

## Processes and Threads

## Learning Outcomes

- An understanding of fundamental concepts of processes and threads

## Major Requirements of an Operating System

- Interleave the execution of several processes to maximize processor utilization while providing reasonable response time
- Allocate resources to processes
- Support interprocess communication and user creation of processes

## Processes and Threads

- Processes:
  - Also called a task or job
  - Execution of an individual program
  - “Owner” of resources allocated for program execution
  - Encompasses one or more threads
- Threads:
  - Unit of execution
  - Can be traced
    - list the sequence of instructions that execute
  - Belongs to a process

Execution snapshot of three single-threaded processes (No Virtual Memory)

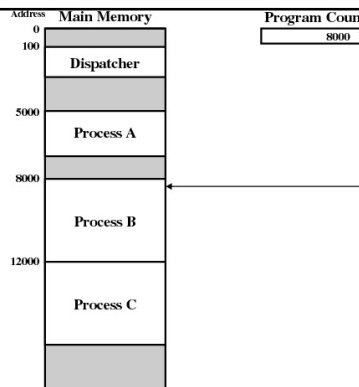


Figure 3.1 Snapshot of Example Execution (Figure 3.1 at Instruction Cycle 13)

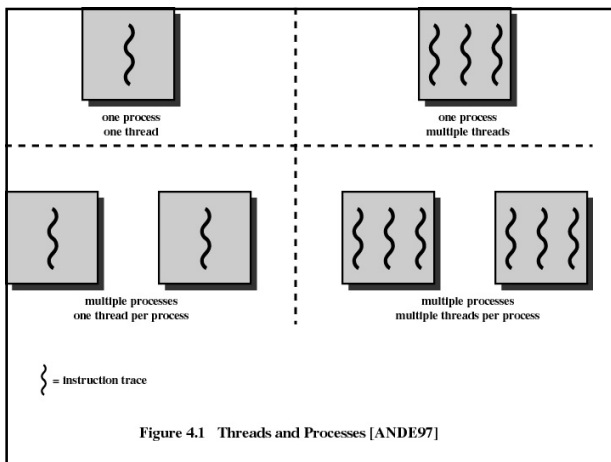
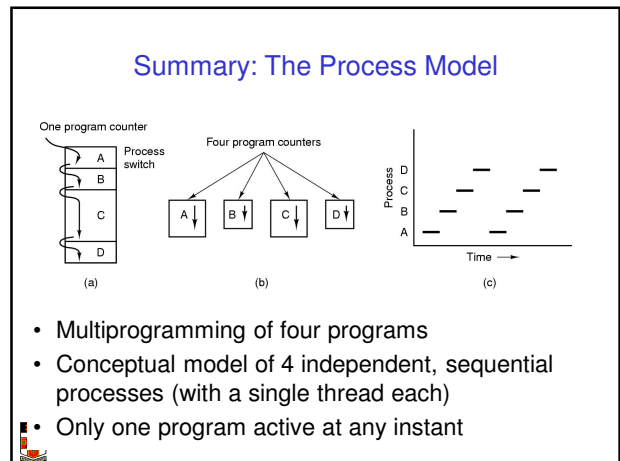
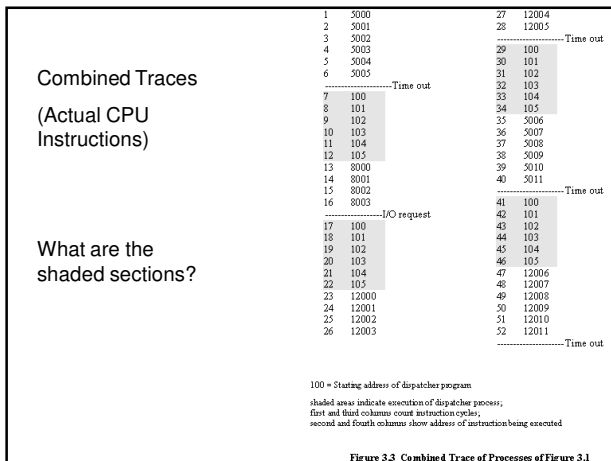
## Logical Execution Trace

5000	8000	12000
5001	8001	12001
5002	8002	12002
5003	8003	12003
5004		12004
5005		12005
5006		12006
5007		12007
5008		12008
5009		12009
5010		12010
5011		12011

(a) Trace of Process A      (b) Trace of Process B      (c) Trace of Process C

5000 = Starting address of program of Process A  
8000 = Starting address of program of Process B  
12000 = Starting address of program of Process C

Figure 3.2 Traces of Processes of Figure 3.1

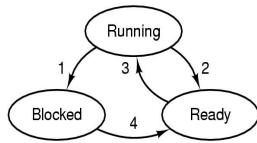


- ### Process and thread models of selected OSes
- Single process, single thread
    - MSDOS
  - Single process, multiple threads
    - OS/161 as distributed
  - Multiple processes, single thread
    - Traditional unix
  - Multiple processes, multiple threads
    - Modern Unix (Linux, Solaris), Windows
- Note: Literature (incl. Textbooks) often do not cleanly distinguish between processes and threads (for historical reasons)
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- ### Process Creation
- Principal events that cause process creation
1. System initialization
    - Foreground processes (interactive programs)
    - Background processes
      - Email server, web server, print server, etc.
      - Called a *daemon* (unix) or *service* (Windows)
  2. Execution of a process creation system call by a running process
    - New login shell for an incoming telnet/ssh connection
  3. User request to create a new process
  4. Initiation of a batch job
- Note: Technically, all these cases use the same system mechanism to create new processes.
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- ### Process Termination
- Conditions which terminate processes
1. Normal exit (voluntary)
  2. Error exit (voluntary)
  3. Fatal error (involuntary)
  4. Killed by another process (involuntary)
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## Process/Thread States



1. Process blocks for input
2. Scheduler picks another process
3. Scheduler picks this process
4. Input becomes available

- Possible process/thread states
  - running
  - blocked
  - ready
- Transitions between states shown

## Some Transition Causing Events

Running → Ready

- Voluntary `yield()`
- End of timeslice

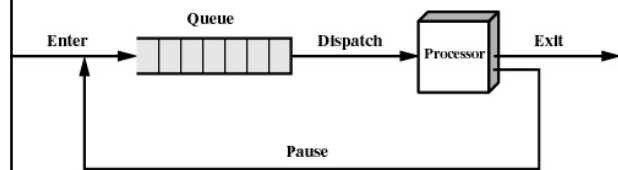
Running → Blocked

- Waiting for input
  - File, network,
- Waiting for a timer (alarm signal)
- Waiting for a resource to become available

## Dispatcher

- Sometimes also called the *scheduler*
  - The literature is also a little inconsistent on with terminology.
- Has to choose a *Ready* process to run
  - How?
  - It is inefficient to search through all processes

## The Ready Queue

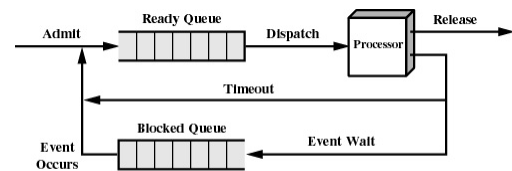


(b) Queuing diagram

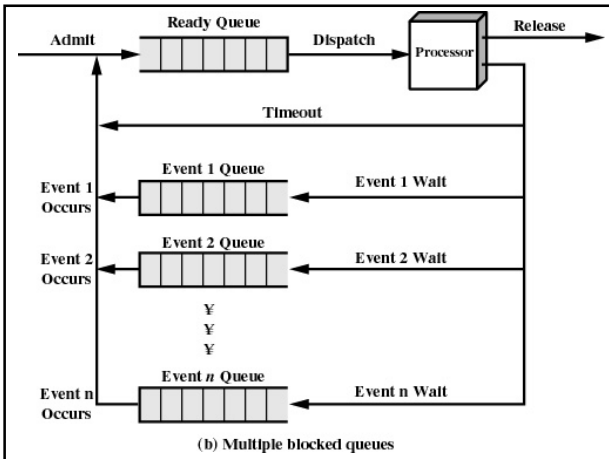
## What about blocked processes?

- When an *unblocking* event occurs, we also wish to avoid scanning all processes to select one to make *Ready*

## Using Two Queues



(a) Single blocked queue



## Implementation of Processes

- A processes' information is stored in a *process control block* (PCB)
- The PCBs form a *process table*
  - Sometimes the kernel stack for each process is in the PCB
  - Sometimes some process info is on the kernel stack
    - E.g. registers in the *trapframe* in OS/161
  - Reality is much more complex (hashing, chaining, allocation bitmaps,...)

P7
P6
P5
P4
P3
P2
P1
P0

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## Implementation of Processes

Process management	Memory management	File management
Registers Program counter Program status word Stack pointer Process state Priority Scheduling parameters Process ID Parent process Process group Signals Time when process started CPU time used Children's CPU time Time of next alarm	Pointer to text segment Pointer to data segment Pointer to stack segment	Root directory Working directory File descriptors User ID Group ID

Example fields of a process table entry

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## Threads

### The Thread Model

(a) Three processes each with one thread  
(b) One process with three threads

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## The Thread Model – Separating execution from the environment.

Per process items	Per thread items
Address space Global variables Open files Child processes Pending alarms Signals and signal handlers Accounting information	Program counter Registers Stack State

- Items shared by all threads in a process
- Items private to each thread

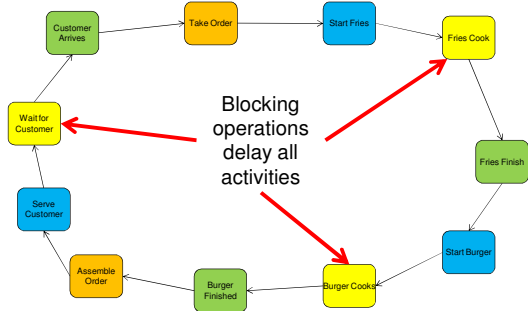
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## Threads Analogy

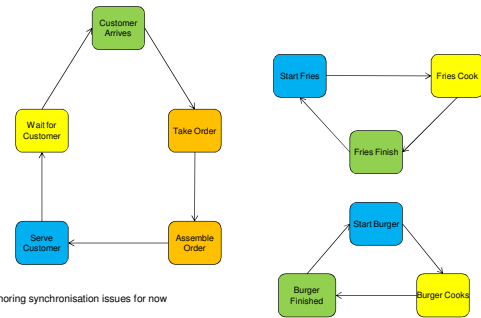
The Hamburger Restaurant

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## Single-Threaded Restaurant

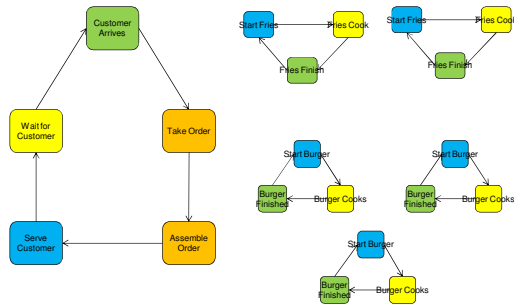


## Multithreaded Restaurant

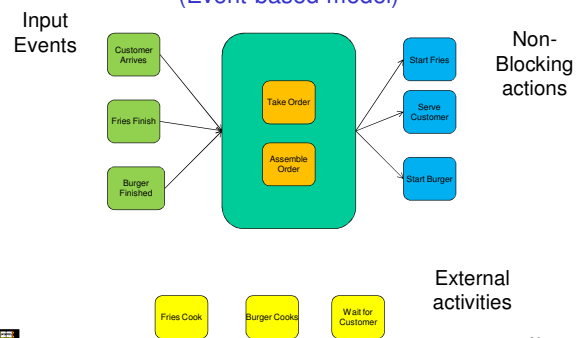


Note: Ignoring synchronisation issues for now

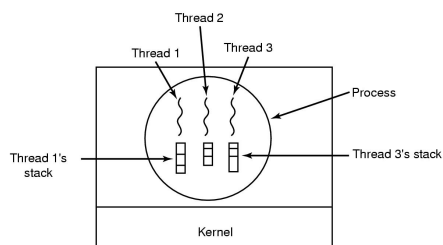
## Multithreaded Restaurant with more worker threads



## Finite-State Machine Model (Event-based model)



## The Thread Model



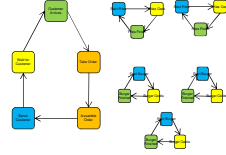
Each thread has its own stack

## Thread Model

- Local variables are per thread
  - Allocated on the stack
- Global variables are shared between all threads
  - Allocated in data section
  - Concurrency control is an issue
- Dynamically allocated memory (malloc) can be global or local
  - Program defined (the pointer can be global or local)

## Observation: Computation State

### Thread Model



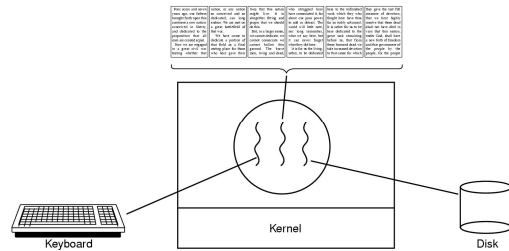
- State implicitly stored on the stack.

### Finite State (Event) Model



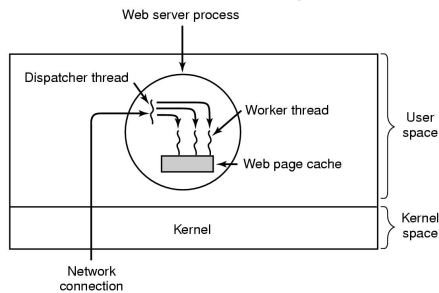
- State explicitly managed by program

## Thread Usage



A word processor with three threads

## Thread Usage



A multithreaded Web server

## Thread Usage

```

while (TRUE) {
    get_next_request(&buf);
    handoff_work(&buf);
}
(a)

while (TRUE) {
    wait_for_work(&buf)
    look_for_page_in_cache(&buf, &page);
    if (page_not_in_cache(&page))
        read_page_from_disk(&buf, &page);
    return_page(&page);
}
(b)
    
```

- Rough outline of code for previous slide
  - (a) Dispatcher thread
  - (b) Worker thread – can overlap disk I/O with execution of other threads

## Thread Usage

Model	Characteristics
Threads	Parallelism, blocking system calls
Single-threaded process	No parallelism, blocking system calls
Finite-state machine	Parallelism, nonblocking system calls, interrupts

Three ways to construct a server

## Summarising “Why Threads?”

- Simpler to program than a state machine
- Less resources are associated with them than a complete process
  - Cheaper to create and destroy
  - Shares resources (especially memory) between them
- Performance: Threads waiting for I/O can be overlapped with computing threads
  - Note if all threads are *compute bound*, then there is no performance improvement (on a uniprocessor)
- Threads can take advantage of the parallelism available on machines with more than one CPU (multiprocessor)