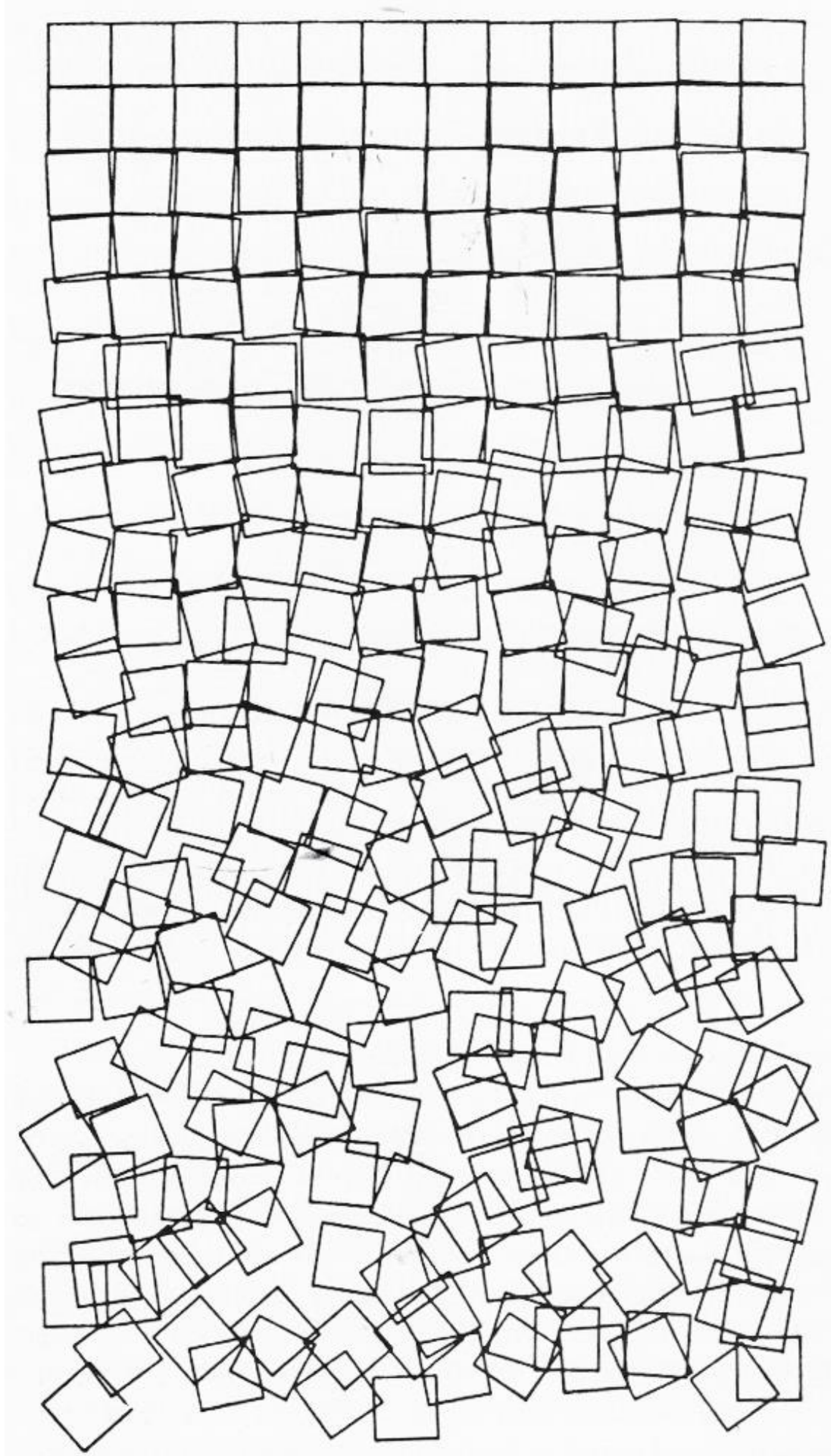
Randomness

(Part 1) Randomness
CS 106 Winter 2021

“Maybe the greatest novelty here is the ability of the computer not only to follow any complex rule of organization but also to introduce an exactly calculated dose of randomness.”

— E.H. Gombrich



Georg Nees, *Gravel Stones* (1971)

Random functions

```
random()

randomSeed()

noise()
```

`random(lo, hi)`

- **Return** a random number at least as big as lo but smaller than hi.
- Get a different answer every time!
- If no value for “lo” is given, it is assumed to be 0.

```
function setup() {
   frameRate(1);
}

function draw() {
   let rn = random(0, 7);
   print(rn);
}
```

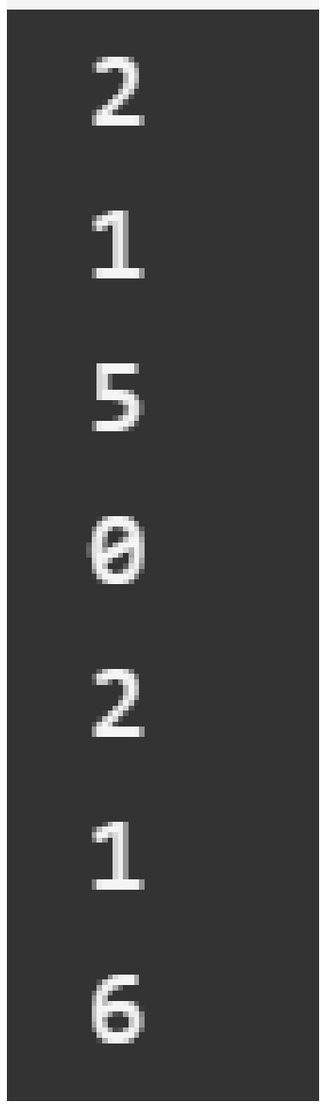
```
5.974395126083483 6
1.5229306022682347
0.49242281849654534
6.452274518075551
1.8180111798888136 2
```

Random Integers

`int(random(0, N))`

- Choose a random integer from the set 0, 1, … **N-1**
- The int() function always rounds down

```
function setup() {
   frameRate(1);
}

function draw() {
   let rn = int(random(0, 7));
   print(rn);
}
```



Flipping a coin

Write a function that simulates flipping a fair coin.

Flip 8 coins at a time

Print the number of heads and tails


```
Heads: 3 Tails: 5
```

Flipping 8 coins at a time (slide 1 of 2)

```
let heads;
let tails;
let th = 0;
let tt = 0;

function preload() {
   heads = loadImage("heads.png");
   tails = loadImage("tails.png");
}

function setup() {
   createCanvas(800, 100);
   heads.resize(0, 100);
   tails.resize(0, 100);
   flipCoins();
}
```

Flipping 8 coins at a time (slide 2 of 2)

```
function flipCoins() {
   background(50);
   let x = 0.0;
   while (x < width) {
      if (random(1) < 0.5) {
         image(heads, x, 0);
         x += heads.width;
         th++;
      } else {
         image(tails, x, 0);
         x += tails.width;
         tt++;
      }
   }
   print("Heads: " + th + " Tails: " + tt);
}

function mousePressed() {
   flipCoins();
}
```

https://openprocessing.org/sketch/1097675

Flipping a biased coin

Write a function that simulates flipping a biased coin.
75% heads, 25% tails

- Take the coinFlips function from last example
- Change the line

“if (random(1) < 0.5) {“

- to

“if (random(1) < 0.75) {“

- Everything else remains the same
- Over time 75% of the flips will be heads. Try it yourself.

```
function flipCoins() {
   background(50);
   let x = 0.0;
   while (x < width) {
      if (random(1) < 0.5) {
         image(heads, x, 0);
         x += heads.width;
         th++;
      } else {
         image(tails, x, 0);
         x += tails.width;
         tt++;
```

One million biased coin flips

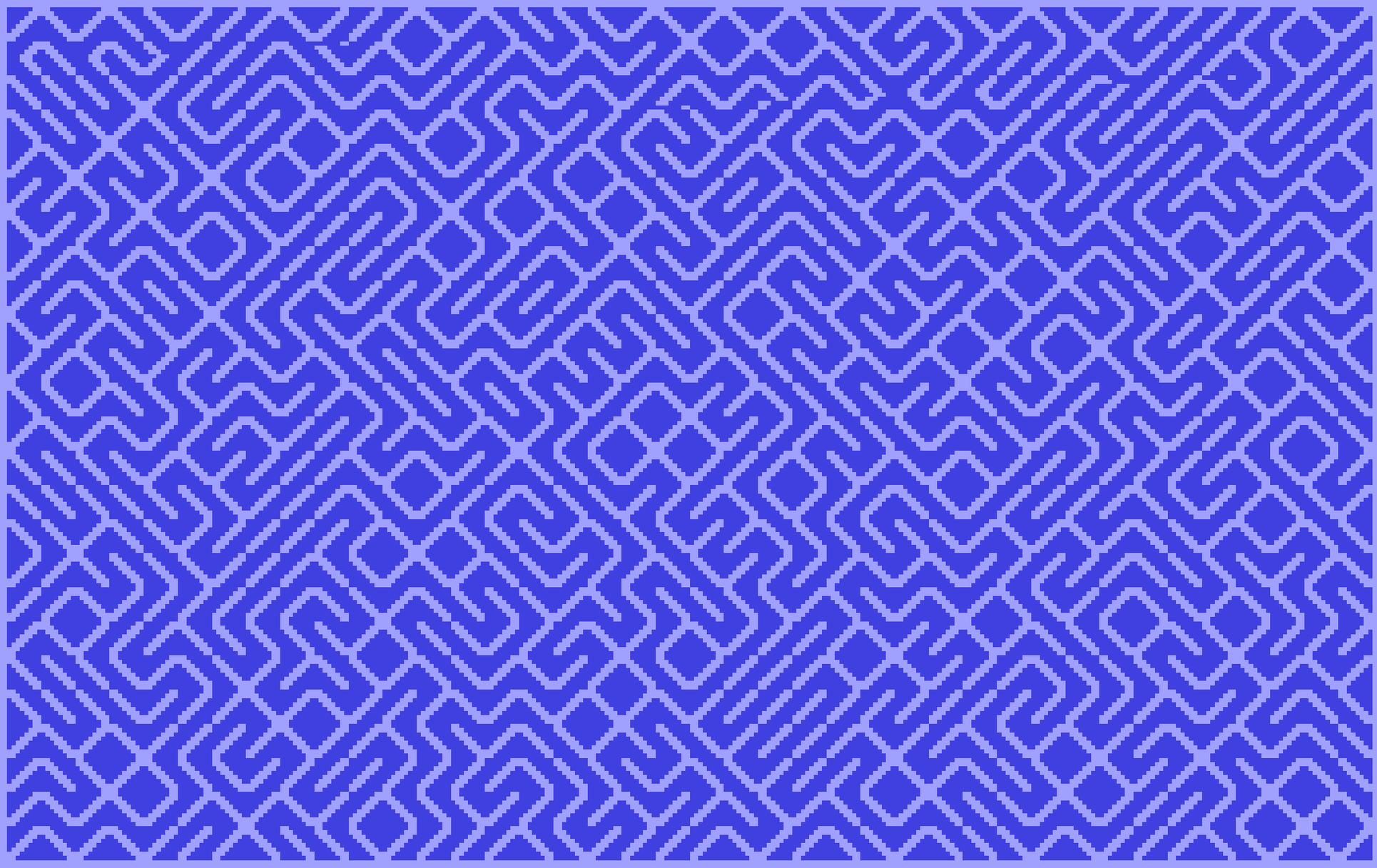
75% heads, 25% tails

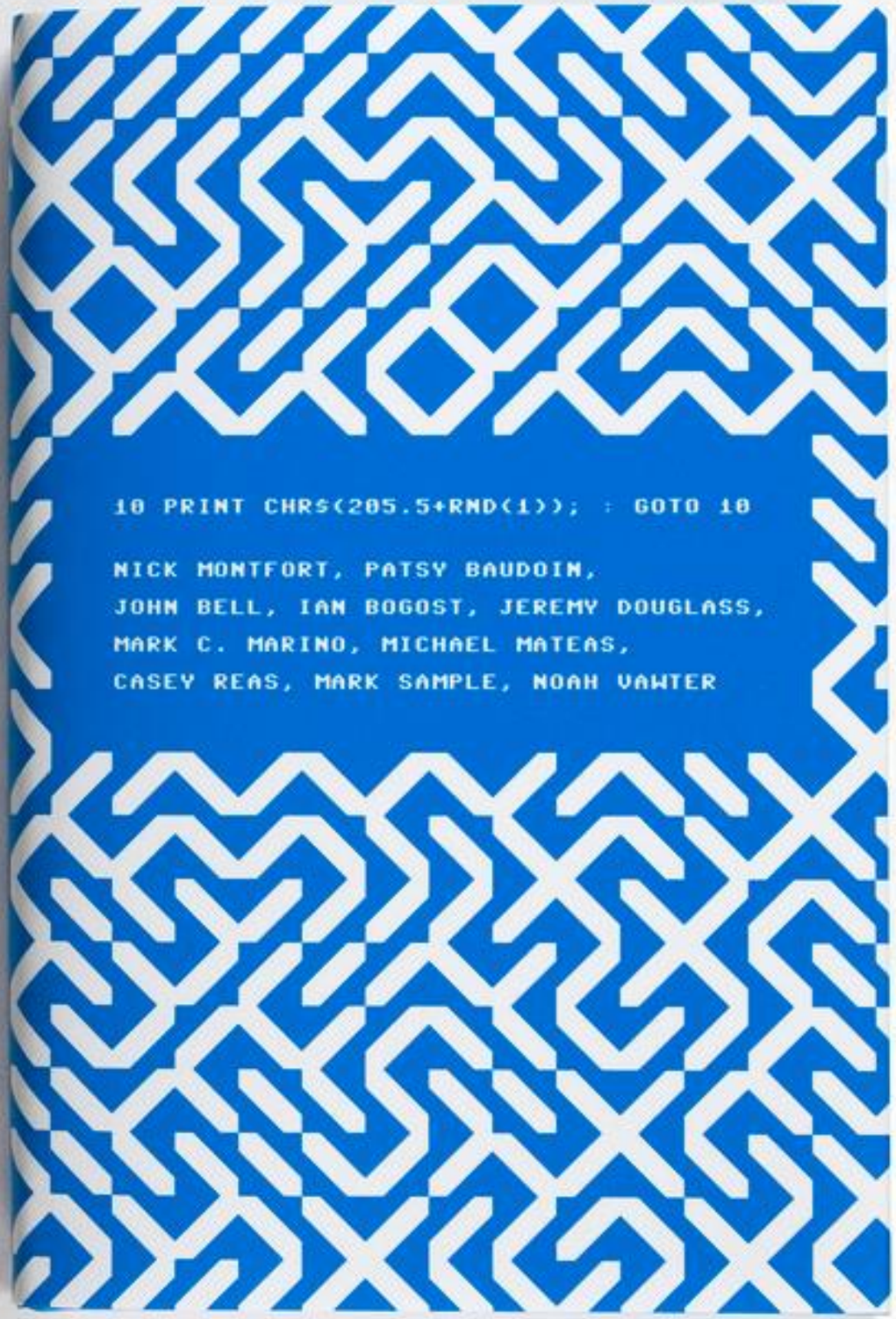
```
let th = 0;
let tt = 0;

function setup() {
   millionBiasedCoinFlips();
}

function millionBiasedCoinFlips() {
   for (let i = 0; i < 1000000; i++) {
      if (random(1) < 0.75) {
         th++;
      } else {
         tt++;
      }
   }
   print("Heads: " + th + " Tails: " + tt);
}
```

```
Heads: 750152 Tails: 249848
```

https://openprocessing.org/sketch/1097760

```
10 PRINT CHR$(205.5+RND(1)); : GOTO 10
```




10 PRINT CHR$(205.5+RND(1)); : GOTO 10
NICK MONTFORT, PATSY BAUDOIN,
JOHN BELL, IAN BOGOST, JEREMY DOUGLASS,
MARK C. MARINO, MICHAEL MATEAS,
CASEY REAS, MARK SAMPLE, NOAH VAWTER

10print.org

Random Grid of Slashes (slide 1 of 2)

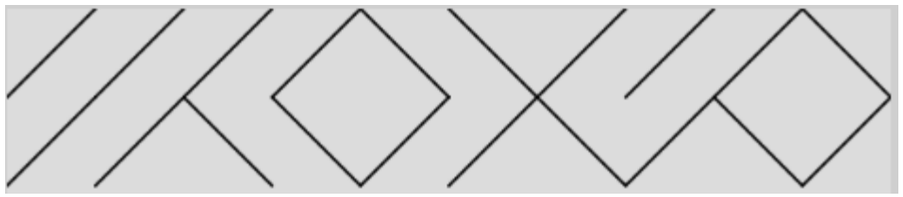
```
let y = 0;
let gridSize = 30;

function setup() {
    createCanvas(300, 300);
    background(220);
}

function mousePressed() {
    for (let i = 0; i < 10; i++) {
        if (random(1) < 0.5) {
            line(i * gridSize, y, i * gridSize + gridSize, y + gridSize);
        } else {
            line(i * gridSize + gridSize, y, i * gridSize, y + gridSize);
        }
    }
    y += gridSize;
}
```

https://openprocessing.org/sketch/1097792

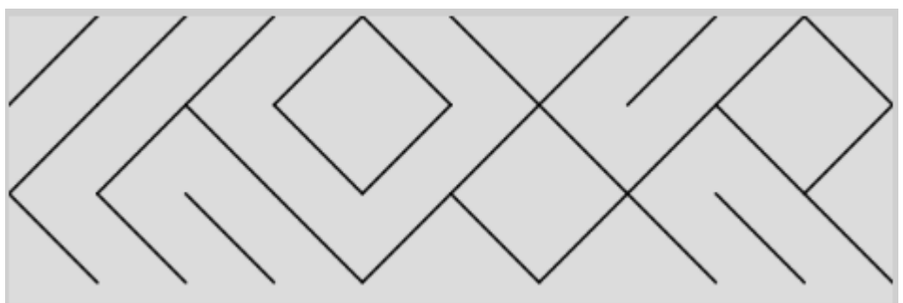
Random Grid of Slashes (slide 2 of 2)

After 1 mouse press

After 2 mouse presses



After 3 mouse presses



Other Resources for 10print

- 10print.org
  - A website about 10print
- Daniel Shiffman video
  - https://www.youtube.com/watch?v=bEyTZ5ZZxZs
- Example from previous years of CS106. Not used in W21.
  - Week6_ TenPrintRandomVis

https://www.youtube.com/watch?v=1cUUfMeOijg

Cloudflare lobby [photo by @mahtin]

Which of the following lines of code might we place in the blank below, giving a function that simulates flipping a coin?

```
function flipCoin() {

}
```

(A) `return random(1) < 0.5;`

(B) `return int(random(2)) === 0;`

(C) `return random(-50, 50) > 0.0;`

(D) `return int(random(6)) % 2 === 0;`

(E) All of the above

Suppose we wished to simulate rolling a six-sided die. Which expression below would be best way to obtain the number rolled?

(A) `random(6)`

(B) `random(7)`

(C) `int(random(6))`

(D) `int(random(6)) + 1`

(E) `int(random(7))`

A fair coin is flipped ten times. Which of the following sequences of flips is the *least* likely to occur?

(A) H H H H H H H H H H

(B) H T H H T H T T T H

(C) H T H T H T H T H T

(D) T T T H T T T H T H

(E) These are all equally likely

Is this sequence of digits random?

0702179860943702770539217176293176752384674818467669405132000568127145263560827785771342757789609017362718787214684409012249534301465495855

**3.14159265358979323846264338327950288419716939937510582097494459230781640628620899862803482534211706798214808651328230664709384460955058223172535940812848111745028410270193852110555964462294895493038196442881097566593344612847564823378678316527120190914564856692346034861045432664821339360726024914127372458700660631558817488152092096282925409171536436789259036001133053054882046652138414695194151160943305727036575959195309218611738193261179310511854807446237996274956735188575272489122793818301194912983367336244065664308602139494639522473719070217986094370277053921717629317675238467481846766940513200056812714526356082778577134275778960917363717872146844090122495343014654958537105079227968925892354201995611212902196086403441815981362977477130996051870721134999999837297804995105973173281609631859502445945534690830264252230825334468503526193118817101000313783875288658753320838142061717766914730359825349042875546873115956286388235378759375195778185778053217122680661300192787661119590921642019893809525720106548586327886593615338182796823030195203530185296899577362259941389124972177528347913151557485724245415069595082953311686172785588907509838175463746493931 9

Most random number generators are like the digits of π: completely deterministic, but *hard to predict.*

These are called **Pseudorandom Number Generators** (PRNGs).

`randomSeed(seed)`

Reset the internal state of p5's PRNG based on the passed-in seed. A given seed will always produce the same sequence of answers to a given sequence of calls to **`random()`**.

randomSeed() always produces the same result

```
function setup() {
  createCanvas(400, 400);
  background(220);

  randomSeed(1);

  print(random(50));
  print(random(50));
  print(random(50));
  print(random(50));
  print(random(50));
}
```

```
11.822776263579726
18.4635336860083O4
25.212101615034044
35.244163183961064
2.5271814316511154
```

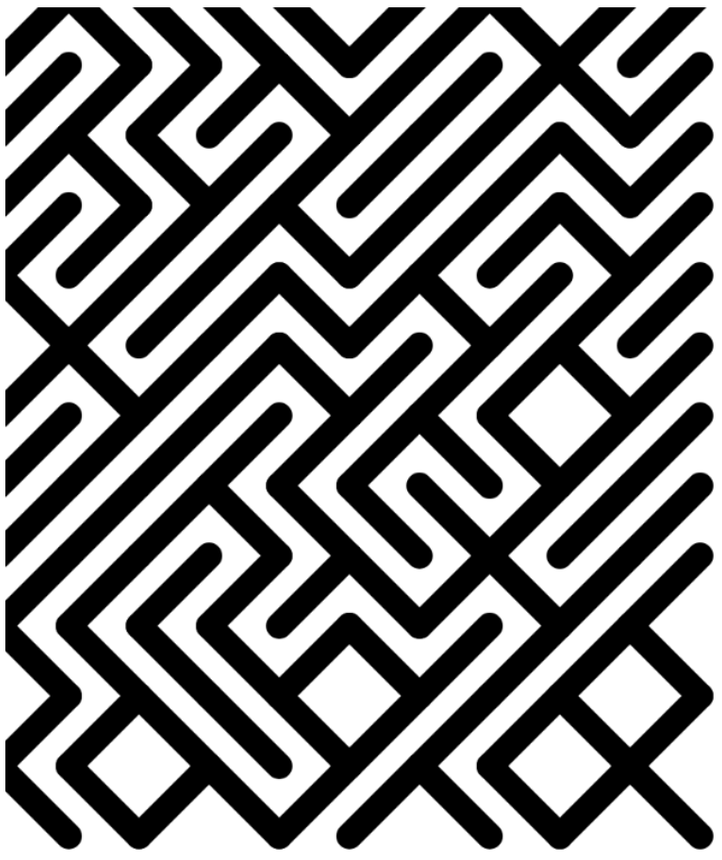
```
11.822776263579726
18.4635336860083O4
25.212101615034044
35.244163183961064
2.5271814316511154
```

```
11.822776263579726
18.4635336860083O4
25.212101615034044
35.244163183961064
2.5271814316511154
```

https://openprocessing.org/sketch/1104392

TenPointRandomSeed (slide 1 of 2)

```
let seed;

function setup() {
   createCanvas(800, 800);
   // It doesn't really matter what seed you
   // start with here.
   seed = 83567345;
}

function keyPressed() {
   if (key === "a") {
      seed -= 1;
   } else if (key === 'd') {
      seed += 1;
   }
}
```



https://openprocessing.org/sketch/1104356

TenPointRandomSeed (slide 2 of 2)

```
function draw() {
   background(255);
   strokeWeight(15);
   randomSeed(seed);

   for (let row = 0; row < 12; ++row) {
      for (let col = 0; col < 10; ++col) {
         let x = col * 40;
         let y = row * 40;

         if (random(1) < 0.5) {
            // Draw a line from NW to SE
            line(x, y, x + 40, y + 40);
         } else {
            // Draw a line from NE to SW
            line(x + 40, y, x, y + 40);
         }
      }
   }
   textSize(24);
   text("Seed: " + seed, 450, 200);
}
```

Pseudorandom number generators are a double-edged sword.

The good: we can always “replay” a sequence of pseudorandom numbers.

The bad: pseudorandom numbers ***are not actually random.***

BallOnRandomLine (slide 1 of 2)

```
let count = 1;
let ballX;
let ballY;

function setup() {
   createCanvas(500, 500);
   noFill();
   frameRate(10);
}
```

https://openprocessing.org/sketch/1104395

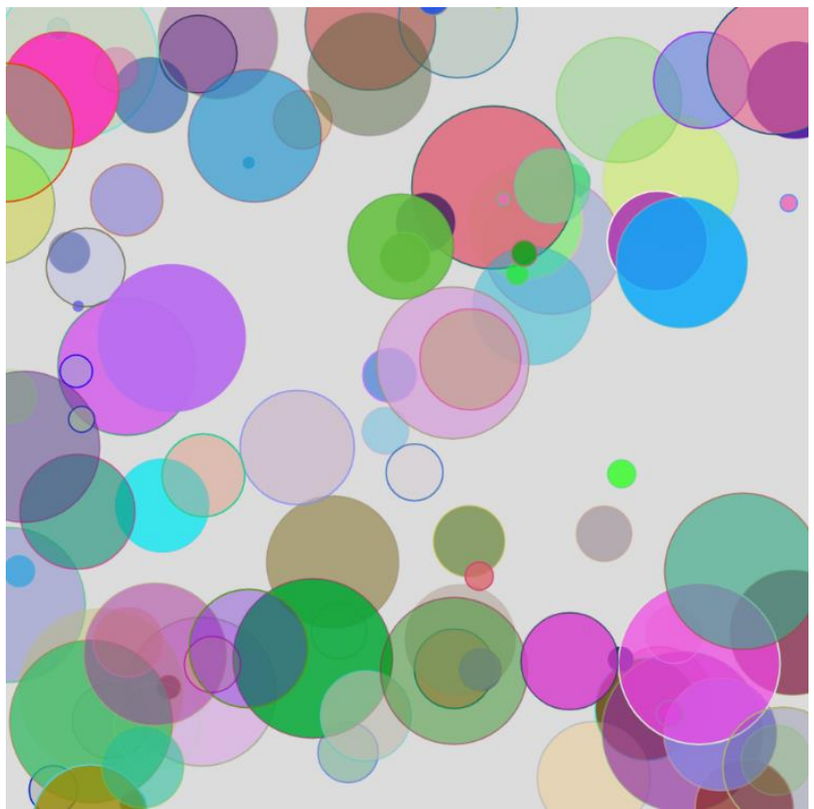
BallOnRandomLine (slide 2 of 2)

```
function draw() {
   background(220);
   randomSeed(0);
   let x = 0;
   let y = height / 2;
   beginShape();
   for (let i = 1; i < width; i = i + 5) {
      if (i === count) {
         ballX = x;
         ballY = y;
      }
      x = i;
      y = random(height / 2 - 20, height / 2 + 20);
      vertex(x, y);
   }
   endShape();
   ellipse(ballX, ballY, 10, 10);
   count = (count + 5) % width;
}
```

CircleSample (slide 1 of 2)

```
let seed = 395345;
let mySlider;

function setup() {
   createCanvas(500, 500);
   createP(" ");
   mySlider = createSlider(1, 1000, 100);
}

function keyPressed() {
   seed = seed + 1;
}
```

https://openprocessing.org/sketch/1104403



CircleSample (slide 2 of 2)

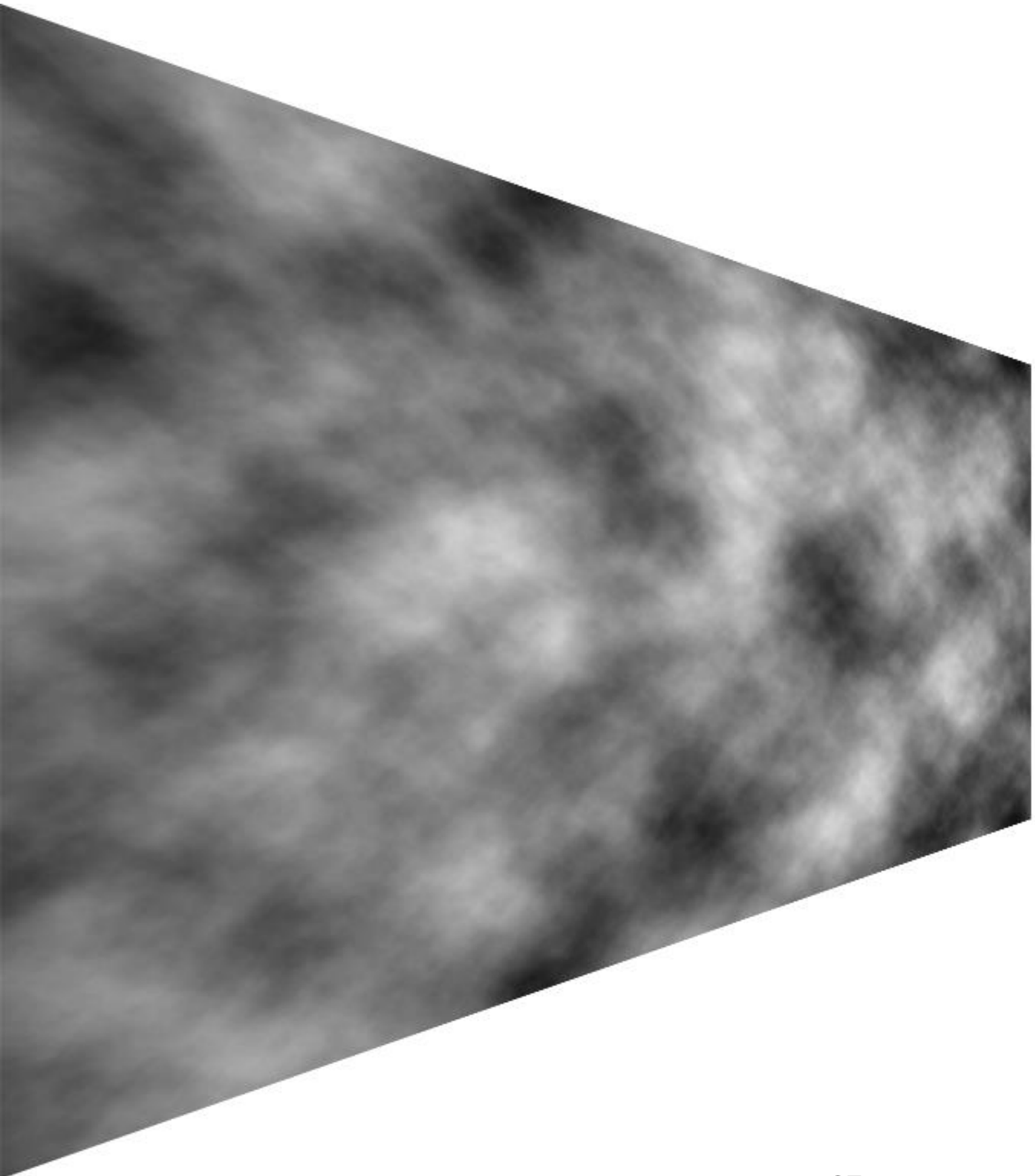
```
function draw() {
   randomSeed(seed);
   background(220);

   let numCircles = int(mySlider.value());

   for (let i = 0; i < numCircles; i++) {
      let d = random(5, 100);
      let x = random(width);
      let y = random(height);
      fill(random(255), random(255), random(255),random(255));
      stroke(random(255), random(255), random(255),random(255));
      ellipse(x, y, d, d);
   }
}
```

Goals

- Understand how to use random() to generate unpredictable behaviour.

- Understand how to use randomSeed() to control the generation of pseudorandom numbers.

- Understand the difference between random numbers and pseudorandom numbers.



(Part 2) Noise

CS 106 Winter 2021

noise()

- Perlin noise is a random sequence generator producing a more natural ordered, harmonic succession of numbers compared to the standard **random()** function.

- It was invented by Ken Perlin in the 1980s and been used since in graphical applications to produce procedural textures, natural motion, shapes, terrains etc.

1D noise()

- Always returns a number between 0-1
- For any given run of your program the same argument always returns the same result.
  - noise(6);
    - Returns a number between 0-1
  - Another call noise(6);
    - Returns the same number

Remember random()

- random(1) returns a number between 0 and 1
- Calling random(1) again returns a different number between 0-1
- random(6) returns a number between 0-6

noise(x) always returns the same number

```
let v;
function setup() {
  let start = 100;
  v = noise(start);// v is between 0 and 1
  print(v);
  v = noise(start);// v is same number as the v above
  print(v);
  v = noise(start);// v is same number as both v above
  print(v);
}
```

Varying the noise() argument
noise() can return similar or dissimilar numbers

```
let v1;
let v2;
let v3;
function setup() {
  let start = 10;

  v1 = noise(start); // returns a number between 0-1

  v2 = noise(start + 0.001);//returns a num close to v1
                            // num is between 0-1 always

  v3 = noise(start + 1);//returns a dissimilar num
                        // number is between 0-1 always

  print(v1, v2, v3);
}
```

Create a smooth line with noise()

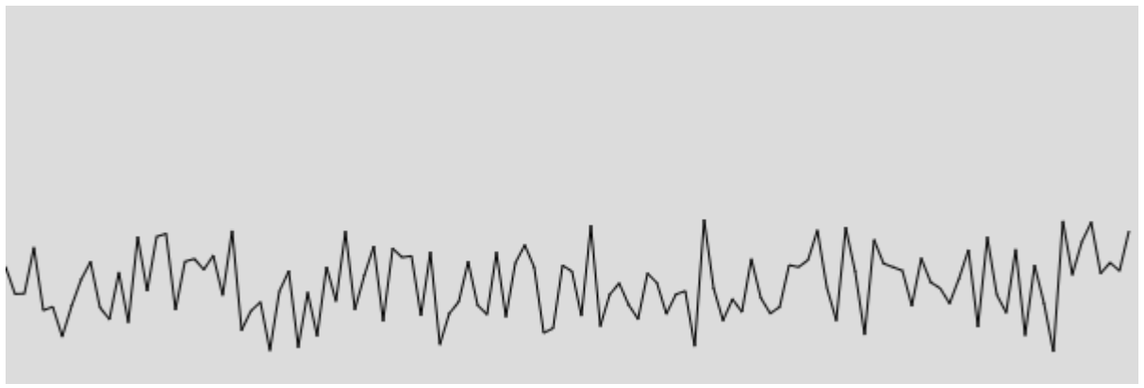
```
// Let's draw a smooth line
function setup() {
  createCanvas(600, 200);
  background(220);
  noFill();
  let v = 10;
  let vInc = 0.05;
  let space = 5;
  let numPoints = width / space;

  beginShape();
  for (let i = 0; i < numPoints; i++) {
    vertex(i * space, height/2 + (noise(v) * 100));
    v = v + vInc;
  }
  endShape();
}
```

Modify the above code: vlnc = 0.001;

- The line is not straight. But it doesn't vary much. It is very smooth.

Modify the above code: vlnc = 1.0;

- The line varies a lot. It is not a smooth line.



Moving Mountains (1 of 2)

```
let vStart = 10;
let v;
let vInc = 0.01;
let xoff = 0;

function setup() {
  createCanvas(600, 200);
  fill(0);
}
```

https://openprocessing.org/sketch/1105435

Moving Mountains (2 of 2)

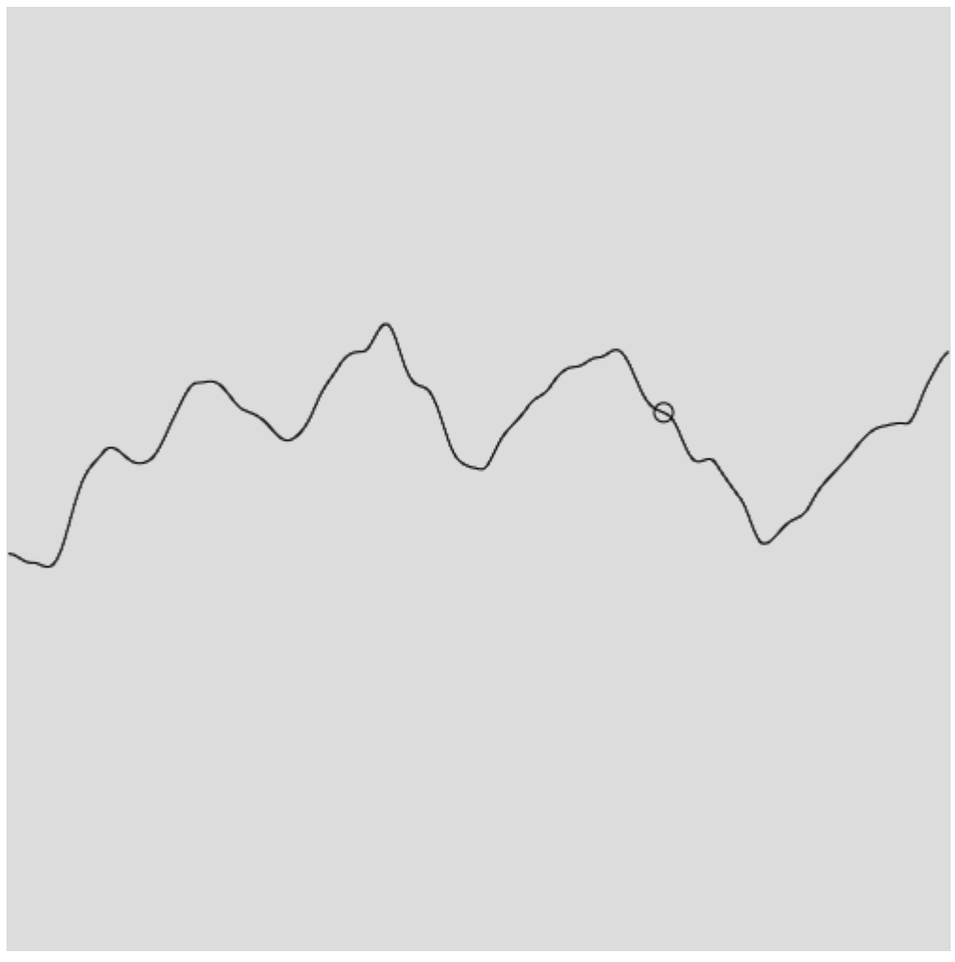
```
function draw() {
  v = vStart + xoff;
  background(220);
  beginShape();
  for (let i = 0; i < width; i++) {
    vertex(i, height/2 + (noise(v) * 100));
    v = v + vInc;
  }
  vertex(width, height);
  vertex(0, height);
  endShape();
  xoff = xoff + .025;
}
```

Moving a ball along a noisey line

- Demo code:
  - “BallOnNoiseyLine”

BallOnNoiseyLine (1 of 2)

```
let count = 1;
let v;
let vInc = 0.01;
let ballX;
let ballY;

function setup() {
  createCanvas(500, 500);
  noFill();
}
```



https://openprocessing.org/sketch/1105466

BallOnNoiseyLine (2 of 2)

```
function draw() {
  background(220);
  v = 1;
  beginShape();
  for (let i = 1; i < width; i++) {
    let x = i;
    let y = map(noise(v), 0, 1, 100, 400);
    vertex(x, y);
    v = v + vInc;
    if (i === count) {
      ballX = x;
      ballY = y;
    }
  }
  endShape();
  ellipse(ballX, ballY, 10, 10);
  count = (count + 1) % width;
}
```

Demo Code

- Demo code:
  - “Noise1DDirectManip”

Direct Manipulation

- Use mouseDragged() function
- Calculate movement of the mouse (left-right or right-left)
- Use mouse movement as Direct Manipulation

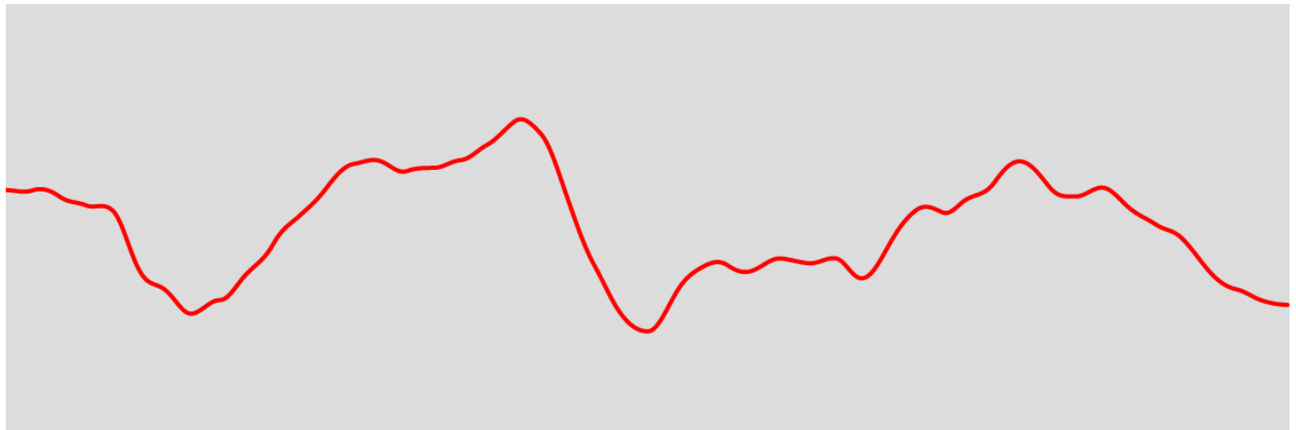
noise1DDirectManip (1 of 2)

```
let dx = 0;
let inc = 0.01;
let start = 10;
let v;

function setup() {
    createCanvas(600, 200);
}
```

https://openprocessing.org/sketch/1105530

noise1DDirectManip (2 of 2)

```
function draw() {
    background(220);
    strokeWeight(2);
    stroke(255, 0, 0);
    noFill();
    v = start - dx;

    beginShape();
    for (let x = 0; x < 600; x++) {
        let y = map(noise(v), 0, 1, 0, height);
        vertex(x, y);
        v += inc;
    }
    endShape();
}

function mouseDragged() {
    dx += (mouseX - pmouseX) * inc;
}
```



2D Noise

- Go through demo code:
  - “Noise2DDirectManip”

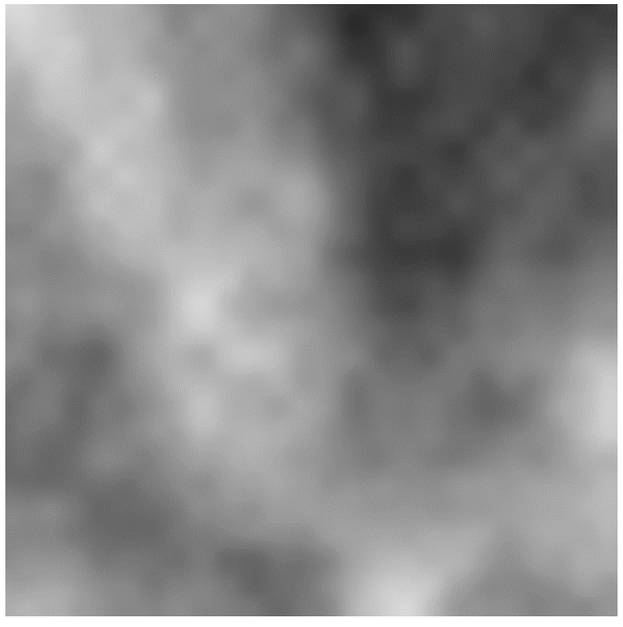
“Noise2DDirectManip” (1 of 2)

```
let tx;
let ty;

// Scaling factor for the noise() function.  Try
// changing this number!
let sc = 100.0;

function setup(){
  createCanvas(300, 300);
}
```

https://openprocessing.org/sketch/1106083

“Noise2DDirectManip” (2 of 2)

```
function draw(){
  background(220);
  for ( let y = 0; y < height; ++y ) {
    for ( let x = 0; x < width; ++x ) {
      v = noise( (x-tx) / sc, (y-ty) / sc );
      set( x, y, color( v * 256.0 ) );
    }
  }
    updatePixels();
}

function mouseDragged(){
  tx += mouseX - pmouseX;
  ty += mouseY - pmouseY;
}
```



Goals

- Be able to write short sketches that use the noise() function.

- Understand how noise() works in 1D and 2D, especially 1D.

- Understand the difference between random() and noise().

Which of these expressions is NOT guaranteed to return a number between 0 and 1?

(A) `random(100) / 100.0`

(B) `random(0, 1);`

(C) `noise(3);`

(D) `noise(0, 1);`

(E) They all return numbers between 0 and 1.

Assume we have the following two lines of code:

```
let a = noise(99.0);
let b = noise(99.01);
```

If noise(99) returns “0.5”, which is the most likely outcome returned by noise(99.01)?

(A) `1.49`

(B) `0.75`

(C) `0.51`

(D) `99.51`

(E) A number between 99 and 99.01

Assume we have the following line of code:

```
let a = noise(99.0);
```

Which is the most likely value of “a”?

(A) `-0.43`

(B) `99`

(C) `0.43`

(D) `A number between 0-99`

The following 3 clicker questions are about this code:

```
createCanvas(400, 100);
let v = noise(10);
let x1 = 100 + (v * 100);
let x2 = x1 + 100;
line(x1, 50, x2, 50);
```

What might the value of “v” be?

(A) **10**

(B) **A number between 0-1**

(C) **A number between 0-10**

The following 3 clicker questions are about this code:

```
createCanvas(400, 100);
let v = noise(10);
let x1 = 100 + (v * 100);
let x2 = x1 + 100;
line(x1, 50, x2, 50);
```

What might the value of “x1” be?

(A) **A number between 0-100**

(B) **A number between 100-200**

(C) **A number between 100.0-101.0**

The following 3 clicker questions are about this code:

```
createCanvas(400, 100);
let v = noise(10);
let x1 = 100 + (v * 100);
let x2 = x1 + 100;
line(x1, 50, x2, 50);
```

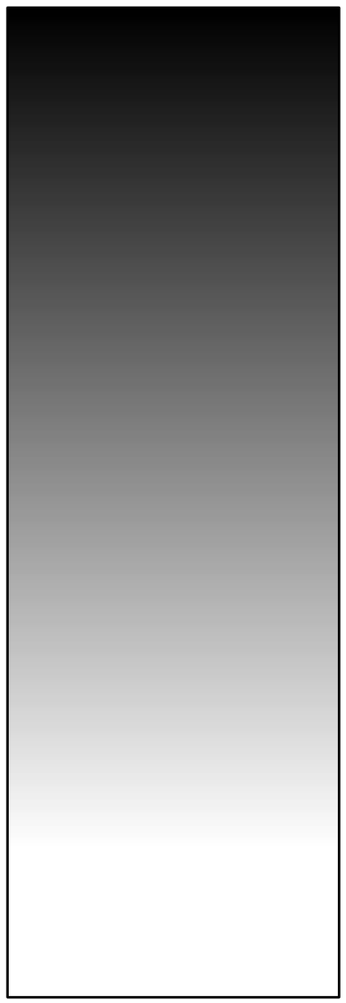
What might the value of “x2” be?

(A) **A number exactly 100 larger than x1**

(B) **A number between 100-200**

(C) **A number between 200-300**

Remember this ex from CS105
“Similar” code is needed this week
Let’s Review the code (next slide)



Draw Gradient:
From CS105 Lecture Slides

```
let shade = 0;

function setup() {
  createCanvas(100, 255);
  background(220);

  for (let y = 0; y <= height; y++) {
    stroke(shade);
    line(0, y, width, y);
    shade += 1;
  }
}
```

Dan Shiffman videos on noise()

- Dan Shiffman has several excellent videos on noise()
  - I.2: Introduction - Perlin Noise and p5.js Tutorial
    - https://www.youtube.com/watch?v=Qf4dIN99e2w
  - I.3: noise() vs random() - Perlin Noise and p5.js Tutorial
    - https://www.youtube.com/watch?v=YcdldZ1E9gU
  - I.4: Graphing 1D Perlin Noise - Perlin Noise and p5.js Tutorial
    - https://www.youtube.com/watch?v=y7sgcFhk6ZM
  - I.5: 2D Noise - Perlin Noise and p5.js Tutorial
    - https://www.youtube.com/watch?v=ikwNrFvnL3g