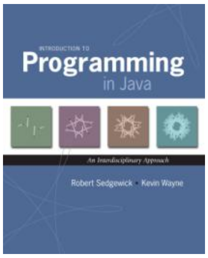
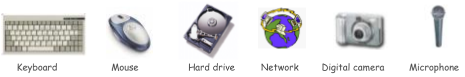
1.5 Input and Output

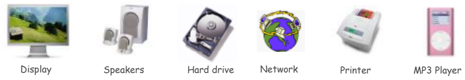


Input and Output

Input devices



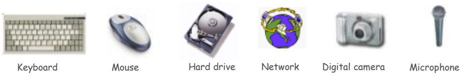
Output devices



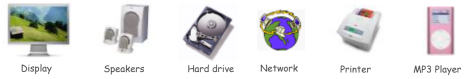
Goal Java programs that interact with the outside world

Input and Output

Input devices



Output devices

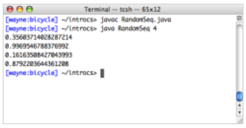


Our approach

- 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

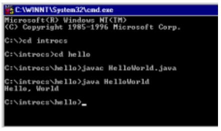
Terminal

Terminal Application where you can type commands to control the operating system



```
[wayne:bicycle] ~/introcs> javac RandomSeq.java
[wayne:bicycle] ~/introcs> java RandomSeq 4
0.35603714028287214
0.9969546788376992
0.16163508427043993
0.8792203644361208
[wayne:bicycle] ~/introcs> 
```

Mac OS X



```
Microsoft(R) Windows NT(TM)
(C) Copyright 1985-1996 Microsoft Corp.

C:\>cd introcs

C:\introcs>cd hello

C:\introcs\hello>javac HelloWorld.java

C:\introcs\hello>java HelloWorld
Hello, World

C:\introcs\hello>_
```

Microsoft Windows

Command-Line Input and Standard Output

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

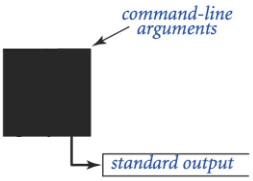
Standard output.

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

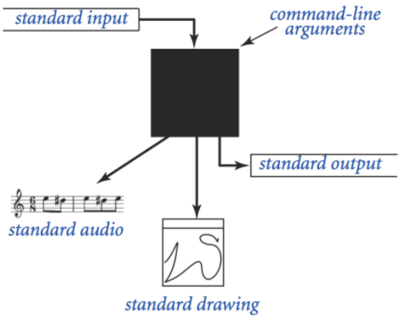
```
public class RandomSeq {
   public static void main(String[] args) {
      int N = Integer.parseInt(args[0]);
      for (int i = 0; i < N; i++) {
         System.out.println(Math.random());
      }
   }
}
```

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

Old Bird's Eye View



New Bird's Eye View



Standard Input and Output

Command-Line Input vs. Standard Input

Command-line input.

- Use command-line input to read in a few user values.
- Not practical for many user inputs.
- Input entered before program begins execution.

Standard input.

- Flexible OS abstraction for input.
- By default, standard input is received from Terminal window.
- Input entered while program is executing.

Standard Input and Output

Standard input `StdIn` is library for reading text input
Standard output `StdOut` is library for writing 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 newline*
void	println()	*print a new line*
void	printf(String f, ...)	*formatted print*

libraries developed for this course (also broadly useful)

Standard Input and Output

To use Download `StdIn.java` and `StdOut.java` from booksite, and put in working directory (or use classpath)

see booksite

```
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 Add
Type the first integer: 1
Type the second integer: 2
Their sum is 3
```

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

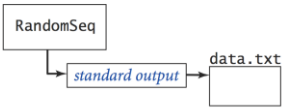
`<Ctrl-d>` for OS X/Linux/Unix/DrJava
`<Ctrl-z>` for Windows

Key point Program does not limit the amount of data

Redirection and Piping

Redirecting Standard Output

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

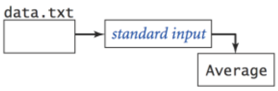


```
% java RandomSeq 1000 > data.txt
```

redirect stdout

Redirecting Standard Input

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

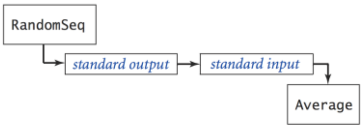


```
% more < data.txt
0.5475375782884312
0.4971087292684019
0.23123808041753813
…

% java Average < data.txt
0.4947655567740991
```

redirect stdin

Connecting Programs

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



pipe stdout of RandomSeq to stdin of Average

```
% java RandomSeq 1000000 | java Average
0.4997970473016028

% java RandomSeq 1000000 | java Average
0.5002071875644842
```

Redirecting Standard Output to a Toast Printer

```
% java HelloWorld > /dev/toaster
```

Standard Drawing

Standard Drawing

Standard drawing `StdDraw` is library for producing 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)     reset x range to (x0, x1)
   void setYscale(double y0, double y1)     reset y range to (y0, y1)
   void setPenRadius(double r)              set pen radius to r
   void setPenColor(Color c)                set pen color to c
   void setFont(Font f)                     set text font to f
   void setCanvasSize(int w, int h)         set canvas to w-by-h  window
   void clear(Color c)                      clear the canvas; color it c
   void show(int dt)                        show all; pause dt milliseconds
   void save(String filename)               save to a .jpg or w.png file
```

Note: Methods with the same names but no arguments reset to default values.

library developed for this course (also broadly useful)

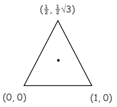
Standard Draw

Standard drawing We provide library `StdDraw` to plot graphics

To use Download `StdDraw.java` and put in working directory

```
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 Triangle
```



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

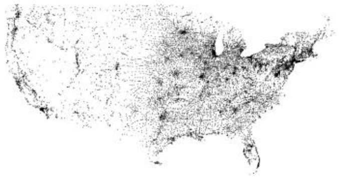
← read in points, and plot them

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 PlotFilter < USA.txt
```

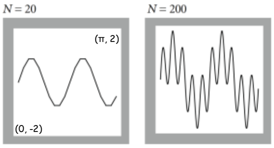
bounding box

coordinates of 13,509 US cities



Plotting a Function

```
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]);
```



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

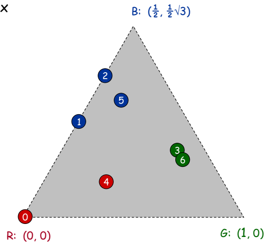
Chaos Game

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 …



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);
      }
   }
}
```

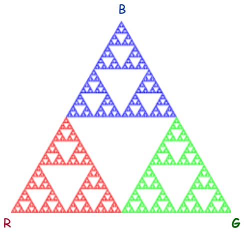
$\frac{1}{2}\sqrt{3}$
(avoid hardwired constants like this)

between 0 and 2

Chaos Game

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

```
% java Chaos 10000
```

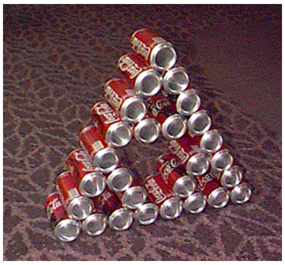


Sierpinski triangle

Commercial Break

http://xkcd.com/543

Commercial Break



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?

20th century sciences Formulas
21st century sciences Algorithms?

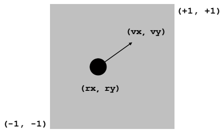
Animation

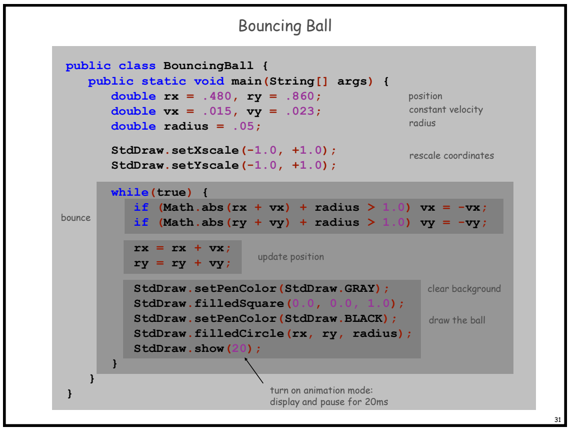
Animation loop Repeat the following:

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

Ex. Bouncing ball

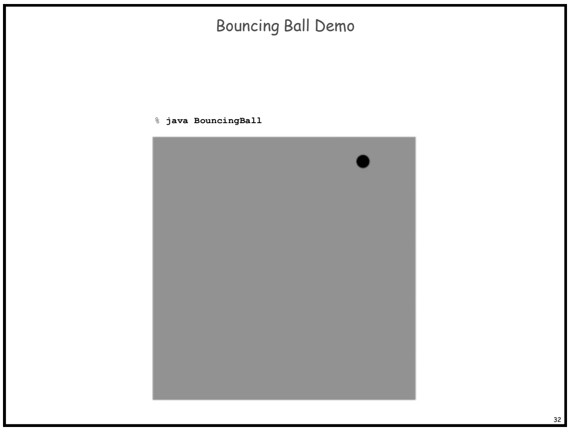
- Ball has position `(rx, ry)` and constant velocity `(vx, vy)`
- Detect collision with wall and reverse velocity





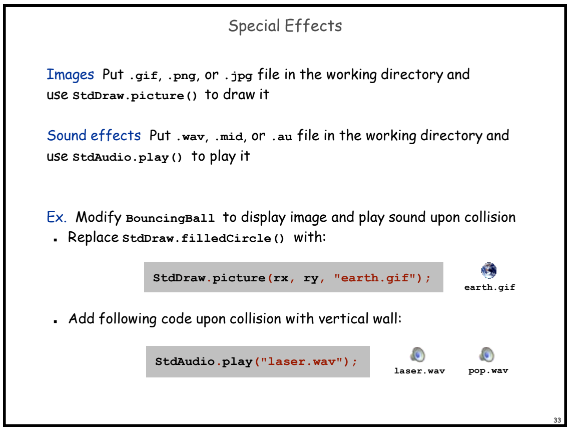
Bouncing Ball

```
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;
         if (Math.abs(ry + vy) + radius > 1.0) vy = -vy;

         rx = rx + vx;
         ry = ry + vy;

         StdDraw.setPenColor(StdDraw.GRAY);
         StdDraw.filledSquare(0.0, 0.0, 1.0);
         StdDraw.setPenColor(StdDraw.BLACK);
         StdDraw.filledCircle(rx, ry, radius);
         StdDraw.show(20);
      }
   }
}
```



Bouncing Ball Demo

```
% java BouncingBall
```



Special Effects

Images Put .gif, .png, or .jpg file in the working directory and use StdDraw.picture() to draw it

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

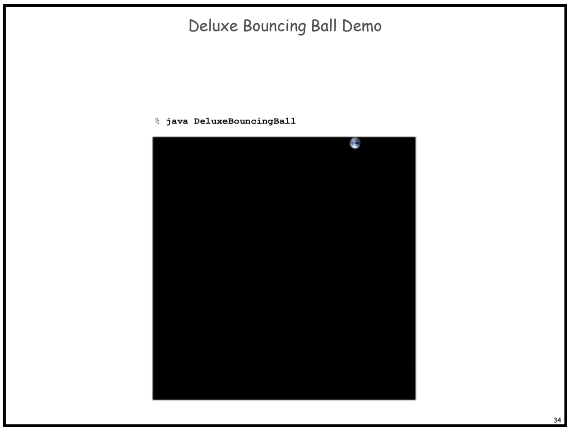
Ex. Modify BouncingBall to display image and play sound upon collision

- Replace StdDraw.filledCircle() with:

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

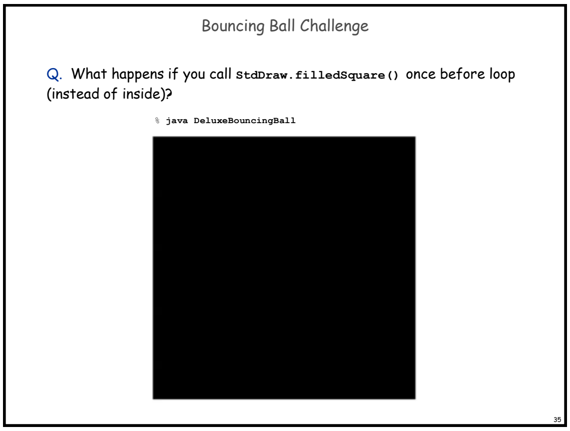
- Add following code upon collision with vertical wall:

```
StdAudio.play("laser.wav");
```



Deluxe Bouncing Ball Demo

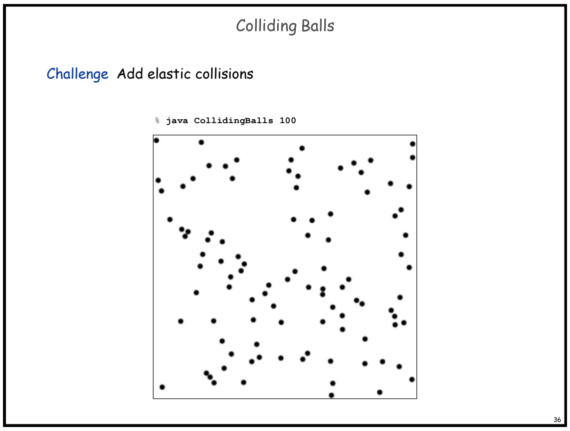
```
% java DeluxeBouncingBall
```



Bouncing Ball Challenge

Q. What happens if you call StdDraw.filledSquare() once before loop (instead of inside)?

```
% java DeluxeBouncingBall
```



Colliding Balls

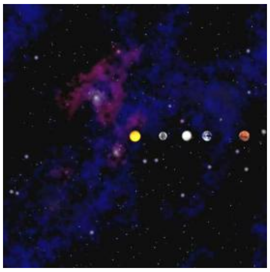
Challenge Add elastic collisions

```
% java CollidingBalls 100
```

N-body Simulation

Challenge Add gravity

```
% java NBody < planets.txt
```



Digital Audio in Java

Standard audio Library for playing digital audio

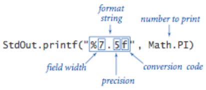
public class StdAudio		
void	play(String file)	*play the given .wav file*
void	play(double[] a)	*play the given sound wave*
void	play(double x)	*play sample for 1/44100 second*
void	save(String file, double[] a)	*save to a .wav file*
double[]	read(String file)	*read from a .wav file*

library developed for this course (also broadly useful)

Formatted Output

StdOut.printf()

- Print complex combinations of text and variables easily
- Use format string with placeholders for variables
- Placeholders specify variable type and output format



```
StdOut.printf("%7.5f", Math.PI)
```

format string

number to print

field width

precision

conversion code

Anatomy of a formatted print statement

Formatted Output

StdOut.printf()

- Print complex combinations of text and variables easily
- Use format string with placeholders for variables
- Placeholders specify variable type and output format

type	*code*	*typical literal*	*sample format strings*	*converted string values for output*
int	d	512	"%14d" "%-14d"	" 512" "512 "
double	f e	1595.1680010754388	"%14.2f" "%.7f" "%14.4e"	" 1595.17" "1595.1680011" " 1.5952e+03"
String	s	"Hello, World"	"%14s" "%-14s" "%-14.5s"	" Hello, World" "Hello, World " "Hello "

Formatted Output

Print planet positions in NBody simulation

\n means print a new line

%11.4e means print a double in scientific notation using at most 11 characters of which four are decimal places

```
StdOut.printf("%d\n", N);
StdOut.printf("%.2e\n", R)
for (int i = 0; i < N; i++) {
    StdOut.printf("%11.4e %11.4e %11.4e %11.4e %11.4e %12s\n",
                  rx[i], ry[i], vx[i], vy[i], mass[i], image[i]);
}
```

```
5
2.50e+11
1.4960e+11 0.0000e+00 0.0000e+00 2.9800e+04 5.9740e+24 earth.gif
2.2790e+11 0.0000e+00 0.0000e+00 2.4100e+04 6.4190e+23 mars.gif
5.7900e+10 0.0000e+00 0.0000e+00 4.7900e+04 3.3020e+23 mercury.gif
0.0000e+00 0.0000e+00 0.0000e+00 0.0000e+00 1.9890e+30 sun.gif
1.0820e+11 0.0000e+00 0.0000e+00 3.5000e+04 4.8690e+24 venus.gif
```