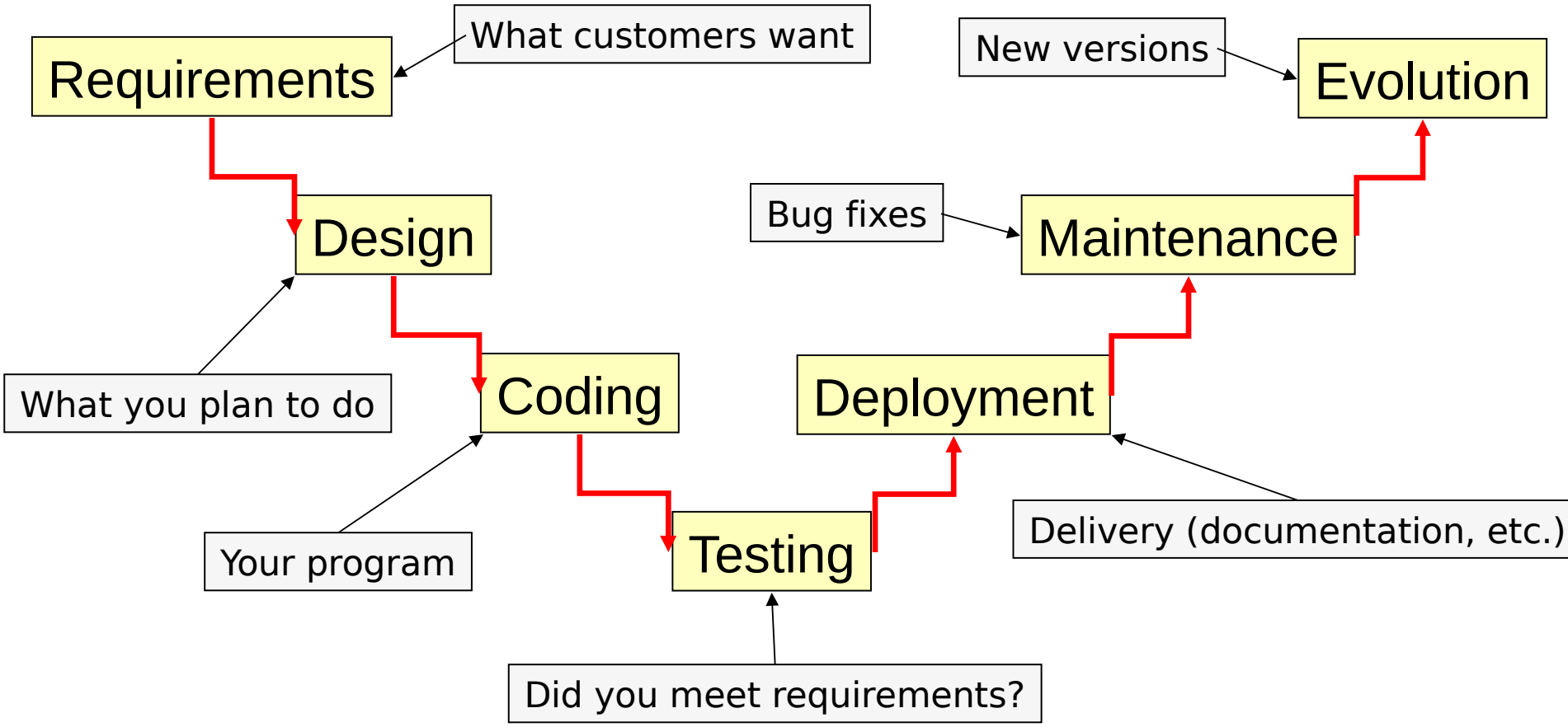
Lecture Set 5: Design and Classes

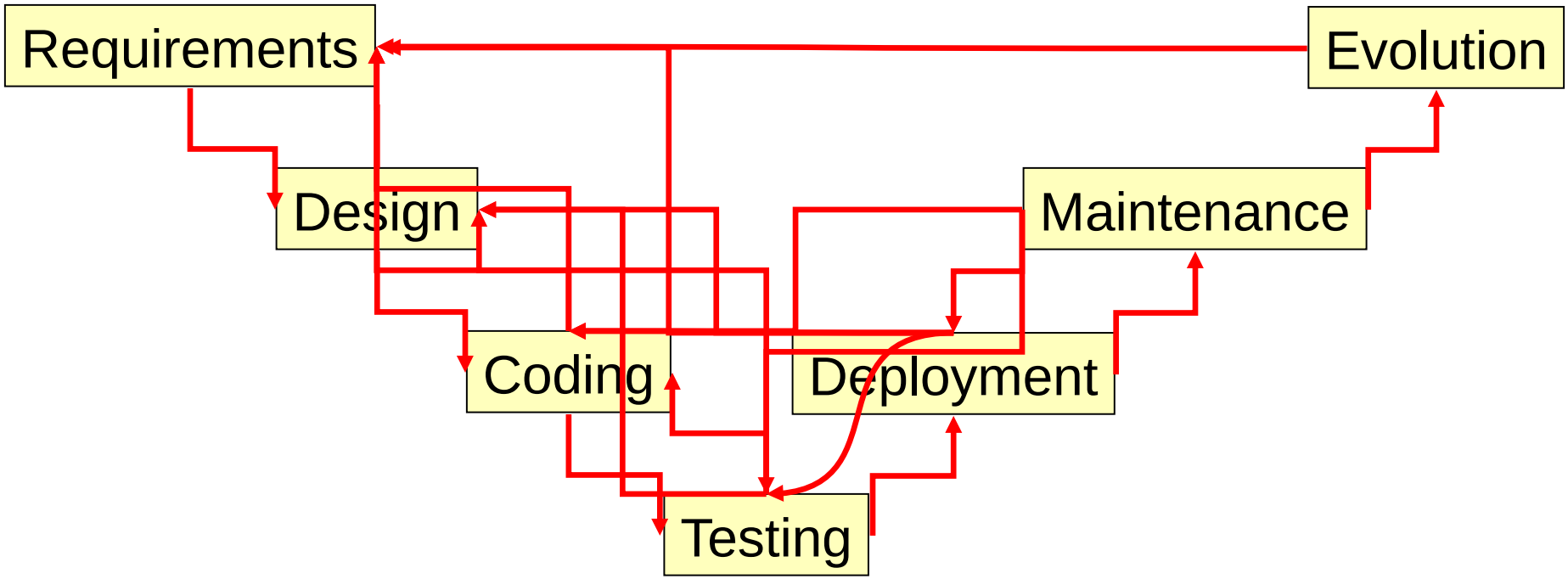
This Set:

- Basics of program design
- Pseudo-code
- Objects and classes
- Heaps
- Garbage Collection
- More about Creating Objects and classes in Java
- Methods
- Equality
- Printing an object
- Constructors, Accessors, Mutators
- Unit testing

The Software Lifecycle ("waterfall")



The Software Lifecycle (actual)



In the Real World, Requirements and Design Rule

Getting requirements right is essential for successful projects

- FBI electronic case file (junked after $180m)
- IRS system upgrade in late 90s (junked after >$2bn)
- FAA air-traffic control (false starts, >$10bn spent)

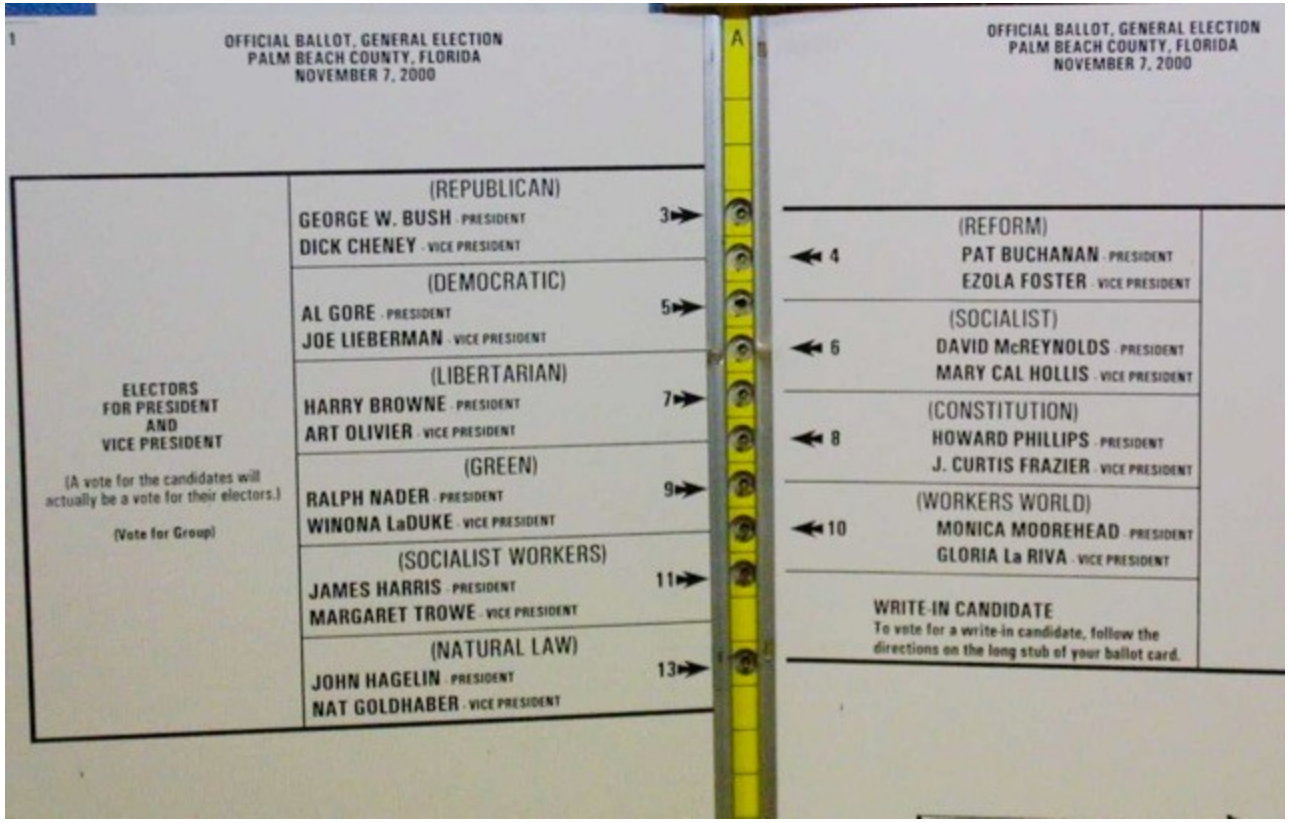
Good design makes other parts of lifecycle easier

In “the real world” coding typically < 30% of total project costs

A good design improves:

- efficiency (speed)
- efficiency (memory)
- ease of coding
- ease of debugging
- ease of expansion

Usability Matters



Program Design

There are many aspects to good design

- Architecture
- Modeling
- Requirements decomposition
- Pseudo-code

In this class we will focus on latter

What Is “Pseudo-code”?

When developing a complex part of a program (an algorithm), one of the tools often useful is pseudo-code.
It's not English, not programming language -- somewhere between.
Captures the flow of the program without worrying about language-specific details.

Objects

Bundles of (related)

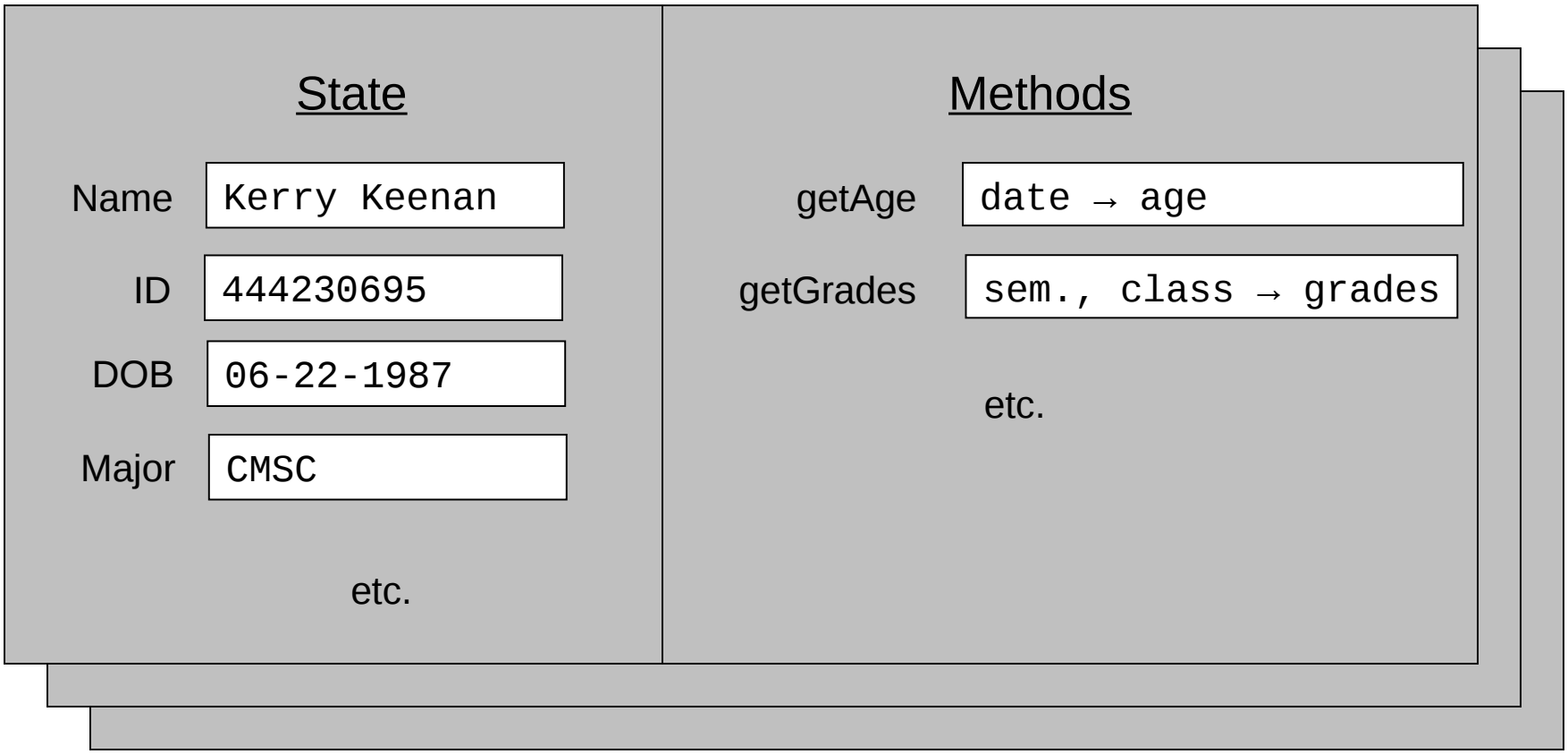
- data (“state”)
- operations (“behavior”)

Data often referred to as instance variables
Operations usually called methods
Invoking operations can change state (values stored in instance variables)

Sample Student Class

State	Methods
Name	getAge: `date → age`
ID	getGrades: `sem., class → grades`
DOB	etc.
Major	
etc.	

Sample Student Object



Accessing State / Methods

If

o is an object

v is an instance variable of the object

`m` is a method of the object

Then

`o.v` is how to access the data `v` in o

`o.m()` is how to invoke `m` in o

So

If you have already done `String str = "Jan"`

Then `str` is a String

`str` is an instance of an object!

Methods of this object: `equals`, `compareTo`, etc.

`str.equals()`, `str.compareTo()`, etc. invokes these methods on that object

Object-Oriented Programming

Programs are collections of interacting objects

Writing programs involves identifying what the objects should be and programming them

Object-oriented languages provide features to ease object-oriented programming

Defining objects involves indentifying

- state
- methods

Classes

"Blueprints" ("templates") for objects

Classes include specifications of

- Instance variables (including types, etc.) to include in objects
- Implementations of methods to include in objects

Classes can include other information also, as will be seen later

- static methods / instance variables
- public / private methods, instance variables
- And so on

StudentClassExample1/Student.java

Student Class Example

Conceptually:
Instance variables:

```
String name

int ID

int dateOfBirth

String major
```

Methods

```
getAge()

getGrades()
```

etc.

The actual class implementation will include code for the methods
This describes a blueprint for student objects

Driver.java

How Are Objects Created?

In Java: using `new`

Recall:

```
Scanner sc = new Scanner(System.in);
```

Invoking new:

creates fresh copies of instance variables in the “heap”

returns the “address” where the fresh variables are stored

Heap? Address?

Heap = “Fresh Memory”

While a program is running, some memory is used to store variables

Terminology: stack

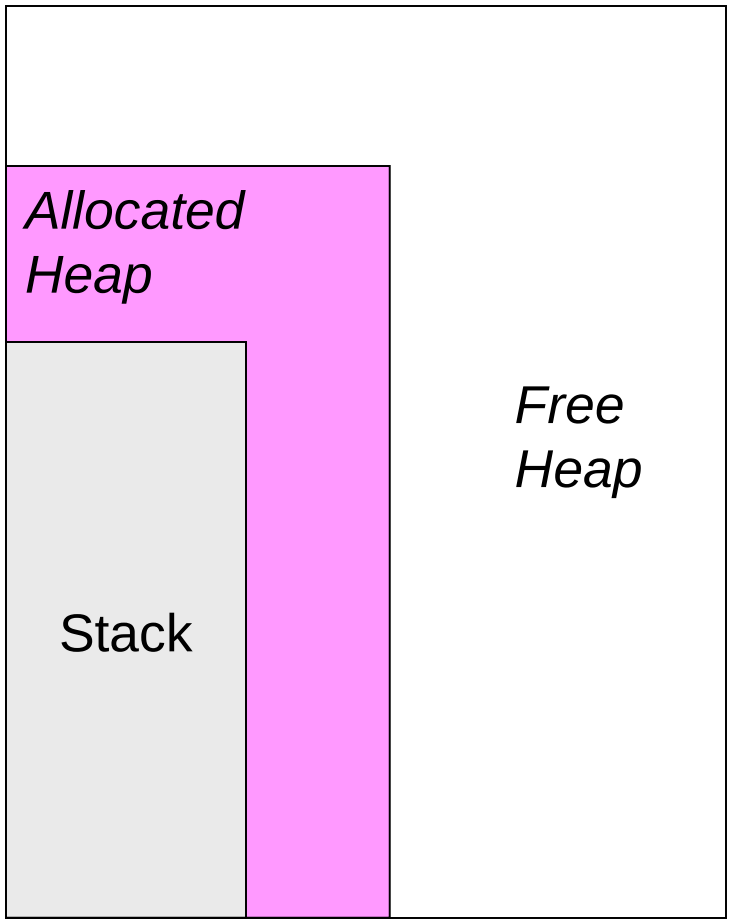
We have been representing the stack as a table, e.g.

Variable	Value
x	3
y	4.5

Rest of memory is called heap and can be used for other purposes, including storing new objects

Main Memory

Stack grows, shrinks during program execution (why?)
So does “allocated heap” (part of heap in use)
Unallocated part of heap is called “free”

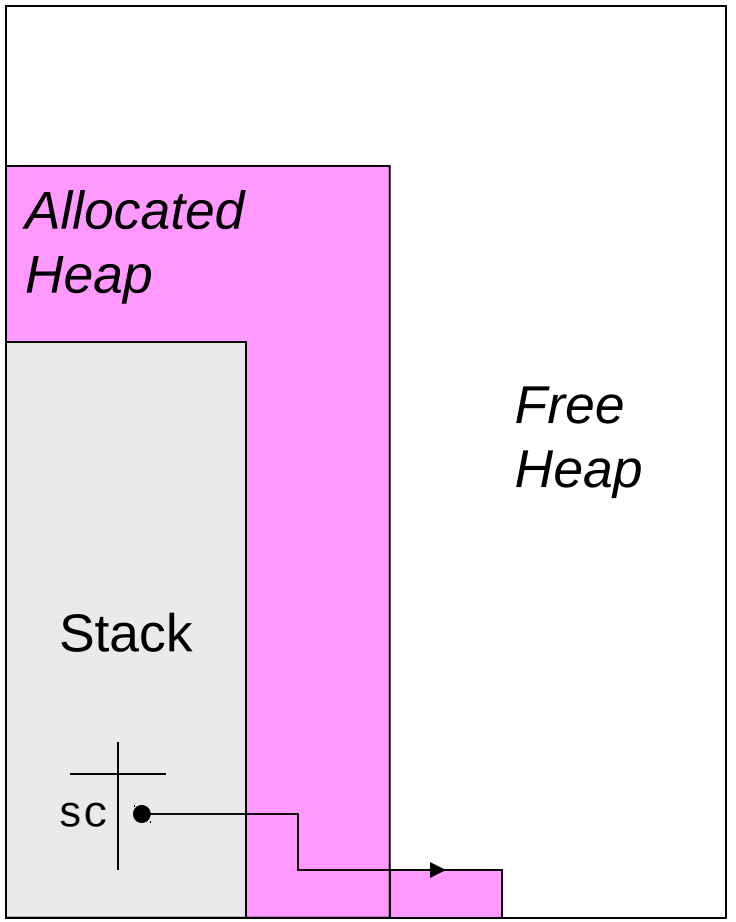


Object Creation

New space allocated in heap to store instance variables

Reference (= address) to this space is returned

```
Scanner sc = new (…);
```



Strings Are Objects

Where is `new` in

```
String name = “Narita”; ?
```

Java provides it!

`String` is special because it is used so often

Java automatically “fills in” `new`

You can too:

```
String name = new String(“Narita”);
```

In Java, 9 Sorts of Variables

8 primitive types
- Types are the 8 built-ins (int, byte, double, etc.)

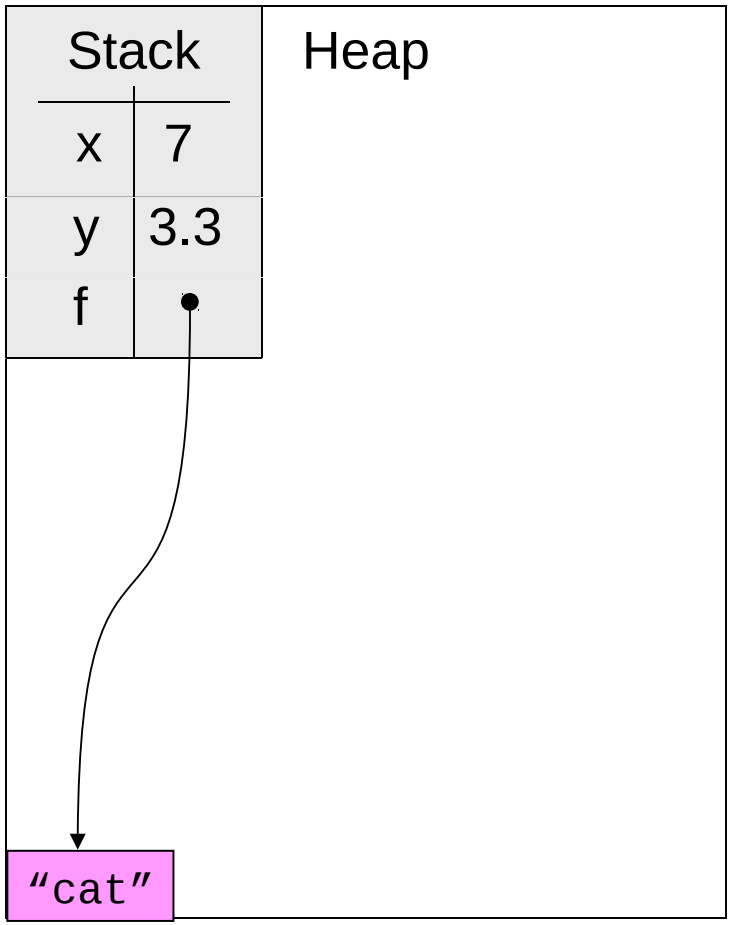
Reference type
- Objects always stored in heap (including all data)
- Reference to objects are another type, and hold one memory address (typically one word)

Stack holds local variables
- e.g. `int x`
- e.g. `String str; //` str is reference variable

Heap holds allocated memory (i.e., with “new”)
- e.g. `Scanner sc = new Scanner(System.in);`
- e.g. `str = “Jan Plane”; //` str is reference created above

Example

```
int x = 7;
float y = 3.3;
String f = "cat";
```



Heap Issues

What happens if new is called and there is no free heap?

Crash!

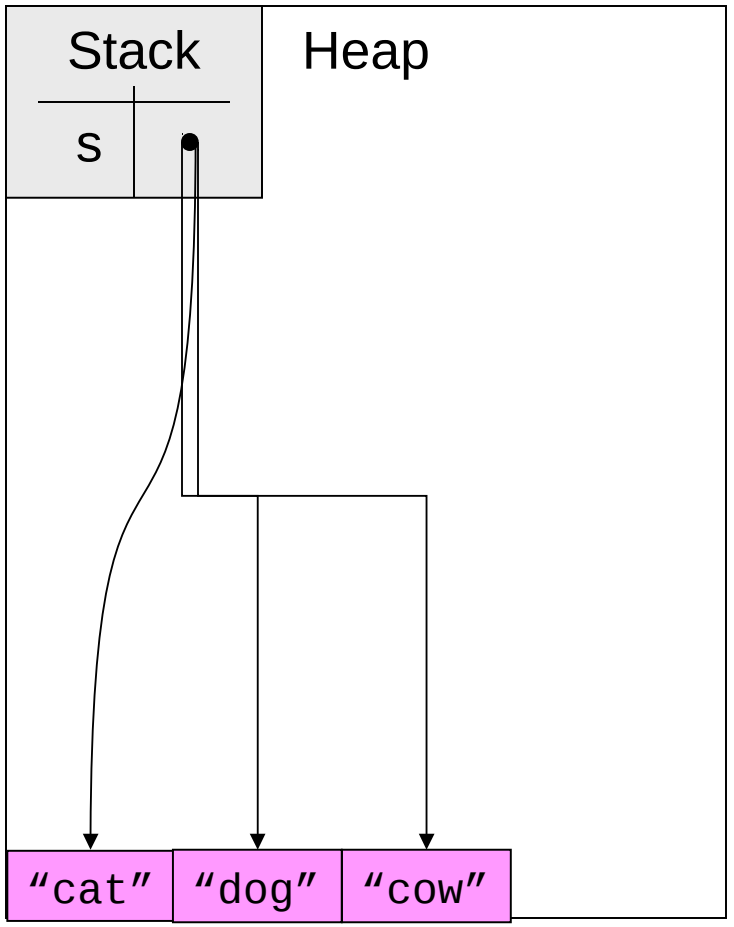
What happens if following are executed?

```
String s;
s = new String("cat");
s = new String("dog");
s = new String("cow");
```

Wasted heap

"cat", "dog" no longer referenced by stack

Crashes become a problem!

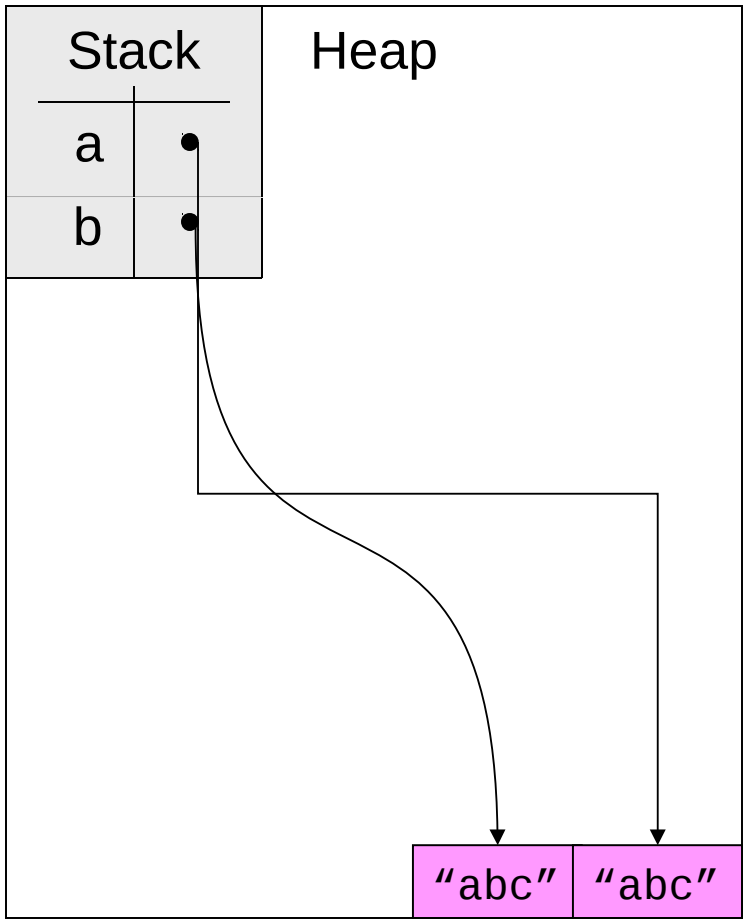


Garbage Collection

This “heap management” or “memory management” issue is central in CS
Java copes by invoking garbage collector to reclaim unused but still-allocated heap space
Garbage collector reclaims memory in allocated heap and returns it to free heap
In previous example, “cat” and “dog” would be reclaimed

Example

```
String a = new String (“abc”);
String b = new String (“abc”);
if (a == b) {
   println (“Equal”);
} else {
   println (“Not equal”);
}
   => Not equal
```



Contrasting Example

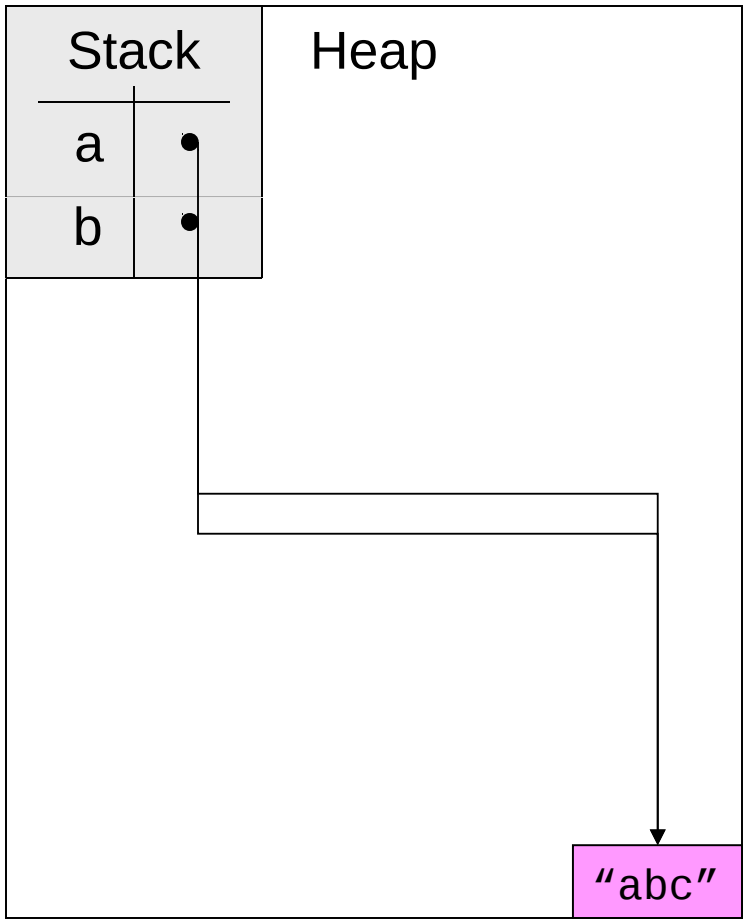
```
String a = new String (“abc”);
String b = a;
if (a == b){
    println (“Equal”);
} else {
    println (“Not equal”);
}
    => Equal
```

This is called ALIASING: Two variables refer to same object.

Can be DANGEROUS!!

What if we really want to make a copy?

```
String a = "abc"
String b = new String(a);
```

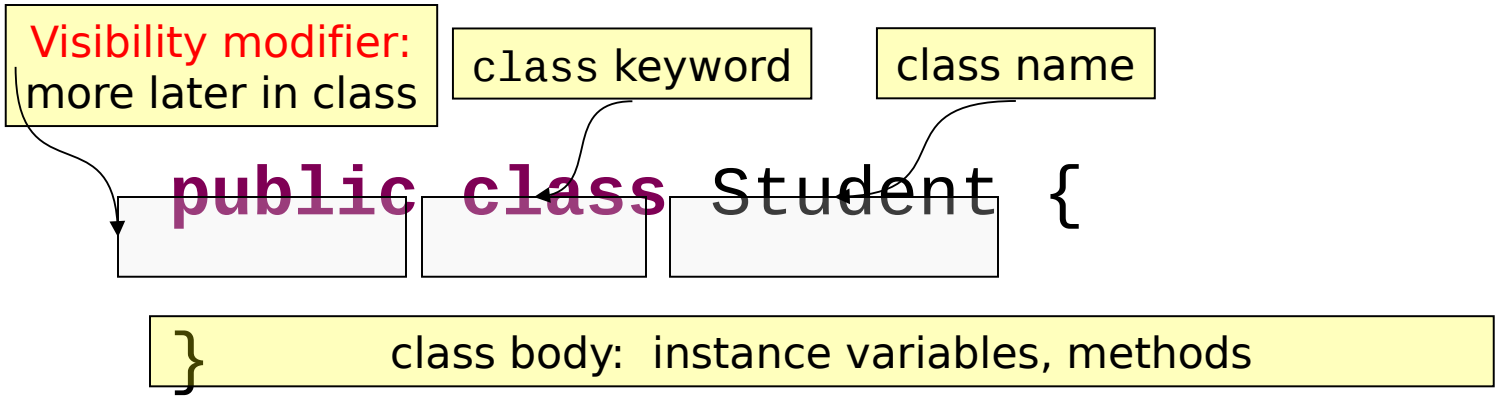


“equals”

== checks if two reference variables refer to the same object
Methods like `str.equals()` check if two different objects have the same “content”
Other classes will have an `equals` method also

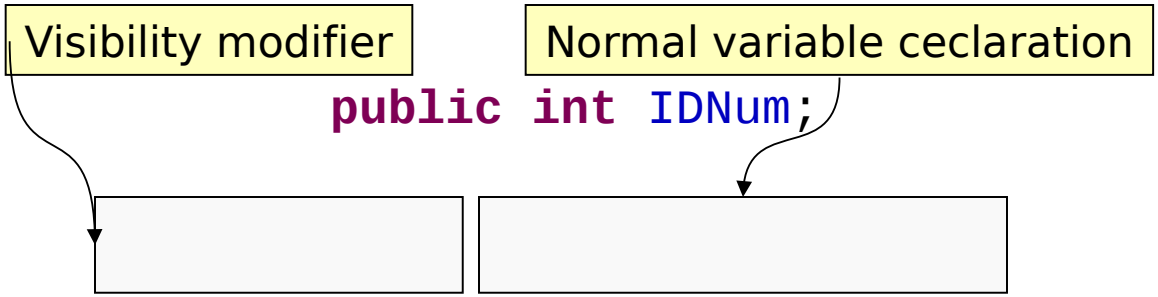
Classes in Java

Class declarations have the following form in Java:



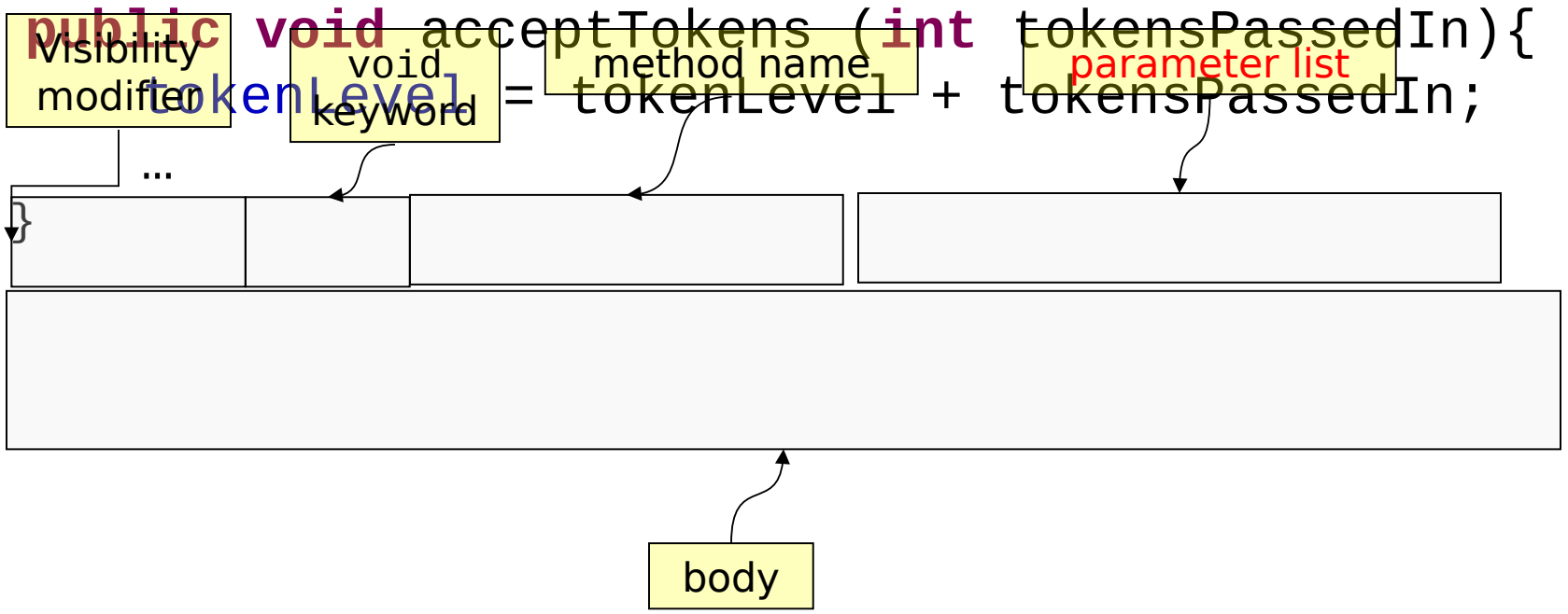
When you create a class in Eclipse, it generates this template for you

Anatomy of an Instance Variable Declaration



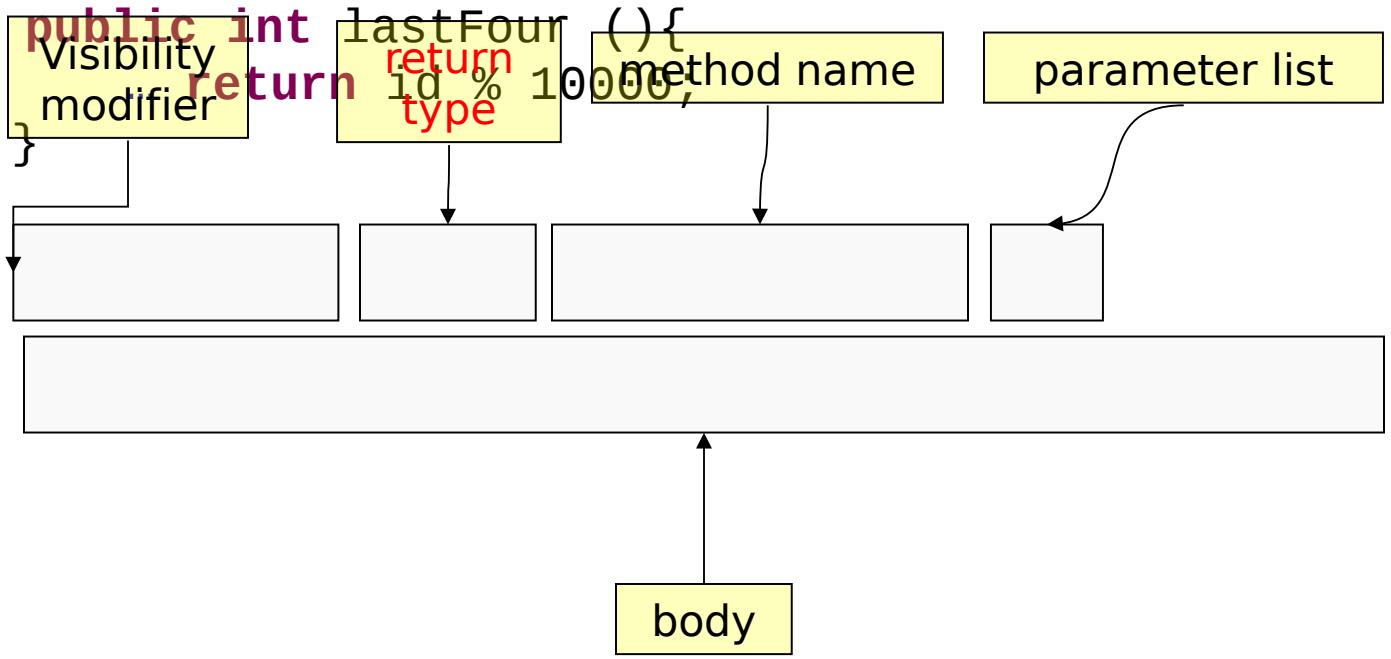
Anatomy of a Method Declaration (1)

… for methods that do not return values



Anatomy of a Method Declaration (2)

… for methods that return values



Return Type

Methods that return values must specify the type of the value to be returned
The bodies of these methods use `return` to indicate when a value is to be returned
The value being returned must have the same type as the return type

Object Creation

Once a class is defined, objects based on that class can be created using new:

```
new Student()
```

To assign an object to a variable, the variable's type must be the class of the object

```
Student s = new Student();
```

Each object has its own copies of all the instance variables in the class (except for certain kinds we'll study later)

Instance variables and methods in an object can be accessed using "." or using setter (mutator) methods

```
s.IDNum = 123456789;
s.setIDNum(123456789);
```

summaryExample/Student.java
CallingOtherMethods.java

Constructors (overloaded)

Special “methods” in class definitions to specify how objects are created
Form of a constructor definition:

```
    Student (String nameDesired, int IDDesired, int
tokensDesired) {
        name = nameDesired;
        id = IDdesired;
        tokenLevel = tokensDesired;
    }
```

Can have more than one constructor, provided argument lists are different

```
    Student (int IDDesired) {
        id = IDDesired;
    }
```

Java includes *default* constructor (no arguments), which you can redefine (overriding the default)

```
    Student () {
        tokenLevel = 3;
    }
```

Equality Testing

- Need to define what it means for two students to be equal

```
public boolean equals(Student otherStudent) {
   if (otherStudent == null) {
      return false;
    } else if (id == otherStudent.id) {
      return true;
    } else {
      return false;
   }
}
```

Objects to Strings

What happens if we try to print a Student object?

invoke `println` using a `Student` object as an argument?

```
Student s1 = new Student ();

System.out.println (s1);
```

Something like this prints:

```
Student@82ba41
```

Java Knows "How" To Print Any Object

Why?

Every class has a default `toString` method

`toString` converts objects into strings

`System.out.println` calls this method to print an object

Default: object type and address

`toString` can be overridden!

```
// The method for converting Students to strings

public String toString () {
  return (name + ": " + id);
}
```

MpgCalculator0/1.java

Static Data Members and Static Methods

Not contained in or associated with an object of that type
Accessed by the **ClassName.variableName** or by **ClassName.methodName** rather than by **objectName.variableName** or by **objectName.methodName**

Set / Get Methods

We have been using = to modify instance variables and accessing variables directly to read values

Generally, this is not good practice because it imposes restrictions on class implementation

Better

- `set` methods to set values (mutators)
- `get` methods to read values (accessors)

Set Methods (Mutators)

```
public void setID(int newID) {
    id = newID;
}
```

Can also do consistency checking

```
public void setTokenLevel(int newTokenLevel) {
  if (newTokenLevel <= 3) {
    tokenLevel = newMonth;
  } else {
    System.out.println (
      "Bad argument to setTokenLevel:  " + newTokenLevel);
  }
}
```

Get Methods (Accessors)

Sole purpose is to return values of state

```
public int getID () {

    return id;

}
```

Why use them?

The state information may not always be stored in a single instance variable, since implementations may change

You give designers option of changing instance variables

Can log/monitor usage

Parameters and Constructors

Recall that methods / constructors can have parameters

```
    public Student (String newName, int IDDesired) {
    name = newName;
        id = IDDesired;
        tokenLevel = 3;
    }
```

What is printed by the following?

```
    String newName = “Joe”;
    Student s = new Student(newName + “ Schmoe”, 123456789);
    System.out.println (s.name);
    System.out.println (newName);
```

```
Joe Schmoe
Joe
```

How Does Java Evaluate Method / Constructor Calls?


```
int newName = "Joe";
Student s = new Student
   (newName + " Schmoe", 123456789);
```

1. Arguments are evaluated using stack in effect at call site (place where method called)

`newName + " Schmoe",` evaluates to `Joe Schmoe`

`123456789` evaluates to `123456789`

2. Stack frame (temporary addition to stack) created to associate method parameters with values
3. Stack frame put into stack
4. Body of method executed in modified stack
5. Stack frame removed from stack

Testing: The problem

Problems:

- need to be able to make sure all parts are tested
- need to know in testing exactly which part was not as expected
- need to be able to keep the tests for modifications made later

Unit testing helps overcome this problems of making sure everything is tested

- Unit testing: test each class and each part of the class (unit) individually
- Goal is to eliminate inconsistencies between the API and the actual working of the code

Unit Testing

Unit testing helps overcome this problems of making sure everything is tested in a structured way

- Unit testing: test each unit individually (micro level – each method or specifically each interaction described in the API)
- Goal is to eliminate errors within classes

Needs for unit testing

- Method for defining tests = inputs, expected outputs
- Method for running tests
- Method for reporting results

One possibility: write a driver for each class

- Driver class contains main method
- main method creates objects in class to be tested, calls methods, prints outputs
- User checks outputs, determines correctness
- Good: easy, no special tools needed
- Bad: tedious, relies on human inspection of outputs

Another approach: JUnit

JUnit

A unit-testing tool for Java
Includes capabilities for:

- Test definition, including output checking
- Test running (execution)
- Result reporting

Seamless integration with Eclipse
Note

- In this class we will use JUnit 3.8.1 for some and Junit 4 for others – to expose you to both
- So, when given a choice select **JUnit 3**

Structure of a JUnit 3.8.1 Test Case


```
import junit.framework.TestCase;

public class FunnyIntegerSetTest01 extends TestCase {

  public void testInsert() {
    FunnyIntegerSet set = new FunnyIntegerSet ();
    set.insert(3);
    assertTrue (set != null);
  }

  public void testFindClosest() {
    FunnyIntegerSet set = new FunnyIntegerSet ();
    set.insert (3);
    set.insert (6);
    assertEquals (6, set.findClosest(5));
  }
}
```

JUnit library

Test case name

Needed (will see why later in semester)

Tests

Assertions (result checker

A Test Case Is … A Class!

assertion checkers

- **`assertTrue(`***`expression`***`);`**
  - If `statement` is true, keep running test; otherwise, halt test, report “fail”
- **`assertFalse(`***`expression`***`);`**
  - If `statement` is false, keep running test; otherwise, halt test, report “fail”
- **`assertEquals(`***`expression1, expression2`***`);`**
  - If `expression1`, `expression2` equal, keep running test; otherwise, halt test, report “fail”

If test terminates without failing an assertion and without throwing an uncaught exception, then it passes that test

It continues with all subsequent tests regardless of passing or failing the current test

Hints on Testing

Give names to tests that relate to class being tested
Develop some tests before you code

- Helps you to clarify what you are supposed to be doing
- Gives you some ready-made tests to run while you code

Use tests to debug
How many tests?

- Statement coverage: develop tests to make sure each statement in class is executed at least once (including constructors)
- Decision coverage: develop tests to make each condition (if statement) in program both true and false
- You should at least reach statement coverage in your own testing

Taking Care of Corner Cases

FunnyIntegerSet example from CVS

- Set of null was a corner case that we needed to test for
- Write new test cases or new asserts in the test cases that already exist to take care of this

```
public void testNullSet(){
    FunnyIntegerSet s = null;
    s.insert(4);
    assertEquals(s.findClosest(3),4);
}
```