Processes and Non-Preemptive Scheduling

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An aside on concurrency

- Timing and sequencing of events are key concurrency issues
- We will study classical OS concurrency issues, including implementation and use of classic OS mechanisms to support concurrency
- In later courses on concurrency and on parallel programming you will revisit this material
- In a later course on distributed systems you may want to use formal tools to better understand and model timing and sequencing
- Emerging CPUs are typically multi core, and multi threaded
  - *Challenges and opportunities to design cost-effective high-performance systems.*

Process (I)

- An instance of a program under execution
  - Program specifying (logical) control-flow (thread)
  - Data
  - Private address space
  - Open files
  - Running environment
- The most important operating system concept
- Used for supporting the concurrent execution of independent or cooperating program instances
- Used to structure applications and systems

Processes (II)

- Classically, processes were, using today's terminology; "Single Threaded"
- Sequential program: Single process
- Parallel program: Multiple cooperating processes
  - This works fine in principle, but interaction among processes incurs significant OS time overhead.

Processes (III)

- “Modern” process: “Process” and “Thread” are separate concepts
- Process—Unit of Resource Allocation—Defines the context
- Thread—Control Thread—Unit of execution scheduling
- Every process must contain one or more threads
- Every (?) thread exists within the context of a process

User- and Kernel-Level Thread Support

- User-level threads within a process are
  - Indiscernible by OS
  - Scheduled by (user-level) scheduler in process
- Kernel-level threads
  - Maintained by OS
  - Scheduled by OS

Supporting and Using Processes

- Multiprogramming
  - Supporting concurrent execution *(parallel or transparently interleaved)* of multiple processes (or threads), often assumed to be related to different problems
  - Achieved by process- or context switching, switching the CPU(s) back and forth among the processes, keeping track of each process' progress
- Concurrent programs
  - Programs (or threads) that exploit multiprogramming for some purpose (e.g. performance, structure)
  - Operating systems is important application area for concurrent programming. Many others (event driven programs, servers, ++)
  - http://csapp.cs.cmu.edu/public/ch12-preview.pdf

Implementing processes

- OS needs to keep track of all processes
  - Keep track of it's progress
  - Parent process
  - Metadata (priorities etc.) used by OS
  - Memory management
  - File management
- Process table with one entry (Process Control Block) per process
- Will also align processes in *queues*

Primitives of Processes

- Creation and termination
  - `fork, exec, wait, kill`
- Signals
  - Action, Return, Handler
- Operations
  - `block, yield`
- Synchronization
  - We will talk about this later

`fork` (UNIX)

- Spawns a new process (with new PID)
- Called in parent process
- Returns in parent *and* child process
- Return value in parent is child’s PID
- Return value in child is ’0’
- Child gets duplicate, but separate, copy of parent’s user-level virtual address space
- Child gets identical copy of parent’s open file descriptors

fork, exec, wait, kill

- Return value tested for error, zero, or positive
- Zero, this is the child process
  - Typically redirect standard files, and
  - Call Exec to load a new program instead of the old
- Positive, this is the parent process
- Wait, parent waits for child's termination
  - Wait issued before corresponding exit: Parent blocks until exit
  - Exit issued before corresponding wait: Child becomes zombie (un-dead) until wait
- Kill, specified process terminates

When may OS switch contexts?

- Only when OS runs
- Events potentially causing a context switch:
  - Process created (`fork`)
  - Process exits (`exit`)
  - Process blocks implicitly (I/O, IPC)
  - Process blocks explicitly (`yield`)
  - User or System Level Trap
    - HW
    - SW: User level System Call
    - Exception
  - Kernel preempts current process
    - Potential scheduling decision at “any of above”
    - *+ “Timer” to be able to limit running time of processes*

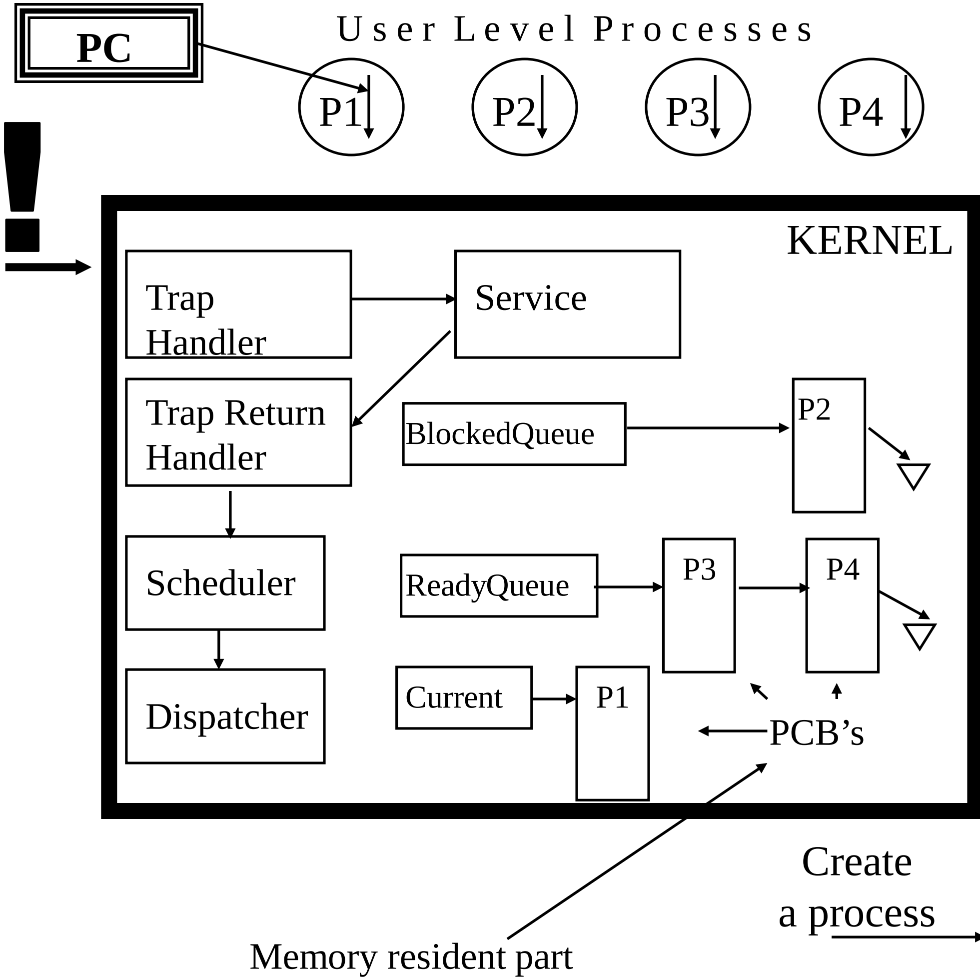
Non-Preemptive scheduling

Preemptive scheduling

Context Switching Issues

- Performance
  - Should be no more than a few microseconds
  - Most time is spent SAVING and RESTORING the context of processes
    - Less processor state to save, the better
      - Pentium has a multitasking mechanism, but SW can be faster if it saves less of the state
    - How to save time on the copying of context state?
      - Re-map (address) instead of copy (data)
- Where to store Kernel data structures “shared” by all processes
    - Memory
- How to give processes a fair share of CPU time
    - Preemptive scheduling, time-slice defines maximum time interval between scheduling decisions

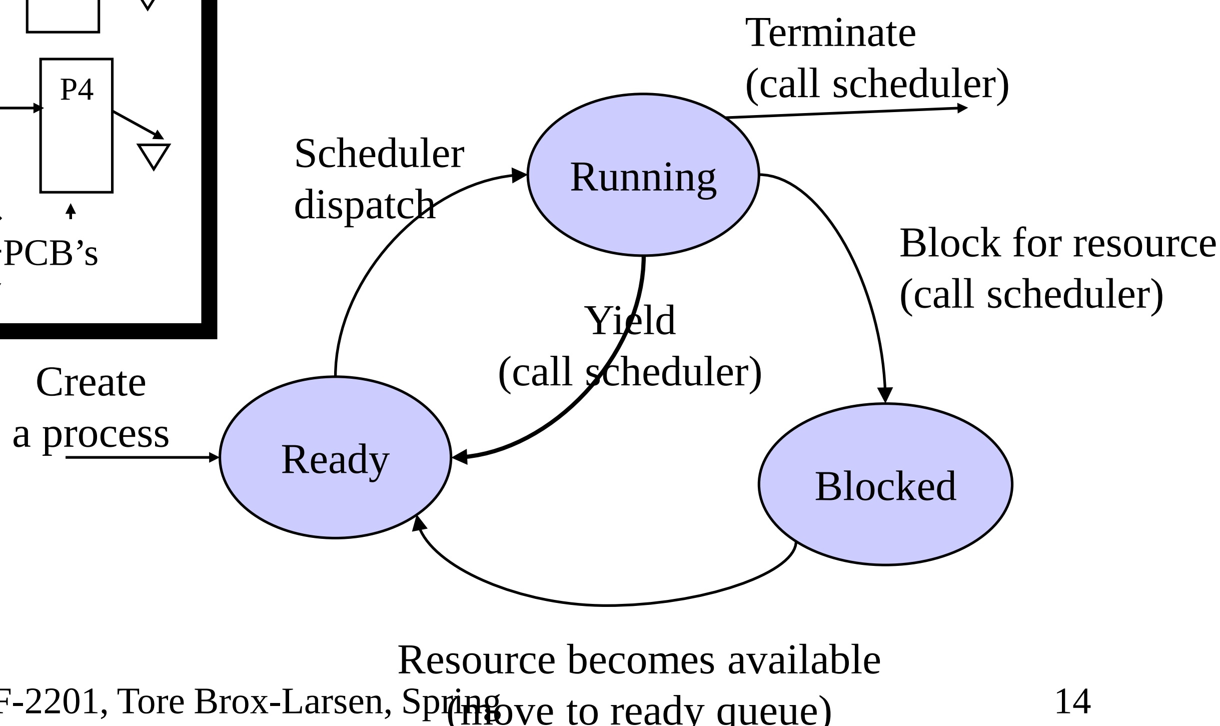
Example Process State Transitions



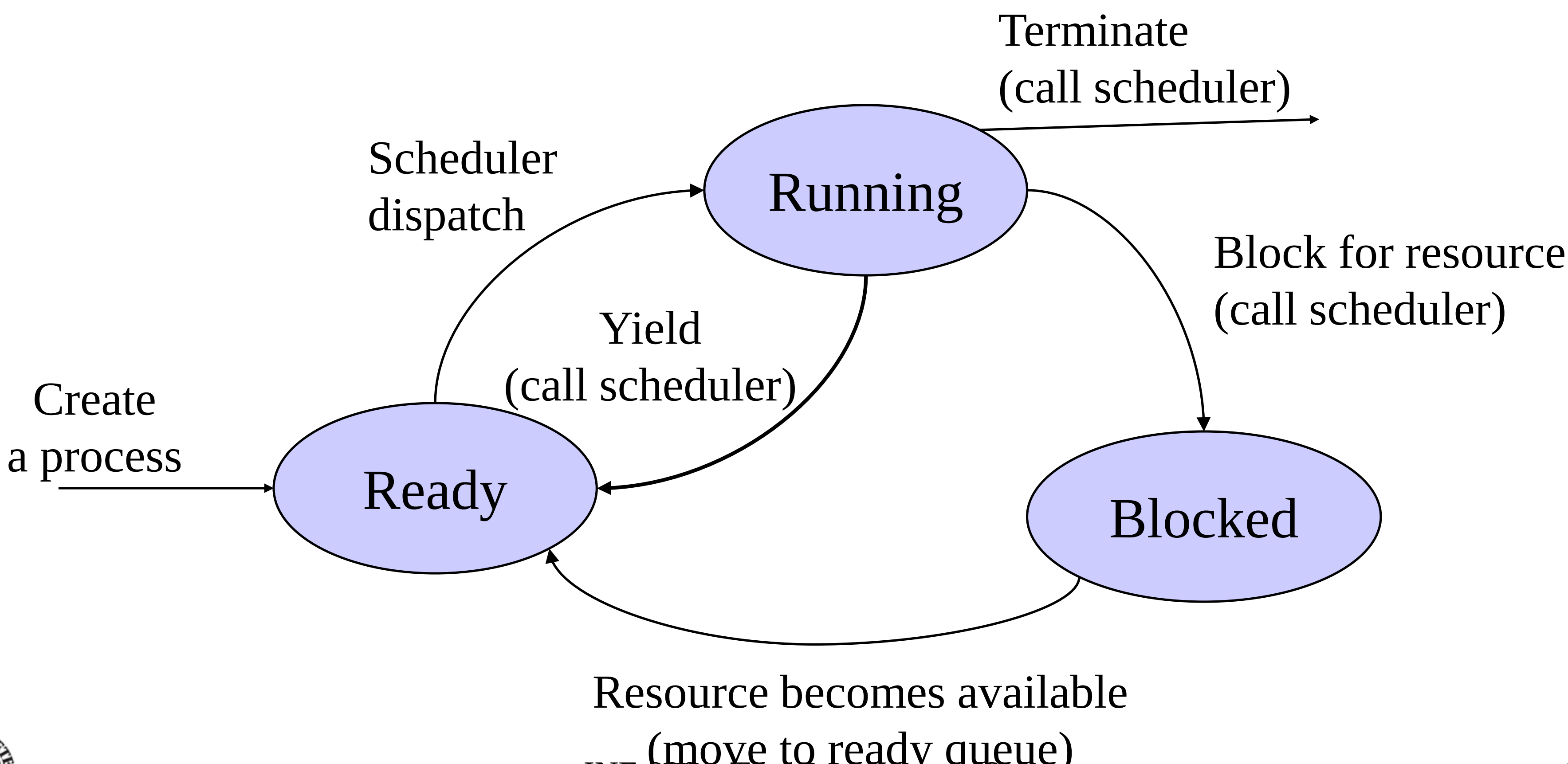
MULTIPROGRAMMING

•Uniprocessor: *Interleaving* ("pseudoparallelism")

•Multiprocessor: *Overlapping* ("true paralellism")



Process State Transition of Non-Preemptive Scheduling



Scheduler

- Non-preemptive scheduler invoked by explicit block or yield calls, possibly also fork and exit
- The simplest form

  Scheduler:

  > **save current process state (store to PCB)**
  >
  > **choose next process to run**
  >
  > **dispatch (load PCB and run)**

- Does this work?
  - **`PCB (something) must be resident in memory`**
  - **`Remember the stacks`**

Stacks

- Remember: *We have only one copy of the Kernel in memory*

  => all processes "execute" the same kernel code

  => Must have a kernel stack for each process
- Used for storing parameters, return address, locally created variables in *frames* or *activation records*
- Each process
  - user stack
  - kernel stack
    - always empty when process is in user mode executing instructions
- Does the Kernel need its own stack(s)?

More on Scheduler

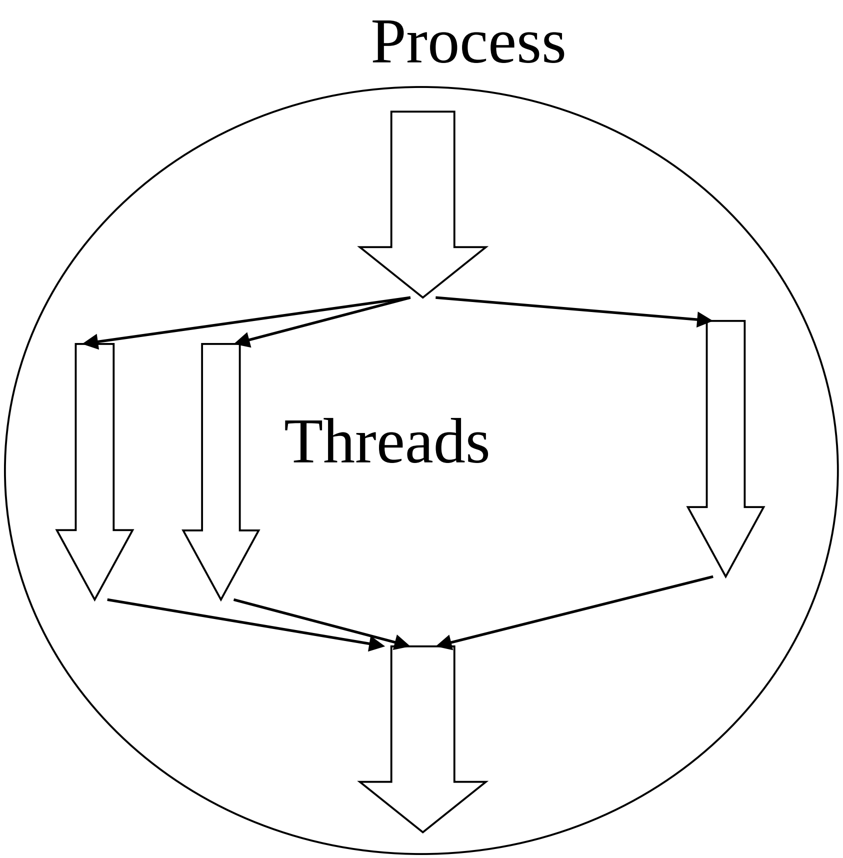
- Should the scheduler use a special stack?
  - Yes,
    - because a user process can overflow and it would require another stack to deal with stack overflow
    - because it makes it simpler to pop and push to rebuild a process's context
    - Must have a stack when booting...
- Should the scheduler simply be a "kernel process"?
  - You can view it that way because it has a stack, code and its data structure
  - This process always runs when there is no user process
    - "Idle" process
      - In kernel or at user level?

Win NT Idle

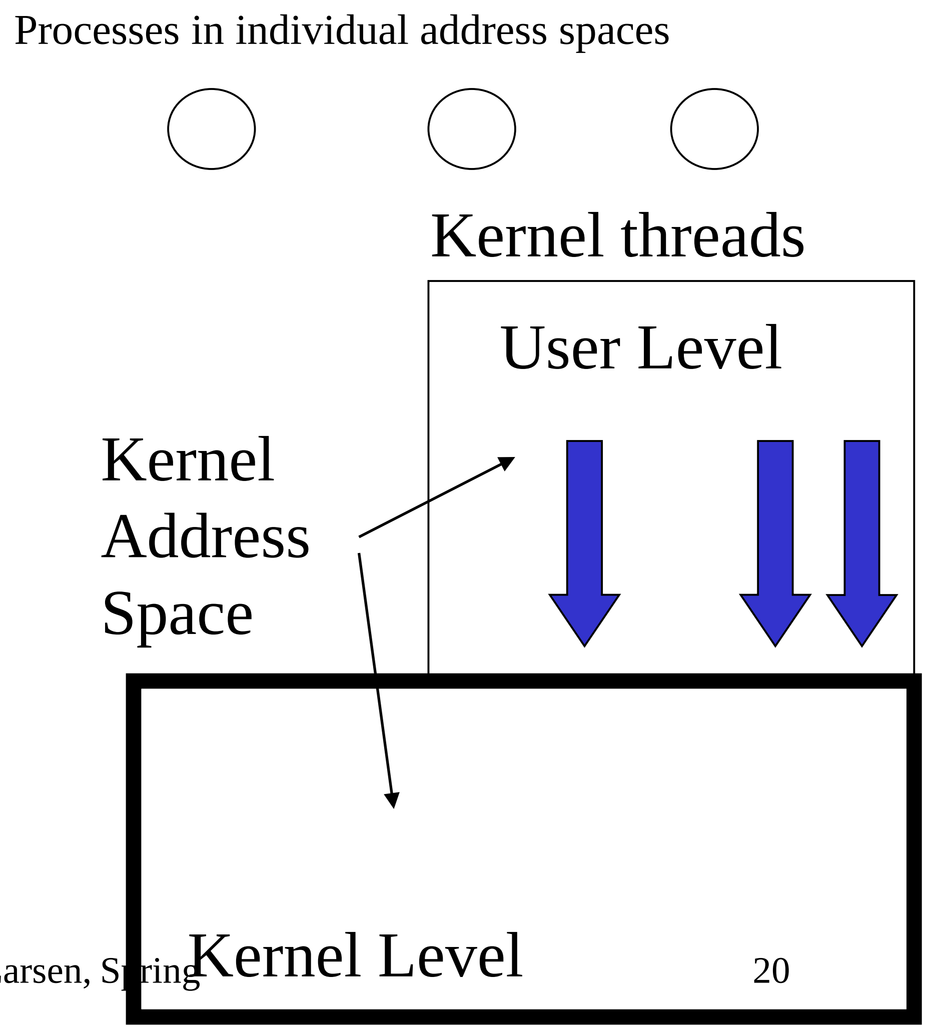
- No runable thread exists on the processor
  - Dispatch Idle Process (really a *thread*)
- Idle is really a dispatcher *in the kernel*
  - Enable interrupt; Receive pending interrupts; Disable interrupts;
  - Analyze interrupts; Dispatch a thread if so needed;
  - Check for deferred work; Dispatch thread if so needed;
  - Perform power management;

Threads and Processes

Trad. Threads



Project OpSys



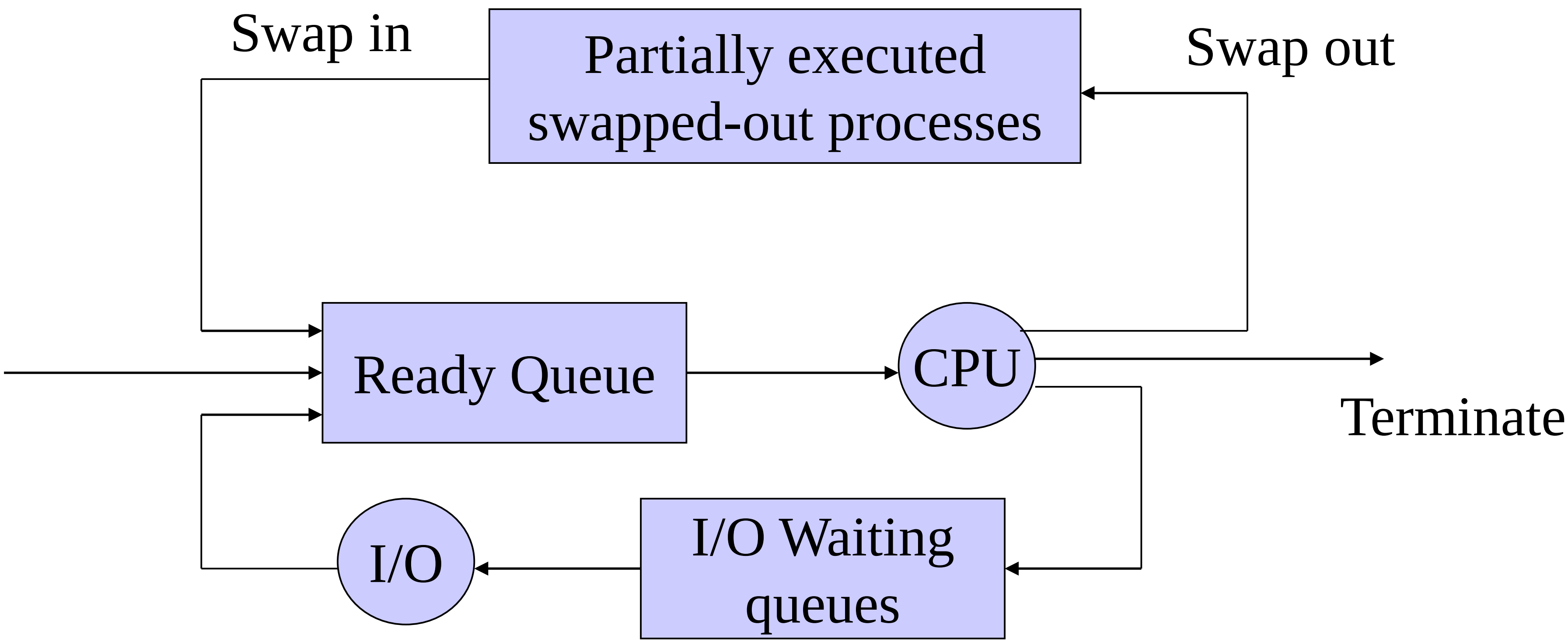
Where Should PCB Be Saved?

- Save the PCB on user stack
  - Many processors have a special instruction to do it efficiently
  - But, need to deal with the overflow problem
  - When the process terminates, the PCB vanishes
- Save the PCB on the kernel heap data structure
  - May not be as efficient as saving it on stack
  - But, it is very flexible and no other problems

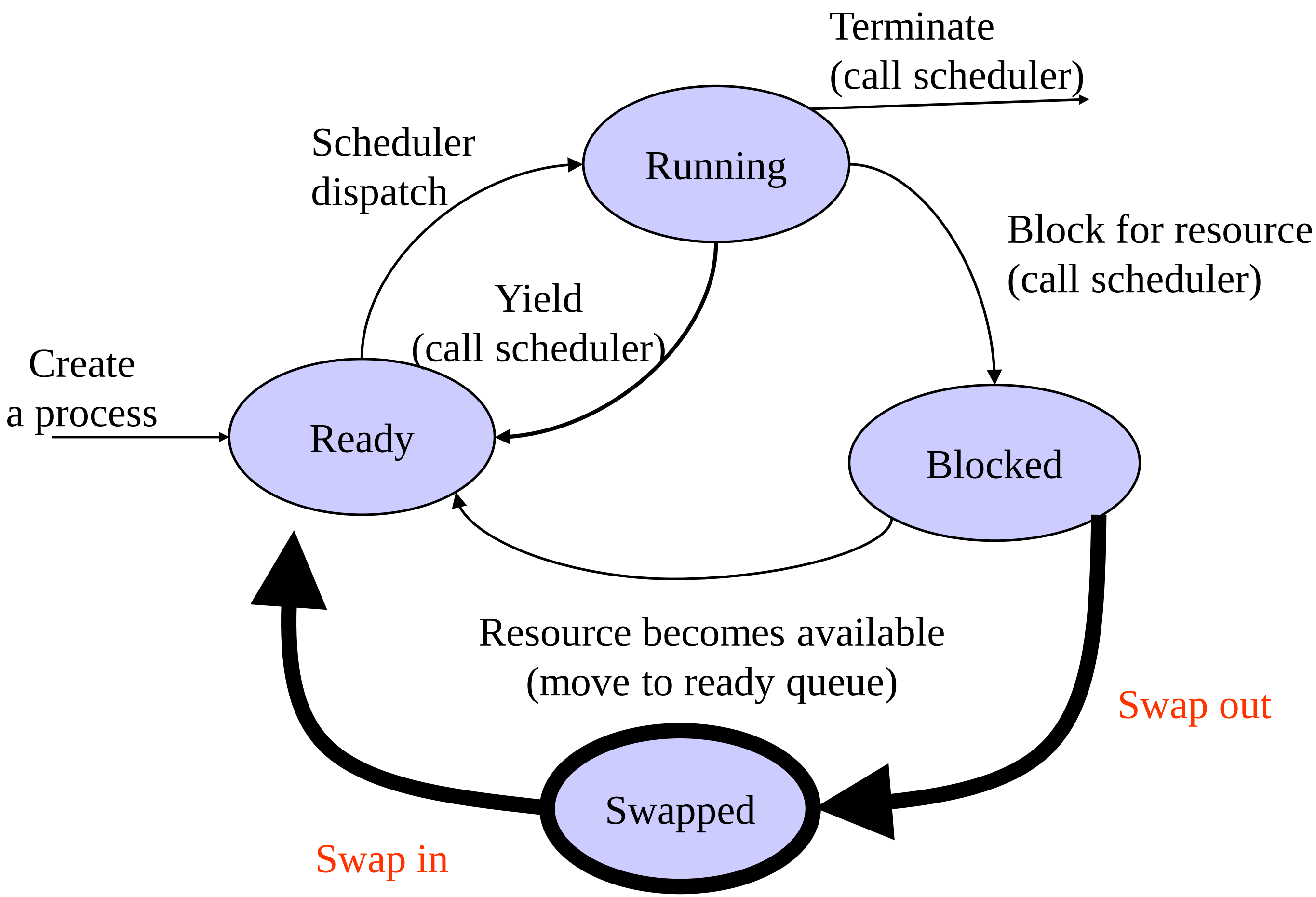
Job swapping

- The processes competing for resources may have combined demands that results in poor system performance
- Reducing the degree of multiprogramming by moving some processes to disk, and temporarily not consider them for execution may be a strategy to enhance overall system performance
  - From which states(s), to which state(s)? *Try extending the following examples using two suspended states.*
- Check&relate: MOS 3e.: Ch. 2.1.7, 3.2.1 and 3.3

Job Swapping, ii



Add Job Swapping to State Transition Diagram



Concurrent Programming w/ Processes

- Clean programming model
  - File tables are shared
  - User address space is private
    - Processes are protected from each other
    - Sharing requires some sort of IPC (InterProcess Communication)
- Slower execution
  - Process switch, process control expensive
  - IPC expensive

I/O Multiplexing: More than one State Machine per Process

- `select` blocks for any of multiple specified I/O events
- Handle (one of the events) that unblocks `select`
  - Advance appropriate state machine
- Repeat
- See http://csapp.cs.cmu.edu/public/ch12-preview.pdf

Concurrent prog. w/ I/O Multiplexing

- Establishes several control flows (state machines) in one process
- Uses `select`
- Offers application programmer more control than process model
- Easy sharing of data among state machines
- More efficient (no process switch to switch between control flows in same process)
- Possibly trickier programming