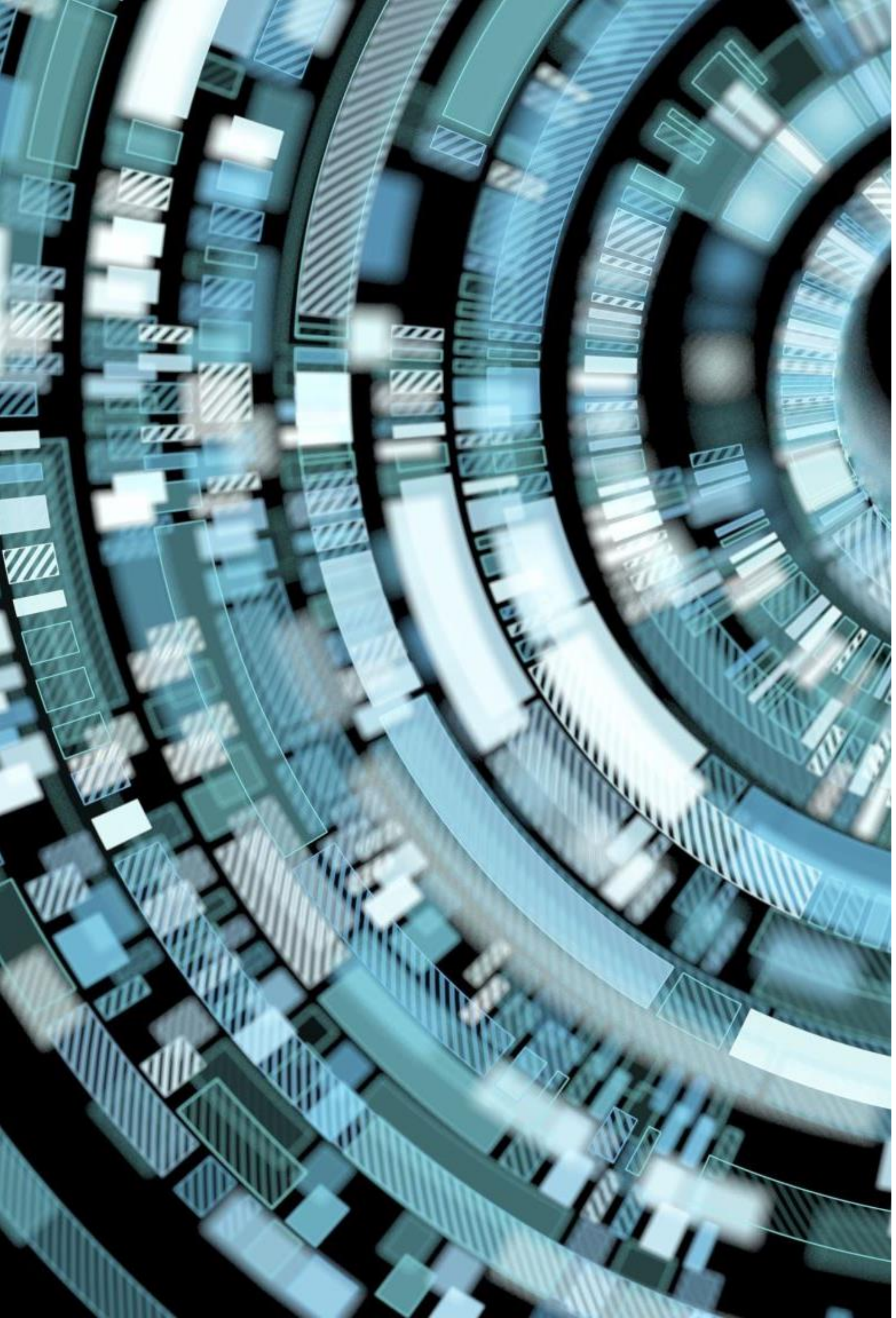
Computer System Design & Application

计算机系统设计与应用A

陶伊达 （TAO Yida）

taoyd@sustech.edu.cn



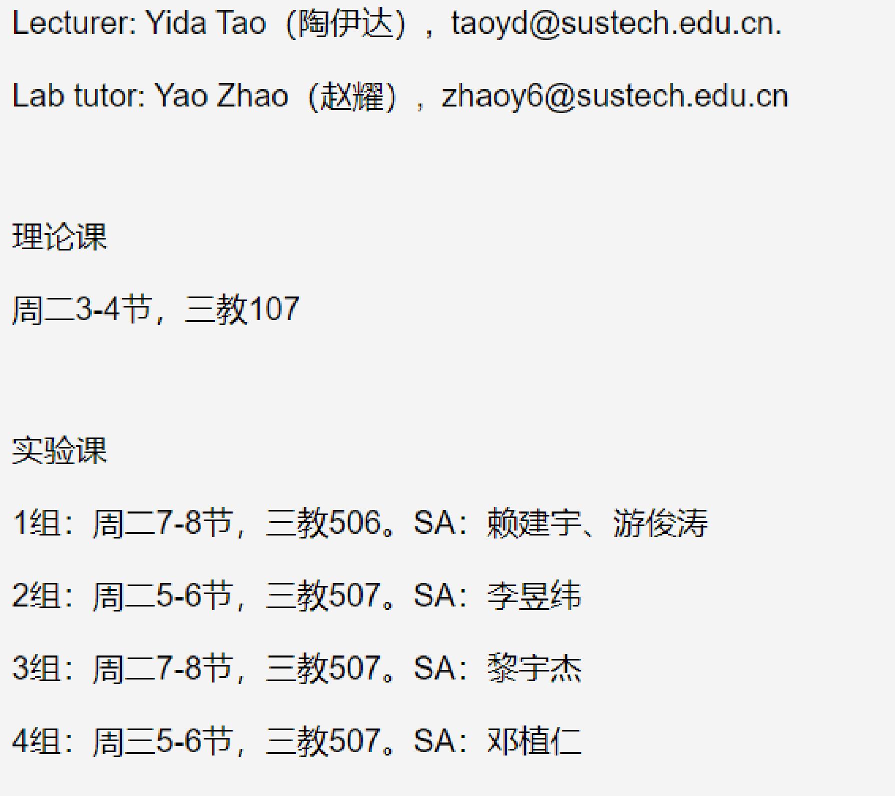
Lecture 1

- Course introduction
- Computer system & programs
- Java review and JVM
- Object-oriented programming concepts
- Software design principles

Course Logistics

- Course website: Blackboard https://bb.sustech.edu.cn/
- Slides and other resources will all be uploaded here.

- Office hours: Wednesday 16:10 – 18:10 pm, CoE South Building, 411B



Lecturer: Yida Tao（陶伊达），taoyd@sustech.edu.cn.

Lab tutor: Yao Zhao（赵耀），zhaoy6@sustech.edu.cn

理论课

周二3-4节，三教107

实验课

1组：周二7-8节，三教506。SA：赖建宇、游俊涛

2组：周二5-6节，三教507。SA：李昱纬

3组：周二7-8节，三教507。SA：黎宇杰

4组：周三5-6节，三教507。SA：邓植仁

Topics covered

Principles

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

……

Utilities

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

……

Functionalities

- File I/O
- GUI
- Networking
- Reflection
- Web development

……

Applications

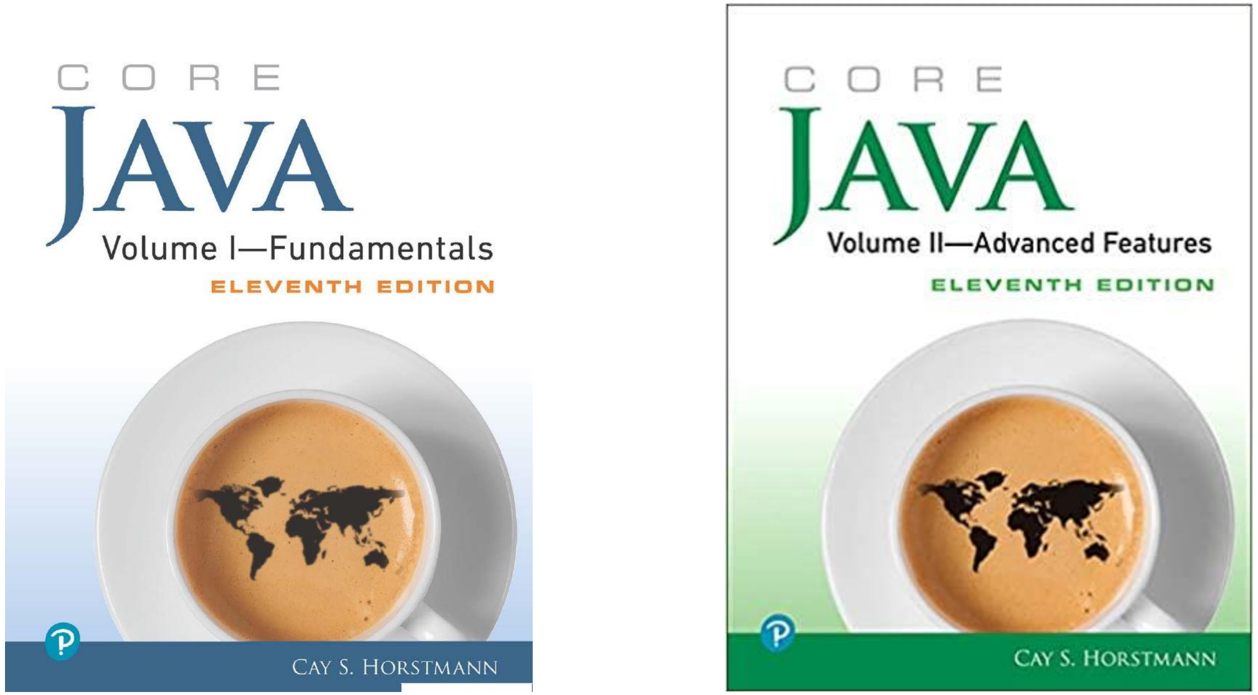
- Text scraping and processing
- Data analytics and visualization
- Web applications & services

……

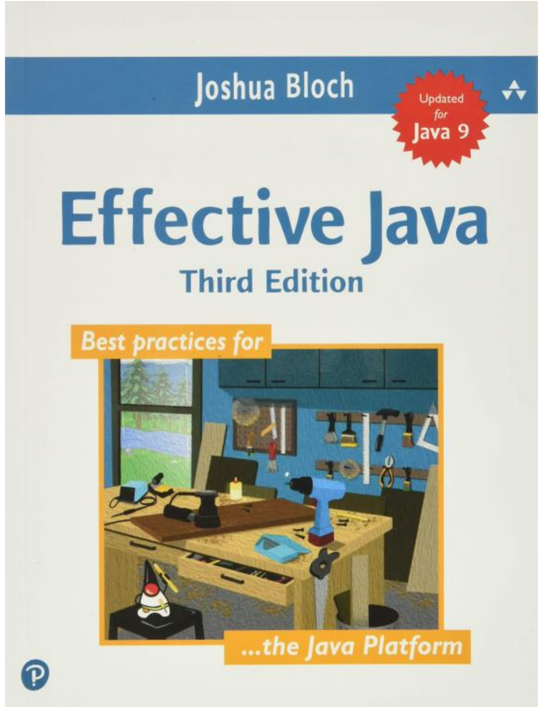
Syllabus
(Negotiable)

- Lecture 1: Computing overview, JVM, Software Design Principles
- Lecture 2: Generics, ADT, Collections
- Lecture 3: Functional programming, Lambda
- Lecture 4: Java 8 Stream API
- Lecture 5: I/O Streams, Encoding
- Lecture 6: Serialization, File I/O, Exception Handling
- Lecture 7: Concurrency, Multithreading
- Lecture 8: Network Programming
- Lecture 9: Reflection, Annotation
- Lecture 10: GUI Intro, JavaFX
- Lecture 11: Java EE, Servlet
- Lecture 12: The Spring Framework
- Lecture 13: Spring Boot
- Lecture 14: JUnit Testing
- Lecture 15: Design Patterns, JVM, Java memory model
- Lecture 16: Project Presentation, Course Review

Reference Books



Core Java Volume I II
Cay S. Horstmann



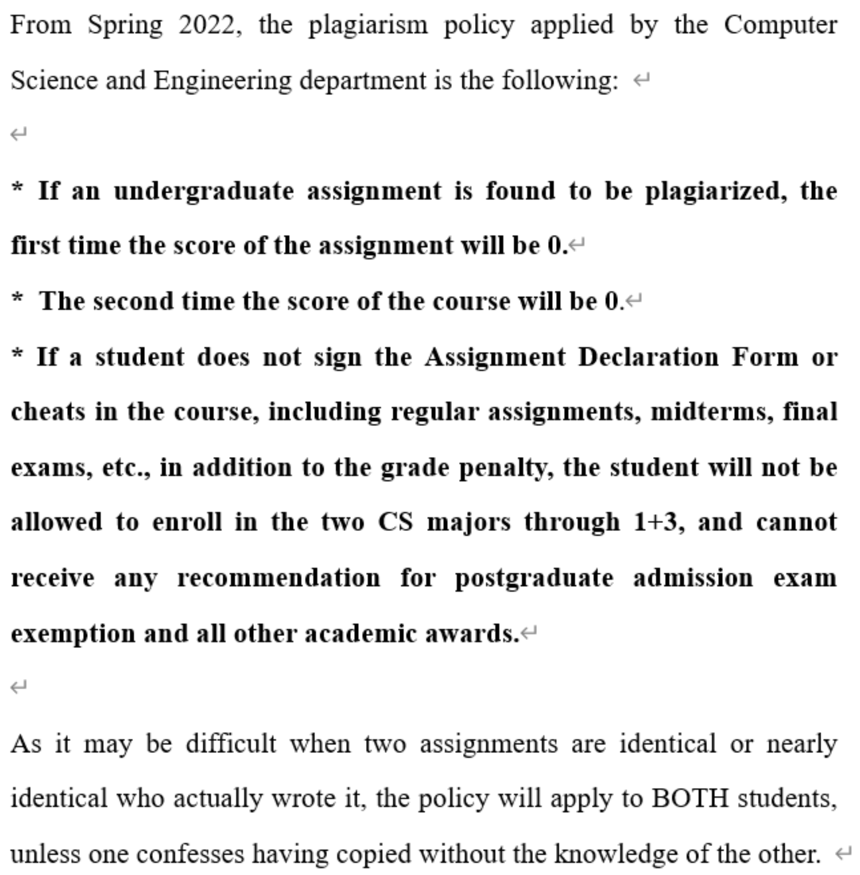
Effective Java
Joshua Bloch

Coursework & Grading Policy

	Score	Description
Assignments	25%	2 assignments Assignment 1: release at week 4 and due at week 7 Assignment 2: release at week 8 and due at week 11
Project	20%	Released around week 9 Team: Preferably 2 people +1 for submitting the final project at week 15 +1 (max) for presenting at week 16 lecture
Labs	15%	Attendance Lab practices (+0.1 points for submitting lab practice onsite, max +1)
Feedback	4%	Submitting feedback at the end of each lab
Quiz	6%	Quizzes, exercises, participation during lectures
Final Exam	30%	Close-book (Two pieces of A4 cheat sheets allowed) No electronic device

Labs start from the 1st week!

Academic Integrity



From Spring 2022, the plagiarism policy applied by the Computer Science and Engineering department is the following: ↵

↵

*** If an undergraduate assignment is found to be plagiarized, the first time the score of the assignment will be 0.**↵

*** The second time the score of the course will be 0.**↵

*** If a student does not sign the Assignment Declaration Form or cheats in the course, including regular assignments, midterms, final exams, etc., in addition to the grade penalty, the student will not be allowed to enroll in the two CS majors through 1+3, and cannot receive any recommendation for postgraduate admission exam exemption and all other academic awards.**↵

↵

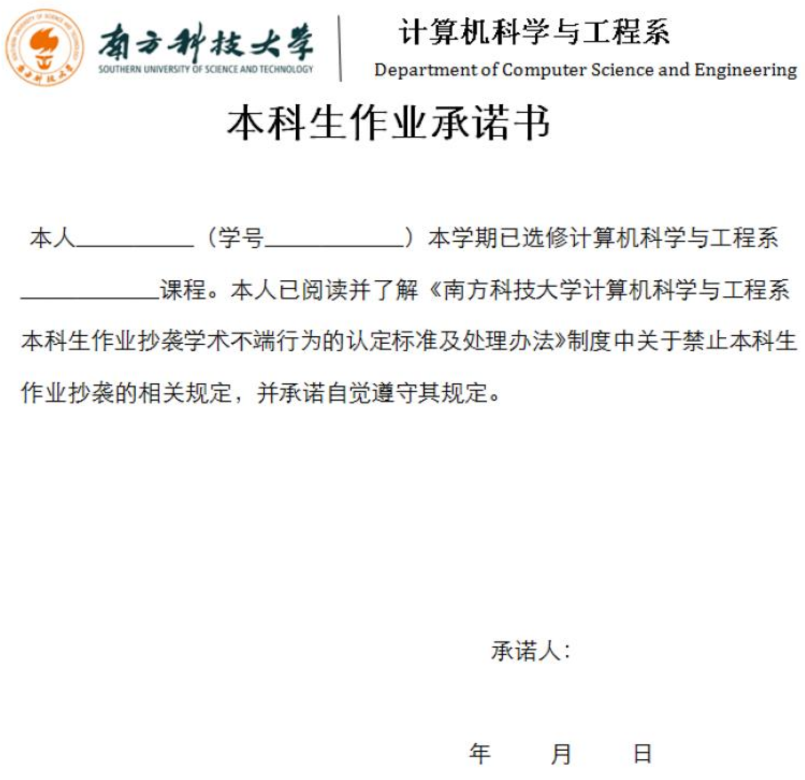
As it may be difficult when two assignments are identical or nearly identical who actually wrote it, the policy will apply to BOTH students, unless one confesses having copied without the knowledge of the other. ↵

- 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.

Academic Integrity

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



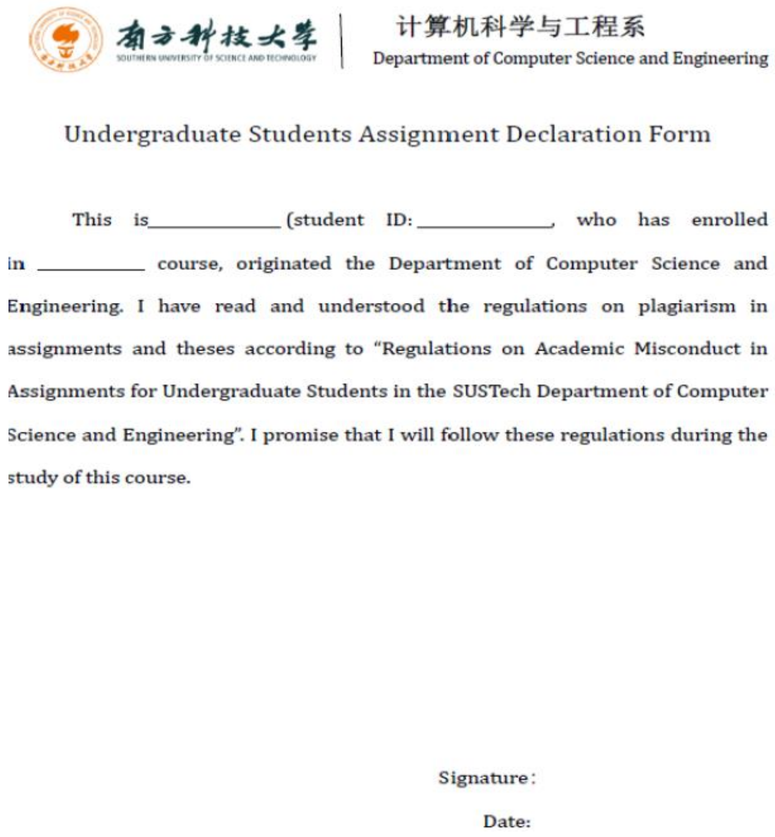
南方科技大学 SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY | 计算机科学与工程系 Department of Computer Science and Engineering

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



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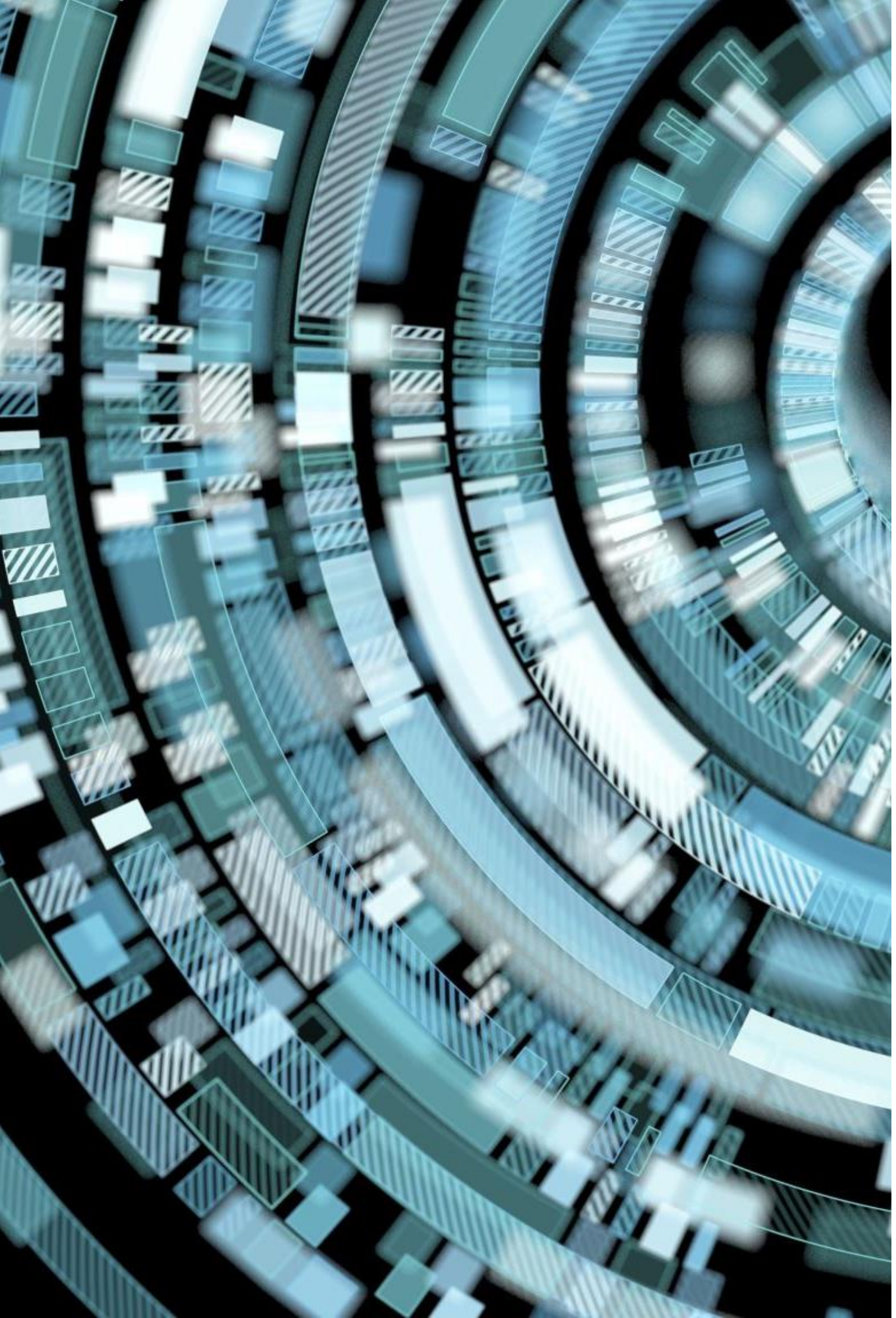
Undergraduate Students Assignment Declaration Form

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:



Lecture 1

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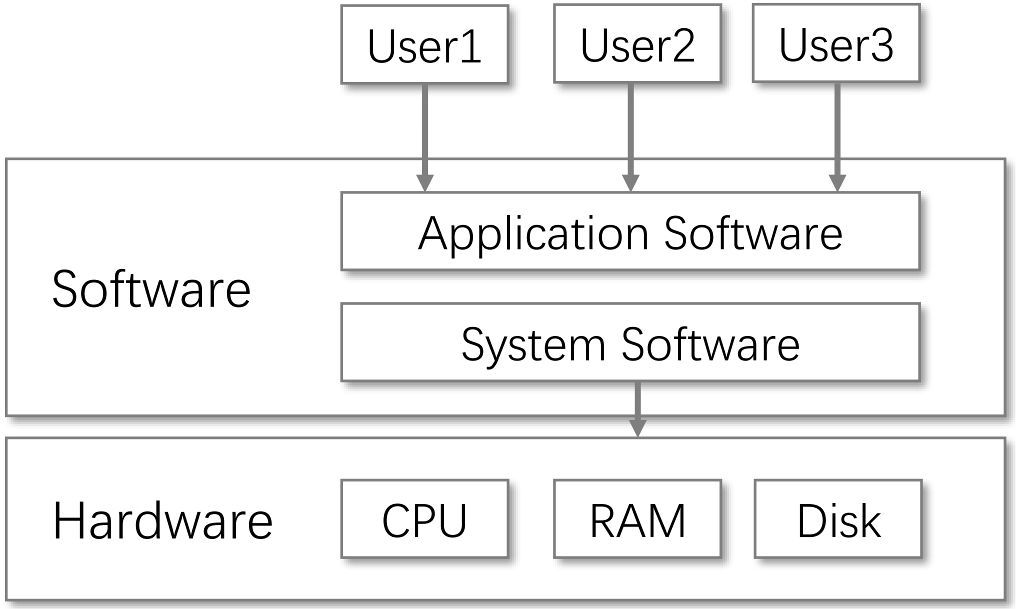
Computer System

- 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

What is a program?



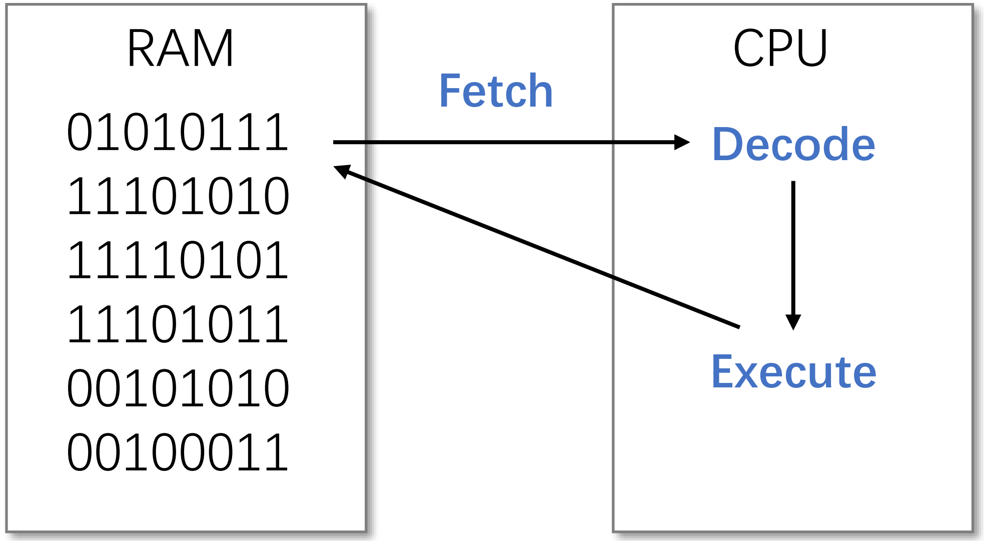
Programs

- 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

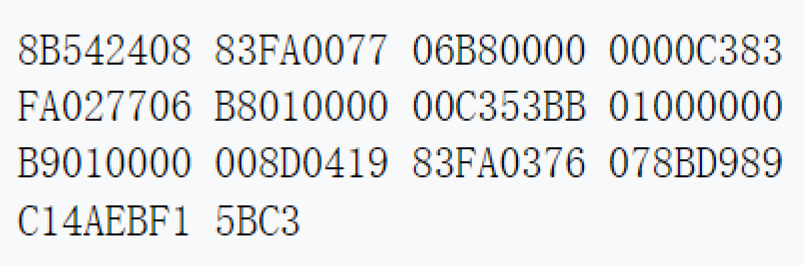
The fetch-execute cycle was first proposed by **John von Neumann**, who is famous for the **Von Neumann architecture**, which is being followed by most computers today



Programs

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

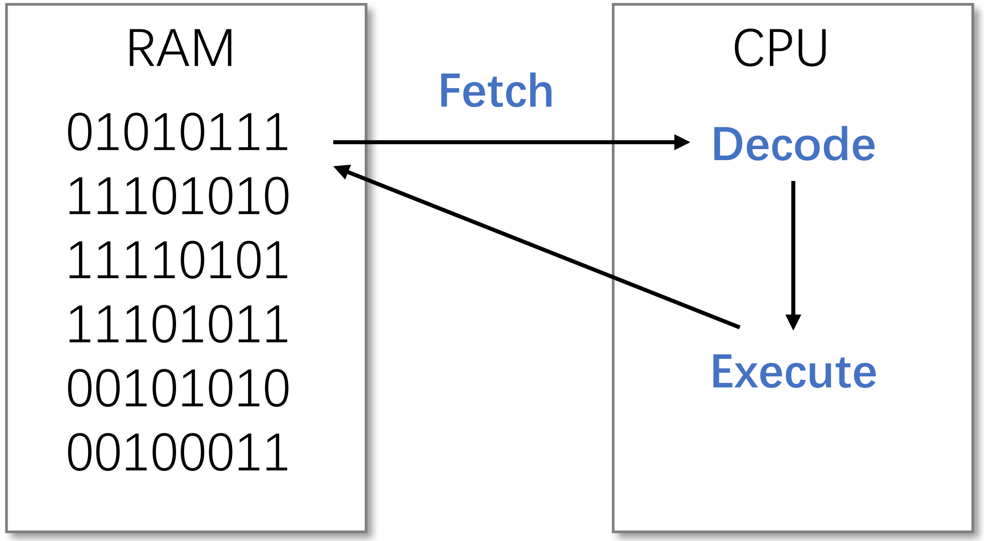
Machine-language instructions are hard to read & write for human.



```
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

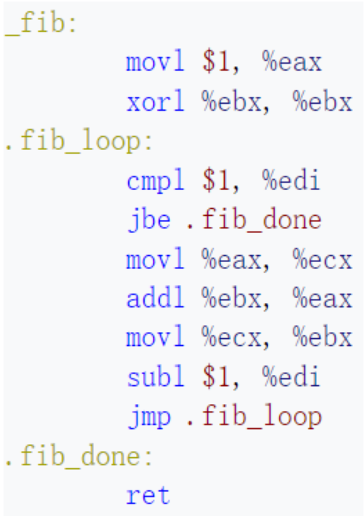
Source: https://en.wikipedia.org/wiki/Low-level_programming_language



Programs

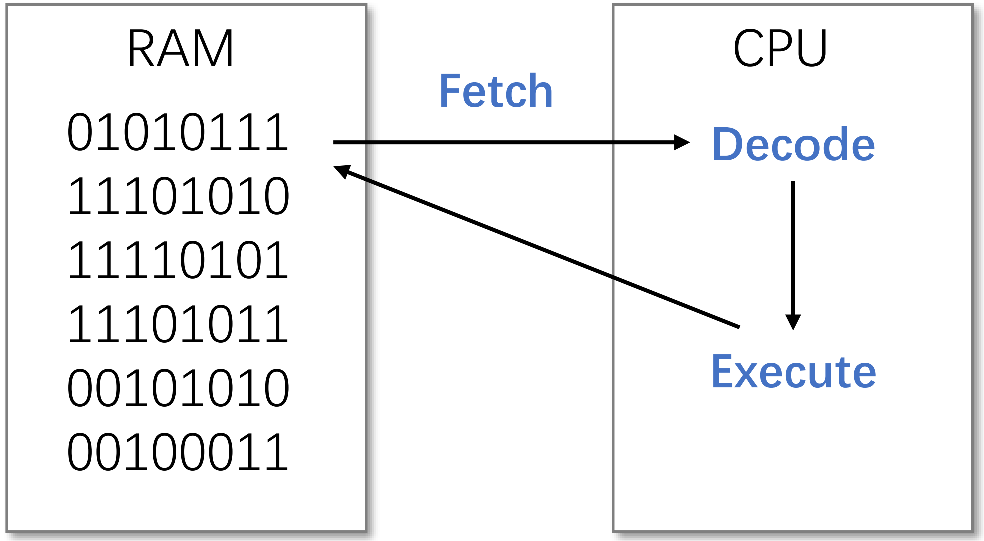
- A sequence of instructions that specifies how to perform a computation

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



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Programs

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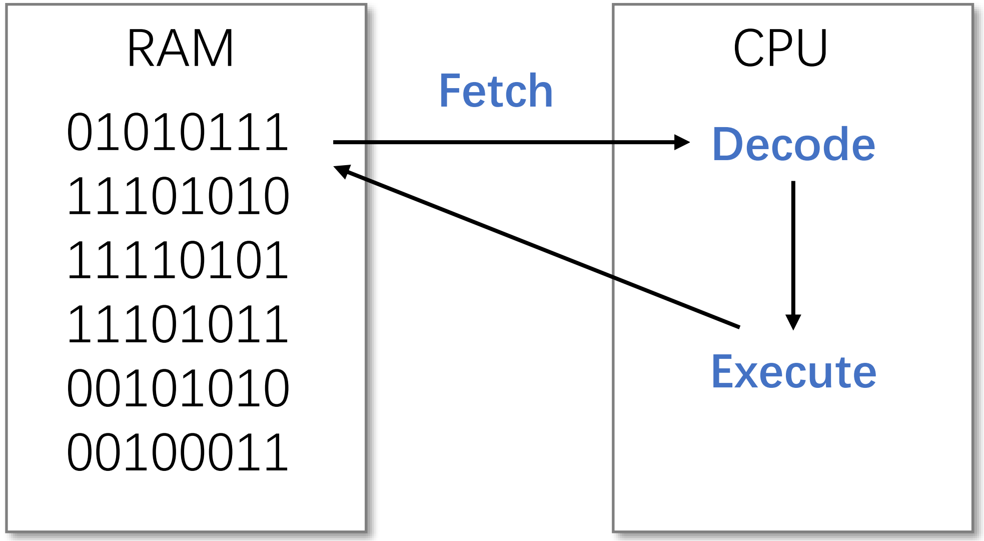
Low-level language provides a level of abstraction on top of machine code



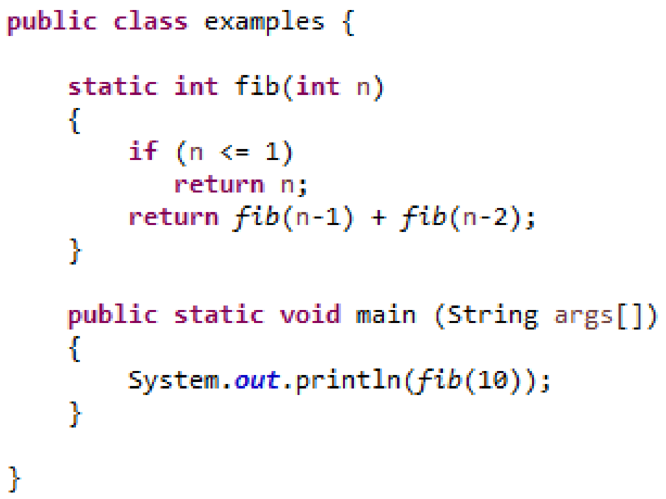
A video game written in assembly

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



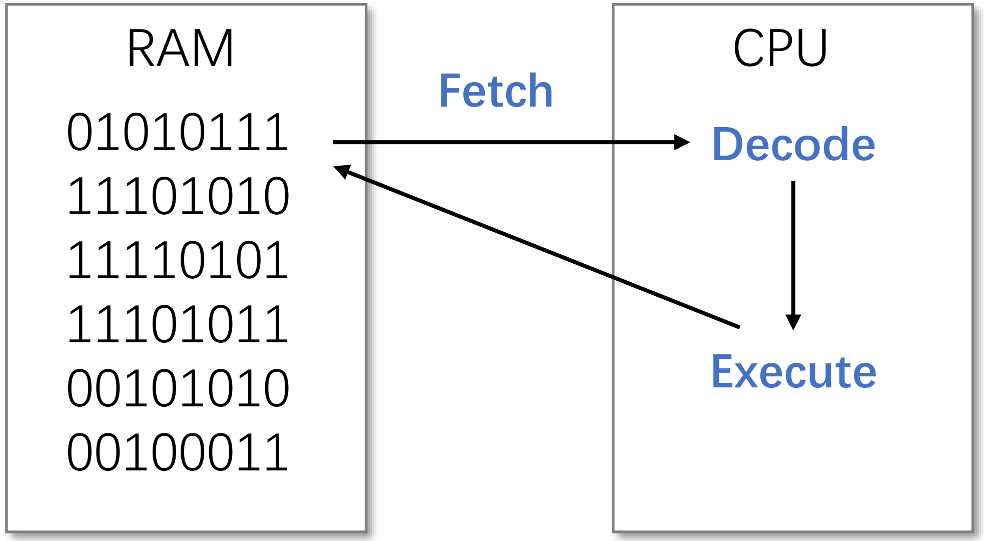
```
public class examples {

    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



Programs

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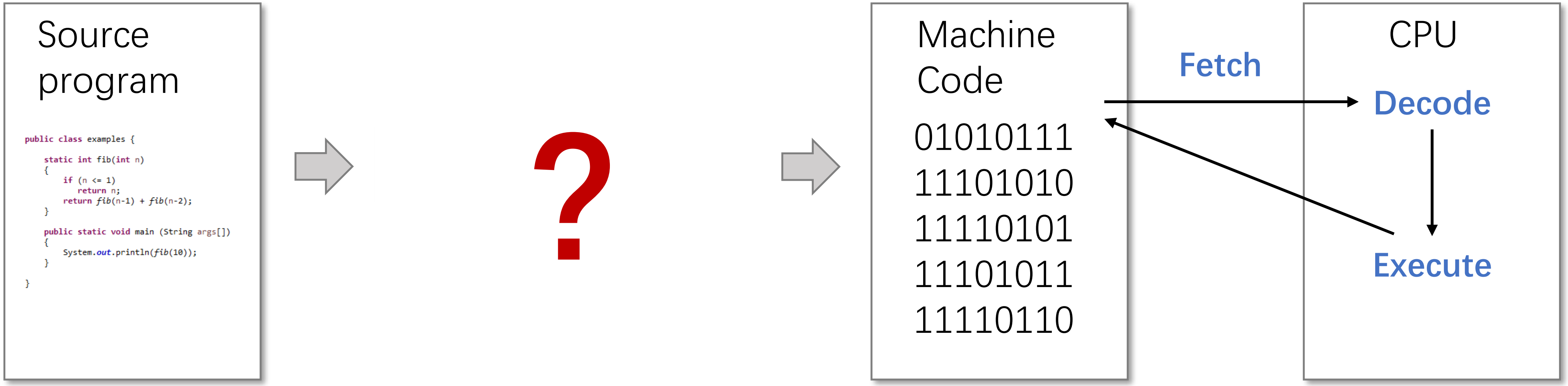

```java
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    }

}
```
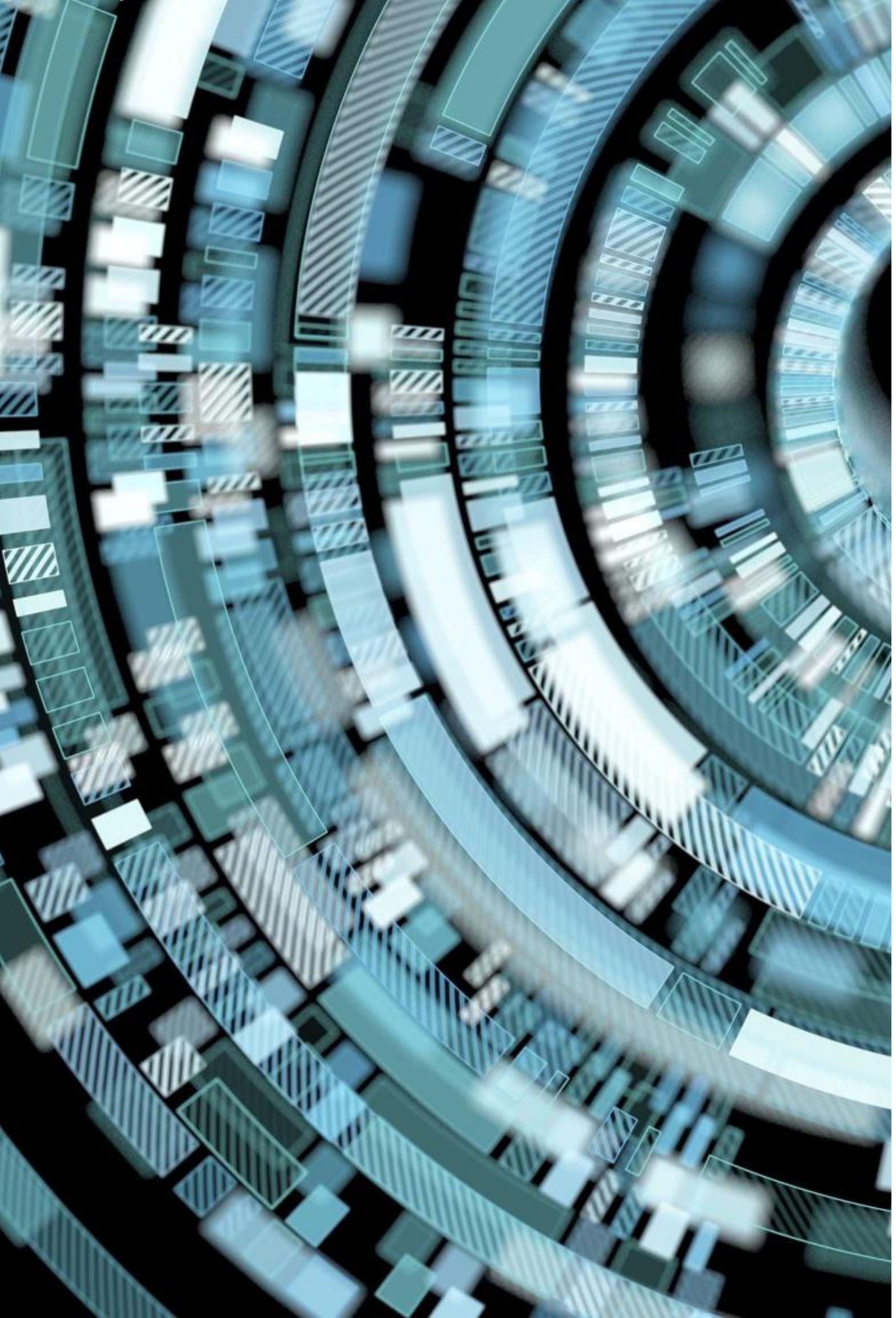

```
01010111
11101010
11110101
11101011
11110110
```

CS202. Computer Organization



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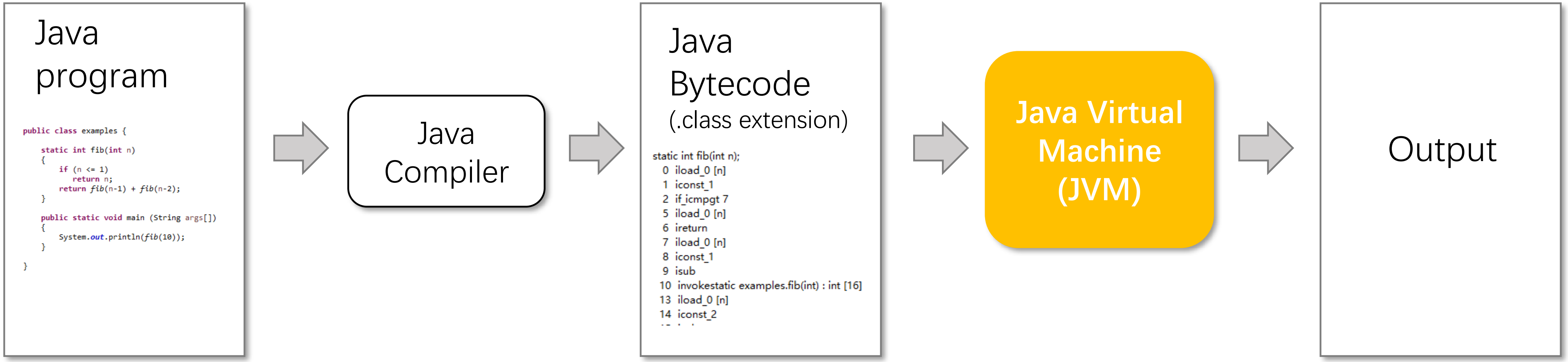
How is a Java program executed?

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



Java program

```java
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        return fib(n-1) + fib(n-2);
    }

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

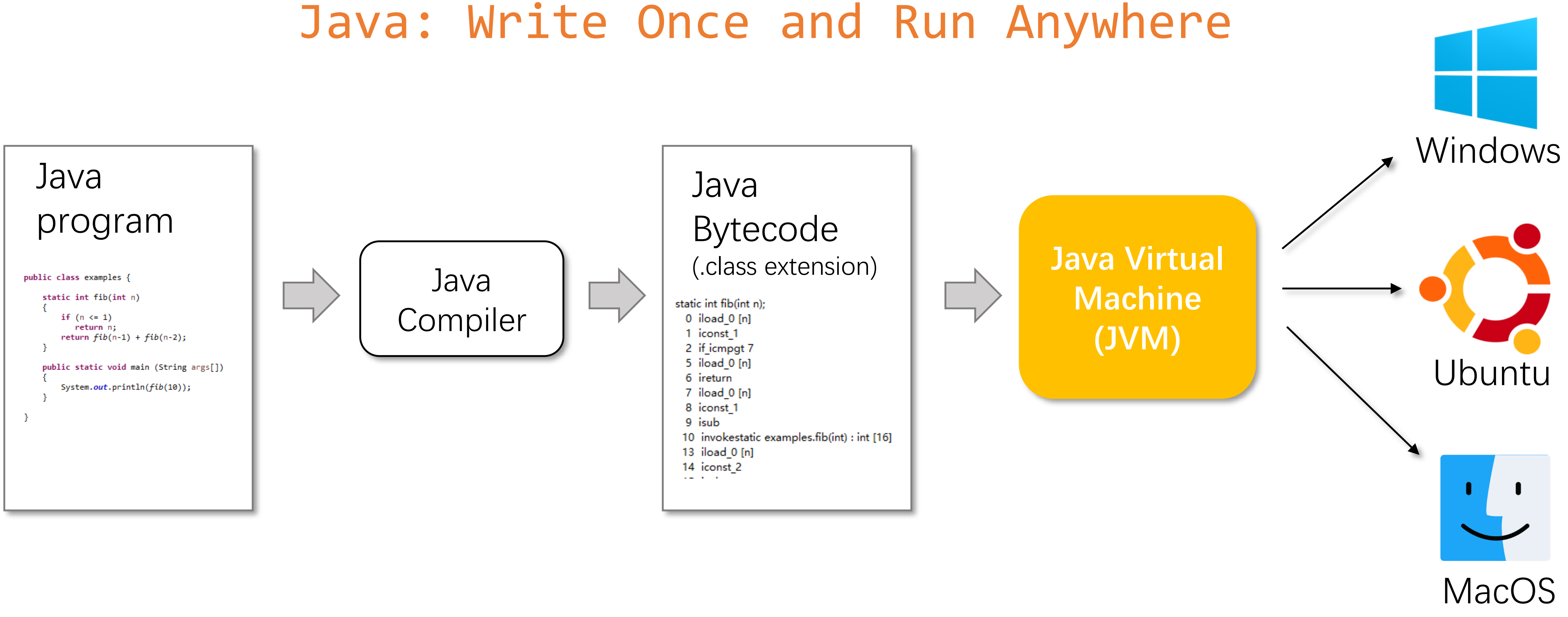
}
```

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)

Java: Write Once and Run Anywhere



Java program

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public class examples {

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        return fib(n-1) + fib(n-2);
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}
```

Java Compiler

Java Bytecode (.class extension)

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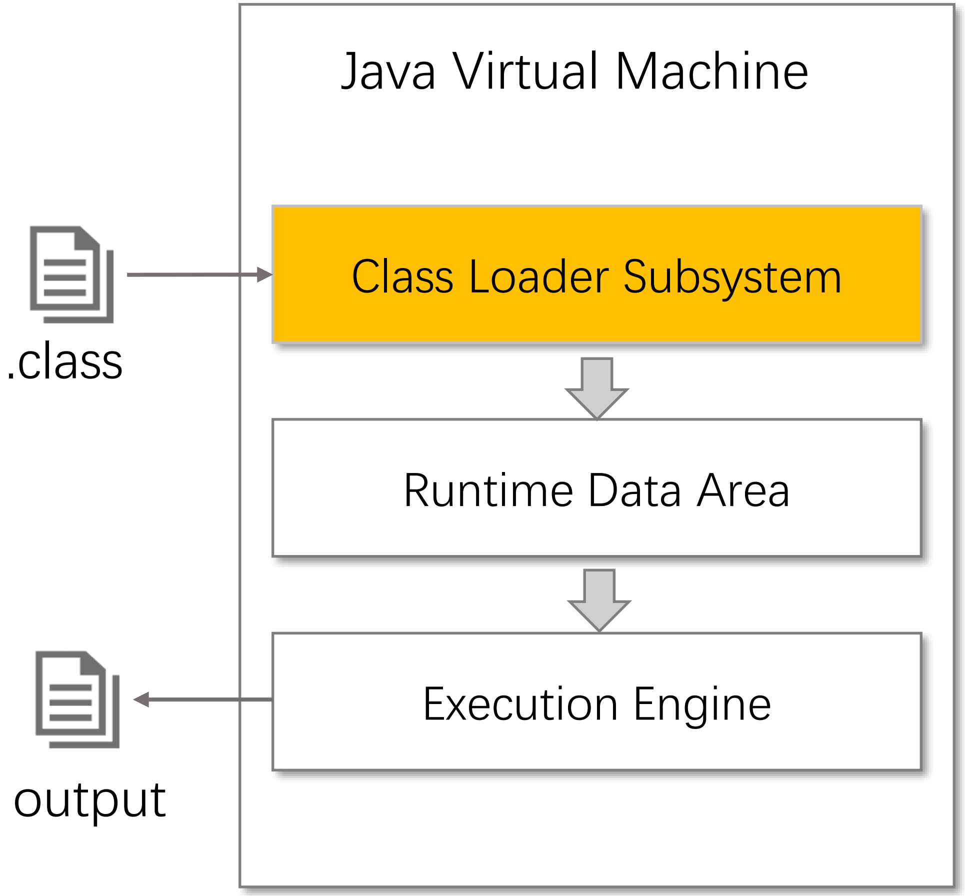
  7  iload_0 [n]
  8  iconst_1
  9  isub
 10  invokestatic examples.fib(int) : int [16]
 13  iload_0 [n]
 14  iconst_2
```

Java Virtual Machine (JVM)

Java Virtual Machine (JVM)

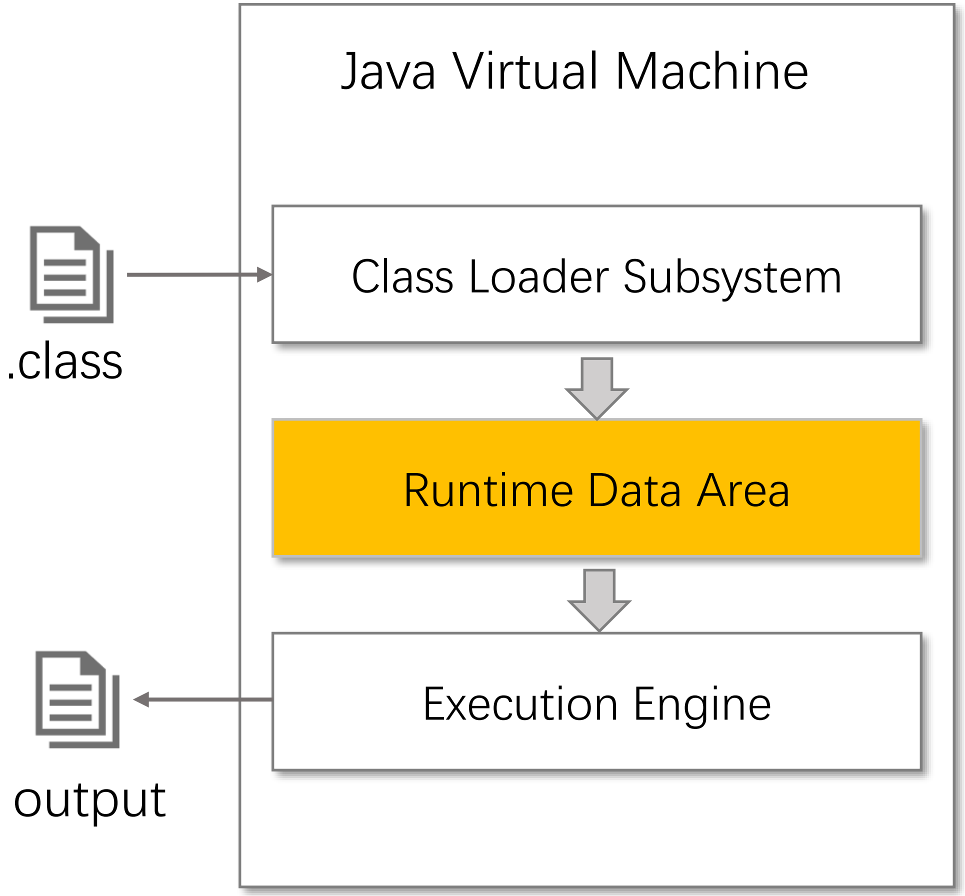


Class Loader

- 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)



Java Virtual Machine

.class

Class Loader Subsystem

Runtime Data Area

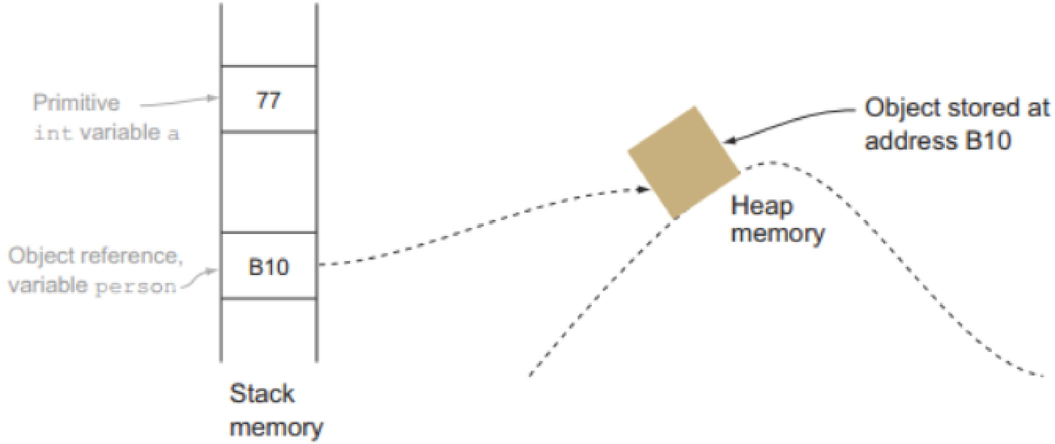
Execution Engine

output

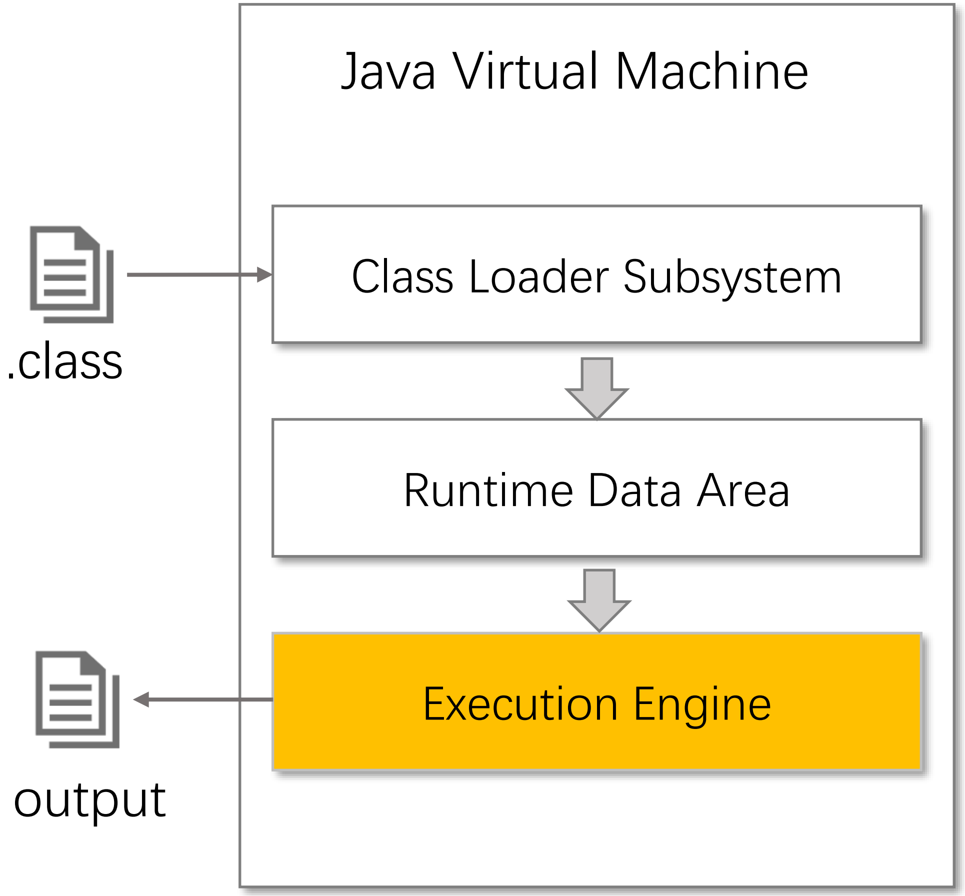
Runtime Data Area

Store all kinds of data and information

- Class-level data in Method Area
- Objects/instances in Heap Area
- Local variables in Stack Area


Primitive int variable a
77
Object reference, variable person
B10
Stack memory
Object stored at address B10
Heap memory

Java Virtual Machine (JVM)



Execution Engine

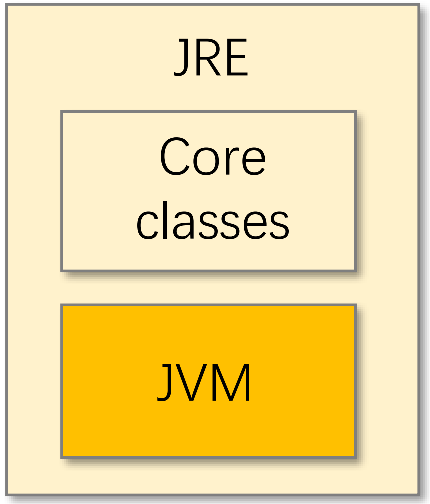
- Translating “run anywhere” .class code to “run on this particular machine” instructions
- Translation is done by Interpreter and JIT Compiler (also for optimization)
- Finally, garbage collector identifies objects that are no longer in use and reclaims the memory

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

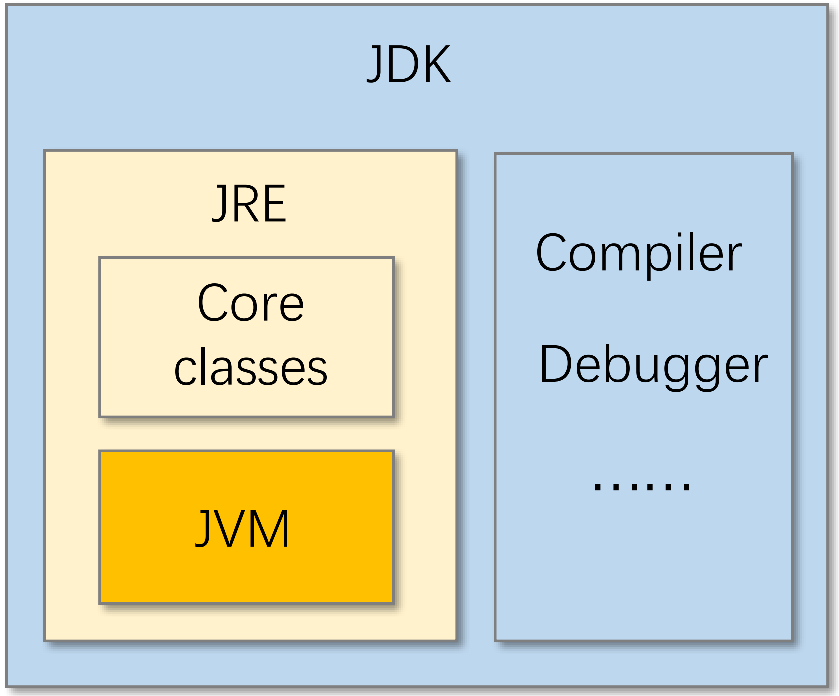
Core classes

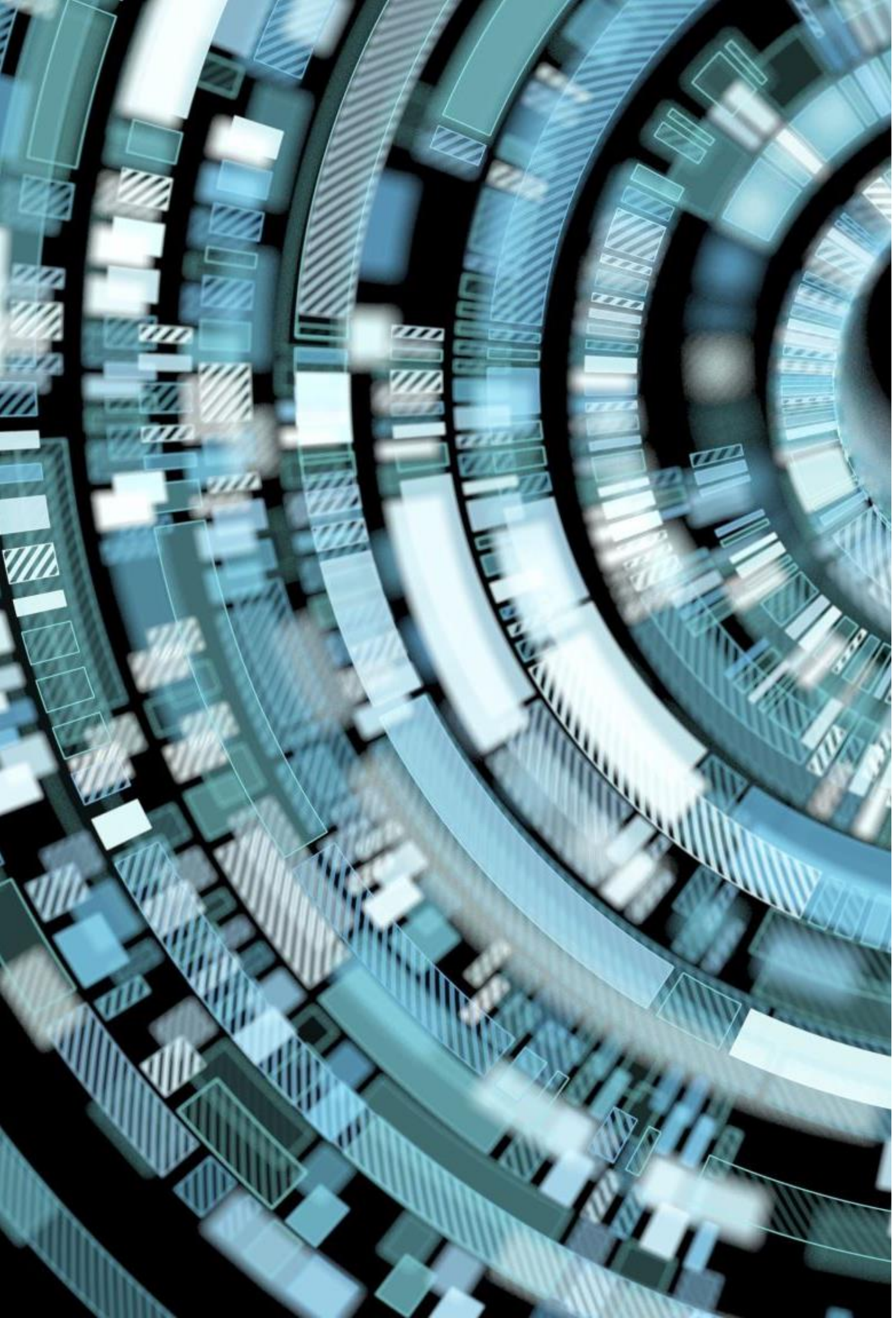
JVM

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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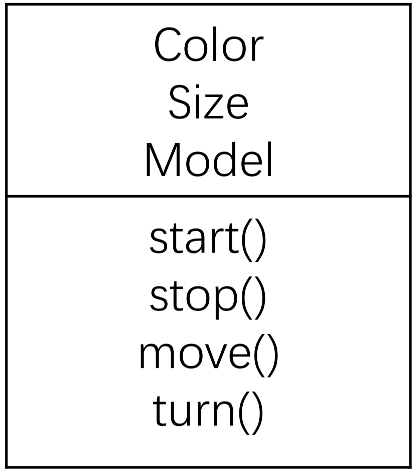
Class, Object, and Instance

- **Class**: a template or blueprint that is used to create objects.
- **Object**: a tangible, concrete entity created from a class, which occupies memory and can be manipulated through its reference.
- **Instance**: a single, specific object created from a class.

Car Class



- Cars have state (e.g., speed, color, model) and behavior (e.g., move, turn, stop).
- A `Car` class consists of fields (hold the states) and methods (represent the behaviors)

Class, Object, and Instance

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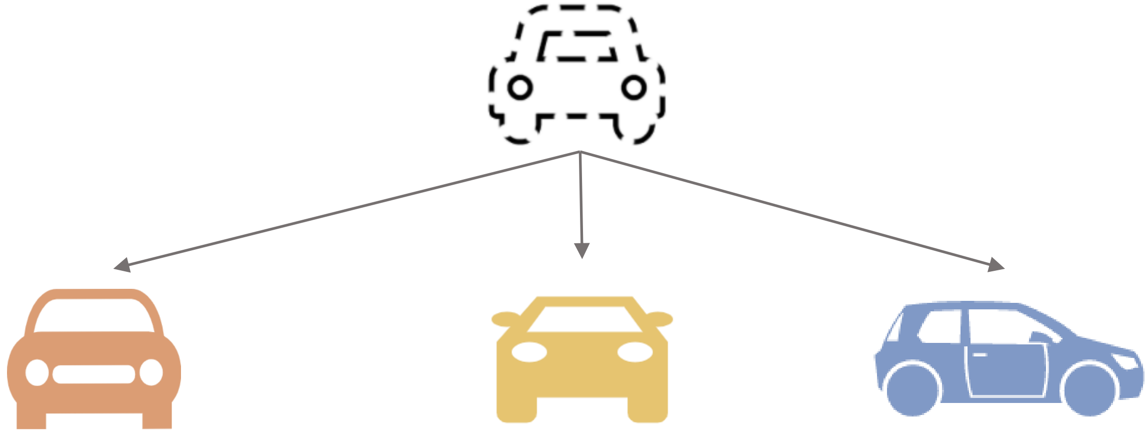
Car Class

Color Size Model

start()
stop()
move()
turn()



Car object
Car instance 1

Car object
Car instance 2

Car object
Car instance 3

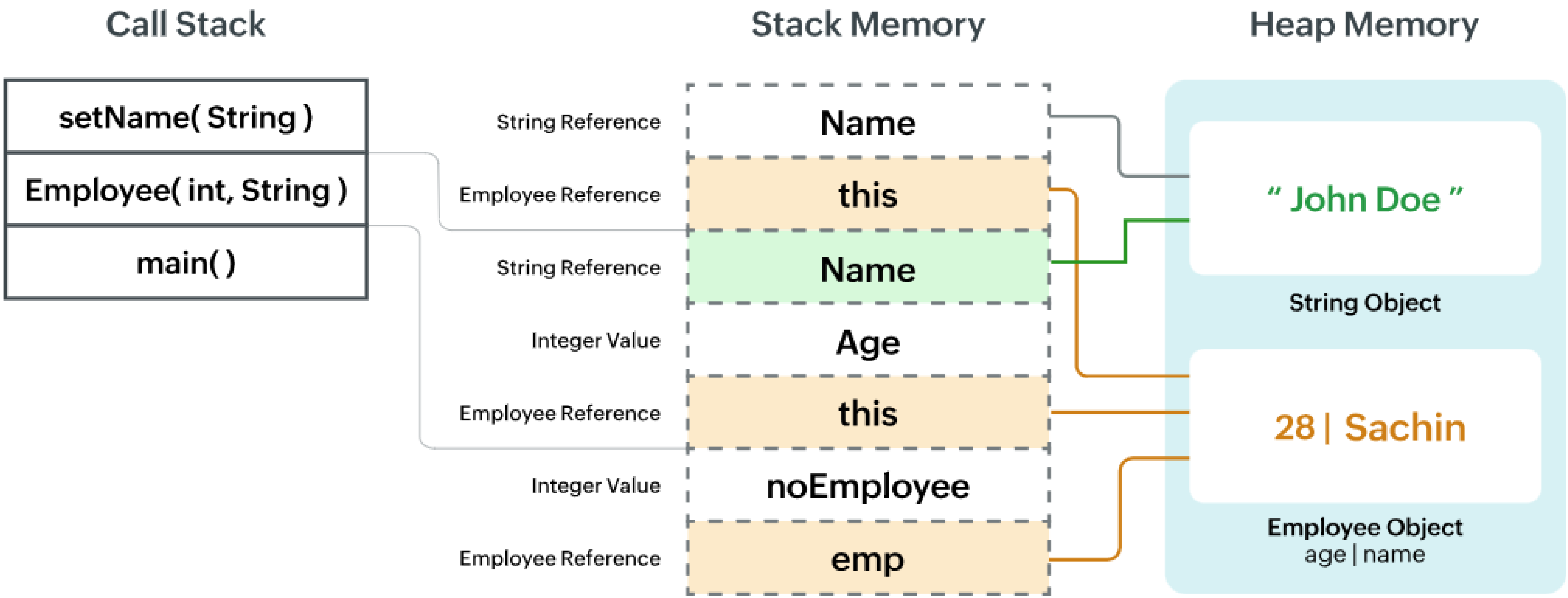
Class, Object, and Instance

- **Class**: a template or blueprint that is used to create objects.
- **Object**: a tangible, concrete entity created from a class, which occupies memory and can be manipulated through its reference.
- **Instance**: a single, specific object created from a class.

```
// Creating two objects of the Car class
Car car1 = new Car("Toyota", "Camry", 2022); // car1 is an object
Car car2 = new Car("Honda", "Civic", 2021);  // car2 is an object

// car1 and car2 are instances of the Car class
// They are two unique instances of the same class
```

Memory Allocation



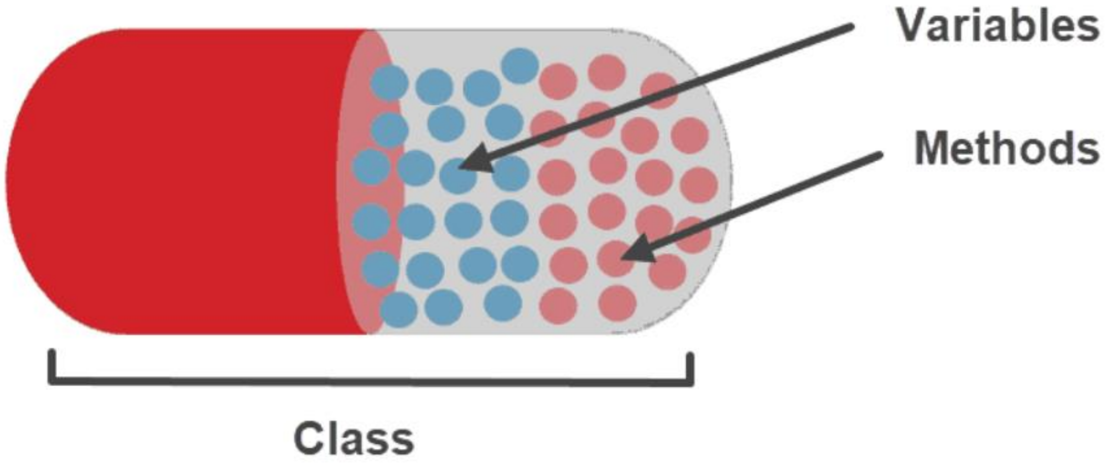
https://www.site24x7.com/learn/java/heap-and-stack-memory-management.html

OOP basic concepts

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

Encapsulation

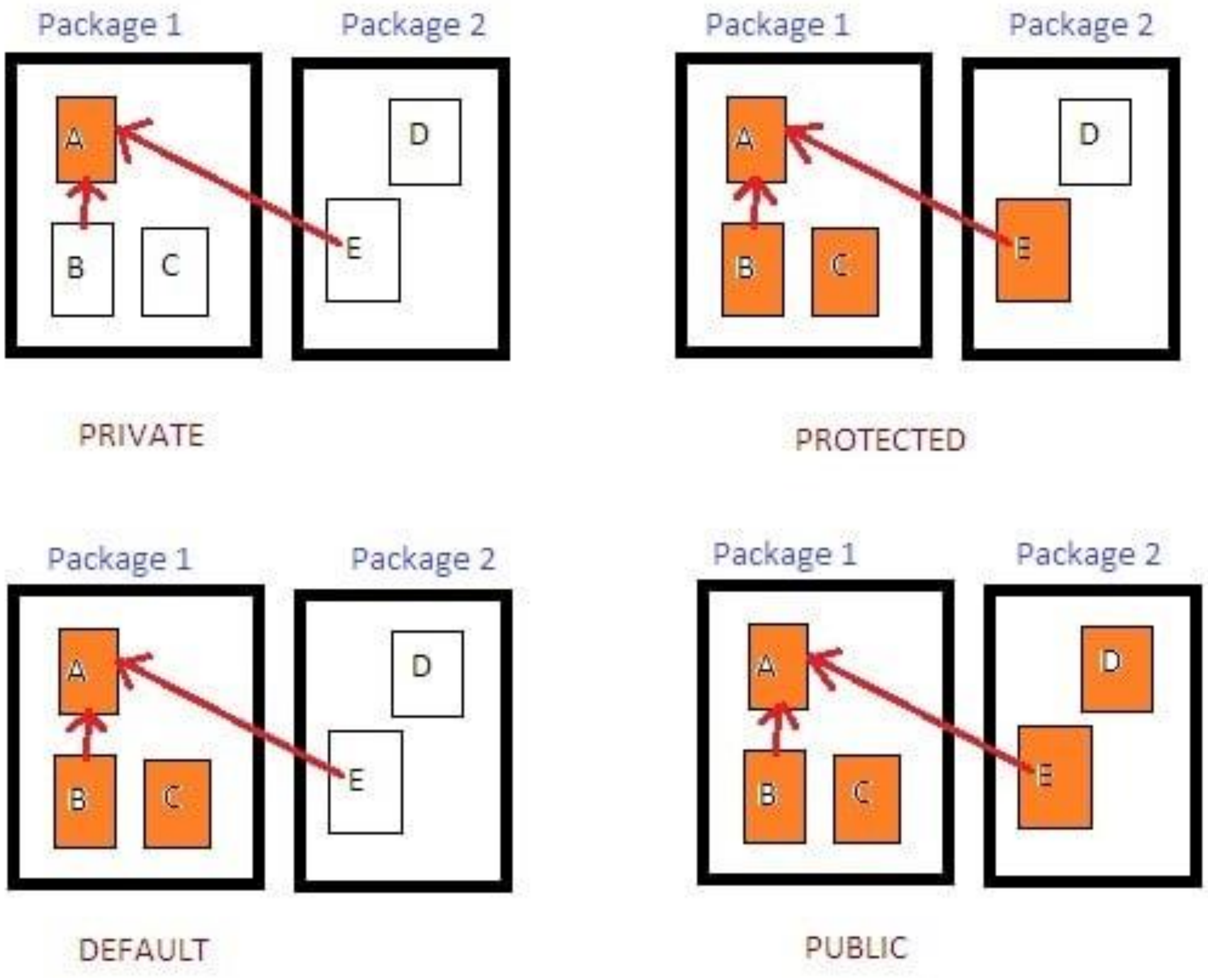
- Bundling the data and functions which operate on that data into a single unit, e.g., a class in Java.
- Program should interact with object data *only* through the object's methods.



Encapsulation is achieved by the **Access Control** mechanism in Java

Access Control

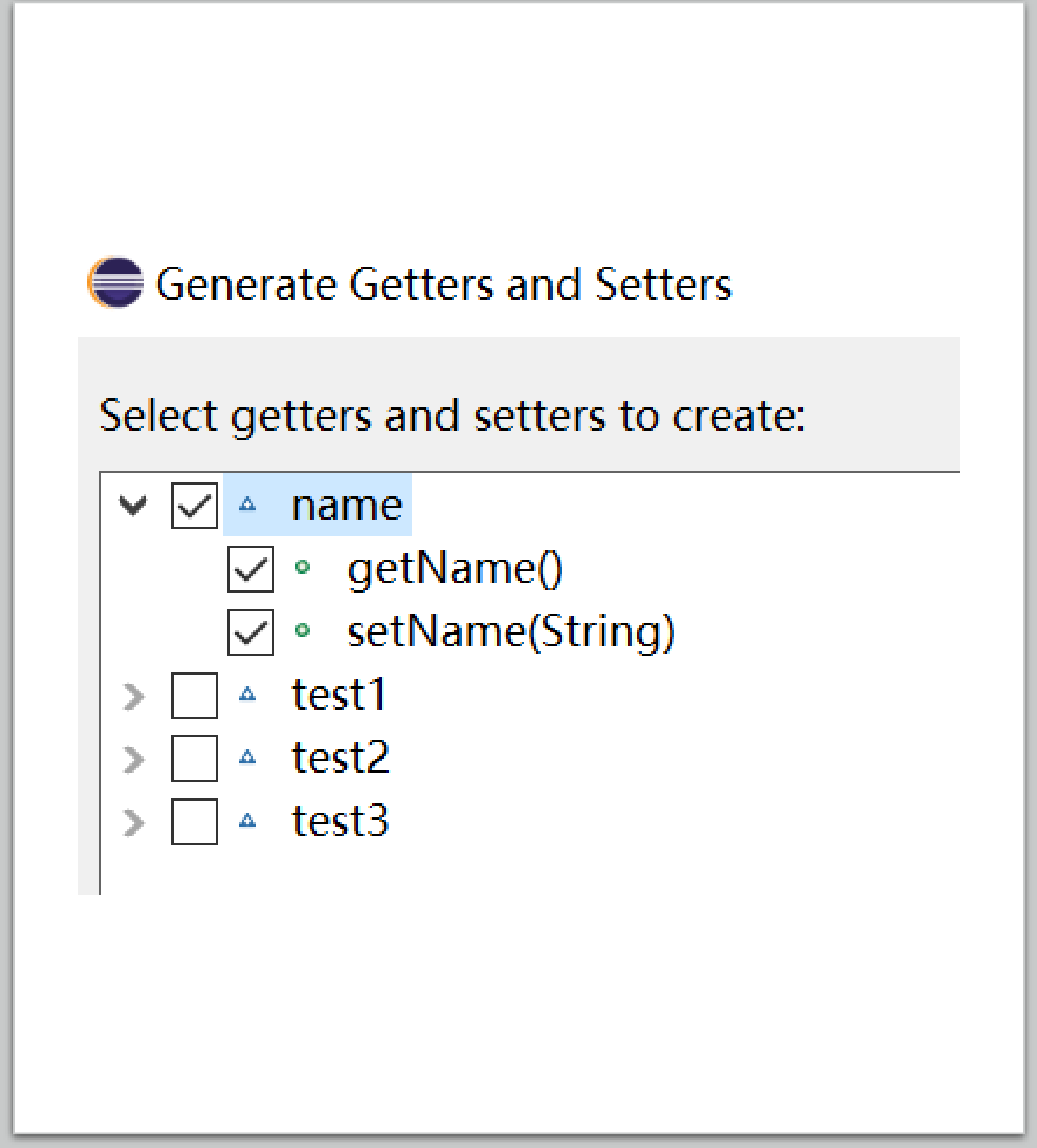
Use access modifiers to determine whether other classes can use a particular field or invoke a particular method



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

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

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

Works, but makes no sense

```
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;
    }
}
```

```
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

Any problem with the code?

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

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

```
Student std = new Student();

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

OOP basic concepts

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

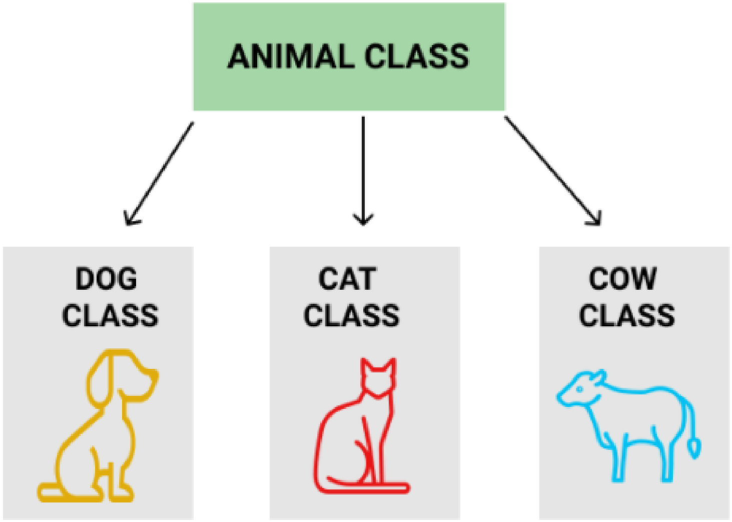
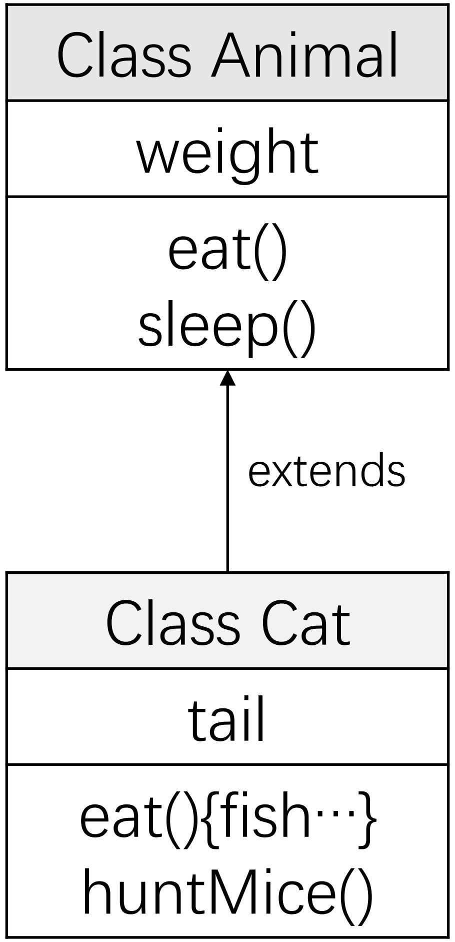


Image source: OOP Inheritance. San Joaquin Delta College. https://eng.libretexts.org/@go/page/34639

Subclass

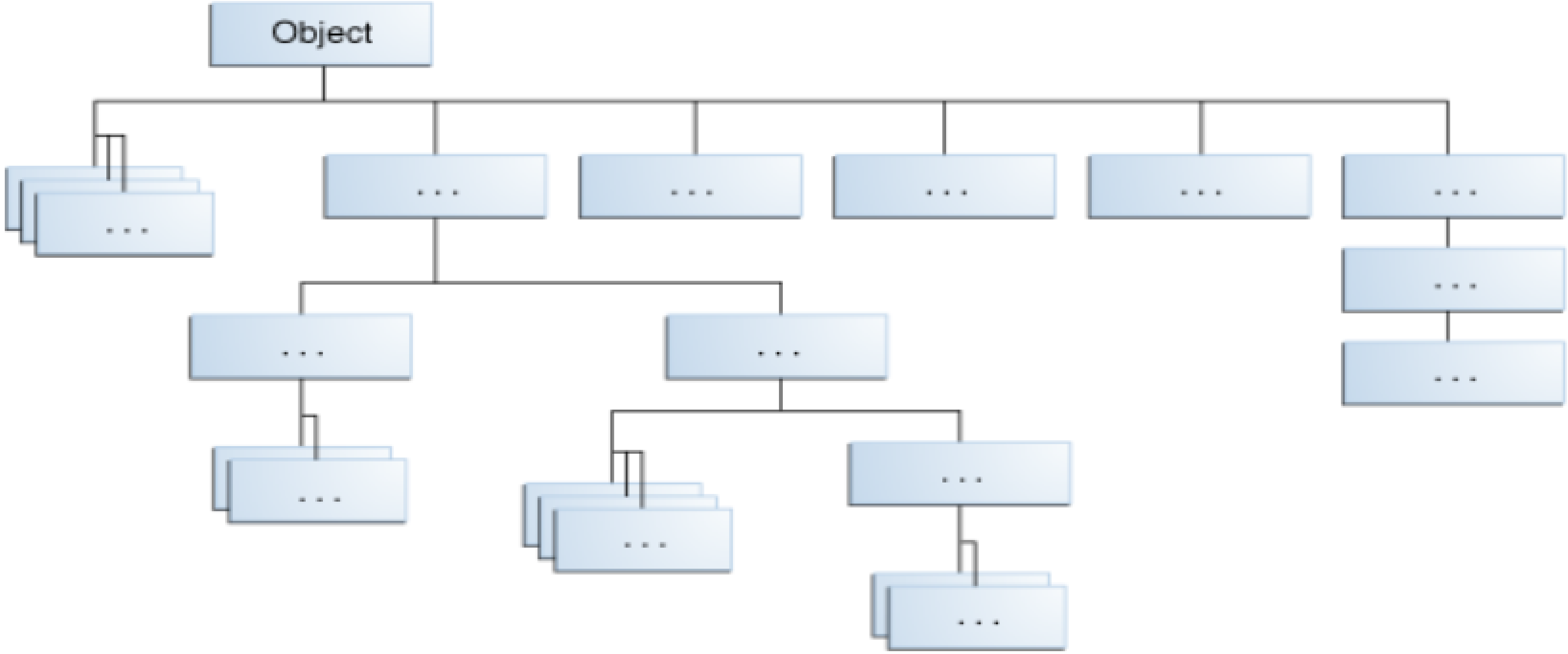
- Subclass could use inherited field directly (`weight`)
- Subclass could declare new fields (`tail`)



- Subclass 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



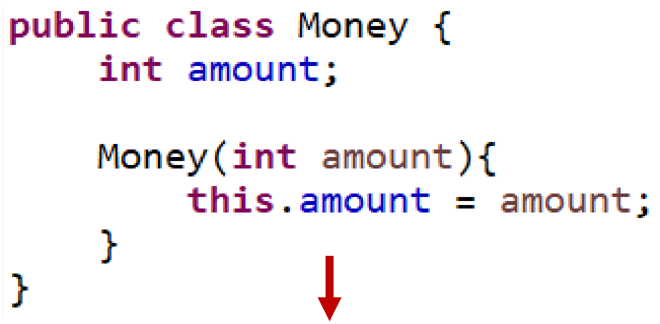
Some classes derive directly from `Object`, others derive from those classes, and so on – forming a tree-like class hierarchy

Object Class

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

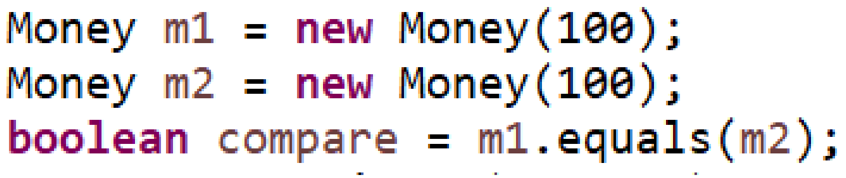
- Providing behaviors common to all the objects, e.g., objects can be compared, cloned, notified, etc.



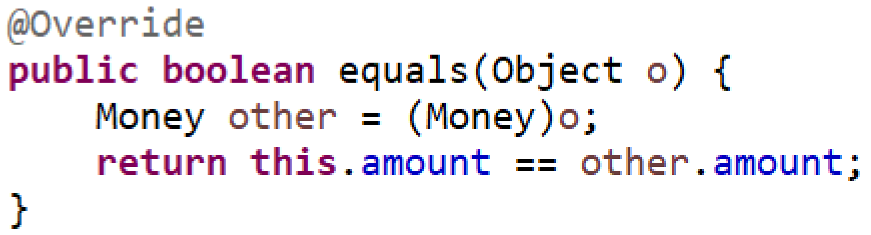
```
public class Money {
    int amount;

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

false



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



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

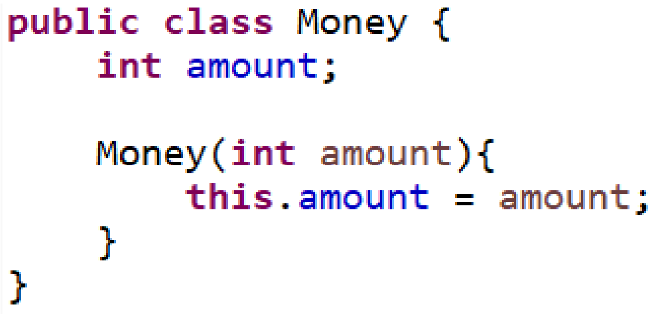
true

Object Class

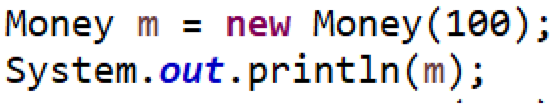
String toString()

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

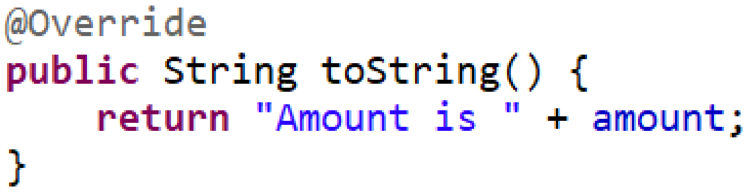
- Providing behaviors common to all the objects, e.g., objects can be compared, cloned, notified, etc.



```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
```

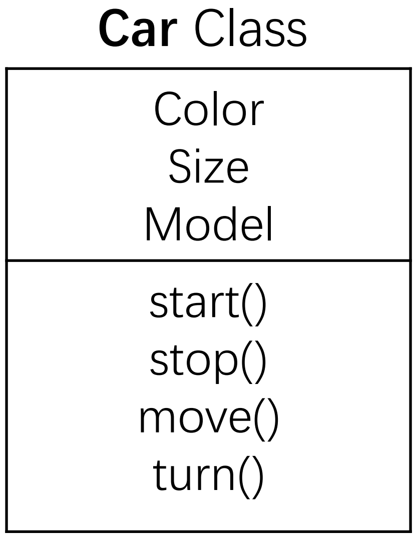
```
Amount is 100
```

OOP basic concepts

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

Abstraction

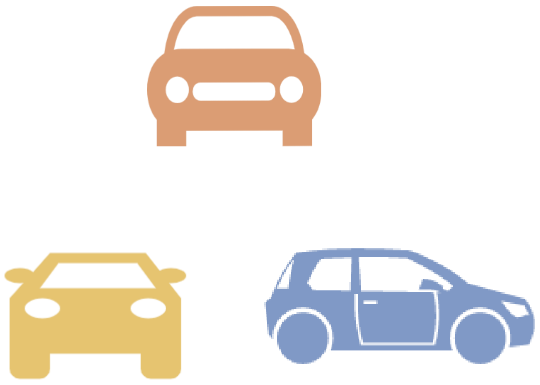
- Abstraction simplifying complex systems by exposing only the necessary details.
- Abstraction solves problem at design level
- Achieved in Java by interface and abstract class



Car Class

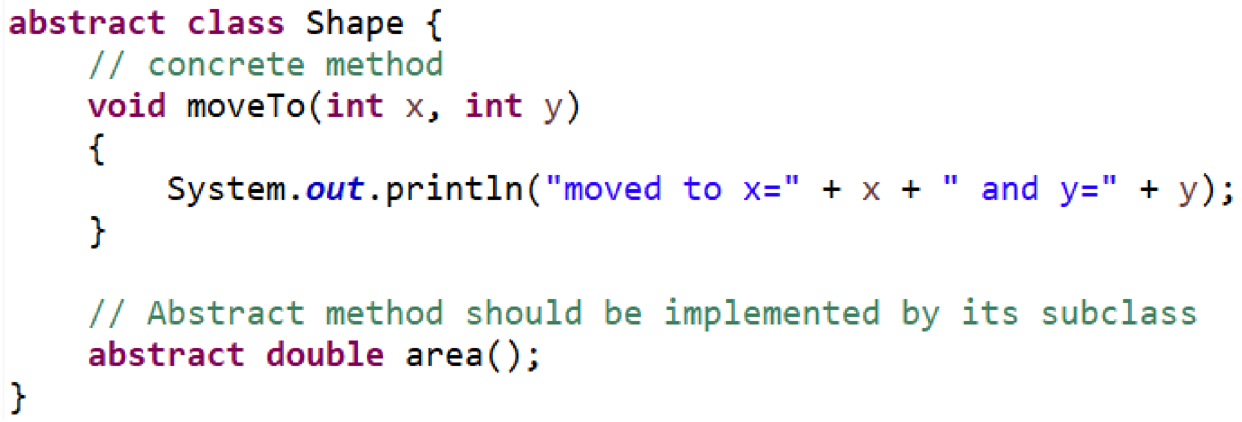
Color
Size
Model

start()
stop()
move()
turn()

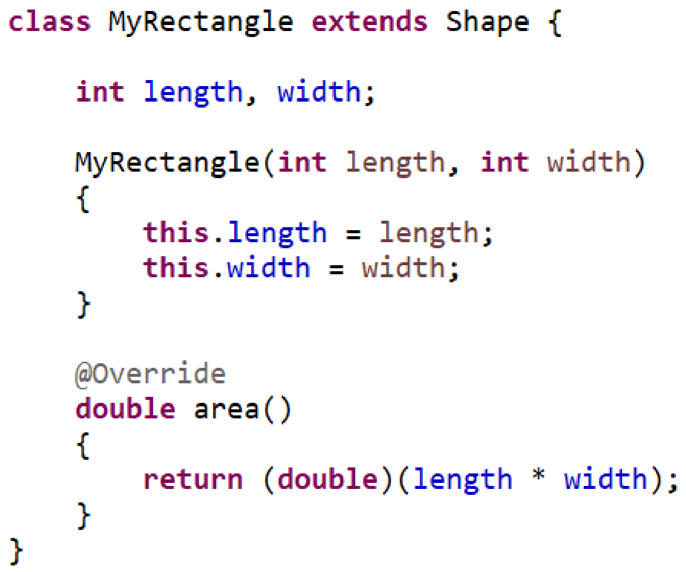


Abstract Class

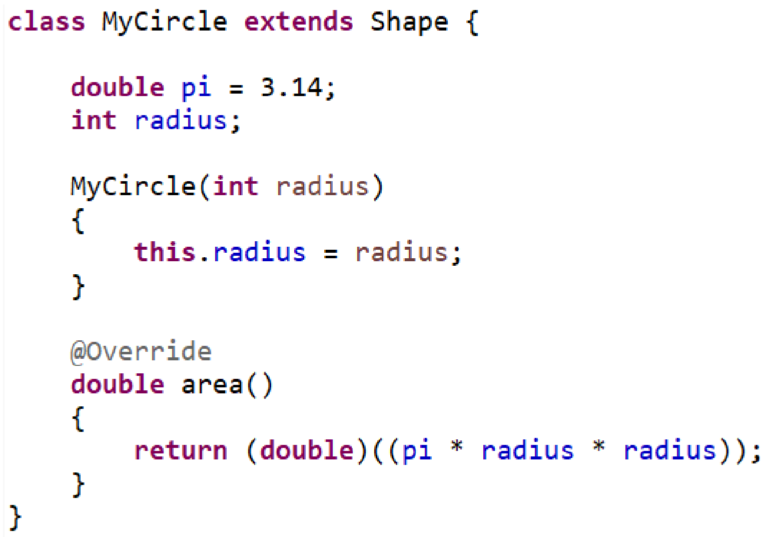
- Purpose: to provide a general guideline or blueprint of a particular concept without having to implement every method; Subclasses should provide the full implementation
- Cannot be instantiated; Subclasses that *extend* the abstract class can be instantiated
- Can have concrete and abstract methods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



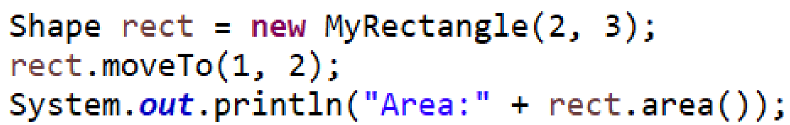
```java
abstract class Shape {
    // concrete method
    void moveTo(int x, int y)
    {
        System.out.println("moved to x=" + x + " and y=" + y);
    }

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



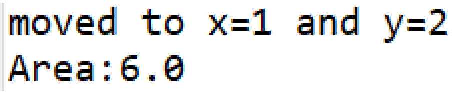
```java
class MyRectangle extends Shape {

    int length, width;

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

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



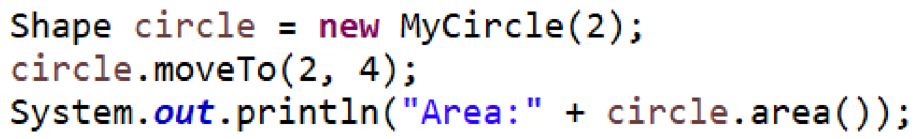
```java
class MyCircle extends Shape {

    double pi = 3.14;
    int radius;

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

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



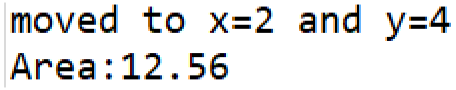
```java
Shape rect = new MyRectangle(2, 3);
rect.moveTo(1, 2);
System.out.println("Area:" + rect.area());
```



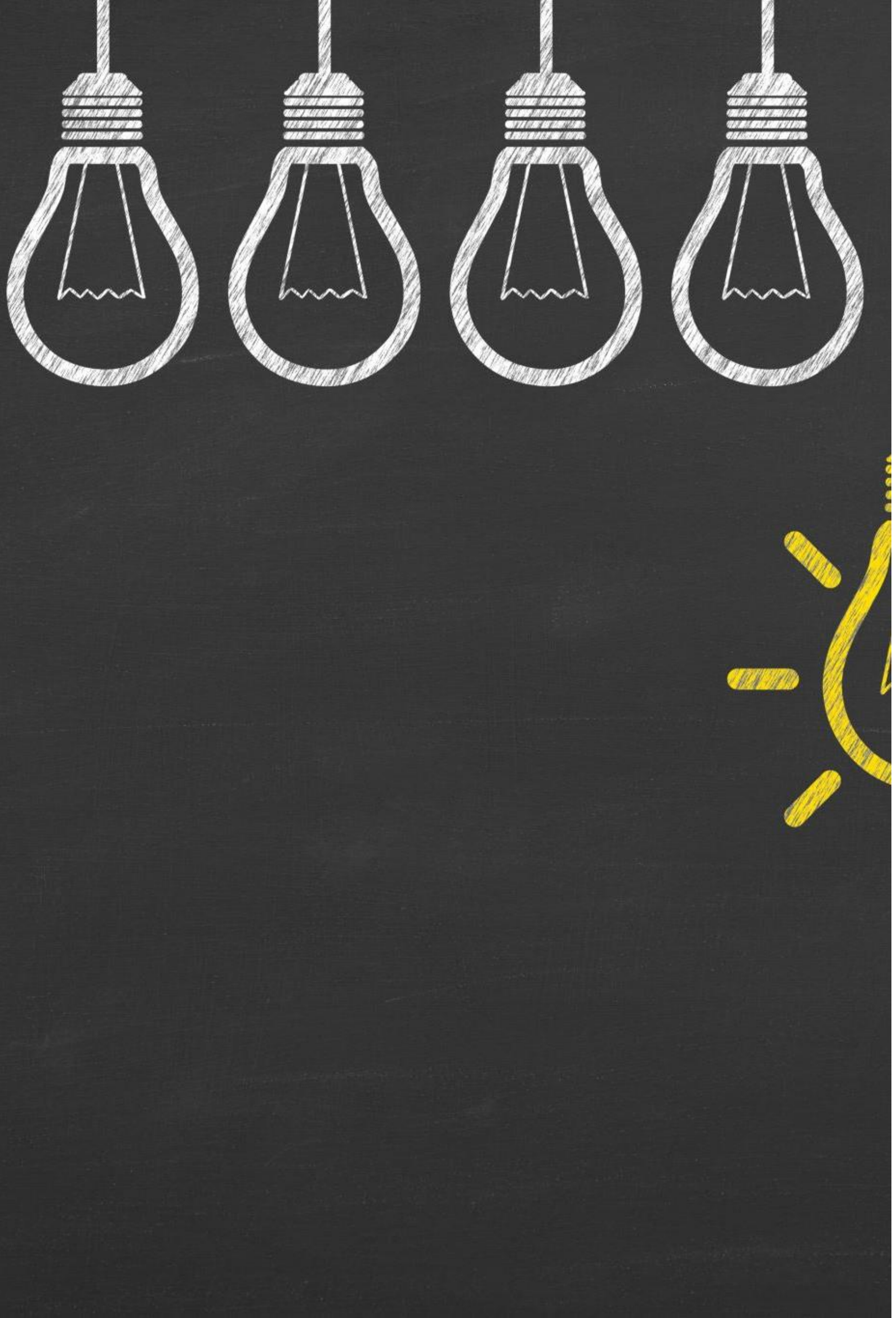
```
moved to x=1 and y=2
Area:6.0
```



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



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

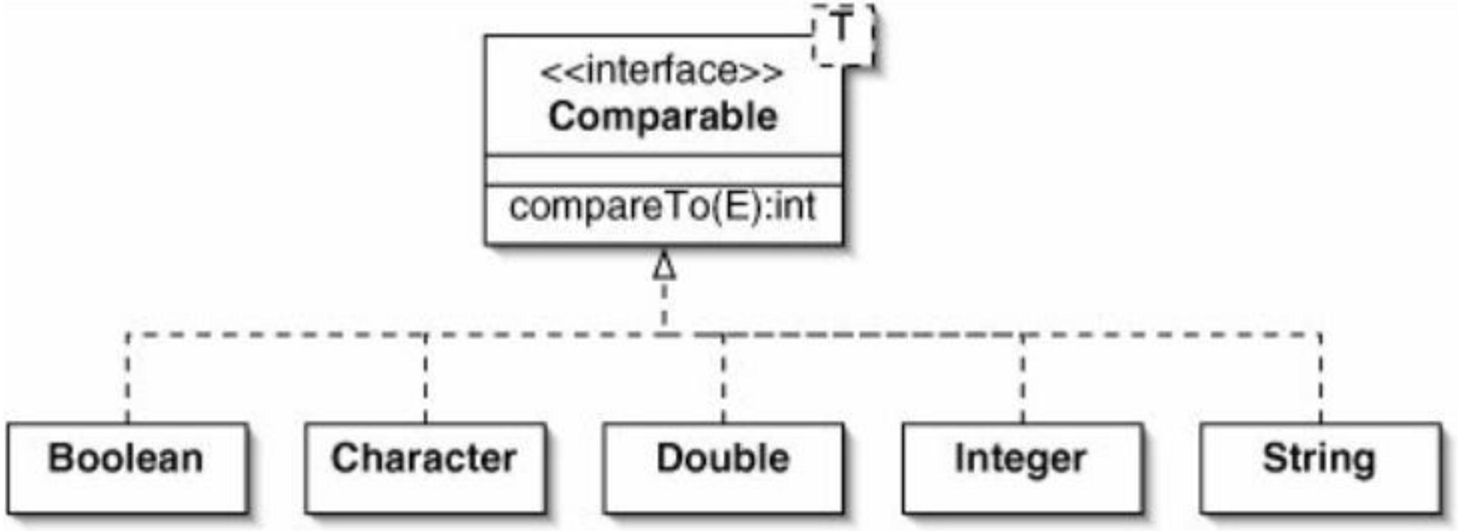


Interface

- 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
  - A class can implement multiple interfaces, but can inherit only one abstract class
  - An abstract classe is used for creating a base class with shared behavior
  - An interface is used for defining contracts that multiple classes (may not be similar) can adhere to

`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.

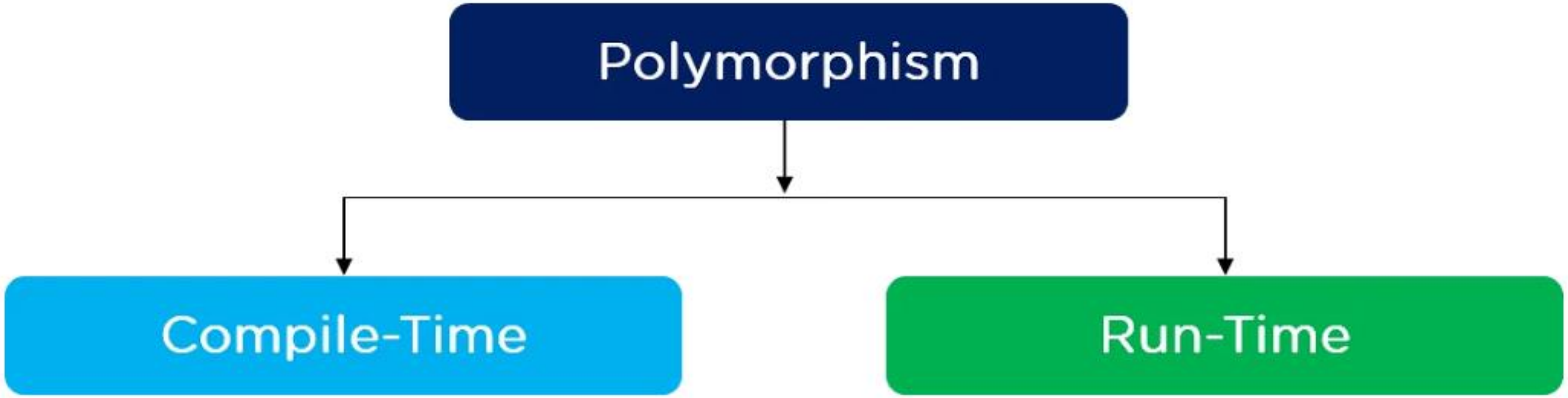


OOP basic concepts

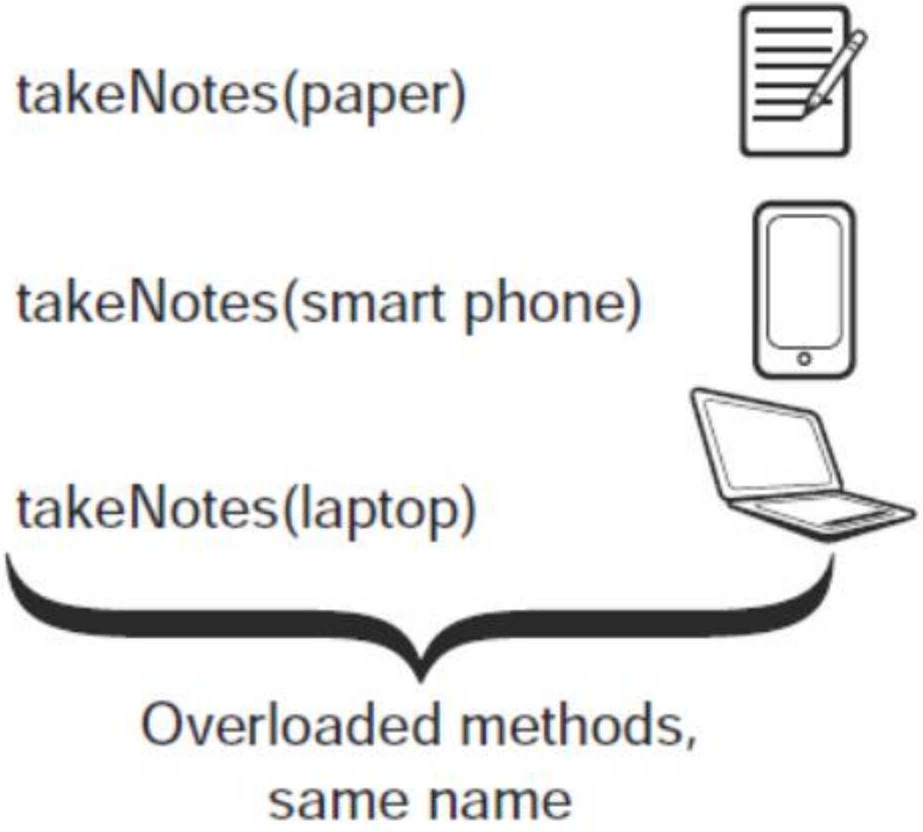
- Encapsulation (封装)
- Inheritance (继承)
- Abstraction (抽象)
- Polymorphism (多态)

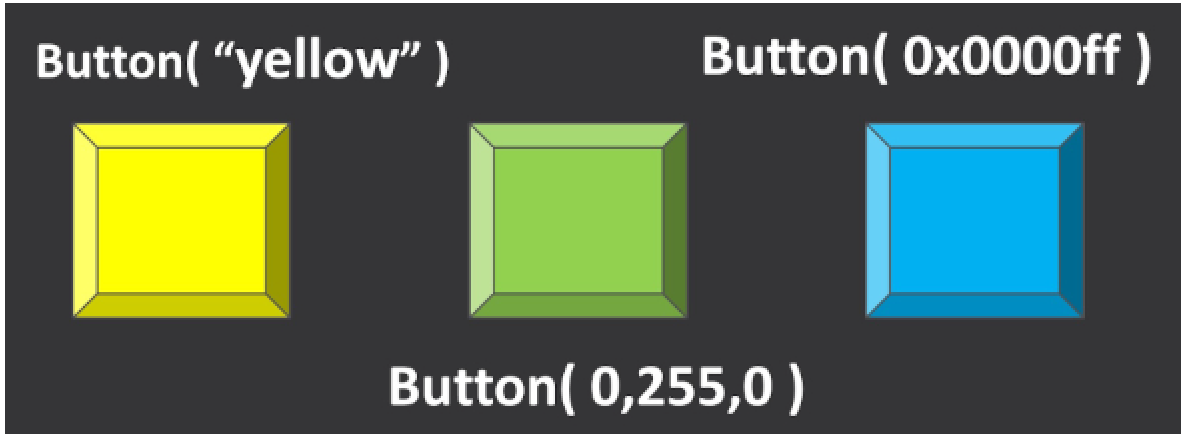
What is Polymorphism?

In general, "polymorphism" refers to the ability of a single entity or concept to take on multiple forms or have multiple meanings.



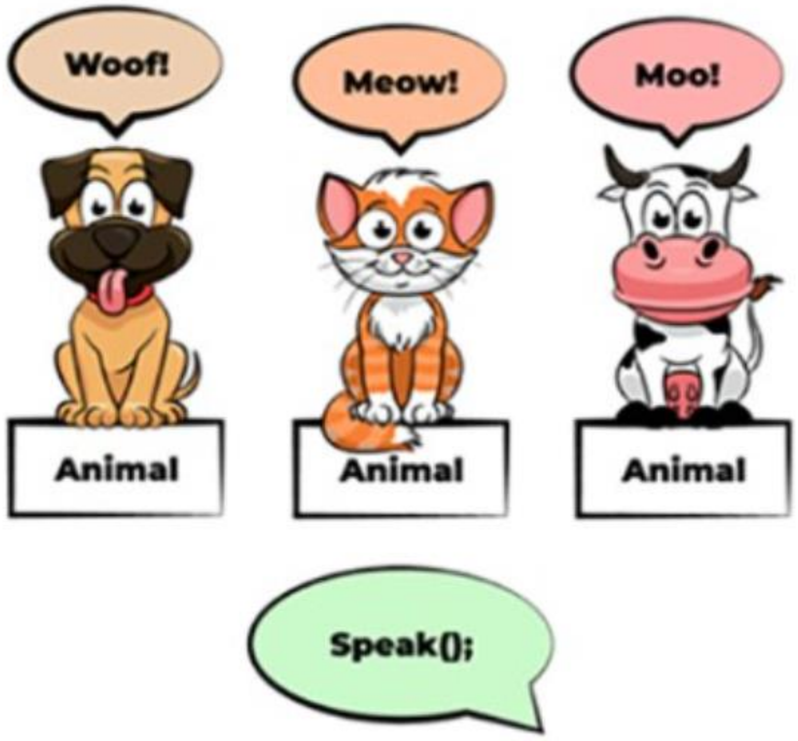
Compile-time Polymorphism

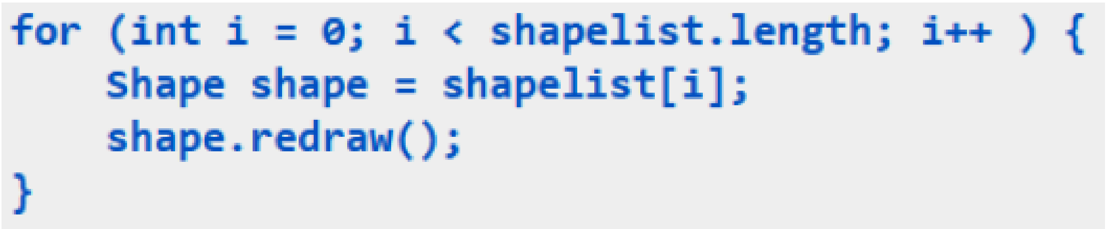




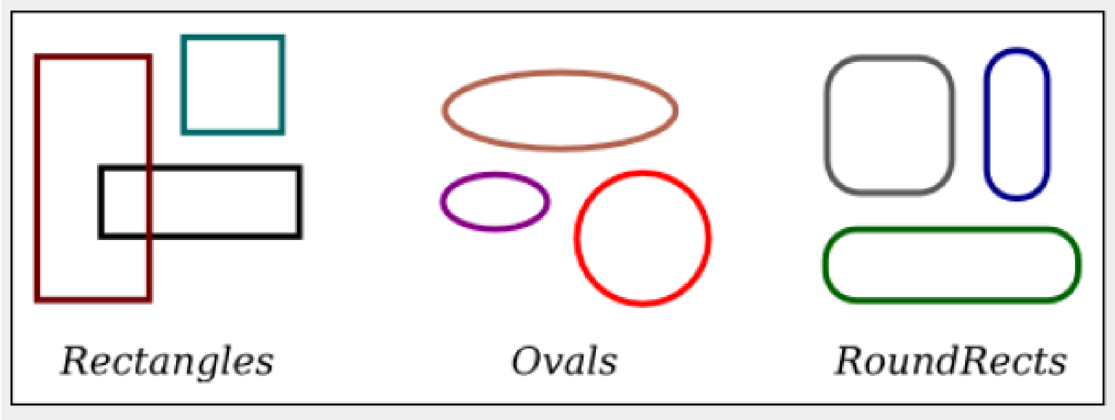
Images:
https://gyansetu-java.gitbook.io/core-java/method-overlaoding
https://www.examtray.com/java/last-minute-java-constructor-overloading-explained-examples-tutorial

Runtime Polymorphism





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



Images: https://codegym.cc/groups/posts/polymorphism-in-java

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

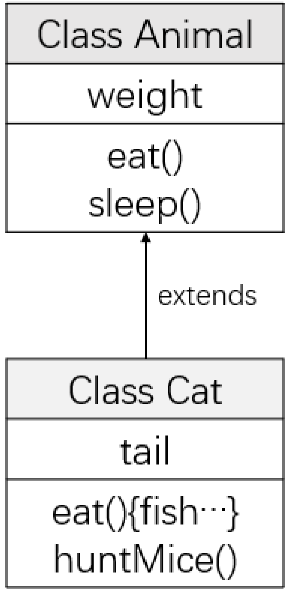
```
class Calculator{
    public int sum(int a, int b){
        return a+b;
    }

    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)

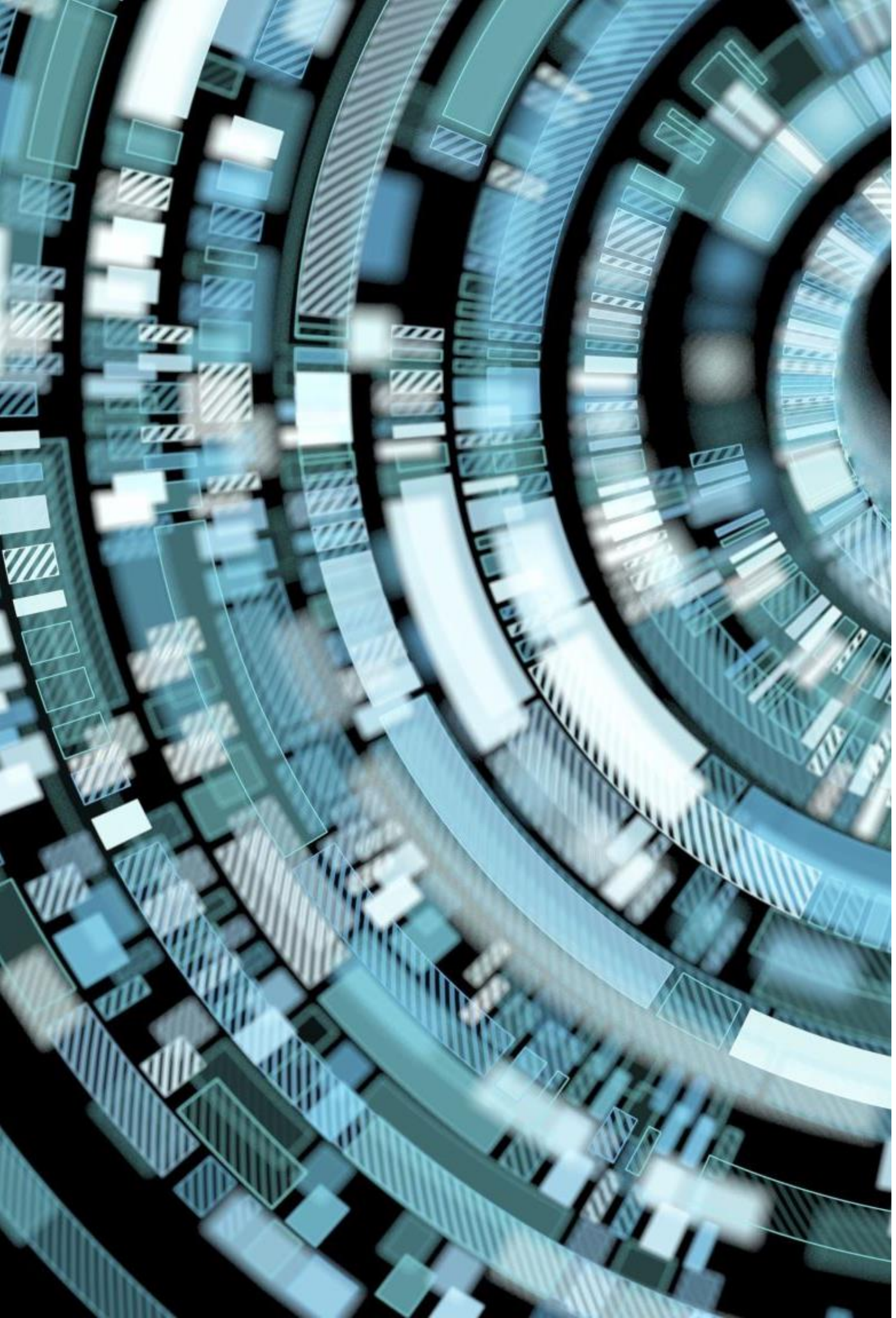
- Mapping is resolved at <u>execution time</u>
- Method overriding (subclass overrides a method in the superclass) are resolved using dynamic binding



```
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



Lecture 1

- Course introduction
- Computer system & programs
- Java review and JVM
- Object-oriented programming concepts
- Software design principles

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*

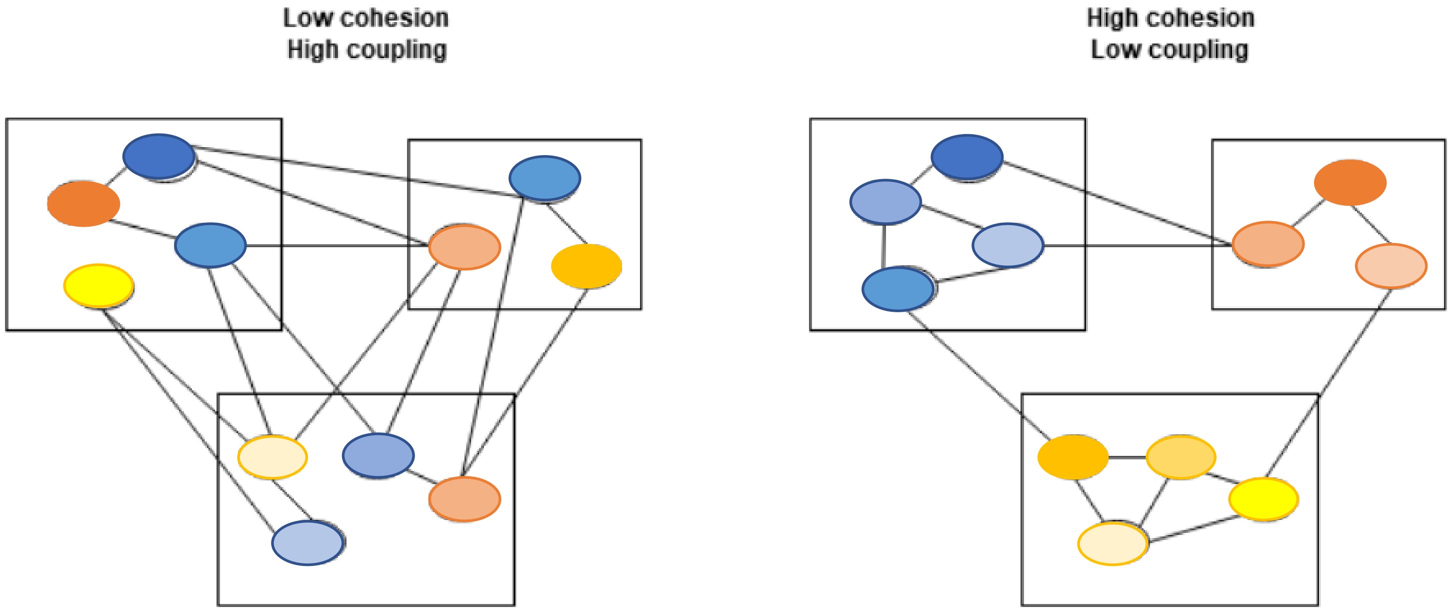
- Cohesion (内聚): How elements of a module are functionally related to each other

- 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

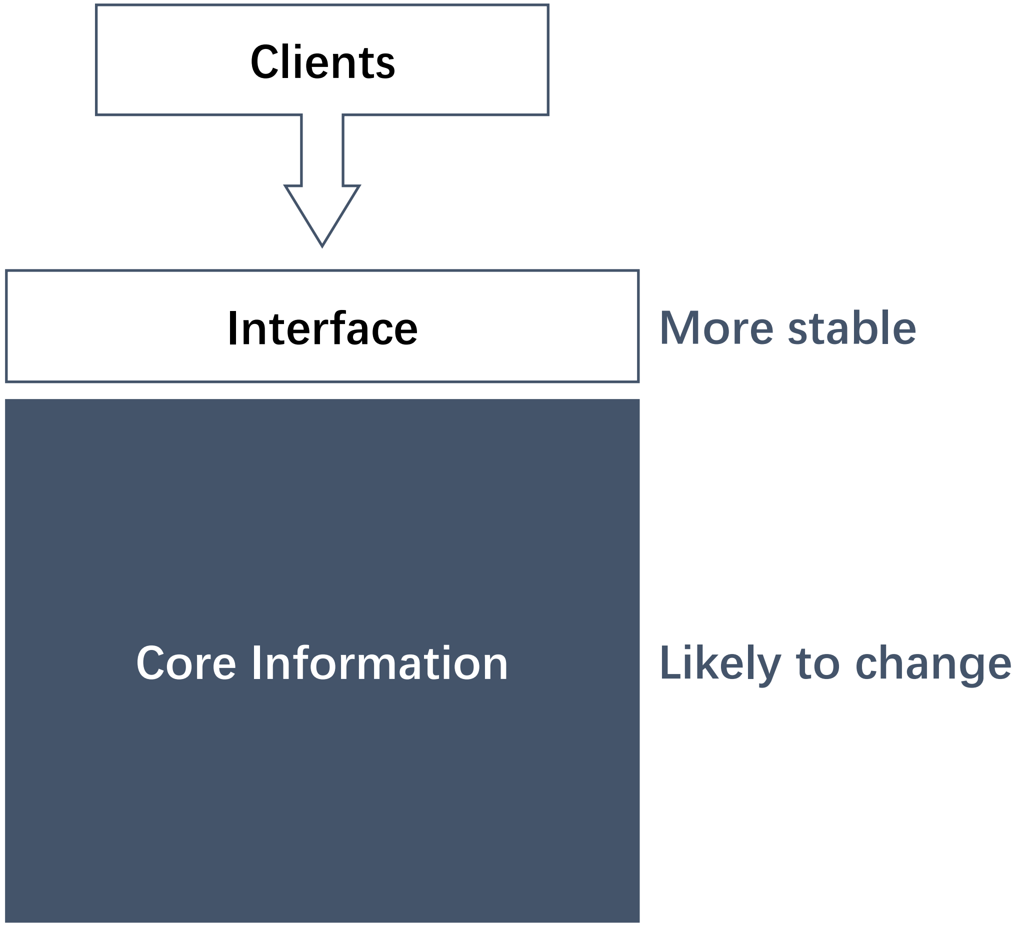
Source: Software Architecture with C++ by Adrian Ostrowski, Piotr Gaczkowski

Information Hiding

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

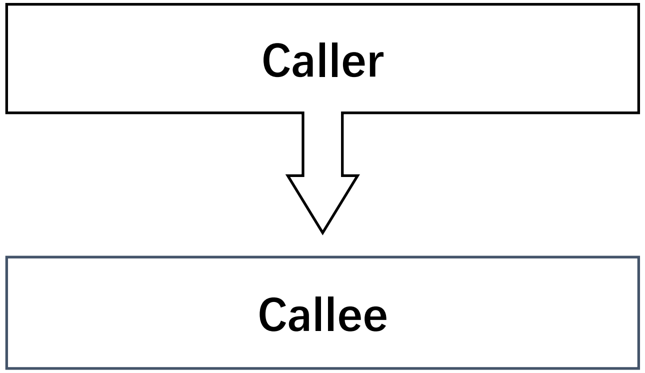
- Advantages: Client programs won't have to change even if the core design or implementation is changed

Increasing coupling -> breaking information hiding



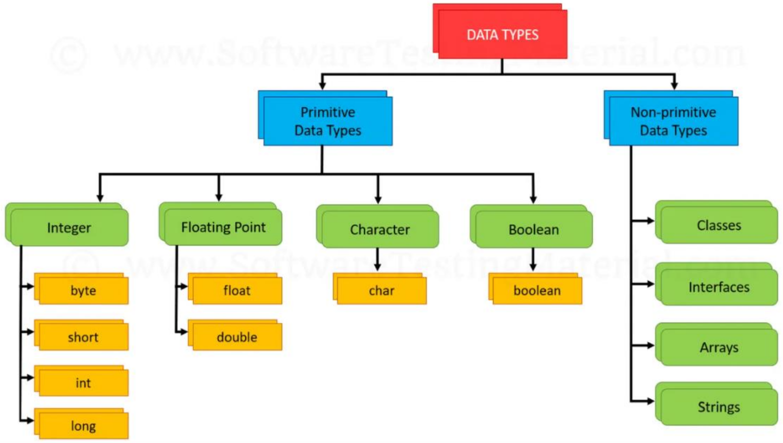
Information Hiding

Example 1. Function Call



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

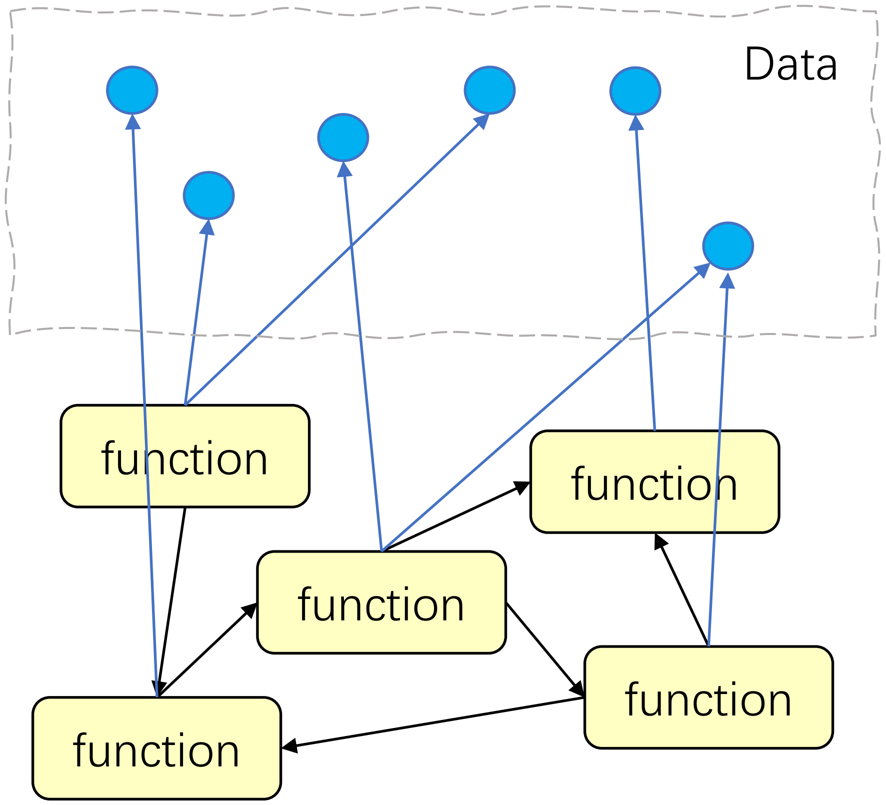
Example 2. Data Representation



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



Data

function

function

function

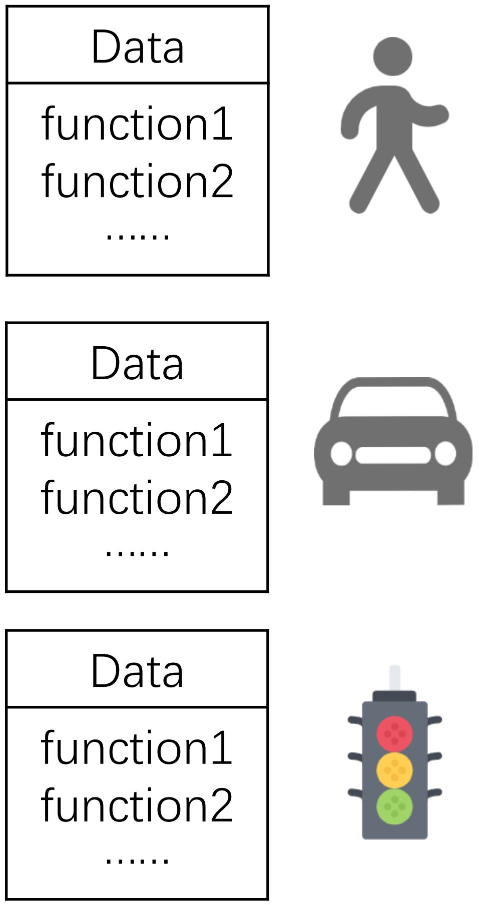
function

function

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

Traffic Control System

Object-oriented Design



Data

function1
function2
……

Data

function1
function2
……

Data

function1
function2
……

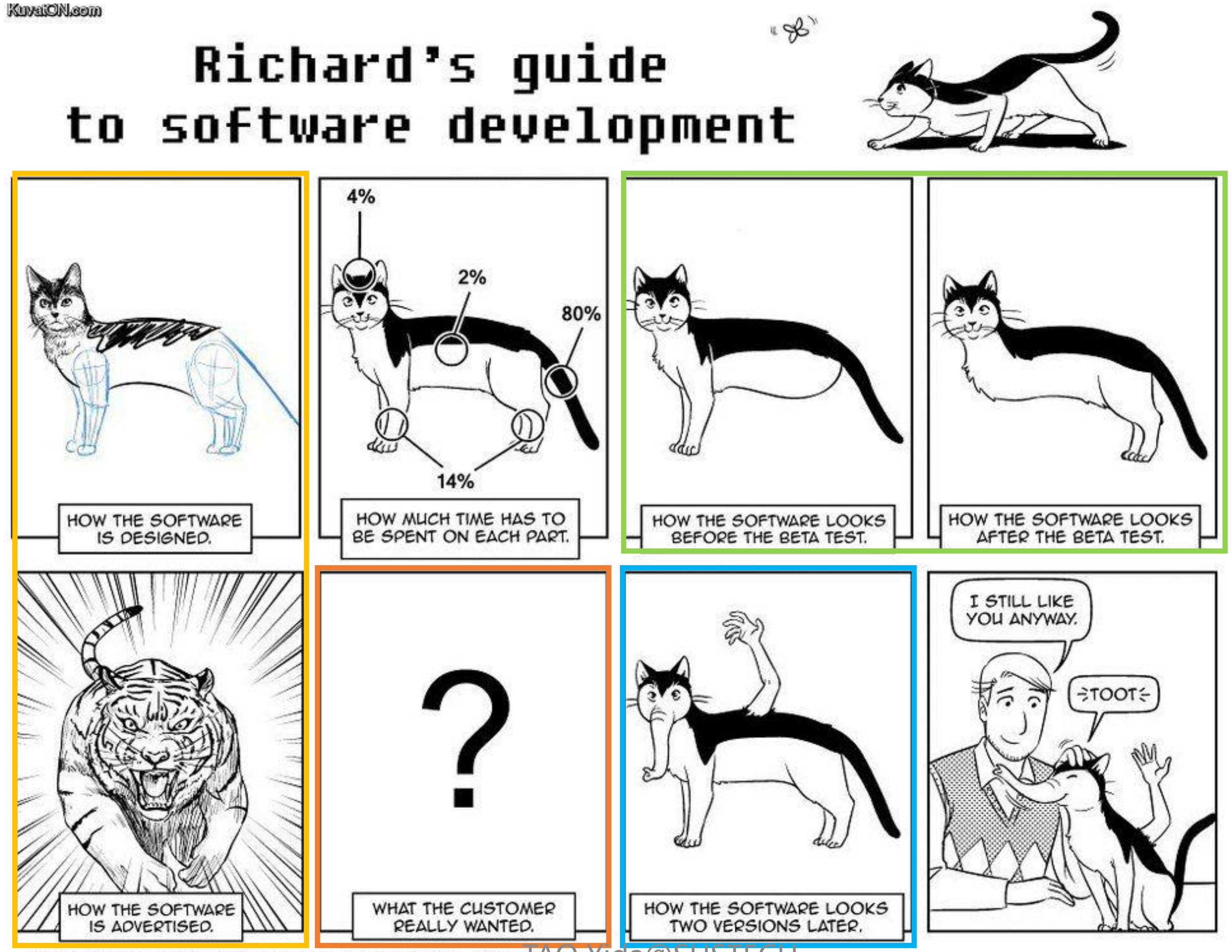
High cohesion. Good information hiding.
Easier to maintain and extend.

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

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.

Tools that help

A version control system to track changes and develop collaboratively

A tool to help programmers write Java code that adheres to a coding standard

Next Lecture

- Generics
- ADT
- Collections