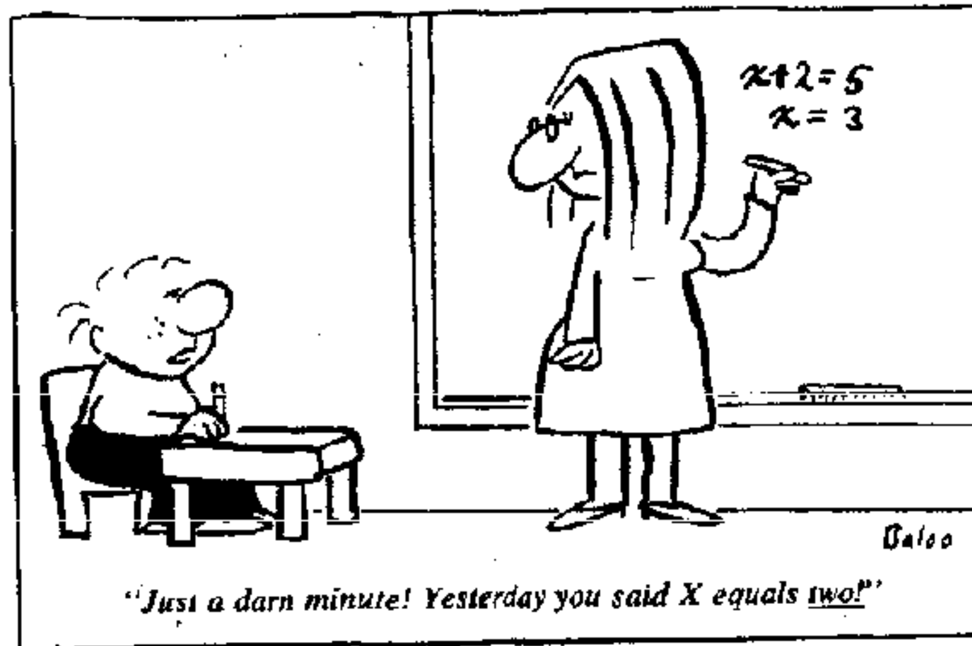
ORF 201

COMPUTER METHODS FOR PROBLEM SOLVING

Lecture 9
Call-by-Value* and Recursion

***When is a Method not like a Function?**



"Just a darn minute! Yesterday you said X equals two!"

(C) Princeton University

Call-by-Value

Can a method change the data in its argument list?

The **n** in **main** is *local* to **main**.

The value of **n** in **SetToSix** is *initially* set to the value of the corresponding variable on the argument list in the method from which the call originated. In this case 37.

```
public class CallByValue
{
      public static void main(String[] args)
      {
         int n;
         n = 37;

         System.out.println("before: n = " + n);
         SetToSix(n);
         System.out.println("after:  n = " + n);
      }

      static void SetToSix(int n)
      {
         System.out.println("inside: n = " + n);
         n = 6;
      }
}
```

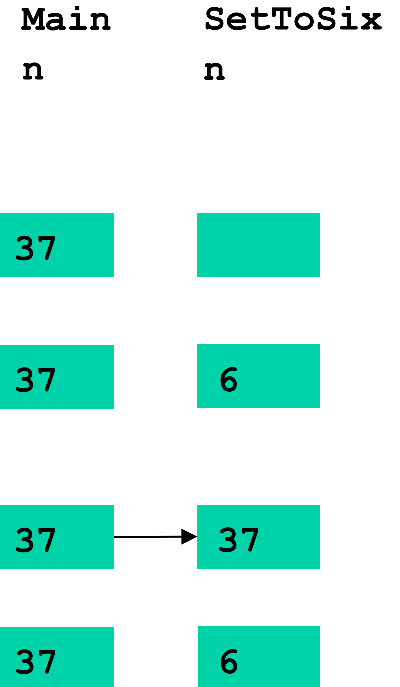
The **n** in **SetToSix** is *local* to **SetToSix**.

Can you guess the last line of output?

```
before:  n = 37
inside:  n = 37
after:   n = __
```

Call-by-Value: Memory View

```
public class CallByValue
{
    public static void main(String[] args)
    {
        int n;
        n = 37;

        System.out.println("before: n = " + n);
        SetToSix(n);
        System.out.println("after:  n = " + n);
    }

    static void SetToSix(int n)
    {
        System.out.println("inside: n = " + n);
        n = 6;
    }
}
```



What about Global Variables?

Can you guess the output?

```
public class CallByValue
{
    static int N;          // a GLOBAL
variable

    public static void main(String[] args)
    {
        N = 314;

        System.out.println("N = " + N);
        SetToSix();
        System.out.println("N = " + N);
    }

    static void SetToSix()
    {
        N = 6;
    }
}
```

```
before:  N = 314
after:   N = ___
```

The argument list is empty. Would the answer be the same if **N** had been passed as an argument?

Global Variables: Memory View

```
public class CallByValue
{
    static int N;

    public static void main(String[] args)
    {
        N = 314;
        System.out.println("N = " + N);
        SetToSix();
        System.out.println("N = " + N);
    }

    static void SetToSix()
    {
        N = 6;
    }
}
```

CallByValue

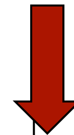
N

0
314
6
6

What about Arrays?

```
public class CallByValue
{
    public static void main(String[] args)
    {
        double[] x = new double[12];
        for (int j=0; j<12; j++) { x[j] = j; }
        System.out.print   ("before: x[7] = " + x[7]);
        ComputeSquares(x);
        System.out.println("after: x[7] = " + x[7]);
        System.out.print   ("before: x[4] = " + x[4]);
        ComputeSqrt(x[4]);
        System.out.println("after: x[4] = " + x[4]);
    }
    static void ComputeSquares(double[] ex)
    {
        for (int j=0; j<12; j++) {
            ex[j] = ex[j]*ex[j];
        }
    }
    static void ComputeSqrt(double y)
    {
        y = Math.sqrt(y);
    }
}
```

What do you think is the output this time?



```
before: x[7] = ___    after: x[7] = ___
before: x[4] = ___    after: x[4] = ___
```

Moral: The *value* that is copied to the called method is a pointer, not the entire pile of stuff to which the pointer points.

Arrays: Memory View

```
public class CallByValue
{
    public static void main(String[] args)
    {
        double[] x = new double[4];

        for (int j=0; j<4; j++) {x[j] = j;}

        ComputeSquares(x);

        ComputeSqrt(x[2]);
    }
    static void ComputeSquares(double[] ex)
    {
        for (int j=0; j<12; j++) {
            ex[j] = ex[j]*ex[j];
        }
    }
    static void ComputeSqrt(double y)
    {
        y = Math.sqrt(y);
    }
}
```

main

x	x[0]	x[1]	x[2]	x[3]
344 (276)	0 (344)	0 (352)	0 (360)	0 (368)
344	0	1	2	3
344	0	1	4	9
344	0	1	4	9

ComputeSquares

ex	ex[0]	ex[1]	ex[2]	ex[3]
344 (556)	0 (344)	1 (352)	4 (360)	9 (368)

ComputeSqrt

y
4 (712)
2

What about Objects?

```
class Zip
{
    int zip; double lat; double lon; double x; double y;
}
public class CallByValue
{
    public static void main(String[] args)
    {
        Zip z;
        z = new Zip();

        z.zip = 90210;
        z.lat = 34.09;
        z.lon = 118.41;
        System.out.print  ("before: zip  = " + z.zip);
        SetToPrinceton(z);
        System.out.println("after: zip = " + z.zip);
    }
    static void SetToPrinceton(Zip zed)
    {
        zed.zip = 8544;
    }
}
```

z is a class variable.
But **z.zip** is an **int**.

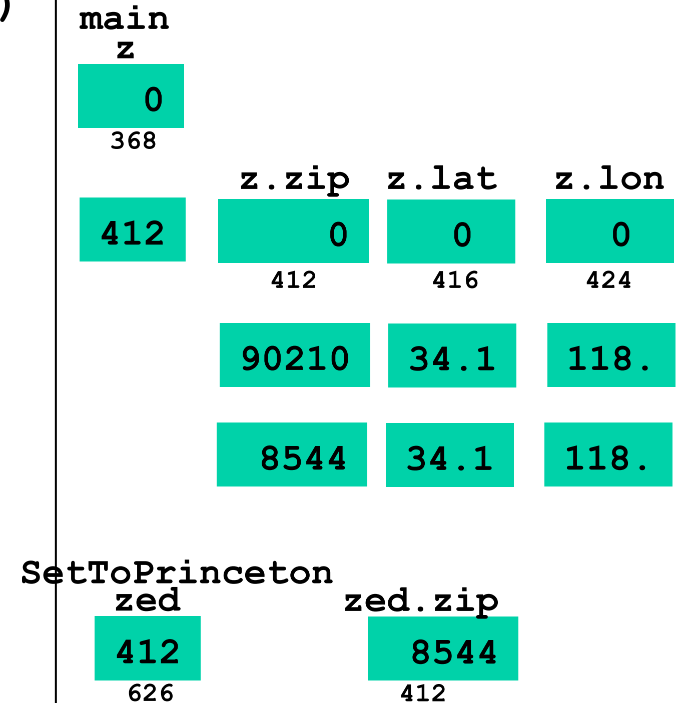
And the output is

```
before: zip = 90210
after:  zip = _____
```

Moral: Class variables are pointers just as arrays are. Therefore, argument passing works the same as it did with arrays.

Objects: Memory View

```
class Zip
{
    int zip; double lat; double lon;
}
public class CallByValue
{
    public static void main(String[] args)
    {
        Zip z;


        z = new Zip();

        z.zip = 90210;
        z.lat = 34.1;
        z.lon = 118.;

        SetToPrinceton(z);
    }
    static void SetToPrinceton(Zip zed)
    {
        zed.zip = 8544;
    }
}
```



Static Variables

```
class SomeStuff
{
     static int s;
     double value;
}
```

Static variable **`s`** belongs to the class **`SomeStuff`**. There is always exactly one "copy of this variable."

Variable **`value`** belongs to *instances* of class **`SomeStuff`**.
- Zero or more instances of this variable can exist at any time.
- They are created by calls to **`new SomeStuff()`**.

Terminology:
- Static variables are called *class variables*.
- Other variables are called *instance variables*.

A Demo Program

```
public class StaticDemo
{
    public static void main(String[] args)
    {
        SomeStuff x, y;

        x = new SomeStuff();
        y = new SomeStuff();

        x.s = 1;
        x.value = 3.14159;

        y.s = 2;
        y.value = 2.71828;

        System.out.println("x.s     = " + x.s);
        System.out.println("x.value = " + x.value);

        System.out.println("y.s     = " + y.s);
        System.out.println("y.value = " + y.value);

        SomeStuff.s = 3;

        System.out.println("x.s     = " + x.s);
    }
}
```

Referring to class variable **`s`** using **`x.s`** is legal but misleading.

`x.s` and **`y.s`** are the same variable.

It is better to use **`SomeStuff.s`**.

Writing **`SomeStuff.value`** is illegal - i.e. it produces a compile-time error.

What's the output?

```
x.s     = ____
x.value = ____
y.s     = ____
y.value = ____
x.s     = ____
```

Recursion

Consider the *factorial* function: $n! = n(n-1)\cdots(3)(2)(1)$

A *natural* way to program it uses the following recursive definition:

$n! = n(n-1)!$ $\quad 0! = 1$

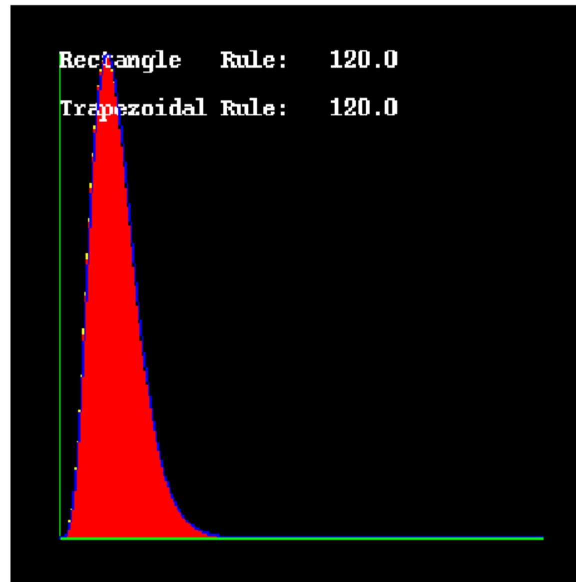
Here's the Java program:

```
import cs1.*;

public class Factorial
{
    public static void main(String[] args)
    {
        int n, n_fact;

        while (true) {
            n = Keyboard.readInt("Enter an integer: ");
            if (n<0) break;

            n_fact = factorial(n);

            System.out.println("n factorial = " + n_fact);
        }
    }

    static int factorial(int k)
    {
        if (k==0) {return 1;}
        else      {return k*factorial(k-1);}
    }
}
```

Digression -- Factorials and Integration

Amazing but true: $n! = \int_0^\infty x^n e^{-x} dx$

Can use a slightly modifed **`Integra.java`** to compute these integrals:



Works even with positive real numbers and even some negative numbers:

$$(-1/2)! = \sqrt{\pi}$$