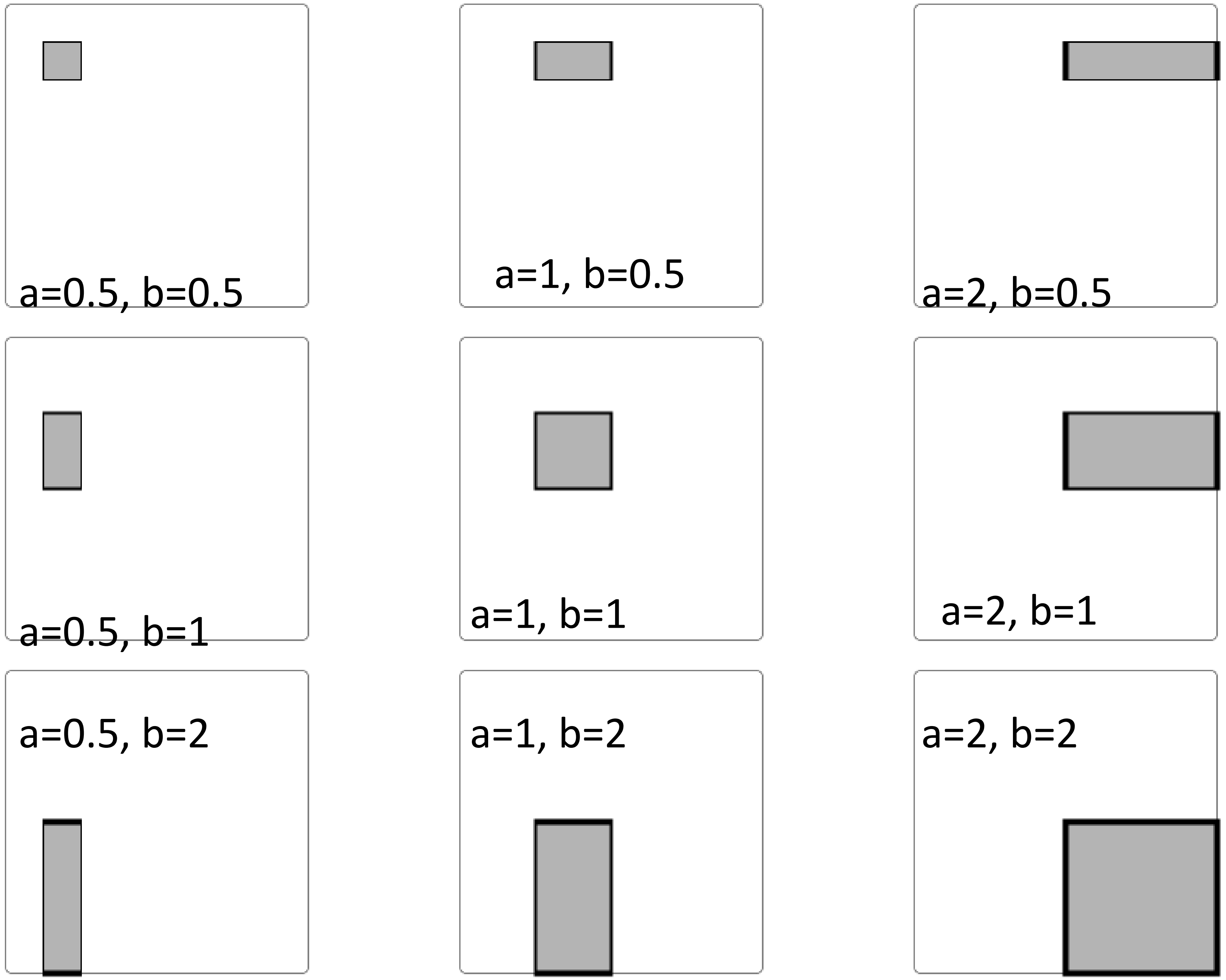
```
rotate( radians( 30 ) );
translate( 100, 0 );
rect( 0, 0, 200, 100 );
```



scale(a, b): Scale the current geometric context by ratios a in the x direction and b in the y direction.

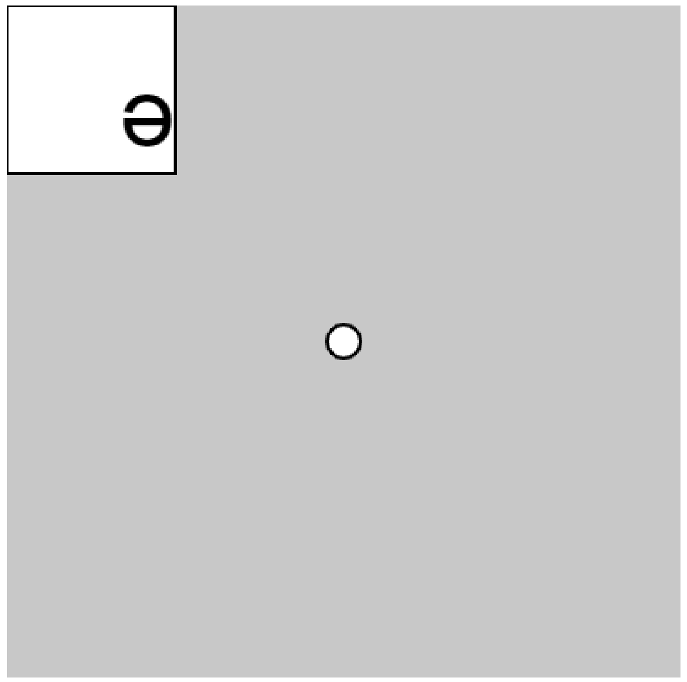
```
createCanvas(200, 200);
scale(a, b);
rect(50, 50, 50, 50);
```

https://openprocessing.org/sketch/1148526

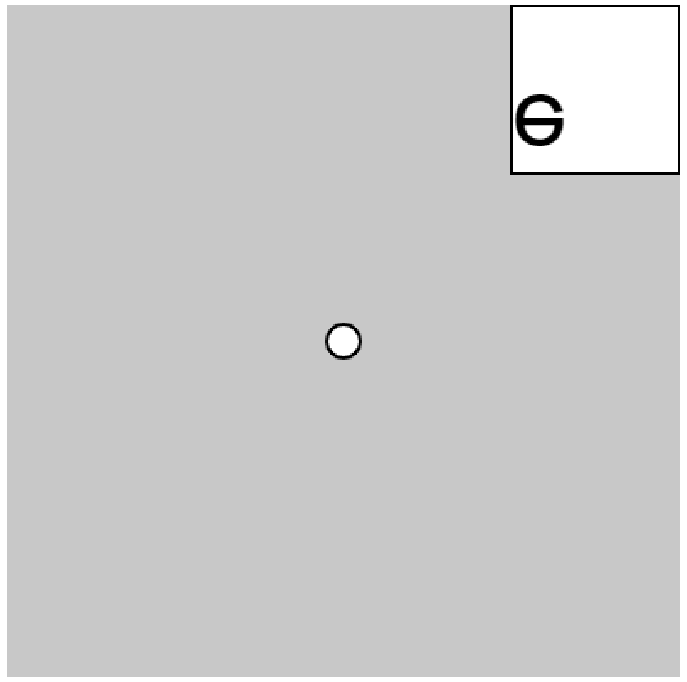


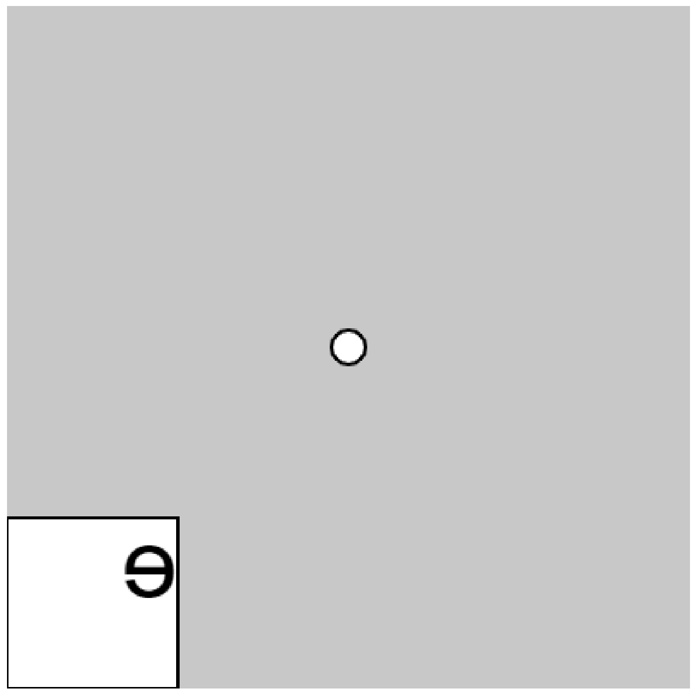
```
createCanvas(200, 200);
background(200);

textAlign(LEFT, TOP);
textSize(30);

ellipseMode(CENTER);
translate(height / 2,
    width / 2);
ellipse(0, 0, 10, 10);

scale(a, b);
rect(50, 50, 50, 50);
text("e", 50, 50);
```

a=-1, b=-1

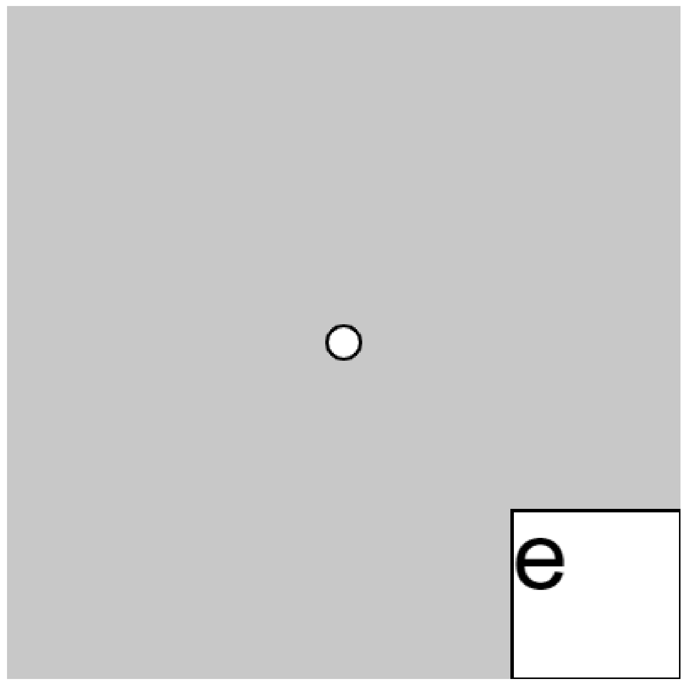


a=1, b=-1





a=-1, b=1

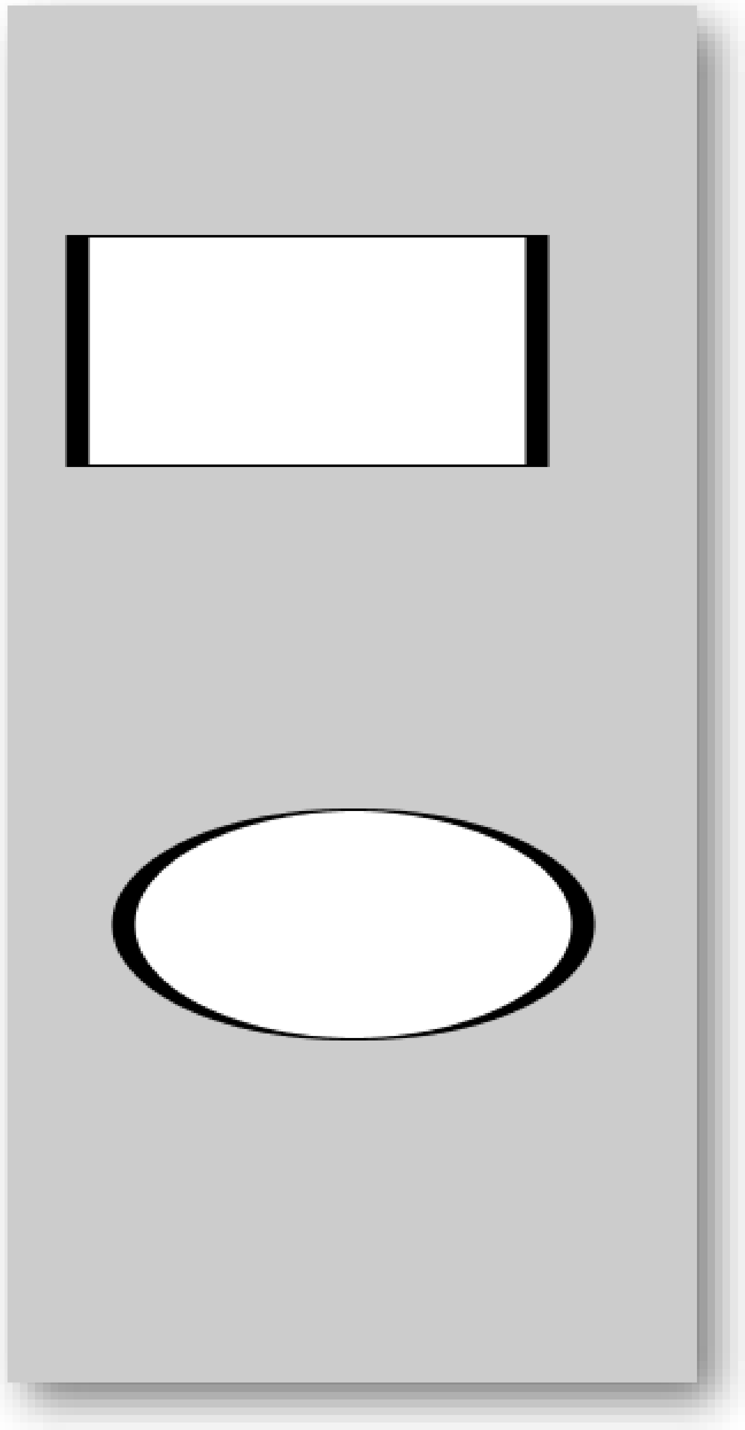


a=1, b=1

https://openprocessing.org/sketch/1148525

Beware: scaling affects strokes too!

```
function setup() {
  createCanvas(300, 600);
  background(200);
  scale(10, 1);
  rect(3, 100, 20, 100);
  ellipse(15, 400, 20, 100);
}
```

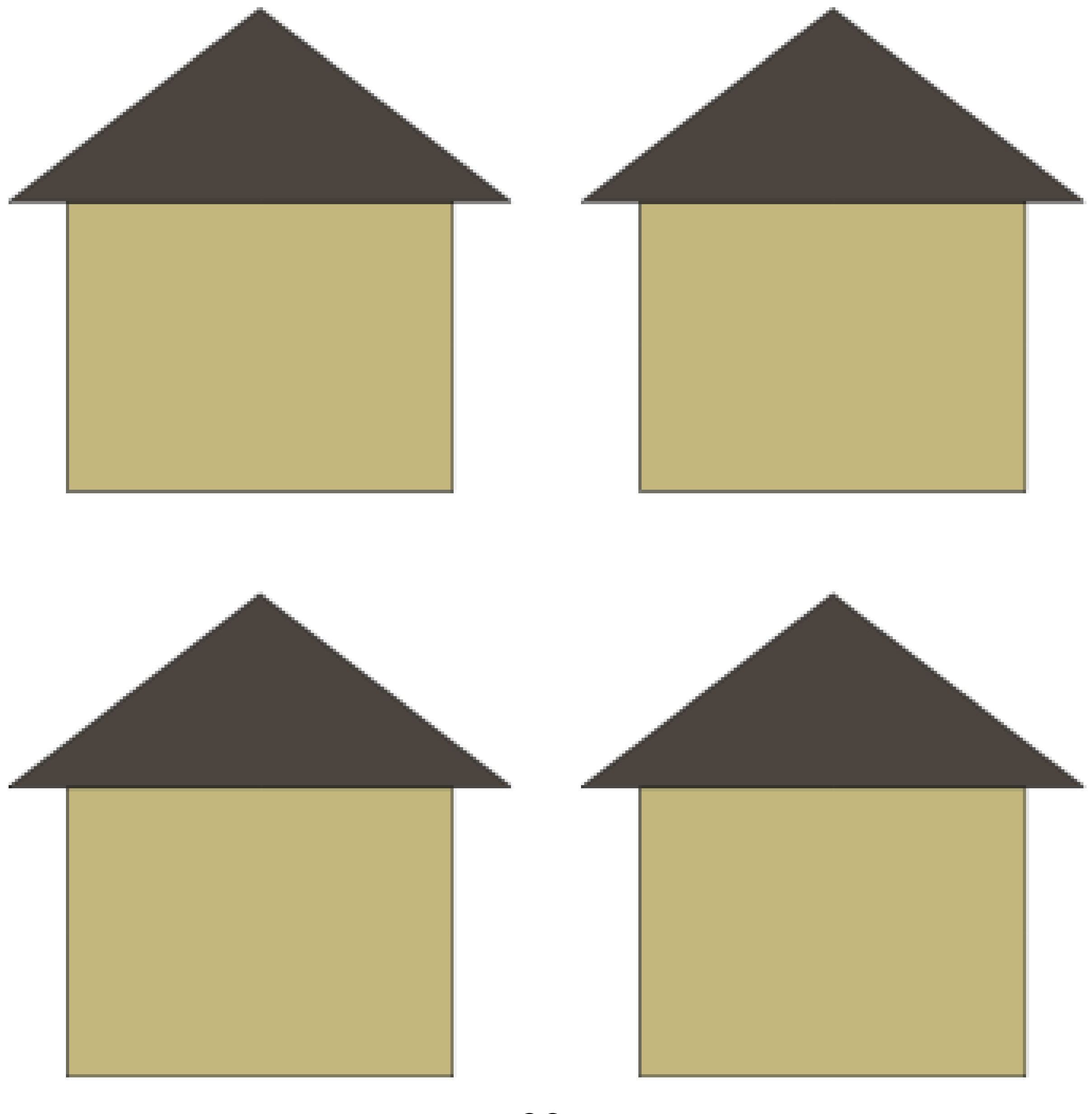


Contexts in a Hierarchy

putting *push* and *pop* to work

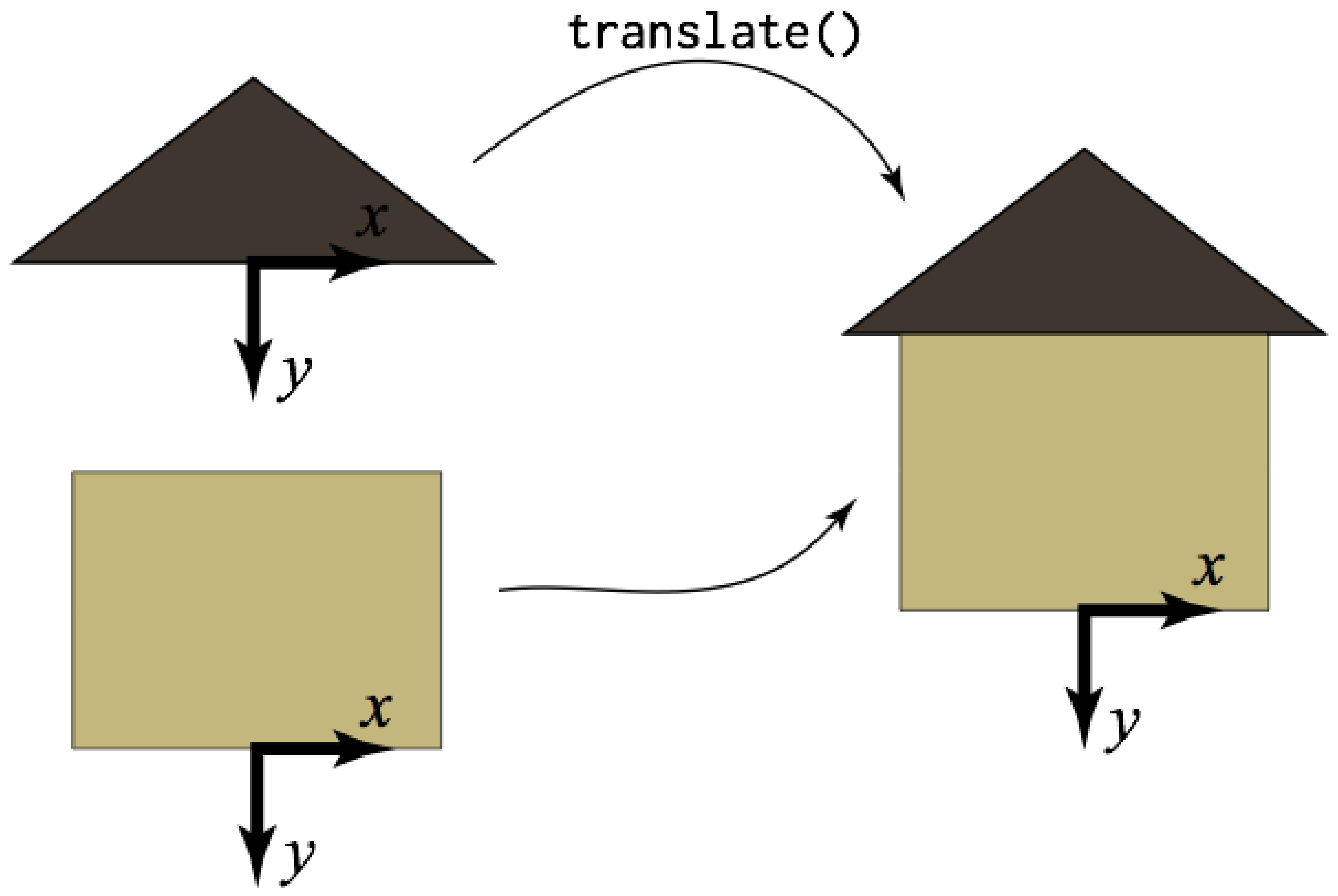
Hierarchical Modelling

With geometric context, we can define functions that express "reusable components" in drawings.



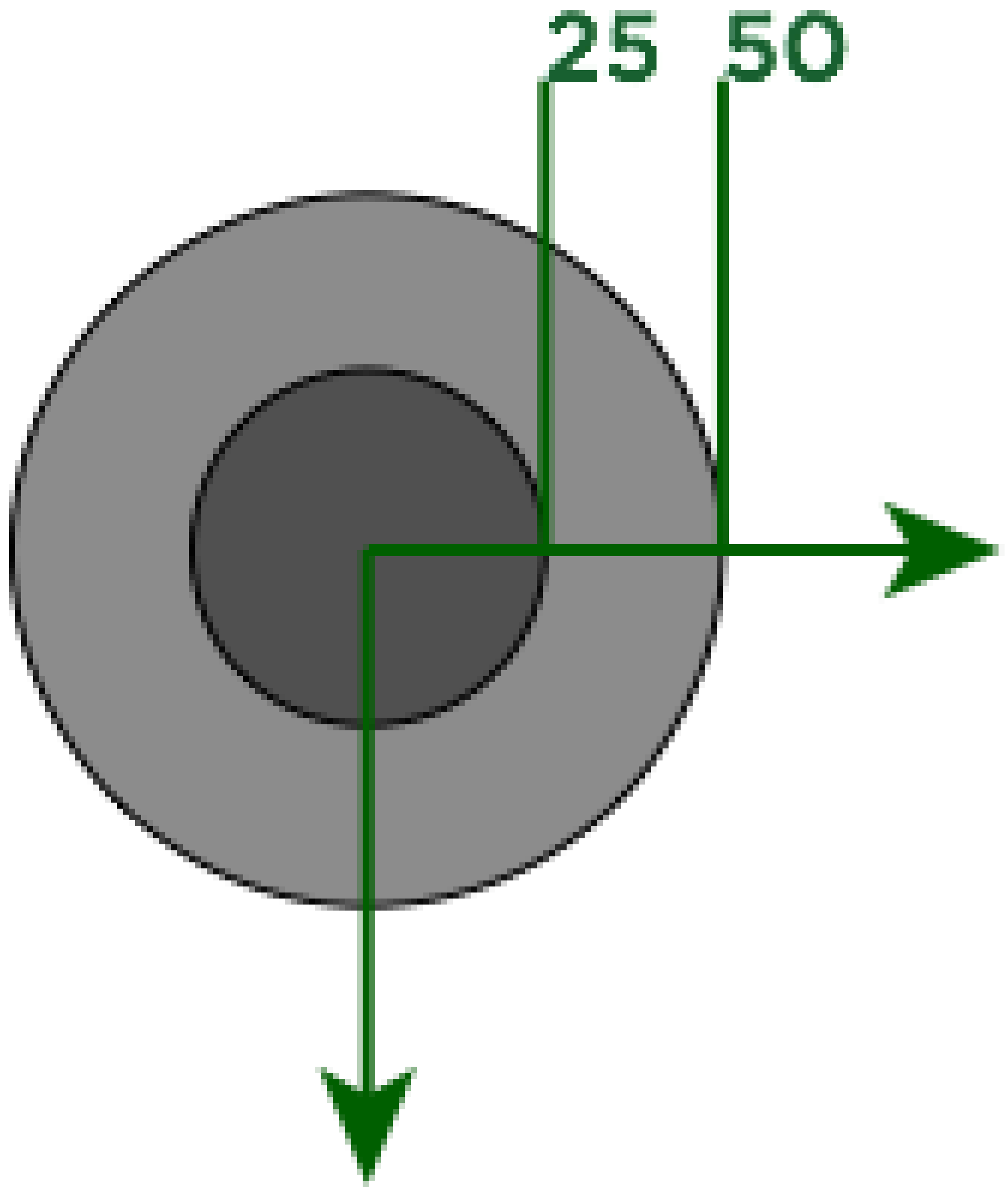
Hierarchical Modelling

Geometric context also lets us express the relative spatial relationships between parts of an object.

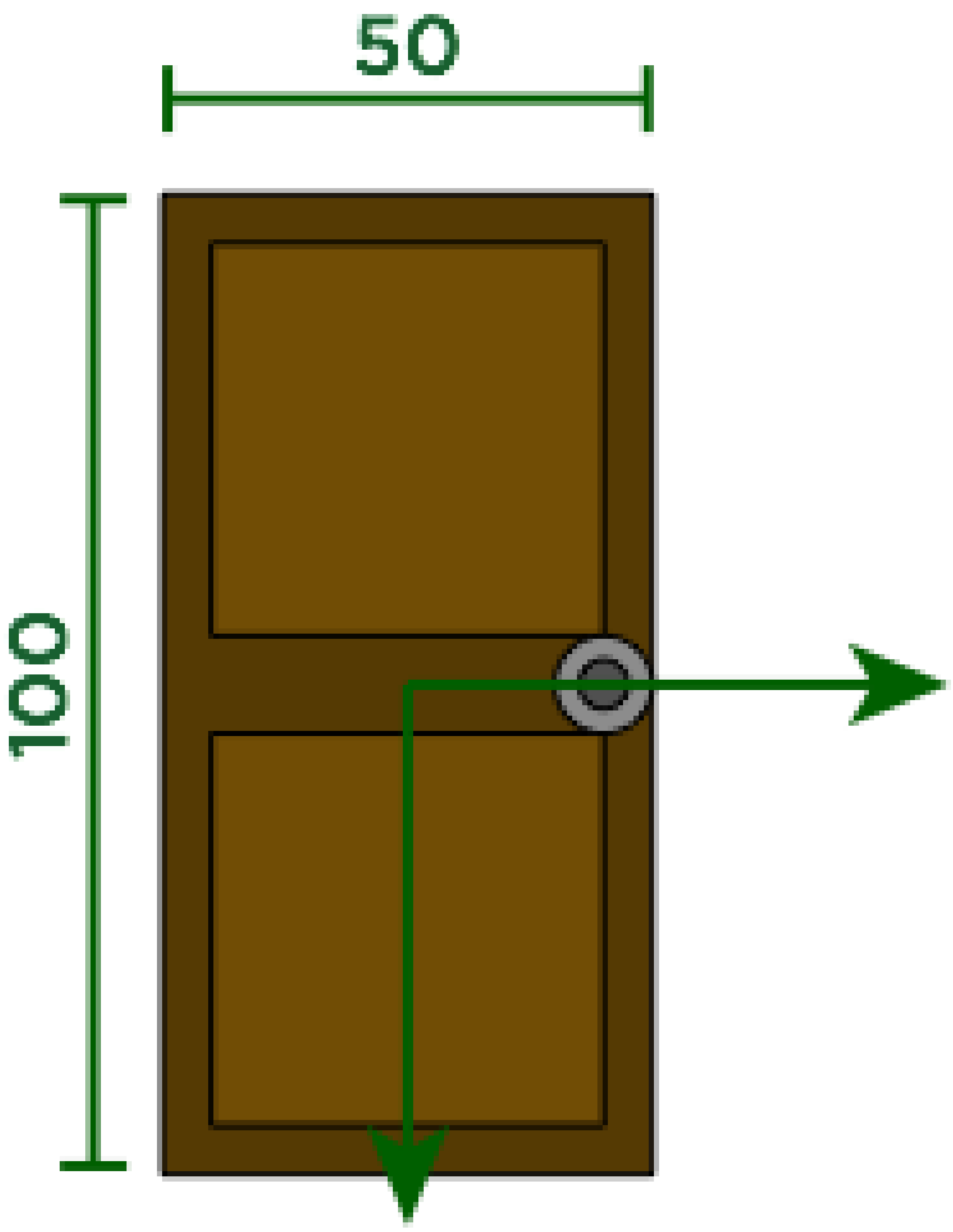


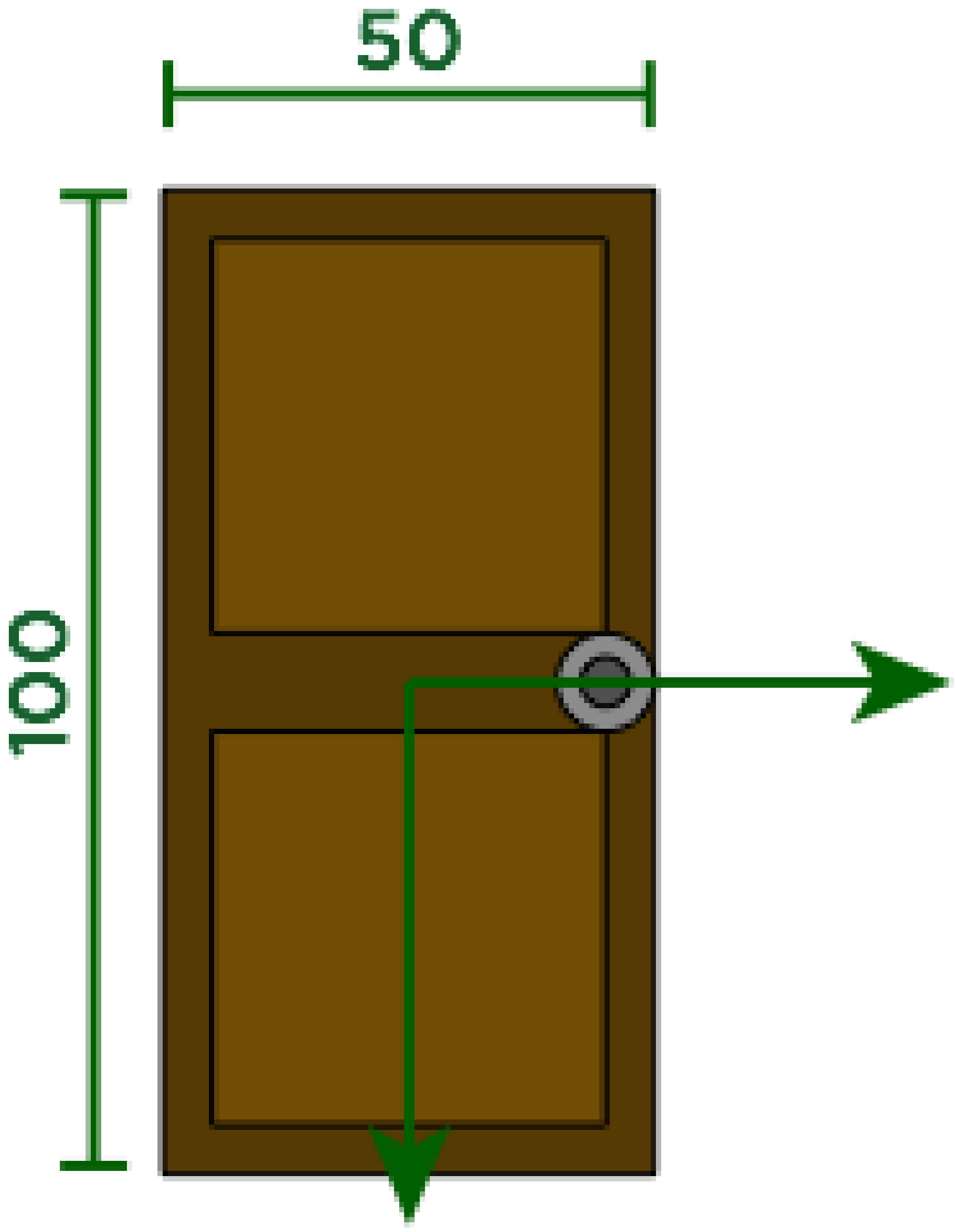
Hierarchical Modelling

We can use these properties to build up complicated, interesting drawings from hierarchies of simpler pieces.

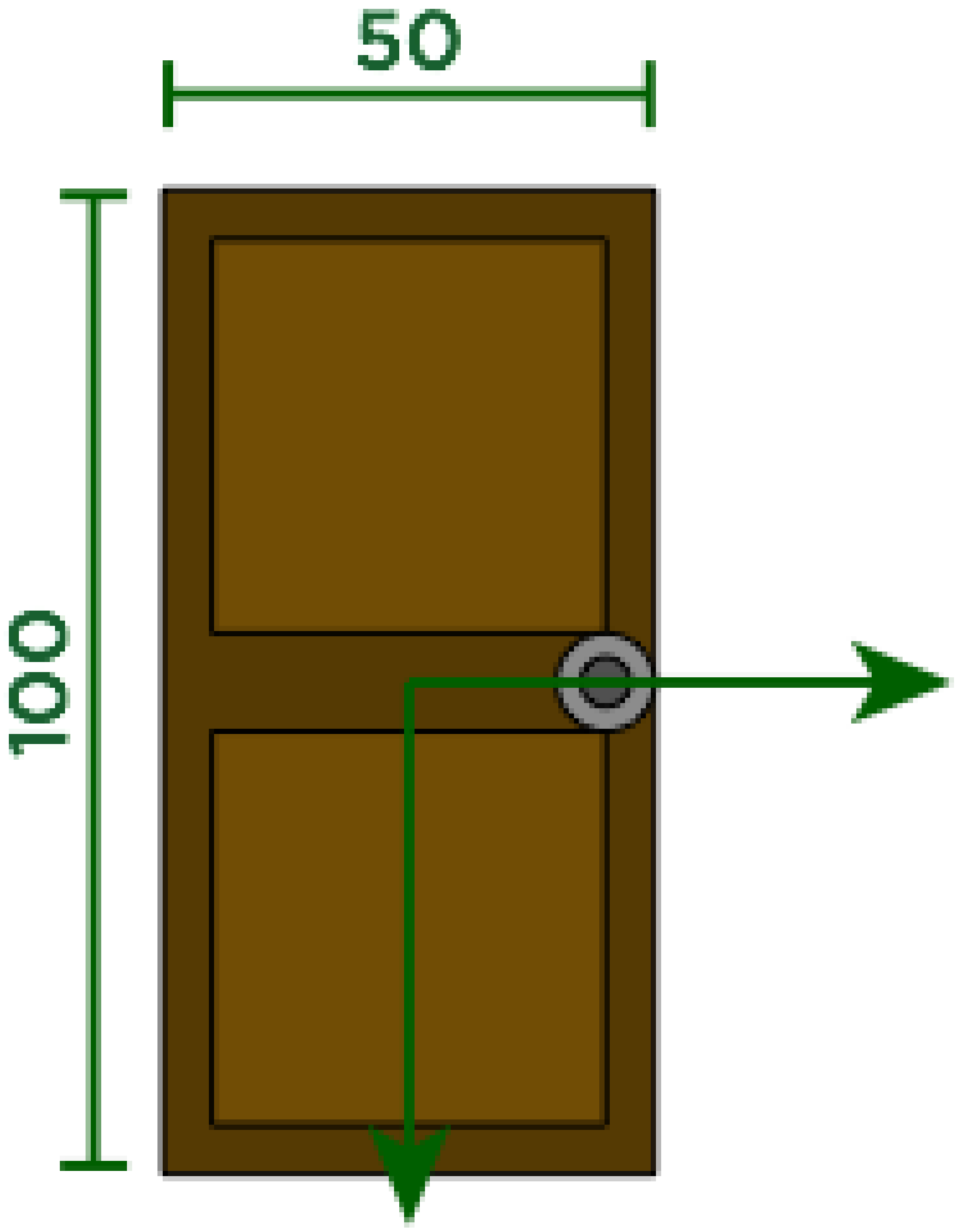


```
function doorknob()
{
  fill( 140 );
  ellipse( 0, 0, 100, 100 );
  fill( 80 );
  ellipse( 0, 0, 50, 50 );
}
```

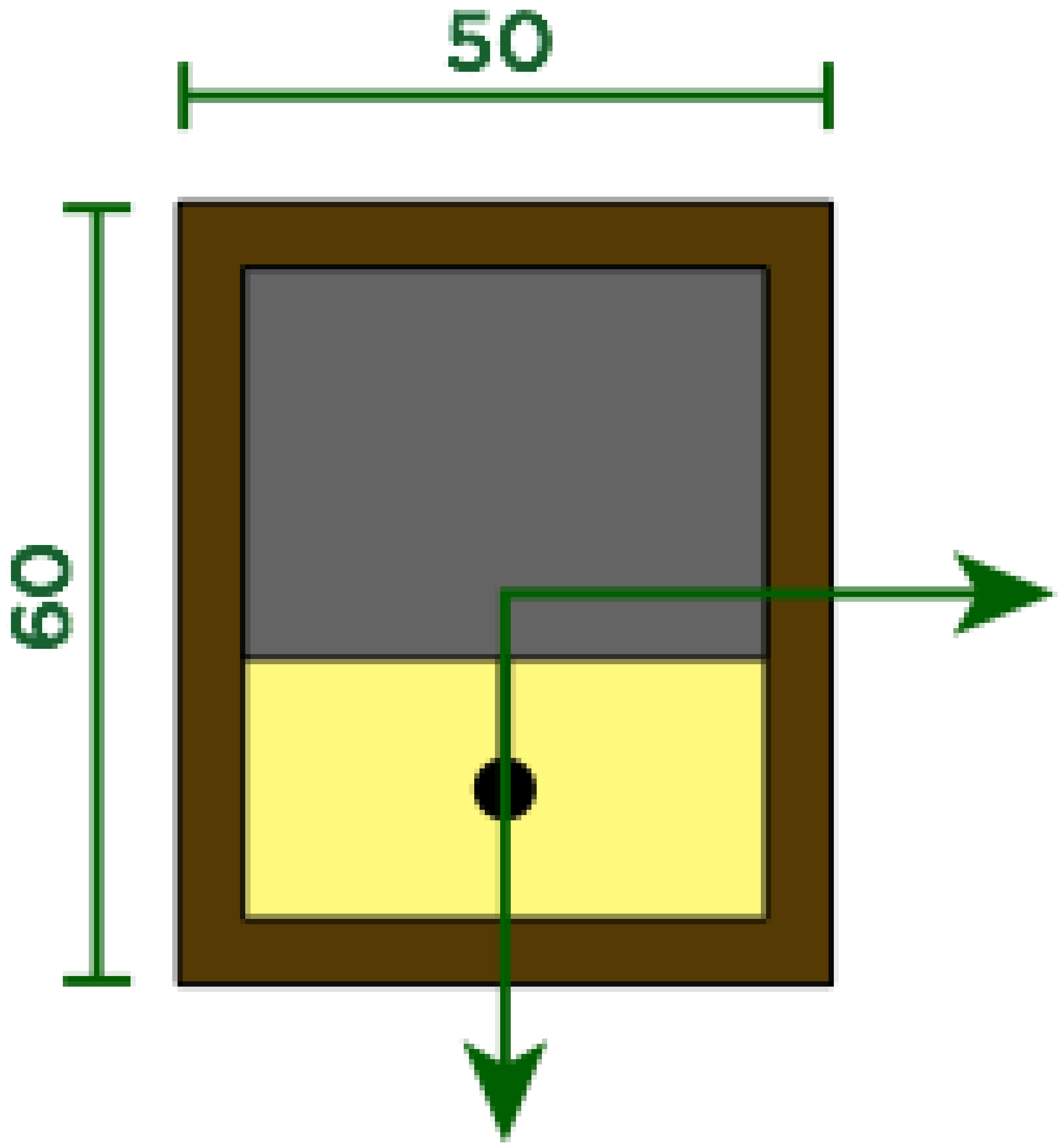

50
100



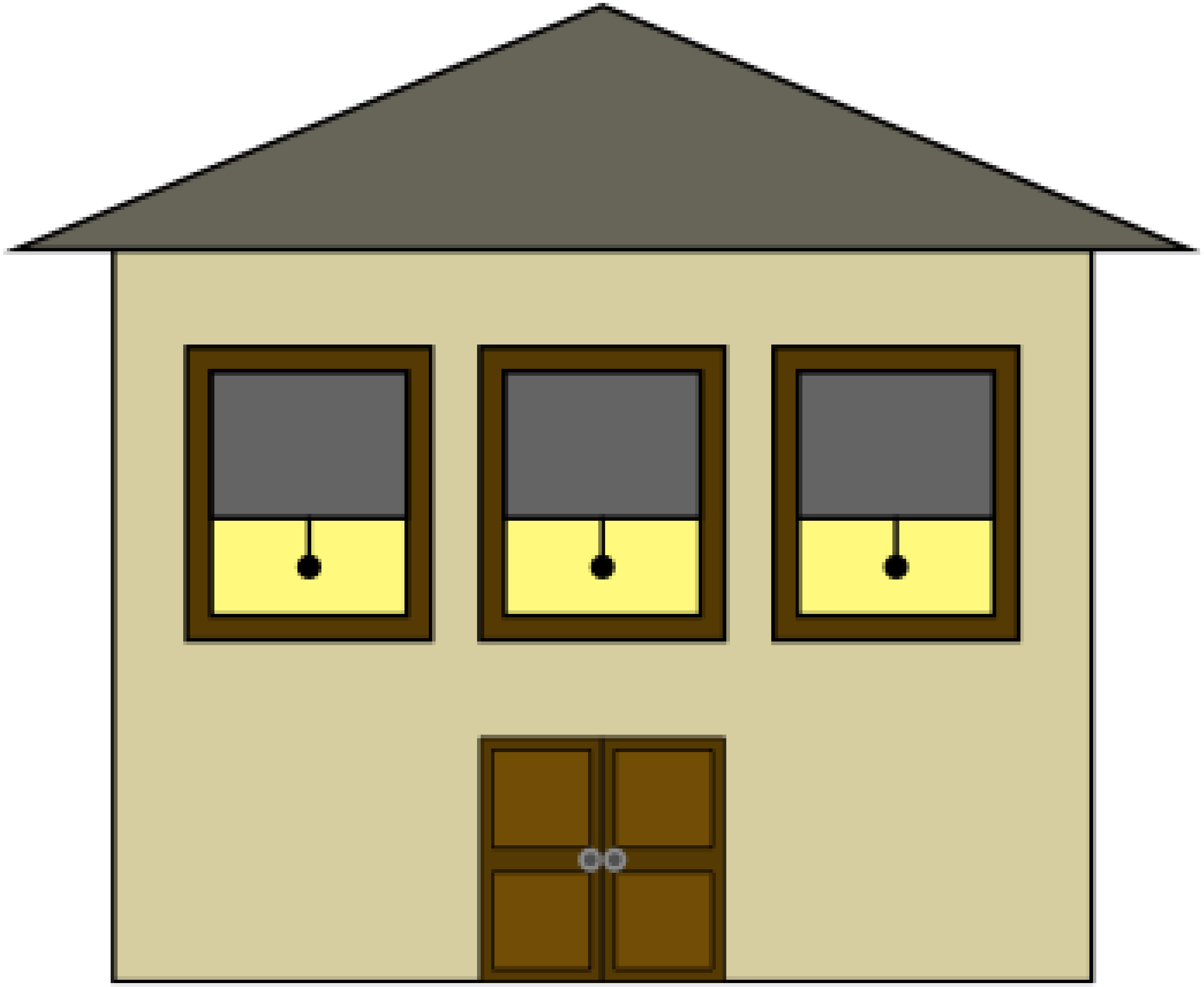
```
function door() {
  fill("#553A03");
  rect(-25, -50, 50, 100);
  fill("#714D05");
  rect(-20, -45, 40, 40);
  rect(-20, 5, 40, 40);
}
```



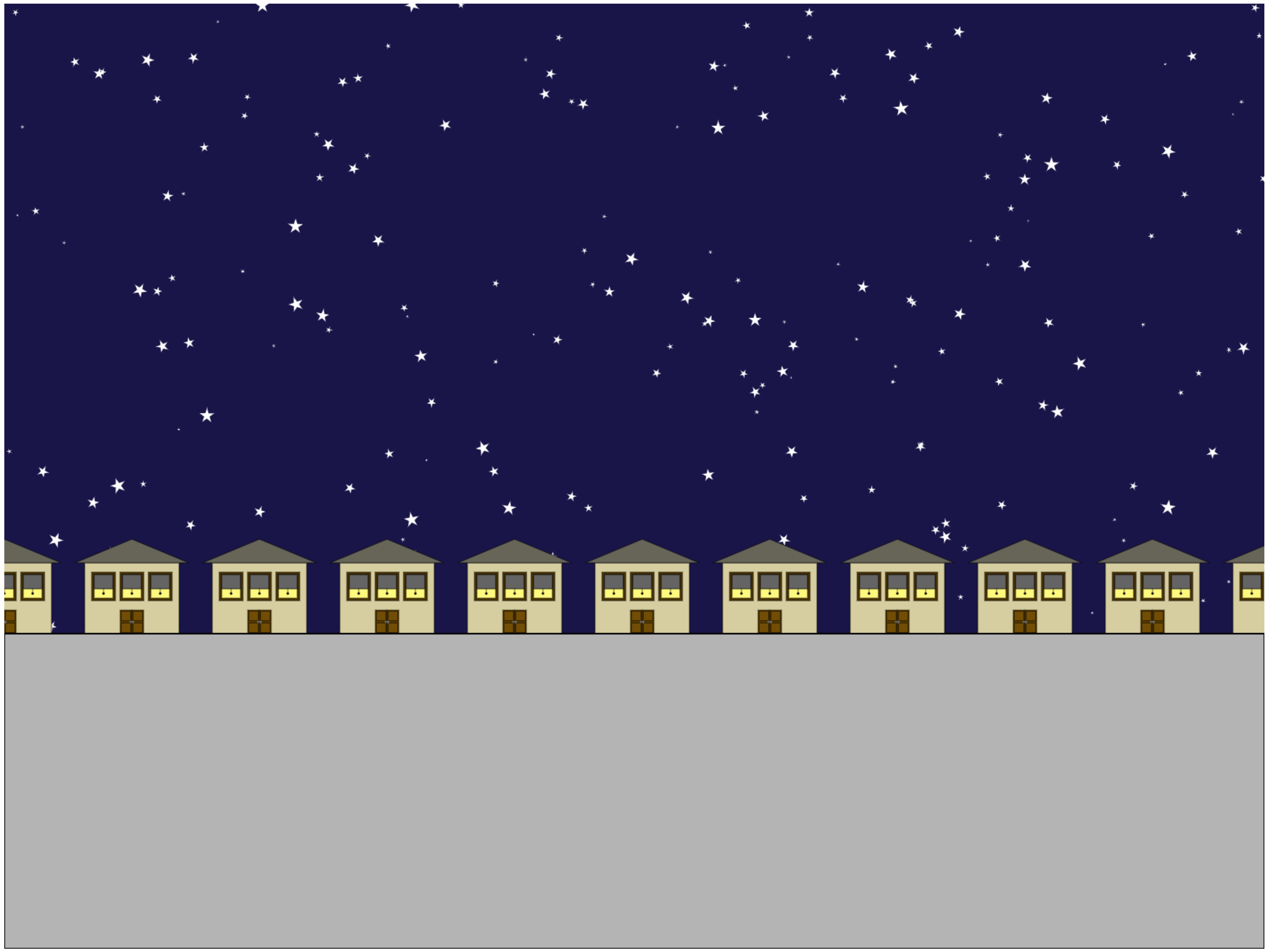
```
function door()
{
  fill( 85, 58, 3 );
  rect( -25, -50, 50, 100 );
  fill( 113, 77, 5 );
  rect( -20, -45, 40, 40 );
  rect( -20, 5, 40, 40 );

  push();
  translate( 20, 0 );
  scale( 0.1 );
  doorknob();
  pop();
}
```



```
function windowFrame() {
   fill(85, 58, 3);
   rect(-25, -30, 50, 60);
   fill(255, 249, 126);
   rect(-20, -25, 40, 50);
   fill(100);
   rect(-20, -25, 40, 30);
   line(0, 5, 0, 15);
   fill(0);
   ellipse(0, 15, 4, 4);
}
```

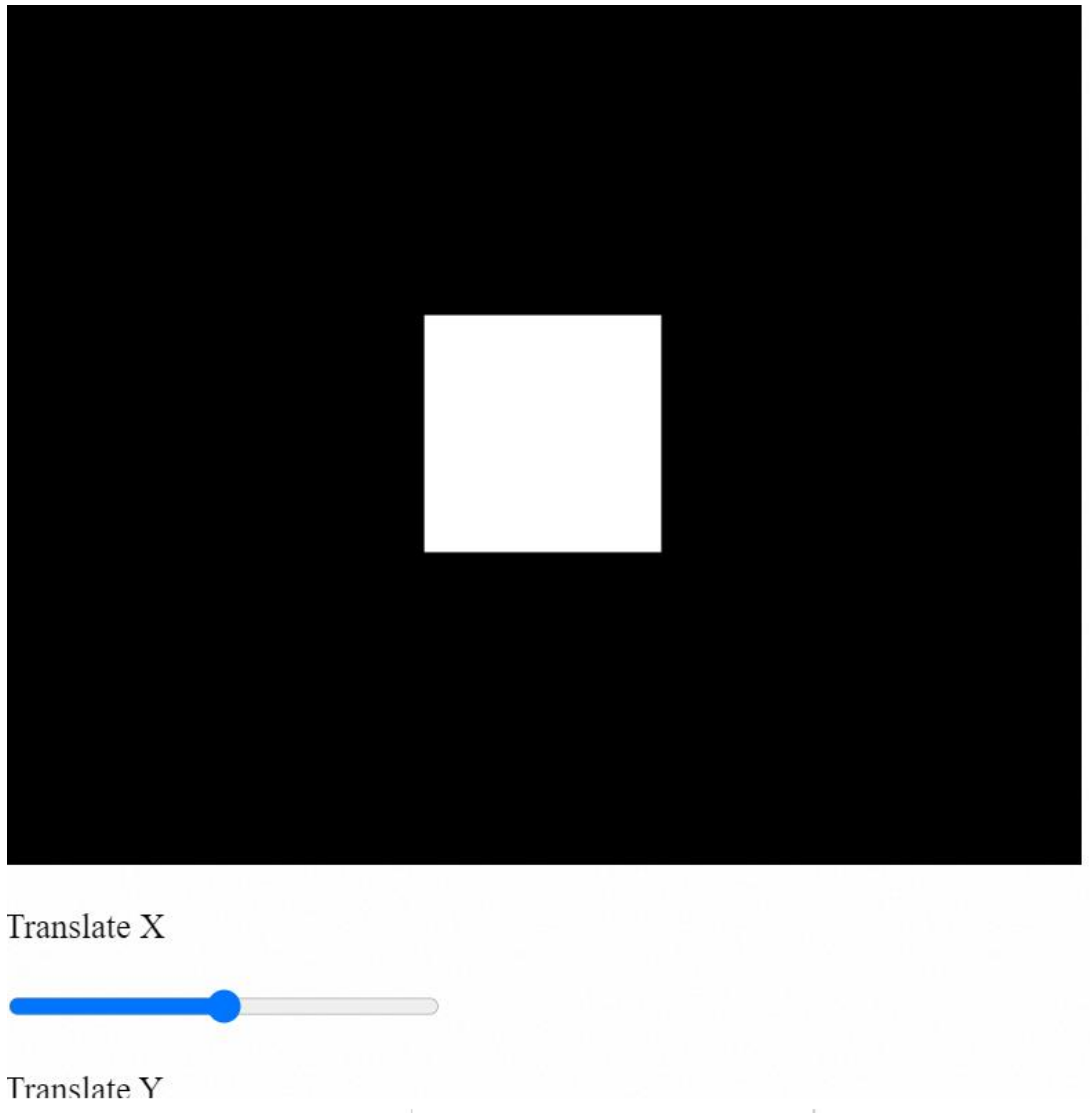


Example: Hierarchical Street



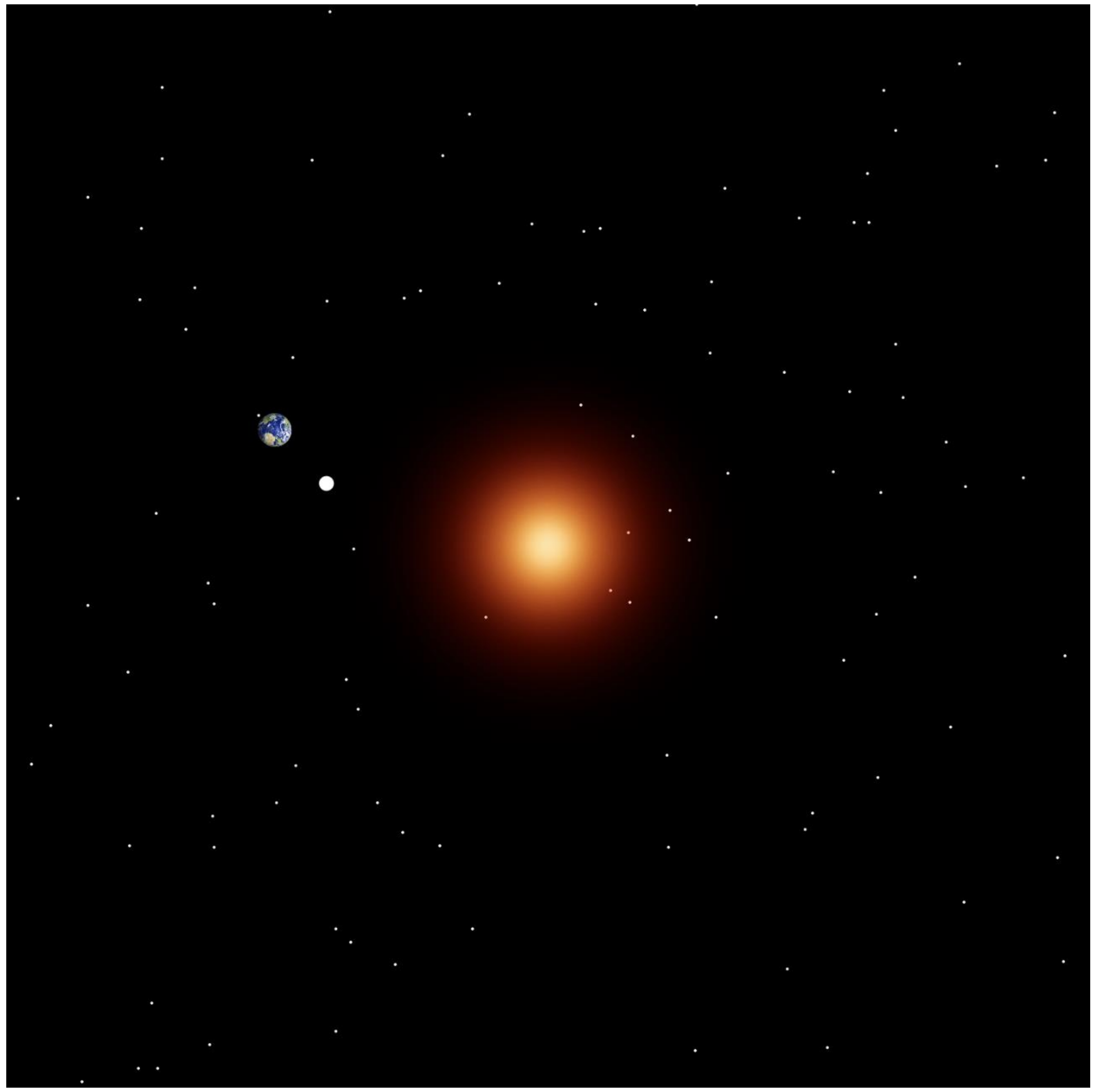
https://openprocessing.org/sketch/1149178

Example: TRS Visualization



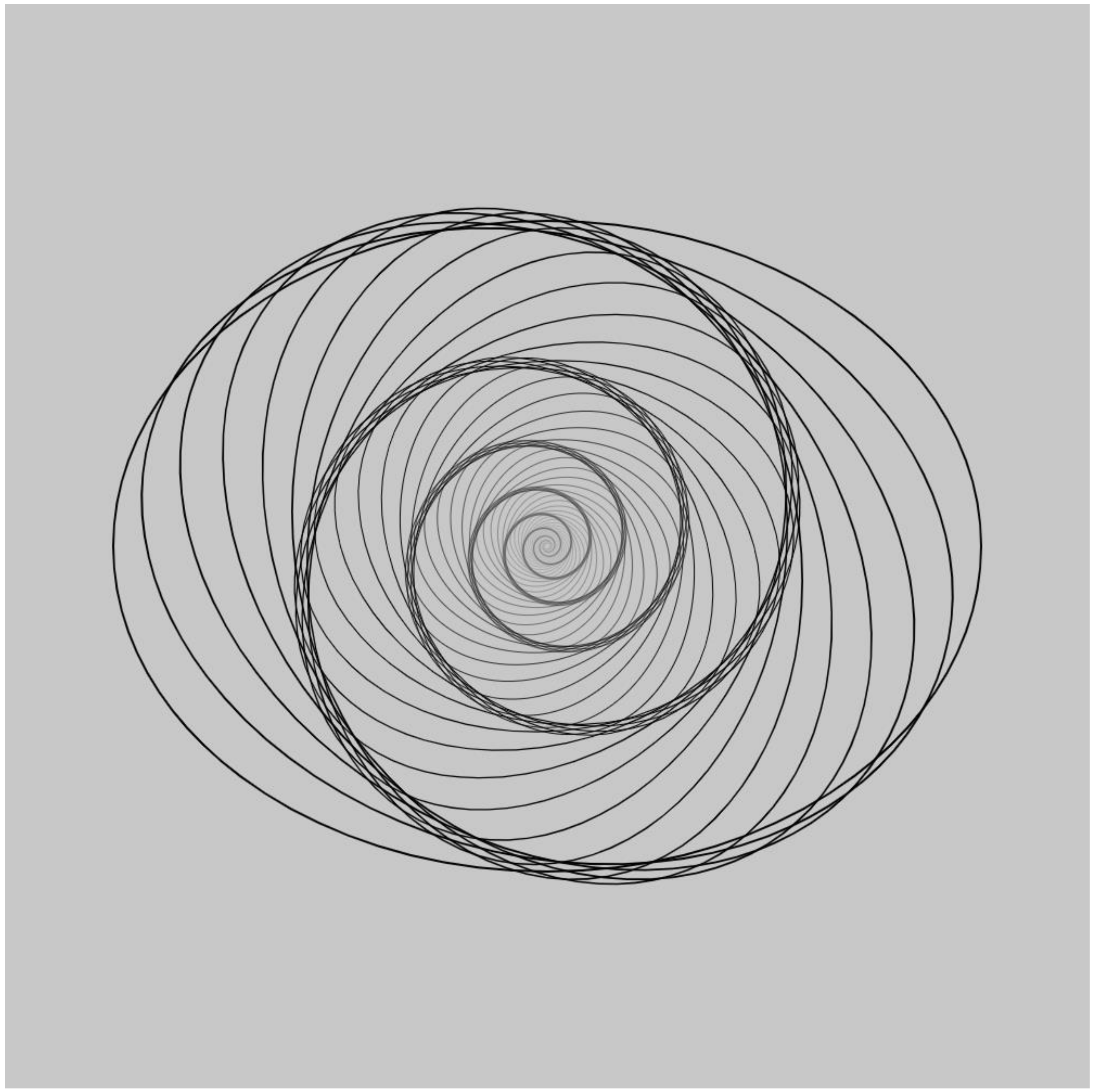
https://openprocessing.org/sketch/1149199

Example: Planets



https://openprocessing.org/sketch/1149234

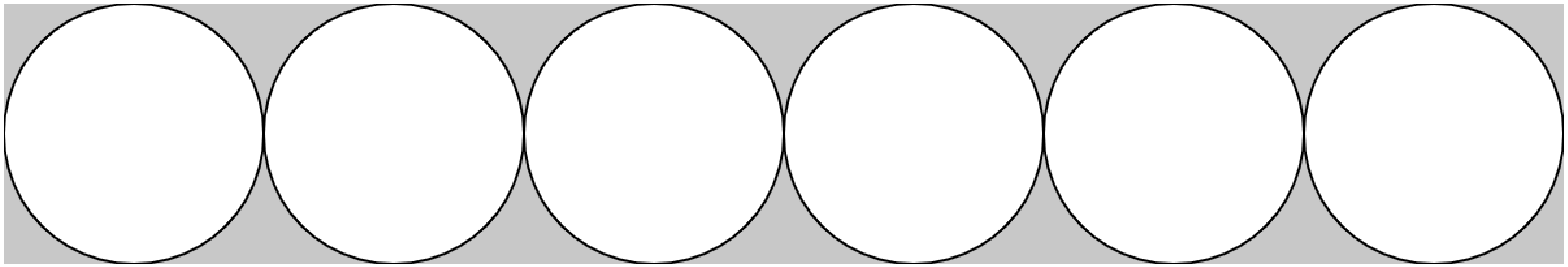
Example: Flying Ellipses



https://openprocessing.org/sketch/1149196

Example: Accumulation

```
function setup() {
    createCanvas(600, 100);
    background(200);
    translate(50, 50);

    for (let i = 0; i < 6; ++i) {
        ellipse(0, 0, 100, 100);
        translate(100, 0);
    }
}
```



Example: Context Affects Everything

https://openprocessing.org/sketch/1149188