

### 3.1 Using 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**.

```

declare a variable (object name)
String s;
call a constructor to create an object
s = new String("Hello, World");
System.out.println(s.substring(0, 5));
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<sup>3</sup> 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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## Color Data Type

**Color.** A sensation in the eye from electromagnetic radiation.

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**API.** Application Programming Interface.

```
public class java.awt.Color (partial list of methods)
```

```
    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>

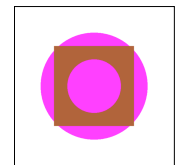
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## Using Colors in Java

**One use of objects.** Store aggregate data in one variable.

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

public class ColorTest {
    public static void main(String[] args) {
        Color magenta = new Color(255, 0, 255);
        Color sienna = new Color(160, 82, 45);
        StdDraw.setPenColor(magenta);
        StdDraw.filledCircle(.5, .5, .67);
        StdDraw.setPenColor(sienna);
        StdDraw.filledSquare(.5, .5, .25);
        StdDraw.setPenColor(magenta);
        StdDraw.filledCircle(.5, .5, .33);
    }
}
```



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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.

## 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 i = 0; i < pic.width(); i++) {
            for (int j = 0; j < pic.height(); j++) {
                Color color = pic.get(i, j);
                Color gray = Luminance.toGray(color);
                pic.set(i, j, gray);
            }
        }
        pic.show();
    }
}
```

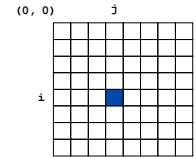
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## Picture Data Type

Raster graphics. Basis for image processing.

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

API.

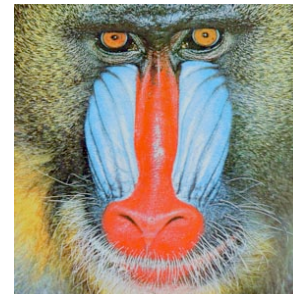


```
public class Picture (our data type for image processing)
    Picture(String s)           create a picture from a file
    Picture(int w, int h)       create a blank w-by-h picture
    int width()                 return the width of the picture
    int height()                return the height of the picture
    Color get(int i, int j)     return the color of pixel (i, j)
    void set(int i, int j, Color c) set the color of pixel (i, j) to c
    void show()                 display the image in a window
    void save(String s)         save the image to a file
```

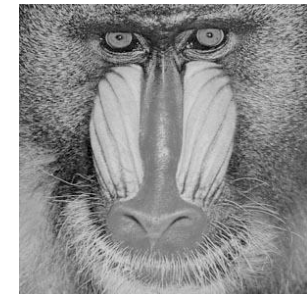
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## Image Processing: Grayscale Filter

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



mandrill.jpg



% java Grayscale mandrill.jpg

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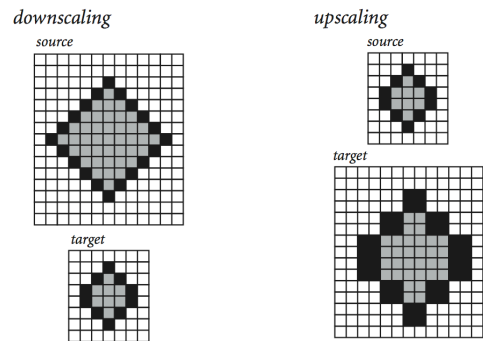
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## Image Processing: Scaling Filter

**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.



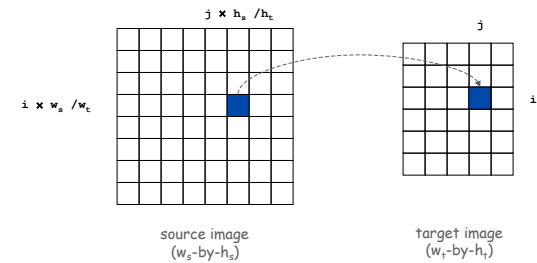
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## Image Processing: Scaling Filter

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



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## Image Processing: Scaling Filter

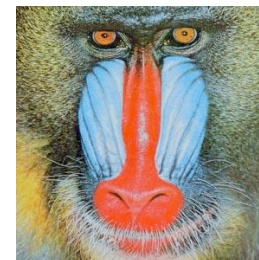
```
import java.awt.Color;

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 ti = 0; ti < w; ti++) {
            for (int tj = 0; tj < h; tj++) {
                int si = ti * source.width() / w;
                int sj = tj * source.height() / h;
                Color color = source.get(si, sj);
                target.set(ti, tj, color);
            }
        }
        source.show();
        target.show();
    }
}
```

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## Image Processing: Scaling Filter

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



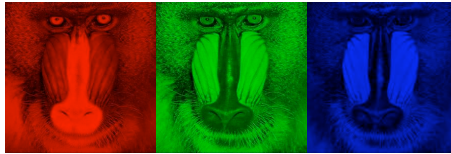
mandrill.jpg



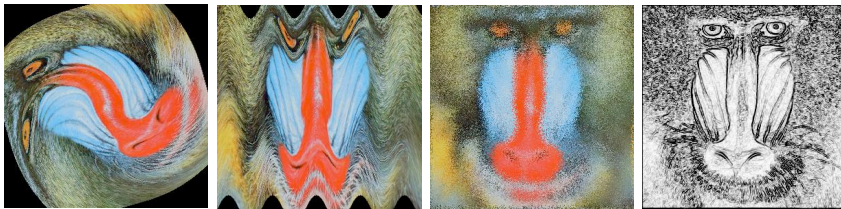
% java Scale 400 200 mandrill.jpg

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## More Image Processing Effects



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)	
int length()	string length
char charAt(int i)	ith character
String substring(int i, int j)	ith through (j-1)st characters
boolean startsWith(String pre)	does string start with pre?
boolean endsWith(String post)	does string end with post?
int indexOf(String s)	index of first occurrence of s
int indexOf(String s, int i)	index of first occurrence of s after i
String concat(String s)	this string with s appended
String toUpperCase()	uppercase version of this string
String toLowerCase()	lowercase version of this string
String replace(char a, char b)	result of changing a 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://java.sun.com/j2se/1.5.0/docs/api/java/lang/String.html>

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## Text Processing

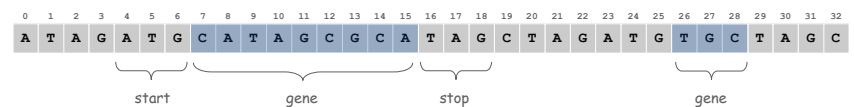
### Gene Finding

**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	multiple of 3	TAGCGCATAGCTAGATGTGCTAGC
	16	TAG	4	CATAGCGCA	TAGCTAGATGTGCTAGC
stop →	20	TAG	-1		TAGATGTGCTAGC
	23	ATG	23		ATGTGCTAGC
	29	TAG	23	TGC	TAGC

## 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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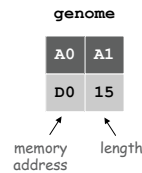
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## OOP Context for Strings

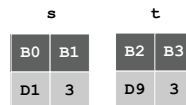
Possible memory representation of a string.

- `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	a	c	a	a	g	c	



- `s = genome.substring(1, 4);`
- `t = genome.substring(9, 12);`



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

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

compare pointers

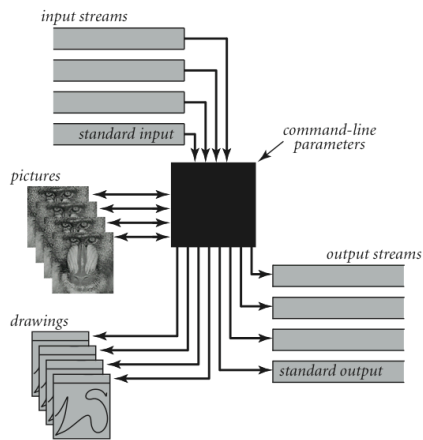
compare character sequences

## In and Out

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## Bird's Eye View (Revisited)



A bird's-eye view of a Java program (revisited again)

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## Non-Standard Input

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]);
        In in1 = new In(args[1]);
        String s = in0.readAll();
        String t = in1.readAll();
        StdOut.println(s.equals(t));
    }
}
```

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## 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

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## 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
459.52
```

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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.** Use at your own financial risk.

**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.