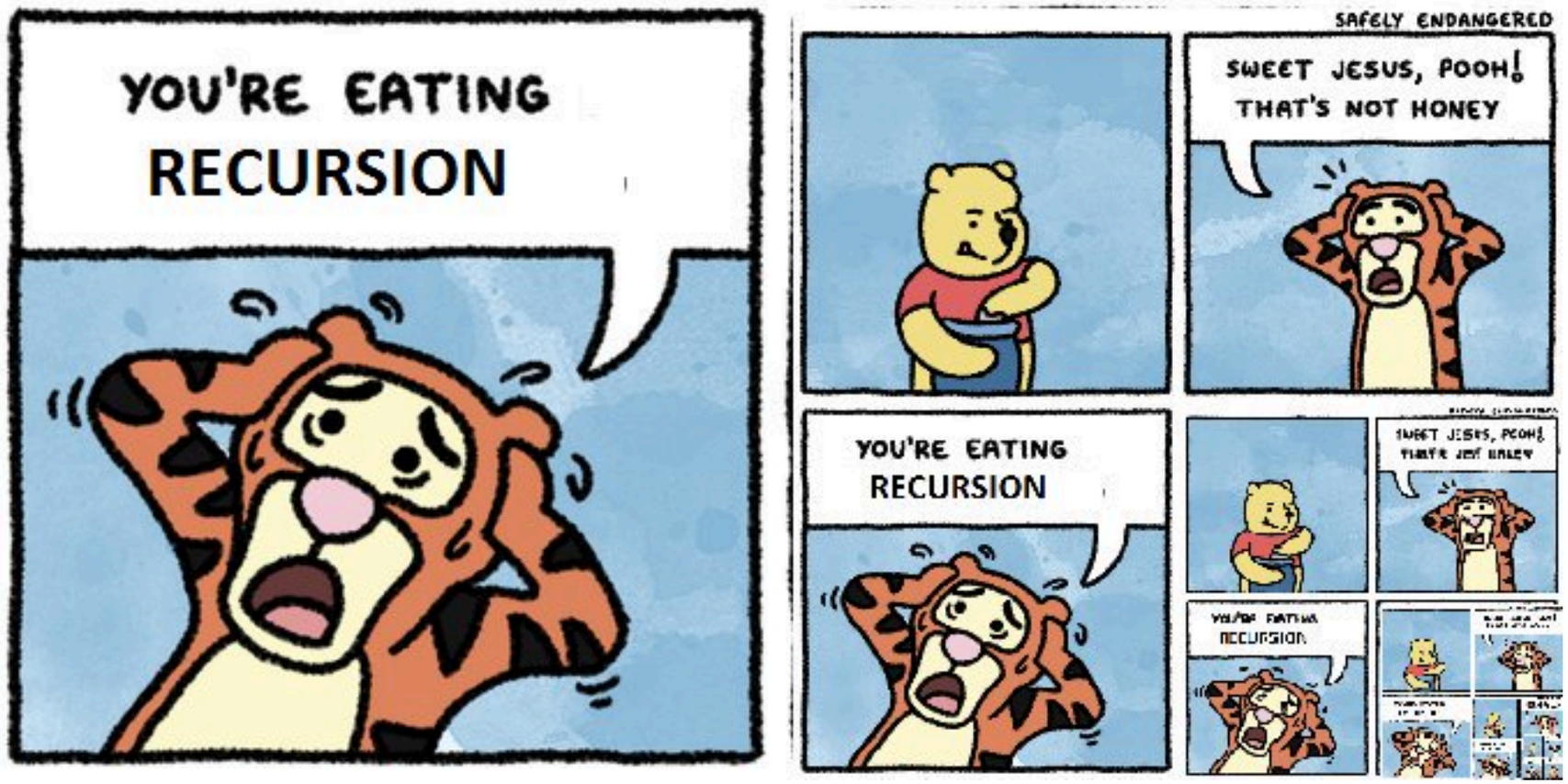
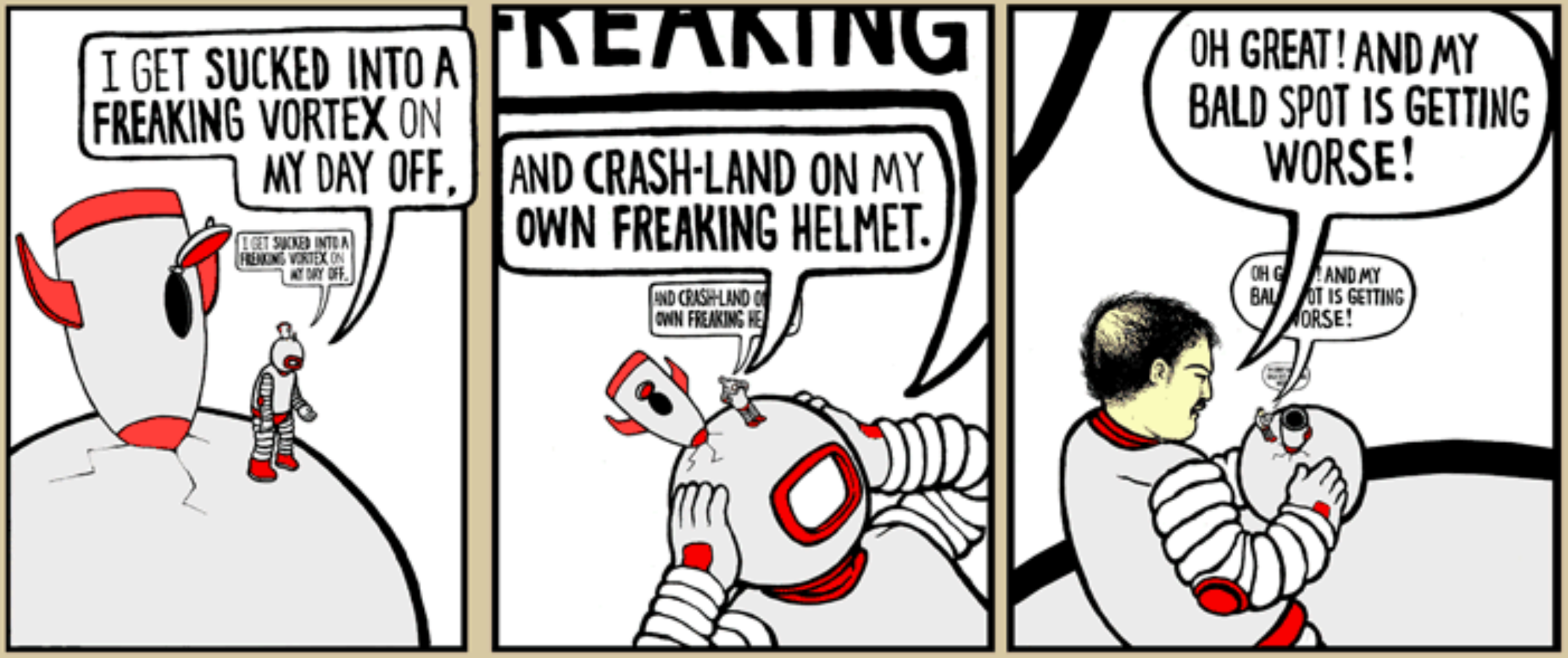
Module 07
CS 106 Winter 2018



[@Zerglinator]?



Perry Bible Fellowship [pbfcomics.com/94/]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recursivedrawing.com

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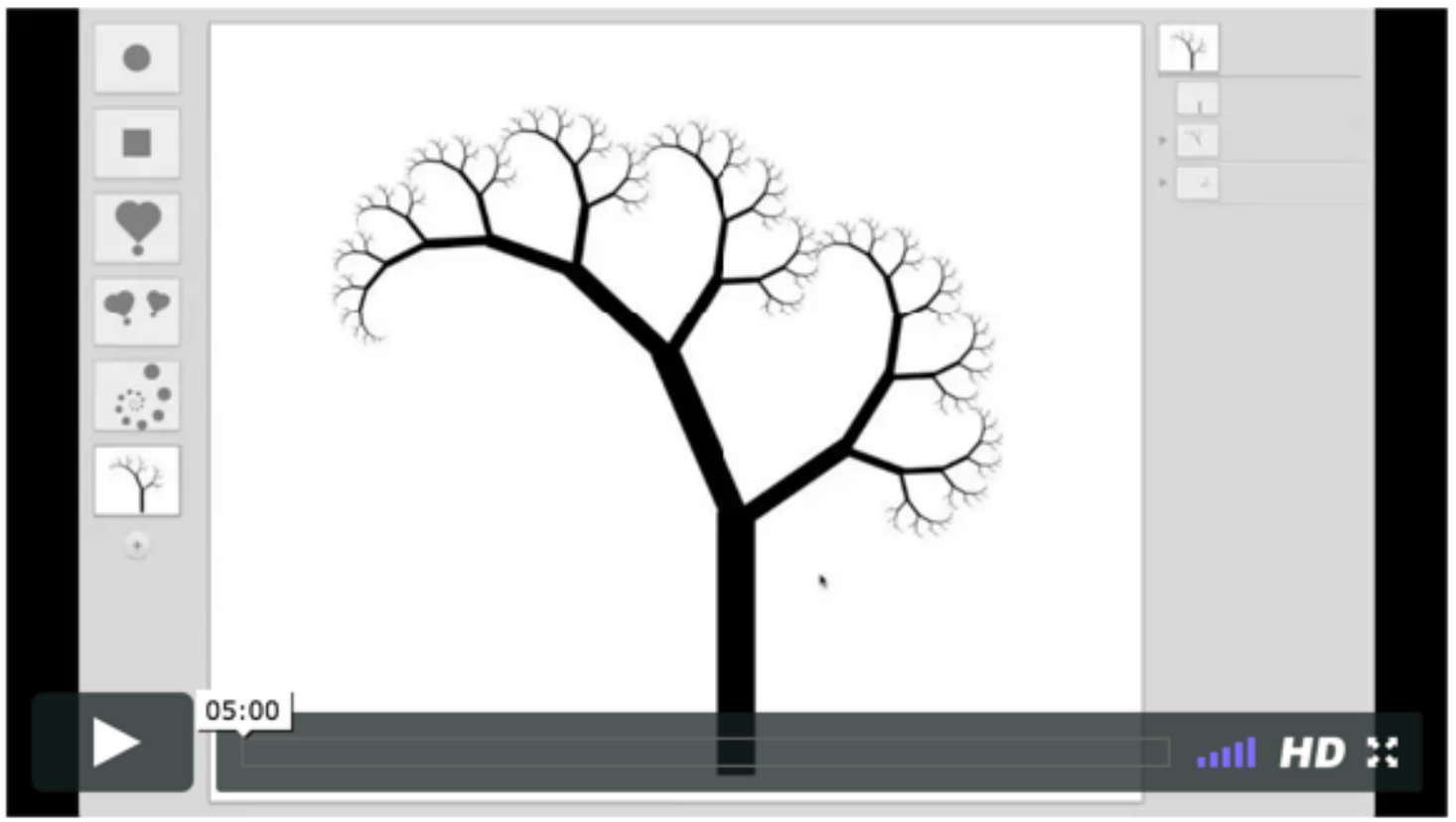
Recursive Drawing is an exploration of user interface ideas towards the development of a spatially-oriented programming environment.

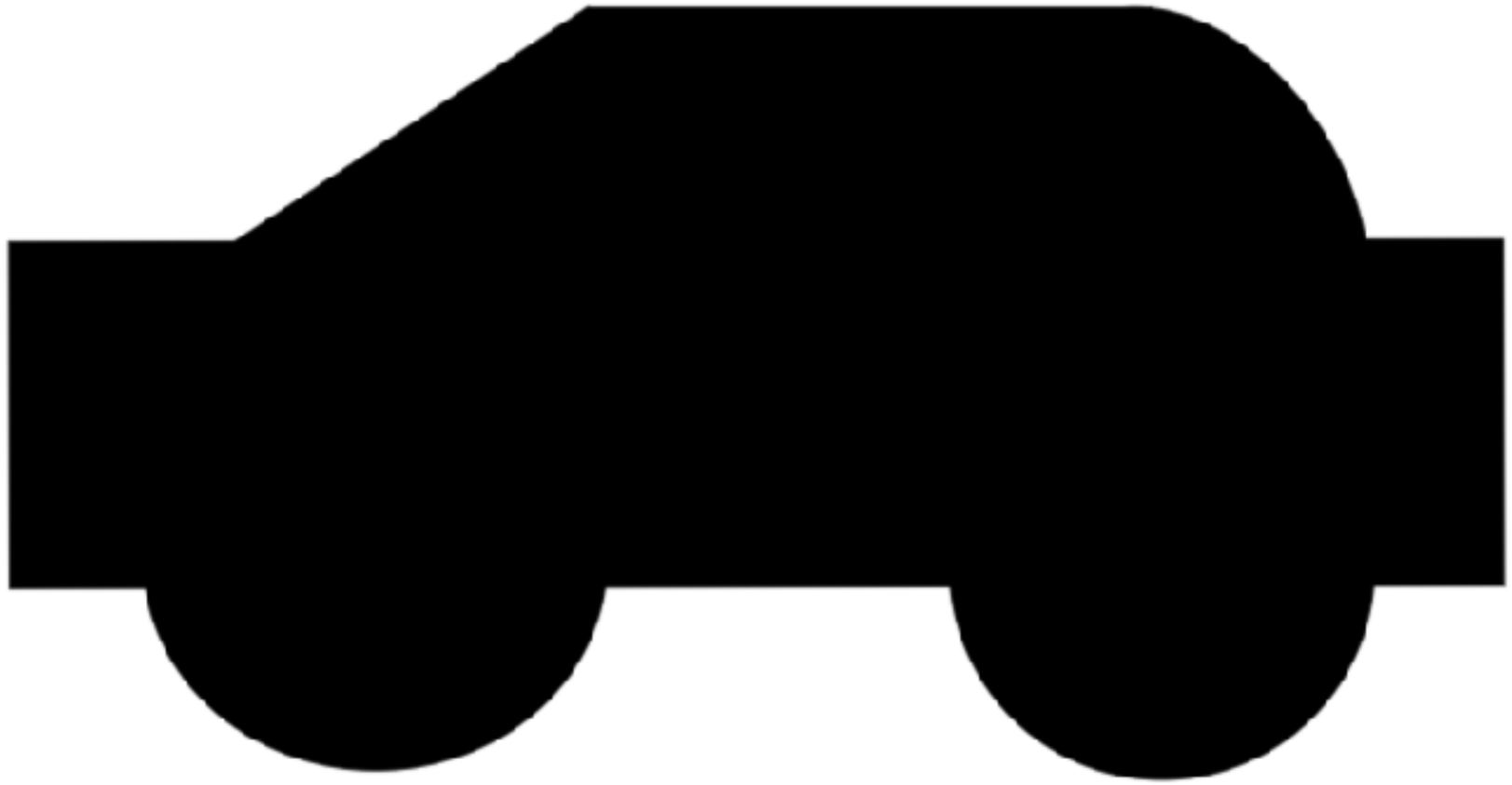


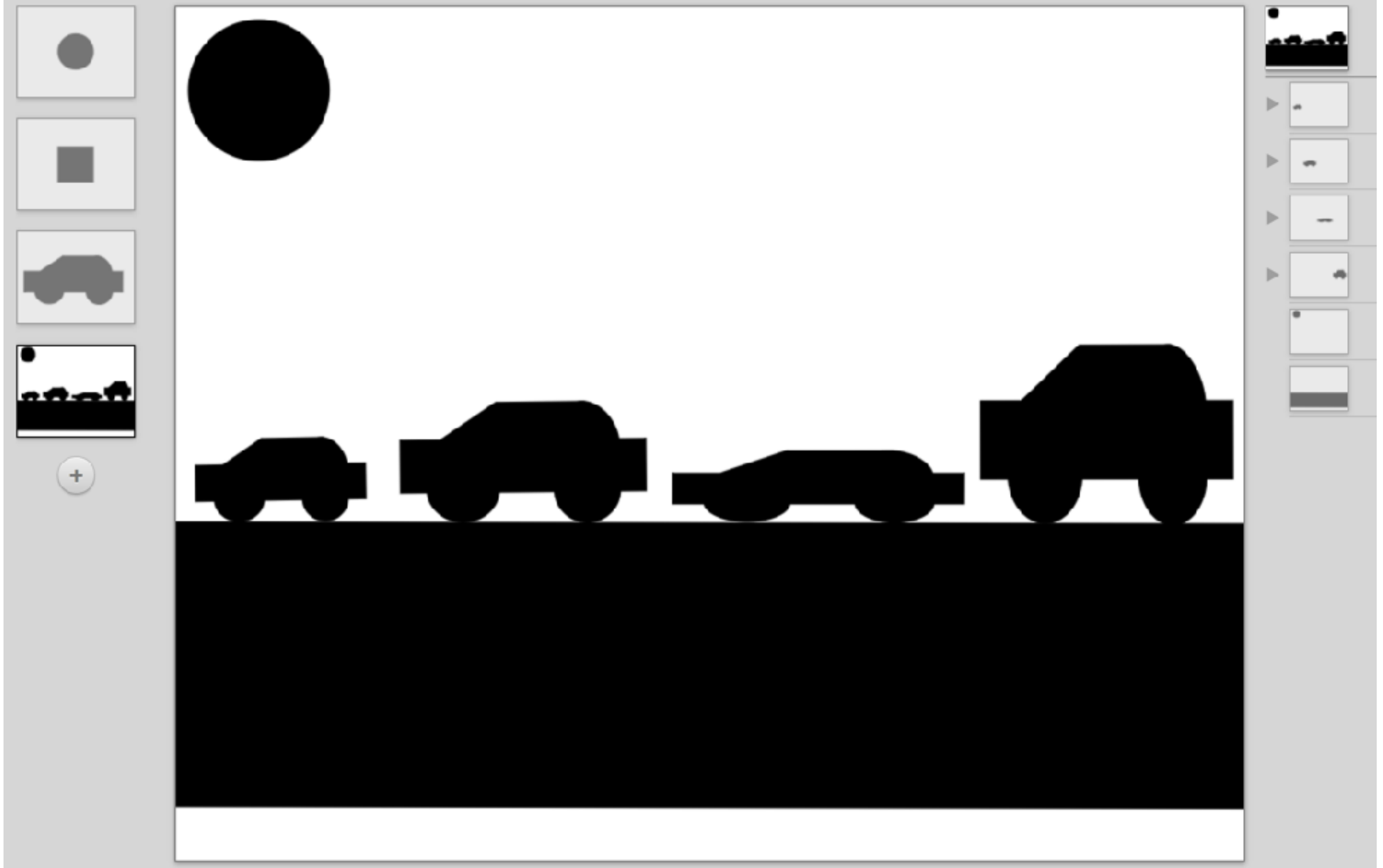
Start Drawing!

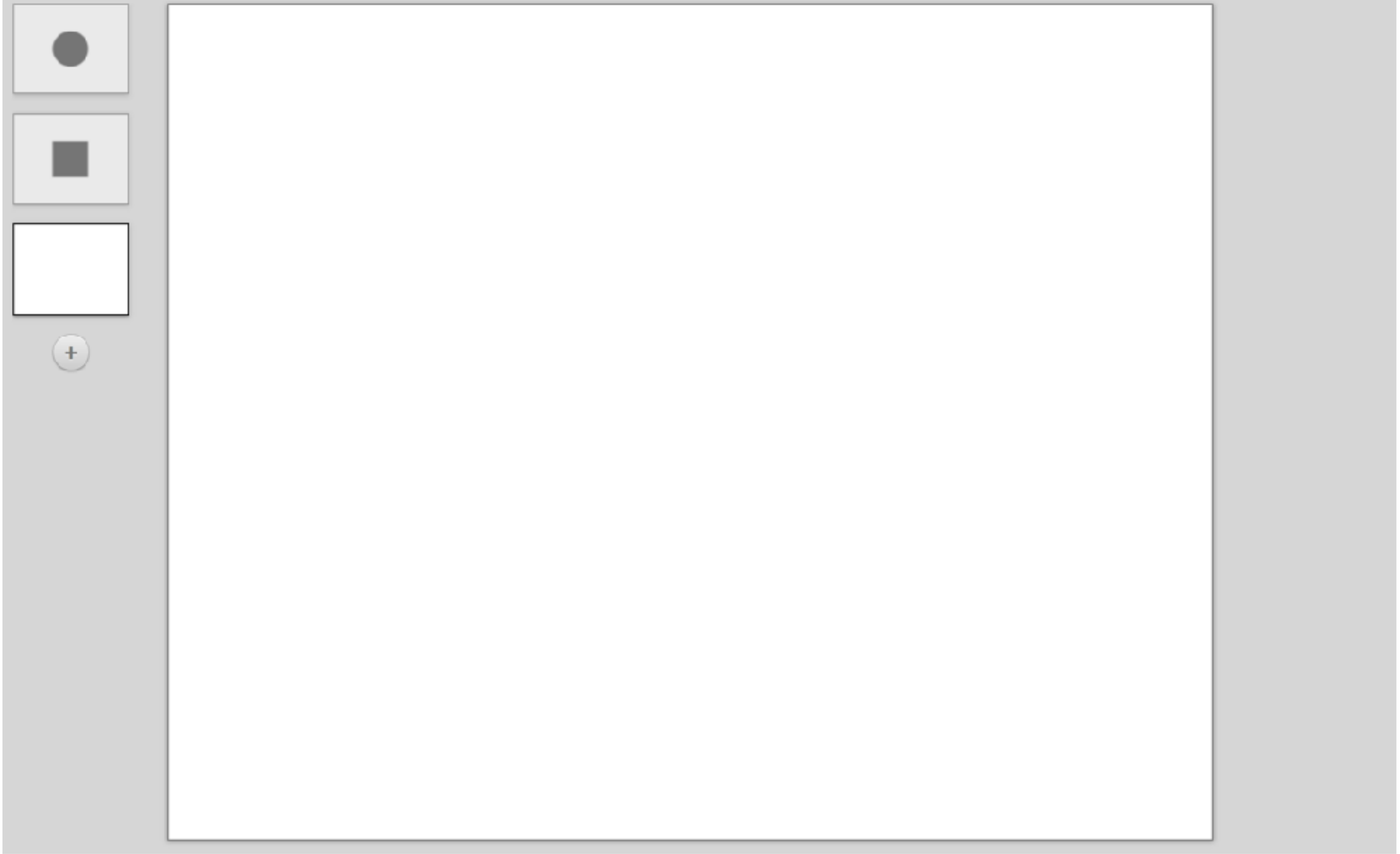
Complete list of instructions

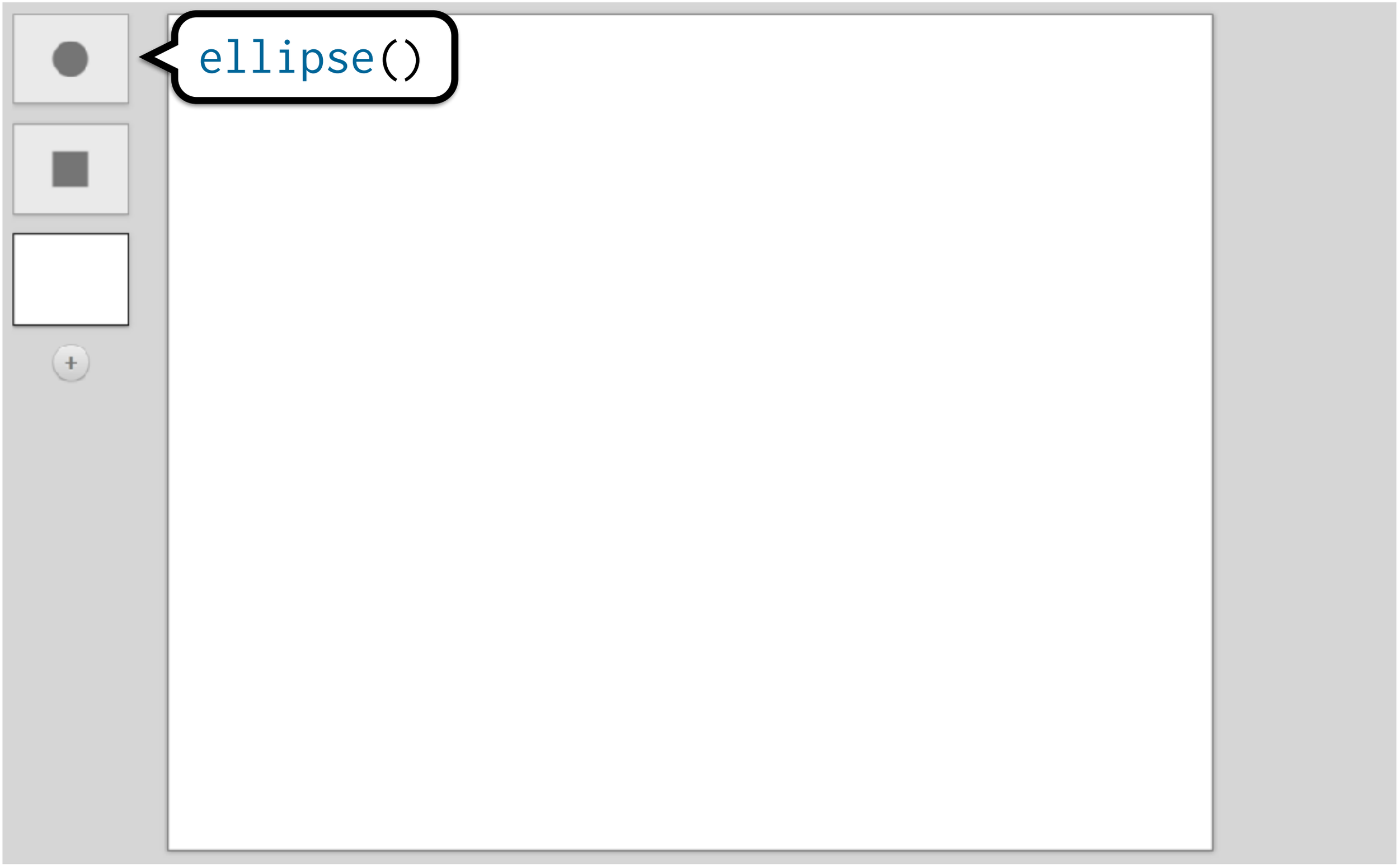
(written up by Rory O'Kane)

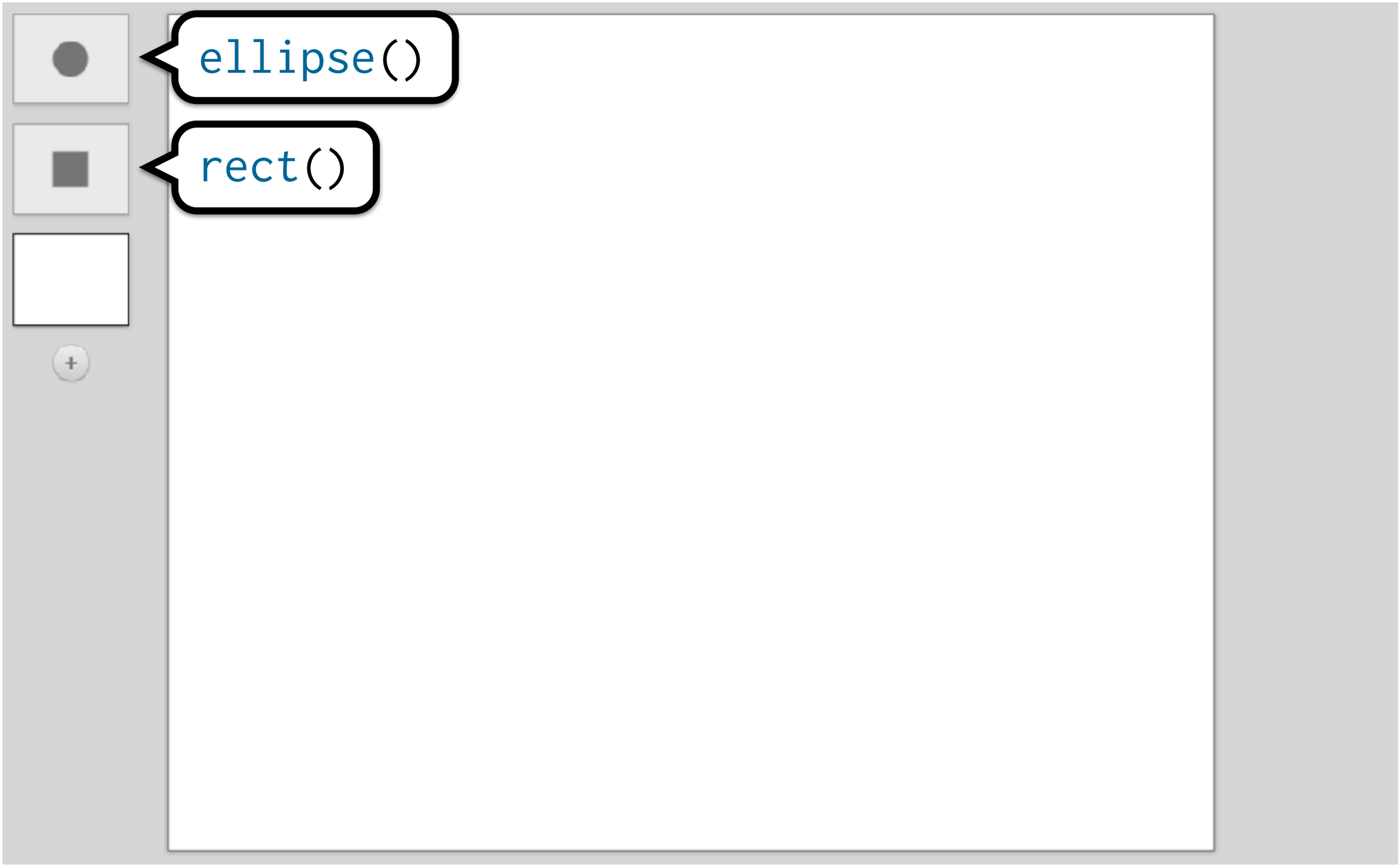
Recursive Drawing is by **Toby Schachman** for his **ITP** thesis project **Alternative Programming Interfaces for Alternative Programmers**.

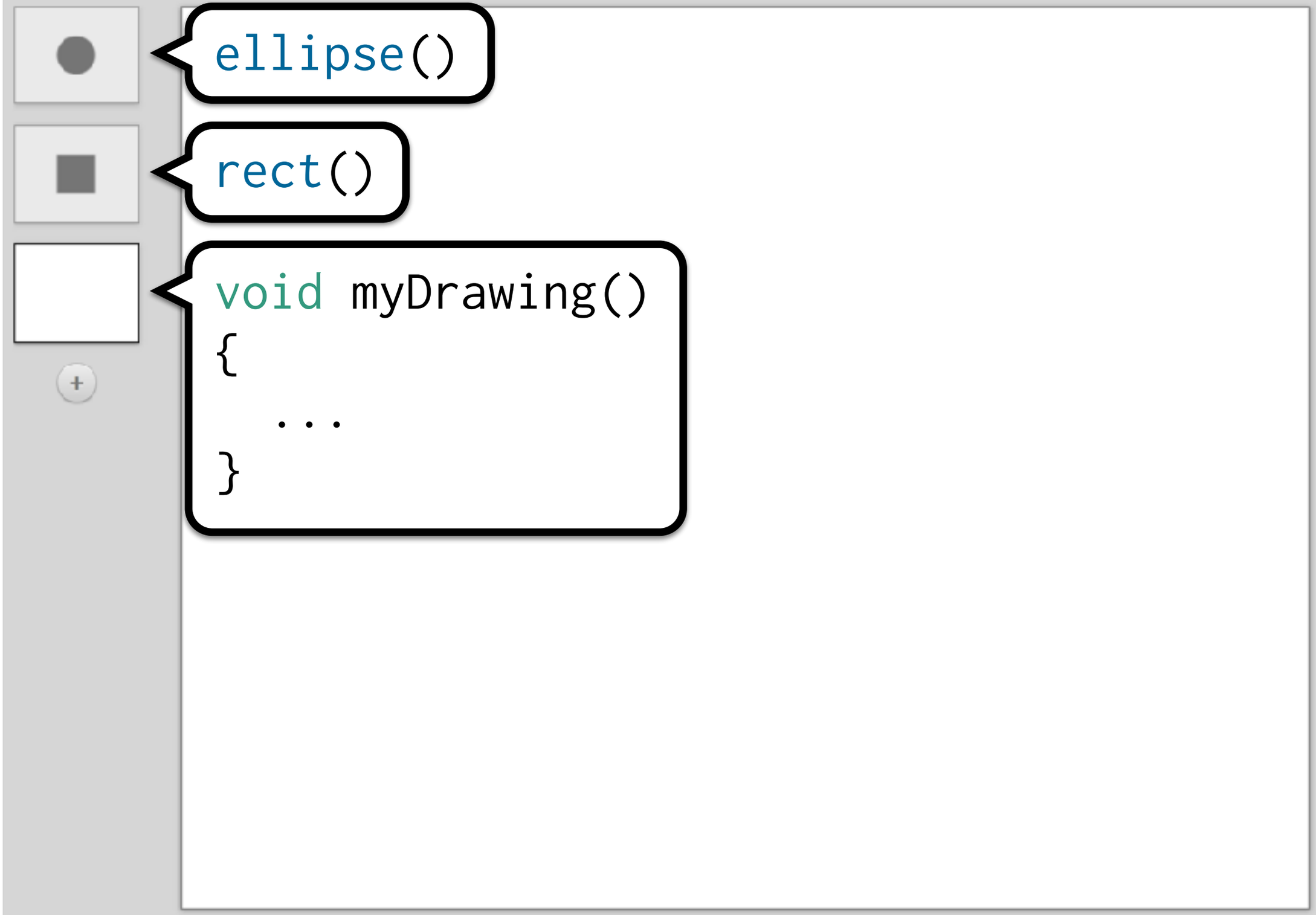


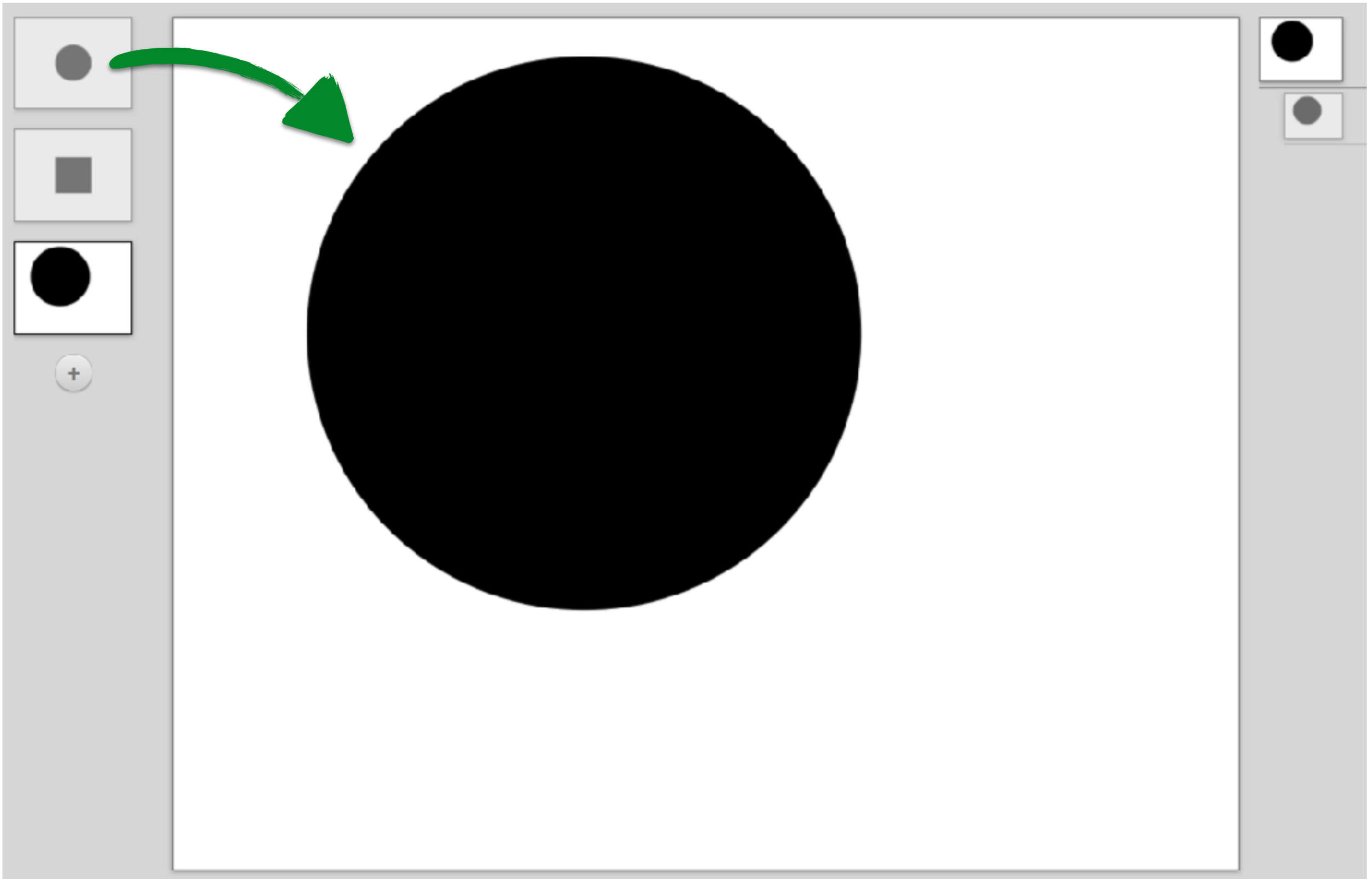


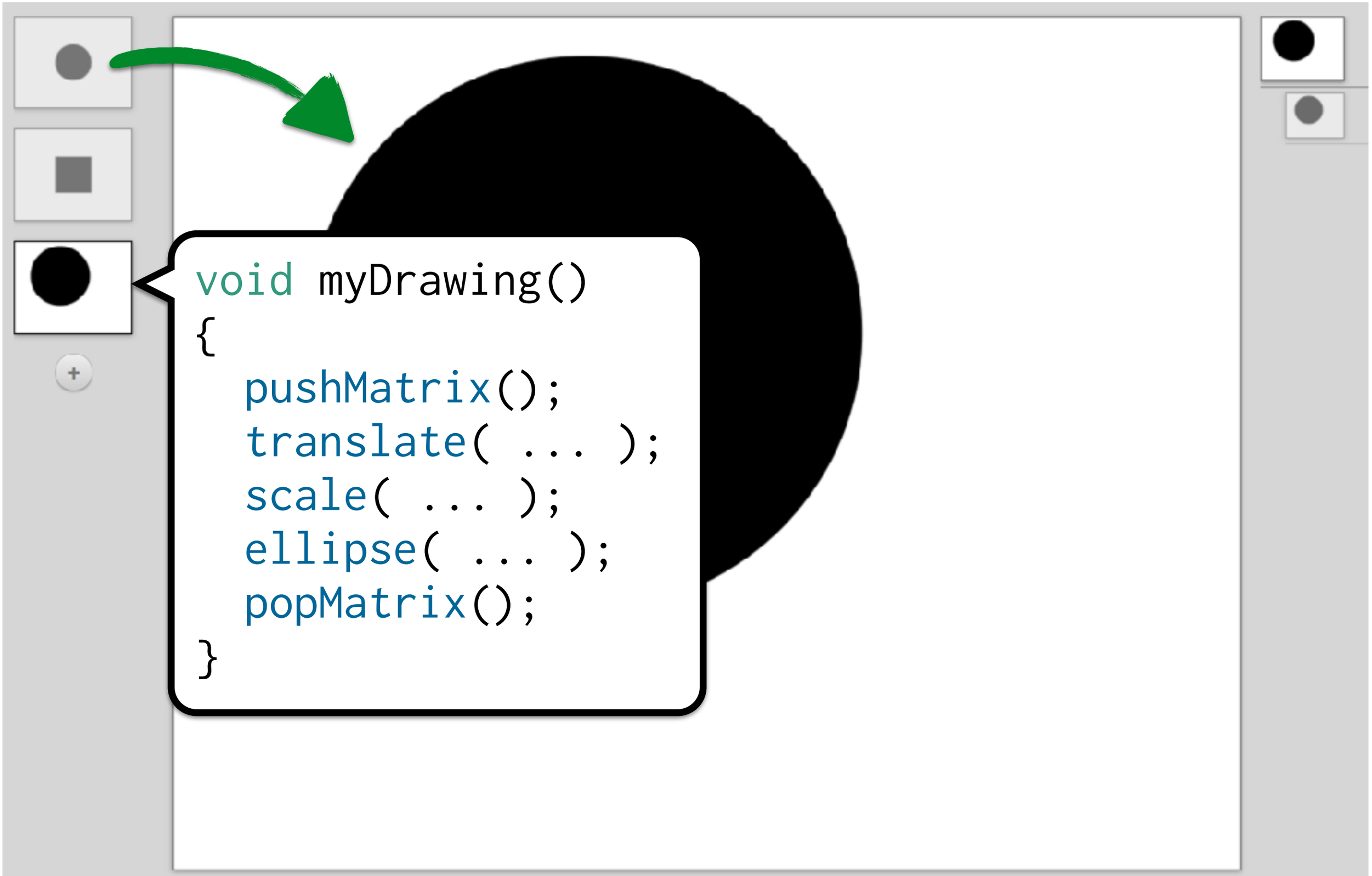


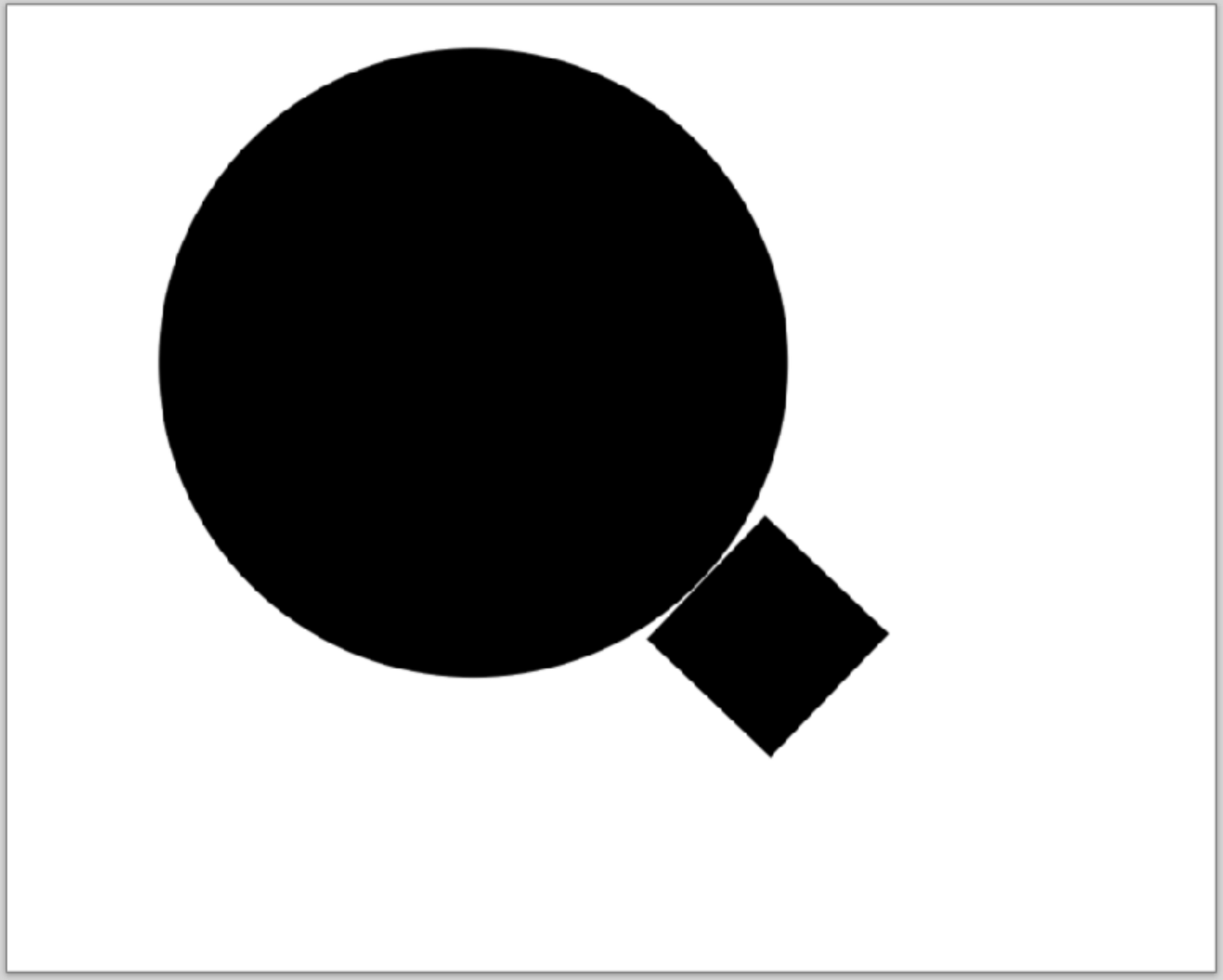

ellipse()

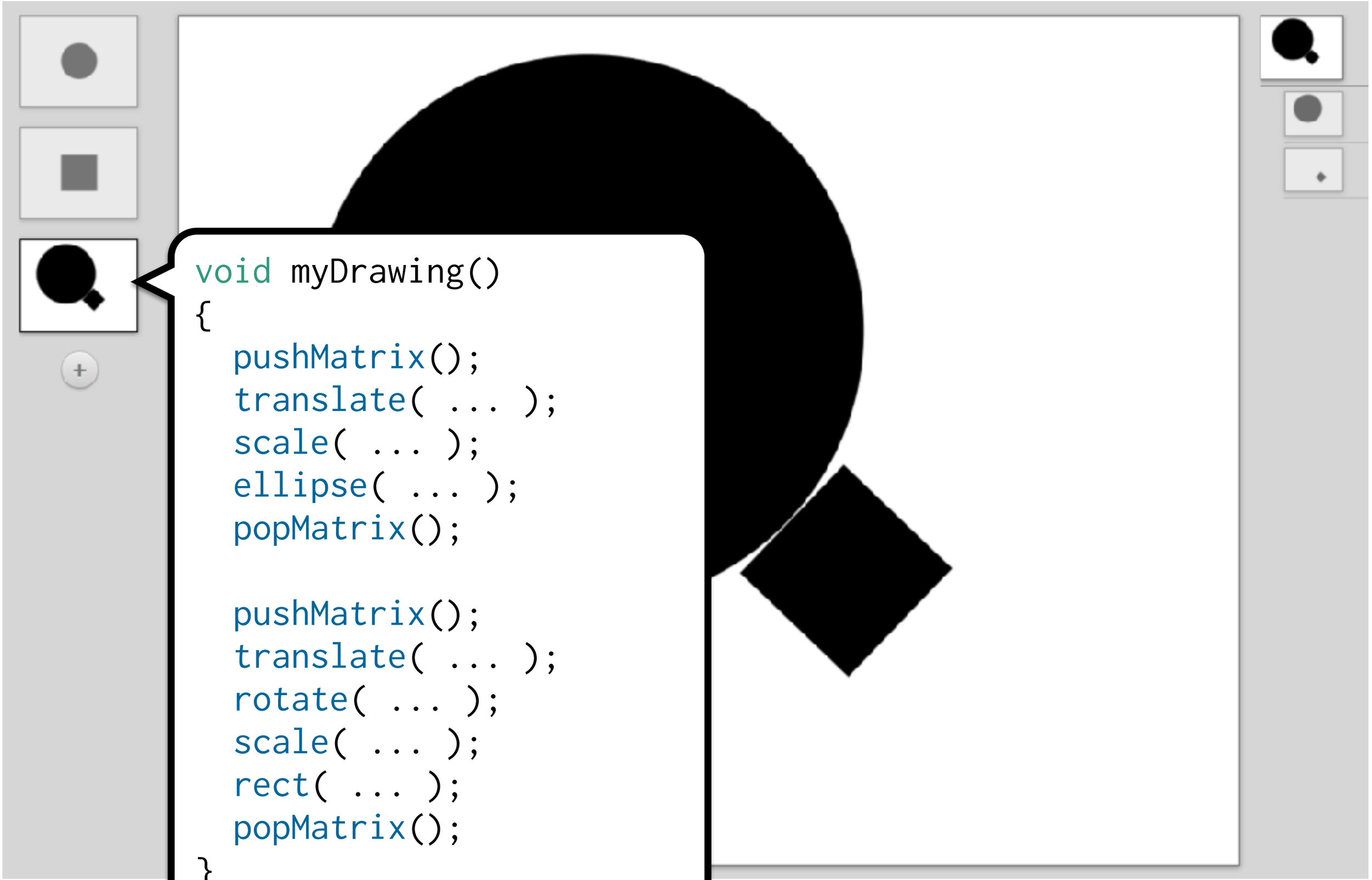

ellipse()
rect()

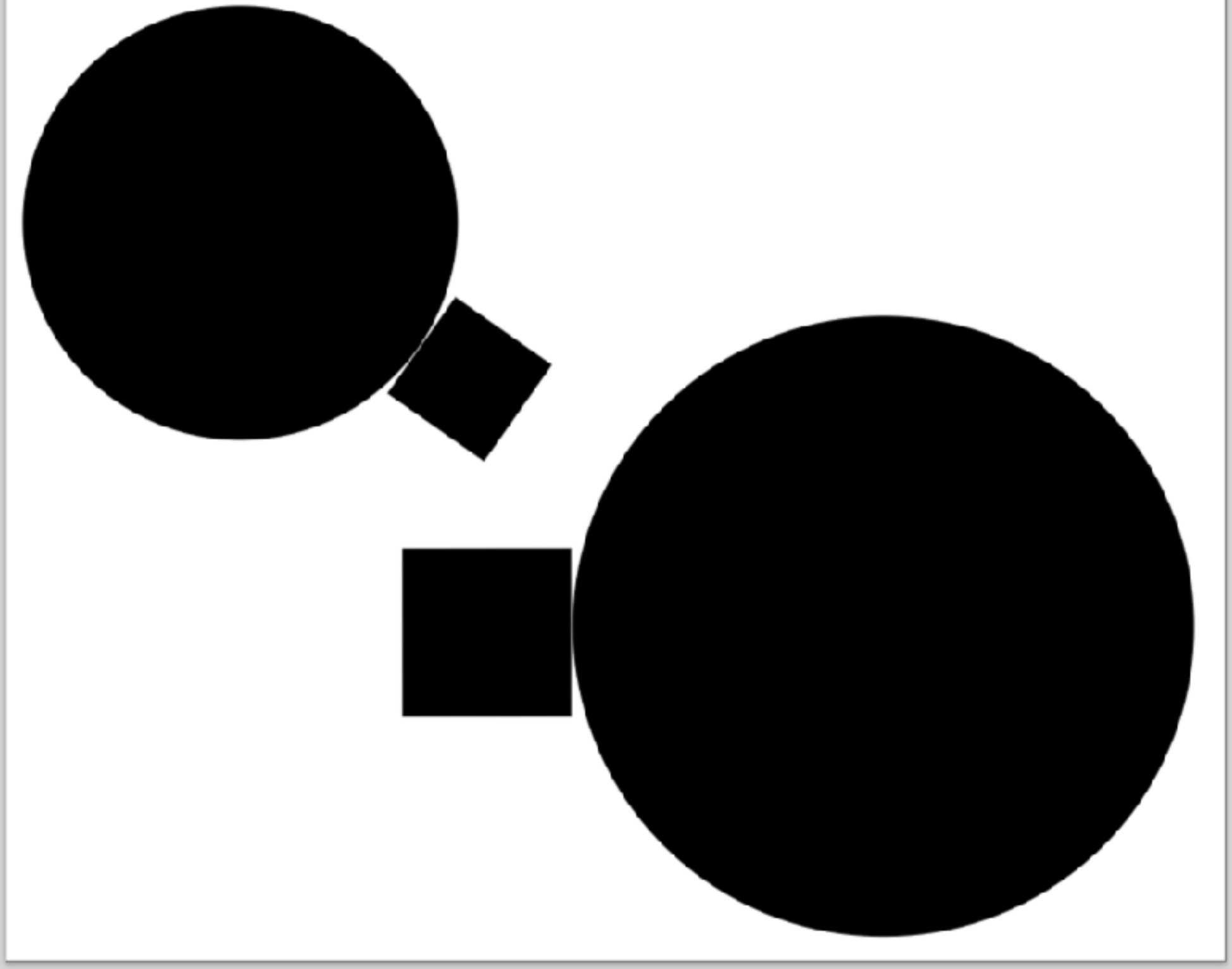

ellipse()
rect()
void myDrawing()
{
...
}

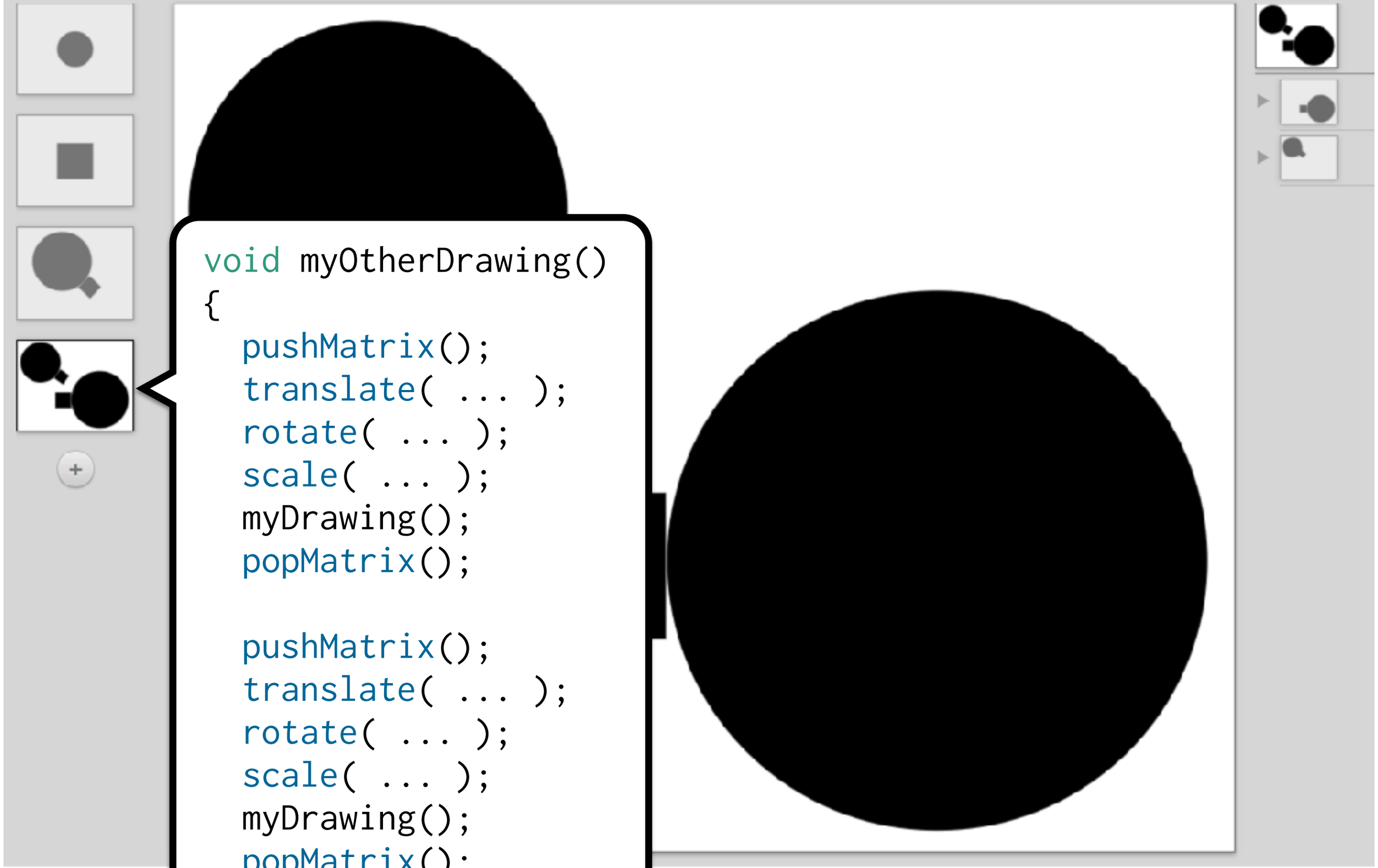


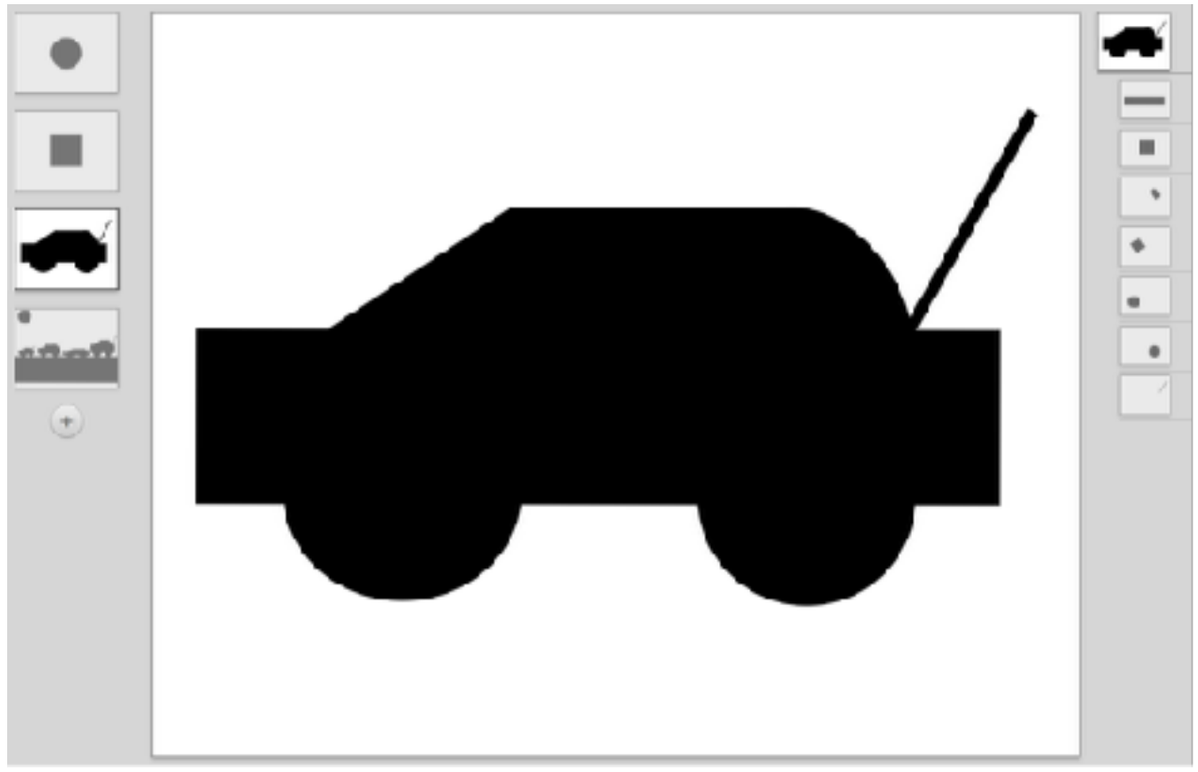

void myDrawing()
{
pushMatrix();
translate(...);
scale(...);
ellipse(...);
popMatrix();
}

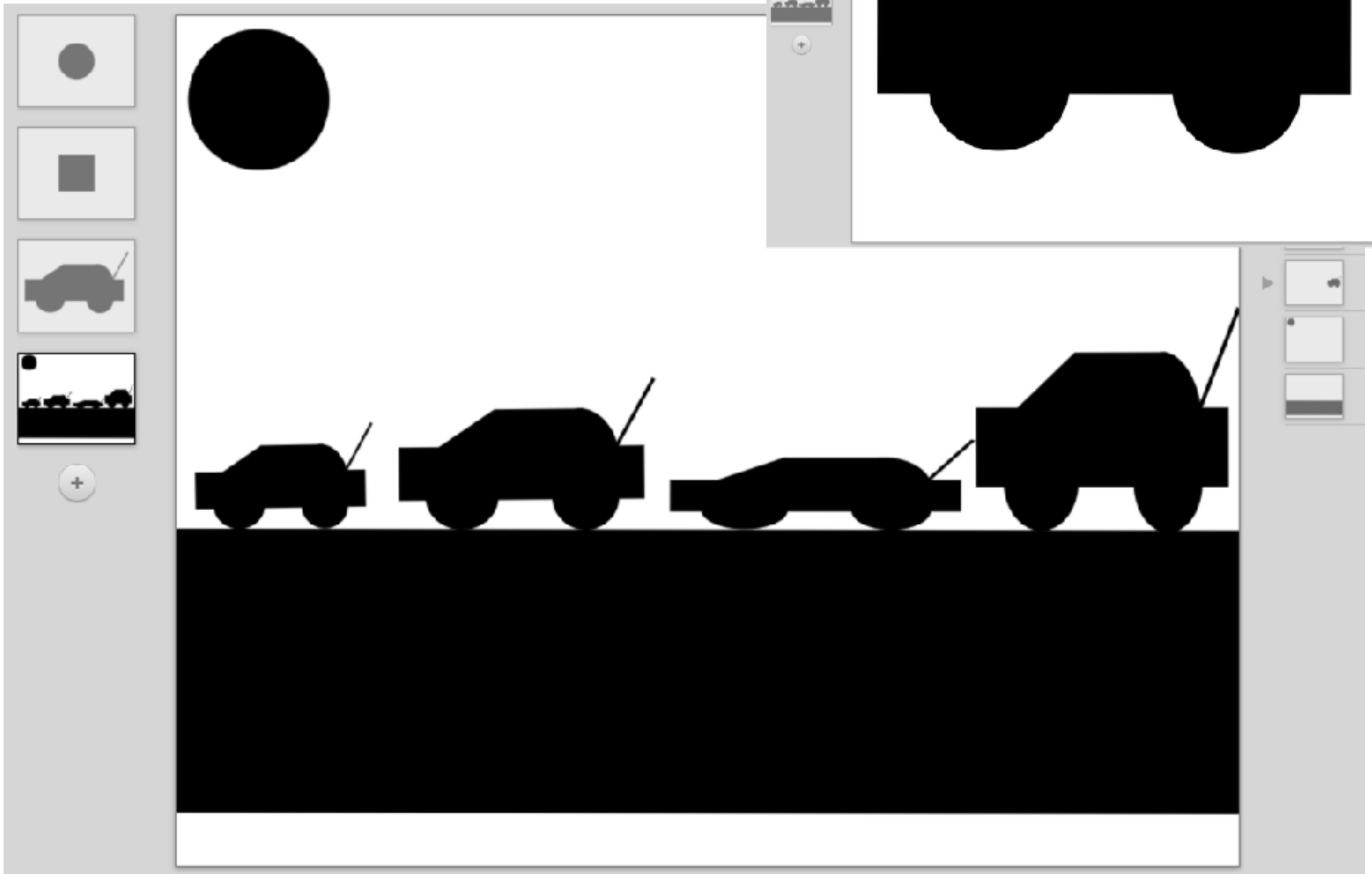


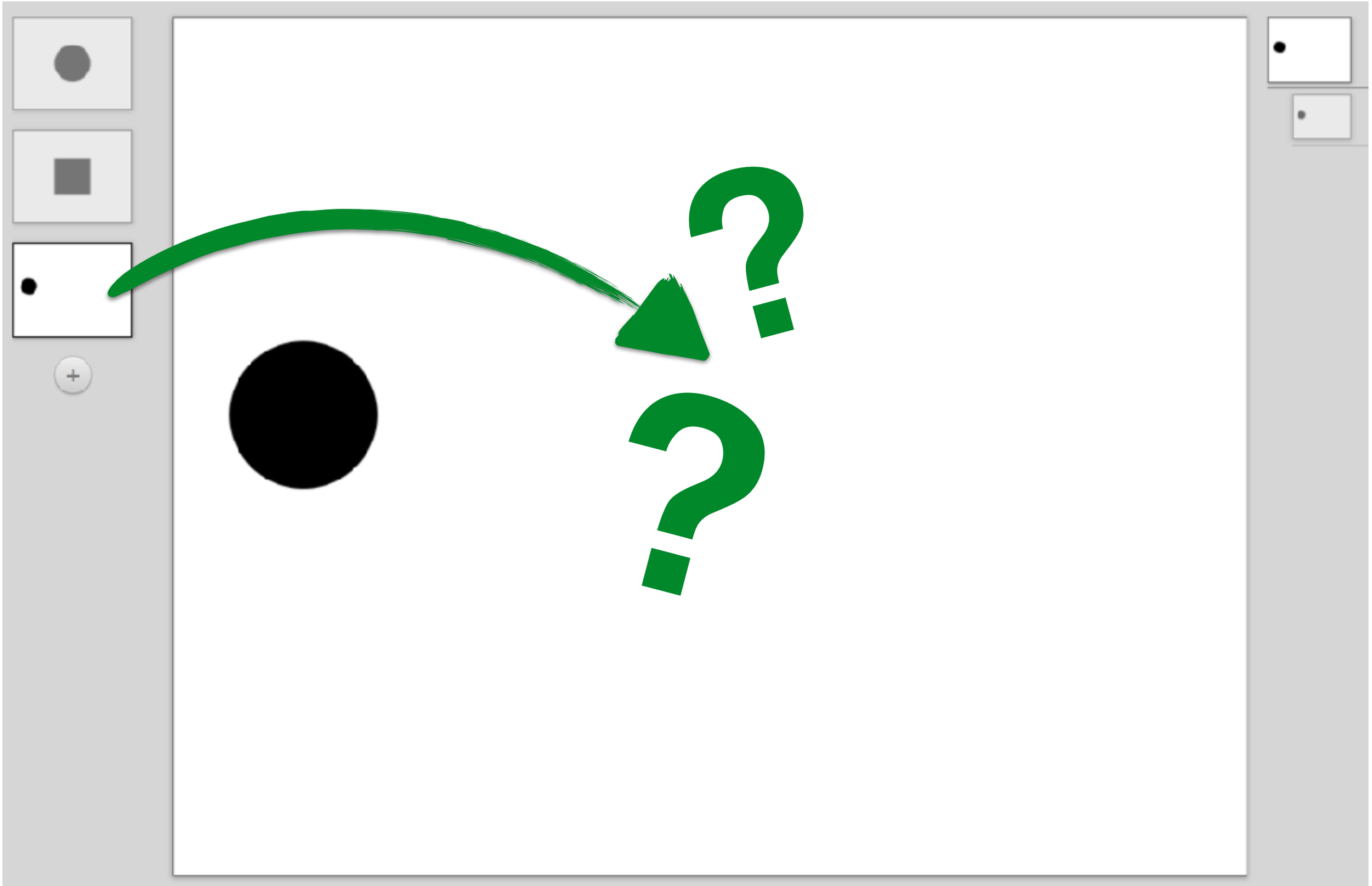

void myDrawing()
{
pushMatrix();
translate(...);
scale(...);
ellipse(...);
popMatrix();
pushMatrix();
translate(...);
rotate(...);
scale(...);
rect(...);
popMatrix();
}

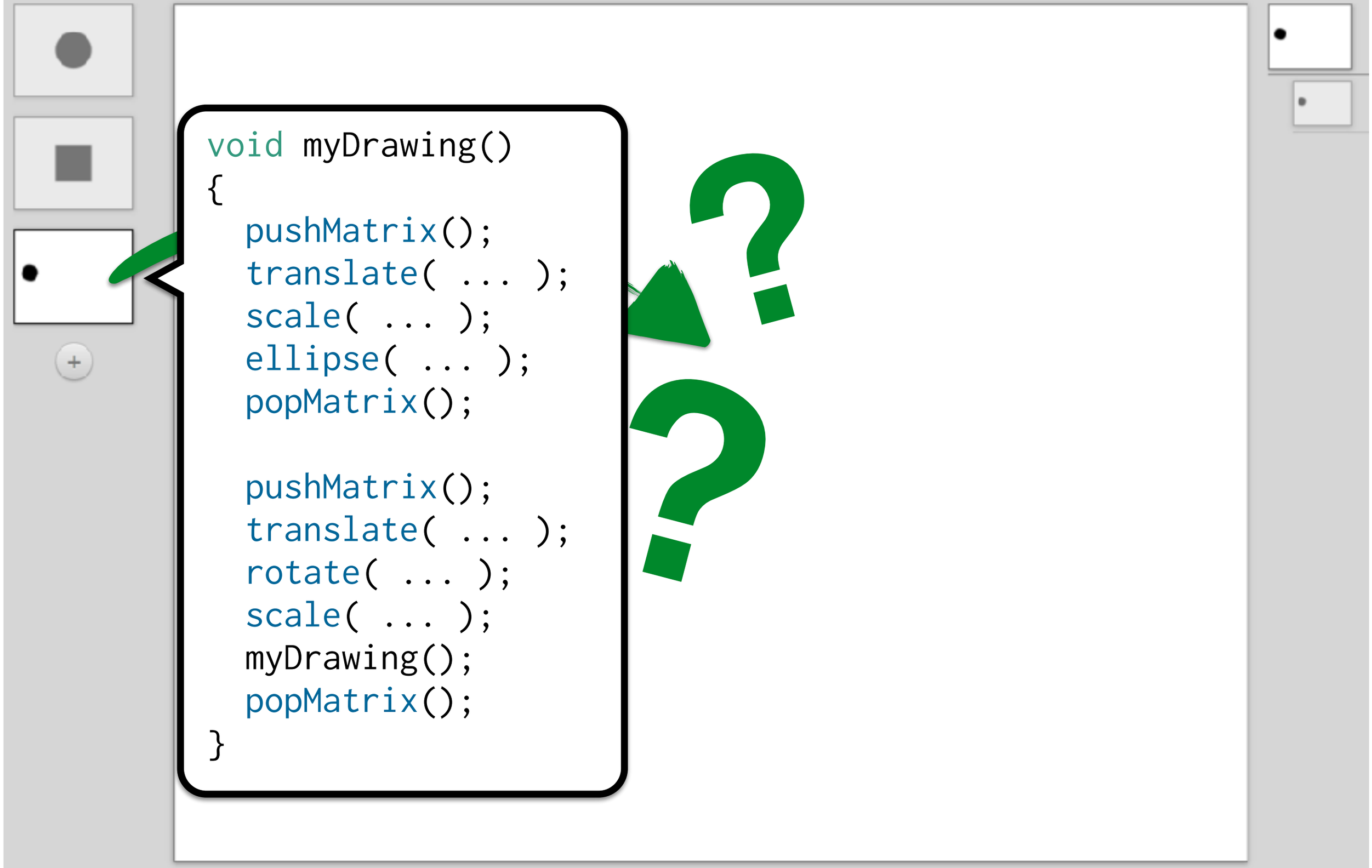


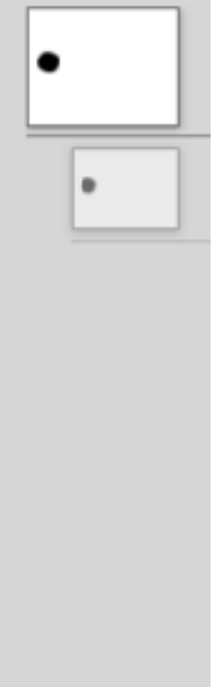

void myOtherDrawing()
{
pushMatrix();
translate(...);
rotate(...);
scale(...);
myDrawing();
popMatrix();
pushMatrix();
translate(...);
rotate(...);
scale(...);
myDrawing();
popMatrix();
}








void myDrawing()
{
pushMatrix();
translate(...);
scale(...);
ellipse(...);
popMatrix();
pushMatrix();
translate(...);
rotate(...);
scale(...);
myDrawing();
popMatrix();
}
?
?



```
void myDrawing()
{
   pushMatrix();
   translate( ... );
   scale( ... );
   ellipse( ... );
   popMatrix();

   pushMatrix();
   translate( ... );
   rotate( ... );
   scale( ... );
   myDrawing();
   popMatrix();
}
```

This doesn't actually work, but it's on the right track.

How to draw myDrawing:

1. Draw a circle
2. Take one step east
3. Draw myDrawing

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    1. Draw a circle
    2. Take one step east
        1. Draw a circle
        2. Take one step east
            1. Draw a circle
            2. Take one step east
                1. Draw a circle
                2. Take one step east
                    1. Draw a circle
                    2. Take one step east
                        1. Draw a circle
                        2. Take one step east
                            1. Draw a circle

```
void myDrawing()
{
  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );
  myDrawing();
  popMatrix();
}

void setup()
{
  size( 600, 100 );
  background( 100 );
  myDrawing();
}
```

```
void myDrawing()
{
  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );
  myDrawing();
  popMatrix();
}

void setup()
{
  size( 600, 100 );
  background( 100 );
  myDrawing();
}
```

What's wrong with this code?

```
void myDrawing()
{
  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );

  myDrawing();


  popMatrix();
}
```

```
void myDrawing()
{
  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );


  popMatrix();
}
```

```
void myDrawing()
{
   ellipse( 50, 50, 100, 100 );

   pushMatrix();
   translate( 150, 0 );
   ellipse( 50, 50, 100, 100 );

   pushMatrix();
   translate( 150, 0 );




   popMatrix();
   popMatrix();
}
```

```
void myDrawing()
{
  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );
  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );

  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );

  ellipse( 50, 50, 100, 100 );

  popMatrix();

  popMatrix();

  popMatrix();
}
```

```
void myDrawing()
{
  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );
  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );

  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );

  ellipse( 50, 50, 100, 100 );

  popMatrix();

  popMatrix();

  popMatrix();

  popMatrix();
}
```

```
void myDrawing()
{
  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );
  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );
  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );
  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );
  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );


  popMatrix();
  popMatrix();
  popMatrix();
  popMatrix();
  popMatrix();
}
```

```
void myDrawing()
{
  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );
  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );

  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );

  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );

  ellipse( 50, 50, 100, 100 );

  popMatrix();

  popMatrix();

  popMatrix();

  popMatrix();

  popMatrix();

  popMatrix();
}
```

```
void myDrawing()
{
  ellipse( 50, 50, 100, 100 );

  pushMatrix();
  translate( 150, 0 );
  myDrawing();
  popMatrix();
}

void setup()
{
  size( 600, 100 );
  background( 100 );
  myDrawing();
}
```

```
void myDrawing( int levels )
{
  ellipse( 50, 50, 100, 100 );

  if ( levels > 0 ) {
    pushMatrix();
    translate( 150, 0 );
    myDrawing( levels - 1 );
    popMatrix();
  }
}

void setup()
{
  size( 600, 100 );
  background( 100 );
  myDrawing();
}
```

```
void myDrawing( int levels )
{
  ellipse( 50, 50, 100, 100 );

  if ( levels > 0 ) {
    pushMatrix();
    translate( 150, 0 );
    myDrawing( levels - 1 );
    popMatrix();
  }
}

void setup()
{
  size( 600, 100 );
  background( 100 );
  myDrawing();
}
```

How many more levels of recursion?

```
void myDrawing( int levels )
{
  ellipse( 50, 50, 100, 100 );

  if ( levels > 0 ) {
    pushMatrix();
    translate( 150, 0 );
    myDrawing( levels - 1 );
    popMatrix();
  }
}

void setup()
{
  size( 600, 100 );
  background( 100 );
  myDrawing();
}
```

How many more levels of recursion?

Are we done yet?

```
void myDrawing( int levels )
{
  ellipse( 50, 50, 100, 100 );

  if ( levels > 0 ) {
    pushMatrix();
    translate( 150, 0 );
    myDrawing( levels - 1 );
    popMatrix();
  }
}

void setup()
{
  size( 600, 100 );
  background( 100 );
  myDrawing();
}
```

How many more levels of recursion?

Are we done yet?

Make progress towards the end.

```
void myDrawing( int levels )
{
  ellipse( 50, 50, 100, 100 );

  if ( levels > 0 ) {
    pushMatrix();
    translate( 150, 0 );
    myDrawing( levels - 1 );
    popMatrix();
  }
}

void setup()
{
  size( 600, 100 );
  background( 100 );
  myDrawing( 6 );
}
```

```
void myDrawing( int levels )
{
  ellipse( 50, 50, 100, 100 );

  if ( levels > 0 ) {
    pushMatrix();
    translate( 150, 0 );
    myDrawing( levels - 1 );
    popMatrix();
  }
}

void setup()
{
  size( 600, 100 );
  background( 100 );
  myDrawing( 6 );
}
```

Choose a number of levels at the outset.

Anatomy of recursion

Every recursive function has three features:

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One or more *recursive cases*: places where the function calls itself to solve a sub-problem.

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One or more *base cases*: places where the function does something without calling itself.

Anatomy of recursion

Every recursive function has three features:

One or more *recursive cases*: places where the function calls itself to solve a sub-problem.

One or more *base cases*: places where the function does something without calling itself.

Every recursive call *makes progress towards a base case*.

Factorial

$1! = 1$
$2! = 1 \times 2 = 2$
$3! = 1 \times 2 \times 3 = 6$
$4! = 1 \times 2 \times 3 \times 4 = 24$
$5! = 1 \times 2 \times 3 \times 4 \times 5 = 120$
...
$n! = 1 \times 2 \times 3 \times 4 \times \ldots \times n$

Factorial

1! = 1
2! = 1 × 2 = 2
3! = 1 × 2 × 3 = 6
4! = 1 × 2 × 3 × 4 = 24
5! = 1 × 2 × 3 × 4 × 5 = 120
…
n! = n × (n-1)!

Factorial

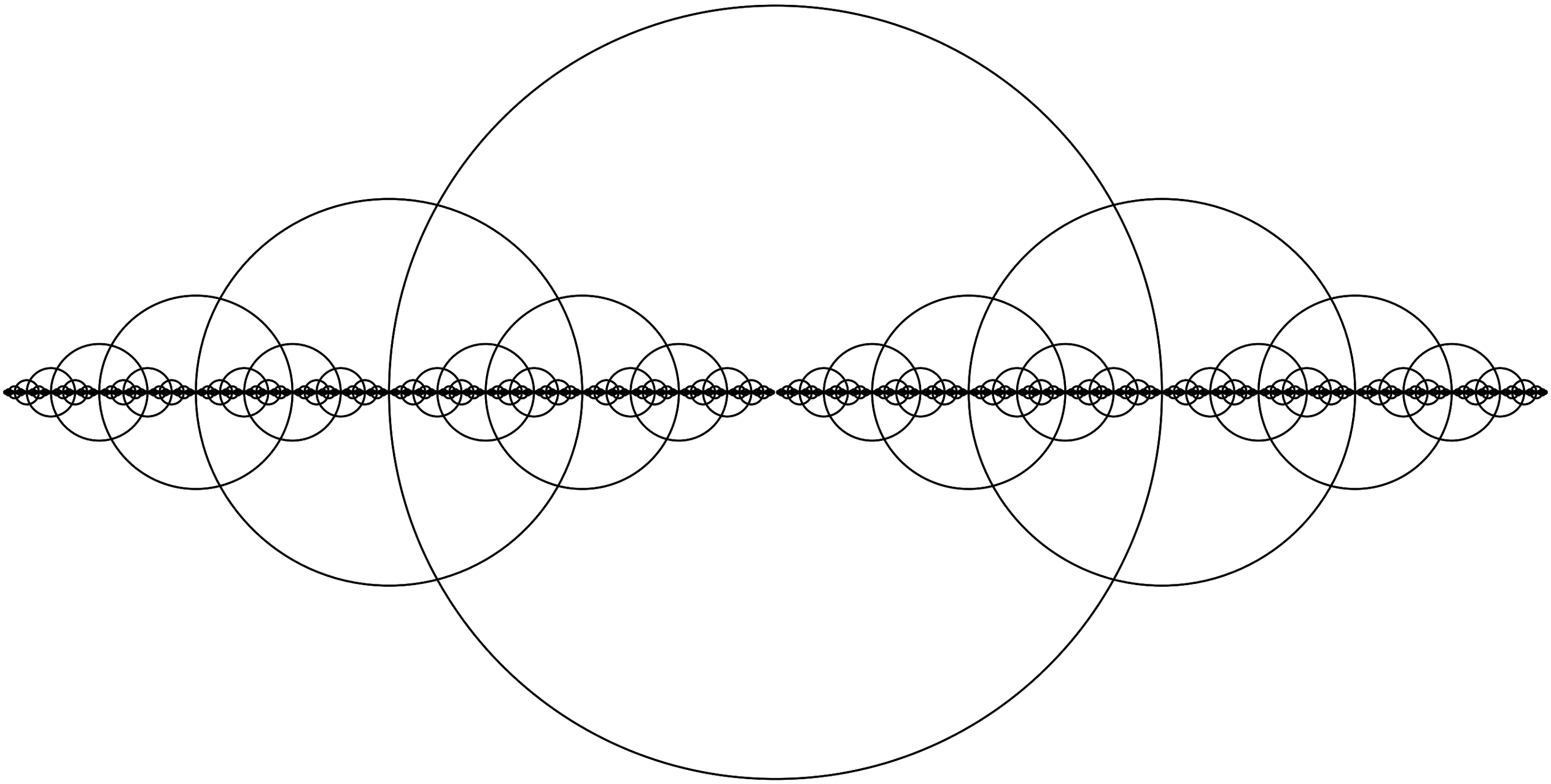
1! = 1
2! = 1 × 2 = 2
3! = 1 × 2 × 3 = 6
4! = 1 × 2 × 3 × 4 = 24
5! = 1 × 2 × 3 × 4 × 5 = 120
…
n! = n × (n-1)!

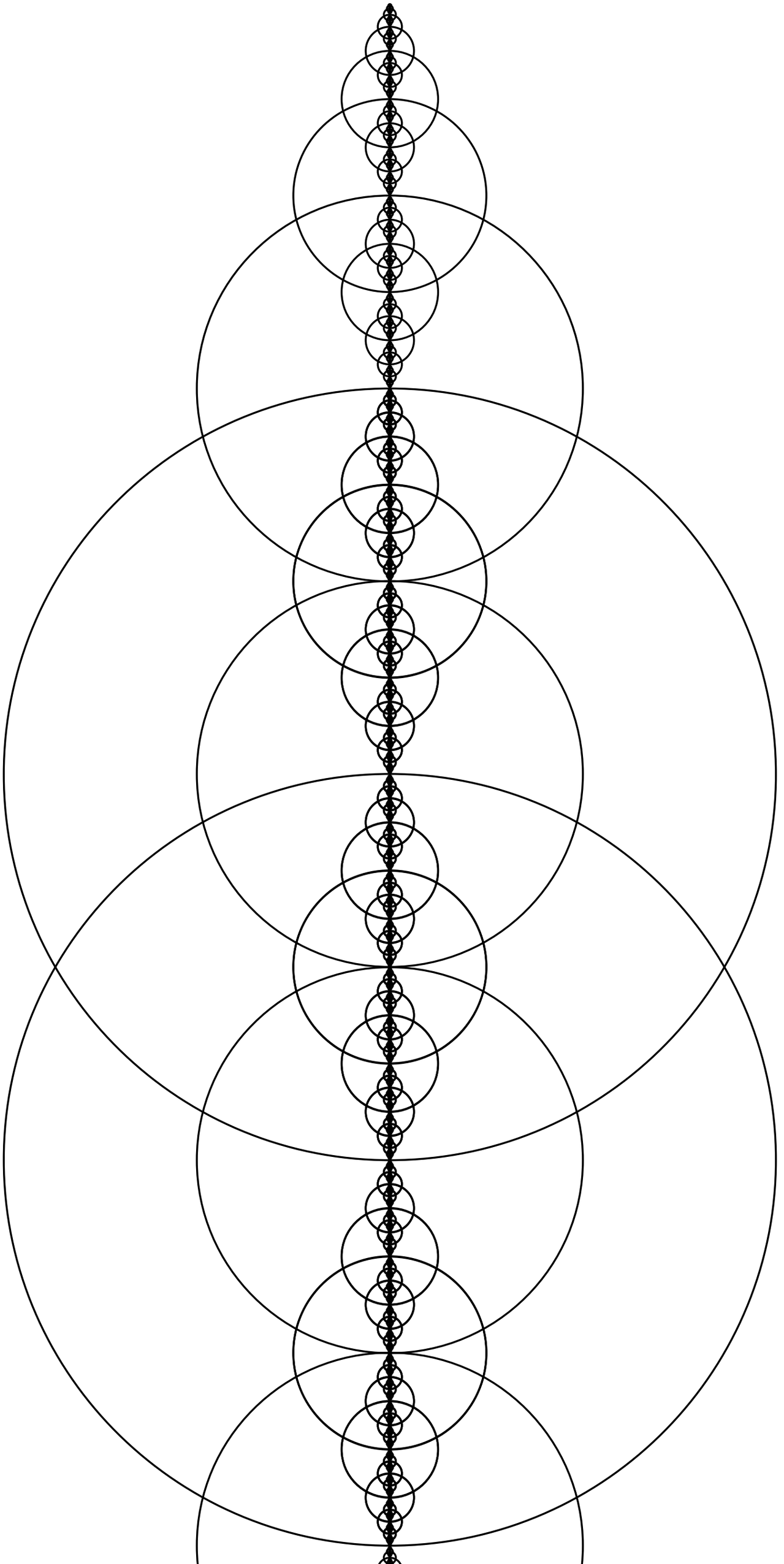
```
int fact( int n )
{
  return n * fact( n - 1 );
}
```

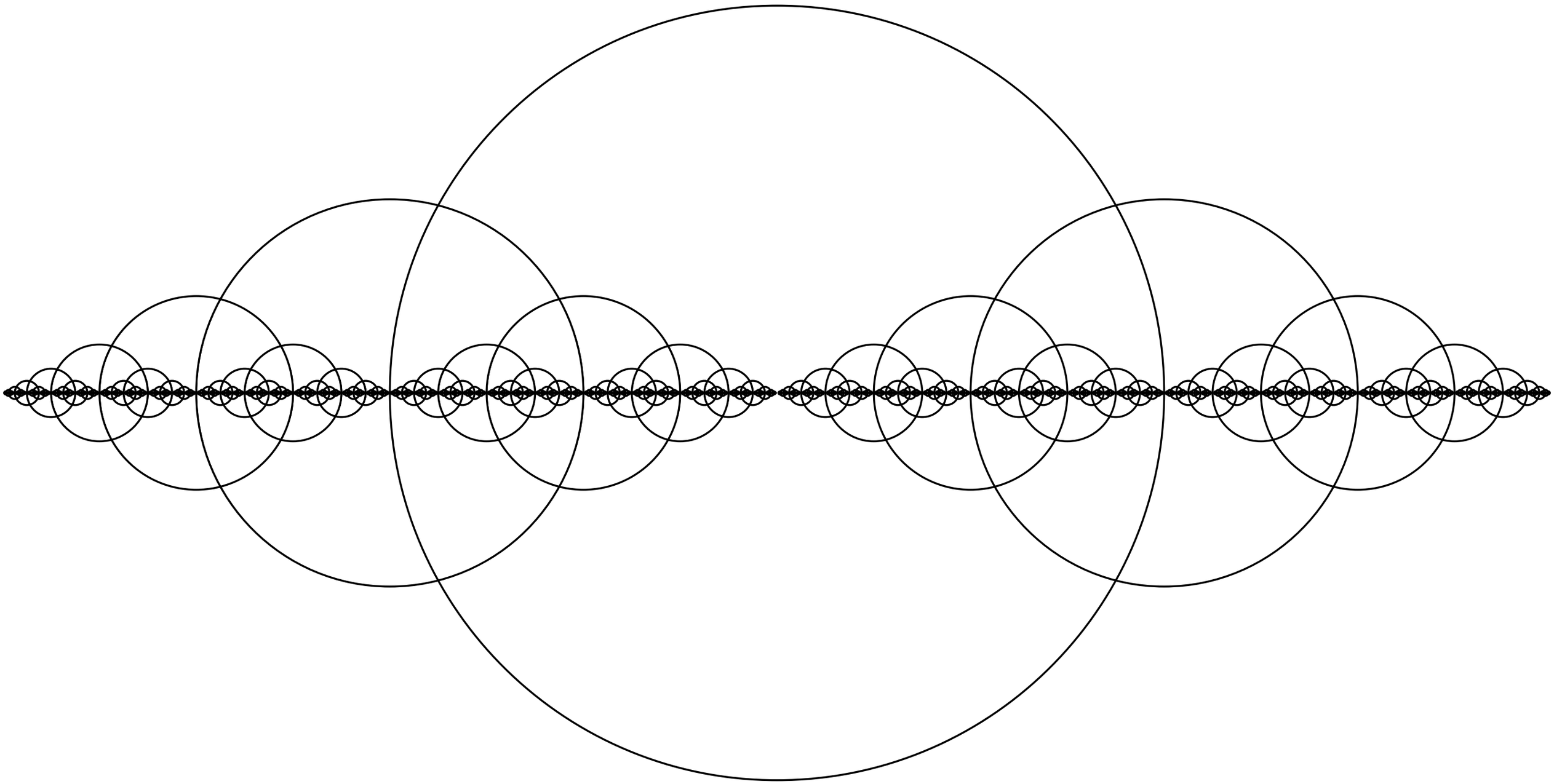
Factorial

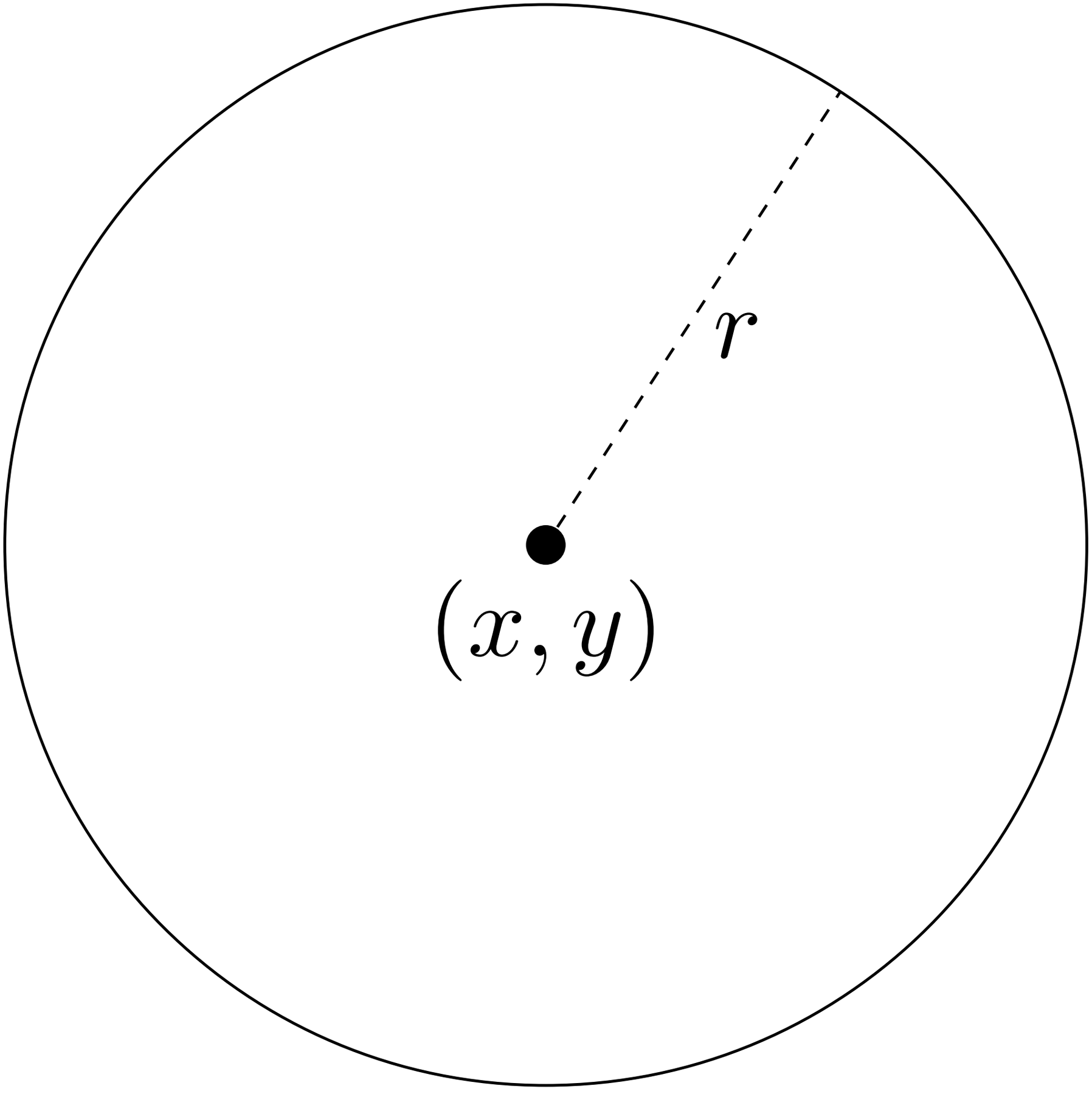
n! = n × (n-1)!

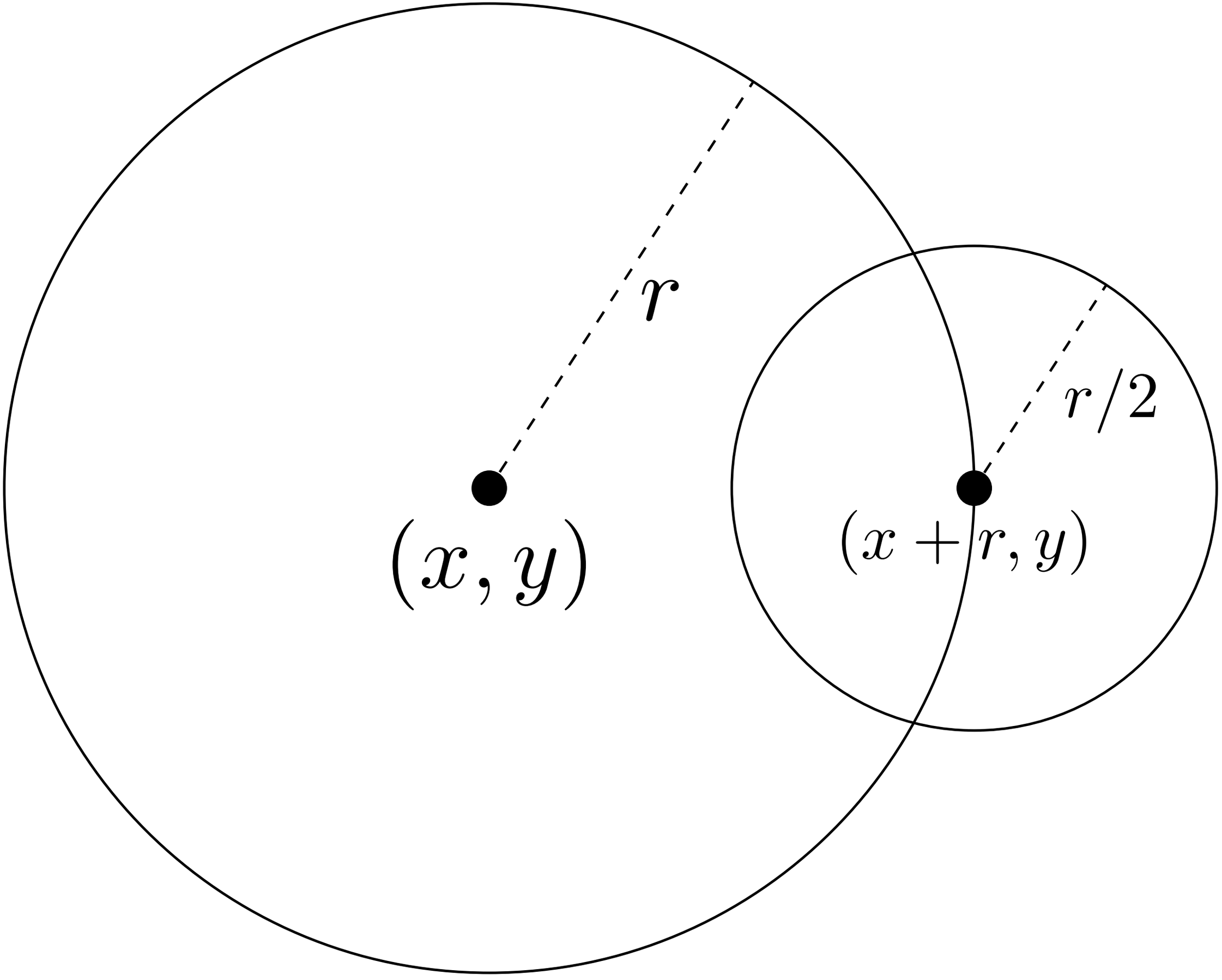
```
int fact( int n )
{
   if ( n == 1 ) {
      return 1;
   } else {
      return n * fact( n - 1 );
   }
}
```

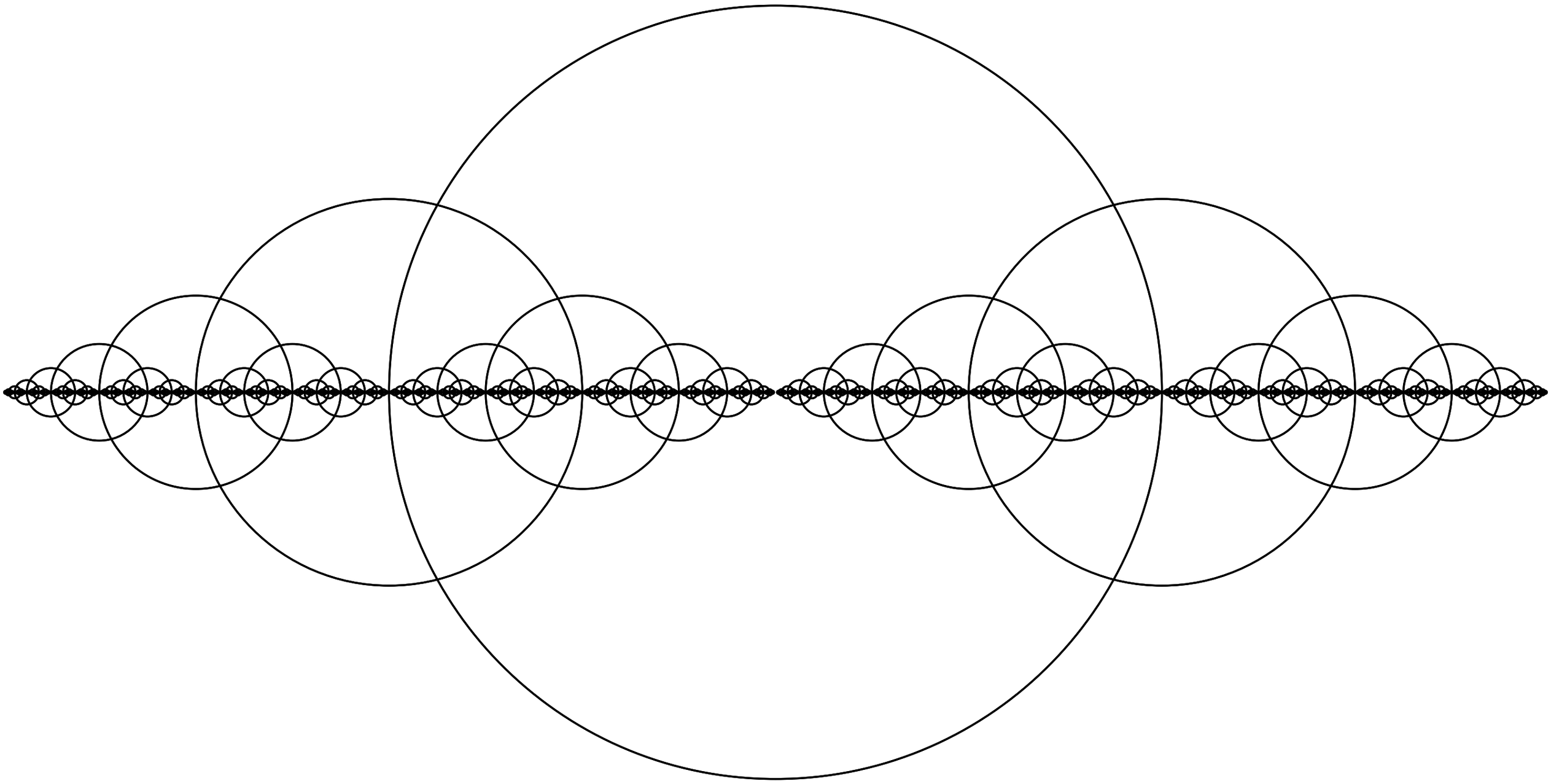


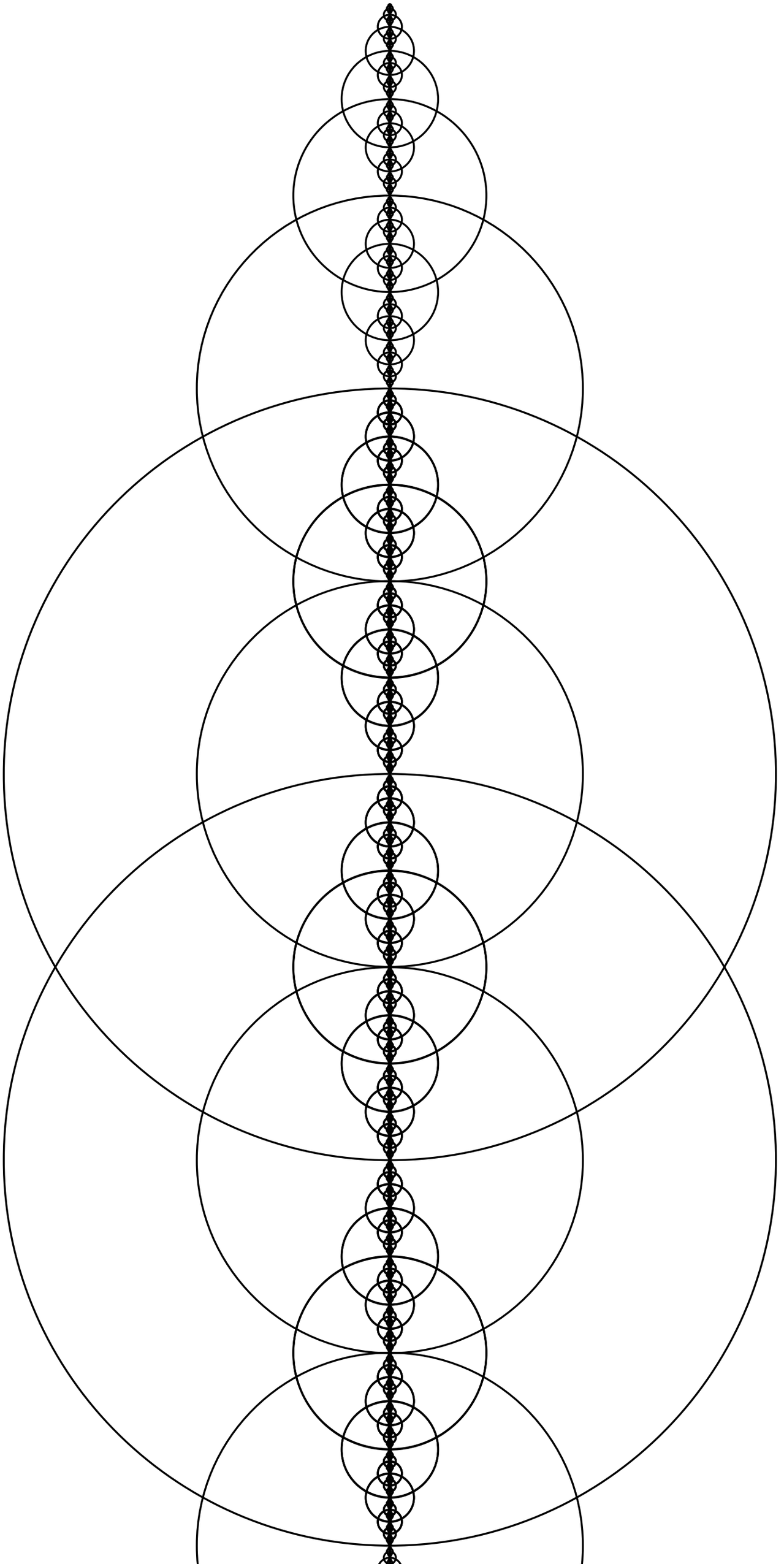


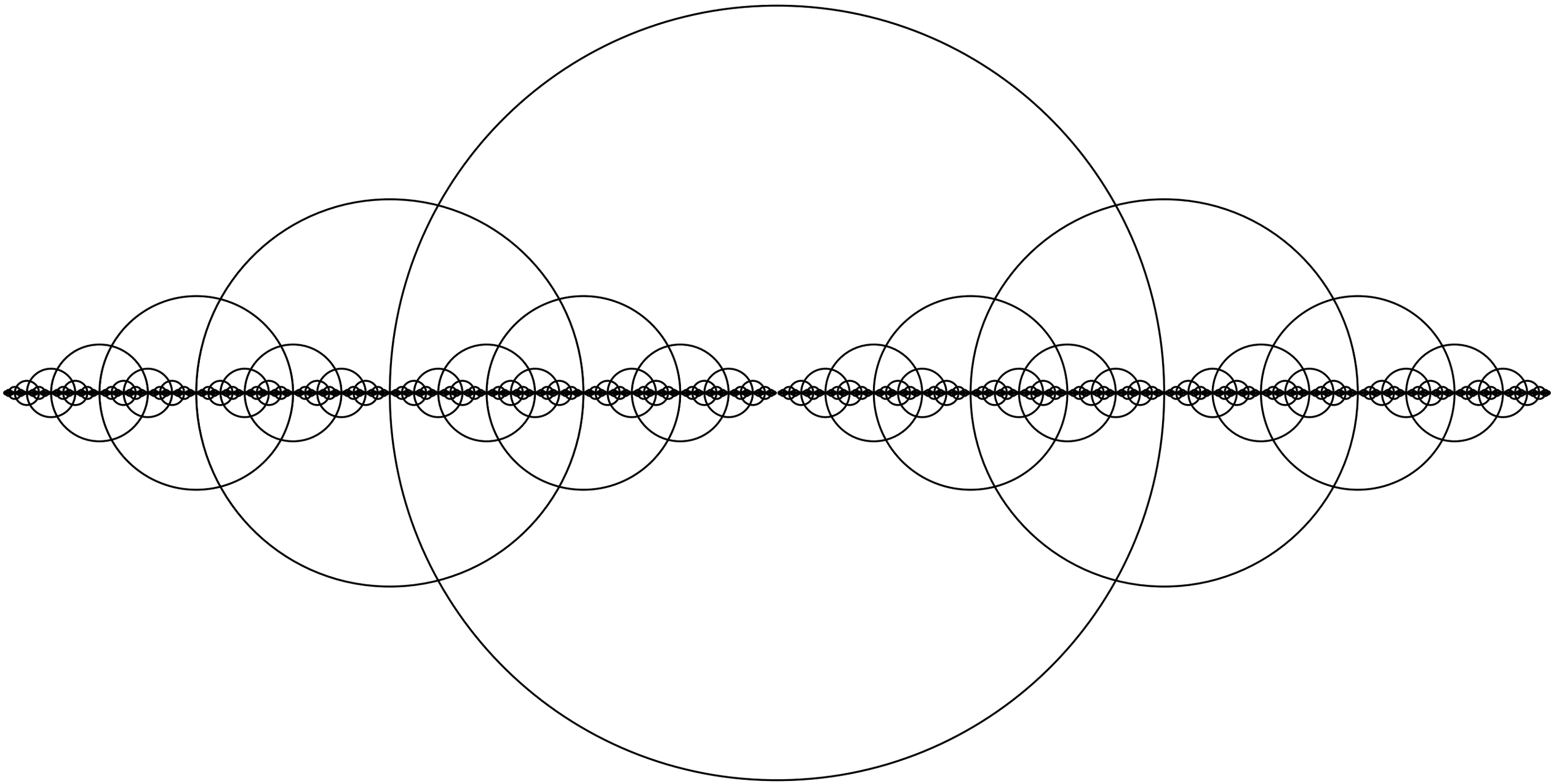


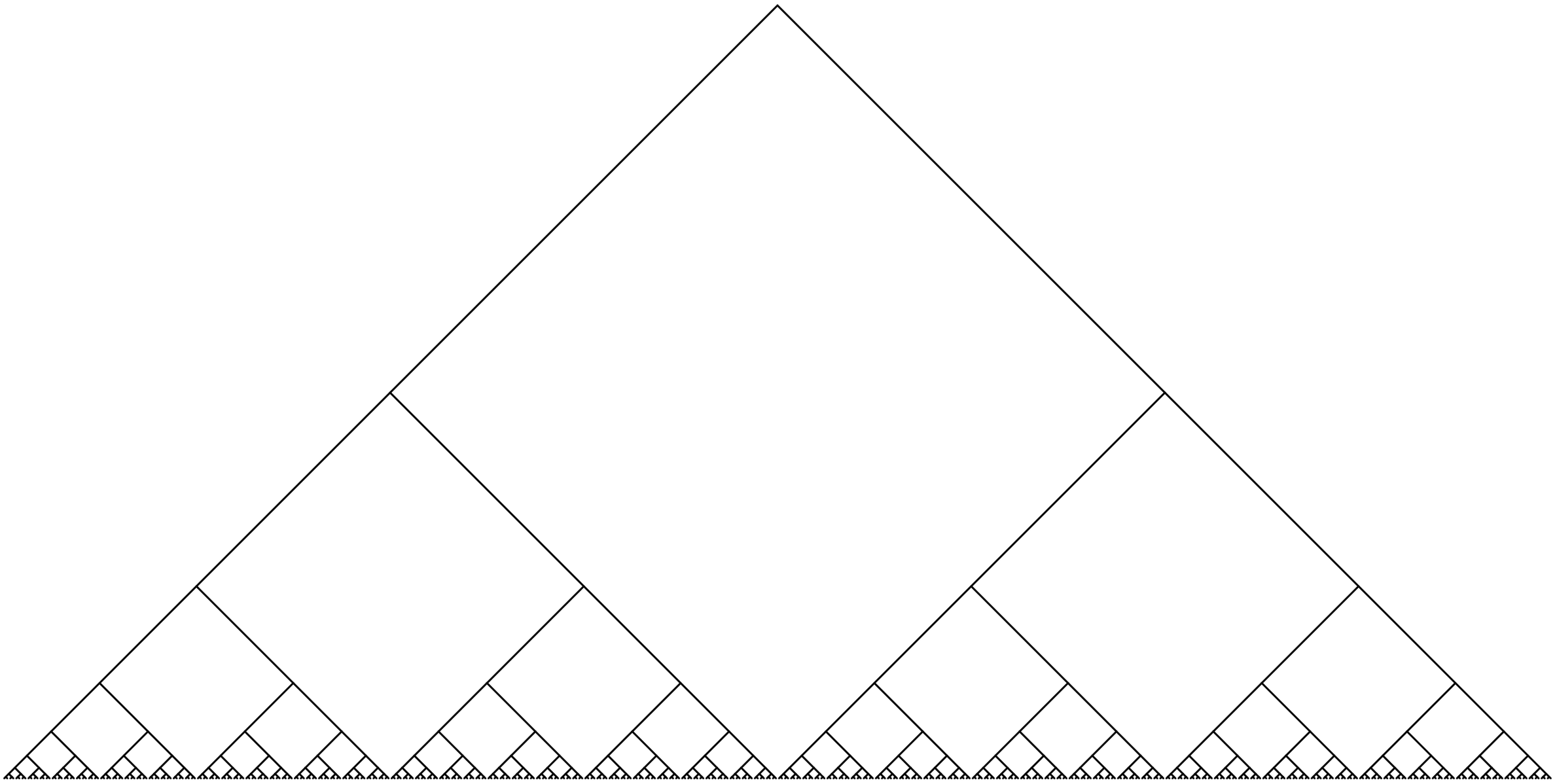

r
(x, y)


r
(x, y)
$r/2$
$(x + r, y)$

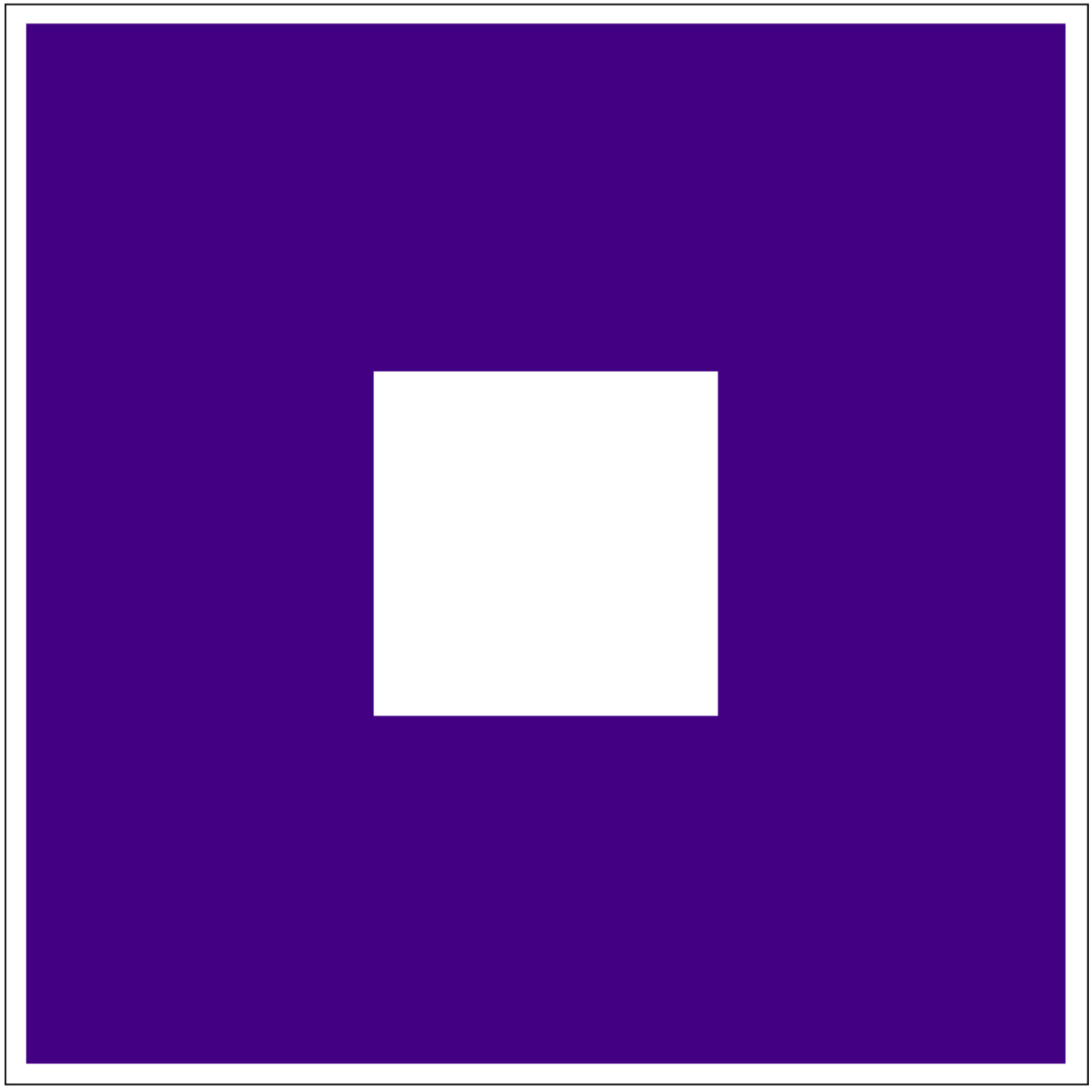




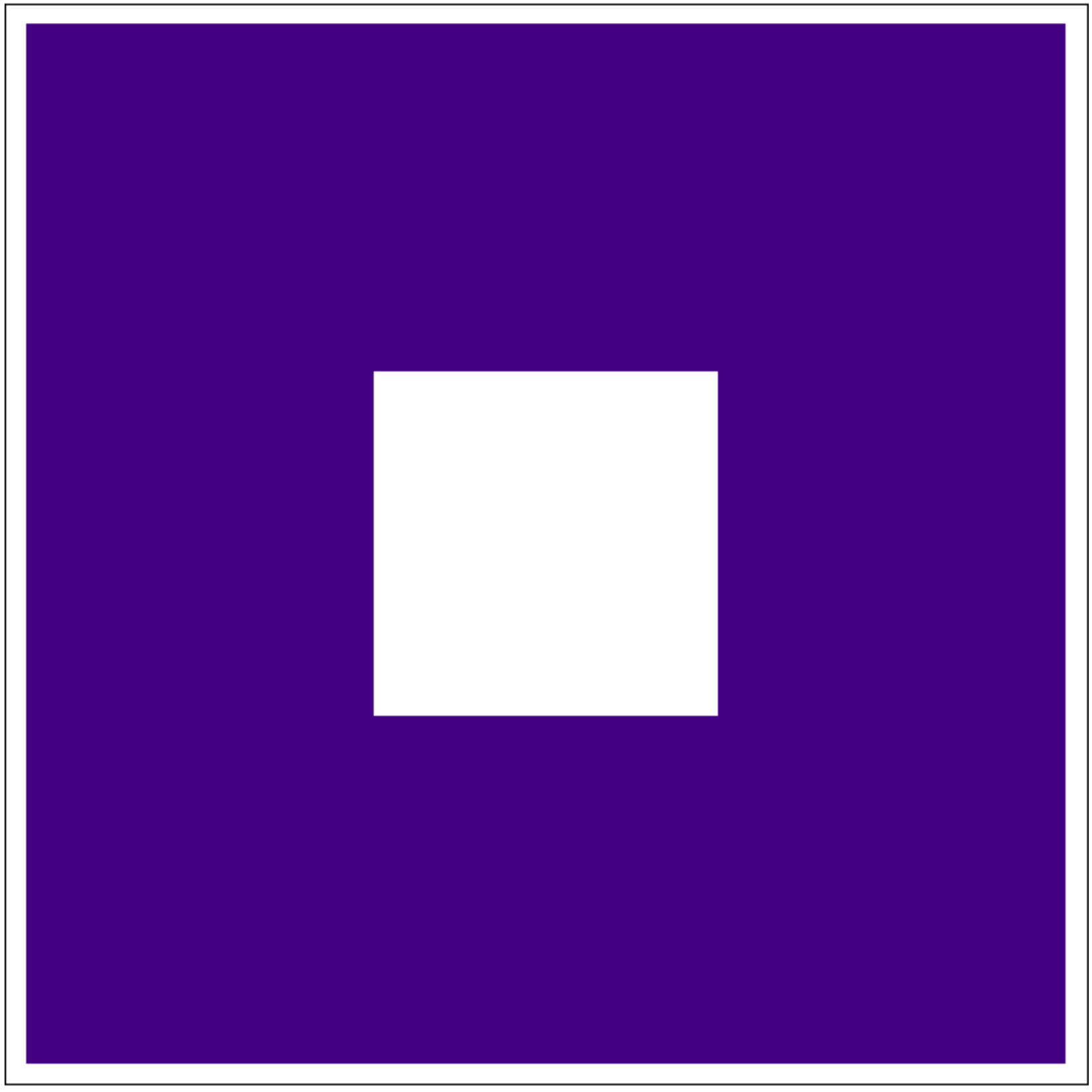




Sierpinski Carpet



Sierpinski Carpet



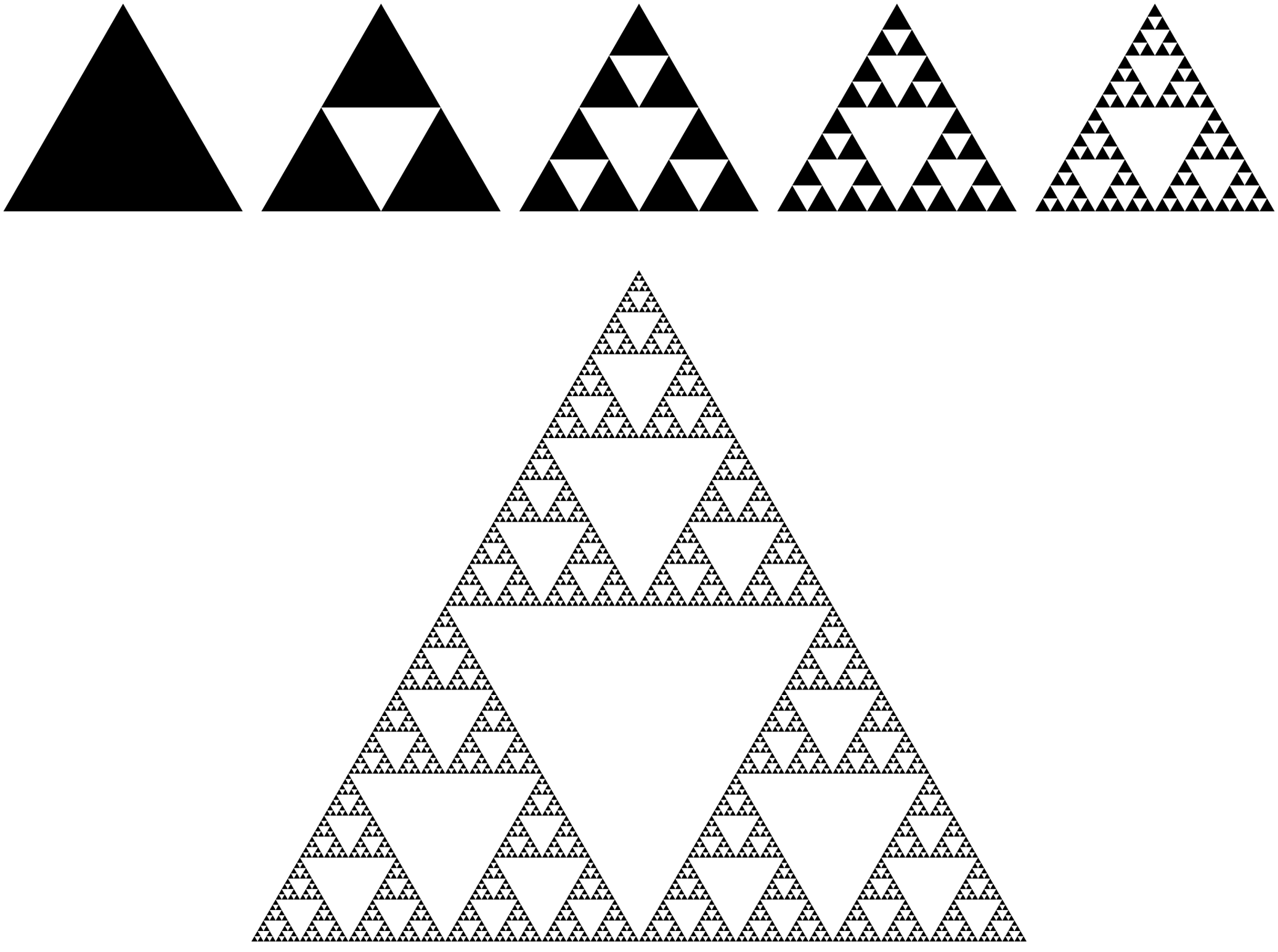
How to draw the carpet:

1. Divide a square into a 3 × 3 grid.
2. Draw the carpet in each cell of the grid, except for the central one.

How to draw the carpet at level *n*:

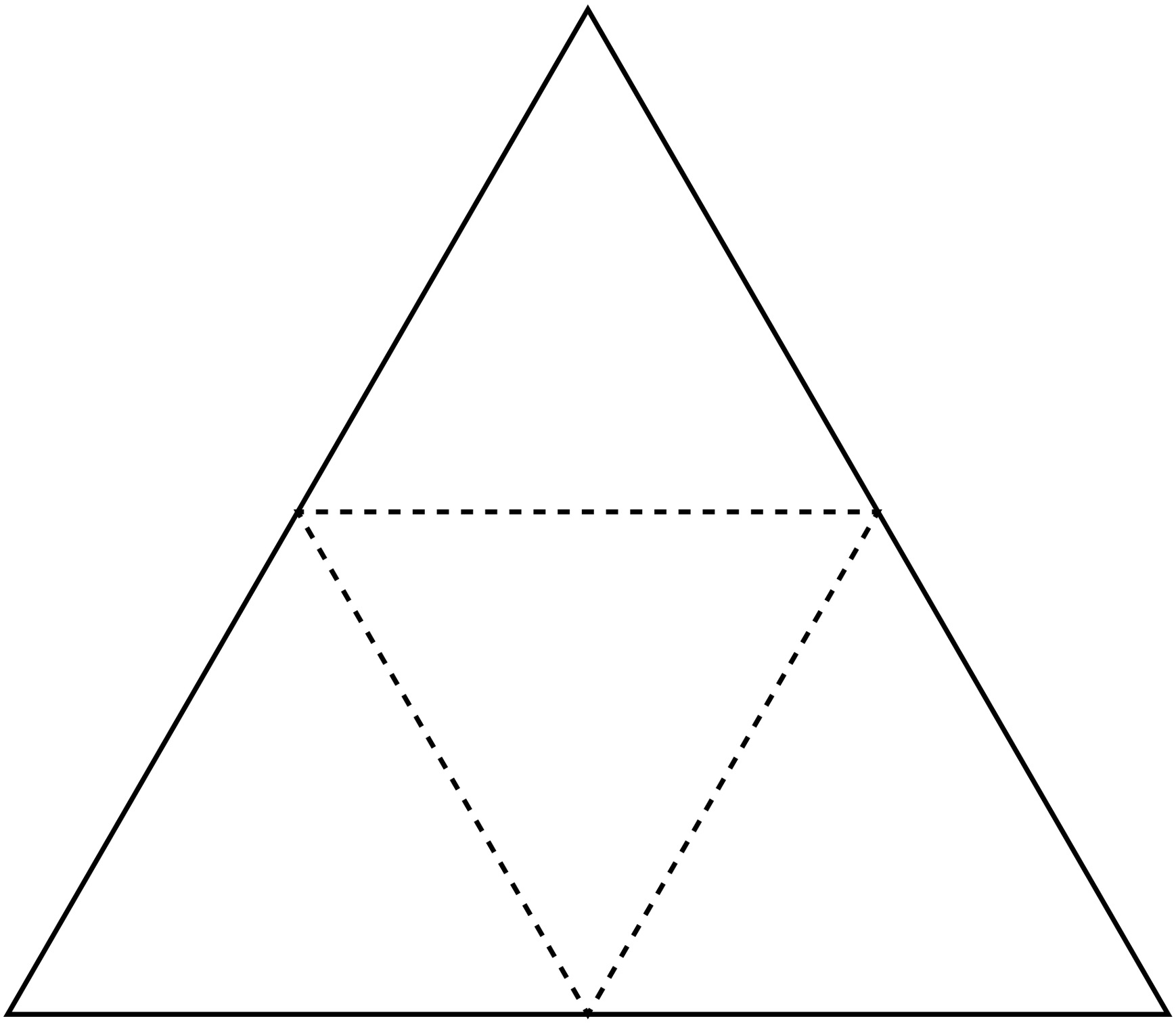
1. If *n* is 0 then just draw a square.
2. Otherwise:
    1. Divide a square into a 3 × 3 grid.
    2. Draw the carpet at level (*n* - 1) in each cell of the grid, except for the central one.

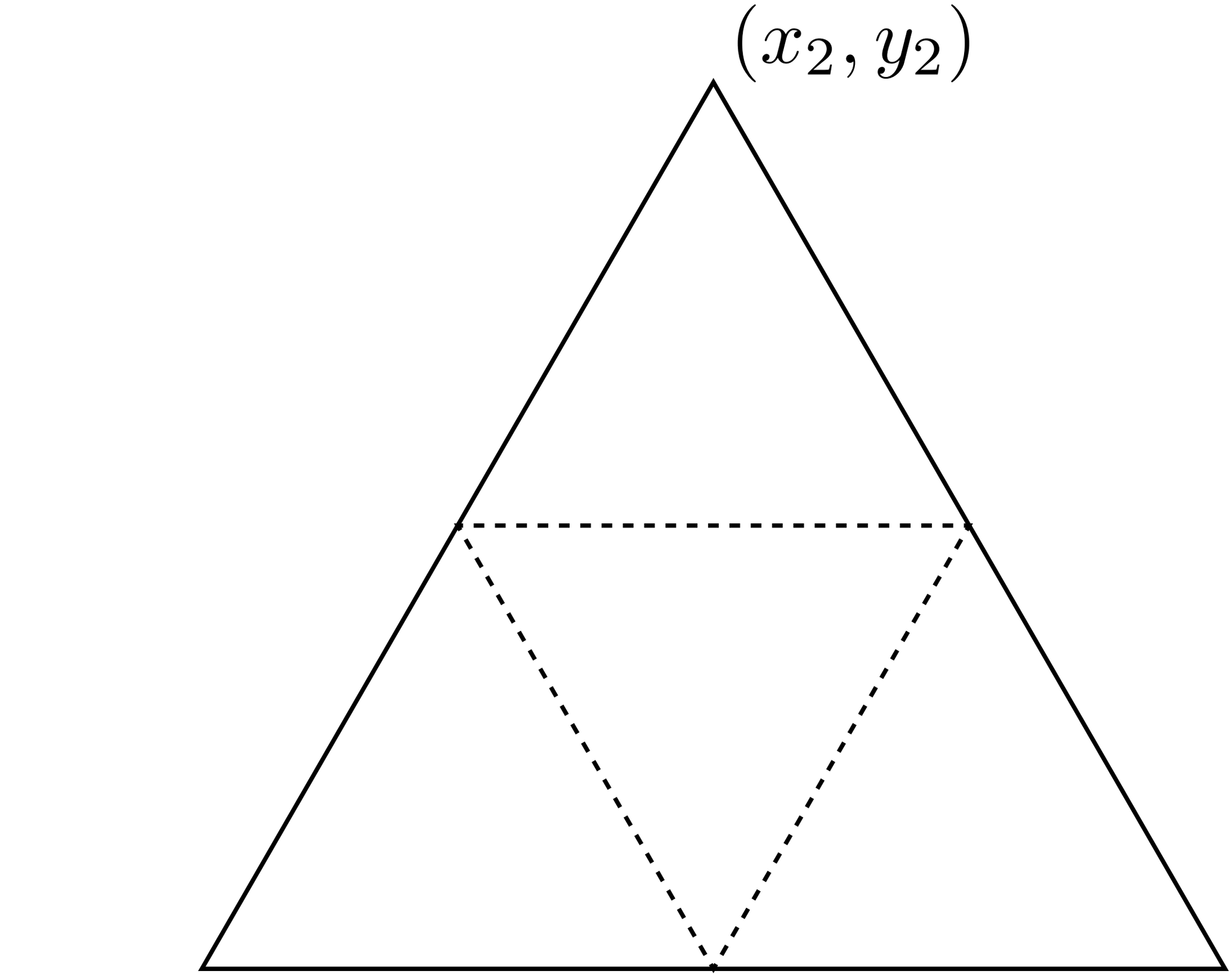
Sierpinski Gasket

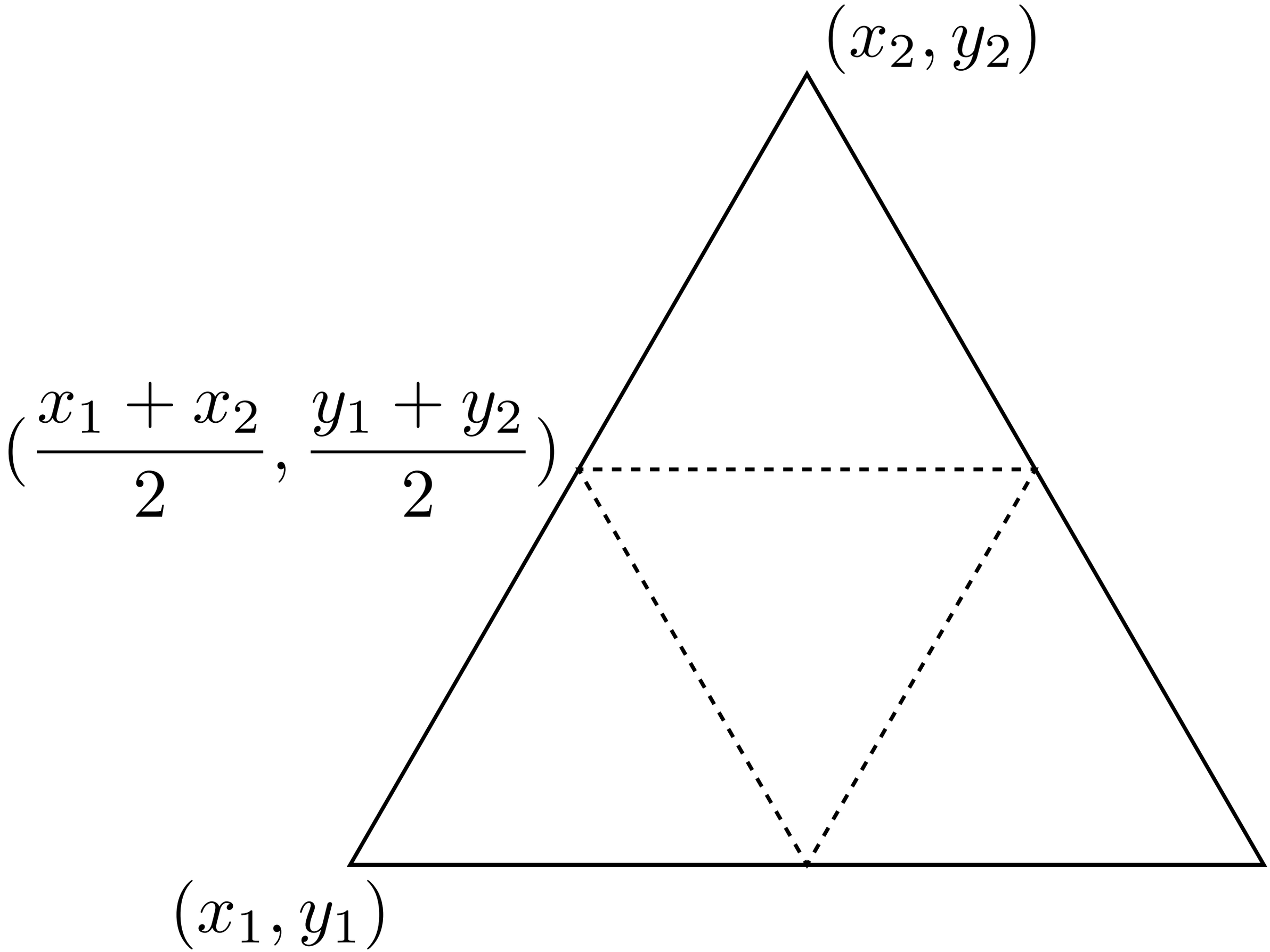


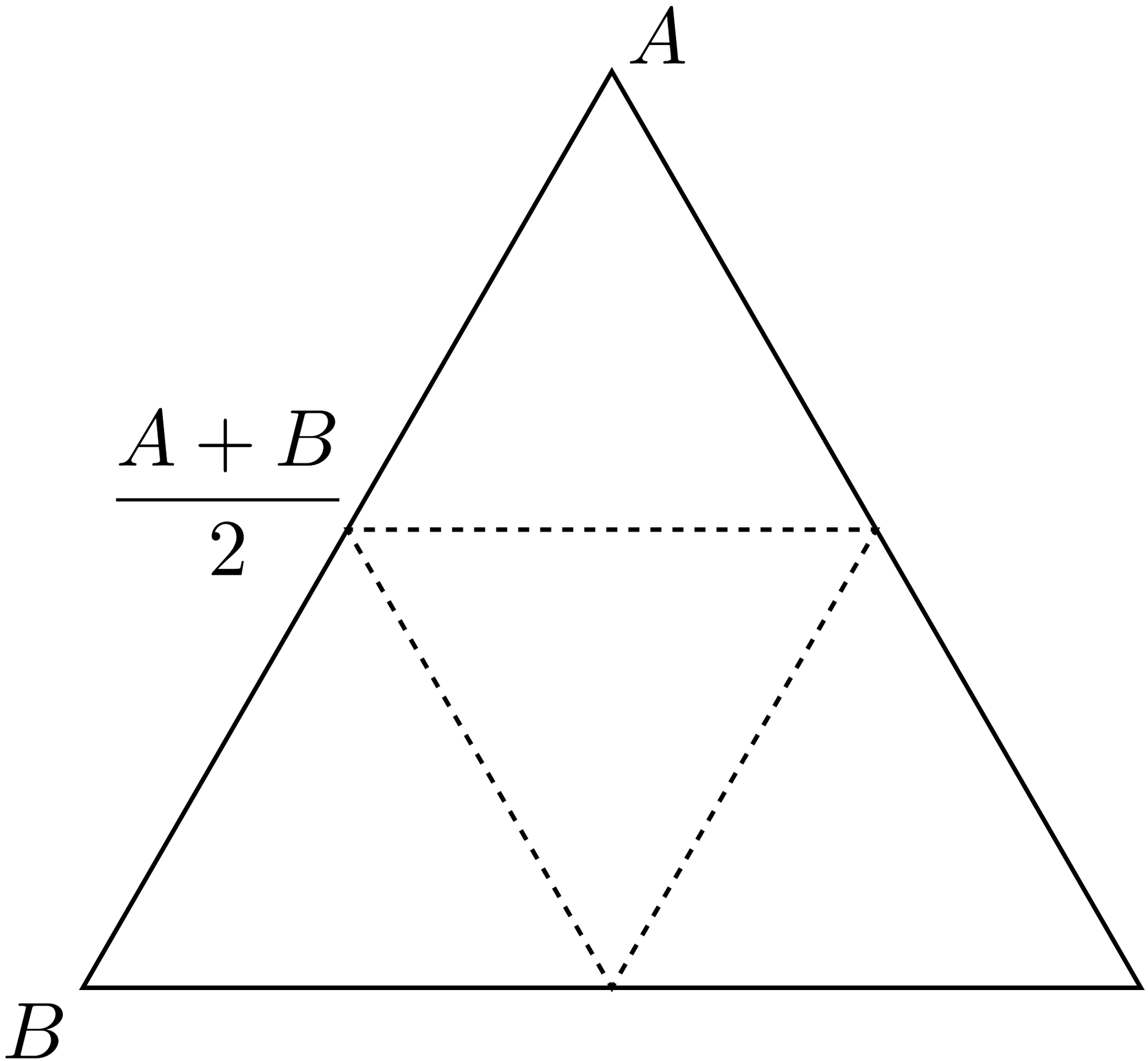
How to draw the gasket at level *n*:

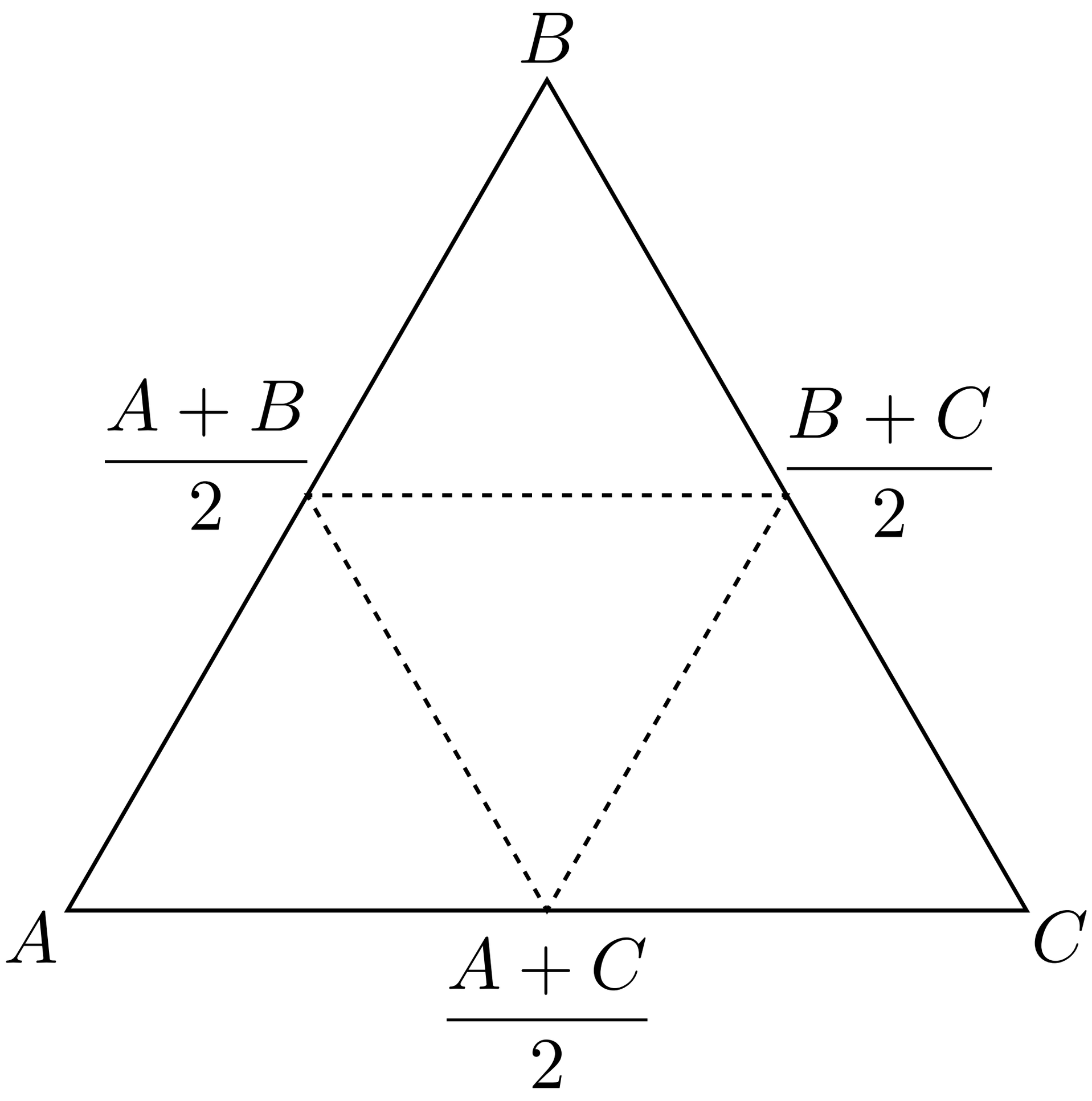
1. If *n* is 0 then just draw a triangle.
2. Otherwise:
    1. Divide a triangle into four.
    2. Draw the gasket at level (*n* - 1) in each sub-triangle, except for the central one.

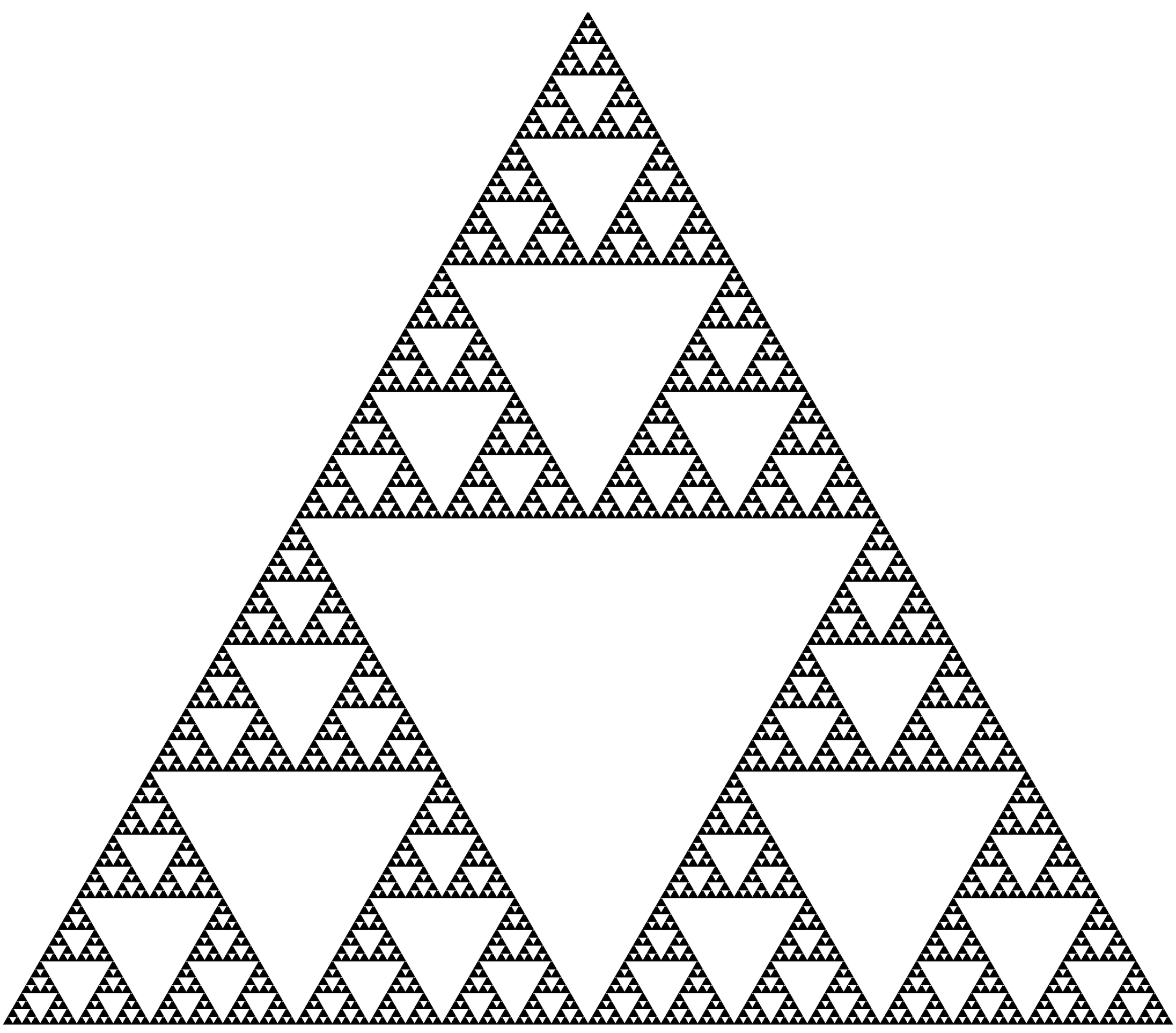


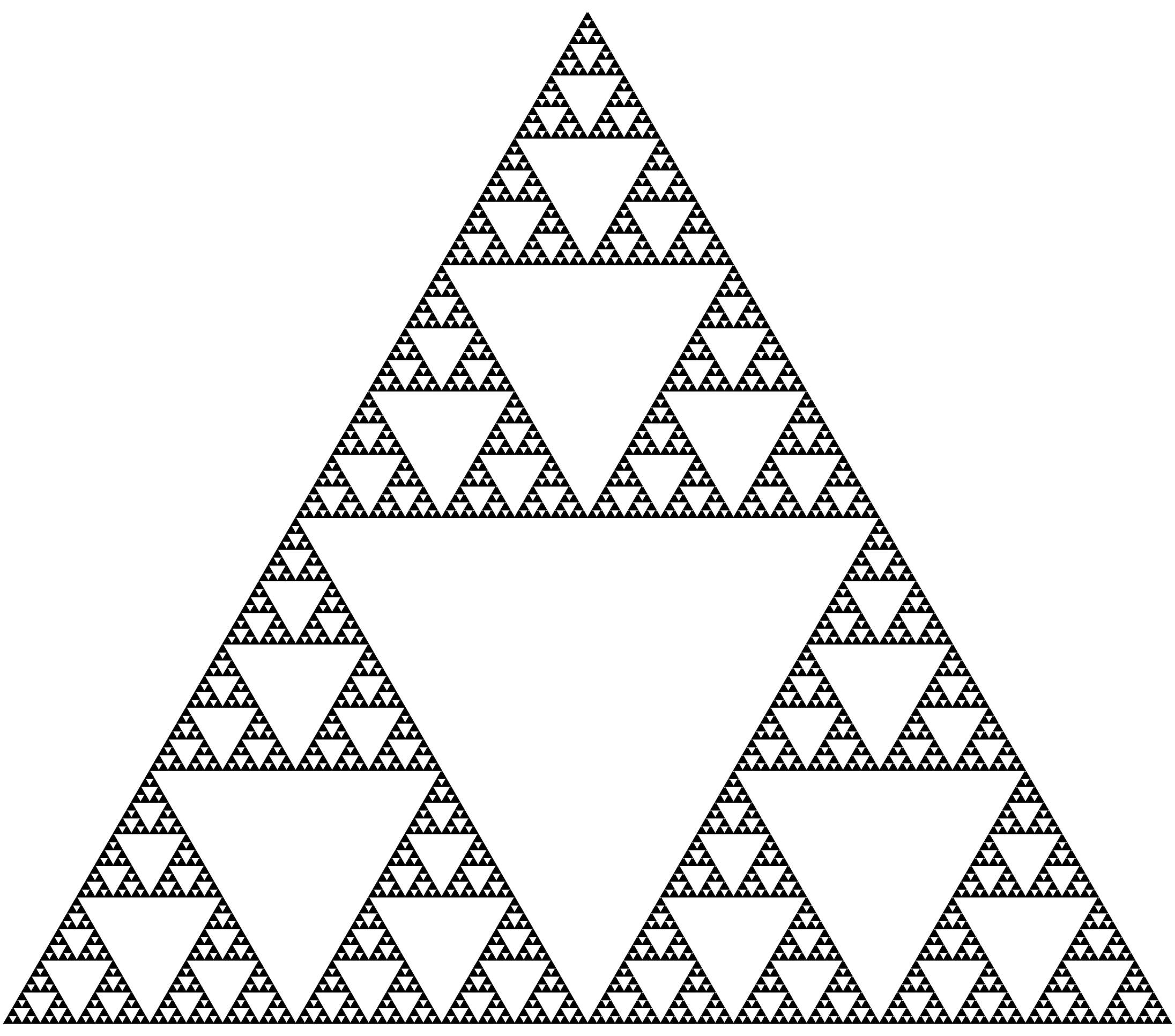

(x_2, y_2)
(x_1, y_1)

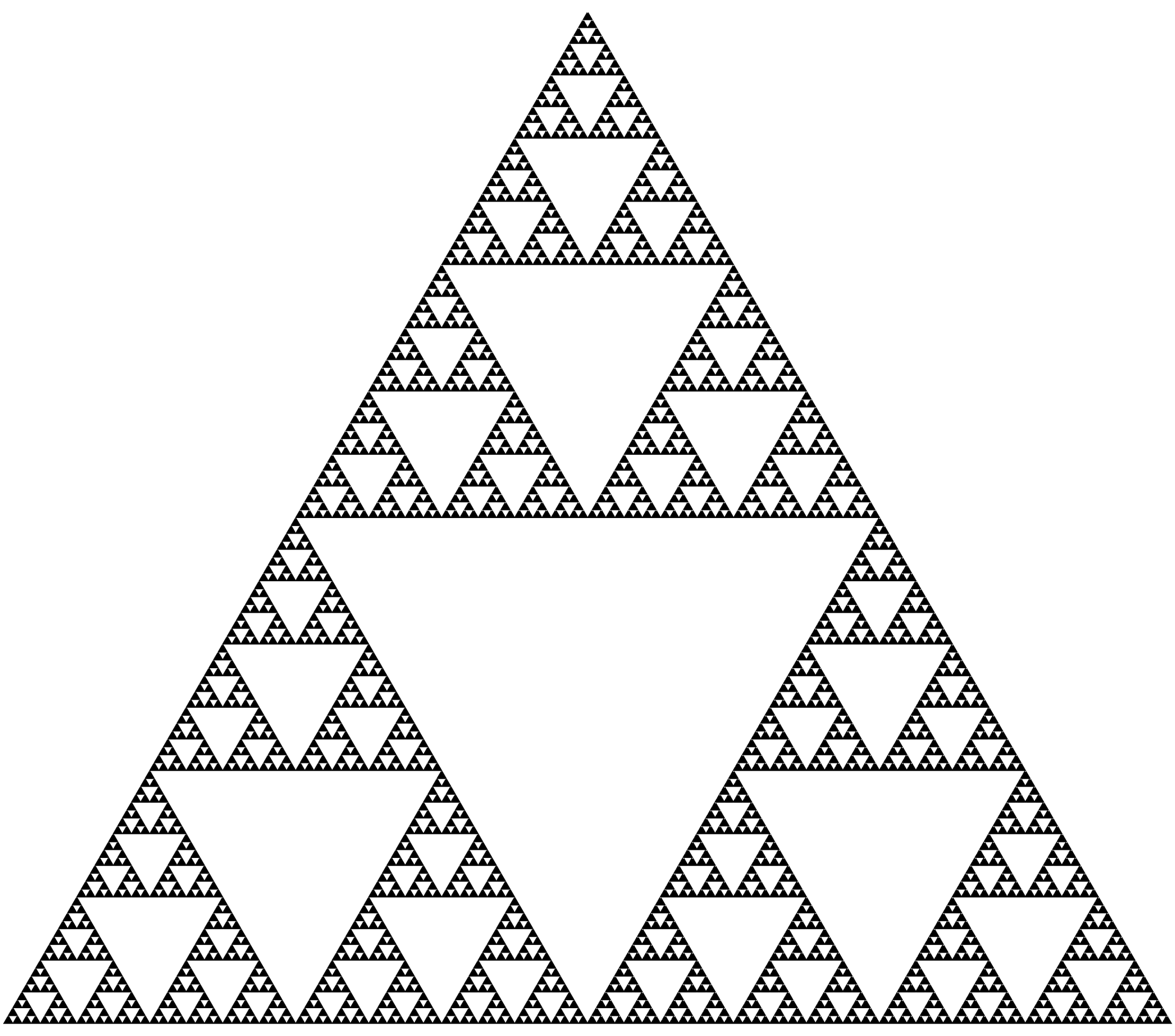

(x_2, y_2)
$(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2})$
(x_1, y_1)

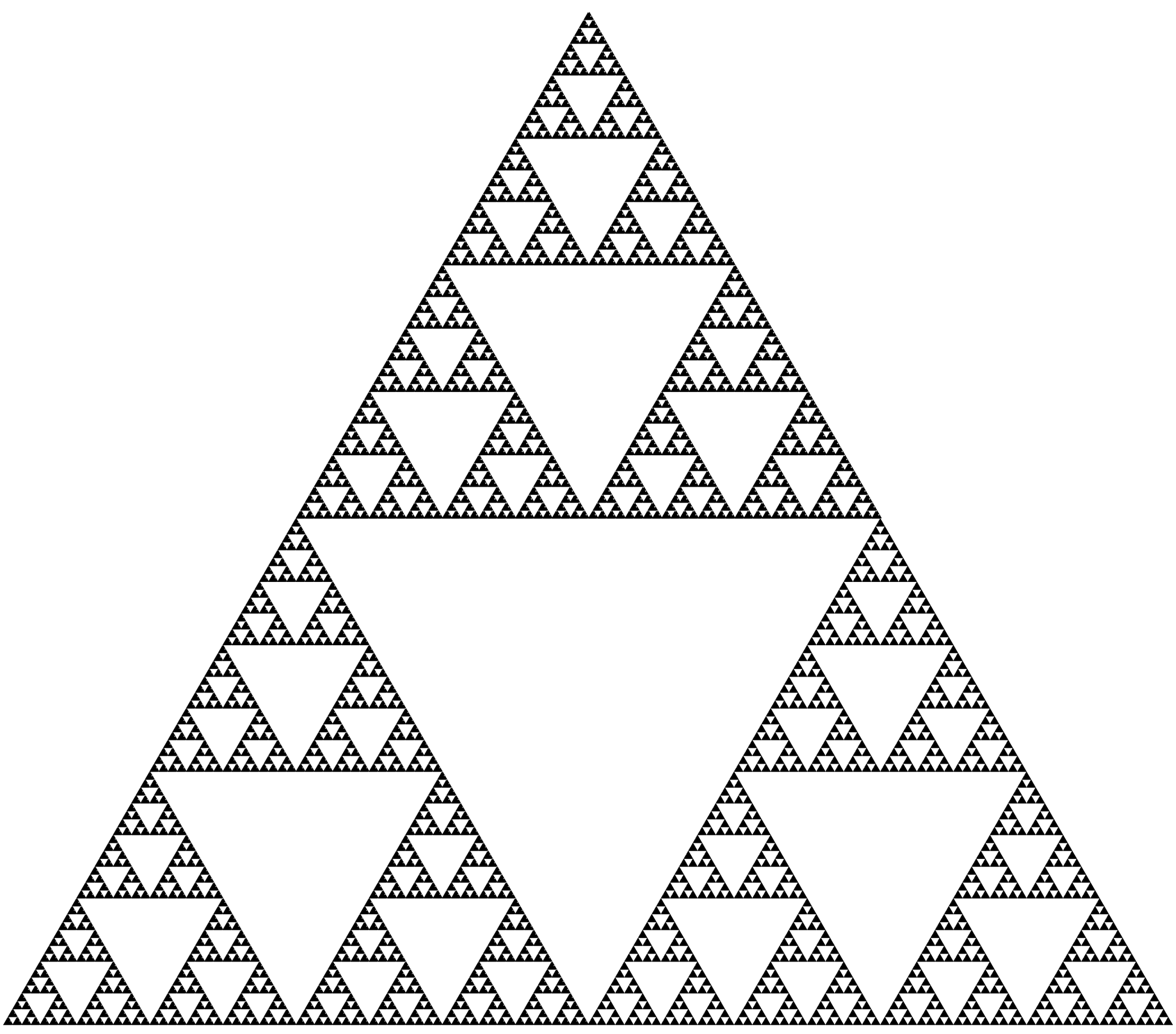

A
$\frac{A+B}{2}$
B


B
$\frac{A+B}{2}$
$\frac{B+C}{2}$
A
C
$\frac{A+C}{2}$









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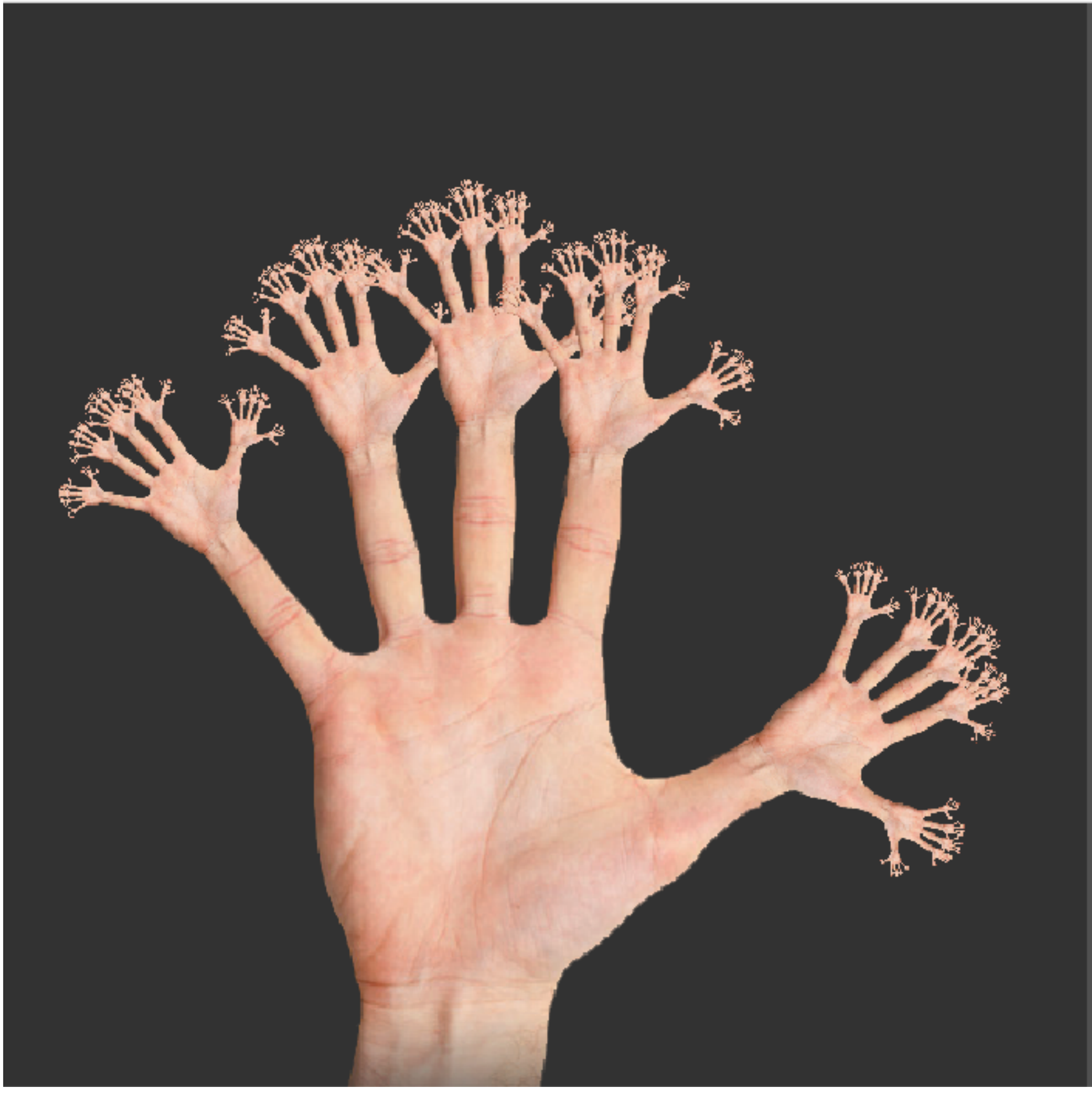

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SHOW OUTLINES

4 LEVELS