Processor Management

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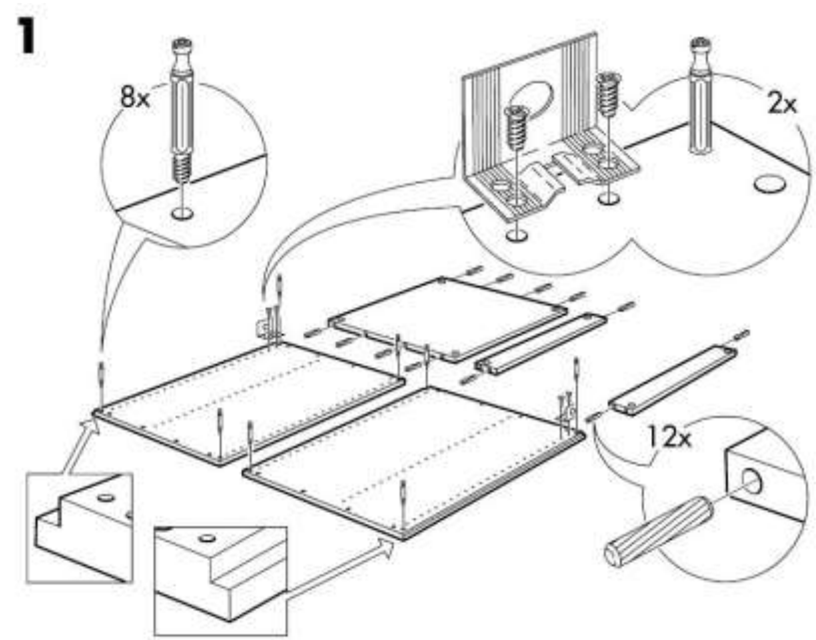
Processor Management

- If you were assembling some IKEA furniture, and following the step-by-step guide of 20 steps.
- Imagine you did step 1, then step 2, then step 3, suddenly the doorbell rang, and you are interrupted.



Processor Management

- You would stop what you are doing and deal with whoever is at the door.
- Then you would return to the assembly, check what step you were on, and then continue on from there (step 4).

Processor Management

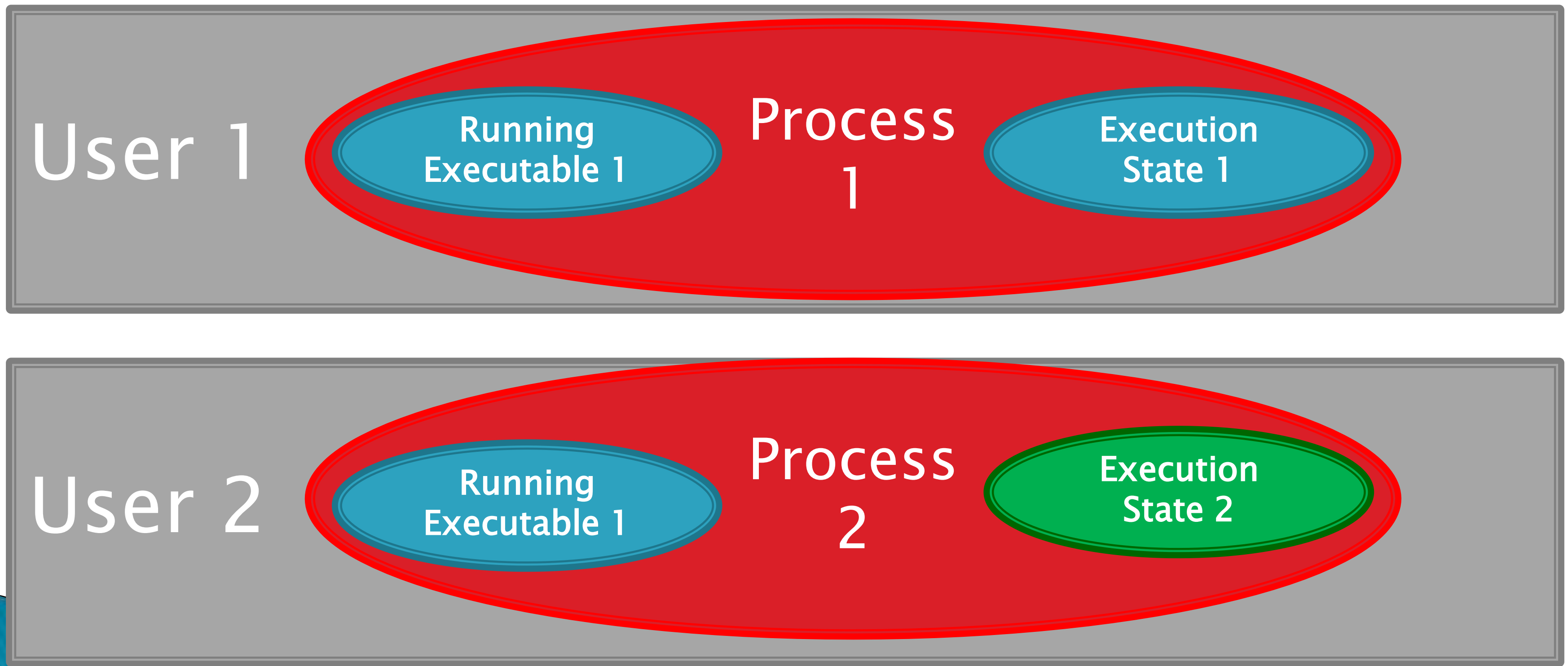
- This is how the computer runs multiple processes simultaneously … you do a few steps on one process, get interrupted, work on other processes, then return to the first process, remembering where you left off from, and continue on.
- This swapping of processes is called a **pre-emptive scheduling policy**.

Processor Management

- A “Process” is the basic unit of execution in the operating system
- A “Process” is the name we give to a program when it is running in memory
  - So a “Program” is the complied executable
  - And a “Process” is the running executable with the execution state.

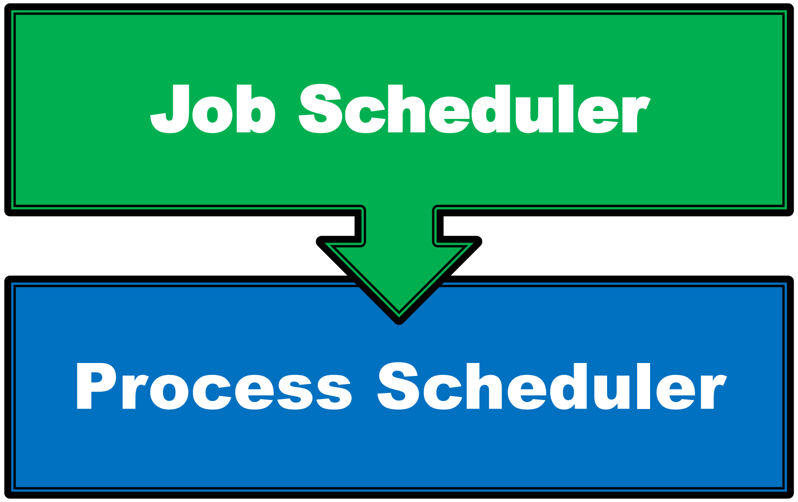
Processor Management

- The same program being run by two different users in the operating system are two different processes

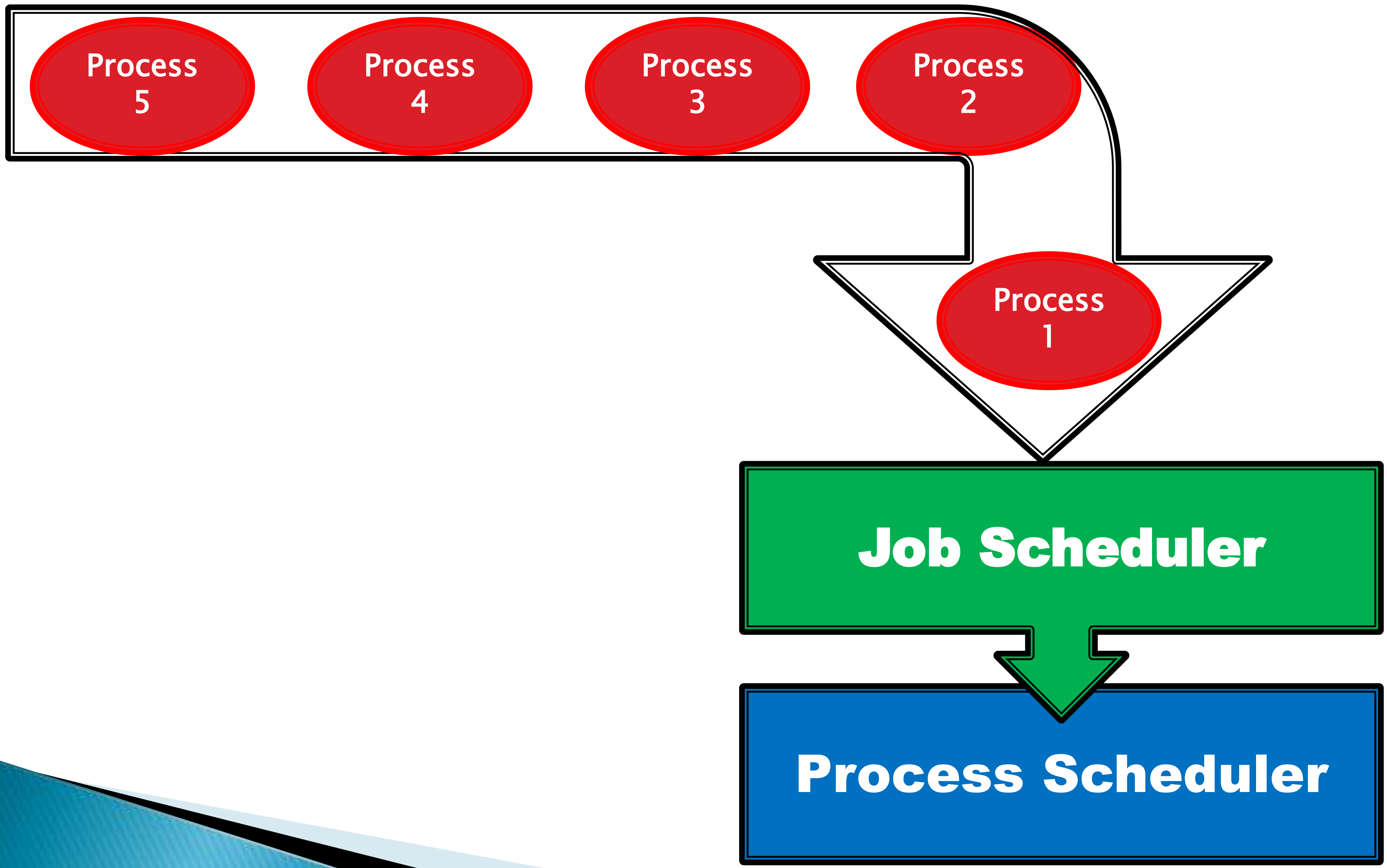


Processor Management

- The Processor Manager is made up of two sub-managers:



Processor Management



Job Scheduler

- We describe a collection of processes as a “job”.
- When the operating systems is presented with a queue of jobs or processes to run, the **Job Scheduler** has the task of deciding which order to run the are jobs in.
- The **Job Scheduler** wants to ensure that the all components of the operating system are busy, and there is no component that is idle.

Job Scheduler

- Let's think about this program:

```
PROGRAM PrintValue:
BEGIN
  Input A;
  Input B;
  C = A + B;
  D = A – B;
  Print "The sum of inputs is: ", C;
  Print "The Difference of inputs is: ", D;
END.
```

Job Scheduler

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I/O

Job Scheduler

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Reading from keyboard

I/O

Job Scheduler

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I/O

I/O

Job Scheduler

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END.
```

I/O

I/O

Writing To screen

Job Scheduler

- Let’s think about this program:

```
PROGRAM PrintValue:
BEGIN
  Input A;
  Input B;                                          I/O
  C = A + B;
  D = A - B;                                        CPU
  Print “The sum of inputs is: “, C;
  Print “The Difference of inputs is: “, D;         I/O
END.
```

Job Scheduler

- Let's think about this program:

```
PROGRAM PrintValue:
BEGIN
  Input A;
  Input B;
  C = A + B;
  D = A – B;
  Print "The sum of inputs is: ", C;
  Print "The Difference of inputs is: ", D;
END.
```

I/O

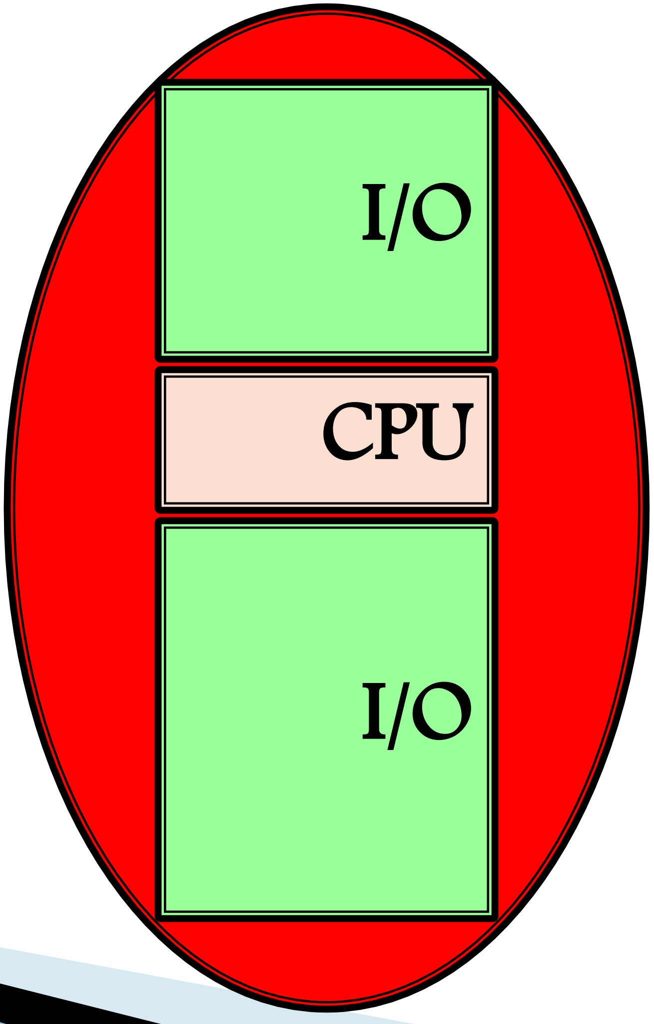
CPU

Doing computation

I/O

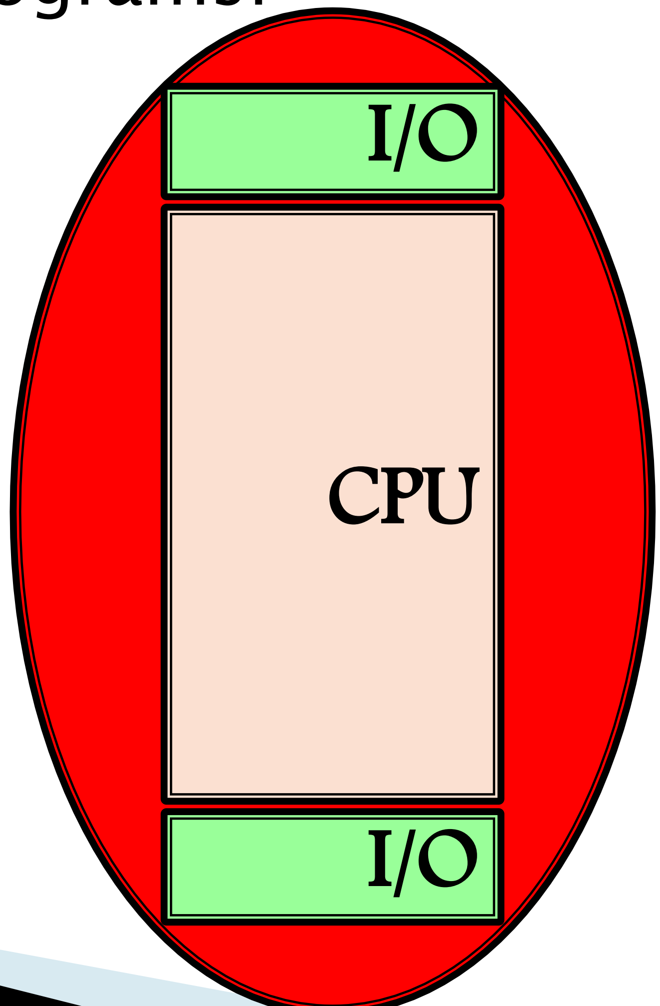
Job Scheduler

- Some programs do a lot of I/O, e.g. Graphics programs:



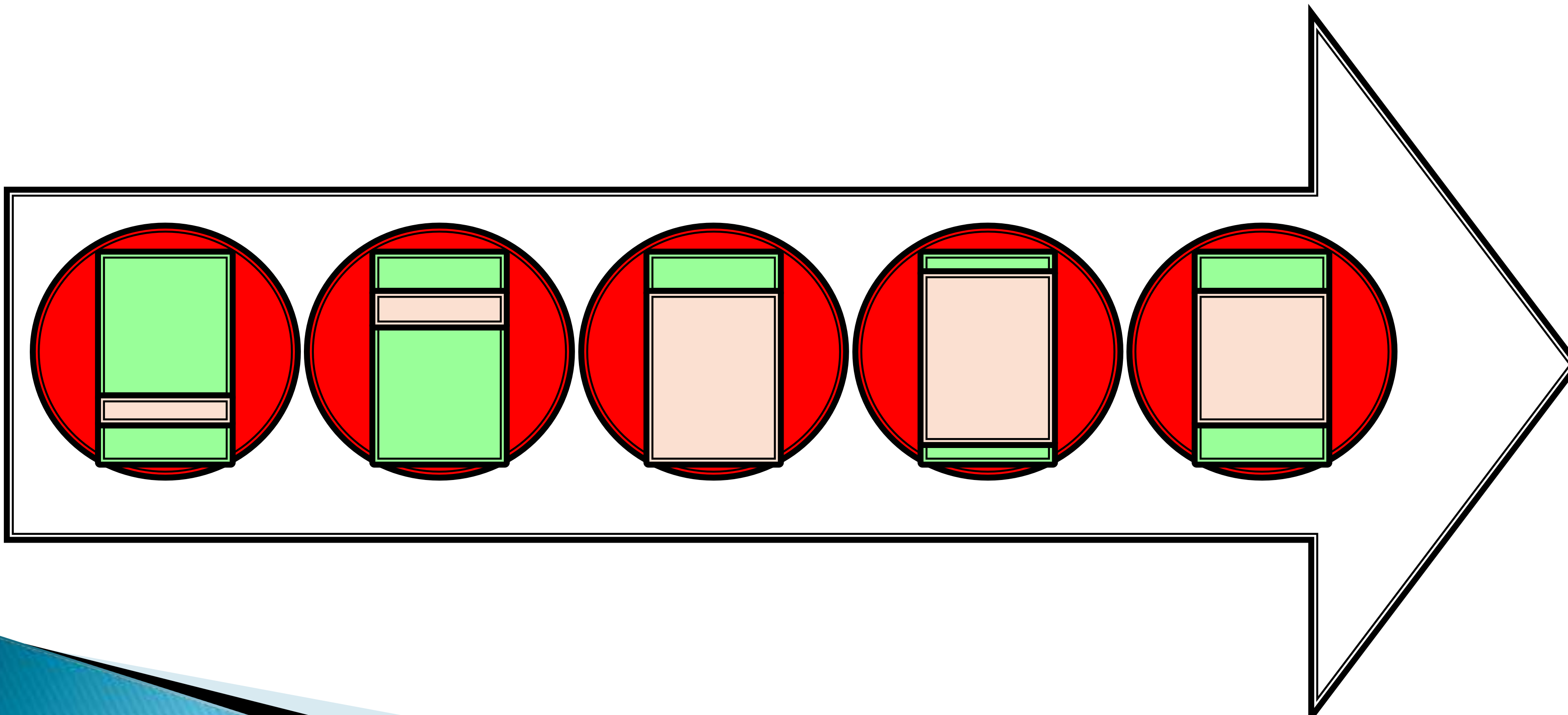
Job Scheduler

- Others do a lot of computation, but little I/O, e.g. maths programs:



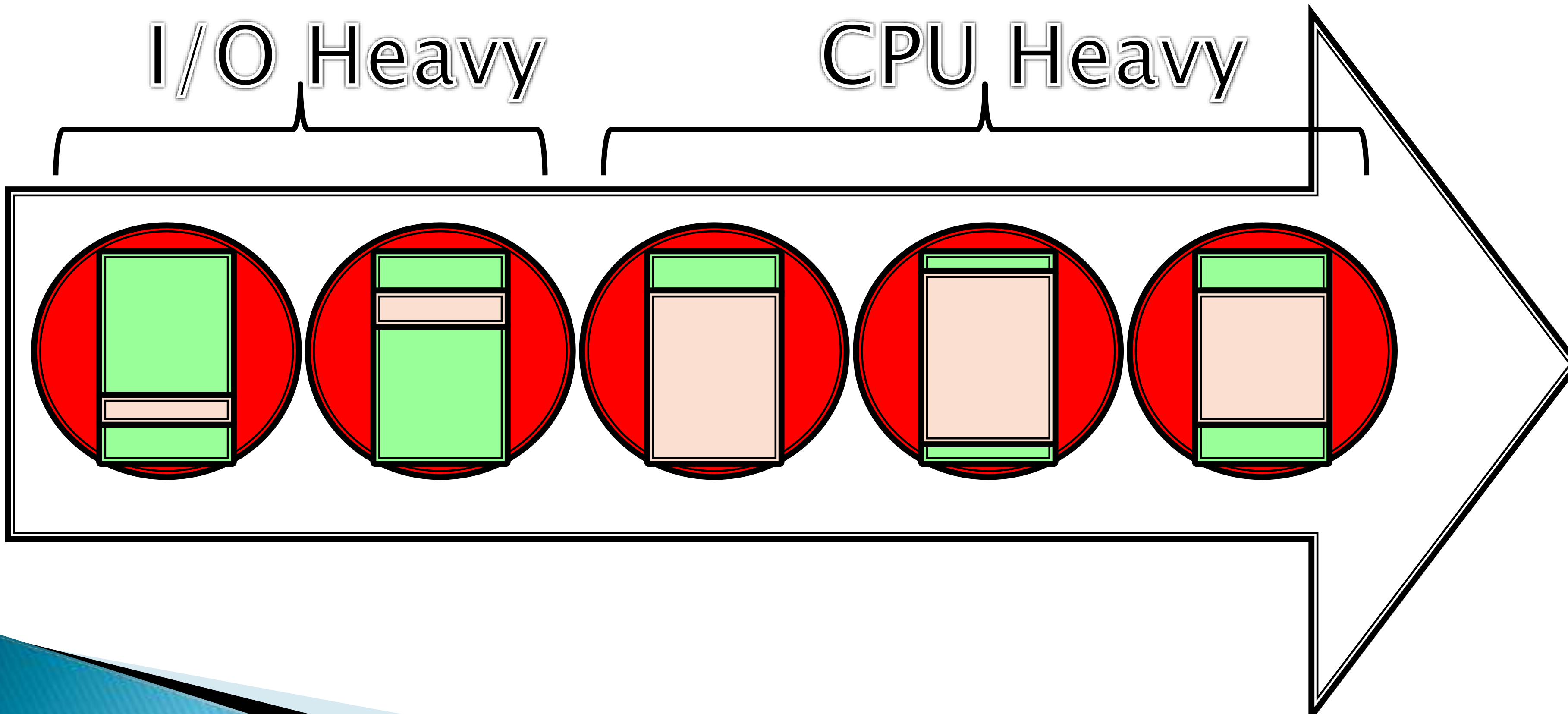
Job Scheduler

- If the job scheduler gets jobs like this:



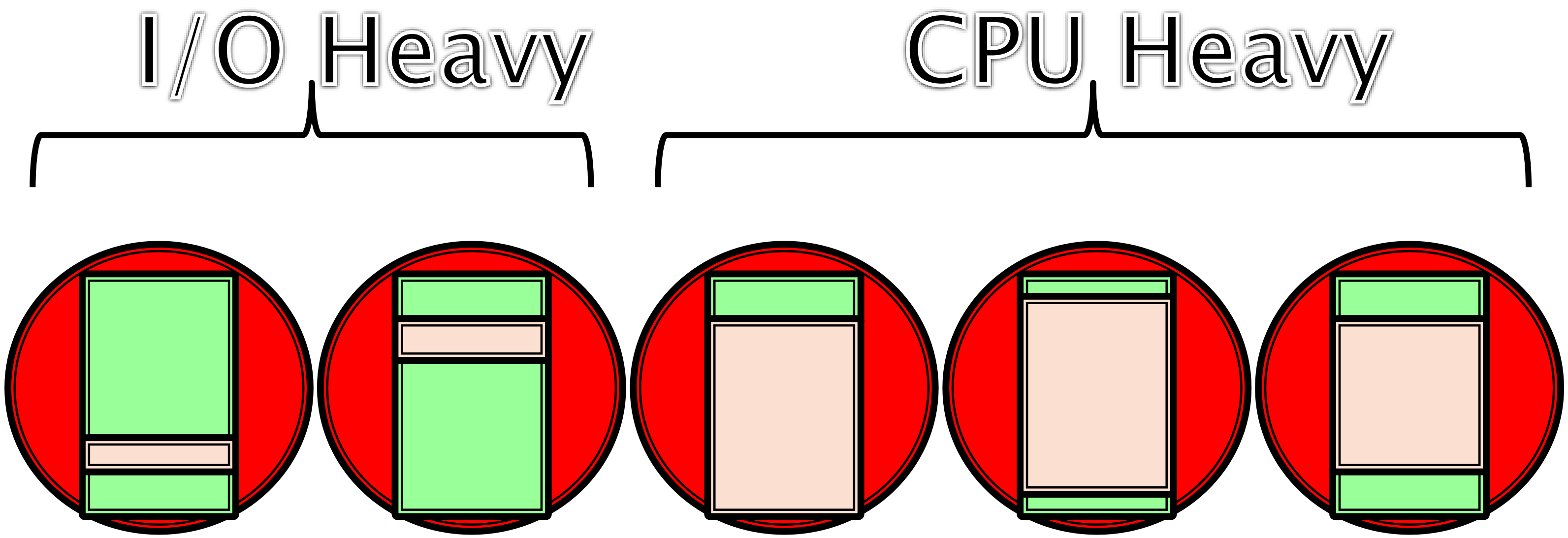
Job Scheduler

- If the job scheduler gets jobs like this:



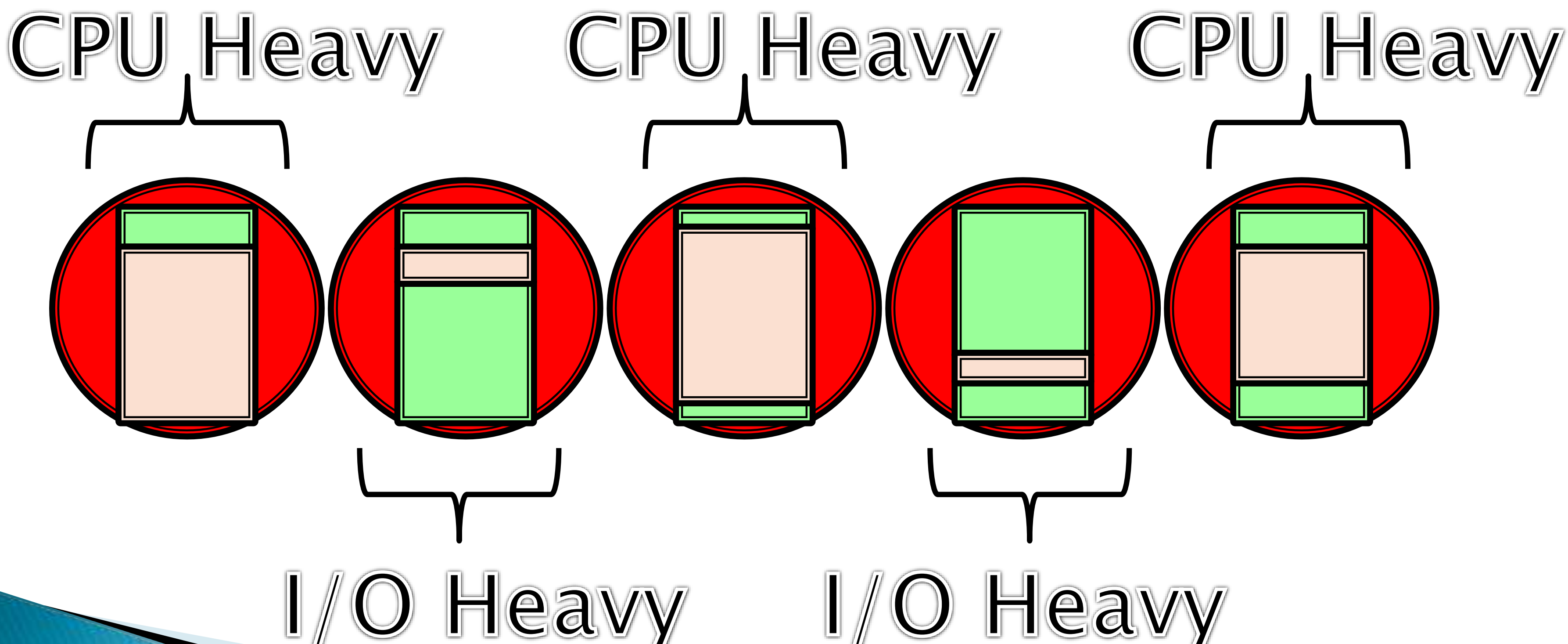
Job Scheduler

- So the job scheduler will take these jobs:



Job Scheduler

- And swap them around, and pass them onto the Process Scheduler



Job Scheduler

- So in this case the Job Scheduler wants to balance the jobs coming in, so that the components of the operating system are all kept busy.
- If we don't change the order of job, the CPU will be very busy, but the I/O component will be idle, and then vice versa.
- This is not an optimal use of resources, so we swap them around.

Job Scheduler

- We'll call jobs that are CPU-bound **Batch Jobs**, and we’ll call jobs that have a lot of I/O operations **Interactive Jobs**.

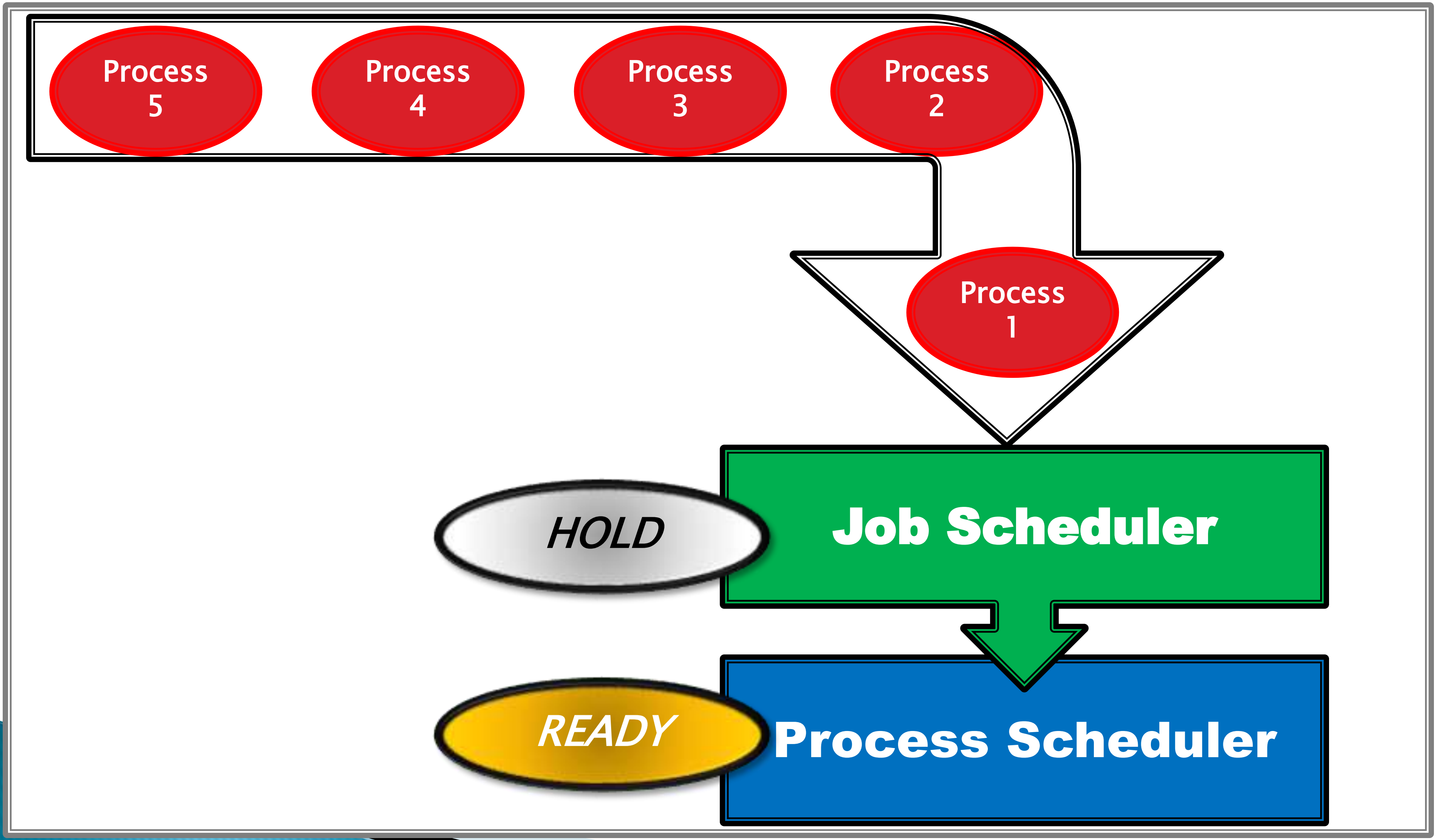
Job Scheduler

- This is the first level of swapping of processes that will occur, and more will be done by the **Process Scheduler**. The **Job Scheduler** is looking at jobs (or groups of processes), and looking at the whole process from a high-level.
- For obvious reasons, the Job Scheduler is also called the **High-Level Scheduler**.

Job Scheduler

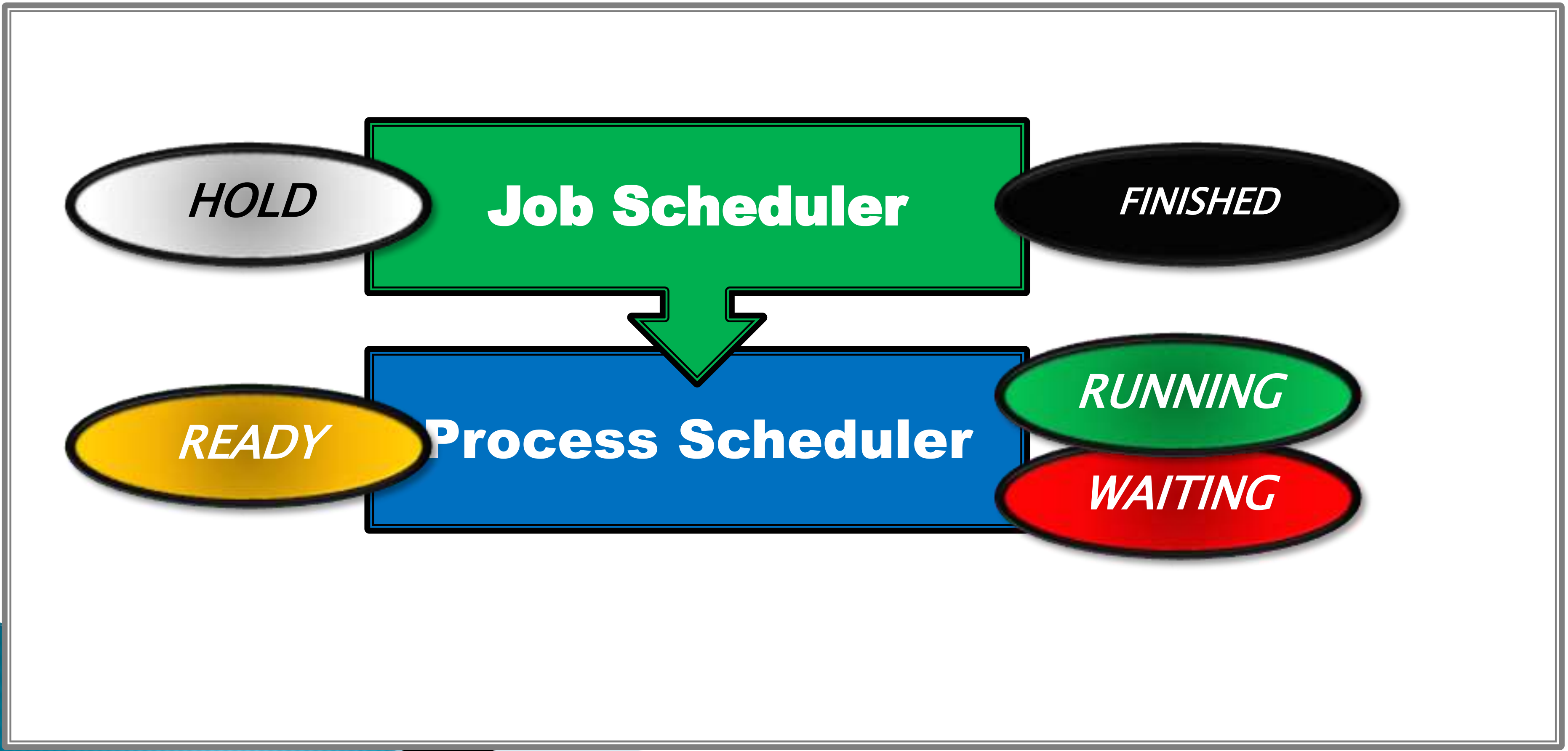
- Every process has a field that records their current status, called the **Process Status**.
- When the process is first passed to the **Job Scheduler** from the operating system, its status is always set as **HOLD.**
- When the **Job Scheduler** passes the process onto the **Process Scheduler**, its status is always changed to **READY**.

Processor Management

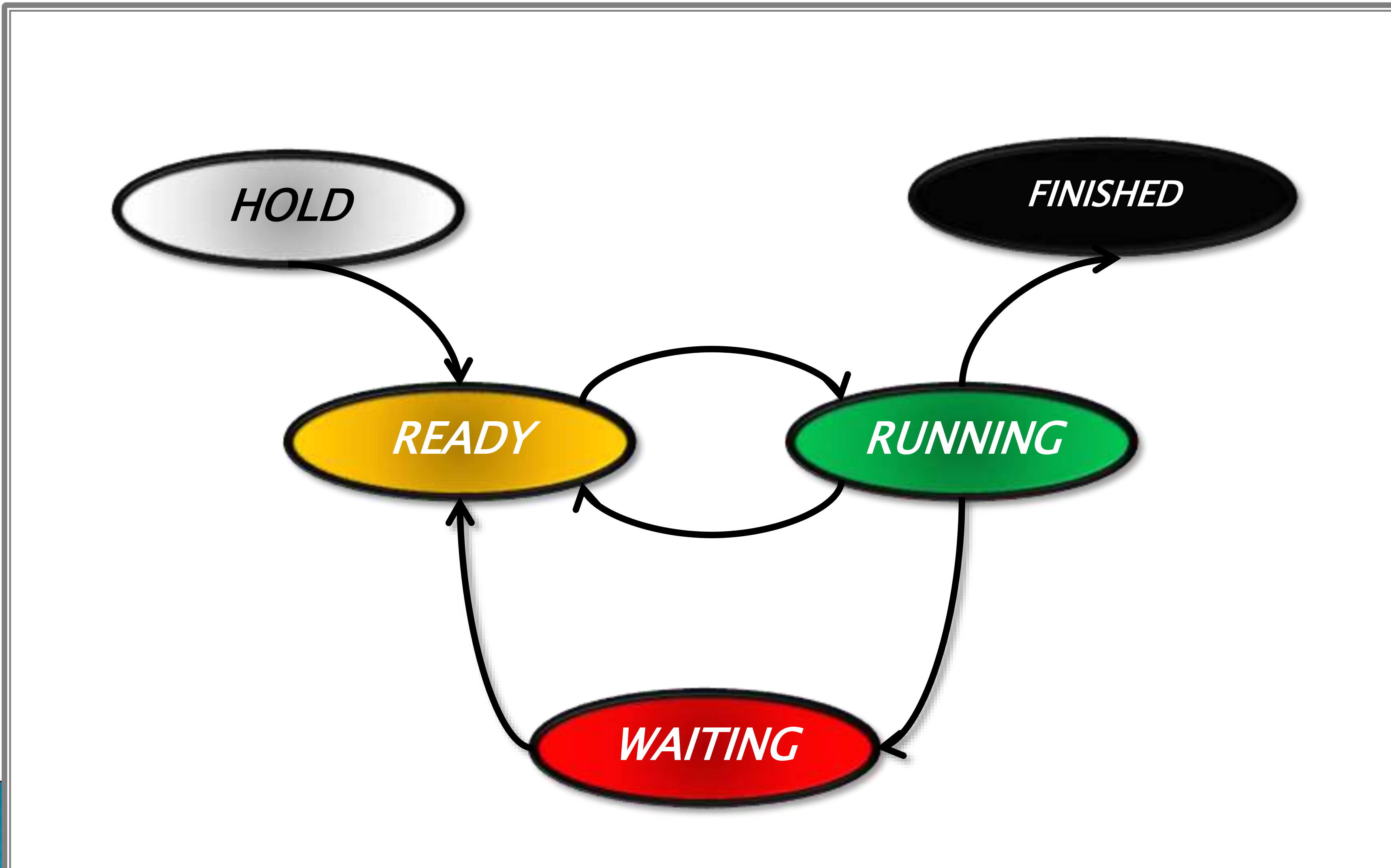


Processor Management

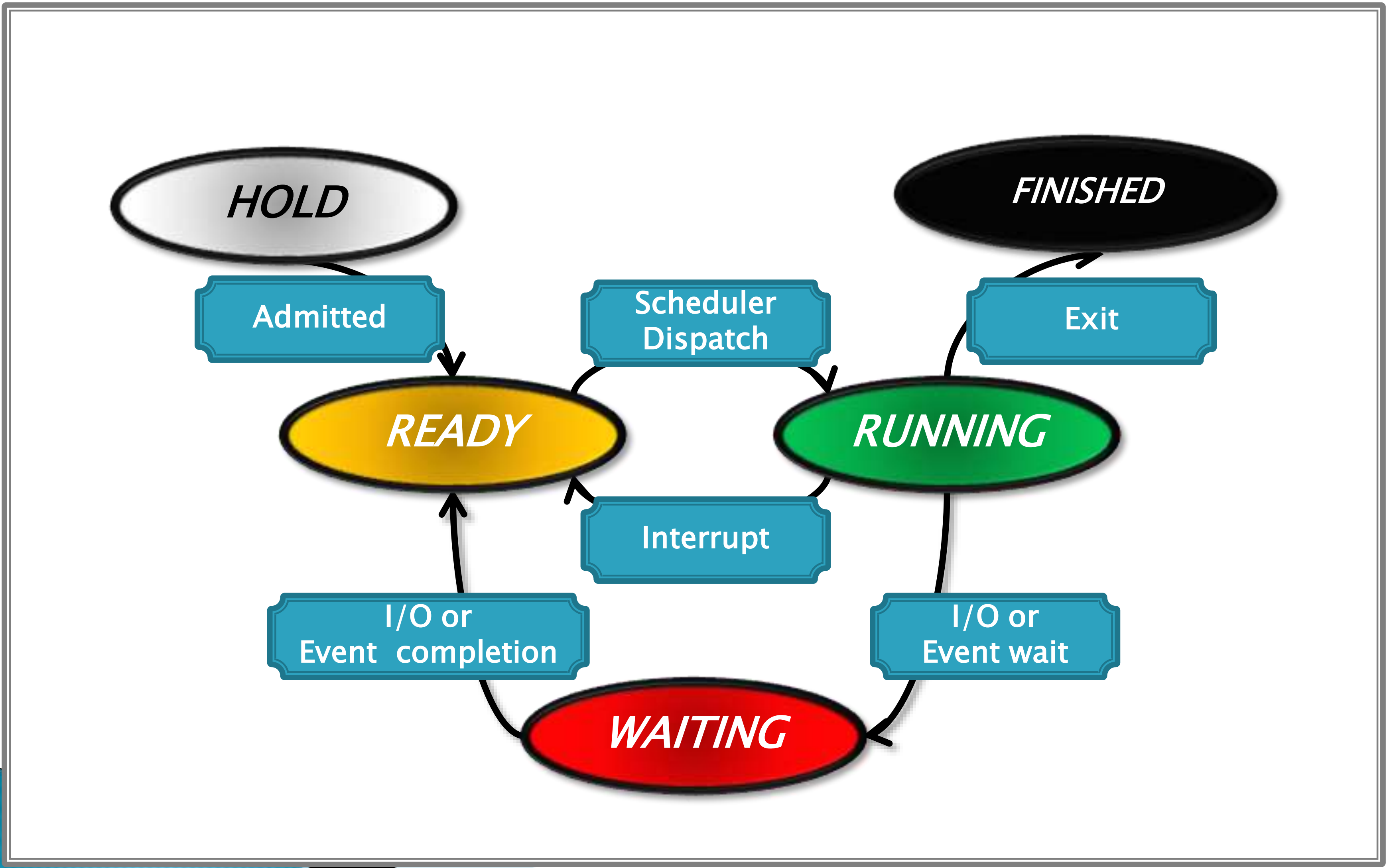
- Other statuses that a process can have are:



Process Scheduler

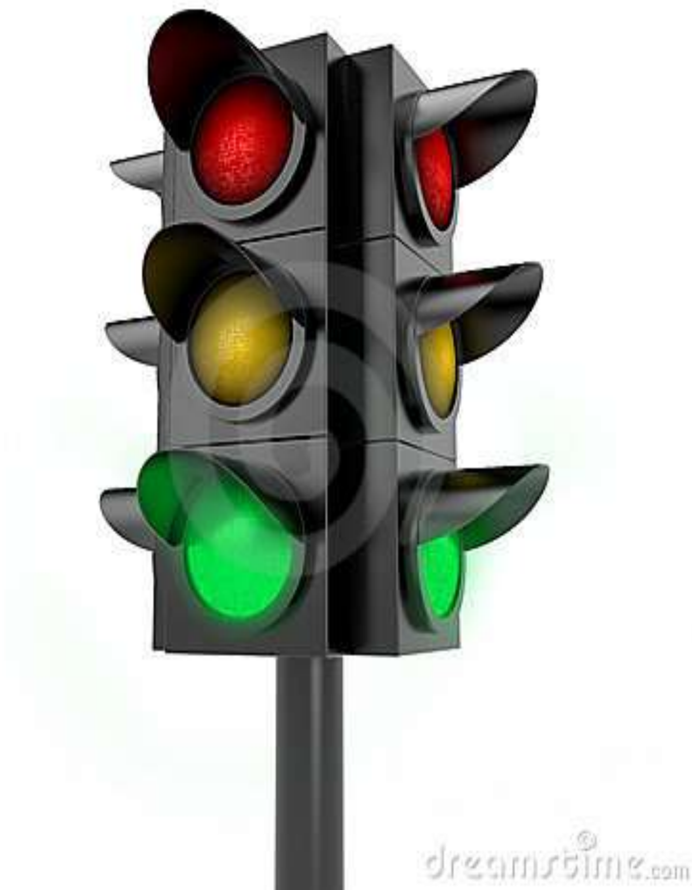


Process Scheduler



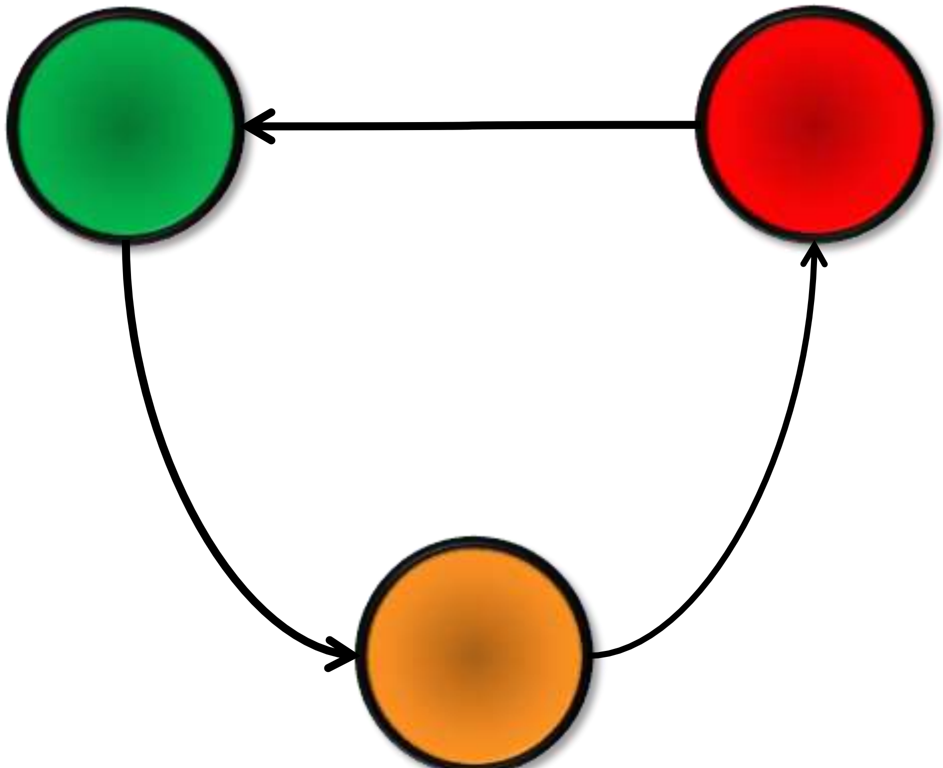
Process Scheduler

- Think about traffic lights:



Process Scheduler

- This is the sequence:



Process Scheduler

- As mentioned previously the process is first passed to the **Job Scheduler** from the operating system, its status is always set as **HOLD.** When the **Job Scheduler** passes the process onto the **Process Scheduler**, its status is always changed to **READY**.

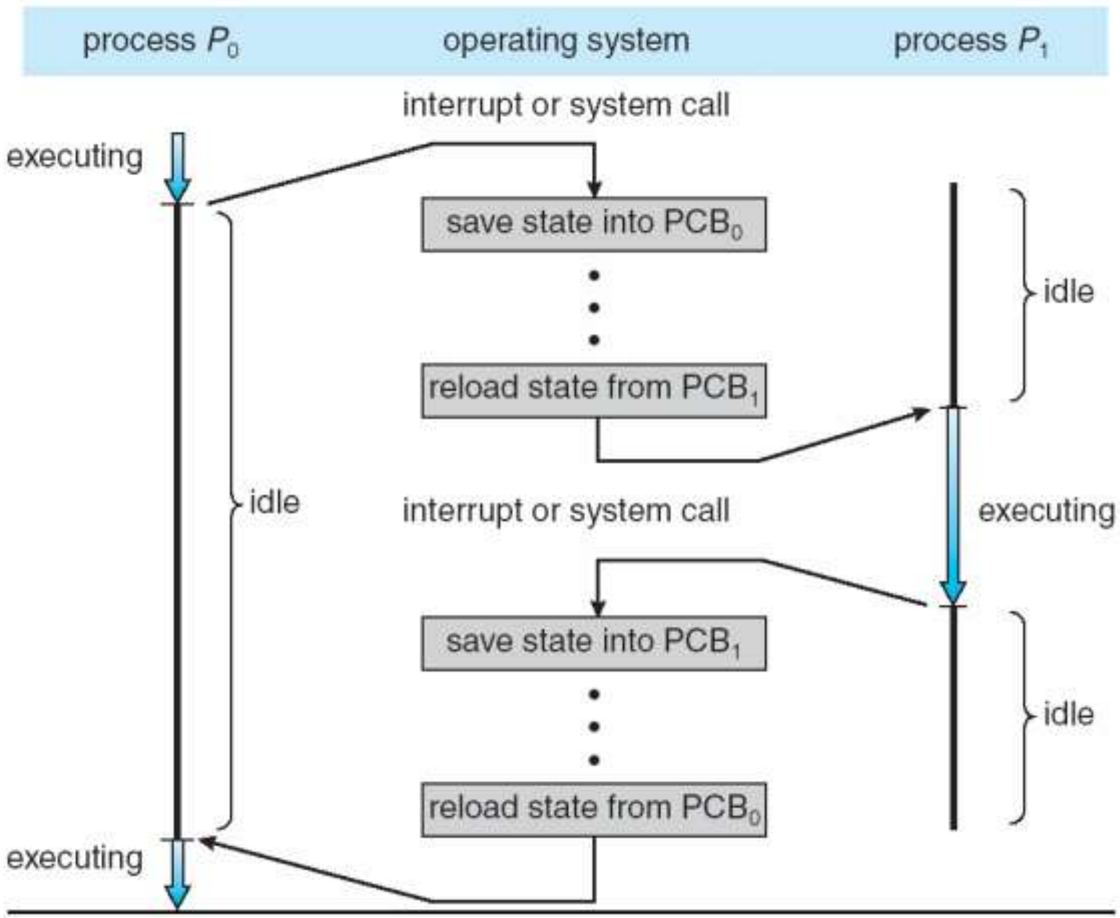
Process Scheduler

- When the CPU is available, the **Process Scheduler** will look at all of the upcoming processes and will select one of them (based on a predefined algorithm) and assuming there is memory free, the process will start running and its status is changed to **RUNNING** by the **Process Scheduler**.

Process Scheduler

- After a predefined time, the process will be interrupted, and another process will take over the CPU, and the interrupted process will have its status changed to **READY** by the **Process Scheduler**. We will remember that this swapping of processes is called a **pre-emptive scheduling policy**.
- When is CPU is available for this process again the process status be changed to **RUNNING** by the **Process Scheduler**.

Process Scheduler



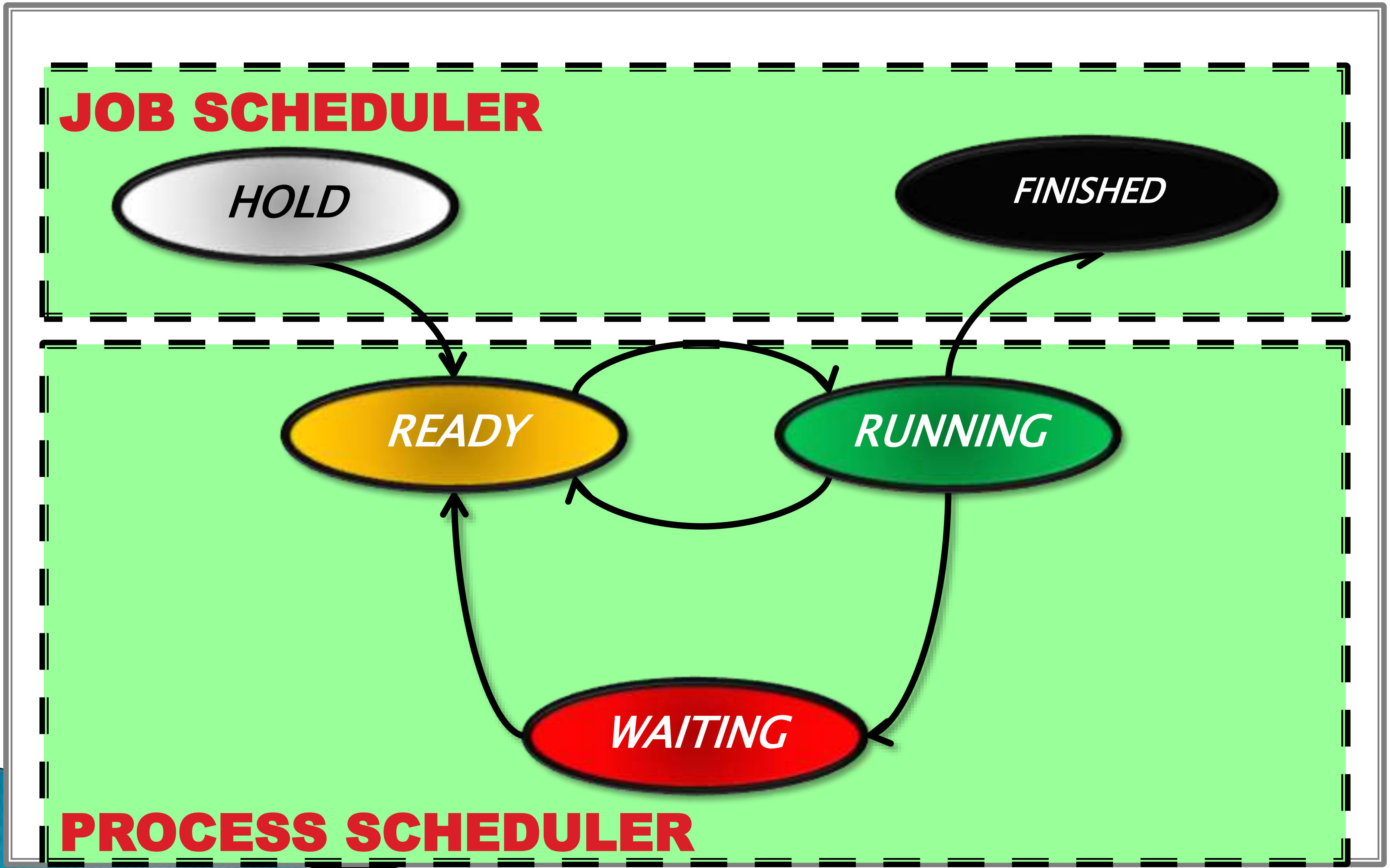
Process Scheduler

- If the process has to wait for some I/O from the user or some other event, it is put in a status of **WAITING** by the **Process Scheduler.**
- When the I/O device lets the **Process Scheduler** know that the I/O is completed, the process status will be changed to **READY** by the **Process Scheduler**.

Process Scheduler

- Finally the process status will be changed to **FINISHED** either when the process has successful completed, or if an error occurs and the process has to terminate prematurely. The status change is usually handled by the **Process Scheduler** informing the **Job Scheduler** of the process completion, and the **Job Scheduler** of changing the status.

Processor Management



Process Control Block (PCB)

- The Process status is only one of a collection of descriptors that are associated with a process.
- Each process has a data structure called a Process Control Block (PCB) associated with it, rather like a passport.

Process Control Block (PCB)

Operating System

Process Control Block (PCB)

Process Control Block (PCB)

Process ID

Process Status

Process State
- Program Counter
- Register Contents
- Main Memory
- Resources
- Process Priority

Accounting

Process Control Block (PCB)

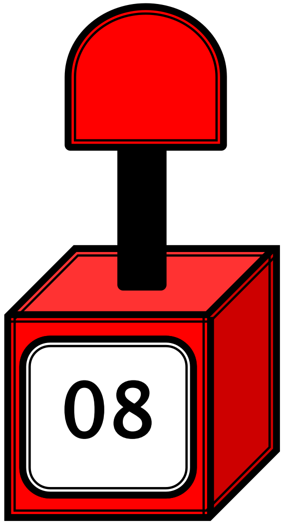
- PROCESS IDENTIFIER
  - Each process is uniquely identified by both the user's identification, and a pointer connecting it to its descriptor.

Process Control Block (PCB)

- **PROCESS STATUS**
  - The current status of the process, it is either:

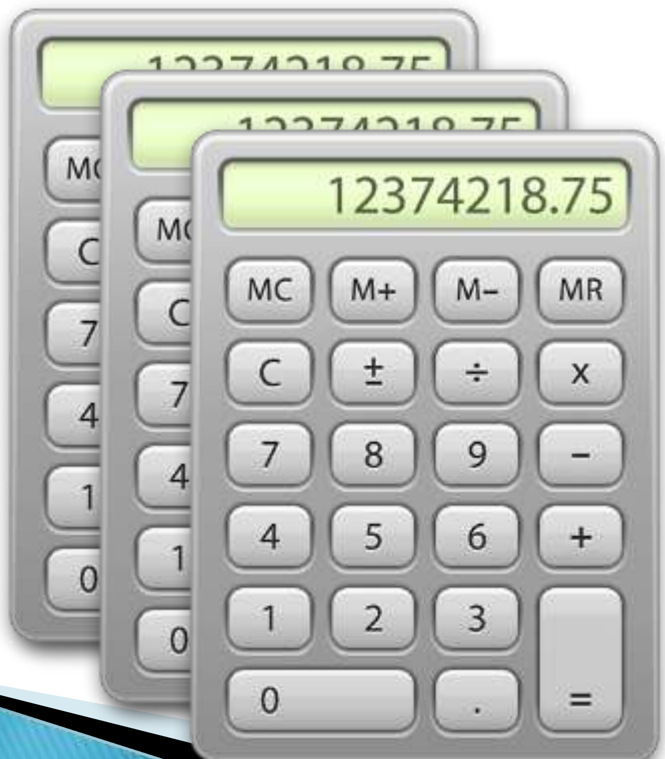
Process Control Block (PCB)

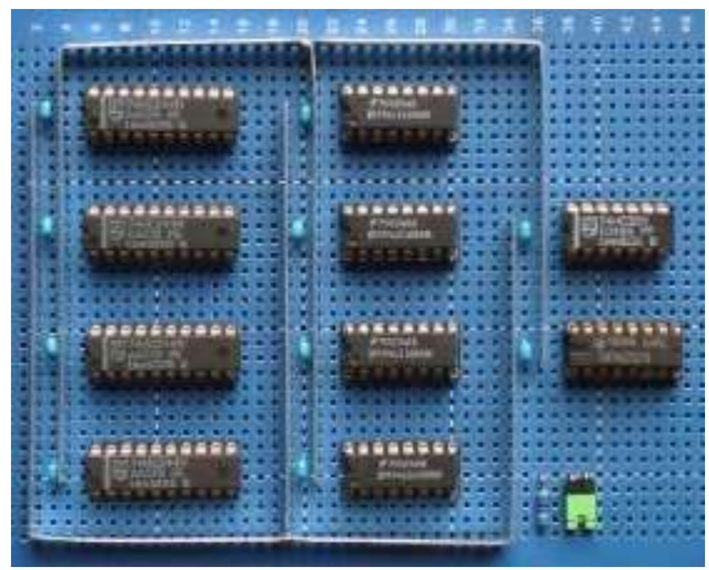
- **PROCESS STATE**
  - **Program counter**
  - Record the current value of the program counter



Process Control Block (PCB)

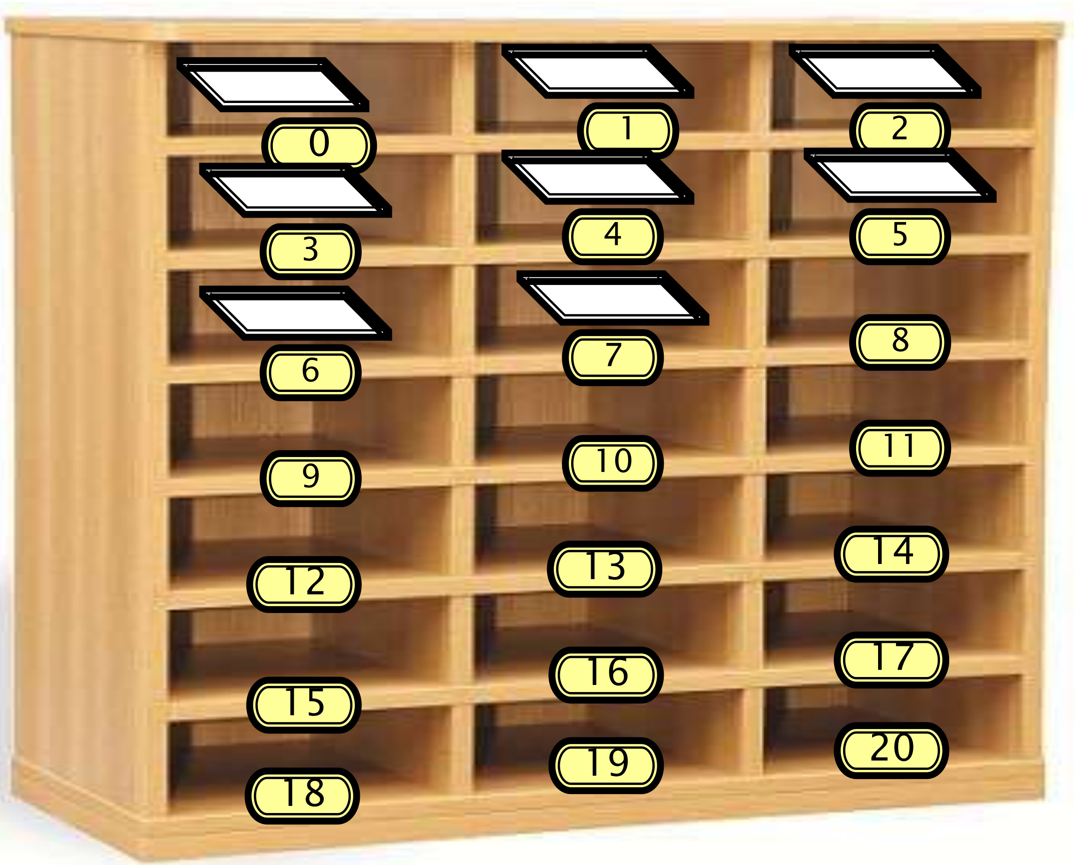
- **PROCESS STATE**
  - **Register Contents**
  - Record the values of the data registers





Process Control Block (PCB)

- **PROCESS STATE**
  - **Main Memory**
  - Record all important information from memory, including most importantly the process location.



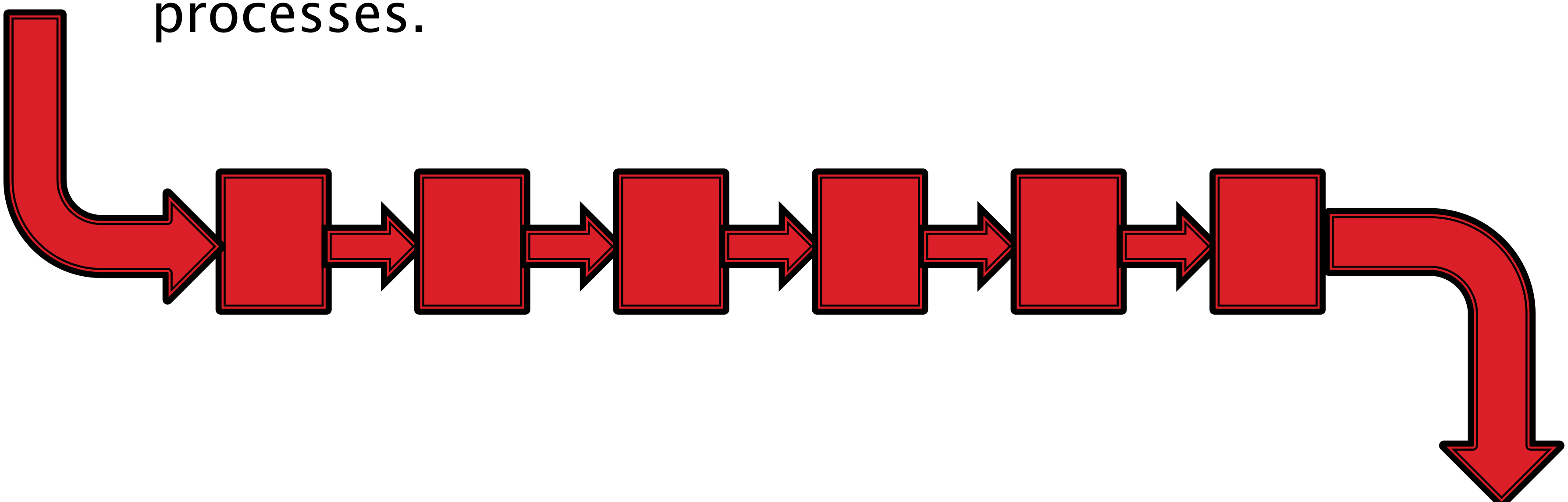
Process Control Block (PCB)

- **PROCESS STATE**
  - **Resources**
  - Record the resources that have been allocated to this job, including files, disk drives, and printers.

ID	TYPE	DETAILS
1	FILE	TXT file starting at memory address 0x456
2	FILE	DAT file starting at memory address 0x087
3	DISK	Disk Drive 4
4	FILE	TXT file starting at memory address 0x673
5	PRINTER	Printer at IP address 172.242.34.65

Process Control Block (PCB)

- PROCESS STATE
  - **Process Priority**
  - The process is assigned a priority, and if the operating system using priorities to schedule processes.



Process Control Block (PCB)

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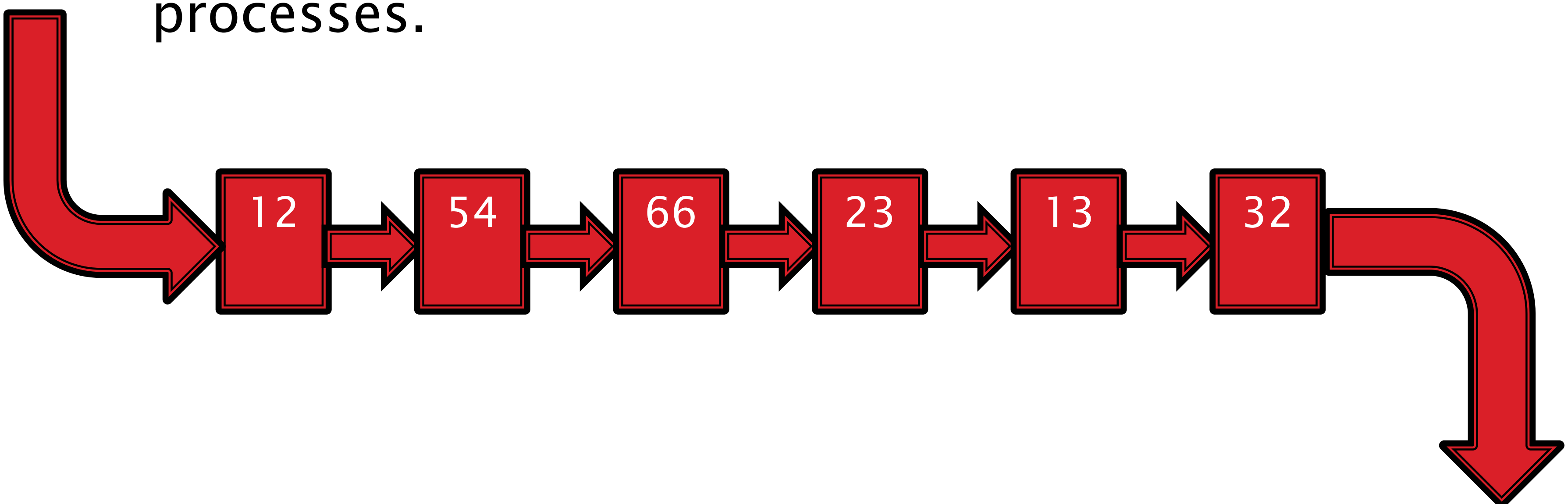

Process Control Block (PCB)

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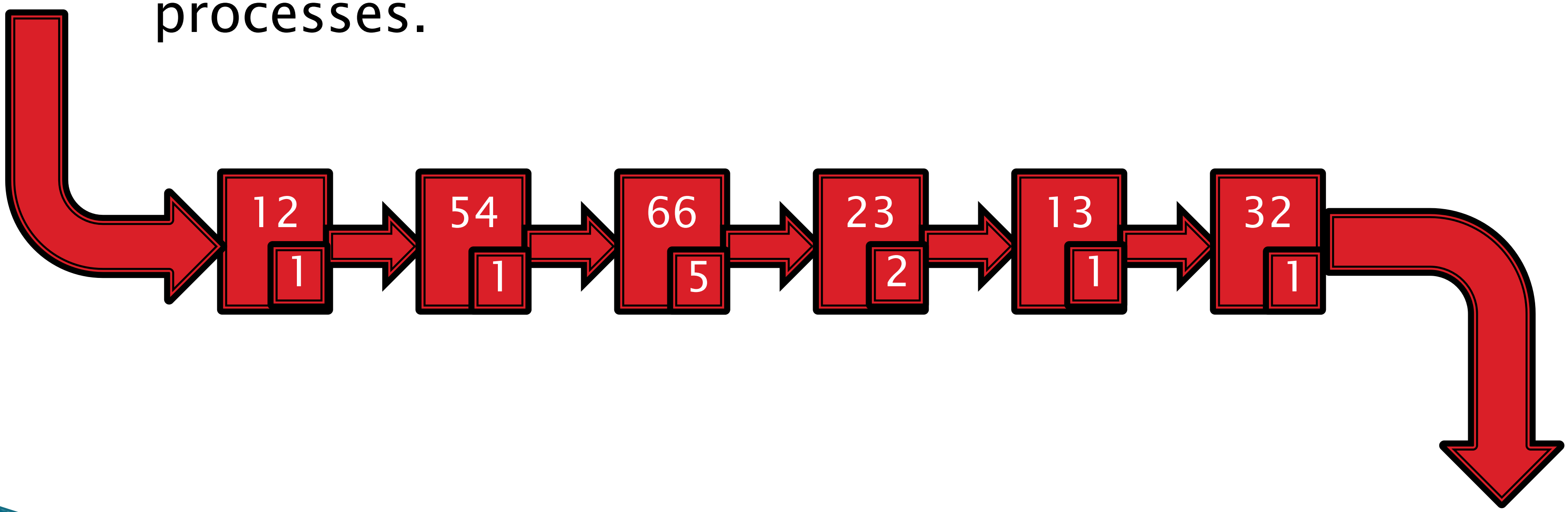

Process Control Block (PCB)

- **ACCOUNTING**
  - This section records some of the performance statistics associated with this process, including:
    - CPU time used so far
    - Time process has been in the system
    - Time taken in memory (Main and secondary)
    - Space taken in memory (Main and secondary)
    - System programs used, compliers, editors, etc.
    - Number and type of I/O operations
    - Time spent waiting for I/O operations completion
    - Number of Input records read and Output records written

Process Control Block (PCB)

Process ID

Process Status

Process State
- Program Counter
- Register Contents
- Main Memory
- Resources
- Process Priority

Accounting

Process Control Block (PCB)

Process ID	457
Process Status	“WAITING”
Process State • Program Counter • Register Contents • Main Memory • Resources • Process Priority	Process State • 245 • R1:23, R2:63, R3:71 • Process Address: 345 • File1, File5, Disk4 • 5
Accounting	CPU: 3, Total Time:34…..

Process Scheduling Policies

Process Scheduling Policies

- What are good policies to schedule processes?

Process Scheduling Policies

- MAXIMUM THROUGHPUT
- Get as many jobs done as quickly as possible.
- There are several ways to achieve this, e.g. run only short jobs, run jobs without interruptions.

Process Scheduling Policies

- **MINIMIZE RESPONSE TIME**
- Ensure that interactive requests are dealt with as quickly as possible.
- This could be achieved by scheduling just with a lot of I/O jobs first, and leave the computational jobs for later.

Process Scheduling Policies

- **MINIMIZE TURNAROUND TIME**
- Ensure that jobs are completed as quickly as possible.
- This could be achieved by scheduling just with a lot of computation jobs first, and leave the I/O jobs for later, so there is no user delays.

Process Scheduling Policies

- **MINIMIZE WAITING TIME**
- Move jobs out of the READY status as soon as possible.
- This could be achieved by reduce the number of users allowed on the system, so that the CPU would be available whenever a job enters the READY status.

Process Scheduling Policies

- **MINIMIZE WAITING TIME**
- Move jobs out of the READY status as soon as possible.
- This could be achieved by reduce the number of users allowed on the system, so that the CPU would be available whenever a job enters the READY status.

Process Scheduling Policies

- **MAXIMISE CPU EFFICIENCY**
- Keep the CPU busy 100% of the time.
- This could be achieved by scheduling just with a lot of computation jobs, and never run the I/O jobs.

Process Scheduling Policies

- ENSURE FAIRNESS FOR ALL JOBS

- Give everyone an equal amount of CPU time and I/O time.

- This could be achieved by giving all jobs equal priority, regardless of it’s characteristics.

Process Scheduling Algorithms

Process Scheduling Algorithms

- Here are six commonly used process scheduling algorithms

Process Scheduling Algorithms

- **First Come, First Served (FCFS)**
- A very simple algorithm that uses a FIFO structure.
- Implemented as a non-pre-emptive scheduling algorithm.
- Works well for **Batch Processes**, where users don't expect any interaction.

Process Scheduling Algorithms

- **Shortest Job Next (SJN)**
- Also called Shortest Job First (SJF).
- A very simple algorithm that schedules processes based on CPU cycle time.
- Implemented as a non-pre-emptive scheduling algorithm.
- Works well for **Batch Processes**, where it is easy to estimate CPU time.

Process Scheduling Algorithms

- **Priority Scheduling**
- An algorithm that schedules processes based on priority.
- Implemented as a non-pre-emptive scheduling algorithm.
- One of the most common algorithms used in systems that are mainly **Batch Processes**.
- If two jobs come in of equal priority are READY, if works on a FIRST COME, FIRST SERVED basis.

Process Scheduling Algorithms

- **Shortest Remaining Time (SRT)**
- A pre-emptive scheduling version of the Shortest Job Next (SJN) algorithm.
- An algorithm that schedules processes based on the one which is nearest to completion.
- It can only be implemented on systems that are only **Batch Processes**, since you have to know the CPU time required to complete each job.

Process Scheduling Algorithms

- **Round Robin**
- A pre-emptive scheduling algorithm that is used extensively in interactive systems
- All active processes are given a pre-determined slice of time ("*time quantum*").
- Choosing the time quantum is the key decision, for interactive systems the quantum must be small, whereas for batch systems it can be longer.

Process Scheduling Algorithms

- **Multi-Level Queues**
- This isn't really a separate scheduling algorithm, it can be used with others.
- Jobs are grouped together based on common characteristics.
- For example, CPU-bound jobs based in one queue, and the I/O-bound jobs in another queue, and the process scheduler can select jobs from each queue based on balancing the load.