Computer Architecture

- Program instructions:
  - Instructions are numbers (ultimately in binary form)
    - 00110101 represents ADD (adding numbers)
    - 10101100 represents MULT (multiplication)
    - 01010111 represents LOAD (load data from memory to a register)
    - 10100111 represents STORE (stores data from a register to memory)

Computer Architecture

- Instructions, or operators may have parameters
  - Adding the contents of registers R1 and R2 and put the result in R3:

$$\underbrace{00110101}_{ADD}\ \underbrace{10001001}_{R1}\ \underbrace{10001010}_{R2}\ \underbrace{10001011}_{R3}$$

    * Loading data from memory cell 26 and put it in register 2

$$\underbrace{11111001}_{LOAD}\ \underbrace{00011010}_{26}\ \underbrace{10001010}_{R2}$$

Computer Architecture

- Different kinds of processors have different *instruction sets* (e.g. Pentium, PowerPC, Alpha, SPARC, Motorola)
  - Each instruction set has different instructions, and associates different numbers to each type of instruction
  - Hence, a program for one type of processor cannot be directly executed by a different processor.

- Portability: the ability to run (execute) a program in more than one type of processor.

Programming Languages

- A program as understood by the computer is a long sequence of words (bits):

```
1101100011101000100100010010100101001001001010
```

  – Machine Language

- But each instruction can be written in a fashion readable by humans:

```
LOAD [26], R1
LOAD 3, R2
ADD R1, R2, R3
STORE R3, [1700000029]
```

  – Assembly language

- Assembler: a program that translates an assembly language program into its machine language equivalent.

Programming Languages

- Assembly is a low-level language
- High-level languages abstract the components of the machine

  ```
  x = y + 3;
  ```

  – Java, C, C++, Python, Perl, ML, Scheme, Prolog, Ada, Pascal, Basic, Fortran, Cobol, ...
- Abstracting the components is good: when implementing an algorithm you don't have to think about the component of the computer. You focus on the problem.
- Compiler: a program that translates a high-level language program into its machine language equivalent.

A simple Java program

```
// This is a very, very, simple program

public class HelloWorld
{
    public static void main(String[] args)
    {
        System.out.println(“Hello, World!”);
    }
}
```

A simple java program

- Java is case-sensitive:

  `HelloWorld`

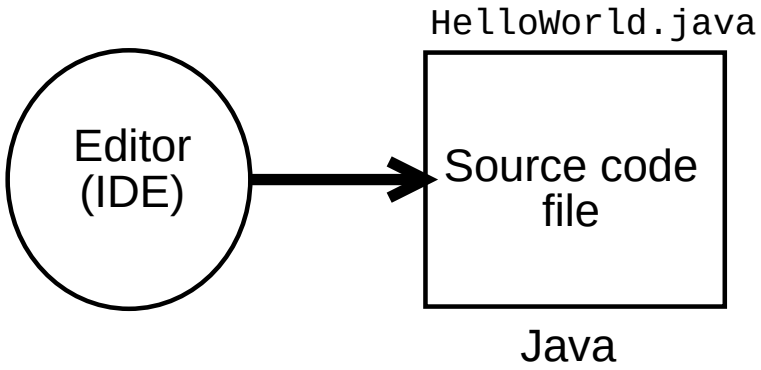
is not the same as

  `helloworld`

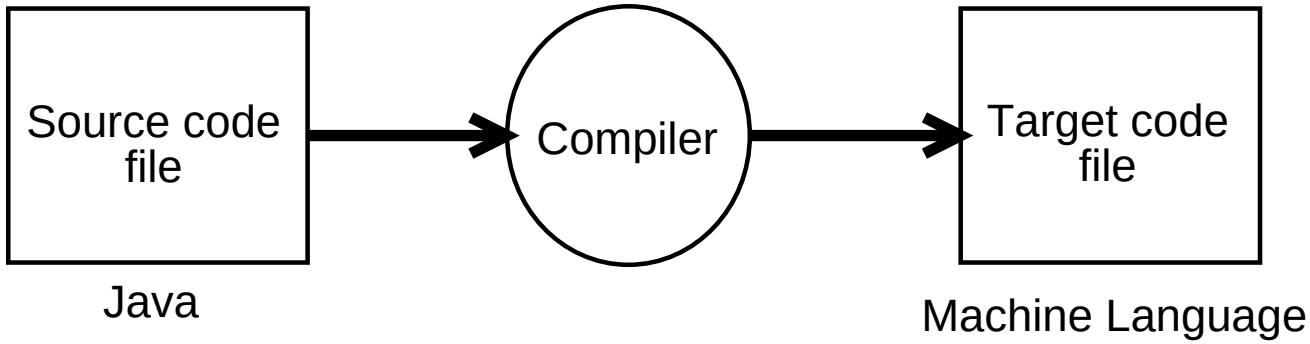
From code to a running program

- Editing
- Compilation/Interpretation
  - Compilation:
    - Translation
    - Execution
  - Interpretation:
    - Execution

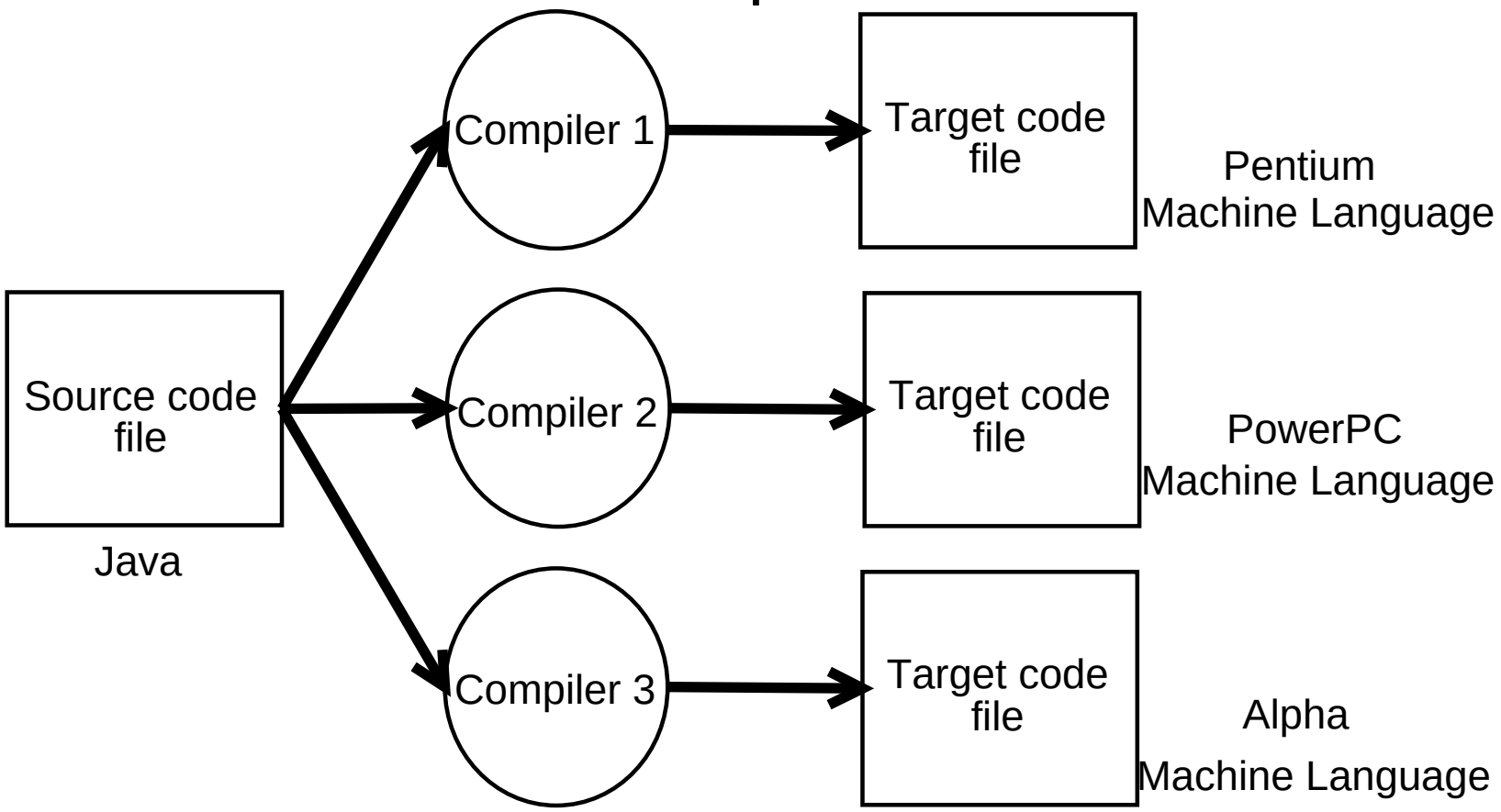
Editing



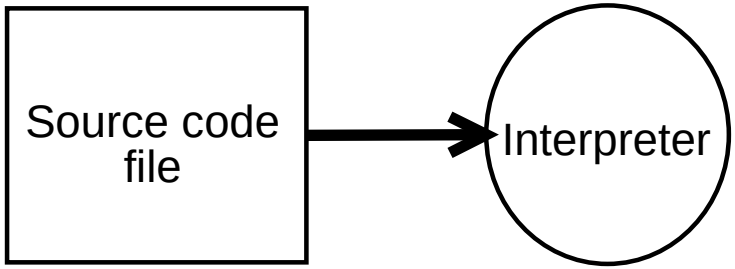
Compilers


Source code file
Compiler
Target code file
Java
Machine Language

Compilers

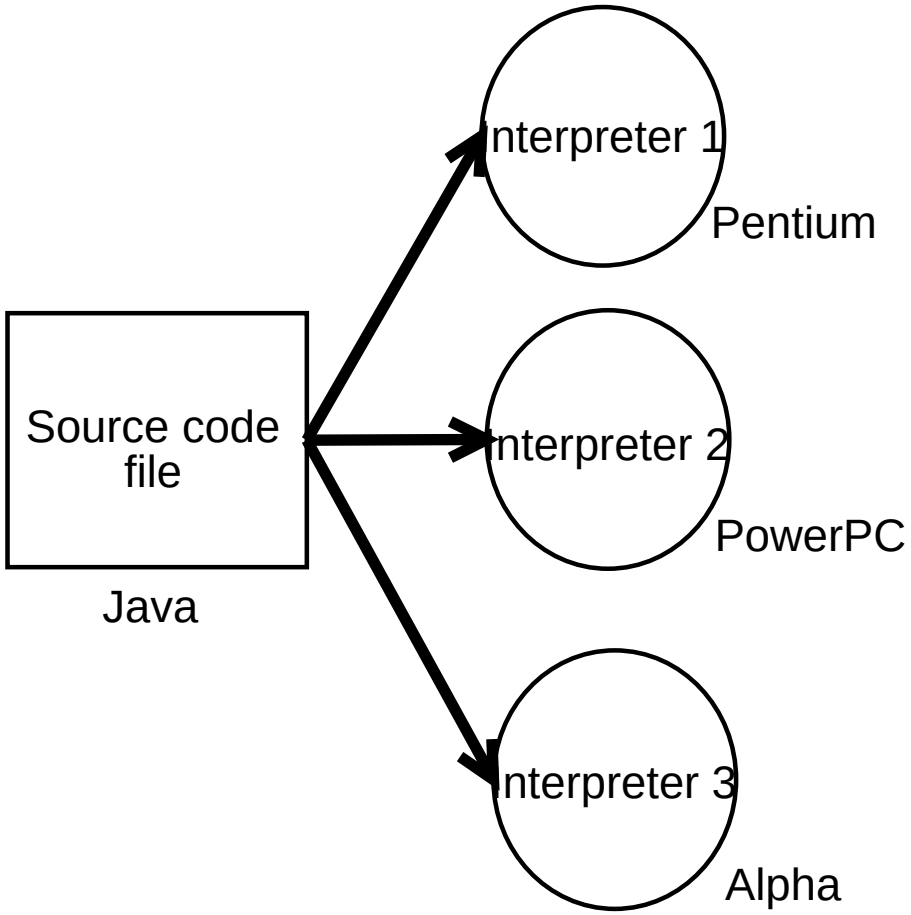

Compiler 1
Target code file
Pentium Machine Language
Source code file
Java
Compiler 2
Target code file
PowerPC Machine Language
Compiler 3
Target code file
Alpha Machine Language

Compilers

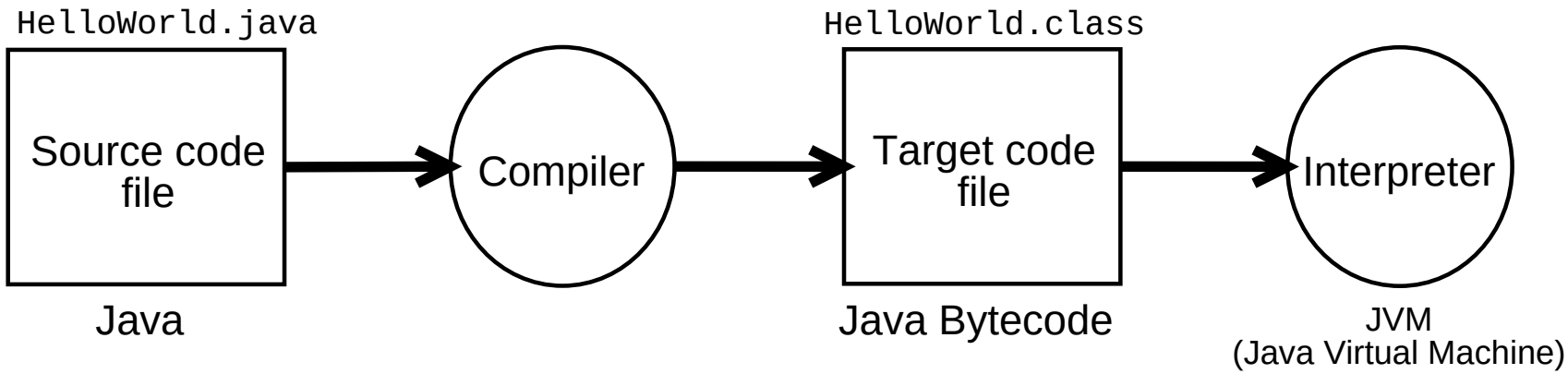


Java

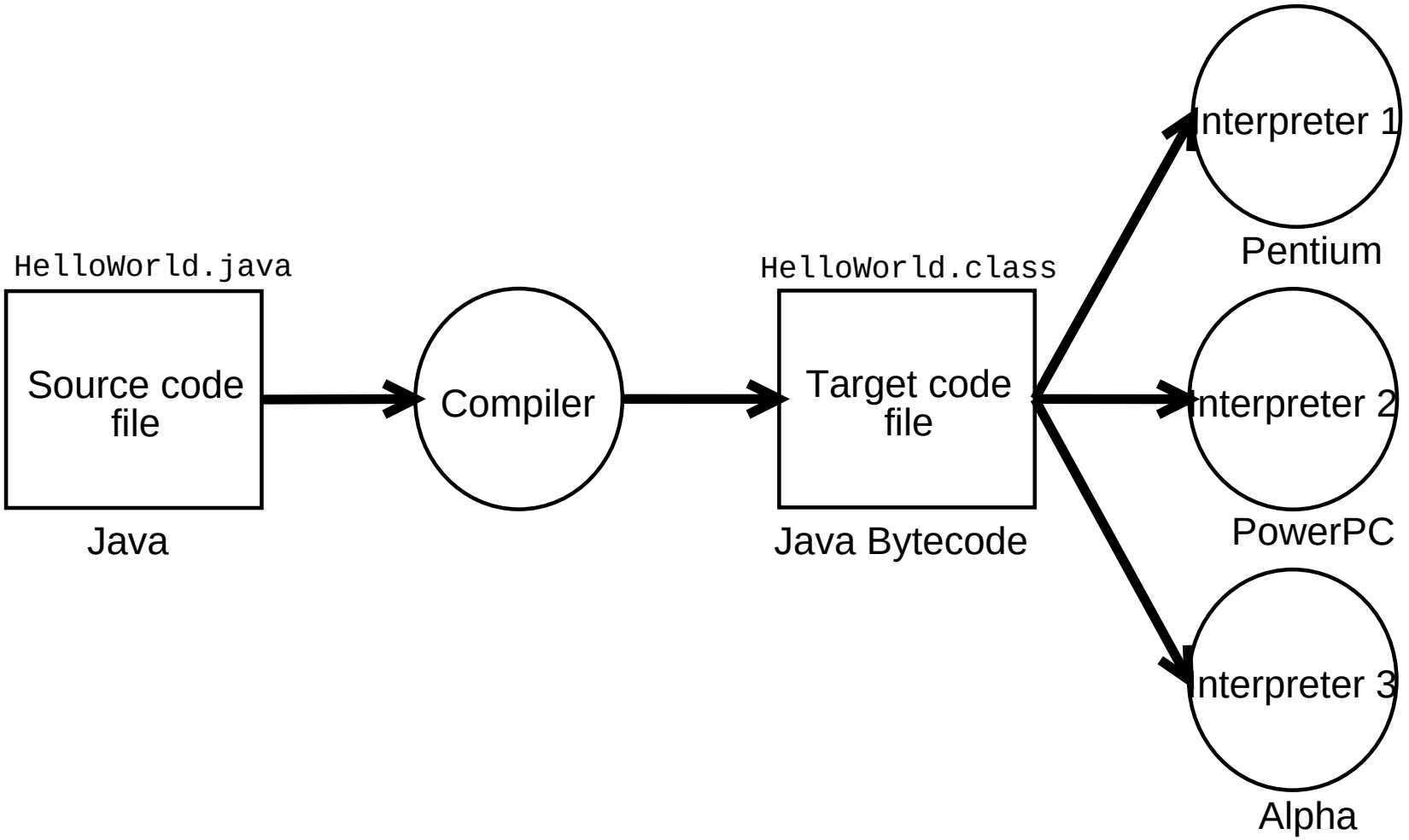
Compilers


Interpreter 1
Pentium
Source code file
Java
Interpreter 2
PowerPC
Interpreter 3
Alpha

Compilers


HelloWorld.java
Source code file
Compiler
HelloWorld.class
Target code file
Interpreter
Java
Java Bytecode
JVM
(Java Virtual Machine)

Compilers


HelloWorld.java
Source code file
Java
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HelloWorld.class
Target code file
Java Bytecode
Interpreter 1
Pentium
Interpreter 2
PowerPC
Interpreter 3
Alpha

Programming Languages

- A programming language is a formal language to describe algorithms
- A language is a means of communication
- A programming language is a means of communication between a human and a computer, but also between humans
- A programming language is formal: well-defined

Languages

- Elements of a language
  - Alphabet
  - Syntax (grammar)
  - Semantics (meaning)
- Elements of Java:
  - Alphabet of Java: ASCII
  - Syntax: 'constructs'
    - Class definitions
    - Method definitions
    - Statements
    - others
  - Semantics: computation

Errors

- Errors:
  - Compile-time errors
  - Run-time errors
    - Exceptions
    - Logical

Programming Languages

- Machine language (binary, processor dependent)
- Assembly language (textual, low-level, processor dependent)
- High-level languages (textual, abstract, processor independent)
  - There are many high-level languages: Java, C, C++, C#, ML, Haskell, Scheme, Prolog, Python, Perl, etc.
  - Different types of languages:
    - Imperative
      - Procedural
      - Object Oriented
      - Concurrent
    - Declarative:
      - Functional
      - Logic
    - Mixed

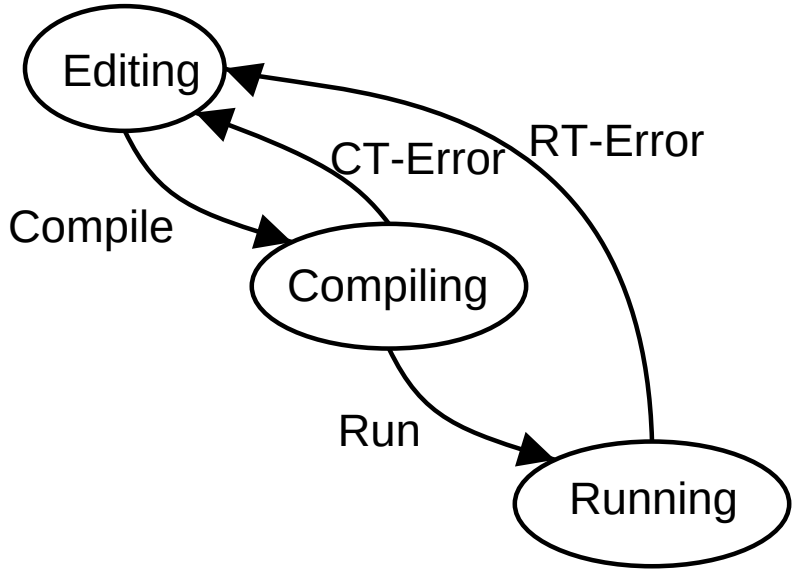
Executing programs

- Editing
- Compilation/Interpretation
  - (Native) Compilation: Translation to machine language + Execution
    - Advantages: Fast, processor specific code is generated
    - Disadvantage: Needs a compiler for each type of processor; generates a different target file for each type of processor
  - Interpretation: Direct execution
    - Advantages: Execution is processor independent. Does not generate a different target file for each possible processor (portability)
    - Disadvantage: Slow execution due to overhead of interpretation.
  - Combined: Translation to bytecode + interpretation of bytecode
    - Best of both worlds: Only one file is generated (portable) and it is faster to execute than direct interpretation (but slower than native compilation.)

Errors

- Errors:
  - Compile-time errors
  - Run-time errors
    - Exceptions
    - Logical

Errors



Basic Java Syntax

- A Java program is made up of one or more *class definitions*
- A class definition is made up of zero or more *method definitions*
- A method definition is made up of zero or more *statements* and *variable declarations*
- Roles:
  - Classes: Modules and Types of objects
  - Methods: procedures, functions, algorithms
  - Statements: instructions

Basic Java Syntax

```
public class ClassName
{
    // Body of ClassName
    // ...
    // List of method definitions
}
```

Basic Java Syntax

```
public class HelloWorld
{
   // Body of ClassName
   // ...
   // List of method definitions
}
```

Basic Java Syntax

```
public class Classname
{
    // method header
    {
        // method body: list of statements
    }
}
```

Basic Java Syntax

```
public class HelloWorld
{
    public static void main(String[] args)
    {
        System.out.println("Hello");
        System.out.println("Good bye");
    }
}
```

Bad Java Syntax

```
public class HelloWorld
{
    System.out.println(“Hello”);
    System.out.println(“Good bye”);
}
```

Bad Java Syntax

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

Bad Java Syntax

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

Indentation

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

Indentation

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

Indentation

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

Indentation

```
public class HelloWorld{public static void main(St
ring[] args){System.out.println(“Hello”);System.ou
t.println(“Good bye”);}}
```

User Interface

- The user interface of a program is the way it interacts with the user: keyboard/mouse/windows/text
- Graphical User Interface:
  - Windows: buttons, text boxes, slidebars, graphics, etc.
  - Input with mouse and keyboard.
- Textual User Interface:
  - Console window: plain text
  - Input: keyboard only
  - Output:

```
System.out.println("text");
```

Introduction to statements

- The print statement

```
System.out.println(string_literal);
System.out.print(string_literal);
```

- String literals:

```
"(almost)any characters"
"This is a string literal"
"String literals can contain almost any character,
"a"
""
"24"
```

Introduction to statements

- String concatenation:

  string_literal + *string_literal*
  string_literal + *number_literal*

  “This is a ”+“message”
  “This is a message”
  “There are ”+70+“ students in this class”

- String literals with numbers are not numbers: “17” is not the same as 17

  “17” + “29”

is

  “1729”

while

  17 + 29

is

  46

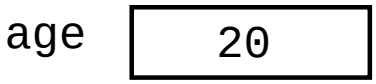
Simple programs

```
// File: PrintingStuff.java
public class PrintingStuff
{
    public static void main(String[] args)
    {
        System.out.println(“This trivial program j
        System.out.println(“prints this text to a
        System.out.println(“Window.”);
    }
}
```

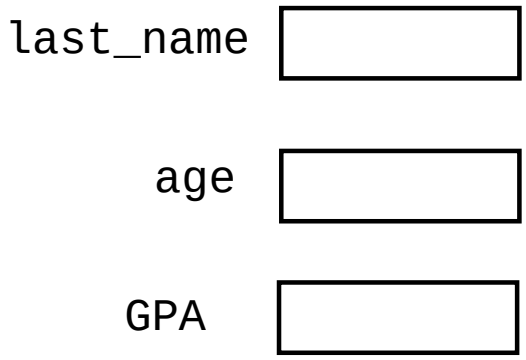
Variables

- A variable is a memory location
- A variable can contain information
- A variable has a symbolic name

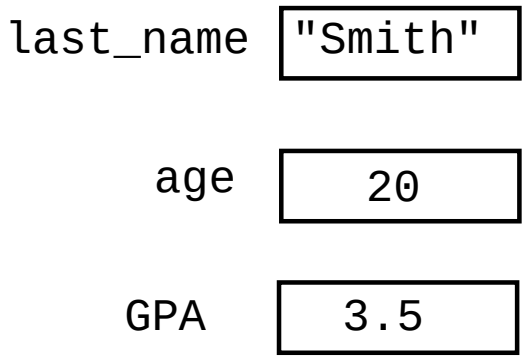
Variables



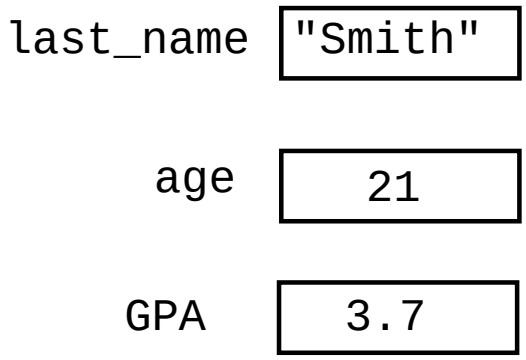
Variables



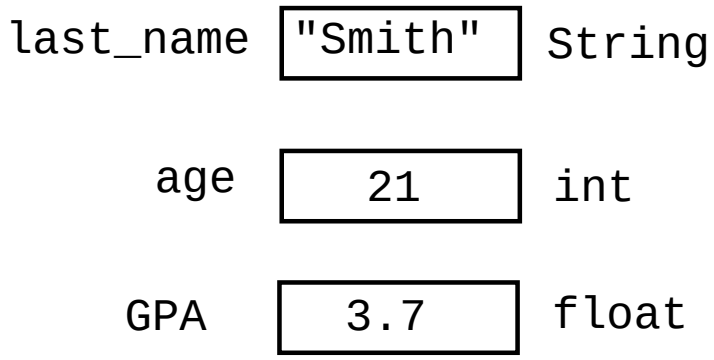
Variables



Variables



Variables



Variable declaration

- A *variable declaration* is a statement that declares tha a variable is going to be used.
- A variable declaration goes inside some method
- A variable declaration has the form:

  type identifier ;

- Examples:

```
String last_name;
int age;
float GPA;
```

Assignment

- An *assignment* is a statement that gives a value to a variable
- An assignment goes inside some method
- An assignment has the form:

  variable = *value*;

- Its meaning it to put the value into the memory location of the variable
- Examples:

```
last_name = "Smith";
age = 20;
```

- Note that the following are *incorrect*:

```
20 = age;
"Smith" = last_name;
```

Assignment

- The variable must be declared before being assigned a value

```
String last_name;
last_name = “Smith”;
```

- But the following is wrong:

```
age = 20;
int age;
```

- The type of the value must be the same as the type of the variable

```
last_name = 20; // Incorrect
age = “Smith”; // Incorrect
```

Variables and String expressions

- Variables can be used with concatenation in String expressions

  “`your age is ”+age`

- is equivalent to

  “`your age is 19`”

- if the variable age contains the value 19

A simple program

```
public class PrintData
{
  public static void main(String[] args)
  {
    String last_name;
    int age;
    last_name = “Smith”;
    age = 20;
    System.out.println(“Your last name is ” + last_name);
    System.out.println(“You are ” + age + “ years old”);
  }
}
```

Java Syntax

- Class definitions

```
public class {
    // methods
}
```

- Method definitions (inside a class)

```
// method header/signature
{
    // statements
}
```

Basic java programs

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

Statements

- Print statement

```
System.out.println(string_expression);
```

- Variable declaration

```
type identifier;
```

- Assignment

```
variable = value;
```

- Statements in a method are executed in *sequential order* from top to bottom

Assignment

- In an assignment

```
variable = value;
```

- the variable must have been declared before,

```
x = 7; // incorrect
int x;
```

- the type of the variable must match the type of the value

```
int x;
x = "7"; // incorrect
```

Sequential execution

```
public class OrderTest
{
    public static void main(String[] args)
    {
        int a;
        int b;
        a = 2;
        b = 3;
        b = 5;
        a = 8;
        System.out.println(a);
        System.out.println(b);
    }
}
```

Sequential execution

```
public class OrderTest
{
    public static void main(String[] args)
    {
        int a;
        int b;
        b = 5;
        a = 8;
        a = 2;
        b = 3;
        System.out.println(a);
        System.out.println(b);
    }
}
```

Sequential execution

```
public class OrderTest
{
    public static void main(String[] args)
    {
        int a;
        int b;
        a = 2;
        b = 5;
        a = 8;
        b = 3;
        System.out.println(a);
        System.out.println(b);
    }
}
```

Some syntactic shortcuts

- Several variables of the same type can be declared in the same variable declaration:

  type var1, var2, ..., varn ;

- Examples:

```
int a;
int b;
```

is equivalent to

```
int a, b;
```

Some syntactic shortcuts

- A variable can be initialized when declared

```
int a;
a = 2;
```

is equivalent to

```
int a = 2;
```

- But a variable cannot be redeclared, so

```
int b = 3;
int b = 2;
```

is incorrect, while the following is correct

```
int b = 3;
b = 2;
```

User Interface

- Interaction between the user and some program
- Textual UI
  - Output:

    ```
    System.out.println(string_expression);
    ```

  - Input:

    ```
    scanner.nextInt();
    scanner.nextLine();
    ```

- Examples:

```
Scanner myScanner = new Scanner(System.in);
int n;
n = myScanner.nextInt();
```

User Interface

```
import java.util.Scanner;
public class UserInputTest {
    public static void main(String[] args)
    {
        Scanner myScanner = new Scanner(System.in);
        String name;
        int age;
        System.out.print(“Enter your name: ”);
        name = myScanner.nextLine();
        System.out.print(“Enter your age: ”);
        age = myScanner.nextInt();
        System.out.println(“Your name is ” + name);
        System.out.println(“You are ” + age + “ years old”);
    }
```

```
}
```

The end