Introduction to Algorithms and Data Structures

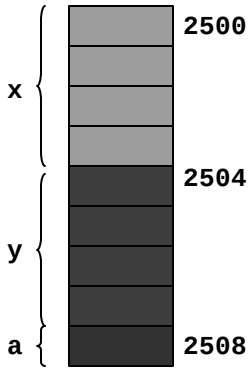
Lecture 3: References and Packages

Variables and Memory

- Variables are stored in main memory at specific addresses that are determined when the program enters the method.
- Variables of different types require different number of bytes to hold their data.

Variables and Memory: An Example

```
public static void main(String[] args)  {
  int x, y;
  byte a
  …
}
```



Objects and References

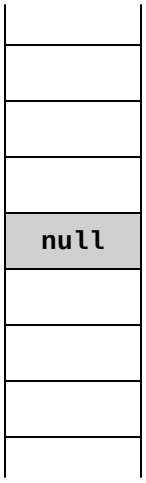
- When an object is declared, space is set aside to hold the address at which the object's data is stored, e.g.,

  `MyClass myObject;`

- There is a location in memory where the address is stored at which all the data about **`myObject`** is contained. The address that is stored is called a ***reference***.

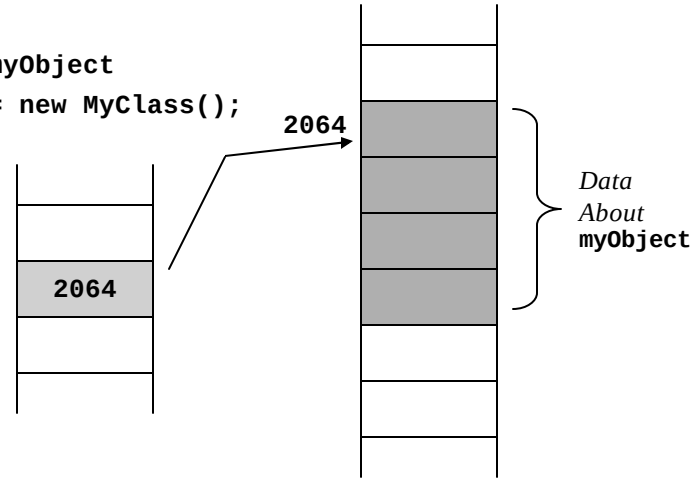
Declaring an Object

```
MyClass myObject;
```



Constructing an Object

```
MyClass myObject
        = new MyClass();
```



ToyClass.java

```
public class ToyClass  {
  private String name;
  private int number;

  public ToyClass(String initialName,
                            int initialNumber)  {
    name = initialName;
    number = initialNumber;
  }

  public ToyClass()  {
    name = "No name yet";
    number = 0;
  }
```

```
  public void set(String newName, int newNumber)  {
    name = newName;
    number = newNumber;
  }

  public String toString()  {
    return(name + " " + number);
  }

  public static void changer(ToyClass aParameter)  {
    aParameter.name = "Hot Shot";
    aParameter.number = 42;
  }

  public boolean equals(ToyClass anotherObject)  {
    return (name.equals(anotherObject.name)
                && number == anotherObject.number);
  }
}
```

TestToyClass.java

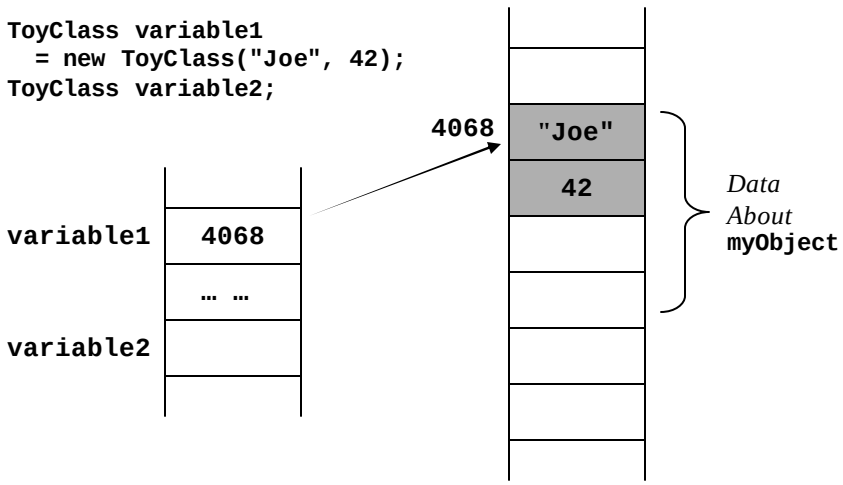
```
public class TestToyClass {
  public static void main(String[] args)  {
    ToyClass variable1 = new ToyClass("Joe", 42);
    ToyClass variable2;
    variable2 = variable1;

    // Now both variables name the same object.
    variable2.set("Josephine", 1);
    System.out.println(variable1);
  }
}
```

Output

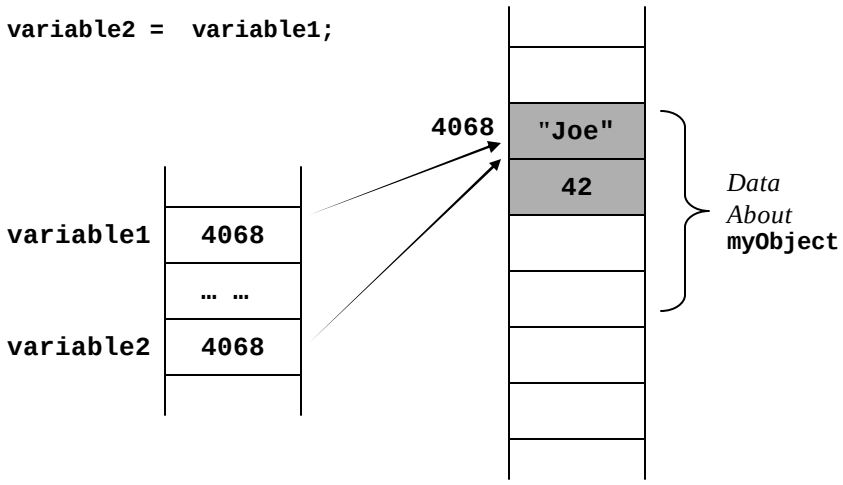
```
Josephine 1
```

Tracing through **TestToyClass**



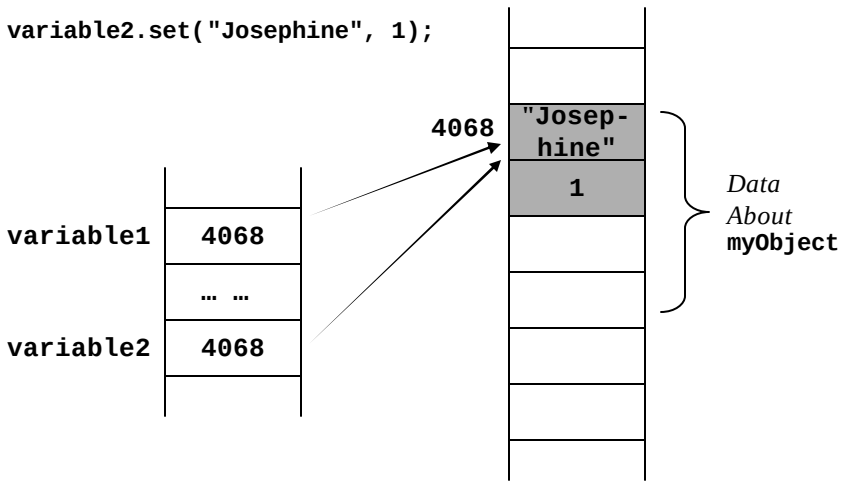
Tracing through **`TestToyClass`** (continued)

```
variable2 =  variable1;
```



Tracing through **`TestToyClass`** (continued)

```
variable2.set("Josephine", 1);
```



Objects As Parameters

- All parameters are passed by value, i.e., the value gets copied over into the method's memory area.
- For objects, it is the reference to the object that gets copied over, i.e., the address at which the object's data appears. Any changes made to an objecct passed as a parameter are permanent; the calling procedure knows about them.

ClassParameterDemo.java – An Example

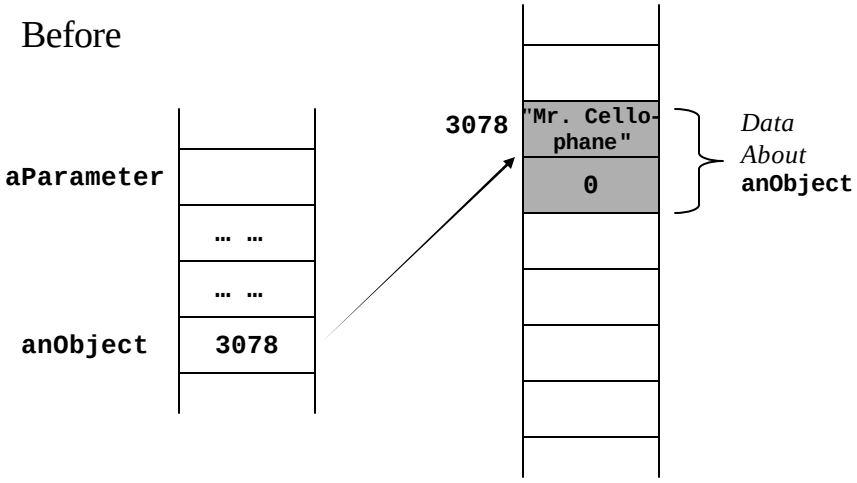
```
public class ClassParameterDemo  {
  public static void main(String[] args)  {
    ToyClass anObject = new ToyClass("Mr.
  Cellophane", 0);
    System.out.println(anObject);
    System.out.println("Now we call changer with
  anObject as argument.");
    ToyClass.changer(anObject);
    System.out.println(anObject);
  }
}
```

Output

```
Mr. Cellophane 0
Now we call changer with anObject as argument.
Hot Shot 42
```

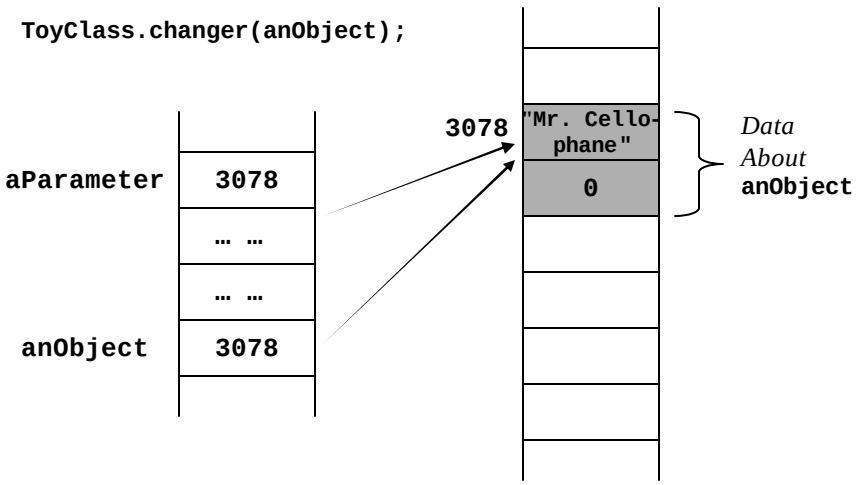
Tracing through **`ClassParameterDemo`**

Before

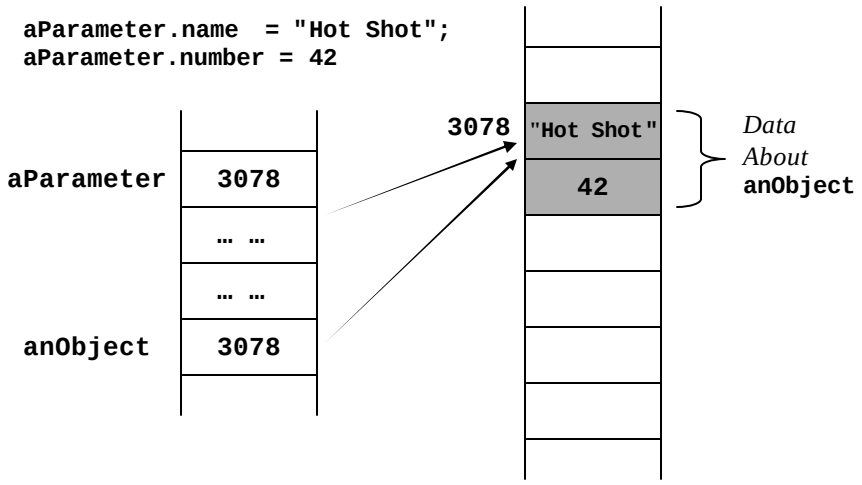


Tracing through **`ClassParameterDemo`** (continued)

```
ToyClass.changer(anObject);
```



Tracing through **`ClassParameterDemo`** (continued)



Comparing Objects

- To test the equality of two objects, it is always a good idea to compare them using a **`equals`** method.
- When you compare two objects using the == operator, you are comparing the two references.

CompareEqualsDemo.java

```
public class CompareEqualsDemo  {
  public static void main(String[] args)  {
    ToyClass object1 = new ToyClass("Slinky", 31),
             object2 = new ToyClass("Slinky", 31);

    if (object1 == object2)
      System.out.println("Equal using \"==\"");
    else
      System.out.println("Not equal using \"==\"");

    if (object1.equals(object2))
      System.out.println("Equal using \"equals\"");
    else
      System.out.println("Not equal using \"equals\"");
  }
}
```

null

- **`null`** is a special constant that can be assigned to any object reference, indicating that is has no “real” value.
- It is also used to indicate when an object has not yet been constructed.

```
YourClass yourObject = null;
…
if (yourObject == null)
System.out.println
              ("No real object here.");
```

Anonymous Objects

- When I write

```
ToyClass variable1 = new ToyClass("Joe", 42);
```

  I am calling a constructor to create an instance of object in memory whose reference is stored in variable 1.
- I can write

```
if (variable1.equal(new ToyClass("JOE", 42)))
  System.out.println("Equal");
else
  System.out.println("Not equal"):
```

- Since I will NEVER want to use `new ToyClass("JOE", 42)` again. This is an ***anonymous object***; it has no name to identify it.

Anonymous Objects Are Temporary

- Writing

```
if (variable1.equal(new ToyClass("JOE", 42)))
  System.out.println("Equal");
else
  System.out.println("Not equal"):
```

  is equivalent to

```
ToyClass temp = new ToyClass("JOE", 42);
if (variable1.equal(temp))
  System.out.println("Equal");
else
  System.out.println("Not equal");
```

Invariants

- An invariant is a statement that is always true. E.g,

```
(for i = 0;  i < 5  i++) {
… …
}
// Invariant i >= 5
```

- A class invariant is a statement that is always true about a class.

Person.java

```
// Class for a person with a name and dates for
// birth and death.
// Class invariant - A Person always has a date
//                   of birth and if there is a
//                   date of birth it precede the
//                   date of birth
public class Person  {
  private String name;
  private Date born;
  private Date died;  // null indicates still
                      // alive
```

```
// Person() - This constructor initializes the
//            Date objects uses their copy
//            constructor.
public Person(String initName,
              Date birthDate, Date deathDate)  {
  if (consistent(birthDate, deathDate))  {
    name = initName;
    born = new Date(birthDate);
    if (deathDate == null)
      died = null;
    else
      died = new Date(deathDate);
  }
  else  {
    System.out.println
           ("Inconsistent dates.  Aborting.");
    System.exit(0);
  }
}
```

```
// Person() - A copy constructor for Person
public Person(Person original)  {
  // It is essential that we determine if the
  // original object exists by seeing if its
  // reference is null or not.
  if (original == null) {
    System.out.println("Fatal error.");
    System.exit(0);
  }
  name = original.name;
  born = new Date(original.born);

  // If we had written born = original.born
  // it would be an example of a privacy leak
  if (original.died == null) // Not a problem
    died = null;
  else
    died = new Date(original.died);
}
```

```
//  Mutator that sets the values for the whole
//  class
public void set(String newName,
            Date birthDate, Date deathDate)  {
  // Make sure that the dates are consistent
  if (consistent(birthDate, deathDate))  {
    name = newName;
    //born cannot be null but died might be
    born = new Date(birthDate);
    if (died == null)
      died = new Date(deathDate);
    else
      died = deathDate;
  }
}
```

```
// toString() - converts a person's data into a
//              String
public String toString()  {
  // First, let's see if there is a date of
  // death
  String diedString;
  if (died == null)
    diedString = ""; // Empty string
  else
    diedString = died.toString();

  // born is converted using Date.toString()
  return(name + ", " + born
                      + "-" + diedString);
}
```

```
// equals() - Returns true if the person's date
//            matches this object.
//            Returns false if not
public boolean equals(Person otherPerson)  {
  if (otherPerson == null)
    return false;
  else
    // We use equals for born because it cannot
    // be null.  We use datesMatch for died
    // because it migt be null
    return (name.equals(otherPerson.name)
        && born.equals(otherPerson.born)
        && datesMatch(died, otherPerson.died));
}
```

```
// datesMatch() - Returns true if the dates are
//                the same or if they are both
//                null.
//                Returns false if not.
private static boolean datesMatch
                (Date date1, Date date2)  {
  if (date1 == null)
    return(date2 == null);
  else if (date2 == null) // and date1 != null
    return false;
  else // both dates are NOT null
    return(date1.equals(date2));
}
```

```
// setBirthDate(Date newDate) - A mutator for
//                              born
//   Precondition: newDate is a consistent date
//                 of birth
// Postcondition: Date of birth of the calling
//                object is newDate
public void setBirthDate(Date newDate)  {
  if (consistent(newDate, died))
    born = new Date(newDate);
  else {
    System.out.println
          ("Inconsistent dates.  Aborting.");
    System.exit(0);
  }
}
```

```
// setDeathDate() - A mutator for deathDate
public void setDeathDate(Date newDate)  {
  if (!consistent(born, newDate))  {
    System.out.println
          ("Inconsistent dates.  Aborting.");
    System.exit(0);
  }

  // A null date of death is valid.  This is
  // different from setBirthDate because
  // birthDate cannot be null.
  if (newDate == null)
    died = null;
  else
    died = new Date(newDate);
}
```

```
// setName() - A mutator for name
//   Precondition: name cannot be null
public void setName(String newName) {
  name = newName;
}

// getName() - An accessor for name
public String getName() {
  return name;
}

// getBirthDate() - An accessor for birthDate
public Date getBirthDate() {
  return new Date(born);
}
```

```
// setBirthYear - A mutator for the person's
//                year of birth
//  Precondition: the date of birth has been
//       set and changing the year will give
//       consistent date of birth.
//  Postcondition: The year of birth is newYear
public void setBirthYear(int newYear) {
  if (born == null)  {
    // Precondition is violated
    System.out.println
            ("Fatal error.  Aborting.");
    System.exit(0);
  }
  born.setYear(newYear);
  if (!consistent(born, died))  {
    System.out.println
         ("Inconsistent dates.  Aborting.");
    System.exit(0);
  }
}
```

```
// setDeathYear - A mutator for the person's
//                year of death
//  Precondition: the date of death has been
//        set and changing the year will give
//        consistent date of death.
//  Postcondition: The year of death is newYear
public void setDeathYear(int newYear)   {
   if (died == null)  {
    // Precondition is violated
    System.out.println
            ("Fatal error.  Aborting.");
    System.exit(0);
  }
  died.setYear(newYear);
  if (!consistent(born, died))  {
    System.out.println
        ("Inconsistent dates.  Aborting.");
    System.exit(0);
  }
}
```

```
// getDeathDate() - An accessor for deathDate
//                  We must ensure that it
//                  exists; else return null
public Date getDeathDate() {
  if (died == null)
    return null;
  else
    return new Date(died);
}
```

```
// To be consistent birthDate must not be null.
// If there is no date of death
// (deathDate == null), that is consistent with
// any birthDate.  Otherwise, the birthDate
// must come before or be equal to the
// deathDate.
private static boolean consistent
         (Date birthDate, Date deathDate) {
  if (birthDate == null)
    return false;
  else if (deathDate == null)
    return true;
  else
    return(birthDate.precedes(deathDate)
             || birthDate.equals(deathDate));
}
```

PersonDemo.java

```
public class PersonDemo {
  public static void main(String[] args)  {
    Person bach
        = new Person("Johann Sebastian Bach",
                  new Date("March", 21, 1685),
                  new Date("July", 28, 1750));
    Person stravinsky
        = new Person("Igor Stravinsky",
                  new Date("June", 17, 1882),
                  new Date("April", 6, 1971));
    Person adams
        = new Person("John Adams",
           new Date("February", 15, 1947), null);
```

```
      System.out.println
                ("A Short List of Composers:");
      System.out.println(bach);
      System.out.println(stravinsky);
      System.out.println(adams);

      Person bachTwin = new Person(bach);
      System.out.println
                ("Comparing bach and bachTwin:");
      if (bachTwin == bach)
        System.out.println
                ("Same reference for both.");
      else
        System.out.println("Distinct copies.");
```

```
    if (bachTwin.equals(bach))
      System.out.println("Same data.");
    else
      System.out.println("Not same data.");
  }
}
```

Output

```
A Short List of Composers:
Johann Sebastian Bach, March 21, 1685-July 28, 1750
Igor Stravinsky, June 17, 1882-April 6, 1971
John Adams, February 15, 1947-
Comparing bach and bachTwin:
Distinct copies.
Same data.
```

Mutable and Immutables Classes

- **Mutable classes** – classes where properties can be changed, either because they are public or because there are mutators for the properties.
- **Immutable classes** – classes whose properties cannot be changed because they are private and there are no mutator methods.

Mutable and Immutable Classes – An Example

- Consider the two methods from **`Person.java`**:

```
public String getName() {
  return name;
}
public Date geBirthDate()  {
  return new Date(born);
}
```

- Why do we return a reference to name but create a duplicate object for born? *Because name cannot be changed directly.*

Changing Strings

- When you write:

```
String greeting = "hello";
greeting  = greeting + " friend";
```

  we are replacing the reference to the object greeting with another reference to a new object that replaces the old greeting.

- If we write:

```
String greeting = "hello";
String helloVariable = greeting;
greeting = greeting + "friend";
System.out.println(helloVariable);
System.out.println(greeting);
```

- The output will be

```
hello
hello friend
```

Packages and Import Statements

- A ***package*** is Java's way of forming a library of classes.
- If you wish to use a package of classes that are not the directory in which you are working, write:

```
import java.util.Scanner; // to include Scanner
Import java.util.*; // to include all of
                    // java.util's classes.
```

Package Names and Directories

- A package can be created by grouping all the classes together in one directory and placing the line

  `Package` *PackageName*`;`

  At the beginning before any Java code.
- Now these classes can be used by adding an import statement to the classes that use it.