Advanced Object Oriented Programming

EECS2030Z

Academic Support Programs: Bethune

- having trouble with your FSC and LSE courses?
  - consider using the Academic Support Programs at Bethune College
  - PASS
    - free, informal, structured, facilitated study groups: http://bethune.yorku.ca/pass/
  - peer tutoring
    - free, one-on-one, drop-in tutoring: http://bethune.yorku.ca/tutoring/

Academic Support Programs: Bethune

- your PASS leader is Glib Sitiugin

Who Am I?

- Dr. Burton Ma
- office
  - Lassonde 2046
  - hours : to be updated on the syllabus page
- email
  - **`burton@cse.yorku.ca`**

Course Format

- everything you need to know is on Moodle
  - `http://learn.lassonde.yorku.ca/`

Labs

- in Prism computing labs (LAS1006 and LAS1004)
- Lab Zero starts in Week 1
  - self-guided, can be done anytime before the start of Week 2
  - using the Prism lab environment
  - using eclipse
- Labs 1-9 consist of a different set of programming problems for each lab
  - each of these labs counts towards 2% of your final grade
- *it is expected that you know how to use the lab computing environment*

Labs

- group lab work is allowed and strongly encouraged for Labs 1-9 (not Lab 0)
  - groups of up to size 3
  - see *Academic Honesty* section of syllabus
    - TLDR Do not submit work that is not wholly your own

Labs

- tips for effective group work
  - alternate who is doing the typing (the *driver*) every few minutes
    - don’t allow the stronger programmer to do everything
    - if you are the stronger programmer then try explaining your thought processes to your group partners
  - if you aren’t typing then you are a *navigator*
    - you should be:
      - □ watching what the driver is doing to catch mistakes
      - □ planning what the group should do next
      - □ developing test cases to test the code that is being written

Labs

- LAS1004 does not have desktop computers
- if you want to attend the regularly scheduled lab and you want to work on your own laptop then you should use LAS1004
- if LAS1006 is full and you don't have a laptop you can borrow a laptop computer from the lab monitor in LAS1006 (requires a student card)

Tests

- all testing occurs during your regularly scheduled lab using the EECS labtest environment

Test	Weight
Test 1	2%
Test 2	25%
Test 3	25%
Exam	30%

- miss a test for an acceptable reason?
  - see *Evaluation: Missed tests* section of syllabus

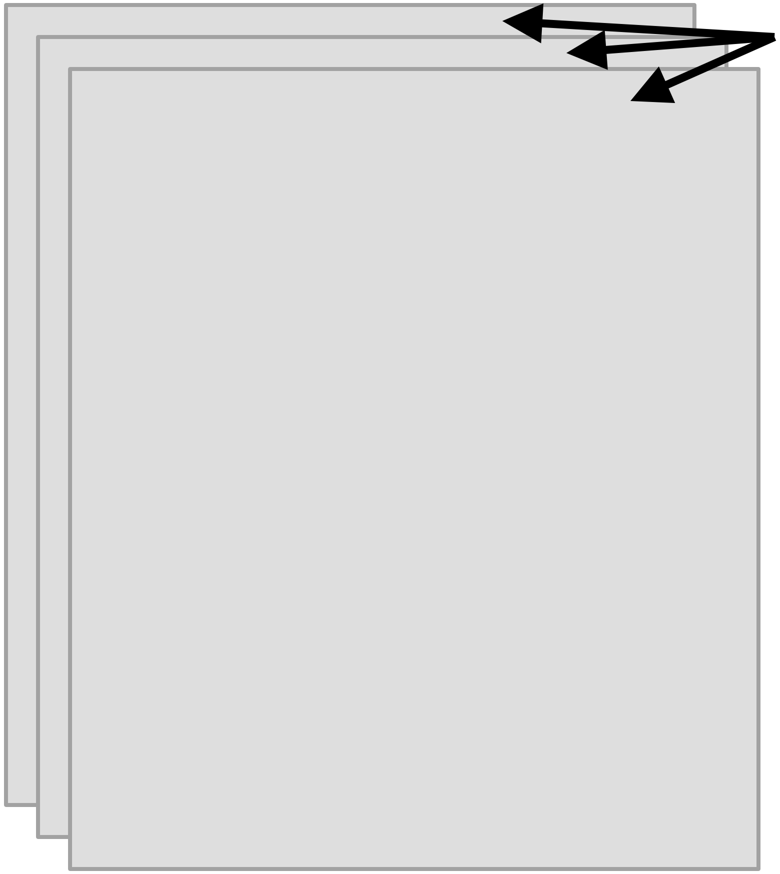
Textbook

- a set of freely available electronic notes is available from the Moodle site
- if you want a textbook the recommended text is *Absolute Java*, 5th Edition or newer by Savitch
- if you want a very concise reference to the language consider *Java 8 Pocket Guide* by Liguori and Liguori

Organization of a Java Program

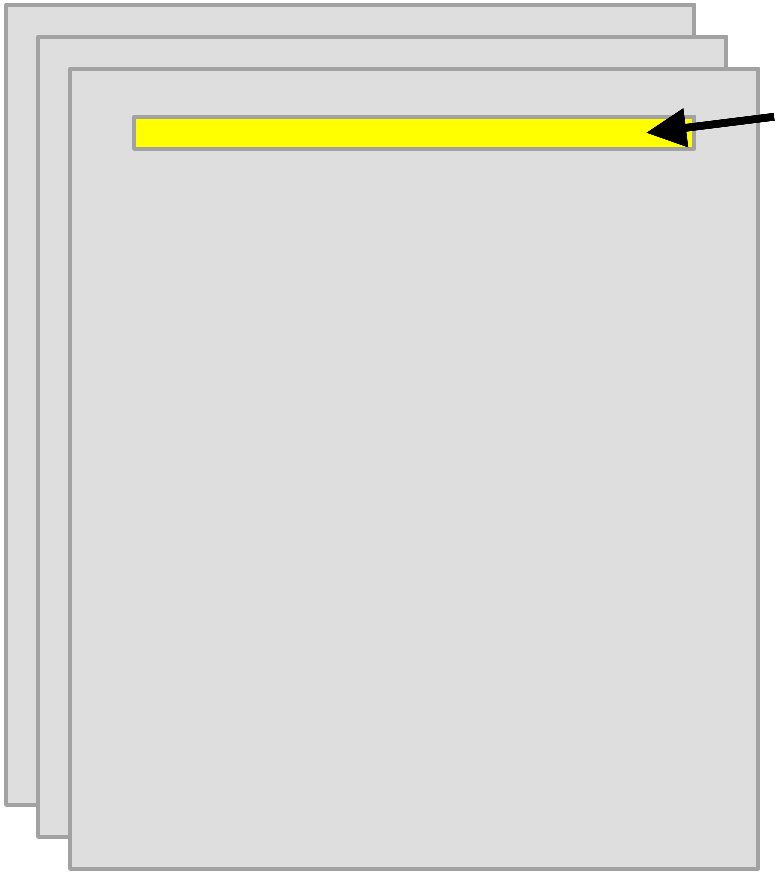
Packages, classes, fields, and methods

Organization of a Typical Java Program



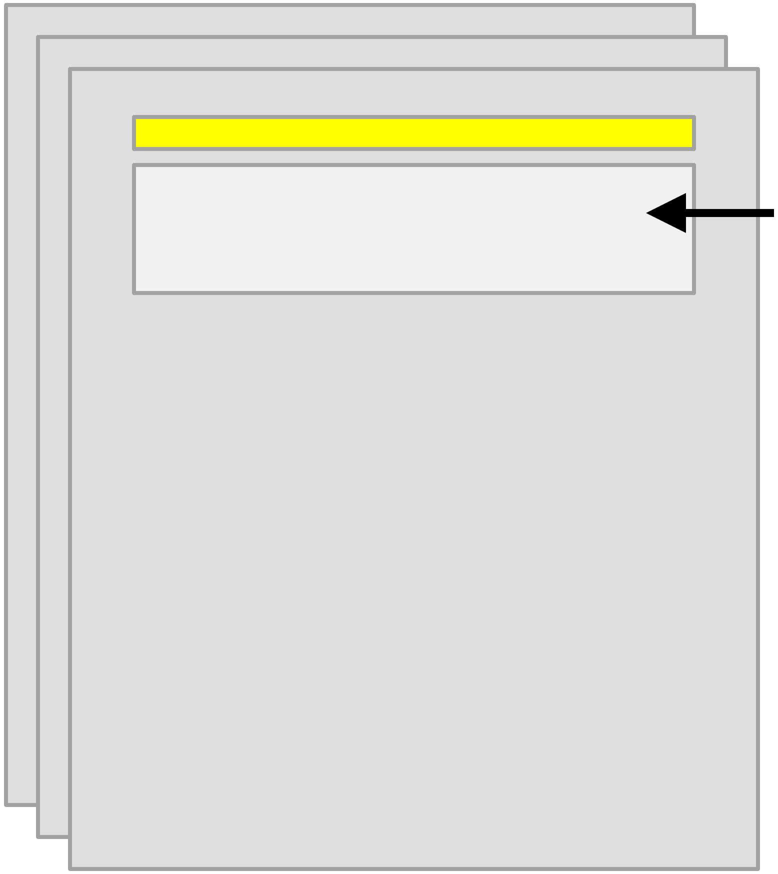
- one or more files

Organization of a Typical Java Program



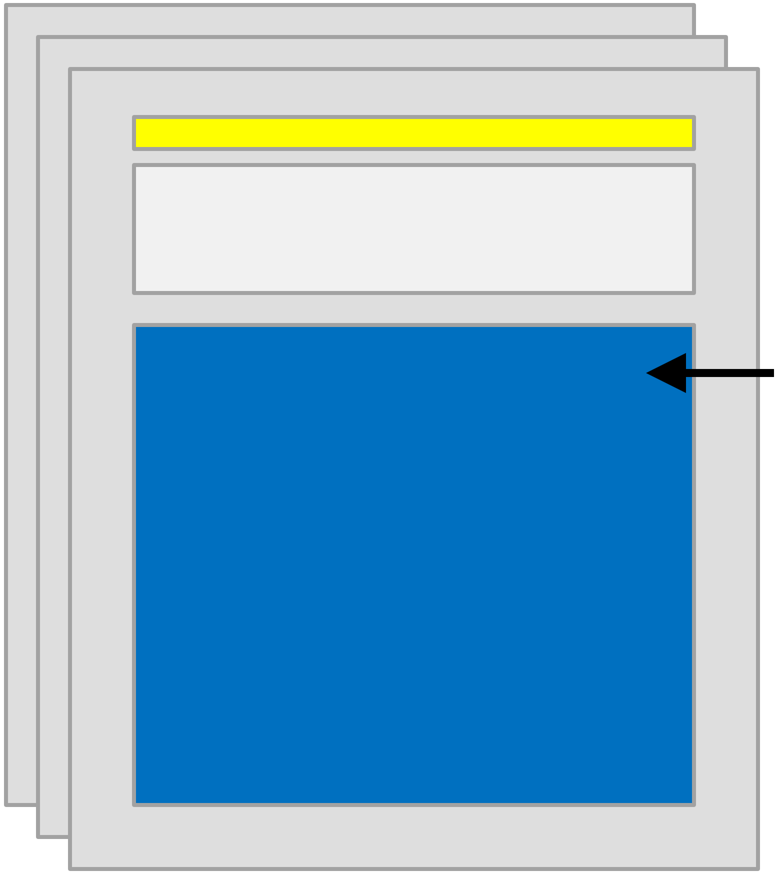
- one or more files
- zero or one package name

Organization of a Typical Java Program



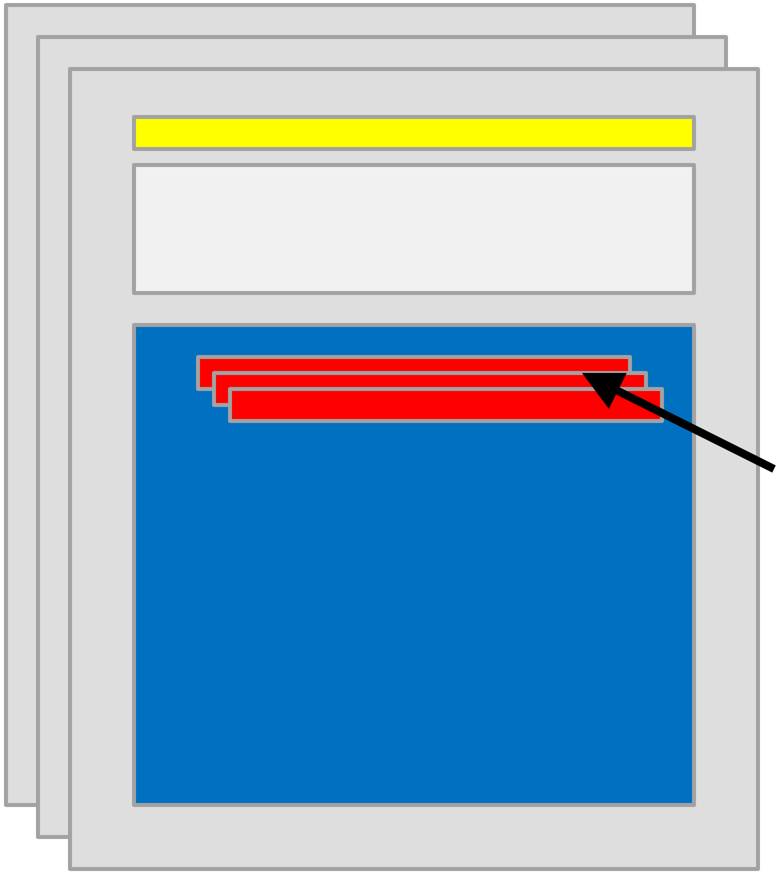
- one or more files
- zero or one package name
- zero or more import statements

Organization of a Typical Java Program



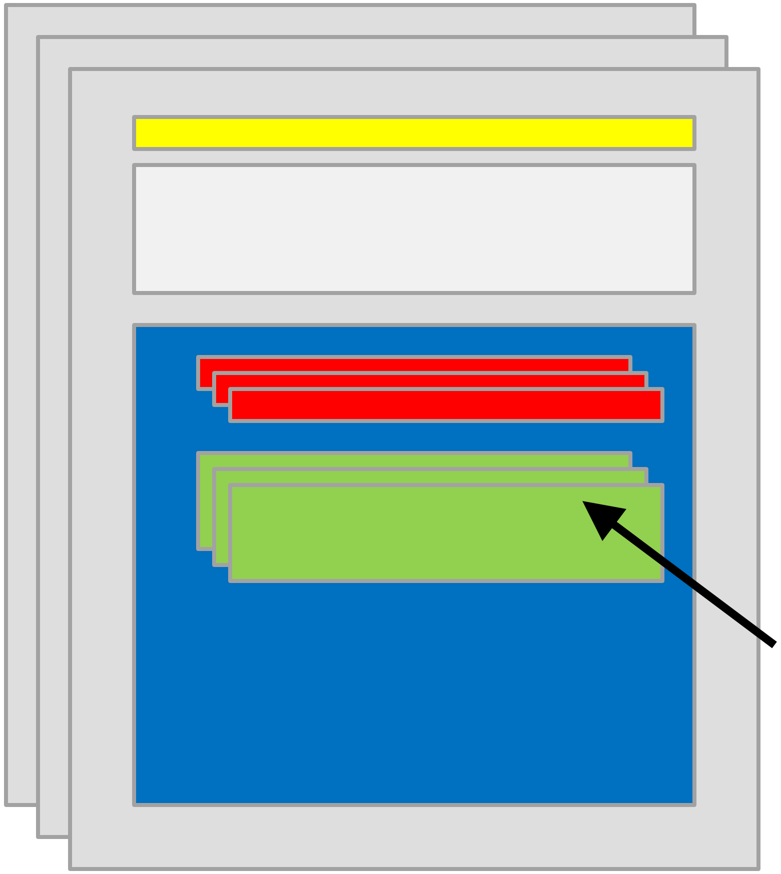
- one or more files
- zero or one package name
- zero or more import statements
- one class

Organization of a Typical Java Program



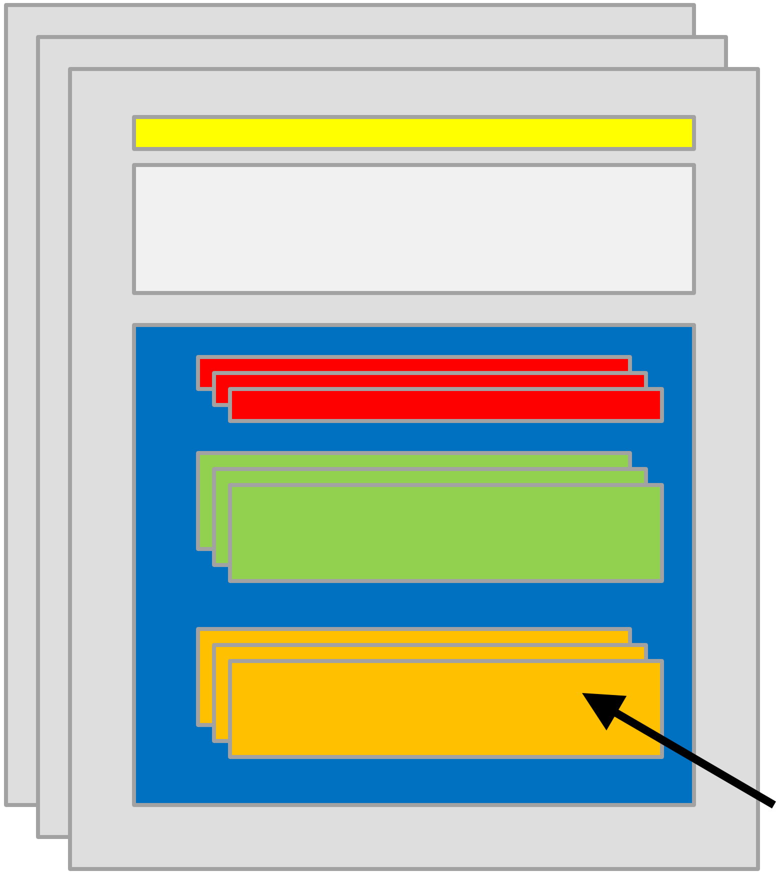
- one or more files
- zero or one package name
- zero or more import statements
- one class
- one or more fields (class variables)

Organization of a Typical Java Program



- one or more files
- zero or one package name
- zero or more import statements
- one class
- zero or more fields (class variables)
- zero or more more constructors

Organization of a Typical Java Program



- one or more files
- zero or one package name
- zero or more import statements
- one class
- zero or more fields (class variables)
- zero or more more constructors
- zero or more methods

Worksheet

- Question 1

Organization of a Typical Java Program

- it's actually more complicated than this
  - static initialization blocks
  - non-static initialization blocks
  - classes inside of classes (inside of classes …)
  - classes inside of methods
  - anonymous classes
  - lambda expressions (in Java 8)

- see http://docs.oracle.com/javase/tutorial/java/javaOO/index.html

Methods

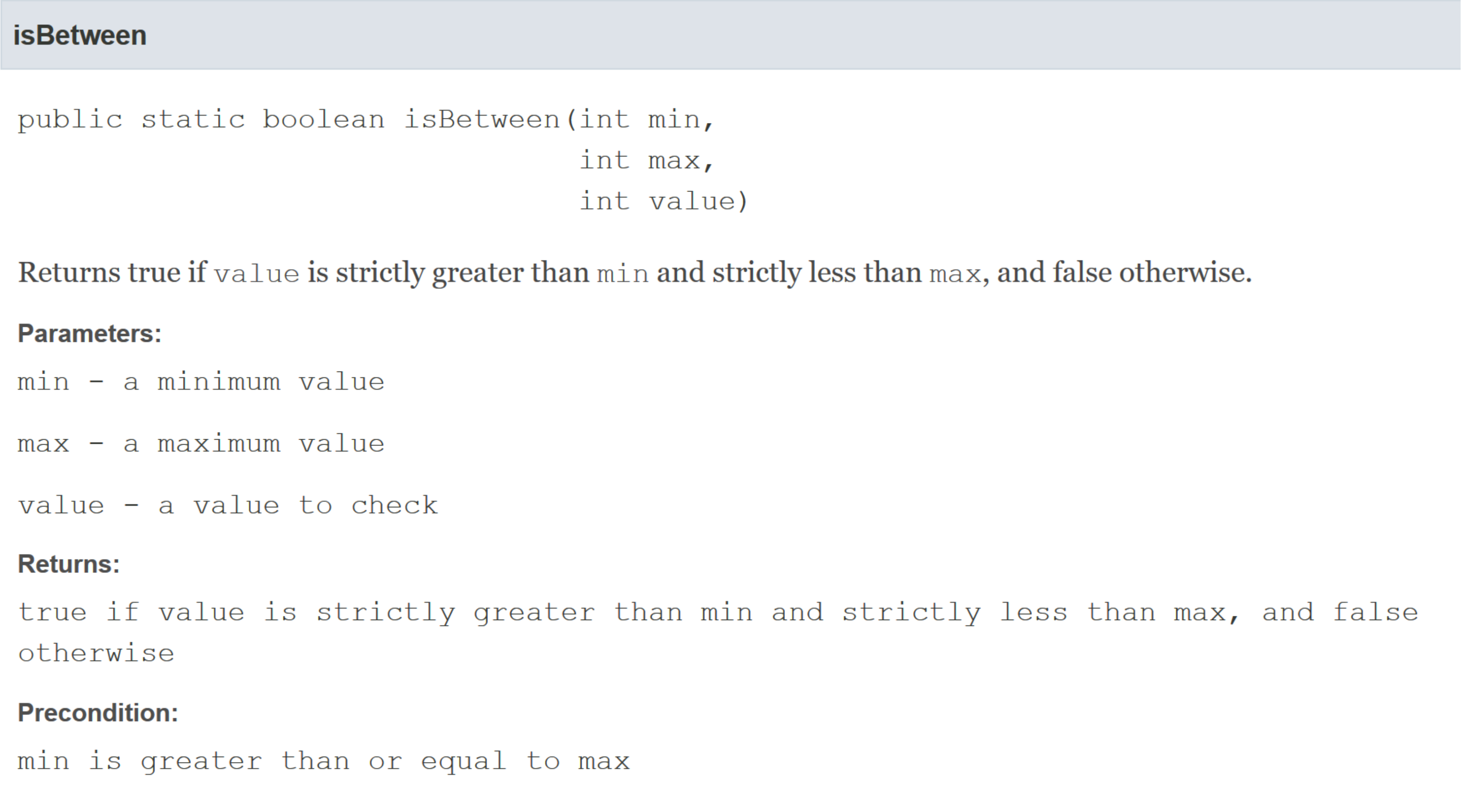
Basics

Methods

- a method performs some sort of computation
- a method is reusable
  - anyone who has access to the method can use the method *without copying the contents of the method*
  - anyone who has access to the method can use the method *without knowing the contents of the method*

- methods are described by their API (application program interface)

Example API method entry



isBetween

```
public static boolean isBetween(int min,
                                int max,
                                int value)
```

Returns true if `value` is strictly greater than `min` and strictly less than `max`, and false otherwise.

Parameters:

`min - a minimum value`

`max - a maximum value`

`value - a value to check`

Returns:

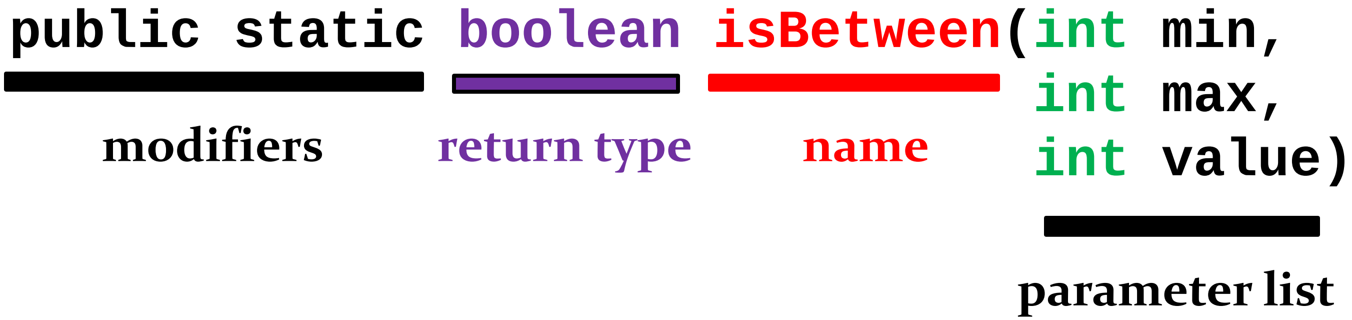
`true if value is strictly greater than min and strictly less than max, and false otherwise`

Precondition:

`min is greater than or equal to max`

Method header

- the first line of a method declaration is sometimes called the *method header*



```
public static boolean isBetween(int min,
                                int max,
                                int value)
```

modifiers

return type

name

parameter list

Method parameter list

- the parameter list is the list of types and names that appear inside of the parentheses

-
  ```
  public static boolean
      isBetween(int min, int max, int value)
  ```

  parameter list

- the names in the parameter list must be unique
  - i.e., duplicate parameter names are not allowed

Method signature

- every method has a *signature*
  - the signature consists of the method name and the types in the parameter list

```
public static boolean isBetween(int min,
                                int max,
                                int value)
```

has the following signature

$$\underbrace{\overbrace{\texttt{isBetween}}^{\text{name}}\texttt{(}\overbrace{\texttt{int, int, int}}^{\text{number and types of parameters}}\texttt{)}}_{\text{signature}}$$

Method signature

- other examples from java.lang.String
  - headers
    - **`String toUpperCase()`**
    - **`char charAt(int index)`**
    - **`int indexOf(String str, int fromIndex)`**
    - **`void getChars(int srcBegin, int srcEnd, char[] dst, int dstBegin)`**
  - signatures
    - **`toUpperCase()`**
    - **`charAt(int)`**
    - **`indexOf(String, int)`**
    - **`getChars(int, int, char[], int)`**

Method signature

- method signatures in a class must be unique
- we can introduce a second method in the same class:

```
public static boolean
  isBetween(double min, double max, double value)
```

- but not this one:

```
public static boolean
  isBetween(int value, int lo, int hi)
```

Method return types

- all Java methods return nothing (**`void`**) or a single type of value
- our method

```
public static boolean
  isBetween(double min, double max, double value)
```

has the return type **`boolean`**

Worksheet

- Question 2

Methods

Preconditions and postconditions

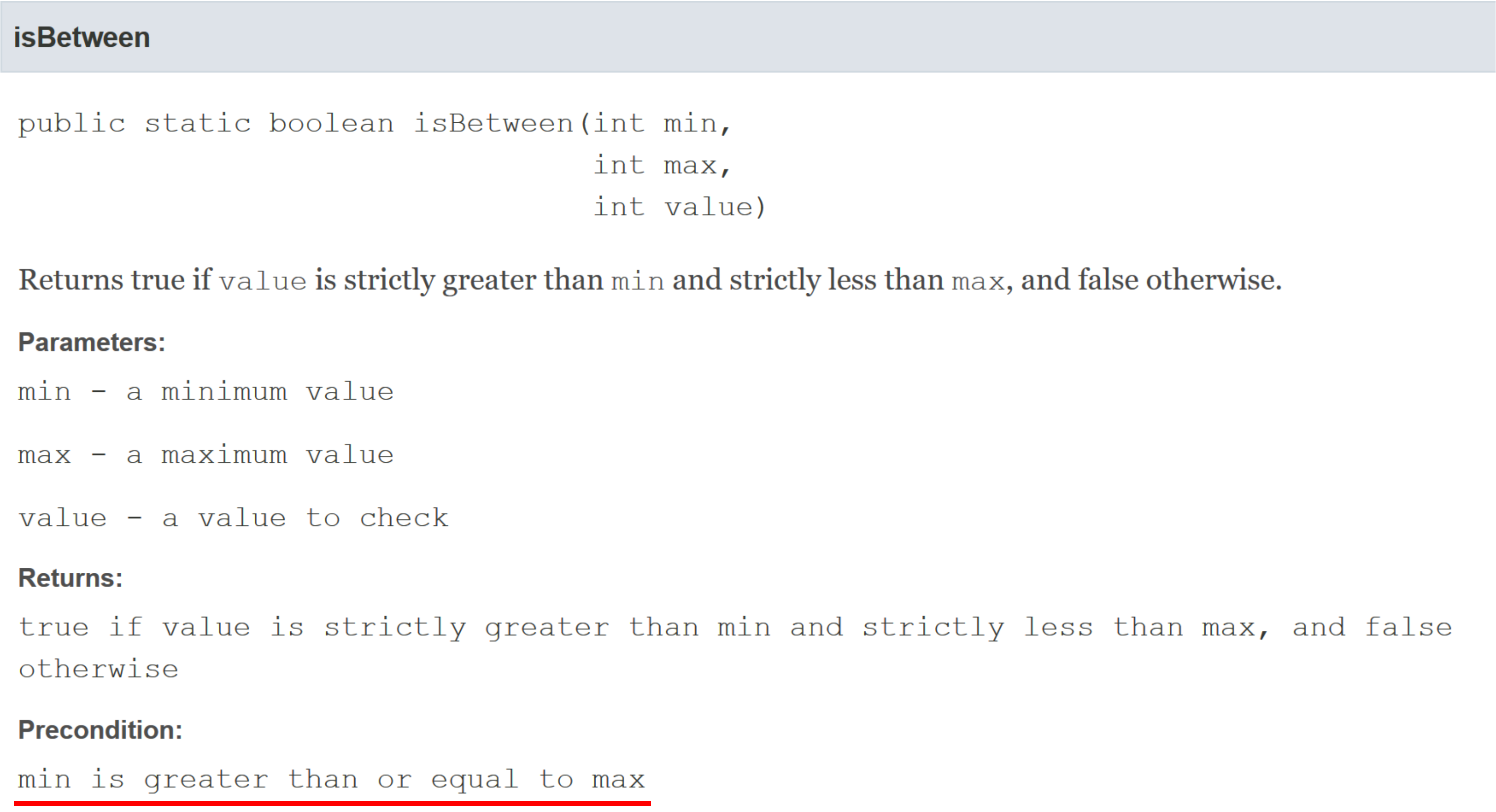
Preconditions and postconditions

- recall the meaning of method pre- and postconditions
- precondition
  - a condition that the *client* must ensure is true immediately before a method is invoked
- postcondition
  - a condition that the *method* must ensure is true immediately after the method is invoked

Preconditions

- recall that a method precondition is a condition that the *client* must ensure is true immediately before invoking a method
  - if the precondition is not true, then the client has no guarantees of what the method will do

- for static methods, preconditions are conditions on the values of the arguments passed to the method
  - you need to carefully read the API to discover the preconditions



isBetween

```
public static boolean isBetween(int min,
                                int max,
                                int value)
```

Returns true if `value` is strictly greater than `min` and strictly less than `max`, and false otherwise.

Parameters:

`min - a minimum value`

`max - a maximum value`

`value - a value to check`

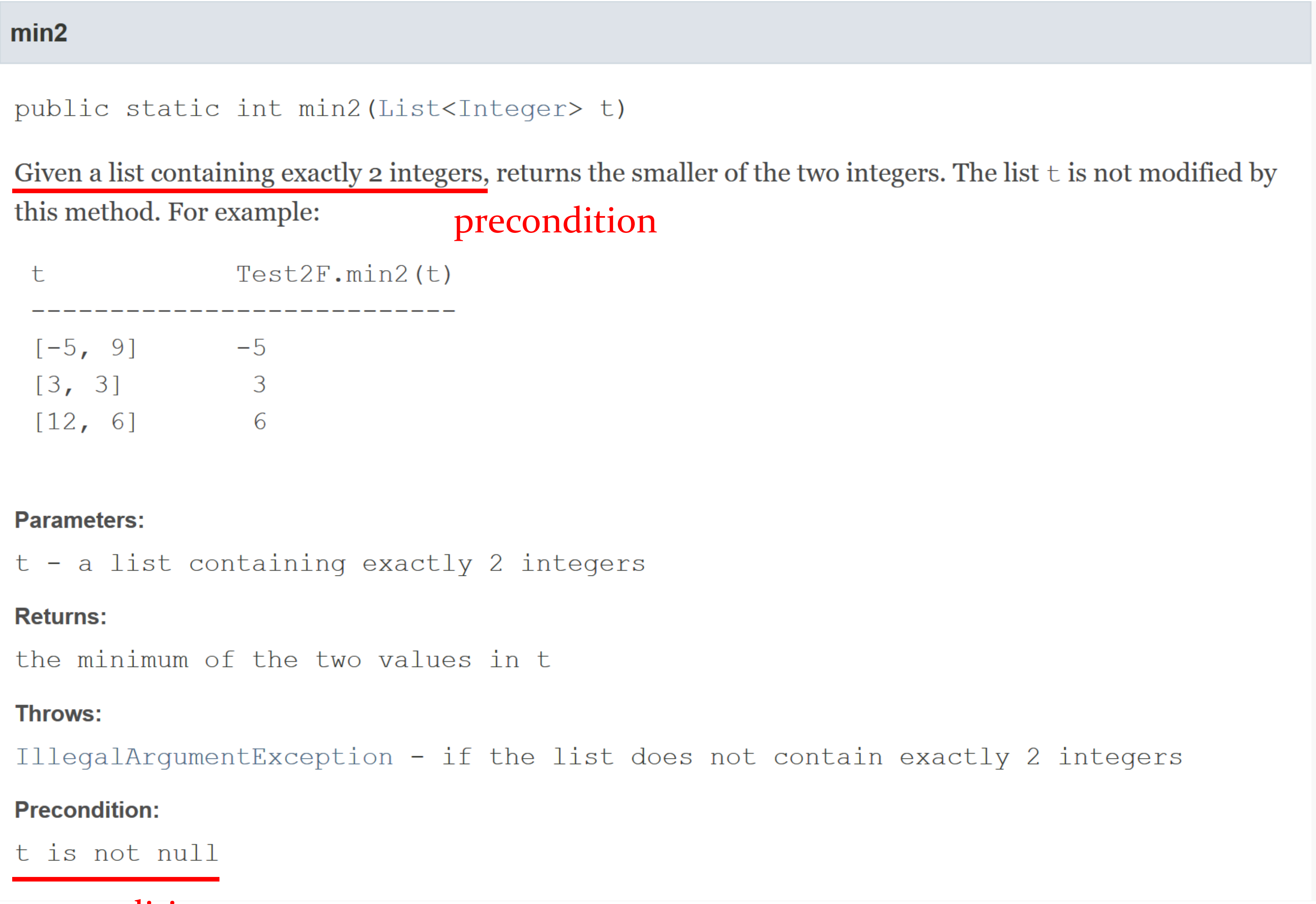
Returns:

`true if value is strictly greater than min and strictly less than max, and false otherwise`

Precondition:

`min is greater than or equal to max`

precondition



min2

```
public static int min2(List<Integer> t)
```

Given a list containing exactly 2 integers, returns the smaller of the two integers. The list t is not modified by this method. For example:

precondition

```
t            Test2F.min2(t)
---------------------------
[-5, 9]      -5
[3, 3]        3
[12, 6]       6
```

Parameters:

t - a list containing exactly 2 integers

Returns:

the minimum of the two values in t

Throws:

IllegalArgumentException - if the list does not contain exactly 2 integers

Precondition:

t is not null

precondition

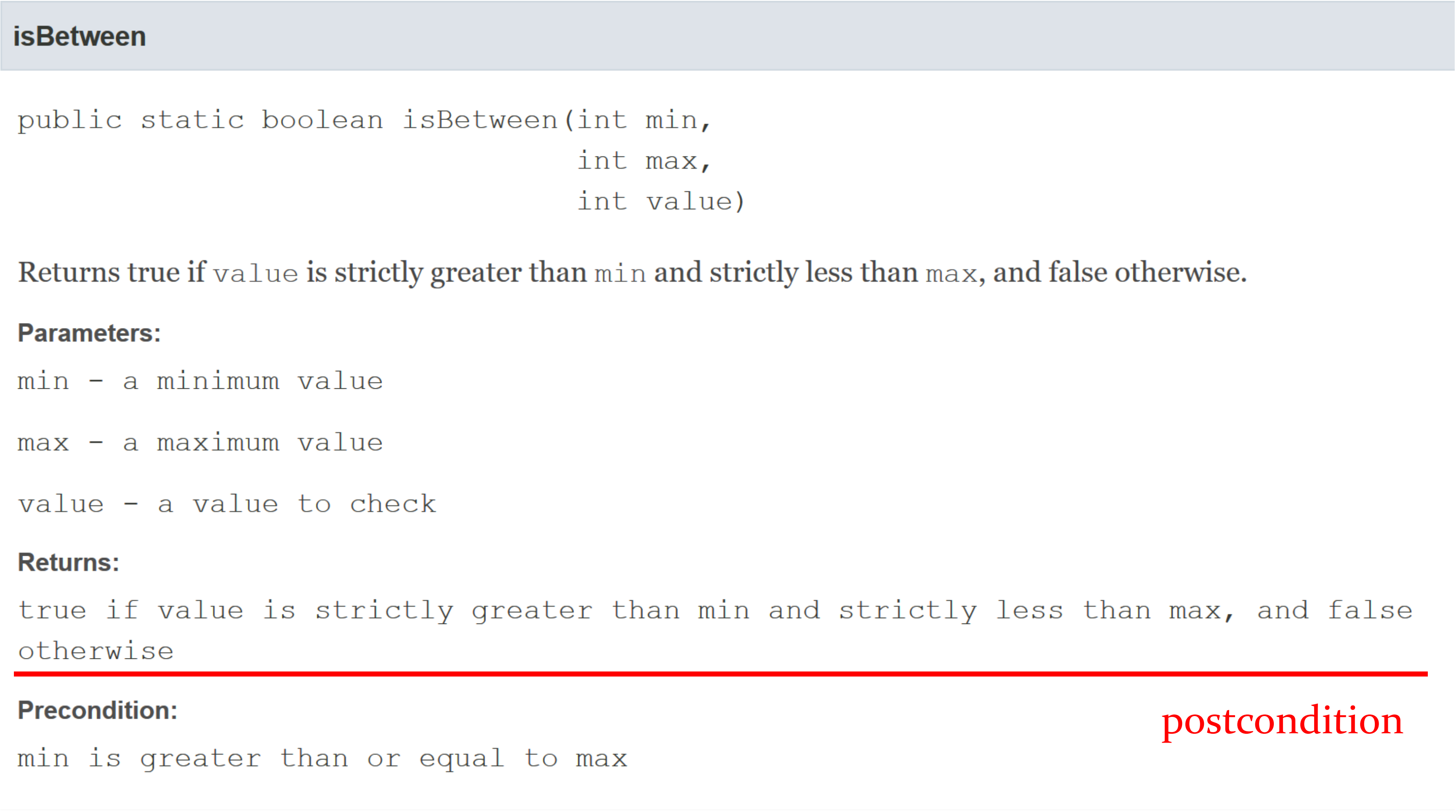
Preconditions

- if a method has a parameter that has reference type then it is almost always assumed that a precondition for that parameter is that it is not equal to **`null`**
- reminders:
  - reference type means “not primitive type”
  - **`null`** means “refers to no object”
    - primitive types are never equal to **`null`**

Postconditions

- recall that a method postcondition is a condition that the *method* must ensure is true immediately after the method is invoked
  - if the postcondition is not true, then there is something wrong with the implementation of the method

- for static methods, postconditions are:
  - conditions on the arguments after the method finishes
  - conditions on the return value



isBetween

```
public static boolean isBetween(int min,
                                int max,
                                int value)
```

Returns true if `value` is strictly greater than `min` and strictly less than `max`, and false otherwise.

Parameters:

`min - a minimum value`

`max - a maximum value`

`value - a value to check`

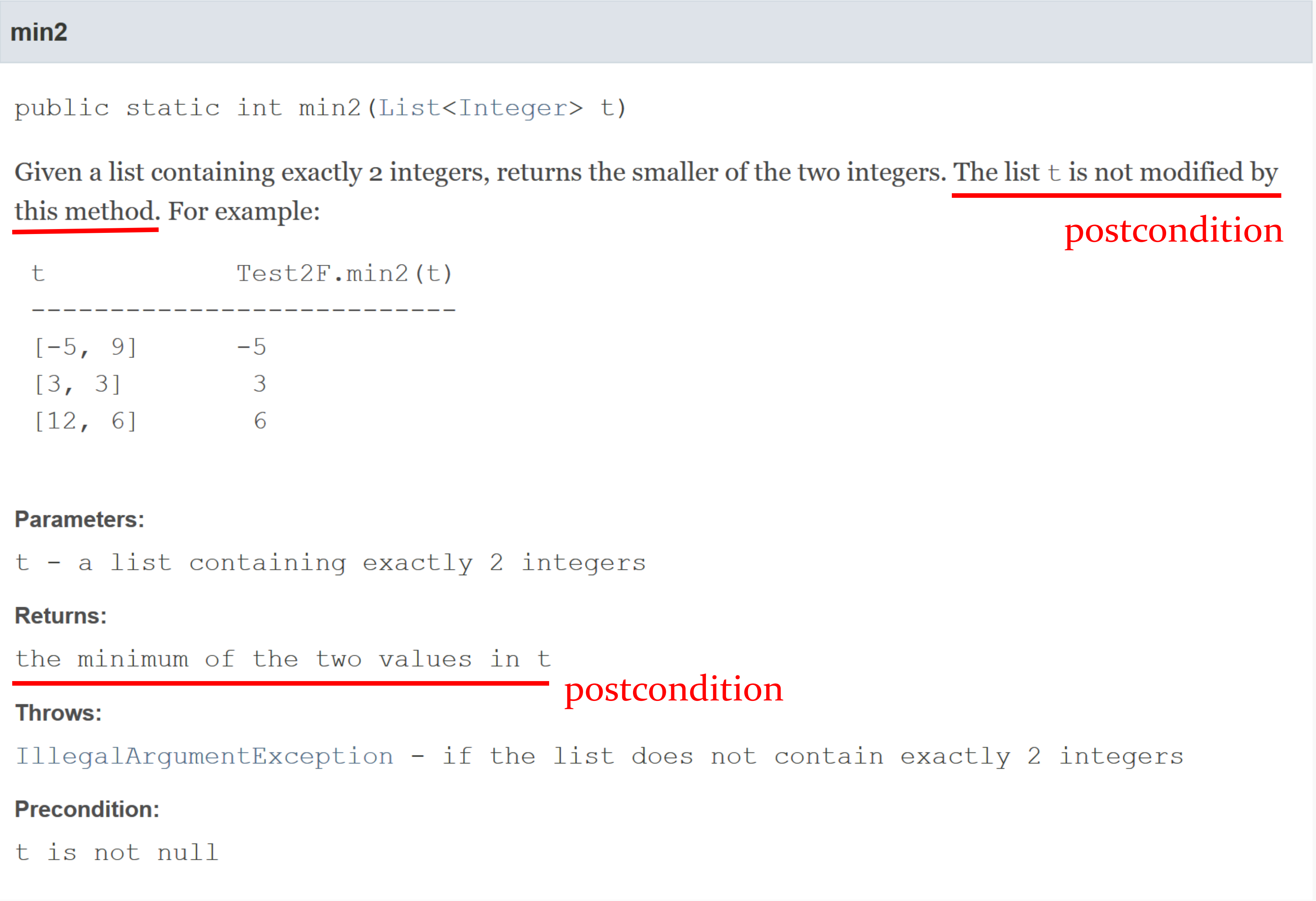
Returns:

`true if value is strictly greater than min and strictly less than max, and false otherwise`

postcondition

Precondition:

`min is greater than or equal to max`



min2

```
public static int min2(List<Integer> t)
```

Given a list containing exactly 2 integers, returns the smaller of the two integers. The list `t` is not modified by this method. For example:

postcondition

```
 t            Test2F.min2(t)
 ---------------------------
 [-5, 9]      -5
 [3, 3]        3
 [12, 6]       6
```

Parameters:

`t - a list containing exactly 2 integers`

Returns:

`the minimum of the two values in t`

postcondition

Throws:

`IllegalArgumentException - if the list does not contain exactly 2 integers`

Precondition:

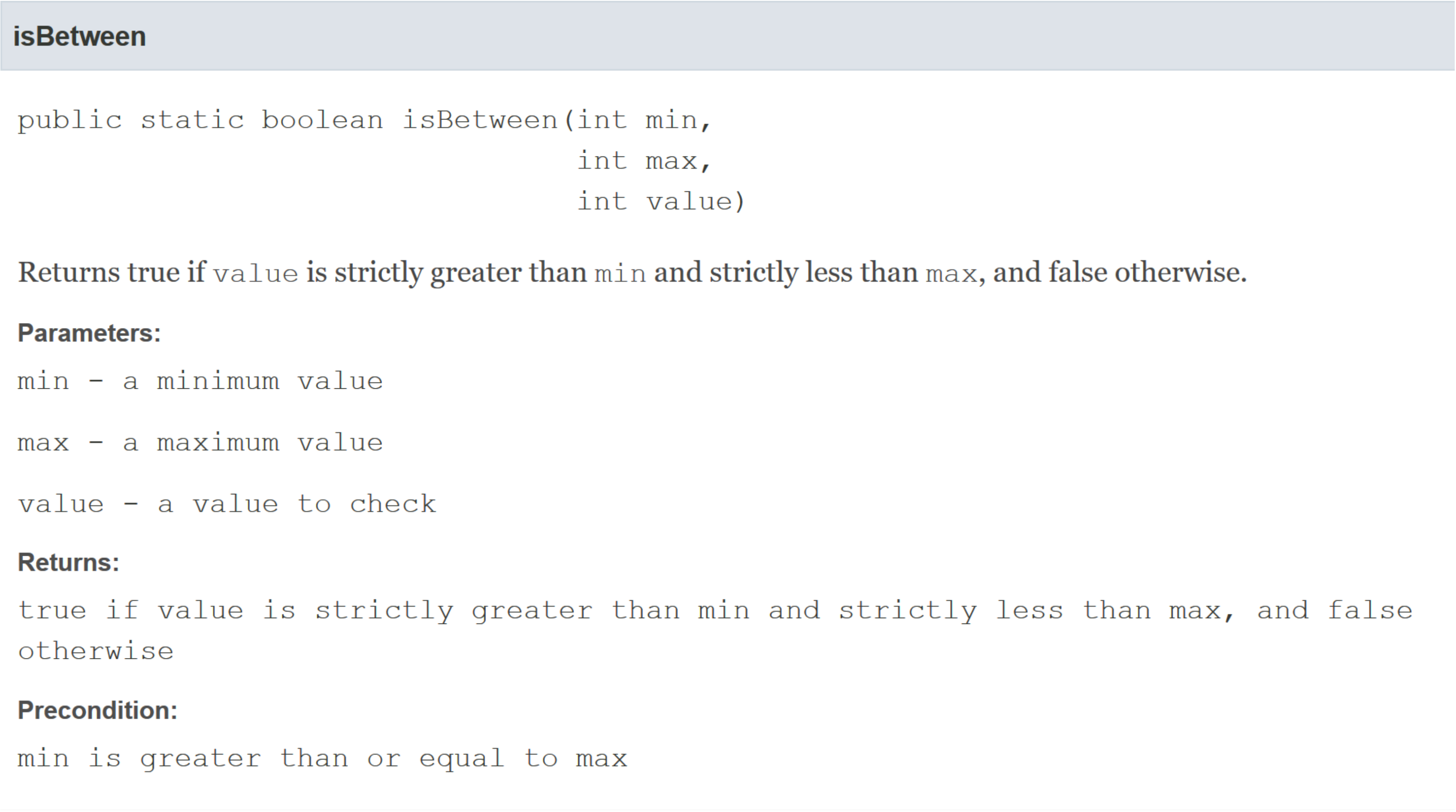
`t is not null`

Worksheet

- Question 3

Methods

Implementation



isBetween

```
public static boolean isBetween(int min,
                                int max,
                                int value)
```

Returns true if `value` is strictly greater than `min` and strictly less than `max`, and false otherwise.

Parameters:

`min - a minimum value`

`max - a maximum value`

`value - a value to check`

Returns:

`true if value is strictly greater than min and strictly less than max, and false otherwise`

Precondition:

`min is greater than or equal to max`

Methods and classes

- in Java every method must be defined inside of a class
- we will try to implement our method so that it matches its API:
  - the method is inside the class named **`Test2F`**
  - the class Test2F is inside the package **`eecs2030.test2`**

- eclipse demonstration here

```java
package eecs2030.test2;

public class Test2F {

}
```

Method body

- a method implementation consists of:
  - the method header
  - a method body
    - the body is a sequence of Java statements inside of a pair of braces **`{ }`**

```java
package eecs2030.test2;

public class Test2F {

    public static boolean isBetween(int min, int max, int value) {

    }

}
```

Methods with parameters

- if a method has parameters, then you can use the parameter names as variables inside your method
  - you cannot create new variables inside the method that have the same name as a parameter
  - you cannot use the parameters outside of the method
    - we say that the *scope* of the parameters is the method body

- you may create additional variables inside your method if you wish
  - we will create a variable to store the return value of the method

```java
package eecs2030.test2;

public class Test2F {

    public static boolean isBetween(int min, int max, int value) {
        boolean result = true;

    }

}
```

```java
package eecs2030.test2;

public class Test2F {

    public static boolean isBetween(int min, int max, int value) {
        boolean result = true;
        if (value <= min) {
            result = false;
        }
        if (value >= max) {
            result = false;
        }

    }

}
```

Methods with return values

- if the method header says that a type is returned, then the method must return a value having the advertised type back to the client
- you use the keyword **`return`** to return the value back to the client

```java
package eecs2030.test2;

public class Test2F {

    public static boolean isBetween(int min, int max, int value) {
        boolean result = true;
        if (value <= min) {
            result = false;
        }
        if (value >= max) {
            result = false;
        }
        return result;
    }

}
```

Method return values

- a method stops running immediately if a return statement is run
  - this means that you are not allowed to have additional code if a return statement is reached
  - however, you can have multiple return statements

```
package eecs2030.test2;

public class Test2F {

    public static boolean isBetween(int min, int max, int value) {
        if (value <= min) {
            return false;
            // code not allowed here
        }
        if (value >= max) {
            return false;
            // code not allowed here
        }
        return true;
        // code not allowed here
    }

}
```

Alternative implementations

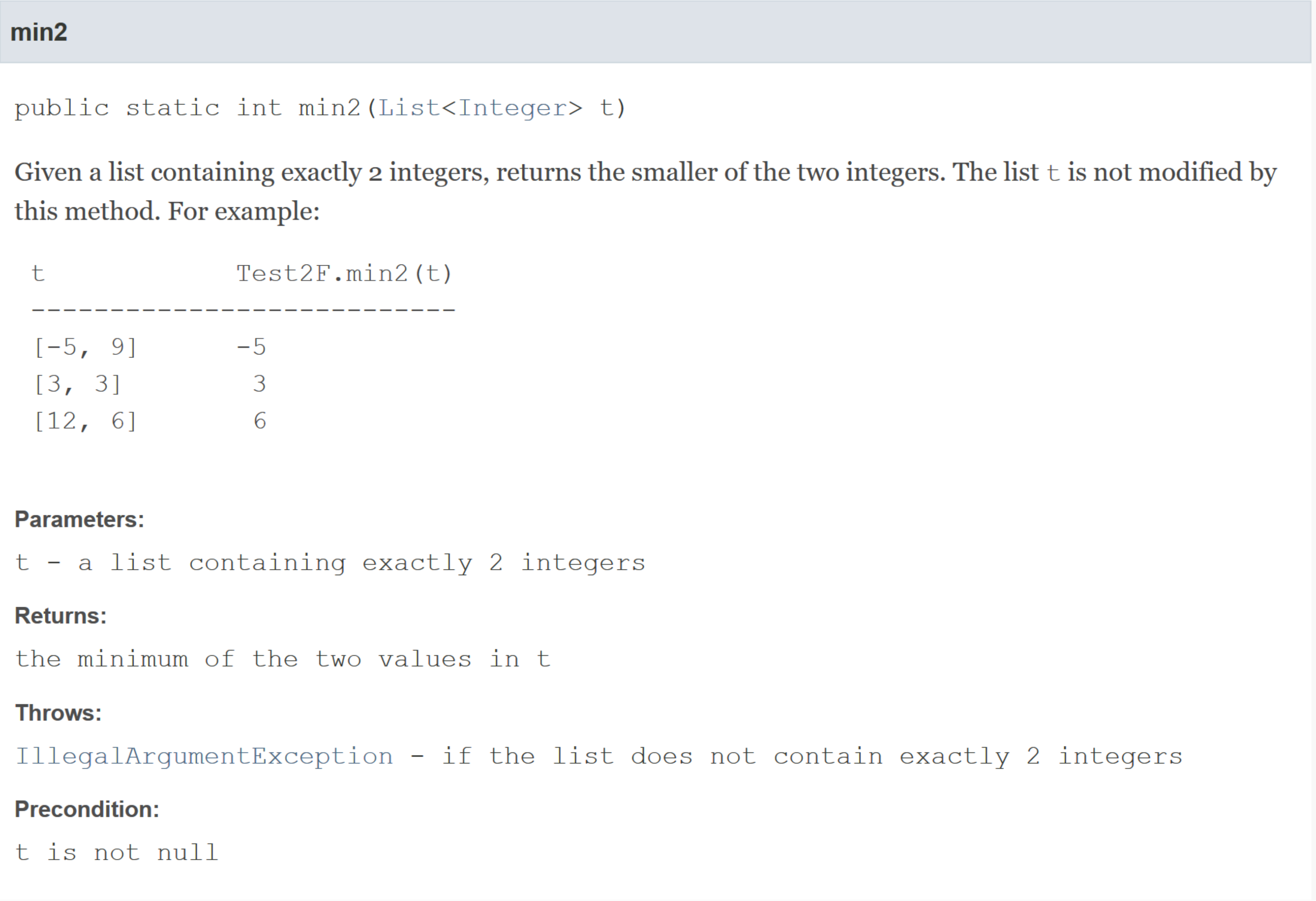
- there are many ways to implement this particular method

```java
package eecs2030.test2;

public class Test2F {

    public static boolean isBetween(int min, int max, int value) {
        if (value <= min || value >= max) {
            return false;
        }
        return true;
    }

}
```

```
package eecs2030.test2;

public class Test2F {

    public static boolean isBetween(int min, int max, int value) {
        if (value > min && value < max) {
            return true;
        }
        return false;
    }

}
```

```java
package eecs2030.test2;

public class Test2F {

    public static boolean isBetween(int min, int max, int value) {
        boolean result = value > min && value < max;
        return result;
    }

}
```

```
package eecs2030.test2;

public class Test2F {

    public static boolean isBetween(int min, int max, int value) {
        return value > min && value < max;
    }

}
```



min2

```
public static int min2(List<Integer> t)
```

Given a list containing exactly 2 integers, returns the smaller of the two integers. The list `t` is not modified by this method. For example:

```
 t             Test2F.min2(t)
 ----------------------------
 [-5, 9]       -5
 [3, 3]         3
 [12, 6]        6
```

Parameters:

`t - a list containing exactly 2 integers`

Returns:

`the minimum of the two values in t`

Throws:

`IllegalArgumentException - if the list does not contain exactly 2 integers`

Precondition:

`t is not null`

```java
package eecs2030.test2;

import java.util.List;

public class Test2F {

    // implementation of isBetween not shown

    public static int min2(List<Integer> t) {

    }
}
```

```java
package eecs2030.test2;

import java.util.List;

public class Test2F {

    // implementation not shown

    public static int min2(List<Integer> t) {
        if (t.size() != 2) {
            throw new IllegalArgumentException("list size != 2");
        }
        int first = t.get(0);
        int second = t.get(1);
    }
}
```

```java
package eecs2030.test2;

import java.util.List;

public class Test2F {

    // implementation not shown

    public static int min2(List<Integer> t) {
        if (t.size() != 2) {
            throw new IllegalArgumentException("list size != 2");
        }
        int first = t.get(0);
        int second = t.get(1);
        if (first < second) {
            return first;
        }
        return second;
    }
}
```

Worksheet

- Question 4

Invoking methods

Pass-by-value

`static` Methods

- a method that is **`static`** is a per-class member
  - client does not need an object reference to invoke the method
  - client uses the class name to access the method

```
boolean isBetween = Test2F.isBetween(0, 5, 2);
```

  - **`static`** methods are also called *class methods*

[notes 1.2.4]

Invoking methods

- a client invokes a method by passing arguments to the method
  - the types of the arguments must be compatible with the types of parameters in the method signature
  - the values of the arguments must satisfy the preconditions of the method contract

```
List<Integer> t = new ArrayList<Integer>();
t.add(100);
t.add(-99);
int min = Test2F.min2(t);
```

argument

Pass-by-value

- Java uses pass-by-value to:
  - transfer the value of the arguments to the method
  - transfer the return value back to the client

- consider the following utility class and its client…

```java
import type.lib.Fraction;

public class Doubler {

  private Doubler() {
  }

  // tries to double x
  public static void twice(int x) {
    x = 2 * x;
  }

  // tries to double f
  public static void twice(Fraction f) {
    long numerator = f.getNumerator();
    f.setNumerator( 2 * numerator );
  }
}
```

```java
import type.lib.Fraction;

public class TestDoubler {

  public static void main(String[] args) {
    int a = 1;
    Doubler.twice(a);

    Fraction b = new Fraction(1, 2);
    Doubler.twice(b);

    System.out.println(a);
    System.out.println(b);
  }

}
```

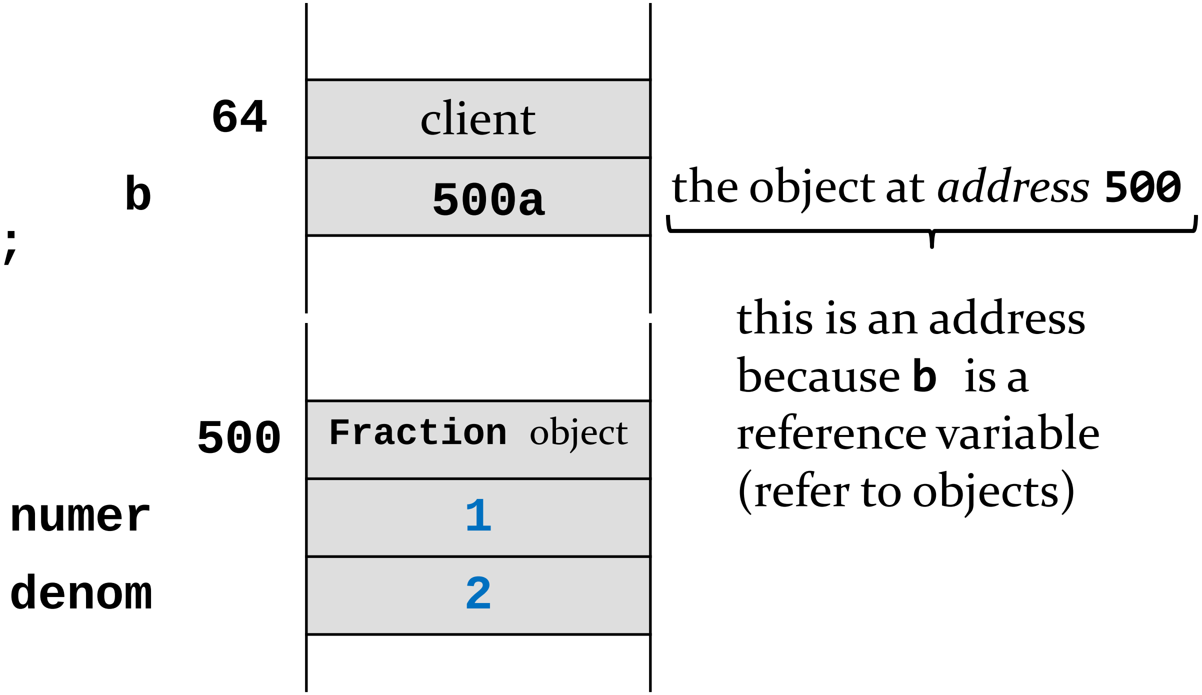
Pass-by-value

- what is the output of the client program?
  - try it and see

- an invoked method runs in its own area of memory that contains storage for its parameters
- each parameter is initialized with *the value* of its corresponding argument

Pass-by-value with reference types

```
Fraction b =
  new Fraction(1, 2);
```



64

client

b

500a

the object at *address* **500**

500

Fraction object

numer

1

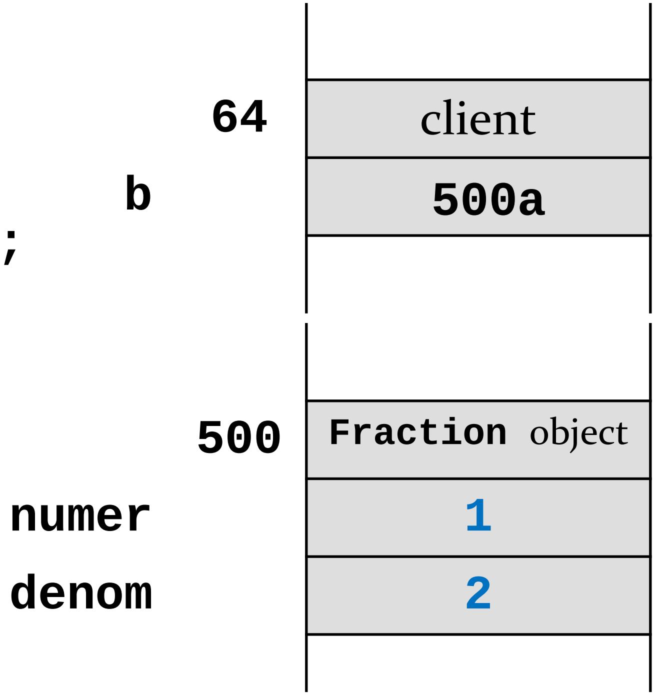
denom

2

this is an address because **b** is a reference variable (refer to objects)

Pass-by-value with reference types

```
Fraction b =
  new Fraction(1, 2);
```



64 client

b **500a**

500 **Fraction** object

numer **1**

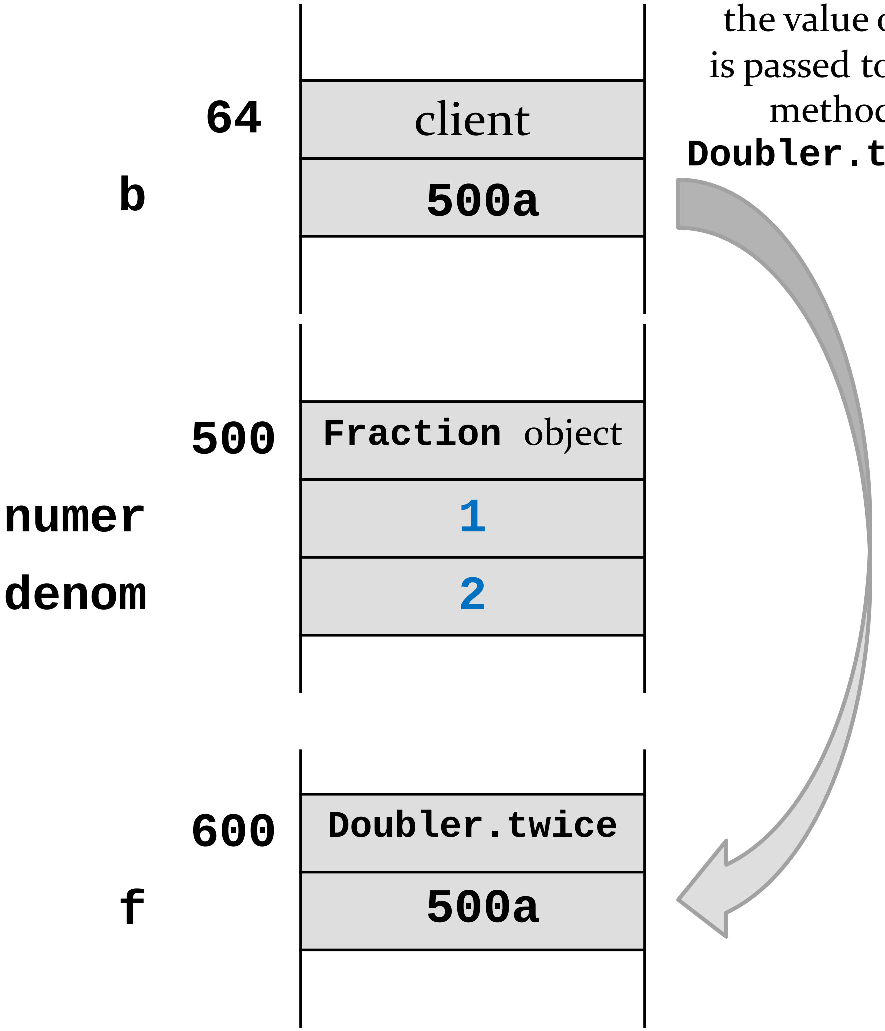
denom **2**

value of **b** is *not* the **Fraction 1/2**

value of **b** is a reference to the new **Fraction** object

Pass-by-value with reference types

```
Fraction b =
  new Fraction(1, 2);
Doubler.twice(b);
```

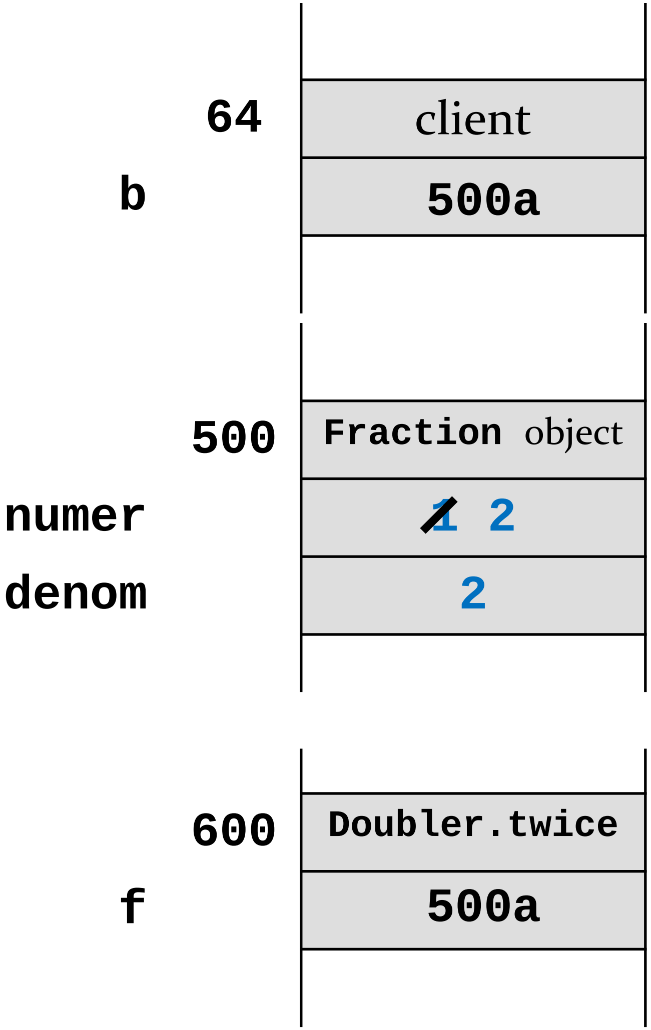


the value of **b**
is passed to the
method
Doubler.twice

parameter **f**
*is an independent
copy* of the value
of argument **b**
(a reference)

Pass-by-value with reference types

```
Fraction b =
  new Fraction(1, 2);
Doubler.twice(b);
```



64 client

b 500a

500 **Fraction** object

numer ~~1~~ 2

denom 2

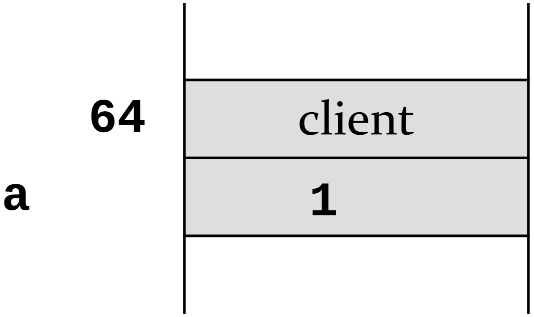
600 **Doubler.twice**

f 500a

Doubler.twice multiplies the numerator of the **Fraction** object by **2**

Pass-by-value with primitive types

```
int a = 1;
```

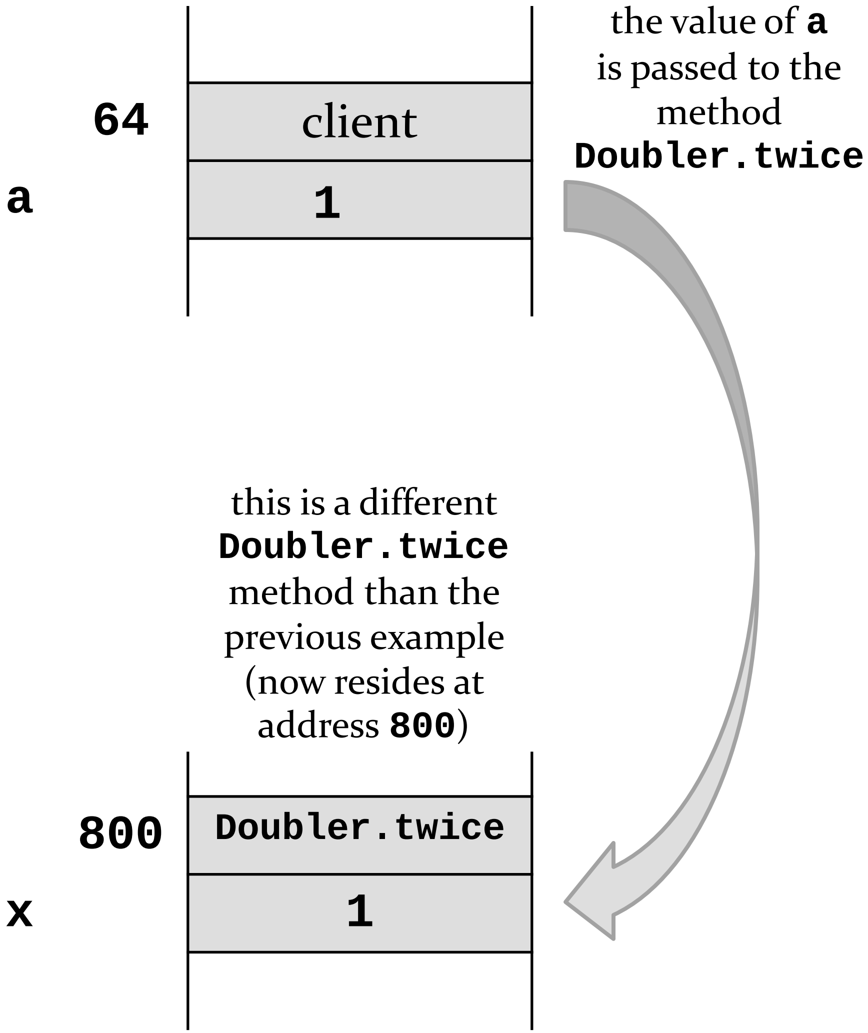


value of **a** is the integer value that we stored

this is the numeric value because **a** is a primitive variable

Pass-by-value with primitive types

```
int a = 1;
Doubler.twice(a);
```



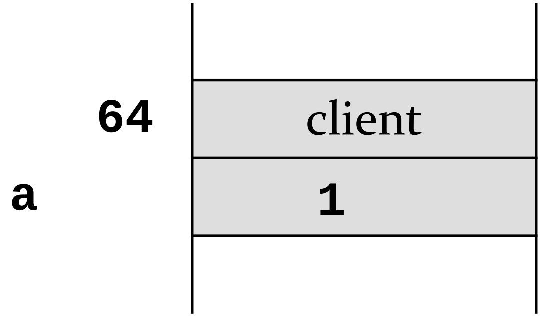
the value of **a** is passed to the method **Doubler.twice**

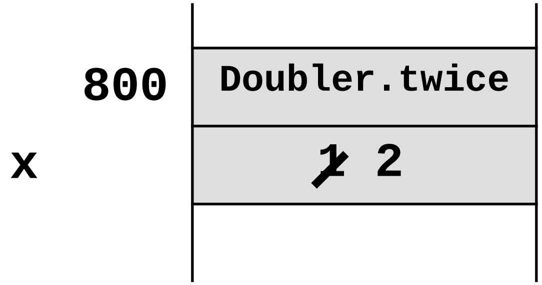
this is a different **Doubler.twice** method than the previous example (now resides at address **800**)

parameter **x** *is an independent copy* of the value of argument **a** (a primitive)

Pass-by-value with primitive types

```
int a = 1;
Doubler.twice(a);
```





`Doubler.twice` multiplies the value of **`x`** by **`2`**; that's it, nothing else happens

Pass-by-value

- Java uses pass-by-value for *all* types (primitive and reference)
  - an argument of primitive type cannot be changed by a method
  - an argument of reference type can have its state changed by a method

- pass-by-value is used to return a value from a method back to the client

Worksheet

- Question 5

Documenting a method

Javadoc

Documenting

- documenting code was not a new idea when Java was invented
  - however, Java was the first major language to embed documentation in the code and extract the documentation into readable electronic APIs

- the tool that generates API documents from comments embedded in the code is called Javadoc

Documenting

- Javadoc processes *doc comments* that immediately precede a class, attribute, constructor or method declaration
  - doc comments delimited by **`/**`** and **`*/`**
  - doc comment written in HTML and made up of two parts
    1. a description
       - □ first sentence of description gets copied to the summary section
       - □ only one description block; can use **`<p>`** to create separate paragraphs
    2. block tags
       - □ begin with **`@`** **`(@param`**, **`@return`**, **`@throws`** and many others)
       - □ **`@pre.`** is a non-standard (custom tag used in EECS1030) for documenting preconditions

Method documentation example

Eclipse will generate an empty Javadoc comment for you if you right-click on the method header and choose **Source→Generate Element Comment**

```
/**
 * @param min
 * @param max
 * @param value
 * @return
 */
public static boolean isBetween(int min, int max, int value) {
    // implementation not shown
}
```

Method documentation example

The first sentence of the documentation should be short summary of the method; this sentence appears in the method summary section.

```
/**
 * Returns true if value is strictly greater than min and strictly
 * less than max, and false otherwise.
 *
 * @param min
 * @param max
 * @param value
 * @return
 */
public static boolean isBetween(int min, int max, int value) {
    // implementation not shown
}
```

Method documentation example

You should provide a brief description of each parameter.

```
/**
 * Returns true if value is strictly greater than min and strictly
 * less than max, and false otherwise.
 *
 * @param min a minimum value
 * @param max a maximum value
 * @param value a value to check
 * @return
 */
public static boolean isBetween(int min, int max, int value) {
    // implementation not shown
}
```

Method documentation example

Provide a brief description of the return value if the return type is not void. This description often describes a postcondition of the method.

```
/**
 * Returns true if value is strictly greater than min and strictly
 * less than max, and false otherwise.
 *
 * @param min a minimum value
 * @param max a maximum value
 * @param value a value to check
 * @return true if value is strictly greater than min and strictly
 * less than max, and false otherwise
 */
public static boolean isBetween(int min, int max, int value) {
    // implementation not shown
}
```

Method documentation example

- if a method has one or more preconditions, you should use the EECS2030 specific **@pre.** tag to document them

Method documentation example

Describe any preconditions using the EECS2030 specific @pre. tag. You have to manually do this.

```
/**
 * Returns true if value is strictly greater than min and strictly
 * less than max, and false otherwise.
 *
 * @param min a minimum value
 * @param max a maximum value
 * @param value a value to check
 * @return true if value is strictly greater than min and strictly
 * less than max, and false otherwise
 * @pre min is greater than or equal to max
 */
public static boolean isBetween(int min, int max, int value) {
    // implementation not shown
}
```

Method documentation example

- if a method throws an exception then you should use the **@throws** tag to document the exception

```
/**
 * Given a list containing exactly 2 integers, returns the smaller of the
 * two integers. The list <code>t</code> is not modified by this method.
 * For example:
 *
 * <pre>
 * t            Test2F.min2(t)
 * ---------------------------
 * [-5, 9]      -5
 * [3, 3]        3
 * [12, 6]       6
 * </pre>
 *
 * @pre t is not null
 * @param t a list containing exactly 2 integers
 * @return the minimum of the two values in t
 * @throws IllegalArgumentException if the list does not contain exactly 2
 * integers
 */
public static int min2(List<Integer> t) {
}
```

HTML markup is also allowed

Worksheet

- Question 6

Utility classes

Review: Java Class

- a class is a model of a thing or concept

- in Java, a class is usually a blueprint for creating objects
  - fields (or attributes)
    - the structure of an object; its components and the information (data) contained by the object
  - methods
    - the behaviour of an object; what an object can do

Utility classes

- sometimes, it is useful to create a class called a *utility class* that is not used to create objects
  - such classes have no constructors for a client to use to create objects
- in a utility class, all features are marked as being **`static`**
  - you use the class name to access these features
- examples of utility classes:
  - **`java.lang.Math`**
  - **`java.util.Arrays`**
  - **`java.util.Collections`**

Utility classes

- the purpose of a utility class is to group together related fields and methods where creating an object is not necessary

- **`java.lang.Math`**
  - groups mathematical constants and functions
  - do not need a **`Math`** object to compute the cosine of a number
- **`java.util.Collections`**
  - groups methods that operate on Java collections
  - do not need a **`Collections`** object to sort an existing **`List`**

Class versus utility class

- a class is used to create *instances* of objects where each instance has its own *state*
- for example:
  - the class **`java.awt.Point`** is used to create instances that represent a location **`(x, y)`** where **`x`** and **`y`** are integers

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

  Point p = new Point(0, 0);      // point (0, 0)
  Point q = new Point(17, 100);   // point (17, 100)
  Point r = new Point(-1, -5);    // point (-1, -5)
}
```

  - each instance occupies a separate location in memory which we can illustrate in a memory diagram

Name	Address		
	100	`Point class`	**`Point`** class is loaded into memory
`x`			
`y`			
	200	`Point instance`	**`Point`** instance with state **`(0, 0)`**
`x`		`0`	
`y`		`0`	
	300	`Point instance`	**`Point`** instance with state **`(17, 100)`**
`x`		`17`	
`y`		`100`	
	400	`Point instance`	**`Point`** instance with state **`(-1, -5)`**
`x`		`-1`	
`y`		`-5`	

continued on next slide

Name	Address		
	500	**`main method`**	the **`main`** method
`p`		**`200a`**	the object at *address* **`200`**
`q`		**`300a`**	the object at *address* **`300`**
`r`		**`400a`**	the object at *address* **`400`**

the variables created in the **`main`** method

these are addresses because **`p`**, **`q`**, and **`r`** are reference variables (refer to objects)

Class versus utility class

- a utility class is *never* used to create objects
- when you use a utility class only the class itself occupies any memory

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

  double x = Math.cos(Math.PI / 3.0);
  double y = Math.sin(Math.PI / 3.0);

  // notice that we never created a Math object
}
```

Name	Address	
	100	**`Math class`**
`PI`		**`3.1415....`**
`E`		**`2.7182....`**
	200	**`main method`**
`x`		**`0.8660....`**
`y`		**`0.5`**

`Math` class is loaded into memory but there are no **`Math`** instances

the *value* **`cos(π/3)`**

the *value* **`sin(π/3)`**

these are values (not addresses) because **`x`** and **`y`** are primitive variables (**`double`**)

A simple utility class

- implement a utility class that helps you calculate Einstein's famous mass-energy equivalence equation $E = mc^2$ where
  - m is mass (in kilograms)
  - c is the speed of light (in metres per second)
  - E is energy (in joules)

Start by creating a package, giving the class a name, and creating the class body block.

```java
package ca.yorku.eecs.eecs2030;

public class Relativity {








}
```

Add a field that represents the speed of light.

```
package ca.yorku.eecs.eecs2030;

public class Relativity {

  public static final double C = 299792458;




}
```

Add a method to compute $E = mc^2$.

```
package ca.yorku.eecs.eecs2030;

public class Relativity {

  public static final double C = 299792458;

  public static double massEnergy(double mass) {
    double energy = mass * Relativity.C * Relativity.C;
    return energy;
  }

}
```

Add a method to compute $E = mc^2$.

```java
package ca.yorku.eecs.eecs2030;

public class Relativity {

  public static final double C = 299792458;

  public static double massEnergy(double mass) {
    double energy = mass * Relativity.C * Relativity.C;
    return energy;
  }

}
```

Here's a program that uses (a client) the **Relativity** utility class.

```
package ca.yorku.eecs.eecs2030;

public class OneGram {

  public static void main(String[] args) {
    double mass = 0.001;
    double energy = Relativity.massEnergy(mass);
    System.out.println("1 gram = " + energy + " Joules");
  }

}
```

Worksheet

- Question 7

Fields

```
public static final double C = 299792458;
```

- a field is a member that holds data
- a constant field is usually declared by specifying

1. modifiers	
1. access modifier	`public`
2. static modifier	`static`
3. final modifier	`final`
2. type	`double`
3. name	`C`
4. value	`299792458`

Fields

- field names must be unique in a class
- the scope of a field is the entire class
- [notes] use the term “field” only for **`public`** fields

`public` Fields

- a **`public`** field is visible to all clients

```
// client of Relativity
int speedOfLight = Relativity.C;
```

`static` Fields

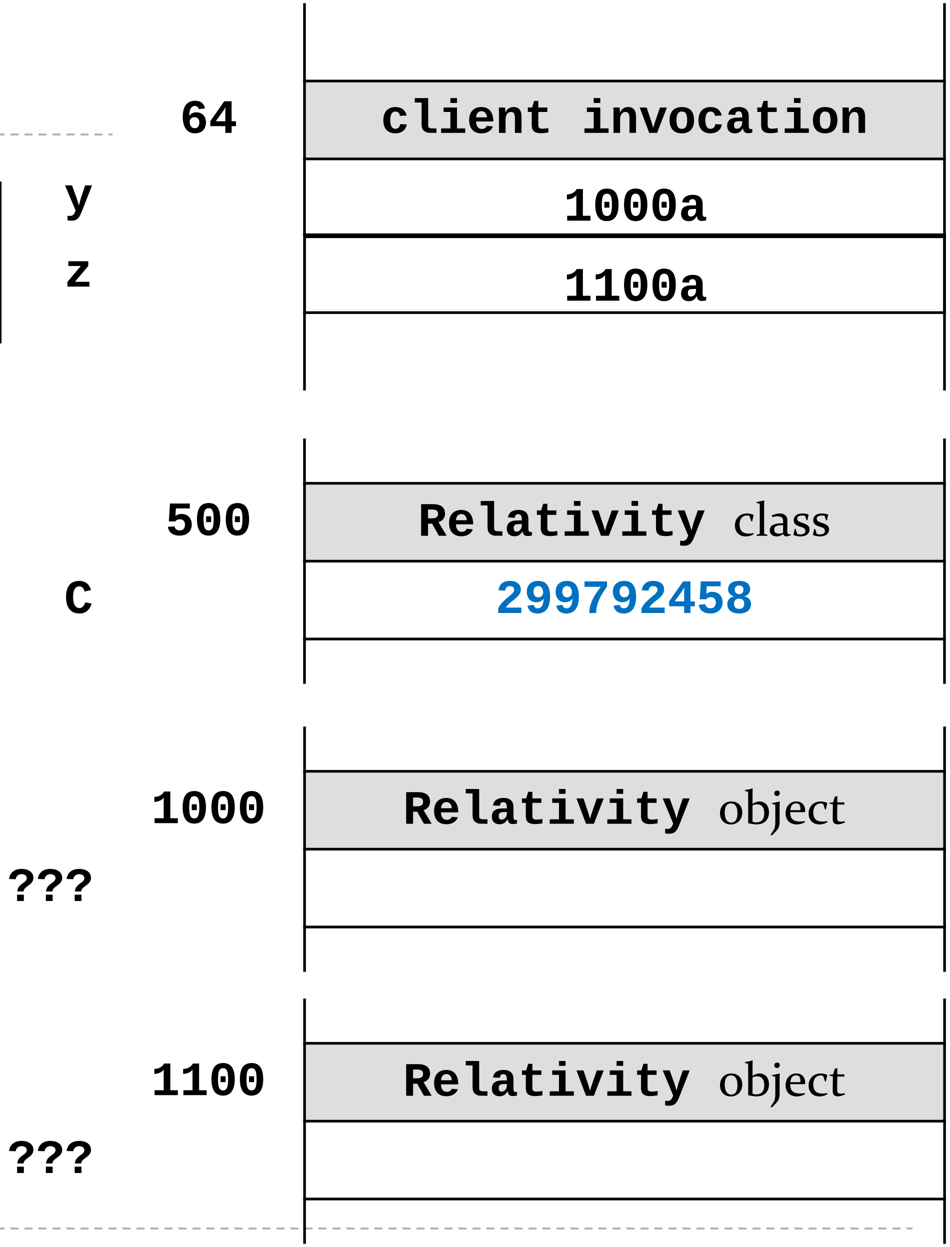
- a field that is **`static`** is a per-class member
  - only one copy of the field, and the field is associated with the class
    - every object created from a class declaring a static field shares the same copy of the field
  - textbook uses the term *static variable*
  - also commonly called *class variable*

`static` Fields

```
Relativity y = new Relativity();
Relativity z = new Relativity();
```

belongs to class

no copy of
`c`



`static` Field Client Access

- a client should access a **`public static`** field without using an object reference
    - use the class name followed by a period followed by the attribute name

```
public static void main(String[] args) {
    double sunDistance = 149.6 * 1e9;
    double seconds = sunDistance / Relativity.C;
    System.out.println(
        "time for light to travel from sun to earth " +
        seconds + " seconds");
}
```

```
time for light to travel from sun to earth 499.01188641643546 seconds
```

static Attribute Client Access

- it is legal, *but considered bad form*, to access a **public static** attribute using an object

```java
public static void main(String[] args) {
    double sunDistance = 149.6 * 1e9;
    Relativity y = new Relativity();
    double seconds = sunDistance / y.C;
    System.out.println(
        "time for light to travel from sun to earth " +
        seconds + " seconds");
}
```

```
time for light to travel from sun to earth 499.01188641643546 seconds
```

`final` Fields

- a field that is **`final`** can only be assigned to once
  - **`public static final`** fields are typically assigned when they are declared

```
public static final double C = 299792458;
```

  - **`public static final`** fields are intended to be constant values that are a meaningful part of the abstraction provided by the class

final Fields of Primitive Types

- **final** fields of primitive types are constant

```
public class Relativity {
  public static final double C = 299792458;
}
```

```
// client of Relativity
public static void main(String[] args) {

  Relativity.C = 100;  // will not compile;
                       // field C
                       // is final and
                       // previously assigned
}
```

final Fields of Immutable Types

- **final** fields of immutable types are constant

```
public class NothingToHide {
  public static final String X = "peek-a-boo";
}
```

```
// client of NothingToHide
public static void main(String[] args) {
  NothingToHide.X = "i-see-you";
                           // will not compile;
                           // field X is final and
                           // previously assigned
}
```

- **String** is immutable
  - it has no methods to change its contents

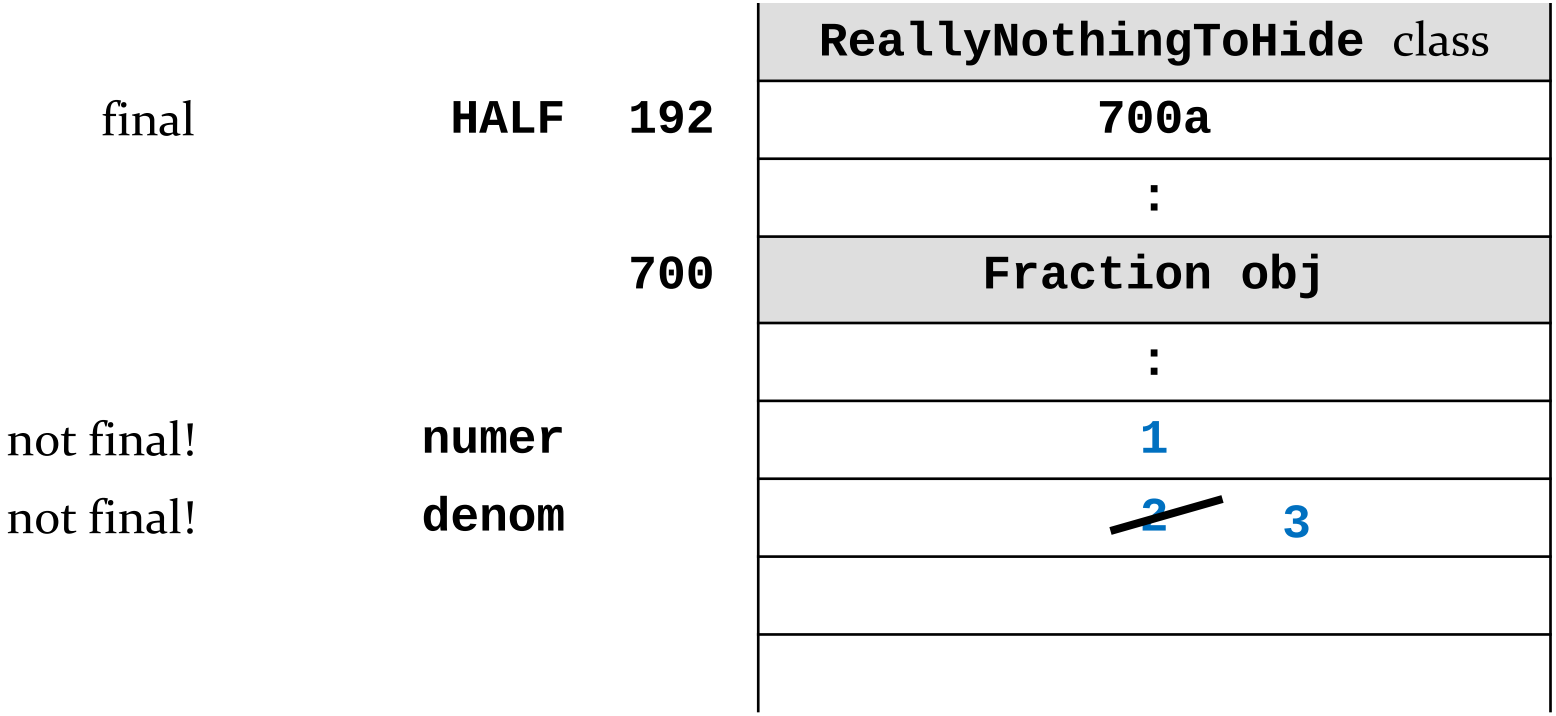
`final` Fields of Mutable Types

- `final` fields of mutable types are not logically constant; their state can be changed

```
public class ReallyNothingToHide {
  public static final Fraction HALF =
                                 new Fraction(1, 2);
}
```

```
// client of ReallyNothingToHide
public static void main(String[] args) {
  ReallyNothingToHide.HALF.setDenominator(3);
                                    // works!!
                                    // HALF is now 1/3
}
```

`final` Fields of Mutable Types



```
ReallyNothingToHide.HALF.setDenominator(3);
```

`final` fields

- avoid using mutable types as **`public`** constants
  - they are not logically constant

`new Relativity` objects

- our **`Relativity`** class does not expose a constructor
  - but

    ```
    Relativity y = new Relativity();
    ```

    is legal

- if you do not define any constructors, Java will generate a default no-argument constructor for you
  - e.g., we get the **`public`** constructor

    ```
    public Relativity() { }
    ```

    even though we did not implement it

Preventing instantiation

- in a utility class you can prevent a client from making new instances of your class by declaring a **`private`** constructor

- a **`private`** field, constructor, or method can only be used inside the class that it is declared in

```java
package ca.yorku.eecs.eecs2030;

public class Relativity {

  public static final double C = 299792458;

  private Relativity() {
    // private and empty by design
  }

  public static double massEnergy(double mass) {
    double energy = mass * Relativity.C * Relativity.C;
    return energy;
  }

}
```