Ahmadu Bello University, Zaria, Nigeria

Department of Computer Science

COSC 211- Object Oriented Programming I

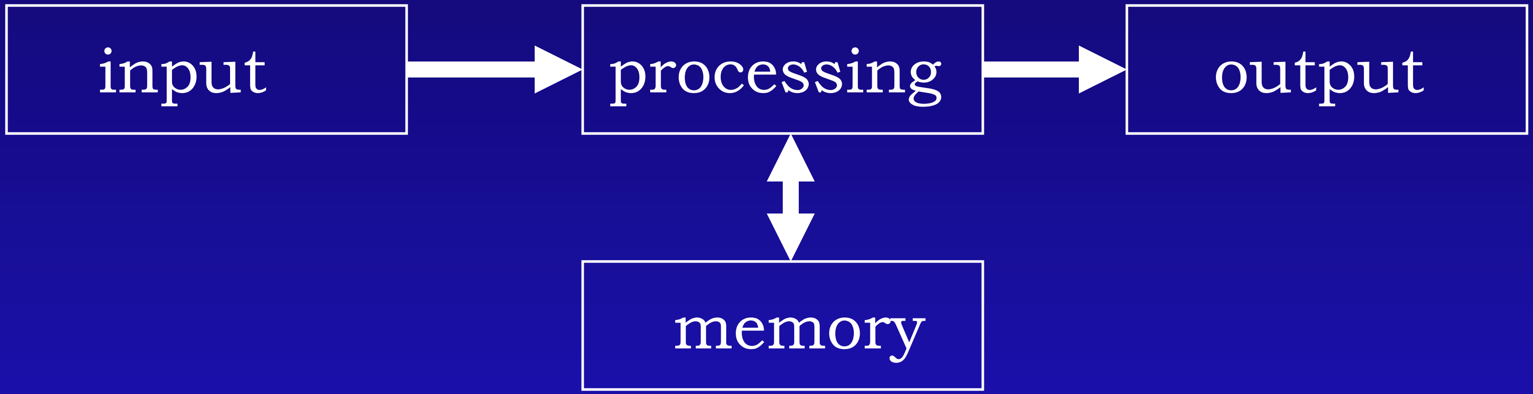
Content

Introduction to Computer Systems

- Lecture Objectives:
  - The student should be able to identify and explain the major components of a computer system in terms of their functions.
- What is a Computer?
- Anatomy of a Computer System
- Computer Software
- Computer Hardware
- Fetch-Decode-Execute Cycle
- CPU Families
- Exercises

What is a Computer System?

- A computer system is an electronic device which can input, process, and output data



- Input data of a computer may represent numbers, words, pictures etc

- Programs that control the operations of the computer are stored inside the computer

Major Components of a Computer System

- A computer system consists of two main parts: hardware and software

- *Hardware* is the physical components and *software* is the non-physical components of a computer system.

- Computer hardware is divided into three major components:
  - 1. Input/Output (I/O) devices
  - 2. Computer memory
  - 3. The Central Processing Unit (CPU)

- Computer software is divided into two main categories:
  - 1. Systems software
  - 2. Applications software

Systems Software

- *System software* manages computer resources and makes computers easier to use

- Systems software can be divided into three categories:

1. Operating System (OS)
   - Examples: Windows XP, UNIX and MacOS

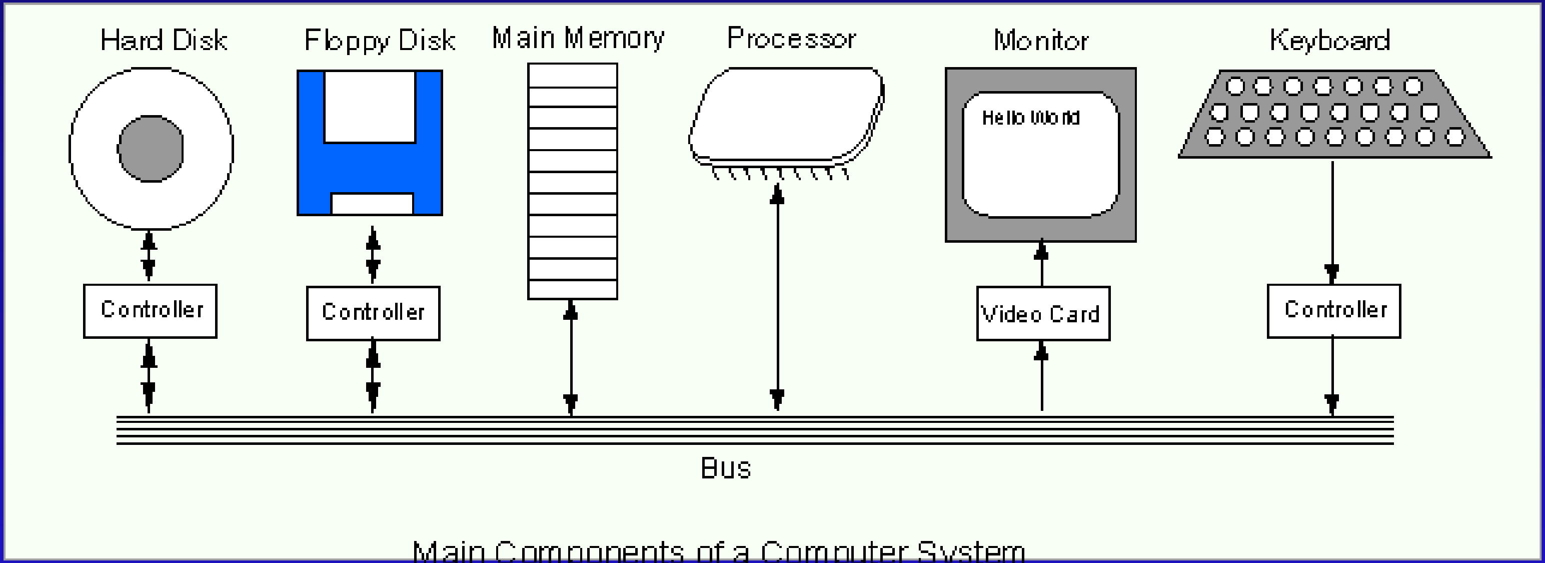
2. System support software
   - Examples: disk-formatting and anti-virus programs.

3. System development software.
   - Example: *Language translators*.

Applications Software

- An applications software enables a computer user to do a particular task
- Example applications software include:
  - Word processors
  - Game programs
  - Spreadsheets (or Excel sheets)
  - Database systems
  - Graphics programs
  - Multimedia applications

Computer Hardware



Main Components of a Computer System

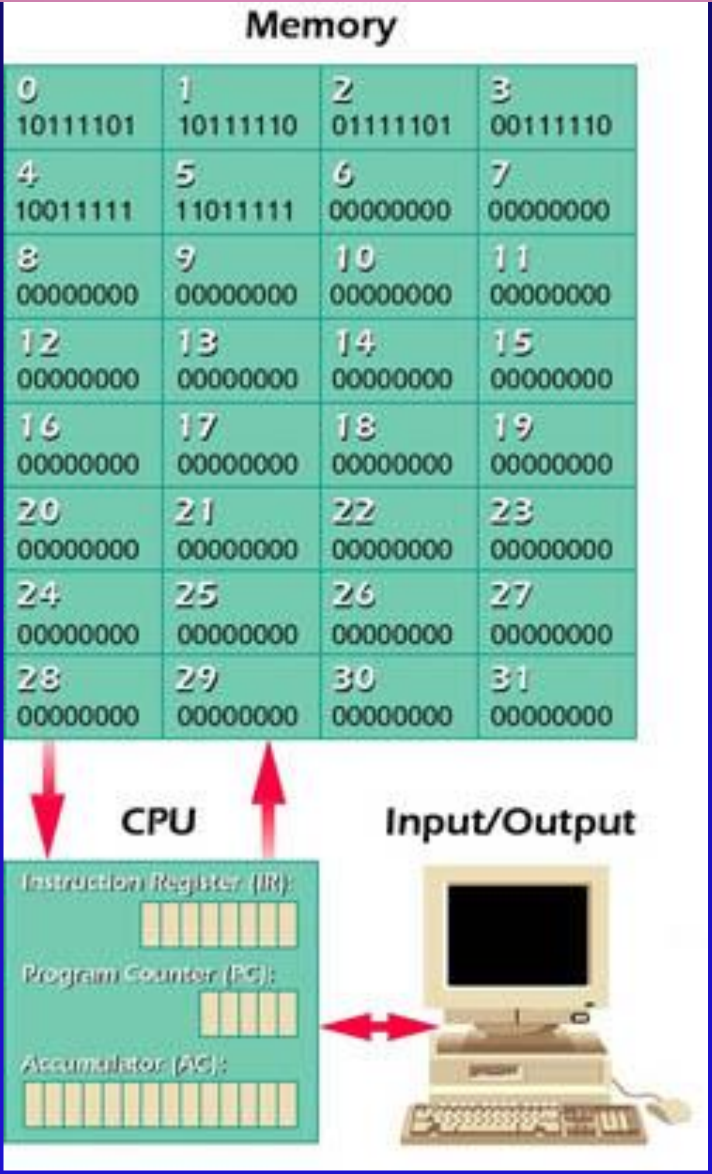
I/O (Input/Output)Devices

- Input devices are used to enter programs and data into a computer system.
  - Examples: keyboard, mouse, microphone, and scanner.
- Output devices are where program output is shown or is sent.
  - Examples: monitor, printer, and speaker.
- I/O devices are slow compared to the speed of the processor.
  - Computer memory is faster than I/O devices: speed of input from memory to processor is acceptable.

Computer Memory

- The main function of computer memory is to store software.
- Computer memory is divided into primary memory and secondary memory.
- Primary memory is divided into random access memory (RAM) and read-only memory (ROM):
  - The CPU can read and write to RAM but the CPU can read from ROM but cannot write to ROM
  - RAM is *volatile* while ROM is not.
- *Secondary memory*
  - Examples of secondary memory devices are: hard disks, floppy disks and CD ROMs

Primary Memory



The CPU

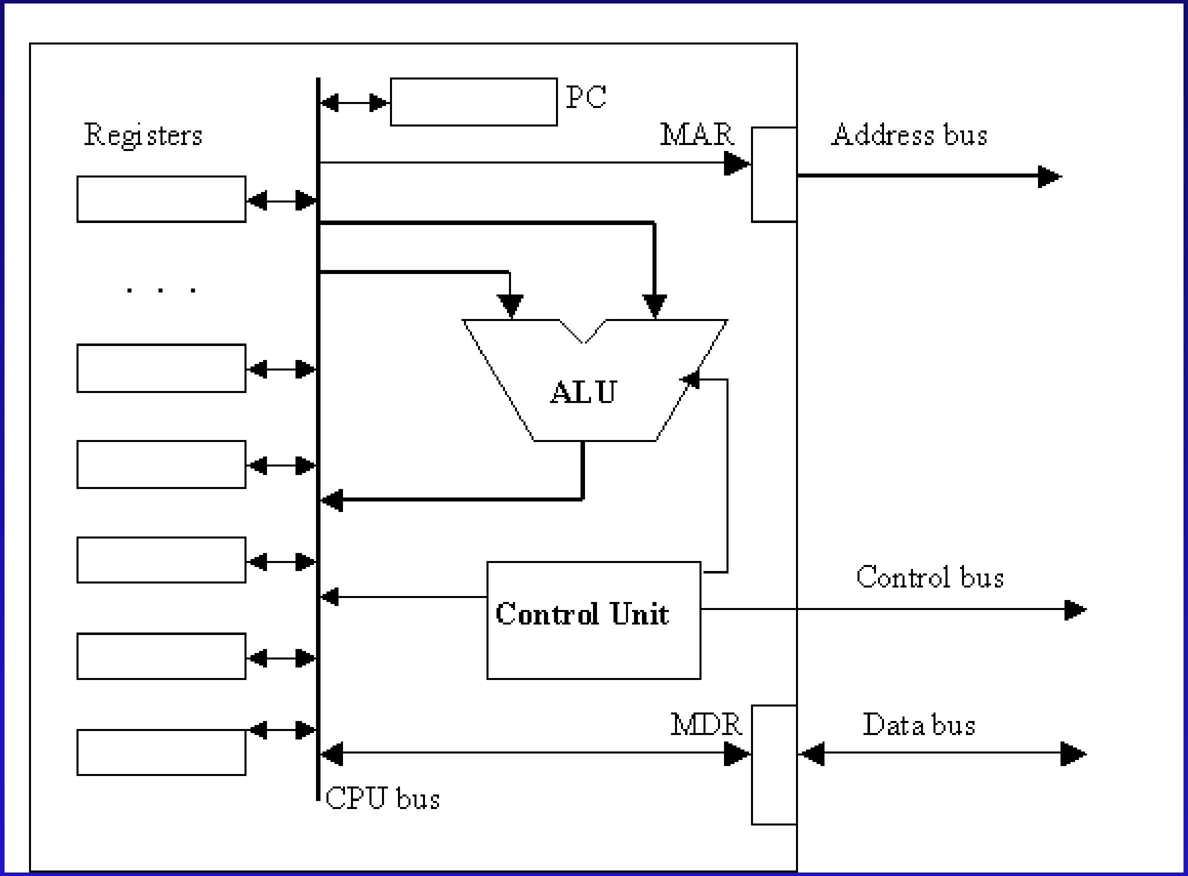
- The CPU is the "brain" of the computer system.
  - The CPU directly or indirectly controls all the other components.

- The CPU has a limited storage capacity.
- Thus, the CPU must rely on other components for storage.

- The CPU consists of:
  - 1. The Arithmetic and Logic Unit (ALU).
  - 2. The Control Unit (CU).
  - 3. Registers.

- The CPU components are connected by a group of electrical wires called the *CPU bus*.

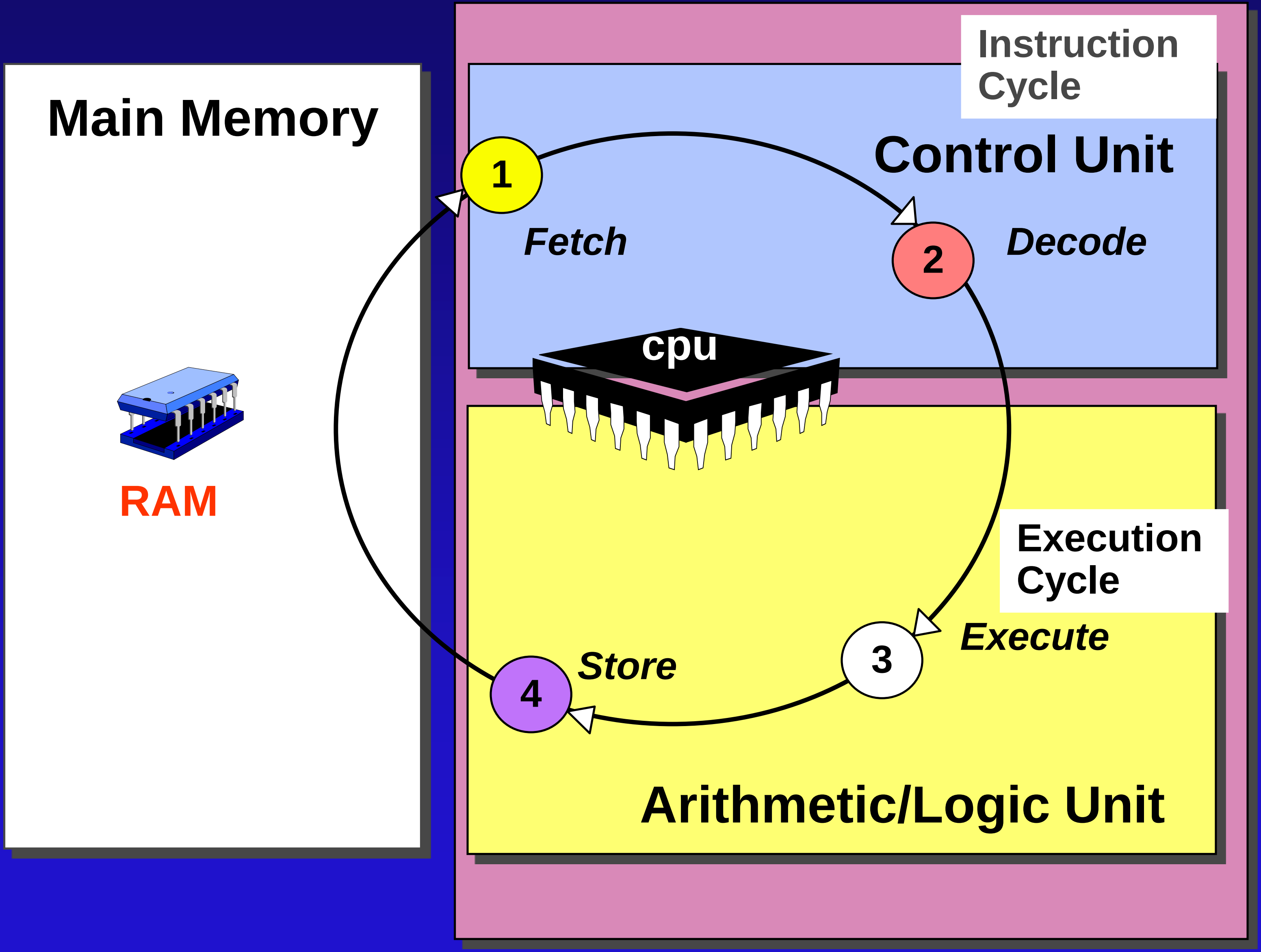
The CPU (cont'd)



Fetch Decode Execute Cycle

- The CPU continuously transfers data to and from memory
- Data transfer is done in units called *instructions* or *words*
- When a computer is switched on, the CPU continuously goes through a process called *fetch-decode-execute cycle*:
  - The Control Unit fetches the current instruction from memory, decodes it and instructs the ALU to execute the instruction.
  - The execution of an instruction may generate further data fetches from memory
  - The result of executing an instruction is stored in either a register or RAM

Fetch-Decode-Execute Cycle (cont'd)



CPU Families

- Different people understand different natural languages.
- Similarly, each processor family understands its own machine language.
- The fundamental difference between computers that are not compatible is in their processors.
- Here are some CPU families:
  - Pentium
  - Power PC
  - SPARC
- The question now is: Is it possible to write a single program that can be understood and correctly executed on machines with different processors?
  - We'll address this question in a subsequent lecture.

Drill Questions

1. Write short notes explaining the functions of each of the following
    1. Computer memory
    2. The CPU
    3. Computer software
2. I/O devices can be used to input into and output from a computer system. Then, is computer memory necessary? Explain.
3. Since the OS controls the hardware and software in a computer system, which programs control the loading of an OS onto a computer system?
4. The system bus consists of three buses. Mention them and explain each of them briefly.
5. Since different CPUs understand different instructions, how are we able to exchange information between machines with different CPUs?

Overview of Programming Paradigms

- Lecture Objectives:
  - Be able to explain the differences between programming languages and programming paradigms.
  - Be able to differentiate between low-level and high-level programming languages and their associated advantages and disadvantages
  - Be able to list four programming paradigms and describe their strengths and weaknesses.
- Introduction to Computer Programming
- Programming Languages
- Programming Paradigms
- Exercises

Computer Programming

- The functions of a computer system are controlled by *computer programs*
- A computer program is a clear, step-by-step, finite set of instructions
- A computer program must be clear so that only one meaning can be derived from it,
- A computer program is written in a computer language called a *programming language*

Programming Languages

- *There are three categories of programming languages:*
  - 1. Machine languages.
  - 2. Assembly languages.
  - 3. High-level languages.
    - Machine languages and assembly languages are also called low-level languages

Programming Languages (cont'd)

- *A Machine language program* consists of a sequence of zeros and ones.
  - Each kind of CPU has its own machine language.
- Advantages
  - Fast and efficient
  - Machine friendly
  - No translation required
- Disadvantages
  - Not portable
  - Not programmer friendly

Assembly Language

- *Assembly language programs* use mnemonics to represent machine instructions
- Each statement in assembly language corresponds to one statement in machine language.
- Assembly language programs have the same advantages and disadvantages as machine language programs.
- Compare the following machine language and assembly language programs:

8086 Machine language program for var1 = var1 + var2 ;	8086 Assembly program for var1 = var1 + var2 ;

1010 0001 0000 0000 0000 0000
0000 0011 0000 0110 0000 0000 0000 0010
1010 0011 0000 0000 0000 0000
	MOV AX , var1
	ADD AX , var2
	MOV var1 , AX

High-Level Programming Languages

- A high-level language (HLL) has two primary components
  - (1) a set of built-in *language primitives and grammatical rules*
  - (2) a translator
- *A HLL language program* consists of English-like statements that are governed by a strict *syntax*.
- Advantages
  - Portable or *machine independent*
  - Programmer-friendly
- Disadvantages
  - Not as efficient as low-level languages
  - Need to be translated
- Examples : C, C++, Java, FORTRAN, Visual Basic, and Delphi.

Programming Paradigms

- Why are there hundreds of programming languages in use today?
  - Some programming languages are specifically designed for use in certain applications.
  - Different programming languages follow different approaches to solving programming problems
- A *programming paradigm* is an approach to solving programming problems.
- A programming paradigm may consist of many programming languages.
- Common programming paradigms:
  - Imperative or Procedural Programming
  - Object-Oriented Programming
  - Functional Programming
  - Logic Programming

Programming Paradigms: Imperative

- In this paradigm, a program is a series of *statements* containing *variables*.
- Program execution involves changing the memory contents of the computer continuously.
- Example of imperative languages are: C, FORTRAN, Pascal, COBOL etc
- Advantages
  - Low memory utilization
  - Relatively efficient
  - The most common form of programming in use today.
- Disadvantages
  - Difficulty of reasoning about programs
  - Difficulty of parallelization.
  - Tend to be relatively low level.

Programming Paradigms: Object-Oriented

- A program in this paradigm consists of *objects* which communicate with each other by *sending messages*
- Example object oriented languages include: Java, C#, Smalltalk, etc
- Advantages
  - Conceptual simplicity
  - Models computation better
  - Increased productivity.
- Disadvantages
  - Can have a steep learning curve, initially
  - Doing I/O can be cumbersome

Programming Paradigms: Functional

- A program in this paradigm consists of *functions* and uses functions in a similar way as used in mathematics
  - Program execution involves functions calling each other and returning results. There are no variables in functional languages.
- Example functional languages include: ML, Miranda^{TM}, Haskell
- Advantages
  - Small and clean syntax
  - Better support for reasoning about programs
  - They allow functions to be treated as any other data values.
  - They support programming at a relatively higher level than the imperative languages
- Disadvantages
  - Difficulty of doing input-output
  - Functional languages use more storage space than their imperative cousins

Programming Paradigms: Logic

- A program in the logic paradigm consists of a set of *predicates* and *rules of inference*.
  - Predicates are statements of fact like the statement that says: water is wet.
- Rules of inference are statements like: If X is human then X is mortal.
    - The predicates and the rules of inference are used to prove statements that the programmer supplies.
- Example: Prolog
- Advantages
  - Good support for reasoning about programs
  - Can lead to concise solutions to problems
- Disadvantages
  - Slow execution
  - Limited view of the world
    - That means the system does not know about facts that are not its predicates and rules of inference.
  - Difficulties in understanding and debugging large programs

Which Programming Paradigm is Best?

- Which of these paradigms is the best?
- The most accurate answer is that there is no best paradigm.
- No single paradigm will fit all problems well.
- Human beings use a combination of the models represented by these paradigms.
- Languages with features from different paradigms are often too complex.
- So, the search of the ultimate programming language continues!

Review Questions

1. List two advantages and two disadvantages of low-level languages.

2. Explain the similarities and differences between an assembly language and a machine language.

3. Mention the programming paradigm to which each of the following languages belongs: Visual Basic, Java, C#, Haskell, Lisp, Prolog, Pascal.

4. Which programming paradigms give better support for reasoning about programs?

5. Which programming paradigms give better support for doing I/O?

Programming Languages Translation

- Lecture Objectives:
  - Be able to list and explain five features of the Java programming language.
  - Be able to explain the three standard language translation techniques.
  - Be able to describe the process of translating high-level languages.
  - Understand the concept of virtual machines and how Java uses this concept to achieve platform independence.
  - Understand the structure of simple Java programs

- Java Programming Language
- Translating High-level Languages
- The Java Virtual Machine
- Java Program Structure
- Exercises

The Java Programming Language

- The object-oriented paradigm is becoming increasingly popular compared to other paradigms.
- The Java programming language is perhaps the most popular object-oriented language today.
- Here are some reasons why Java is popular:
  - *1. Simple*.
    - Compared to many modern languages, the core of the Java language is simple to master.
  - *2. Object-oriented*.
    - Java is an object-oriented language and therefore it has all the benefits of OO languages described earlier.
  - *3. Secure*.
    - The Java system controls what parts of your computer a program access.
  - *4. Architecture neutral*.
    - A Java program will run identically on every platform. We will explain how Java achieves this portability later in this session.
  - 5. *Java is for Internet applications*
    - Java was designed so that it can download programs over the Internet and execute them.

High Level Language Translators

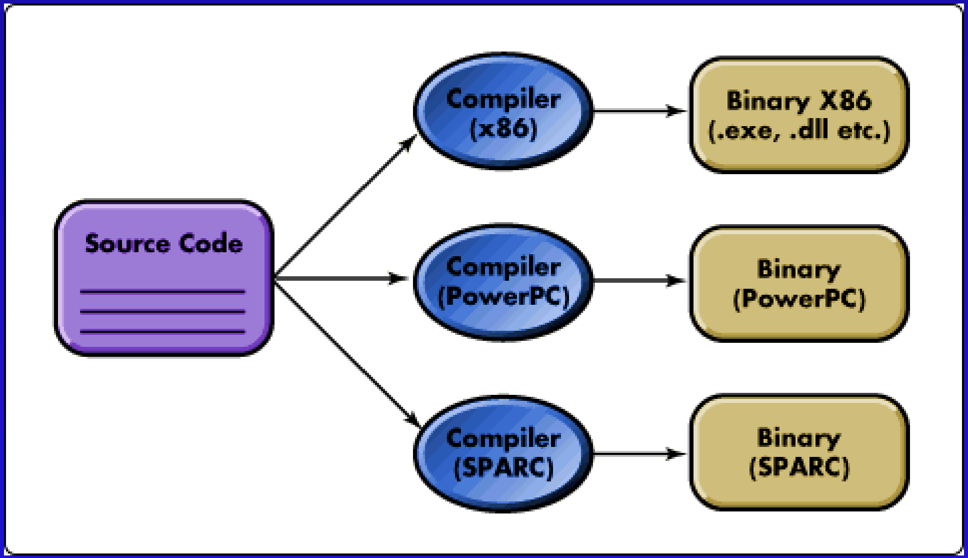
- As mentioned earlier, one of the disadvantages of a high-level language is that it must be translated to machine language.
- High-level languages are translated using language translators.
- A *language translator* is that translates a high-level language program or an assembly language program into a machine language program.
- There are three types of translators:
  - 1. Assemblers.
  - 2. Compilers.
  - 3. Interpreters.

High Level Language Translators

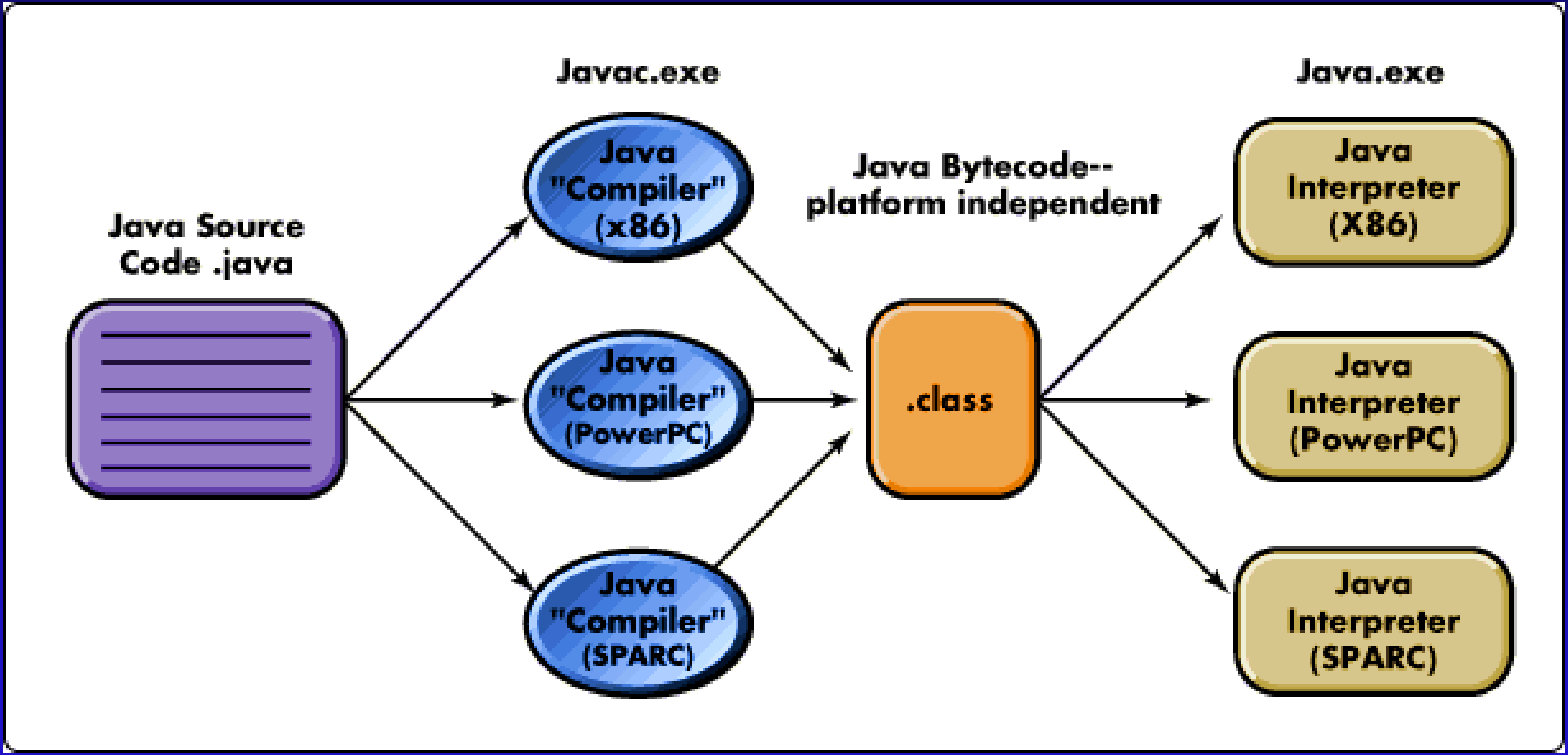
- *Assemblers*
  - An assembler is a program that translates an assembly language program, written in a particular assembly language, into a particular machine language.
- *Compilers*
  - A compiler is a program that translates a high-level language program, written in a particular high-level language, into a particular machine language.
- *Interpreters*
  - An interpreter is a program that translates a high-level language program, one instruction at a time, into machine language.
  - As each instruction is translated it is immediately executed.
  - Interpreted programs are generally slower than compiled programs because compiled programs can be optimized to get faster execution.
- Note that:
  - Some high-level languages are compiled while others are interpreted.
  - There are also languages, like Java, which are first complied and then interpreted

Compilation Process: Traditional Compilers

- In the traditional compilation process, the compiler produces machine code for a specific family of processors
- For example, given a source program, a compiler for the x86 family of processors will produce binary files for this family of processors.
- A disadvantage of this compilation method is that the code produced in each case is not portable.
- To make the resulting code portable, we need the concept of a virtual machine as we discuss in the following page.



Compilation Process: Java Compilers



Java Virtual Machine

- Instead of producing a processor-specific code, Java compilers produce an intermediate code called *bytecode*.
- *The bytecode is also a binary code but is not specific to a particular CPU*.
- A Java compiler will produce exactly the same bytecode no matter what computer system is used.
- The Java bytecode is then interpreted by the Java Virtual Machine (JVM) interpreter.
- Notice that each type of computer system has its own Java interpreter that can run on that system.
- This is how Java achieves compatibility.
  - It does not matter on what computer system a Java program is compiled, provided the target computer has a Java Virtual machine.

Structure of Simple Java Programs

- The following figure shows a simplified structure of Java programs. We will consider a more detailed structure of Java programs later in this course.

```
  public class ClassName {
      public static void main(String[] args ){
       statement 1
       statement 2
        * * *
       statement N
      }
}
```

- A Java program consists of essential elements called classes. The classes in a program are used to create specific things called objects.

Source Program: Example

- This is an example of a Java source program

```
public class Greeting {
    public static void main(String[] args
){System.out.println(“Good Morning.”);
    }
}
```

- You must type this program and save it in a file named Greeting.java
- Java is case sensitive and has a free-form layout
- *The words public, class, static, void, main and etc are called* reserved or keyword words
- The meaning of the words is fixed by the language. For now, they must appear in the places shown.

Structure of Simple Java Programs (cont'd)

- By contrast, the word Greeting, varies from program to program.
  - What exactly goes there is chosen by the programmer.
- The first line, public class Greeting, start s a new class called Greeting.
- Classes are a fundamental concept in java. Their role is as factories for objects.
- But here we are using the Greeting class as a container for our program's instructions.
- Java requires that all program instructions be placed inside methods and that every method must be placed inside a class.
- Thus we must define methods that would contain our instructions and a class that holds the methods.
- In our program, main() is our only method while Greeting is our class.

Structure of Simple Java Programs (cont'd)

- At this point, simply regard

```
public class ClassName{
...
}
```

as a necessary part of the plumbing that is required to write a java program.

- The construction

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

is where we define the method main ( )

Structure of Simple Java Programs (cont'd)

- The parameter String[] args is a required part of the main method.
- At this time, simply consider

```
public class ClassName{
    public static void main (String[] args){
    ...
    }
}
```

as yet another part of the plumbing for the time being, simply put all instructions between the curly braces {} of the main() method.

- There is no limit to the number of instructions that can be placed inside the body of the main method.

- Our program contains only one instruction, that is

```
    System.out.println ("Good Morning");
```

Structure of Simple Java Programs: Printing Output

- The instruction,

  `System.out.println(“Good Morning”);`

  prints a line of text namely `“Good Morning”.`

- A program can send the string : to a window, to a file, to a networked computer.
  - However, our program prints the string to the terminal window. That is the monitor.

- Terminal window is represented in java by an object called out and out object is contained in the System class.

- The System class contains useful objects and methods to access System resources. To use the out object in the System class, you must to refer to it as System.out

- To use System.out object, specify what you want to do to it. In this case, you want to print a line of text. The println() method carries out this.

Structure of Simple Java Programs: Printing Output

- The println() method prints a string or a number and then start a new line. For example
  - The sequence of statements:

```
System.out.println (“Good”);
System.out.println (“Morning.”);
```

  prints two lines of text

```
Good
Morning.
```

  - The statement:

```
System.out.println (3 + 4);
```

  prints the number

```
 7
```

- There is a second method called print(), which print an item without starting a new line. For example

```
System.out.print (“Good”);
System.out.println (“ Morning.”);
```

  prints a single line

```
Good Morning.
```

Escape Sequences

- An escape sequence is a special two-character sequence representing another character. Suppose you want to display a string containing quotation marks, such as

```
Hello, “World”!
```

- you can’t use

```
System.out.println(“Hello, “World”!“);
```

- To display quotation marks in the above example, you should write:

```
System.out.println(“Hello, \“World\”!“);
```

- Therefore, \” is an escape sequence representing quotation mark “ .

- Similarly, \n an escape sequence representing a new line or line feed character. Printing a new line starts of a new line on the display. For example the statement:

```
System.out.println(“*\n ** \n *** \n);
```

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- For example the statement:

```
System.out.println(“*\n ** \n *** \n);
```

prints the following

```
*
**
***
```

Example 2

An agent sold a property worth N50000. If the buyer pays the agent 7% of the sale amount, find the agent’s commission and the total amount that the buyer must pay. The following program computes the agent’s commission and the total amount the buyer must pay. Study the program and try to relate it with the above java fundamentals

you learned so far. What would be the output of the program?

```
public class Interest{
    public static void main (String[] args) {
        System.out.print (“The agent’s commission is: ” );
        System.out.println (50000 * 0.07 );
        System.out.print (“Total amount the buyer pays is: ”);
        System.out.println (50000 + 50000*0.07);
    }
}
```

Fundamental Data Types

- Primitive Data Types
- Variable declaration
- Numbers and Constants
- Arithmetic Operators
- Arithmetic Operator Precedence
- The Math Class
- Assignment statement
- Increment and Decrement operators
- Writing Algebraic Expressions in Java
- Math Functions: Examples
- Casting

Primitive Data Types

- Java has eight primitive data types as described below.

Type	Size	Range
`byte`	1 byte	-128 to 127
`short`	2 bytes	-32,768 to 32,767
`int`	4 bytes	about –2 billion to 2billion
`long`	8 bytes	about –10E18 to +10E18
`float`	4 bytes	-3.4E38 to +3.4E38
`double`	8 bytes	1.7E308 to 1.7E308
`char`	2 bytes	A single character
`boolean`	1 byte	true or false

- Other information is represented in Java as Objects.

Variable Declaration

- A variable can be declared to hold a data value of any of the primitive types.
- A variable is a named memory location in which a value is stored.
- A variable name is a sequence of letters and digits starting with a letter.

```
int         counter;
int         numStudents = 583;
long        longValue;
long        numberOfAtoms = 1237890L;
float       gpa;
float       batchAverage = 0.406F;
double      e;
double      pi = 0.314;
char        gender;
char        grade = ‘B’;
boolean     safe;
boolean     isEmpty = true;
```

Numbers and Constants

- By default, whole numbers are int and real numbers are double.
- However, we can append a letter at the end of a number to indicate its type.
- Upper and lower case letters can be used for ‘float’ (F or f), ‘double’ (D or d), and ‘long’ (l or L):
- Float and double numbers may be expressed in scientific notation: number * 10^{exponent} as:

  number E integerExponent or *number e integerExponent*

```
float maxGrade = 100f;
double temp = 583d;
float temp = 5.5; // Error as 5.5 is double
float temp = 5.5f;
long y = 583L;
double x = 2.25e-6;
```

- One use of the modifier final is to indicate symbolic constants.
- By convention, symbolic constants are written in uppercase letters. Underscores separate words:

```
final double SPEED_OF_LIGHT = 3.0E+10;

final double CM_PER_INCH = 2.54;

final int MONTH_IN_YEAR = 12;
```

Arithmetic Operators

- A simple arithmetic expression has the form:

  op1 Operator op2

  where:

Operator	Description
+	Adds op1 and op2
−	Subtracts op2 from op1
*	Multiplies op1 by op2
/	Divides op1 by op2
%	Remainder of dividing op1 by op2

Arithmetic Operators (Cont'd)

- The operators give results *depending on the type of the operands*.

- If operand1 and operand2 are integer, then the result is also integer. But if either operand1 and/or operand2 is double, then the result is double.

- Examples:

Arithmetic expression	**Value**
`1 / 2`	`0`
`86 / 10`	`8`
`86 / 10.0`	`8.6`
`86.0 / 10`	`8.6`
`86.0 / 10.0`	`8.6`
`86 % 10`	`6`

Arithmetic Operator Priority

- An expression is a sequence of variables, constants, operators, and method calls that evaluates to a single value.
- Arithmetic expressions are evaluated according to priority rules.
- All binary operators are evaluated in left to right order.
- In the presence of parenthesis, evaluation starts from the innermost parenthesis.

Operators	Priority (Precedence)
+ - (unary)	1
* / %	2
+ - (binary)	3

Expression	Value
3 + 7 % 2	4
(2 – 5) * 5 / 2	-7
2 – 5 + 3	0

The Math class

- Many mathematical functions and constants are included in the Math class of the Java library. Some are:

Function /constant	**Meaning**
sqrt(x)	Returns the square root of x.
abs(x)	Returns the absolute value of x, x can be double, float, int or long.
cos(a), sin(a), tan(a)	Returns the trigonometric cosine/sine/tangent of an angle given in radians
exp(x)	Returns the exponential number e raised to the power of x
log(x)	Returns the natural logarithm (base e) of x
max(x, y) , min(x, y)	Returns the greater/smaller of two values, x and y can be double, float, int or long
pow(x, y)	Returns x^y
PI	The approximate value of PI

- Syntax to call a function in the Math class: `Math.functionName(ExpressionList)`
- Syntax to access a constant in the Math class: `Math.ConstantName`
- Example: `Math.PI * Math.max(4 * y, Math.abs(x – y))`

Assignment Statement

- Syntax:

```
variable = expression;
```

- The expression on the right –hand side is evaluated and the result is assigned to the variable on the left-hand side.

- The left-hand side must be a variable.

- Examples:

```
a = 5;
b = a;
b = b + 12;   // valid:  assignment operator , =, is not an equality operator
c = a + b;
a + b = c;   //  invalid:  left side not a variable
```

Assignment Statement (cont'd)

- To exchange (or to swap) the contents of two variables, a third variable must be used.

- Example:

```
double x = 20.5, y = -16.7, temp;
 temp = x;
 x = y;
 y = temp;
```

Short Hand Assignment Operators

- Java provides a number of short hand assignment operators:

Short-Form	Equivalent to
`op1 += op2`	op1 = op1 + op2
`op1 -= op2`	op1 = op1 – op2
`op1 *= op2`	op1 = op1 * op2
`op1 /= op2`	op1 = op1 / op2
`op1 %= op2`	op1 = op1 % op2

- Example:

```
a += 5;     // equivalent to a = a + 5;
```

Increment and Decrement Operators

- Increment/decrement operations are very common in programming. Java provides operators that make these operations shorter.

Operator	Use	Description
++	op++	Increments op by 1;
++	++op	Increments op by 1;
--	op--	Decrements op by 1;
--	--op	Decrements op by 1;

- Example:

```
int  y = 20; x = 10, z;
y++ ;
z = x + y;
```

Writing Algebraic Expressions in Java

- All operators must be explicit especially multiplications.
- For a fraction, you must use parenthesis for the numerator or denominator if it has addition or subtraction.

Algebraic expression	**Java expression**
$Z = \frac{4X + Y}{X_2} - 2Y$	z = (4 * x + y) / x2 – 2 * y
$Z = \sqrt{X + Y^2}$	z = Math.sqrt(x + Math.pow(y, 2))

Example1

- The following example computes the roots of a quadratic equation using the formula:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Algorithm:

```
» a = 1
» b = -5
» c = 6
» root1 = (-b + sqrt(b * b – 4 * a * c ) )  / ( 2 * a)
» root2 = (-b - sqrt(b * b – 4 * a * c ) )  / ( 2 * a)
» print root1, root2
```

- Java code:

```java
public class QuadraticEquation {
  public static void main(String[] args) {
   double a = 1, b = -5, c = 6;
   double root1 = (-b + Math.sqrt(b*b - 4*a*c))/(2*a);
   double root2 = (-b - Math.sqrt(b*b - 4*a*c))/(2*a);
   System.out.println("The roots are: "+root1 + " ,"+root2);
  }
}
```

Example2

- The following example calculates the area and circumference of circle.
- Algorithm:
  - radius = 3
  - area = pi * radius^2
  - circumference = 2 * pi * radius
  - print area, circumference

```
public class Circle {
  public static void main(String[]args) {
    double area, circumference;
    int radius = 3;
    area = Math.PI * Math.pow(radius, 2);
    circumference = 2 * Math.PI * radius;
    System.out.println("Area = " + area + " square cm");
    System.out.println("Circumference = " + circumference + " cm");
   }
}
```

Casting

- A cast is an explicit conversion of a value from its current type to another type.
- The syntax for a cast is: `(type)  expression`
- Two of the cases in which casting is required are:

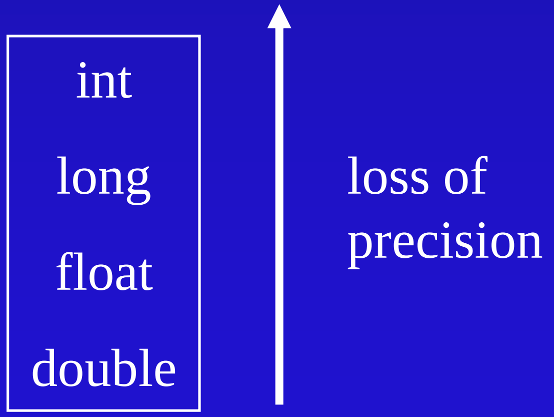
1. To retain the fractional part in integer divisions:

```
int sumOfGrades;
int numberOfStudents;
double average;
// . . .
average =  (double) sumOfGrades / numberOfStudents;
```

Note: The cast operator has higher priority than all arithmetic operators.

2. When a type change will result in loss of precision

```
int sum = 100;
 float temp = sum; //temp now holds 100.0
 float total = 100F;
 int temp  = total; // ERROR
 int start  = (int) total;
```



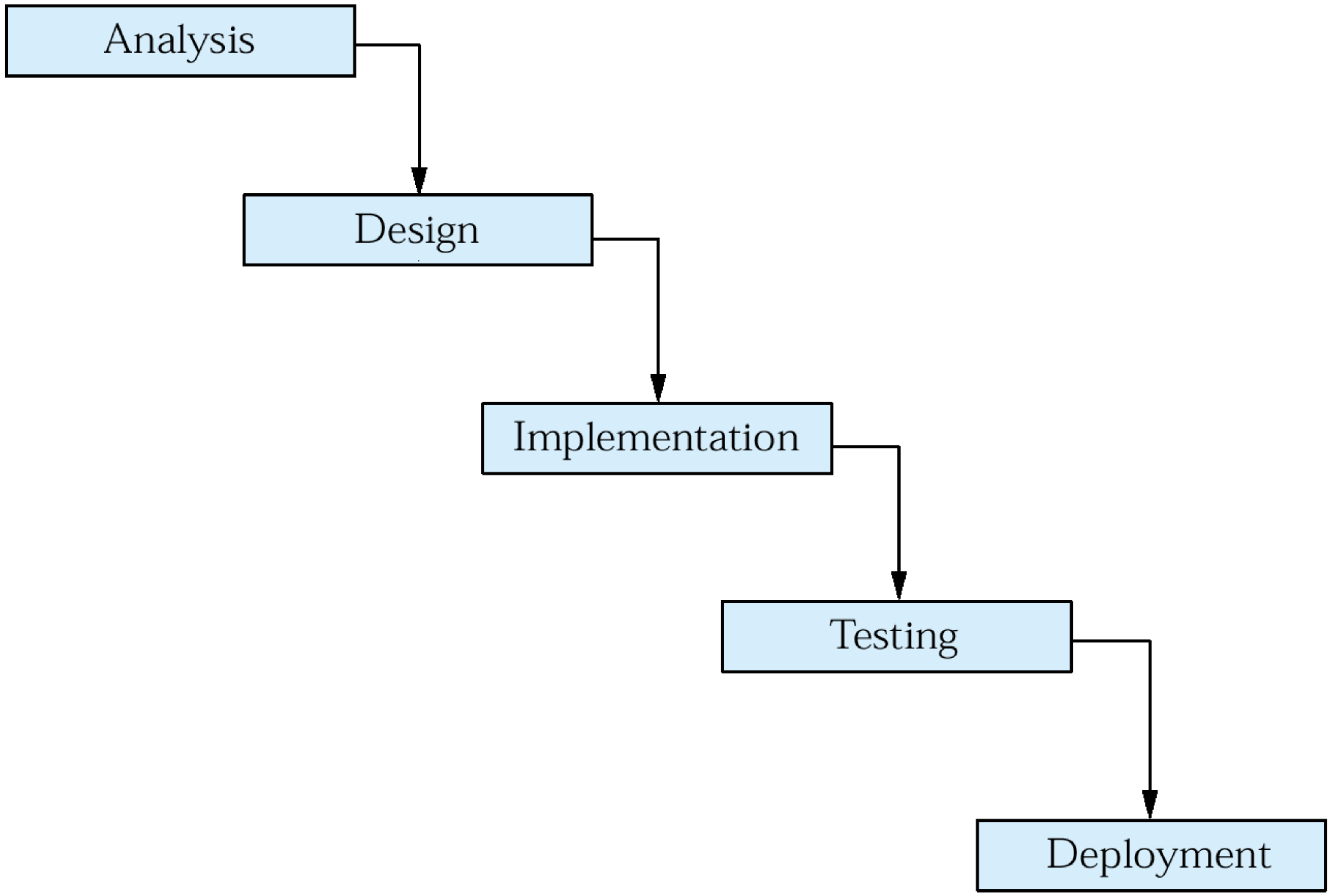
Algorithms and Problem Solving

- Problem Solving
- Problem Solving Strategy
- Algorithms
- Sequential Statements
- Examples

Problem Solving

- Solving a problem means that we know the way or the method to follow manually from the start till the end.
- Having the method known, the same method is used by the computer to solve the problem but faster and with higher precision.
- If we do not know how to solve a problem ourselves, the computer will not be of any help in this regard.
- The strategy for solving a problem goes through the following stages:
  - Analysis: in this stage, we should find what the problem should do.
  - Design : the way or method of how your problem is solved is produced
  - Implementation: the method found in design is then coded here in a given programming language.
  - Testing: here we verify that the program written is working correctly
  - Deployment : finally the program is ready to use

Problem Solving Strategy



Algorithms

- An algorithm is a sequence of instructions that solve a problem.

- An algorithm has the following properties:
  - No ambiguity in any instruction
  - No ambiguity which instruction is next
  - Finite number of instructions
  - Execution must halt

- The description of the instructions can be given in English like statements called pseudo-code

- The flow control of instructions has three types:
  - Sequential
  - Selection
  - Iteration

Sequential Statements

- Instructions in this type of flow control are executed one after the other in sequence

- These statements include:

  - Assignment statement
  - Method calls

Example1

- Write a program that assigns the Cartesian coordinates of two points (x1, y1) and (x2, y2) and displays the distance between them using the following formula.

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

- Algorithm:
  - » Get a value for x1 (e.g., x1 = 1)
  - » Get a value for y1 (e.g., y1 = 1)
  - » Get a value for x2 (e.g., x2 = 4)
  - » Get a value for y2 (e.g., y2 = 6)
  - » Calculate the distance using the formula:
    - – distance = sqrt((x2 – x1) ^ 2 + (y2 – y1) ^ 2)
  - » print distance

Example1 (cont'd)

- Java code:

```
public class Distance {
  public static void main(String[] args) {
   double x1, y1, x2, y2, dist;
   x1 = 1.0;
   y1 = 1.0;
   x2 = 4.0;
   y2 = 6.0;
   dist = Math.sqrt(Math.pow(x2-x1,2)+ Math.pow(y2-y1,2));
   System.out.println("The distance is " + dist);
  }
}
```

Example2

- Write a program that finds the area of a triangle given the length of its sides: a, b, c. Use a = 3, b = 4, c = 5 to test your solution.

$$area = \sqrt{s\cdot(s-a)\cdot(s-b)\cdot(s-c)}$$

$$s = \frac{a+b+c}{2}$$

- Algorithm:
  - » Get the value of a (e.g., a = 3)
  - » Get the value of b (e.g., b = 4)
  - » Get the value of c (e.g., c = 5)
  - » Calculate s using the formula s = (a + b + c) / 2
  - » Calculate area using the formula area = sqrt(s* (s – a) * (s – b) * (s – c))
  - » print area

Example2 (cont'd)

- Java code:

```
public class Distance {
  public static void main(String[] args) {
    double a, b, c, area;
    a = 3.0;
    b = 4.0;
    c = 5.0;
    s = (a + b + c ) / 2.0;
    area = Math.sqrt(s * (s - a) * (s - b) * (s - c) );
    System.out.println("The area is " + area);
  }
}
```

Basic Object-Oriented Concepts

- Object-Oriented Paradigm
- What is an Object?
- What is a Class?
- Constructing Objects from a class
- Problem Solving in OO languages
- More OO Concepts
- Strength of Object-Oriented Paradigm

Object-Oriented Paradigm

- To truly understand Java, we need to understand the paradigm on which it is built on: the Object-Oriented Paradigm (OOP).
- OOP is a model whereby a problem domain is modeled into objects, so that problem solving is by interaction among objects.
- OOP is a more natural model compared to other models since OOP's approach is exactly the way humans view problem solving.
- We take a closer look at the main ingredients of the model: Objects and Classes.

What is an Object?

- An object is an individual, identifiable entity, either real or abstract, that has a well-defined boundary.
- An object has two main properties, namely:
  - State: each object has *attributes*, whose values represent its state.
  - Behavior, each object has a set of behavior.

- Example of an object: You, the student following this Lecture, are an object.
  - Your attributes include your name, your GPA, your major, etc.
  - You also have a set of behavior, including attending lectures, solving home works, telling someone your GPA, sleeping, etc.

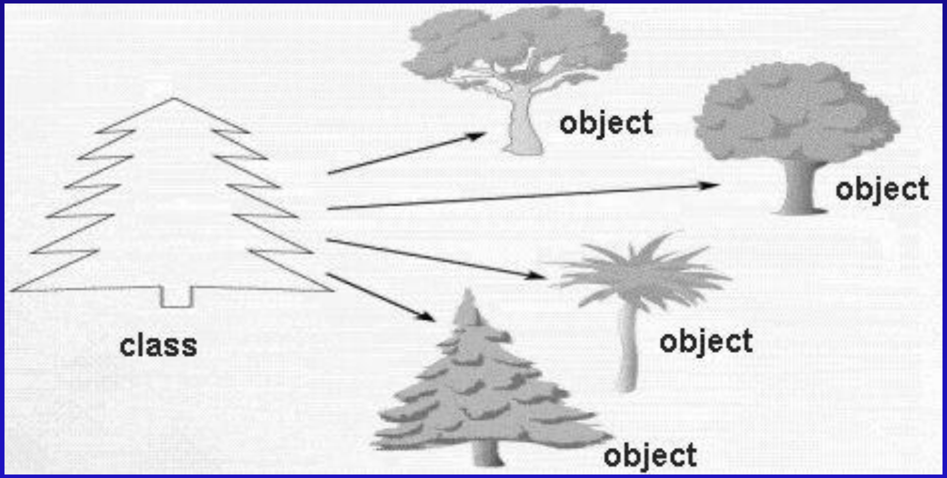
… What is an Object?

- Other examples of objects are:
  - The instructor delivering this lecture.
  - This room.
  - This lecture.
  - This University.
  - CSC211.
  - Your Bank Account

- Try to list some of the attributes and set of behavior for each of the above objects.
- Also look around you and identify the objects you can see or imagine.

What is a Class?

- A class is a general specification of attributes and behavior for a set of objects.
- Each object is an instance of a class. It shares the behavior of the class, but has specific values for the attributes.
- Thus, a class can be viewed as an abstract specification, while an object is a concrete instance of that specification.



- An example of a class is Student, an abstract entity that has attributes and a set of behavior.
- However, unless we have an actual student, we cannot say what the ID number is or what the major is.

What is a Class? (cont’d)

- The following table shows further examples of classes and their instances:

Classes	Instances of (or Objects)
Instructor	Sahalu Junaidu
University	ABU
Course	CSC211
Bank Account	Ahmad’s Bank Account

- Identify the classes for the objects you identified in the exercise on Slide#68.

Constructing Objects from a Class

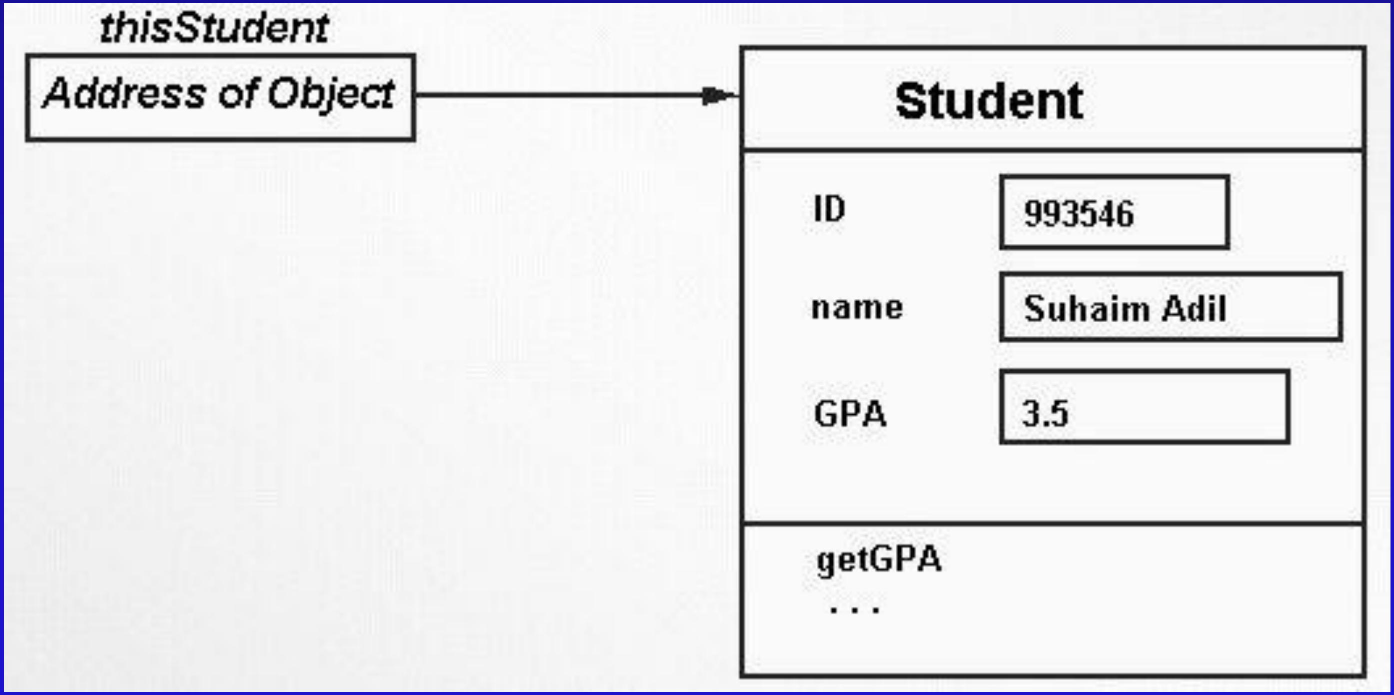
- Our main task is to design and implement classes to be used in creating objects.
- This involves defining the variables, methods and constructors.
- To create an object from a class, we use the ***new*** operator, a constructor, and supply construction parameters (if any).
- Example, we create an object from the Student class as follows:

```
Student thisStudent =
          new Student(993546, “Suhaim Adil”,  3.5);
```

… Constructing Objects from a Class

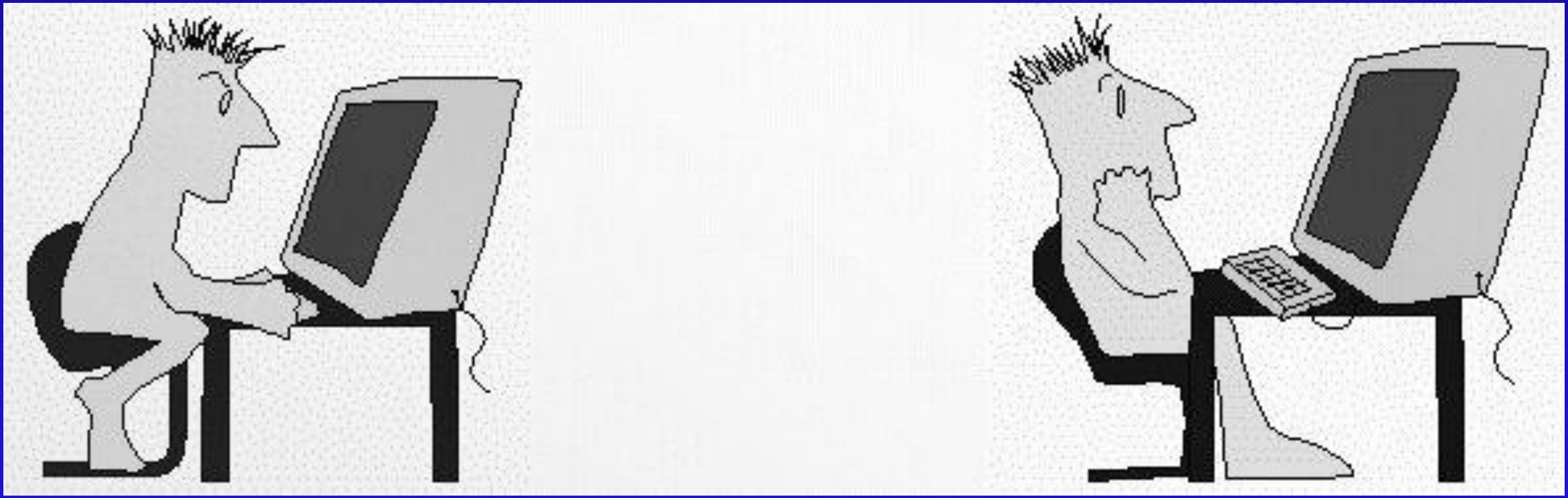
```
Student thisStudent =
        new Student(993546, “Suhaim Adil”,  3.5);
```

- The relationship between the reference variable, ***thisStudent***, and the object created is shown by the following figure:



Problem Solving in OO languages

- In the real world, problems are solved by interaction among objects.
- If you have a problem with your car, you take it to a mechanic for repair.
- Similarly, in OO programming languages, problems are solved by interactions among objects.
- Objects interact by sending messages among themselves.



Problem Solving in OO languages

```
Student thisStudent =
        new Student(993546, “Suhaim Adil”,  3.5);
```

- Messages are sent using the following general syntax:

```
referenceVariable.methodName
```

- To know the GPA of the student object we created, a message is sent as follows:

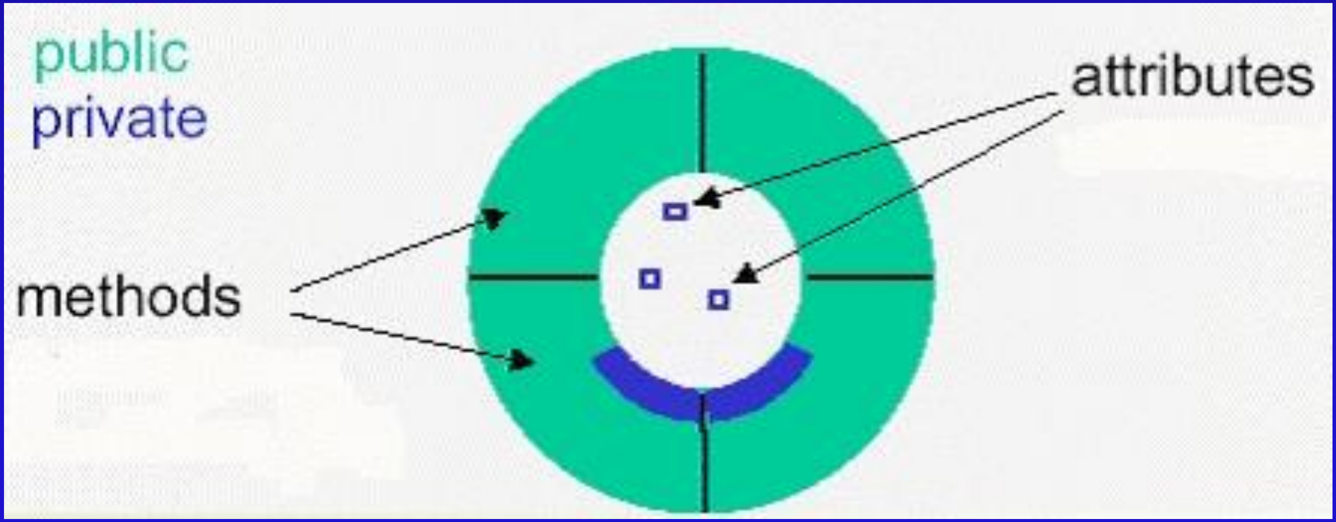
```
double gpa = thisStudent.getGPA();
```

- We have been sending messages to the `System.out` object in previous examples.

```
System.out.println(“Salaaam Shabaab”);
```

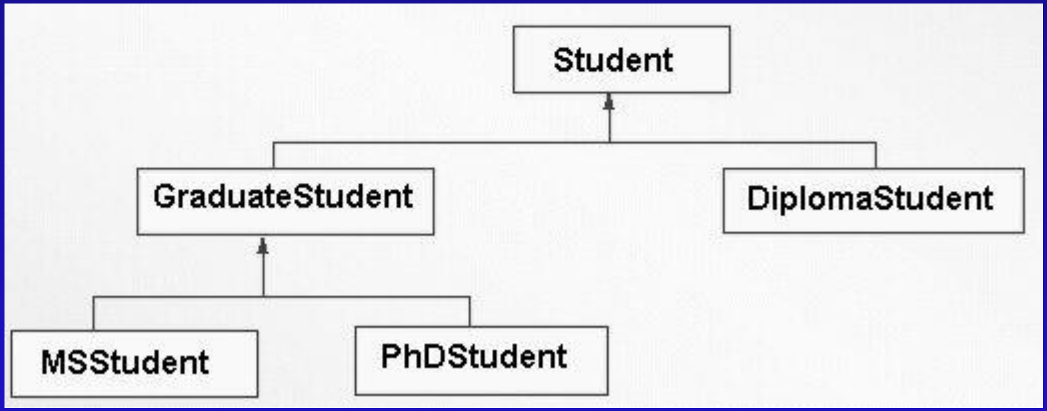
Encapsulation

- Having understood the main ingredients of OOP, we can now take a closer look at its main features.
- One of the key features is the bringing together of data and operations – Encapsulation.
- Encapsulation, also called information hiding, allows an object to have full control of its attributes and methods.
- The following shows how an object encapsulates its attributes and methods.



Inheritance

- Another powerful feature of OOP is inheritance.
- Classes are organized in hierarchical structure.
- For example, the following shows a Student class and its related sub-classes:



- The advantage is code-reusability.
- After implementing the Student class, to implement the GraduateStudent, we inherit the code of Student.

Strength of the OO Paradigm

- We conclude this introduction to OOP by summarizing its main advantages:
  - It allows the production of software which is easier to understand and maintain.
  - It provides a clear mapping between objects of the problem domain (real world objects) and objects of the model.
  - It supports code reuse and reduces redundancy.
  - It allows "off the shelf" code libraries to be reused..
  - It allows the production of reliable (secure) software..

Strings and String Operations

- What is a String?
- Internal Representation of Strings
- Getting Substrings from a String
- Concatenating Strings
- Comparing Strings
- Finding the index of a character or Substring
- Case Conversion and Trimming of Strings
- Strings are Immutable!
- Program Example
- More String Methods?

What is a String?

- A String is a sequence of characters enclosed in double quotes. E.g. "Salaam Shabaab"
- "A" is a string but 'A' is a character
- String processing is a very frequent application.
- Thus, Java provides special support for strings.
- A string is an instance of Java's built in String class. Thus, strings are objects.
- Like any object, a string object can be created using the *new* operator as in:

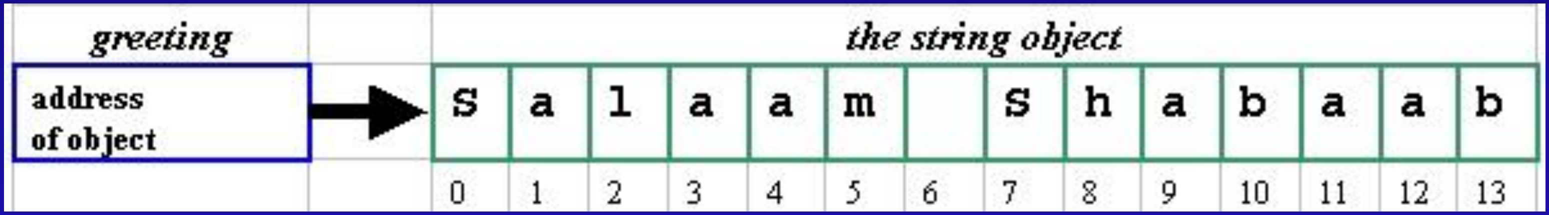
  ```
  String greeting = new String("Salaam Shabaab");
  ```
- Java allows a String object to be created without the use of *new*, as in:

  ```
  String greeting = "Salaam Shabaab";
  ```

Internal Representation of Strings

- Internally, String objects are represented as a sequence of characters indexed from 0.
- For example, the following string is represented as shown below:

  String greeting = “Salaam Shabaab”;



- Many string methods return results based on this indexing:

`char charAt(int index)`	Returns the character at position index from this string.

- For example, the statement: char letter = greeting.charAt(5); stores the character ‘m’ in the character variable letter.

Internal Representation of Strings (cont’d)

- We can also ask a string object its length by calling its *`length()`* method:

`int length()`	Returns the length of this string.

- For example, the statement:

```
int charCount = greeting.length();
```

stores **14** in the integer variable `charCount`.

Getting Substring from a String

- A common operation on Strings is extracting a substring from a given string.

`String **substring**(int start)`	Returns the substring from *start* to the end of the string.
`String **substring**(int start, int end)`	Returns the substring from *start* to *end* but not including the character at end.

- For example, the statement:

```
String sub2 = greeting.substring(7)
```

creates the substring "Shabaab" that is referred to by sub2.

- For example, the statement:

```
String sub1 = greeting.substring(0, 6);
```

creates the substring "Salaam" that is referred to by sub1.

- What is the effect of the following statement?

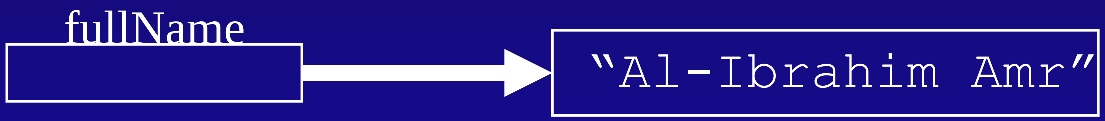
```
String sub3 = greeting.substring(8, 12);
```

Concatenating Strings

- Concatenation means joining two or more strings together.
- Java allows two strings to be concatenated using the ‘+’ operator.

Example:

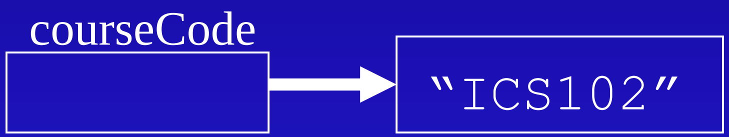
```
String firstName = “Amr”;
String lastName = “Al-Ibrahim”;
String fullName = lastName+” “+firstName;
```



- If one of the operands in an expression is a string, Java automatically converts the other to a string and concatenates them.

Example:

```
String course = “ICS”;
int code = 102;
String courseCode = course+code;
```



- We frequently use the concatenation operator in *println* statements:

```
System.out.println(“The area =“+area);
```

- You need to be careful with concatenation operator. For example, what is the output of the following statement?:

```
System.out.println(“Sum =“+5+6);
```

Comparing Strings

- Strings are compared by comparing their characters left to right. Unicode codes are used in the comparison.
- Note that lowercase letters are different from uppercase letters.
- The String class has the following methods for checking whether two strings are equal:

`boolean` **`equals`**`(String another)`	Returns true if another is the same as this string.
`boolean` **`equalsIgnoreCase`**`(String another)`	Returns true if ***another*** is the same as this string, treating lower and upper case letters as the same.

- The following table shows some examples of applying these methods. Assuming the following declarations:

```
String s1 = "Salaam";
String s2 = "Shabaab";
String s3 = "SALAAM";
```

`s1.equals(s2)`	false
`s1.equals("Salaam")`	true
`s1.equals(s3)`	false

- What is the result of s1.equalsIgnoreCase(s3) ?

Comparing Strings (cont'd)

- Sometimes we need to know if a string is less than another.
- Accordingly, the String class has the following additional comparison methods:

`int compareTo(String another)`	Returns a negative number if this string is less than ***another***, 0 if they are equal and a positive number if this string is greater than ***another***.
`int compareToIgnoreCase(String another)`	Same as above but treating lower and upper case letters as the same. .

- Assuming the following declarations:

```
String s1 = "Salaam";
String s2 = "Shabaab";
String s3 = "SALAAM";
```

we have:

`s1.compareTo(s2)`	a negative number
`s2.compareTo(s1)`	a positive number

- What is the result of `s1.compareToIgnoreCase(s3)`?

Finding the index of a Character or Substring

➢ The following methods return an index given a character or substring:

`int` **`indexOf`**`(int code)`	Returns the index of the first occurrence of a character whose Unicode is equal to code.
`int` **`indexOf`**`(String substring)`	Same as above but locates a substring instead.
`int` **`lastIndexOf`**`(int code)`	Returns the index of the last occurrence of a character whose Unicode is equal to code.
`int` **`lastIndexOf`**`(String substring)`	Same as above but locates a substring instead.

➢ The table below shows some examples, assuming the declaration:

```
String greeting = “Salaam Shabaab”;
```

`int index = greeting.indexOf(‘a’)`	1
`int index = greeting.lastIndexOf(‘a’)`	12
`int index = greeting.indexOf(98)`	10
`int index = greeting.indexOf(“haba”)`	8

Case Conversion and Trimming of Strings

- It can be useful to convert a string to upper or lower case.

`String` **`toLowerCase`**`()`	Returns the lower case equivalent of this string.
`String` **`toUpperCase`**`()`	Returns the lower case equivalent of this string.

- For example, the statements:

```
String greeting = “Salaam Shabaab”;
String greeting2 = greeting.toUpperCase();
```

create two string objects. The object referenced by `greeting2` stores “SALAAM SHABAAB”

- Another useful method of String is `trim()`:

`String` **`trim`**`()`	Removes leading and trailing white spaces.

- For example, the statement:

```
String s = “     Salaam    “.trim();
```

stores “Salaam” in the string referenced by `s`.

- Note that return `'\r'`, tab `'\t'`, new line `'\n'` and space `' '` are all white space characters.
- All the methods of the String class can also be applied to anonymous string objects

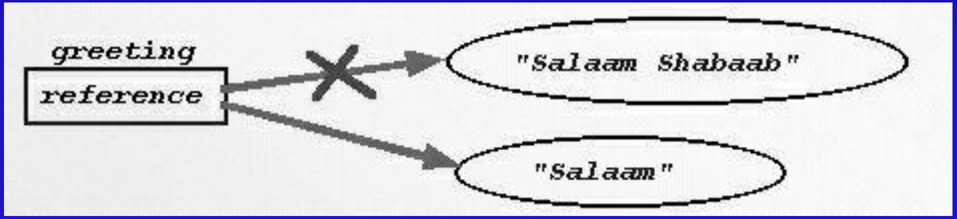
(also called string literals) as shown in the above example.

Strings are Immutable!

- Another special feature of Strings is that they are immutable. That is, once a string object is created, its content cannot be changed.
- Thus, all methods that appear to be modifying string objects are actually creating and returning new string objects.
- For example, consider the following:

```
String greeting = "Salaam Shabaab";
greeting = greeting.substring(0,6);
```

Instead of changing the *greeting* object, another object is created. The former is garbage collected.



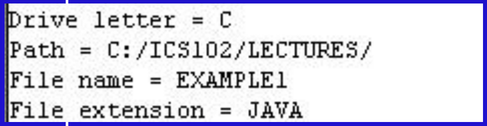
- The fact that Strings are immutable makes string processing very efficient in Java.

Program Example

- The following shows a program that uses some String methods.
- It breaks a full path for a file into drive letter, path, file name and extension and prints the result in upper case.

```
public class BreakPath {
    public static void main(String[] args) {
        String fullPath = "c:/ics102/lectures/Example1.java";
        fullPath = fullPath.toUpperCase();
        char driveLetter = fullPath.charAt(0);
        int lastSlashIndex = fullPath.lastIndexOf('/');
        String path = fullPath.substring(0, lastSlashIndex+1);
        int dotIndex = fullPath.indexOf('.');
        String file = fullPath.substring(lastSlashIndex+1, dotIndex);
        String extension = fullPath.substring(dotIndex+1);
        System.out.println("Drive letter = "+driveLetter);
        System.out.println("Path = "+path);
        System.out.println("File name = "+file);
        System.out.println("File extension = "+extension);
    }
}
```

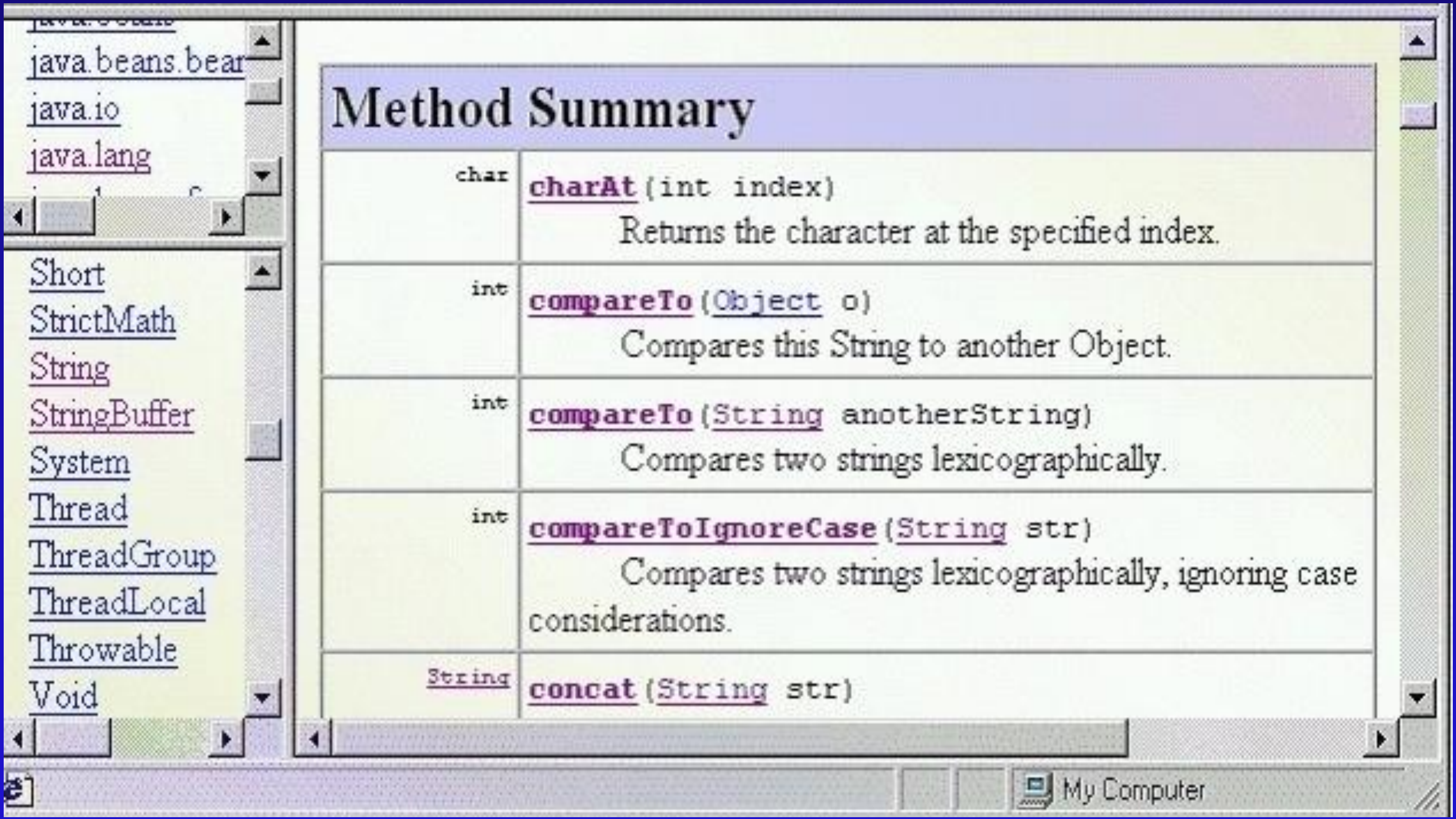
Output:



```
Drive letter = C
Path = C:/ICS102/LECTURES/
File name = EXAMPLE1
File extension = JAVA
```

More String Methods?

- We have discussed some of the most important methods of the String class.
- For a complete list, check the Java SDK documentation.



Method Summary

char	charAt(int index) Returns the character at the specified index.
int	compareTo(Object o) Compares this String to another Object.
int	compareTo(String anotherString) Compares two strings lexicographically.
int	compareToIgnoreCase(String str) Compares two strings lexicographically, ignoring case considerations.
String	concat(String str)

Introduction to Console Input

- Primitive Type Wrapper Classes
- Converting Strings to Numbers
- `System.in` Stream
- Scanner
- Reading Strings
- Numeric Input

Primitive Type Wrapper Classes

- Java uses primitive types, such as `int` and `char`, for performance reasons.
- However, there are times when a programmer needs to create an object representation for one of these primitive types.
- Java provides a Wrapper class for each primitive type. All these classes are in the *java.lang* package:

Primitive type	**Wrapper class**
char	Character
double	Double
float	Float
int	Integer
long	Long
byte	Byte
boolean	Boolean
void	Void

String to Number Conversion

- Wrapper classes are used to provide constants and general methods for the primitive data types.
- Each of the Wrapper classes Double, Float, Integer, and Long has a method to convert the string representation of a number of the corresponding primitive type into its numeric format:

Wrapper class	**parse method**
Double	parseDouble(string)
Float	parseFloat(string)
Integer	parseInt(string)
Long	parseLong(string)

String to Number Conversion

- Examples:

```
int numStudents = Integer.parseInt(“500”);
String inputLine = “3.5”;
double studentGPA = Double.parseDouble(inputLine);
val = Integer.parseInt(str);
```

System.in stream

- In Java I/O is handled by streams.

- An input stream is an object that takes data from an input source and delivers that data to a program.

- An output stream is an object that takes data from a program and delivers it to an output destination. *[e.g., System.out that corresponds to the monitor]*

- In Java, console input is usually accomplished by reading from the input stream System.in of the class java.lang.System

- System.in represents the standard input stream (i.e., it corresponds to the keyboard).

Scanner Class

- To be able to read characters, strings, or numbers, *System.in* must be wrapped in other objects.

- java.util.Scanner class is used to read strings and primitive types, and must be imported into a program to be used.

- A Scanner object can be set up to read input from various sources, including the user typing values on the keyboard

- The following line creates a Scanner object that reads data typed by the user from the keyboard:

```
Scanner input = new Scanner (System.in);
```

- The new operator creates the Scanner object

Example: Reading String

- Once created, the Scanner object can be used to invoke various input methods, such as:

name = input.nextLine();

- The nextLine method reads all of the input until the end of the line is found

```
import java.util.Scanner;
public class ReadString{
    public static void main(String[] args){
          Scanner input = new Scanner(System.in);
          System.out.println("Enter a line of text:");
          String message = input.nextLine();
          System.out.println("You entered: " + message);
   }
}
```

Example: Numeric Input

```
import java.util.Scanner;
 public class ReadIntegers{
     public static void main(String[] args){
              Scanner input = new Scanner(System.in);

         System.out.println("Enter two integers on separate lines:");
         int num1 = input.nextInt();
         int num2 = input.nextInt();
         System.out.println("Sum = " + (num1 + num2));
     }
  }
```

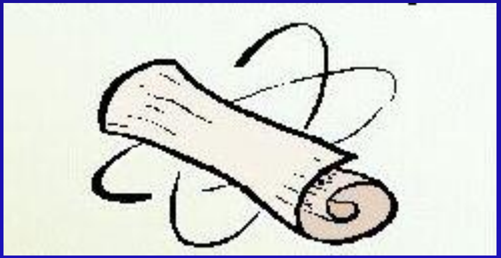
Introduction to Classes

- Motivation
- Class Components
- Instance Variables
- Constructors
- The Student Class
- Exercises

Motivation: The Problem

- Primitive Data types and Strings are not enough to write useful real-life programs.
- Example of some real life problems:

Student Information System



Bank Transaction System

Airline Reservation System

Hospital Management System

Motivation: The Solution

- Solution : Interaction among Objects.

- Our main concern: how to design classes as templates for objects.

Class Components

- A class has following elements:
  - Identity
  - Attributes
  - Methods

- Graphical Representation of a class (UML diagram):

Identity
Attributes
Methods

Example:

Student
studentID name gpa
getName changeGPA getID

Class Identity

- Class naming convention:
  - Noun or Noun phrase
  - First letter of each word capitalized. No underscores.

- Examples: Tree, DatePalm, Student,
  GraduateStudent, BankAccount, InputStreamReader

- Syntax:

```
    modifier class ClassName{
    attributes
    methods
  }
```

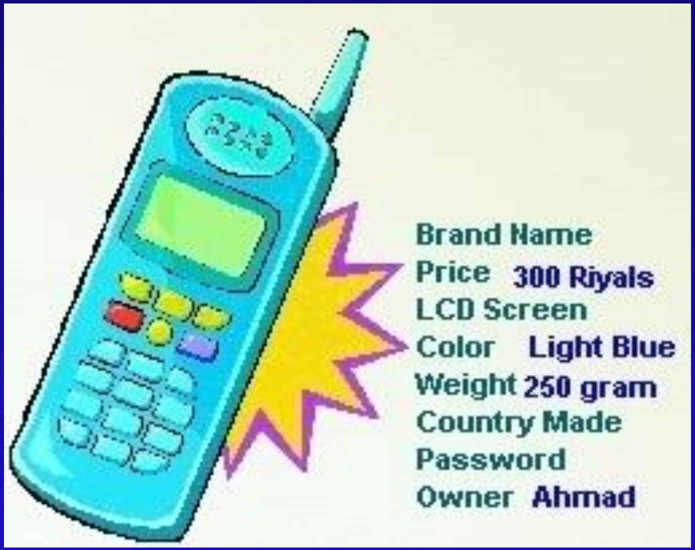
- Example:

```
  public class Student{
     . . .
  }
```

classes are unique

Class Attributes

- Attributes are the distinctive characteristic, quality, or feature that contribute to make objects of a class unique.
- Each attribute has a value.
- An attribute could be of simple type or it could be another class type.
- Some attribute values change over time.
- Objects store their attribute values in instance variables.
- It is good practice to make attributes private.



Attributes: Syntax & Naming

- Attribute naming convention:
  - Noun, noun phrase or adjective
  - Starts with small letter and each
  - phrase's first letter capitalized

Good attribute names	Bad attribute names
studentName	readBook
color	Color
yearlySalary	yearlysalary

- Syntax:

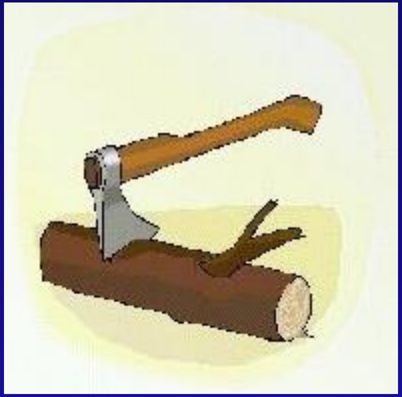
```
accessModifier type attributeName;
accessModifier type attributeName = initialValue;
```

- Example:

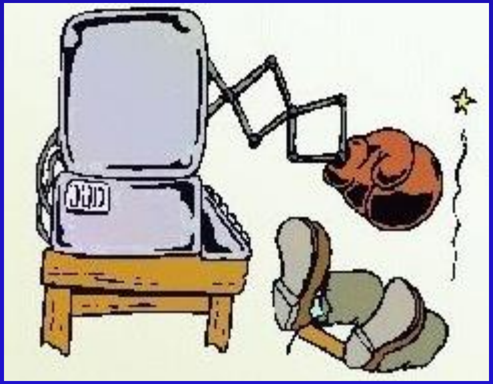
```
private int id;
private double gpa;
```

Methods

- Methods are the actions that an object performs. Through methods objects interact and pass messages to other objects.



- The behavior of an object depends on its attribute values and the operations performed upon it.



Methods: Syntax & Naming

- Method naming convention:
  - Verb or verb phrase
  - Starts with small letter and each
  - phrase's first letter capitalized

Good method names	Bad method names
getName	GetName
changeGPA	studentInformation
registerCourse	playfootball

- Syntax:

```
modifier returnType methodName(parameterType parameter,...){
         statements
         return expression;
 }
```

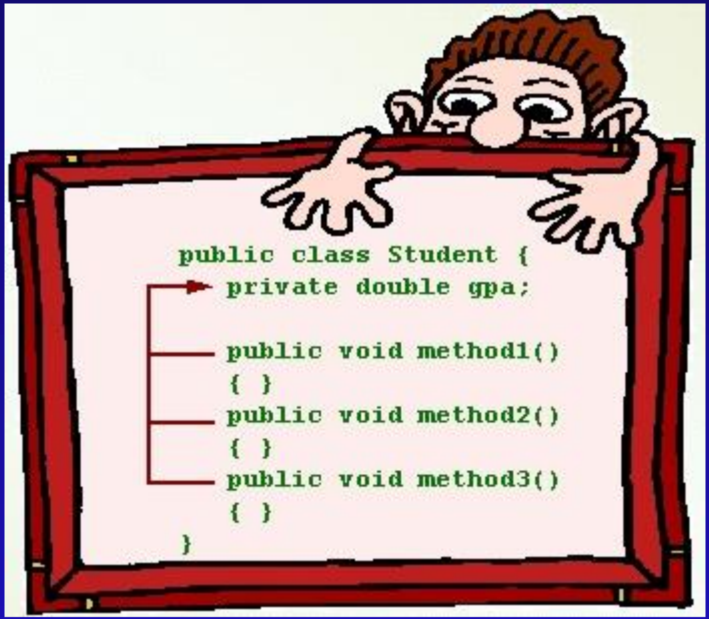
- Example:

```
 public double calculateAverage(int value1, int value2){
         double average = (value1 + value2) / 2.0;
         return average;
  }
```

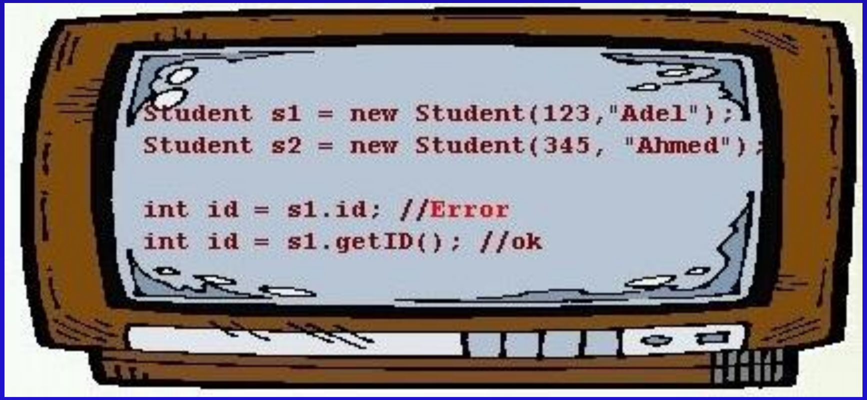
Instance Variables

- State of an object: the set of values that describe the object.
- Each object stores its state in one or more instance variables.

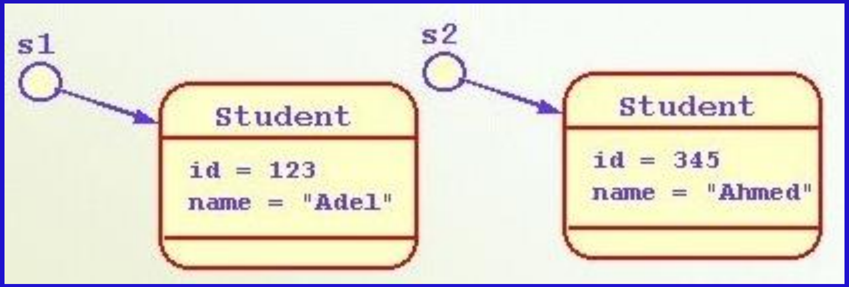
  private double gpa ;
- Scope of an Instance variable: the part of the program in which you can access the variable.
- In Java, the scope of a variable is the block in which that variable is declared.
- Private instance variables can be accessed directly only in the methods of the same class.
- We can gain access to private instance variables through public methods in that class.
- Each object of a class has its own copy of an instance variable.



```
public class Student {
    private double gpa;

    public void method1()
    { }
    public void method2()
    { }
    public void method3()
    { }
}
```

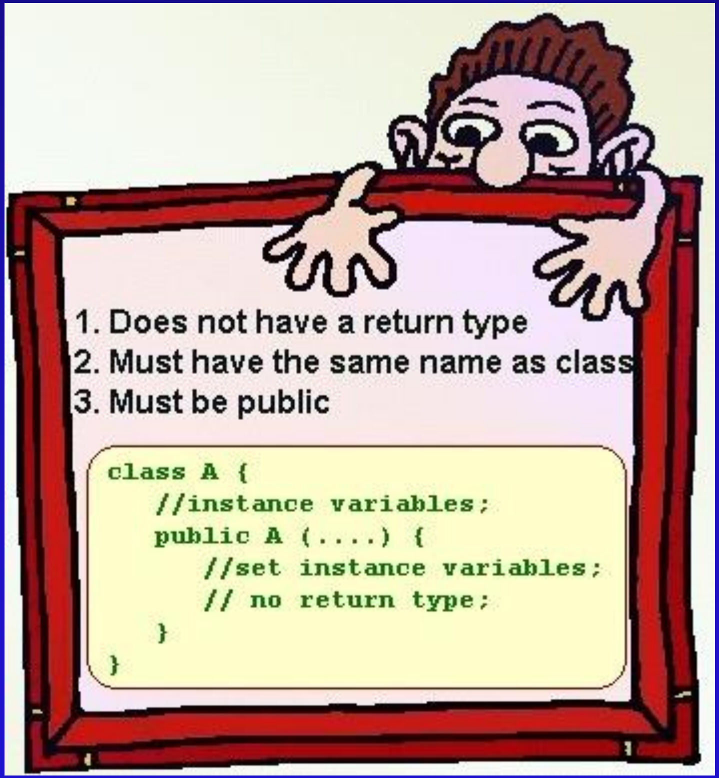


```
Student s1 = new Student(123,"Adel");
Student s2 = new Student(345, "Ahmed");

int id = s1.id; //Error
int id = s1.getID(); //ok
```



Constructors

- In addition to instance variables and methods, a class may have one or more constructors.
- Constructors are used to initialize the instance variables of an object at the time of creating the object.
- What is the difference between a constructor and a method?
- A constructor:



1. Does not have a return type
2. Must have the same name as class
3. Must be public

```
class A {
    //instance variables;
    public A (....) {
        //set instance variables;
        // no return type;
    }
}
```

4. Is invoked using the new operator.

The Student Class

```java
public class Student{
  private int id;
  private String name;
  private double gpa;
  public Student(int theID, String theName, double theGPA){
       id = theID;
       name = theName;
       gpa = theGPA;
  }
  public String getName(){
       return name;
  }
  public int getID(){
       return id;
  }
  public double getGPA(){
       return gpa;
  }
}
```

Must be stored in a file called: **Student.java**

The TestStudent Class

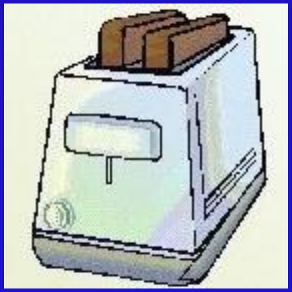
```
public class TestStudent{
    public static void main(String[] args){
        Student  student =
                   new Student(999999, “Ahmad Muhammad”, 3.2);
        System.out.println(“Name: ” + student.getName());
        System.out.println(“ID#: ” + student.getID());
        System.out.println(“GPA: ” +student.getGPA());
    }
}
```

- Note: Two or more classes may be placed in a single Java file. In that case:
  - Only one class can be public; namely the class containing the main method.
  - The name of the Java file must be that of the public class.

Exercises

- What is the difference between a constructor and a method?
- What are constructors used for? How are they defined?
- Think about representing an alarm clock as a software object. Then list some characteristics of this object in terms of states and behavior. Draw the class in UML diagram.

- Repeat the previous question for a Toaster Object.



Introduction to Classes II

- Default Constructor
- this Keyword
- Car Example
- Exercises

Default Constructor

- `Question`: What happens if a constructor is not defined in a class?
- `Answer`: A default constructor is created automatically.

- A default constructor:
  - Has no parameter
  - Initializes instance variables with default values
  - Is not provided if a constructor is already defined

```
class Student{
   private int id;
   private String name;
   private double gpa;

   // no constructor defined

   public String getName(){
    return name;
   }
 }
```

Instance variable of type:	default value
boolean	false
byte	(byte) 0
short	(short) 0
int	0
long	0L
float	0F
double	0D
char	\u0000
object reference	null

Overloading Constructors

- Java allows more than one Constructor
- Problem: All constructors will have the same name!
- Solution: Overloading
- Each constructor will have different parameters

```
class Student{
   private  int id;
   private String name;
   private double gpa;
    public Student(int theID, String theName, double theGPA){
            id = theID;
            name = theName;
           gpa = theGPA;
      }
     public Student(int theID, String theName){
            id = theID;
            name = theName;
           // gpa is initialized to 0.0
      }

         // . . .
}
```

this Keyword

- Reference to the current object
- Two usages of this keyword:

1. To refer to the fields and methods of this object
   Purpose: resolve conflict in naming.
2. From a constructor of a lass call another constructor of the same class.

```
class Student{
   private  int id;
   private String name;
   private double gpa;
    public Student(int id, String name, double gpa){
            this.id = id;
            this.name = name;
           this.gpa = gpa;
      }
     public Student(int id, String name){
            this(id, name, 0.0);
      }

          // . . .
}
```

Example: Car Class

- Suppose we want to design a class that calculates the fuel consumption of a car in kilometers per liter.
- This calculation is possible if we know three things:

  1. The initial reading of the odometer
  2. The final reading of the odometer
  3. The number of liters used.

Knowing these information items,

the consumption (in km per liters) =
(finalOdometerReading - initialOdometerReading)/litersUsed

Car class (cont'd)

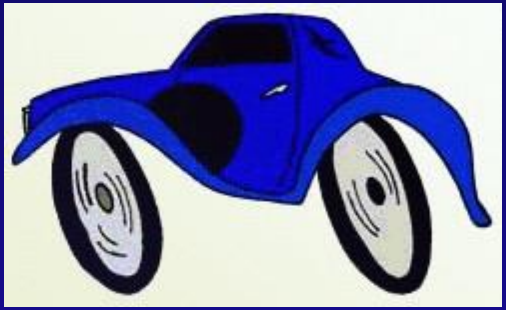
```
class Car{
         int initialOdometerReading, finalOdometerReading;
        double litersUsed;
        public Car(int initReading, int finalReading, double liters){
                  initialOdometerReading = initReading;
                 finalOdometerReading = finalReading;
                 litersUsed = liters;
        }
        public Car(int finalReading, double liters){  //used to create new car objects
                 finalOdometerReading = finalReading;
                 litersUsed = liters;
       }
        public double getKilometersPerLiter(){
                  return (finalOdometerReading – initialOdometerReading) / litersUsed; // assumes litersUsed is not
zero
        }}
```

Car class: Test program

```
public class TestCar{

     public static void main( String[ ] args){
          Car car1 = new Car( 32456, 32776,  40.0);

          System.out.println("Fuel consumption for car1 is " +  car1. getKilometersPerLiter( ) + " km/liter");

         Car car2 = new Car( 365,  30.0);

          System.out.println("Fuel consumption for car2 is " +  car2. getKilometersPerLiter( ) + " km/liter");


}
```

Exercises

1. Add a boolean method called `isEconomyCar` to the Car class. This method will return true if the fuel consumption is less that 5 kilometers per liter.



2. Add a boolean method called `isFuelGuttler` to the Car class.

3. This method will return true if the fuel consumption is more that 15 KM/Liter

4. Implement a class **Product.** A product has a name and a price. Supply methods printProduct( ) , getPrice( ) , and setPrice().

5. Write **a** test program that makes two products, prints them, reduces their prices by 5 Naira, and then prints them again.

6. Implement a class Circle that has methods getArea ( ) and getCircumference (). In the constructor, supply the radius of the circle.

Selection

Outline

- Relational Operators
- Boolean Operators
- Truth Tables
- Precedence Table
- Selection and Algorithms
- The if -else statement
- Variations of if-else statement
- The switch statement

Relational Operators

- In addition to arithmetic operators which produce numeric results, relational operators are used in comparisons.

Operator	Meaning
==	equal
!=	not equal
>	greater than
>=	greater than or equal
<	less than
<=	less than or equal

- The result of a comparison is Boolean (i.e., true or false)

- Example: `x == Math.sqrt(y);`

Boolean Operators

- Connecting relational expressions requires another set of operators called boolean operators:

Operator	Meaning
&&	logical and
||	logical or
!	negation

- Examples:
  - `grade >= 0 && grade <= 100.0`
  - `ch == ‘q’ || ch == ‘Q’`

Truth Tables

- Let p and q be Boolean or relational expressions
  - Truth table for negation:

p	! p
true	false
false	true

  - Truth table for logical and:

p	q	p && q
true	true	true
true	false	false
false	true	false
false	false	false

  - Truth table for logical or:

p	q	p | | q
true	true	true
true	false	true
false	true	true
false	false	false

Precedence Table

Operator Type	Code
postfix	*expr*++ *expr*--
unary	++*expr* --*expr* +*expr* -*expr* !
creation or cast	new (*type*)*expr*
Multiplicative	* / %
Additive	+ -
relational	< > <= >=
equality	== !=
Logical AND	&&
Logical OR	||
assignment	= += -= *= /= %=

Highest precedence

Lowest precedence

Statements

- Statements can be simple or compound.
- A number of statements can be grouped together to form one compound statement by enclosing these statements in curly brackets { }

Selection and Algorithms

- We have seen that flow control is divided into three types:
  - Sequential
  - Selection
  - Iteration

- In Selection, we select one alternative based on a criterion (condition)

Selection and Algorithms (cont'd)

- Assume that we want to find the status of a student given his GPA.
- Algorithm:

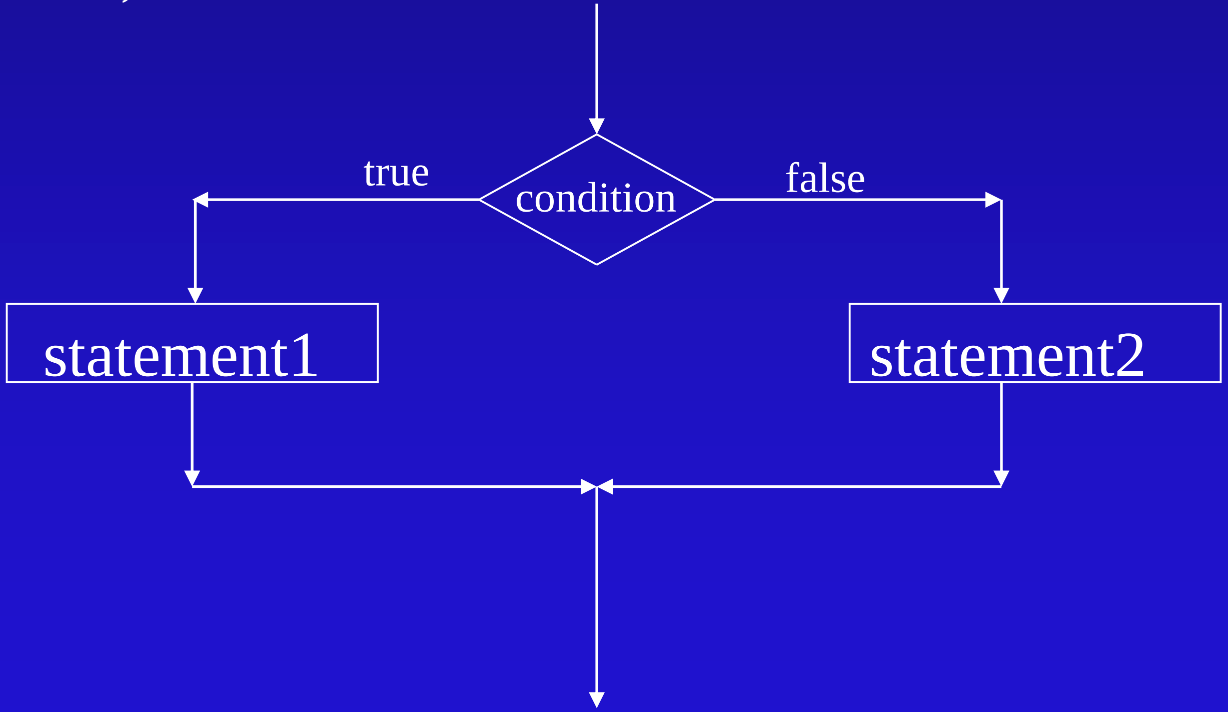
```
» Get GPA
» if GPA >= 2
      status = "good standing"
» else
      status="under probation"
```

The if–else statement

- The general structure is:

```
if(condition)
  statement1
else
  statement2
```

- The condition is evaluated first; statement1 is executed if result is true otherwise statement2 is executed.



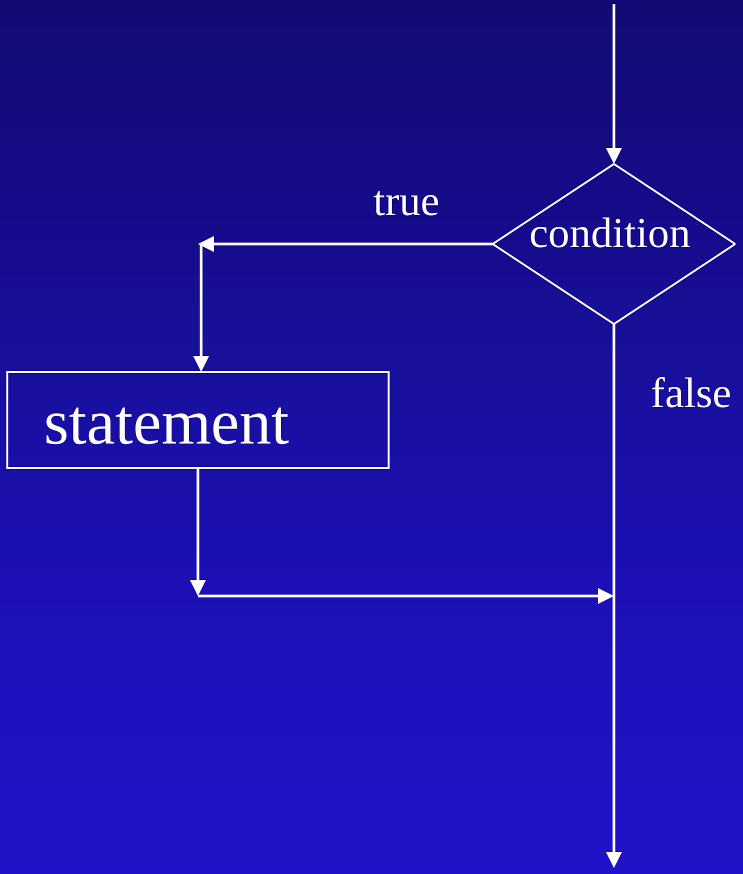
Example

```
public String getStatus( )
{
     String status;
     if(gpa >= 2)
       status = "good standing";
     else
      status = "under probation";
     return status;
}
```

Variation of if-else statement: if-statement

- The else part in the if may be omitted if nothing needs to be done when the condition is false.
- In such cases, the general structure is:

```
    if(condition)
      statement
```



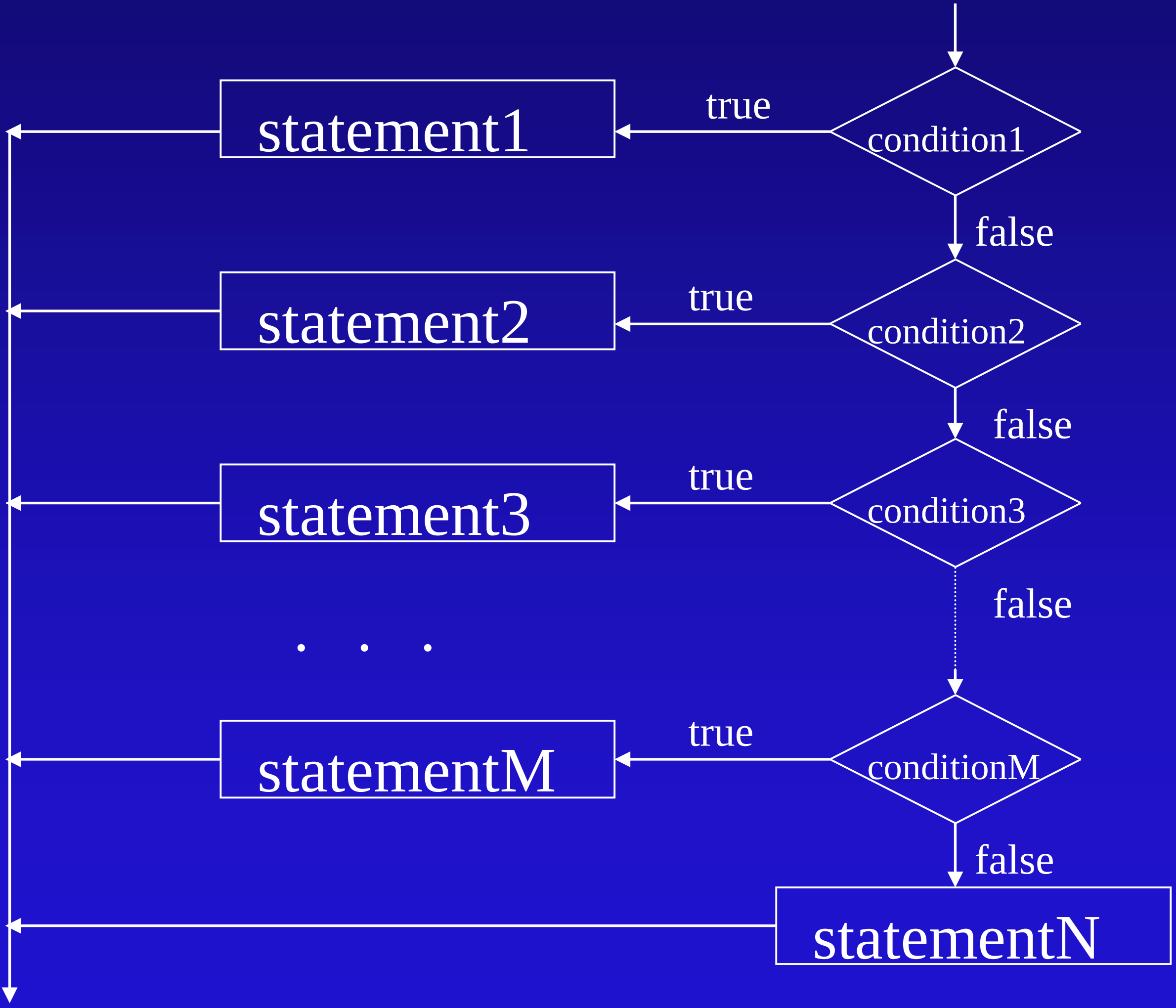
- Example:Finding the maximum of three numbers:

```
max = num1;
if(num2 > max)
  max = num2;

if(num3 > max)
  max = num3;
```

Variation of if-else Statement: Nested if statement

- The else part of an if-else statement may contain another if-statement to provide multiple selection
- The general structure is:

```
if(condition1)
  statement1
else if(condition2)
  statement2
 ...
else
  statementN
```



- Note: The else part may be missing.

Example: Convert a Day Code to a Day Name

```
import java.io.*;
class DayOfWeek1 {
   public static void main(String[] args) throws IOException {
      BufferedReader stdin = new BufferedReader( new InputStreamReader(System.in));
      System.out.print("Enter a number [1 .. 7]: ");
      String input = stdin.readLine();
      int dayNumber = Integer.parseInt(input);
      if(dayNumber == 1)
         System.out.println("Saturday");
      else if(dayNumber == 2)
         System.out.println("Sunday");
      else if(dayNumber == 3)
          System.out.println("Monday");
      else if(dayNumber == 4)
         System.out.println("Tuesday");
      else if(dayNumber == 5)
         System.out.println("Wednesday");
      else if(dayNumber == 6)
         System.out.println("Thursday");
      else if(dayNumber == 7)
         System.out.println("Friday");
      else
         System.out.println("Wrong input");
  }}
```

The switch statement

- When selecting among many alternatives, the switch statement may be used.
- The general structure is:

```
switch(controllingExpression)
{
  case value1 :    Statements;
                   break;
  case value2 :    Statements;
                   break;
  ...
  default :        Statements;
}
```

- The controllingExpression must have a byte, char, short, or int value.
- A case label value must be a unique constant value or a constant expression of type byte, char, short, or int.
- The statements of the case label that equals the value of the controllingExpression are executed; otherwise if there is no matching case label, the statements of the default label, if present, are executed.

Example

```
import java.io.*;
class DayOfWeek2 {
   public static void main(String[] args) throws IOException {
      BufferedReader stdin = new BufferedReader(new
                  InputStreamReader(System.in));
      System.out.print("Enter a number [1 .. 7]: ");
      String input=stdin.readLine();
      int dayNumber=Integer.parseInt(input);
      switch(dayNumber){
       case 1:  System.out.println("Saturday"); break;
         case 2:  System.out.println("Sunday");    break;
         case 3:  System.out.println("Monday");    break;
         case 4:  System.out.println("Tuesday");   break;
         case 5:  System.out.println("Wednesday"); break;
         case 6:  System.out.println("Thursday");  break;
         case 7:  System.out.println("Friday");    break;
        default: System.out.println("Wrong input");
      }
  }}
```

Example: Classifying a character

```
➢ // . . .
  System.out.println("Enter a character: ");
  char ch = (stdin.readLine()).charAt(0);
  if(! Character.isLetter(ch))
    System.out.println(ch + " IS NOT A LETTER");
  else{
    switch(ch){
      case 'a': case 'A':
      case 'e': case 'E':
      case 'i': case 'I':
      case 'o': case 'O':
      case 'u': case 'U': System.out.println(ch + " IS A VOWEL");
                          break;
      default: System.out.println(ch + " IS A CONSONANT");
    }
  }
 // . . .
```

➢ Note: **Character** is a wrapper class for the primitive type **char**. It contains several methods to process characters. It is defined in java.lang package

Outline

- Iteration and Algorithms
- The while loop
- The for loop
- The do while loop

Iteration and Algorithms

- We have seen that flow control has three types:
  - Sequential
  - Selection
  - Iteration

- In the third control, a statement/statements will be executed repeatedly, a number of times, based on a criterion (condition)

Iteration and Algorithms

- Assume that we want to find the sum of numbers from 1 to n

- Algorithm

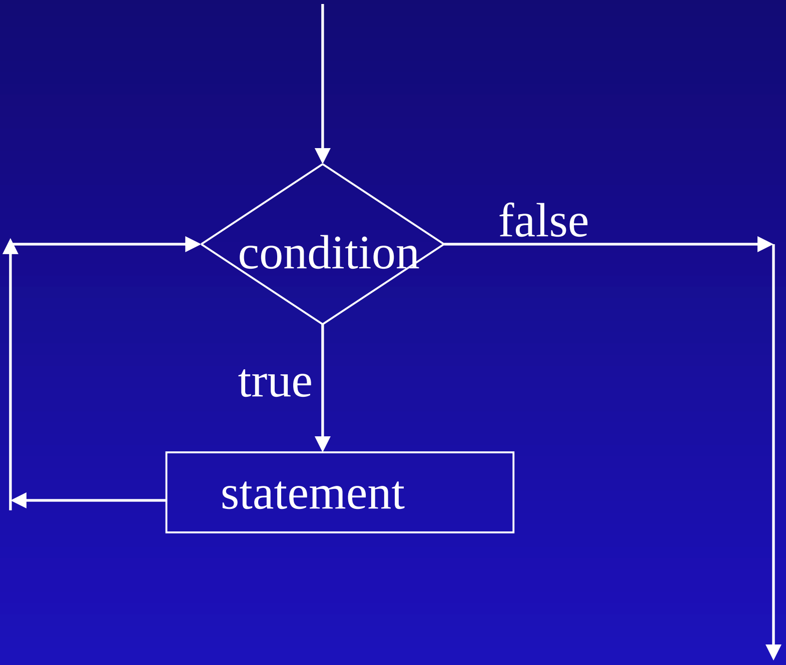
```
sum = 0
index = 1
while index <= n
    sum = sum + index
    index = index + 1
```

The while loop

- This loop is a precondition loop or 0-trip loop.
- The general structure is

```
while (condition)
    statement
```

- The condition is evaluated first.
- Statement is executed if condition is true.
- The condition is evaluated again and again until it evaluates to false.



Example

```
public static int sum1toN(int n){
   int sum = 0, index = 1;
   while ( index <= n )
       {
               sum += index;
               index++;
       }
   return sum;
}
```

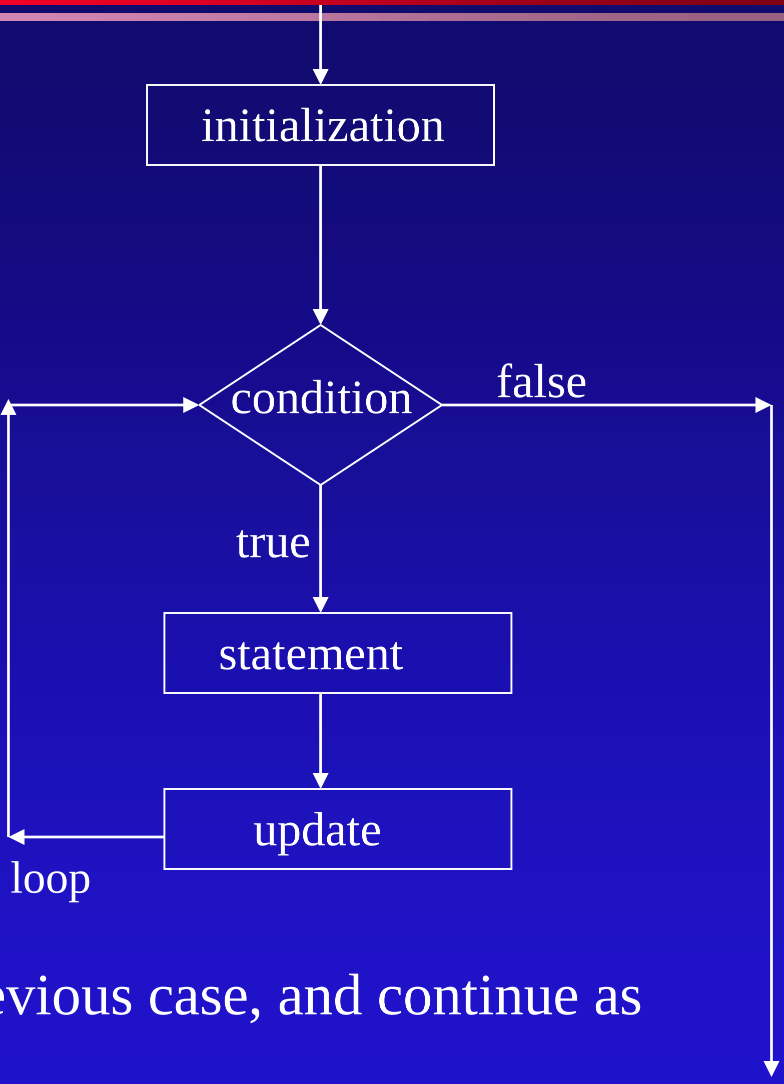
- Notes: when using the while loop notice the following:
  - use braces if more than one statement to be repeated
  - initialize the variable used in the condition before the loop
  - update the variable inside the loop

The for loop

- This loop is precondition loop or 0-trip loop.
- The general structure is

  for (initialization; condition; update)
      statement

- First the initialization is executed once.
- The condition is evaluated next.
  - if the condition is true then
    - execute statement
    - execute update
  - if condition is false then
    - continue execution at the statement following the for loop
- Evaluate condition again, if it was true in the previous case, and continue as in the step above



Example

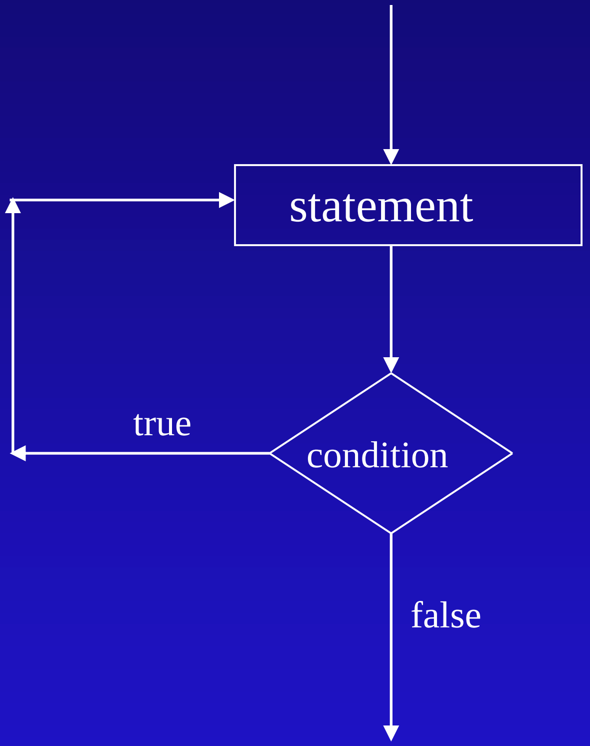
```
public static int sum1toN(int n){
   int sum = 0, index = 1;
   for ( index = 1; index <= n; index++)
        sum += index;
   return sum;
}
```

The do while loop

- This loop is post condition loop or 1-trip loop.
- The general structure is

```
do
   statement
while (condition);
```

- The statement is executed first.
- The condition is evaluated next.
  - If the condition is true, the statement is executed again and again until it evaluates to false.



Example

```
public static int sum1toN(int n){
  int sum = 0, index = 1;
  do
  {
      sum += index;
      index++;
  }while ( index <= n );
  return sum;
}
```

Nested Loops

- Loops can be nested and will be executed such that for every iteration of the outer loop, all the iterations of the inner loop.
- The inner loop must be completely inside the outer loop.
- Loop indexes must be different.

Example

```
public static void multiplicationTable(int n){
   int row, col;
   for (row = 1; row <= n; row++)
   {
        for (col =1; col <= n; col++)
                System.out.print(row*col + "\t");
        System.out.println( );
   }
}
```

String Tokenization

- What is String Tokenization?
- The StringTokenizer class
- Examples

What is String Tokenization?

- So far we have been reading our input one value at a time.
- Sometimes it is more natural to read a group of input at a time.
- For example, when reading records of students from a text file, it is natural to read a whole record at a time.

```
     "995432 Al-Suhaim Adil   3.5"
```

- The nextLine() method of the Scanner class can read a group of input as a single String object.
- The problem is, how do we break this string object into individual words known as *tokens*?

```
 "995432"
"Al-Suhaim Adil"
"3.5"
```

- This process is what String tokenization is about.

The StringTokenizer Class

- The StringTokenizer class, of the java.util package, is used to break a String object into individual tokens.
- It has the following constructors:

Constructor	function
`StringTokenizer(String str)`	Creates a StringTokenizer object that uses white space characters as delimiters.
`StringTokenizer(String str, String delimiters)`	Creates a StringTokenizer object that uses the characters in *delimiters* as separators.
`StringTokenizer(String str,String delimiters,boolean returnTokens)`	Creates a StringTokenizer object that uses characters in *delimiters* as separators and treats separators as tokens.

StringTokenizer Methods

- The following are the main methods of the StringTokenizer class:

Method	**function**
`String nextToken() throws NoSuchElementException`	Returns the next token as a string from this StringTokenizer object. Throws an exception if there are no more tokens.
`int  countTokens()`	Returns the count of tokens in this StringTokenizer object that are not yet processed by *nextToken()* -- initially all.
`boolean  hasMoreTokens()`	Returns true if there are more tokens not yet processed by *nextToken()*.

How to apply the methods

- To break a string into tokens, first, a StringTokenizer object is created.

```
String myString = "I like Java very much";
 StringTokenizer  tokenizer  =  new StringTokenizer(myString);
```

- Then any of the following loops can be used to process the tokens:

```
while(tokenizer.hasMoreTokens()){
   String token = tokenizer.nextToken();
   // process token
 }
```

or

```
int tokenCount = tokenizer.countTokens();
 for(int k = 1; k <= tokenCount; k++){
   String token = tokenizer.nextToken();
   // process token
 }
```

Example 1

- The following program reads grades from the keyboard and finds the average. The grades are read in one line.

```
import java.util.Scanner;
import java.util.StringTokenizer;
public class TokenizerExample1{
  public static void main(String[] args)throws IOException{
     Scanner input = new Scanner(System.in);
     System.out.print("Enter grades in one line:");
     String inputLine = input.nextLine();
     StringTokenizer tokenizer = new StringTokenizer(inputLine);
     int count = tokenizer.countTokens();
     double sum = 0;
     while(tokenizer.hasMoreTokens())
        sum += Double.parseDouble(tokenizer.nextToken());
     System.out.println("\nThe average = "+ sum / count);
  }
}
```

Example 2

- This example shows how to use the second constructor of StringTokenizer class.
- It tokenizes the words in a string, such that the punctuation characters following the words are not appended to the resulting tokens.

```
import java.util.StringTokenizer;
public class TokenizerExample2{
  public static void main(String[] args){
    String inputLine =
       "Hi there, do you like Java? I do;very much.";
    StringTokenizer tokenizer =
       new StringTokenizer (inputLine, ",.?;:! \t\r\n");
    while(tokenizer.hasMoreTokens())
       System.out.println(tokenizer.nextToken());
   }
}
```

Output:

```
Hi
there
do
you
like
Java
I
do
very
much
```

Example 3

- This example shows how to use the third constructor of StringTokenizer class.
- It tokenizes an arithmetic expression based on the operators and returns both the operands and the operators as tokens.

```
import java.util.StringTokenizer;
public class TokenizerExample3{
  public static void main(String[] args){
     String inputLine = "(2+5)/(10-1)";
     StringTokenizer tokenizer = new
          StringTokenizer(inputLine,"+—*/()",true);
      while(tokenizer.hasMoreTokens())
         System.out.println(tokenizer.nextToken());
   }
}
```

Output:

```
(
2
+
5
)
/
10
-
1
)
```

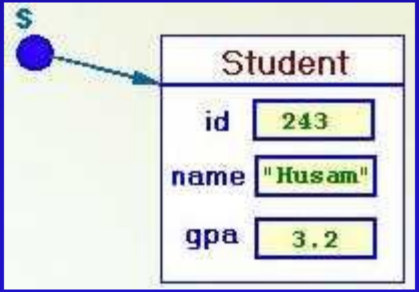
Introduction to Methods

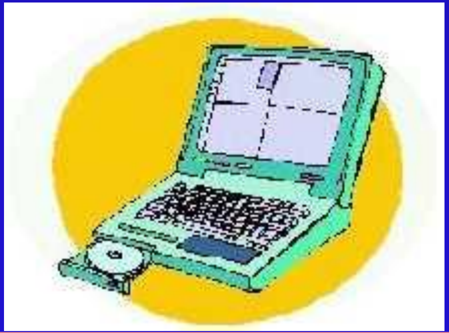
- ➢ Method Calls
- ➢ Parameters
- ➢ Return Type
- ➢ Method Overloading
- ➢ Accessor & Mutator Methods
- ➢ Student Class: Revisited

Method Calls

- The set of methods defined for an object determines the behavior of that object.
- For example, for an object of Student class; methods: getID, setGPA, and getName will make the behavior of this object known to us.
- After creating an object from a class, a series of methods are called to accomplish some tasks.
- The following code creates a Student object, then it increments the GPA of this student by 0.1:

```
Student s = new Student(243, "Husam" , 3.1);
double  gpa = s.getGPA();
s.setGPA(gpa + 0.1) ;
```





Methods: Syntax & Naming

- Syntax

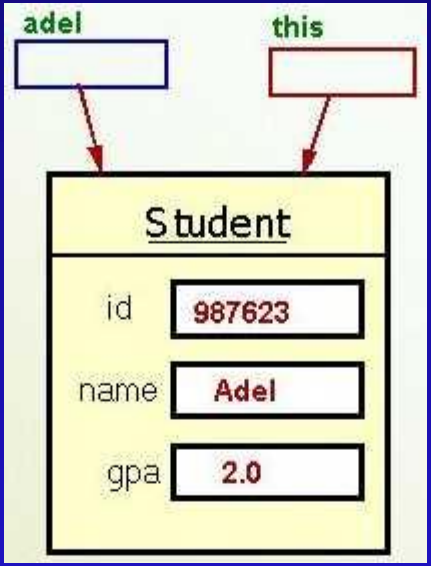
```
modifier returnType methodName(paraType p1,..){
        statement1;
        statement2;
          …
         statementn;
         return expression;
}
```

Example

```
public double calculateAverage(int n1, int n2){
   double average = (n1+ n2) / 2.0;
   return average;
  }
}
```

Parameters

```
//main method
Student adel  = new Student(987623," Adel", 1.9);
double increment = 0.1;
adel.setGPA(adel.getGPA()+ increment);
```



- Actual parameter: Constant, variable or expression in method call.
- Example: 2.0 and adel (implicit actual parameter).

```
 //method in Student Class
 public void setGPA(double gpa){
   this.gpa = gpa;
 }
```

- Formal parameter: Variable in the method definition
- Example: grade and this (implicit formal parameter).

Self-check Exercise

- What is the difference between actual parameters and formal parameters?
- What are the problems in the following two program segments of method headers and method calls?

```
// method call
double a = 1.5;
int b = 4;
objectReference.methodA(a, b);
// method header
public void methodA(int n, double x) {.....}
```

```
// method call
double a = 1.5;
int b = 4, c = 2;
objectReference.methodB(a, b, c);
// method header
public void methodB(double x,int n) {.....}
```

- Can we pass an Object reference as an actual parameter?

Return Type

- The return type indicates the type of value the method returns – a primitive type or object reference.

- If no value or reference is returned by a method, the return type is specified as void.

```
public double getGPA(){
   return gpa;
}
public void setGPA(double newGPA){
   gpa = newGPA;
}
```

- A Java method cannot return more than one value.

Method Overloading

- Methods can be overloaded.
- Overloaded methods:
  - Two or more methods of the same class with the same name but different signatures.
  - The return type of a method is not counted as part of its signature .
- Formal parameters of overloaded constructors and methods must NOT have the same type, order, and count.
- Example: Valid overloading:

```
public  double  compute(int num, int  num2){.    .    .}
public  double  compute(int num, double  num2){.    .    .}
public  double  compute(int num) {.    .    .}
```

- Example: Invalid overloading:

```
public double compute(int num) { . . . }
public int compute(int num) { . . .  }
```

Accessor Methods

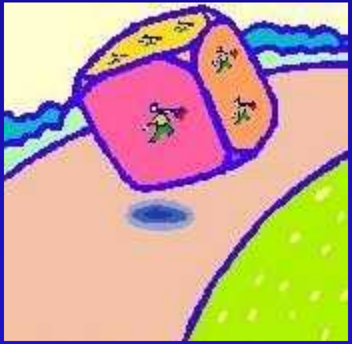
- Encapsulation: Data + Methods to operate on the data.
- Only methods of the same class can directly access its private instance variables.
- A public method that returns the private value of an instance variable of an object is called an accessor method.

```
public class Student{
   private int id;
   private String name;
   private double;
   public String getName(){
     return name;
   }
   public int getID(){
      return id;
   }
   public double getGPA(){
      return gpa;
    }
}
```

Mutator Methods

- A method that changes the value of some instance variable is called a mutator method.

```
public class Student{
  private int id;
  private String name;
  private double gpa;
  // . . .
  public void setGPA(double newGPA){
      gpa = newGPA;
  }
  // . . .
}
```



- Classes that do not have any mutator methods are called immutable classes. (Example: String class).

Student class

```
public class Student{
 private int id;
 private String name;
 private double gpa;
 public Student(int id String
   name, double gpa){
   this.id = id;
   this.name = name;
   this.gpa = gpa;
 }
 public Student(int id, String
   name){
  this(id, name, 0.0);
}
```

```
  public String getName(){
    return name;
  }

  public int getID(){
    return id;
  }
  public double getGPA(){
   return gpa;
  }
  public void setGPA(double
    newGPA){
    gpa = newGPA;
  }
}
```

Exercises

- Write a test program for the Student class. Create two students. Test all accessor and mutator methods.

- Add another constructor to the Student class such that it will take only the name as argument. The ID will be set to 000 and GPA to 0.0

- Add a method called evaluate(gpa). This method will return strings "honor". "good standing" or "under probation" according to the value of gpa.

Introduction to Methods

- Type of Variables
- Static variables
- Static & Instance Methods
- The toString
- equals methods
- Memory Model
- Parameter Passing

Types of Variables

- There are four types of variables in Java:

variable	declaration	scope	life-time	comment
instance variable	Outside all methods, not proceeded by keyword static	Throughout the class definition	Throughout the object life	Property of each object
static or class variable	Outside all methods, proceeded by keyword static. Example: public static int numberOfCircles;	Throughout the class definition	Throughout the program life	Property of the class. All objects of this class share one copy of the variable.
local variable	Within a method body	Throughout its method	Whenever its method is invoked	Property of each object
formal parameter	In a method or constructor header	Throughout its constructor or method	Whenever its method is invoked	Property of each object

Note: Unnecessary use of static variables should be avoided.

Type of Variables (cont’d)

static variable

instance variable

formal parameter

formal parameter

local variable

```
public class Circle{
   private static int numberOfCircles;
   private double radius;

   public Circle(double theRadius){
     radius = theRadius;
     numberOfCircles++;
    }

    public void setRadius(double newRadius){
       radius = newRadius;
    }
    public double getArea(){
      double area = Math.PI * radius * radius;
      return area;
    }
}
```

Static vs. Instance Methods

	static or class method	instance method
Declaration	Proceeded by static keyword. Example: public static double sqrt(double x)	Not proceed by static keyword. Example: public double getGPA()
How to call?	ClassName.methodName(parameters) or objectName.methodName(parameters) Example: Math.sqrt(x)	objectName.methodName(parameters) Example: student1.getGPA()
What can be accessed?	Can access constants and static variables; but cannot access instance variables.	Can access constants, static variables, and instance variables.
What can be referenced?	Cannot refer to the this reference.	Can refer to the this reference
When to use?	Implement a task that is not specifically related to an object or that does not need an object.	Implement a particular behavior of an object.

The finalize Method

- A class whose objects need to perform some task when they are no longer referred to and are about to be garbage collected should redefine the finalize method of the Object class:

```
void finalize()
```

Example

```
class Circle{
  private static int numberOfCircles;

  private double radius;

  public Circle(double theRadius){
    radius = theRadius;
    numberOfCircles++;
  }

  public void finalize(){
   numberOfCircles--;
  }

  public static int getCount(){
    return numberOfCircles;
  }
}
```

```
public class StaticTest{
 public static void main(String[] args){
   System.out.println(Circle.getCount());
   Circle circle1 = new Circle(4.0);
   Circle circle2 = new Circle(2.5);
   System.out.println(circle2.getCount());
   circle1 = null;
  /* Request the garbage collector to
     perform a garbage-collection pass */
   System.gc();
   System.out.println(Circle.getCount());
 }
}
```

Output:

```
0
2
1
```

toString Method

- Prints the content of an object.
- It is recommended to add `toString()` method when designing a new class.
- When `toString()` is provided it is automatically invoked when object name is used where string is expected (print, concatenation)
- When `toString()` is NOT provided, `toString()` of standard Object class is used, with the following format:

  `ClassName@memoryLocation`
- Example:

```
class Student{
      private int id;
     private String name;
     private double gpa;
     // . . .
     public String toString(){
        return "Name: " + name + ", ID: " + id + ", GPA: " + gpa;
     }

  }
```

```
Student student = new Student(123, "Ahmad", 3.5);
System.out.println(student);
Output:
Name: Ahmad, ID: 123, GPA: 3.5
```

equals Method

- Compares between the contents of two objects.
- Operator == compares *only references* of two objects.
- It is important to provide equals method when designing a class.
- When this method is not provided the equals method of standard Object class is used (compares only the references)
- Example:

```
class Student{
  private int id;
  private String name;
  private double gpa;
 public Student(int id, String name,
  double gpa){
     this.id = id;
     this.name = name;
     this.gpa = gpa;
  }

 public boolean equals(Student student){
    return this.id == student.id ;
   }
}
```

```
public class TestStudent{
  public static void main(String[] args){
    Student s = new Student(123,"Ahmed",3.2);
    Student x = new Student(123,"Ahmed",3.2);
    Student y = new Student(456, "Yusuf", 2.0);
    System.out.println(s.equals(x));
    System.out.println(s == x);
    System.out.println(x.equals(y));
}
```

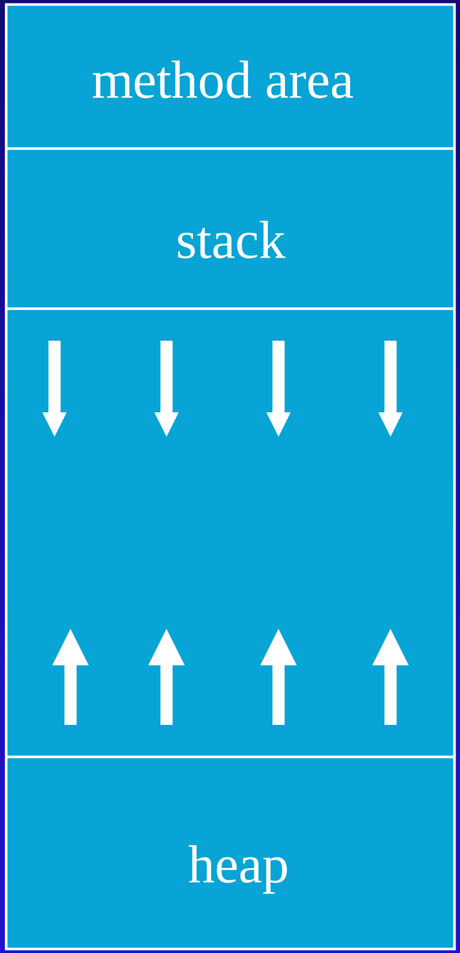
Output:

```
true
false
false
```

Memory Model of JVM

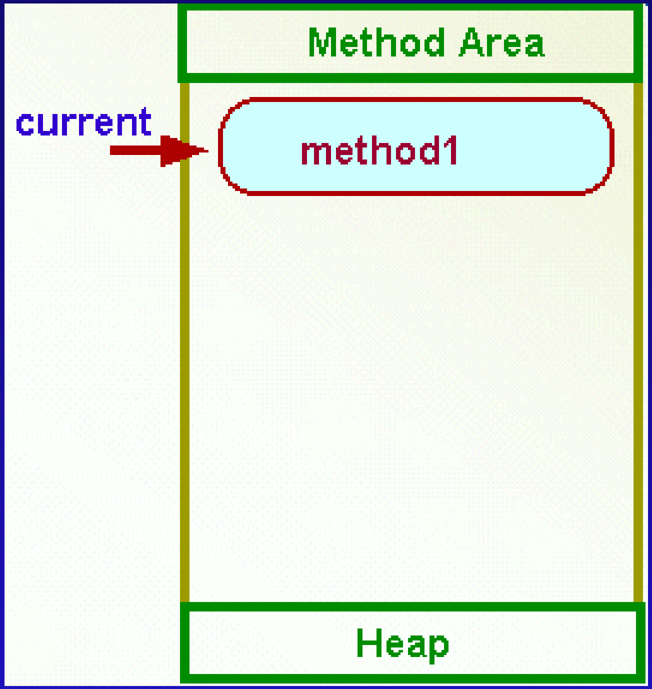
- To execute a Java program:
  - first compile it into bytecode,
  - then invoke the JVM which loads and executes it.

- JVM divides the memory into three main areas:
  - Method Area:
    - The bytecode for each method in the class
    - The class variables (static variables)
    - Class information - modifies, etc
    - Methods' information - modifies, return type, etc
  - Heap:
    - Memory allocation for object instance variables
    - Reference to Method Area containing class data
  - Stack:
    - Keeps track of the order from one method call to another



Stack

```
class A{
 void method1(){
   method2();
 }
 void method2(){
   method3();
   method4 ();
 }
 void method3(){
   statements ;
 )
 void method4()
   statements ;
 }
}
```



- Activation Record:
  - local variables and parameters
  - reference to objects created by the method
  - return address and return value of the method

Parameter Passing

- Actual parameters of a method call may contain:
  - Simple or primitive data types (int, double, etc.)
  - Object References.

- In case of simple data type:
  - The value is copied in corresponding formal parameters.
  - Thus, changing the value in the method will not affect the original value.

- In case of object reference:
  - Another reference is created which points to the same object.
  - This other reference may be used to change the values of the object.

Parameter Passing Example

```
public class StudentTest{
  static int i = 10;
  public static void main(String[] args) {
   String str = "First Message";
   Student s1 =new Student(123, "Khalid" ,1.3);
   Student s2=new Student(456, "Amr", 3.1);
   System.out.println("i = " + i);
   System.out.println("str = " + str);
   System.out.println("Student1: " + s1);
   System.out.println("Student2: " + s2);
   mixUp(i, str, s1, s2);
   System.out.println("i = " + i);
   System.out.println("str = " + str);
   System.out.println("Student1: " + s1);
   System.out.println("Student2: " + s2);
  }
  static void mixUp(int i, String str, Student
   i++;
   str =  "Second Message";
   one = two;
   one.setGPA(3.4);  one. setName("Ali");
   }
}
```

Output:

```
i = 10
str = First Message
Student1: Name: Khalid, ID: 123, GPA: 1.3
Student2: Name: Amr, ID: 456, GPA: 3.1
i = 10
str = First Message
Student1: Name: Khalid, ID: 123, GPA: 1.3
Student2: Name: Ali, ID: 456, GPA: 3.4
```

One-Dimensional Arrays

- What are and Why 1-D arrays?
- 1-D Array Declaration
- Accessing elements of a 1-D Array
- Initializer List
- Passing Array as a parameter
- What if size is unknown?
- Array as return type to methods
- Array of Objects

What are and Why 1D-arrays?

- Some applications require several values in the memory at the same time.
- For example: counting the number of students whose grades are above the *average* in a class of 30
- This involves scanning through the grades two times:
  - First to compute the *average* and second, to count those above average
- How can we scan through 30 grades two times?

1. Declare 30 variables to store the grades – inconvenient

```
double grade1 = Double.parseDouble(stdin.readLine());
double grade2 = Double.parseDouble(stdin.readLine());
.   .   .
double grade30 = Double.parseDouble(stdin.readLine());
double average = (grade1 + grade2 + . . . + grade30) / 30;
int count = 0;
if(grade1 > average) count++;
if(grade2 > average) count++;
. . .
if(grade30 > average) count++;
```

What are and Why 1D-arrays? (cont’d)

2. Use a loop to find the average and ask the user to re-type the values or re-read them from a file for
the second scan --inconvenient

```
 double grade, average, sum = 0;
for(int i = 1; i <= 30; i++){
  grade = Double.parseDouble(stdin.readLine());
  sum += grade;
}
average = sum / 30;
int count = 0;
for(int i = 1; i <= 30; i++){
 grade = Double.parseDouble(stdin.readLine());
 if(grade > average) count++;
}
```

- Is there a better approach? - Yes, this is what 1-D arrays are for.

- An array is a contiguous collection of variables of the same type, referenced using a single variable. The type is called the "base type" of the array.

1-D Array Declaration

- For any type T, T[ ] is a class, whose instances are arrays of type T.
- Thus, the following statement declares a reference variable, *b*, of type T array:

```
T[]  b;
```

- For any positive integer n, the following expression creates a new T[ ] object of size n and stores its reference in *b:*

```
b = new  T[n] ;
```

- As usual, the two expressions can be combined together as:

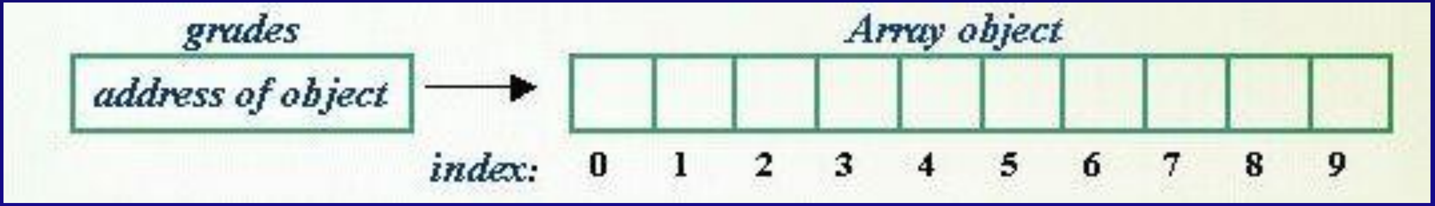
```
T[] b = new T[n] ;
```

- For example, the following declares an *int[]* , *grades*, of size 10:

```
int[] grades = new int[10];
```

1-D Array Declaration (cont'd)

```
int[] grades = new int[10];
```



- The declaration of an array of size n creates n variables of base type.
- These variables are indexed starting from 0 to n-1.
- Each array object has a public instance variable, length, that stores the size of the array.
- Thus, the following statement prints 10, the size of grades:

```
        System.out.println(grades.length);
```

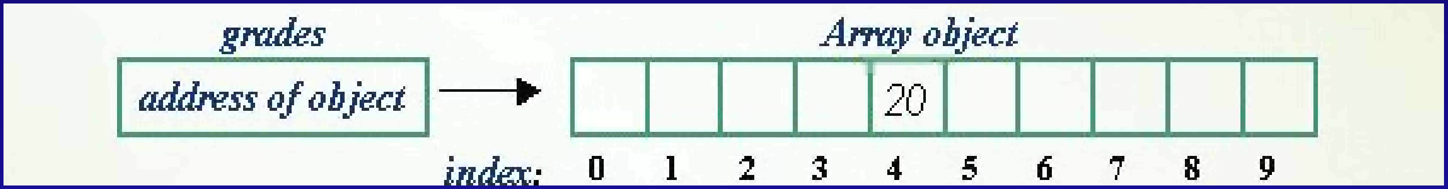
- Other examples of 1D-array declaration are:

```
    double[] price = new double[500];
    boolean[] flag = new boolean[20];
```

Accessing Elements of a 1-D Array

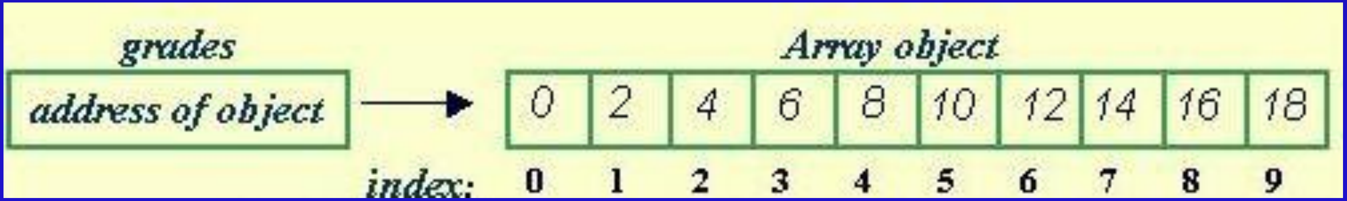
- A particular variable is accessed by indexing the array reference with the index of the variable in bracket:

```
grades[4]   =   20;
```



- The following example, initializes each variable with twice its index:

```
int[] grades = new int[10];
for(int i = 0; i < grades.length; i++)
  grades[i] = 2*i;
```



- The use of *grades.length* makes the code more general.

Accessing Elements of a 1-D Array (Cont'd)

- The following prints the values of the array initialized by the example in the previous slide.

```
for(int i = 0; i < grades.length; i++)
   System.out.print(grades[i] + "  ");
```

- Output:

```
0 2 4 6 8 10 14 16 18
```

- Note: Trying to access an element with an invalid index causes a run-time error:

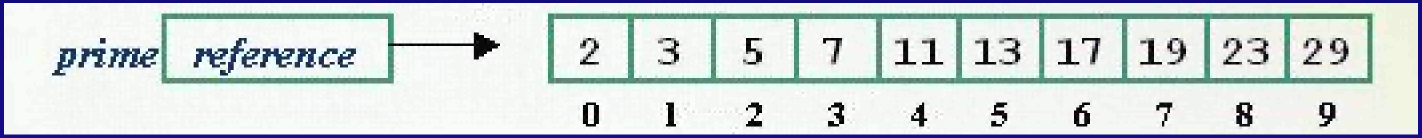
  ArrayIndexOutOfBoundsException:

```
int x = grades[10]; // run-time error
```

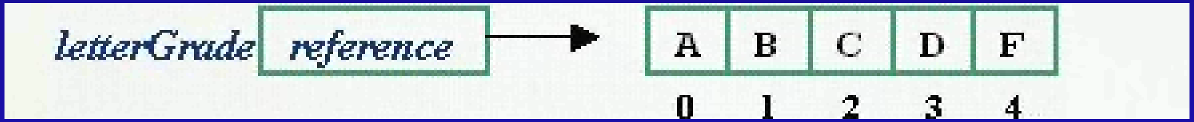
Initializer List

- Initializer list can be used to instantiate and initialize an array in one step:

```
int[]   prime   =   {2,   3,   5,   7,   11,   13,   17,   19,   23,   29};
```



```
char[]   letterGrade   =   {'A',   'B',   'C',   'D',   'F'};
```



- It is actually the compiler that fills the gap. Thus, in the first example, the compiler would add the following:

```
int[]   prime   =   new   int[10];
prime[0]   =   2;   prime[1]   =   3;   ...   prime[9]   =   29;
```

- Observe that when an initializer list is used:
  - The new operator is not required.
  - The size is not required; it is computed by the compiler.

Passing Array as a Parameter

- To make a method accept an array as argument we must specify its type in the parameter list.
- The following method prints the content of an int array passed to it as parameter:

```
public static void printArray(int[] a){
   for(int i = 0; i < a.length; i++)
      System.out.print(a[i]+ “   ");
   System.out.println();
}
```

- A method can change the values of an array passed to it as parameter:

```
public static void doubleArray(int[] a){
   for(int i = 0; i < a.length; i++)
      a[i] = a[i] * 2;
}
```

Passing Array as a Parameter (cont'd)

- It is only the reference to the actual array that is passed.
- Thus, any changes done by a method affect the actual array.
- The following uses the two methods of the last slide:

```
public static void main(String[] args){
    int[] grades = {5, 7, 6, 8, 10};
    System.out.println("Grades before doubling:");
    printArray(grades);
    doubleArray(grades);
    System.out.println("Grades after doubling:");
    printArray(grades);
}
```

- The output is:

```
Grades before doubling:
5    7    6    8    10
Grades after doubling:
10   14   12   16   20
```

What if size is Unknown?

- The size of an array must be specified before it can be created..
- If the actual size is not known, a reasonably large size is specified.
- An extra variable is then used to keep count of the values stored..

```
public static void main(String[] args)throws IOException{
    BufferedReader stdin = new BufferedReader(
                                new InputStreamReader(System.in));
    double[]grade = new double[100];
    int gradeCount = 0;
    System.out.print("EnterNextGrade:");
    double value = Double.parseDouble(stdin.readLine());
    while(value >= 0 && gradeCount < 100){
      grade[gradeCount] = value;
      gradeCount++;
      System.out.print("EnterNextGrade (negative number to terminate):");
      value = Double.parseDouble(stdin.readLine());
    }
    double average = getAverage(grade,gradeCount);
    System.out.println("The average grade is: " + average);
    System.out.println("Grades above average are:");
    printAboveAverage(grade, gradeCount, average);
 }
```

What if size is unknown? (cont’d)

```
public static double getAverage(double[] a, int count){
  if(count == 0) throw new IllegalArgumentException(“zero count”);
  double sum = 0;
  for(int i = 0 ; i < count; i++)
     sum = sum + a[i];
  return sum/count;
}
 public static void printAboveAverage(double [ ] a, int count,
double average){
   for(int i =0 ; i < count; i++)
     if(a[i] > average)
       System. out. println(a[i]);
 }
```

Array as return Type to Methods

- Methods can also have arrays as their return type.
- The following creates two arrays a and b of same size n and print their dot product:

  $a_0b_0 + a_1b_1 + a_2b_2 + \ldots + a_{n-1}b_{n-1}$

```
public static double[] createArray(int size) throws IOException{
   double[] array = new double[size];
   for(int i = 0; i <size; i++){
     System.out.print("Enter element #" + (i+1) + ": ");
     array [i] = Double.parseDouble(stdin.readLine());
   }
   return array;
 }
  public static void main( String [ ] args) throws IOException {
   int size;
   System.out.print("Enter array size: ");
   size = Integer.parseInt(stdin.readLine());
   double[] a = createArray(size);
   double[] b = createArray(size);
   System.out.println ( "The dot product = "+dotProduct(a, b));
 }
```

- The implementation of dotProduct is left as an exercise.

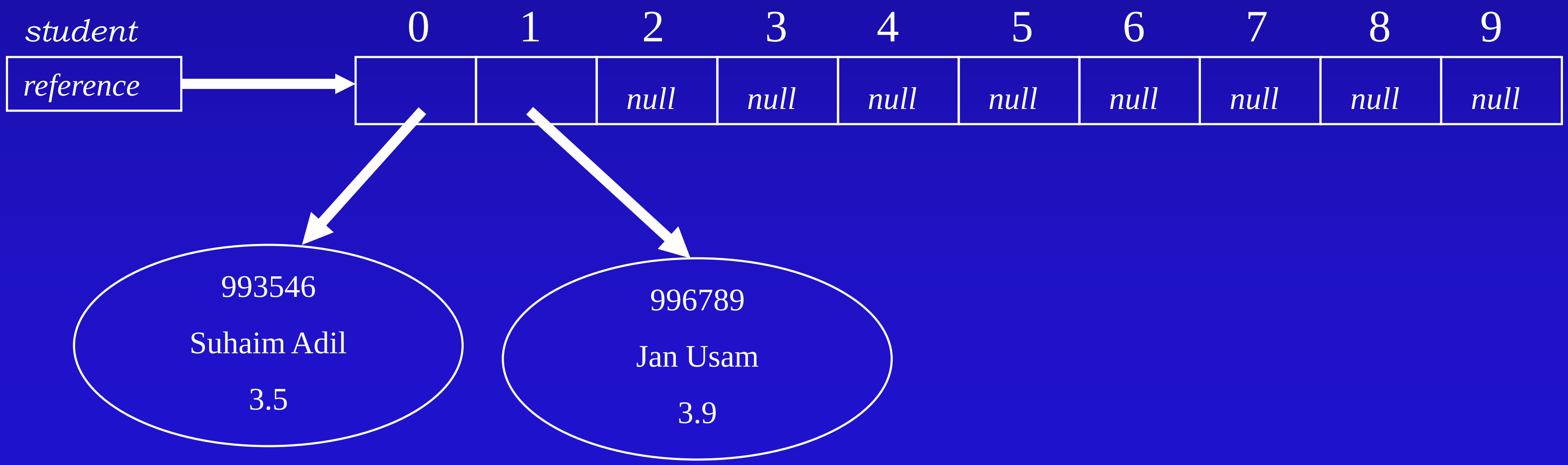
Array of Objects

- So far, our examples have been on arrays of primitive types.
- We can equally create arrays whose elements are objects.
- We can create an array to store 10 Student objects as follows:

```
Student[] student = new Student[10];
```

- However, only the references to the Student objects are stored.
- The figure shows the array after adding two Student objects.

```
student[0] = new Student(993546, "Suhaim Adil", 3.5);
student[1] = new Student(996789, "Jan Usam", 3.9);
```



Array of Objects (cont'd)

- The following method takes size, and returns an array initialized with size Student objects.

```
    public static Student[] createArray(int size) throws IOException{
      Student[] array = new Student[size];
      String name;
      int id;
      double gpa;
      for(int i = 0; i < size; i++){
         System.out.print("ID Number : ");
         id = Integer.parseInt(stdin.readLine());
         System.out.print("Name : ");
         name = stdin.readLine();
         System.out.print("GPA : ");
         gpa = Double.parseDouble(stdin.readLine());
         array[i] = new Student(id, name, gpa);
      }
      return array;
}
```

Array of Objects (cont'd)

- Each array element is treated exactly as a reference to an object.
- For example, to call the getName() method of the object at cell 0:

```
        student[0].getName();
```

- The following takes an array of Students and prints those with GPA>=2.0

```
    public static void printGoodStanding(Student[] student){
        for (int i=Q; i<student.length; i++)
            if(student[i].getGPA() >= 2.0)
                System.out.println(student[i]);
    }
```

- The two methods are called as follows:

```
     public static void main(String[] args) throws lOException {
         int size;
         System.out.print("Enter number of students: ");
         size = Integer.parselnt(stdin.readLine());
         Student[] student = createArray(size);
         printGoodStanding(student);
     }
```

Dynamic Arrays

- Why Dynamic Arrays?
- A Dynamic Array Implementation
- The Vector Class
- Program Example
- Array Versus Vector

Why Dynamic Arrays?

- A problem with arrays is that their size must be fixed at creation.
- Thus, once an array of size n is declared, it cannot be extended to hold more than n elements.
- But the programmer may not know the size required.
- Is there a way out?
- Yes, Java provides the *Vector class* in *the java.util package that* can grow dynamically as needed.
- To understand how it works, we shall implement a similar class.

A Dynamic Array Implementation

- The following defines a class that works like array but whose size can grow dynamically:

```
public class DynamicArray{
    private int[] b;
    private int numberOfElements;
    //Constructor: Creates an array with default size of 10
    public DynamicArray(){
        b = new int[10];
    }
    //Constructor: Creates an array with specified size
    public DynamicArray(int size){
        b = new int[size];
    }
    public int size(){
        return numberOfElements;
    }
    public int capacity(){ // returns total number of cells
        return b.length;     // including unused ones
    }
```

A Dynamic Array Implementation

```
      public int getElement(int i){
          if(i < 0 || i > numberOfElements - 1)
            throw new IllegalArgumentException("index out of Bounds");
          return b[i];
       }
       public void set(int i, int value){
          if(i < 0 || i > numberOfElements)
            throw new IllegalArgumentException("index out of Bounds");
          if(i == numberOfElements && i == b.length){
            // For efficiency purposes, double the array capacity
            int[] newb = new int[2*b.length];
            for(int k = 0; k < numberOfElements; k++)
               newb[k] = b[k];
             b = newb;
          }
          b[i] = value;
          if(i == numberOfElements)
             numberOfElements++;
       }}
```

Our Class Versus Array

- We can create an instance of our DynamicArray class as follows:

```
DynamicArray c = new DynamicArray(20);
```

- c can be viewed as an *int* array of size 20. However, c can store more than 20 integers.

- How we access and modify content of c is also slightly different:
  1. Corresponding to: `b[i]` , we use a function call: `c.getElement(i)`
  2. Corresponding to: `b[i]=value;` , we use a function call: `c.set(i,value);`
  3. Corresponding to: `b.length` , we use a function call: `c.capacity()`

The Vector Class

- *Vector* is similar to our *DynamicArray*, but it has much more.
- It has the following Constructors:

`Vector()`	Creates a vector of size 10, It doubles the capacity when exhausted.
`Vector(int initialCapacity)`	Creates a vector of size initialCapacity, It doubles the capacity when exhausted.
`Vector(int initialCapacity, int increment)`	Creates a vector of size initialCapacity, increases by *increment when* the capacity is exhausted.

- To Create a vector with an initial capacity of 20 elements:

```
Vector v = new Vector(20);
```

Adding an Element

- The base type of our DynamicArray is int What about Vector?
- The base type of Vector is *Object*.
- Thus, primitive types must be wrapped using wrapper classes.
- Elements can be added using the following add method:

`add(Object element)`	Adds element to the next empty cell, increases the capacity if necessary.

- The following adds 10 objects into a vector of initial capacity 4:

```
Vector v = new Vector(4);
for(int i = 0; i < 10; i++)
     v.add(new Integer(i*2));
```

- The capacity is automatically increased to take the 10 objects

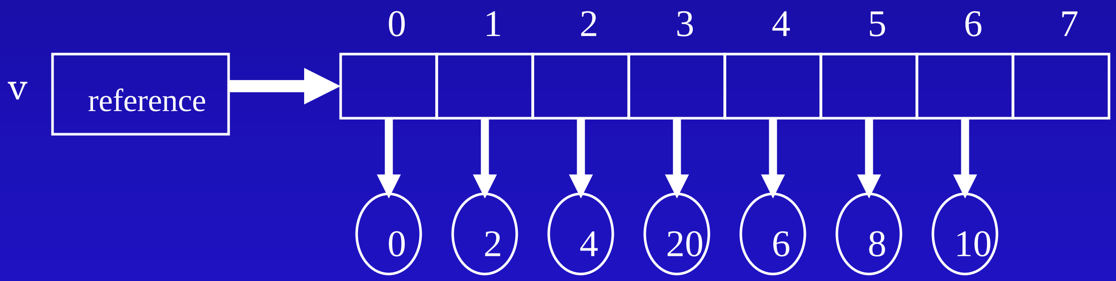
Adding an Element (cont'd)

- The following add method can also be used to add an element:

`add(int index, Object element)`	Adds element at index, shifts element at index and beyond, if any, by 1. Increases capacity if necessary. If index < 0 or index > size, it throws IndexOutOfBoundsException.

- The following adds 6 objects into a vector, it then inserts an Integer object with value of 20 at index 3:

```
Vector v = new Vector(4);
for(int i = 0; i < 6; i++)
     v.add(new Integer(i*2));
 v.add(3, new Integer(20));
```



- Note that this method does not allow an empty cell in-between:

```
v.add(8, new Integer(100)); // Run-time error, cell 7 will be empty
```

Accessing and Changing an Element

- The following method can be used to access an element:

`Object get(int index)`	Returns the element at index. throws IndexOutOfBoundsException if index < 0 or index > size.

- However since the return type is object, we have to cast-down to get the original object.

- The following prints the result of dividing the element at index 3 with 2:

```
      Integer element = (Integer) v.get(3);
      System.out.println(element.intValue() / 2);
```

- To modify an element we use the `set` method:

`Object set(int index, Object element)`	Replaces the object at index with element and returns the replaced object. Throws IndexOutOfBoundsException if index < 0 or index > size.

- The following replaces the element at index 3 with 100:

```
      v.set(3, new Integer(100));
```

Searching for an Element

- To check if an element is in a vector, use the `contains` method:

`boolean contains(Object element)`	Returns true if element is contained in the vector and false otherwise .

- The `contains` method uses the equals method of the vector element in its search.
- The following checks if the vector v contains 100:

```
 if(v.contains(new Integer(100))
   System.out.println("100 found");
else
   System.out.println("100 not found");
```

- If you also need to know the index of the object when found, use:

`int indexOf(Object element)`	Returns the index of element if found; -1 otherwise.

```
int index = v.indexOf(new Integer(100));
if(index != -1)
   System.out.println("100 found at index " + index);
 else
    System.out.println("100 not found");
```

Size versus Capacity

➢Two related accessor methods for the Vector class are:

`int capacity()`	Returns the current capacity of the vector.
`int size()`	Returns the actual number of elements stored in the vector.

➢ size() is more useful. It is usually used in a loop to process all the vector elements

```
public static void main(String[] args){
   Vector v = new Vector(4);
   System.out.println("SIZE\tCAPACITY");
   for(int i = 0; i < 10; i++){
      v.add(new Integer(i*2));
      System.out.println(v.size()+"\t"
        + v.capacity());
    }
    for(int i = 0; i < v.size(); i++)
      System.out.println(v.get(I) + "  ");
 }
```

Output:

```
SIZE        CAPACITY
1            4
2            4
3            4
4            4
5            8
6            8
7            8
8            8
9            16
10           16
0   2   4   6   8   10   12   14   16   18
```

Removing an Element

- An element can be removed from a vector using any of the following methods:

`boolean remove(Object element)`	Removes element from the vector and returns true if successful; returns false if element is not found. The elements after the removed element are shifted to the left
`Object remove(int index)`	Removes element at index and returns it; throws IndexOutOfBoundsException if index < 0 or index > size. The elements after the removed element are shifted to the left

- The following removes 100 from a vector v and prints a message if successful:

```
if(v.remove(new Integer(100))
 System.out.println("100 removed");
else
  System.out.println("100 not found");
```

- Does the capacity of a vector shrink automatically after a deletion?:
- No. However, we can use the following method to shrink it:

`void trimToSize()`	Trims the capacity of this vector to be the vector's current size.

Program Example

- The following example reads an unknown number of grades, it then prints the average and the grades above the average:

```
public static void main(String[] args)throws IOException{
   Vector grade = new Vector();
   readGrades(grade);
   double average = getAverage(grade);
   System.out.print(“The average grade is: “ + average);
   System.out.print(“Grades above average are: “);
   printAboveAverage(grade, average);
}

public static void readGrades(Vector v)throws IOException{
   BufferedReader stdin = new BufferedReader(new InputStreamReader(System.in));
   System.out.print(“Enter grade: “);
   double value = Double.parseDouble(stdin.readLine());
   while(value >= 0){
      v.add(new Double(value));
      System.out.print(“Enter next grade(negative value to terminate): “ );
      value = Double.parseDouble(stdin.readLine());
    }
  }
```

Program Example (cont'd)

```
public static double getAverage(Vector v){
    if(v.size() == 0)
      throw new IllegalArgumentException("vector size is zero");
    double sum = 0;
    for(int i = 0; i < v.size(); i++){
      Double element = (Double) v.get(i);
      sum = sum + element.doubleValue();
    }
    return sum/v.size();
  }
  public static void printAboveAverage(Vector v, double average){
    for(int i = 0; i < v.size(); i++){
      Double element = (Double) v.get(i);
      if(element.doubleValue() > average)
         System.out.println(element);
     }
  }
```

Array versus Vector

- Vectors can grow and shrink, arrays cannot.
- Vector elements must be object references. Array elements can be object references or a primitive type.

Multi-Dimensional Arrays

- Why do we Need 2-D arrays?
- 2-D Array Declaration
- Referencing Elements of a 2-D Array
- What is the Meaning of length in a 2-D array?
- 2-D Array Initializers
- Processing 2-D arrays
- Closer Look at 2-D Arrays in Java
- Ragged Arrays

Why do we Need 2-D arrays?

- The same reason that necessitated the use of 1-D arrays can be extended to 2-D and other multi-D Arrays.
- For example, to store the grades of 30 students, in 5 courses require multiple 1-D arrays.
- A 2-D array allows all these grades to be handled using a single variable.
- This idea can be easily extended to other higher dimensions.
- Thus, we shall focus on 2-D arrays.
- A 2-D array is a contiguous collection of variables of the same type, that may be viewed as a table consisting of rows and columns.

2-D Array Declaration

- For any type T, T[ ][ ] is a class of 2-D arrays of base type T.

- Thus, the following statement declares a reference variable, b, of type 2-D array of base type T.

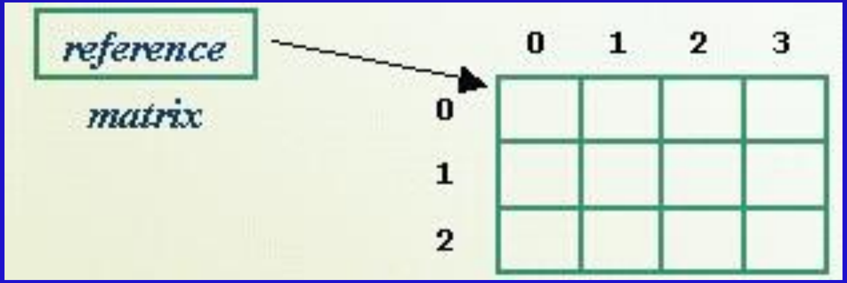
```
    T[][] b;
```

- For any two positive integers r and c, the following expression creates a 2-D array of type T with r rows, c columns and stores its reference in b.

```
    b = new T[r][c];
```

- The following creates a 2-D array, matrix, of int type with 3 rows and 4 columns:

```
    int[][] matrix = new int[3][4];
```



- Both rows and columns are indexed from zero.

Referencing Elements of a 2-D Array

- A particular element of a 2-D array, b, is referenced as:

```
b[RowIndex][columnIndex]
```

- For example, given the declaration:

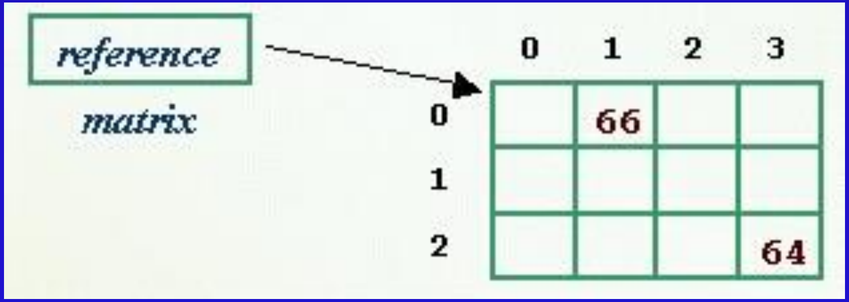
```
int[][] matrix = new int[3][4];
```

- The following stores 64 in the cell with row index 2, column index 3.

```
matrix[2][4] = 64;
```

- We use the same format to refer to an element in an expression:

```
matrix[0][1] = matrix[2][4] + 2;
```



What is the Meaning of length in a 2D-array?

- Suppose a matrix is declared as a 2D-array as:

```
int[][] matrix = new int[3][4];
```

- Then `matrix.length` returns the number of rows in matrix; 3 in this case.

- We can use this number to process a particular column:

```
int sumColumn0 = 0;
for(int rowIndex = 0; rowIndex < matrix.length; rowIndex++)
      sumColumn0 = somColumn0 + matrix[rowIndex][0];
```

- To manipulate a particular row n, We use the expression: `matrix[n].length` to obtain its length:

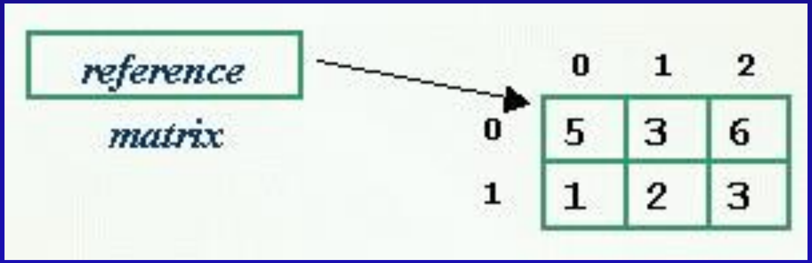
```
int sumRow2 = 0;
for(int columnIndex = 0; columnIndex < matrix[2].length; columnIndex++)
    sumRow2 = sumRow2 + matrix[2][columnIndex];
```

2D-Array Initializers

- We can declare and initialize a 2D-array in one statement as follows:

```
int[][] matrix = {{5, 3, 6}, {1, 2, 3}};
```

- Thus, each row is represented by a 1D-array initializer.



- To have three rows, we just add another 1D-array initializer:

```
int[][] matrix = {{5, 3, 6}, {1, 2, 3}, {8, 4, 3}};
```

- Again, this notation can be extended to higher dimensions.

General Algorithm - Processing 2-D Arrays

- • We can extend algorithms for processing 1-D arrays to 2-D arrays by using nested loops.
- To process an array row-wise, we use:

```
for(int rowIndex = 0; rowIndex < array.length; rowIndex++){
     process row# rowIndex;
  }
```

- But processing a row involves processing each element in that row.

```
for(int rowIndex = 0; rowIndex < array.length; rowIndex++){
     //  process row# rowIndex
     for(int columnIndex = 0; columnIndex < array[rowIndex].length;
columnIndex++)
          process element array[rowIndex][columnIndex]
 }
```

- To process an array, whose columns have equal length, column-wise, we use:

```
for(int columnIndex = 0; columnIndex < array[0].length;
columnIndex++){
     //  process column# columnIndex
     for(rowIndex = 0; rowIndex < array.length; rowIndex++)
          process element array[rowIndex][columnIndex]
 }
```

Examples on Processing 2-D arrays

- The following method prints the elements of a 2-D array one row per line.

```
public void print2Darray(int[][] matrix){
   for(int rowIndex = 0; rowIndex < matrix.length; rowIndex++){
     //  process row# rowIndex
     for(int columnIndex = 0; columnIndex < matrix[rowIndex].length; columnIndex++)
       System.out.print(array[rowIndex][columnIndex] + "\t");
   System.out.println();
 }
```

- The following method takes two matrices of equal dimensions and return their sum.

```
public int[][] sum2Darray(int[][] a, int[][] b){
  int[][] matrix = new int[a.length][a[0].length];
   for(int rowIndex = 0; rowIndex < matrix.length; rowIndex++)
     for(int columnIndex = 0; columnIndex < matrix[rowIndex].length; columnIndex++)
       matrix[rowIndex][columnIndex] = a[rowIndex][columnIndex]+
                                        b[rowIndex][columnIndex] ;
   return matrix;
 }
```

Processing 2D-Arrays of Objects

- Assume the Student class has the following additional members:

```
      private double grade;
       public double getGrade(){
            return grade;
       }
```

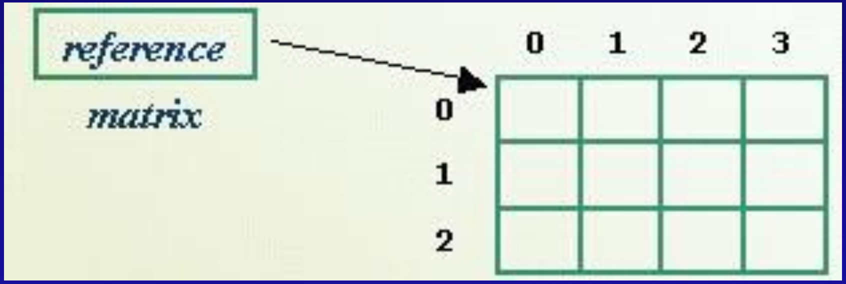
- Then the following method takes a 2D Student array representing a multi-section course and returns the overall average:

```
public double overallAverage(Student[][] student){
    double sum = 0; int numberOfStudents = 0;
    for(int section = 0; section < student.length; section++)
        for(int count = 0; count < student[section].length; count++){
            sum = sum + student[section][count].getGrade() ;
            numberOfStudents++;
        }
    return  sum / numberOfStudents;
  }
```

A closer look at 2D-arrays in Java

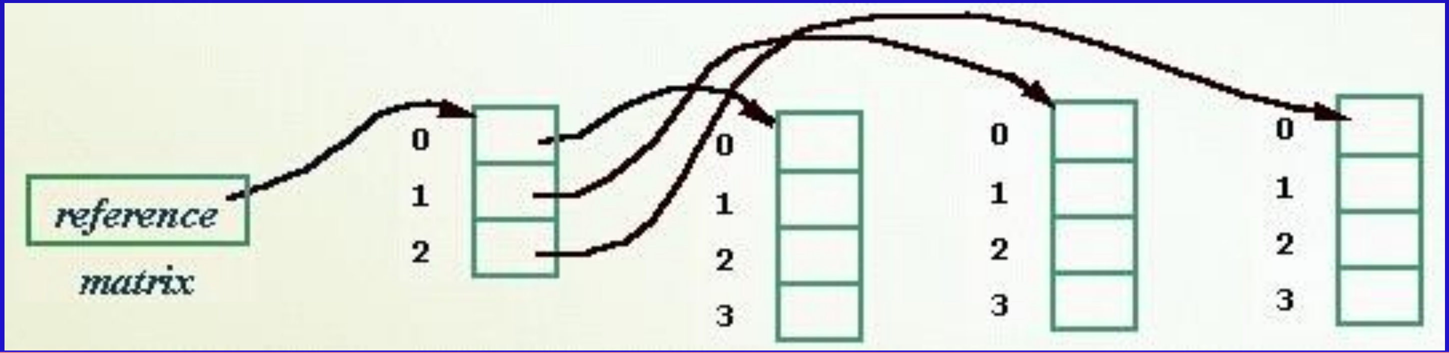
- So far, we have described a 2D-array as a table, consisting of rows and columns:

```
int[][] matrix = new int[3][4];
```



- Although this is natural, in Java a 2D-array is actually a 1D-array whose elements are references to 1D-array objects.

- Here is the actual representation:

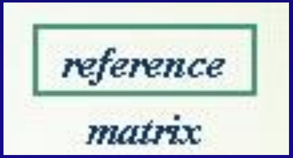


A Closer Look at 2D-Arrays in Java (cont'd)

- The creation of the 2D-array involves three steps:

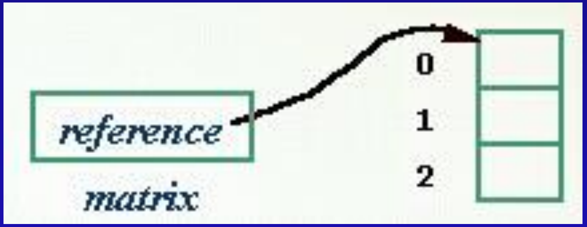
1. The creation of the reference matrix:

```
int[][] matrix;
```



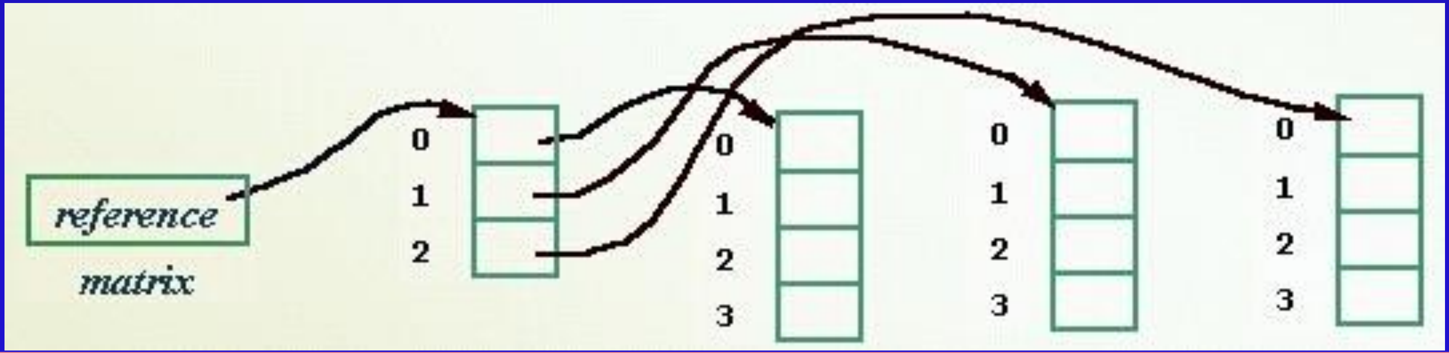
2. The creation of a 1D-array whose elements are references to 1D-arrays:

```
matrix = new int[3][];
```



3. The creation of the individual 1D-arrays:

```
for(int i = 0; i < matrix.length; i++)
    matrix[i] = new int[4];
```

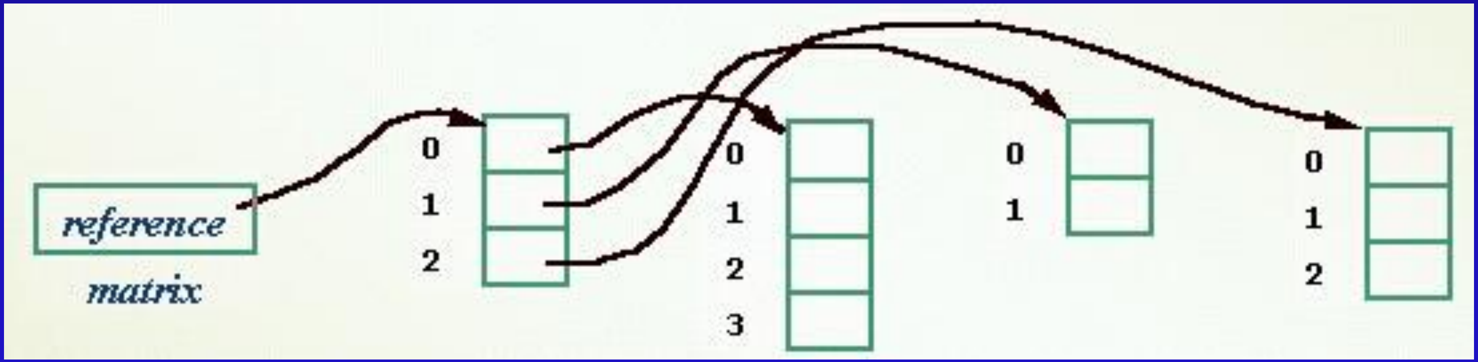


Ragged Arrays

- Since each column of a 2-D array is actually a separate 1D-array, each column may have a different length.

- For example, we could have the following:

```
int[][] matrix = new int[3][];
matrix[0] = new int[4];
matrix[1] = new int[2];
matrix[2] = new int[3];
```

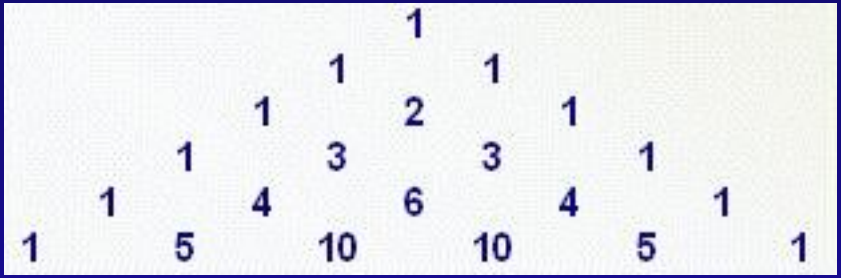


- This type of 2D-array where the columns are not of the same size is called a ragged array.

- Ragged arrays can be used to save memory space in some programming situations.

Example: Using a Ragged Array

- Pascal's triangle has many applications in Mathematics:



- The following method returns a ragged array representing Pascal's triangle of n rows:

```
public static int[][] pascalTriangle(int n){
       int[][] b = new int[n][];
       for(int i = 0; i < n; i++){
           // Create row I of Pascal's triangle
           b[i] = new int[i+1];
           b[i][0] = 1;
           for(int k = 1; k < i; k++)
                b[i][k] = b[i - 1][k - 1] + b[i - 1][k];
            b[i][i] = 1;
       }
      return b;
  }
```

Introduction to Recursion

- Introduction to Recursion
- Example 1: Factorial
- Example 2: Reversing Strings
- Example 3: Fibonacci
- Infinite Recursion
- Review Exercises

Introduction to Recursion

- *We saw earlier that a method can call another method leading to the creation of activation records on the runtime stack.*

- Recursion is one of the powerful techniques of solving problems.

- A *recursive method* is a method that calls itself *directly or indirectly*

- A *well-defined* recursive method has:
  - A base case that *determines the stopping condition in the method*
  - A recursive step *which must always get "closer" to the base case from one invocation to another*.

- The code of a recursive method must *be structured to* handle both the base case and the recursive case.

- Each call to the method sets up a new execution environment, *with new parameters and local variables*.

Example 1: The Factorial Function

$$\texttt{factorial(n)} = \begin{cases} 1, & \text{if } n = 0 \\ \texttt{n*factorial(n-1)}, & \text{if } n > 0 \end{cases}$$

```
public class Factorial{
  public static void main(String[] 
args){
     long answer = factorial(5);
     System.out.println(answer);
 }
```

```
public long factorial(int n) 
{
    if(n == 0)
       return 1L;
    else
       return n*factorial(n-
1);
 }
```

The Factorial: Sample Execution Trace

```
factorial (6) =
              =   (6*factorial(5))
              =   (6*(5*factorial(4)))
              =   (6*(5*(4*factorial(3))))
              =   (6*(5*(4*(3*factorial(2)))))
              =   (6*(5*(4*(3*(2*factorial(1))))))
              =   (6*(5*(4*(3*(2*1)))))
              =   (6*(5*(4*(3*2))))
              =   (6*(5*(4*6)))
              =   (6*(5*24))
              =   (6*120)
              =   720
```

Example 2: Reversing Strings

```
public void reverseString(String str, int i) {
    if(i < str.length()){
         reverseString(str, i+1);
         System.out.print(str.charAt(i));
     }
 }
```

Example 3: The Fibonacci Function

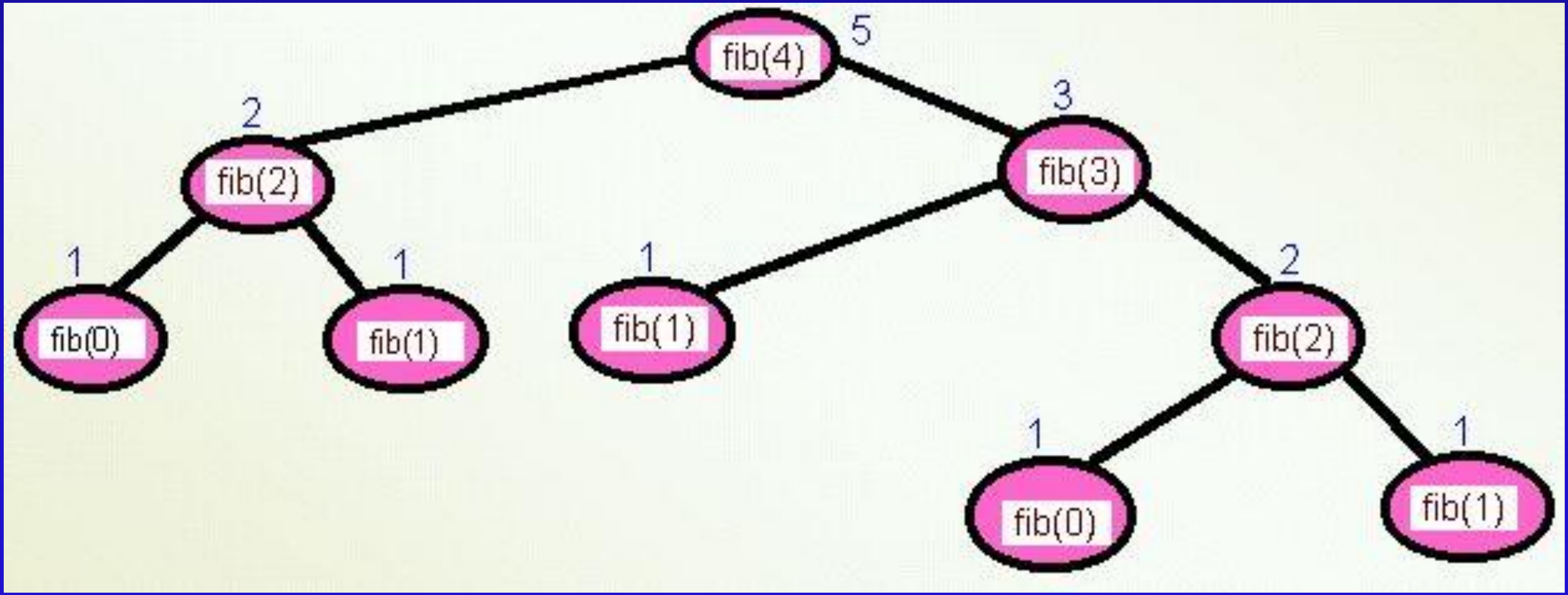
$$\text{fibonacci}(n) = \begin{cases} 1, & \text{if } n < 2 \\ \text{fibonacci}(n-1) + \text{fibonacci}(n-2), & \text{if } n >= 2 \end{cases}$$

```
public class Fibonacci{
   public static void
     main(String[] args){
      long answer = fibonacci(4);
      System.out.println(answer);
     }
}
```

```
public static long fibonacci(int n) {
  if (n < 2)
      return 1L;
 else
   return fibonacci(n-1) + fibonacci(n-2);
 }
```

Fibonacci Call Tree

```
public static long fibonacci(int n) {
  if (n < 2)
      return 1L;
  else
     return fibonacci(n-1) + fibonacci(n-2);
}
```



Infinite Recursion

- A recursive method must always call itself with a smaller argument
- Infinite recursion results when:
  - The base case is omitted.
  - Recursive calls are not getting closer to the base case.
- In theory, infinite recursive methods will execute “forever”
- In practice, the system reports a stack overflow error.

Drill Questions

1. Write a recursive method `public int sumUpTo(int n)` which adds up all integers from 1 to n.

2. Write a recursive method `public int multiply(x,y)` that multiplies two integers `x` and `y` using repeated additions and without using multiplication.

3. Write a recursive method

   `public int decimalToBinary(int n)` that takes and integer parameter and prints its binary equivalent.

4. Write a recursive method

   `public boolean isPalindrome(String str)`

   that returns true if str is a palindrome and returns false otherwise.

Note: *a palindrome is a string that has the same characters when read from left to right or from right to left (Examples: eye, radar, madam, dad, mom, 202)*.

Exception Handling

- Introduction to Exceptions
- How exceptions are generated
- A partial hierarchy of Java exceptions
- Checked and Unchecked Exceptions
- What exceptions should be handled?
- How exceptions are handled
- Unreachable catch-blocks
- The semantics of the try statement
- Recovering from Exceptions

Introduction to Exceptions

- A program may have one or more of three types of errors:
  - Syntax errors or Compile-time errors.
  - Run-time or Execution-time errors.
  - Logic errors.

- A Java exception is an object that describes a run-time error condition that has occurred in a piece of Java code or in the Java run-time System.

- All Java exception classes are subclasses of the Throwable class.

- Most exception classes are defined in the java.io and java.lang packages.

- Other packages like: java.util, java.awt, java.net, java.text also define exception classes.

- A piece of Java code containing statements to handle an exception is said to catch the exception; otherwise it is said to throw that exception.

How Exceptions are Generated

- Exceptions can be generated in two ways:
  - By the Java run-time system.
  - By the programmer using the *throw* statement.

- Common forms of the throw statement are:
  - `throw new ThrowableClass();`
  - `throw new ThrowableClass(string);`

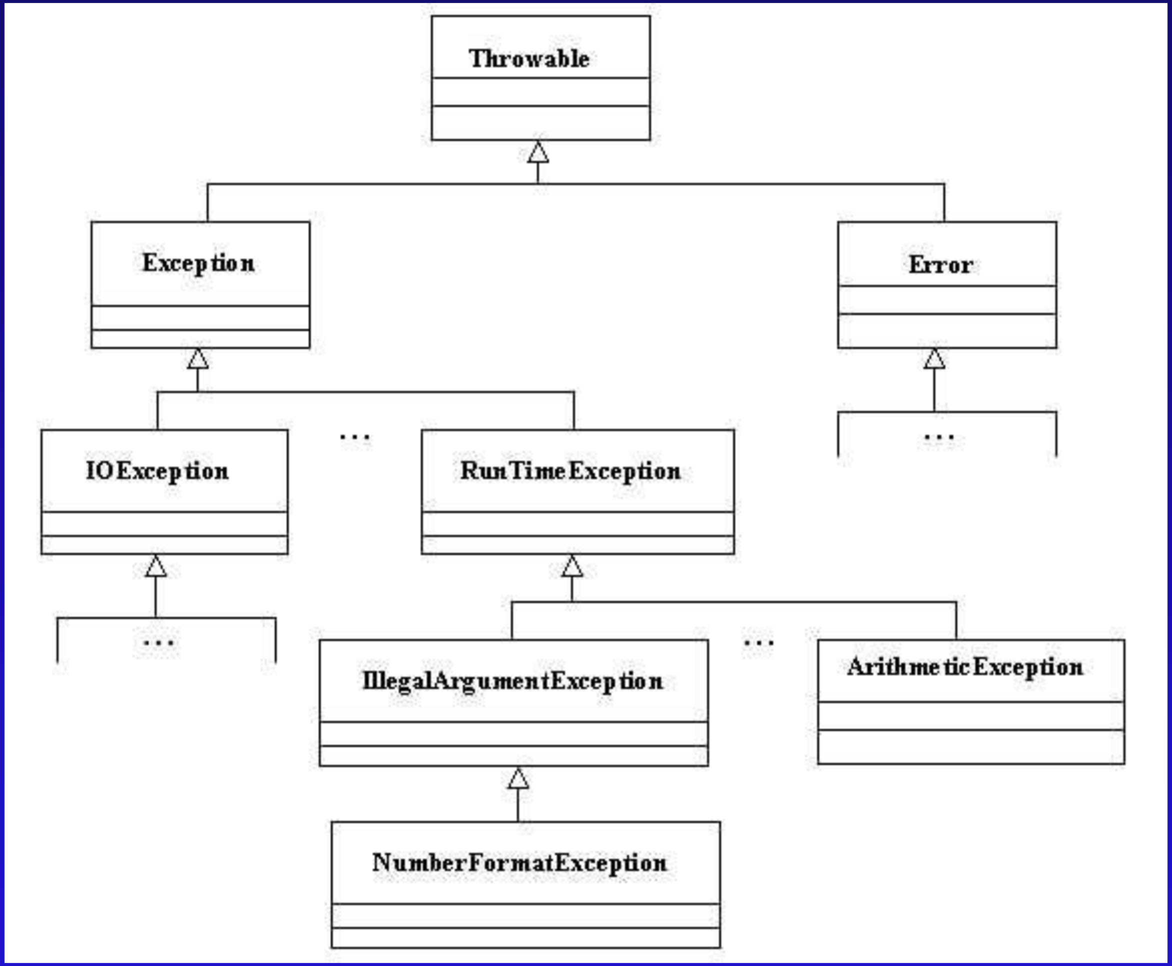
  where ThrowableClass is either Throwable or a subclass of Throwable.

- Examples:

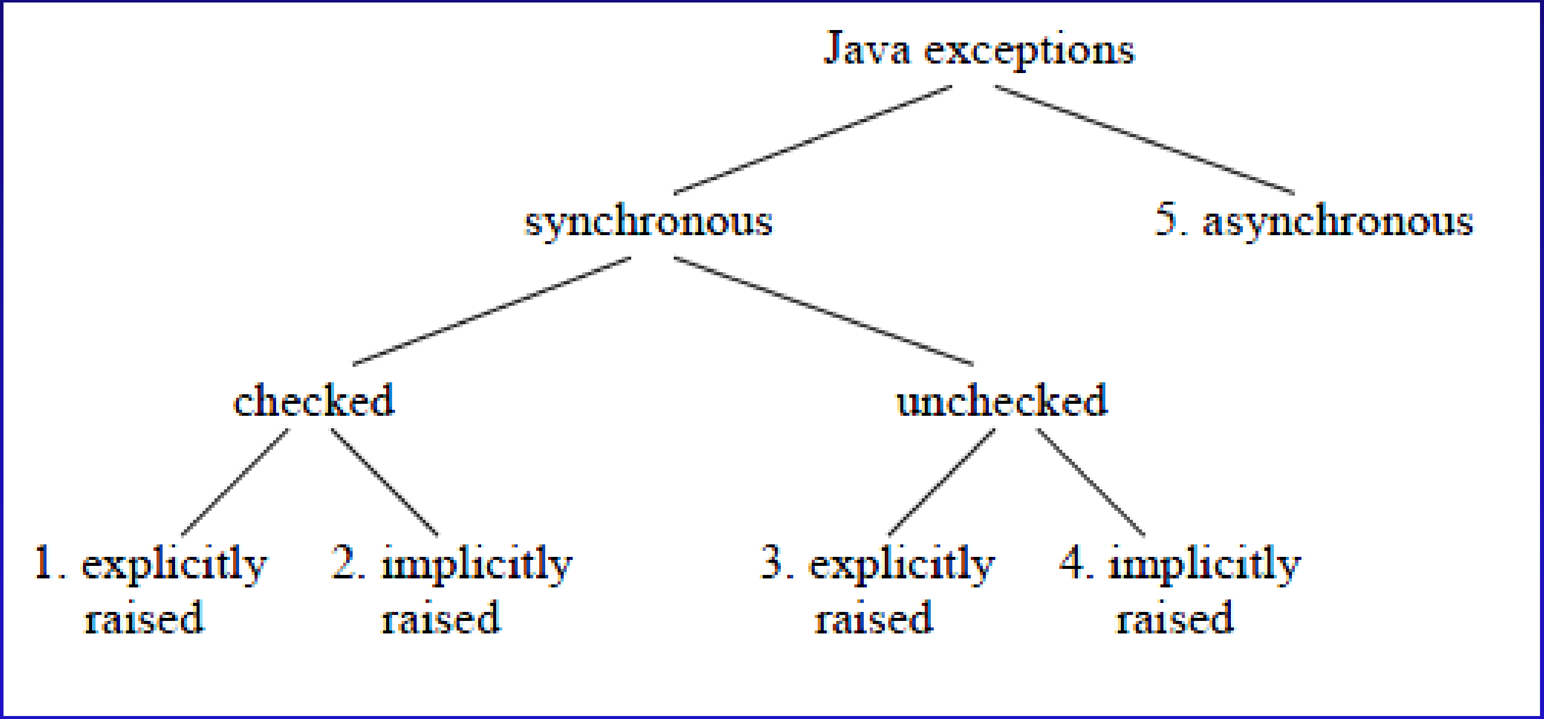
```
  if(divisor == 0)
       throw new ArithmeticException(“Error - Division by zero”);
```

```
if(withdrawAmount < 0)
   throw new InvalidArgumentException(“Error – Negative withdraw amount”);
else
    balance -=  withdrawAmount;
```

A partial hierarchy of Java exceptions



A partial hierarchy of Java exceptions



Checked and Unchecked Exceptions

- Java exceptions are classified into two categories: checked exceptions and unchecked exceptions:
  - Checked exception: An object of Exception class or any of its subclasses except the subclass RunTimeException.
  - Unchecked exception:
    - An object of the Error class or any of its subclasses.
    - An object of RunTimeException or any of its subclasses.

- A method that does not handle checked exceptions it may generate, must declare those exceptions in a throws clause; otherwise a compile-time error occurs.

- A method may or may not declare, in a throws clause, unchecked exceptions it may generate but does not handle.

- Syntax of a throws clause:

```
accessSpecifier returnType methodName(parameters)throws
        ExceptionType1, ExceptionType2, ..., ExceptionTypeN {
     // method body
  }
```

- Note: When a method declares that it throws an exception, then it can throw an exception of that class or any of its subclasses.

Checked and Unchecked Exceptions (cont'd)

➢ Examples:

```
public static void main(String[] args) throws IOException{
    // . . .
    String  name = stdin.readLine();
    // . . .
 }
```

If IOException is not handled, the throws IOException is required

```
public static void main(String[] args){
   // . . .
   int num1 = num2 / num3;
   // . . .
 }
```

Statement will generate ArithmeticException if num3 is zero.

The method may or may not contain a throws ArithmeticException clause

What Exceptions Should be Handled?

- Exceptions of class IOException and its subclasses should be handled.
  - They occur because of bad I/O operations (e.g., trying to read from a corrupted file).

- Exceptions of class RuntimeException and its subclasses and all subclasses of Exception (except IOException) are either due to programmer-error or user-error.

  - Programmer-errors should not be handled. They are avoidable by writing correct programs.
  - User-errors should be handled.
  - Example: Wrong input to a method may generate:

    ArithmeticException, IllegalArgumentException, or NumberFormatException.

- The exceptions of class Error and its subclasses should not be handled.
  - They describe internal errors inside the Java run-time system. There is little a programmer can do if such errors occur.
  - Examples: OutOfMemoryException, StackOverflowException.

How Exceptions are Handled

- Java uses try-catch blocks to handle exceptions.
- try-catch blocks have the form:

```
try{
  statementList
}
catch(ExceptionClass1  variable1){
  statementList
}
catch(ExceptionClass2  variable2){
  statementlist
}
  .   .   .
 catch(ExceptionClassN  variableN){
   statementlist
 }
```

- A statement or statements that may throw exceptions are placed in the try-block.
- A catch-block defines how a particular kind of exception is handled.

Unreachable catch-blocks

- A catch-block will catch exceptions of its exception class together with any of its subclasses.
  - Example: Since ArithmeticException is a subclass of Exception, the following code will cause compile-time error because of unreachable code:

```
try{
 int a = 0;
 int b = 42 / a;
}
catch(Exception  e){
  System.out.println(e);
}
catch(ArithmeticException e){
  System.out.println("There is an arithmetic exception");
}
```

The Semantics of the try Statement

- A catch block cannot catch an exception thrown by another try block, except in the case of nested try blocks.
- When a try block is executed, there are three possible cases:

1. No exception is generated:
   - All the statements in the try block are executed .
   - No catch block is executed.
   - Processing continues with the statement following all the catch blocks for the try block.
2. An exception is thrown and there is a matching catch block.
   - The statements in the try block following the statement that caused the exception are NOT executed.
   - The first matching catch block is executed.
   - No other catch block is executed.
   - Processing continues with the statement following all the catch clauses for the try block.
3. An exception is thrown and there is no matching catch block.
   - Control is immediately returned (propagated) to the method that called this method that caused the exception.
   - The propagation continues until the exception is caught, or until it is passed out of the Java program, where it is caught by the default handler in the Java-runtime System.
   - The default exception handler displays a string describing the exception.

Recovering from Exceptions

- The code to recover from an exception is usually a loop that repeats as long as the condition that causes the exception has not been removed.
- Example:

```
    import java.io.*;
    public class TestException{
      public static void main(String[] args)throws IOException{
      BufferedReader stdin = new BufferedReader(new InputStreamReader(System.in));
        int number = 0;
        boolean  done = false;
        do{
           try{ System.out.println("Enter an integer: ");
             number = Integer.parseInt(stdin.readLine().trim());
             done = true;
           }
           catch(NumberFormatException e){
             System.out.println("Error - Invalid input!");
           }
        }while(! done);
        System.out.println("The number entered is " + number);
      }
 }
```

Recovering from Exceptions (cont'd)

- Example:

```
import java.io.*;
class BankAccount{
   private int accountNumber;
   private double balance;
    public void deposit(double amount){
       if(amount < 0)
          throw new IllegalArgumentException("Negative deposit");
        else
          balance += amount;
     }
     //...
 }
 public class BankAccountTest{
    public static void main(String[] args)throws IOException{
       //...
       boolean done = false;
       do{
          System.out.println("Enter amount to deposit:");
           double amount = Double.parseDouble(stdin.readLine());
            try{
              account.deposit(amount);
              done = true;
             }
       catch(IllegalArgumentException e){System.out.println(e);}
         }while(! done);
     }
}
```

Text File I/O

- I/O streams
- Opening a text file for reading
- Closing a stream
- Reading a text file
- Writing and appending to a text file

I/O streams

- Files can be classified into two major categories: Binary files and Text files.
  - A binary file is a file whose contents must be handled as a sequence of binary digits.
  - A text file is a file whose contents are to be handled as a sequence of characters.
- Why use files for I/O?
  - Files provide permanent storage of data.
  - Files provide a convenient way to deal with large quantities of data.
- Recall that in In Java, I/O is handled by objects called streams.
- The standard streams are System.in, System.out, and System.err.

Opening a Text File for Reading

- A stream of the class Scanner is created and connected to a text file for reading as follows:

```
Scanner input = new Scanner(new File(filename));
```

  - Where filename is a File object or a constant string or a String variable containing the name or the full path of the file to be read.
    - Example of valid filenames: "myinput.txt", "C:\\homework\\StudentTest.java", "C:/homework/StudentTest.java"

- File class belong to the java.io package, it must be imported for it to be used.

Closing a Stream

- When a program has finished writing to or reading from a file, it should close the stream connected to that file by calling the close method of the stream:

```
streamName.close();
Eg. input.close();
```

- The close method is defined as:

```
public  void  close()
```

- When a stream is closed, the system releases any resources used to connect the stream to a file.

- If a program does not close a stream before the program terminates, then the system will automatically close that stream.

Reading a Text File

- After a stream has been connected to a text-file for reading, the nextLine or next methods of the stream can be used to read from the file:
  - `public String nextLine()`
  - `public int nextInt()`

- The nextLine method reads a line of input from the file and returns that line as a string.

Reading a Text File: Example1

- The following program displays the contents of the file myinput.txt on the screen by reading one character at a time:

```
import java.io.*;
public class ShowFile{
  public static void main(String[] args)throws IOException{
        int input; Scanner  fin = null;
        try{
          fin = new Scanner(new File("myinput.txt"));
        }catch(FileNotFoundException e){
            System.out.println("Error - File myinput.txt not found");
            System.exit(1);
        }
        while(( input = fin.hasNext()) != -1)
            System.out.print((char) input);
        fin.close();
   }}
```

Reading a Text File: Example2

- The following program displays the ID, number of quizzes taken, and average of each student in grades.txt:

```
import java.io.*;import java.util.StringTokenizer;import java.util.Scanner;
public class QuizResults{
  public static void main(String[] args)throws IOException{
     Scanner  inputStream = new Scanner(new File("grades.txt"));
         StringTokenizer tokenizer; String inputLine,  id; int  count; double  sum;
         System.out.println("ID#   Number of Quizzes          Average\n");
         while(inputLine = inputStream.hasNext()){
           tokenizer = new StringTokenizer(inputLine);
           id = tokenizer.nextToken();
           count = tokenizer.countTokens();
           sum = 0.0;
           while(tokenizer.hasMoreTokens())
                  sum += Double.parseDouble(tokenizer.nextToken( ));
           System.out.println(id + "   " + count + "   ″ + sum / count);
         } }}
```

Opening a Text File for Writing

- A stream is created and connected to a text file for writing by a statement of the form: .

```
PrintWriter streamName = new PrintWriter(new File(filename));
```

  - Any preexisting file by the same name and in the same folder is destroyed. If the file does not exist it is created.
  - Any preexisting file by the same name is not destroyed. If the file does not exist it is created.

- Both PrintWriter and File classes belong to java.io package.

Writing to a Text File

- The PrintWriter class has methods print and println.
  - The print method prints output without generating a new line.
  - The println method prints output, it then generates a new line.
- Each constructor of the FileWriter can throw an IOException:
  - `public FileWriter(String filename) throws IOException`
  - `public FileWriter(String filename , boolean  appendFlag)throws IOException`

Example: Appending to a Text-file

- The following program appends a message to the file datafile.txt

```
import java.io.*;

public class FileAppend{

  public static void main(String[] args)throws IOException{

     String  message  =  "Java is platform independent";

     PrintWriter  outputStream =

         new PrintWriter(new FileWriter("datafile.txt", true));

     outputStream.println(message);

     outputStream.close();

  }

}
```

Example: Writing to a Text File

- The following program copies the first 200 non-blank characters from one file to another.

```
import java.io.*;
public class FileCopy{
  public static void main(String[] args){
      int  input;
      BufferedReader fin = null;
      PrintWriter fout = null;
      try{
        fin = new BufferedReader(new FileReader("myinput.txt"));
      }
      catch(FileNotFoundException e){
          System.out.println("Input File not found");
          System.exit(1);
      }
      try{
         fout = new PrintWriter(new FileWriter("myoutfile.txt"));
      }
     catch(IOException e){
        System.out.println("Error opening output file");
        System.exit(1);
     }
```

Example: Writing to a Text File (cont'd)

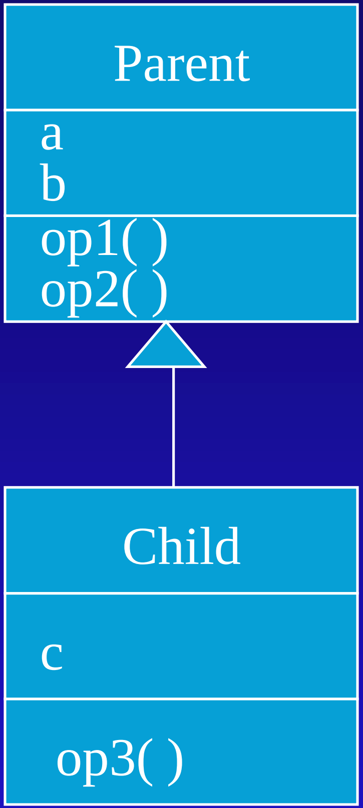
```
      try{
           int count  = 0;
           while((input = fin.read()) != -1 && count < 200){
                 char ch = (char) input;
                 if(ch != ‘ ’){
                    fout.print(ch);
                    count++;
                 }
            }
      }
      catch(IOException e){
        System.out.println("Error in reading the file myinput.txt");
      }
      try{
          fin.close();
          fout.close();
      }
      catch(IOException e){
        System.out.println("Error in closing a file");
      }
      System.out.println("File copied successfully”);
   }
}
```

Introduction to Inheritance

- What is Inheritance?
- Superclass vs. Subclass
- Why Inheritance?
- Subclass Syntax
- Final Classes
- Class Hierarchy
- Subclass Constructors
- Example
- Exercises

What is Inheritance?

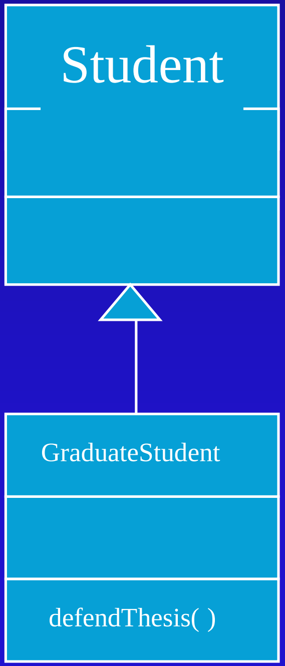
- Inheritance is a mechanism for enhancing existing, working classes.
- A new class can inherit from a more general existing class.
- For Class Child:
  - Attributes:
    - Inherited: a , b
    - not inherited: c
  - Methods:
    - Inherited: op1( ) , op2( )
    - not inherited: op3( )

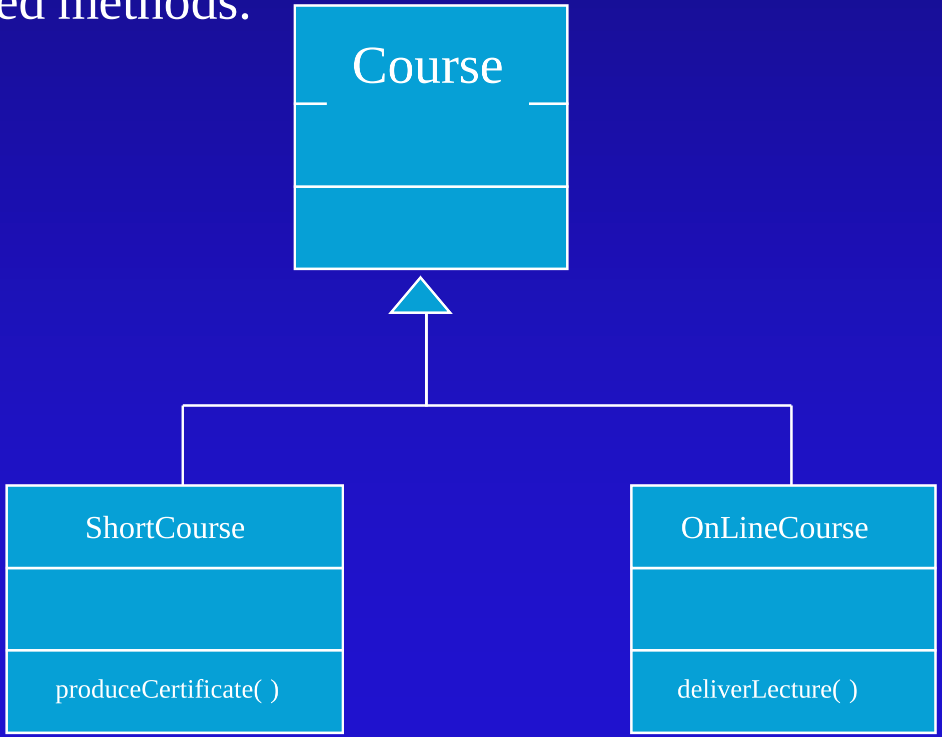


- Note: Constructors and private members of a class are not inherited by its subclasses.
- Java supports single inheritance: A subclass has one parent only.
- In multiple inheritance a subclass can have more than one parent.

Superclass vs. Subclass

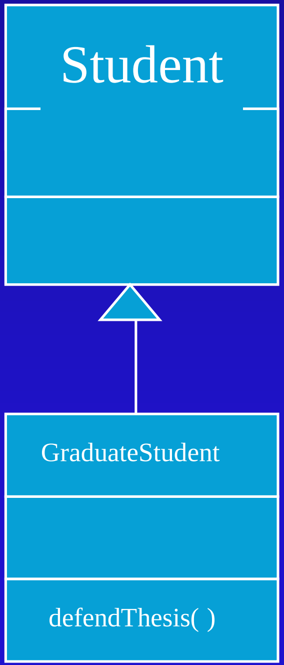
- Superclass:
  - A general class from which a more specialized class (a subclass) inherits.
- Subclass:
  - A class that inherits variables and methods from a superclass but adds instance variables, adds methods, or redefines inherited methods.

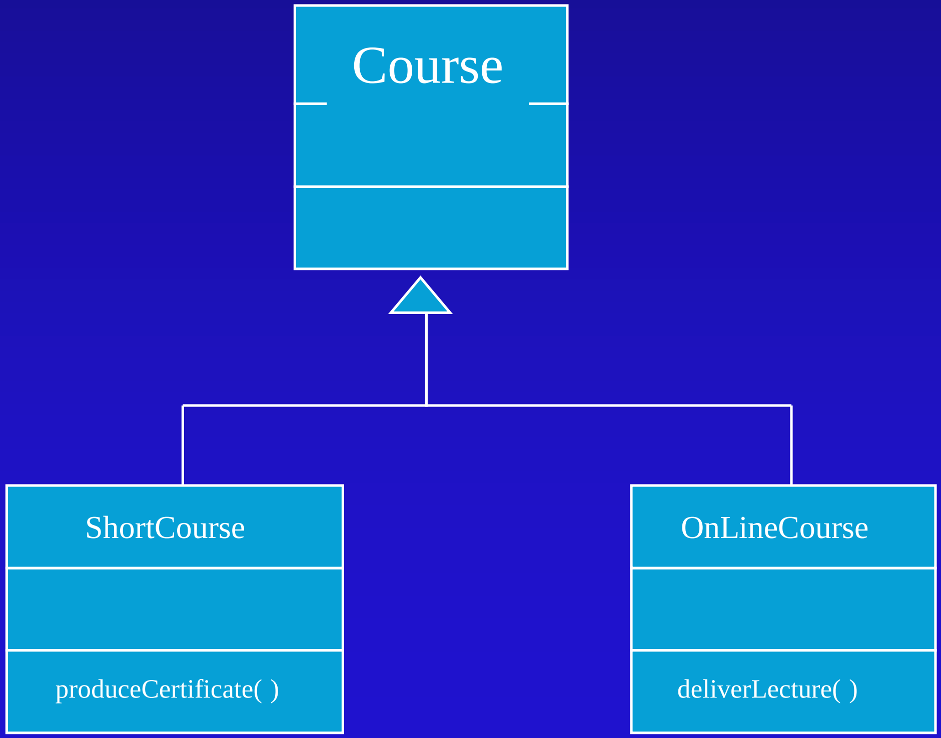




isA relationship

- A subclass-superclass pair defines “isA” relationship:
  - A graduate student is a student.
  - A short course is a course.
  - An online course is a course.
  - A graduate student is a student.





Why Inheritance?

- Through inheritance we gain software reuse.
- Helps in writing structured programs.
- It is more natural and closer to real world.

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Subclass Syntax

```
class SubclassName extends SuperclassName

{

    variables

    methods

}
```

➢ Example:

```
class GraduateStudent extends Student

{

     String thesisTitle;

     . . .

     defendThesis(){. . .}

     . . .

}
```

Final Classes

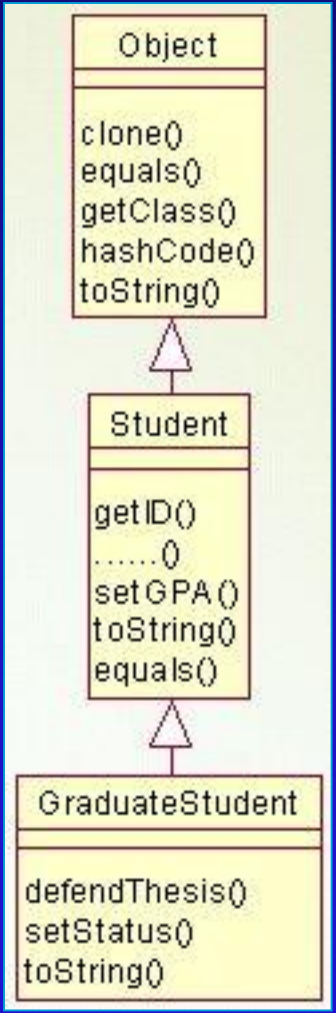
- A class that is declared as final cannot be extended or subclassed.

```
final class className
{
    variables
    methods
}
```

- Examples of final classes are:
  - java.lang.System.
  - The primitive type wrapper classes: Byte, Character, Short, Integer, Long, Float, and Double.

Class Hierarchy

- In Java, every class that does not extend another class is a subclass of the Object class. that is defined in the java.lang package.
- Thus, classes in Java form a hierarchy, with the Object class as the root.
- Example of a class hierarchy:



Subclass Constructors

- To initialize instance variables of a superclass, a subclass constructor invokes a constructor of its superclass by a call of the form:

```
        super(paraneters);
```

- This statement must be the first statement within the constructor of the subclass.

- Example:

```
public GraduateStudent(int id, String name, double gpa, String thesisTitle){
    super(id, name, gpa);
    this.thesisTitle = thesisTitle;
 }
```

- If the first statement in a constructor does not explicitly invoke another constructor with this or super; Java implicitly inserts the call: super( );. If the superclass does no have a no-argument constructor, this implicit invocation causes compilation error.

- Constructor calls are chained; any time an object is created, a sequence of constructors is invoked; from subclass to superclass on up to the Object class at the root of the class hierarchy.

Example

```
class Vehicle{
   private String vehicleIdNumber ;
   private String vehicleChassisNumber ;
   private String model ;
  public Vehicle(String vin, String vcn, String model){
       vehicleIdNumber = vin;
       vehicleChassisNumber = vcn;
       this.model = model;
   }
    public String toString( ){
       return "Vehicle ID = " + vehicleIdNumber +
       "\nVehicle  Chassis Number = " +
            vehicleChassisNumber + "\nVehicle Model = " + model;
     }

     public boolean equals(Vehicle vehicle){
         return this.vehicleChassisNumber ==
                                  vehicle.vehicleChassisNumber;
     }
}
```

```
class Bus extends Vehicle{
   private int numberOfPassengers ;
   public Bus(int numPassengers, String vin, String vcn, String model){
            super(vin, vcn, model) ;
            numberOfPassengers = numPassengers ;
    }

      public int getNumberOfPassengers( ){
            return numberOfPassengers ;
    }
}
```

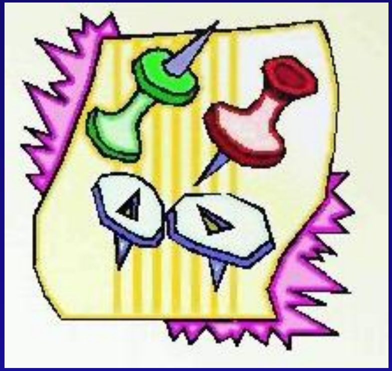
Example (cont’d)

```
class Truck extends Vehicle{
   private double cargoWeightLimit ;
   public Truck(double weightLimit, String vin, String vcn, String model){
        super(vin, vcn, model) ;
        cargoWeightLimit = weightLimit ;
    }

     public double getCargoWeightLimit( ){
         return cargoWeightLimit ;
     }
}
```

```
public class VehicleTest{
  public static void main(String[] args){
      Vehicle vehicle = new
          Vehicle ("QMY 489", "MX-0054322-KJ", "BMW 500");
      Bus bus1 = new  Bus(30, "TMK 321", "AF-987654-WR",
                              "MERCEDEZ BENZ");
      Bus bus2 = new Bus(30, "2348976", "AF-987654-WR",
                              "MERCEDEZ BENZ");
      Truck truck = new
         Truck(10.0, "DBS 750", "RZ-70002345-PN", "ISUZU");

     System.out.println(vehicle) ;
     System.out.println(bus1) ;
     System.out.println(truck) ;
      if(bus1.equals(bus2))
          System.out.println("Bus1 and Bus2 are the same") ;
       else
         System.out.println("Bus1 and Bus2 are not the same") ;
   }
}
```

Exercises

Question 1:
What inheritance relationships would you establish among the following classes: Student, Professor, Teaching Assistant, Employee, Secretary, DepartmentChairman, Janitor, Person, Course, Seminar, Lecture, ComputerLab



Question 2:
In the following pairs of classes, identify
the superclass and the subclass: Manager -Employee,
Polygon -Triangle, Person - Student, Vehicle - Car, Computer-Laptop,
Orange - Fruit.

Introduction to Inheritance

- Access Modifiers
- Methods in Subclasses
- Method Overriding
- Converting Class Types
- Why up-cast?
- Why Down-cast?
- Exercises

Access Modifiers

weaker access privilege

↓

stronger access privilege

Access Modifier	Members with the access modifier can be accessed directly by:
private	• Methods of their own class only.
protected	• Methods of their own class. • Methods of subclasses and other classes in the same package. • Methods of subclasses in different packages.
No access modifier (default or package access)	• Methods of their own class. • Methods of subclasses and other classes in the same package.
public	• Methods of all classes in all packages.

Methods in Subclasses

- A method in a subclass can be:
  - A new method defined by the subclass.
  - A method inherited from a superclass.
  - A method that redefines (i.e., overrides) a superclass method.

New method

Overridden method

```
public class GraduateStudent extends Student{
     private String thesisTitle ;
     public GraduateStudent(. . .){ . . .}
     public String getThesisTitle() {return thesisTitle; }
     public String toString( ){ . . .}
     . . .
}
```

Inherited methods: getID( ), getName( ), getGPA( ), setGPA( ), etc.

Method Overriding

- A subclass overrides a method it inherits from its superclass if it defines a method with the same name, same return type, and same parameters as the supercalss method.
- Each of the following causes compilation error:
  - The overriding method has a weaker access privilege than the method it is overriding.
  - The overriding method has the same signature but different return type to the method it is overriding.
- A method declared as final, final returnType methodName(. . .) , cannot be overridden.

- A subclass can access an overridden method can by a call of the form:

```
        super.methodName(parameters) ;
```

- Note: We have already come across examples of method overriding when we discussed the redefinition of the toString and the equals methods in the previous lectures.

Method Overriding Example1

```
public class Student{
    private int id; private String name; private double gpa;
    . . .
    public String toString(){return “ID: “ + id + “,Name: “ + name
     + “, GPA: “ + gpa; }
}
```

```
public class GraduateStudent extends Student{
     String thesisTitle;
     . . .
     public String toString(){
       return super.toString() + “, Thesis Title:” + thesisTitle;
     }
}
```

Method Overriding Example2

```
public class Student{
    protected int id; protected String name; protected double gpa;
    . . .
    public String toString(){return “ID: ‟ + id + “,Name: ‟ + name
     + “, GPA: ‟ + gpa;
    }
}
```

```
public class GraduateStudent extends Student{
     String thesisTitle;
     . . .
     public String toString(){
       return “ID: ‟ + id + “,Name: ‟ + name
         + “, GPA: ‟ + gpa + “, Thesis Title: ‟ + thesisTitle;
     }
}
```

Converting between Class Types

- A widening conversion (up casting) can be done without a class cast:

```
GraduateStudent gradstudent = new GraduateStudent(...);
Student student = gradstudent;
```

  - However, the reference student cannot access members of GraduateStudent even if they are public:

```
String title = student.getThesisTitle(); // Compile time error
```

- A narrowing conversion (down casting) requires a class cast; otherwise a compile time error occurs:

```
Object object = new Object();
String string = object ; // Compile time error
```

Converting between Class Types (cont'd)

- A narrowing conversion in which a superclass reference does not refer to a subclass does not cause a compilation error; but it causes a runtime error: java.lang.ClassCastException:

```
Object object = new Object();
 String string = (String) object;
```

- A narrowing conversion is valid, if the superclass reference refers to a subclass:

```
Object object = new Object();
 String string1 = "KFUPM";
 object = string1;
 String string2 = (String) object;
 int j = ((String) object).length();
```

Why Up-cast?

- One use of up-casting is to write methods that are general.
- Example:

```
class Vehicle{
   private String vehicleIdNumber ;
   private String vehicleChassisNumber ;
   private String model ;
    // . . .
   public boolean equals(Vehicle vehicle){
       return this.vehicleChassisNumber ==
          vehicle.vehicleChassisNumber;
   }
}

class Bus extends Vehicle{
   private int numberOfPassengers ;
// . . .
}
```

```
class Truck extends Vehicle{
   private double cargoWeightLimit ;
// . . .
}

public class VehicleTest{
  public static void main(String[] args){
  // . . .
 boolean x = vehicle1.equals(vehicle2);
 boolean y = bus1.equals(bus2);
 boolean z = truck1.equals(truck2);
 // . . .
}
```

Why down-cast?

- Example:

```
public class Employee {
 …
}
```

```
public class Manager extends Employee {
  public getDepartmentName() { . . . }
  …
}
```

```
Employee e = new Manager(. . .);
String string = e.getDepartmentName();
```

compile time error. getDepartmentName( ) is not a member of Employee.

Use down-casting to overcome the difficulty.

```
Manager m = (Manager)e;
String string = m.getDepartmentName();
```

Exercises

1. Question 1:
   a) Write a class Employee with a name and salary.
   b) Make a class Manager inherit from Employee. Add an instance variable, named department, of type String. Supply a method toString that prints the manager's name, department, and salary.
   c) Make a class Executive inherit from Manager. Supply a method toString that prints the string "Executive", followed by the information stored in the Manager superclass object.
   d) Supply a test program that tests these classes and methods.

2. Question 2:
   a) Implement a superclass Person. A person has a name and a year of birth.
   b) Make two classes, Student and Instructor, inherit from Person. A student has a major, and an instructor has a salary. Write the class definitions, the constructors, and the method toString for all classes.
   c) Supply a test program that tests these classes and methods.