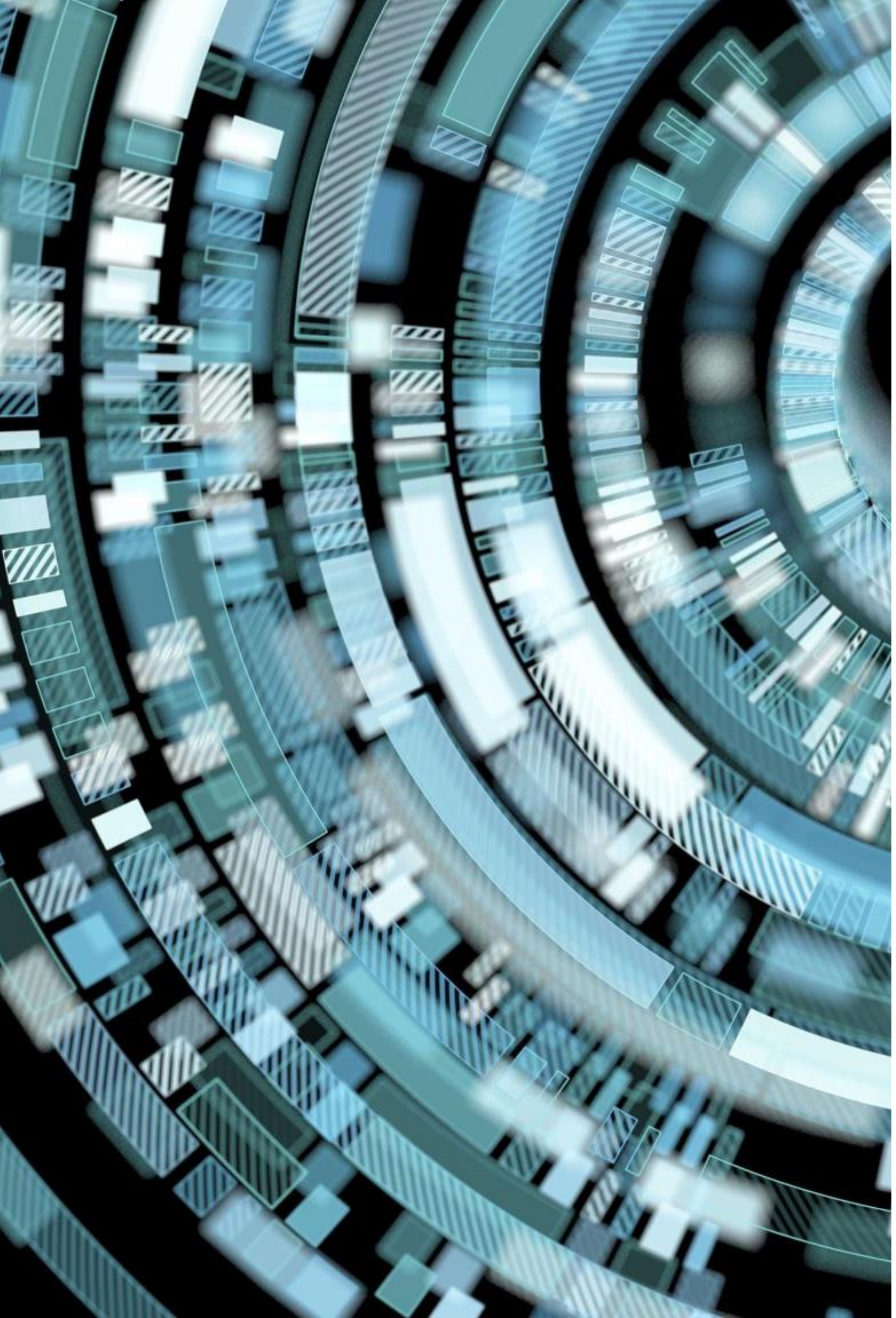
Computer System Design & Application

计算机系统设计与应用A

陶伊达 （TAO Yida）

taoyd@sustech.edu.cn



Lecture 1

- Course introduction
- Computer system & programs
- Java overview, JVM, and Virtualization
- Java programming basics
- Software design principles
- Object-Oriented Programming Basics

Course Logistics

Lecturer: 陶伊达, taoyd@sustech.edu.cn

Lab Tutor: 赵耀, zhaoy6@sustech.edu.cn

理论课 （1-16周）

每周二下午，7-8节，荔园2栋102

实验课 （1-16周）

实验1班	周三下午，5-6节	二教101	赵耀（SA：吴伟，吴培霖）
实验2班	周三上午，3-4节	二教101	赵耀（SA：王力爽，李伯岩）
实验3班	周三下午，5-6节	荔园6栋408机房	陶伊达 (SA：黄炜杰，钟万里)

Course Logistics

- Course website: Sakai (CS209A_2022_Spring)
  Slides and other resources will all be uploaded here.

- Office hours: Monday 10:30 – 11:30 am

- Lecture QQ group: 596585409

Course Objective

- An understanding of new topics in programming and computer application system design
- An understanding of design principles and good practices in software application design & development
- An understanding of advanced programming topics and skills useful for scientific & engineering students
- Using Java to solve practical problems efficiently and effectively

Topics covered

Principles

- OOP
- Design patterns
- Functional programming
- Reusable software
- Software engineering

……

Utilities

- Exception handling
- Generic collections
- Lambdas & Streams
- Testing

……

Functionalities

- File I/O
- GUI
- Networking
- Web applications
- Web services

……

Applications

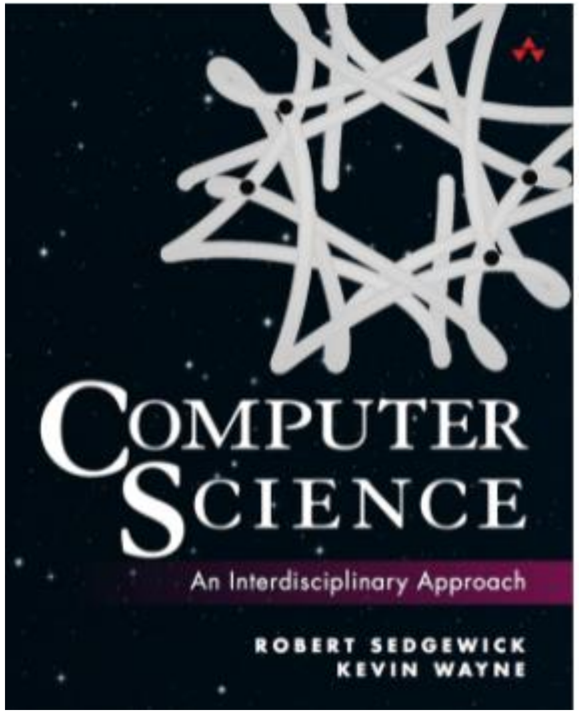
- Data analytics and visualization
- Text scraping and processing

……

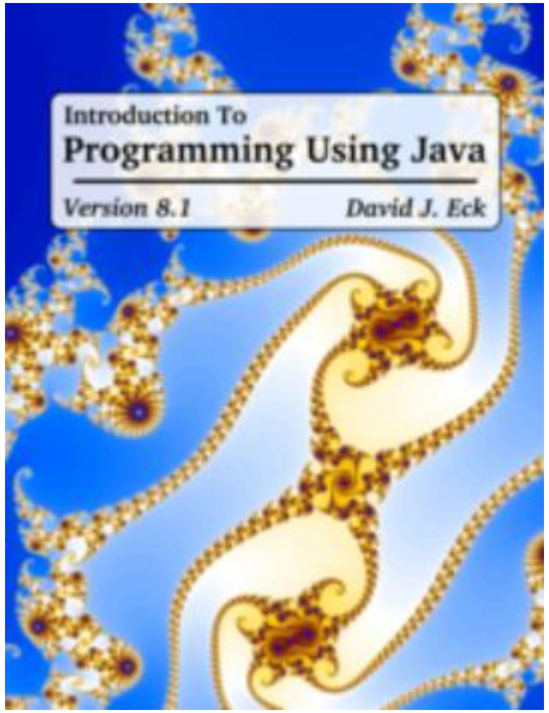
Syllabus
(Negotiable)

- Lecture 1: Computing overview, Java and OOP basics
- Lecture 2: OOP, Exception handling, File I/O, Persistence
- Lecture 3: Generics, ADT, Collection,
- Lecture 4: Functional programming, Lambda, Stream API
- Lecture 5: Reusable software, GUI intro
- Lecture 6: JavaFX, data visualization
- Lecture 7: Concurrency, Multithreading
- Lecture 8: Networking, Socket
- Lecture 9: Web application, database
- Lecture 10: Web services, REST
- Lecture 11: Software engineering process, testing
- Lecture 12: Text Processing, web scraping
- Lecture 13: Design patterns, refactoring
- Lecture 14: Scoping, Reflection, etc.
- Lecture 15: Miscellaneous

Reference Books

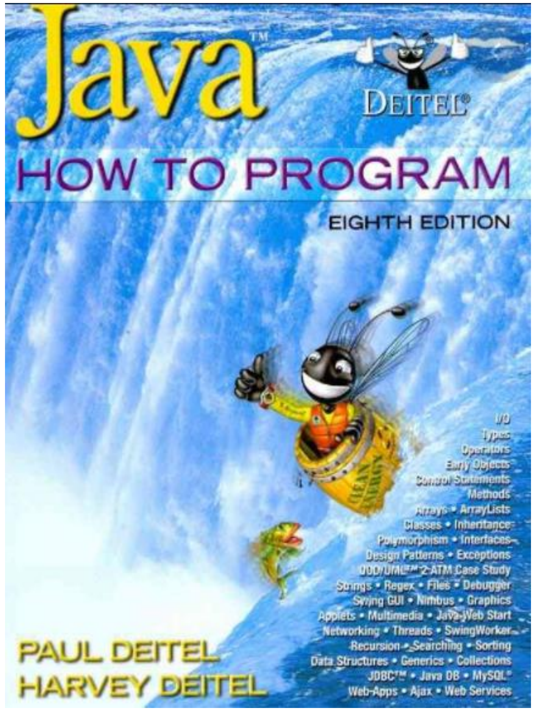


Computer Science: An Interdisciplinary Approach
Robert Sedgewick and Kevin Wayne.
https://introcs.cs.princeton.edu/java/home/

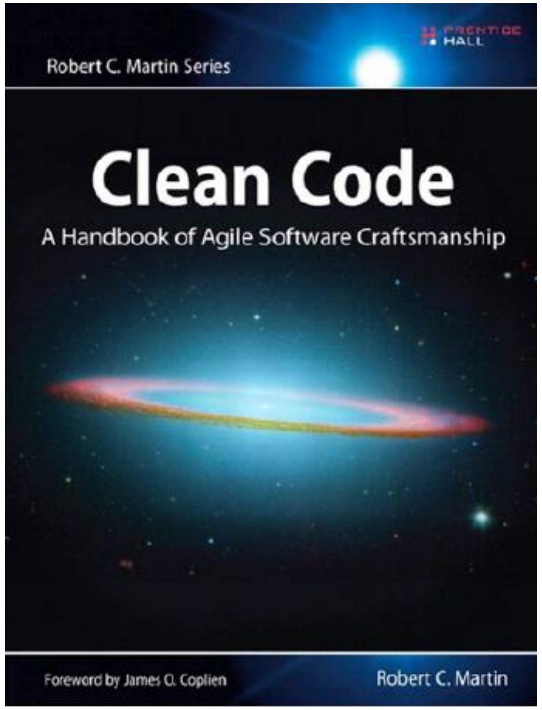


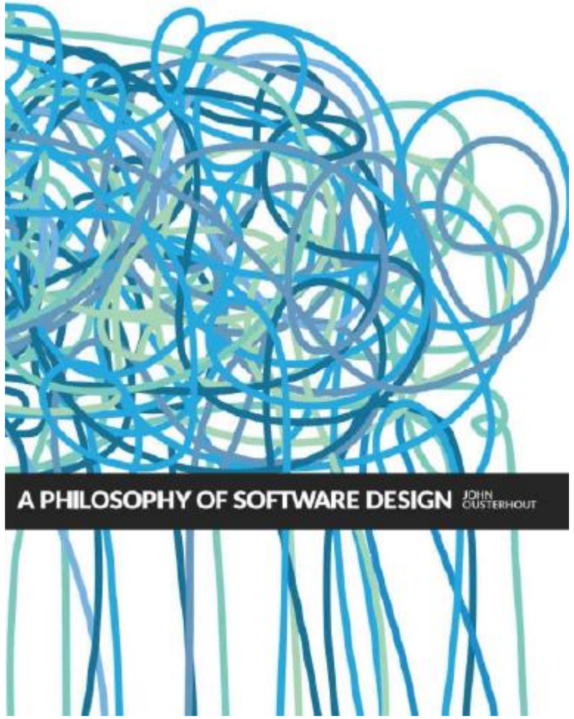
Introduction to Programming Using Java, 8th Edition
David J. Eck
https://math.hws.edu/eck/cs124/javanotes8/

Reference Books


Java™
DEITEL®
HOW TO PROGRAM
EIGHTH EDITION
I/O
Types
Operators
Early Objects
Control Statements
Methods
Arrays • ArrayLists
Classes • Inheritance
Polymorphism • Interfaces
Design Patterns • Exceptions
OOD/UML™ 2 ATM Case Study
Strings • Regex • Files • Debugger
Swing GUI • Nimbus • Graphics
Applets • Multimedia • Java Web Start
Networking • Threads • SwingWorker
Recursion • Searching • Sorting
Data Structures • Generics • Collections
JDBC™ • Java DB • MySQL®
Web-Apps • Ajax • Web Services
PAUL DEITEL
HARVEY DEITEL

Cay Horstmann
Java Concepts
3/e
Late Objects
Includes Java 8 coverage
WILEY


PRENTICE HALL
Robert C. Martin Series
Clean Code
A Handbook of Agile Software Craftsmanship
Foreword by James O. Coplien
Robert C. Martin



Coursework & Grading Policy

	Score	Description
Labs	15%	12 labs (negotiable), 1.25 points each (0.25 for attendance + 1 for task completion)
Assignments	20%	2 assignments, 10 points each Assignment 1: release at week 4 and due at week 6 Assignment 2: release at week 6 and due at week 8
Quiz	10%	Quizzes during lectures (5%) Online test during lab at week 8 (5%)
Project	25%	Released before week 8 Team: Preferably 2 people Implementation 20%, Presentation 5%
Final Exam	30%	Open book No electronic device

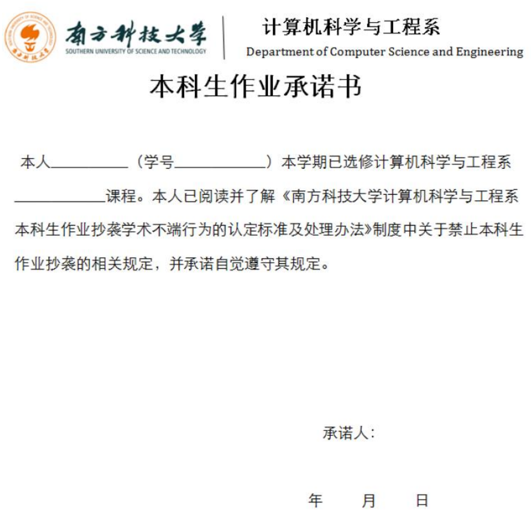
Labs start from the 1st week!

Academic Integrity

- It's OK to work on an assignment with a friend, and think together about the program structure, share ideas and even the global logic. At the time of actually writing the code, you should write it alone.
- It's OK to use in an assignment a piece of code found on the web, as long as you indicate in a comment where it was found and don't claim it as your own work.
- It's OK to help friends debug their programs (you'll probably learn a lot yourself by doing so).
- It's OK to show your code to friends to explain the logic, as long as the friends write their code on their own later.

- It's NOT OK to take the code of a friend, make a few cosmetic changes (comments, some variable names) and pass it as your own work.

Please submit the form before the end of the course selection & drop period!



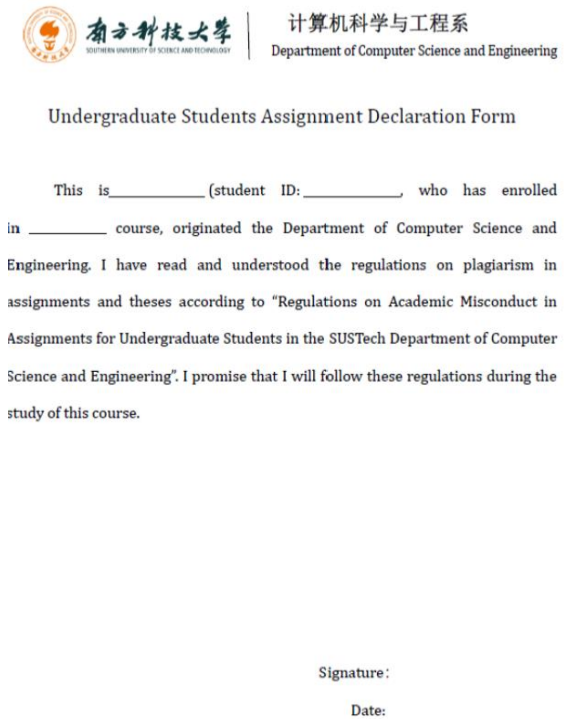
南方科技大学 SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY | 计算机科学与工程系 Department of Computer Science and Engineering

本科生作业承诺书

本人__________（学号___________）本学期已选修计算机科学与工程系___________课程。本人已阅读并了解《南方科技大学计算机科学与工程系本科生作业抄袭学术不端行为的认定标准及处理办法》制度中关于禁止本科生作业抄袭的相关规定，并承诺自觉遵守其规定。

承诺人：

年　　月　　日



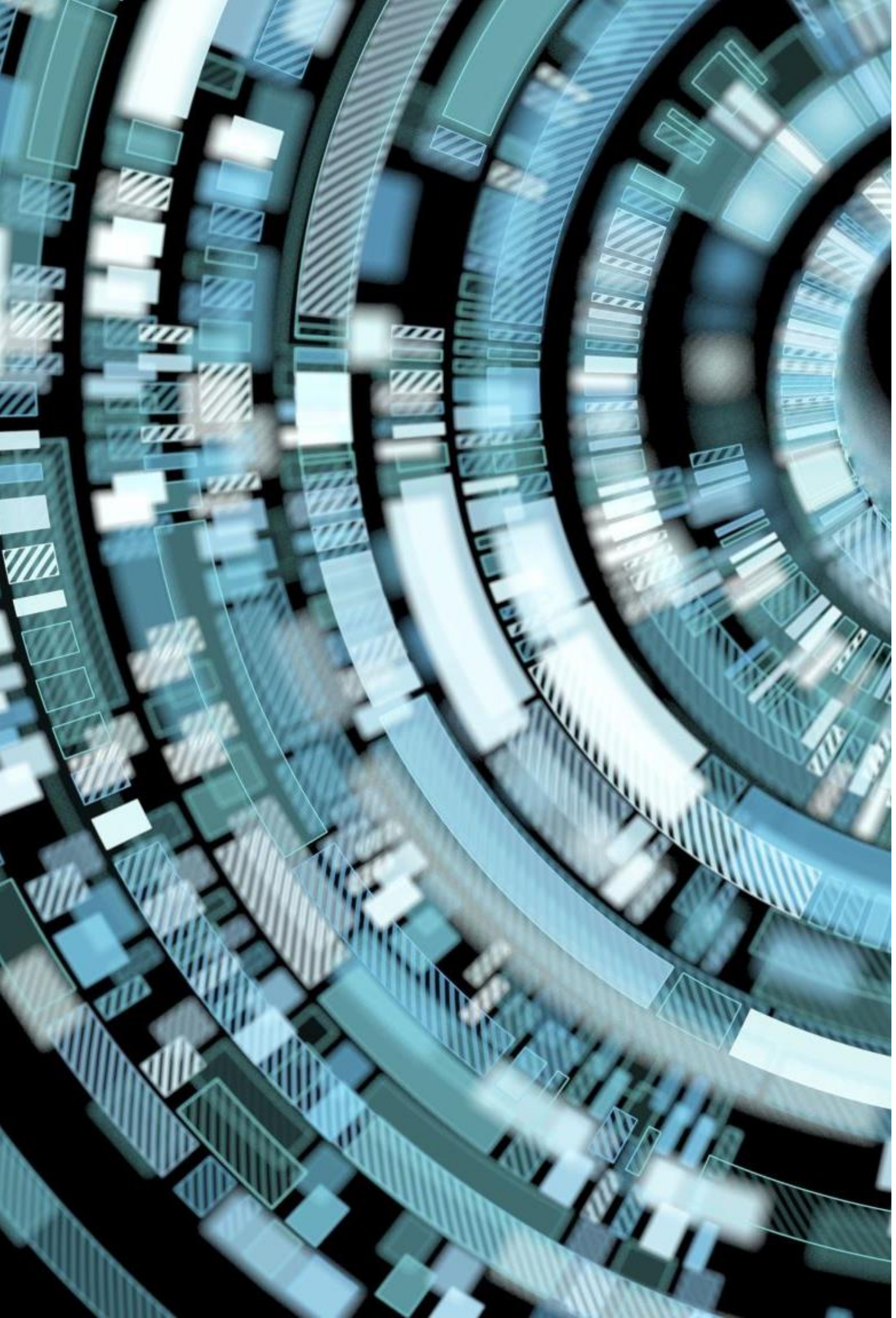
南方科技大学 SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY | 计算机科学与工程系 Department of Computer Science and Engineering

Undergraduate Students Assignment Declaration Form

This is__________(student ID:__________, who has enrolled in _________ course, originated the Department of Computer Science and Engineering. I have read and understood the regulations on plagiarism in assignments and theses according to "Regulations on Academic Misconduct in Assignments for Undergraduate Students in the SUSTech Department of Computer Science and Engineering". I promise that I will follow these regulations during the study of this course.

Signature:

Date:



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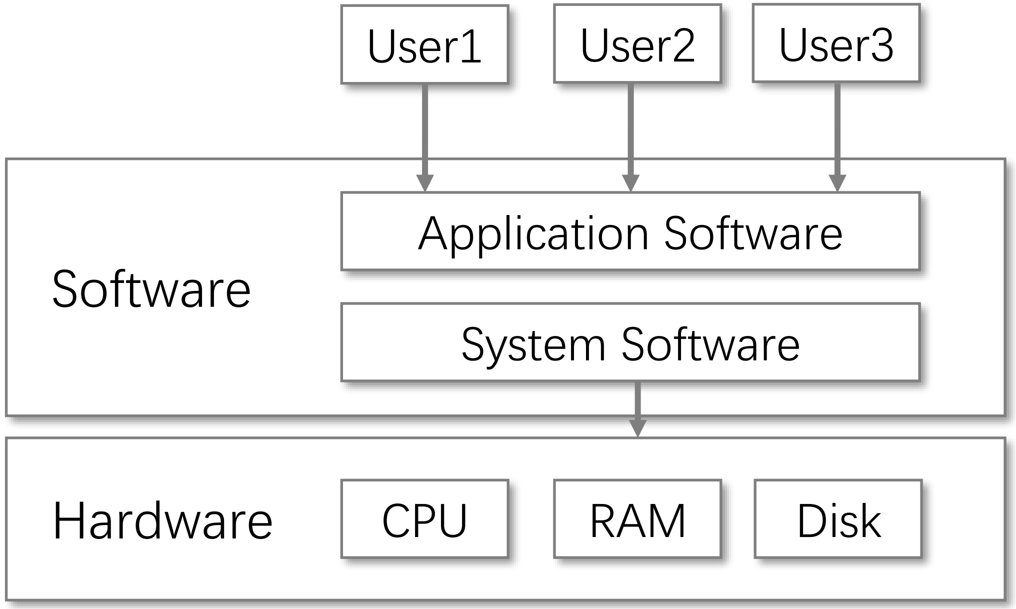
Computer System

- Hardware
  - The physical parts: CPU, keyboard, disks

- Software
  - System software: a set of programs that control & manage the operations of hardware, e.g., OS
  - Application software: a set of programs for end users to perform specific tasks, e.g., browser, media player



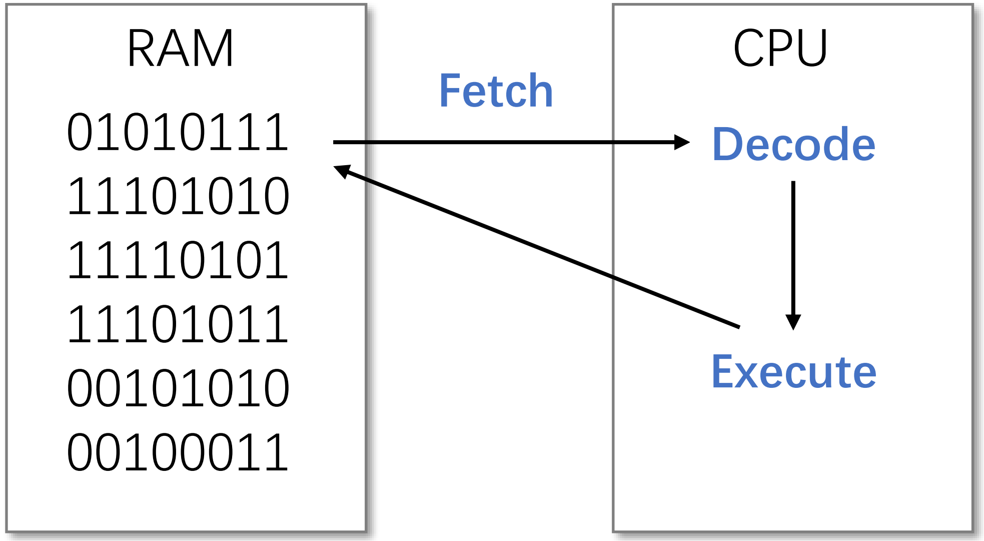
Programs

- A sequence of instructions that specifies how to perform a computation

Fetch-Decode-Execute Cycle

- **Fetch**: Get the next instruction from memory
- **Decode**: Interpret the instruction
- **Execute**: Pass the decoded info as a sequence of control signals to relevant CPU units to perform the action

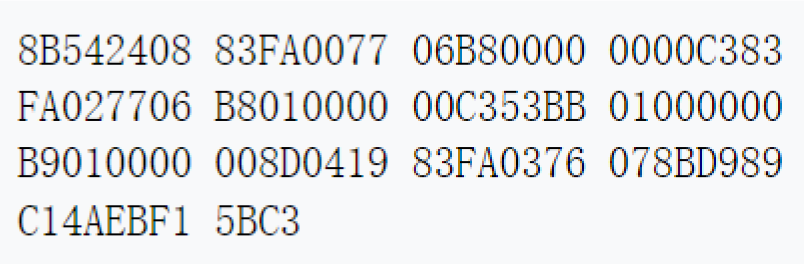
The fetch-execute cycle was first proposed by **John von Neumann**, who is famous for the **Von Neumann architecture**, which is being followed by most computers today



Programs

- A sequence of instructions that specifies how to perform a computation

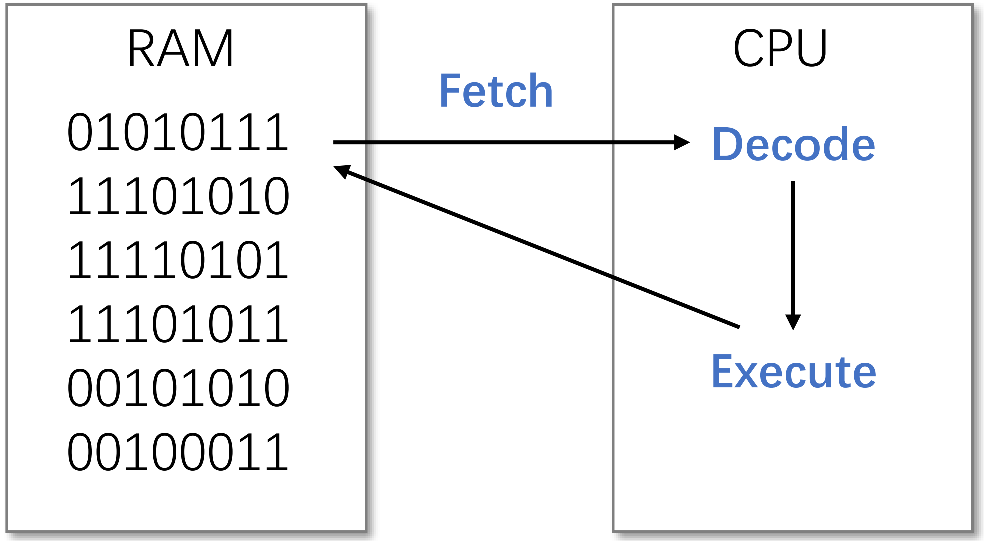
☹ **Machine-language instructions are hard to read & write for human.**



```
8B542408 83FA0077 06B80000 0000C383
FA027706 B8010000 00C353BB 01000000
B9010000 008D0419 83FA0376 078BD989
C14AEBF1 5BC3
```

A function in hexadecimal (十六进制) to calculate Fibonacci number

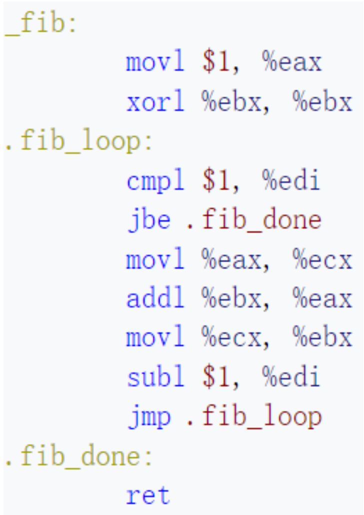
Source: https://en.wikipedia.org/wiki/Low-level_programming_language



Programs

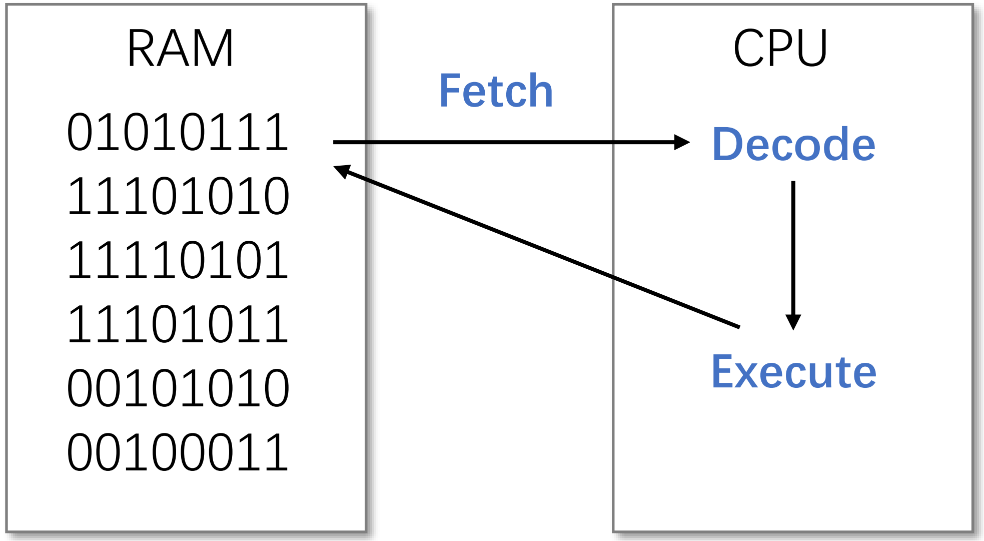
- A sequence of instructions that specifies how to perform a computation

Low-level language provides a level of abstraction on top of machine code



```
_fib:
        movl $1, %eax
        xorl %ebx, %ebx
.fib_loop:
        cmpl $1, %edi
        jbe .fib_done
        movl %eax, %ecx
        addl %ebx, %eax
        movl %ecx, %ebx
        subl $1, %edi
        jmp .fib_loop
.fib_done:
        ret
```

A function in assembly (汇编) to calculate Fibonacci number



RAM

01010111
11101010
11110101
11101011
00101010
00100011

Fetch

CPU

Decode

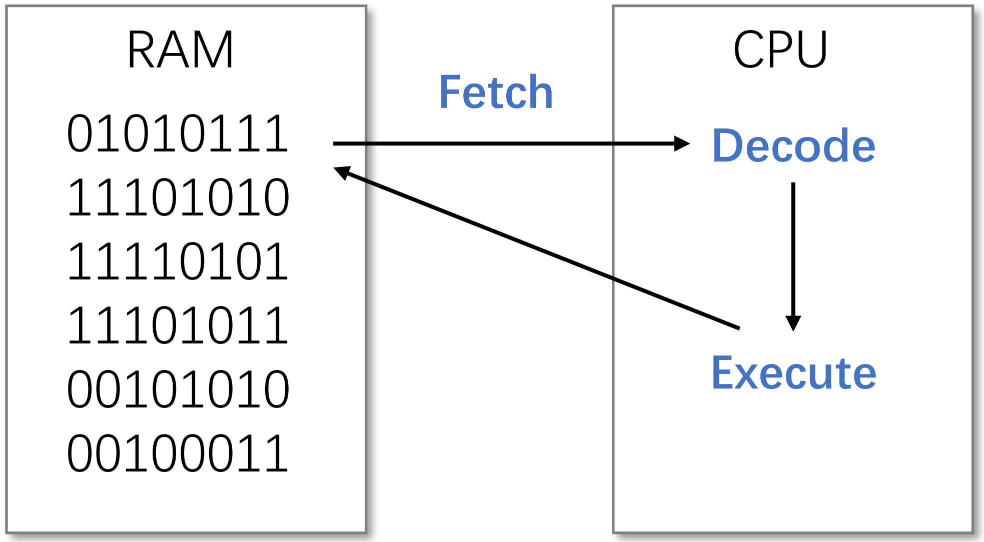
Execute

Source: https://en.wikipedia.org/wiki/Low-level_programming_language

Programs

- A sequence of instructions that specifies how to perform a computation

Low-level language provides a level of abstraction on top of machine code



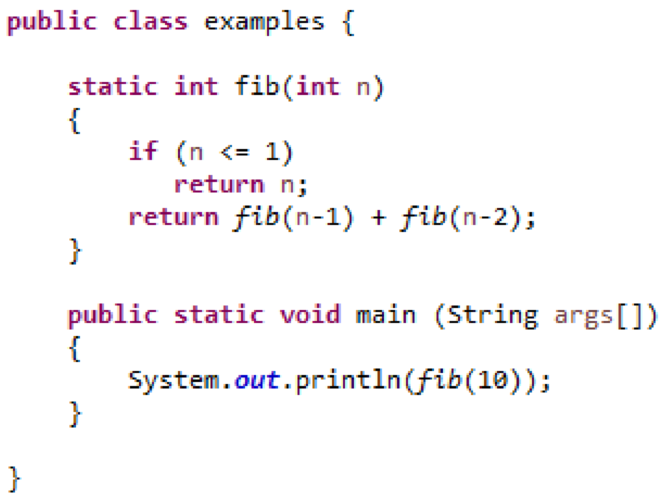
A video game written in assembly

Source: https://en.wikipedia.org/wiki/Prince_of_Persia_(1989_video_game)

Programs

- A sequence of instructions that specifies how to perform a computation

High-level language (e.g., C++, Java, Python, etc.) provides stronger abstraction and resembles more of natural language



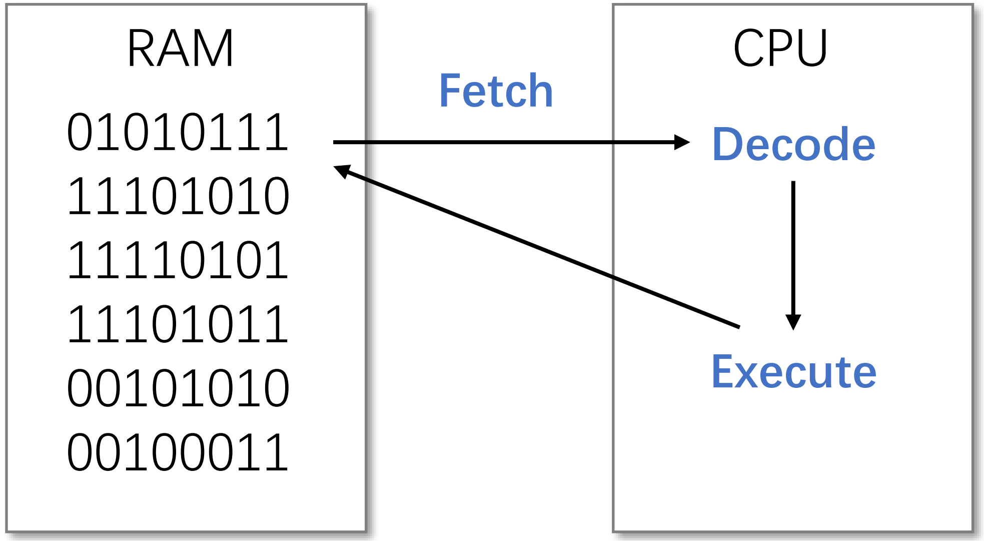
```
public class examples {

    static int fib(int n)
    {
        if (n <= 1)
           return n;
        return fib(n-1) + fib(n-2);
    }

    public static void main (String args[])
    {
        System.out.println(fib(10));
    }

}
```

A function in Java to calculate Fibonacci number



RAM

01010111
11101010
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00100011

Fetch

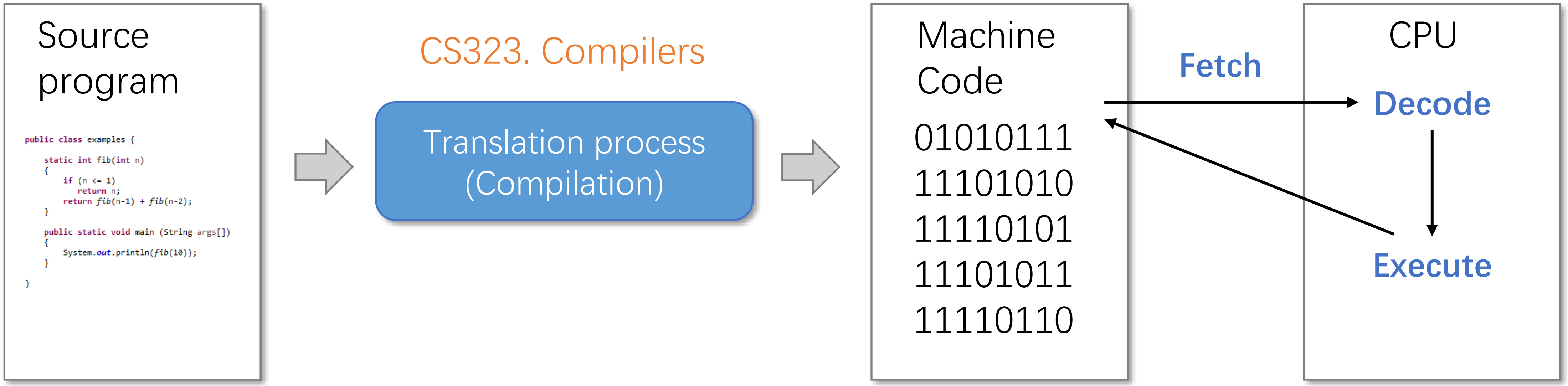
CPU

Decode

Execute

Programs

- A sequence of instructions that specifies how to perform a computation



Source program

```
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    {
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}
```

CS323. Compilers

Translation process (Compilation)

Machine Code

01010111
11101010
11110101
11101011
11110110

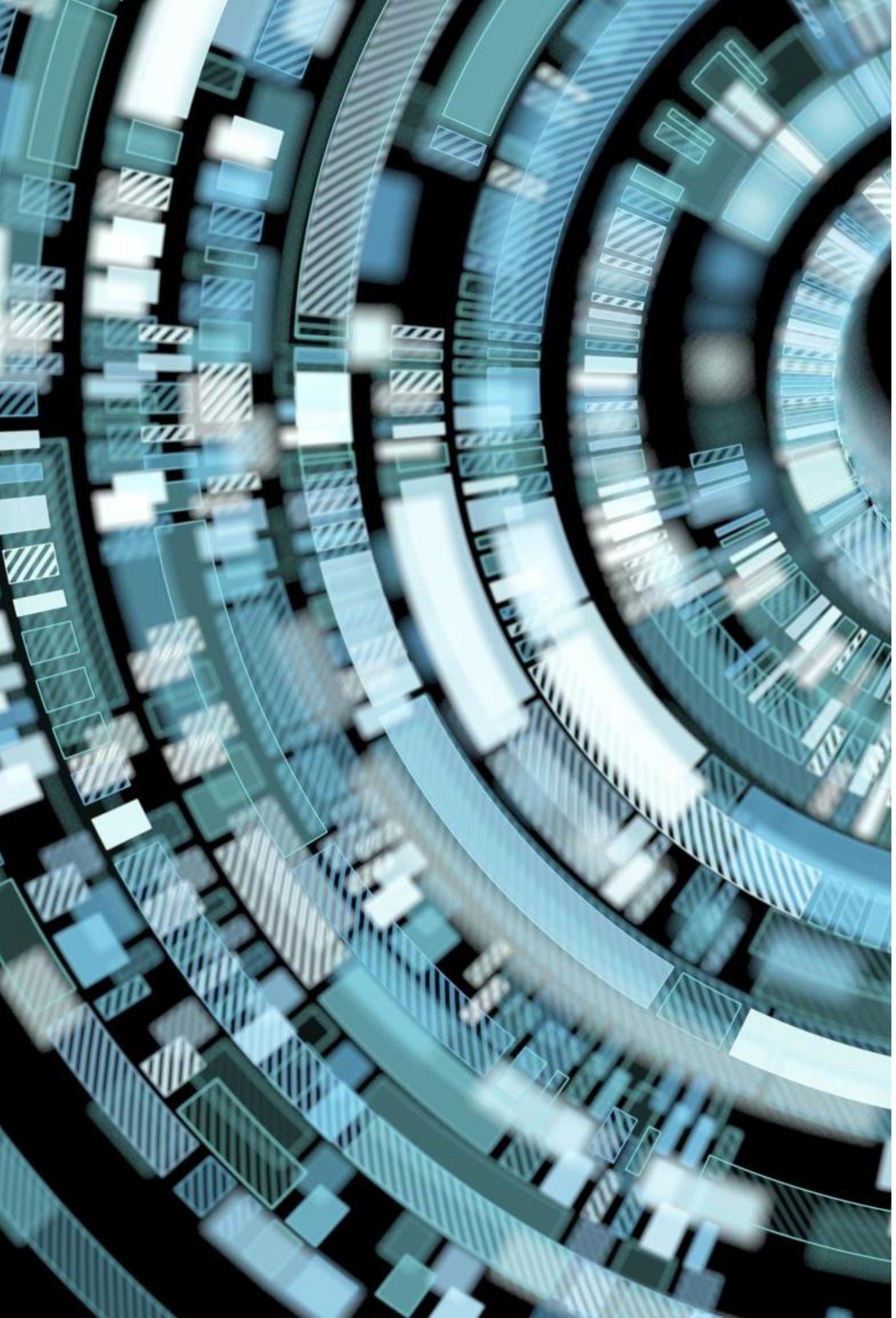
Fetch

CPU

Decode

Execute

CS202. Computer Organization



Lecture 1

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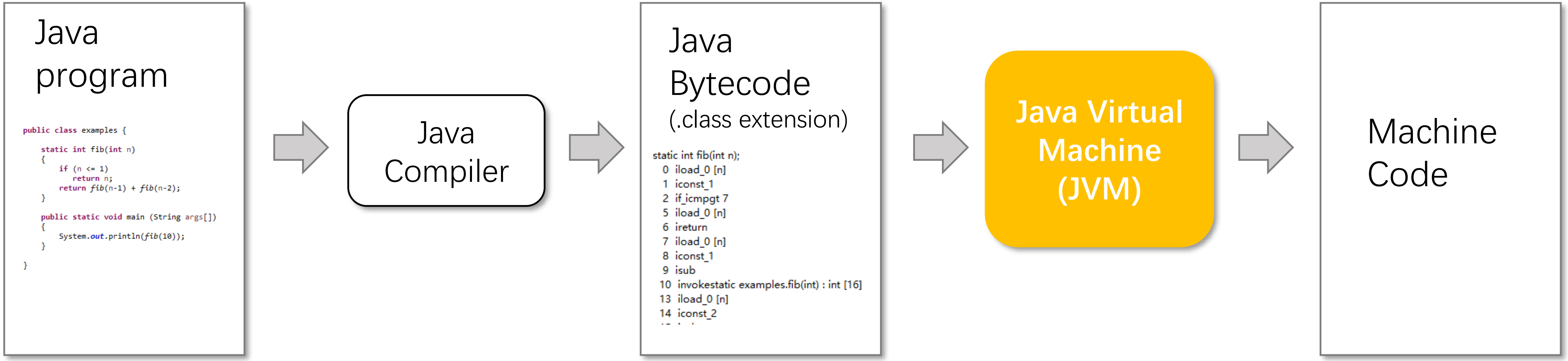
How is a Java program executed?

- Same principle: high-level source → low-level/machine code



Java program

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

}
```

Java Compiler

Java Bytecode (.class extension)

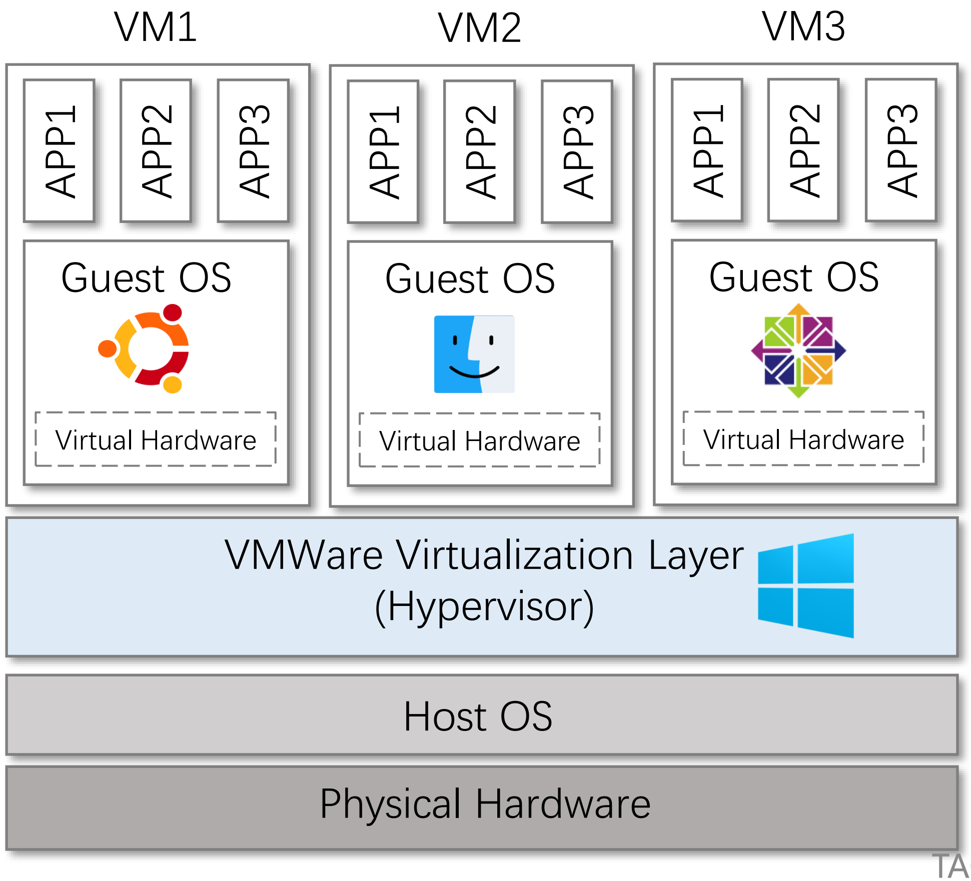
```
static int fib(int n);
  0  iload_0 [n]
  1  iconst_1
  2  if_icmpgt 7
  5  iload_0 [n]
  6  ireturn
  7  iload_0 [n]
  8  iconst_1
  9  isub
 10  invokestatic examples.fib(int) : int [16]
 13  iload_0 [n]
 14  iconst_2
```

Java Virtual Machine (JVM)

Machine Code

Virtualization

- Creating a virtual (instead of actual) version of something, such as hardware, server, operating system, etc., hiding the physical characteristics of the computing platform



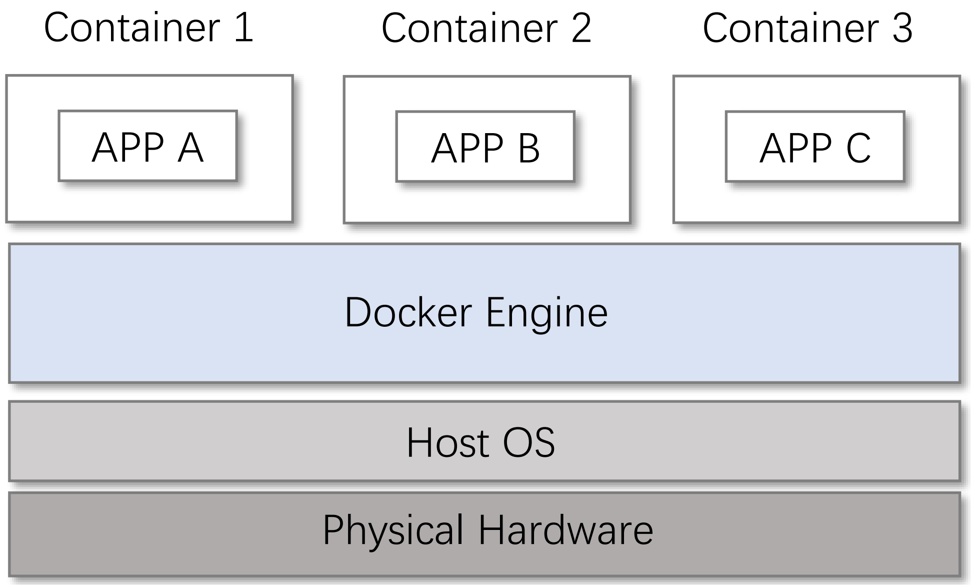
- Physical computer (host machine) runs the host OS

- Virtualization uses a software layer (hypervisor) to simulate the hardware

- Different guest OS could be created, which interacts with the virtual hardware

Virtualization

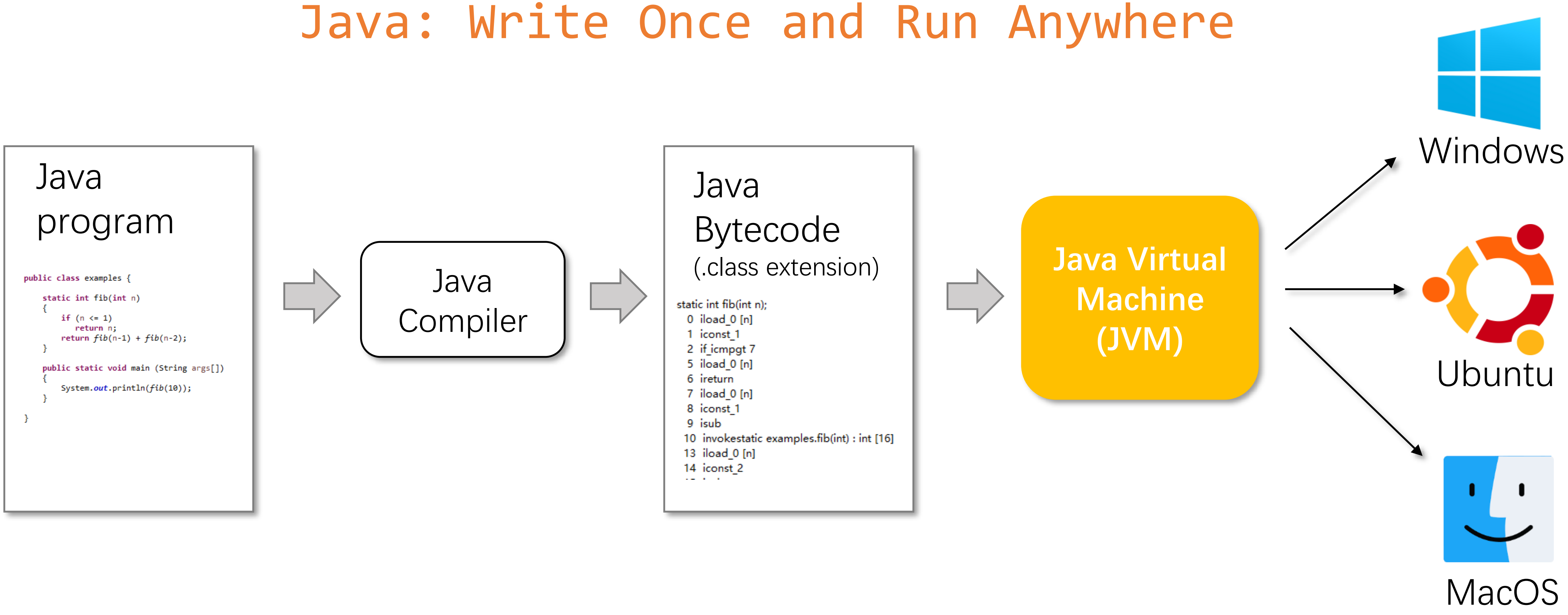
- Creating a virtual (instead of actual) version of something, such as hardware, server, operating system, etc., hiding the physical characteristics of the computing platform



- A container consists of all the dependencies required to run an application, and isolates these dependencies from other containers on the same machine
- Containers virtualize the OS
- More lightweight, more portable

Java Virtual Machine (JVM)

Java: Write Once and Run Anywhere



Java program

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   6  ireturn
   7  iload_0 [n]
   8  iconst_1
   9  isub
  10  invokestatic examples.fib(int) : int [16]
  13  iload_0 [n]
  14  iconst_2
```
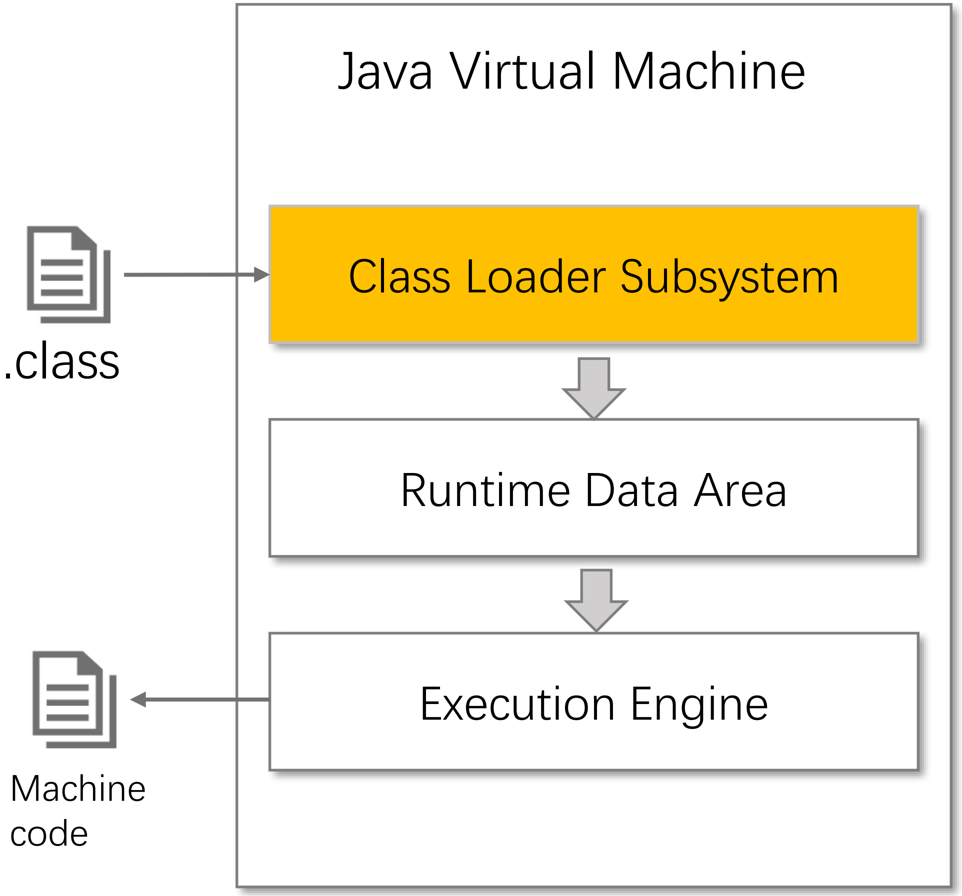

Java Virtual Machine (JVM)

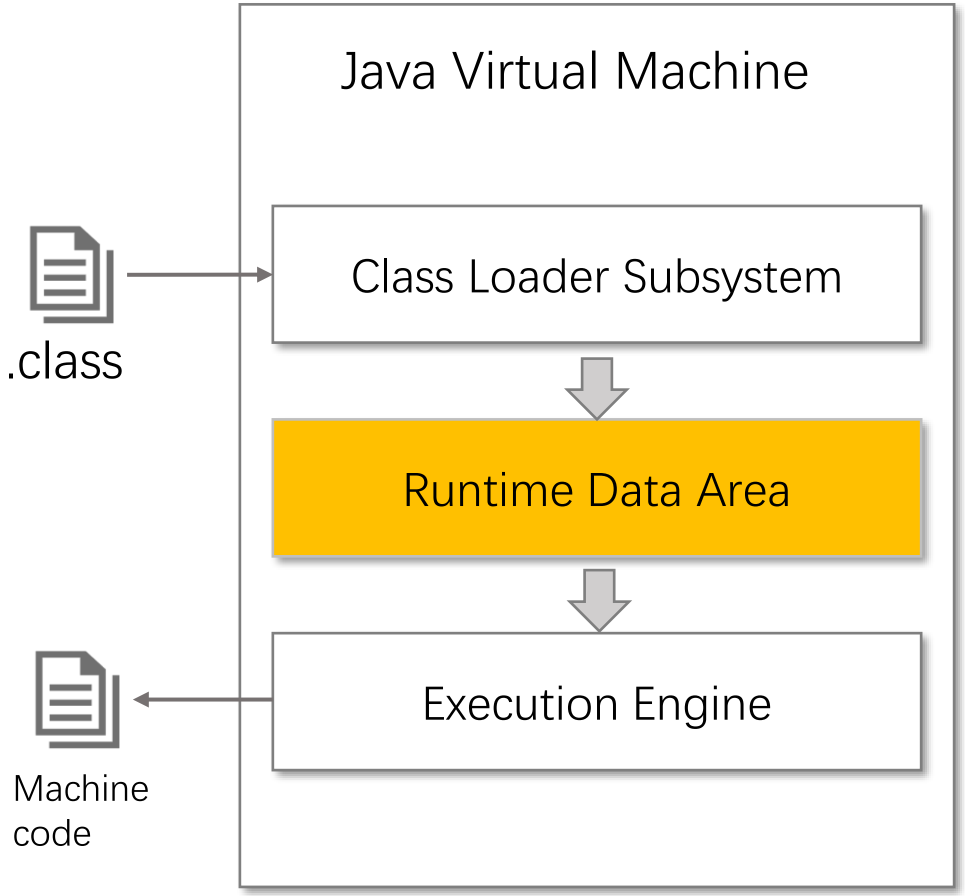
Java Virtual Machine (JVM)



Class Loader

- Locating and loading necessary .class or .jar (**J**ava **AR**chive, aggregations of .class files) files into memory
  - .jar that offers standard Java packages (e.g., java.lang, java.io)
  - .class and .jar (dependency) for your application, which is specified in *classpath*
- Errors occur when class loader fails to locate a required .class

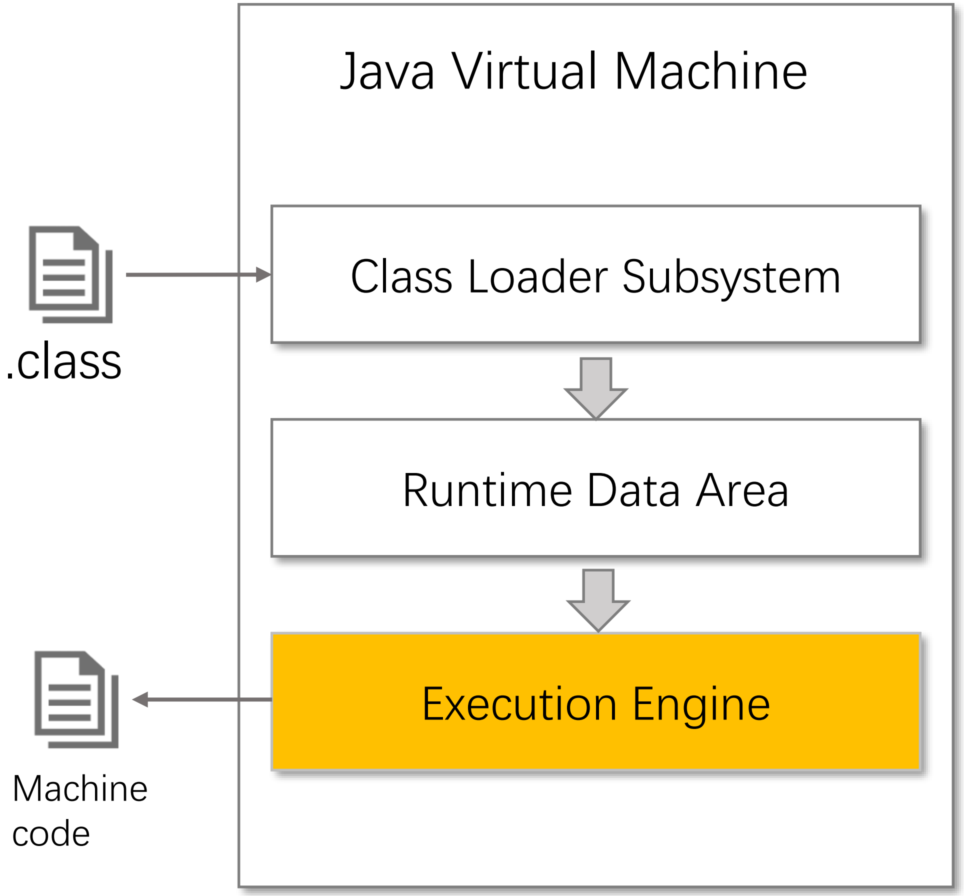
Java Virtual Machine (JVM)



Runtime Data Area

- Store all kinds of data and information
  - Class-level data in Method Area
  - Objects/instances in Heap Area
  - Local variables in Stack Area
- Support for threads, allowing tasks to be performed independently and concurrently

Java Virtual Machine (JVM)



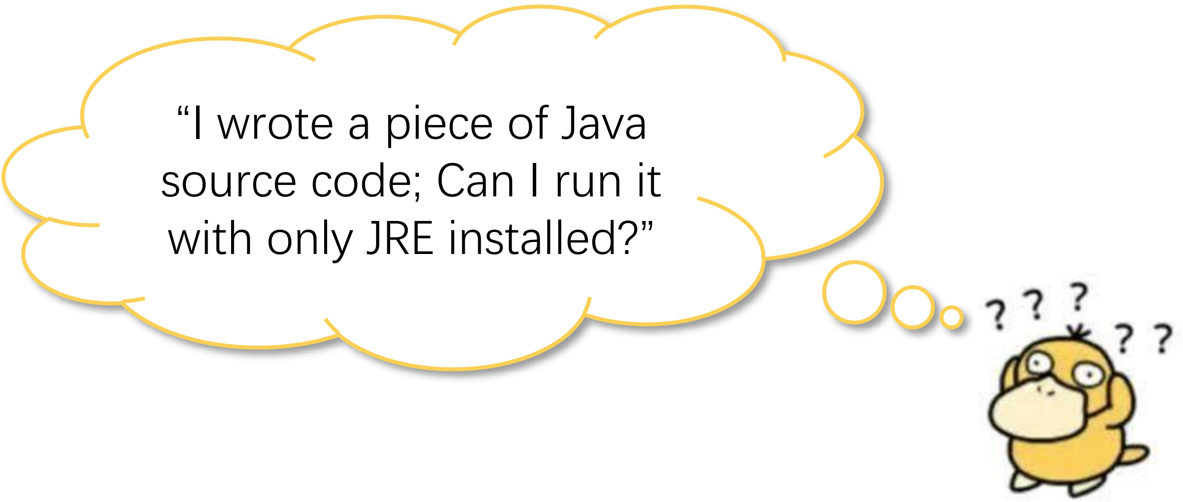
Execution Engine

- Translating “run anywhere” .class code to “run on this particular machine” instructions
- Translation is done by Interpreter and JIT Compiler (also for optimization)
- Finally, garbage collector identifies objects that are no longer in use and reclaims the memory

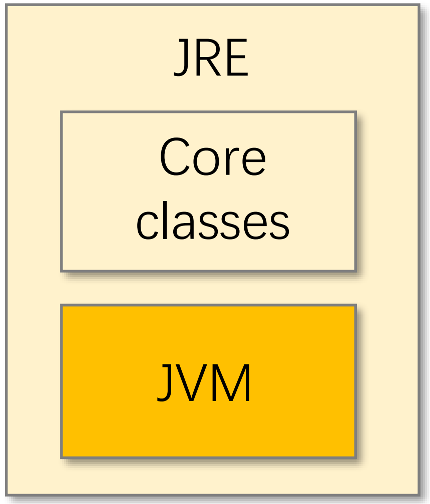
JVM, JRE, and JDK

JRE: **J**ava **R**untime **E**nvironment

- Contains JVM and Core Java Classes (e.g., java.io, java.lang) for built-in functionalities
- Could be used to execute Java programs or applications



"I wrote a piece of Java source code; Can I run it with only JRE installed?"



JRE

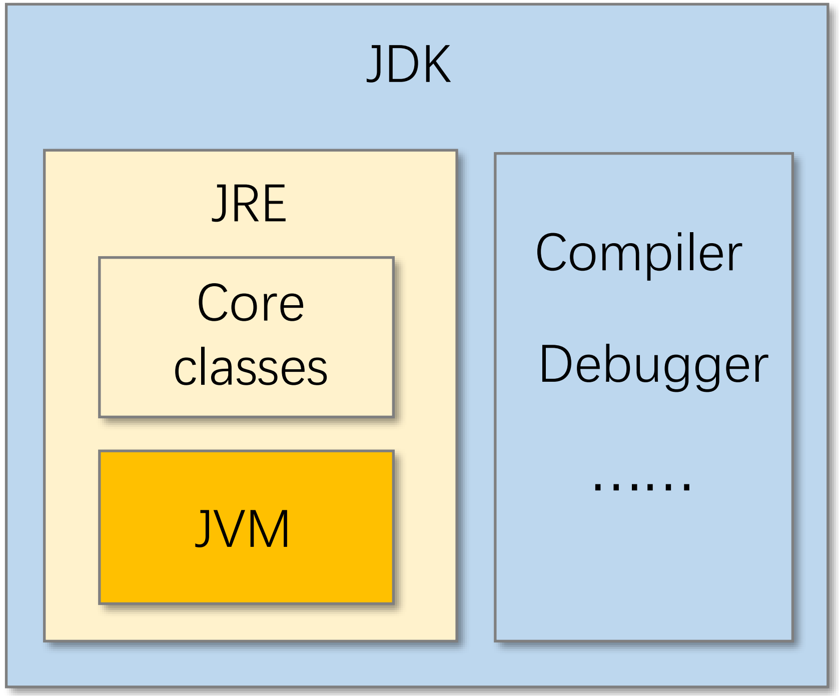
Core classes

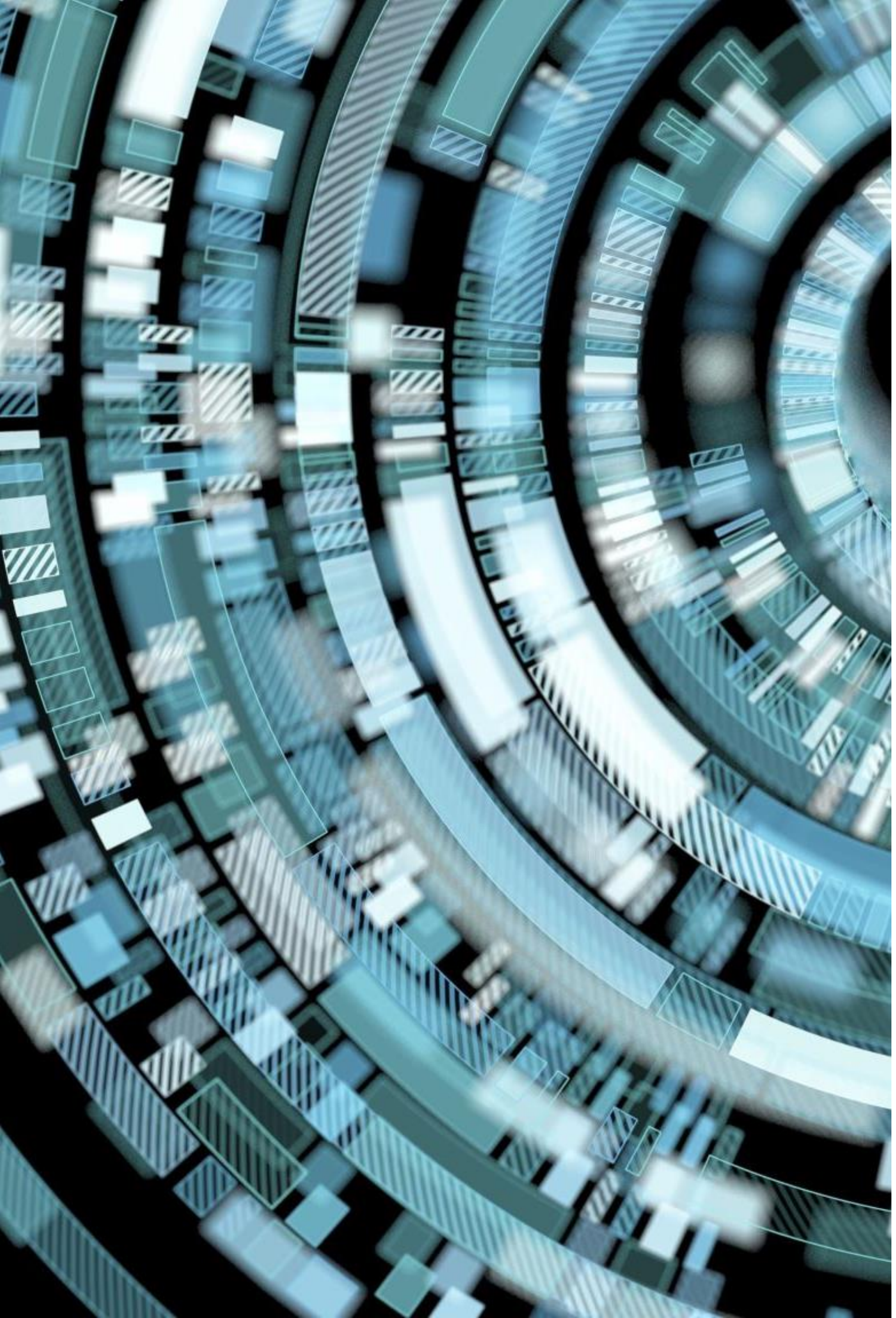
JVM

JVM, JRE, and JDK

JDK: **J**ava **D**evelopment **K**it

- Contains JRE and development tools, e.g., compiler, debugger, etc. (no need to install JRE separately if JDK is already installed)
- Compiler transform source code to byte code (.class) then JRE kicks in
- Usage scenarios for JRE and JDK





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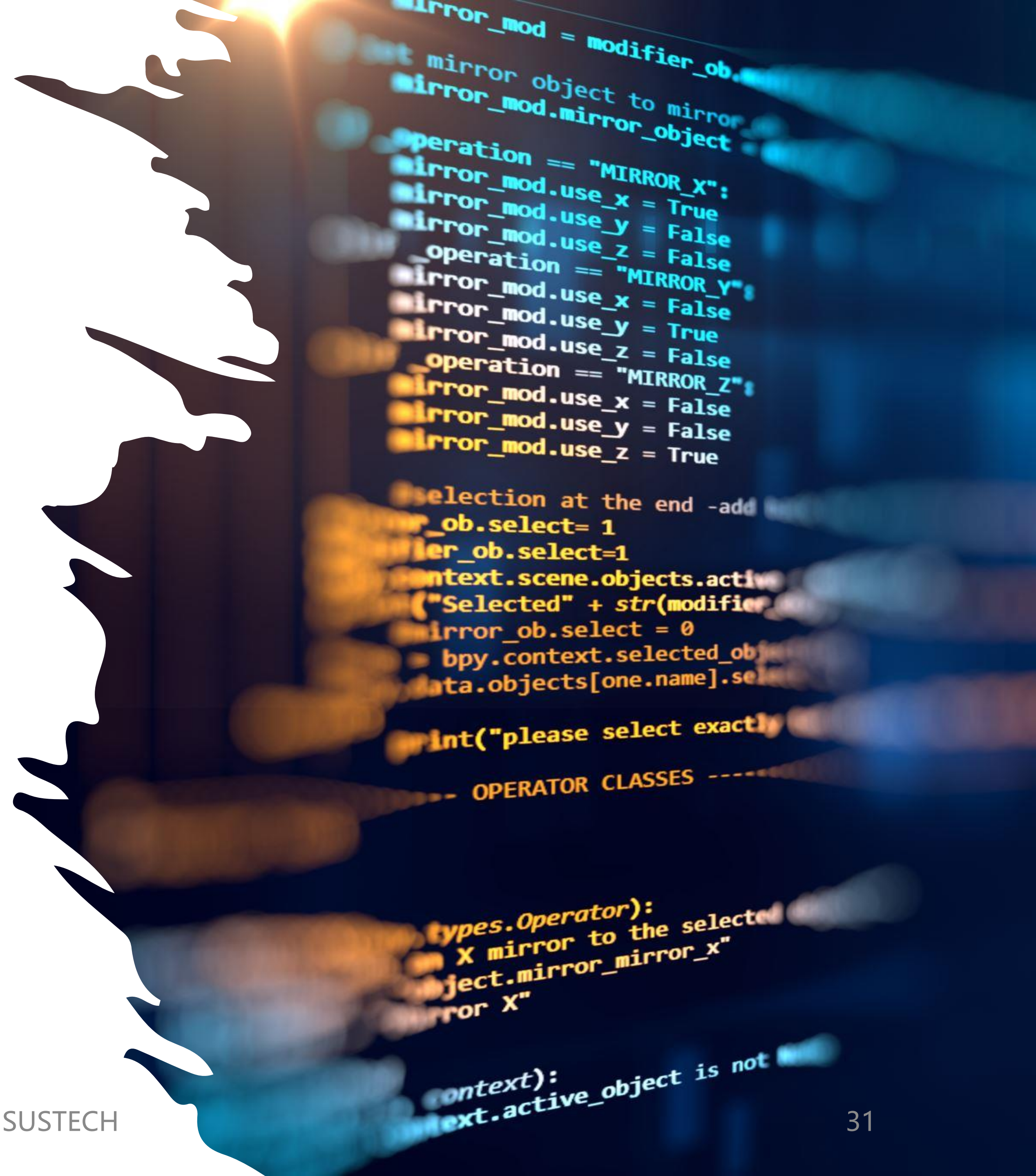
Programming Basics

- Data Types
    - Primitive Types
    - Reference Types (Non-primitive Types)
        - Strings
        - Arrays

- Controls
    - Conditionals
    - Loops



Data Types

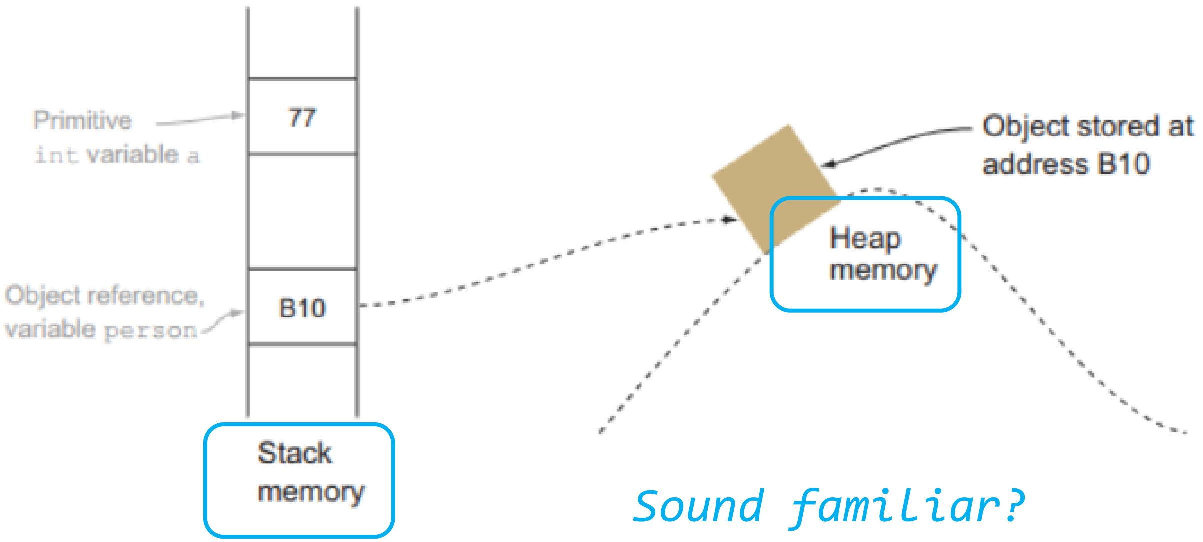
Primitive Type

- A primitive-type variable can store exactly one value of its declared type at a time
- Primitive-type variables have default values
- The sizes of primitive types vary

Type	Size	Default
boolean	1 bit	false
byte	1 byte	0
char	2 bytes	0
short	2 bytes	0
int	4 bytes	0
long	8 bytes	0
float	4 bytes	0
double	8 bytes	0

Reference Type

- A reference-type variable stores a *memory location* that refers to an object
- The sizes are the same (location address)
- Can invoke methods, default is null



Sound familiar?

Image Source: OCA Java SE 7, https://stackoverflow.com/questions/8790809

Strings

More memory efficient!

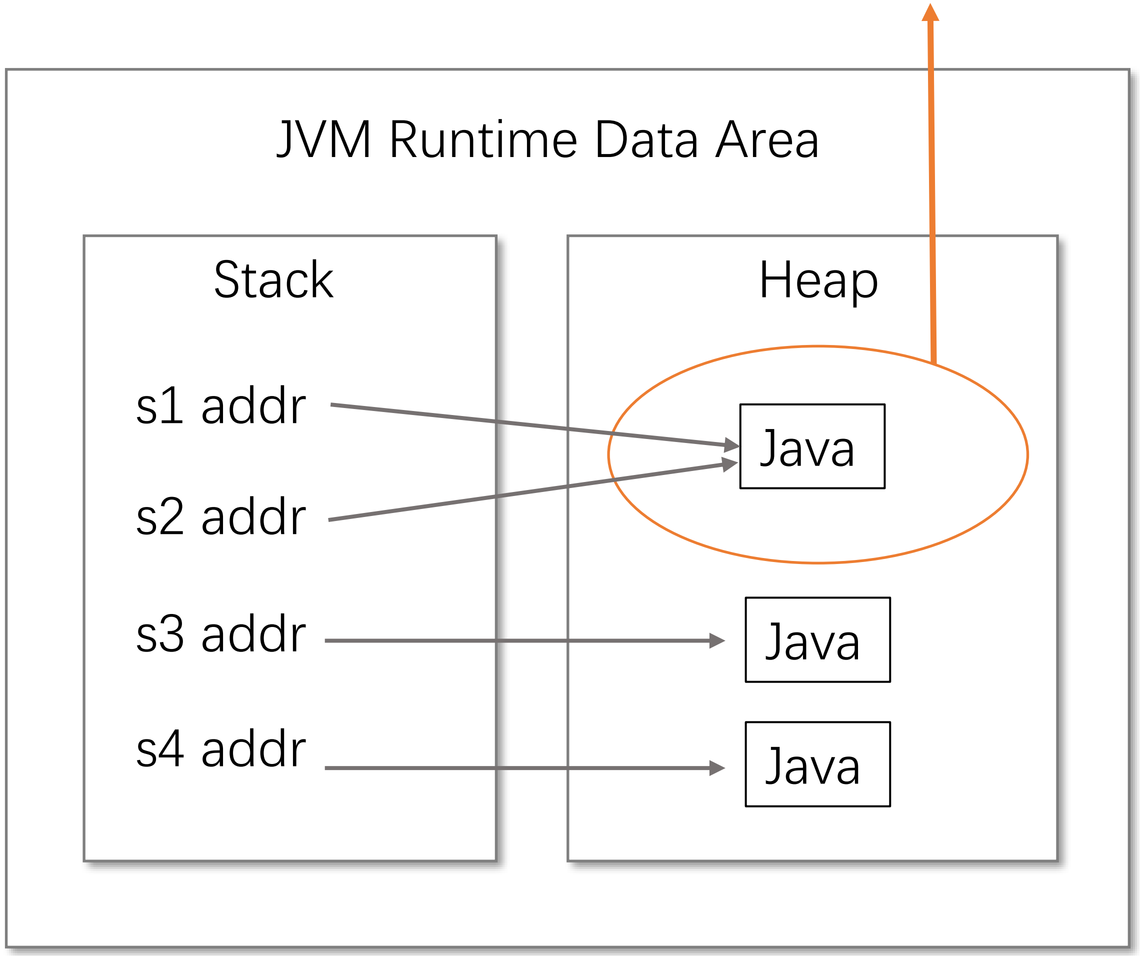
String Constant Pool: Store string objects created by string literals

- Ways to create `String` object
  - By using string literal
  - By using the `new` keyword

Refer to the same object if the content is the same

```
// Strings created using String literal
String s1 = "Java";
String s2 = "Java";

// Strings created using 'new' keyword
String s3 = new String("Java");
String s4 = new String("Java");
```

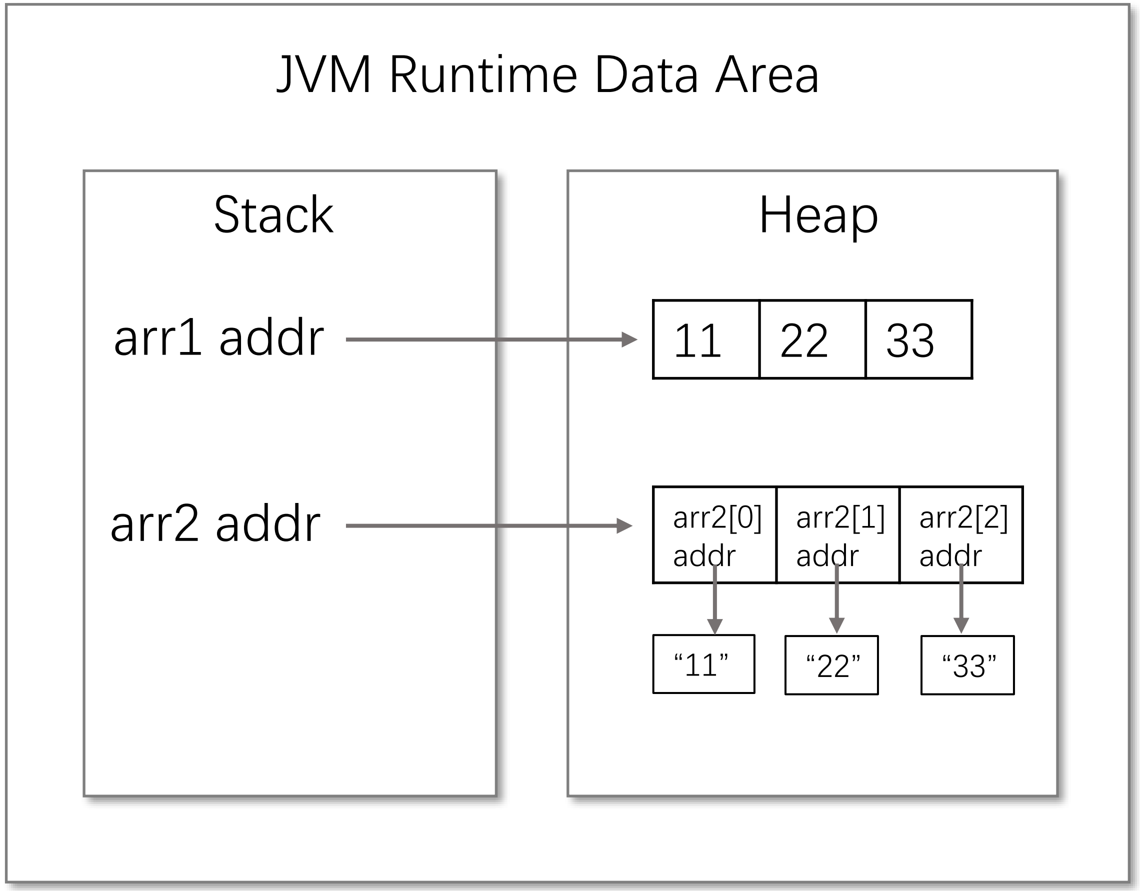
Create a new object even if the content is the same



Arrays

- Arrays are reference types
- Contain multiple variables of the same data type (primitive or reference type)

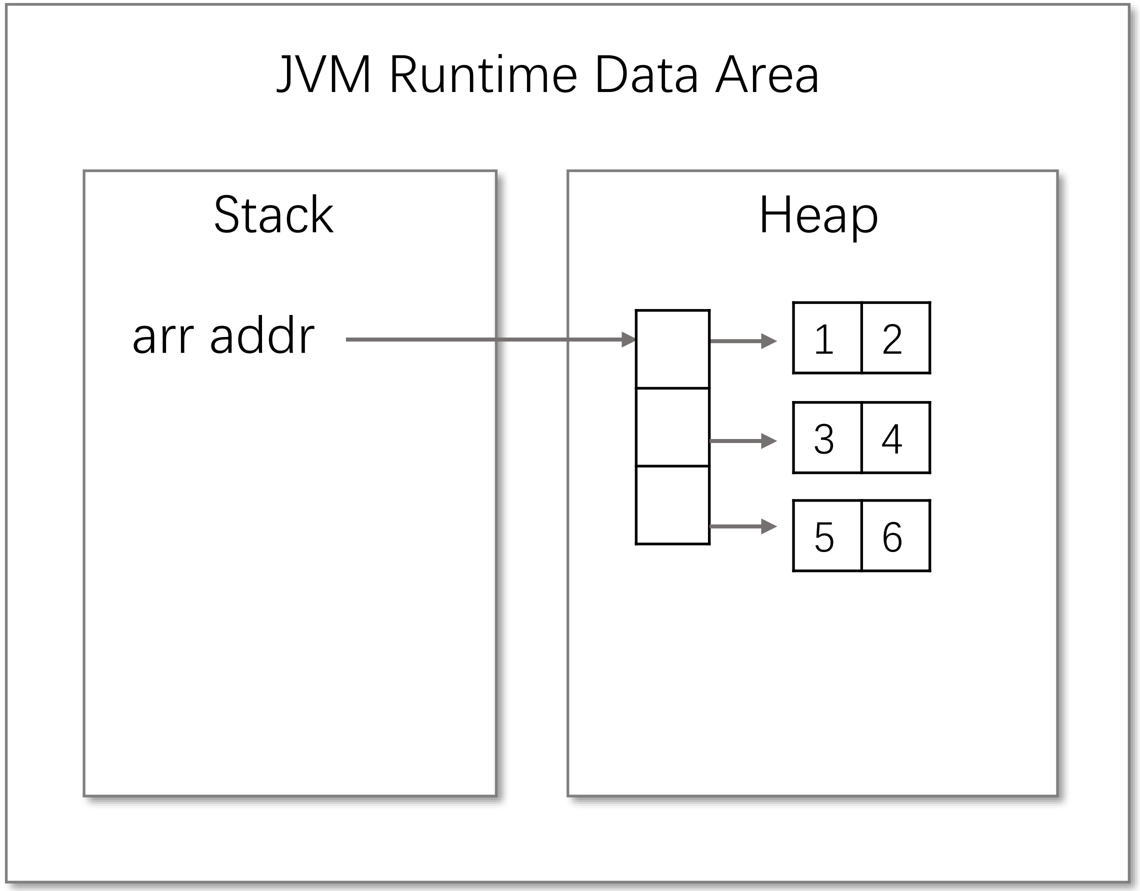
```
int arr1[] = { 11, 22, 33 };

String arr2[] = {"11", "22", "33"};
```



Arrays

```
int[][] arr = {
        {1,2},
        {3,4},
        {5,6}
};    // a 3x2 array
```

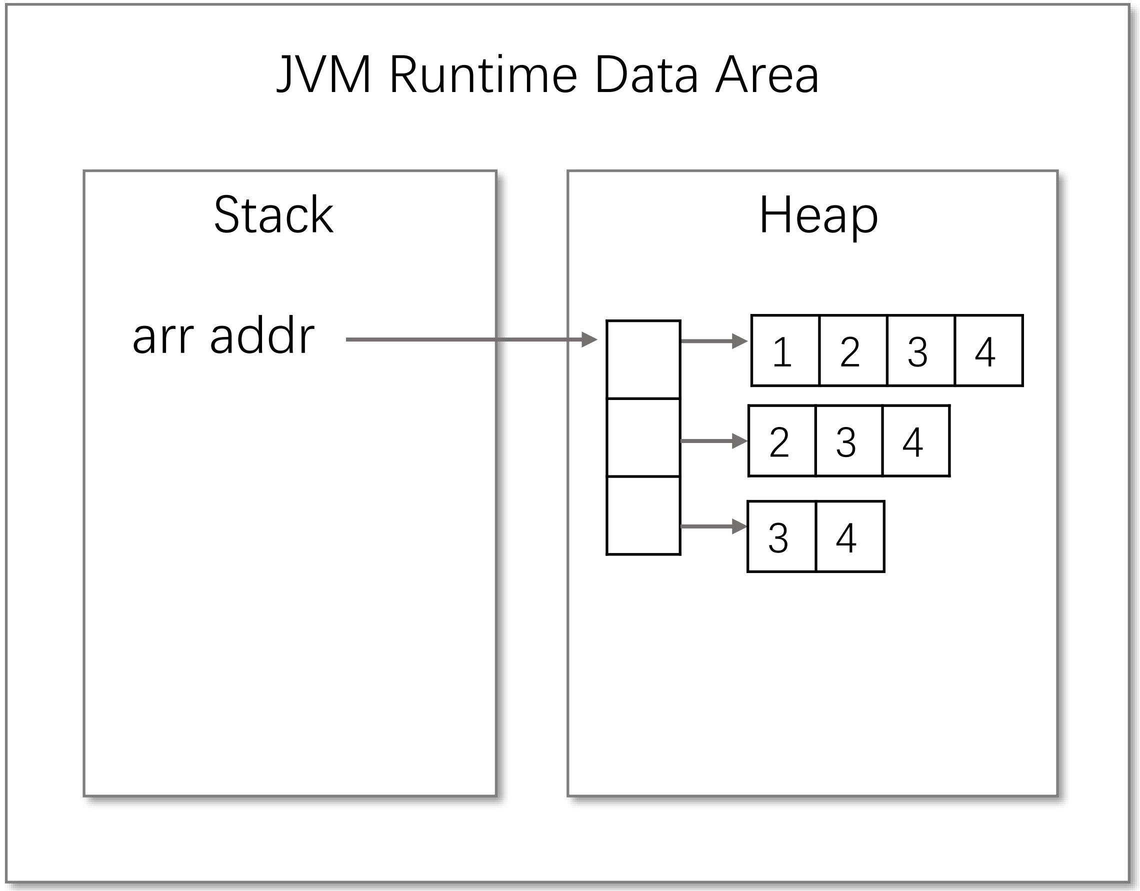
- Two-dimensional arrays (table or matrix)
- A table with *m* rows and *n* columns is actually an array of length m, each entry of which is an array of length n
- Use `a[i]` to refer to the ith row, and `a[i][j]` to refer to the jth column of the ith row



Arrays

```
int[][] arr = {
        {1,2,3,4},
        {2,3,4},
        {3,4}
};    // a ragged/jagged (不规则的) array
```

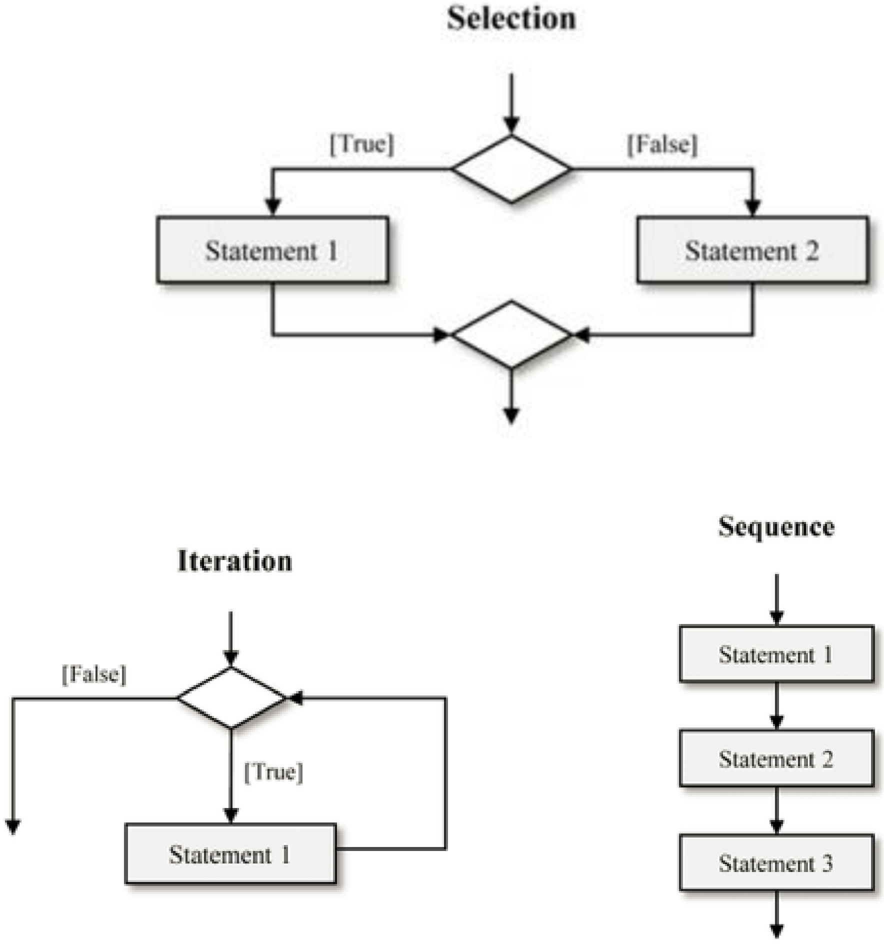
- Two-dimensional arrays (table or matrix)
- A table with *m* rows and *n* columns is actually an array of length m, each entry of which is an array of length n
- Use `a[i]` to refer to the i^{th} row, and `a[i][j]` to refer to the j^{th} column of the i^{th} row



Controls

- Conditionals: handling decisions
  - Perform different actions depending on whether a condition is TRUE
  - if, else, switch

- Loops: handling iteration
  - Perform the same actions repetitively until a certain condition is satisfied
  - for, while



Matrix Multiplication

```java
public int[][] mulmat (int[][] a, int[][] b) {
        int m = a.length;
        int l = b.length;
        int n = b[0].length;

        int[][] c = new int[m][n];

        for(int j=0;j<m;j++){
                for(int i=0;i<n;i++){
                        for(int k=0;k<l;k++){
                                c[j][i]+=a[j][k]*b[k][i];
                        }
                }
        }
        return c;
}
```

Default:0

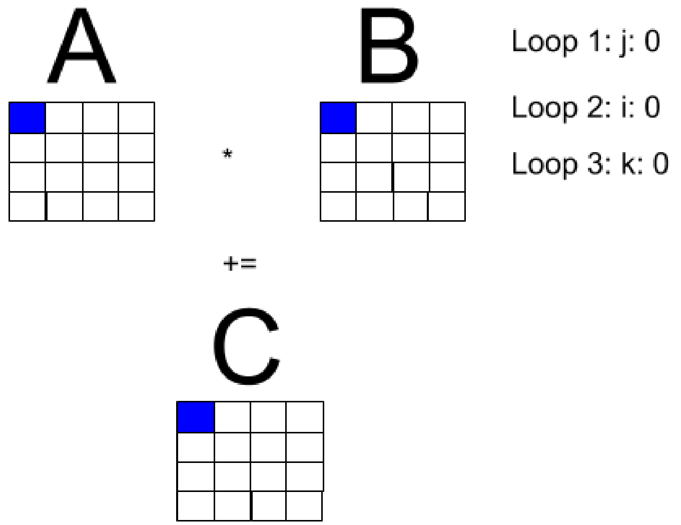
Slowest

Fastest

A: m x l

B: l x n

C: m x n $C_{ji} = \sum_k A_{jk} \times B_{ki}$

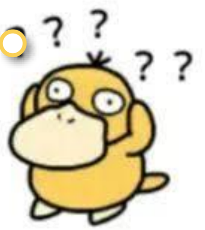


Gif source: https://boydjohnson.dev/blog/concurrency-matrix-multiplication/

Prime Factorization

- A prime number has exactly 2 factors: 1 and the number itself (e.g., 2, 3, 5, 7, 11, 13, etc.).
- Prime factorization: represent a number as a product of prime numbers (e.g., 60=2x2x3x5)

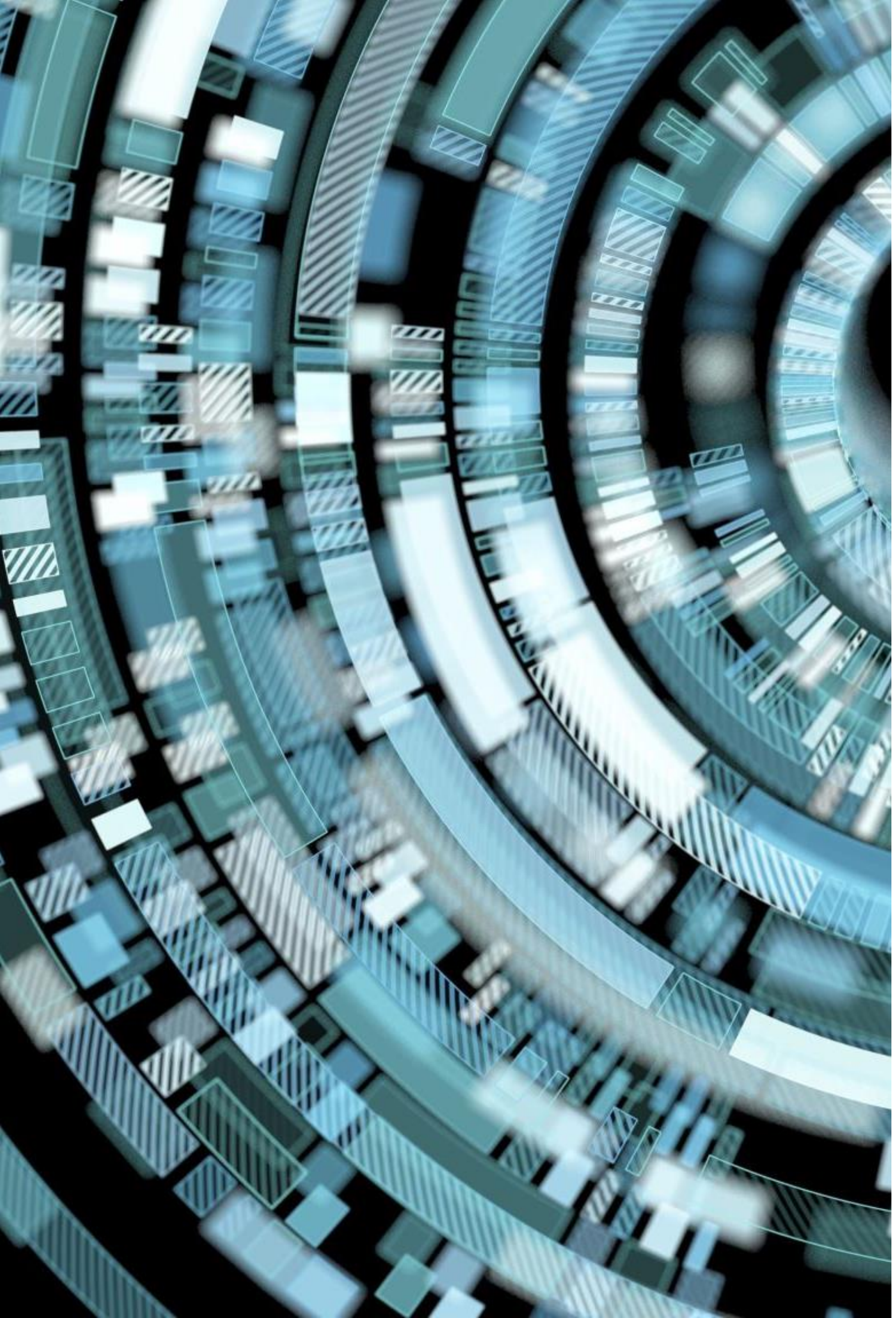
How to find all the prime numbers whose product equals to a given number?



Prime Factorization

```java
public static void factorization(int num)
{
    // for each potential prime factor i
    for(int i=2; i<num; i++){
        // if i is a factor of num, divide it out
        // and check again
        while(num % i == 0){
            System.out.print(i + " ");
            num = num/i;
        }
    }
    // be careful for the last number!
    if(num!=1){
        System.out.println(num);
    }
    else{
        System.out.println();
    }
}
```

num	i	output
60	2	2
30	2	2
15	2	
15	3	3
5	3	
5	4	
5		5



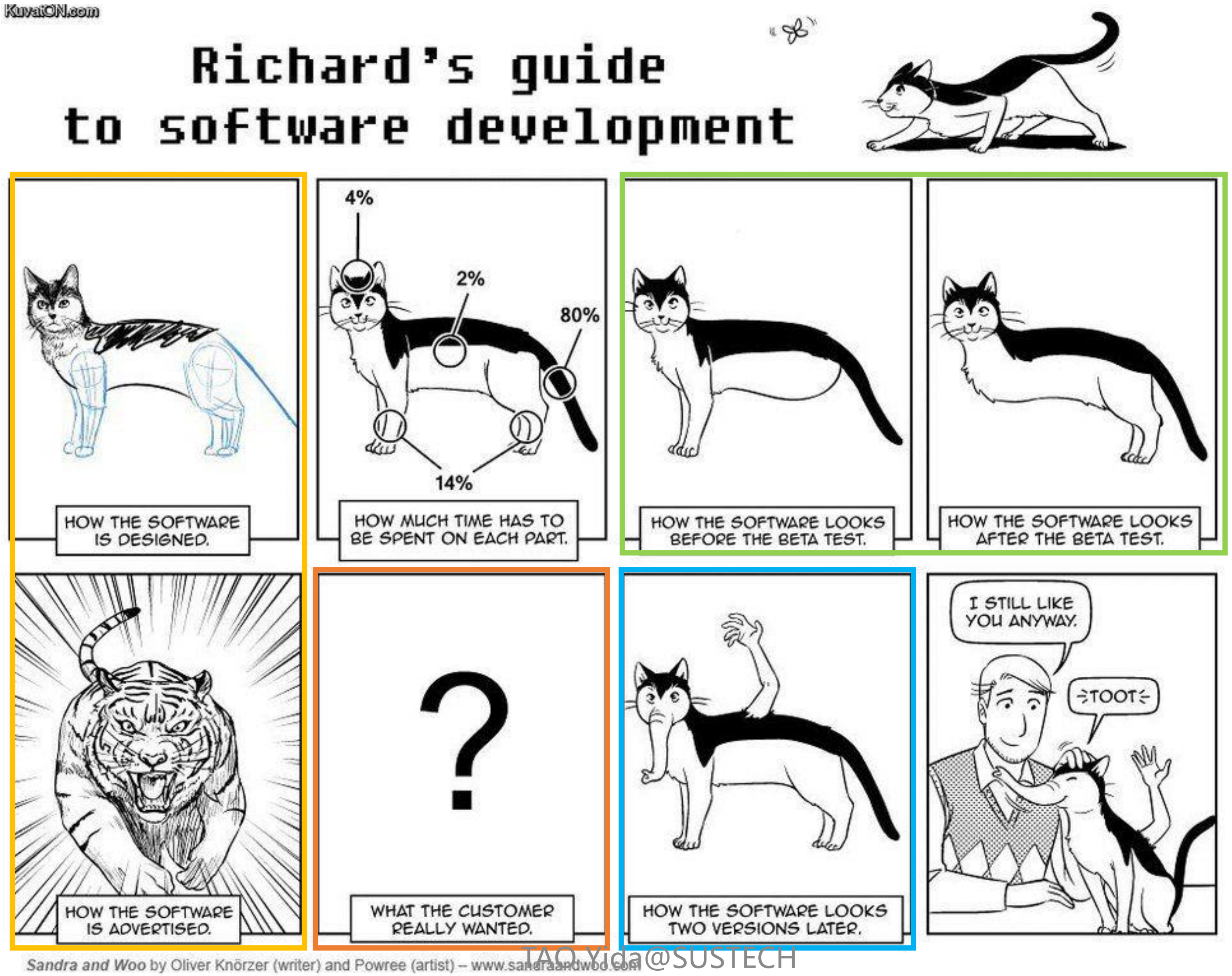
Lecture 1

- Course introduction
- Computer system & programs
- Java overview, JVM, and Virtualization
- Java programming basics
- Software design principles
- Object-Oriented Programming basics

Software design & development are complex

Requirement is evolving, sometimes deviates from the original design a lot

Requirement is hard to define, even customers themselves don't even know


KuvatON.com
Richard's guide to software development
HOW THE SOFTWARE IS DESIGNED.
4%
2%
80%
14%
HOW MUCH TIME HAS TO BE SPENT ON EACH PART.
HOW THE SOFTWARE LOOKS BEFORE THE BETA TEST.
HOW THE SOFTWARE LOOKS AFTER THE BETA TEST.
HOW THE SOFTWARE IS ADVERTISED.
?
WHAT THE CUSTOMER REALLY WANTED.
HOW THE SOFTWARE LOOKS TWO VERSIONS LATER.
I STILL LIKE YOU ANYWAY.
TOOT
Sandra and Woo by Oliver Knörzer (writer) and Powree (artist) – www.sandraandwoo.com

Changes to one part could mysteriously affect other parts

Different designs could fulfill the same functionality; Hard to evaluate.

Communication is vital

- Conway’s Law: Any organization that designs a system (defined broadly) will produce a design whose structure is a copy of the organization's communication structure.

Enjoy the teamwork in group projects!

Software Design Principles

- High Cohesion (高内聚)
- Low Coupling (低耦合)
- Information Hiding (信息隐藏)

High Cohesion, Low Coupling

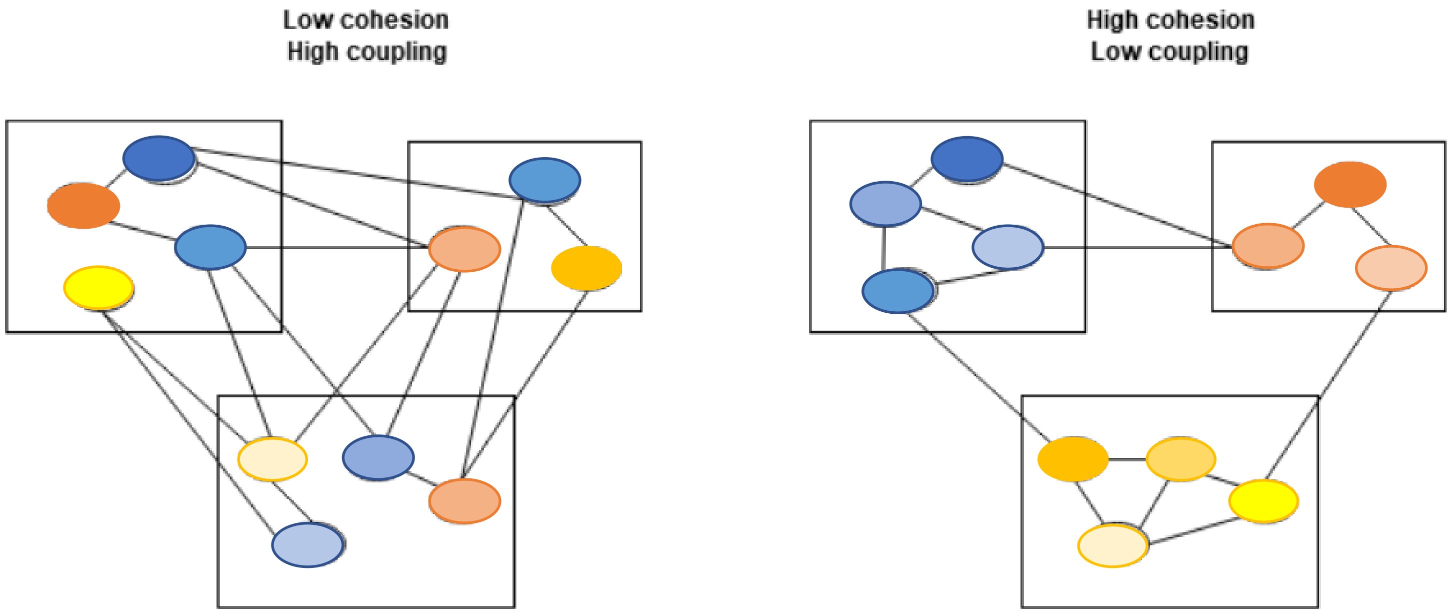
- Modules (模块): A complex software system can be divided into simpler pieces called *modules*

- Cohesion (内聚): How elements of a module are functionally related to each other

- Coupling (耦合): How different modules depend on each other

High Cohesion, Low Coupling

- High cohesion: modules are self-contained and have a single, well-defined purpose; all of its elements are directly related to the functionality that is meant to be provided by the module
- Low coupling: modules should be as independent as possible from other modules, so that changes to one module will have minimal impact on other modules



Difficult to read, understand, reuse, test, and maintain

Easy to understand, extend, and modify

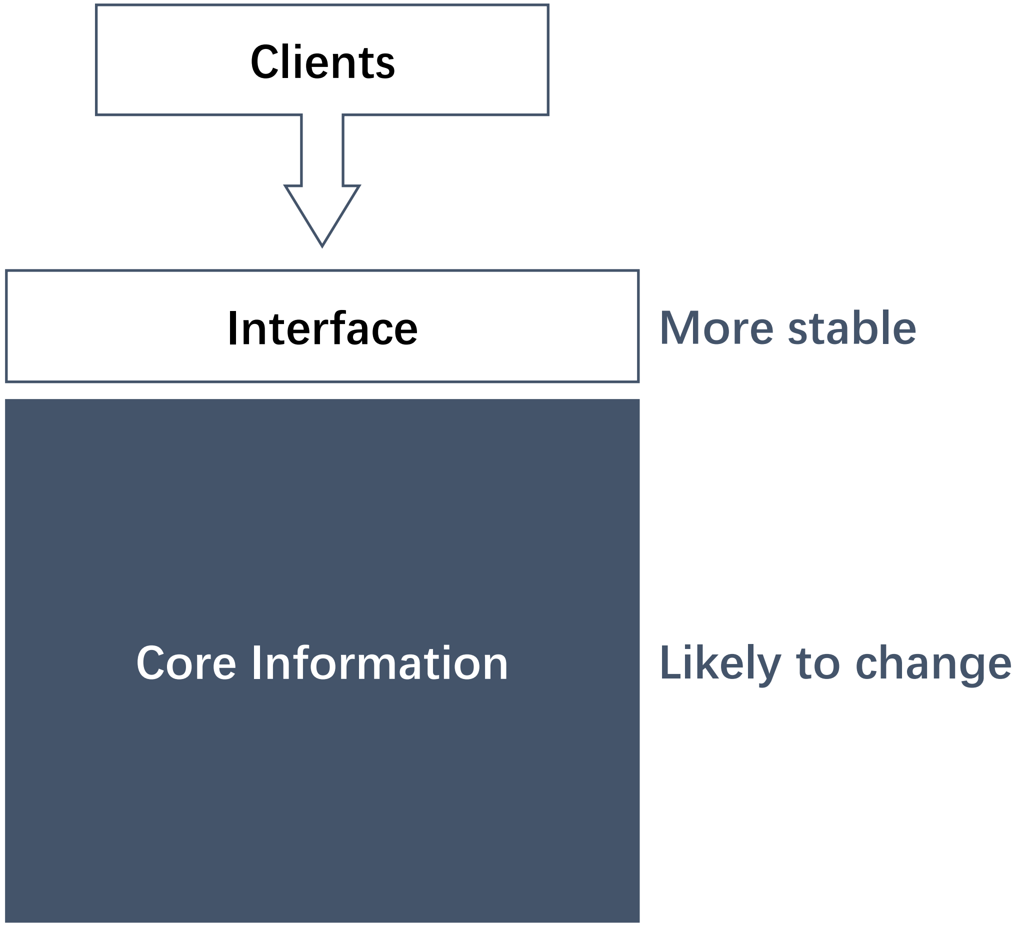
Source: Software Architecture with C++ by Adrian Ostrowski, Piotr Gaczkowski

Information Hiding

- Key idea: Hiding certain information, such as design decisions, data, and implementation details, from client programs

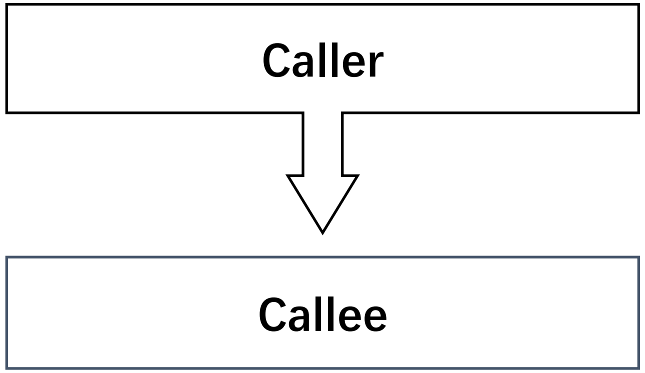
- Advantages: Client programs won't have to change even if the core design or implementation is changed

Increasing coupling -> breaking information hiding



Information Hiding

Example 1. Function Call

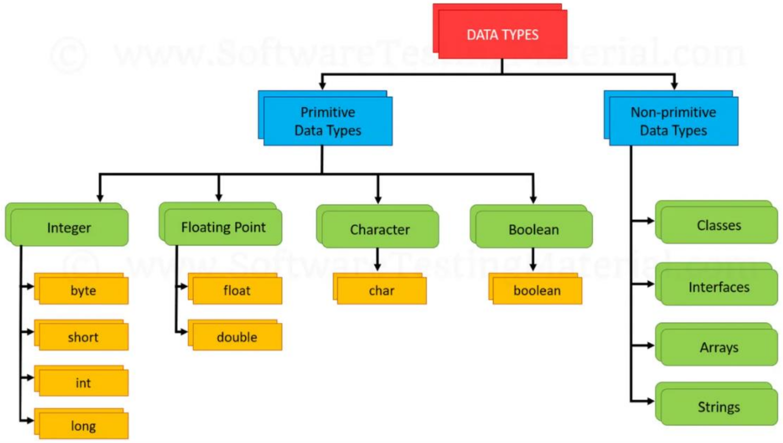


Caller

Callee

The caller function doesn’t have to know how the callee function works internally; it only has to know callee’s arguments and return type

Example 2. Data Representation

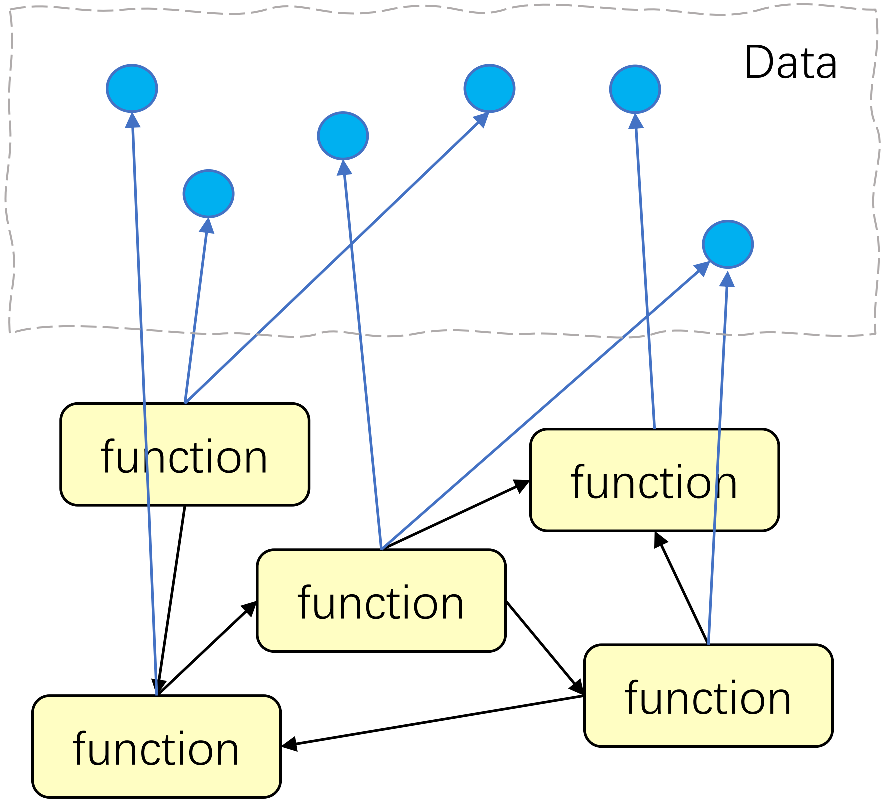


You don’t need to know how a data type is implemented in order to use it;

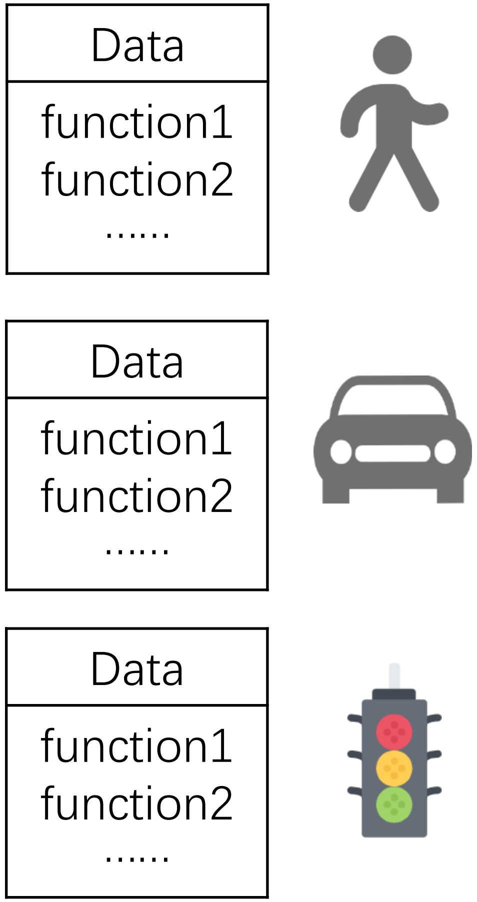
Image source: https://www.softwaretestingmaterial.com/data-types-in-java/

Procedural Design

Object-oriented Design



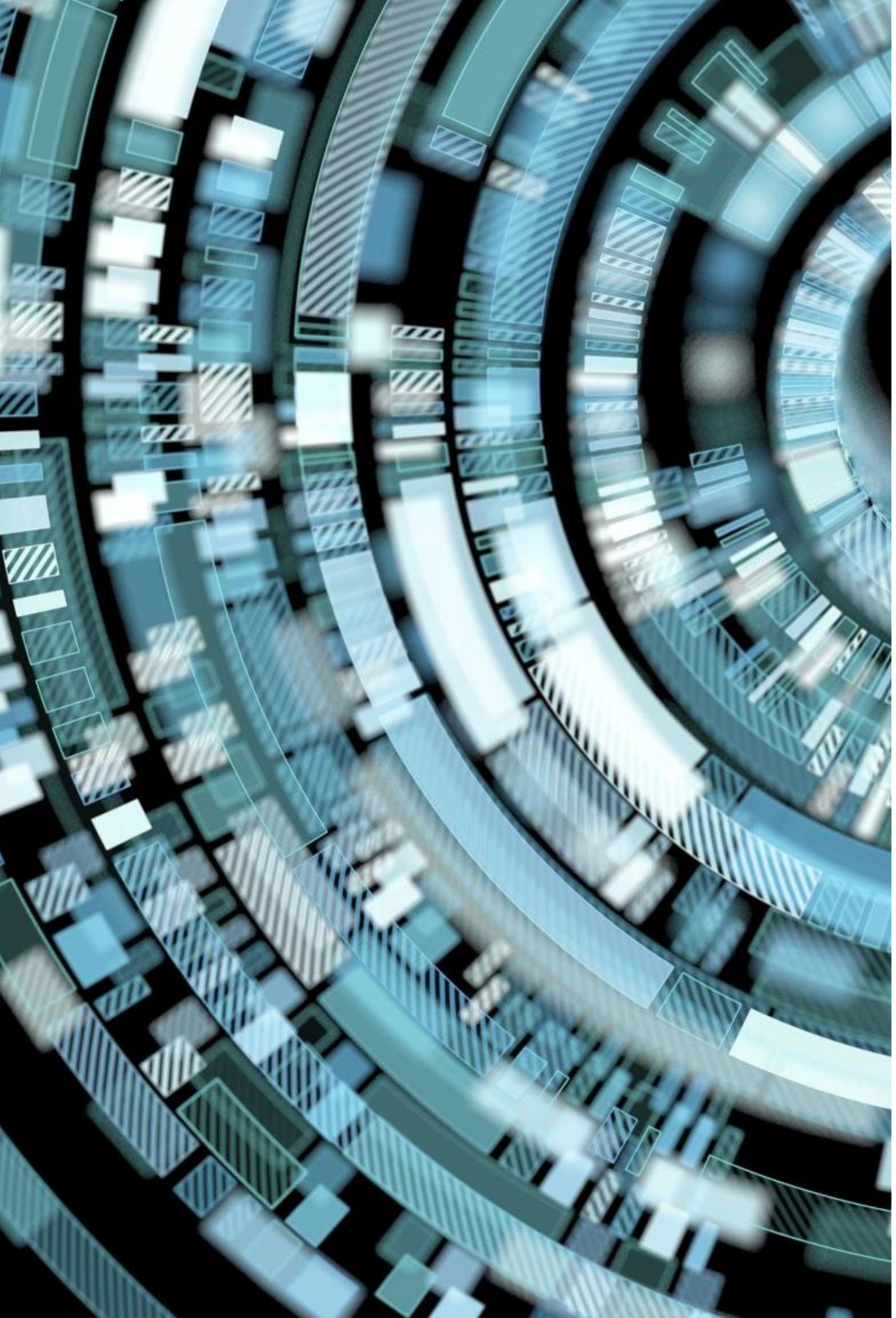
Traffic Control System



High coupling. Reduced information hiding. Hard to make changes and to scale.

High cohesion. Good information hiding. Easier to maintain and extend.

Image source: https://www.hseblog.com/cross-road-safely/



Lecture 1

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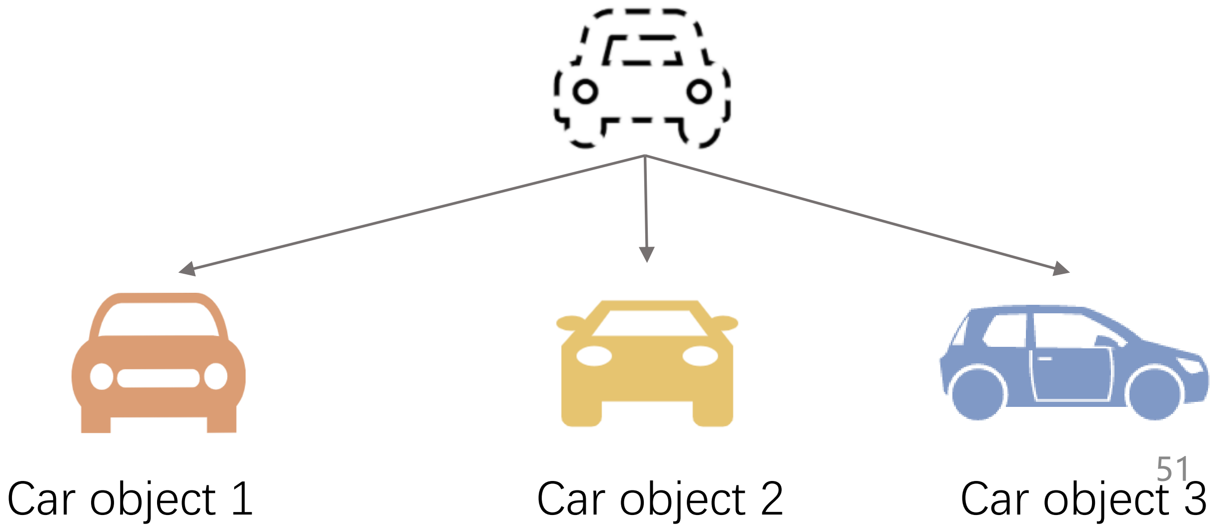
Class, Object, and Instance

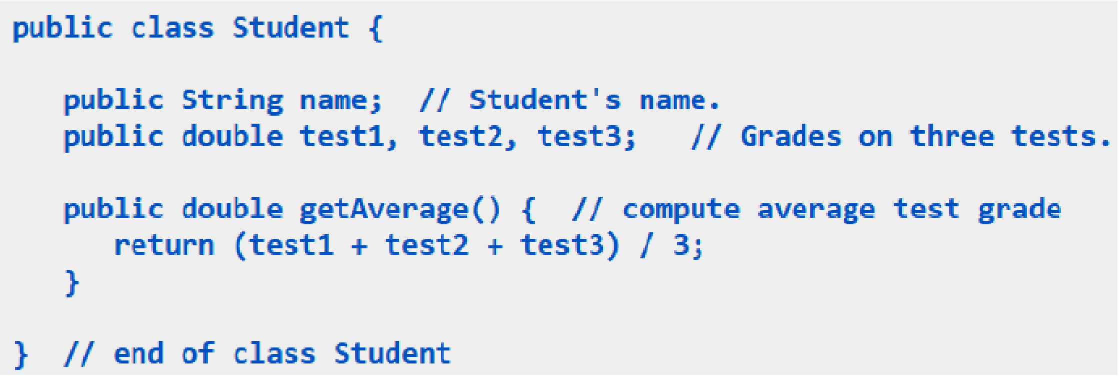
- Object: Conceptually similar to real-world objects; Consist of <u>state</u> and <u>behaviors</u>. E.g., Cars have state (speed, color, model) and behavior (move, turn, stop).
- Class: a <u>template</u> or <u>blueprint</u> that is used to create objects. Consist of <u>fields</u> (hold the states) and <u>methods</u> (represent the behaviors)
  - A given object is an instance of a class.
  - Reference (non-primitive) data type.

Car Class

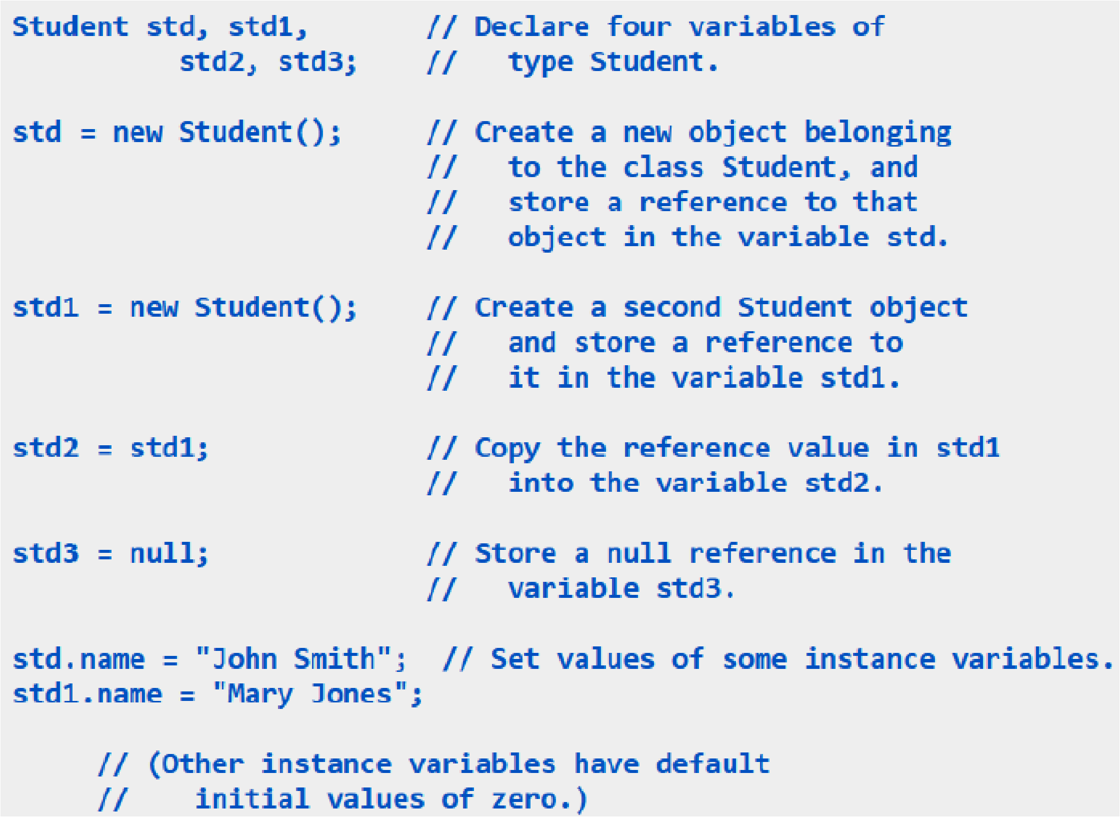
Color Size Model

Start()
Stop()
Move()
Turn()

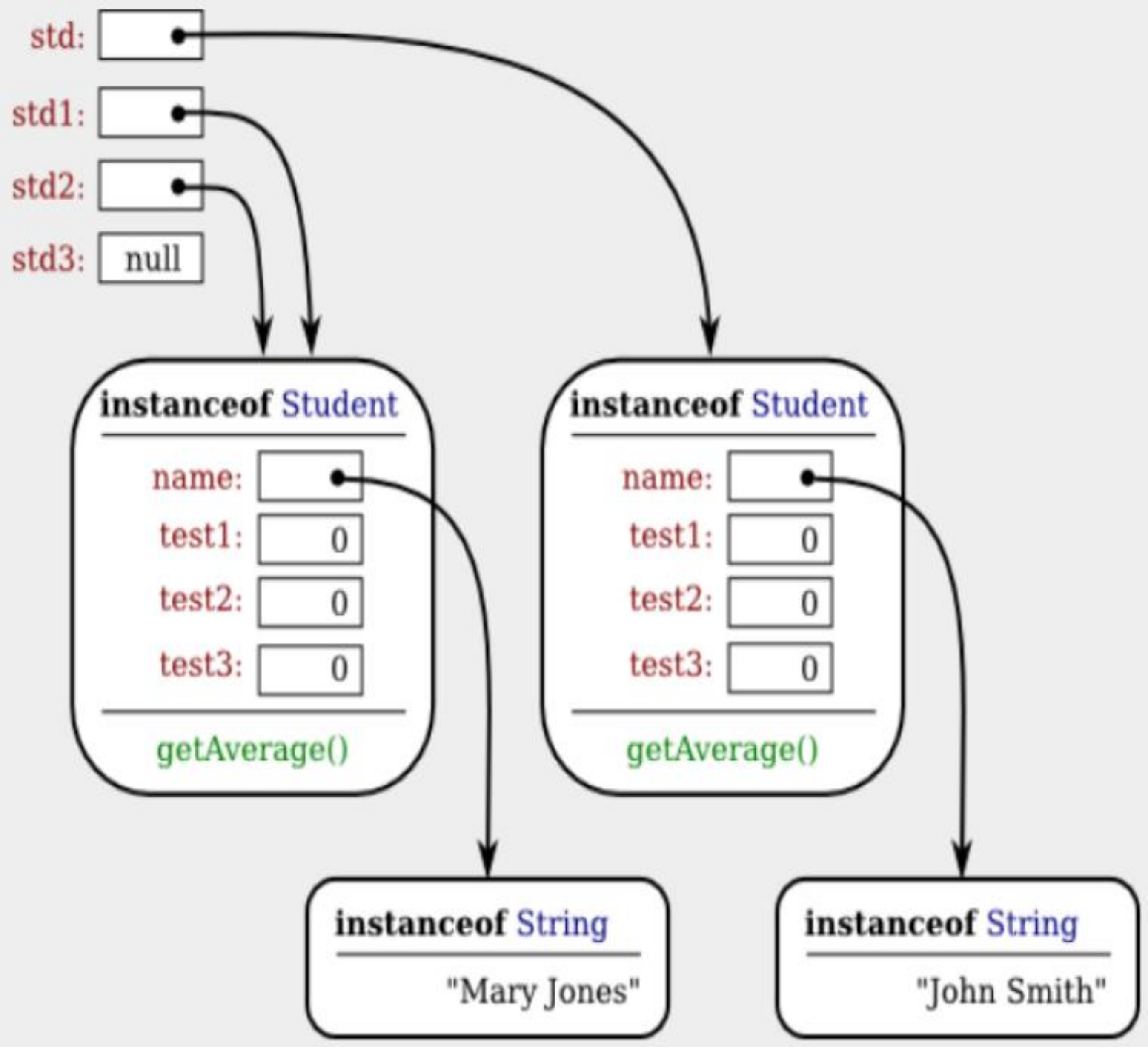




```
public class Student {

   public String name;  // Student's name.
   public double test1, test2, test3;   // Grades on three tests.

   public double getAverage() {  // compute average test grade
      return (test1 + test2 + test3) / 3;
   }

}  // end of class Student
```



```
Student std, std1,       // Declare four variables of
          std2, std3;    //   type Student.

std = new Student();     // Create a new object belonging
                         //   to the class Student, and
                         //   store a reference to that
                         //   object in the variable std.

std1 = new Student();    // Create a second Student object
                         //   and store a reference to
                         //   it in the variable std1.

std2 = std1;             // Copy the reference value in std1
                         //   into the variable std2.

std3 = null;             // Store a null reference in the
                         //   variable std3.

std.name = "John Smith";  // Set values of some instance variables.
std1.name = "Mary Jones";

     // (Other instance variables have default
     //    initial values of zero.)
```



How std, std1, std2, std3 are stored?

OOP basic concepts

- Encapsulation (封装)
- Abstraction (抽象)
- Inheritance (继承)
- Polymorphism (多态)

Encapsulation

- Bundling the data and functions which operate on that data into a single unit, e.g., a class in Java.
- Think of it as a protective shield that prevents the data from being accessed by the code outside this shield.

Sound familiar?

Encapsulation or information hiding is achieved by the **Access Control** mechanism in Java

Access Control

- Use access modifiers to determine whether other classes can use a particular field or invoke a particular method

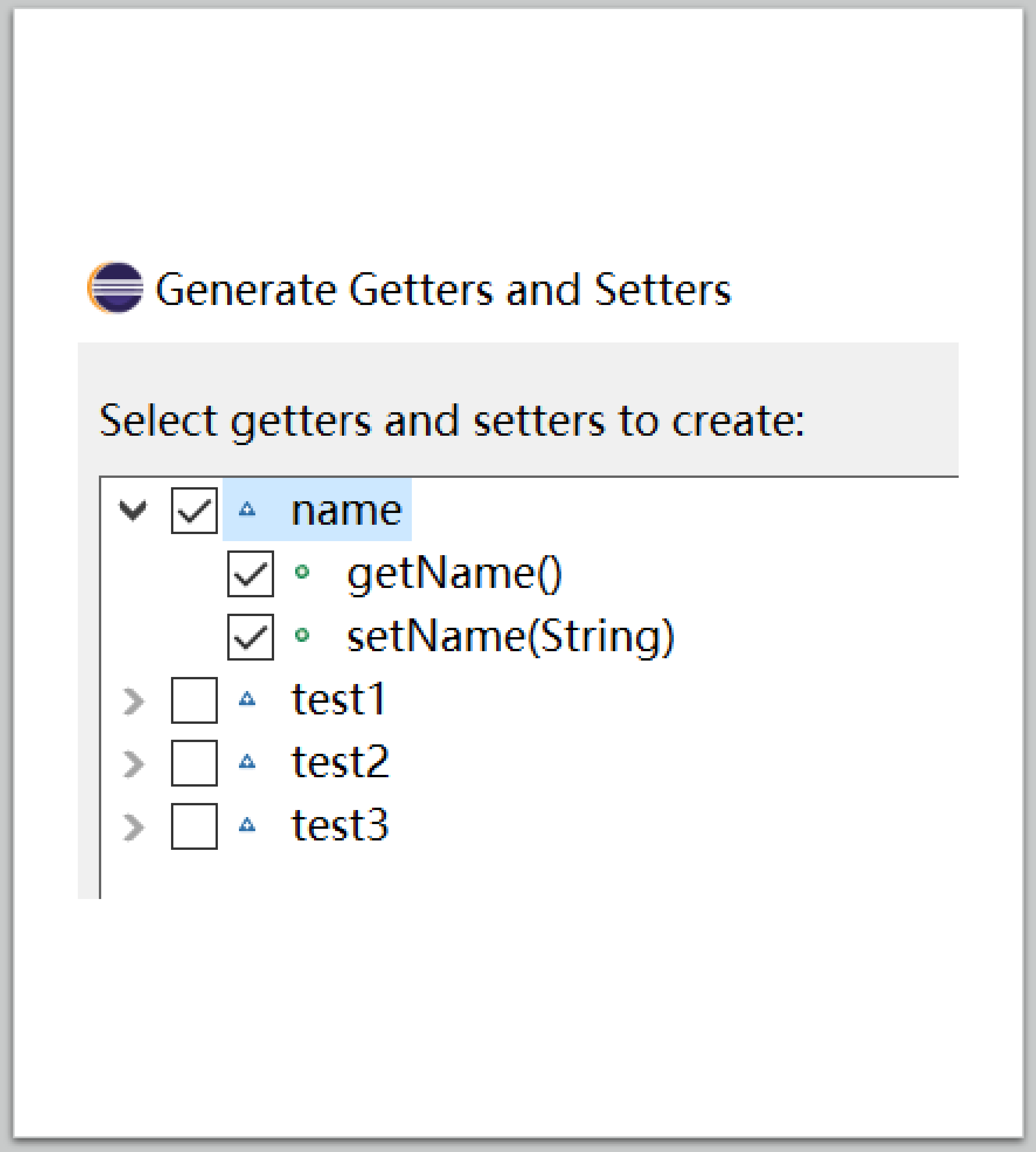
Visibility

- At the top level (class or interfaces)
  - package-private (default): visible only within its own package
  - public: visible to all classes everywhere
- At the member level (fields or methods)
  - private: can only be accessed in its own class
  - package-private (default): visible only within its own package
  - protected: can be accessed within its own package and by a subclass of its class in another package.
  - public: visible to all classes everywhere

Access Control

- Rule of thumb: always make classes or members as inaccessible as possible (using the most restricted access modifier)

- Getter and Setter
  - Getter (accessor): use getXXX() to read the data
  - Setter (mutator): use setXXX() to modify the data



Generate Getters and Setters

Select getters and setters to create:

- ☑ name
  - ☑ getName()
  - ☑ setName(String)
- □ test1
- □ test2
- □ test3

Getters and Setters

```java
public class Student {
        public String name;
        public double test;
}
```

```java
Student std = new Student();
std.test = -1;
std.test = 200;
std.name = null;
```

Works, but makes no sense

```java
public class Student {
    private String name;
    private double test;

    public void setTest(double test) {
        if(test<0 || test>100) {
        throw new IllegalArgumentException
                    ("invalid test score!");
        }
        this.test = test;
    }
}
```

```java
Student std = new Student();
std.setTest(-1);
```

Getters and setters allow additional logics such as validation and error handling to be added more easily without affecting the clients

Getters and Setters

```java
public class Student {
        private int[] scores = new int[]{100,90,95};

        public int[] getScores() {
                return scores;
        }
}
```

Any problems with the code?

```java
Student std = new Student();

int[] scores = std.getScores();
// [100, 90, 95], expected
System.out.println(Arrays.toString(scores));

scores[0] = 10;

// [10, 90, 95], Why scores, which is private, could still be modified?
System.out.println(Arrays.toString(std.getScores()));
```

The getter method returns a reference of the internal variable scores directly, so the outside code can obtain this reference and makes change to the internal object.

Getters and Setters …?

Further Reading

- Getter Eradicator by Martin Fowler. https://martinfowler.com/bliki/GetterEradicator.html
- Tell-Don't-Ask by Martin Fowler. https://martinfowler.com/bliki/TellDontAsk.html
- Why use getters and setters? https://stackoverflow.com/questions/1568091/

OOP basic concepts

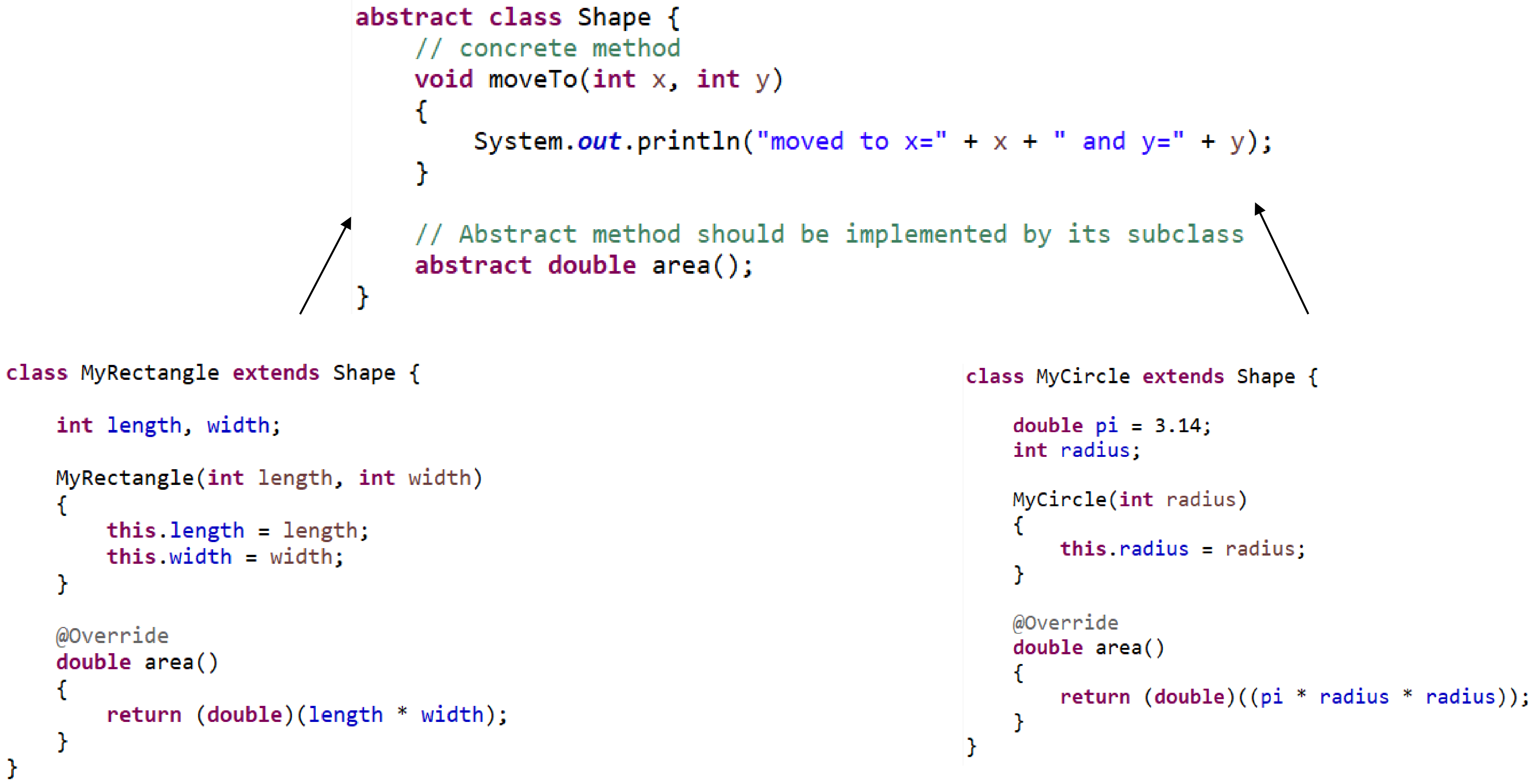
- Encapsulation (封装)
- Abstraction (抽象)
- Inheritance (继承)
- Polymorphism (多态)

Abstraction

- Identifying and providing only essential ideas to users while hiding background details
- Abstraction solves problem at design level (what should be done) while Encapsulation solves problem at implementation level (how it should be done)
- Achieved in Java by interface and abstract class

Abstract Class

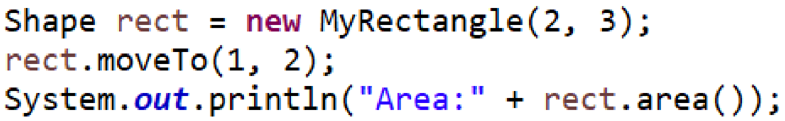
- Purpose: to provide a general guideline or blueprint of a particular concept without having to implement every method; Subclasses should provide the full implementation
- Cannot be instantiated; Subclasses that *extend* the abstract class can be instantiated
- Can have concrete and abstract methods
  - Abstract methods (no implementation): Subclasses must provide the implementation
  - Concrete methods (with implementation): Subclasses could inherit or override it



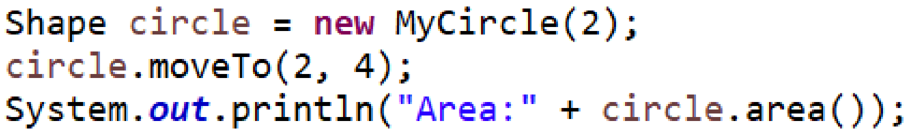
```
abstract class Shape {
    // concrete method
    void moveTo(int x, int y)
    {
        System.out.println("moved to x=" + x + " and y=" + y);
    }

    // Abstract method should be implemented by its subclass
    abstract double area();
}
```

```
class MyRectangle extends Shape {

    int length, width;

    MyRectangle(int length, int width)
    {
        this.length = length;
        this.width = width;
    }

    @Override
    double area()
    {
        return (double)(length * width);
    }
}
```

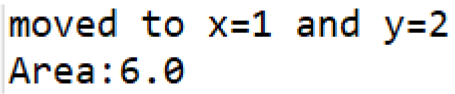
```
class MyCircle extends Shape {

    double pi = 3.14;
    int radius;

    MyCircle(int radius)
    {
        this.radius = radius;
    }

    @Override
    double area()
    {
        return (double)((pi * radius * radius));
    }
}
```



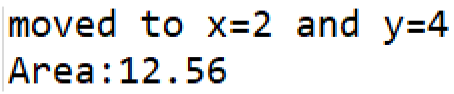
```
Shape rect = new MyRectangle(2, 3);
rect.moveTo(1, 2);
System.out.println("Area:" + rect.area());
```



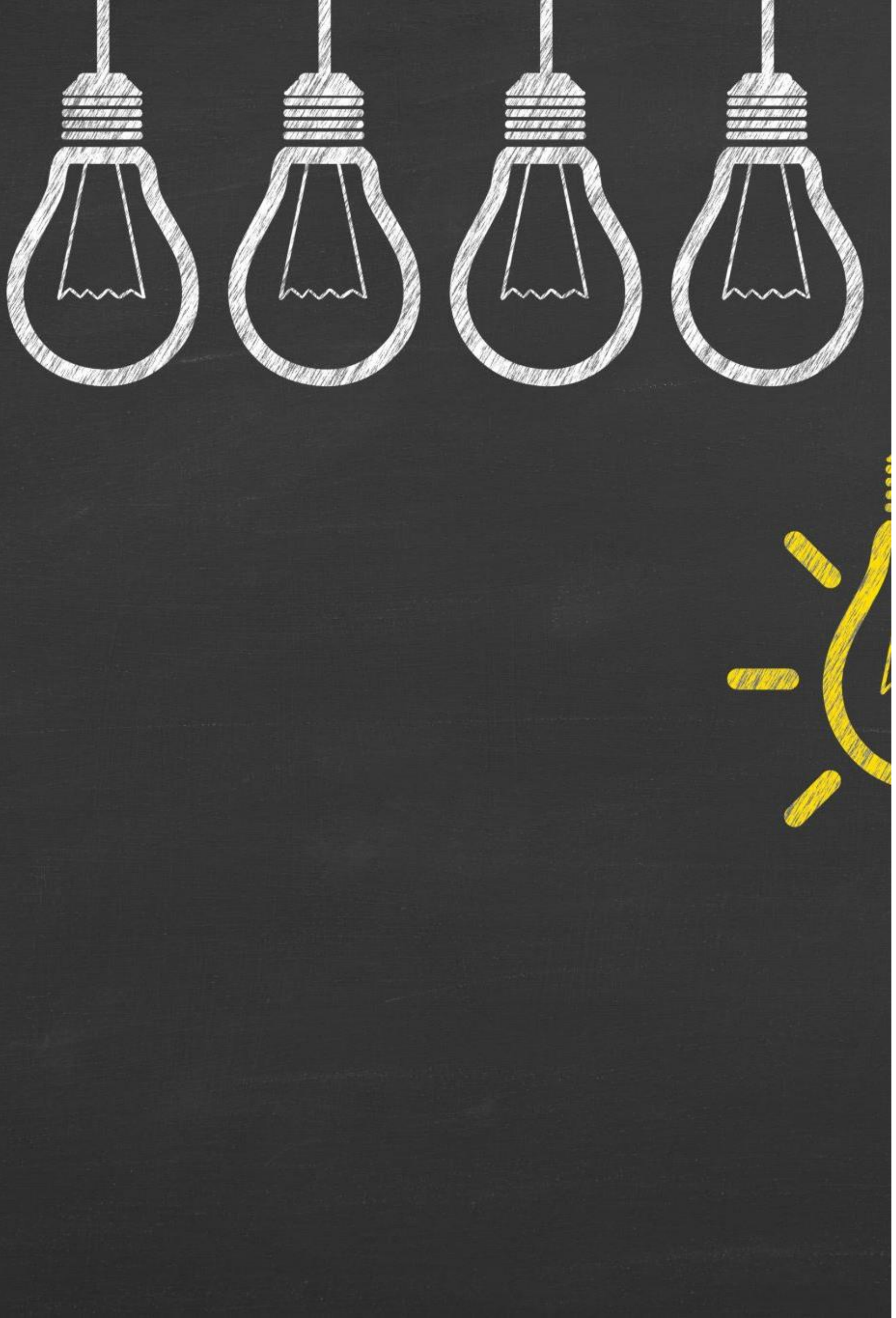
```
Shape circle = new MyCircle(2);
circle.moveTo(2, 4);
System.out.println("Area:" + circle.area());
```



```
moved to x=1 and y=2
Area:6.0
```

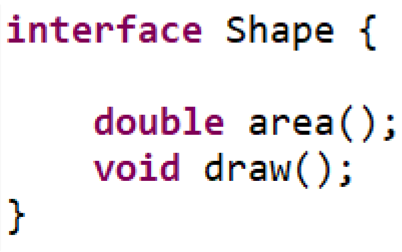


```
moved to x=2 and y=4
Area:12.56
```

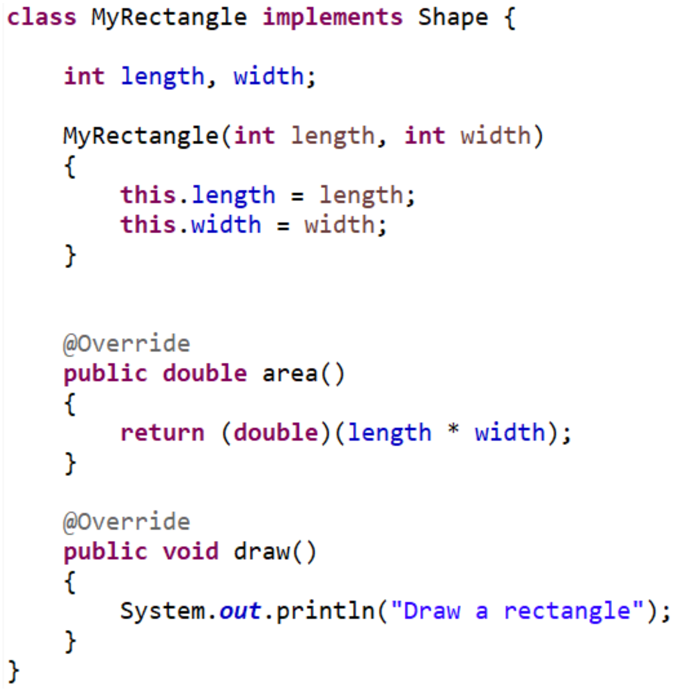


Interface

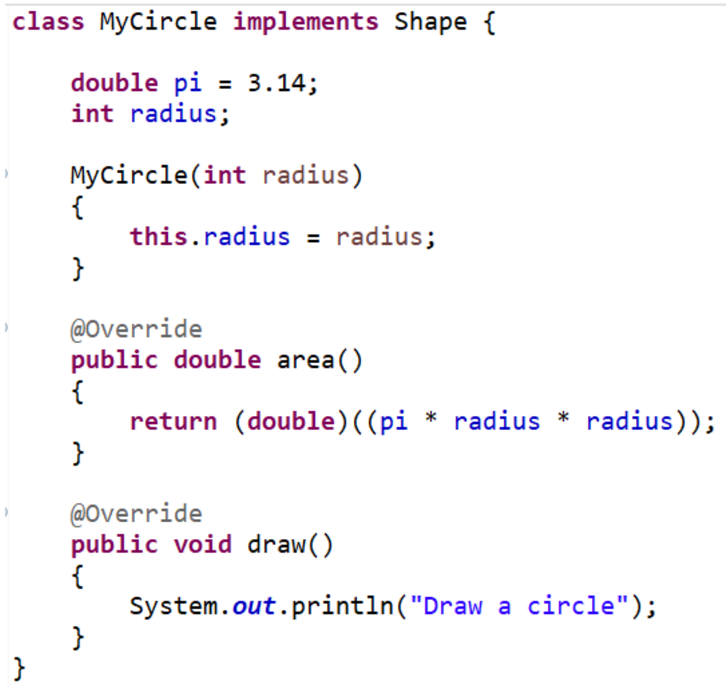
- A group of related abstract methods with empty bodies (i.e., an *interface* or *contract* to the outside world)
- Classes that implement an interface must override all of its methods (should conform to the “contract” and implement all the behavior it promises to provide)
- Compared to Abstract Class
  - An interface cannot be instantiated; Classes that *implement* interfaces can be instantiated
  - ~~Does not have concrete methods~~ (not anymore after Java 8)
  - A class can implement multiple interfaces, but can inherit only one abstract class



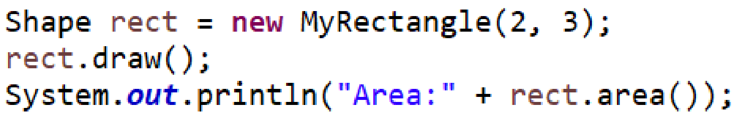
```java
interface Shape {

    double area();
    void draw();
}
```



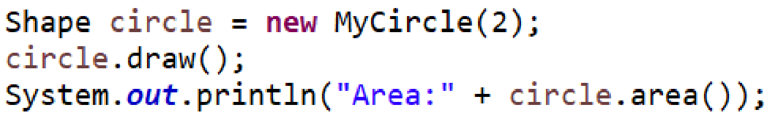
```java
class MyRectangle implements Shape {

    int length, width;

    MyRectangle(int length, int width)
    {
        this.length = length;
        this.width = width;
    }


    @Override
    public double area()
    {
        return (double)(length * width);
    }

    @Override
    public void draw()
    {
        System.out.println("Draw a rectangle");
    }
}
```



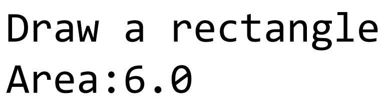
```java
class MyCircle implements Shape {

    double pi = 3.14;
    int radius;

    MyCircle(int radius)
    {
        this.radius = radius;
    }

    @Override
    public double area()
    {
        return (double)((pi * radius * radius));
    }

    @Override
    public void draw()
    {
        System.out.println("Draw a circle");
    }
}
```



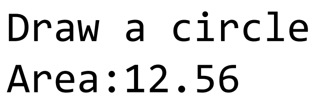
```java
Shape rect = new MyRectangle(2, 3);
rect.draw();
System.out.println("Area:" + rect.area());
```



```java
Shape circle = new MyCircle(2);
circle.draw();
System.out.println("Area:" + circle.area());
```



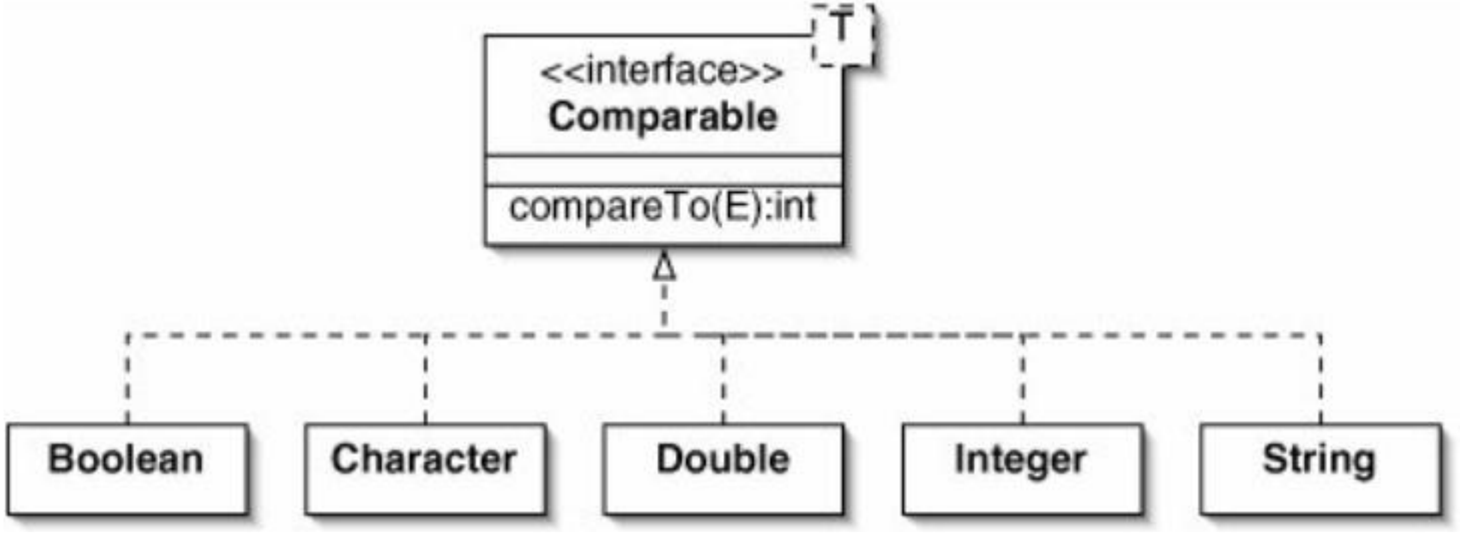
```
Draw a rectangle
Area:6.0
```



```
Draw a circle
Area:12.56
```

`java.lang.Comparable` Interface

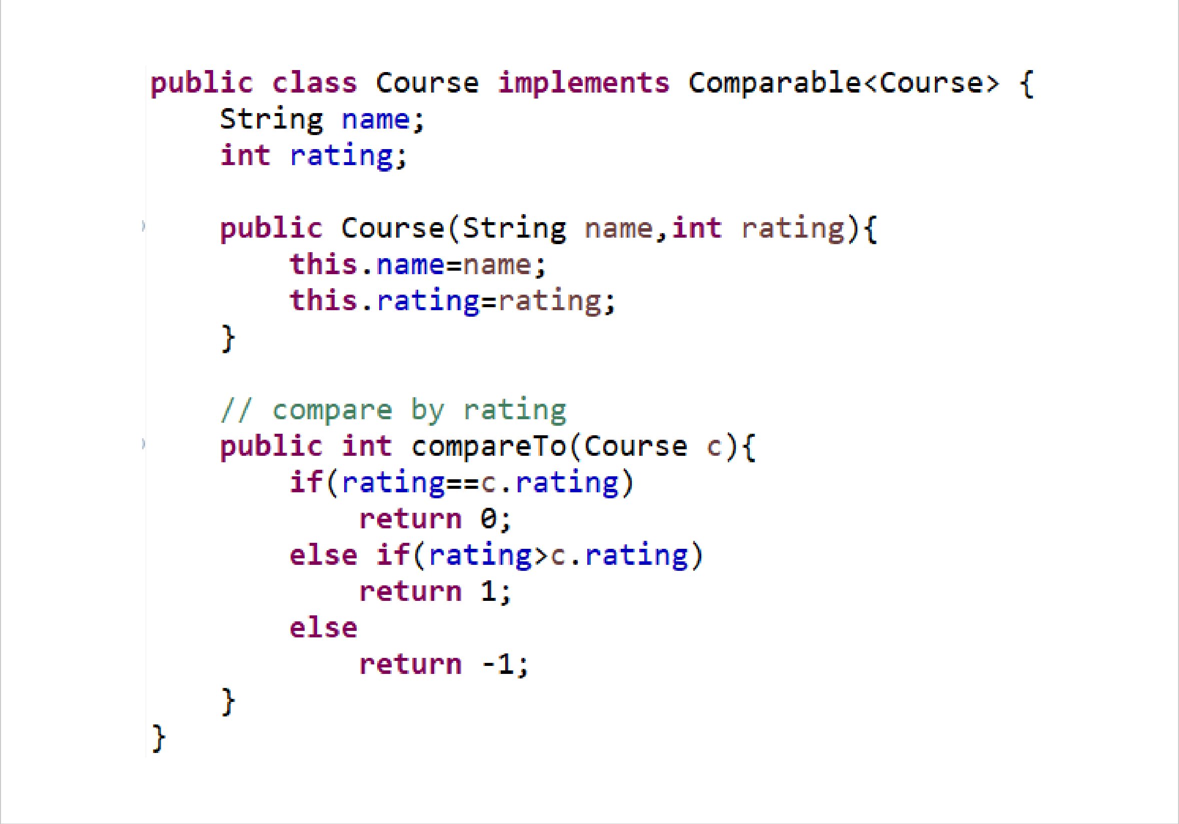
- Contains only one abstract method: `int compareTo(T o)`
- Compares this object with the specified object for order. Returns a negative integer, zero, or a positive integer as this object is less than, equal to, or greater than the specified object.



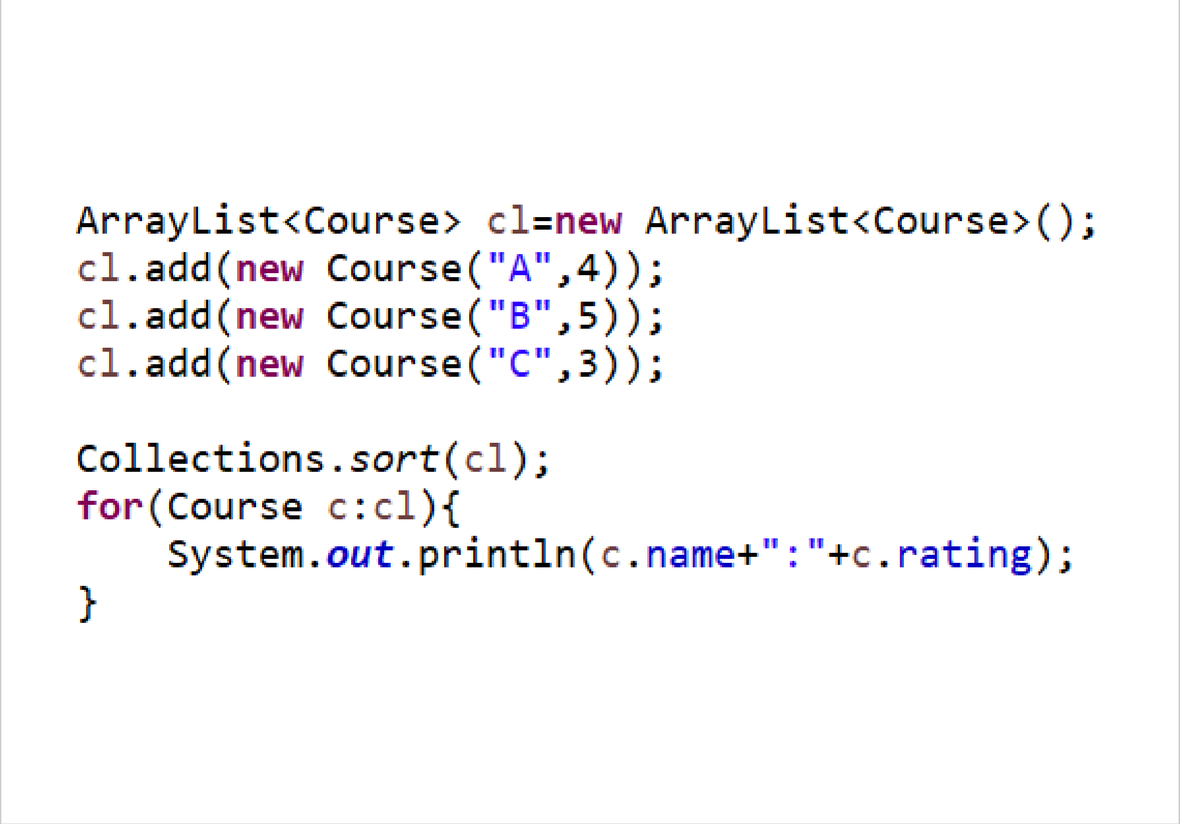
Wrapper classes (use primitive types as objects) and String class already implement the Comparable interface

java.lang.Comparable

- To sort the objects of user-defined custom classes, we need to implement the Comparable interface (i.e., `compareTo(T)`)



```java
public class Course implements Comparable<Course> {
    String name;
    int rating;

    public Course(String name,int rating){
        this.name=name;
        this.rating=rating;
    }

    // compare by rating
    public int compareTo(Course c){
        if(rating==c.rating)
            return 0;
        else if(rating>c.rating)
            return 1;
        else
            return -1;
    }
}
```



```java
ArrayList<Course> cl=new ArrayList<Course>();
cl.add(new Course("A",4));
cl.add(new Course("B",5));
cl.add(new Course("C",3));

Collections.sort(cl);
for(Course c:cl){
    System.out.println(c.name+":"+c.rating);
}
```

OOP basic concepts

- Encapsulation (封装)
- Abstraction (抽象)
- Inheritance (继承)
- Polymorphism (多态)

Inheritance

- Motivation: objects are similar and share common logics

- Inheritance allows a new class (subclass, child class, derived class) to be created by deriving variables and methods from an existing class (superclass, parent class, base class)

- Reduce code redundancy & support good code reuse

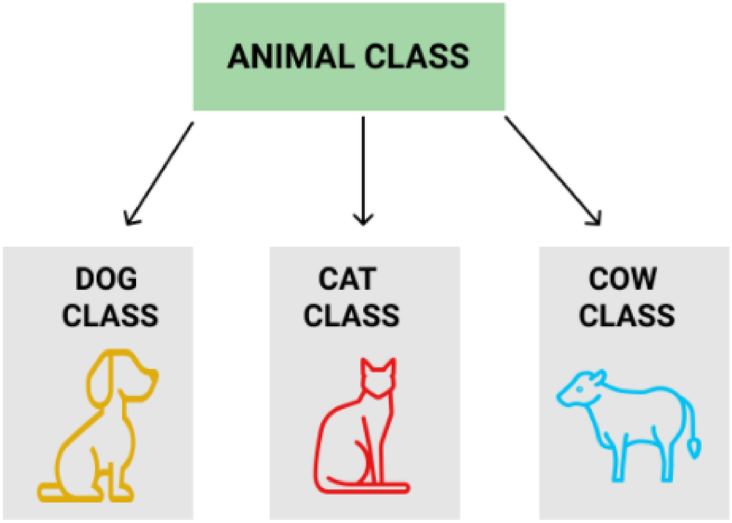
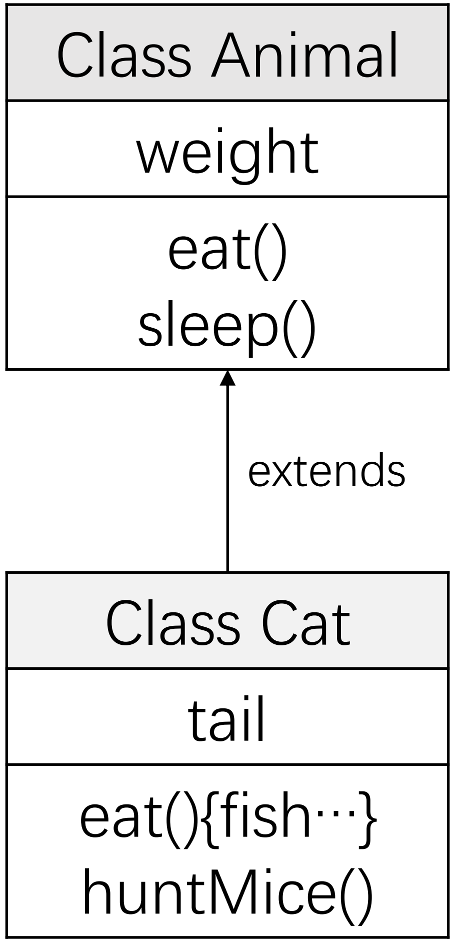


Image source: OOP Inheritance. San Joaquin Delta College. https://eng.libretexts.org/@go/page/34639

Subclass

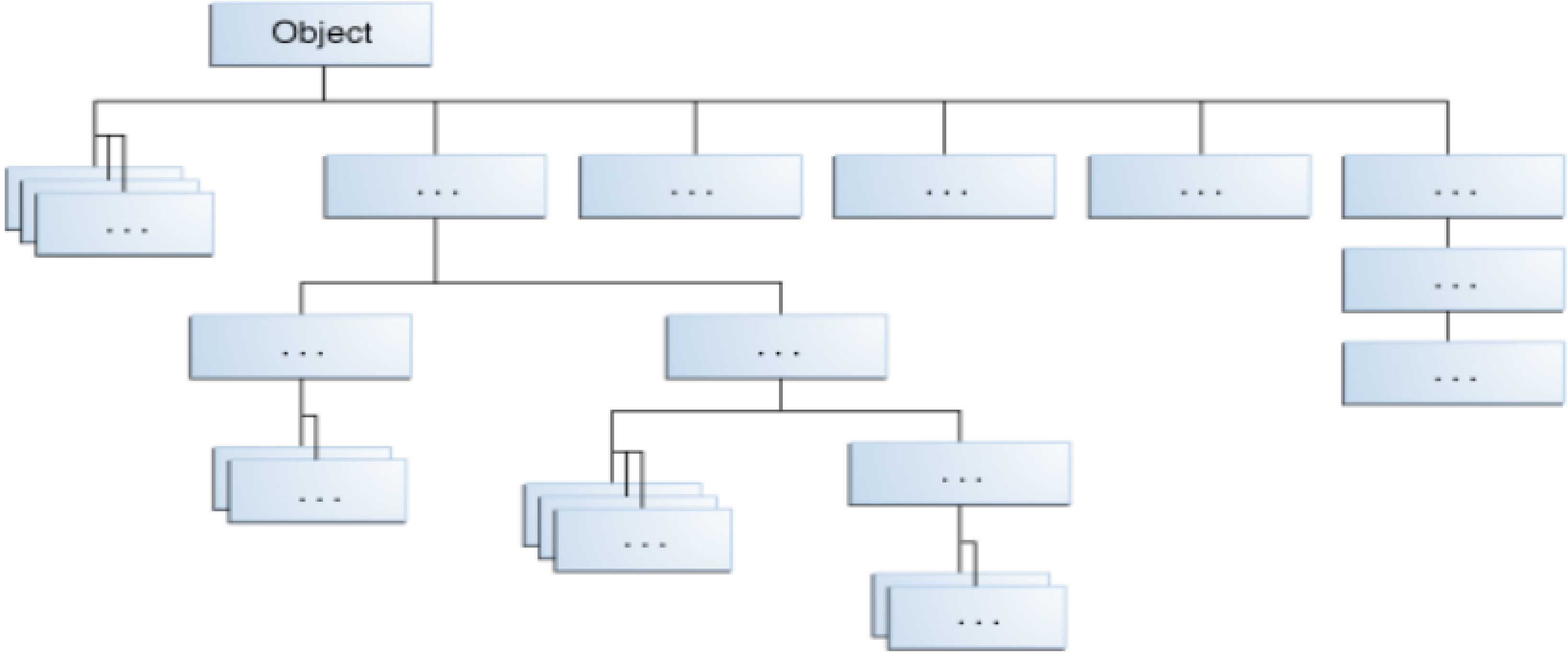
- Subclass could use inherited field directly (`weight`)
- Subclass could declare new fields (`tail`)
- Subclass cannot inherit private members from superclass



- Subclass could use inherited method directly (`sleep()`)
- Subclass could override methods in superclass (`eat()`)
- Subclass could declare new methods (`huntMice()`)

The Java Class Hierarchy

- The `Object` class (in `java.lang` package) is the parent class of all the classes



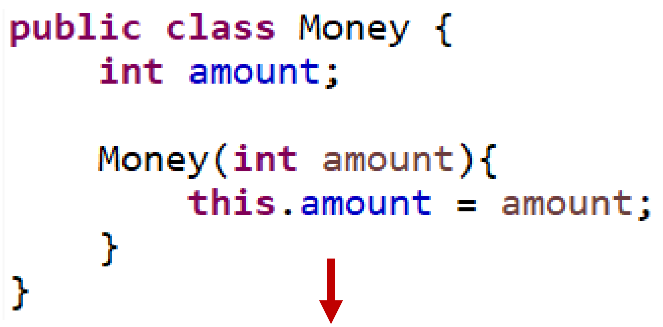
Some classes derive directly from `Object`, others derive from those classes, and so on – forming a tree-like class hierarchy

Object Class

- Providing behaviors common to all the objects, e.g., objects can be compared, cloned, notified, etc.

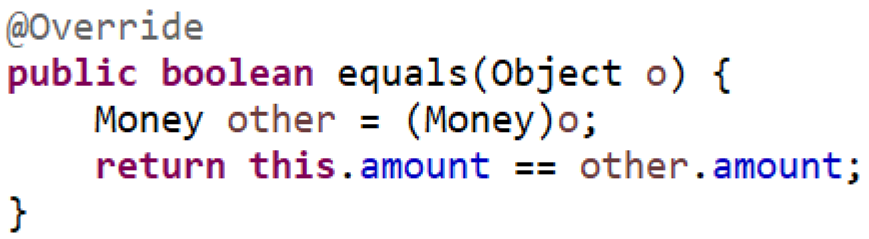
```
boolean equals(Object obj)
```

Indicates whether another obj is "equal to" this one; return True only if two variables refer to the same physical object in memory



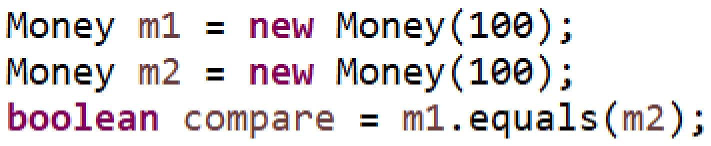
```
public class Money {
    int amount;

    Money(int amount){
        this.amount = amount;
    }
}
```

false



```
@Override
public boolean equals(Object o) {
    Money other = (Money)o;
    return this.amount == other.amount;
}
```

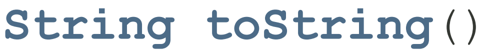
true



```
Money m1 = new Money(100);
Money m2 = new Money(100);
boolean compare = m1.equals(m2);
```

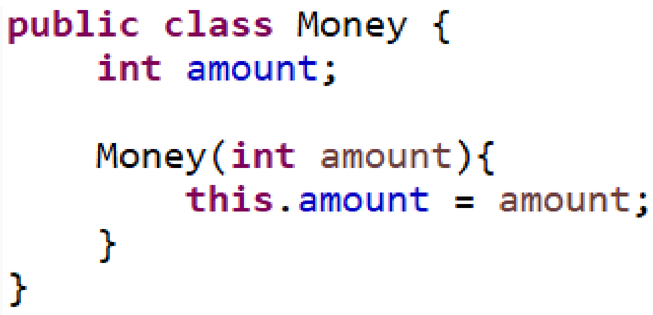
Object Class

- Providing behaviors common to all the objects, e.g., objects can be compared, cloned, notified, etc.

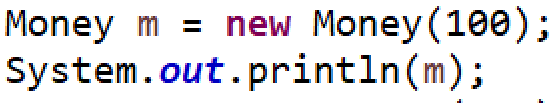


```
String toString()
```

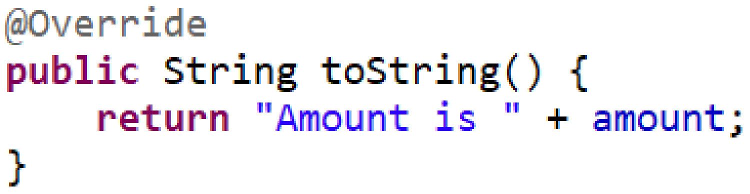
Returns a string representation of the object. Default is the name of the class + “@” + hashCode



```java
public class Money {
    int amount;

    Money(int amount){
        this.amount = amount;
    }
}
```



```java
Money m = new Money(100);
System.out.println(m);
```



```java
@Override
public String toString() {
    return "Amount is " + amount;
}
```

```
Money@515f550a
```

```
Amount is 100
```

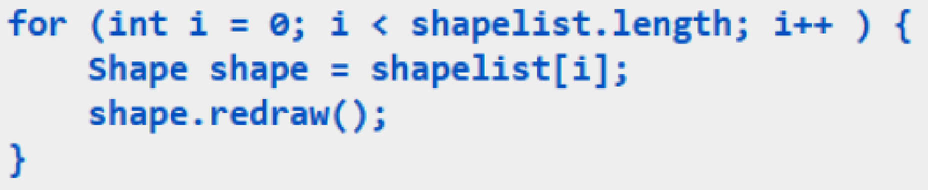
OOP basic concepts

- Encapsulation (封装)
- Abstraction (抽象)
- Inheritance (继承)
- Polymorphism (多态)

Polymorphism

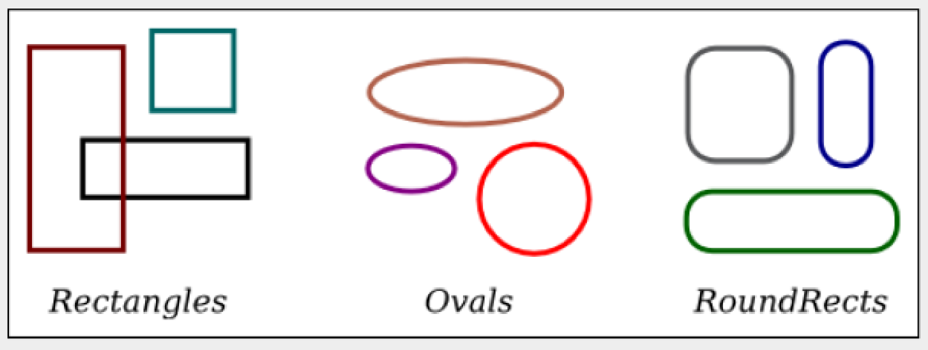
- An object could take many forms
- The same action could be performed in many different ways

- Suppose that `shapelist` is a variable of type `Shape[]`; the array has already been created and filled with data.
- Some of the elements in the array are `Rectangles`, some are `Ovals`, and some are `RoundRects`
- Implementations for drawing are different, but we don't have to declare different `draw()`



```
for (int i = 0; i < shapelist.length; i++ ) {
    Shape shape = shapelist[i];
    shape.redraw();
}
```

Same action



Many forms

Binding

- Mapping the name of the method to the final implementation.
- Static binding vs Dynamic binding

Static binding (early binding)

- Mapping is resolved at compile time
- Method overloading (methods with the same name but different parameters) are resolved using static binding

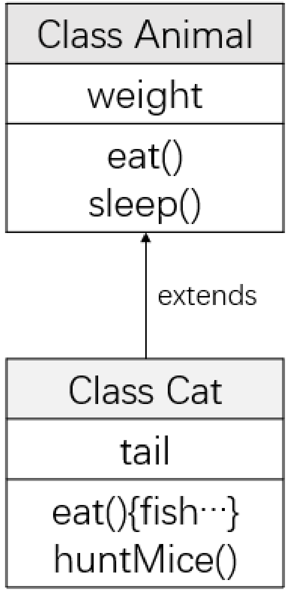
```
class Calculator{
    public int sum(int a, int b){
        return a+b;
    }

    public int sum(int a, int b, int c){
        return a+b+c;
    }
}
```

Binding

- Mapping the name of the method to the final implementation.
- Static binding vs Dynamic binding

Dynamic binding (late binding)

- Mapping is resolved at execution time
- Method overriding (subclass overrides a method in the superclass) are resolved using dynamic binding



```
Animal x = new Cat();
x.eat();
```

✓ Compilation ok, since Animal type has eat() method

✓ At execution time, x refers to a Cat object, so invoking Cat’s eat() method

Next Lecture

- Exception handling
- File I/O
- Encoding
- Persistence
- Serialization