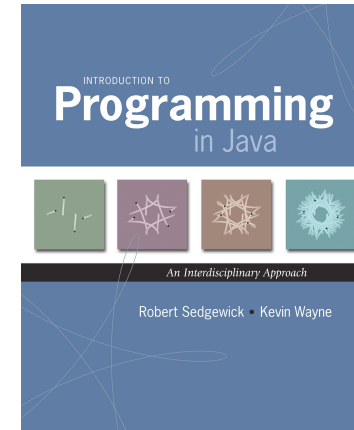




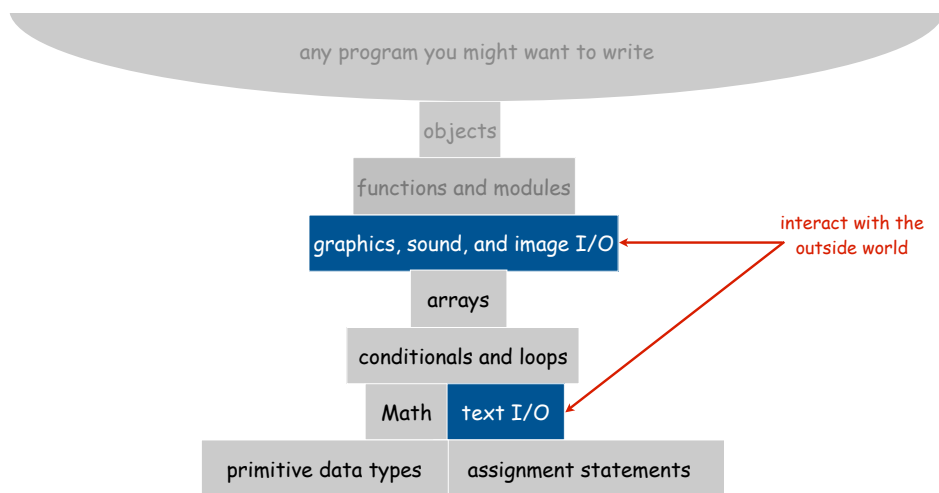
1

## 1.5 Input and Output



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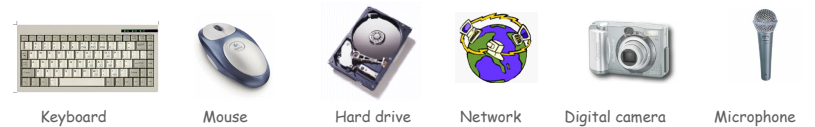
### A Foundation for Programming



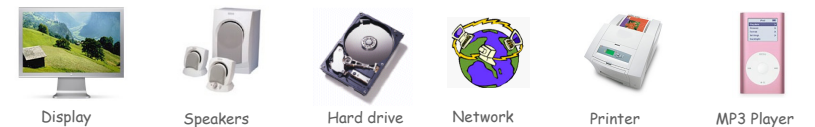
3

### Input and Output

#### Input devices.



#### Output devices.



**Goal.** Java programs that interact with the outside world.

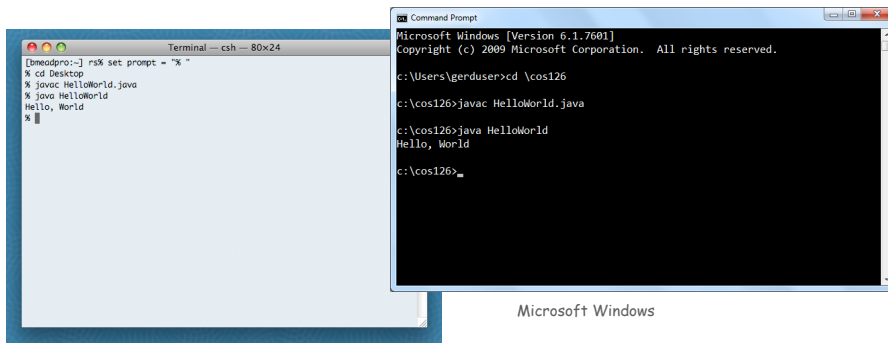
#### Our approach.

- Define Java libraries of functions for input and output.
- Use operating system (OS) to connect Java programs to: file system, each other, keyboard, mouse, display, speakers.

4

## Terminal

**Terminal.** Application for typing commands to control the operating system.



Mac Terminal

Microsoft Windows

5

## Command-Line Input and Standard Output

**Command-line input.** Read an integer  $N$  as command-line argument.

**Standard output.**

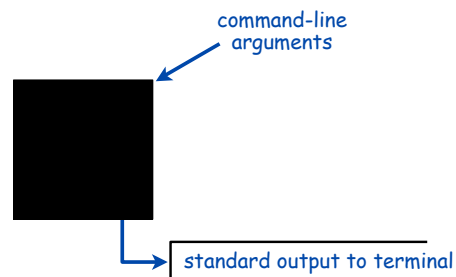
- Flexible OS abstraction for output.
- (In Java, output from `System.out.println()` goes to standard output.)
- By default, standard output is sent to the terminal.

```
public class RandomSeq
{
    public static void main(String[] args)
    {
        int N = Integer.parseInt(args[0]);
        for (int i = 0; i < N; i++)
            StdOut.println(Math.random());
    }
}
```

```
% java-introcs RandomSeq 4
0.9320744627218469
0.4279508713950715
0.08994615071160994
0.6579792663546435
```

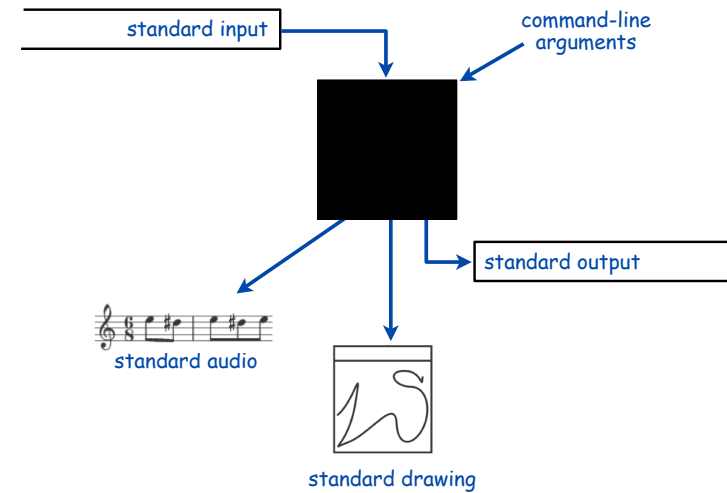
6

## Old Bird's Eye View



7

## New Bird's Eye View



8

# Standard Input and Output

## Command-Line Input vs. Standard Input

### Command-line inputs.

- Useful for providing a **few** user values (arguments) to a program.
- Not practical for a large number of user inputs.
- Input entered **before** program begins execution.

### Standard input.

- Flexible OS abstraction for input.
- Useful for providing an **unlimited amount** of data to a program.
- By default, standard input is received from Terminal window.
- Input entered **while** program is executing.

## Standard IO Warmup

**To use.** If you installed your programming environment correctly in Assignment 0, then you're all set: use `javac-introcs` and `java-introcs`. Otherwise, download `stdIn.java` and `stdOut.java` from the booksite, and put in working directory (with `Add.java`).

```
public class Add
{
    public static void main(String[] args)
    {
        StdOut.print("Type the first integer: ");
        int x = StdIn.readInt();
        StdOut.print("Type the second integer: ");
        int y = StdIn.readInt();
        int sum = x + y;
        StdOut.println("Their sum is " + sum);
    }
}
```

```
% java-introcs Add
Type the first integer: 1
Type the second integer: 2
Their sum is 3
```

## Standard IO Example: Averaging A Stream of Numbers

**Average.** Read in a stream of numbers, and print their average.

```
public class Average
{
    public static void main(String[] args)
    {
        double sum = 0.0; // cumulative total
        int n = 0; // number of values
        while (!StdIn.isEmpty())
        {
            double x = StdIn.readDouble();
            sum = sum + x;
            n++;
        }
        StdOut.println(sum / n);
    }
}
```

```
% java-introcs Average
10.0 5.0 6.0
3.0 7.0 32.0
<Ctrl-d>
10.5
```

**Key point.** Program does not limit amount of data.

<ctrl-d> is OS X/Linux/Unix/DrJava EOF  
<ctrl-z> is Windows analog

## Standard Input and Output

**Standard input.** `StdIn` library has methods to read text input.

**Standard output.** `StdOut` library has methods to write text output.

```
public class StdIn
{
    boolean isEmpty()    true if no more values, false otherwise
    int readInt()       read a value of type int
    double readDouble() read a value of type double
    long readLong()    read a value of type long
    boolean readBoolean() read a value of type boolean
    char readChar()    read a value of type char
    String readString() read a value of type String
    String readLine()  read the rest of the line
    String readAll()   read the rest of the text
}
```

```
public class StdOut
{
    void print(String s)    print s
    void println(String s) print s, followed by a newline
    void println()         print a new line
    void printf(String f, ...) formatted print
}
```

libraries developed  
for this course  
(and also broadly useful)



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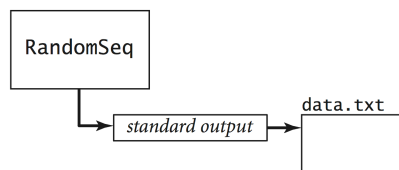
## Redirection and Piping

(but not in Dr. Java!)

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## Redirecting Standard Output

**Redirecting standard output.** Use OS directive to send standard output to a file for permanent storage (instead of terminal window).



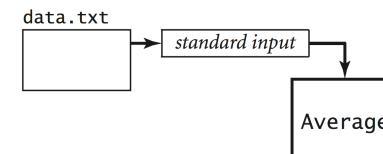
```
% java-introcs RandomSeq 1000 > data.txt
```

redirect standard output

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## Redirecting Standard Input

**Redirecting standard input.** Use OS directive to read standard input from a file (instead of terminal window).



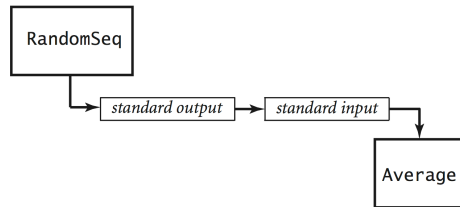
```
% more < data.txt
0.5475375782884312
0.4971087292684019
0.23123808041753813
...
% java-introcs Average < data.txt
0.4947655567740991
```

redirect standard input

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## Connecting Programs

**Piping.** Use OS directive to make the standard output of one program become the standard input of another.



```
% java-introcs RandomSeq 1000000 | java-introcs Average
0.4997970473016028

% java-introcs RandomSeq 1000000 | java-introcs Average
0.5002071875644842
```

pipe standard output to standard input

**Key point.** Program does not limit amount of data.

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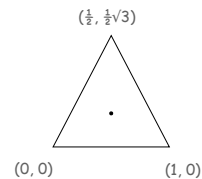
## Standard Drawing

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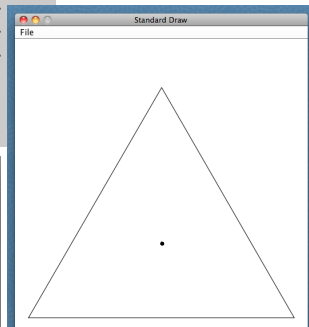
## "Hello World" for Standard Draw

**To use.** If you installed your programming environment correctly in Assignment 0, you're all set. Otherwise, download `stdDraw.java` and put in working directory (with `Triangle.java`).

```
public class Triangle
{
    public static void main(String[] args)
    {
        double t = Math.sqrt(3.0) / 2.0;
        StdDraw.line(0.0, 0.0, 1.0, 0.0);
        StdDraw.line(1.0, 0.0, 0.5, t);
        StdDraw.line(0.5, t, 0.0, 0.0);
        StdDraw.point(0.5, t/3.0);
    }
}
```



```
%
%
% java-introcs Triangle
```



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## Data Visualization

**Plot filter.** Read in a sequence of  $(x, y)$  coordinates from standard input, and plot using standard drawing.

```
public class PlotFilter
{
    public static void main(String[] args)
    {
        double xmin = StdIn.readDouble();
        double ymin = StdIn.readDouble();
        double xmax = StdIn.readDouble();
        double ymax = StdIn.readDouble();
        StdDraw.setXscale(xmin, xmax);
        StdDraw.setYscale(ymin, ymax);

        while (!StdIn.isEmpty())
        {
            double x = StdIn.readDouble();
            double y = StdIn.readDouble();
            StdDraw.point(x, y);
        }
    }
}
```

rescale  
coordinate  
system

read in points,  
and plot them

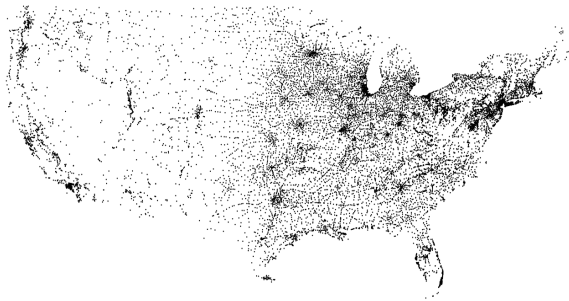
21

## Data Visualization

```
% more < USA.txt
669905.0 247205.0 1244962.0 490000.0
1097038.8890 245552.7780
1103961.1110 247133.3330
1104677.7780 247205.5560
...

% java-introcs PlotFilter < USA.txt
```

bounding box  
coordinates of 13,509 US cities  
find link to USA.txt in Booksite 1.5

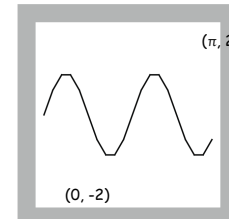


22

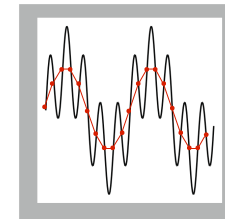
## Plotting a Function with StdDraw

```
double[] x = new double[N+1];
double[] y = new double[N+1];
for (int i = 0; i <= N; i++)
{
    x[i] = Math.PI * i / N;
    y[i] = Math.sin(4*x[i]) + Math.sin(20*x[i]);
}
StdDraw.setXscale(0, Math.PI);
StdDraw.setYscale(-2.0, +2.0);
for (int i = 0; i < N; i++)
    StdDraw.line(x[i], y[i], x[i+1], y[i+1]);
```

N = 20



N = 200



Lesson 1: Plotting is simple.

Lesson 2: If you don't plot enough points, you might miss something!

$$y = \sin 4x + \sin 20x, x \in [0, \pi]$$

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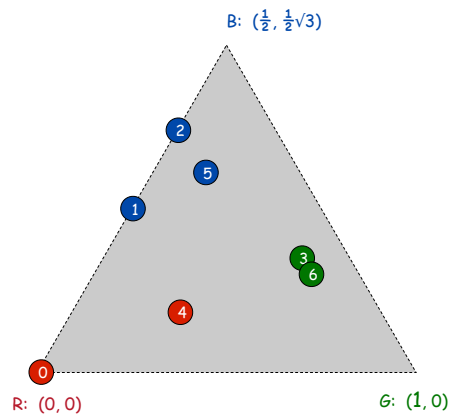
## Chaos Game

**Chaos game.** Play on equilateral triangle, with vertices R, G, B.

- Start at R.
- Repeat the following  $N$  times:
  - pick a random vertex
  - move halfway between current point and vertex
  - draw a point in color of vertex

Q. What picture emerges?

B B G R B G ...



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## Example: Chaos Game

```
public class Chaos
{
    public static void main(String[] args)
    {
        int T = Integer.parseInt(args[0]);
        double[] cx = { 0.000, 1.000, 0.500 };
        double[] cy = { 0.000, 0.000, 0.866 };

        double x = 0.0, y = 0.0;
        for (int t = 0; t < T; t++)
        {
            int r = (int) (Math.random() * 3);
            x = (x + cx[r]) / 2.0;
            y = (y + cy[r]) / 2.0;
            StdDraw.point(x, y);
        }
    }
}
```

$\frac{1}{2}\sqrt{3}$   
(best to avoid hardwired constants like this)

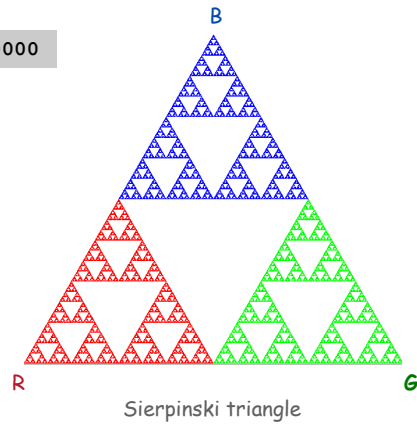
result: 0, 1, or 2

25

## Chaos Game

**Easy modification.** Color point according to random vertex chosen using `StdDraw.setPenColor(StdDraw.RED)` to change the pen color.

```
% java-introcs Chaos 10000
```

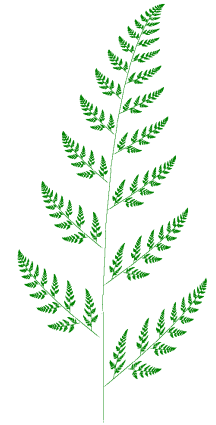


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## Barnsley Fern

**Barnsley fern.** Play chaos game with different rules.

probability	new x	new y
2%	.50	.27y
15%	$-.14x + .26y + .57$	$.25x + .22y - .04$
13%	$.17x - .21y + .41$	$.22x + .18y + .09$
70%	$.78x + .03y + .11$	$-.03x + .74y + .27$



- Q. What does computation tell us about nature?
- Q. What does nature tell us about computation?

20<sup>th</sup> century sciences. Formulas.

21<sup>st</sup> century sciences. Algorithms?

30

## Standard Drawing

**Standard drawing.** `StdDraw` library has methods to produce graphical output.

```
public class StdDraw
{
    void line(double x0, double y0, double x1, double y1)
    void point(double x, double y)
    void text(double x, double y, String s)
    void circle(double x, double y, double r)
    void filledCircle(double x, double y, double r)
    void square(double x, double y, double r)
    void filledSquare(double x, double y, double r)
    void polygon(double[] x, double[] y)
    void filledPolygon(double[] x, double[] y)
    void setXscale(double x0, double x1)
    void setYscale(double y0, double y1)
    void setPenRadius(double r)
    void setFont(Font f)
    void setCanvasSize(int w, int h)
    void clear(Color c)
    void show(int dt)
    void save(String filename)
    void picture(double x, double y, String filename)
}

```

reset x range  
reset y range

clear canvas; color it c  
show all; pause dt msec.  
save to .jpg or .png file  
plot image file on canvas

library developed  
for this course  
(and also broadly useful)



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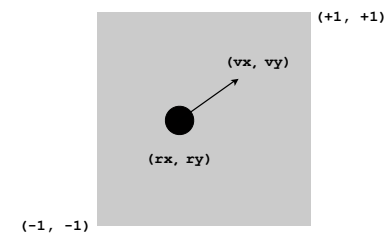
## Animation

**Animation loop.** Repeat the following:

- Clear the screen.
- Move the object.
- Draw the object.
- Display and pause for a short while.

**Ex.** Bouncing ball.

- Ball has position  $(rx, ry)$  and constant velocity  $(vx, vy)$ .
- Detect collision with wall and reverse velocity.



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## Bouncing Ball

```
public class BouncingBall
{
    public static void main(String[] args)
    {
        double rx = .480, ry = .860;
        double vx = .015, vy = .023;
        double radius = .05;

        StdDraw.setXscale(-1.0, +1.0);
        StdDraw.setYscale(-1.0, +1.0);

        while(true)
        {
            if (Math.abs(rx + vx) + radius > 1.0) vx = -vx;    bounce
            if (Math.abs(ry + vy) + radius > 1.0) vy = -vy;

            rx = rx + vx;    update position
            ry = ry + vy;

            StdDraw.setPenColor(StdDraw.GRAY);    clear background
            StdDraw.filledSquare(0.0, 0.0, 1.0);
            StdDraw.setPenColor(StdDraw.BLACK);
            StdDraw.filledCircle(rx, ry, radius);    draw the ball
            StdDraw.show(20);    ← turn on animation mode:
                                   display and pause for 20ms
        }
    }
}
```

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## Bouncing Ball Demo

```
% java-introcs BouncingBall
```



34

## Special Effects

**Images.** Put `.gif`, `.png`, or `.jpg` file in the working directory and use `StdDraw.picture()` to draw it on a black background.

**Sound effects.** Put `.wav`, `.mid`, or `.au` file in the working directory and use `StdAudio.play()` to play it.

← stay tuned for more on StdAudio

**Ex.** Modify `BouncingBall` to display image and play sound upon collision.

- Replace `StdDraw.filledCircle()` with:

```
StdDraw.picture(rx, ry, "earth.gif");
```

- Add following code upon collision with walls:

```
StdAudio.play("laser.wav"); // vertical walls
StdAudio.play("pop.wav");   // horizontal walls
```

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## Digital Audio in Java

**Standard audio.** Library for playing digital audio.

```
public class StdAudio
{
    void play(String file)    play the given .wav file
    void play(double[] a)    play the given sound wave
    void play(double x)      play sample for 1/44100 second
    void save(String file, double[] a) save to a .wav file
    double[] read(String file) read from a .wav file
}
```

← library developed  
for this course  
(also broadly useful)

**Stay tuned.** Example client in next lecture.

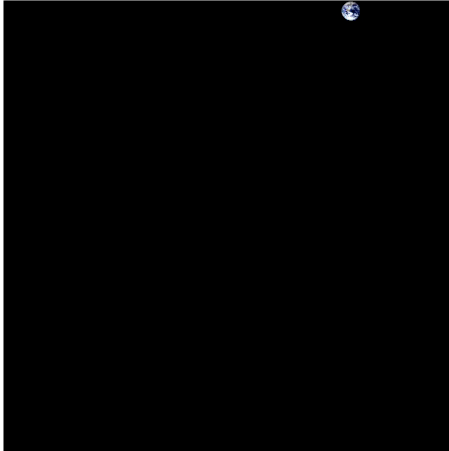


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## Deluxe Bouncing Ball Demo

```
% java-introcs DeluxeBouncingBall
```



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## Deluxe Bouncing Ball Challenge

Q. What happens if you call `stdDraw.filledSquare()` **before** instead of inside loop?

```
public class DeluxeBouncingBall
{
    public static void main(String[] args)
    {
        double rx = .480, ry = .860;
        double vx = .015, vy = .023;
        double radius = .03;
        StdDraw.setXscale(-1.0, +1.0);
        StdDraw.setYscale(-1.0, +1.0);
        while(true)
        {
            if (Math.abs(rx + vx) + radius > 1.0)
            { vx = -vx; StdAudio.play("laser.wav"); }
            if (Math.abs(ry + vy) + radius > 1.0)
            { vy = -vy; StdAudio.play("pop.wav"); }
            rx = rx + vx;
            ry = ry + vy;
            StdDraw.filledSquare(0.0, 0.0, 1.0);
            StdDraw.picture(rx, ry, "earth.gif");
            StdDraw.show(20);
        }
    }
}
```

```
public class DeluxeBouncingBall
{
    public static void main(String[] args)
    {
        double rx = .480, ry = .860;
        double vx = .015, vy = .023;
        double radius = .03;
        StdDraw.setXscale(-1.0, +1.0);
        StdDraw.setYscale(-1.0, +1.0);
        StdDraw.filledSquare(0.0, 0.0, 1.0);
        while(true)
        {
            if (Math.abs(rx + vx) + radius > 1.0)
            { vx = -vx; StdAudio.play("laser.wav"); }
            if (Math.abs(ry + vy) + radius > 1.0)
            { vy = -vy; StdAudio.play("pop.wav"); }
            rx = rx + vx;
            ry = ry + vy;
            StdDraw.picture(rx, ry, "earth.gif");
            StdDraw.show(20);
        }
    }
}
```

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## Deluxe Bouncing Ball Challenge

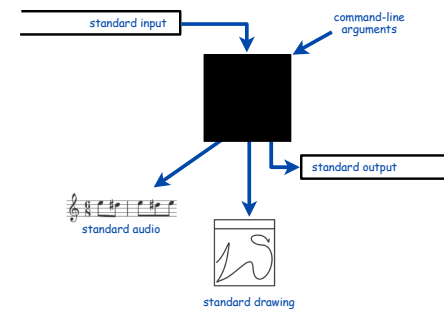
Q. What happens if you call `stdDraw.filledSquare()` **before** instead of inside loop?

```
% java-introcs DeluxeBouncingBall
```



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## Input/Output Summary



**Command-line arguments.** Parameters to control your program.

**Standard input.** Data for your program to process.

**Standard output.** Results of your program, or data for another program.

**Standard drawing.** Graphical output.

**Standard audio.** Sound output.

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## The NBody Assignment

Challenge. Add gravity.

```
% java-introcs NBody 100000000 25000 < planets.txt
```

