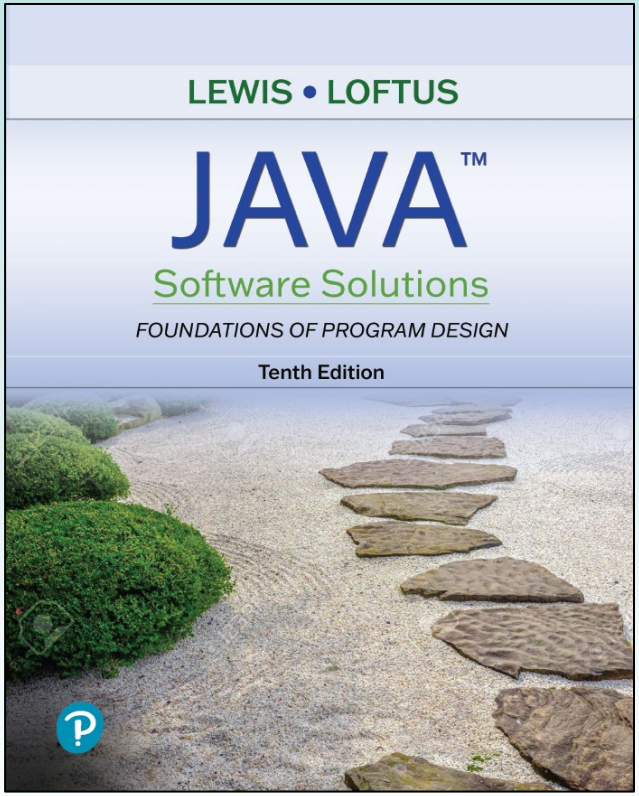
Chapter 1
Introduction



Java Software Solutions
Foundations of Program Design
10th Edition

edited BPK 08/06/2026

John Lewis
William Loftus

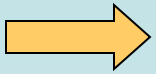
Focus of the Course

- Object-Oriented Software Development
  - Java programming language
  - program design, implementation, and testing
  - object-oriented concepts
    - classes
    - objects
    - encapsulation
    - inheritance
    - polymorphism
  - graphical user interfaces are in CS 152
    - ☺ means skip these pages

Introduction

- Chapter 1 focuses on:
  - components of a computer
  - how computers store and manipulate information
  - ☺ computer networks
    - (read on your own)
  - ☺ the Internet and the World Wide Web
    - (read on your own)
  - programming and programming languages
  - introduction to Java
  - overview of object-oriented concepts

Outline



Computer Processing

Hardware Components

☺ **Networks**

The Java Programming Language

Program Development

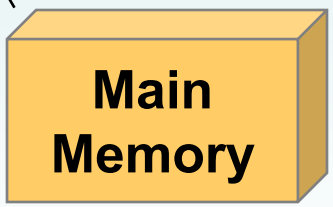
Object-Oriented Programming

§1.1 Hardware and Software

- Hardware
  - the physical, tangible parts of a computer
  - CPU, memory
  - keyboard, monitor, disks, wires, chips, etc.
- Software
  - programs and data
    - both are bit patterns stored in memory

CPU and Main Memory

Chip that executes programs: "brain" of the computer



Primary storage area for programs and data that are in active use

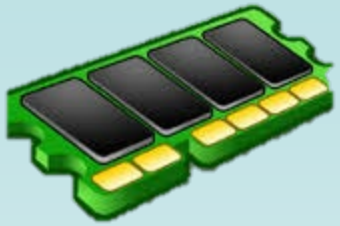
Implemented using RAM chips

CPU

- Performs the individual instructions of a program
- The “brain” of a computer system
- Processes data, directs the activity of the entire computer system
- CPU and memory are the core of a computer system
- *Processor* is another word for *CPU*

Memory

Memory is the hardware that stores information.



Storage and *memory* are synonymous.

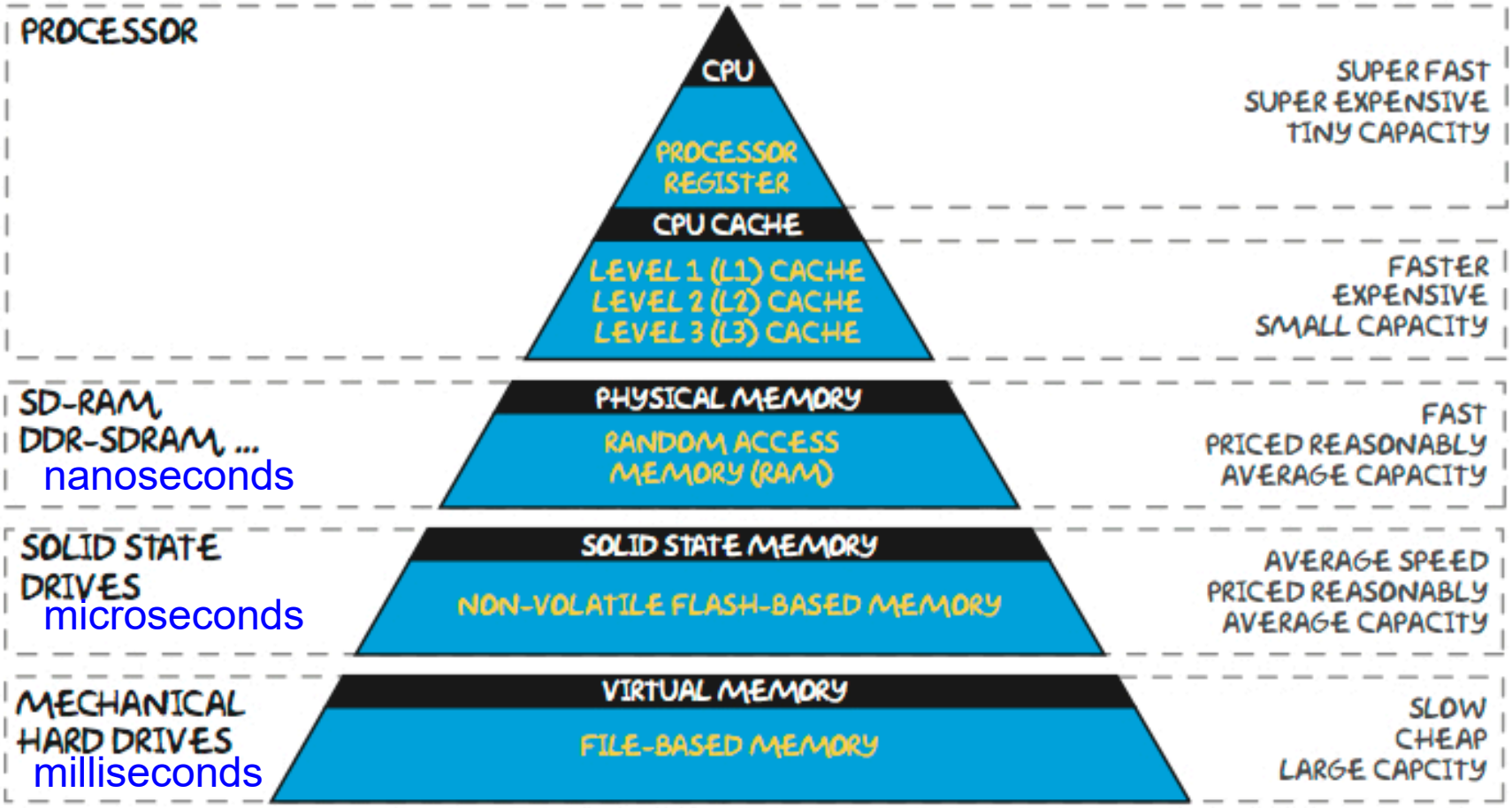
Information is encoded as **bits** (ones and zeros).

Two categories of memory:

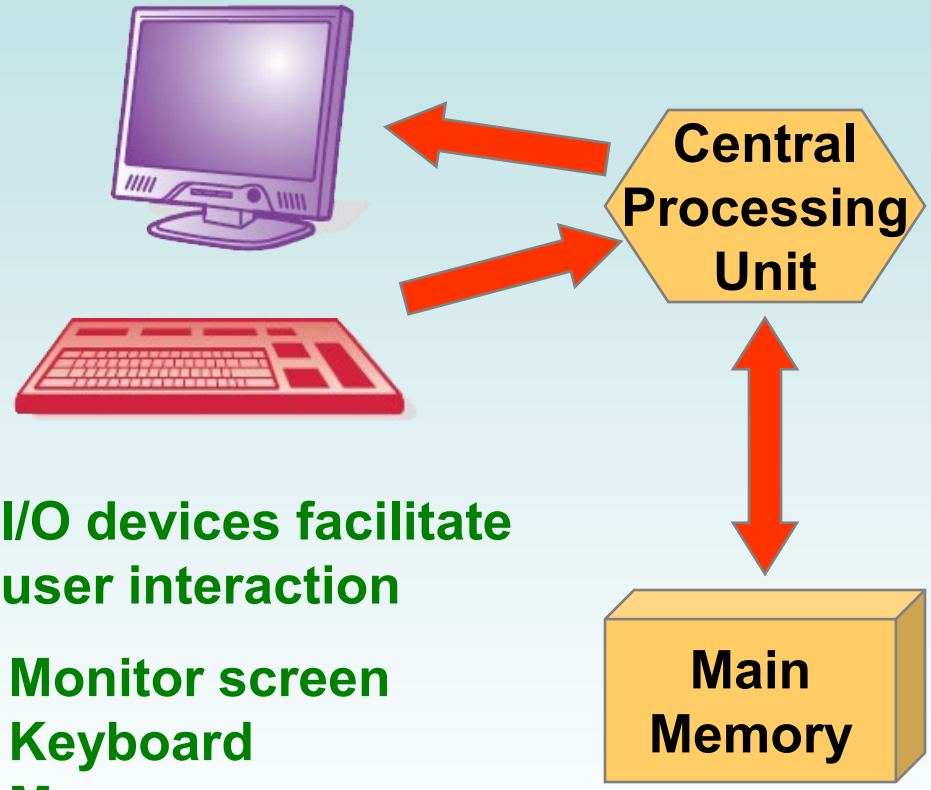
Main memory – closely connected to the processor, not permanent, fast access

Secondary memory – permanent (unless explicitly erased), large capacity, slow access

THE MEMORY HIERARCHY



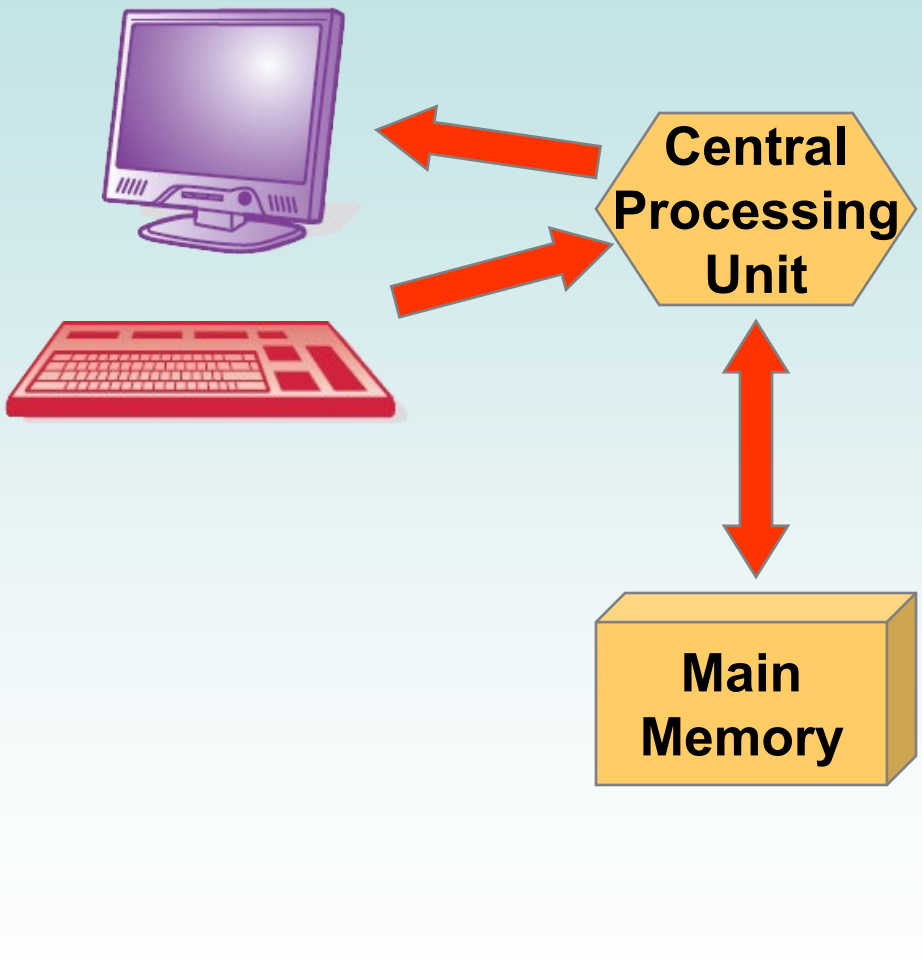
Input / Output Devices



I/O devices facilitate user interaction

Monitor screen
Keyboard
Mouse
Touch screen

Secondary Memory Devices



Secondary memory devices provide long-term storage

Information is moved between main and secondary memory as needed

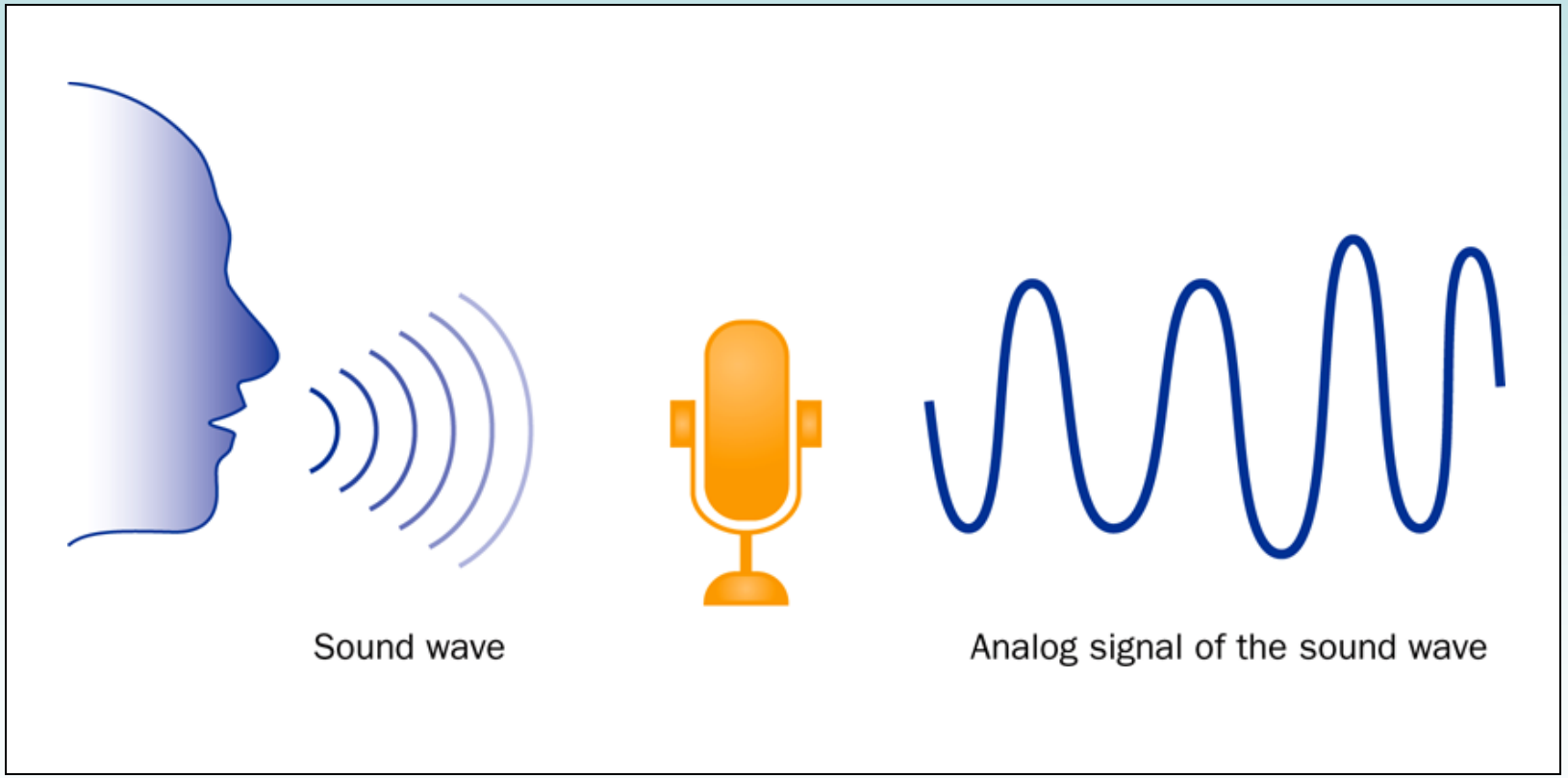
Software Categories

- Operating System (OS)
  - controls all machine activities
  - provides the user interface to the computer
  - manages resources such as the CPU and memory
  - Windows, Mac OS, Unix, Linux, Android
- Application program
  - term for software that runs under control of an OS
  - word processors, data bases, games, web browsers, music & video players
- Most operating systems and application programs have a *graphical user interface* (GUI)

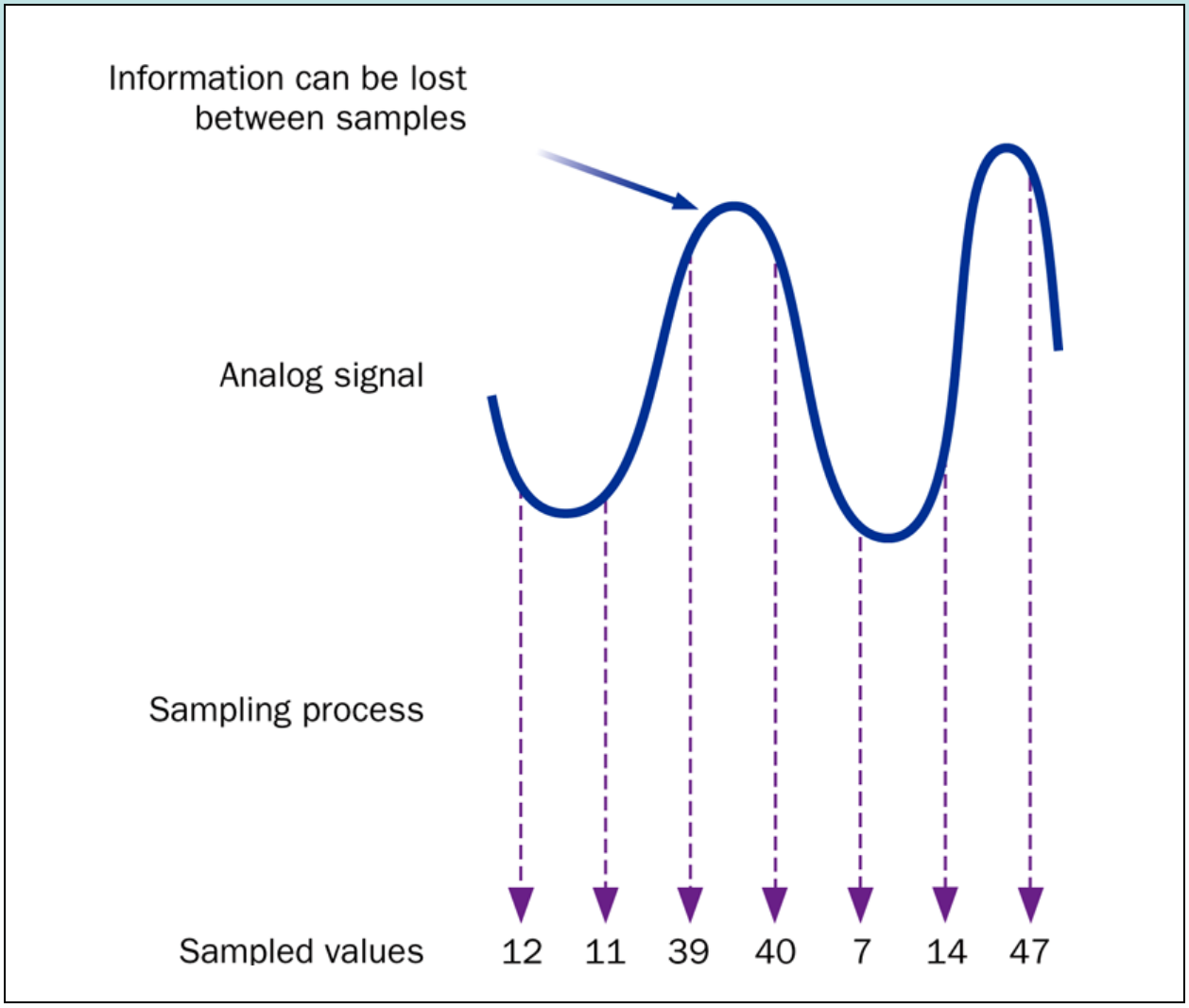
Analog vs. Digital

- There are two basic ways to store and manage data:
  - *Analog*
    - continuous, in direct proportion to the data represented
    - music on a vinyl record album - a needle rides on ridges in the grooves that are directly proportional to the voltages sent to the speaker
    - Image on film – density on film proportional to world
  - *Digital*
    - the information is broken down into pieces, and each piece is represented separately
    - *sampling* – record discrete values of the analog representation
    - music on a compact disc - the disc stores numbers representing specific voltage levels sampled at specific times
    - Image file – locations are discrete (pixels), values are 0-255

Analog Information



Sampling

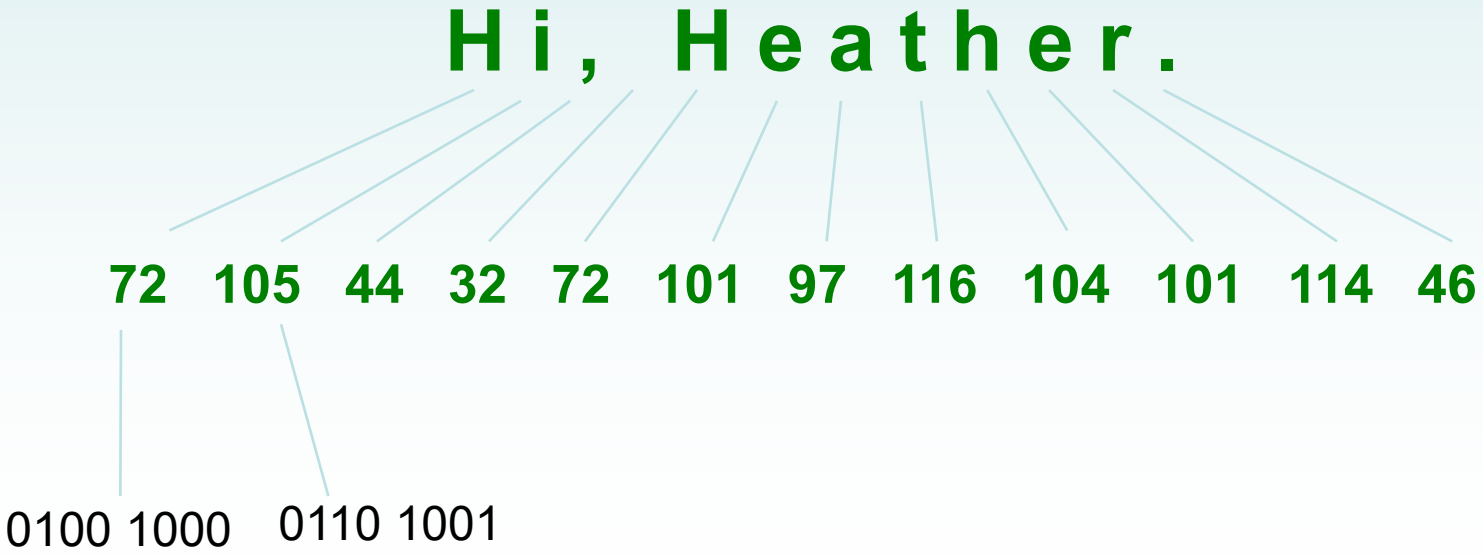


Digital Information

- Computers store all information digitally:
  - numbers
  - text
  - graphics and images
  - audio
  - video
  - program instructions
- Information is *digitized* – broken into discrete pieces and represented as patterns of bits

Representing Text Digitally

- Every character is stored as a “number” (actually a sequence of 8 or 16 bits), including spaces, digits, and punctuation
- Corresponding upper and lower case letters are separate characters



Binary Patterns

- Once information has been digitized, it is represented and stored in memory using *binary patterns*
- A single binary digit (0 or 1) is called a *bit*
  - like a light bulb that is either on (1) or off (0)

- Patterns of bits are used to store values and programs
- bit patterns are often called “binary numbers” (even when they are not being used for numbers)
- Memory is usually organized into byte: a group of 8 bits that can hold 256 different patterns.

Bit Patterns

1 bit	2 bits	3 bits	4 bits	
0	00	000	0000	1000
1	01	001	0001	1001
	10	010	0010	1010
	11	011	0011	1011
		100	0100	1100
		101	0101	1101
		110	0110	1110
		111	0111	1111

Each additional bit doubles the number of possible patterns

Bit Patterns

- Each pattern can represent a particular item
- There are 2^N patterns of N bits
- Therefore, N bits are needed to represent 2^N unique items

How many items can be represented by

1 bit ?	$2^1 = 2$ **items**
2 bits ?	$2^2 = 4$ **items**
3 bits ?	$2^3 = 8$ **items**
4 bits ?	$2^4 = 16$ **items**
5 bits ?	$2^5 = 32$ **items**

Puzzle

How many bits would you need to represent each of the 50 United States using a unique pattern of bits?

Puzzle

How many bits would you need to represent each of the 50 United States using a unique pattern of bits?

Five bits wouldn't be enough, because 2^5 is 32.

Six bits would give us 64 patterns, and some wouldn't be used.

000000 Alabama
000001 Alaska
000010 Arizona
000011 Arkansas
000100 California
000101 Colorado

etc.

Binary Data

- There are many methods to represent data in binary.
- No universal way to represent numbers with bits.
- No universal way to represent characters with bits.
- A particular scheme is called a data type.

With “8-bit unsigned binary” 2^8 integers 0-255 can be represented:

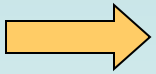
0 – 00000000 1 – 00000001 2 – 00000010 3 – 00000011

4 – 00000100 5 – 00000101 6 – 00000110 7 – 00000111

. . .

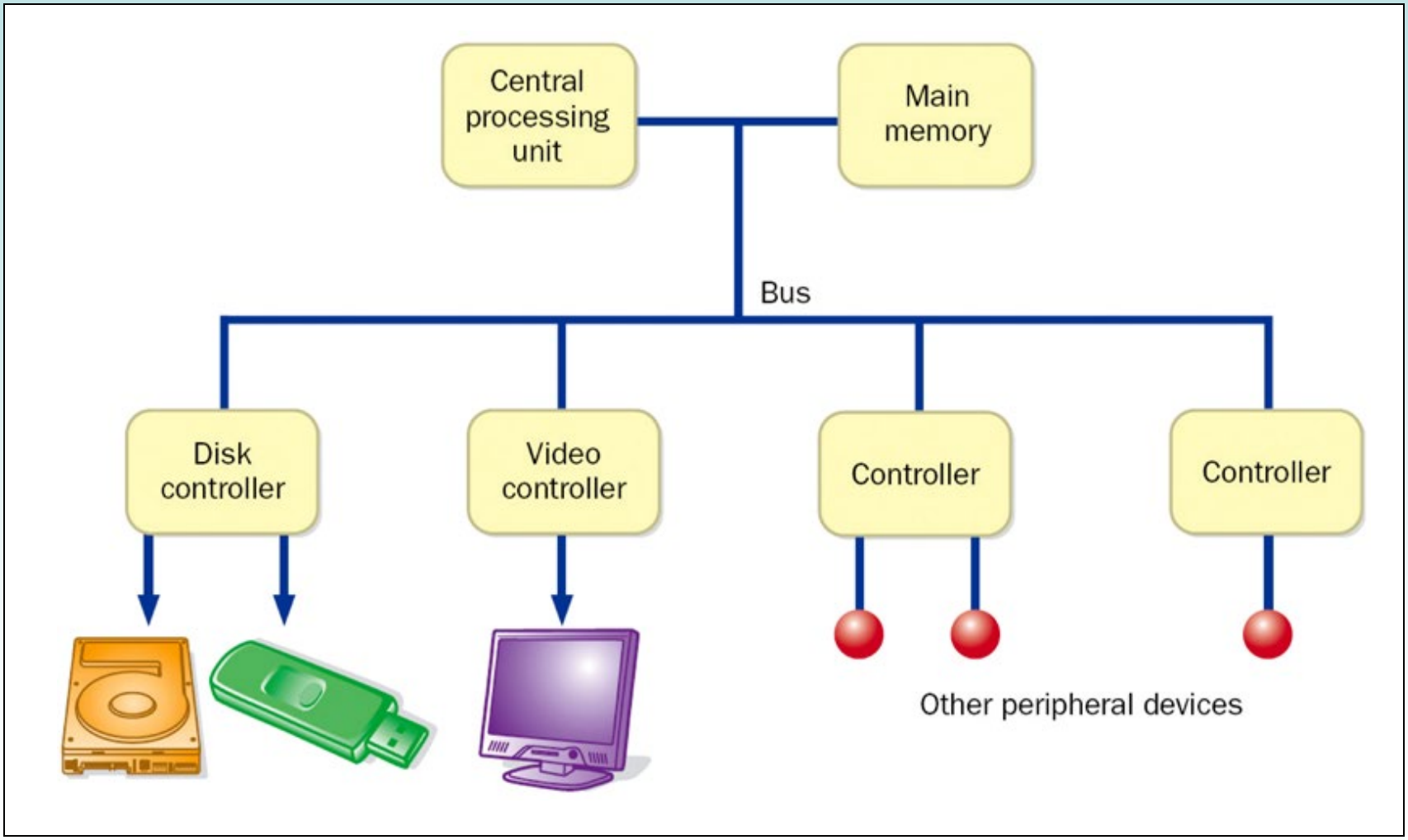
252 – 111111100 253 – 11111101 254 – 11111110 255 – 11111111

Outline



- **Computer Processing**
- **Hardware Components**
- ☺ **Networks**
- **The Java Programming Language**
- **Program Development**
- **Object-Oriented Programming**

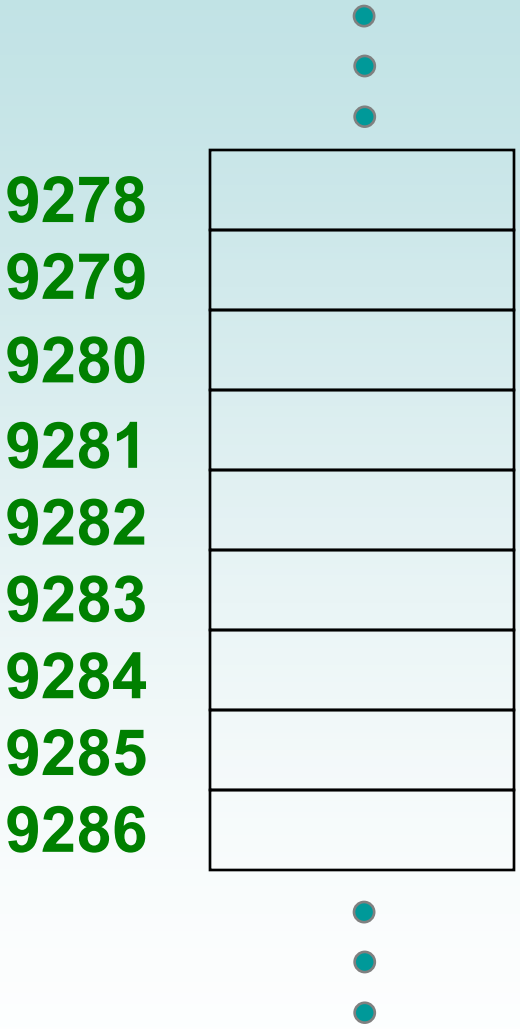
§1.2 Hardware Components



☺ A Computer Specification

- Consider the following specification for a personal computer:
  - 4 GHz Intel Core i7 processor
  - 8 GB RAM
  - 1 TB Hard Disk
  - DVD-RW
  - 17” Flat Screen Video Display with 1280 x 1024 resolution
  - Network Connectivity
  - Audio

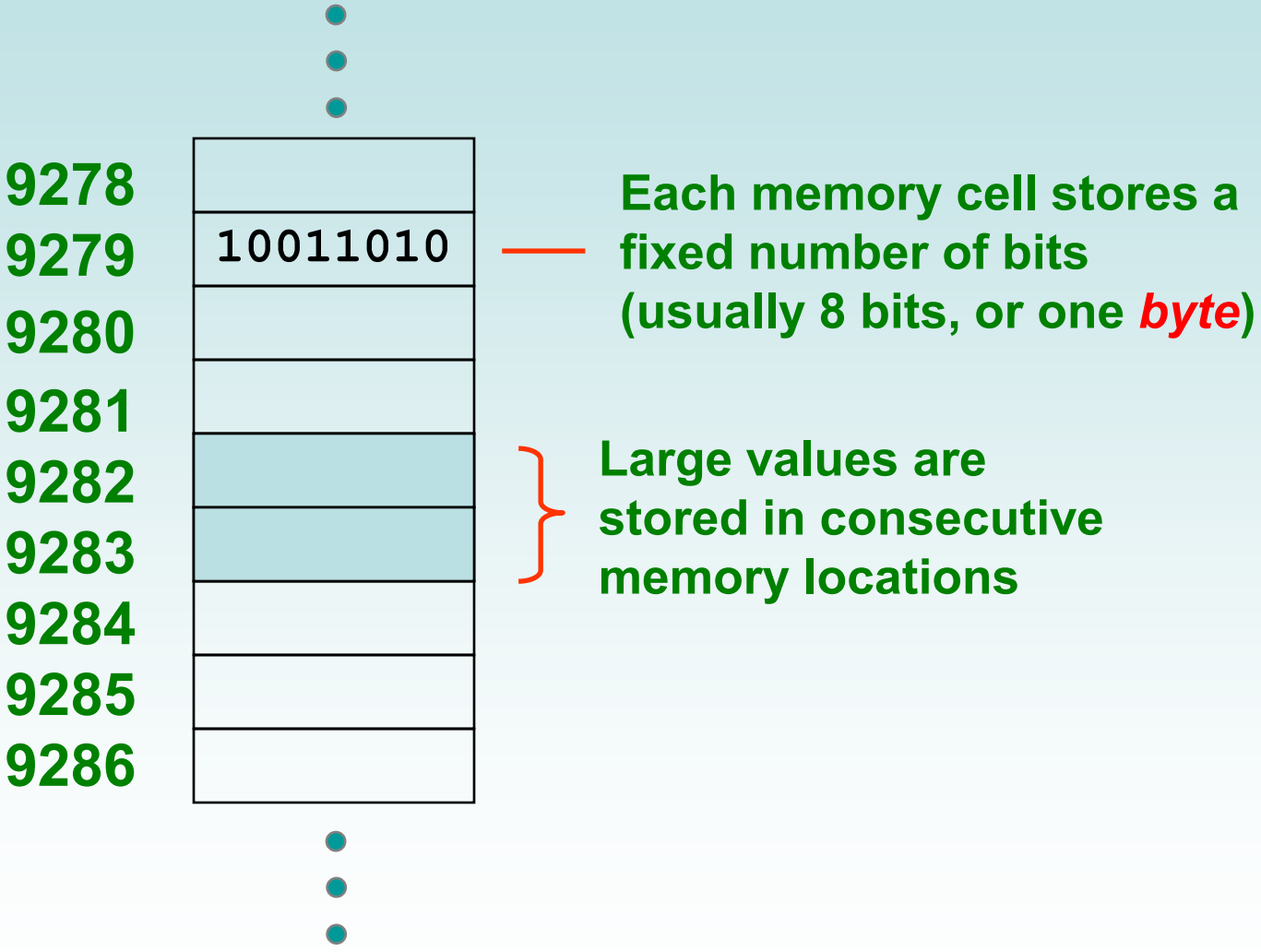
Memory



Main memory is divided into many memory locations (or *bytes*)

Each byte has a numeric *address*, which uniquely identifies it

Storing Information



Storage Capacity

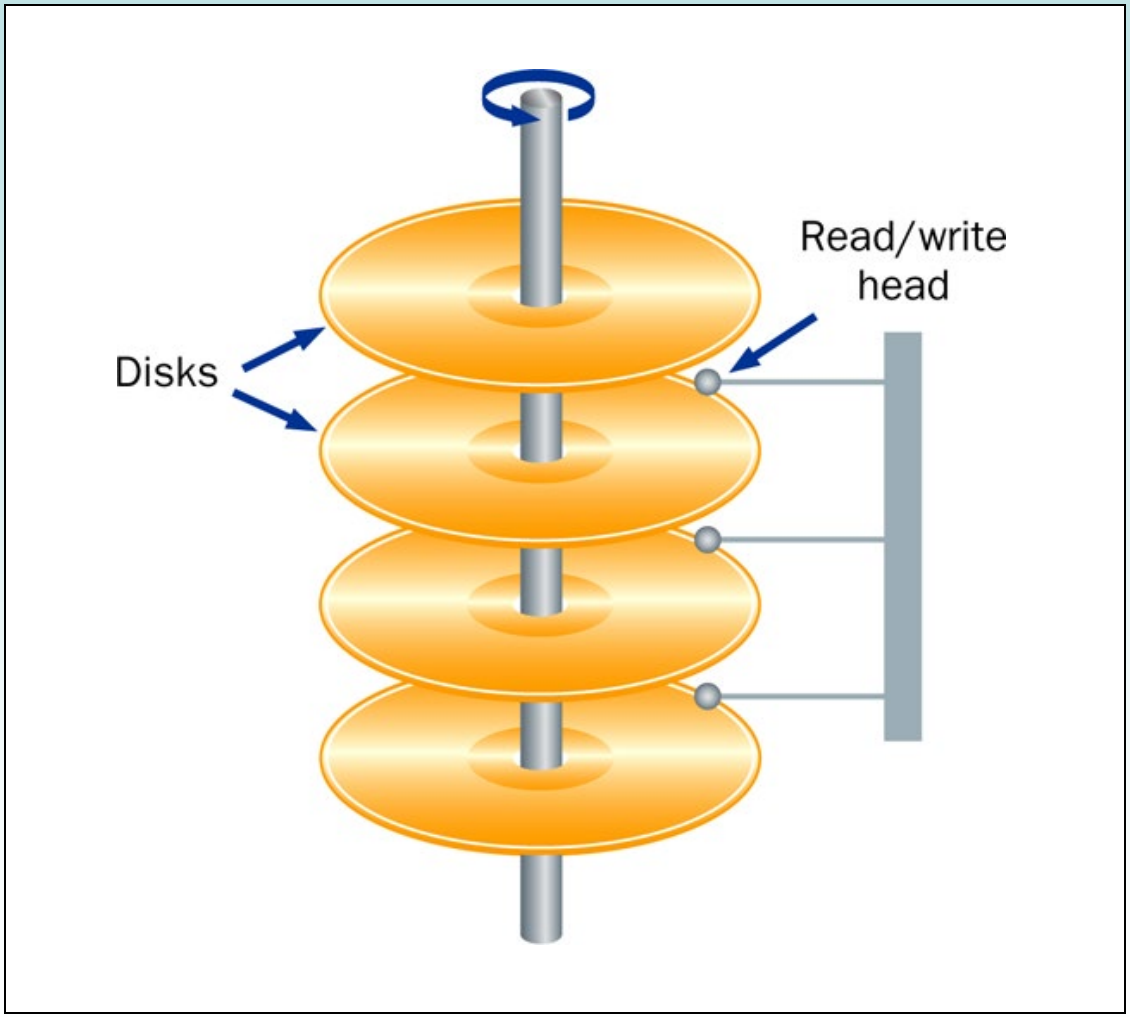
- Every memory device has a *storage capacity*, indicating the number of bytes it can hold
- Capacities are expressed in various units:

Unit	Symbol	Number of Bytes
kilobyte	KB	2^{10} = 1024
megabyte	MB	2^{20} (over one million)
gigabyte	GB	2^{30} (over one billion)
terabyte	TB	2^{40} (over one trillion)
petabyte	PB	2^{50} (a whole bunch)

Memory

- Main memory is *volatile* - stored information is lost when electric power is removed
- Secondary memory devices are *nonvolatile*
- Main memory and disks are *direct access* devices - information can be reached directly
  - The terms *direct access* and *random access* mean the same thing
- A magnetic tape is a *sequential access* device since its data is arranged in a linear order - you must get by the intervening data in order to access other information

Hard Disk Drive



RAM vs. ROM

- *RAM* - Random Access Memory (direct access)
- *ROM* - Read-Only Memory (direct access)
- The terms RAM and main memory are basically interchangeable
- ROM could be a set of memory chips, or a separate device, such as a CD ROM
- Both RAM and ROM are random (direct) access devices
- RAM probably should be called Read-Write Memory

☺ Compact Discs

- A CD-ROM is portable read-only memory
- A microscopic pit on a CD represents a binary 1 and a smooth area represents a binary 0
- A low-intensity laser reflects strongly from a smooth area and weakly from a pit
- A CD-Recordable (CD-R) drive can be used to write information to a CD once
- A CD-Rewritable (CD-RW) can be erased and reused
- The speed of a CD drive indicates how fast (max) it can read and write information to a CD

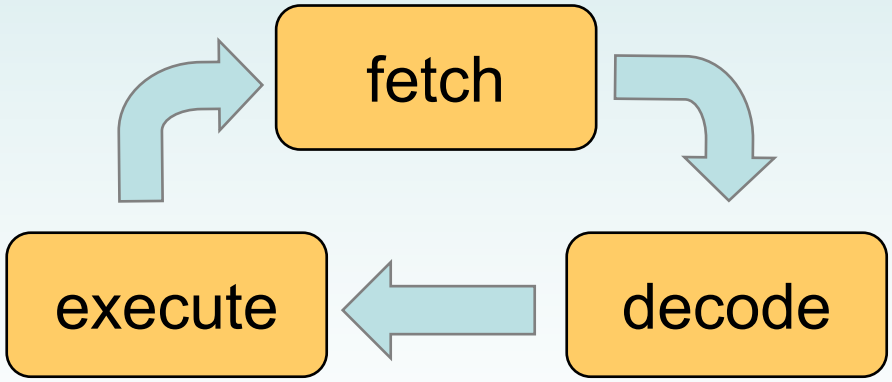
☺ DVDs

- A DVD is the same physical size as a CD, but can store much more information
- The format of a DVD stores more bits per square inch
- A CD can store 650 MB, while a standard DVD can store 4.7 GB
  - A double sided DVD can store 9.4 GB
  - Other advanced techniques can bring the capacity up to 17.0 GB
- Like CDs, there are DVD-R and DVD-RW discs

The Central Processing Unit

- A CPU on a chip is called a *microprocessor*
- It continuously follows the *fetch-decode-execute cycle* (the *machine cycle*):

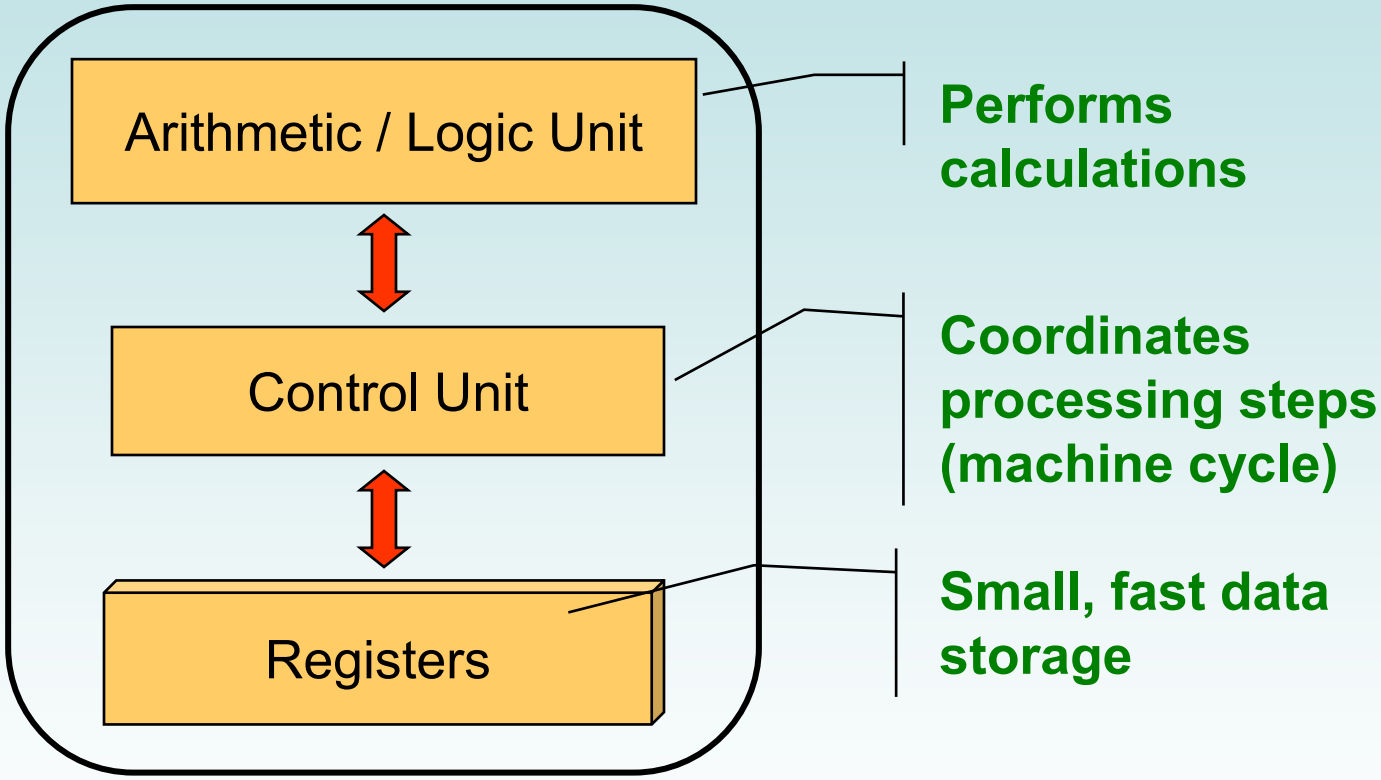
Retrieve next machine instruction from main memory



Carry out the instruction

Determine what the instruction says to do

The Central Processing Unit



The Central Processing Unit

- The speed of a CPU is controlled by the *system clock*
  - *the clock can't go faster than the electronics can handle*
  - *speed of signals in copper partly determines this*
- The system clock generates an electronic pulse at regular intervals
  - *The speed is usually measured in gigahertz (GHz)*
- The pulses coordinate the activities of the CPU
  - *like a conductor's baton with an orchestra*

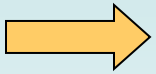
☺ Monitor

- The size of a monitor (17") is measured diagonally, like a television screen
- A monitor has a certain maximum *resolution* , indicating the number of picture elements, called *pixels*, that it can display (such as 1280 by 1024)
- High resolution (more pixels) produces sharper pictures

Outline

Computer Processing

Hardware Components



☺ Networks

The Java Programming Language

Program Development

Object-Oriented Programming

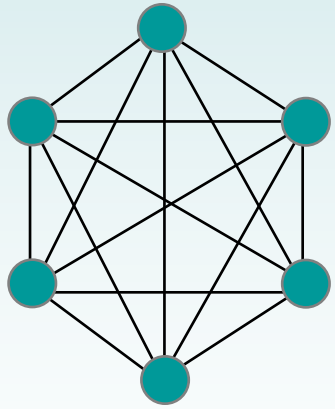
☺ §1.3 Networks

- A *network* is two or more computers that are connected so that data and resources can be shared
- Most computers are connected to some kind of network
- Each computer has its own *network address*, which uniquely identifies it among the others
- A *file server* is a network computer dedicated to storing programs and data that are shared among network users

☺ Network Connections

- Each computer in a network could be directly connected to every other computer in the network
- These are called *point-to-point* connections

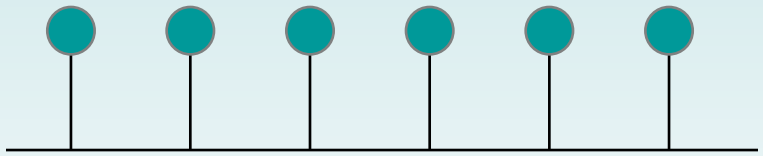
Adding a computer requires a new communication line for each computer already in the network



This technique is not practical for more than a few close machines

☺ Network Connections

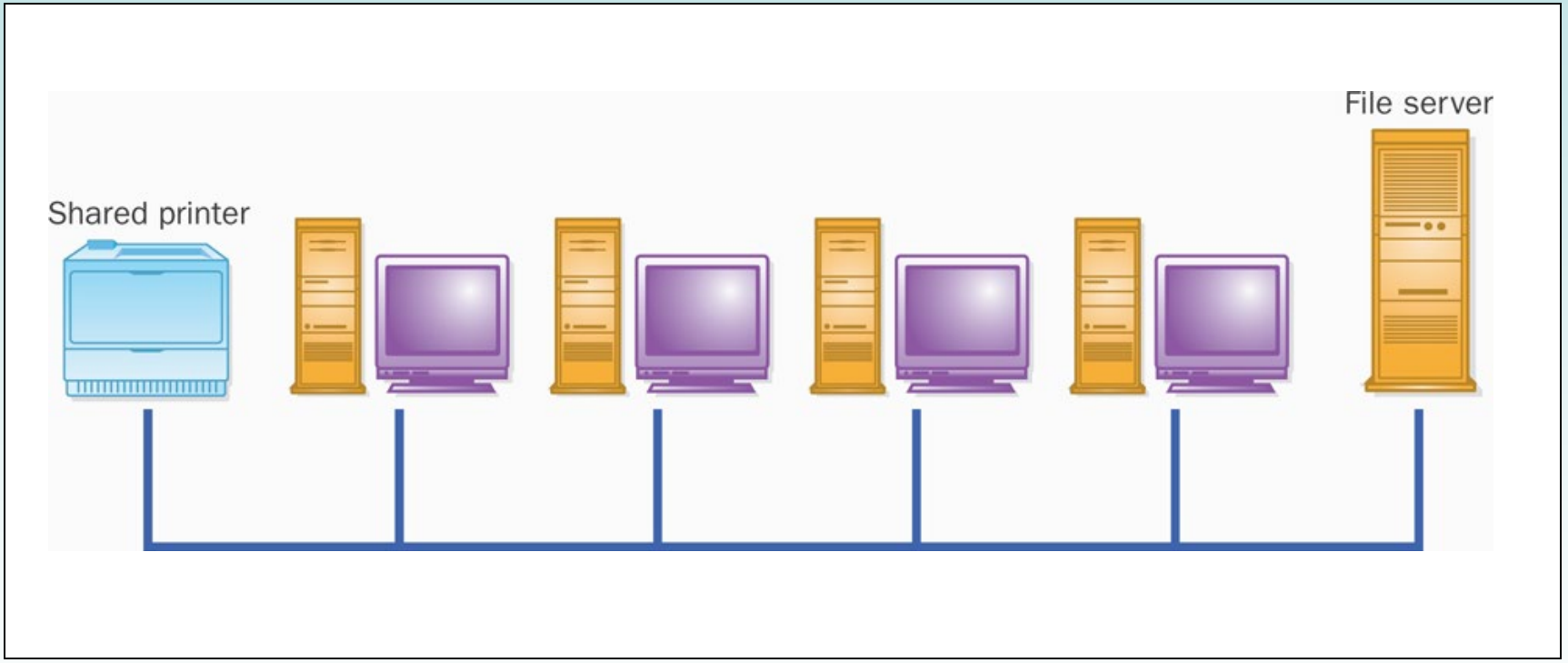
- Most networks share a single communication line
- Adding a new computer to the network is relatively easy



Network traffic must take turns using the line, which introduces delays

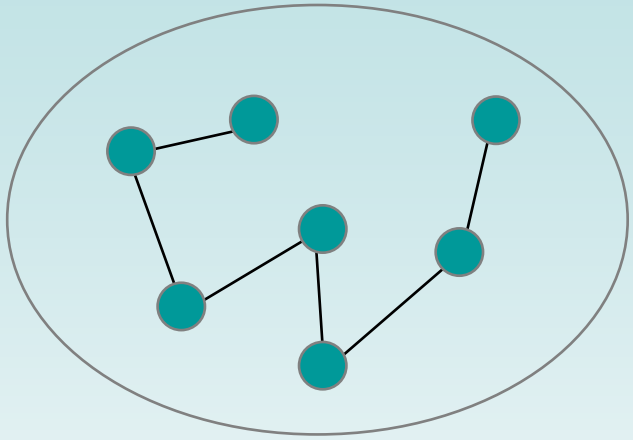
Often information is broken down in parts, called *packets*, which are sent to the receiving machine and then reassembled

☺ A Computer Network



☺ Local-Area Networks

A *Local-Area Network* (LAN) covers a small distance and a small number of computers

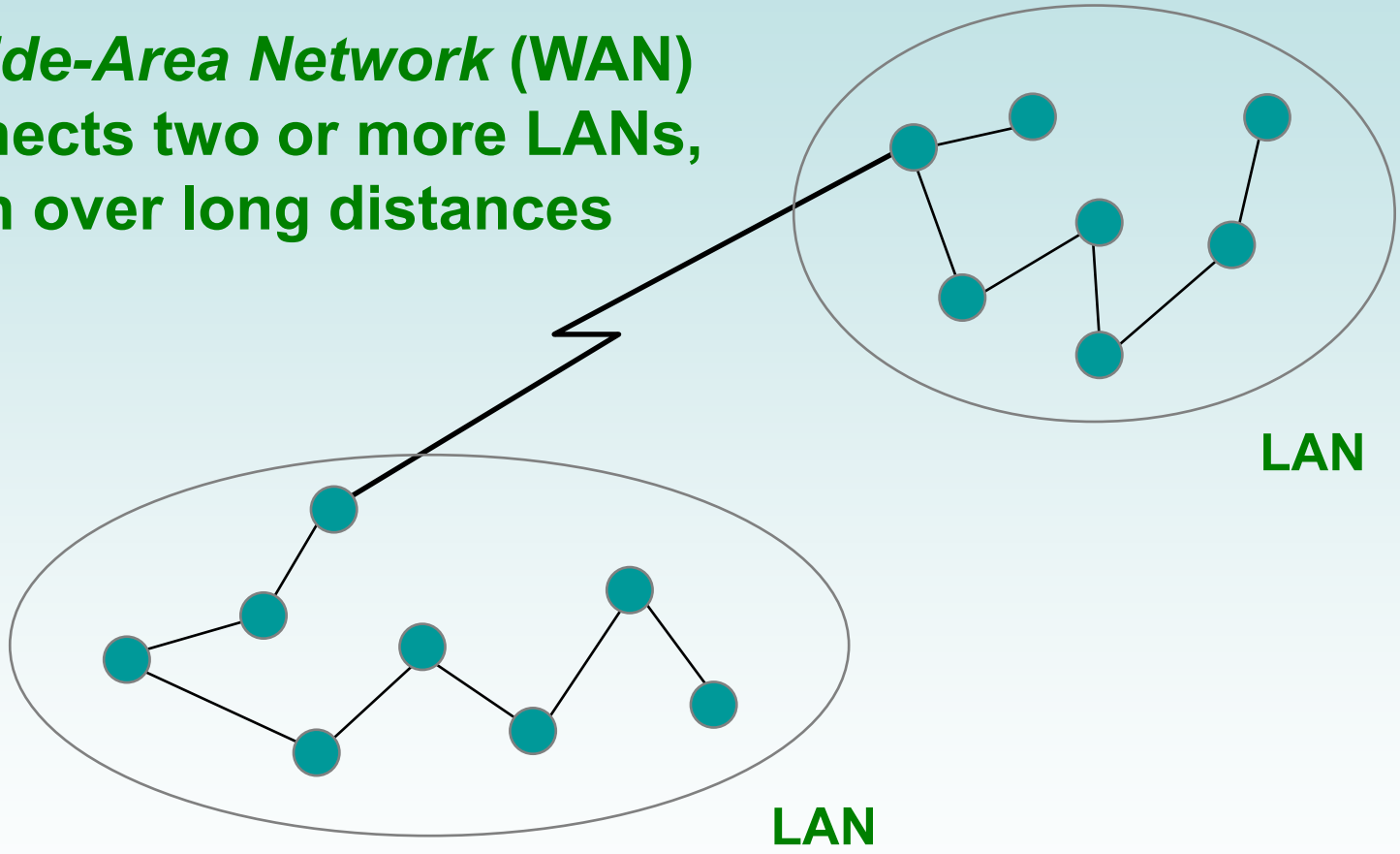


LAN

A LAN often connects the machines in a single room or building

☺ Wide-Area Networks

A *Wide-Area Network* (WAN) connects two or more LANs, often over long distances



☺ The Internet

- The *Internet* is a WAN which spans the planet
- The word Internet comes from the term *internetworking*
- It started as a United States government project, sponsored by the Advanced Research Projects Agency (ARPA)
  - originally it was called the ARPANET
- The Internet grew quickly throughout the 1980s and 90s

☺ TCP/IP

- A protocol is a set of rules that determine how things communicate with each other
- The software that manages Internet communication follows a suite of protocols called *TCP/IP*
- The *Internet Protocol* (IP) determines the format of the information as it is transferred
- The *Transmission Control Protocol* (TCP) dictates how messages are reassembled and handles lost information

☺ IP and Internet Addresses

- Each computer on the Internet has a unique *IP address*, such as:

```
204.192.116.2
```

- Most computers also have a unique Internet name, which also is referred to as an *Internet address*:

```
hector.vt.edu
```

```
kant.gestalt-llc.com
```

- The first part indicates a particular computer (`hector`)
- The rest is the *domain name*, indicating the organization (`vt.edu`)

☺ Domain Names

- The last part of a domain name, called a *top-level domain* (TLD), supposedly indicates the type of organization:

edu	**educational institution**
com	**commercial entity**
org	**non-profit organization**
net	**network-based organization**

Sometimes the suffix indicates the country:

uk	**United Kingdom**
au	**Australia**
ca	**Canada**
se	**Sweden**

Additional TLDs have been added:

biz, info, tv, name

☺ Domain Names

- A domain name can have several parts
- Unique domain names mean that multiple sites can have individual computers with the same local name
- When used, an Internet address is translated to an IP address by software called the *Domain Name System* (DNS)
- There is no one-to-one correspondence between the sections of an IP address and the sections of an Internet address

☺ The World Wide Web

- The *World Wide Web* allows many different types of information to be accessed using a common interface
- A *browser* is a program which accesses network resources and presents them
  - Popular browsers: Internet Explorer, Safari, Firefox
- Resources presented include:
  - text, graphics, video, sound, audio, executable programs
- A Web document usually contains *links* to other Web documents, creating a *hypermedia* environment
- The term Web comes from the fact that information is not organized in a linear fashion

☺ The World Wide Web

- Web documents are often defined using the *HyperText Markup Language* (HTML)
- Information on the Web is found using a *Uniform Resource Locator* (URL):

```
http://www.cnn.com

http://www.vt.edu/student_life/index.html

ftp://java.sun.com/applets/animation.zip
```

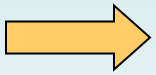
- A URL specifies a protocol (http), a domain, and possibly specific documents

Outline

Computer Processing

Hardware Components

Networks



The Java Programming Language

Program Development

Object-Oriented Programming

§1.4 Java Programming Language

- The Java programming language was created by Sun Microsystems, Inc.
- It was introduced in 1995 and it's popularity grew quickly
- A *programming language* is a **formal language**:
  - symbols used in the language and syntax rules are exactly specified
- A programming language employs a set of rules that dictate how the words and symbols can be put together to form valid *program statements*

Java Program Structure

- In Java:
  - A program is made up of one or more *classes*
  - A class contains one or more *methods*
    - A method describes something the program can do
  - A method contains program *statements*
    - A statement is one step in performing a method
- The program you create with a text editor is called a *source file*
- A Java program always contains a class that contains a method called `main`
- Only one class can have `main`
- See `Lincoln.java`

```java
//********************************************************************
//  Lincoln.java       Author: Lewis/Loftus
//
//  Demonstrates the basic structure of a Java application.
//********************************************************************

public class Lincoln
{
   //-----------------------------------------------------------------
   //  Prints a presidential quote.
   //-----------------------------------------------------------------
   public static void main (String[] args)
   {
      System.out.println("A quote by Abraham Lincoln:");

      System.out.println("Whatever you are, be a good one.");
   }
}
```

Go to https://www.w3schools.com/java/

Change the class name from *Lincoln* to *Main*

Or: https://www.codiva.io/

Output

```
A quote by Abraham Lincoln:
Whatever you are, be a good one.
```

```
//********                                                    **********
//  Lincol
//
//  Demons
//*************************************************************************

public class Lincoln
{
   //-----------------------------------------------------------------
   //  Prints a presidential quote.
   //-----------------------------------------------------------------
   public static void main (String[] args)
   {
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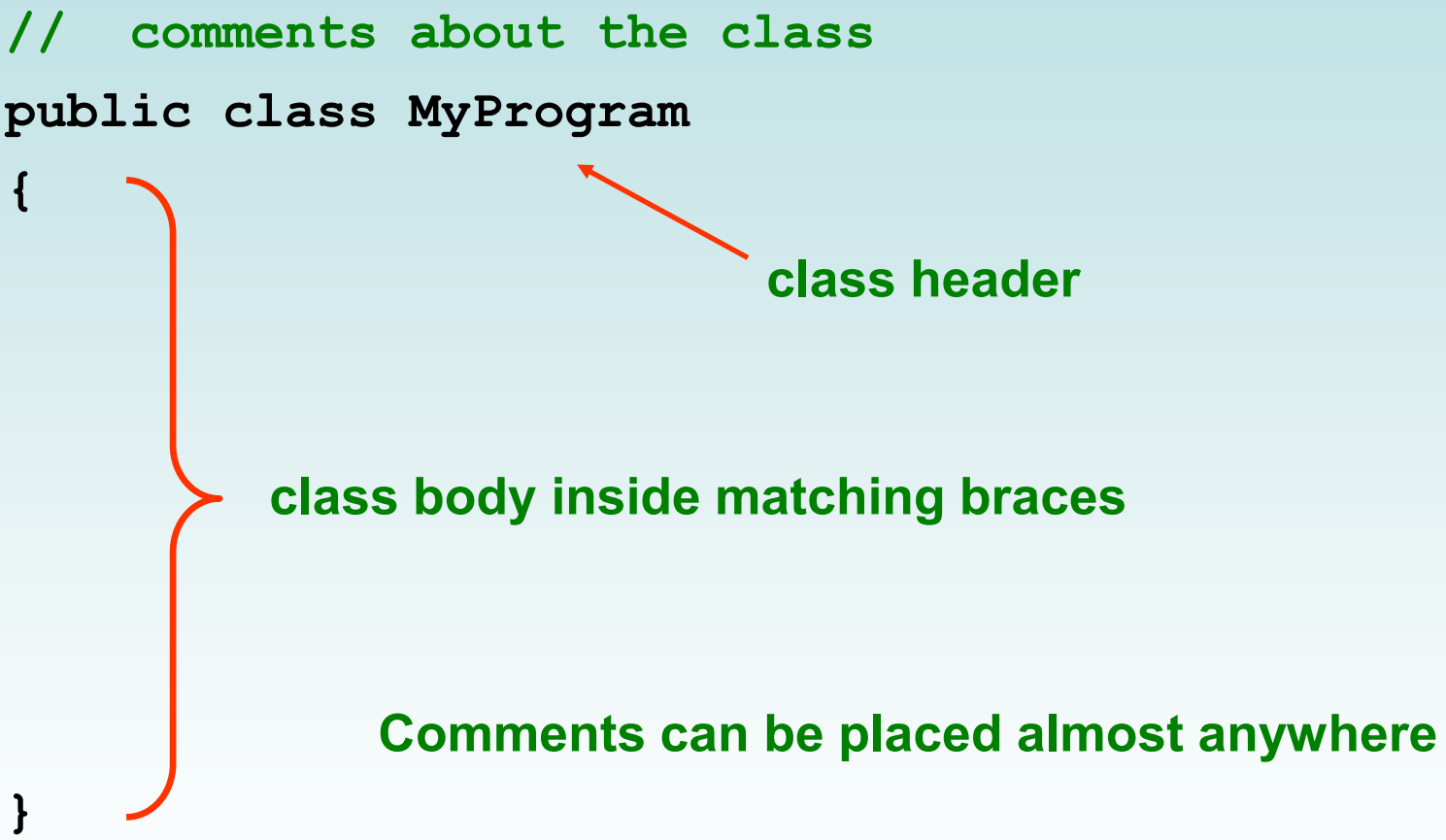
Java Program Structure



Java Program Structure

```
//  comments about the class
public class MyProgram
{
   //  comments about the method
   public static void main( String[] args )
   {

   }

}
```

method body

method header

Comments

- Comments are for humans looking at a program.
- They explain the purpose of the program and describe processing steps.
- They do not affect how a program works.
- Java comments can take three forms:

```
// this comment runs to the end of the line

/*  this comment runs to the terminating
    symbol, even across line breaks        */

/** this is a javadoc comment   */
```

Identifiers

- *Identifiers* are the names for things in a program
- A Java identifier can be made up of letters, digits, the underscore character _ , and the dollar sign $, but no spaces or other punctuation.
- Identifiers *cannot begin with a digit*
- Java is *case sensitive*: `Total`, `total`, and `TOTAL` are different identifiers 
- By convention, programmers use different case styles for different types of identifiers, such as
  - *title case* for class names - `Lincoln`
  - *upper case* for constants - `MAXIMUM`

Identifiers

- Sometimes the programmer chooses the identifier (such as `Lincoln`)
- Sometimes a program uses another programmer's code, so uses the identifiers in it (such as `println`)
- Special words called *reserved words* already have a meaning in the language
  - A reserved word cannot be used in any other way

Reserved Words

- The Java reserved words:

`abstract`	`else`	`interface`	`switch`
`assert`	`enum`	`long`	`synchronized`
`boolean`	`extends`	`native`	`this`
`break`	`false`	`new`	`throw`
`byte`	`final`	`null`	`throws`
`case`	`finally`	`package`	`transient`
`catch`	`float`	`private`	`true`
`char`	`for`	`protected`	`try`
`class`	`goto`	`public`	`void`
`const`	`if`	`return`	`volatile`
`continue`	`implements`	`short`	`while`
`default`	`import`	`static`	
`do`	`instanceof`	`strictfp`	
`double`	`int`	`super`	

Quick Check

Which of the following are valid Java identifiers?

```
grade
quizGrade
NetworkConnection
frame2
3rdTestScore
MAXIMUM
MIN_CAPACITY
student#
Shelves1&2
Grand Total
```

Quick Check

Which of the following are valid Java identifiers?

`grade`	Valid
`quizGrade`	Valid
`NetworkConnection`	Valid
`frame2`	Valid
`3rdTestScore`	Invalid – cannot begin with a digit
`MAXIMUM`	Valid
`MIN_CAPACITY`	Valid
`student#`	Invalid – cannot contain the '#' character
`Shelves1&2`	Invalid – cannot contain the '&' character
`Grand Total`	Invalid – cannot contain a space

White Space

- Spaces, blank lines, and tabs are called *white space*
- White space is used to separate words and symbols in a program
- Extra white space is ignored
  - If syntax calls for one space, more than one can be used

Program Formatting

- A valid Java program can be formatted many ways
- Programs should be formatted to enhance readability, using consistent indentation
- See *Java Coding Guidelines*, appendix F in text
- See `Lincoln2.java` and `Lincoln3.java`

```
//********************************************************************
//  Lincoln2.java       Author: Lewis/Loftus
//
//  Demonstrates the basic structure of a Java application.
//********************************************************************

public class Lincoln{public static void main (String[] args){
System.out.println ("A quote by Abraham Lincoln:");
System.out.println ("Whatever you are, be a good one.");}}
```

```
//********************************************************************
//  Lincoln3.java       Author: Lewis/Loftus
//
//  Demonstrates the basic structure of a Java application.
//********************************************************************

        public class
Lincoln3
{
public static void main (String
[] args)
            {
      System.out.
println ("A quote by Abraham Lincoln:”
                  );


      System.out.println ("Whatever you are, be a good one.");
   }
                           }
```

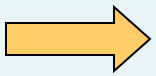
Outline

Computer Processing

Hardware Components

Networks

The Java Programming Language



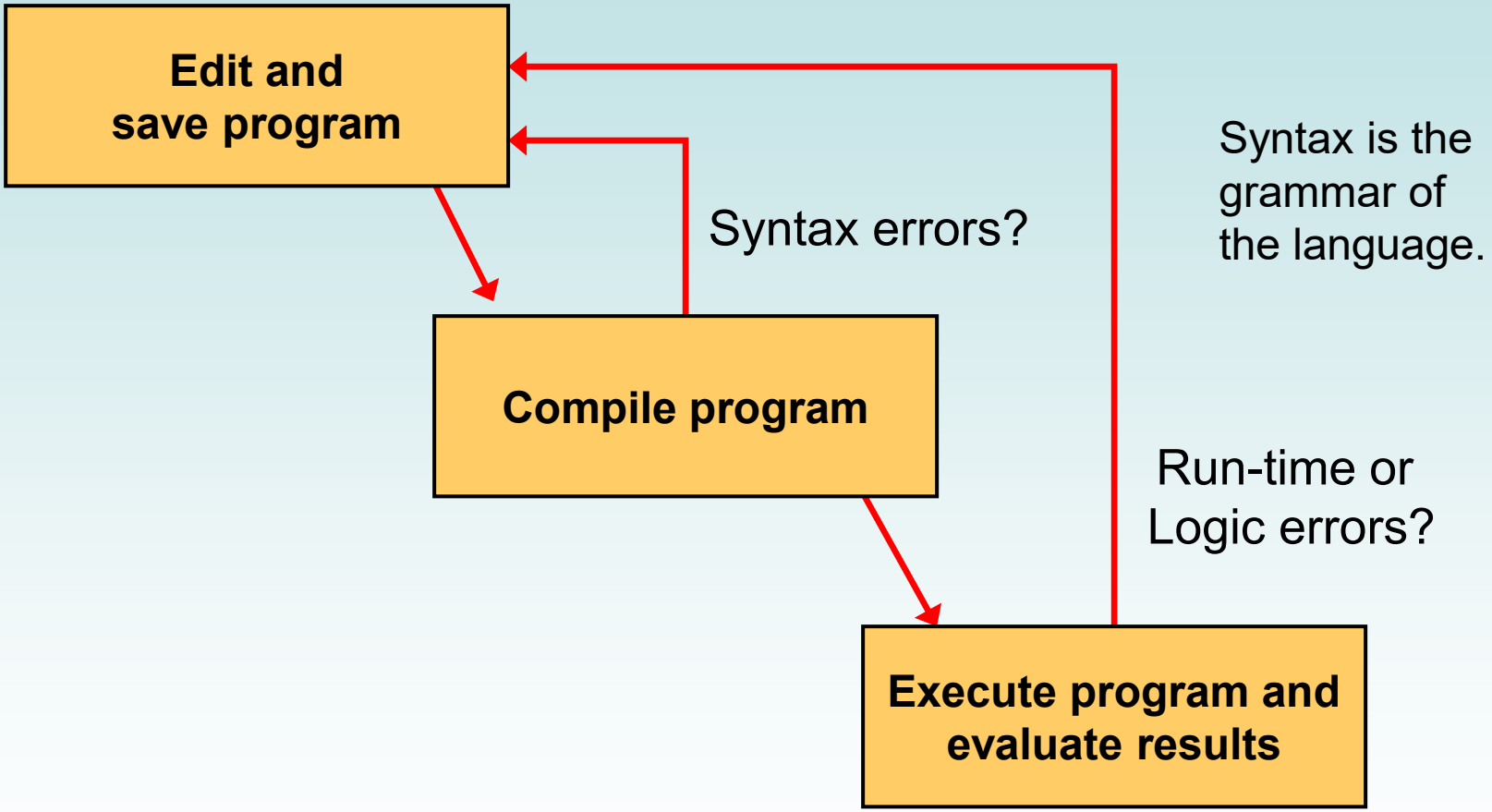
Program Development

Object-Oriented Programming

§1.5 Program Development

- Developing a program involves:
  - writing the program in a specific programming language (such as Java) using a text editor
    - source code (source file)
  - translating the program into a form that the computer can execute
    - ultimately, needs to be instructions that the processor can perform electronically
    - machine code (for Java: byte code) see slide 72
  - executing the program
    - finding and fixing errors
- Often all of these are put together into one environment
  - BlueJ, Eclipse, DrJava, …
  - On line Java compiler

Basic Program Development



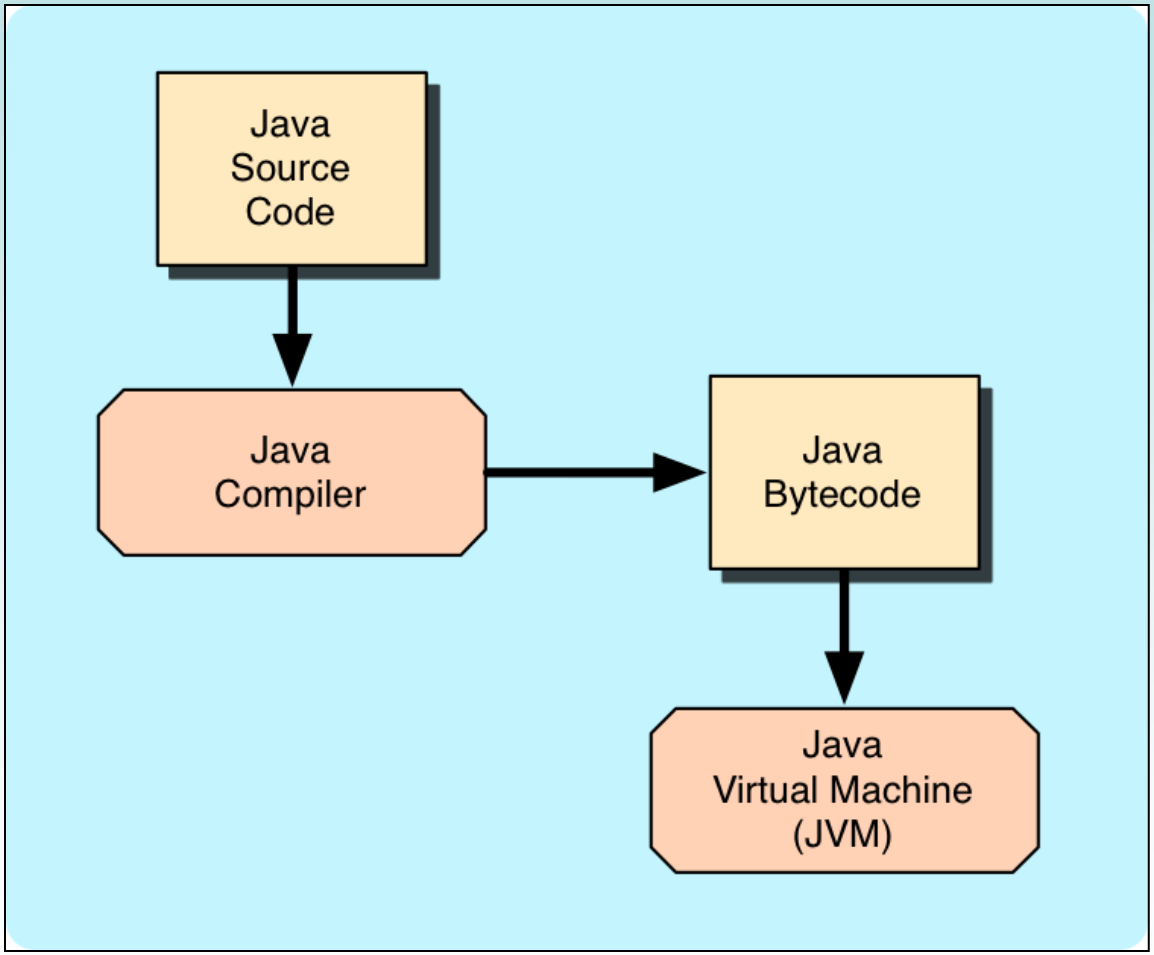
Programming Languages

- Each type of CPU executes a particular *machine language* (recall the machine cycle, slide 35)
- A program must be translated into that machine language before it can be executed
- A *compiler* is software which translates *source code* into a specific target language
- That target language is the machine language for a particular CPU type
- The Java approach is somewhat different

Java Translation

- The Java compiler translates Java source code into a special representation called *bytecode*
- Java bytecode is not the machine language for any traditional CPU
- Bytecode is executed by the *Java Virtual Machine* (JVM)
  - a CPU implemented in software
- Therefore, Java bytecode is not tied to any particular hardware
- Java is considered to be *architecture-neutral*

Java Translation



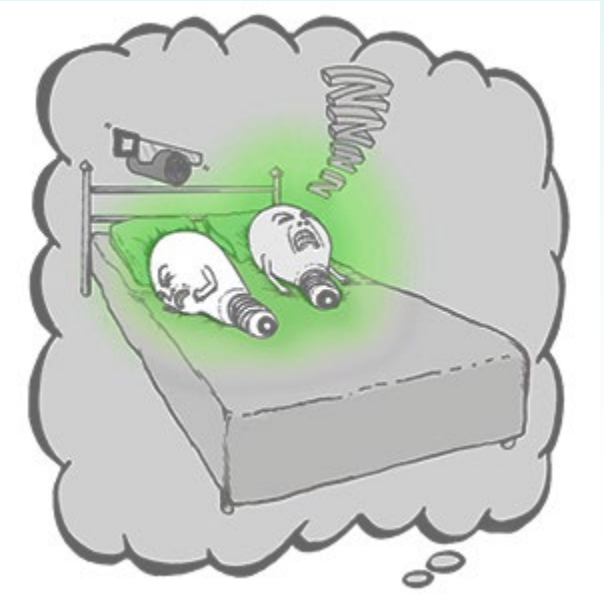
Development Environments

- There are many programs that support the development of Java software, including:
  - Java Development Kit (JDK)
    - commands entered from the command line
  - Eclipse
  - DrJava
  - NetBeans
  - BlueJ
- Details differ, but the underlying compilation and execution process is the same

Syntax and Semantics

- The *syntax rules* of a language define how we can put together symbols, reserved words, and identifiers to make a valid program
- The *semantics* of a program statement define what that statement means (its purpose or role in a program)
- A program that is syntactically correct is not necessarily logically (semantically) correct

Colorless green ideas sleep furiously.



Errors

- A program can have three types of errors
- The compiler will find syntax errors and other basic problems (*compile-time errors*)
  - If compile-time errors exist, an executable version of the program is not created
- A problem can occur during program execution, such as trying to divide by zero, which causes a program to terminate abnormally (*run-time errors*)
  - Sometimes called a “bug”
- A program may run, but produce incorrect results, perhaps using an incorrect formula (*logical errors*)
  - Also called a “bug”

Outline

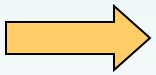
Computer Processing

Hardware Components

Networks

The Java Programming Language

Program Development

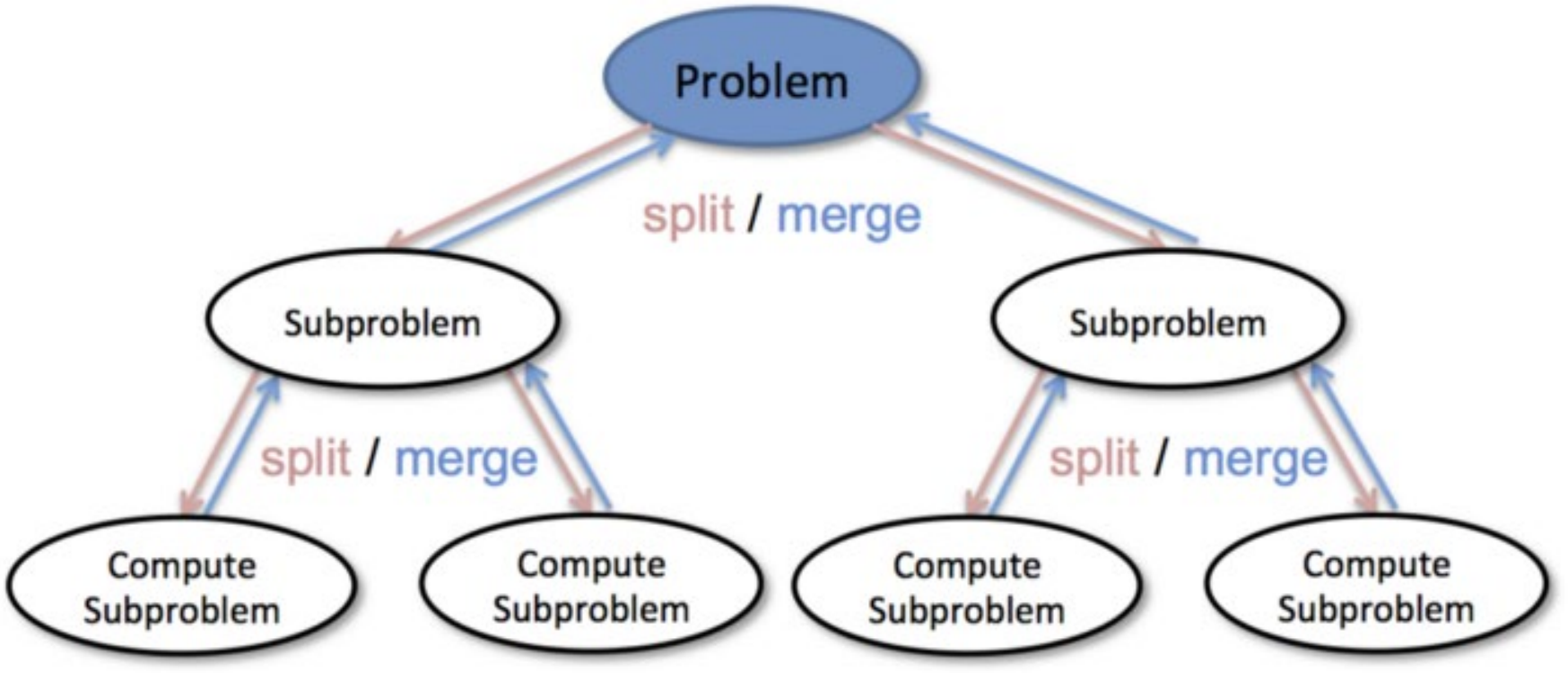


Object-Oriented Programming

Problem Solving

- The key to designing a solution is breaking it down into manageable pieces
  - Divide and Conquer
- An *object-oriented approach* lends itself to this kind of solution decomposition
- Our programs have pieces called objects and classes

Divide and Conquer



§1.6 Object-Oriented Programming

- A software object is a fundamental piece of a Java program
- Objects can represent real-world entities
  - an object might represent a particular employee in a company
  - an object might represent a dragon in a game
- A program might have dozens (or thousands) of objects
- Java objects are like “real world” objects
  - Makes thinking about them easier

Objects

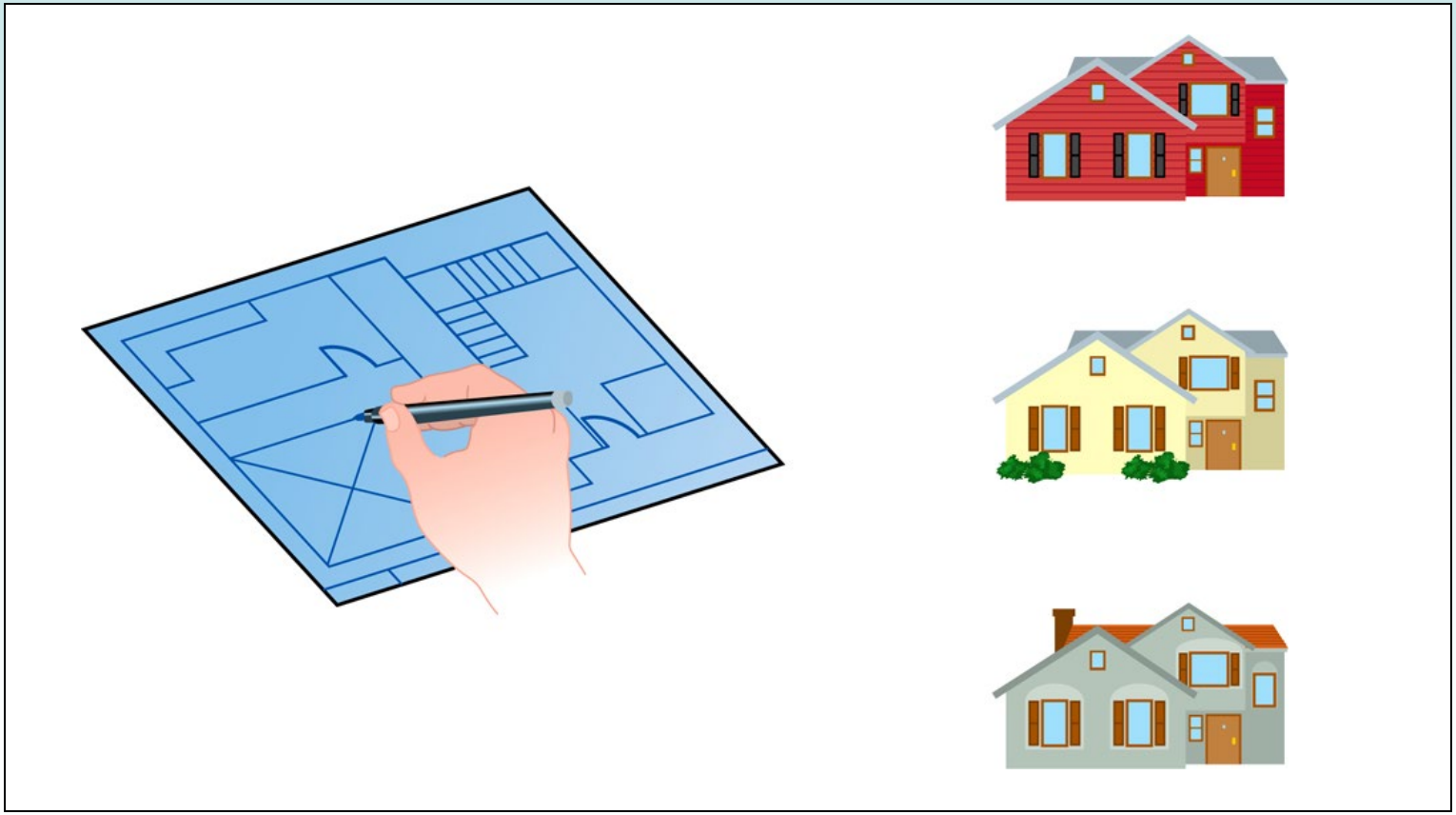
- An object has:
  - *identity* - it is a thing separate from other objects
  - *state* - characteristics
  - *behavior* - what it can do (or what can be done to it)
- My bank account is a different object than your bank account
- The state of a bank account includes its account number and its current balance
- The behaviors of a bank account include making deposits and withdrawals
  - The behavior of an object might change its state

Classes

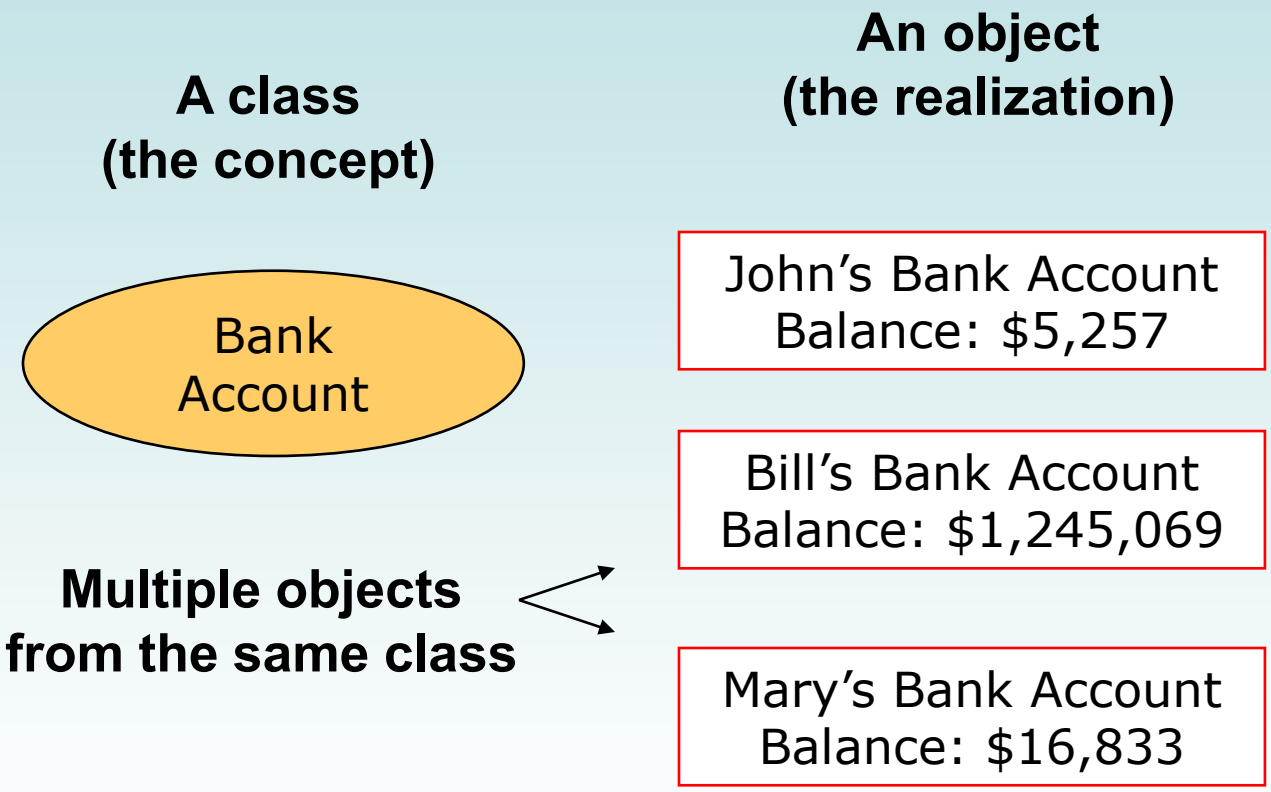
- An object is described by a *class*
- A class is the “blueprint” of an object
- A class represents a concept, and an object is an actual instance of that class
- As a program runs, software objects are created and destroyed
- Many objects can be created from the same class
  - lots of bank accounts
  - lots of dragons

Class == Blueprint

- One blueprint to create several similar, but different, houses:

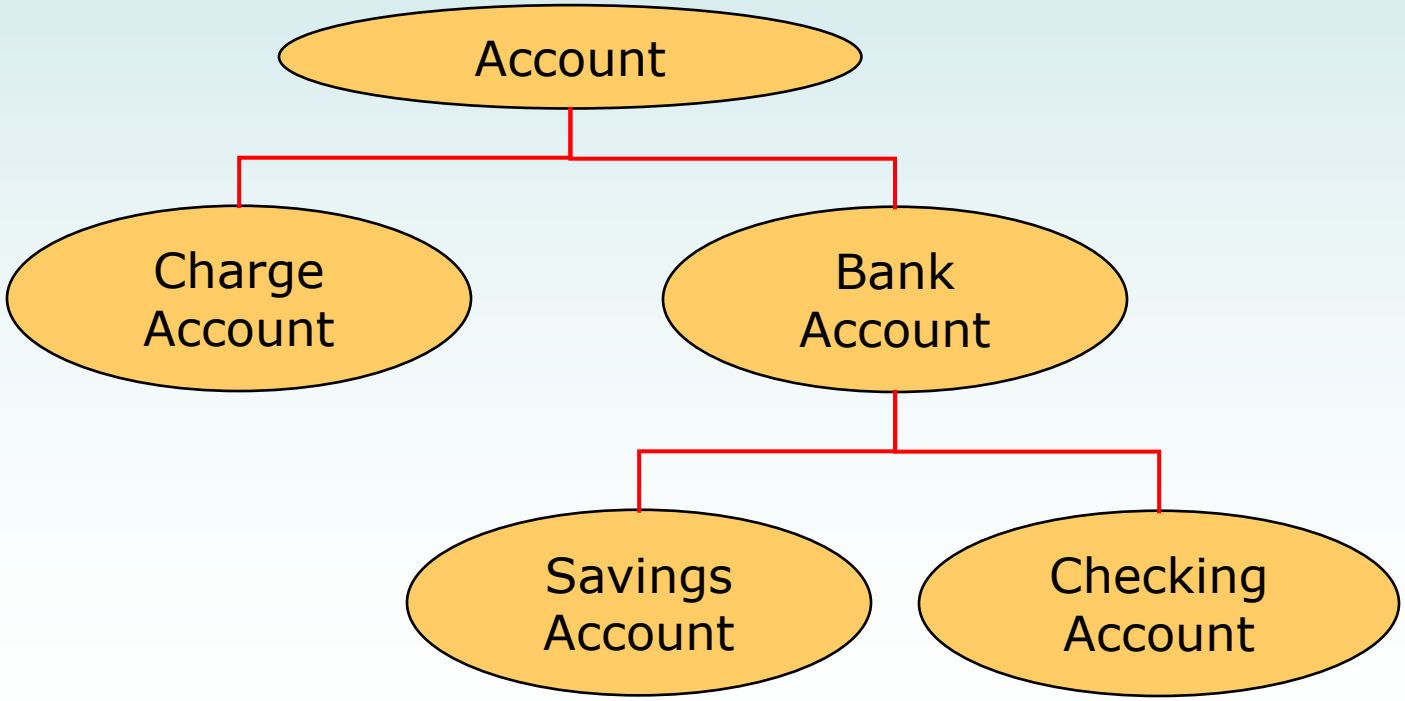


Objects and Classes



Inheritance

- One class can be used to derive another via *inheritance*
- Classes are organized into hierarchies



Summary

- Chapter 1 focused on:
  - components of a computer
  - how those components interact
  - how computers store and manipulate information
  - computer networks
  - the Internet and the World Wide Web
  - programming and programming languages
  - an introduction to Java
  - an overview of object-oriented concepts