COMPUTER SYSTEM OVERVIEW

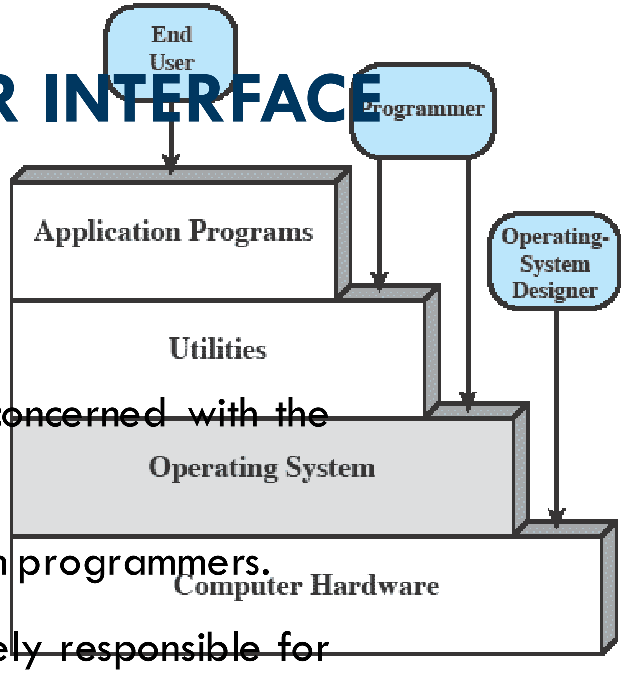
OPERATING SYSTEM

- A program that controls the execution of application programs
- An interface between applications and hardware

Main objectives of an OS:

- Convenience
- Efficiency
- Ability to evolve

THE OPERATING SYSTEM AS A USER/COMPUTER INTERFACE

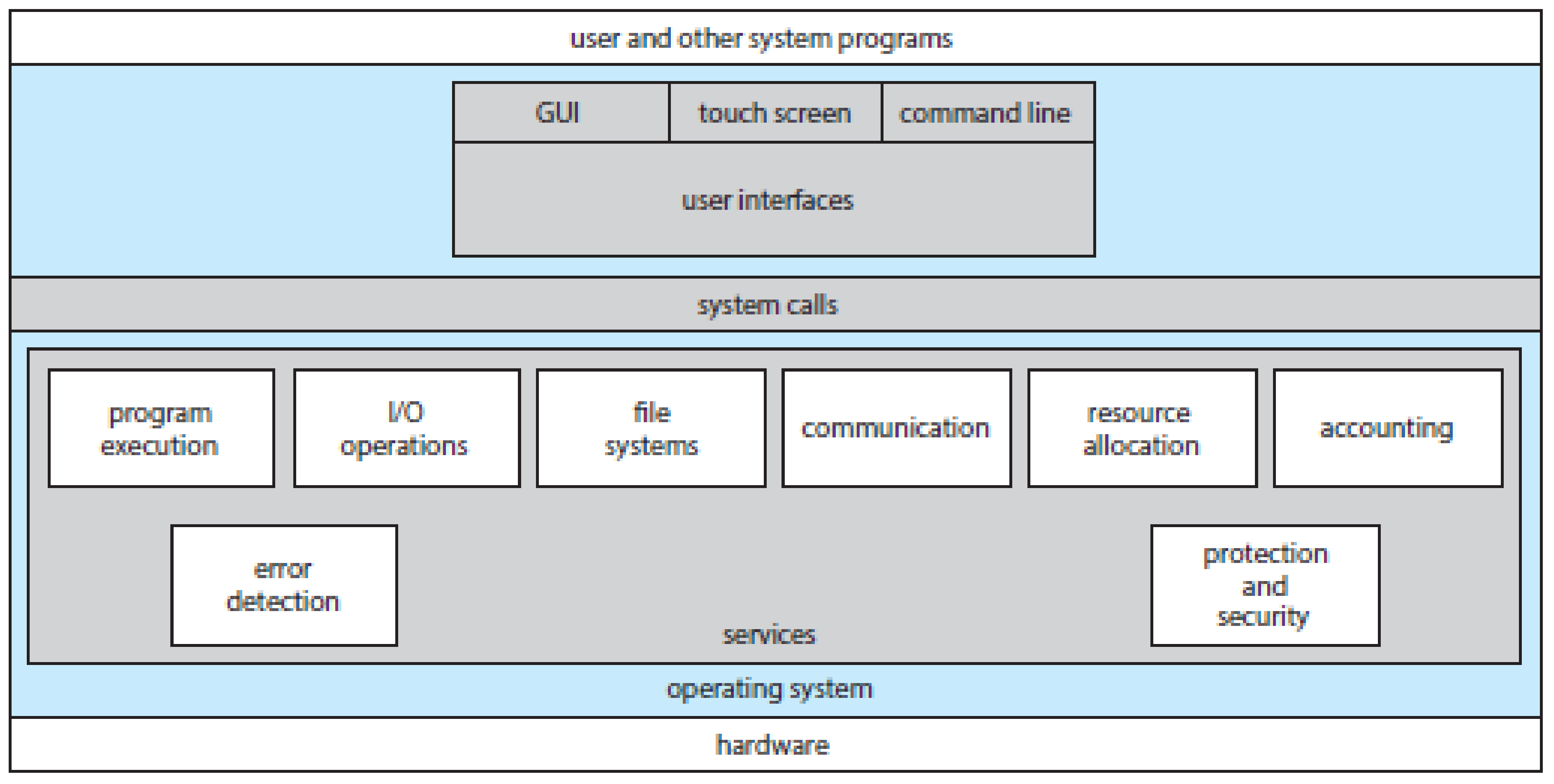


- The end user generally views a computer system in terms of a set of applications and is not concerned with the details of computer hardware.
- Application can be expressed in a programming languages and are developed by an application programmers.
- If one were to develop an application program as a set of machine instructions that is completely responsible for controlling the computer hardware, and it would be a very complex undertaking.
- To ease this chore, a set of system programs is provided. Some of these programs are referred to as utilities, or library programs. These implement frequently used functions that assist in program creation, the management of files, and the control of I/O devices.
- **A programmer** will make use of these facilities in developing an application, and the application, while it is running, will invoke the utilities to perform certain functions.
- **The most important collection of system programs comprises the OS.**
- The OS masks the details of the hardware from the programmer and provides the programmer with a convenient interface for using the system. It acts as mediator, making it easier for the programmer and for application programs to access and use those facilities and services.

OPERATING SYSTEM SERVICES

- Operating systems provide an environment for execution of programs and services to programs and users
- OS typically provides services in the following areas:
- **User interface**
- **Program development**
- **Program execution**
- **Access to I/O devices**
- **Controlled access to files**
- **System access**
- **Error detection and response**
- **Communication**
- **Accounting**

A VIEW OF OPERATING SYSTEM SERVICES



OPERATING SYSTEM SERVICES

- **User interface** - Almost all operating systems have a user interface (**UI**).
  - Varies between **Command-Line** (**CLI**), **Graphics User Interface** (**GUI**), **Batch**
- **Program execution** - The system must be able to load a program into memory and to run that program, end execution, either normally or abnormally (indicating error)
- **I/O operations** - A running program may require I/O, which may involve a file or an I/O device
- **File-system manipulation** - The file system is of particular interest. Programs need to read and write files and directories, create and delete them, search them, list file Information, permission management.
- **Communications** – Processes may exchange information, on the same computer or between computers over a network
  - Communications may be via shared memory or through message passing (packets moved by the OS)
- **Error detection** – OS needs to be constantly aware of possible errors
  - May occur in the CPU and memory hardware, in I/O devices, in user program
  - For each type of error, OS should take the appropriate action to ensure correct and consistent computing
  - Debugging facilities can greatly enhance the user's and programmer's abilities to efficiently use the system

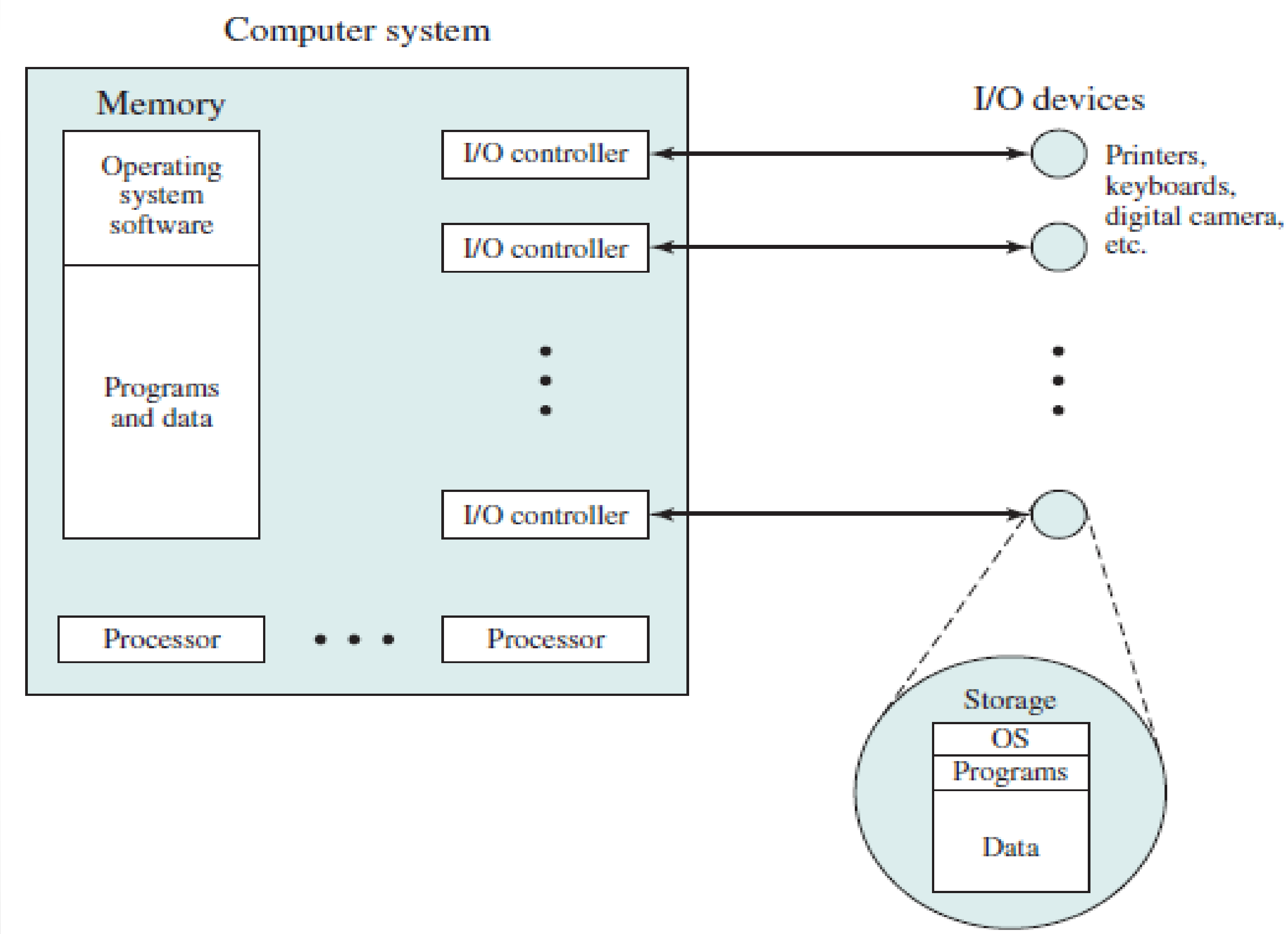
OPERATING SYSTEM SERVICES (CONT.)

- Another set of OS functions exists for ensuring the efficient operation of the system itself via resource sharing
  - **Resource allocation -** When multiple users or multiple jobs running concurrently, resources must be allocated to each of them
    - Many types of resources - CPU cycles, main memory, file storage, I/O devices.
  - **Accounting -** To keep track of which users use how much and what kinds of computer resources
  - **Protection and security -** The owners of information stored in a multiuser or networked computer system may want to control use of that information, concurrent processes should not interfere with each other
    - **Protection** involves ensuring that all access to system resources is controlled
    - **Security** of the system from outsiders requires user authentication, extends to defending external I/O devices from invalid access attempts

THE OPERATING SYSTEM AS RESOURCE MANAGER

- A computer is a set of resources for moving, storing, & processing data
- The OS is responsible for managing these resources
- The OS exercises its control through software i.e. ;
- Functions in the same way as ordinary computer software i.e. ;
- Program, or suite of programs, executed by the processor
- Frequently relinquishes control and must depend on the processor to allow it to regain control

THE OPERATING SYSTEM AS RESOURCE MANAGER



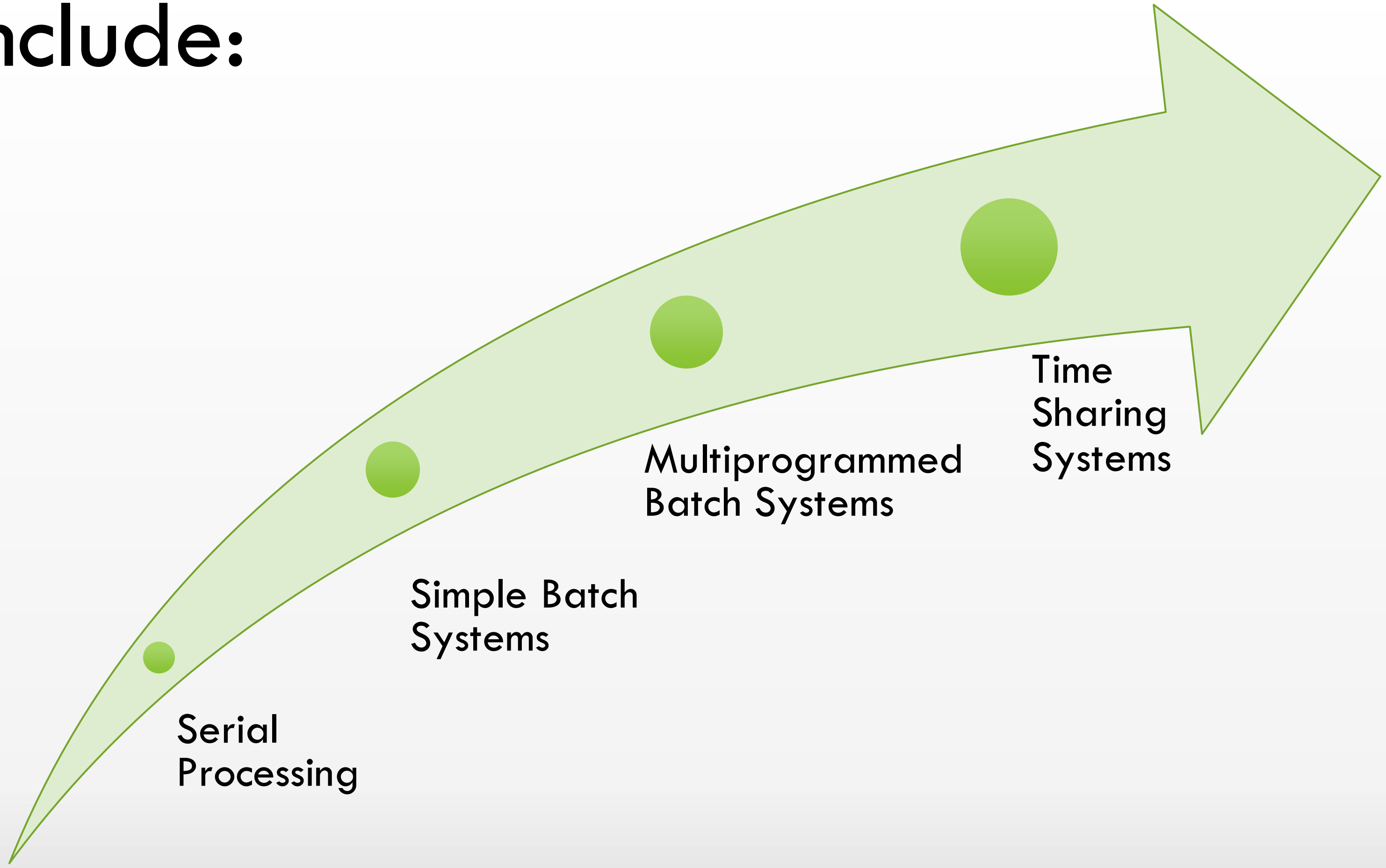
EASE OF EVOLUTION OF AN OPERATING SYSTEM

A major OS will evolve over time for a number of reasons:

- **Hardware upgrades**
- **New types of hardware**
- **New services**
- **Fixes**

THE EVOLUTION OF OPERATING SYSTEMS

Stages include:



SERIAL PROCESSING

Earliest computers, late 1940s to the mid-1950s

- No Operating System
- The programmer interacted directly with the computer hardware
- These computers were run from a console consisting of display lights, toggle switches, some form of input device, and a printer.
- Programs in machine code were loaded via the input device (e.g., a card reader).
- If an error halted the program, the error condition was indicated by the lights.
- If the program proceeded to a normal completion, the output appeared on the printer.
- This mode of operation could be termed ***serial processing***, as users have access to the computer in series

Problems

- **Scheduling:**

Most installations used a hardcopy sign-up sheet to reserve computer time. A user might sign up for an hour and finish in 45 minutes; this would result in wasted computer processing time. On the other hand, the user might run into problems, not finish in the allotted time, and be forced to stop before resolving the problem.

- **Setup time:**

A considerable amount of time was spent just on setting up the program to run.

A single program, called a **job**, could involve loading the compiler plus the high-level language program (source program) into memory, saving the compiled program (object program), and then loading and linking together the object program and common functions. Each of these steps could involve mounting or dismounting tapes or setting up card decks. If an error occurred, the hapless user typically had to go back to the beginning of the setup sequence. Thus, a considerable amount of time was spent just in setting up the program to run

SIMPLE BATCH SYSTEMS

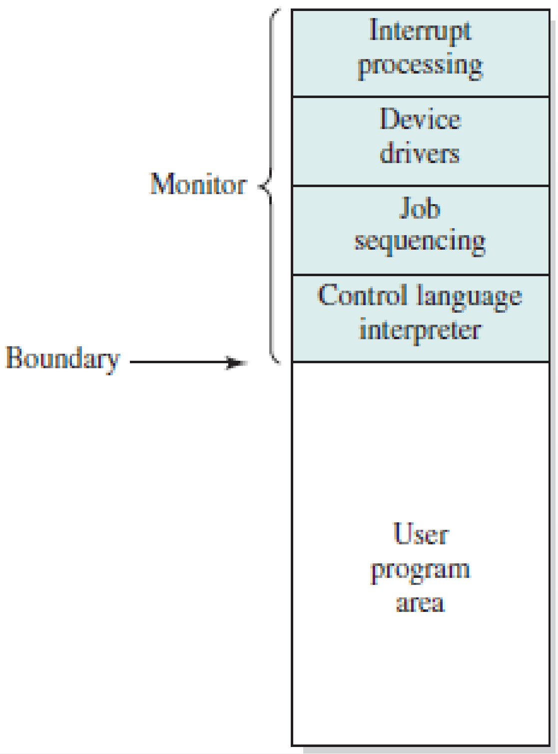
- Early computers were very expensive
  - important to maximize processor utilization
  - the wasted time due to scheduling and setup time was unacceptable.

- The idea behind the simple batch-processing is the use of a piece of software known as the **monitor**.
  - user no longer has direct access to the processor.
  - the user submits the job on cards to a computer operator, who batches the jobs together sequentially and places the entire batch on an input device, for use by the monitor.
  - Each program is constructed to branch back to the monitor when it completes processing
  - monitor automatically begins loading the next program.

SIMPLE BATCH PROCESSING SYSTEMS

MONITOR POINT OF VIEW

- *Resident Monitor* is software always in memory
- Monitor controls the sequence of events
- Monitor reads in job and gives control
- Job returns control to monitor



PROCESSOR POINT OF VIEW

- Processor executes instruction from the memory containing the monitor
- Executes the instructions in the user program until it encounters an ending or error condition
- "*control is passed to a job*" means processor is fetching and executing instructions in a user program
- "*control is returned to the monitor*" means that the processor is fetching and executing instructions from the monitor program

SIMPLE BATCH PROCESSING
ADVANTAGES

- **The monitor performs a scheduling function.** A batch of jobs is queued up, and jobs are executed as rapidly as possible, with no intervening idle time.

- **The monitor improves job setup time.** With each job, instructions are included in a primitive form of **job control language (JCL)**. This is a special type of programming language used to provide instructions to the monitor.
  - A simple example is that of a user submitting a program written in the programming language FORTRAN plus some data to be used by the program.

SIMPLE BATCH PROCESSING

DESIRABLE HARDWARE FEATURES

- The monitor, or batch OS, is simply a computer program. It relies on the ability of the processor to fetch instructions from various portions of main memory to alternately seize and relinquish control. Certain other hardware features are also desirable:

Memory protection for monitor

- while the user program is executing, it must not alter the memory area containing the monitor

Timer

- prevents a job from monopolizing the system

Privileged instructions

- can only be executed by the monitor

Interrupts

- gives OS more flexibility in controlling user programs

SIMPLE BATCH SYSTEMS
MODES OF OPERATION

- Considerations of memory protection and privileged instructions lead to the concept of modes of operation.

User Mode

- user program executes in user mode
- certain areas of memory are protected from user access
- certain instructions may not be executed

Kernel Mode

- monitor executes in kernel mode
- privileged instructions may be executed
- protected areas of memory may be accessed

SIMPLE BATCH PROCESSING
OVERHEAD

- Processor time alternates between execution of user programs and execution of the monitor
- Sacrifices:
  - some main memory is now given over to the monitor
  - some processor time is consumed by the monitor
- Despite overhead, the simple batch system improves utilization of the computer.

INEFFICIENCY OF SIMPLE BATCH PROCESSING

- Processor is often idle even with automatic job sequencing provided by a simple batch OS. Its because I/O devices are slow compared to processor
- In Uniprogramming, the processor spends a certain amount of time executing, until it reaches an I/O instruction; it must then wait until that I/O instruction concludes before proceeding

(a) Uniprogramming

Read one record from file	15 μs
Execute 100 instructions	1 μs
Write one record to file	15 μs
Total	31 μs

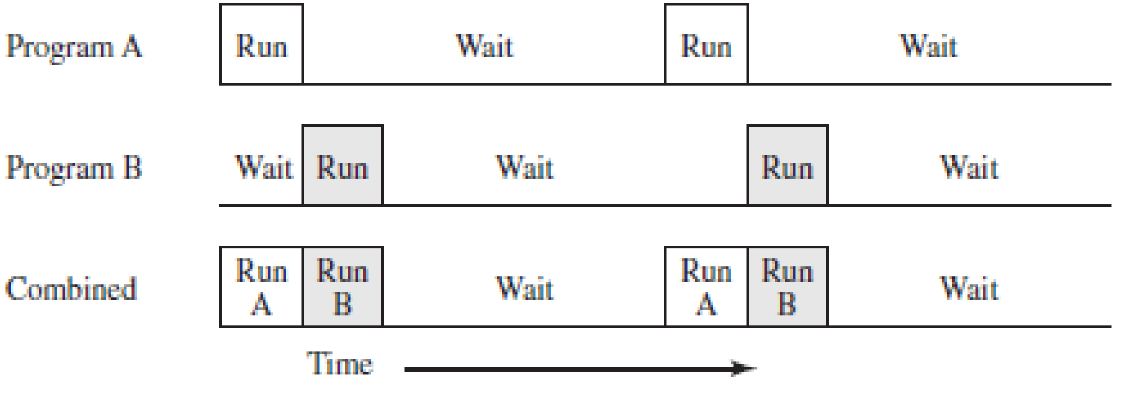
$$\text{Percent CPU utilization} = \frac{1}{31} = 0.032 = 3.2\%$$

MULTIPROGRAMMING BATCH SYSTEMS

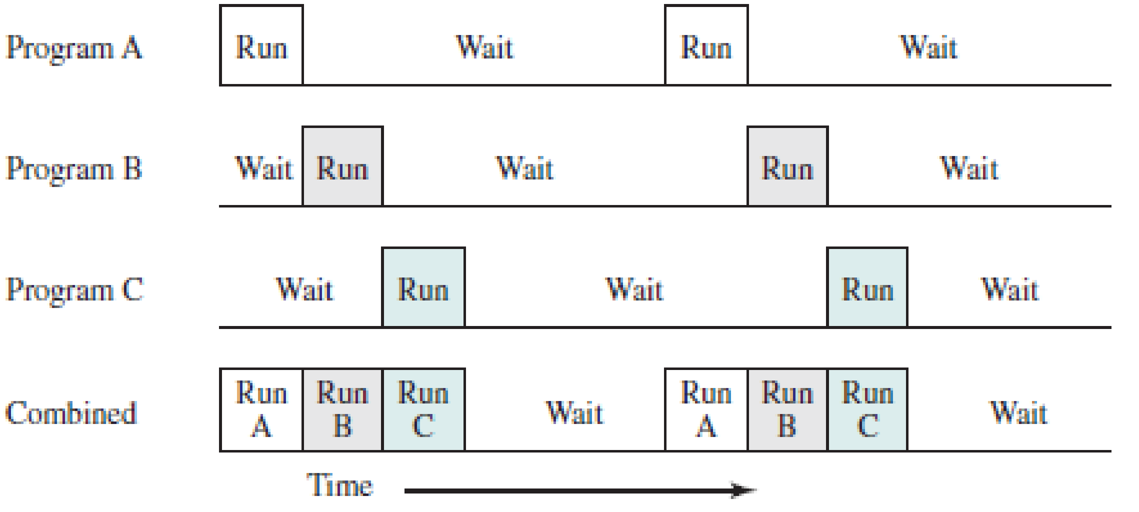
- **Multiprogramming** also known as **multitasking**

- Multiprogramming was designed to keep the processor and I/O devices, including storage devices, simultaneously busy to achieve maximum efficiency.

- The key mechanism is this: Memory is expanded to hold the OS (resident monitor) and multiple user programs. When one job needs to wait for I/O, the processor can switch to the other job residing in main memory, which is likely not waiting for I/O.



(b) Multiprogramming with two programs



(c) Multiprogramming with three programs

MULTIPROGRAMMING EXAMPLE

Table 2.1 Sample Program Execution Attributes

	JOB1	JOB2	JOB3
Type of job	Heavy compute	Heavy I/O	Heavy I/O
Duration	5 min	15 min	10 min
Memory required	50 M	100 M	75 M
Need disk?	No	No	Yes
Need terminal?	No	Yes	No
Need printer?	No	No	Yes

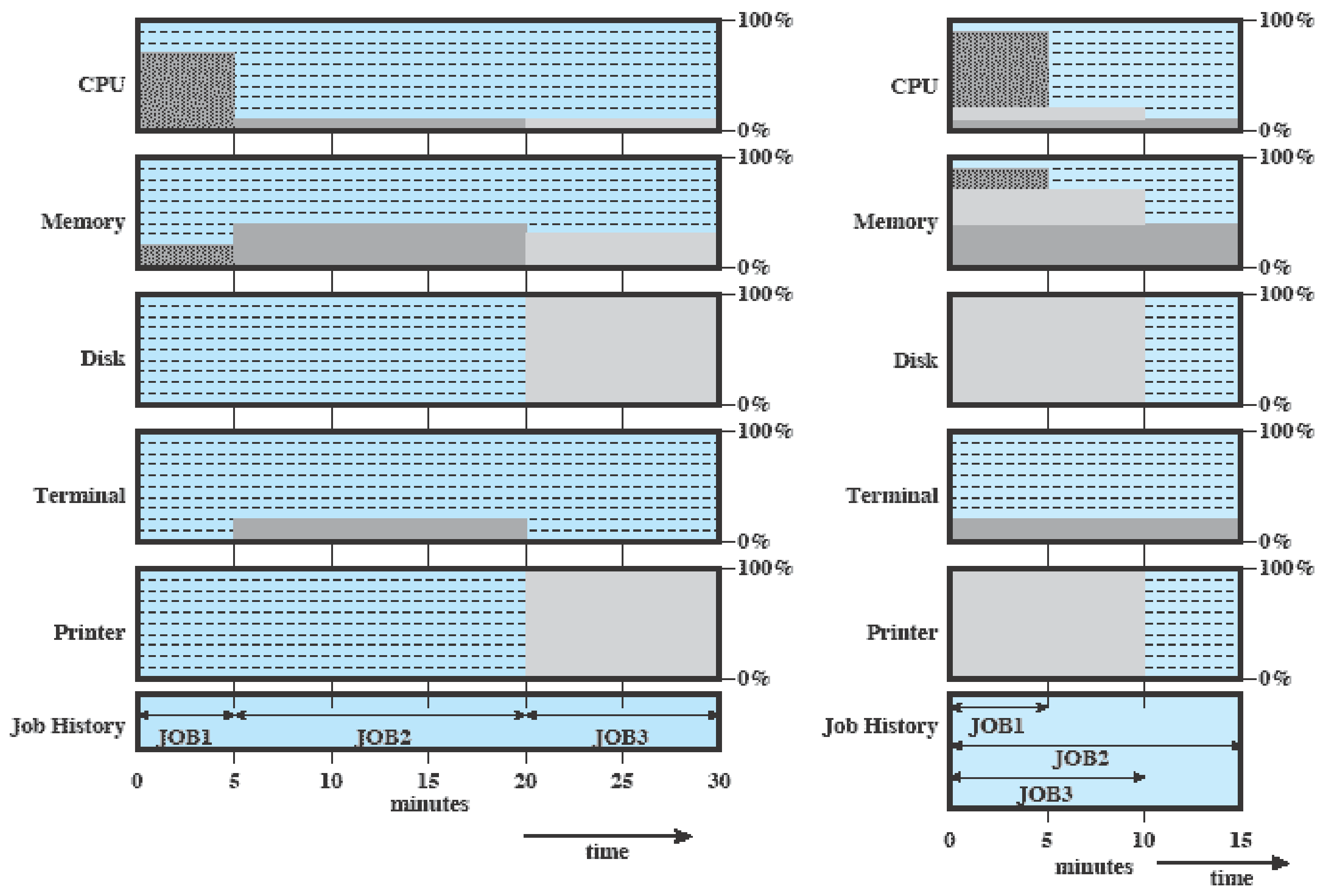
MULTIPROGRAMMING EXAMPLE

Table 2.2 Effects of Multiprogramming on Resource Utilization

	Uniprogramming	Multiprogramming
Processor use	20%	40%
Memory use	33%	67%
Disk use	33%	67%
Printer use	33%	67%
Elapsed time	30 min	15 min
Throughput	6 jobs/hr	12 jobs/hr
Mean response time	18 min	10 min

MULTIPROGRAMMING

UTILIZATION HISTOGRAMS



(a) Uniprogramming

(b) Multiprogramming

TIME-SHARING SYSTEMS

- With the use of multiprogramming, **batch processing** can be quite efficient.
- However, for many jobs, it is desirable to provide a mode in which the user interacts directly with the computer.
- So, another line of development was **general-purpose time sharing**.
- The key design objective is **responsiveness** to the individual user and yet, for cost reasons, be able to support many users simultaneously. These goals are compatible because of the relatively slow reaction time of the user. For example, if a typical user needs an average of 2 seconds of processing time per minute, then close to 30 such users should be able to share the same system without noticeable interference.

- A time-sharing system can be used to handle multiple interactive jobs
- Processor time is shared among multiple users
- Multiple users simultaneously access the system through terminals, with the OS interleaving the execution of each user program in a short burst or quantum of computation

REAL-TIME TRANSACTION PROCESSING SYSTEMS

- An other important line of development has been real-time transaction processing systems.
- In transaction processing, an interactive mode is essential, a number of users are entering queries or updates against a database. An example is an airline reservation system.
- The key difference between the transaction processing system and the time-sharing system is that the former is limited to one or a few applications, whereas users of a time-sharing system can engage in program development, job execution, and the use of various applications. In both cases, system response time is paramount.

BATCH MULTIPROGRAMMING VS. TIME SHARING

	Batch Multiprogramming	Time Sharing
Principal objective	Maximize processor use	Minimize response time
Source of directives to operating system	Job control language commands provided with the job	Commands entered at the terminal

COMPATIBLE TIME-SHARING SYSTEMS

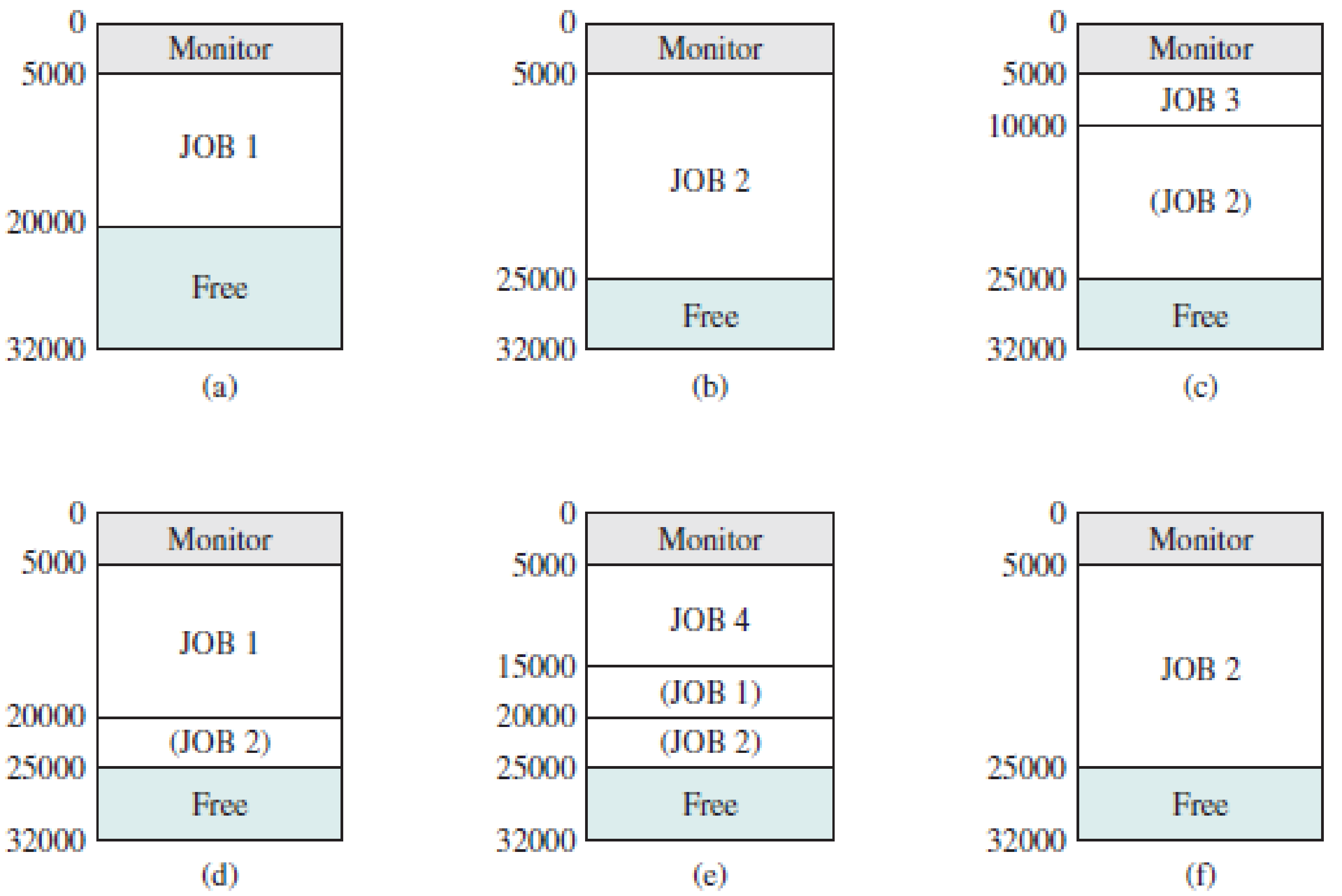
CTTS

- Compatible Time-Sharing System (CTTS)
- One of the first time-sharing operating systems
- Developed at MIT by a group known as Project MAC
- Ran on a computer with 32,000 36-bit words of main memory, with the resident monitor consuming 5000 of that
- To simplify both the monitor and memory management a program was always loaded to start at the location of the 5000th word

TIME SLICING

- System clock generates interrupts at a rate of approximately one every 0.2 seconds
- At each interrupt OS regained control and could assign processor to another user
- At regular time intervals the current user would be preempted and another user loaded in
- Old user programs and data were written out to disk
- Old user program code and data were restored in main memory when that program was next given a turn

CTTS EXAMPLE



MAJOR ACHIEVEMENTS

There have been four major theoretical advances in the development of operating systems:

- **Processes**
- **Memory management**
- **Information protection and security**
- **Scheduling and resource management**

Taken together, these four areas span many of the key design and implementation issues of modern operating systems.

THE PROCESS

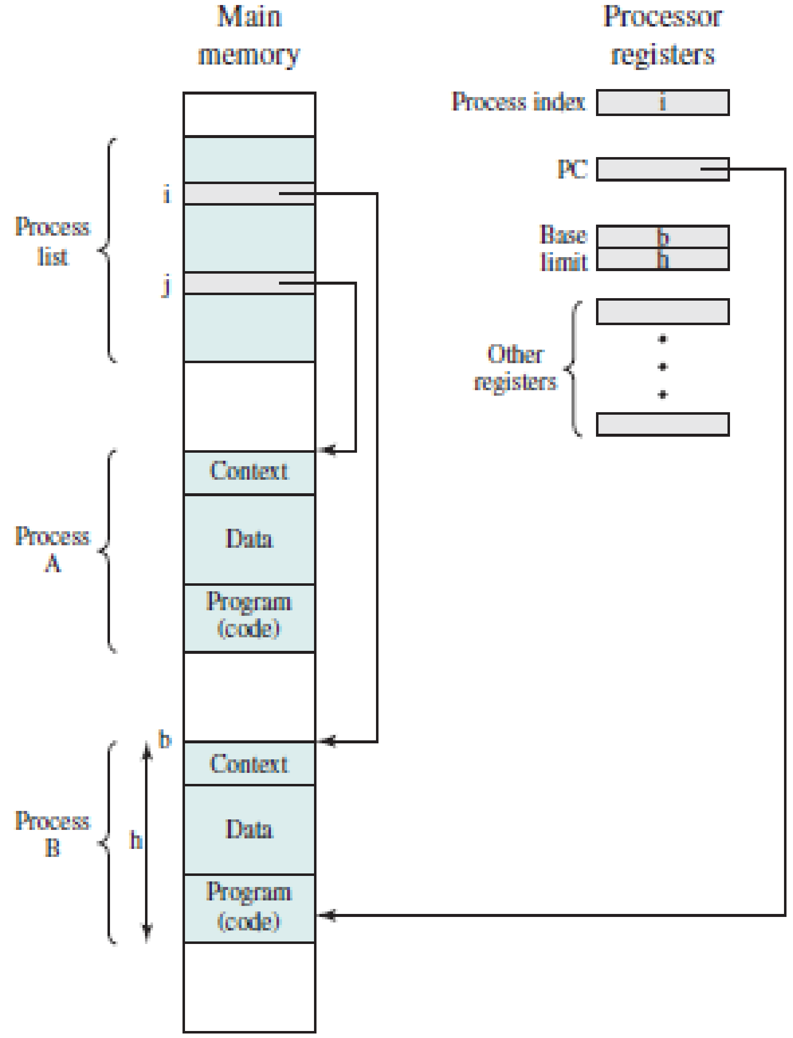
- Central to the design of operating systems is the concept of ***process***.
- It is more general term than *job*. Some of the definitions have been given for the term ***process*** *are:*
    - ***A program in execution***
    - ***An instance of a program running on a computer***
    - ***The entity that can be assigned to and executed on a processor***
    - ***A unit of activity characterized by a single sequential thread of execution, a current state, and an associated set of system resources***
- The concept of process should become clearer as we proceed.

CONCEPT OF PROCESS

- The concept of the process provides the foundation. We can think of a process as consisting of three components:
- An executable program
- The associated data needed by the program (variables, work space, buffers, etc.)
- The execution context of the program
- The last element, **execution context**, or **process state**, is essential, it is the internal data by which the OS is able to supervise and control the process. This internal information is separated from the process, because the OS has information not permitted to the process.
- **The context includes all of the information that the OS needs to manage the process and that the processor needs to execute the process properly. The context includes the contents of the various processor registers, such as the program counter and data registers. It also includes information of use to the OS, such as the priority of the process and whether the process is waiting for the completion of a particular I/O event, process state.**

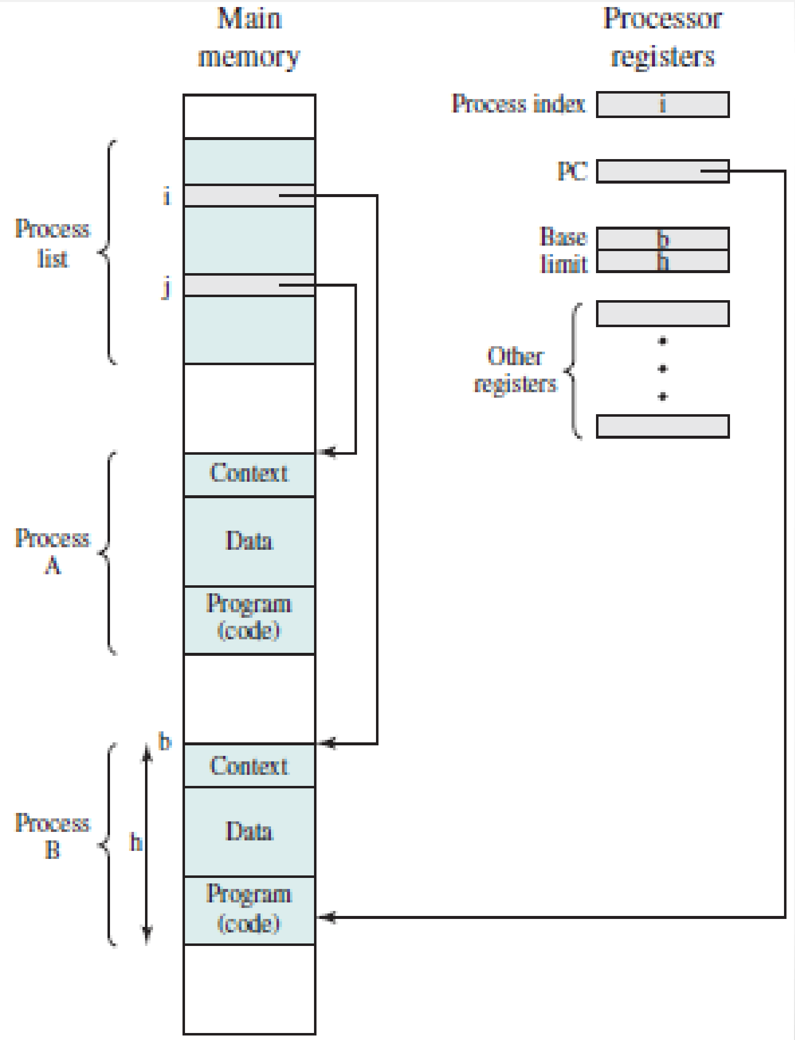
TYPICAL PROCESS IMPLEMENTATION

- Example shows how two processes A and B may be managed.
- A block of memory is allocated to each process that contains the program, data, and context information.
- Each process is recorded in a process list built and maintained by the OS.
- The process list contains one entry for each process, which includes a pointer to the location of the block of memory that contains the process.
- The entry may also include part or all of the execution context of the process. The remainder of the execution context is stored elsewhere, perhaps with the process itself (as indicated in Figure) or frequently in a separate region of memory.



TYPICAL PROCESS IMPLEMENTATION

- The process index register contains the index into the process list of the process currently controlling the processor.
- The program counter points to the next instruction in that process to be executed.
- The base and limit registers define the memory occupied by the process as starting address and the size.
- The program counter and all data references are interpreted relative to the base register and must not exceed the value in the limit register. This prevents interprocess interference.
- Process index register indicates that process B is executing.
- Process A was previously executing but has been temporarily interrupted. The contents of all the registers at the moment of A's interruption were recorded in its execution context. Later, the OS can perform a process switch and resume execution of process A.



TYPICAL PROCESS IMPLEMENTATION

- Thus, the process is realized as a data structure. This structure allows the development of powerful techniques for ensuring coordination and cooperation among processes.

- New features can be designed and incorporated into the OS (e.g., priority) by expanding the context to include any new information needed to support the feature.

KEY ELEMENTS OF AN OPERATING SYSTEM FOR MULTIPROGRAMMING