National University of Computer and Emerging Sciences

Processes

Process

- A computer program in execution on a machine is a process
- More formally:
- “A ***Sequential stream of Execution*** in its own ***address space***”
- Two parts to a process

1) **Sequential Execution**:

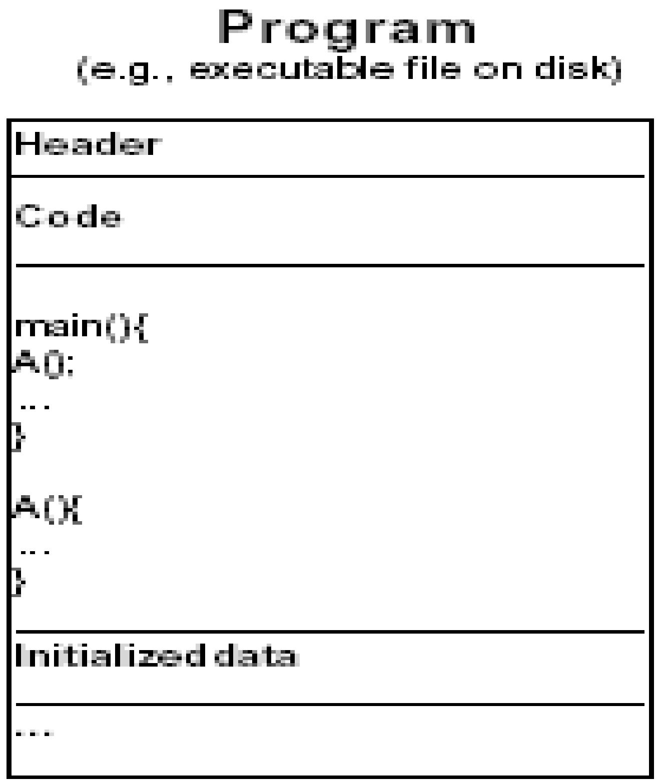
  - no concurrency inside a process
  - everything happens sequentially

Process Address Space

- A list of memory locations from some min (usually 0) to some max that a process can read and write.
- Contains
  - the executable program
  - program’s data
  - Stack???
  - Associated with a process is a set of registers e.g. PC,SP and other information to run the program.

Process =? Program

- **Program:** series of commands (e.g. C statements, assembly commands, shell commands)



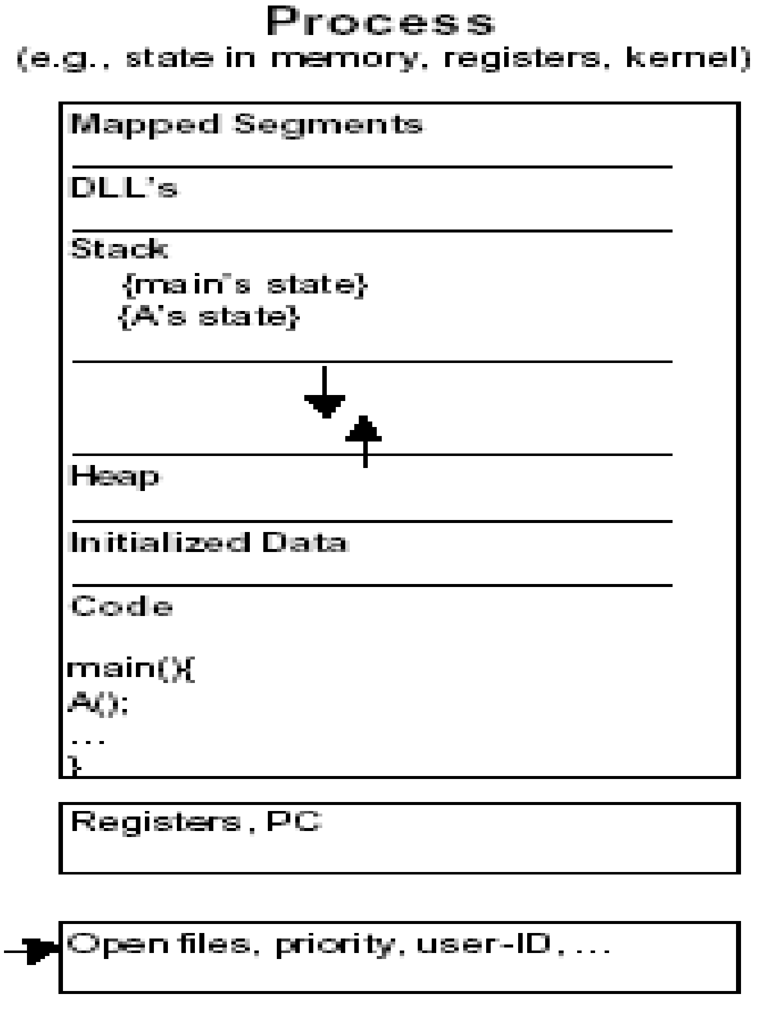
Process =? Program

1) Several processes may be associated with the same program;

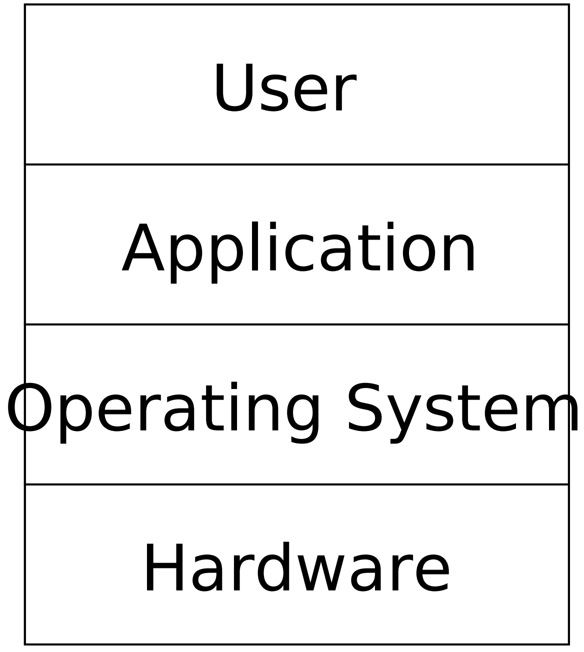
- I run *dir*, you run *dir* – same program, different processes

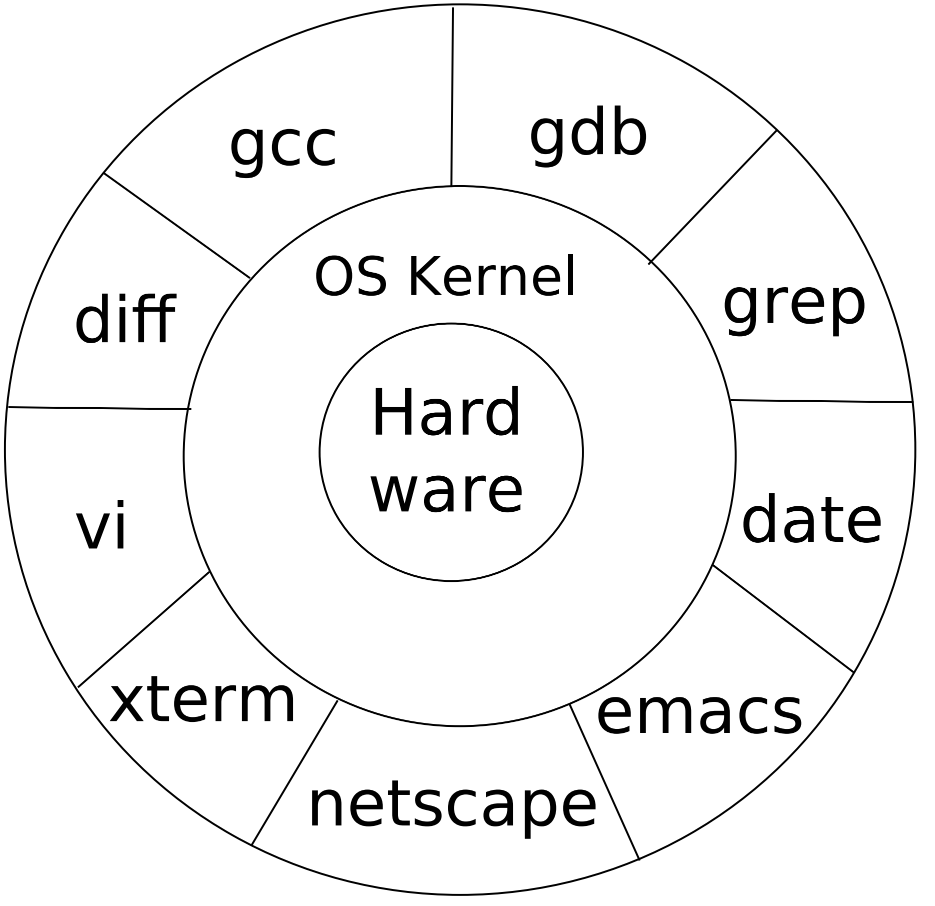
2) A program can invoke more than one process to get the job done

Process =? Program



The Operating System controls the machine





Process

- A Context for Computation
- Defined by:
  - Its CPU state:?
    - (register values)
  - Its address space:?
    - (memory contents)
  - Its environment:?
    - (as reflected in operating system tables)
- CPU registers contain the current state

  1. Processor Status Word (PSW): includes bits
     - Privileged or normal
     - Outcome of the last arithmetic operation (zero,-ve, +ve, overflow, carry)
     - Which interrupts are allowed and which are not

CPU State

2. Instruction Register (IR):
   - The current instruction being executed
3. Program Counter (PC):
   - Address of the next instruction to be executed
4. Stack Pointer (SP):
   - the address of the current stack frame, including function's local variables and return information.
5. General purpose registers:
   - used to store addresses and data values as directed by the compiler.

Memory Contents

- Only a small part of an application's data can be stored in registers. The rest is in memory.
- Typically divided into a few segments:
  - Text?
    - The application's code
    - Read-only?
    - might be shared by a number of processes
  - Data
    - The application's predefined data structures
  - Heap?
    - An area from which space can be allocated dynamically at runtime, using functions like **`new`** or **`malloc`**.
  - Stack?
    - Where register values are saved
    - local variables allocated
    - All the addressable memory together is called?
- The process's address space.

Environment

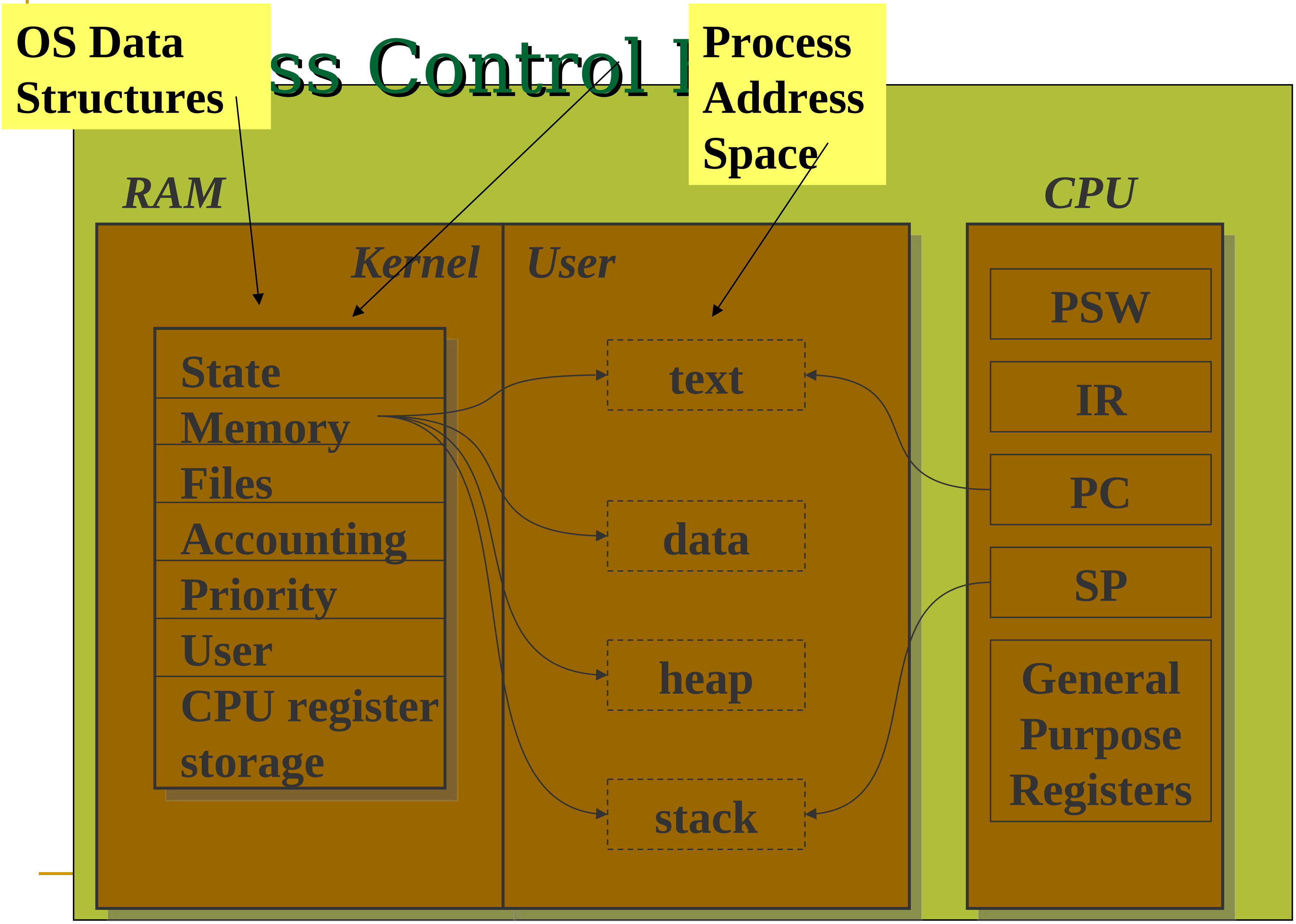
- Contains the relationships with other entities???
- A process does not exist in a vacuum
- It typically has connections with other entities, such as???
  - A terminal where the user is sitting.
  - Open files
  - Communication channels to other processes, possibly on other machines.
- These are listed in various operating system tables.

Process Control Block

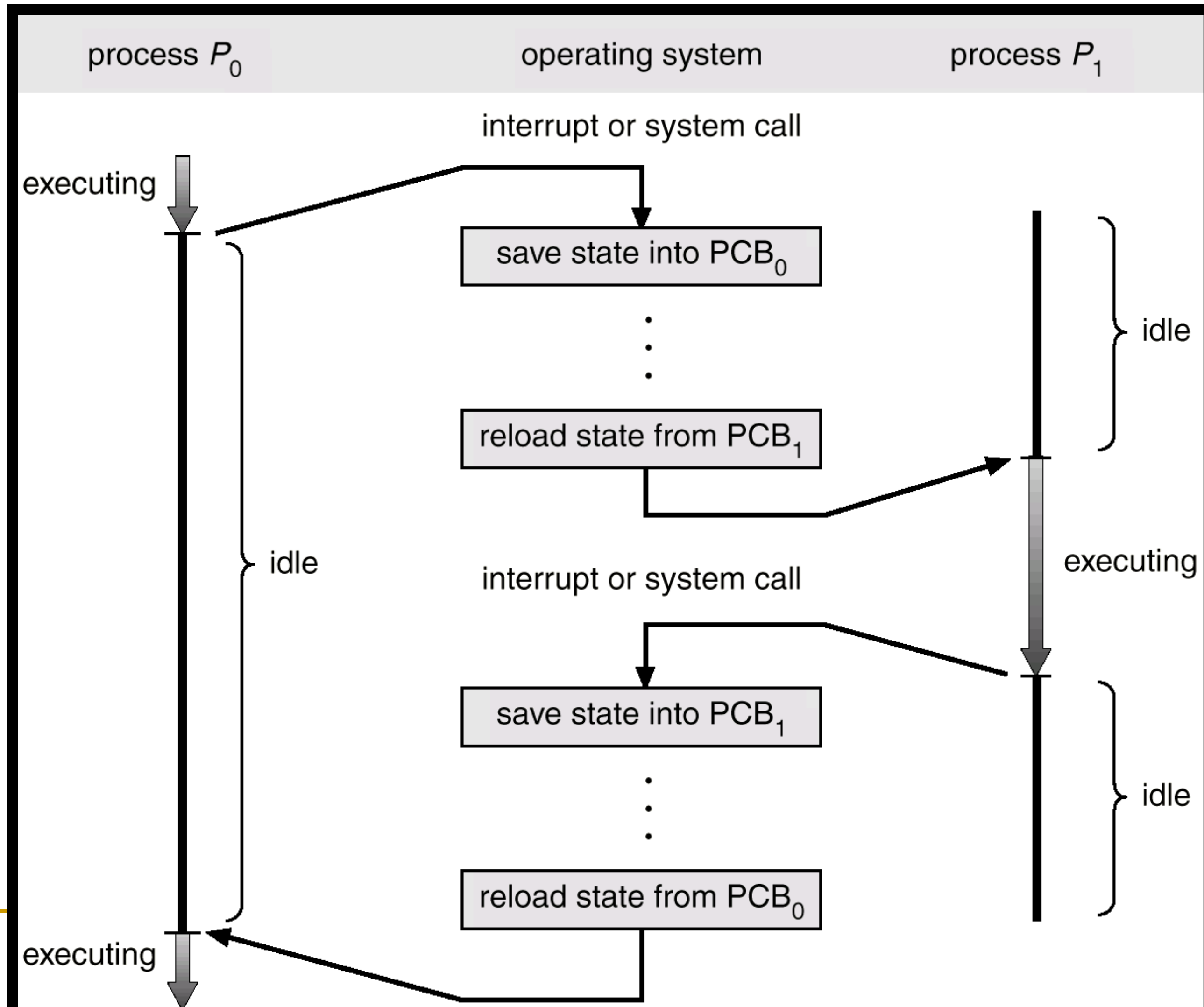
- The OS keeps all the data it needs about a process in the process control block (PCB)
- Thus another definition of a process:
  - “the entity described by a PCB”
- This includes many of the data items described above, or at least pointers to where they can be found
  - e.g. for the address space

Included information

- The identifier of the process (a process identifier, or PID)
- Register values for the process including, notably, the program counter and stack pointer values for the process.
- The address space for the process
- Priority
- Process accounting information, such as when the process was last run, how much CPU time it has accumulated, etc.
- Pointer to the next PCB i.e. pointer to the PCB of the next process to run
- I/O Information (i.e. I/O devices allocated to this process, list of opened files, etc)


OS Data Structures
ss Control
Process Address Space
RAM
CPU
Kernel
User
State
Memory
Files
Accounting
Priority
User
CPU register storage
text
data
heap
stack
PSW
IR
PC
SP
General Purpose Registers

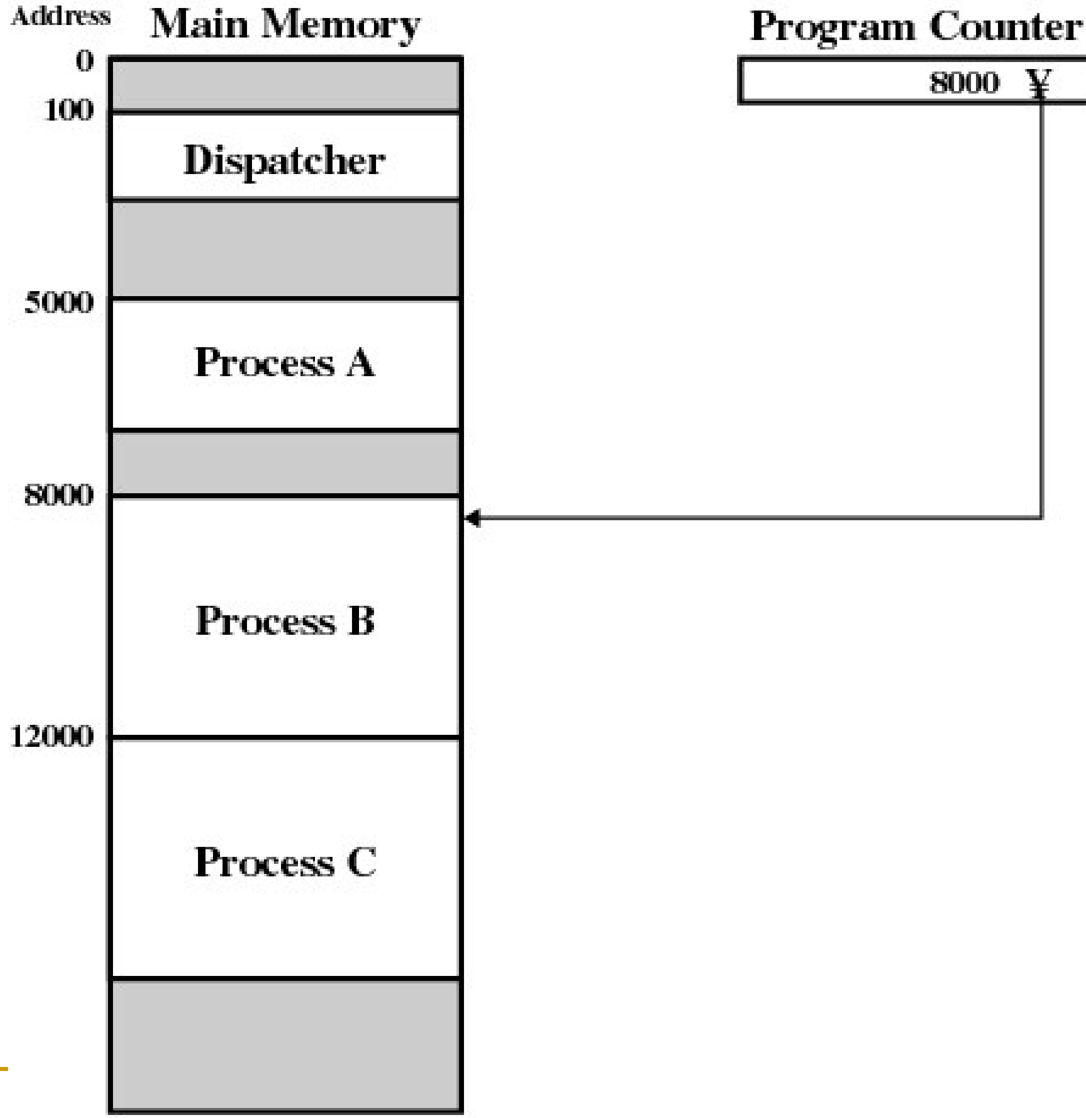
CPU Switch From Process to Process



CPU Switch From Process to Process

- Switching a process requires
  - Saving the state of old process
  - Loading the saved state of the new process
- This is called ***Context Switch***
- Part of OS responsible for switching the processor among the processes is called ***Dispatcher***

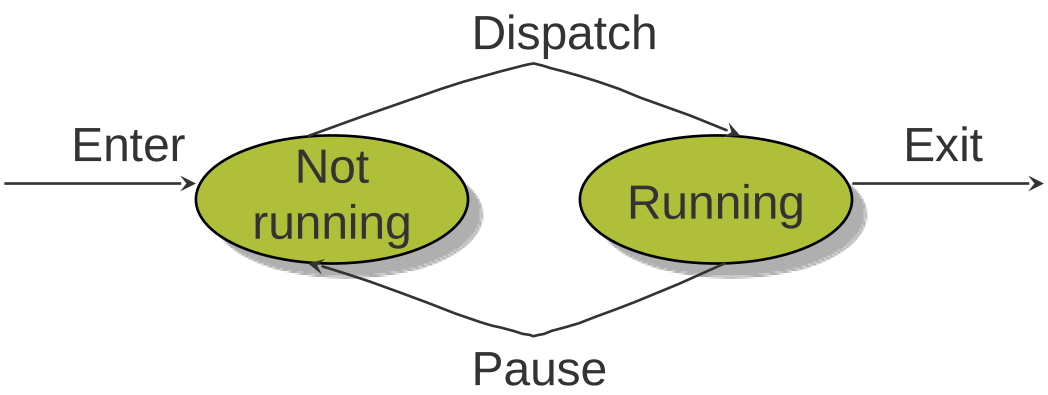
Process Example



Process States

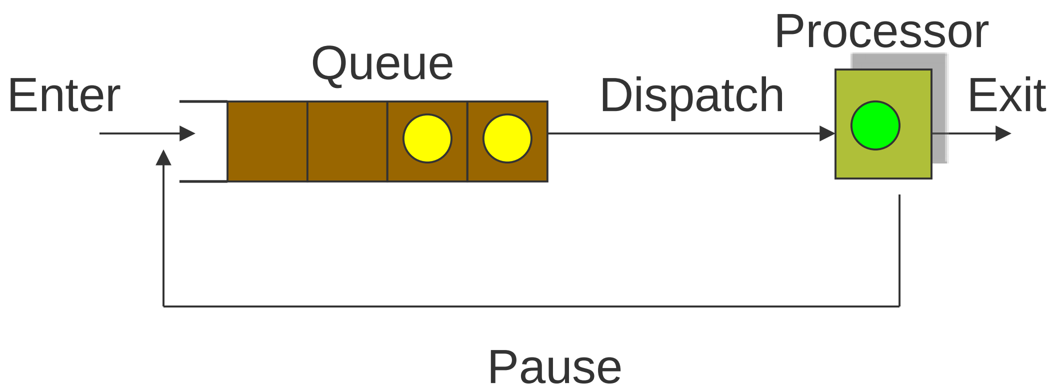
- At any given time a process is either running or not running
- Number of states
  - Running
  - Not Running
- When the OS creates a process, the process is entered into which state?
  - Not Running

Two-state process model



- Number of processes ***Running*** at a particular time?
- Number of processes ***Not Running*** at a particular time?
- Data Structure?
- Processes that are ***Not Running*** at a particular time should be kept in some sort of a ***queue***

Two-state process model



Dispatcher **is now redefined:**

- Moves processes to the waiting queue
- Remove completed/aborted processes
- Select the next process to run

How process state changes1

Ready

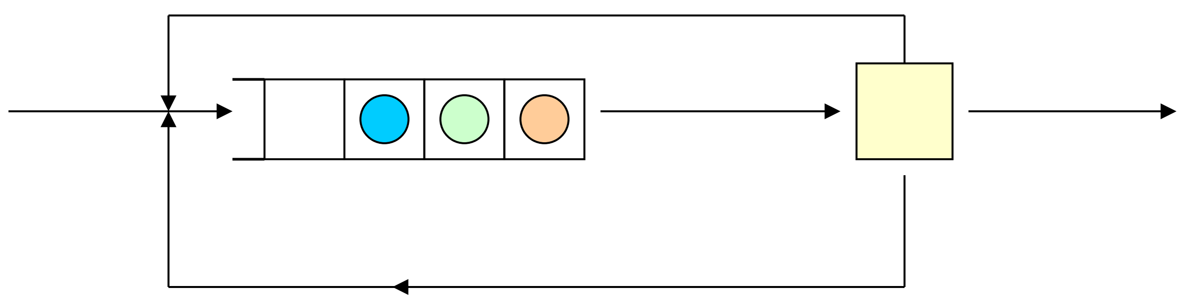
```
→ a := 1
  b := a + 1
  c := b + 1
  read a file
  a := b - c
  c := c * b
  b := 0
```

Ready

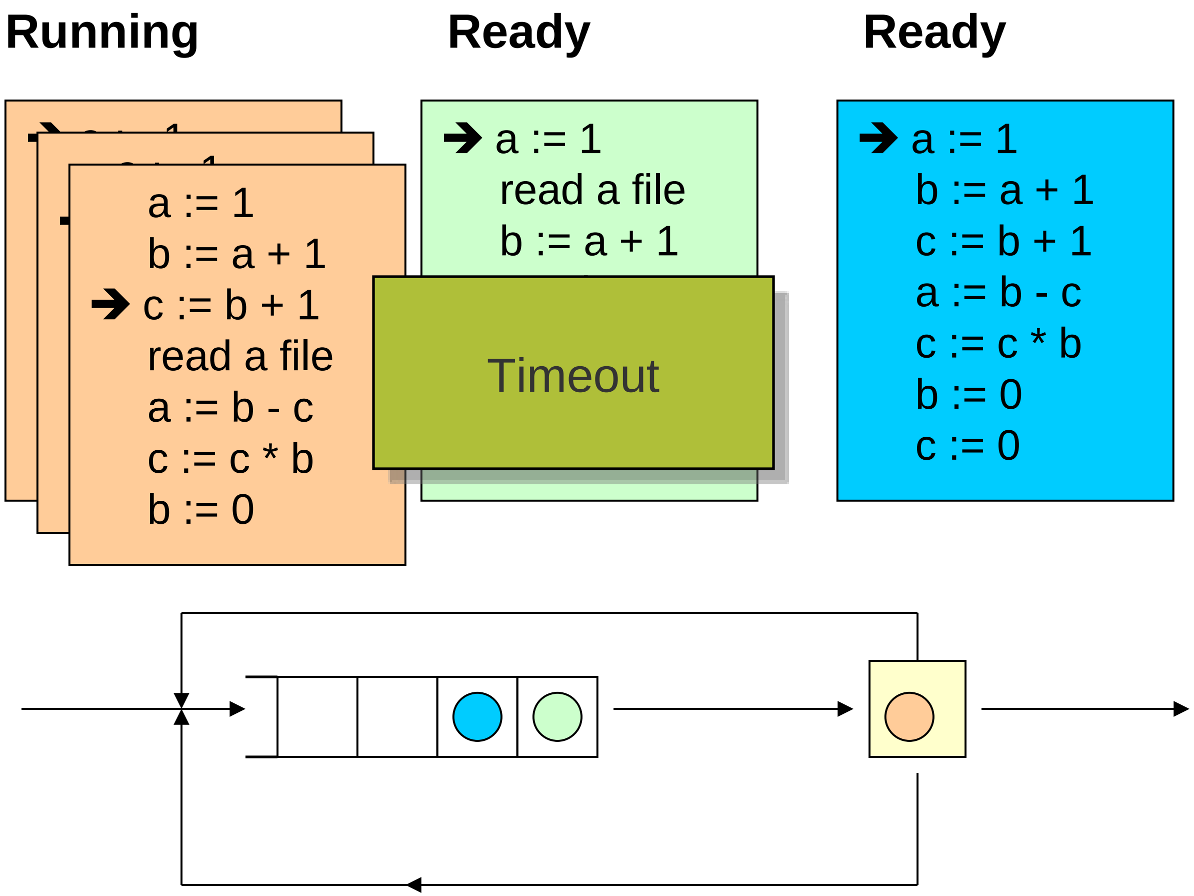
```
→ a := 1
  read a file
  b := a + 1
  c := b + 1
  a := b - c
  c := c * b
  b := 0
```

Ready

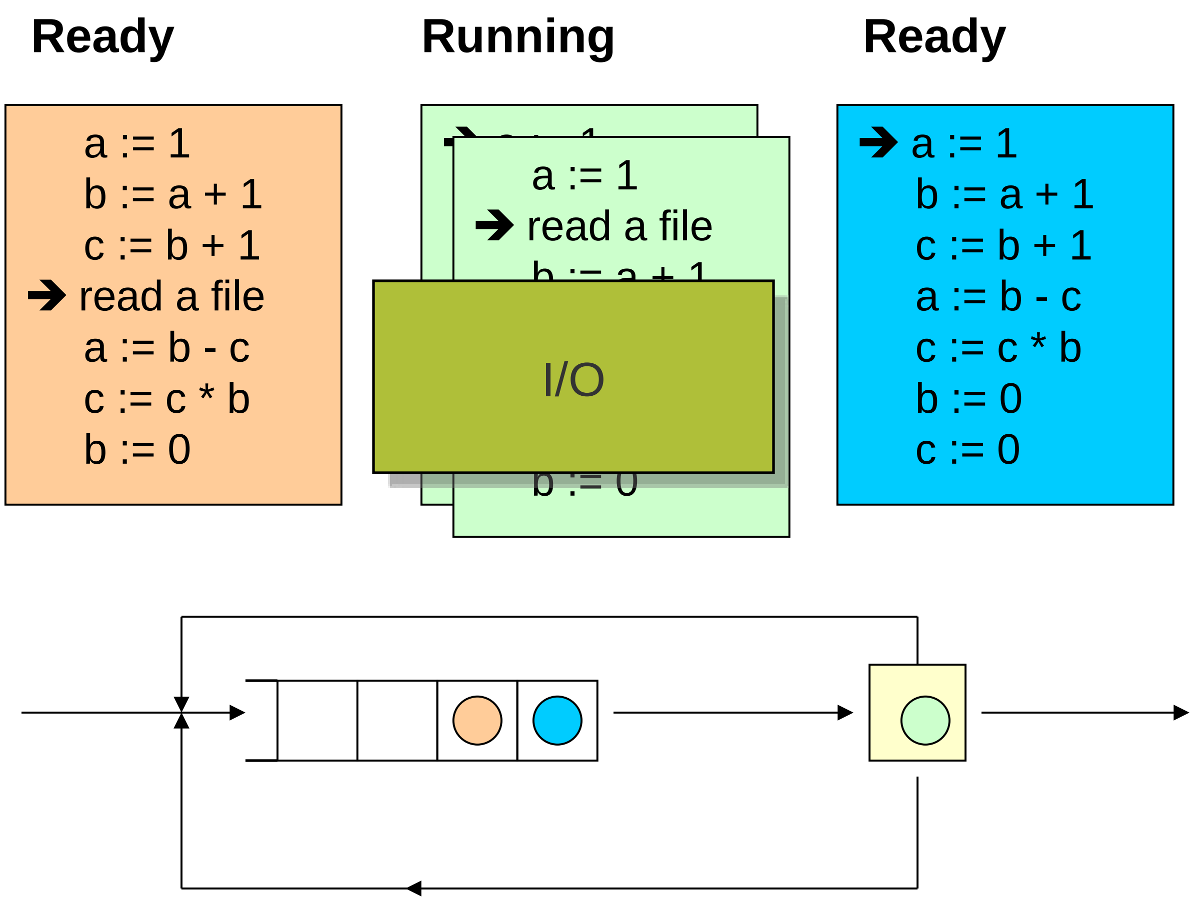
```
→ a := 1
  b := a + 1
  c := b + 1
  a := b - c
  c := c * b
  b := 0
  c := 0
```



How process state changes2

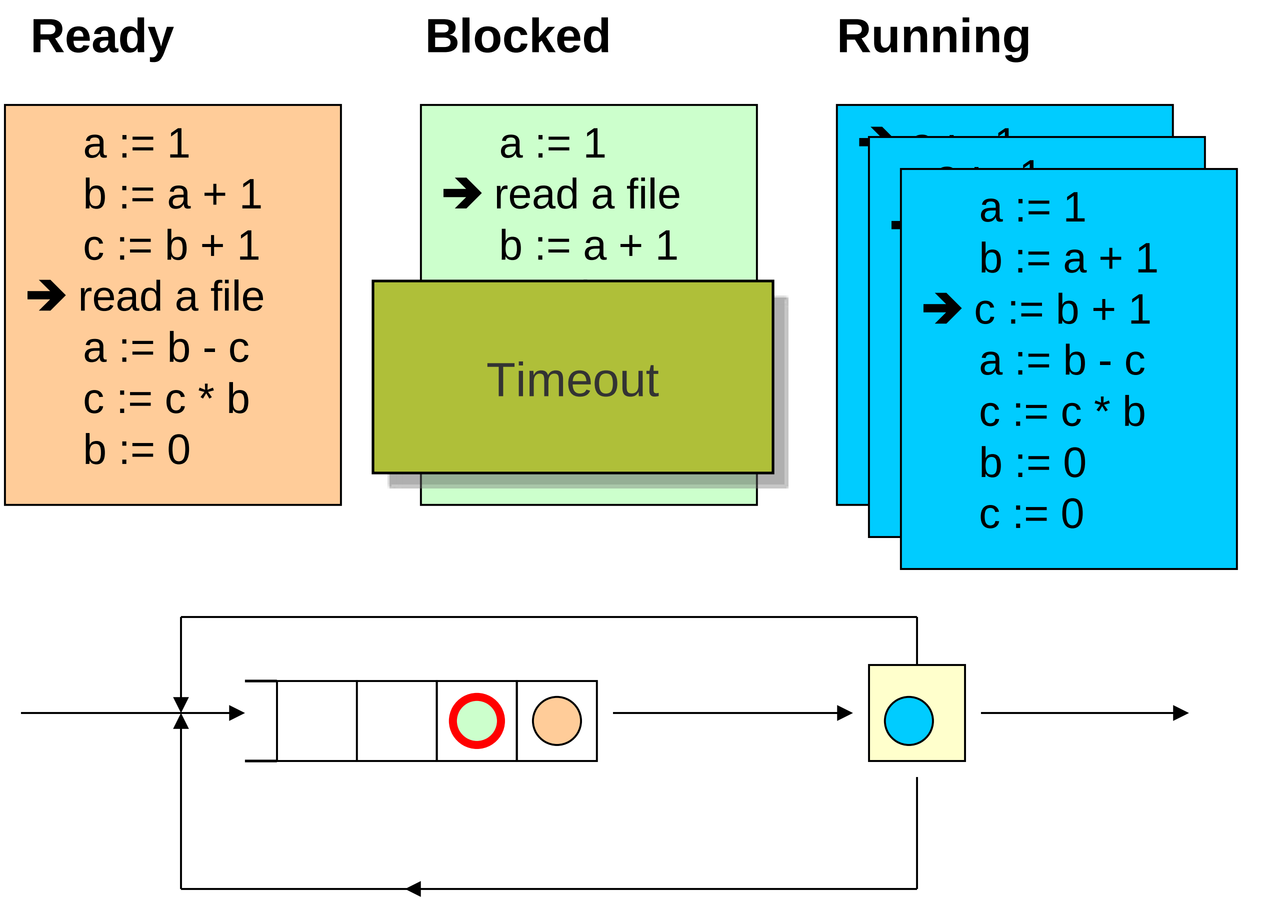


How process state changes3



23

How process state changes4



24

How process state changes5

Running

a := 1
b := a + 1
c := b + 1
➔ read a file
a := b - c
c := c * b
b := 0

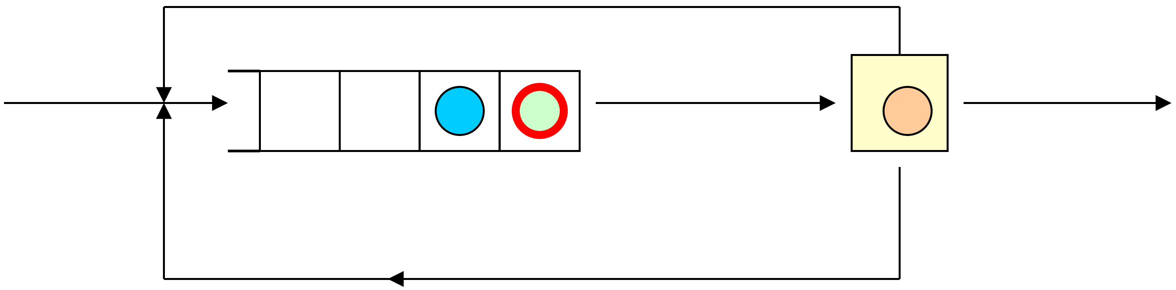
Blocked

a := 1
➔ read a file
b := a + 1

I/O

Ready

a := 1
b := a + 1
c := b + 1
➔ a := b - c
c := c * b
b := 0
c := 0



25

How process state changes6

Blocked

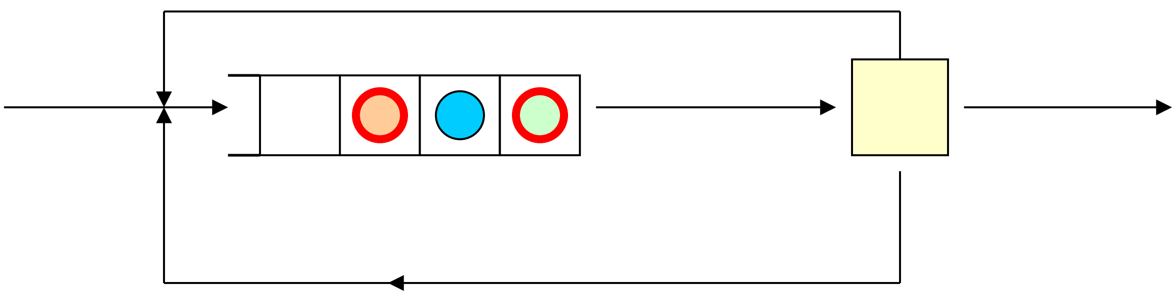
```
    a := 1
    b := a + 1
    c := b + 1
➔ read a file
    a := b - c
    c := c * b
    b := 0
```

Blocked

```
    a := 1
➔ read a file
    b := a + 1
    c := b + 1
    a := b - c
    c := c * b
    b := 0
```

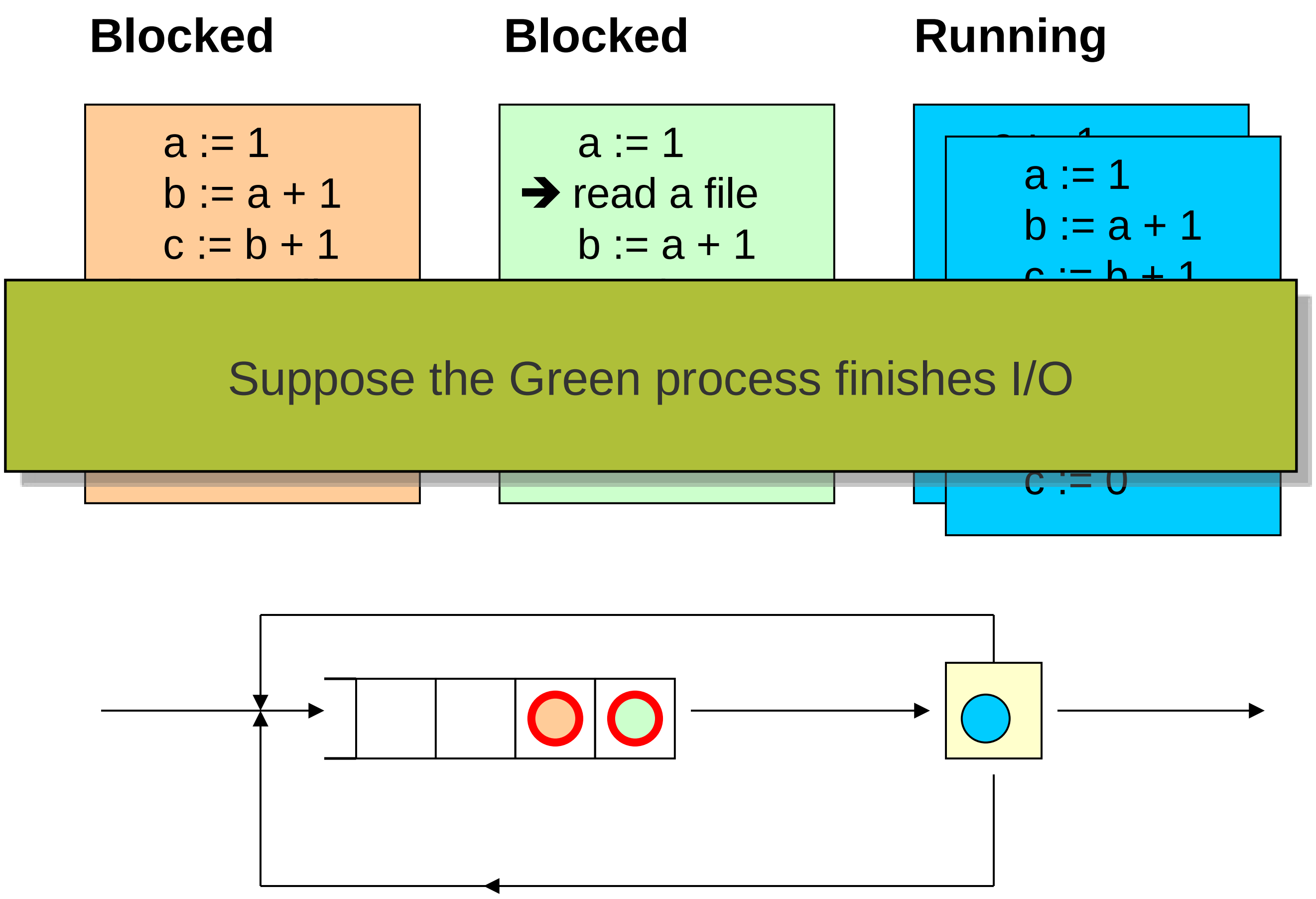
The Next Process to Run cannot be simply selected from the front

```
➔ a := b - c
    c := c * b
    b := 0
    c := 0
```

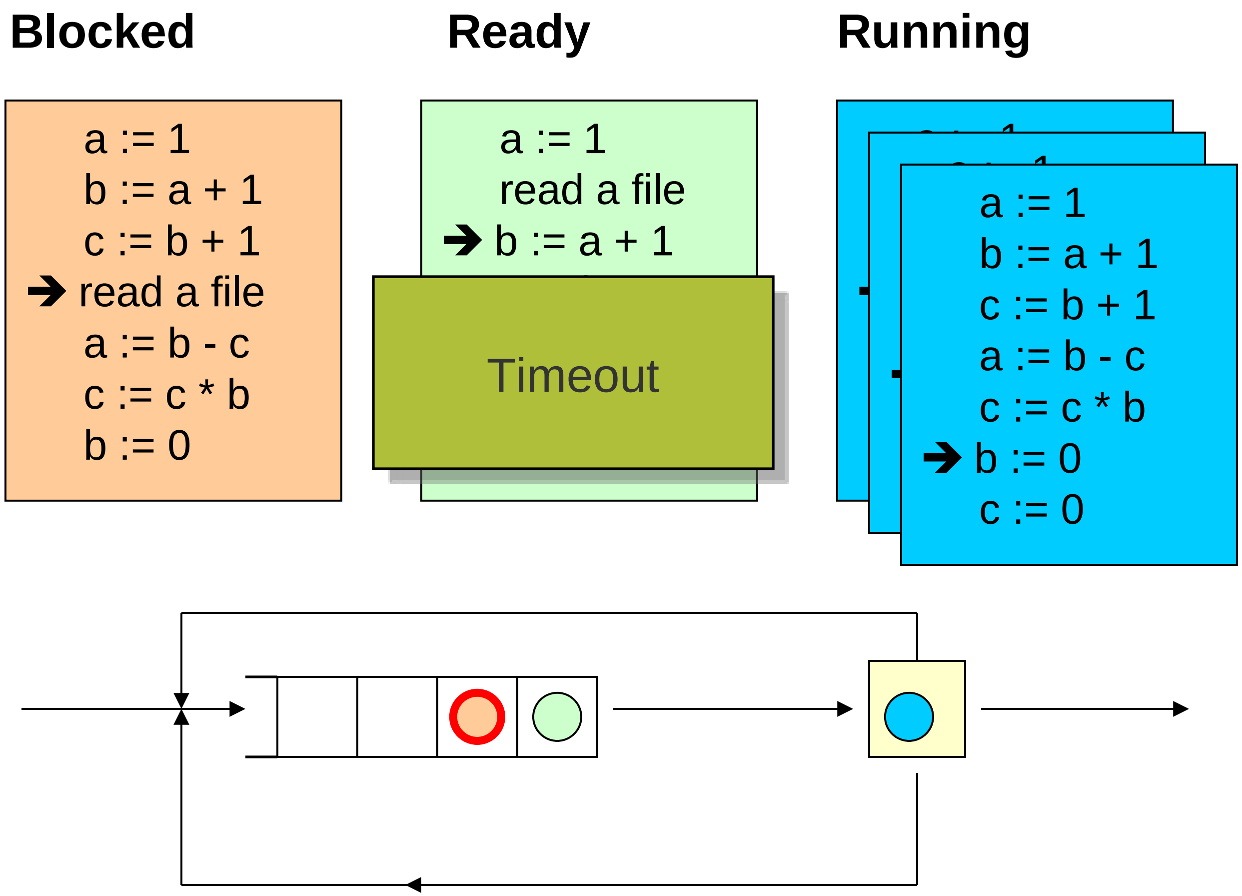


26

How process state changes7

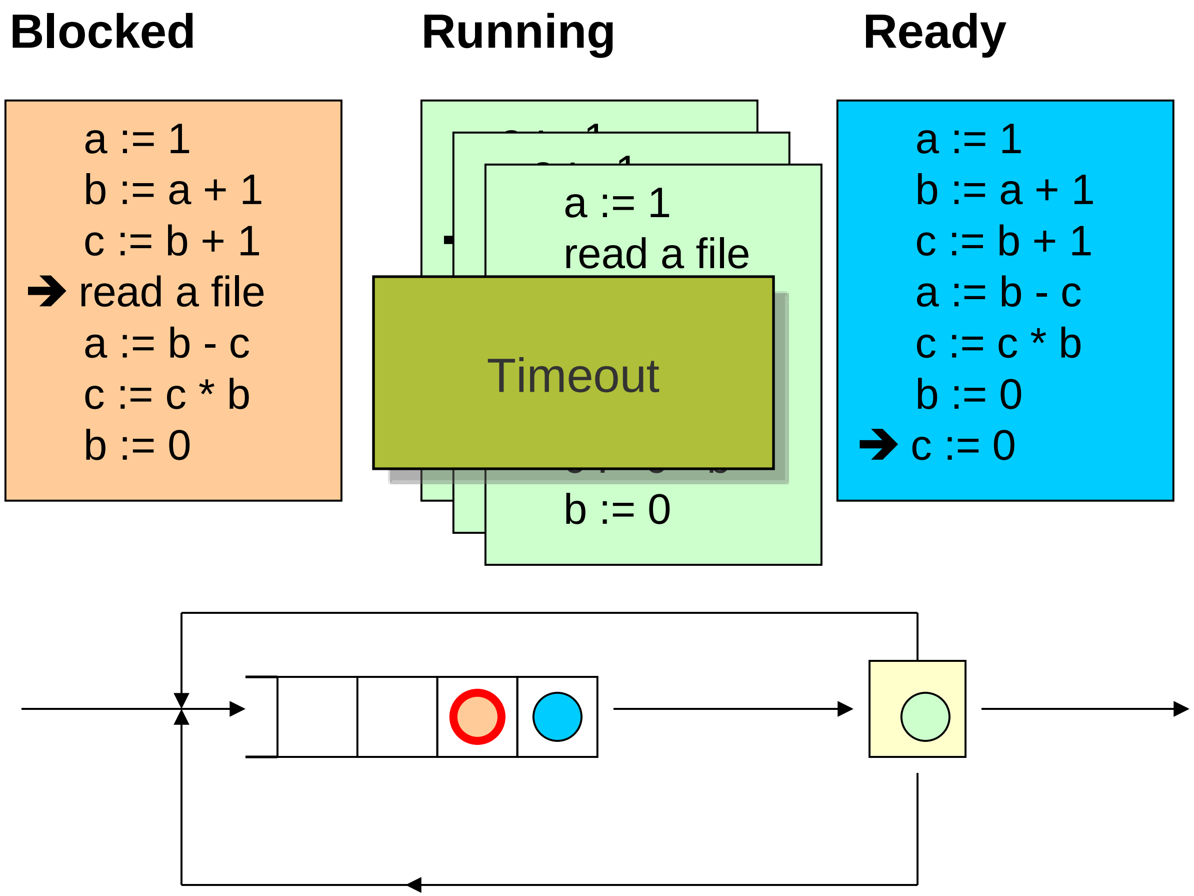


How process state changes8



28

How process state changes9



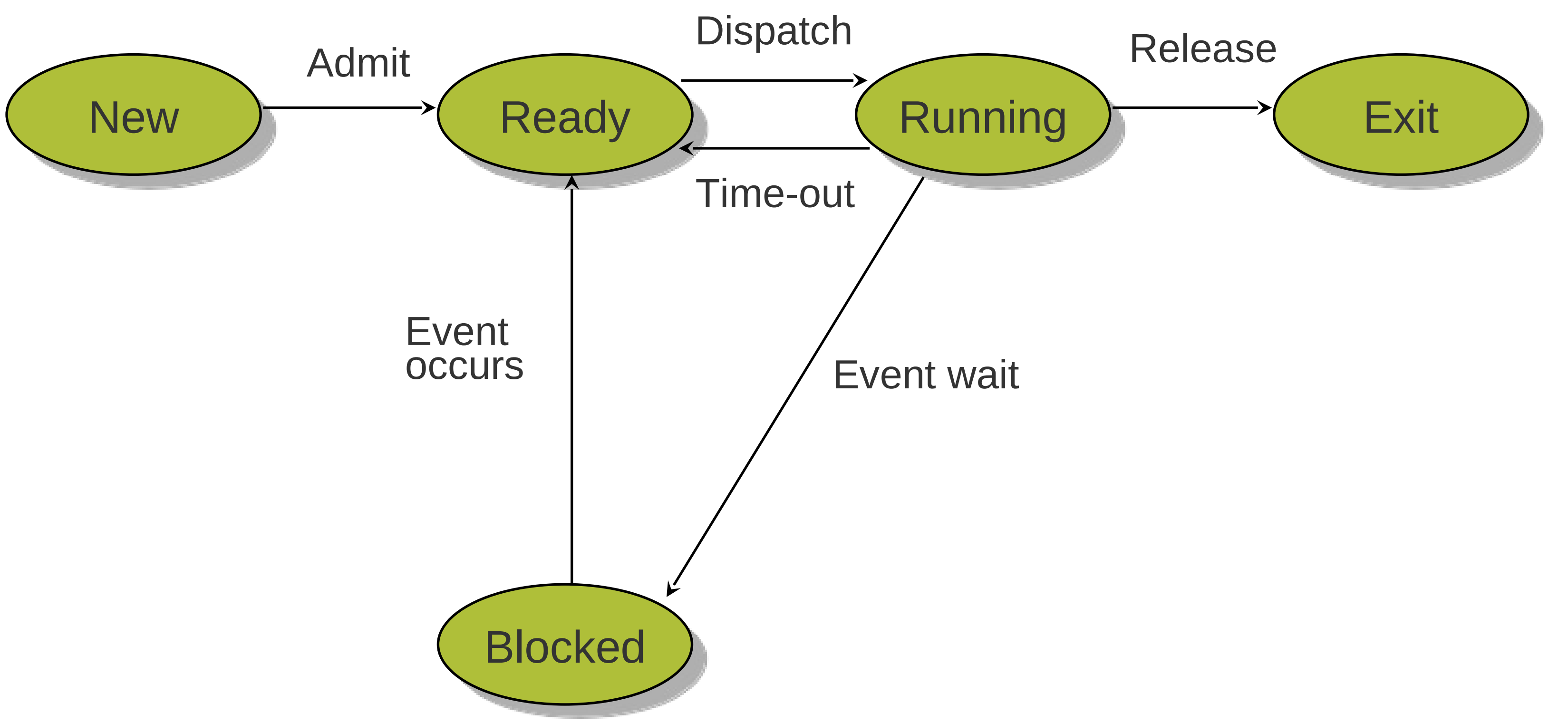
Problem in Two-state Process model

- A process may be waiting for I/O request
- A single queue for both the ready to run and waiting processes
- The dispatcher cannot simply select the process at the front, it can be a busy process
- In the worst case, it has to scan the whole queue to find the next process to run
- Solution?
- Split the Not Running state to:
  - Waiting
  - Ready

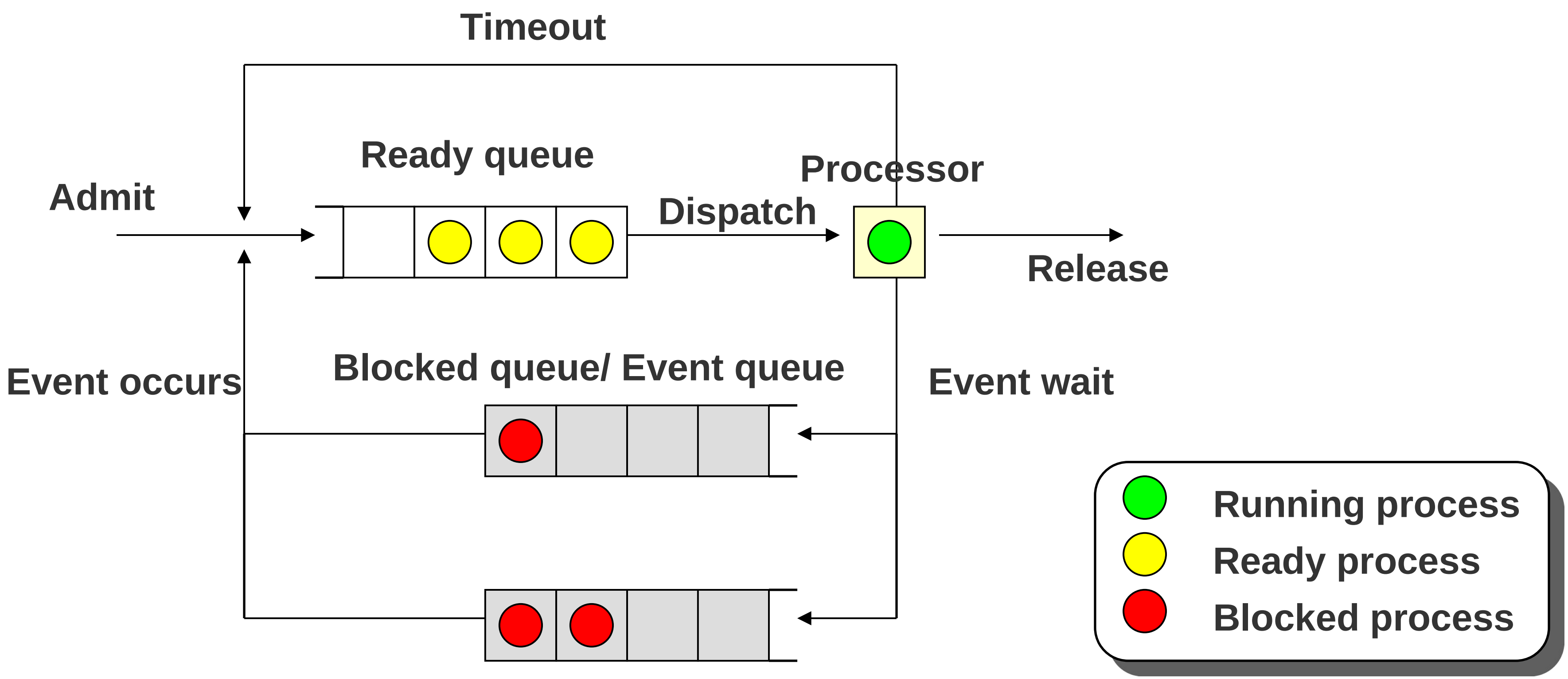
Five-state Process Model

- *Running*: currently being run
- *Ready*: ready to run
- *Blocked*: waiting for an event (I/O)
- *New*: just created, not yet admitted to set of runnable processes
- *Exit*: completed/error exit

Five-state Process Model



Blocked Queues

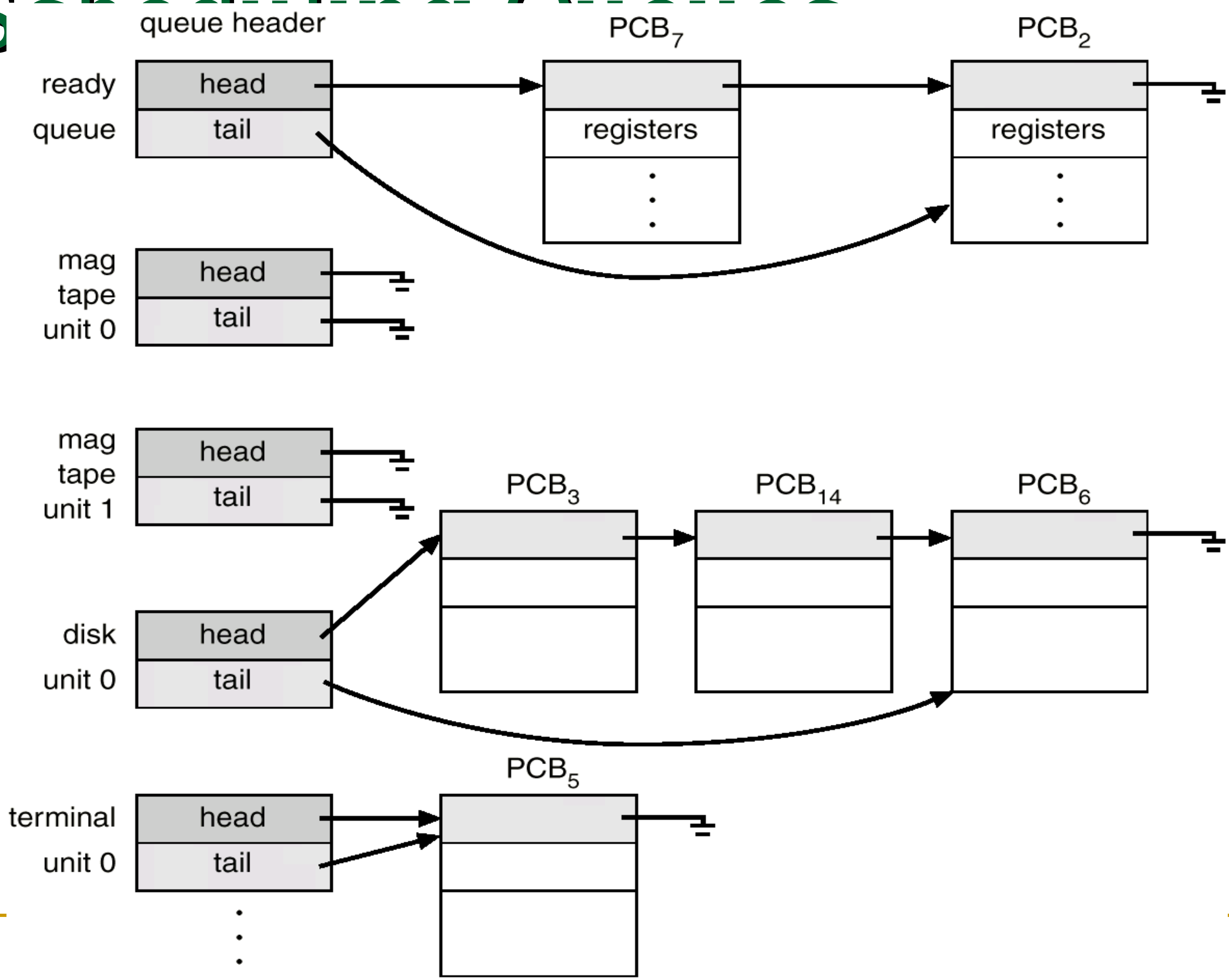


Further Enhancement:
A separate queue holds the processes waiting for different event.

Scheduling Queues

- The queues are generally stored as linked lists
- A queue header points to the first and the final PCB's in the list
- We extend each PCB to include a pointer field that points to the next PCB in the ready queue

Scheduling Queues



Schedulers

- Short term Scheduler or CPU Scheduling
  - Which program is to be run next
- Long term Scheduler or Job Scheduler
  - Which ready jobs should be brought to memory
  - May need to invoke only when a process leaves the system
  - Must make a careful selections

Process Types

- Most processes can be described as either I/O bound or CPU bound
- I/O bound:
  - Spends more of its time doing I/O than doing computations
- CPU bound:
  - Spends more of its time doing computations than doing I/O
- If all processes are I/O bound,
  - The ready queue will almost always be empty
- If all processes are CPU bound,
  - The I/O waiting queue will almost always be empty, devices will go unused
  - System will again be unbalanced

Process Types

- Sometimes OS may swap a blocked process to disk to free up more memory
- Or to improve process mix
- This is called ***Swapping***