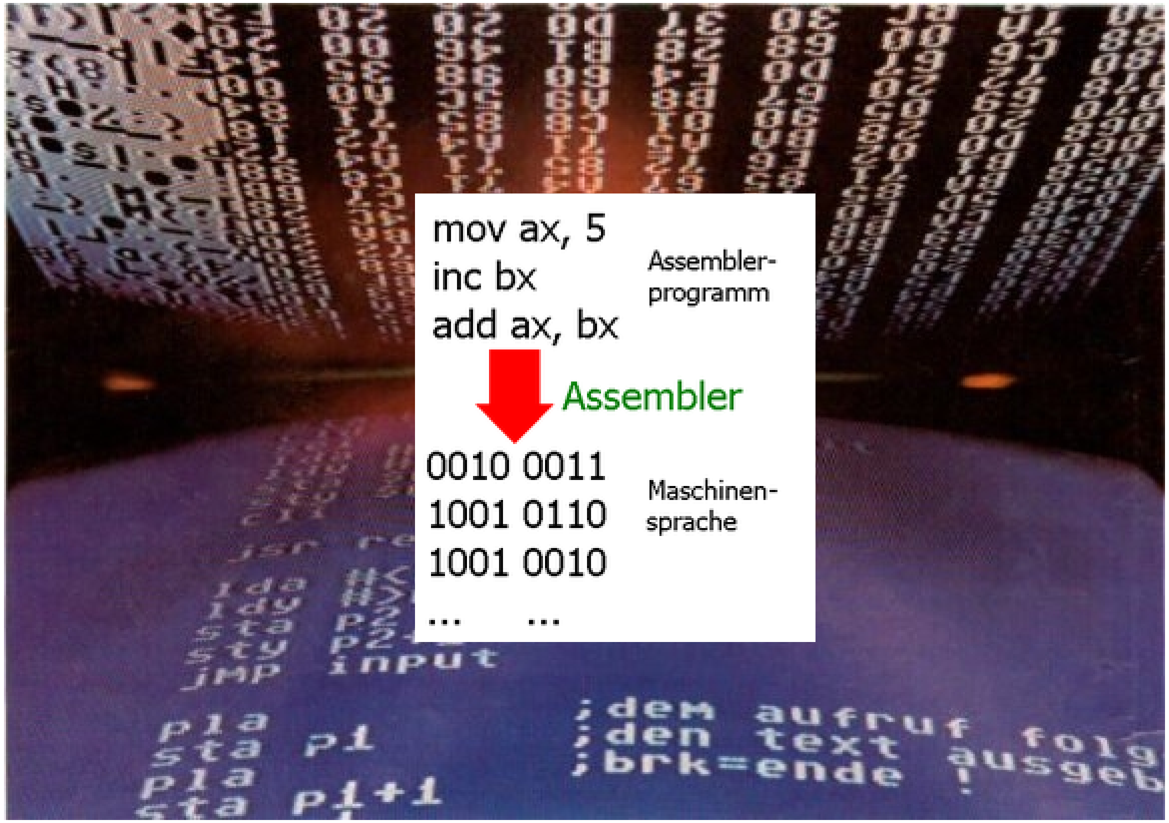
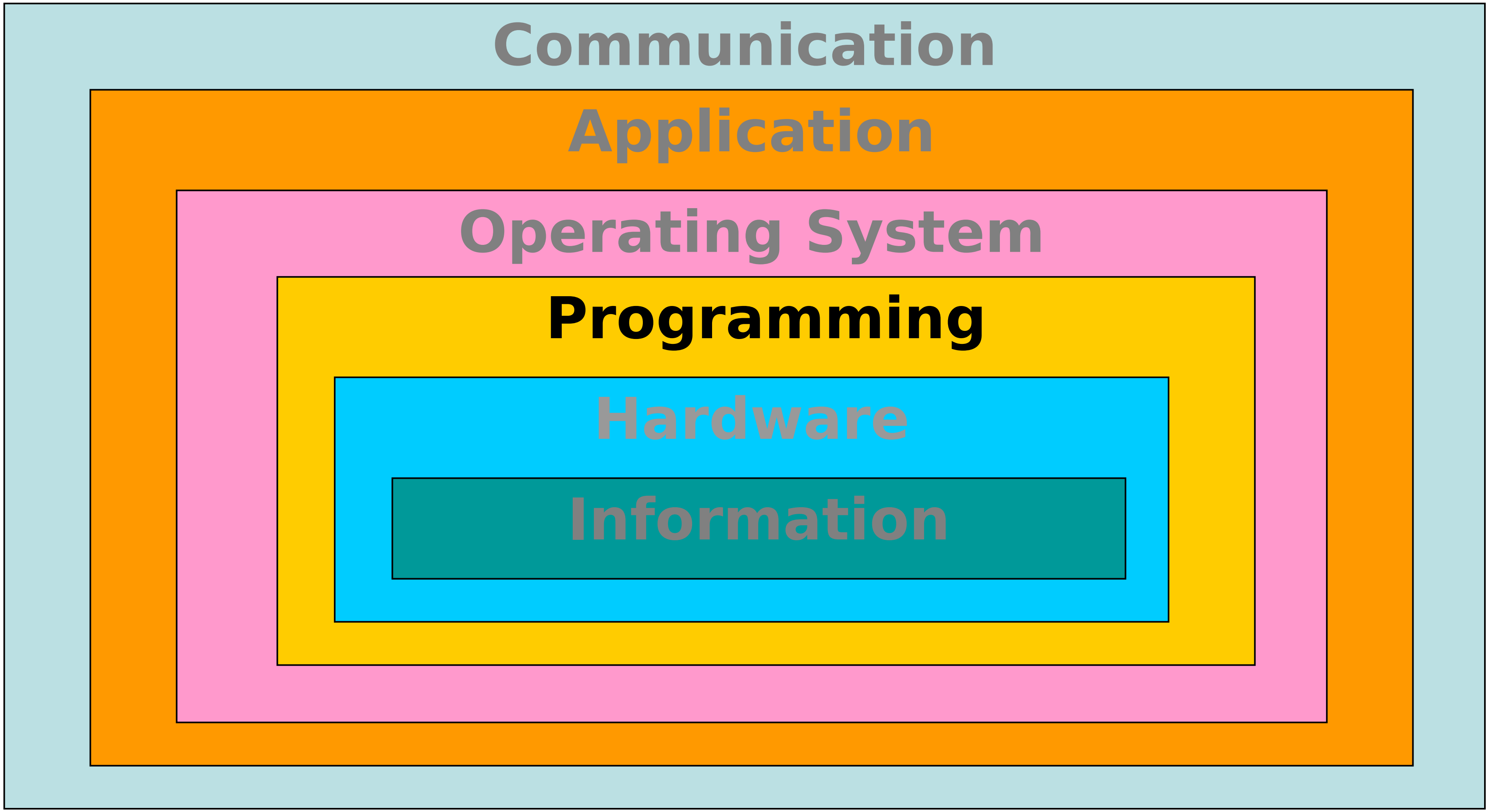
Chapter 7

Low Level Programming Languages



Layers of a Computing System



Chapter Goals

- List the operations that a computer can perform
- Describe the important features of a virtual computer
- Distinguish between immediate mode addressing and direct addressing
- Convert a simple algorithm into a machine-language program
- Distinguish between machine language and assembly language
- Describe the steps in creating and running an assembly-language program

Computer Operations

- A computer is a programmable electronic device that can store, retrieve, and process data
- Data and instructions to manipulate the data are logically the same and can be stored in the same place
- Store, retrieve, and process are actions that the computer can perform on data

Machine Language

- **Machine language** The instructions built into the hardware of a particular computer
- Initially, humans had no choice but to write programs in machine language because other programming languages had not yet been invented

Machine Language

- Every processor type has its own set of specific machine instructions
- The relationship between the processor and the instructions it can carry out is completely integrated
- Each machine-language instruction does only one very low-level task

Pep/7: A Virtual Computer

- **Virtual computer** A hypothetical machine designed to contain the important features of real computers that we want to illustrate
- Pep/7
  - designed by Stanley Warford
  - has 32 machine-language instructions
- We are only going to examine a few of these instructions

Features in Pep/7

- The memory unit is made up of 4,096 bytes
- Pep/7 Registers/Status Bits Covered
  - The program counter (PC) (contains the address of the next instruction to be executed)
  - The instruction register (IR) (contains a copy of the instruction being executed)
  - The accumulator (A register)
  - Status bit N (1 if A register is negative; 0 otherwise)
  - Status bit Z (1 if the A register is 0; and 0 otherwise)

Features in Pep/7

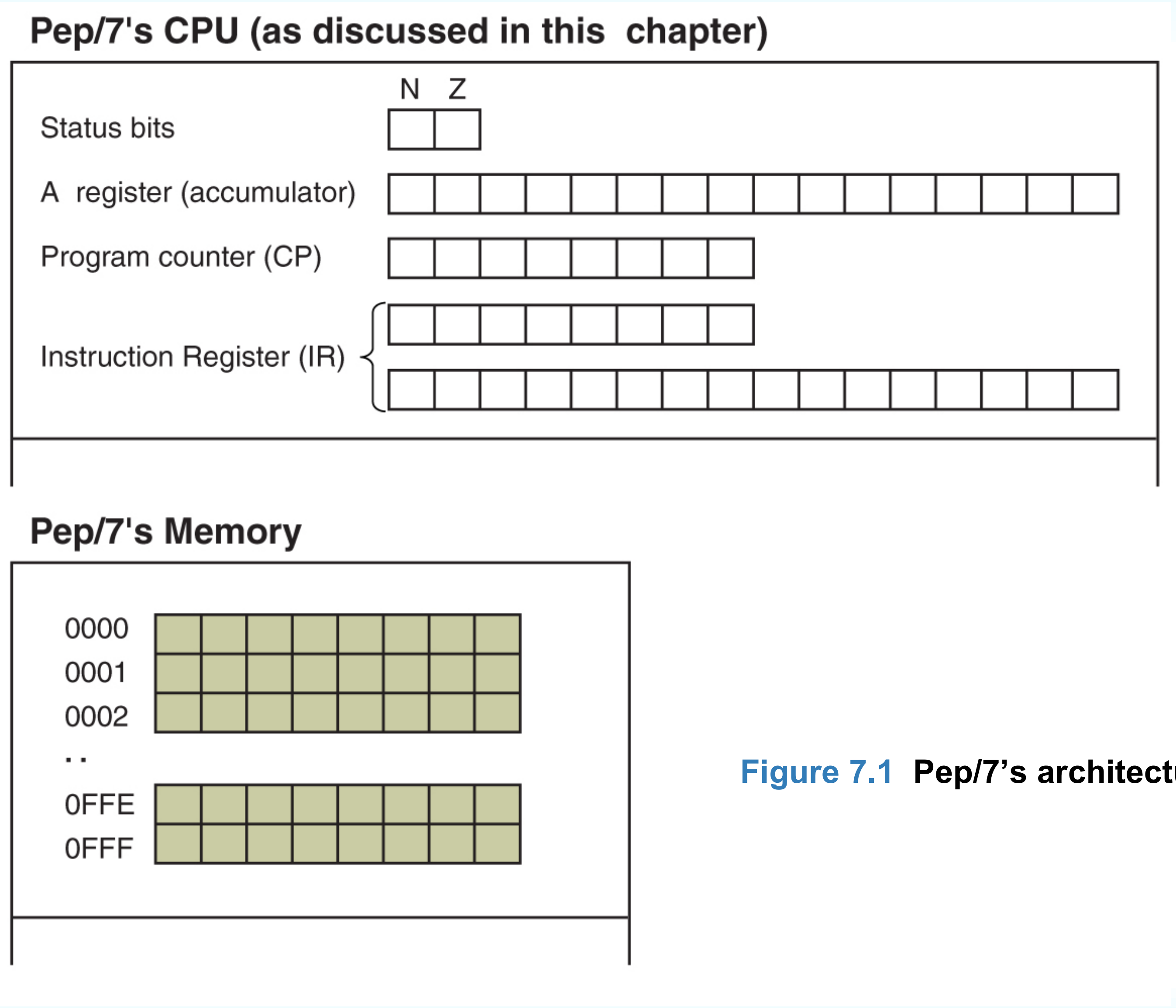
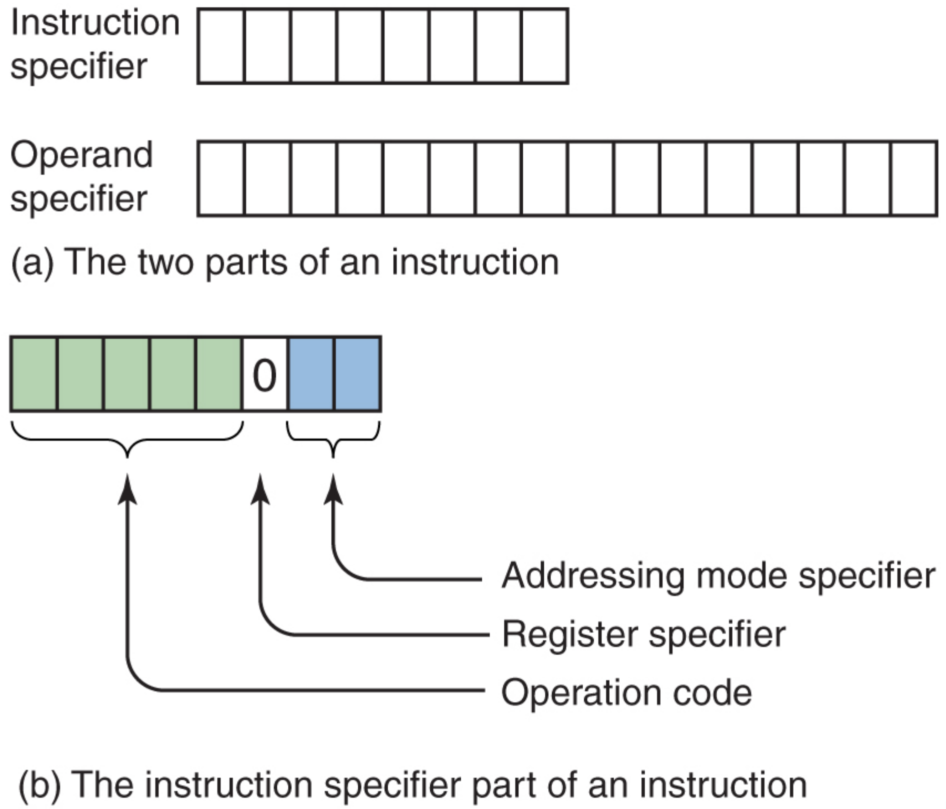


Figure 7.1 **Pep/7's architecture**

Instruction Format

- There are two parts to an instruction
  - The 8-bit instruction specifier
  - And optionally, the 16-bit operand specifier



Instruction Format

- The instruction specifier is made up of several sections
  - The operation code
  - The register specifier
  - The addressing-mode specifier

Instruction Format

- The *operation code* specifies which instruction is to be carried out
- The 1-bit *register specifier* is 0 if register A (the accumulator) is involved, which is the case in this chapter.
- The 2-bit *addressing-mode specifier* says how to interpret the operand part of the instruction

Instruction Format

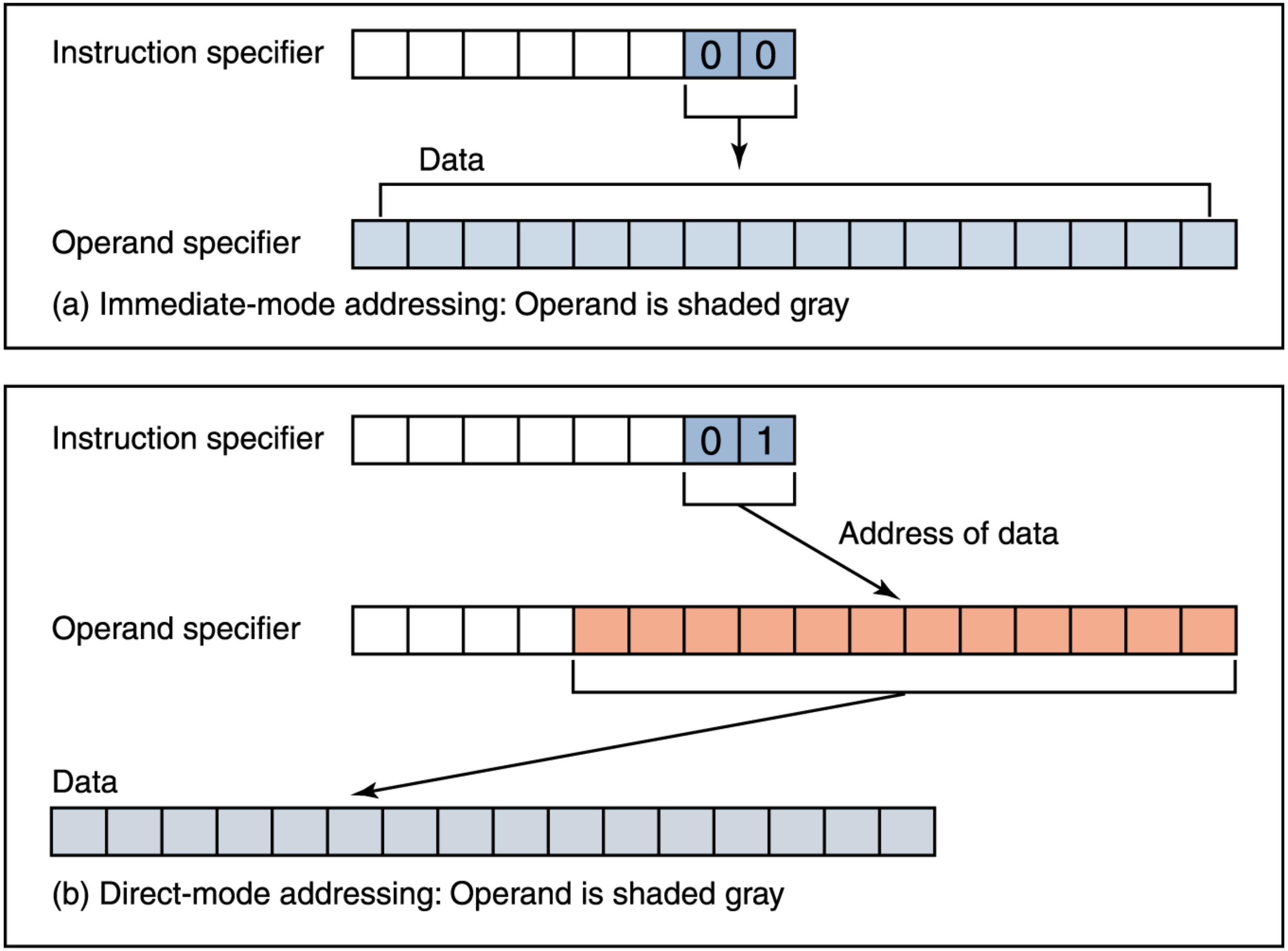


Figure 7.3 **Difference between immediate-mode and direct-mode addressing**

Some Sample Instructions

Opcode	Meaning of Instruction
00000	Stop execution
00001	Load operand into a register (either A of X)
00010	Store the contents of register (either A or X) into operand
00011	Add the operand to register (either A or X)
00100	Subtract the operand from register (either A or X)
11011	Character input to operand
11100	Character output from operand

Figure 7.3 **Subset of Pep/7 instructions**

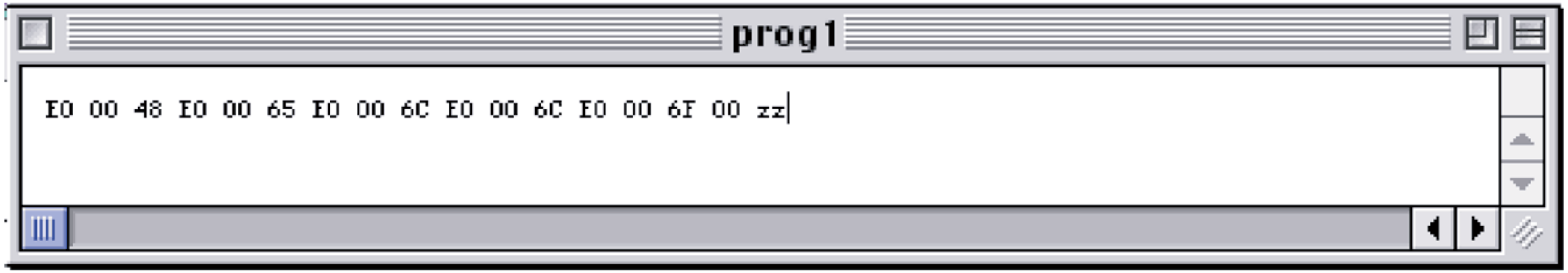
A Program Example

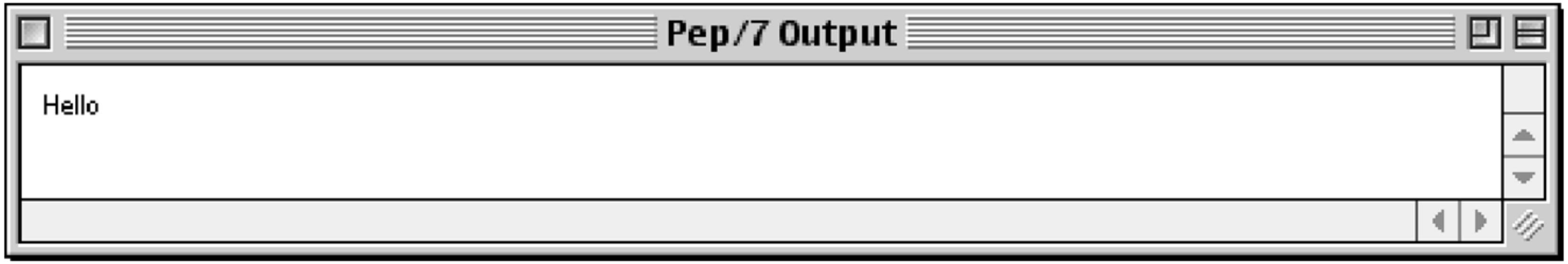
- Let’s write "Hello" on the screen

Module	Binary Instruction	Hex Instruction
Write "H"	11100000 0000000001001000	E0 0048
Write "e"	11100000 0000000001100101	E0 0065
Write "l"	11100000 0000000001101100	E0 006C
Write "l"	11100000 0000000001101100	E0 006C
Write "o"	11100000 0000000001101111	E0 006F
Stop	00000000	00

Pep/7 Simulator

- A program that behaves just like the Pep/7 virtual machine behaves
- To run a program, we enter the hexadecimal code, byte by byte with blanks between each





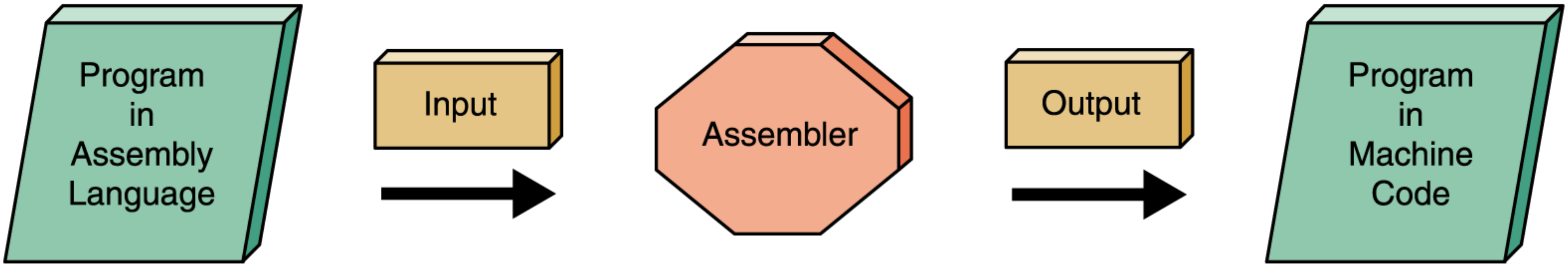
Assembly Language

- **Assembly languages** A language that uses mnemonic codes to represent machine-language instructions
  - The programmer uses these alphanumeric codes in place of binary digits
  - A program called an assembler reads each of the instructions in mnemonic form and translates it into the machine-language equivalent

Pep/7 Assembly Language

Mnemonic	Operand, Mode Specifier	Meaning of Instruction
STOP		Stop execution
LOADA LOADA	h#008B,i h#008B,d	Load 008B into register A Load the contents of location 8B into register A
STOREA	h#008B,d	Store the contents of register A into location 8B
ADDA ADDA	h#008B,i h#008B,d	Add 008B to register A Add the contents of location 8B to register A
SUBA SUBA	h#008B,i h#008B,d	Subtract 008B from register A Subtract the contents of location 8B from register A
CHARI	h#008B,d	Read a character and store it into byte 8B
CHARO	c#/B/,i h#008B,d	Write the character B Write the character stored in byte 8B
DECI DECO DECO	h#008B,d h#008B,i h#008B,d	Read a decimal number and store it into location 8B Write the decimal number 139 (8B in hex) Write the decimal number stored in 8B

Assembly Process



A Simple Program

Set sum to 0
Read num1
Add num1 to sum
Read num2
Add num2 to sum
Read num3
Add num3 to sum
Write sum

Our Completed Program

```
        BR Main          ;branch to location Main
sum:    .WORD d#0        ;set up word with zero as the contents
num1:   .BLOCK d#2       ;set up a two byte block for num1
num2:   .BLOCK d#2       ;set up a two byte block for num2
num3:   .BLOCK d#2       ;set up a two byte block for num3
Main:   LOADA sum,d      ;load a copy of sum into accumulator
        DECI num1,d      ;read and store a decimal number in num1
        ADDA num1,d      ;add the contents of num1 to accumulator
        DECI num2,d      ;read and store a decimal number in num2
        ADDA num2,d      ;add the contents of num2 to accumulator
        DECI num3,d      ;read and store a decimal number in num3
        ADDA num3,d      ;add the contents of num2 to accumulator
        STOREA sum,d     ;store contents of the accumulator into sum
        DECO sum,d       ;output the contents of sum
        STOP             ;stop the processing
        .END             ;end of the program
```

Status Bits

Status bits allow a program to make a choice.

BRLT Set the PC to the operand, if N is 1

(A register is *less than* zero)

BREQ Set the PC to the operand, if Z is 1

(A register is *equal to* zero)

Testing

- **Test plan** A document that specifies how many times and with what data the program must be run in order to thoroughly test the program
- A **code-coverage** approach designs test cases to ensure that each statement in the program is executed.
- A **data-coverage** approach designs test cases to ensure that the limits of the allowable data are covered.

Chapter 8

High Level Programming Languages

Chapter Goals

- Describe the translation process and distinguish between assembly, compilation, interpretation, and execution
- Name four distinct programming paradigms and name a language characteristic of each
- Describe the following constructs: stream input and output, selection, looping, and subprograms
- Construct Boolean expressions and describe how they are used to alter the flow of control of an algorithm
- . . . Some Hands-On

Compilers

- **Compiler** A program that translates a high-level language program into machine code
- High-level languages provide a richer set of instructions that makes the programmer's life even easier

Compilers

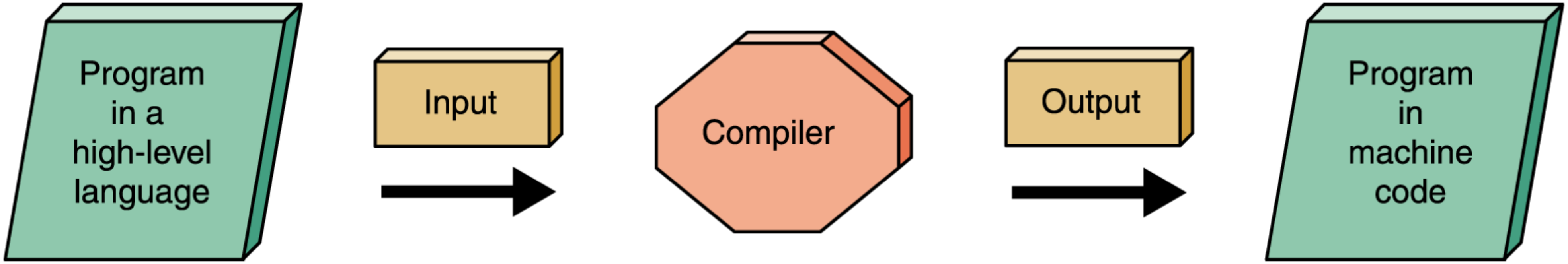


Figure 8.1 **Compilation process**

Interpreters

- **Interpreter** A translating program that translates and executes the statements in sequence
  - Unlike an assembler or compiler which produce machine code as output, which is then executed in a separate step
  - An interpreter translates a statement and then immediately executes the statement
  - Interpreters can be viewed as *simulators*

Java

- Introduced in 1996 and swept the computing community by storm
- Portability was of primary importance
- Java is compiled into a standard machine language called **Bytecode**
- A software interpreter called the JVM (Java Virtual Machine) takes the Bytecode program and executes it

Programming Language Paradigms

- *What is a paradigm*?
- A set of assumptions, concepts, values, and practices that constitute a way of viewing reality

Programming Language Paradigms

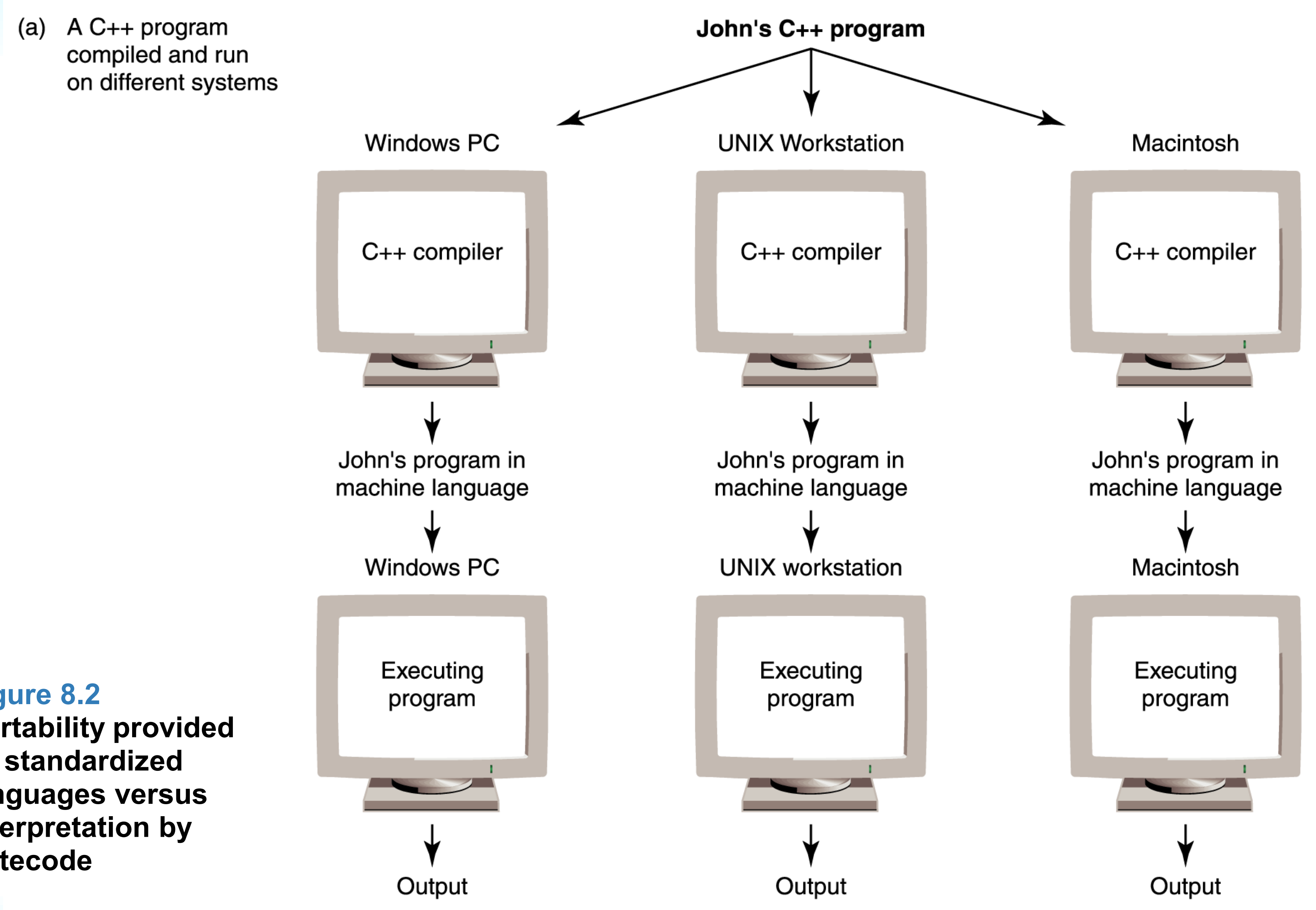


Figure 8.2
Portability provided by standardized languages versus interpretation by Bytecode

Programming Language Paradigms

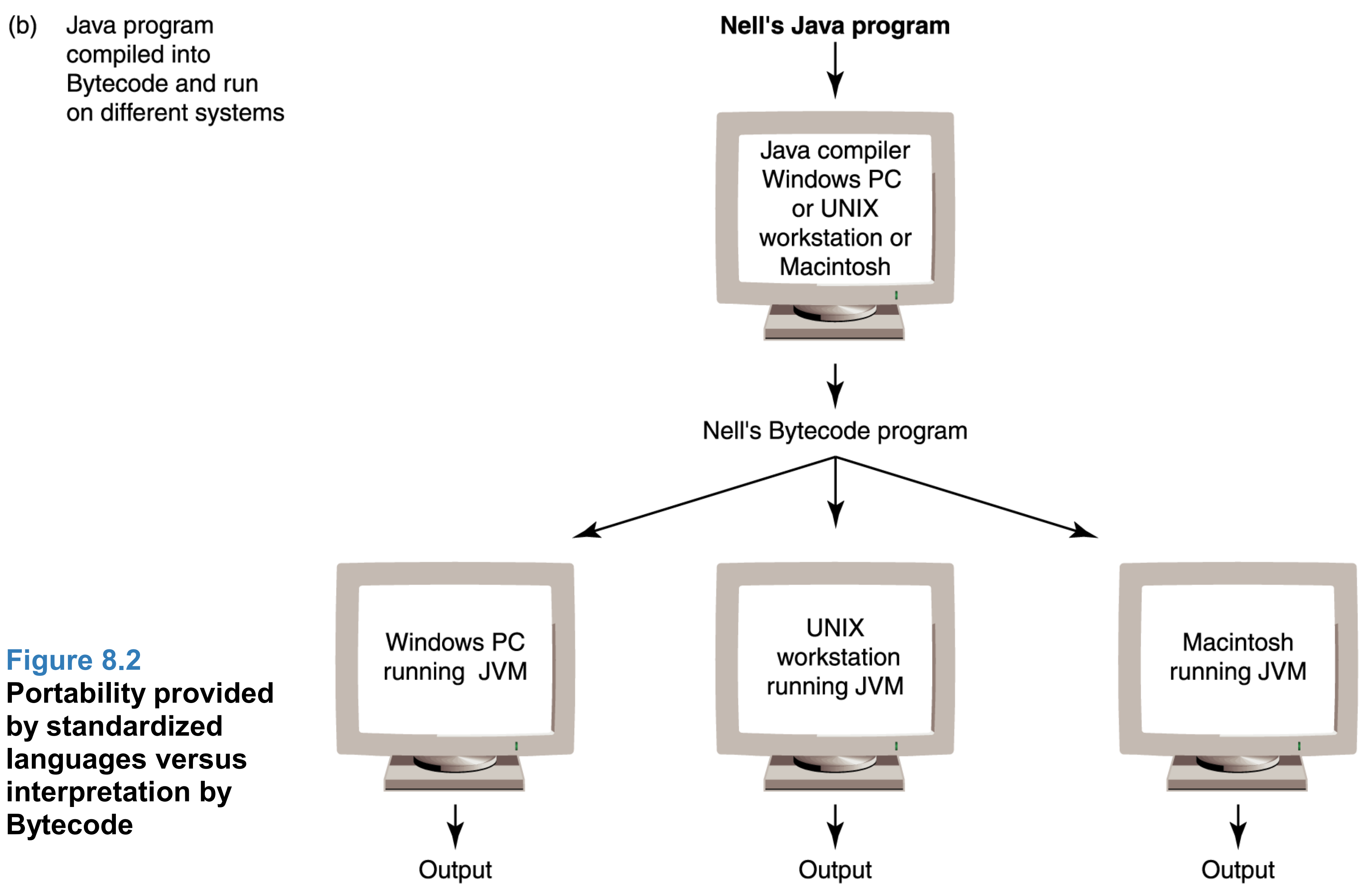


Figure 8.2
Portability provided by standardized languages versus interpretation by Bytecode

Programming Language Paradigms

- Imperative or procedural model
  - FORTRAN, COBOL, BASIC, C, Pascal, Ada, and C++
- Functional model
  - LISP, Scheme (a derivative of LISP), and ML

Programming Language Paradigms

- Logic programming
  - PROLOG
- Object-oriented paradigm
  - SIMULA and Smalltalk
  - C++ is as an imperative language with some object-oriented features
  - Java is an object-oriented language with some imperative features

Functionality of Imperative Languages

- **Sequence** Executing statements in sequence until an instruction is encountered that changes this sequencing
- **Selection** Deciding which action to take
- **Iteration** (looping) Repeating an action

Both selection and iteration require the use of a Boolean expression

Boolean Expressions

- **Boolean expression** A sequence of identifiers, separated by compatible operators, that evaluates to *true* or *false*
- Boolean expression can be
  - A Boolean variable
  - An arithmetic expression followed by a relational operator followed by an arithmetic expression
  - A Boolean expression followed by a Boolean operator followed by a Boolean expression

Boolean Expressions

- **Variable** A location in memory that is referenced by an identifier that contains a data value

  Thus, a Boolean variable is a location in memory that can contain either *true* or *false*

Boolean Expressions

- A relational operator between two arithmetic expressions is asking if the relationship exists between the two expressions
- For example, *xValue* < *yValue*

Relationship	Symbol
equal to	= or ==
not equal to	<> or != or /=
less than or equal to	<=
greater than or equal to	>=
less than	<
greater than	>

Strong Typing

- **Strong typing** The requirement that only a value of the proper type can be stored into a variable
- **Data type** A description of the set of values and the basic set of operations that can be applied to values of the type

Data Types

- Integer numbers
- Real numbers
- Characters
- Boolean values
- Strings

Integers

- The range varies depending upon how many bytes are assigned to represent an integer value
- Some high-level languages provide several integer types of different sizes
- Operations that can be applied to integers are the standard arithmetic and relational operations

Reals

- Like the integer data type, the range varies depending on the number of bytes assigned to represent a real number
- Many high-level languages have two sizes of real numbers
- The operations that can be applied to real numbers are the same as those that can be applied to integer numbers

Characters

- It takes one byte to represent characters in the ASCII character set
- Two bytes to represent characters in the Unicode character set
- Our English alphabet is represented in ASCII, which is a subset of Unicode

Characters

- Applying arithmetic operations to characters doesn’t make much sense
- Comparing characters does make sense, so the relational operators can be applied to characters
- The meaning of “less than” and “greater than” when applied to characters is “comes before” and “comes after” in the character set

Boolean

- The Boolean data type consists of two values: ***true*** and ***false***
- Not all high-level languages support the Boolean data type
- If a language does not, then you can simulate Boolean values by saying that the Boolean value ***true*** is represented by 1 and ***false*** is represented by 0

Strings

- A string is a sequence of characters considered as one data value
- For example: ***“This is a string.”***
  - Containing 17 characters: one uppercase letter, 12 lowercase letters, three blanks, and a period
- The operations defined on strings vary from language to language
  - They include concatenation of strings and comparison of strings in terms of lexicographic order

Declarations

- **Declaration** A statement that associates an identifier with a variable, an action, or some other entity within the language that can be given a name so that the programmer can refer to that item by name

Declarations

Language	Variable Declaration

Ada	`sum : Float := 0; --set up word with 0 as contents`
	`num1: Integer;    --set up a two-byte block for num1`
	`num2: Integer;    --set up a two-byte block for num2`
	`num3: INTEGER;    --set up a two-byte block for num3`
	`...`
	`num1:= 1;`

VB.NET	`Dim sum As Single = 0.0F ' set up word with 0 as contents`
	`Dim num1 As Integer ' set up a two-byte block for num1`
	`Dim num2 As Integer ' set up a two-byte block for num2`
	`Dim num3 As Integer ' set up a two-byte block for num3`
	`...`
	`num1 = 1`

C++/Java	`float sum = 0.0;    // set up word with 0 as contents`
	`int num1;           // set up a block for num1`
	`int num2;           // set up a block for num2`
	`int num3;           // set up a block for num3`
	`...`
	`num1 = 1;`

Declarations

- **Reserved word** A word in a language that has special meaning
- **Case-sensitive** Uppercase and lowercase letters are considered the same

Assignment statement

- **Assignment statement** An action statement (not a declaration) that says to evaluate the expression on the right-hand side of the symbol and store that value into the place named on the left-hand side
- **Named constant** A location in memory, referenced by an identifier, that contains a data value that cannot be changed

Assignment Statement

	Constant Declaration

Ada	`Comma     : constant Character := ',';`
	`Message   : constant String := "Hello";`
	`Tax_Rate : constant Float := 8.5;`

VB.NET	`Const WORD1 As Char = ","c`
	`Const MESSAGE As String = "Hello"`
	`Const TaxRate As Double = 8.5`

C++	`const char COMMA = ',';`
	`const string MESSAGE = "Hello";`
	`const double TAX_RATE = 8.5;`

Java	`final char COMMA = ',';`
	`final String MESSAGE = "Hello";`
	`final double TAX_RATE = 8.5;`

Homework

- Read Chapter Seven, Concentrate on Slides
- Read Chapter Eight, Secs 8.1 & 8.2

Mid-Term

- Take Home Exam – Non-Trivial (think!)
- Cover Chapters 1-5 & 16 & Anything Covered In Class
- Given Out: Oct 11
- **Due Back: Oct 18**
- **No Lateness!!!**
- **You can email, if you like :)**

Have A Nice Weekend!