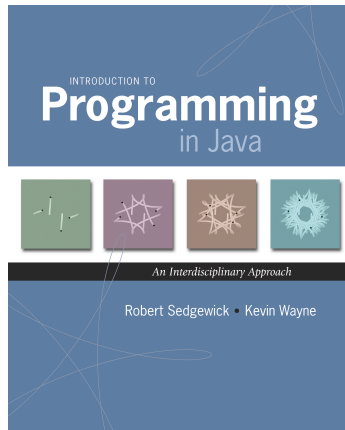
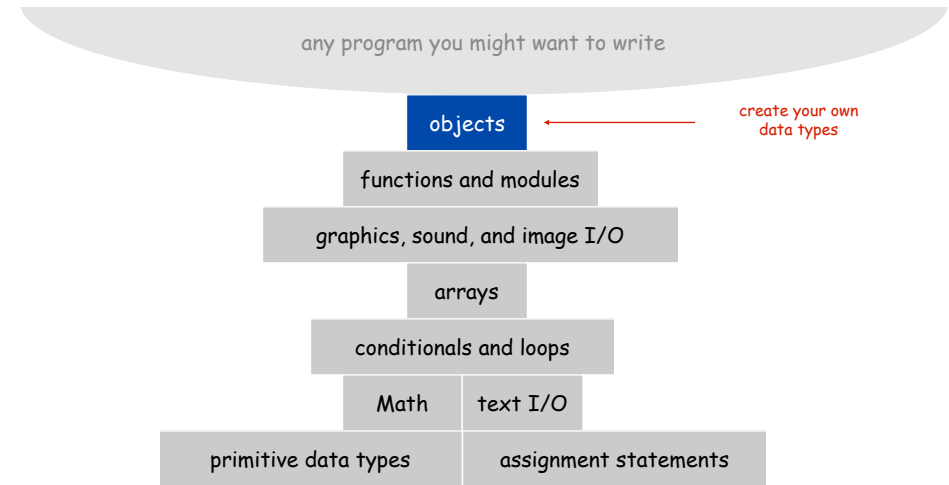


3.1 Using Data Types



Introduction to Programming in Java: An Interdisciplinary Approach · Robert Sedgewick and Kevin Wayne · Copyright © 2008 · * * *



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) → String s;
call a constructor to create an object → new String("Hello, World");
object name → s
call a method that operates on the object's value → s.substring(0, 5)

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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	Red
0	255	0	Green
0	0	255	Blue
255	255	255	White
0	0	0	Black
255	0	255	Magenta
105	105	105	Grey

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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.

API. Application Programming Interface.

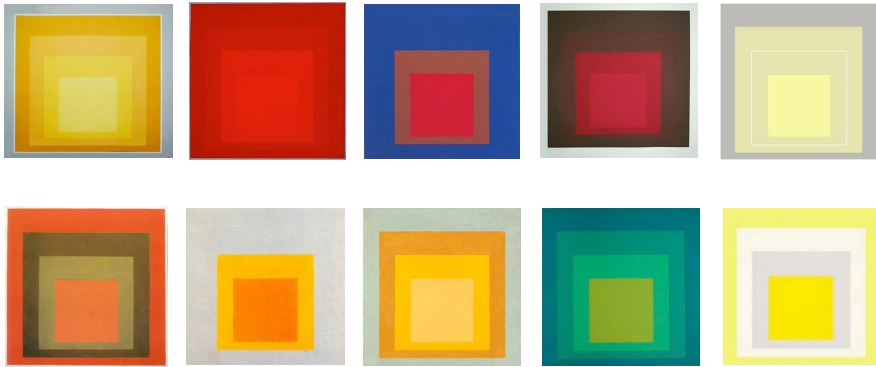
```
public class java.awt.Color  
  
    Color(int r, int g, int b)  
    int getRed()           red intensity  
    int getGreen()        green intensity  
    int getBlue()         blue intensity  
    Color brighter()       brighter version of this color  
    Color darker()        darker version of this color  
    String toString()      string representation of this color
```

<http://java.sun.com/j2se/1.5.0/docs/api/java/awt/Color.html>

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Albers Squares

Josef Albers. Revolutionized the way people think about color.

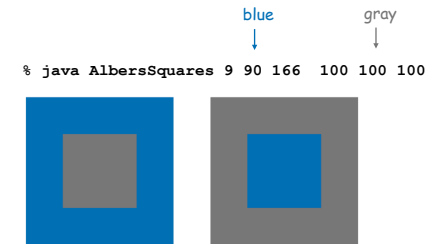


Homage to the Square by Josef Albers (1949-1975)

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Albers Squares

Josef Albers. Revolutionized the way people think about color.



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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]);
        int b1 = Integer.parseInt(args[2]);
        Color c1 = new Color(r1, g1, b1); // first color

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

        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);
    }
}
```

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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;
    }
}
```

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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;
}
```




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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;
}
```

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

round double to nearest int

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

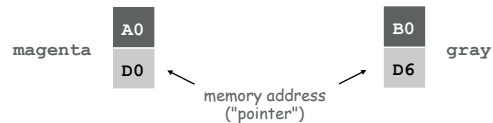
Bottom line. We are writing programs that manipulate color.

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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.

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References

René Magritte. "This is not a pipe."



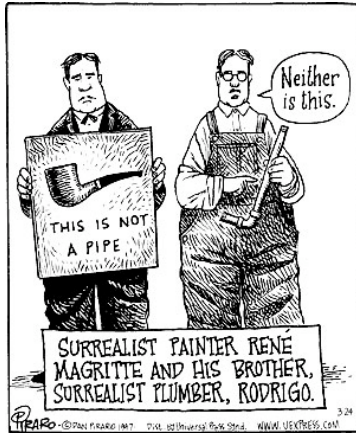
Java. This is not a color.

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

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

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This is Not a Pipe



Dan Pinaro, <http://www.uexpress.com>

Neither is this.

```
% java RandomSeq 10000 | java Average
```

Picture Data Type

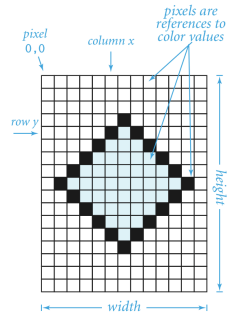
Raster graphics. Basis for image processing.

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

API.

```
public class Picture
    Picture(String filename)
    Picture(int w, int h)
    int width()
    int height()
    Color get(int x, int y)
    void set(int x, int y, Color c)
    void show()
    void save(String filename)
```

create a picture from a file
create a blank w-by-h picture
return the width of the picture
return the height of the picture
return the color of pixel (x, y)
set the color of pixel (x, y) to c
display the image in a window
save the image to a file



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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();
    }
}
```

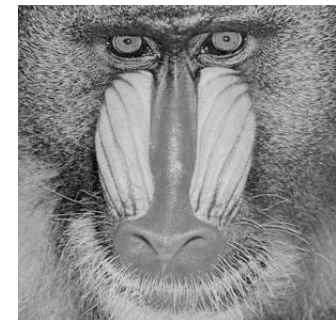
19

Image Processing: Grayscale Filter

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



mandrill.jpg



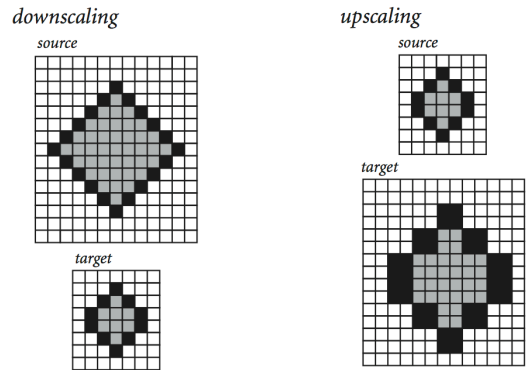
```
% java Grayscale mandrill.jpg
```

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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.

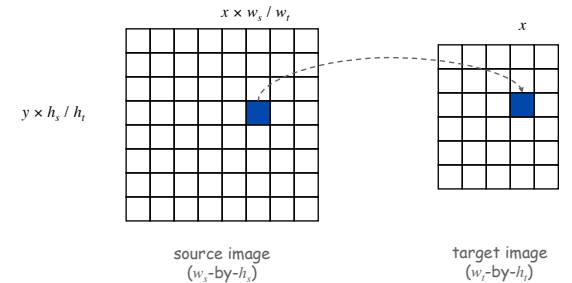


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Goal. Shrink or enlarge an image to desired size.

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.



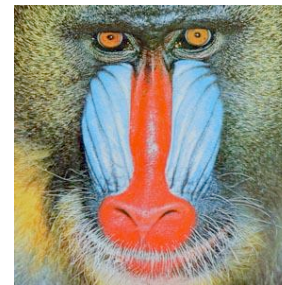
22

```
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 < w; tx++) {
            for (int ty = 0; ty < h; ty++) {
                int sx = tx * source.width() / w;
                int sy = ty * source.height() / h;
                Color color = source.get(sx, sy);
                target.set(tx, ty, color);
            }
        }
        source.show();
        target.show();
    }
}
```

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

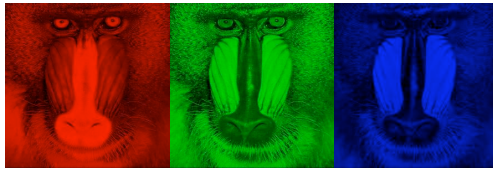


mandrill.jpg

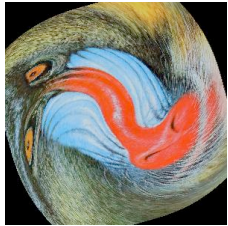


% java Scale mandrill.jpg 400 200

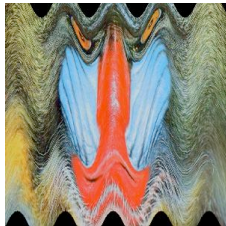
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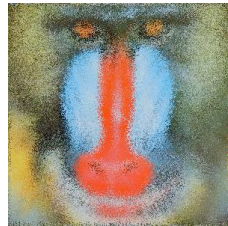
RGB color separation



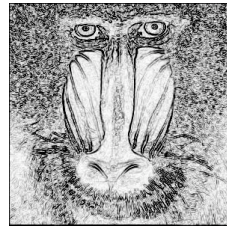
swirl filter



wave filter



glass filter



Sobel edge detection

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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 as to bs
String[] split(String delim)	strings between occurrences of delim
boolean equals(String t)	is this string's value the same as t's?
...	

<http://java.sun.com/javase/6/docs/api/java/lang/String.html>

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Text Processing

Typical String Processing Code

<i>is the string a palindrome?</i>	<pre>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; }</pre>
<i>extract file name and extension from a command-line argument</i>	<pre>String s = args[0]; int dot = s.indexOf("."); String base = s.substring(0, dot); String extension = s.substring(dot + 1, s.length());</pre>
<i>print all lines in standard input that contain a string specified on the command line</i>	<pre>String query = args[0]; while (!StdIn.isEmpty()) { String s = StdIn.readLine(); if (s.contains(query)) StdOut.println(s); }</pre>
<i>print all the hyperlinks (to educational institutions) in the text file on standard input</i>	<pre>while (!StdIn.isEmpty()) { String s = StdIn.readString(); if (s.startsWith("http://") && s.endsWith(".edu")) StdOut.println(s); }</pre>

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Gene Finding

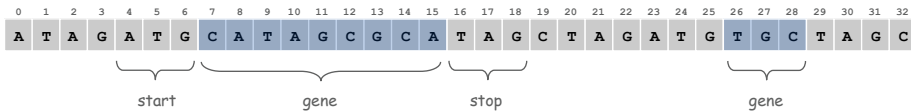
Pre-genomics era. Sequence a human genome.

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]



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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	output	remaining portion of input string
	0		-1		ATAGATGCATAGCGCATAGCTAGATGTGCTAGC
	1	TAG	-1		TAGATGCATAGCGCATAGCTAGATGTGCTAGC
	4	ATG	4		ATGCATAGCGCATAGCTAGATGTGCTAGC
start	9	TAG	4		TAGCGCATAGCTAGATGTGCTAGC
	16	TAG	4	CATAGCGCA	TAGCTAGATGTGCTAGC
stop	20	TAG	-1		TAGATGTGCTAGC
	23	ATG	23		ATGTGCTAGC
	29	TAG	23	TGC	TAGC

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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
```

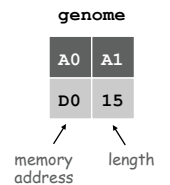
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OOP Context for Strings

Possible memory representation of a string.

- `genome = "aacaagttacaagc";`

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



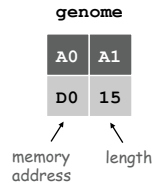
32

OOP Context for Strings

Possible memory representation of a string.

- genome = "aacaagtttacaagc";

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



- s = genome.substring(1, 5);
 - t = genome.substring(9, 13);
- | | | | |
|----|----|----|----|
| s | | t | |
| B0 | B1 | B2 | B3 |
| D1 | 4 | D9 | 4 |

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

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

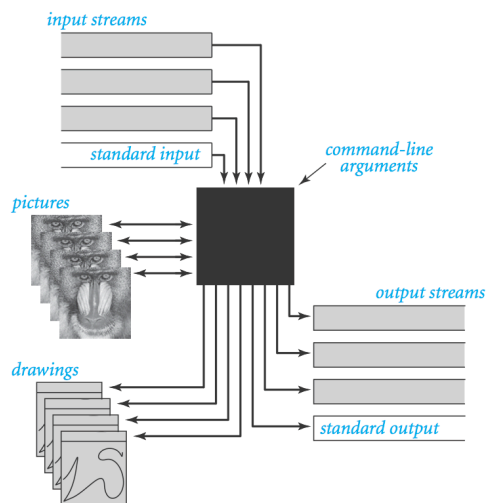
compares pointers

compares character sequences

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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));
    }
}
```

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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

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 `` and `` 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
459.52

```

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.