Inf1-OP

Functions aka Static Methods

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Functions / Static Methods

Why are functions so helpful?

Lets consider a program that helps you save your pocket money towards a saving goal.

Why Functions

```
public class Duplication0 {
    public static void main(String[] args) {
        String boyFirstName = "Jock";
        String boySecondName = "McIness";
        String boyName = boyFirstName + " " + boySecondName;
        int boyWeeklyPocketMoney = 2;
        int boySavingsTarget = 10;
        int boyWeeksToTarget =  boySavingsTarget / boyWeeklyPocketMoney;
        System.out.print(boyName + " needs to save for ");
        System.out.println(boyWeeksToTarget + " weeks");

        String girlFirstName = "Jane";
        String girlSecondName = "Andrews";
        String girlName = girlFirstName + " " + girlSecondName;
        int girlWeeklyPocketMoney = 3;
        int girlSavingsTarget = 9;
        int girlWeeksToTarget = girlSavingsTarget / girlWeeklyPocketMoney;
        System.out.print(girlName + " needs to save for ");
        System.out.println(girlWeeksToTarget + " weeks");
    }
}
```

Why Functions

Output

```
% java Duplication0
Jock McIness needs to save for 5 weeks
Jane Andrews needs to save for 3 weeks
```

Why Functions

Lots of duplicate code in this implementation.

```
public class Duplication0 {
    public static void main(String[] args) {
        String boyFirstName = "Jock";
        String boySecondName = "McIness";
        String boyName = boyFirstName + " " + boySecondName;
        int boyWeeklyPocketMoney = 2;
        int boySavingsTarget = 10;
        int boyWeeksToTarget =  boySavingsTarget / boyWeeklyPocketMoney;
        System.out.print(boyName + " needs to save for ");
        System.out.println(boyWeeksToTarget + " weeks");

        String girlFirstName = "Jane";
        String girlSecondName = "Andrews";
        String girlName = girlFirstName + " " + girlSecondName;
        int girlWeeklyPocketMoney = 3;
        int girlSavingsTarget = 9;
        int girlWeeksToTarget = girlSavingsTarget / girlWeeklyPocketMoney;
        System.out.print(girlName + " needs to save for ");
        System.out.println(girlWeeksToTarget + " weeks");
    }
}
```

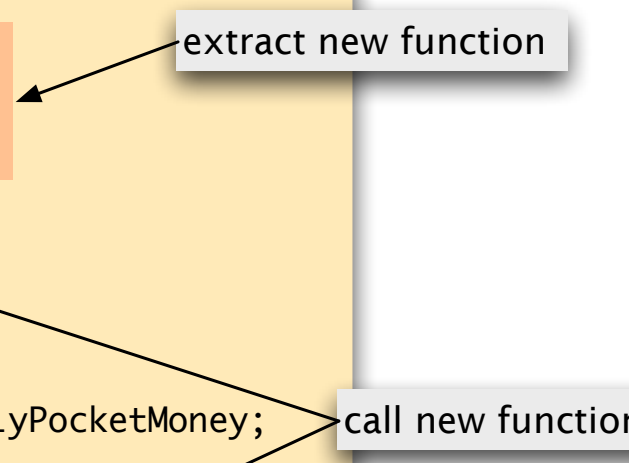
Why Functions

```
public class Duplication1 {

    public static String joinNames(String n1, String n2){
        return n1 + " " + n2;
    }

    public static void main(String[] args) {
        String boyName = joinNames("Jock", "McInnes");
        int boyWeeklyPocketMoney = 2;
        int boySavingsTarget = 10;
        int boyWeeksToTarget =  boySavingsTarget / boyWeeklyPocketMoney;
        System.out.print(boyName + " needs to save for ");
        System.out.println(boyWeeksToTarget + " weeks");

        String girlName = joinNames("Jane", "Andrews");
        int girlWeeklyPocketMoney = 3;
        int girlSavingsTarget = 9;
        int girlWeeksToTarget = girlSavingsTarget / girlWeeklyPocketMoney;
        System.out.print(girlName + " needs to save for ");
        System.out.println(girlWeeksToTarget + " weeks");
    }
}
```



Why Functions

```
public class Duplication2 {

    public static String joinNames(String n1, String n2){
        return n1 + " " + n2;
    }

    public static int weeksToSavePocketMoney(int pocketMoney,
                                             int savingsTarget){
        return savingsTarget / pocketMoney;
    }

    public static void main(String[] args) {
        String boyName = joinNames("Jock", "McInnes");
        int boyWeeksToTarget =  weeksToSavePocketMoney(2, 10);
        System.out.print(boyName + " needs to save for ");
        System.out.println(boyWeeksToTarget + " weeks");

        String girlName = joinNames("Jane", "Andrews");
        int girlWeeksToTarget =  weeksToSavePocketMoney(3, 9);
        System.out.print(girlName + " needs to save for ");
        System.out.println(girlWeeksToTarget + " weeks");
    }
}
```

extract new function

call new function

Why Functions

```
public class Duplication3 {

    public static String joinNames(String n1, String n2){
        return n1 + " " + n2;
    }

    public static int weeksToSavePocketMoney(int pocketMoney,
                                             int savingsTarget){
        return savingsTarget / pocketMoney;
    }

    public static void printWeeksToSave(String name, int target){
        System.out.print(name + " needs to save for ");
        System.out.println(target + " weeks");
    }

    public static void main(String[] args) {
        String boyName = joinNames("Jock", "McInnes");
        printWeeksToSave(boyName, weeksToSavePocketMoney(2, 10));
        String girlName = joinNames("Jane", "Andrews");
        printWeeksToSave(girlName, weeksToSavePocketMoney(3, 9));
    }
}
```

extract new function

call new function

Functions and Modularity

Advantages of breaking a program into functions:

- decomposition of a complex programming task into simpler steps
- reducing duplication of code within a program
- enabling reuse of code across multiple programs
- hiding implementation details from callers of the function, hence
- readability, via well-chosen names.

Whenever you can clearly separate tasks within programs, you should do so.

Aim for methods of no more than 10-15 lines. Shorter is often good.

Modularity via Functions

Easier to change code broken down into functions.

```
public class Duplication4 {

    public static String joinNames(String n1, String n2){
        String title;
        if (n1 == "Jock") title = "Master";
        else title = "Miss";
        return title + " " + n1 + " " + n2;
    }

    public static int weeksToSavePocketMoney(int pocketMoney, int savingsTarget){
        double sweeties = 0.25;
        double reducedPocketMoney = pocketMoney * (1 - sweeties);
        return (int) (savingsTarget / reducedPocketMoney);
    }

    public static void printWeeksToSave(String name, int target){
        System.out.println();
        System.out.println("***********************************************");
        System.out.println(name + " needs to save for " + target + " weeks");
    }

    public static void main(String[] args) {
        String boyName = joinNames("Jock", "McInnes");
        printWeeksToSave(boyName, weeksToSavePocketMoney(2, 10));

        String girlName = joinNames("Jane", "Andrews");
        printWeeksToSave(girlName, weeksToSavePocketMoney(3, 9));
    }
}
```

Modularity via Functions

Output

```
% java Duplication4

**************************************************
Master Jock McInnes needs to save for 6 weeks

**************************************************
Miss Jane Andrews needs to save for 4 weeks
```

Wrapping code up in functions makes it much easier to localize modifications.

Taking a Closer Look

Lets calculate the Euclidian Distance between two points.

Euclidian Distance between two Points

- Given some 'special' point $\mathbf{p}$, how close are various other points to $\mathbf{p}$?
- Useful, for example, if tyring to find the closest point to $\mathbf{p}$.
- Use Euclidean distance — restricted to 2D case, where $\mathbf{p} = (p_0, p_1)$ etc.:

$$dist(\mathbf{p}, \mathbf{q}) = \sqrt{(p_0 - q_0)^2 + (p_1 - q_1)^2}$$

Euclidian Distance between two Points

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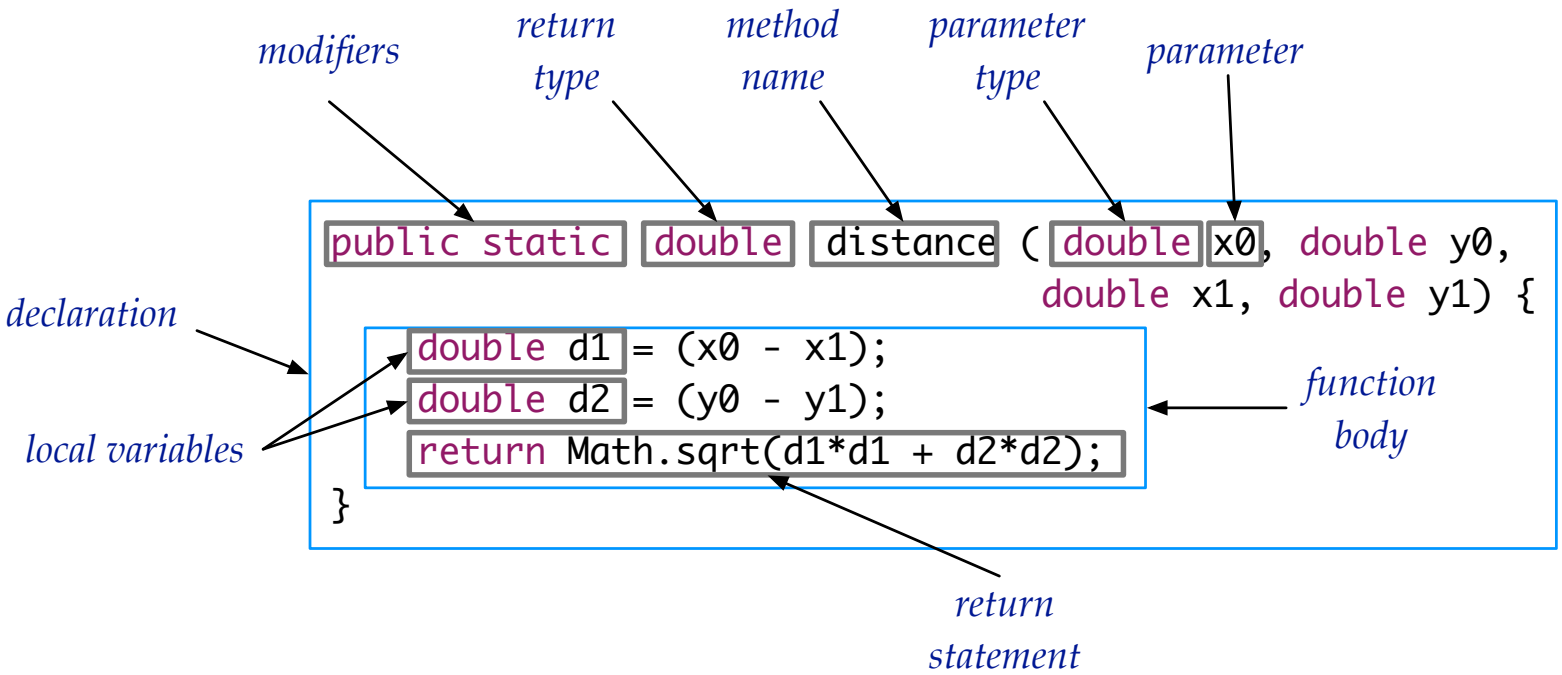
$$dist(\mathbf{p}, \mathbf{q}) = \sqrt{(p_0 - q_0)^2 + (p_1 - q_1)^2}$$

```
public static double distance(double x0, double y0,
                              double x1, double y1) {
    double d1 = x0 - x1;
    double d2 = y0 - y1;
    return Math.sqrt(d1*d1 + d2*d2);
}
```

Anatomy of a Java Function

```
public static  double  distance ( double x0, double y0,
                                  double x1, double y1) {
    double d1 = (x0 - x1);
    double d2 = (y0 - y1);
    return Math.sqrt(d1*d1 + d2*d2);
}
```

Anatomy of a Java Function



Calling a Function

Literal arguments

```
double d = distance(3.0, 5.0, 14.25, 2.70);
```

Variable arguments

```
double p0 = 3.0;
double p1 = 5.0;
double q0 = 14.25;
double q1 = 2.70;

double d = distance(p0, p1, q0, q1);
```

Flow of Control with Functions

Schematic Structure of Program

```
public class PointDistance {

    public static double distance(double x0, double y0,
                                  double x1, double y1) {
        ...
    }

    public static void main(String[] args) {
        ...

        double dist = distance(p0, p1, q0, q1);

        ...

    }
}
```

Flow of Control with Functions

Functions provide a new way to control the flow of execution.

What happens when a function is called:

- Control transfers to the code in body of the function.
- Parameter variables are assigned the values given in the call.
- Function code is executed.
- Return value is assigned in place of the function call in the calling code.
- Control transfers back to the calling code.

Pass by Value

- Pass by Value: parameter variables are assigned the values given by arguments to the call.
- The function only has access to the values of its arguments, not the arguments themselves.
- Consequently, changing the value of an argument in the body of the code has no effect on the calling code.

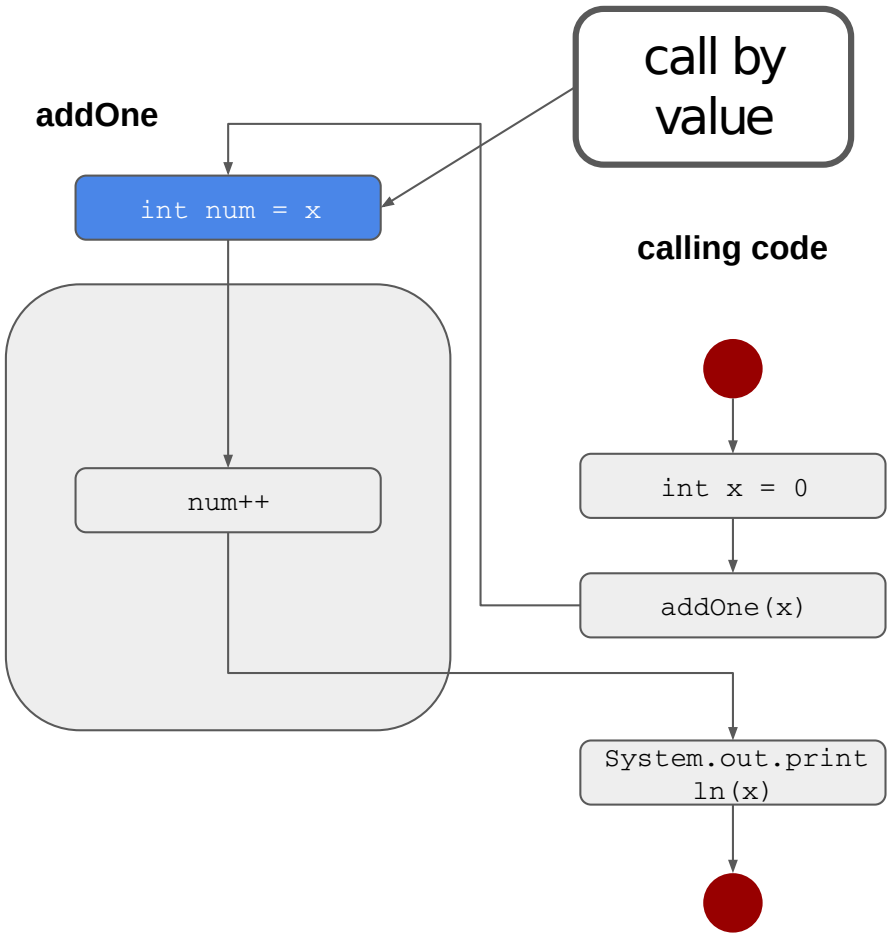
Pass by Value

```
public class AddOne {
    public static void addOne(int num) {
         num++;
     }
    public static void main(String[] args) {
         int x = 0;
         addOne(x);
         System.out.println(x);
     }
}
```

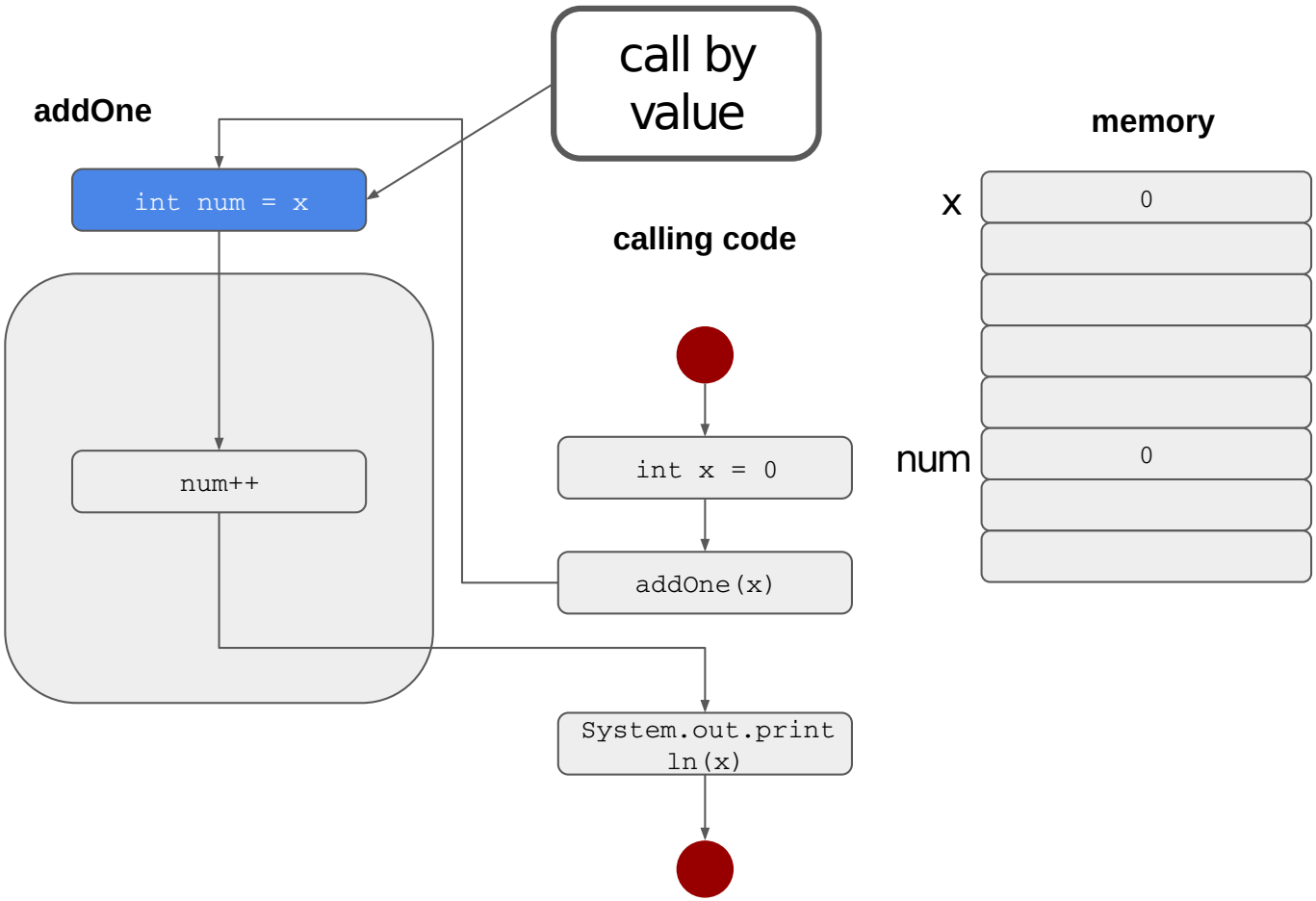
Output

```
% java AddOne
0
```

Pass by Value



Pass by Value



Pass by Value: Arrays

Array types are reference types, so things work a bit differently with arrays as arguments:

- the array itself (and its length) cannot be changed;
- but its elements can be changed.
- So changing the value of the element of an array is a side-effect of the function.

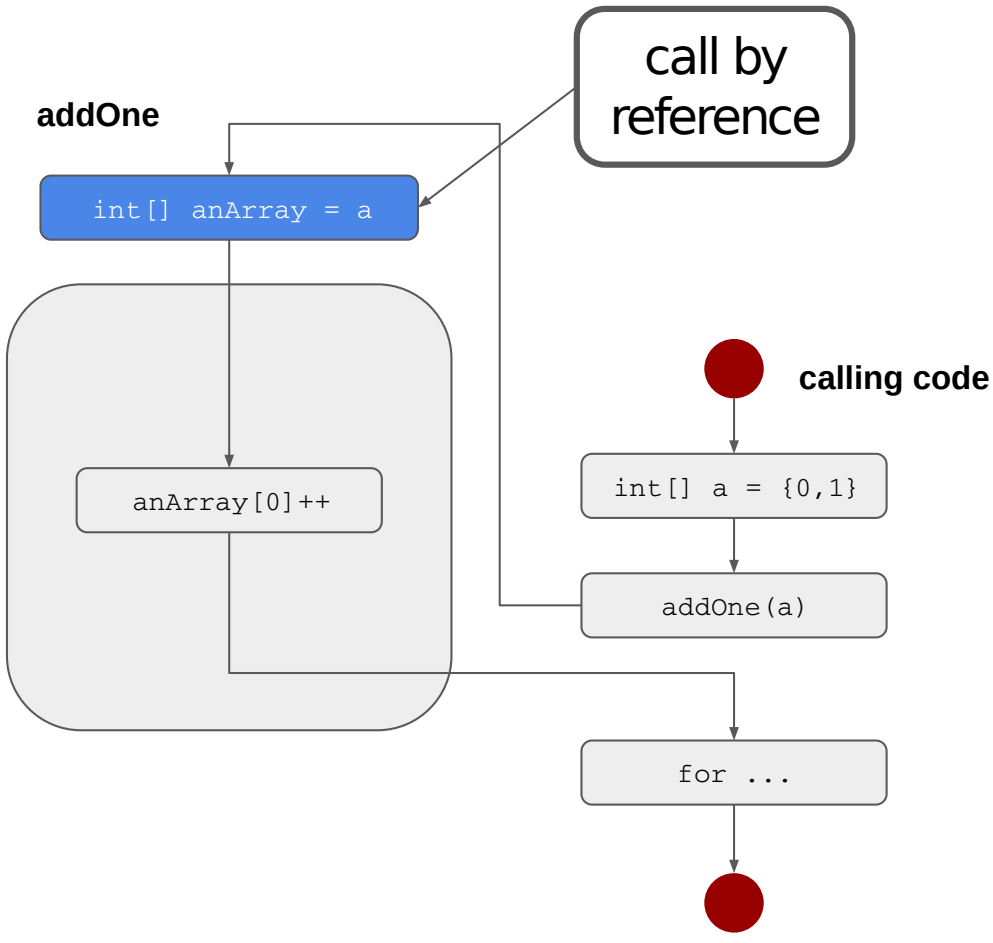
Pass by Value: Arrays

```
public class AddOne {
  public static void addOne(int[] anArray) {
       anArray[0]++;
   }
  public static void main(String[] args) {
       int[] a = { 0, 1 };
       addOne(a);
       for (int i = 0; i < a.length; i++) {
           System.out.println(a[i]);
       }
  }
}
```

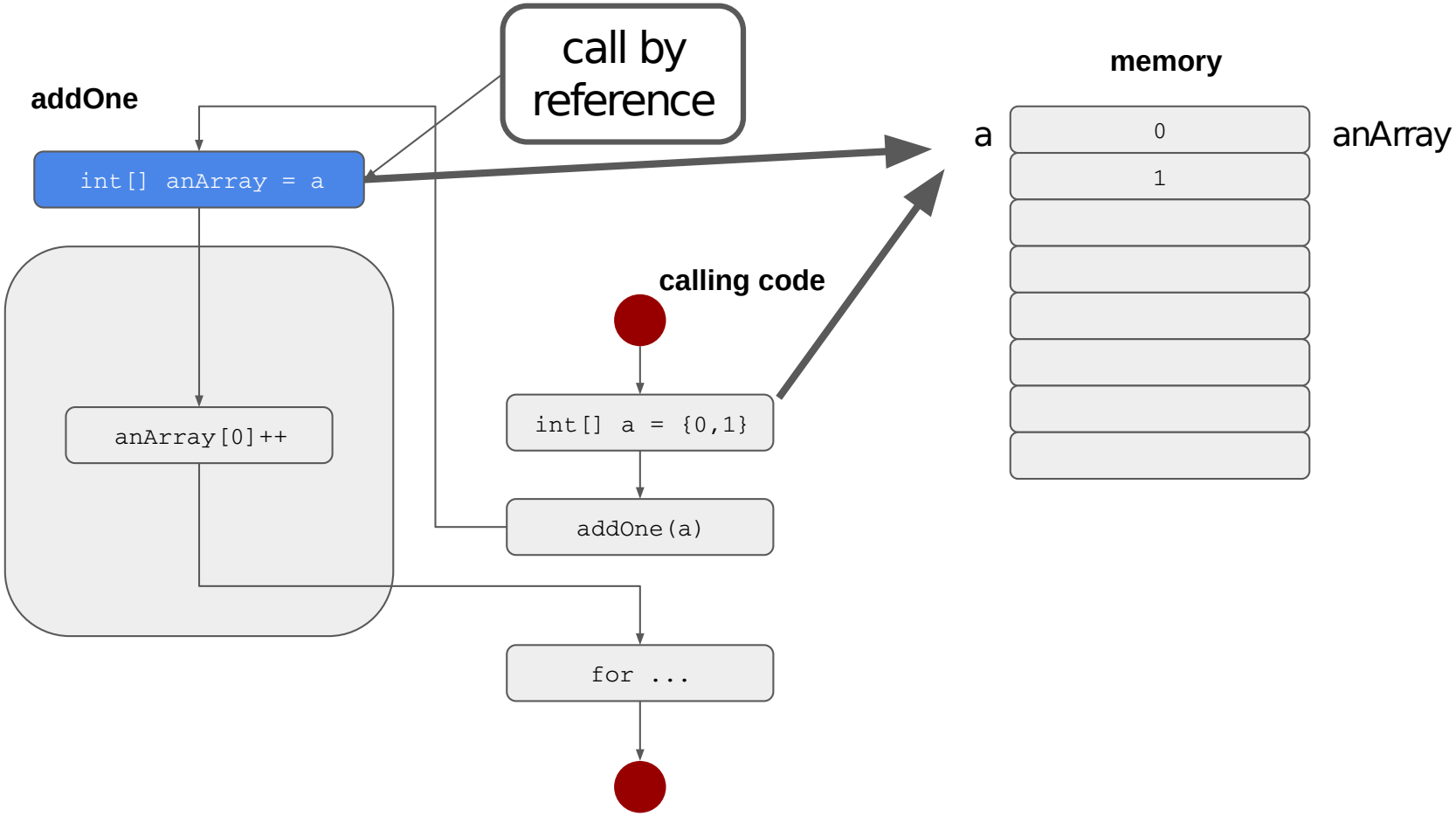
Output

```
% java AddOne
1
1
```

Pass by Reference



Pass by Reference



Signature

The signature of a Java function consists of its name and its parameter list (number and type of parameters, in order).

Example signature

```
max(int x, int y)
```

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The signature of a Java function consists of its name and its parameter list (number and type of parameters, in order).

Example signature

```
max(int x, int y)
```

However, it's often convenient to use the term more loosely to refer to the head of the function definition:

Example head of definition

```
public static int max(int x, int y)
```

Return

- Return type of a function is stated in the header of the function declaration.
- A function declared void doesn't return a value.
- Any function with a non-void return type *rtype* must contain a statement of the form

  ```
  return returnValue;
  ```

  where the data type of `returnValue` matches the type *rtype*.

Cubes, 1

Cubes, version 1

```
public class Cubes1 {
   public static int cube(int i) {
        int j = i * i * i;
        return j;
    }
   public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        for (int i = 0; i <= n; i++) {
            System.out.println(i + " " + cube(i));
       }
    }
}
```

Cubes, 1

Cubes, version 1

```
public class Cubes1 {
   public static int cube(int i) {
        int j = i * i * i;
        return j;
    }
   public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        for (int i = 0; i <= n; i++) {
            System.out.println(i + " " + cube(i))
       }
    }
}
```

Output

```
% java Cubes1 6
0 0
1 1
2 8
3 27
4 64
5 125
6 216
```

Cubes, 2

Cubes, version 2

```
public class Cubes2 {
   public static int cube(int i) {
        int i = i * i * i;
        return i;
    }
   public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        for (int i = 0; i <= n; i++) {
            System.out.println(i + " " + cube(i));
       }
    }
}
```

Cubes, 2

Cubes, version 2

```
public class Cubes2 {
   public static int cube(int i) {
        int i = i * i * i;
        return i;
    }
   public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        for (int i = 0; i <= n; i++) {
            System.out.println(i + " " + cube(i));
       }
    }
}
```

Compile-time error

Duplicate local variable i

Cubes, 3

Cubes, version 3

```
public class Cubes3 {
   public static int cube(int i) {
        int j = i * i * i;
   }
   public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        for (int i = 0; i <= n; i++) {
            System.out.println(i + " " + cube(i));
       }
    }
}
```

Cubes, 3

Cubes, version 3

```
public class Cubes3 {
   public static int cube(int i) {
        int j = i * i * i;
   }
   public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        for (int i = 0; i <= n; i++) {
            System.out.println(i + " " + cube(i));
       }
    }
}
```

Compile-time error

```
This method must return a result of type int
```

Cubes, 4

Cubes, version 4

```
public class Cubes4 {
   public static int cube(int i) {
        i = i * i * i;
        return i;
    }
   public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        for (int i = 0; i <= n; i++) {
            System.out.println(i + " " + cube(i));
       }
    }
}
```

Cubes, 4

Cubes, version 4

```
public class Cubes4 {
   public static int cube(int i) {
        i = i * i * i;
        return i;
    }
   public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        for (int i = 0; i <= n; i++) {
            System.out.println(i + " " + cube(i));
       }
    }
}
```

Don't do that!

Cubes, 5

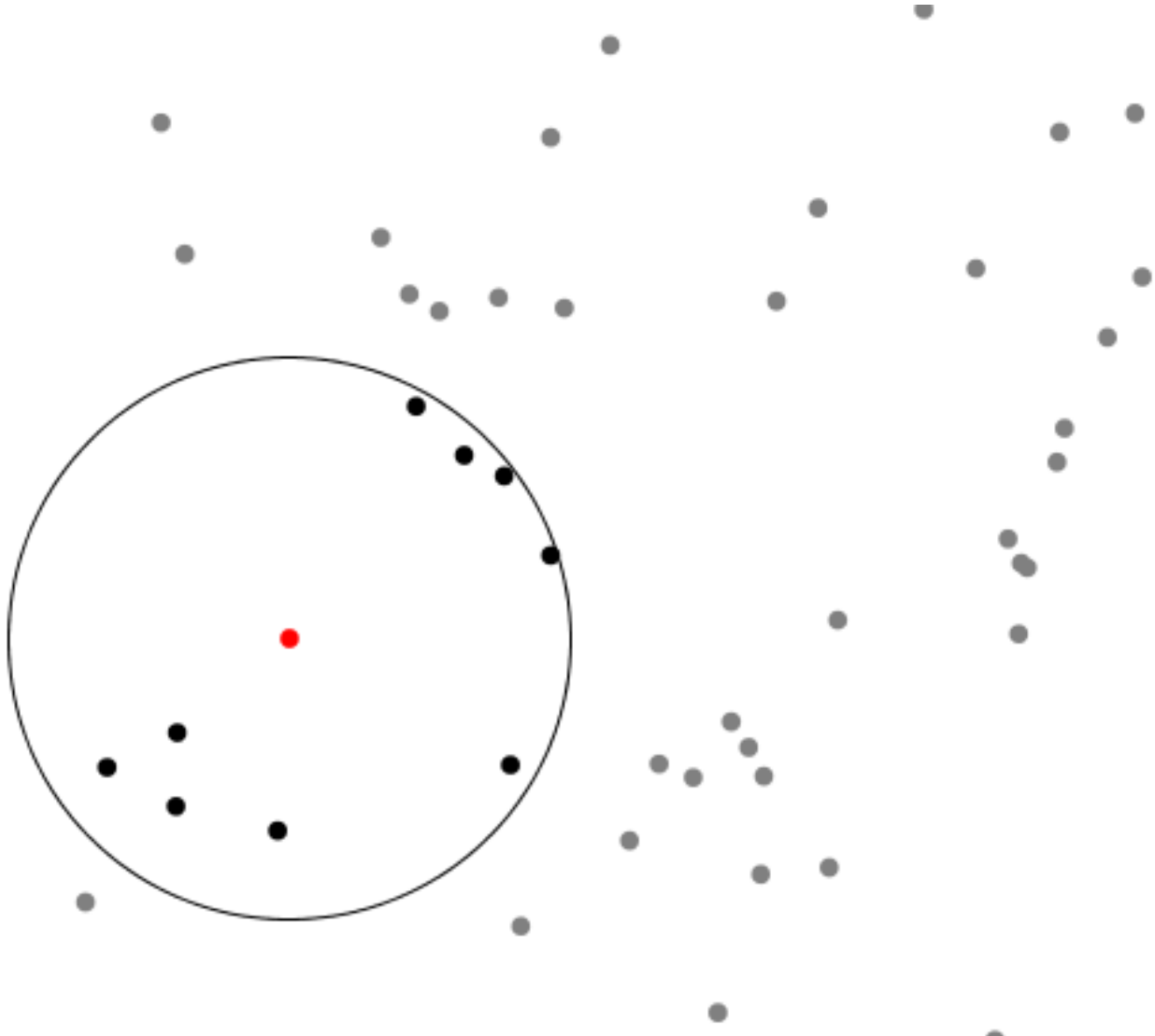
Cubes, version 5

```
public class Cubes5 {
   public static int cube(int i) {
       return i * i * i;
    }
   public static void main(String[] args) {
        int n = Integer.parseInt(args[0]);
        for (int i = 0; i <= n; i++) {
            System.out.println(i + " " + cube(i));
       }
    }
}
```

Breaking Down Code as a Development Strategy

Lets find the nearest neighbour to a central point.

Find Nearest Neighbour to a Central Point



Sequence of x-y point coordinates as arguments to program

Solution

```
class NearestNeighbourBad {
    public static void main(String[] args) {
        int N = args.length;
        if (N % 2 != 0) N--; // ignore final arg if odd number
        double[] points = new double[N];

        for(int i = 0; i < N; i++)
            points[i] = Double.parseDouble(args[i]);

        double[] centre = { points[0], points[1] }; // first point is our centre
        System.out.printf("Centre lies at (%5.2f, %5.2f)\n", centre[0], centre[1]);

        double[] neighbours = new double[points.length - 2];
        for(int i = 2; i < points.length; i++) // all except the first are neighbours
            neighbours[i - 2] = points[i];

        double[] dists = new double[neighbours.length / 2];
        for(int i = 0; i < neighbours.length; i += 2) { // step over two at a time to get x and y
            double d1 = centre[0] - neighbours[i];
            double d2 = centre[1] - neighbours[i + 1];
            dists[i / 2] = Math.sqrt(d1*d1 + d2*d2);
        }

        for(int i = 0; i < dists.length; i++)
            System.out.printf("Distance to (%5.2f, %5.2f) is %5.2f\n",
                    neighbours[(i*2)], neighbours[(i*2) + 1], dists[i]);

        double min = dists[0];
        for(int i = 1; i < dists.length; i++)
            if (dists[i] < min) min = dists[i];

        System.out.printf("Minimum distance to centre is %5.2f\n", min);
    }
}
```

Easy, Right?

Easy, Right?

Don't worry. Breaking this down into functions will make this much easier!

What do we need to do?

What do we need to do?

- parse arguments

What do we need to do?

- parse arguments
- get centre

What do we need to do?

- parse arguments
- get centre
- print centre

What do we need to do?

- parse arguments
- get centre
- print centre
- get neighbours

What do we need to do?

- parse arguments
- get centre
- print centre
- get neighbours
- calculate distances

What do we need to do?

- parse arguments
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- print centre
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- parse arguments
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- print centre
- get neighbours
- calculate distances
- print distances
- calculate minimum

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- calculate minimum
- print minimum

What do we need to do?

- parse arguments
- get centre
- print centre
- get neighbours
- calculate distances
- print distances
- calculate minimum
- print minimum

Lets think about what we need for those steps.

The flow of the data

What do we need to do?

- points $\leftarrow$ parse arguments $\leftarrow$ arguments
- get centre
- print centre
- get neighbours
- calculate distances
- print distances
- calculate minimum
- print minimum

Lets think about what we need for those steps.

The flow of the data

What do we need to do?

- points $\leftarrow$ parse arguments $\leftarrow$ arguments
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- print centre
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- calculate distances
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- calculate minimum
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Lets think about what we need for those steps.

The flow of the data

What do we need to do?

- points $\leftarrow$ parse arguments $\leftarrow$ arguments
- centre $\leftarrow$ get centre $\leftarrow$ points
- print centre
- get neighbours
- calculate distances
- print distances
- calculate minimum
- print minimum

Lets think about what we need for those steps.

The flow of the data

What do we need to do?

- points $\leftarrow$ parse arguments $\leftarrow$ arguments
- centre $\leftarrow$ get centre $\leftarrow$ points
- print centre $\leftarrow$ centre
- get neighbours
- calculate distances
- print distances
- calculate minimum
- print minimum

Lets think about what we need for those steps.

The flow of the data

What do we need to do?

- points $\leftarrow$ parse arguments $\leftarrow$ arguments
- centre $\leftarrow$ get centre $\leftarrow$ points
- print centre $\leftarrow$ centre
- neighbours $\leftarrow$ get neighbours $\leftarrow$ points
- calculate distances
- print distances
- calculate minimum
- print minimum

Lets think about what we need for those steps.

The flow of the data

What do we need to do?

- points ← parse arguments ← arguments
- centre ← get centre ← points
- print centre ← centre
- neighbours ← get neighbours ← points
- distances ← calculate distances ← centre, neighbours
- print distances
- calculate minimum
- print minimum

Lets think about what we need for those steps.

The flow of the data

What do we need to do?

- points ← parse arguments ← arguments
- centre ← get centre ← points
- print centre ← centre
- neighbours ← get neighbours ← points
- distances ← calculate distances ← centre, neighbours
- print distances ← distances
- calculate minimum
- print minimum

Lets think about what we need for those steps.

The flow of the data

What do we need to do?

- points ← parse arguments ← arguments
- centre ← get centre ← points
- print centre ← centre
- neighbours ← get neighbours ← points
- distances ← calculate distances ← centre, neighbours
- print distances ← distances
- minimum ← calculate minimum ← distances
- print minimum

Lets think about what we need for those steps.

The flow of the data

What do we need to do?

- points ← parse arguments ← arguments
- centre ← get centre ← points
- print centre ← centre
- neighbours ← get neighbours ← points
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- print distances ← distances
- minimum ← calculate minimum ← distances
- print minimum ← minimum

Lets think about what we need for those steps.

The flow of the data

What do we need to do?

- points ← parse arguments ← arguments
- centre ← get centre ← points
- print centre ← centre
- neighbours ← get neighbours ← points
- distances ← calculate distances ← centre, neighbours
- print distances ← distances
- minimum ← calculate minimum ← distances
- print minimum ← minimum

Lets think about what we need for those steps.

The flow of the data

That is it!

Main Function for Nearest Neighbour

```
public static void main(String[] args) {
    double[] points = parseArguments(args);
    double[] centre = getCentre(points);
    printCentre(centre);
    double[] neighbours = getNeighbours(points);
    double[] distances = calcDistances(centre, neighbours);
    printDistances(distances, neighbours);
    double minimum = calcMinimum(distances);
    printMinimum(minimum);
}
```

Main Function for Nearest Neighbour

```
public static void main(String[] args) {
    double[] points = parseArguments(args);
    double[] centre = getCentre(points);
    printCentre(centre);
    double[] neighbours = getNeighbours(points);
    double[] distances = calcDistances(centre, neighbours);
    printDistances(distances, neighbours);
    double minimum = calcMinimum(distances);
    printMinimum(minimum);
}
```

This is simply what we just developed plus some types and brackets.

All that is left to do is write some simple functions.

Function Signatures / Headers

```
class NearestNeighbour {
 public static double[] parseArguments(String[] args) {...}
 public static double[] getCentre(double[] points) {...}
 public static void printCentre(double[] centre) {...}
 public static double[] getNeighbours(double[] points) {...}
 public static double distance(double x0, double y0,
                               double x1, double y1) {...}
 public static double[] calcDistances(double[] centre,
                                      double[] neighbours) {...}
 public static void printDistances(double[] dists,
                                   double[] neighbours) {...}
 public static double calcMinimum(double[] dists) {...}
 public static void printMinimum(double min) {...}

 public static void main(String[] args) {
     double[] points = parseArguments(args);
     double[] centre = getCentre(points);
     printCentre(centre);
     double[] neighbours = getNeighbours(points);
     double[] distances = calcDistances(centre, neighbours);
     printDistances(distances, neighbours);
     double minimum = calcMinimum(distances);
     printMinimum(minimum);
 }
}
```

Arguments

```
public static double[] parseArguments(String[] args) {
    int N = args.length;
    if (N % 2 != 0) N--; // ignore final arg if odd number
    double[] p = new double[N];

    for(int i = 0; i < N; i++)
        p[i] = Double.parseDouble(args[i]);

    return p;
}

public static void main(String[] args) {
    double[] points = parseArguments(args);
    ...
}
```

Centre

```
public static double[] getCentre(double[] points) {
    // first point is our centre
    double[] c = { points[0], points[1] };
    return c;
}

public static void printCentre(double[] centre) {
    System.out.printf("Centre lies at (%5.2f, %5.2f)\n",
            centre[0], centre[1]);
}

public static void main(String[] args) {
    ...
    double[] centre = getCentre(points);
    printCentre(centre);
    ...
}
```

Neighbours

```
public static double[] getNeighbours(double[] points) {
    double[] n = new double[points.length - 2];
    // all except the first are neighbours
    for(int i = 2; i < points.length; i++)
        n[i - 2] = points[i];
    return n;
}

public static void main(String[] args) {
    ...
    double[] neighbours = getNeighbours(points);
    ...
}
```

Distance Calculation

```
public static double distance(double x0, double y0,
                              double x1, double y1) {
    double d1 = x0 - x1;
    double d2 = y0 - y1;
    return Math.sqrt(d1*d1 + d2*d2);
}


public static double[] calcDistances(double[] centre, double[] neighbours) {
    double[] dists = new double[neighbours.length / 2];
    // step over two at a time to get x and y
    for(int i = 0; i < neighbours.length; i += 2)
        dists[i / 2] = distance(centre[0], centre[1],
                                neighbours[i], neighbours[i + 1]);
    return dists;
}

public static void main(String[] args) {
    ...
    double[] distances = calcDistances(centre, neighbours);
    ...
}
```

Distance Print

```
public static void printDistances(double[] dists, double[] neighbours) {
    for(int i = 0; i < dists.length; i++)
        System.out.printf("Distance to (%5.2f, %5.2f) is %5.2f\n",
                neighbours[(i*2)], neighbours[(i*2) + 1], dists[i]);
}

public static void main(String[] args) {
    ...
    printDistances(distances, neighbours);
    ...
}
```

Minimum

```
public static double calcMinimum(double[] dists) {
    double min = dists[0];
    for(int i = 1; i < dists.length; i++)
        if (dists[i] < min) min = dists[i];
    return min;
}

public static void printMinimum(double min) {
    System.out.printf("Minimum distance to " +
            "centre is %5.2f\n", min);
}

public static void main(String[] args) {
    ...
    double minimum = calcMinimum(distances);
    printMinimum(minimum);
}
```

Functions and Modularity

Advantages of breaking a program into functions:

- decomposition of a complex programming task into simpler steps
- reducing duplication of code within a program
- enabling reuse of code across multiple programs
- hiding implementation details from callers of the function, hence
- readability, via well-chosen names.

Whenever you can clearly separate tasks within programs, you should do so.

Aim for methods of no more than 10-15 lines. Shorter is often good.

Summary: Using Functions / Static Methods

Java functions:

- Take zero or more input arguments.
- Return at most one output value.
- Can have side effects; e.g., send output to the terminal.

Summary: Using Functions / Static Methods

Structuring your code with methods has the following benefits:

- encourages good coding practices by emphasizing discrete, reusable methods;
- encourages self-documenting code through good organization;
- when descriptive names are used, high-level methods can read more like a narrative, reducing the need for comments;
- reduces code duplication.

Summary: Using Functions / Static Methods

- What about recursive functions?
  - Basic concepts same as in Haskell.
  - One exercise (factorial) in week fourth's labsheets.
- Refactoring improves the structure of code without changing the functionality of the application.

Reading

The order of topics in the Java Tutorial is different from the order of these slides, so at this point there isn't an ideal match: the following reading anticipates some things we'll cover later.

Java Tutorial

(Re)read pp33-37; then read pp87-99.

i.e., read the first part of Chapter 2 *Object-Oriented Programming Concepts* carefully now, but stop at *Inheritance*; and read the first part of Chapter 4 *Classes and Objects*, stopping at *Objects*.