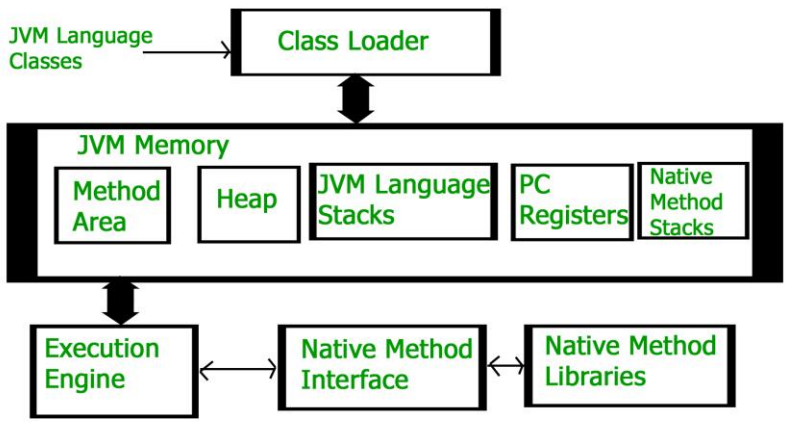
JVM Architecture : Working of JVM

What is Java Virtual Machine (JVM) ?

- It acts as a run-time engine to run Java applications.
- It is the one that actually calls the **main** method present in a java code.
- JVM is a part of **JRE**(Java Runtime Environment).
- Java applications are called **WORA** (Write Once Run Anywhere).
- We can develop Java code on one system and run on any other Java enabled system without any adjustment. This is all possible because of JVM.
- When we compile a *.java* file, *.class* files(contains byte-code) with the same class names present in *.java* file are generated by the Java compiler. This *.class* file goes into various steps when we run it. These steps together describe the whole JVM.



The 3 major section that the compiled program goes through when it is run are:

- Class Loader Subsystem
- JVM Memory
- Execution Engine

Class Loader Subsystem

It is mainly responsible for three activities.

1. Loading
2. Linking
3. Initialization

1. Loading

- The Class loader **reads the *.class* file**, generate the corresponding binary data and save it in method area.
- For each ***.class*** file, JVM stores following information in method area.
    - Fully qualified name of the loaded class and its immediate parent class.
    - Whether ***.class*** file is related to Class or Interface or Enum.
    - Modifier, Variables and Method information etc.
- **After loading *.class* file**, JVM creates an object of type Class to represent this file in the heap memory.
- Please note that this object is of type Class predefined in ***java.lang package***.
- This Class object can be used by the programmer for getting class level information like name of class, parent name, methods and variable information etc.
- To get this object reference we can use *getClass()* method of **Object class** discussed in other important concepts section.

```
package com.learn.java.sec1.jvm_architecture;

import java.lang.reflect.Field;
import java.lang.reflect.Method;

class Student  {
    private String name;
    private int roll_No;

    public String getName() {
        return name;
    }

    public void setName(String name) {
        this.name = name;
    }

    public int getRoll_no()  {
        return roll_No;
```

```
    }

    public void setRoll_no(int roll_no) {
        this.roll_No = roll_no;
    }
}


public class ClassObjectJVM {
    public static void main (String[] args) {
        Student s1 = new Student();

        // Getting hold of Class object created by JVM.
        Class c1 = s1.getClass();

        // Printing type of object using c1.
        System.out.println("Name of class: " + c1.getName());

        // getting all methods in an array
        System.out.println("\nAll the Declared Methods of the class: ");
        Method m[] = c1.getDeclaredMethods();
        for (Method method : m) {
            System.out.println(method.getName());
        }

        // getting all fields in an array
        System.out.println("\nAll the Declared Fields of the class: ");
        Field f[] = c1.getDeclaredFields();
        for (Field field : f) {
            System.out.println(field.getName());
        }

    }
}
```

Output:

Note:- For every loaded *.class* file, only one object of Class is created.

```
Student s2 = new Student();
// c2 will point to same object where c1 is pointing
Class c2 = s2.getClass();
System.out.println(c1==c2); // true
```

2. Linking

- It Performs verification, preparation and (optionally) resolution.
- **Verification:**
    - It ensures the ***correctness of .class file*** i.e. it check whether this file is properly formatted and generated by valid compiler or not.
    - If ***verification fails***, we get run-time exception ***java.lang.VerifyError***.
- **Preparation:**
    - JVM ***allocates memory for class variables*** and initializing the memory to default values.
- **Resolution:**
    - It is the process of ***replacing symbolic references from the type with direct references***.
    - It is done by searching into method area to locate the referenced entity.

3. Initialization

- In this phase, all static variables are assigned with their values defined in the code and static block(if any).
- This is executed from top to bottom in a class and from parent to child in class hierarchy.
- In general, there are three class loaders :
    - **Bootstrap class loader:**
        - Every JVM implementation must have a bootstrap class loader, capable of loading trusted classes.
        - It loads core java API classes present in ***JAVA_HOME/jre/lib*** directory.
        - This path is popularly known as bootstrap path. It is implemented in native languages like C, C++.
    - **Extension class loader:**
        - It is ***child of bootstrap class loader***.

        - It loads the classes present in the extensions directories ***JAVA_HOME/jre/lib/ext*(Extension path)** or any other directory specified by the java.ext.dirs system property.
        - It is implemented in java by the ***sun.misc.Launcher$ExtClassLoader*** class.
    - **System/Application class loader:**
        - It is ***child of extension class loader***.
        - It is responsible to load classes from application class path.
        - It internally uses Environment Variable which mapped to java.class.path.
        - It is also implemented in Java by the ***sun.misc.Launcher$AppClassLoader*** class.

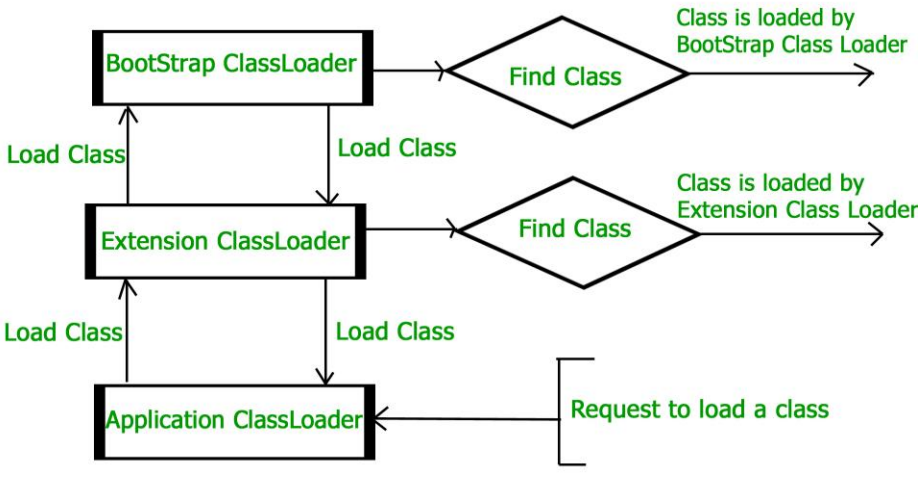
```
public class Test {
    public static void main(String[] args) {
        // String class is loaded by bootstrap loader, and
        // bootstrap loader is not Java object, hence null
        System.out.println(String.class.getClassLoader());

        // Test class is loaded by Application loader
        System.out.println(Test.class.getClassLoader());
    }
}
```

Output:

```
null
sun.misc.Launcher$AppClassLoader@73d16e93
```

Notes:

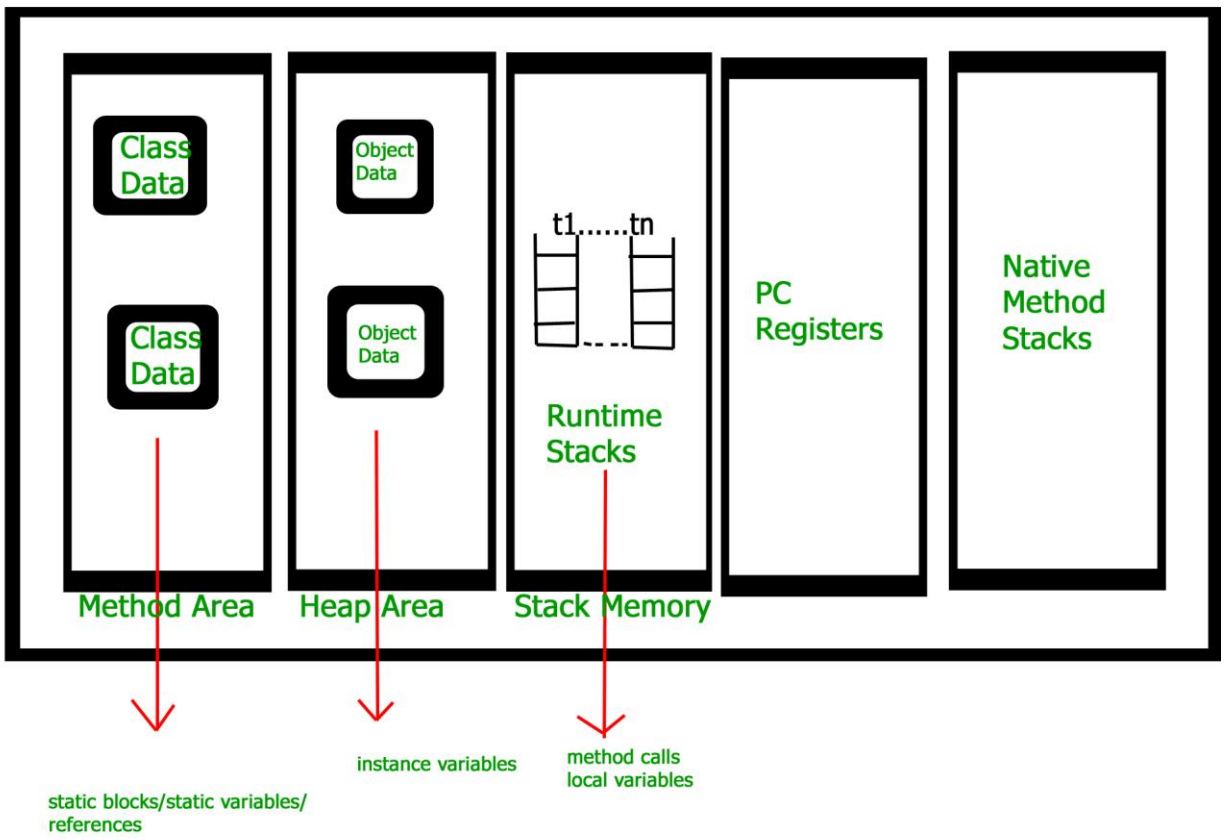
- JVM follow Delegation-Hierarchy principle to load classes.
- System class loader delegate load request to extension class loader and extension class loader delegate request to boot-strap class loader.
- If class found in boot-strap path, class is loaded otherwise request again transfers to extension class loader and then to system class loader.
- At last if system class loader fails to load class, then we get run-time exception ***java.lang.ClassNotFoundException***.



JVM Memory

Components of JVM Memory

- **Method area :**
    - In method area, all class level information like class name, immediate parent class name, methods and variables information etc. are stored, including static variables.
    - There is only one method area per JVM, and it is a shared resource.
- **Heap area :**
    - Information of all objects is stored in heap area.
    - There is also one Heap Area per JVM. It is also a shared resource.
- **Stack area :**
    - For every thread, JVM create one run-time stack which is stored here.
    - Every block of this stack is called activation record/stack frame which store methods calls.
    - All local variables of that method are stored in their corresponding frame.
    - After a thread terminate, it's run-time stack will be destroyed by JVM.
    - It is not a shared resource.
- **PC Registers :**
    - Store address of current execution instruction of a thread.
    - Obviously each thread has separate PC Registers.
- **Native method stacks :**
    - For every thread, separate native stack is created.
    - It stores native method information.



##Execution Engine

- Execution engine execute the *.class* (bytecode).
- It reads the byte-code line by line, use data and information present in various memory area and execute instructions.
- It can be classified in 3 parts:
    - **Interpreter:**
        - It interprets the bytecode line by line and then executes.
        - The disadvantage here is that when one method is called multiple times, every time interpretation is required.
    - **Just-In-Time Compiler(JIT):**
        - It is used to increase efficiency of interpreter.
        - It compiles the entire bytecode and changes it to native code.
        - So whenever interpreter see repeated method calls, JIT provide direct native code for that part so re-interpretation is not required, thus efficiency is improved.
    - **Garbage Collector:**
        - It destroy un-referenced objects.
        - Refer Garbage Collector.

Java Native Interface (JNI).

- It is an interface which interacts with the Native Method Libraries and provides the native libraries(C, C++) required for the execution.
- It enables JVM to call C/C++ libraries and to be called by C/C++ libraries which may be specific to hardware.
- Native Method Libraries:
    - It is a collection of the Native Libraries(C, C++) which are required by the Execution Engine.