Review

• Cellular Automata
• The Game of Life
  – 2D arrays, 3D arrays
• Review Array Problems
• Challenge
Up until now ...

• All movement and sizing of graphical objects have been accomplished by modifying object coordinate values \((x, y)\) and drawing in the default coordinate system.

There is another option...

• We can leave coordinate values unchanged, and modify the coordinate system in which we draw.
The commands that draw these two ellipses are identical.

What has changed is the coordinate system in which they are drawn.
Three ways to transform the coordinate system:

1. Translate
   – Move axes left, right, up, down ...

2. Scale
   – Magnify, zoom in, zoom out ...

3. Rotate
   – Tilt clockwise, tilt counter-clockwise ...
Scale

- All coordinates are multiplied by an x-scale-factor and a y-scale-factor.
- The size of everything is magnified about the origin (0,0)
- Stroke thickness is also scaled.

```plaintext
scale( factor );
scale( x-factor, y-factor );
```
void setup() {
    size(500, 500);
    smooth();
    noLoop();

    line(1, 1, 25, 25);
}
void setup() {
  size(500, 500);
  smooth();
  noLoop();

  scale(2, 2);
  line(1, 1, 25, 25);
}

example2.pde
void setup() {
  size(500, 500);
  smooth();
  noLoop();

  scale(20,20);
  line(1, 1, 25, 25);
}
void setup() {
    size(500, 500);
    smooth();
    noLoop();

    scale(2, 5);
    line(1, 1, 25, 25);
}

draw()
The best way to see what is happening, is to look at a grid drawn in the coordinate system.

```cpp
void grid() {
    grid(-100, 100, 10, -100, 100, 10);
}

void grid(float x1, float x2, float dx,
          float y1, float y2, float dy) {
    // Draw grid
    stroke(225,225,255);
    for (float x=x1; x<=x2; x+=dx) line(x,y1,x,y2);
    for (float y=y1; y<=y2; y+=dy) line(x1,y,x2,y);

    // Draw axes
    float inc = 0.005*width;
    float inc2 = 2.0*inc;
    stroke(0);
    fill(0);
    line(x1,0,x2,0);
    triangle(x2+inc2,0,x2,inc,x2,-inc);
    text("x",x2+2*inc2,inc2);
    line(0,y1,0,y2);
    triangle(0,y2+inc2,inc,y2,-inc,y2);
    text("y",inc2,y2+2*inc2);
}
```
void setup() {
    size(500, 500);
    background(255);
    smooth();
    noLoop();
}

void draw() {
    grid();
    scale(2,2);
    grid();
    grid();
}
void draw() {
    grid();
    fill(255);
    ellipse(50, 50, 40, 30);

    scale(2, 2);
    grid();
    fill(255);
    ellipse(50, 50, 40, 30);
}
Translate

– The origin of the coordinate system (0,0) is shifted by the given amount in the x and y directions.

```plaintext
translate( x-shift, y-shift);
```
void draw() {
  grid();
  translate(250, 250);
  grid();
}

grid2.pde
void draw() {
    grid();
    fill(255);
    ellipse(50, 50, 40, 30);

    translate(250, 250);
    grid();
    fill(255);
    ellipse(50, 50, 40, 30);
}
Transformations can be combined

– Combine Scale and Translate to create a coordinate system with the y-axis that increases in the upward direction
– Axes can be flipped using negative scale factors

– Order in which transforms are applied matters!
void draw() {
    translate(0, height);
    scale(4, -4);
    grid();
}
Rotate

– The coordinate system is rotated around the origin by the given angle (in radians).

rotate( radians );
void draw() {
    rotate( 25.0 * (PI/180.0) );
    grid();
}

grid4.pde
void draw() {
    translate(250.0, 250.0);
    //rotate( 25.0 * (PI/180.0) );
    //scale( 2 );
    grid();
}

grid4.pde
void draw() {
    translate(250.0, 250.0);
    rotate( 25.0 * (PI/180.0) );
    //scale( 2 );
    grid();
}

grid4.pde
void draw() {
    translate(250.0, 250.0);
    rotate( 25.0 * (PI/180.0) );
    scale( 2 );
    grid();
}
void draw() {
    grid();
    fill(255);
    ellipse(50, 50, 40, 30);

    translate(250.0, 250.0);
    rotate( 25.0 * (PI/180.0) );
    scale(2);
    grid();
    fill(255);
    ellipse(50, 50, 40, 30);
}
Some things to remember:

1. Transformations are cumulative.

2. All transformations are cancelled each time `draw()` exits.
   - They must be reset each time at the beginning of `draw()` before any drawing.

3. Rotation angles are measured in radians
   - $\pi$ radians = 180°
   - radians = (PI/180.0) * degrees

4. Order matters
```java
String[] word = new String[]
{"A","B","C","D","E","F","G","H","I","J","K","L","M","N","O","P","Q","R","S","T","U","V","W","X","Y","Z","0","1","2","3","4","5","6","7","8","9"};

void setup() {
    size(500, 500);
    smooth();
    noLoop();
}

void draw() {
    background(255);
    translate(250,250);
    fill(0);
    for (int i=0; i<word.length; i++) {
        text(word[i], 0.0, -150.0);
        rotate(10.0 * (PI/180.0));
    }
}
```

Each time through the loop an additional 10 degrees is added to the rotation angle.

Total rotation accumulates.
Each time through the loop an initial rotation angle is set, incremented, and saved in a global.

Transformations reset each time draw() is called.

example4.pde