Department of Physics,
Computer Science & Engineering

CPSC 410 – Operating Systems I

Operating System Overview

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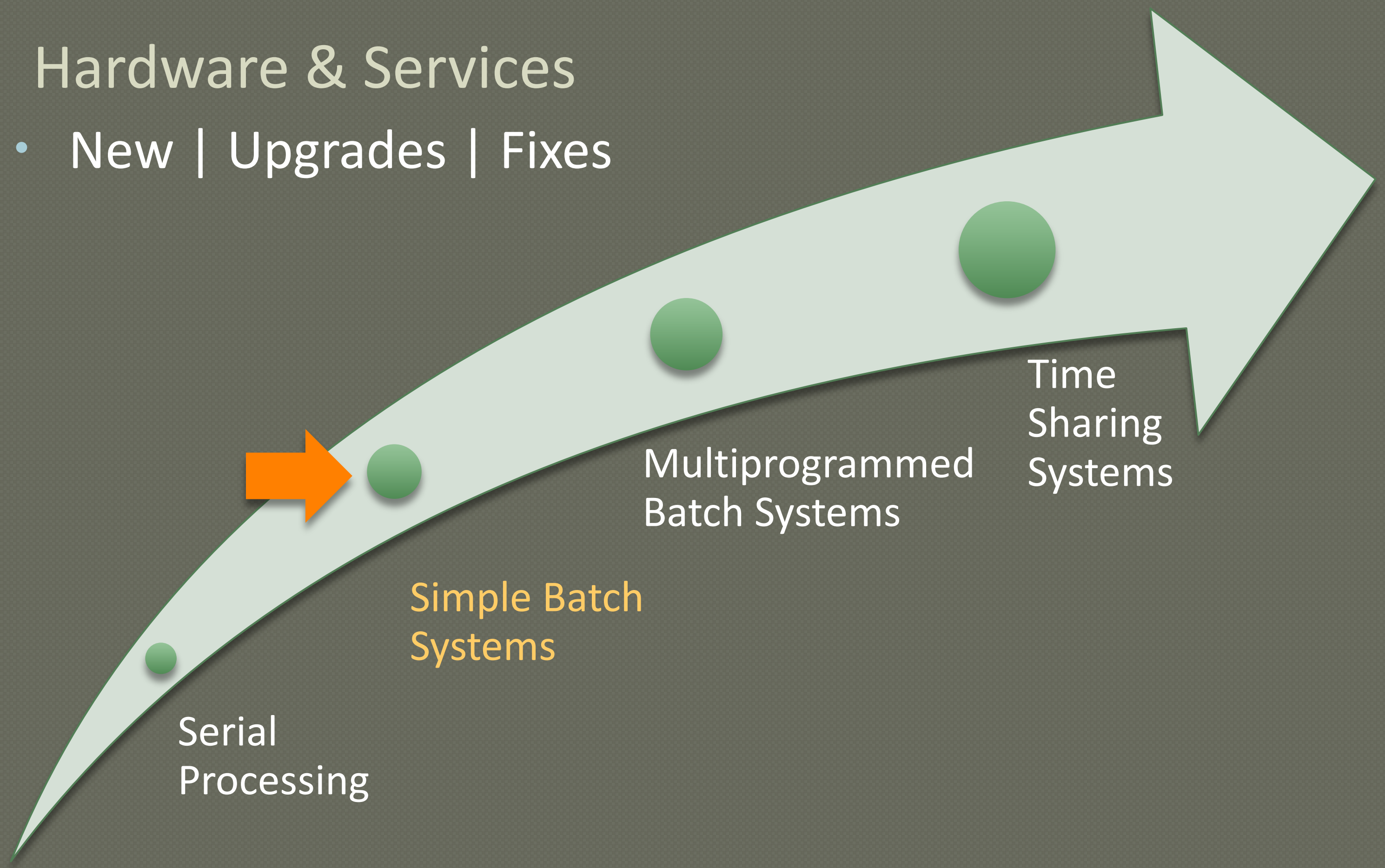
Topics

- OS evolution
  - Serial, Batch, Multi-programming, Time sharing
- Achievements
  - Process, Memory management, Scheduling, System structure

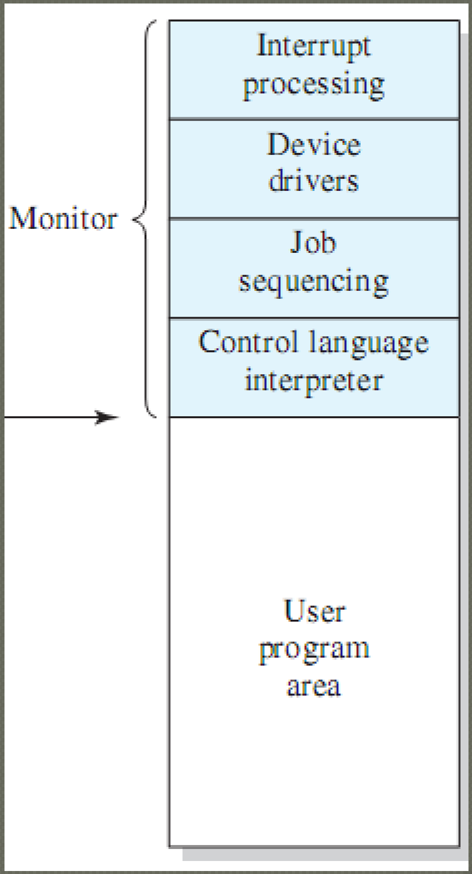
Evolution

- Reasons for OS to evolve
  - Hardware & Services
    - New | Upgrades | Fixes



OS Evolution

- Simple Batch Systems
  - improving computer utilization
    - programmer has no direct access to computer
    - operator batches jobs, feeds them to an input device, then…
  - Monitor (aka Batch OS)
    - program controlling the execution of jobs
    - 1. monitor reads next job & yields control of CPU to the job
      - “control is passed to a job” : CPU starts running user program
    - 2. user program ends & monitor continues running again
      - “control is returned to the monitor” : CPU runs monitor



OS Evolution

- Simple Batch Systems (II)
  - Job Control Language (JCL)
    - Instructions meant for the monitor (like pre-processing)
      - $JOB $FTN <source code> $LOAD $RUN <data> $END
  - Hardware support of Monitor
    - Memory protection
      - Memory where monitor resides is out-of-bounds for jobs
    - Timer
      - Notifies when jobs run longer than anticipated
    - Privileged instructions
      - Instructions that only the monitor can execute (e.g., load job)
    - Interrupts
      - Signals giving CPU a degree of flexibility

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	User Mode	Kernel Mode
Applies to…	User programs	Monitor
Memory access	Restricted	Unrestricted
Instructions	Limited	Unlimited

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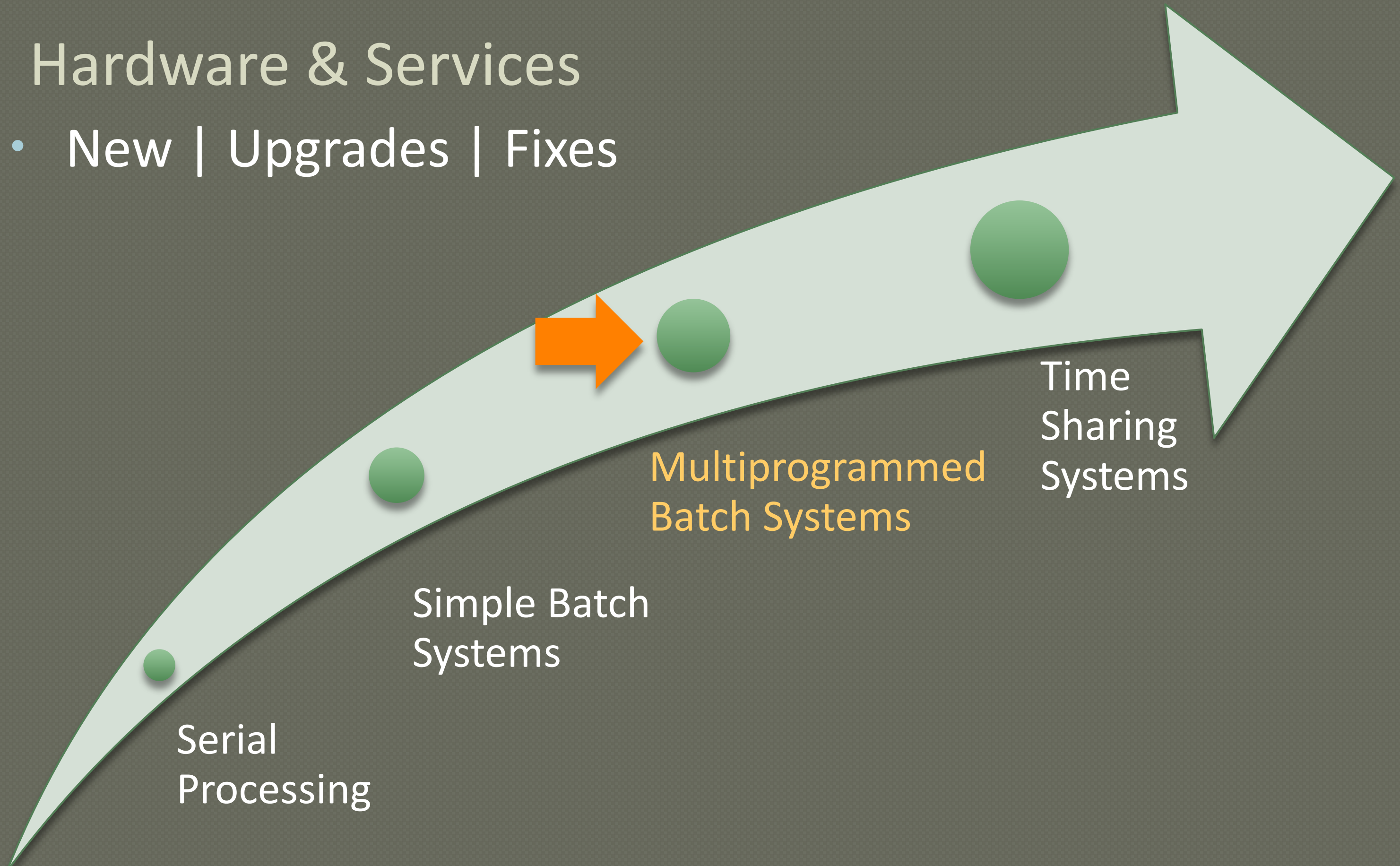
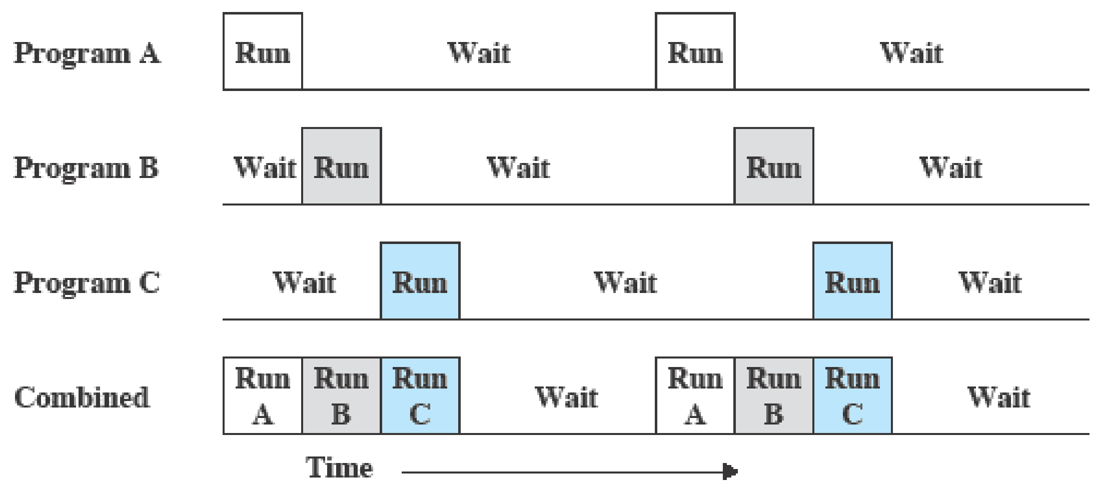


Multiprogramming



(c) Multiprogramming with three programs

- Multiprogramming
  - also known as multitasking
  - memory is expanded to hold three, four, or more programs and switch among all of them

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

Utilization Histograms

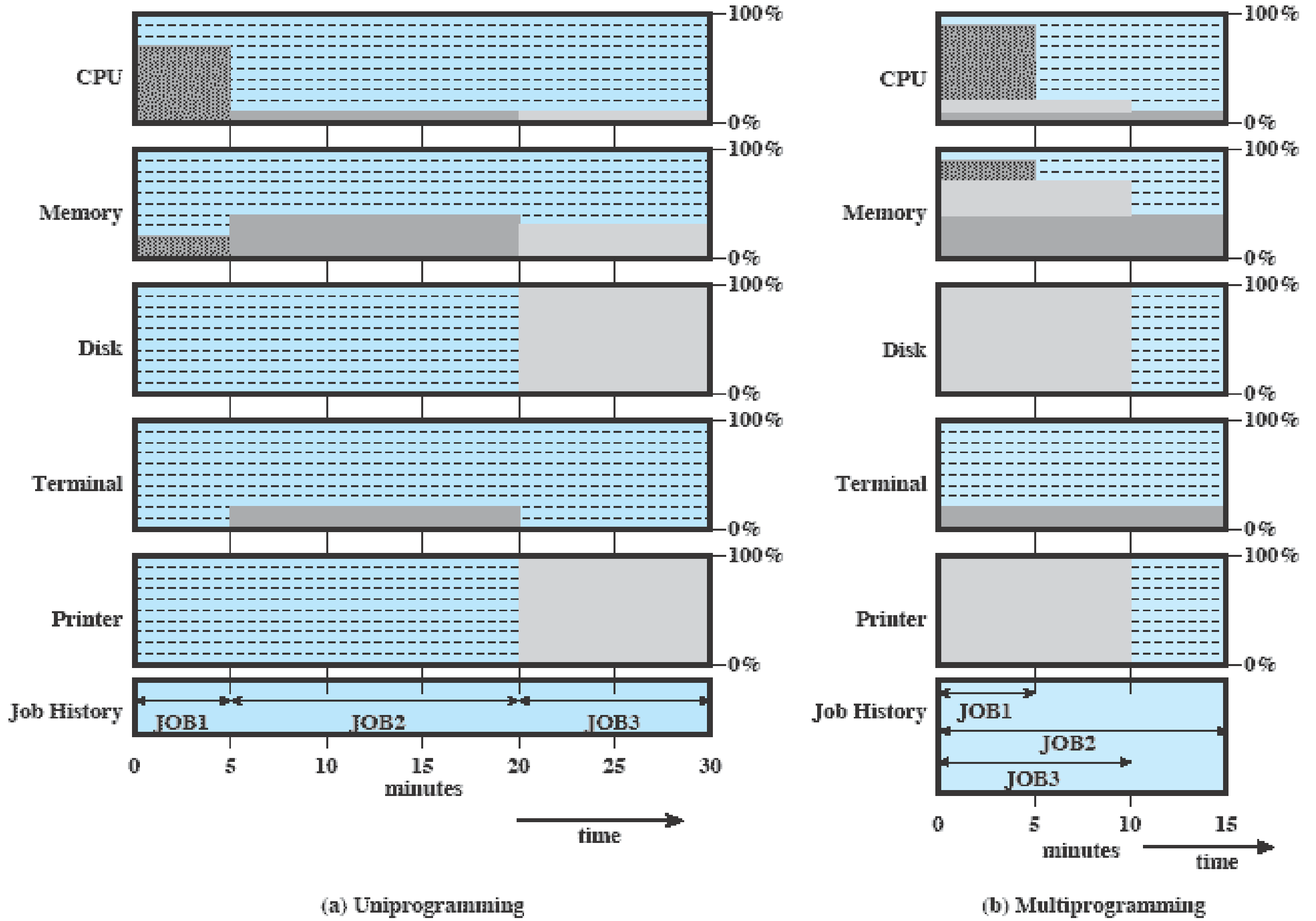


Figure 2.6 Utilization Histograms

Effects 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

Know how to calculate these numbers please

Evolution

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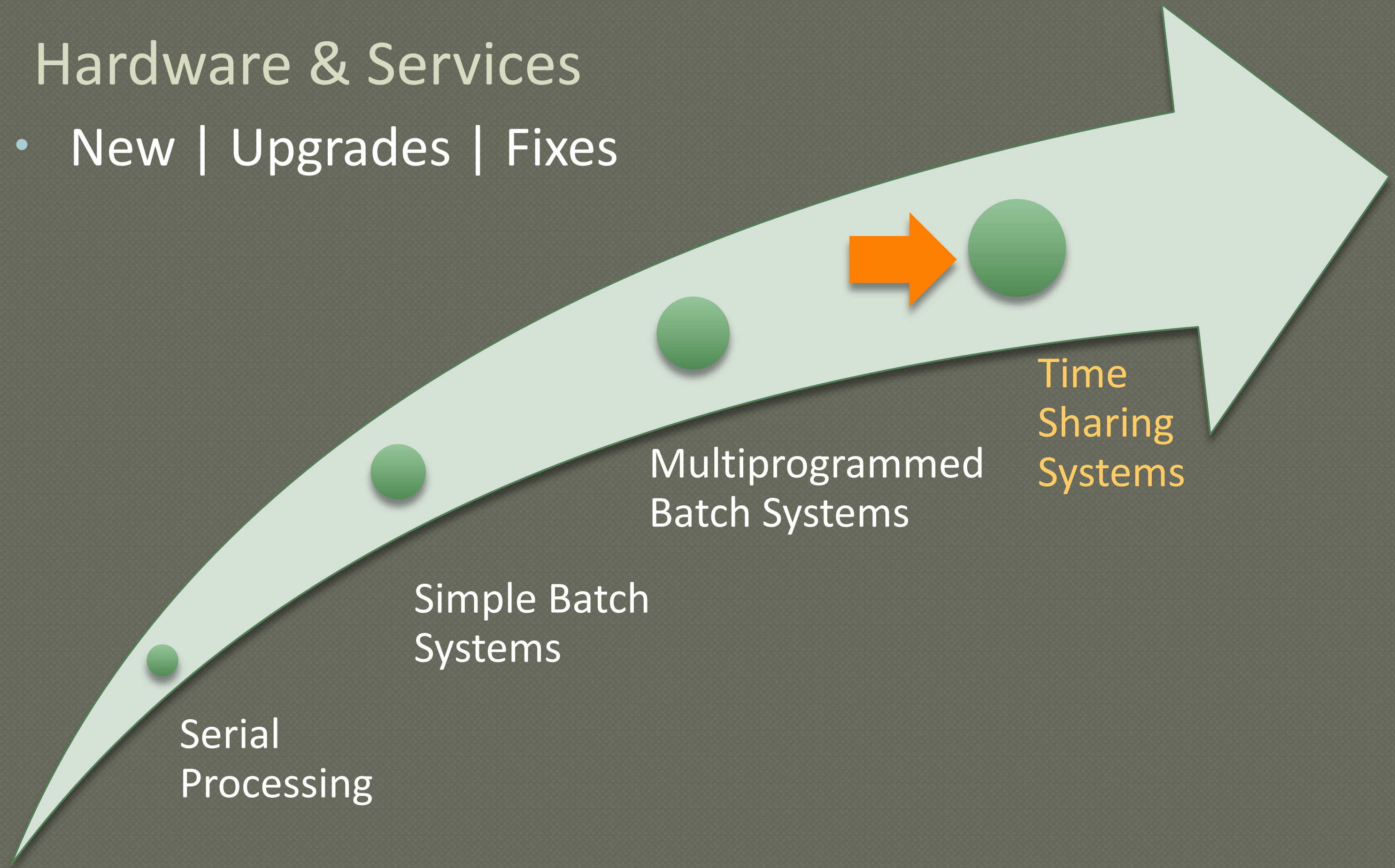


OS Evolution

Time Sharing Systems

- Users access system simultaneously using terminals
- Time Slicing
  - Timer generates interrupts every 0.x seconds (small number)
  - OS preempts current program and loads in another
  - Preempted program & data are stored to disk (in old days)
  - *(but keep an eye on swapping overhead!)*
- Multi-Programming vs. Time sharing

	Batch Multi-programming	**Time sharing**
Objective	Maximize processor use	Minimize response time
Source of instructions	Job Control Language (JCL)	Commands entered in terminal

Chapter 2 Topics

- OS evolution
  - Serial, Batch, Multi-programming, Time sharing
- Achievements
  - Process, Memory management, Scheduling, System structure

Achievements

- Major advances in OS development
  - Processes
    - Definition, Errors, Components
  - Memory management
    - OS responsibilities, Virtual memory
  - Scheduling & resource management
  - System structure

Process

- Fundamental to the structure of operating systems

A *process* is just an instance of a running program

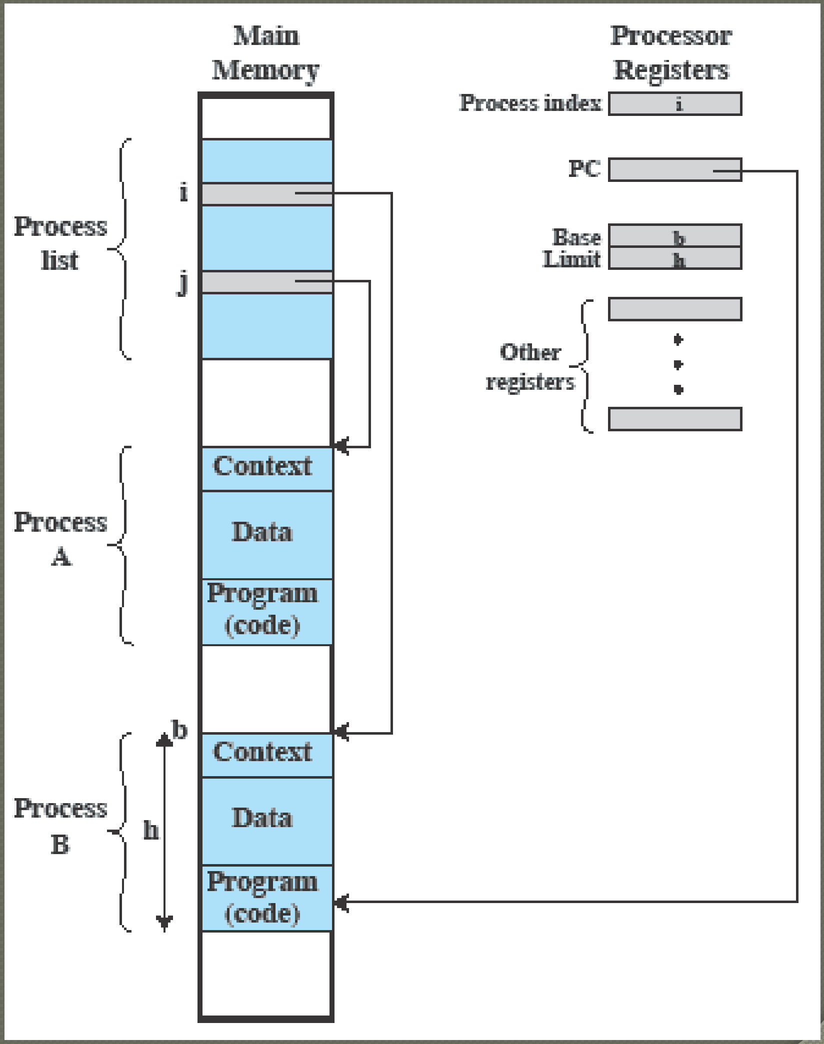
Process - Causes of Errors

- **Improper synchronization**
  - a program must wait until the data are available in a buffer
  - improper design of the signaling mechanism can result in loss or duplication
- **Failed mutual exclusion**
  - more than one user or program attempts to make use of a shared resource at the same time

- **Nondeterminate program operation**
  - program execution is interleaved by the processor when memory is shared
  - the order in which programs are scheduled may affect their outcome
- **Deadlocks**
  - it is possible for two or more programs to be hung up waiting for each other
  - may depend on the chance timing of resource allocation and release

Process Management

- Processes (components)
  - Executable code
  - Data
    - e.g., variables, buffers, …
  - Execution context (aka "process state")
    - internal data used by the OS to control the process
      - e.g., registers, priority, whether it is waiting for an I/O event



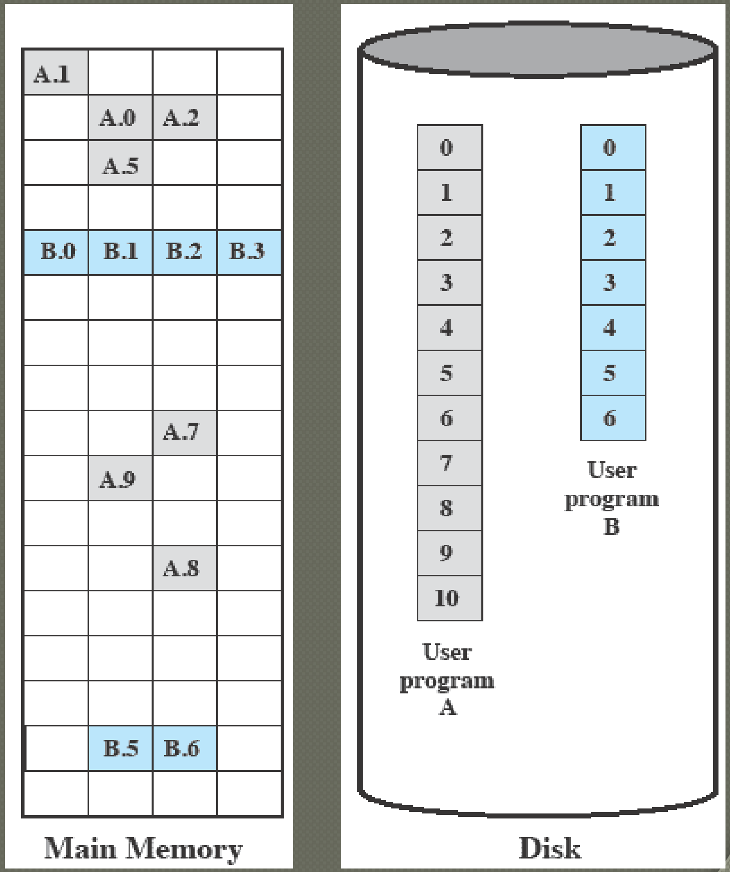
Achievements

- Memory management (OS responsibilities)
  - Process isolation
    - Processes… …are prevented from interfering with each other
  - Automatic allocation & management
    - …are not concerned about their own allocation
  - Support of modular programming
    - …are able to add/remove modules
  - Protection & access control
    - …are assured the integrity of data in shared memory
  - Long-term storage
    - …are able to store data for later runs (including power down)

How to handle simultaneous processes if they do not fit all in main memory?

Achievements

- Memory management (Virtual Memory)
  - Handling many processes with limited memory
  - Paging
    - Processes are broken into blocks (aka pages)
      - Pages can be anywhere in main memory
    - CPU uses virtual addresses to find instructions/data
      - Addresses are page number + offset within page



Achievements

- Scheduling & resource management
  - OS manages resources (main memory, I/O devices, processors) and schedules their use by processes
  - Fairness
    - Equal processes given equal and fair access to resources.
  - Differential responsiveness
    - Different processes treated differently according to their needs.
  - Efficiency
    - Overall performance is a goal
      - maximize throughput
      - minimize response time
      - accommodate as many users as possible

These criteria conflict (what's the right balance?)

Achievements

- System structure
  - Until Recently
    - OS are monolithic programs
    - processes are linearly executed

What to do about it?

  - Now Microkernel Architecture
    - Keep essential functions in kernel
      - memory addressing, scheduling, …
    - Modularize the rest (towards object-oriented approach)
      - modules dynamically linked, easier to replace
  - Advantages
    - low coupling – dynamically load modules when needed, encourages flexible API design – need new schedular? Provide library that meets schedular API, load at runtime
    - works well with distributed OS – illusion of unified memory & resources

Achievements

- System structure
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What to do about it?

  - Symmetric multiprocessing (add CPUs)
    - 2+ CPU run in parallel (hardware + OS exploiting it)
    - Processes scheduled to separate CPU (but share resources)
  - Multi-threading (divide processes)
    - Process broken into parts that run concurrently (own thread)
    - Process = ∑ (threads = concurrent unit of work)
    - Programmers control scope & timing of concurrency

Multiprogramming

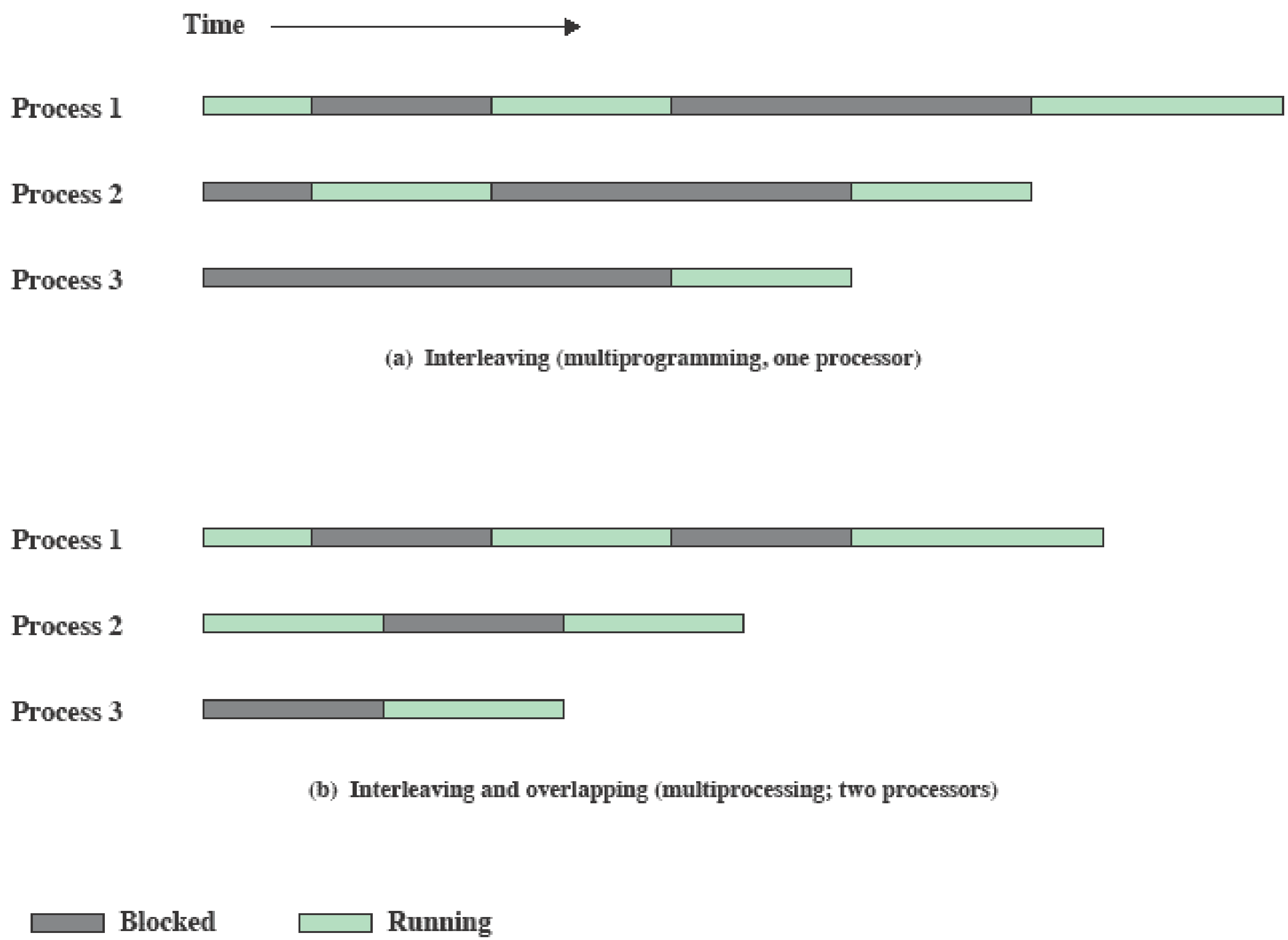

Figure 2.12 Multiprogramming and Multiprocessing

Symmetric multiprocessing

Challenges

- Kernel concurrency: Kernel processes allow concurrent CPU access (state integrity)
- Scheduling: Scheduling across CPUs must be coordinated (avoid duplicated runs)
- Synchronization: Access to resources must be synchronized (use locks)
- Memory management: Page reuse (coordinating page replacements)
- Fault tolerance: Graceful degradation

Parallelism opportunities

- Multiprogramming & multi-threading in each processor
- A process could have its threads executed in different CPUs

- Processes scheduled to separate CPU (but share resources)
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Done!