Chapter 2: Computer Hardware, Software Evolution, and Computer Architecture

- Generations of Computers
- Characteristics and Types of Computers
- Software Generations
- Microcomputer Architecture

Definition of a Computer

- a general purpose,
- programmable,
- information processor
- with input and output

- Fixed Program Computer (embedded)
- Stored Program Computer

Computer vs Human

- Input - Five senses
- Central Processing Unit (CPU) - brain
- Output - Body Parts
- Memory - Human memory

- Hardware
  - Physical components
- Software
  - Programs for operations and problem solving

Computer Generations

Generation 0: Mechanical Calculators (relays)

Generation 1: Vacuum Tube Computers

Generation 2: Transistor Computers

Generation 3: Integrated Circuits

Generation 4: Microprocessors

Computer Generations

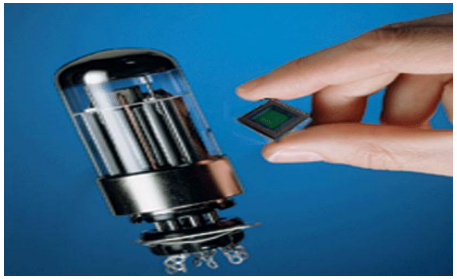
- Generations of Computers
  - First Generation (1946-59)
  - Second Generation(1957-64)
  - Third Generation(1965-70)
  - Fourth Generation(1970-90)
  - Fifth Generation(1990 till date)

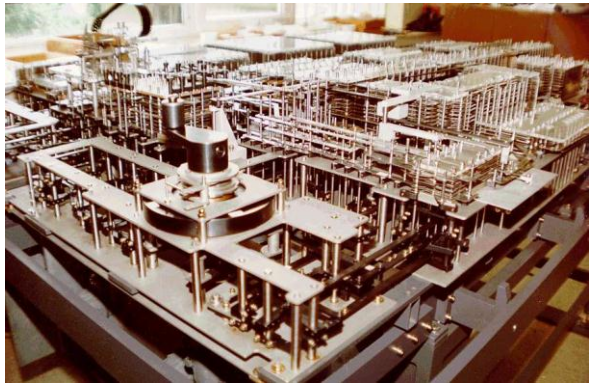
Computer Generations

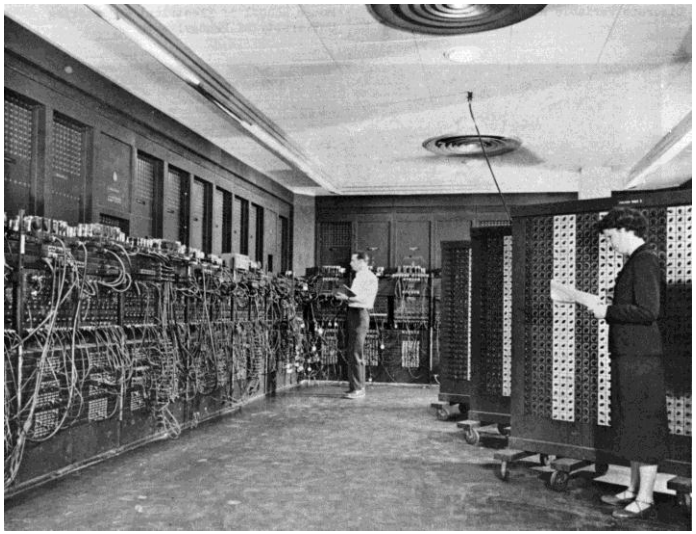
	First Generation	**Second Gen.**	**Third Gen.**	**Fourth Gen.**
Technology	Vacuum Tubes	Transistors	Integrated Circuits (multiple transistors)	Microchips (millions of transistors)
Size	Filled Whole Buildings	Filled half a room	Smaller	Tiny - Palm Pilot is as powerful as old building sized computer

Generation 1 : ENIAC

The ENIAC (Electronic Numerical Integrator and Computer) was unveiled in 1946: the first all-electronic, general-purpose digital computer







Used machine languages and magnetic tapes

First Generation Hardware

Vacuum Tubes

Large, not very reliable, generated a lot of heat

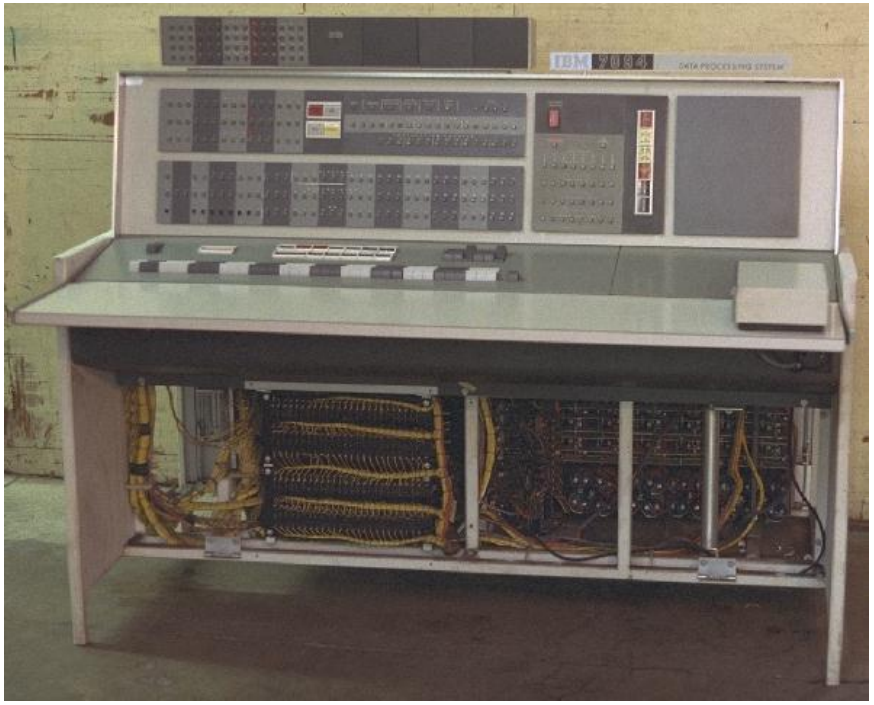
Magnetic Drum

Memory device that rotated under a read/write head

Card Readers → Magnetic Tape Drives

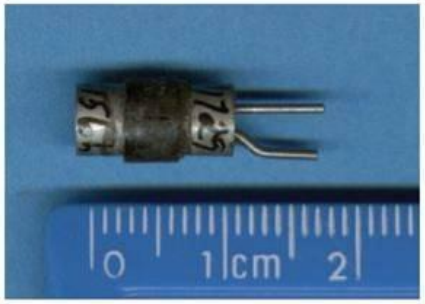
Sequential auxiliary storage devices

Generation 2: IBM7094



These machines used assembly language.

Second Generation Hardware



Transistor

Replaced vacuum tube, fast, small, durable, cheap

Magnetic Cores

Replaced magnetic drums, information available instantly

Magnetic Disks

Replaced magnetic tape, data can be accessed directly

Generation 3: Integrated Circuits

Seymour Cray created the Cray Research Corporation
Cray-1: $8.8 million, 160 **million instructions per seconds** and 8 **Mbytes** of memory

Used high level programming languages

Third Generation Hardware

Integrated Circuits

Replaced circuit boards, smaller, cheaper, faster, more reliable

Transistors

Now used for memory construction

Terminal

An input/output device with a keyboard and screen

Generation 4: VLSI

Improvements to IC technology made it possible to integrate more and more transistors in a single chip

- SSI (Small Scale Integration): 10-100
- MSI (Medium Scale Integration): 100-1,000
- LSI (Large Scale Integration): 1,000-10,000
- VLSI (Very Large Scale Integration): >10,000

Microprocessors

Fourth Generation Hardware

Very Large-scale Integration

Great advances in chip technology

PCs, the Commercial Market, Workstations

Personal Computers and Workstations emerge

New companies emerge: Apple, Sun, Dell …

Laptops, Tablet Computers, and Smart Phones

Everyone has his/her own portable computer

Generation 5?

The term “Generation 5” is used sometimes to refer to all more or less “sci fi” future developments

- Voice recognition
- Artificial intelligence
- Quantum computing
- Bio computing
- Nano technology
- Learning
- Natural languages
- Parallelism & Networking

Parallelism & Networking: in 1997, highly parallel Deep Blue beat Kasparov in speed chess match.

About quantum computing and Optical Computing

Photonics (Photonic Computing) or **Optical Computing** is about using light as information carrier in computer systems.

Quantum computing studies **computation** systems (**quantum computers**) that make direct use of **quantum**-mechanical phenomena, such as superposition and entanglement, to perform operations on data.

Quantum computers are different from binary digital electronic **computers** based on transistors.
In quantum computing, a **qubit** (/ˈkjuːbɪt/) or quantum bit (sometimes qbit) is a unit of quantum information—the quantum analogue of the classical bit. A **qubit** is a two-state quantum-mechanical system, such as the polarization of a single photon: here the two states are vertical polarization and horizontal polarization.

Types of computers

- With respect to physical size, speed, storage capacity, and price

➢ In terms of size
  - ✓ ☐ small
  - ✓ ☐ medium
  - ✓ ☐ large

* The details are left as a Reading Assignment

  - Microcomputers
  - Minicomputers
  - Mainframe Computers
  - Super computers

Computer HW & SW

- Capabilities of Computers
  - Huge Data Storage
  - Input and Output
  - Processing
  - *Hardware stores and transmits data, software processes data.*

Is the CPU only a Hardware?

Computer HW & SW

Characteristics of Computers

- High Processing Speed
- Accuracy
- Reliability
- Versatility
- Diligence

DILLIGENCE : A Computer can work for long hours with the same accuracy and speed because it is free from problems of boredom or lack of concentration.

VERSATILITY : The working of computer with different types of data is known as versatility.

Reliability: Produces the same or identical result repeatedly for the same input

History of computing technology

ENIAC (1946):

- 18,000 vacuum tubes, 1,500 relays
- weighed 30 tons, consumed 140 kwatts

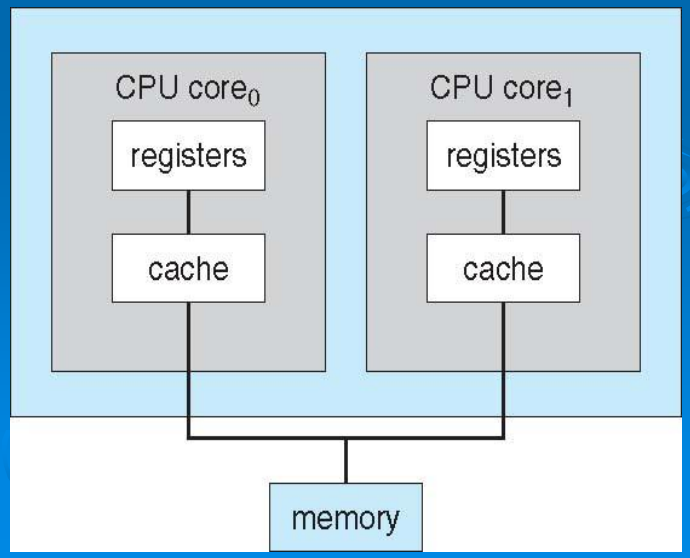
DYK?

When were "modern" computers invented?
When were computers accessible/affordable to individuals?
When was the Internet born?
When was the Web invented?
How did Bill Gates get so rich?

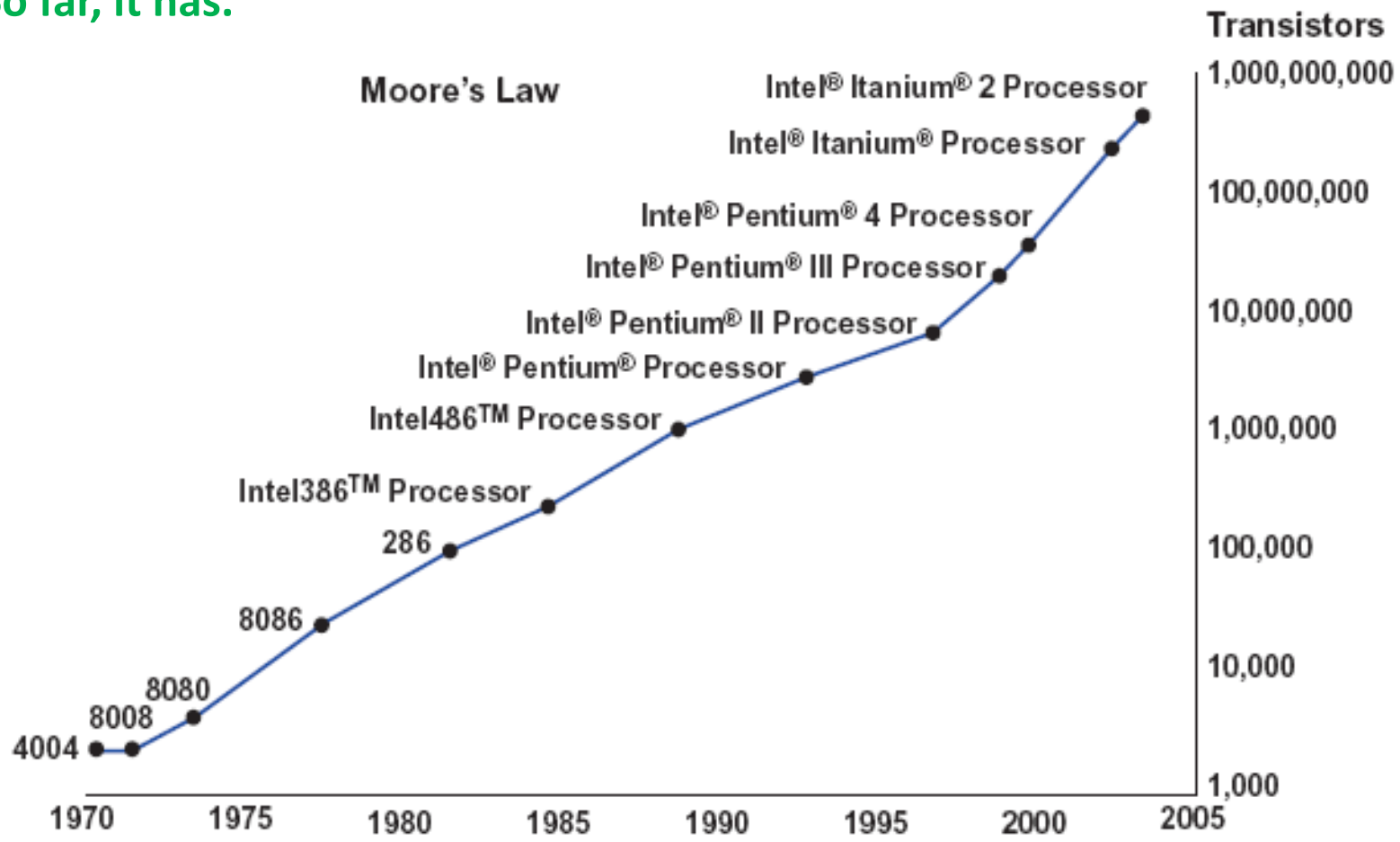
The history of computers can be divided into generations, with each generation defined by a technological breakthrough

0. gears and relays (mechanical)
   - ➔ 1. vacuum tubes (electronic and machine language) **Why Vacuum?**
     - ➔ 2. transistors (assembly)
       - ➔ 3. integrated circuits (high level languages)
         - ➔ 4. very large scale integration (OOP)
           - ➔ 5. parallel processing & networking (Natural languages)

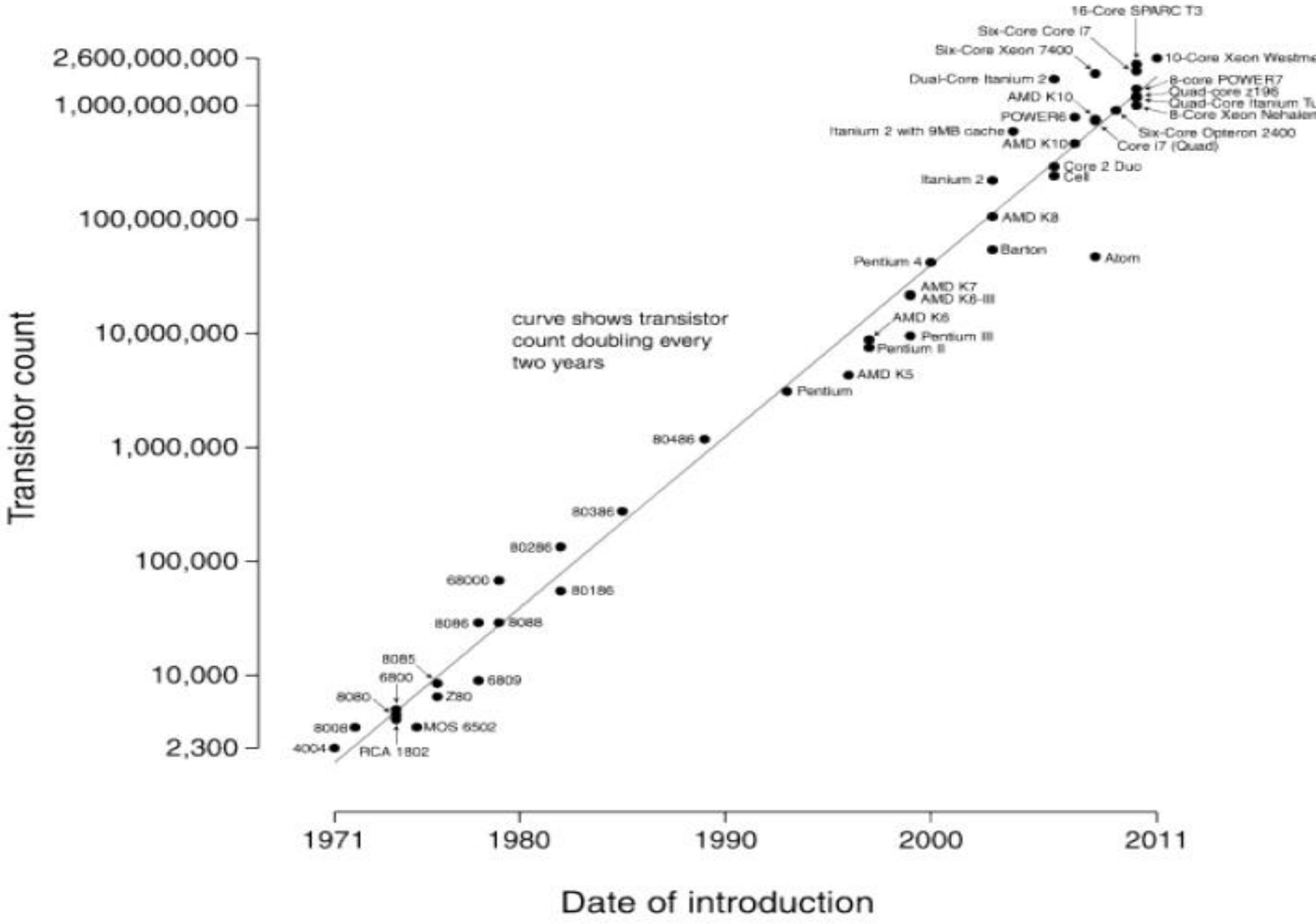
- The three directions of computer development are **miniaturization**, **speed**, and **affordability**
- **Integration (and Mass Production), Core Technology (Multiprocessors), Cost reduction by half every 2 years**



Moore's law suggests that computer power will double every 18 to 24 months. So far, it has.



Microprocessor Transistor Counts 1971-2011 & Moor's Law

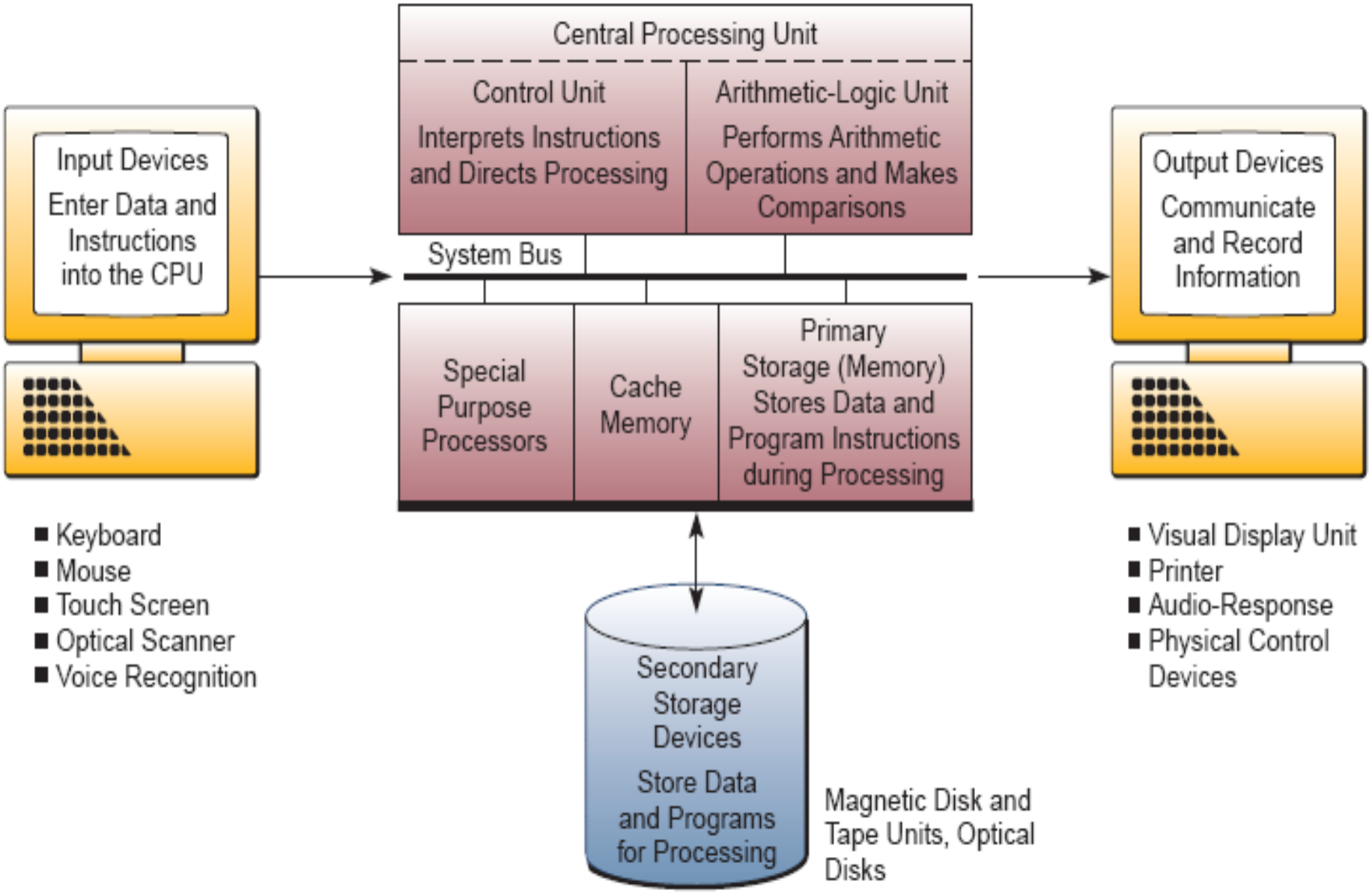


What Hardware Components Contribute to the Speed of a Computer?

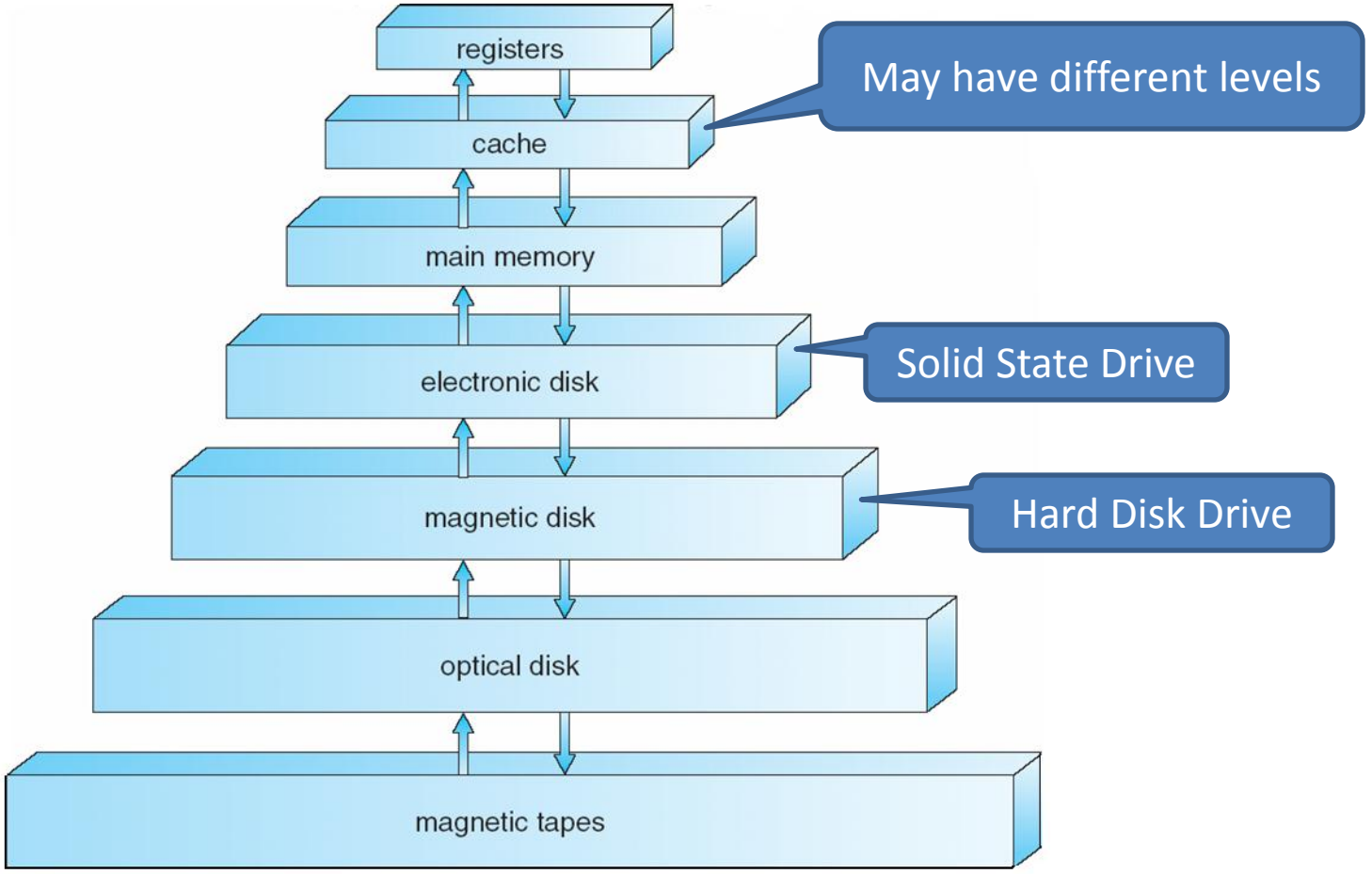
Component	Speed measured by	Units	Description
CPU	Clock speed	gHz	The time it takes to complete a **cycle**
Motherboard	Bus speed	mHz	How much data can move across the bus simultaneously.
RAM	Data transfer rate	MB/s	The time it takes for data to be transferred from memory to system.
Hard Disk	Access time	ms	The time it takes before the disk can transfer data.
	Data transfer rate	MBit/s	The time it takes for data to be transferred from disk to system.

The computer system concept

A computer is a system of hardware components and functions



Storage-Device Hierarchy



Performance of Various Levels of Storage

Level	1	2	3	4
Name	registers	cache	main memory	disk storage
Typical size	< 1 KB	> 16 MB	> 16 GB	> 100 GB
Implementation technology	custom memory with multiple ports, CMOS	on-chip or off-chip CMOS SRAM	CMOS DRAM	magnetic disk
Access time (ns)	0.25 – 0.5	0.5 – 25	80 – 250	5,000.000
Bandwidth (MB/sec)	20,000 – 100,000	5000 – 10,000	1000 – 5000	20 – 150
Managed by	compiler	hardware ??	operating system	operating system
Backed by	cache	main memory	disk	CD or tape

Storage capacities are frequently measured in kilobytes (KB), megabytes (MB), gigabytes (GB), or terabytes (TB). Although kilo means 1,000 in the metric system, the computer industry uses K to represent 1,024 (or 2^{10}) storage positions. For example, a capacity of 10 megabytes is really 10,485,760 storage positions, rather than 10 million positions. A petabyte is more than 1 quadrillion bytes (2^{50}).

byte	$\rightarrow$ 8 bits		
kilobyte (KB)	$\rightarrow 2^{10}$ bytes	=	1,024 bytes (= 8,192 bits)
megabyte (MB)	$\rightarrow 2^{20}$ bytes	=	1,048,576 bytes (= 8,388,608 bits)
gigabyte (GB)	$\rightarrow 2^{30}$ bytes	=	1,073,741,824 bytes (= 8,589,934,592 bits)
terabyte (TB)	$\rightarrow 2^{40}$ bytes	=	1,099,511,627,776 bytes (= 8,796,093,022,208 bits)

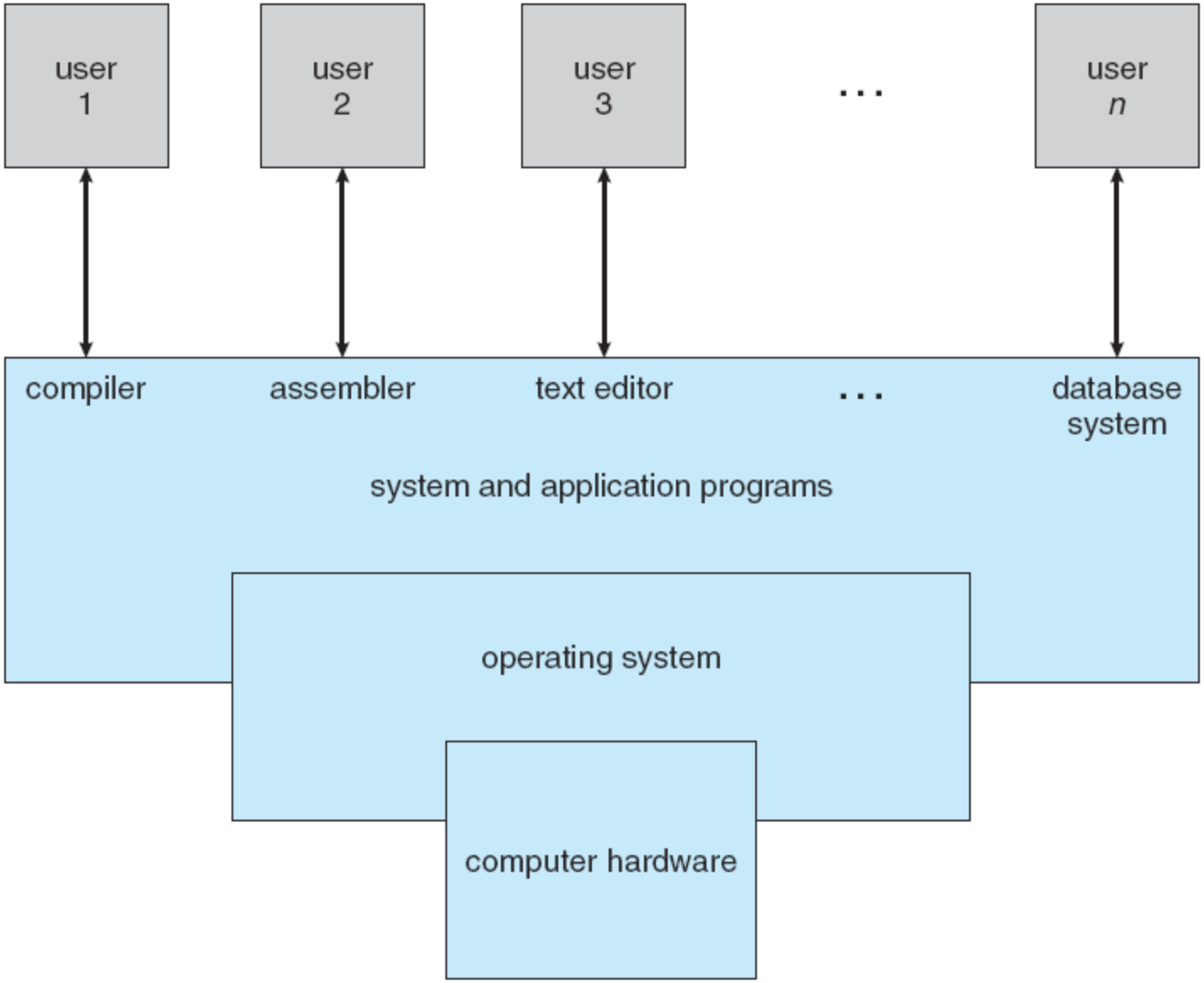


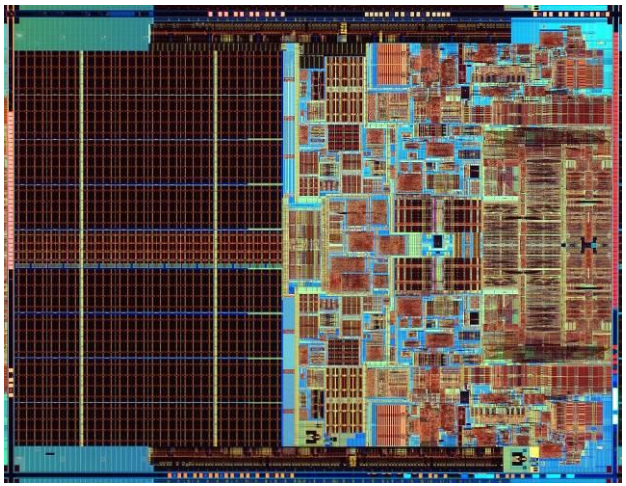
Figure 1.1 Abstract view of the components of a computer system.

Central Processing Unit (CPU)

the CPU is the "brains" of the computer, responsible for controlling its inner workings

- made of *circuitry* – electronic components wired together to control the flow of electrical signals
- the circuitry is embedded in a small silicon chip, 1-2 inches square
- despite its small size, the CPU is the most complex part of a computer
  (CPU circuitry can have 100's of millions of individual components)

- commercial examples: Intel Core 2 Duo, Intel i5, AMD Sempron, AMD Athlon



Solid-State Drives (SSD)

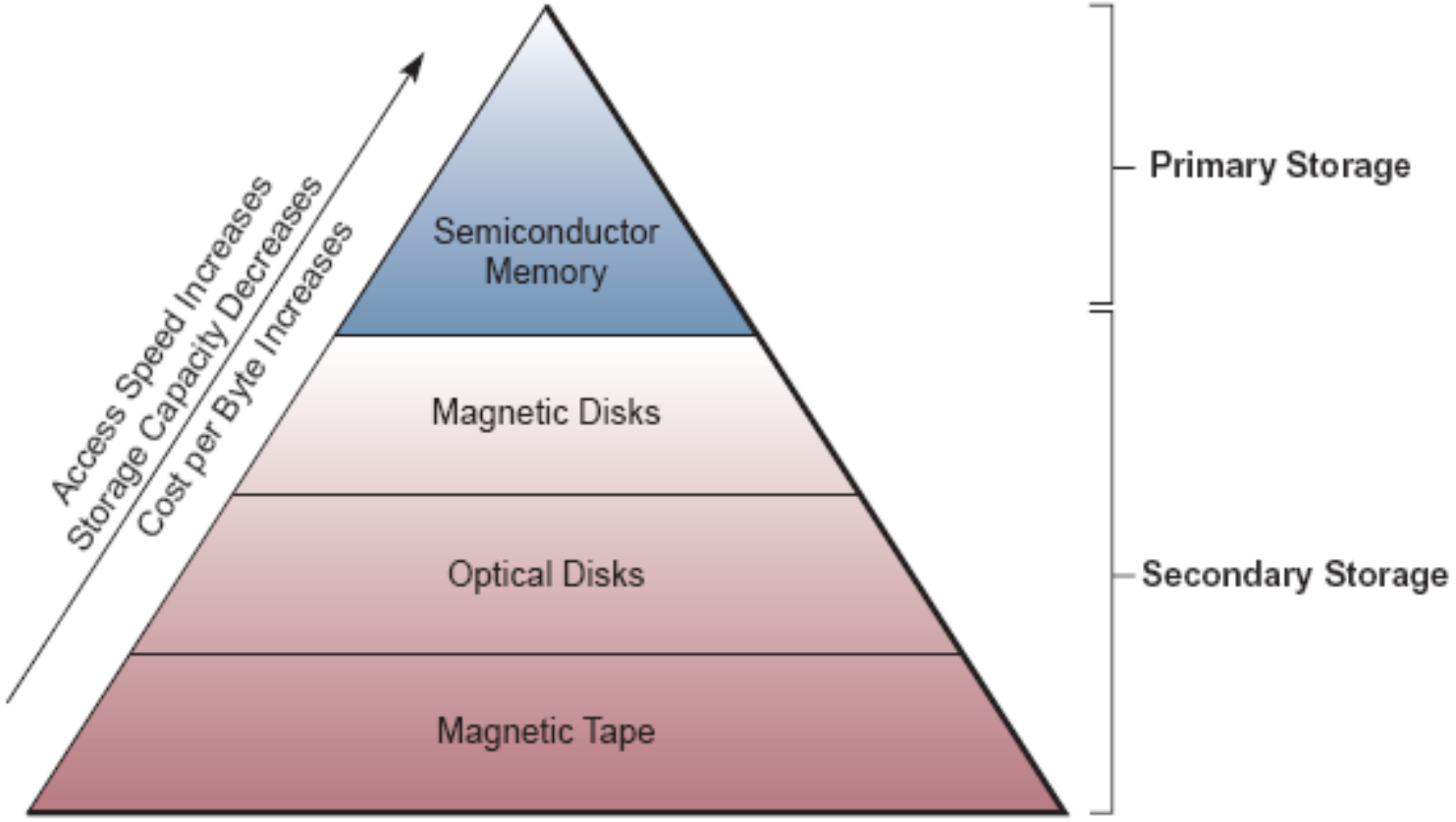
A traditional HDD consists of a spinning disk with a read/write head on a mechanical arm, known as an actuator. An **SSD**, on the other hand, has an array of semiconductor memory organized as a disk drive, using integrated circuits rather than magnetic or optical storage media.

SSD has no mechanical moving parts; Flash memory, faster and lighter than HDD

Solid state device: based entirely on semiconductor

Storage media cost, speed, and capacity trade-offs.

Note how cost increases with faster access speeds but decreases with the increased capacity of storage media.



Hardware vs. Software

Sample HW, SW specification of a computer

		Desktop System 1	Desktop System 2
	CPU	2.2 GHz Intel Celeron 450	3.2 GHz Intel Core i5
HARDWARE	Memory		
	Cache	512 KB cache	4 MB cache
	RAM	4 GB RAM	8 GB RAM
	Hard Drive	320 GB hard drive	1 TB hard drive
	CD-ROM/DVD	DVD+/−RW drive	DVD+/−RW drive
	Input/Output		
	Keyboard	USB multifunction keyboard	wireless multifunction keyboard
	Pointing Device	USB optical mouse	wireless optical mouse
	Screen	20" HD flatscreen monitor	24" HD flatscreen monitor
	Speakers	Multimedia Speaker System	Dolby Surround Sound Speakers
	Network Adapter	Integrated 10/100/1000 Ethernet	Integrated 10/100/1000 Ethernet Integrated wireless card & antenna
SOFTWARE	Operating System	Windows 7 Home Premium	Windows 7 Professional
	Web Browser	Internet Explorer 8	Internet Explorer 8
	Productivity Suite	Microsoft Works 9	Microsoft Office Professional 2007
	Security	McAfee Security Center	McAfee Security Center

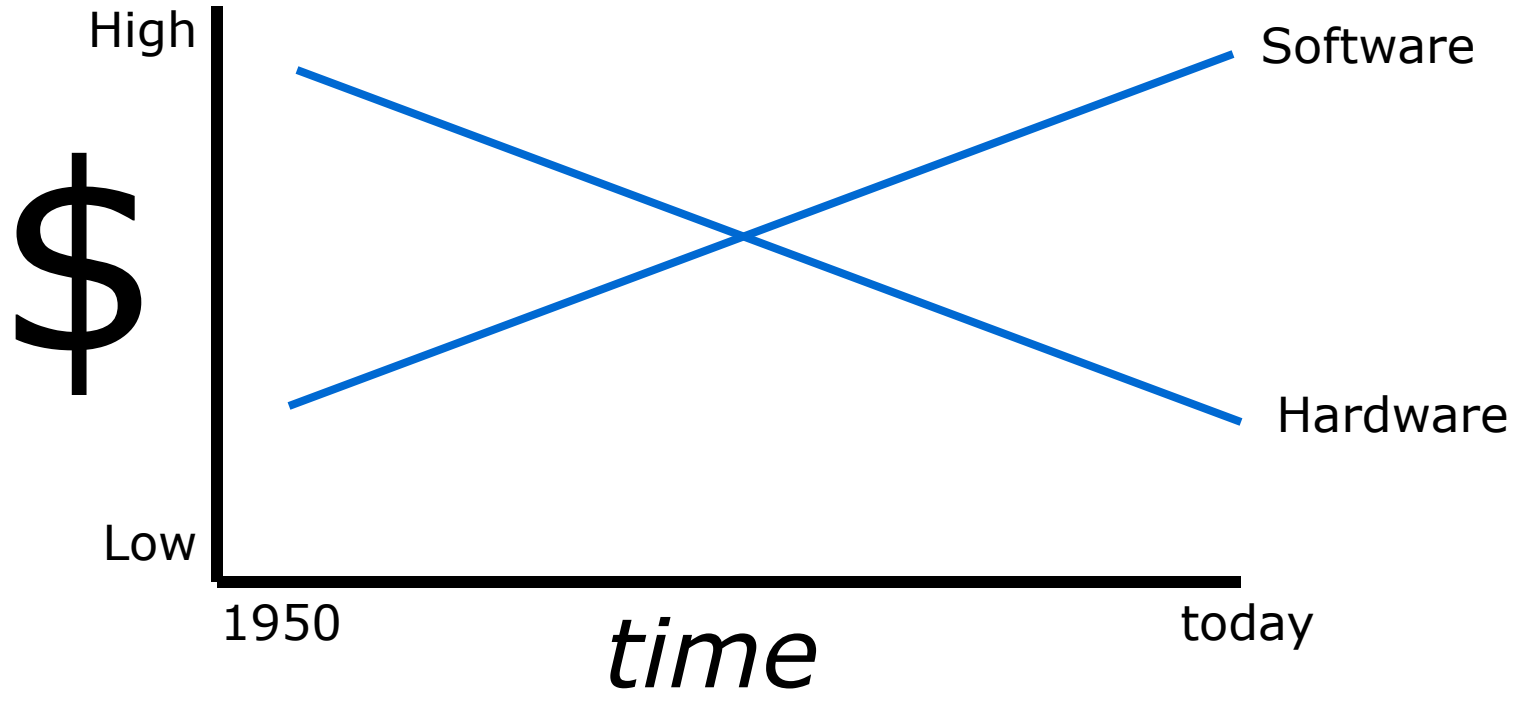
1) If you could build your own personal computer, what components would you purchase? Put together a list of the components you would use to create it, including a computer case, motherboard, CPU, hard disk, RAM, and DVD drive. How can you be sure they are all compatible with each other? How much would it cost? How does this compare to a similar computer purchased from a vendor such as Dell or HP?

2) What is the current state of solid-state drives vs. hard disks? Do original research online where you can compare price on solid-state drives and hard disks. Be sure you note the differences in price, capacity, and speed.

Software Generations

Software is the general term for various kinds of programs used to operate and manipulate computers and their peripheral devices. One common way of describing **hardware and software** is to say that software can be thought of as the **variable** part of a computer and hardware as the **invariable** part.

Cost against Time graph for Software and Hardware Development



Why is software development expensive?

First Generation Software (1951-1959)

Machine Language

Computer programs written in binary (1s and 0s)

Assembly Languages and Translators

Programs written using mnemonics, which were translated into machine language

Programmer Changes

Programmers divided into two groups: application programmers and systems programmers

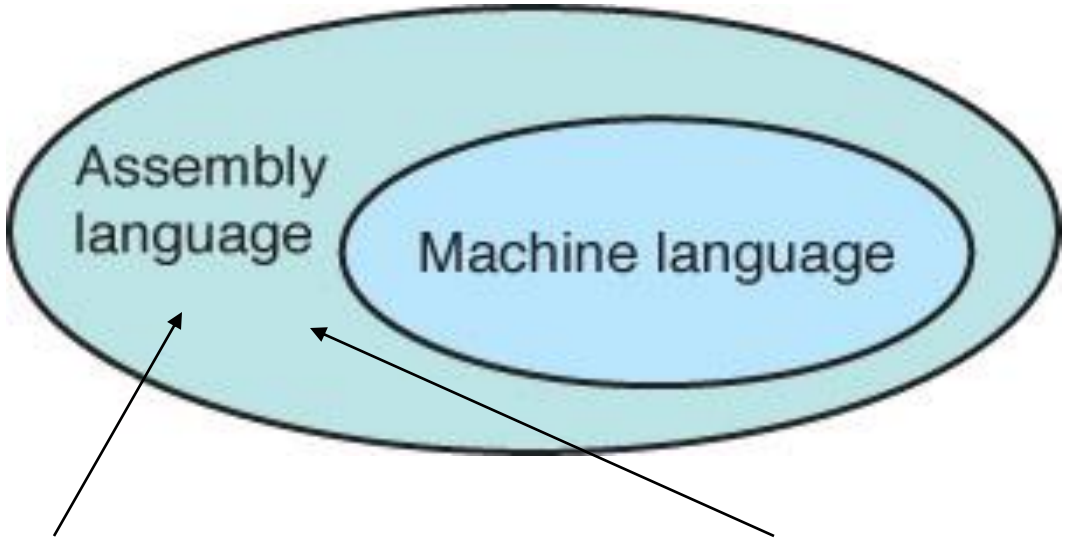
- Computers only for programmers, professionals, expert users
- Not for the general public and novice users (**not affordable and requires skill**)
- Universities, big organizations, military were using computers

First Generation Software Cont...

- Batch orientation
- Limited distribution
- Custom software
- Proprietary software ultimately used by the same person or organization
- Implementation but not engineering (no well established set of rules followed)

First Generation Software

Assembly/Machine



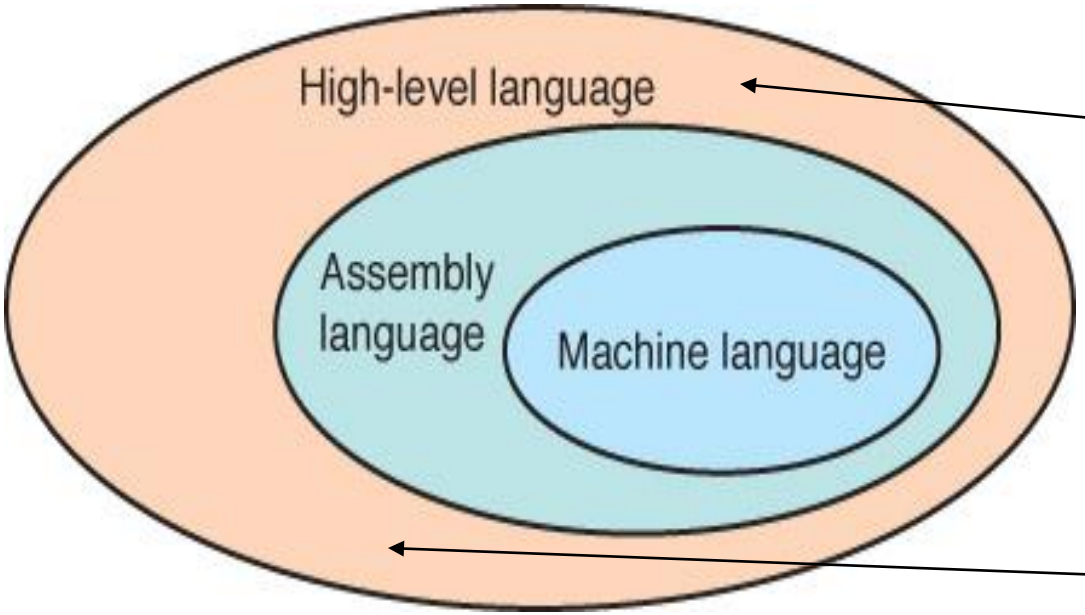
Systems programmers *write* the assembler (translator)

Applications programmers *use* assembly language to solve problems

Second Generation Software (1959-1965)

High-level Languages

English-like statements made programming easier:
Fortran, COBOL, Lisp



Systems programmers *write* translators for high-level languages

Application programmers *use* high-level languages to solve problems

Third Generation Software (1965-1971)

Systems Software

Utility programs

Language translators

Operating system, which decides which programs to run and when

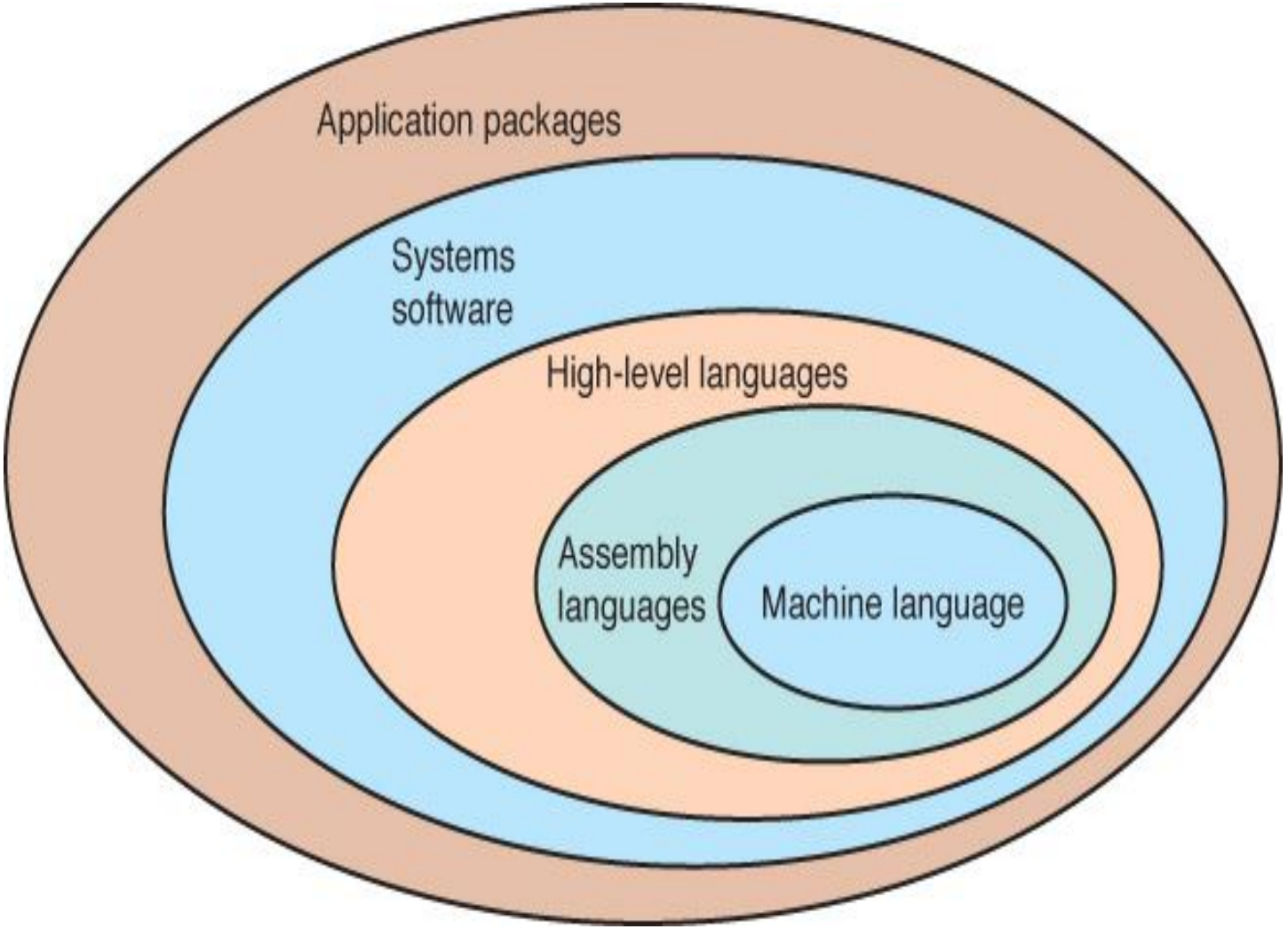
Separation between Users and Hardware

- Computer programmers write programs to be used by general public (i.e., nonprogrammers);
- Computer programmers began to write programs to be used by people who did not know how to program

Third Generation Software Cont...

- Multi-user and multi-processing
- Real-time
- Database
- Product software
- HCI (DOS, WINDOWS)
- Control process (Software Engineering)
- Introduction of software houses

Third Generation Software (1965-1971)



The layers of software surrounding hardware continue to grow

Fourth Generation Software (1971-1989)

Structured and OOP Programming

Pascal
C++
Java (Some functionalities overlap with fifth generation)

New Application Software for Users

Spreadsheets
Word processors
Database management systems

- **Convenience, affordability, usability, portability**

Fourth Generation Software

- Distributed systems (networked systems)
- Embedded “intelligence”
- Low cost hardware (mass production)
- Customer impact
- Concurrency
- Global and local area network
- High bandwidth
- Heavy demand on software developers

Fifth Generation Software
(1990- present)

Microsoft

Windows operating system and other Microsoft application programs dominate the market

Object-Oriented Design

Based on a hierarchy of data objects (i.e. Java)

World Wide Web

Allows easy global communication through the Internet

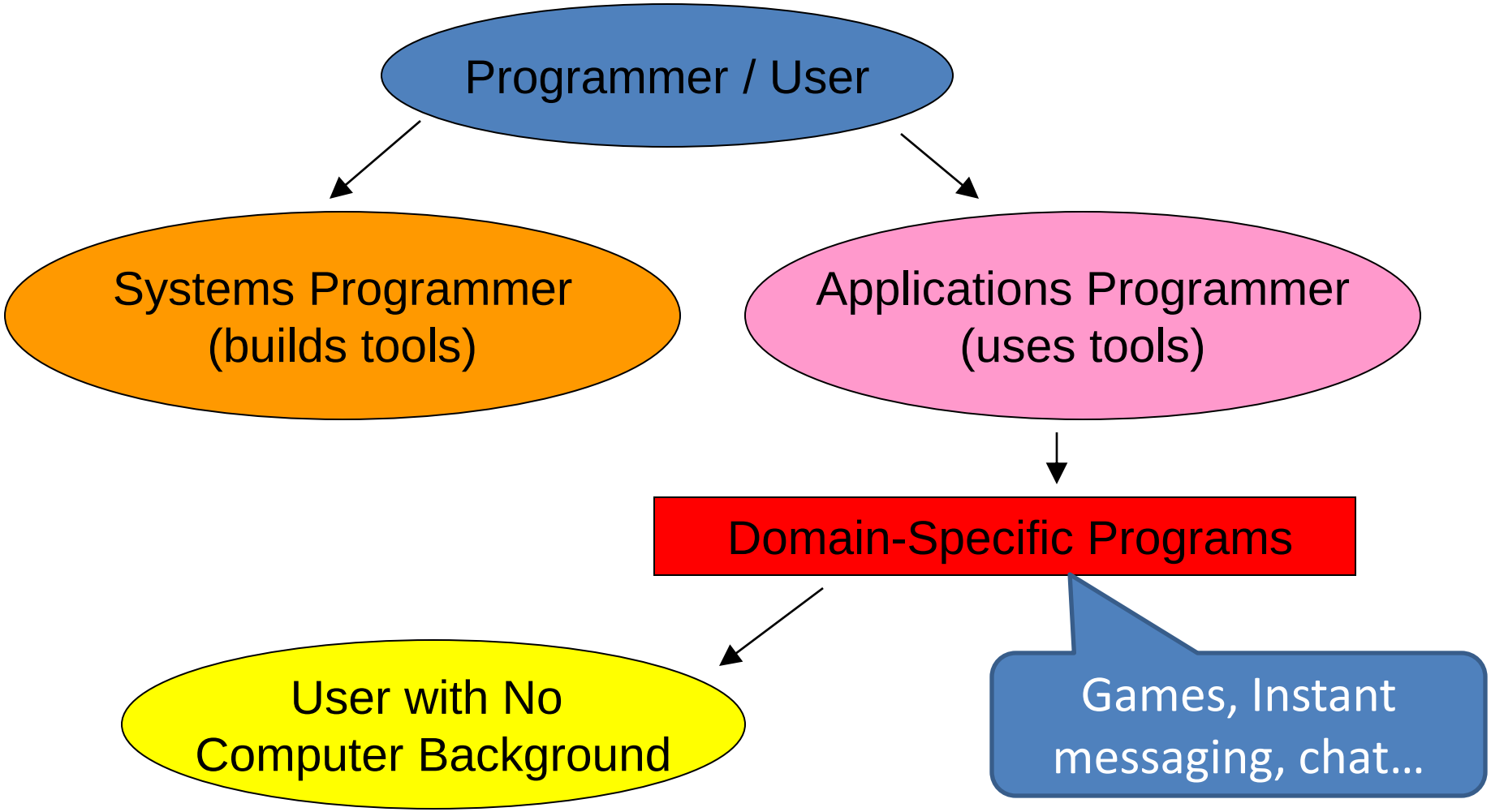
New Users

Today's user needs no computer knowledge
Computer is like commodity

Fifth Generation Software

- Powerful desktop systems
- Object Oriented Technology
- Expert systems
- Artificial Neural Networks (implanted in beings)
- Parallel computing
- Pattern recognition and human like information processing capability
- Knowledge engineering
- Replacing conventional Software Development approaches

Computing as a Tool



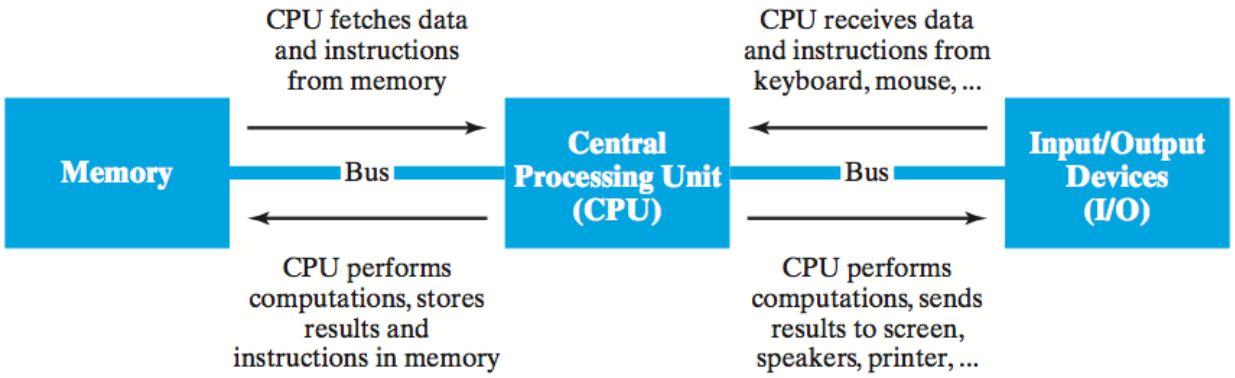
von Neumann Architecture

although specific components may vary, virtually all modern computers have the same underlying structure

- known as the *von Neumann architecture*
- named after computer pioneer, John von Neumann, who popularized the design in the early 1950's

the von Neumann architecture identifies 3 essential components

1. *Input/Output Devices (I/O)* allow the user to interact with the computer
2. *Memory* stores information to be processed as well as programs (instructions specifying the steps necessary to complete specific tasks)
3. *Central Processing Unit (CPU)* carries out the instructions to process information



von Neumann popularized the idea of a "stored program" computer

- store both data and programs in Memory
- Central Processing Unit (CPU) executes by loading program instructions from memory and executing them in sequence
- interact with the user via Input / Output devices

virtually all modern machines follow this *von Neumann Architecture*