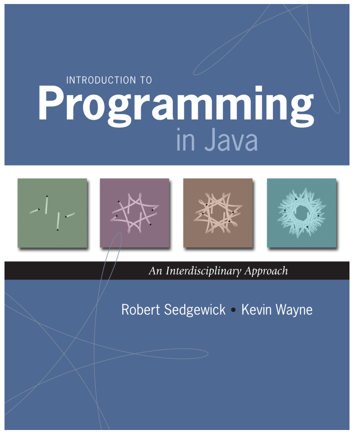
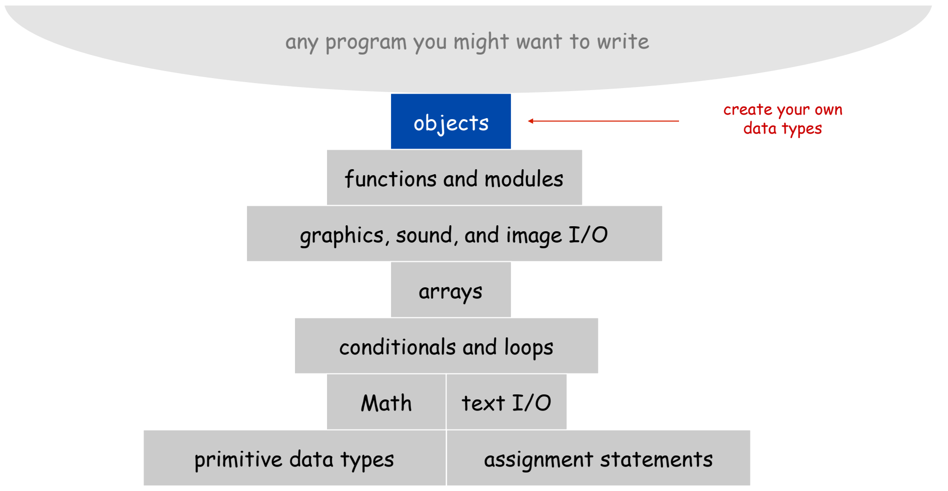
3.1 Using Data Types



A Foundation for Programming



Data Types

Data type. Set of values and operations on those values.

Primitive types. Ops directly translate to machine instructions.

Data Type	Set of Values	Operations
`boolean`	`true`, `false`	not, and, or, xor
`int`	-2^{31} to $2^{31} - 1$	add, subtract, multiply
`double`	any of 2^{64} possible reals	add, subtract, multiply

We want to write programs that process other types of data.
- Colors, pictures, strings, input streams, …
- Complex numbers, vectors, matrices, polynomials, …
- Points, polygons, charged particles, celestial bodies, …

Objects

Object. Holds a data type value; variable name refers to object.

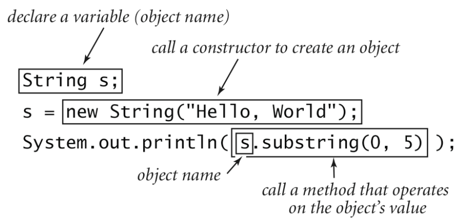
Impact. Enables us to create our own data types;
define operations on them; and integrate into our programs.

Data Type	Set of Values	Operations
`Color`	24 bits	get red component, brighten
`Picture`	2D array of colors	get/set color of pixel (i, j)
`String`	sequence of characters	length, substring, compare

Constructors and Methods

To construct a new object: Use keyword `new` and name of data type.

To apply an operation: Use name of object, the dot operator, and the name of the method.



```
String s;
s = new String("Hello, World");
System.out.println( s.substring(0, 5) );
```

declare a variable (object name)
call a constructor to create an object
object name
call a method that operates on the object's value

Image Processing

Color Data Type

Color. A sensation in the eye from electromagnetic radiation.

Set of values. [RGB representation] 256^3 possible values, which quantify the amount of red, green, and blue, each on a scale of 0 to 255.

R	G	B	Color
255	0	0	🟥
0	255	0	🟩
0	0	255	🟦
255	255	255	⬜
0	0	0	⬛
255	0	255	🟪
105	105	105	▨

Color Data Type

Color. A sensation in the eye from electromagnetic radiation.

Set of values. [RGB representation] 256^3 possible values, which quantify the amount of red, green, and blue, each on a scale of 0 to 255.

API. Application Programming Interface.

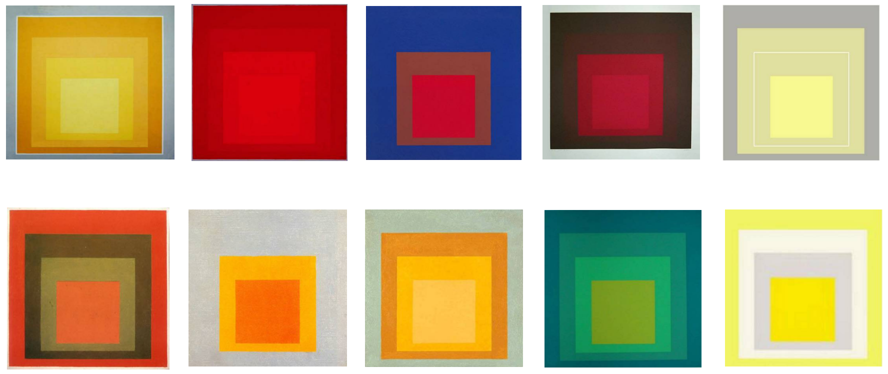
`public class java.awt.Color`

	`Color(int r, int g, int b)`	
`int`	`getRed()`	*red intensity*
`int`	`getGreen()`	*green intensity*
`int`	`getBlue()`	*blue intensity*
`Color`	`brighter()`	*brighter version of this color*
`Color`	`darker()`	*darker version of this color*
`String`	`toString()`	*string representation of this color*
`boolean`	`equals(Color c)`	*is this color's value the same as* `c`*'s?*

http://download.oracle.com/javase/6/docs/api/java/awt/Color.html

Albers Squares

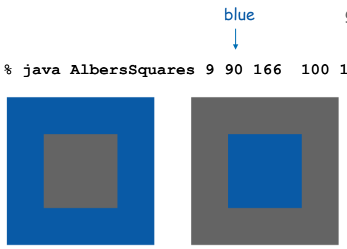
Josef Albers. Revolutionized the way people think about color.


Homage to the Square by Josef Albers (1949-1975)

Albers Squares

Josef Albers. Revolutionized the way people think about color.

```
% java AlbersSquares 9 90 166  100 100 100
```



Using Colors in Java

```
import java.awt.Color;                              to access Color library

public class AlbersSquares {
   public static void main(String[] args) {
      int r1 = Integer.parseInt(args[0]);
      int g1 = Integer.parseInt(args[1]);             first color
      int b1 = Integer.parseInt(args[2]);
      Color c1 = new Color(r1, g1, b1);

      int r2 = Integer.parseInt(args[3]);
      int g2 = Integer.parseInt(args[4]);             second color
      int b2 = Integer.parseInt(args[5]);
      Color c2 = new Color(r2, g2, b2);

      StdDraw.setPenColor(c1);
      StdDraw.filledSquare(.25, .5, .2);              first square
      StdDraw.setPenColor(c2);
      StdDraw.filledSquare(.25, .5, .1);

      StdDraw.setPenColor(c2);
      StdDraw.filledSquare(.75, .5, .2);              second square
      StdDraw.setPenColor(c1);
      StdDraw.filledSquare(.75, .5, .1);
   }
}
```

Monochrome Luminance

Monochrome luminance. Effective brightness of a color.

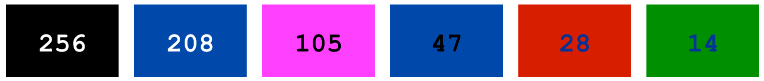
NTSC formula. $Y = 0.299r + 0.587g + 0.114b$.

```
import java.awt.Color;

public class Luminance {

   public static double lum(Color c) {
      int r = c.getRed();
      int g = c.getGreen();
      int b = c.getBlue();
      return .299*r + .587*g + .114*b;
   }
}
```

Color Compatibility

Q. Which font colors will be most readable with which background colors on computer and cell phone screens?

A. Rule of thumb: difference in luminance should be ≥ 128.



```
public static boolean compatible(Color a, Color b) {
   return Math.abs(lum(a) - lum(b)) >= 128.0;
}
```

Grayscale

Grayscale. When all three R, G, and B values are the same, resulting color is on grayscale from 0 (black) to 255 (white).

Convert to grayscale. Use luminance to determine value.

```
public static Color toGray(Color c) {
   int y = (int) Math.round(lum(c));
   Color gray = new Color(y, y, y);
   return gray;
}
```

round double to nearest int

red	green	blue		
9	90	166	this color	🟦
74	74	74	grayscale version	◼
0	0	0	black	⬛

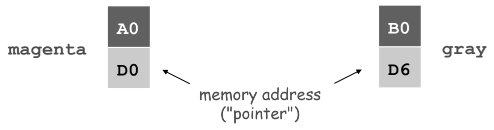
$0.299 * 9 + 0.587 * 90 + 0.114 * 166 = 74.445$

Bottom line. We are writing programs that manipulate color.

OOP Context for Color

Possible memory representation.

D0	D1	D2	D3	D4	D5	D6	D7	D8
255	0	255	0	0	0	105	105	105



Object reference is analogous to variable name.

- We can manipulate the value that it holds.
- We can pass it to (or return it from) a method.

References

René Magritte. "This is not a pipe."

Java. This is not a color.

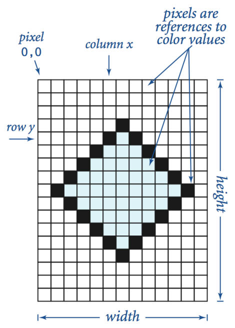
```
Color sienna = new Color(160, 82,  45);
Color c = sienna.darker();
```

OOP. Natural vehicle for studying abstract models of the real world.

Picture Data Type

Raster graphics. Basis for image processing.

Set of values. 2D array of `Color` objects (pixels).



API.

public class Picture

	Picture(String filename)	*create a picture from a file*
	Picture(int w, int h)	*create a blank w-by-h picture*
int	width()	*return the width of the picture*
int	height()	*return the height of the picture*
Color	get(int x, int y)	*return the color of pixel (x, y)*
void	set(int x, int y, Color c)	*set the color of pixel (x, y) to c*
void	show()	*display the image in a window*
void	save(String filename)	*save the image to a file*

Image Processing: Grayscale Filter

Goal. Convert color image to grayscale according to luminance formula.

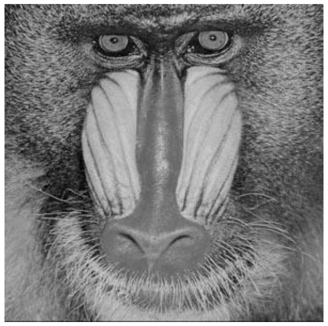
```
import java.awt.Color;

public class Grayscale {
   public static void main(String[] args) {
      Picture pic = new Picture(args[0]);
      for (int x = 0; x < pic.width(); x++) {
         for (int y = 0; y < pic.height(); y++) {
            Color color = pic.get(x, y);
            Color gray  = Luminance.toGray(color);
            pic.set(x, y, gray);
         }
      }
      pic.show();
   }
}
```

from before

Image Processing: Grayscale Filter

Goal. Convert color image to grayscale according to luminance formula.

mandrill.jpg



`% java Grayscale mandrill.jpg`

Image Processing: Scaling Filter

Goal. Shrink or enlarge an image to desired size.

Downscaling. To shrink, delete half the rows and columns.
Upscaling. To enlarge, replace each pixel by 4 copies.

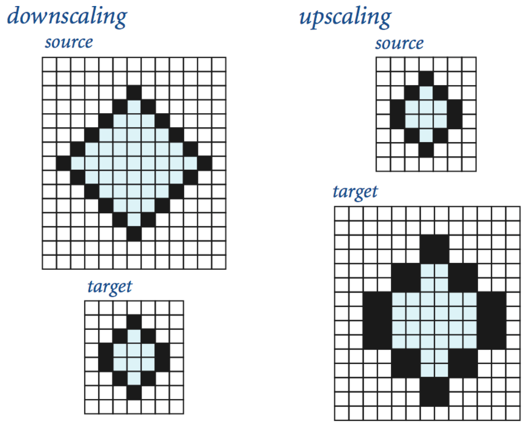
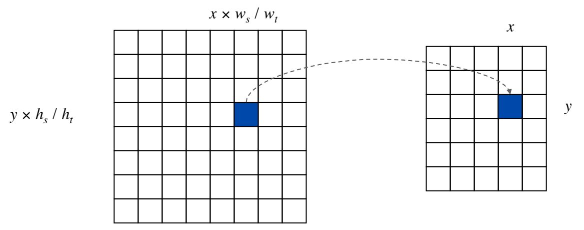


Image Processing: Scaling Filter

Goal. Shrink or enlarge an image to desired size.

Uniform strategy. To convert from w_s-by-h_s to w_t-by-h_t:

- Scale column index by w_s / w_t.
- Scale row index by h_s / h_t.
- Set color of pixel (x, y) in target image to color of pixel $(x \times w_s / w_t,\ y \times h_s / h_t)$ in source image.



source image (w_s-by-h_s)

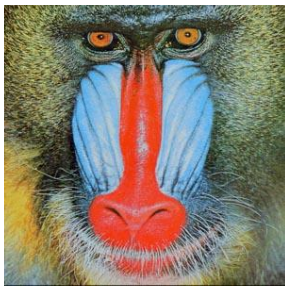
target image (w_t-by-h_t)

Image Processing: Scaling Filter

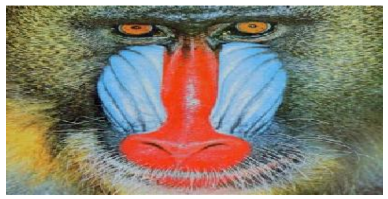
```
import java.awt.Color;

public class Scale {
   public static void main(String[] args) {
      String filename = args[0];
      int w = Integer.parseInt(args[1]);
      int h = Integer.parseInt(args[2]);
      Picture source = new Picture(filename);
      Picture target = new Picture(w, h);
      for (int tx = 0; tx < target.width(); tx++) {
         for (int ty = 0; ty < target.height(); ty++) {
            int sx = tx * source.width()  / target.width();
            int sy = ty * source.height() / target.height();
            Color color = source.get(sx, sy);
            target.set(tx, ty, color);
         }
      }
      source.show();
      target.show();
   }
}
```

Image Processing: Scaling Filter

Scaling filter. Creates two `Picture` objects and two windows.

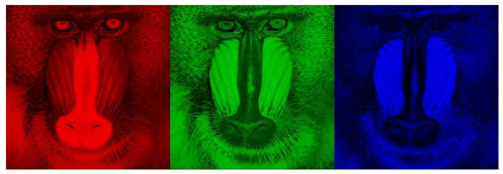


`mandrill.jpg`
`(298-by-298)`

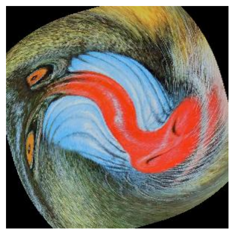


`% java Scale mandrill.jpg 400 200`

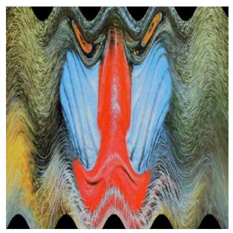
More Image Processing Effects



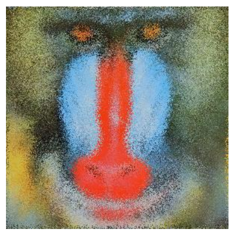
RGB color separation



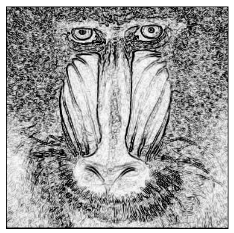
swirl filter



wave filter



glass filter



Sobel edge detection

Text Processing

String Data Type

String data type. Basis for text processing.
Set of values. Sequence of Unicode characters.

API.

public class String (Java string data type)

	`String(String s)`	*create a string with the same value as* `s`
`int`	`length()`	*string length*
`char`	`charAt(int i)`	`i`*th character*
`String`	`substring(int i, int j)`	`i`*th through* (`j-1`)*st characters*
`boolean`	`contains(String sub)`	*does string contain* `sub` *as a substring?*
`boolean`	`startsWith(String pre)`	*does string start with* `pre`*?*
`boolean`	`endsWith(String post)`	*does string end with* `post`*?*
`int`	`indexOf(String p)`	*index of first occurrence of* `p`
`int`	`indexOf(String p, int i)`	*index of first occurrence of* `p` *after* `i`
`String`	`concat(String t)`	*this string with* `t` *appended*
`int`	`compareTo(String t)`	*string comparison*
`String`	`replaceAll(String a, String b)`	*result of changing* `a`*s to* `b`*s*
`String[]`	`split(String delim)`	*strings between occurrences of* `delim`
`boolean`	`equals(String t)`	*is this string's value the same as* `t`*'s?*

http://download.oracle.com/javase/6/docs/api/java/lang/String.html

Typical String Processing Code

is the string a palindrome?

```
public static boolean isPalindrome(String s)
{
   int N = s.length();
   for (int i = 0; i < N/2; i++)
      if (s.charAt(i) != s.charAt(N-1-i))
         return false;
   return true;
}
```

extract file name and extension from a command-line argument

```
String s = args[0];
int dot = s.indexOf(".");
String base      = s.substring(0, dot);
String extension = s.substring(dot + 1, s.length());
```

print all lines in standard input that contain a string specified on the command line

```
String query = args[0];
while (!StdIn.isEmpty())
{
   String s = StdIn.readLine();
   if (s.contains(query)) StdOut.println(s);
}
```

print all the hyperlinks (to educational institutions) in the text file on standard input

```
while (!StdIn.isEmpty())
{
   String s = StdIn.readString();
   if (s.startsWith("http://") && s.endsWith(".edu"))
      StdOut.println(s);
}
```

Gene Finding

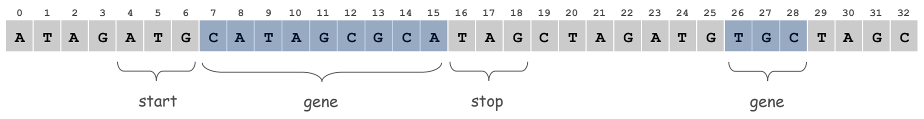
Pre-genomics era. Sequence a human genome.
Post-genomics era. Analyze the data and understand structure.

Genomics. Represent genome as a string over { A, C, T, G } alphabet.

Gene. A substring of genome that represents a functional unit.

- Preceded by ATG. [start codon]
- Multiple of 3 nucleotides. [codons other than start/stop]
- Succeeded by TAG, TAA, or TGA. [stop codons]

Goal. Find all genes.



Gene Finding: Algorithm

Algorithm. Scan left-to-right through genome.
- If start codon, then set `beg` to index `i`.
- If stop codon and substring is a multiple of 3
  - output gene
  - reset `beg` to -1

i	codon		beg	gene	*remaining portion of input string*
	start	*stop*			
0			-1		ATAGATGCATAGCGCATAGCTAGATGTGCTAGC
1		TAG	-1		ATAGATGCATAGCGCATAGCTAGATGTGCTAGC
4	ATG		4		ATAGATGCATAGCGCATAGCTAGATGTGCTAGC
9		TAG	4		ATAGATGCATAGCGCATAGCTAGATGTGCTAGC
16		TAG	4	$\overbrace{\text{CATAGCGCA}}^{\text{multiple of 3}}$	ATAGATGCATAGCGCATAGCTAGATGTGCTAGC
20		TAG	-1		ATAGATGCATAGCGCATAGCTAGATGTGCTAGC
23	ATG		23		ATAGATGCATAGCGCATAGCTAGATGTGCTAGC
29		TAG	23	TGC	ATAGATGCATAGCGCATAGCTAGATGTGCTAGC

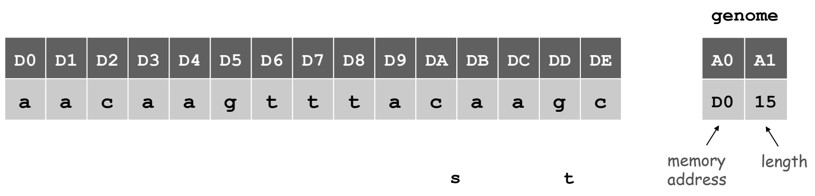
Gene Finding: Implementation

```
public class GeneFind {
   public static void main(String[] args) {
      String start  = args[0];
      String stop   = args[1];
      String genome = StdIn.readAll();

      int beg = -1;
      for (int i = 0; i < genome.length() - 2; i++) {
         String codon = genome.substring(i, i+3);
         if (codon.equals(start)) beg = i;
         if (codon.equals(stop) && beg != -1) {
            String gene = genome.substring(beg+3, i);
            if (gene.length() % 3 == 0) {
               StdOut.println(gene);
               beg = -1;
            }
         }
      }
   }
}
```

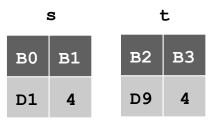
```
% more genomeTiny.txt
ATAGATGCATAGCGCATAGCTAGATGTGCTAGC

% java GeneFind ATG TAG < genomeTiny.txt
CATAGCGCA
TGC
```

OOP Context for Strings

Possible memory representation of a string.
- `genome = "aacaagtttacaagc";`


genome
D0 D1 D2 D3 D4 D5 D6 D7 D8 D9 DA DB DC DD DE
a a c a a g t t t a c a a g c
A0 A1
D0 15
memory address
length

- `s = genome.substring(1, 5);`
- `t = genome.substring(9, 13);`



s and t are different strings that share the same value "acaa"

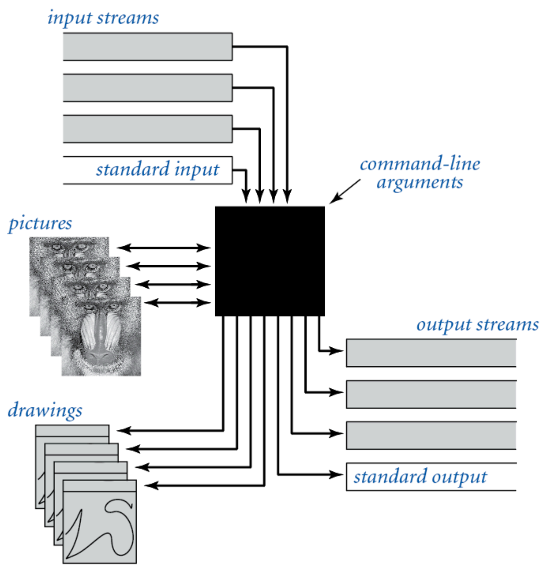
- `(s == t)` is `false`, but `(s.equals(t))` is `true`.

compares pointers

compares character sequences

In and Out

Bird's Eye View (Revisited)



Non-Standard Input

or use OS to redirect from one file

Standard input. Read from terminal window.
Goal. Read from several different input streams.

`In` data type. Read text from stdin, a file, a web site, or network.

Ex: Are two text files identical?

```
public class Diff {
   public static void main(String[] args) {
      In in0 = new In(args[0]);   ← read from one file
      In in1 = new In(args[1]);   ← read from another file
      String s = in0.readAll();
      String t = in1.readAll();
      StdOut.println(s.equals(t));
   }
}
```

Screen Scraping

Goal. Find current stock price of Google.

```
...
<tr>
<td class="yfnc_tablehead1" width="48%">
Last Trade:
</td>
<td class="yfnc_tabledata1">
<big>
<b>459.52</b>
</big>
</td>
</tr>
<tr>
<td class="yfnc_tablehead1" width="48%">
Trade Time:
</td>
<td class="yfnc_tabledata1">
11:45AM ET
</td>
</tr>
...
```

`http://finance.yahoo.com/q?s=goog`

NYSE symbol

Screen Scraping

Goal. Find current stock price of Google.

- `s.indexOf(t, i)`: index of first occurrence of pattern `t` in string `s`, starting at offset `i`.
- Read raw html from `http://finance.yahoo.com/q?s=goog`.
- Find first string delimited by `<b>` and `</b>` after `Last Trade`.

```
public class StockQuote {
   public static void main(String[] args) {
      String name = "http://finance.yahoo.com/q?s=";
      In in = new In(name + args[0]);
      String input = in.readAll();
      int start    = input.indexOf("Last Trade:", 0);
      int from     = input.indexOf("<b>",  start);
      int to       = input.indexOf("</b>", from);
      String price = input.substring(from + 3, to);
      StdOut.println(price);
   }
}
```

```
% java StockQuote goog
616.50
```

Day Trader

Add bells and whistles.
- Plot price in real-time.
- Notify user if price dips below a certain price.
- Embed logic to determine when to buy and sell.
- Automatically send buy and sell orders to trading firm.

Warning. Please, please use at your own financial risk.

The New Yorker, September 6, 1999

OOP Summary

Object. Holds a data type value; variable name refers to object.

In Java, programs manipulate references to objects.
- Exception: primitive types, e.g., `boolean`, `int`, `double`.
- Reference types: `String`, `Picture`, `Color`, arrays, everything else.
- OOP purist: language should not have separate primitive types.

Bottom line. We wrote programs that manipulate colors, pictures, and strings.

Next time. We'll write programs that manipulate our own abstractions.