Java

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Index

Introduction

What is Java?

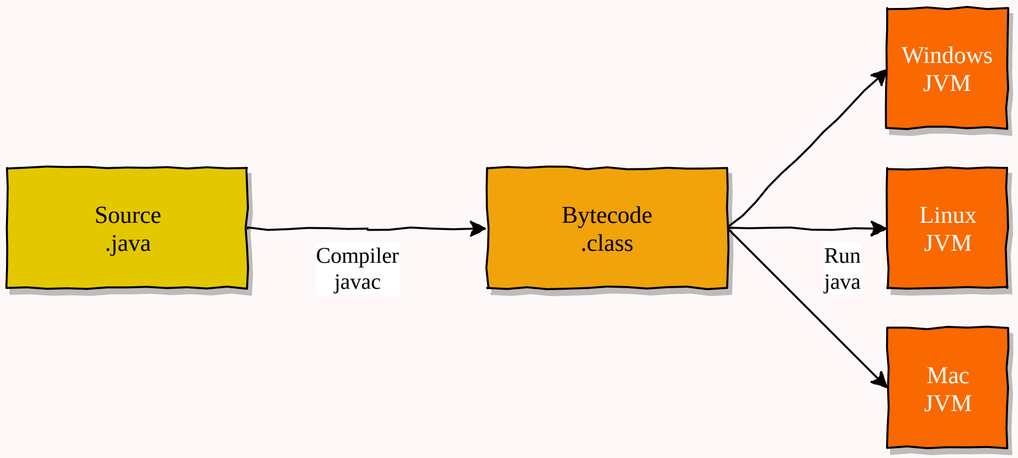
- Designed by: James **Gosling** (1995)
- Created by Sun Microsystems now owned by **Oracle**.
- Java is **open source** (under the GPL).
- Key **characteristics**:
  - General-purpose
  - Object-oriented (class-based)
  - Automatic memory management
  - Write-once / Run-everywhere

Java Editions

- **Java Card** - Smart **cards** and similar small memory footprint devices.
- **Java ME** - Micro Edition for **embedded** and **mobile** devices (IoT).
- **Java SE** - Standard Edition for regular Java applications. Mainly **desktop** and command-line apps.
- **Java EE** - Enterprise Edition for enterprise-oriented applications and servlets. Mainly large-scale **web**-oriented applications.

Compiling and Running

- Compiled into **bytecode** using the command **javac**.
- Bytecode can be run, using the command **java**, in any OS, as long as there is a Java Virtual Machine (**JVM**).
- Compiling and executing can be done using the Java Development Kit (**JDK**).
- The Java Runtime Environment (**JRE**) can be used instead for executing only.



Resources

- Book: Thinking in Java, 4th edition
- Book: Java Programming
- JDK 11 Documentation

Basics

Types

- Java is **strongly typed** so every variable must have a type.
- Java is **not a pure OOP language** so variables can have a **primitive** type or be a reference to an **object**.
- In Java, **arrays** are objects.
- There are no pointers but:
  - Primitive variables are stored as **values**.
  - Objects are stored as **references**.

Primitive Types

Primitive type are the most basic data types in Java.

Types	Size (bits)	Minimum Value	Maximum Value	Precision
byte	8	-128	127	From +127 to -128
char	16	0	$2^{16}-1$	All Unicode characters
short	16	-2^{15}	$2^{15}-1$	From +32,767 to -32,768
int	32	-2^{31}	$2^{31}-1$	From +2,147,483,647 to -2,147,483,648
long	64	-2^{63}	$2^{63}-1$	From +9,223,372,036,854,775,807 to -9,223,372,036,854,775,808
float	32	2^{-149}	$(2-2-23)\cdot 2^{127}$	From 3.402,823,5 E+38 to 1.4 E-45
double	64	2^{-1074}	$(2-2^{-52})\cdot 2^{1023}$	From 1.797,693,134,862,315,7 E+308 to 4.9 E-324
boolean	—	—	—	false, true
void	—	—	—	—

Literals

Java Literals are syntactic representations of boolean, character, numeric, or string data.

- **Boolean**: true or false.
- **Character**: 16-bit characters inside single quotes ('a'). Can be cast to int or long.
- **String**: Inside double quotes ("Java").
- **Integer**: Decimal (1234), Octal with a leading zero (02322), hexadecimal starting with 0x (0x4D2) or binary starting with 0B (0B10011010010). Ending with L if we want a long type integer (1234L).
- **Floating Point**: Ending with F or D for single and double precision (double is the default). Can be a decimal fraction or an exponential notation (0.1234 or 1234E-4).

Variables

Local variables are created by:

- giving it a **unique name**; and
- assigning it a **data type**.

```
int i;
```

Local variables must be given a value explicitly before being used:

```
int i; i = 10;
```

This can be done in a single statement:

```
int i = 10;
```

Conditional Blocks

Java has all the conditional blocks you would expect from a C-family programming language:

```
if (condition) {      // Curly brackets when more than one statement
  doSomething();
  doSomethingElse();
} else
  doAnotherThing();
```

And also:

```
switch (variable) {                 // variable must be of the correct type
  case 1: doSomething();
    break;                          // don't forget the break
  case 2: doSomethingElse();
    break;
  default: doSomethingDefault();
    break;
}
```

Loop Blocks

Loop blocks are also the expected ones. The **while-loop**:

```
while (condition) {
  doSomething();
}
```

Also a **do-while** variant:

```
do {
  doSomething();          // executed at leat once
} while (condition);
```

And, of course, the **for-loop**:

```
for (int i = 0; i < 10; i++) {
  doSomething(i);         // i from 0 to 9
}
```

Operators

Arithmetic and boolean operators are also very similar to other C-family languages:

- Assignment: `= += -= *= /=`
- Numerical: `+ - * / % ++ --`
- Relational: `== != < > <= >=`
- Boolean: `&& || !`
- Bitwise: `& | ^ ~ << >> >>>`
- Tertiary: `?:`
- Type casting: `(type)`

Be careful with the == operator. It compares primitive types by value; but **compares objects by reference**.

Standard Input and Output

Writing to the screen can be accomplished using one of two methods:

```
System.out.print("Hello world");
System.out.println("Hello world");  // also changes line
```

Reading from the keyboard can be done using the **Scanner** class from *java.util* package:

```
Scanner scanner = new Scanner(System.in); // Instantiating a new Scanner object
String line = scanner.nextLine();         // Reading a line
System.out.println(line);                 // Printing out the line
int number = scanner.nextInt();           // We can also read primitive types
```

Naming Convention

Names should follow the standard naming convention:

Type	Form	Capitalization	Example
Class or Interface	Noun	First word letter capitalized	PoliceCar
Methods	Verb	First word letter capitalized (except first one)	turnSirenOn()
Variables	—	First word letter capitalized (except first one)	carPlate
Constants	—	Uppercase with underscores separating words	MAX_SPEED
Packages	—	Starting with top-level domain, lowercase separated by periods	com.lpoo.util

Strings

- In Java Strings are **immutable**, so they cannot be modified once created.
- String are a class defined in the *java.lang* **package** (more on that later):

The + operator **concatenates** strings:

```
String hello = "Hello";
String world = "World";
String sentence = hello + " " + world;
```

String are objects, so to compare them we **must** use the **equals** method:

```
if (hello.equals(world)) {  // hello == world would compare the references
  doSomething(i);
}
```

Hello World

In Java, **everything** must **belong** to a **class**.

That means our customary **Hello World** example looks like this:

```
public class HelloWorld {
  public static void main(String[] args) { // when we run a class this method
    System.out.println("Hello, World");    // runs first
  }
}
```

Don't worry too much about the syntax for now.

Arrays

Arrays

In Java, an **array** is an **object**. This object has a given type for the contained primitive types or objects (int, char, String, ...).

An array can be declared in several ways:

```
int[] array;  // recommended
int array[];  // identical but less used
```

These arrays have been declared but haven't been instantiated yet. We can do it in a few different ways:

```
array = new int[10];                          // 10 default elements
array = new int[]{1, 2, 3, 4, 5, 6, 7, 8, 9, 10}; // works anywhere
int[] other = {1, 2, 3, 4, 5, 6, 7, 8, 9, 10};    // only works in the declaration
```

The default value depends on the data type. For objects it's **null**, for numeric types it's **0**, for booleans is **false** and for chars it's **'\u0000'** (whose decimal equivalent is 0).

Using Arrays

The size of an array can be obtained by using the **length** attribute:

```
for (int i = 0; i < array.length; i++)
  System.out.println(array[i]);  // getting the value at index i
```

A simpler way of **looping** over an array is:

```
for (int element : array)       // element must be the same type
{                               // as the array internal values
  System.out.println(element);
}
```

Multidimensional Arrays

Arrays can have more than one **dimension**:

```
int[][] array = {{  0,  1,  2,  3,  4 },
                 {  5,  6,  7,  8,  9 },
                 { 10, 11, 12, 13, 14 }};
System.out.println(array[0][3]); // 3
System.out.println(array[1][4]); // 9
```

Sub-arrays can even have **different** lengths:

```
int[][] array = {{       0       },
                 {    1, 2, 3    },
                 { 4, 5, 6, 7, 8 }};
System.out.println(array[0].length); // 1
System.out.println(array[1].length); // 3
```

OOP

Abstractions

All programming languages provide **abstractions**:

- **Assembly** is an abstraction of **machine-code**.
- **Imperative** programming is an abstraction of **assembly**.

But they force us to think about the structure of the **machine** and not the structure of the **problem**.

OOP provides an abstraction where **elements** of the problem are **objects** in the solution space.

OOP allows you to describe the problem in terms of the **problem**, rather than in terms of the **computer** where the solution will run.

Objects

Alan Kay[1] on the five pillars of *Smalltalk*:

1. **Everything** is an object.
2. A program is a bunch of objects telling each other what to do by sending **messages**.
3. Each object has its own **memory** made up of **other objects**.
4. Every object has a **type**.
5. All objects of a particular type can receive the **same messages**.

"An object has state, behavior and identity" — **Grady Booch**[2], 1994.

"An object is characterized by a number of operations and a state which remembers the effect of these operations" — **Ivar Jacobson**[2], 1996.

1. Inventor of the Smalltalk language.
2. Two of the developers of UML (together with James Rumbaugh).

Object Oriented Pillars (A PIE)

Data **A**bstraction:

> *Clear separation between the **public interface** of a data type, and its concrete implementation.*

Polymorphism:

> *A **single symbol** can **represent** a **multitude** of **different types**.*

Inheritance:

> *Objects can **inherit properties** and **behaviors** from **other** objects.*

Encapsulation (2 different concepts):

> *A mechanism that: (1) allows **restricting access** to some of the **object's components** (2) facilitates the **bundling** of **data** with the **operations** on that data.*

Classes

Classes

- All **objects**, while being **unique**, are also part of a **class** of objects that have **characteristics** and **behaviors** in common.
- Objects that are identical — **except** for their **state** — are grouped together into **classes of objects**.
- Classes **extend** the programming language by adding new **data types**.

- Each class is defined by its **interface**.
- The **interface** determines the **requests** that you can make for a particular object.
- An object **provides services** and can use **other objects'** services to accomplish it.

Classes in Java

- In Java, public classes must be declared in a file with the **same name** but with a **.java** extension.
- This means that a Java file can have, at most, **one** public class.
- For example, inside a file called **Light.java** you could have:

```
public class Light {
  // ...
}
```

- As this is a **public** class, it can be accessed from anywhere.

Fields

- Objects store data inside **fields** (also called *member variables*).
- Each object keeps its **own** storage for its fields.
- **Ordinary** fields are **not shared** among objects.

```
public class Light {
  private boolean isOn = false;
  private int level = 100;
}
```

- Usually, fields should be made **private** so they can be accessed only from inside the object they belong to.
- Objects from other classes can access them using the class *public interface* (methods).

Methods

- Methods are how we **communicate** with objects.
- When we **invoke** or **call** a method we are asking the object to carry out a **task**.
- Each method has a **name**, input **parameters**, a **return** type and a **visibility**.

```
public class Light {
  public void turnOn() {
    this.isOn = true;
  }

  public void turnOff() {
    this.isOn = false;
  }

  public void setLevel(int level) {
    this.level = level;
  }
}
```

Visibility

For a **class**:

- **public**: can be referenced anywhere in the **application**.
- **protected**: can be referenced only in the **package**.
- **private**: only in **nested** classes, can be accessed only in the **outer** class.

For a **variable**:

- **public**: can be referenced anywhere in the **application**.
- **protected**: can be referenced only in **sub-classes** and in the same **package**.
- **package** (no modifier / default): can be referenced only in the same **package**.
- **private**: can be accessed only in the **class** it is defined in.

For a **method**:

- **public**: can be called anywhere in the **application**.
- **protected**: can be called only in **sub-classes** and in the same package.
- **package** (no modifier): can be called only in the same **package**.
- **private**: can be called only in the **class** it is defined in.

Keyword *this*

- **this** is a reference to the current object — the object whose method or constructor is currently running.
- You can treat the reference just like any other **object reference**.

- If you are calling a method from **within** another method of the **same** class, you **do not** need to use *this*.
- If you are referring to a field from **within** a method of the **same** class, you **do not** need to use *this*. But you should, for **readability** purposes (and sometimes to avoid **ambiguity**).

Constructor

- Constructors are special methods that are used to create **new objects**.
- Constructors have the **same name** as the class.
- Constructors **do not** have a explicit return type — they **implicitly** return the type they are constructing.
- Constructors can be **overloaded**.

```
public class Light {
  public Light() {
    this.isOn = false;
    this.level = 50;
  }

  public Light(int level) {
    this.isOn = false;
    this.level = level;
  }
}
```

Constructor Chaining

- Within a constructor, you can use the **this** keyword to invoke **another** constructor in the **same** class.
- This has to be the **first statement** of the constructor.

```java
public class Light {
  public Light() {
    this(50);
  }

  public Light(int level) {
    this.isOn = false;
    this.level = level;
  }
}
```

Setters and Getters

- Object fields are usually kept **private** to improve **encapsulation**.
- It is common to provide public **setter** and **getter** methods to access and modify the value of a private field.

```java
public class Light {
    private boolean isOn;
    private int level;

    // ...

    public void setLevel(int level) {
        this.level = level;
    }

    public int getLevel() {
        return level;
    }
}
```

Static

- **Static fields** belong to the class instead of a specific object.
- **Static methods** can only access the static context of the class.

```
public class Light {
  private static int MAX_LEVEL = 100;

  public static int getMaximumLevel() {
    return Light.MAX_LEVEL;
  }
}
```

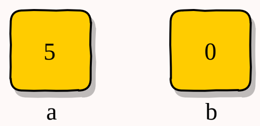
```
System.out.println(Light.getMaximumLevel()); // no need for an object
```

Objects

Objects

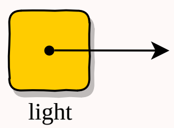
When a **primitive type** variable is declared, its value is **stored** directly in its **memory** location.

```
int a = 5, b; // if a field, b is initialized with a default value of 0.
```



When an **object** is declared, it only contains a reference to the actual object.

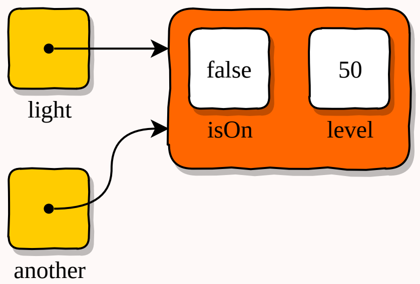
```
Light light; // if a field, light is initialized with a default value of null.
```



Instantiation

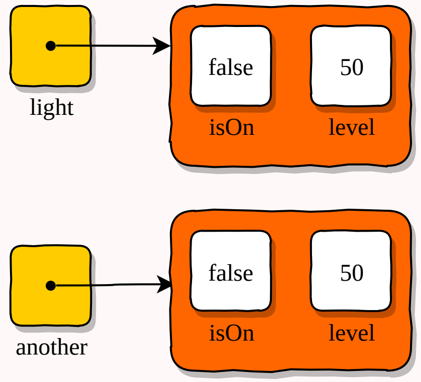
To create a new object, we just have to call its constructor using the **new** keyword:

```
Light light = new Light();
Light another = light;      // this only copies the reference
```



Cloning

If we need to have two instances of the same object, we must use the **clone()** method. To use clone, our class must implement the **Cloneable** interface and override the **clone()** method making it **public**.




```
public class Light implements Cloneable{
  @Override
  public Object clone() throws CloneNotSupportedException {
    return super.clone();
  }
}

Light light = new Light();
Light another = light.clone();
```

Final

- The **final** keyword, allows us to declare **fields** and **variables** that **cannot be changed**.
- This only applies to the variable itself, so in the case of objects we can modify the **object** but not its **reference**.
- Can be used together with **static** to create **global constants**.

```
final Light light = new Light();
light.setLevel(50);
light = new Light(); // error
```

```
final int level = 50;
level = level + 10; // error
```

```
public class Light {
  private final static int MAX_LEVEL = 100;
}
```

Parameters

Objects are passed to methods by **reference**; while **primitive** variables are passed by **value**.

```
private void change(int a, Light light) {
  a = a + 10;
  light.setLevel(80);
}

public void doSomething() {
  int a = 10;
  Light light = new Light(); // level = 50

  change (a, light);

  System.out.println(a); // 10
  System.out.println(light.getLevel()); // 80
}
```

Inheritance

Inheritance

- The mechanism of **basing** a class (or object) upon another class (or object), retaining a **similar** implementation.
- Inheritance should be used to establish a **is-a** relationship between classes.

- In Java, inheritance is **class-based**.
- In Java, there is **no multiple-inheritance**.
- In Java, if unspecified, all classes are based on the root **Object** class.

Extends

- The **extends** keywords allows a class to define a **different** superclass, inheriting all methods and fields from it.
- The **super** keyword allows calling a **constructor** from the superclass.
- You can **only** extend **one** class.

Tip: You don't have to provide any constructors for your class, but you must be careful when doing this. The compiler automatically provides a no-argument, default constructor for any class without constructors. This default constructor will call the no-argument constructor of the superclass. In this situation, the compiler will complain if the superclass doesn't have a no-argument constructor so you must verify that it does.

Extends

```
public class Shape {
    private String color;

    public Shape(String color) {
        this.color = color;
    }
}

public class Rectangle extends Shape {
    private int x1, x2, y1, y2;

    public Rectangle(int x1, int x2, int y1, int y2, String color) {
        super(color);

        this.x1 = x1;
        this.x2 = x2;
        this.y1 = y1;
        this.y2 = y2;
    }
}
```

Overriding

Java allows classes to **override** superclass methods, providing that:

- The access modifier (visibility) for an overriding method can allow **more**, but **not less**, access than the overridden method.
- **Final** methods can not be overridden.
- **Static** methods can not be overridden.
- **Private** methods can not be overridden.
- The overriding method must have **same return type** (or **subtype**).

We can call a parent class method using the **super** keyword.

```java
public class Animal {
  public void talk() { System.out.println("Animal says:"); }
  public final void eat() { /* ... */ }
}
public class Dog extends Animal {
  public void talk() {
    super.talk();
    System.out.println("Woof!");
  }
}
```

Abstract Classes

- **Abstract** classes cannot be instantiated but can be **extended**:
- They are used to:
    - Define **methods** which can be **used** by the inheriting subclass.
    - Define abstract methods which the inheriting subclass **must implement**.
    - Provide a **common interface** for their subclasses.

```
public abstract class Animal {
    public abstract void talk();
}
public class Dog extends Animal {
    // This method must be implemented or the
    // class must be declared abstract.
    public void talk() {
        System.out.println("Woof!");
    }
}
```

Interfaces

- Java does not allow multiple-inheritance but it has **interfaces**.
- An interface is like a **fully abstract** class (only abstract methods).
- A class can implement **several interfaces**.
- Interfaces can be used in order to achieve **polymorphism**.

```
public interface Runner { public void run();  }
public interface Walker { public void walk(); }
public interface Eater  { public void eat();  }

public abstract class Animal implements Eater, Walker{
    public abstract void talk();
}

public class Dog extends Animal implements Runner {
    public void talk() {  } // all these
    public void eat()  {  } // methods
    public void run()  {  } // have to be
    public void walk() {  } // implemented
}
```

Polymorphism

In Java, a variable of a given type may be **assigned** a value of **any subtype**, and a method with a parameter of a given type may be **invoked** with an argument of **any subtype** of that type.

```
public void race(Runner r1, Runner r2) { /* ... */ }

public void main() {
  Dog d1 = new Dog();
  Runner d2 = new Dog();

  race (d1, d2);
}
```

Polymorphism

In Java, the method to be called is decided at **runtime**, based on the runtime type of the object.

```
public class Animal{
    public void talk() { System.out.println("Hello!"); };
}

public class Dog extends Animal {
    public void talk() { System.out.println("Woof!");  }
}

public class Cat extends Animal {
    public void talk() { System.out.println("Meow!");  }
}

public void main() {
    Animal a1 = new Animal(); a1.talk(); // Hello!
    Animal a2 = new Dog(); a2.talk();    // Woof!
    Animal a3 = new Cat(); a3.talk();    // Meow!
}
```

Methods to Override

Equals

As we have seen with **Strings**, when we want to compare objects we shouldn't use the **==** operator as it will only return true if the two objects are the same (have the same reference).

We should instead **override** the **equals(Object)** methods from the **Object** class.

The **correct** way to do so looks something like:

```java
@Override
public boolean equals(Object o) {
  if (this == o) return true;                       // are the references equal
  if (o == null) return false;                      // is the other object null
  if (getClass() != o.getClass()) return false; // both objects the same class

  Point p = (Point) o;                              // cast the other object
  return x == p.getX() && y == p.getY();            // actual comparison
}
```

Hash Code

Another important method is the **hashCode()** method. This method should return the **same value** for **two objects** that are **equal**. So normally, when overriding the **equals(Object)** method you should also override the **hashCode()** method.

You can see the **hash code** at work in the **HashSet** data structure (which we will see in detail later on):

- When an element is **added**, the **hash code** is used to decide in which **bucket** it should be **stored**.
- When **searching** for an object, we only need to compare it (using **equals(Object)**) with objects in the same bucket.

Hash Code Implementation

To implement the **hashCode()** method, we should use a **subset** of the fields that are used in **equals(Object)**.

A possible implementation would be:

```
@Override
public int hashCode() {
  return Objects.hash(x, y);
}
```

To String

Another useful method from the **Object** class is the **toString()** method. This method returns a representation of any **Object** as a **String**. The default implementation is not very useful:

```
System.out.println(new Point(1, 2)); // Point@3e2
```

But we can **override** it and make it **better**:

```
@Override
public String toString() {
    return "Point (" + x + ", " + y + ")";
}
```

So that we get:

```
System.out.println(new Point(1, 2)); // Point (1, 2)
```

Garbage Collection

Garbage Collection

- Automatic **garbage collection** is the process of looking at **heap** memory, identifying which objects are in use and which are not, and deleting the unused objects.
- An **in use** object, or a referenced object, means that some part of your program still maintains a pointer to that object.
- In Java, this process is done automatically so developers do not have to worry about **memory leaks**. Or do they?

Packages

Packages

- A **package** contains a **group** of classes, **organized** together under a single **namespace**.
- Classes in the **same package** can access each other's **package-private** and **protected** members.
- The package that a class belongs to is specified with the **package** keyword (first statement):

```
package com.example;
```

Packages are **stored** in the form of structured **directories**. For example: package "*com.example*" would be stored in directory "*com/example*".

Importing

To use a class from another package we must first import it:

```
import com.example.HelloWorld;
import com.example.*; // imports all classes from the package

// ...
  HelloWorld hw = new HelloWorld();
```

It is important to understand that **import** is simply used by the compiler to let you name your classes by their **unqualified** name.

Without the import statement this would still be valid:

```
com.example.HelloWorld hw = new com.example.HelloWorld();
```

Exceptions

Exceptions

- When an error occurs within a method, the flow of execution of the program stops immediately, the method creates an **Exception** object and hands it off to the **runtime system**.
- The **runtime system** attempts to find something to **handle** it by following the **ordered list of methods** that have been called to get to the method where the error occurred.

```
public void someCode() {
  HelloWorld hw = null;
  hw.hello();              // Not a good idea!
}

public void moreCode() {
  someCode();
}

public void code() {
  try {
    moreCode();
  } catch (NullPointerException e) {
    // do something about the error
  }
}
```

Throw

The **throw** keyword is used to **explicitly** throw an exception (any sub-class of **Throwable**) from a method or any block of code. User defined exceptions typically extend **Exception** class.

```java
public void someCode() throws VeryBadThingHappenedException {
  throw new VeryBadThingHappenedException("Boom!");
}

public void moreCode() throws VeryBadThingHappenedException {
  someCode();
}

public void code() {
  try {
    moreCode();
  } catch (VeryBadThingHappenedException e) {
    // do something about the error
  }
}
```

Throws

If the **compiler** thinks there is **a chance** of rising an exception inside a method, then it will force us to either: 1) **catch** that exception, or 2) **declare** that we will **throw** that exception.

```
public void someCode() throws VeryBadThingHappenedException {
  throw new VeryBadThingHappenedException("Boom!");
}

public void moreCode() throws VeryBadThingHappenedException {
  someCode();
}
```

In this example, the **moreCode()** method is calling a method that **throws** an Exception, so it has to **throw** it also or **catch** it.

Finally

- The **finally** block always executes when the a try block exits.
- This ensures that the **finally** block is executed even if an **unexpected** exception occurs or an accidental return statement is added.
- Putting **cleanup code** in a **finally** block is always a **good practice**, even when no exceptions are anticipated.

```
public void code() {
  try {
    moreCode();
  } catch (VeryBadThingHappenedException e) {
    // do something about the error
  } finally {
    // clean up code
  }
}
```

Throw or Catch

The decision between **throwing** an exception and **catching** it might be an hard one:

- Methods should **catch** an exception if they can **handle** it locally.
- Methods should **throw** an exception if there is **nothing** they can do about it.

Catching an exception and **doing nothing** about it, besides printing the stack trace, is **always a bad idea**.

Collections

Collections

- A **Collection** is a **group** of individual objects represented as a **single unit**.
- Java provides the **Collection Framework** which defines several classes and interfaces to represent a group of objects as a single unit.
- The Collection interface (**java.util.Collection**) and Map interface (**java.util.Map**) are the two main interfaces of Java Collection classes.

Collection Classes

- **Set** : Doesn't allow duplicates: HashSet (Hashing based), TreeSet (balanced BST based; implements SortedSet)...
- **List** : Can contain duplicates and elements are ordered: LinkedList (linked list based), ArrayList (dynamic array based), Stack, Vector, ...
- **Queue** : Typically order elements in FIFO order: LinkedList, PriorityQueue (not in FIFO order)...
- **Deque** : Elements can be inserted and removed at both ends: ArrayDeque, LinkedList...
- **Map** : Contains Key value pairs. Doesn't allow duplicates: HashMap and TreeMap (implements SortedMap).

Parameterized Collections

Java Collections are **parameterized** (using **Generics** — more about this later).

This means that we can define the **type of data** that the collection will **store**.

```
List<Animal> animals = new ArrayList<>();
animals.add(new Dog());
animals.add(new Cat());
```

```
for (Animal animal : animals) {
  animal.talk();
}
```

Notice that we used **List** instead of **ArrayList** to declare the variable. **List** is the **interface** that all lists **implement** and **ArrayList** is a **concrete instantiation** of that interface.

This is the "*Return the most specific type, accept the most generic type*" **principle**.

List

Some examples on how to use **lists**:

```
Dog dog = new Dog();
Cat cat = new Cat();

List<Animal> animals = new ArrayList<>();

animals.add(dog); animals.add(cat); // Adding some animals

for (Animal animal : animals)       // Looping over the collection
  animal.talk();

animals.get(0).talk();              // Element at position 0 (dog)

animals.remove(0);                  // Removing element at position 0
animals.remove(cat);                // Removing the cat

animals.clear();                    // Removing all elements
```

Set

Some examples on how to use **sets**:

```
Set<Point> points = new HashSet<Point>();

points.add(new Point(1, 2));       // returns true
points.add(new Point(1, 2));       // returns false

System.out.println(points.size()); // prints 1

points.contains(new Point(2, 3));  // returns false
points.contains(new Point(1, 2));  // returns true
```

Map

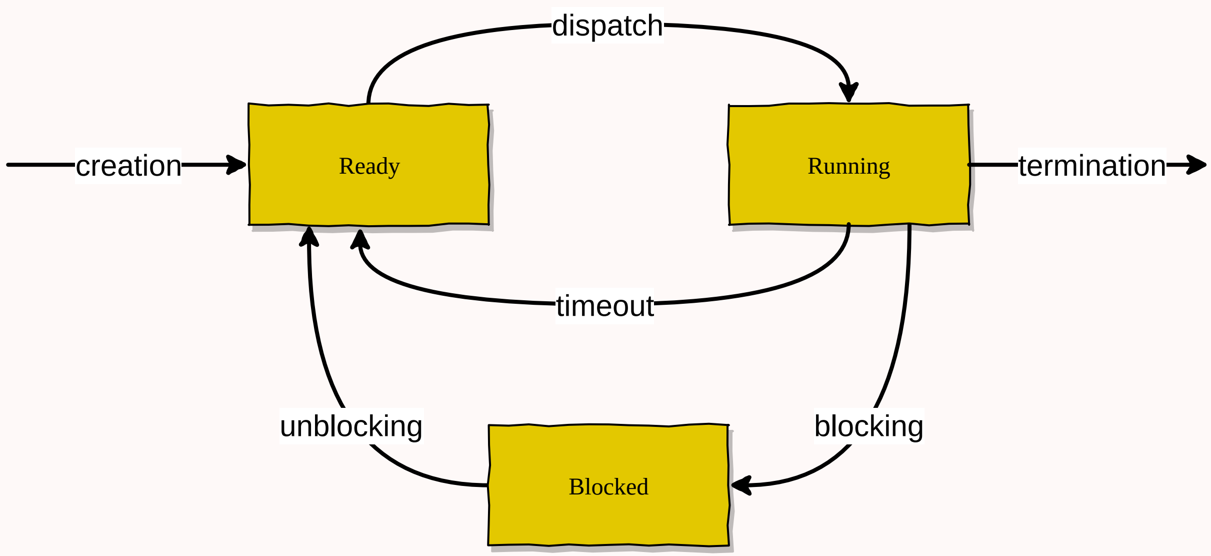
Some examples on how to use **maps**:

```
Map<String, Point> locations = new HashMap<String, Point>();

locations.put("John", new Point(1, 2));
locations.put("Mary", new Point(2, 4));

locations.get("John");                  // returns Point (1, 2)
locations.get("Carl");                  // returns null

locations.remove("Mary");

locations.containsKey("John");          // returns true;
locations.containsKey("Mary");          // returns false;
```

Threads

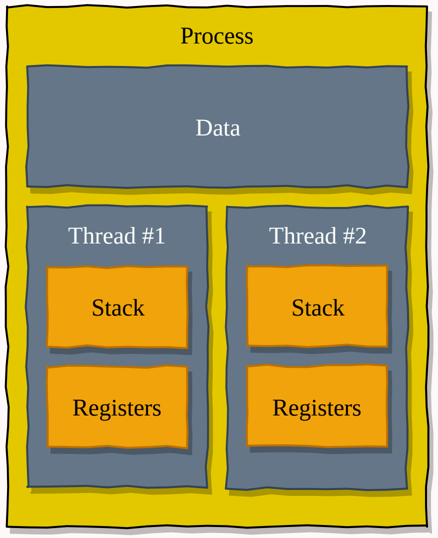
Processes

Multitasking is a method to allow **multiple processes** to share processors and other system resources.



Threads

A process may be made up of **multiple threads** of execution that execute instructions concurrently.



Threads are **lightweight processes** that have their own **stack** but have access to **shared data**.

Why threads?

Until now, all our code has been running in a **single main thread**.

But what happens if we need to block to read data from some source but still want our state and view to be updated?

```
public void run() {
  while (true) {
    draw();                           // Draws the current game state
    processKey(screen.readInput()); // "Read input" blocks waiting for a key
                                      // to be pressed.
    doStep();                         // Makes our game move forward
                                      // e.g. enemies move
  }
}
```

Threads in Java (1)

There are two different ways to create a new thread in Java.

1) Extend the **Thread** class and override the **run()** method:

```
public class GameUpdater extends Thread {
  @Override
  public void run() {
    // Do something
  }
}

new GameUpdater().start();
```

Or just:

```
new Thread() {
  @Override
  public void run() {
    // Do something
  }
}.start();
```

Threads in Java (2)

There are two different ways to create a new thread in Java.

2) Implement the **Runnable** interface and start a **Thread** with it:

```
class GameUpdater implements Runnable {
  @Override
  public void run() {
    // do something
  }
}

new Thread(new GameUpdater()).start();
```

Or just:

```
new Thread(new Runnable() {
  @Override
  public void run() {
    // do something
  }
}).start();
```

Thread Class

The thread class has a series of useful methods:

- **void start()** - Causes this thread to **begin** execution; the Java Virtual Machine calls the **run** method of this thread.
- **static Thread currentThread()** - Returns a **reference** to the **currently** executing **thread** object.
- **long getId()** - Returns the **identifier** of this Thread.
- **void join()** - **Waits** for this thread to **die**.
- **boolean isAlive() and isInterrupted()** - Tests whether this thread is **alive** or has been **interrupted**.
- **static Thread interrupted()** - Checks if current thread has been interrupted and **resets flag**.

Interrupt

A thread **cannot order** another thread to stop. It has to **ask nicely**:

```
Thread t = new Thread() {
  @Override
  public void run() {
    while (true) {
      System.out.println("I'm alive!");
      if (isInterrupted()) break;
    }
  }
};

t.start();
// Sometime later
t.interrupt();
```

Sleep

The **Thread.sleep()** method can be used to pause the execution of current thread for specified time in milliseconds.

If the thread is interrupted during that time, an Exception is raised:

```
Thread t = new Thread() {
  @Override
  public void run() {
    while (true) {
      System.out.println("I'm alive!");
      try {
        Thread.sleep(100);
      } catch (InterruptedException e) {
        System.out.println("Interrupted");
        break;
      }
      if (isInterrupted()) break;
    }
  }
};
```

Multi-Threading

Multi-threading programming can be **tricky**!

```
class Model {
  int a = 0, b = 0;
  public void increment() { a++; b++; }
}

class View {
  public void draw(Model model) {
    System.out.println(model.a + " - " + model.b);
  }
}
```

```
Model m = new Model(); View v = new View();

new Thread() {
  public void run() { while (true) { m.increment(); } }
}.start();

new Thread() {
  // This will not always print two equal values
  public void run() { while (true) v.draw(m); }
}.start();
```

Synchronized Blocks

- To make threads play nice with each other, we can use **synchronized** blocks.
- Synchronized blocks use a mechanism known as **monitor locks** (or intrinsic locks).
- A **synchronized block** uses an object as a **lock**.
- **No** two threads can **enter** a **synchronized** block if using the **same object** as a lock.

Synchronized Block Example

Each loop is synchronized on the **same object** (the Model **m**).

So, **v.draw()** will never be called while **m.increment()** is being executed.

```
Model m = new Model(); View v = new View();

new Thread() {
  public void run() {
    while (true)
      synchronized (m) { m.increment(); }
  }
}.start();

new Thread() {
  public void run() {
    while (true)
      synchronized (m) { v.draw(m); }
  }
}.start();
```

Synchronized Methods

When a **synchronized method** is called, it **automatically** acquires the **intrinsic lock** for that **method's object** and **releases** it when the method **returns**.

```
class Model {
  int a = 0, b = 0;
  public synchronized void increment() { a++; b++; }
  public synchronized void draw() { System.out.println(a + " - " + b); }
}

Model m = new Model();

new Thread() {
  public void run() {
    while (true) { m.increment(); }
  }
}.start();


new Thread() {
  public void run() {
    while (true) { m.draw(); }
  }
}.start();
```

Wait and Notify

Sometimes we need a thread to wait until something happens.

The **Object.wait()** method, pauses a thread until another thread calls **Object.notify()** on the same object.

Calls to wait and notify must be **synchronized**.

```
Thread thread = new Thread() {
  @Override
  public synchronized void run() {
    try {
      wait();
      // Do something
    } catch (InterruptedException e) {
      e.printStackTrace();
    }
  }
};

thread.start();
// Sometime later
synchronized (thread) {
  thread.notify();
}
```

Input and Output

Streams

All fundamental I/O in Java is based on **streams**.

A stream represents a **flow** of **data** with a **writer** at one end and a **reader** at the other.

Abstract Streams

- **InputStream** and **OutputStream** are the basic **abstract** input and output stream for **unstructured bytes**.
- All other byte streams are built on top of these two classes.

- **Reader** and **Writer** are the basic **abstract** input and output stream for **unicode chars**.
- All other character stream are built on top of these two classes.

File Streams

FileInputStream, **FileOutputStream**, **FileReader** and **FileWriter** are implementations of **InputStream**, **OutputStream**, **Reader**, and **Writer** that read from and write to files on the local filesystem.

The **File** class represents a file in the local filesystem.

Examples:

```
FileInputStream fos = new FileInputStream(new File("level10.lvl"));
int b = fos.read();
```

```
FileReader fr = new FileReader(new File("level10.lvl"))
char c = (char) fos.read();
```

Bridge Streams

- **InputStreamReader** and **OutputStreamWriter** are classes that convert bytes to characters and vice versa.
- **DataInputStream** and **DataOutputStream** are specialized stream filters that add the ability to read and write primitive types.
- **ObjectInputStream** and **ObjectOutputStream** are stream filters that are capable of writing serialized Java objects and reconstructing them.

Example:

```
DataOutputStream dos = new DataOutputStream(
  new FileOutputStream( new File( "highscore.txt" ) )
);
dos.writeChars("HighScore");
dos.writeInt(1000);
dos.flush();
dos.close();
```

Buffered Streams

BufferedInputStream, **BufferedOutputStream**, **BufferedReader** and **BufferedWriter** add buffering capabilities to other streams. This increases efficiency.

Example:

```
DataOutputStream dos = new DataOutputStream(
  new BufferedOutputStream(
    new FileOutputStream( new File( "highscore.txt" ) )
  )
);
dos.writeChars("HighScore");
dos.writeInt(1000);
dos.flush();
dos.close();
```

Resources

Resources are pieces of data that **are part**, and can be **accessed**, from within a Java application.

When you create a **Java Gradle** project in **IntelliJ**, a folder for *resources* will be created inside both the **main** and **test** *src* folders.

To access them you can do something like this:

```
private static List<String> readLines(int levelNumber) throws IOException {
  URL resource = RoomLoader.class.getResource("/rooms/" + levelNumber + ".lvl");
  BufferedReader br = new BufferedReader(new FileReader(resource.getFile()));

  List<String> lines = new ArrayList<>();
  for (String line; (line = br.readLine()) != null; )
      lines.add(line);

  return lines;
}
```