Computer Science Major

What my friends think I do.

What my mom thinks I do.

What society thinks I do.

What my professor thinks I do in class.

What I think I do.

What I actually do.

PerceptionvsFact.com

COMP 250: Java Reference Types & Object Oriented Programming

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Slides adapted from M. Blanchette

Methods

- Method (a.k.a. function, procedure, or routine):
  - Piece of code that carries a specific computation
  - Can be called (executed) from anywhere in the code (if they are public)
  - Can take one or more parameters (arguments) as input
  - Can return a value (or an array, or any object)

```
public static float square( float x ) {
    float s = x*x;
    return s;
}
```

- Local variables:
  - Variables declared inside a method (e.g. s).
  - They are discarded after the method finishes being executed.

```
public class Course{
  // prints welcoming statement. Takes no arguments. Returns nothing
 public static void printWelcome() {
       System.out.println("Welcome to COMP 250");
   }

   // prints welcoming statement for the given courseID. Returns nothing
   public static void printWelcome(int courseID) {
       System.out.println("Welcome to COMP " + courseID);
   }

   // returns the letter grade for the given percent grade
   public static char getGradeFromPercent( double percent) {
       char grade;
       if ( percent >= 0.8 ) grade =  'A';
       if ( percent >= 0.7 && percent < 0.8 ) grade =  'B';
        if (percent < 0.7) grade = 'C';
       return grade;
   }

   public static void main (String args[]) {
       printWelcome();
       printWelcome( 203 );
       char g = getGradeFromPercent(0.67);
       System.out.println("The grade is " + g);
       grade = 'A';      // compilation error: 'grade' was only defined inside
     // getGadeFromPercent method
   }
}
```

Why are methods useful?

- **Code re-use**: a method can be called (executed) as often as we want, from anywhere in the program. No need to duplicate code.
- **Encapsulation**: Allows to think of a piece of code as a black box with a well-defined function. Users don't need to know *how* the method works, only *what* the method does: what are its arguments, what does it return.
- **Makes program much easier to design, understand and debug**

Parameter passing

```
// Returns area a circle of radius r
static double circleArea(double r) {
    double a = 3.1416 * r * r ;
     r = -1 ;  // just to see what happens
    return a ;
}

public static void main(String args[]) {
  double radius = 2;
  double area = circleArea(radius);
  System.out.println("Radius:”
          + radius + " Area: ” + area );
}

Output:  Radius: 2 Area:12.5664
```

Memory (stack)

The truth about parameter passing

- What happens when a method is called?
  1. The flow of execution of the code calling the method is interrupted.
  2. If the methods takes some arguments, these arguments are allocated in memory (stack). They are initialized with the value of the arguments provided by the caller.
  3. If variables are declared within the method, they are also put on the stack.
  4. The code of the method is executed. This may include calling other methods.
  5. When the code of the method has been executed, it may return a value to the caller. All local variables and arguments created on the stack are discarded.
- Summary: Parameters are passed by value
  - The method called receives a *copy* of the parameters passed
  - Since it is working a copy, the method *can't change the original*
  - But watch out with arrays and non-primitive types...

```
static void stupidIncrement( int a ) {
    int i = a;
    i = i + 1;
    System.out.println("In stupidIncrement, i = " + i);
}
static void fakeAssign( int a, int b) {
    a = b;
    System.out.println("In fakeAssign, a = " + a + " and b = " + b );
}
static int add(int a, int b) {
    int sum = a + b;
    a = 0;
    return sum;
}
static public void main(String args[]) {
    int a = 1, b = 2, i = 9;
    fakeAssign( a, b );
    System.out.println("After fakeAssign a:" + a + "    b: " + b + "      i:" + i);
    stupidIncrement(b);
    System.out.println("After stupid a:" + a + "     b:" + b + "     i:" + i);
    stupidIncrement(i);
    System.out.println("Again after stupid a:" + a + "     b:" + b + "     i:" + i);
    a = add(i, a);
    System.out.println("After add a:" + a + "        b:" + b + "       i:" + i);
    System.out.println("sum = " + sum);   // this causes an compilation error
}                                          // because sum is only defined inside "add"
```

Output:

```
In assign, a =2  and b =  2
AfterfakeAssign  a:1    b:2   c:9   // because in fakeAssign, we were working
// only on copies of the original a and b
In stupidIncrement, i = 3
After stupidIncrement, a: 1      b: 2     i: 9     // the variable i used in
                                  // fakeAssign has nothing to do
                                  // with the variable i defined in main
In stupidIncrement, i = 10
Again after stupidIncrement a: 1      b: 2     i: 9
After add a: 10     b: 2      i: 9
```

Parameter passing with arrays

```
static void changeArray( int a[] ) {
    System.out.println(“First, a[0] is “ + a[0]);
    a[0]=2;
    System.out.println(”Then, a[0] is " + a[0]);
    a = new int[2];
    a[0]=3;
    System.out.println("Then, a[0] is " + a[0]);
}
public static void main(String args[]) {
   int[] array;
   array = new int[3];
   array[0] = 1;
   changeArray(array);
   System.out.println("Finally, array[0] is " + array[0] );
}
```

Memory (stack)

Memory (heap)

Strings

- Strings store sequences of characters
- Strings behave just like arrays (but they're more than that)

```
String s;    // s is a reference to a String. Currently, it's a null String
String s = "Hello";
char c = s.charAt(1);   // c is 'e'
int l=s.length();    // l is 5
String t = s.substring(1,3);    // t is a new string with "el"
String u = "Hello";
if (u==s) System.out.println("they are ==");       // won't be printed
if (s.equalsTo(u)) System.out.println("They are equalsTo");  // this will be
```

- Complete description of String operations:

https://docs.oracle.com/javase/7/docs/api

[Downey Appendix B]

Input/Output

- Java has a large number of ways to read in and write out data. We will use only the most basic.
- To import IO libraries, start your code with:
  import java.io.*; // this should be the first line of your code
- To read data from keyboard:

```
// First open a stream from which data will be read
BufferedReader keyboard = new BufferedReader(new
    InputStreamReader(System.in) );
System.out.println("Enter your name:");
String name = keyboard.readLine();    // reads one line from the keyboard
System.out.println("Enter your age:");
String ageString = keyboard.readLine();
int age = Integer.parseInt(ageString); // convert the string into an integer
keyboard.close();                      // close the stream when we are done
```

Input

- To read data from file named "myFile.txt":

```
BufferedReader myFile = new BufferedReader(new
                                    FileReader( "myFile.txt" ) );
String line = myFile.readLine();
```

- To read from an URL:

```
URL mcgill= new URL( "http://www.cs.mcgill.ca" );
URLConnection mcgillConn = mcgill.openConnection();
BufferedReader myURL = new BufferedReader(new
    InputStreamReader( mcgillConn.getInputStream () ) );
String header = myURL.readLine();
```

Output

- To write data to a file named "myOutput.txt":

```
BufferedWriter myFile = new BufferedWriter(new
    FileWriter( "myOutput.txt” ) );
String line="Hello my friends!";
myFile.writeLine(line);
...
myFile.close();
```

- Good tutorial on IO:
  - http://java.sun.com/docs/books/tutorial/essential/io/
- Full documentation:
  - https://docs.oracle.com/javase/7/docs/api

Programming style and comments

- How?
- Choose meaningful names for methods and variables. Stick to your conventions. e.g. int nbSides; getPlayersList(montrealExpos)
- Add comments to clarify any piece of code whose function is not obvious
- Give a short description of each method:
  - what does it do?
  - what arguments does it expect?
  - what assumptions are made?
  - what does it return?
  - Side-effects?
- Do not overcomment!

- Why?
- Makes re-use easier (even for you!)
- Makes finding and solving bugs easier
- Allows others to use your code
- Easier to convince your boss (or TA!) that your code is working
- Easier to analyze the efficiency of the solution

Object-Oriented Programming (OOP)

- Idea: User-defined types to complement primitive types like int, float...
- Definition of a new type is called a **class**. It contains:
  - Data
  - Methods: Code for performing operations on this data
- Example: the class String contains
  - Data: Sequence of characters
  - Operations: capitalize, substring, compare...
- Example: we could define a class Matrix with
  - Data: an m x n array of numbers
  - Operations: multiply, invert, determinant, etc.

Why OOP?

- Think of a set of classes as a toolbox:
  - You know what each tool does
  - You don't care how it does it
- OOP allows to think more abstractly:
  - Each class has a well defined interface
  - We can think in terms of functionality rather than in terms of implementation
- The creator of a class can implement it however he/she wants, as long the class fulfills the specification of the interface

A first example

```
// The new type created is called SportTeam
class SportTeam {

    // The class has four members
   String homeTown;
   int victories, losses, points;

   public static void main(String[] args) {
        // we can declare variables of type SportTeam
        SportTeam expos;

       // this creates an object of typeSportTeam and expos now references it.
        expos = new SportTeam();
        expos.victories = 62;
        expos.homeTown = "Montreal";
        SportTeam alouettes = new SportTeam();
        alouettes.victories = 11;
    }
}
```

```
class SportTeam {
   String homeTown;
   int victories, losses, points;
   // Constructors are methods used to initialize members of the class
   public SportTeam() {   // constructors are declared with no return type.
      victories=losses=points=0;
      homeTown=new String("Unknown");
    }
   // Constructors can have arguments
   public SportTeam(String town) {
       victories=losses=points=0;
       homeTown=town;
    }
    public static void main(String[] args) {
       // now we can declare variables of type SportTeam
       SportTeam expos, alouettes;
       expos = new SportTeam();
       alouettes = new SportTeam("Montreal");
     }
}
```

```
public class SportTeam {
   String homeTown;
   int victories, losses, points;
   public SportTeam() { /* see previous page */}
   public SportTeam(String town) { /* see previous page */}
   // this method returns a string describing the SportTeam
   public String toString() {
      return homeTown + " : " + victories + " victories, " + losses +
                                          " losses, for " + points + " points.";
    }
    public static void main(String[] args) {
        // now we can declare variables of type SportTeam
        SportTeam expos, alouettes;
        expos = new SportTeam();
        alouettes = new SportTeam("Montreal");
        expos.victories=62;
        alouettes.victories = expos.victories - 52;
        String report = alouettes.toString();
        System.out.println(report);
     }
}
```


THAT MOMENT YOU REALIZED
THAT PLATO TALKED ABOUT OBJECT ORIENTED PROGRAMMING BEFORE MODERN COMPUTERS EXISTED...
quickmeme.com

Private vs public

- We don't want to let any part of a program access members of a class
  - It might disrupt the internal consistency of the object (e.g. one may increase the number of victories without increasing the number of points)
  - We want to hide as much as possible the inside of a class, to enforce abstraction.
- Solution:
  - Make these members private (they can only be used from inside the class)
  - Allow access to these members only through predefined public methods

```
public class SportTeam {
   public String homeTown;      // can be changed from within any class
   private int victories, losses, points; // can only be changed from within
                                          // the SportTeam
   public SportTeam() { /* see previous page */}
   public SportTeam(String town) { /* see previous page */}
   public String toString() { /* see previous page */}
   public void addWin() {
       victories++;
       points+=2;
    }
    public static void main(String[] args) {
       // now we can declare variables of type SportTeam
       SportTeam expos, alouettes;
       expos = new SportTeam();
       alouettes = new SportTeam("Montreal");
       alouettes.addWin();
       String report = alouettes.toString();
     }
}
```

```
public class SportTeam {
    ... (from previous slides)
}

public class League {
    int nbTeams;
    public SportTeam teams[];   // an array of SportTeam

    League(int n) {       // constructor
     nbTeams = n;
     for (int i = 0 ; i < n ; i++ ) teams[i] = new SportTeam();
    }

    public static void main(String args[]) {
        League NHL = new league(30);
        NHL.teams[0].hometown = “Montreal”;
        NHL.teams[0].addWin();
   }
}
```

Assignments and equality testing

Non-primitive types are just references to objects!

```
public static void main(String[] args) {
   SportTeam expos, alouettes;
   SportTeam baseball, football;
   expos = new SportTeam();
   alouettes = new SportTeam("Montreal");
   alouettes.addWin();
   baseball = new SportTeam();
   football = alouettes;
   if ( expos == baseball ) System.out.println("expos == baseball");
   if ( football == alouettes ) System.out.println("alouettes == football");
   football.addWin();
   System.out.println(alouettes.toString());
   System.out.println(football.toString());
   football = new SportTeam("Toronto");
   System.out.println(alouettes.toString());
   System.out.println(football.toString());
}
```

This

- Sometimes, it can be useful for an object to refer to itself:
  - the **this** keyword refers to the current object
- We could rewrite the constructor as:

```
public SportTeam() {
    this.victories = this.losses = this.points = 0;
    this.homeTown = new String("Unknown");
  }
```

- If there was a league object that needed to be updated:
  - league.addTeam(this);

Static members

- Normally, each object has its own copy of all the members of the class, but...
- Sometimes we want to have members that shared by all objects of a class
- The **static** qualifier in front of a member (or method) means that all objects of that class share the same member

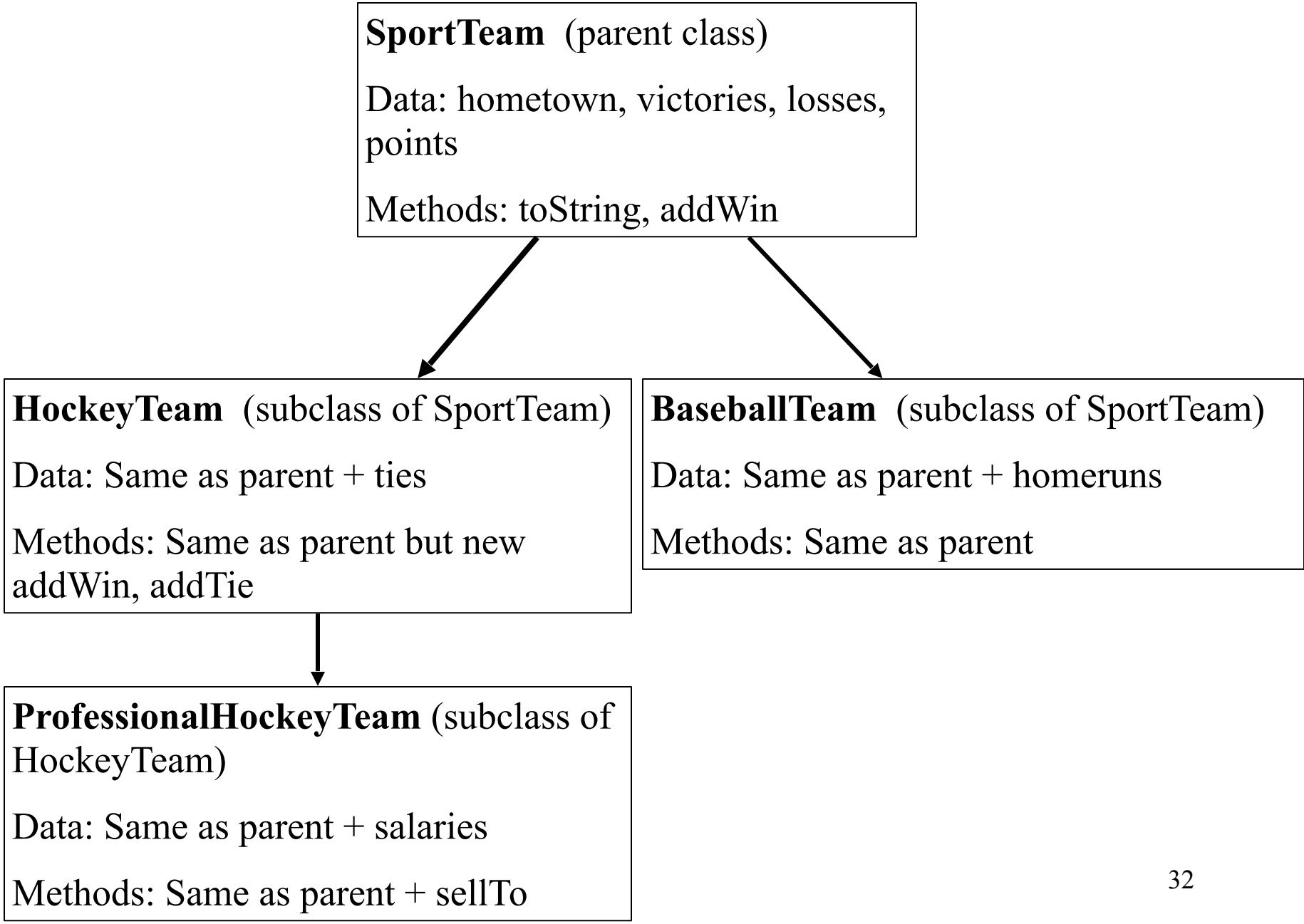
```
public class SportTeam {
   public String homeTown;
   private int victories, losses, points;
   static public double exchangeRate;    /* all objects of type SportTeam share
                                            the same exchangeRate */
   public SportTeam() { /* see previous page */}
   public SportTeam(String town) { /* see previous page */}
   public String toString() { /* see previous page */}
   public addWin() { /* see previous page */}
    public static void main(String[] args) {
       // now we can declare variables of type SportTeam
       SportTeam expos, alouettes;
       SportTeam.exchangeRate = 1.57;    /* static members can be used without
                                            an actual object */
       expos = new SportTeam();
       alouettes = new SportTeam("Montreal");
       expos.exchangeRate = 1.58;                  // or from one particular object
       System.out.println("Rate from expos: " + expos.exchangeRate);
       System.out.println("Rate from alouettes: " + alouettes.exchangeRate);
    }
}
```

Inheritance

- Suppose you need to write a class X whose role would be very similar to an existing class Y. You could
  - Rewrite the whole code anew
    - Time consuming, introduces new bugs, makes maintenance a headache
  - Copy the code of Y into X, then make your changes
    - Maintenance problem: you need to maintain both X and Y
  - Inherit the code from Y, but override certain methods
    - Code common to X and Y is kept in Y. New methods are added in X

Inheritance - Example

- You want to extend SportTeam to make it specific to certain sports
  - HockeyTeam
    - Has all the members defined in sportTean, but also number of ties.
    - Number of points = 3 * victories + 1 * ties
  - BaseballTeam
    - Has all the members defined in SportTeam, but also number of homeruns


SportTeam (parent class)
Data: hometown, victories, losses, points
Methods: toString, addWin
HockeyTeam (subclass of SportTeam)
Data: Same as parent + ties
Methods: Same as parent but new addWin, addTie
BaseballTeam (subclass of SportTeam)
Data: Same as parent + homeruns
Methods: Same as parent
ProfessionalHockeyTeam (subclass of HockeyTeam)
Data: Same as parent + salaries
Methods: Same as parent + sellTo

```
public class HockeyTeam extends SportTeam {
   private int ties;
   public HockeyTeam() {    // constructor for HockeyTeam
     super();               // super() calls the constructor of the superclass
     ties=0;
    }

    public void addWin() {
      super.addWin();         /* This calls the addWin method provided by the
                                 parent class */
       points++;              /* Since points is private, this wouldn't compile.
                                 We need to declare points as "protected"
                                 instead of private to allow access to subclasses */
     }

    public void addTie() {
      ties++;
       points++;
     }
}
```

Types and dispatch

```
public static void main(String args[]) {
    HockeyTeam habs;
    habs = new HockeyTeam();
    habs.hometown = "Montreal";
    habs.addWin();                          /* The addWin method called is the one
                                        from HockeyTeam. habs.points is 3*/
    habs.addTie();                                  // ties is now 1, points is 4
    System.out.println(habs.toString());    /* HockeyTeam doesn't provide a
                                    toString() method but SportTeam
    does, so that's the one called */
    SportTeam bruins = new HockeyTeam();  /* this is legal because HockeyTeam
                                                is a subtype of SportTeam */
    bruins.addWin();    // bruins.points is now 3
    HockeyTeam leafs = new SportTeam();   /* this is NOT legal because
                            SportTeam is not a subtype of
            HockeyTeam */
}
```

Exceptions - When things go wrong

- Some things are outside programmer's control:
  - User types "Go expos" when asked to enter number of victories
  - Try to open a file that doesn't exist
  - Try to compute sqrt(-1)
  - ...
- Exception mechanism allows to deal with these situations gracefully
  - When problem is detected, the code throws an exception
  - The execution of the program stops. JVM looks for somebody to catch the exception
  - The code that catches the exception handles the problem, and execution continues from there
  - If no code catches exception, the program stops with error message
- An exception is an object that contains information about what went wrong.

Throwing exceptions

Syntax:

```
try {
   <block of code>
}
catch (exceptiontype1 e1) {
   <block of code>
}
catch (exceptiontype2 e2) {
    <block of code>
}
...
finally {
   <block of code>
}
```

```
static double mySqrt(double x) {
   try {
      if (x<=0) throw new
                ArithmeticException(”Sqrt is defined
                  only for positive numbers");
    /* Code for computing sqrt goes here */
    }
    catch (ArithmeticException e) {
       System.out.println("The mySqrt operation
failed with error: ” +  e );
       return 0;
    }
}
```

Methods throwing exceptions

- Sometimes, it is not appropriate for a method to handle the exception it threw
- Methods can throw exceptions back to the caller:

```
static double mySqrt(double x)
        throws ArithmeticException {
  if (x<0) {
    throw new ArithmeticException(”Sqrt of "
        + x + " is not defined");
    }
    /* Code for computing sqrt goes here */
}
```

```
public static void main(String args[]) {
  double x = 0, y = 0, z = 0 ;
  try {
     x = mySqrt(10);
     y = mySqrt(-2);
     z = mySqrt(100);
  }
  catch ( ArithmeticException e ) {
     System.out.println(e.toString());
  }
  // what is the value of x, y, z now?
  // x is 1, y and z are zero
```

Java resources

- Java Application Programming Interface (API)

  http://docs.oracle.com/javase/7/docs/api//

- Java books: 1594 different books on Amazon
  - The Java Programming Language -- by Ken Arnold (Author), et al;
    By the authors of Java itself. The ultimate reference. Not easy to read for beginners.
  - Java in a Nutshell, Fourth Edition, by David Flanagan
    A text version of the Java API