Chapter 4 Lectures

Stallings - 9ed

Process

- Two characteristics:
  - Resource ownership
    - process includes a virtual address space to hold the process image
  - Scheduling/execution
    - follows an execution path that may be interleaved with other processes
  - These two characteristics are treated independently by the OS

Process

- **process**
  - sometimes referred to as *task* or *job*
  - refers to resource of ownership
  - (addresses the 1st characteristic)
- **thread** or **lightweight process**
  - this is the unit of dispatching
  - (addresses the 2nd characteristic)

Multithreading

- Operating system supports multiple threads of execution within a single process
  - MS-DOS supports a single thread
  - UNIX supports multiple user processes but only supports one thread per process
  - Windows, Solaris, Linux, Mach, OS X, and OS/2 support multiple threads
    - e.g. OS X 10.6 (snow leopard) offers POSIX threads (or pthreads, POSIX 1003.1c standard), and Cocoa threads

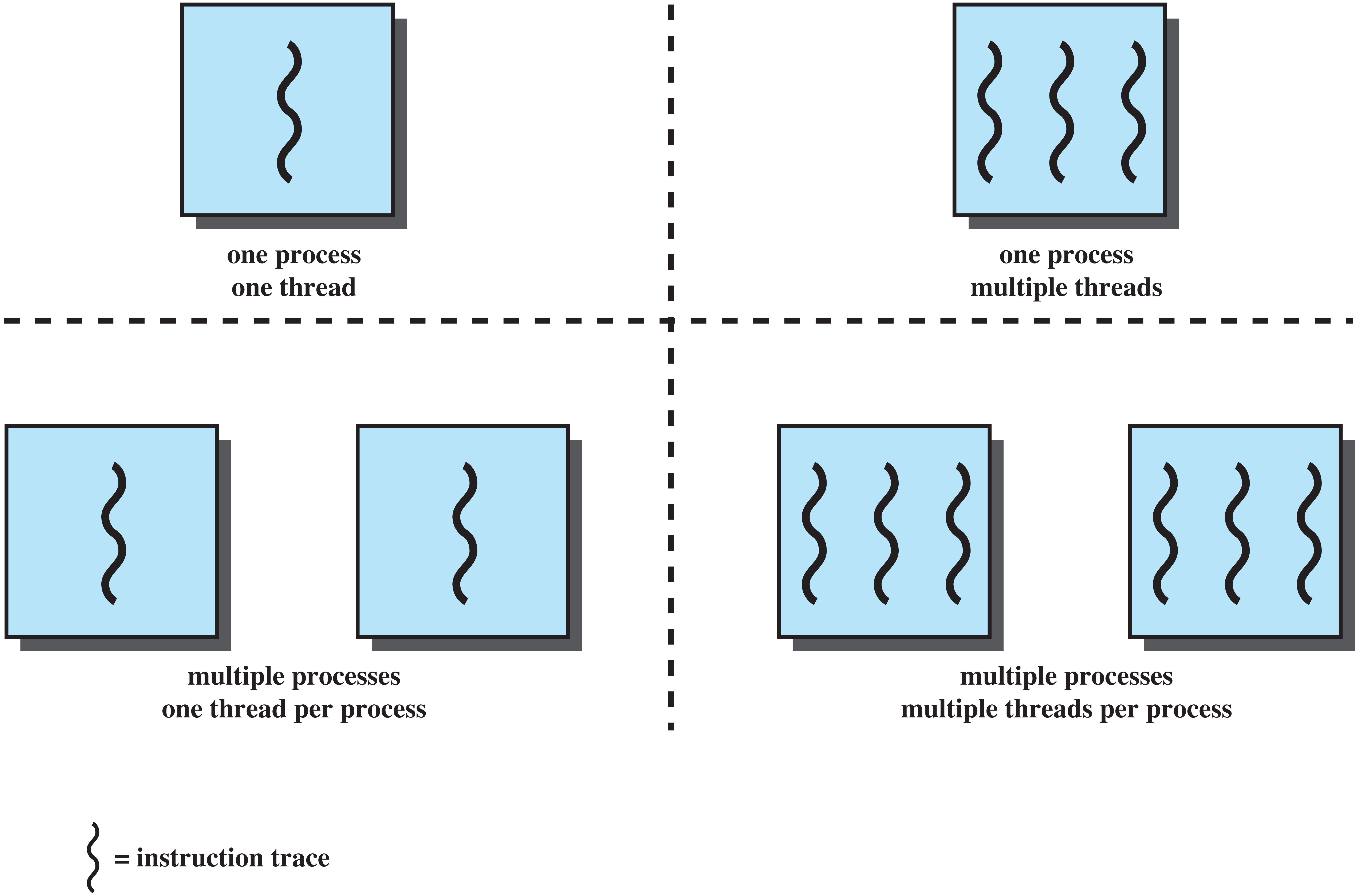


Figure 4.1 Threads and Processes

Process

- In multithreaded environment a **process** is the unit of resource allocation and a unit of protection
- Processes
  - Have a virtual address space which holds the process image
  - Protected access to processors, other processes, files, and I/O resources

Thread

- Within a process there are one or more threads, each with the following:
  - an execution state (running, ready, etc.)
  - a saved thread context when not running
    - may view a thread as an independent program counter operating within a process
  - an execution stack
  - some per-thread static storage for local variables
  - access to the memory & resources of its process
    - all threads of a process share this

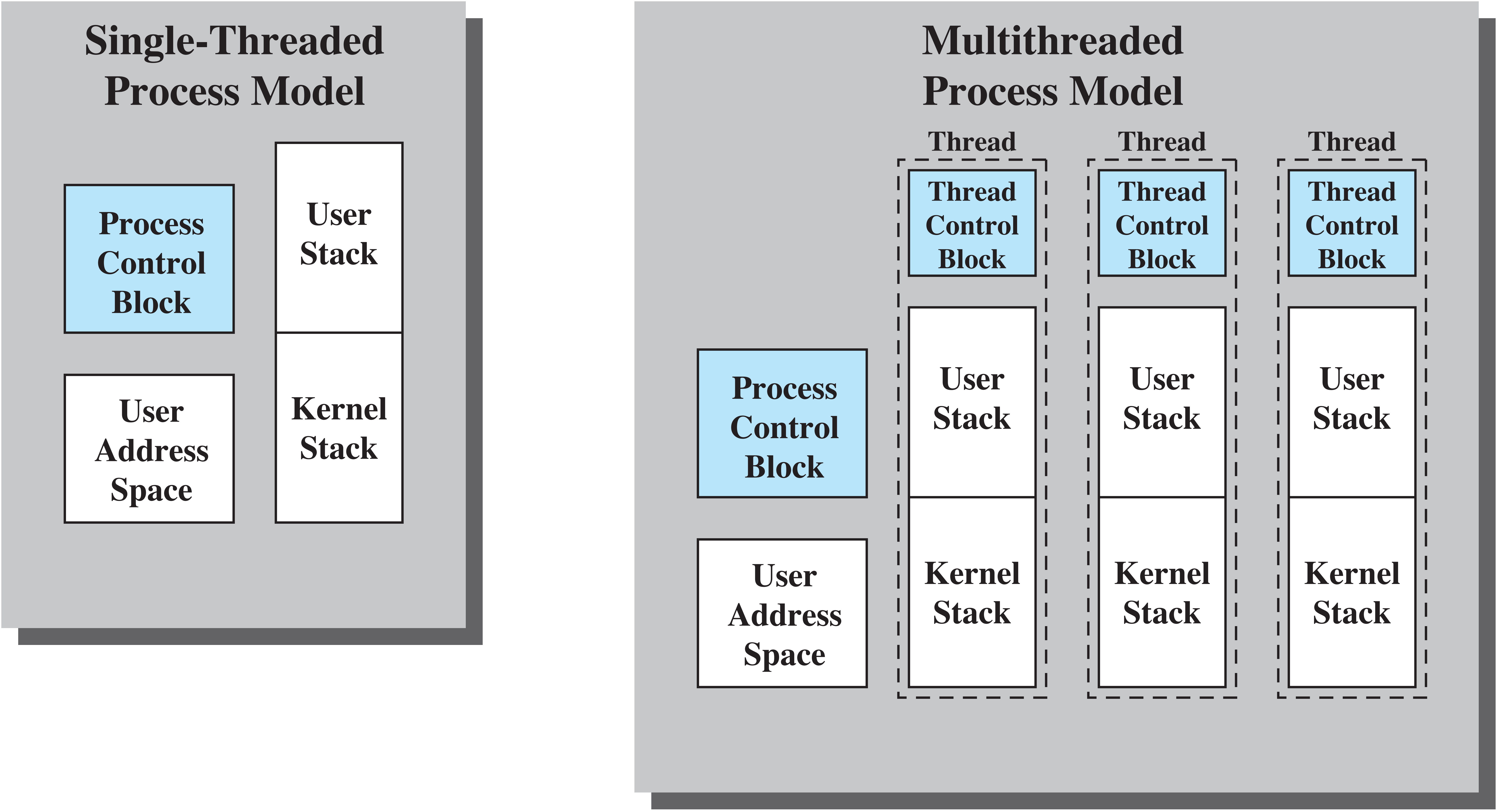


Figure 4.2 Single Threaded and Multithreaded Process Models

Benefits of Threads

- Takes less time to create a new thread than a process
- Less time to terminate a thread than a process
- Less time to switch between two threads within the same process
- Since threads within the same process share memory and files, they can communicate with each other without invoking the kernel

Threads in a Single-User Multiprocessing System

- Foreground to background work
  - e.g. spreadsheet, multiple threads display menues, read user input, update spreadsheet etc.
- Asynchronous processing
  - e.g. thead in word processor to periodically flush RAM to disk

Threads in a Single-User Multiprocessing System

- Speed of execution
  - e.g. a process may compute one batch of data while reading in the next.
  - in multiprocessor: true parallel execution of threads in a process
- Modular program structure
  - thread model can be used to "group" activities of process

Threads

- Suspending a process
  - suspends all threads of the process since all threads share the same address space
- Termination of a process
  - terminates all threads within the process

Thread States

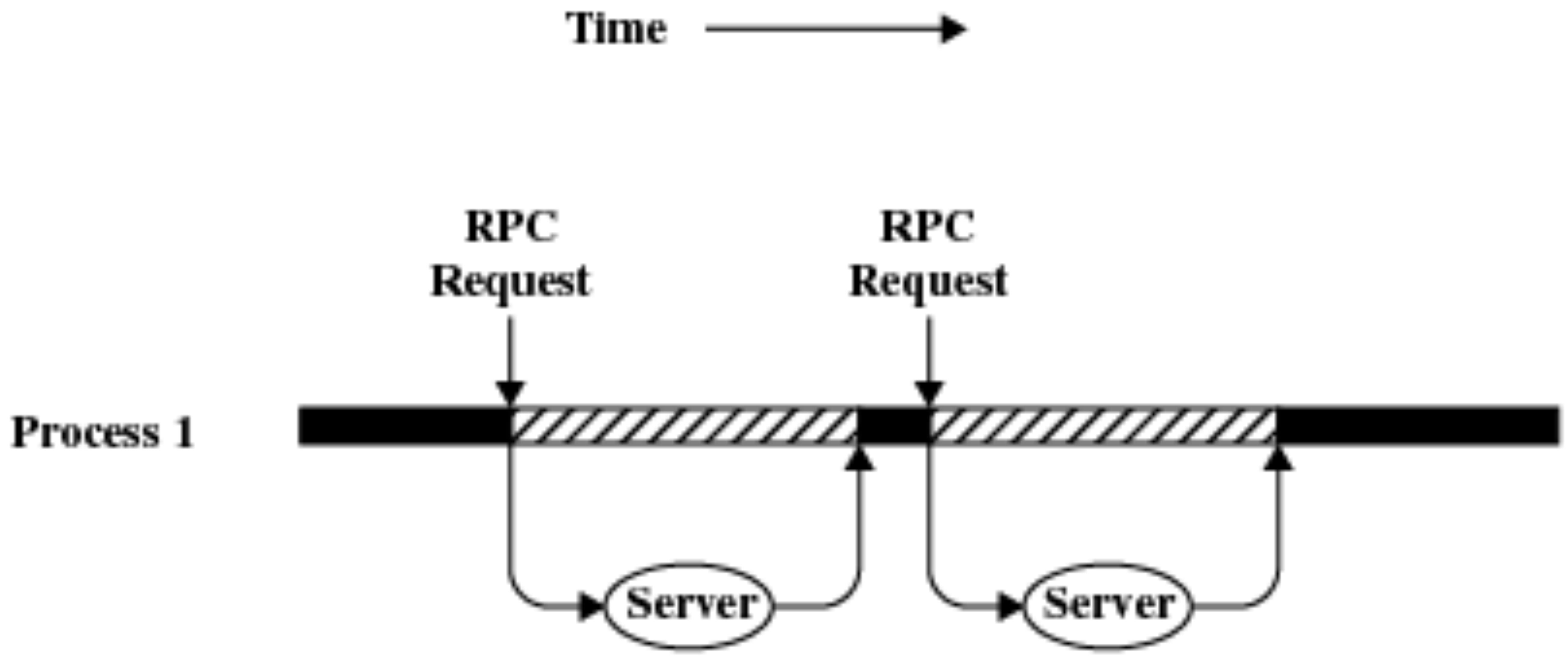
- States of a thread
  - Spawn
    - when process is spawned
    - thread may spawn other threads
    - each thread has its own:
      - register context, state space, and place in ready queue
  - Block
    - when thread waits for event
      - saves user registers, PC and stack pointer

Thread States

- States of a thread
  - Unblock
    - when blocking event occurs
    - thread is moved to ready queue
  - Finish
    - register context and stack is deallocated

Remote Procedure Call Using Single Thread

What is a RPC?



(a) RPC Using Single Thread

Remote Procedure Call Using Threads

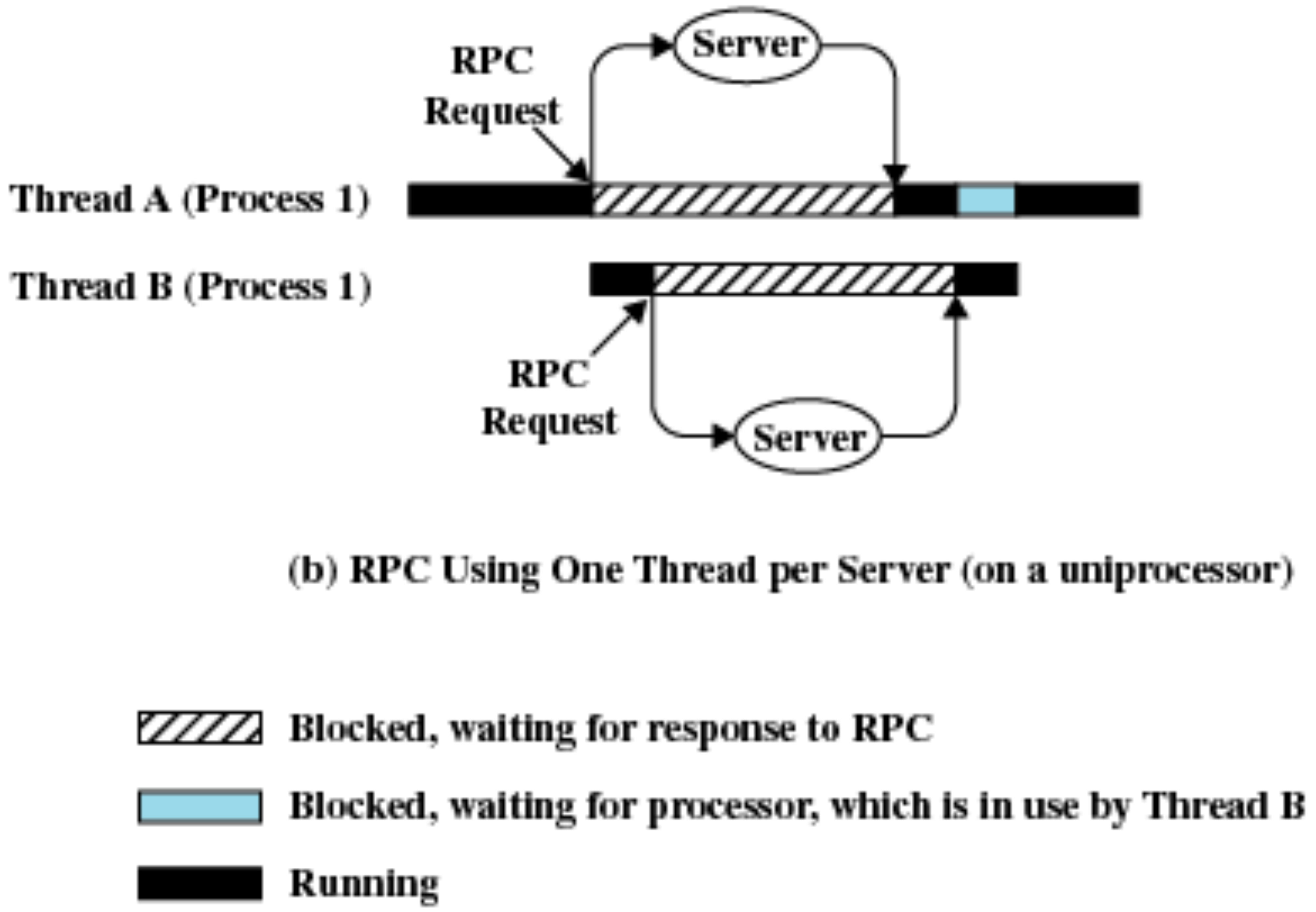


Figure 4.3 Remote Procedure Call (RPC) Using Threads

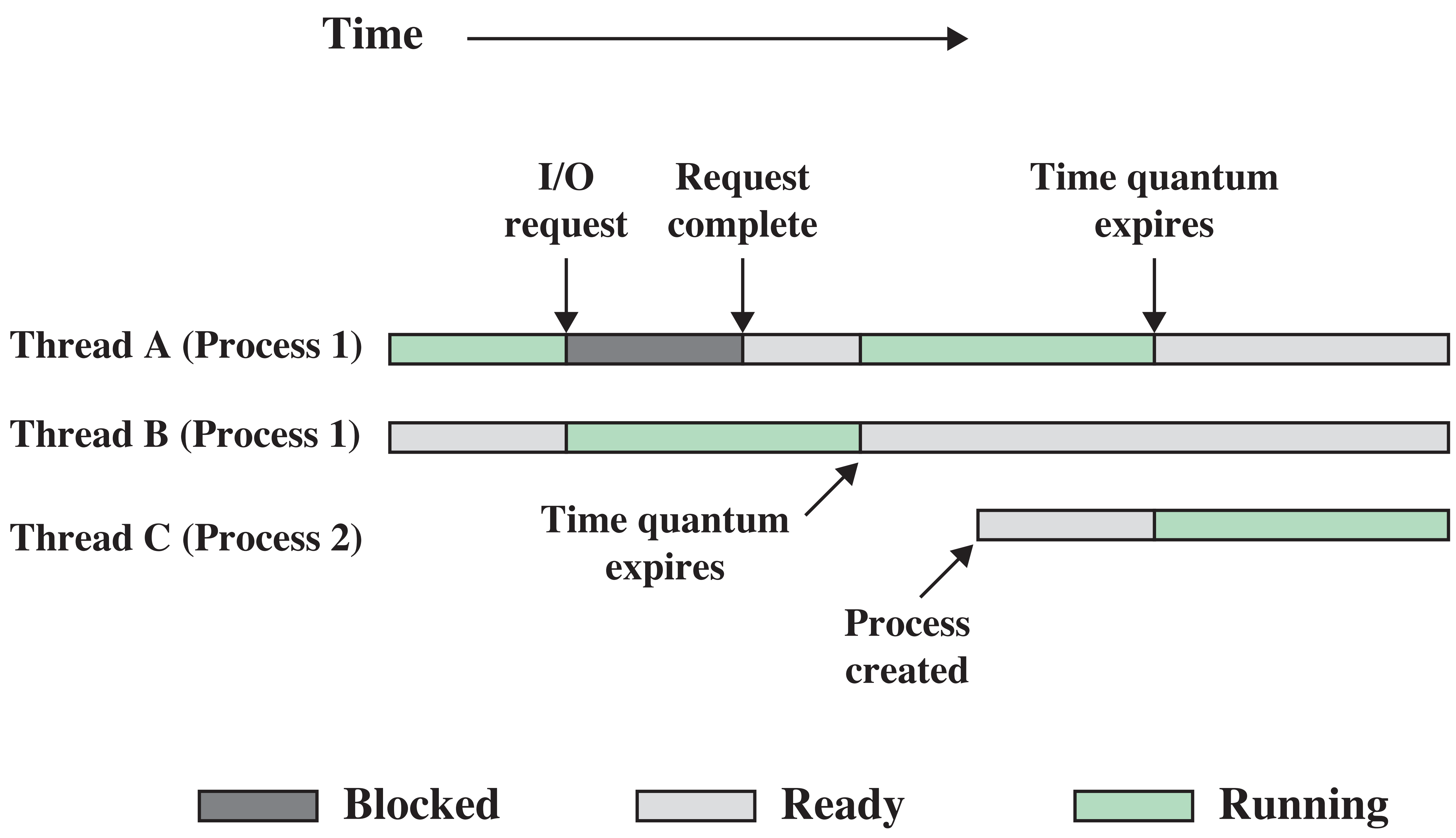


Figure 4.4 Multithreading Example on a Uniprocessor

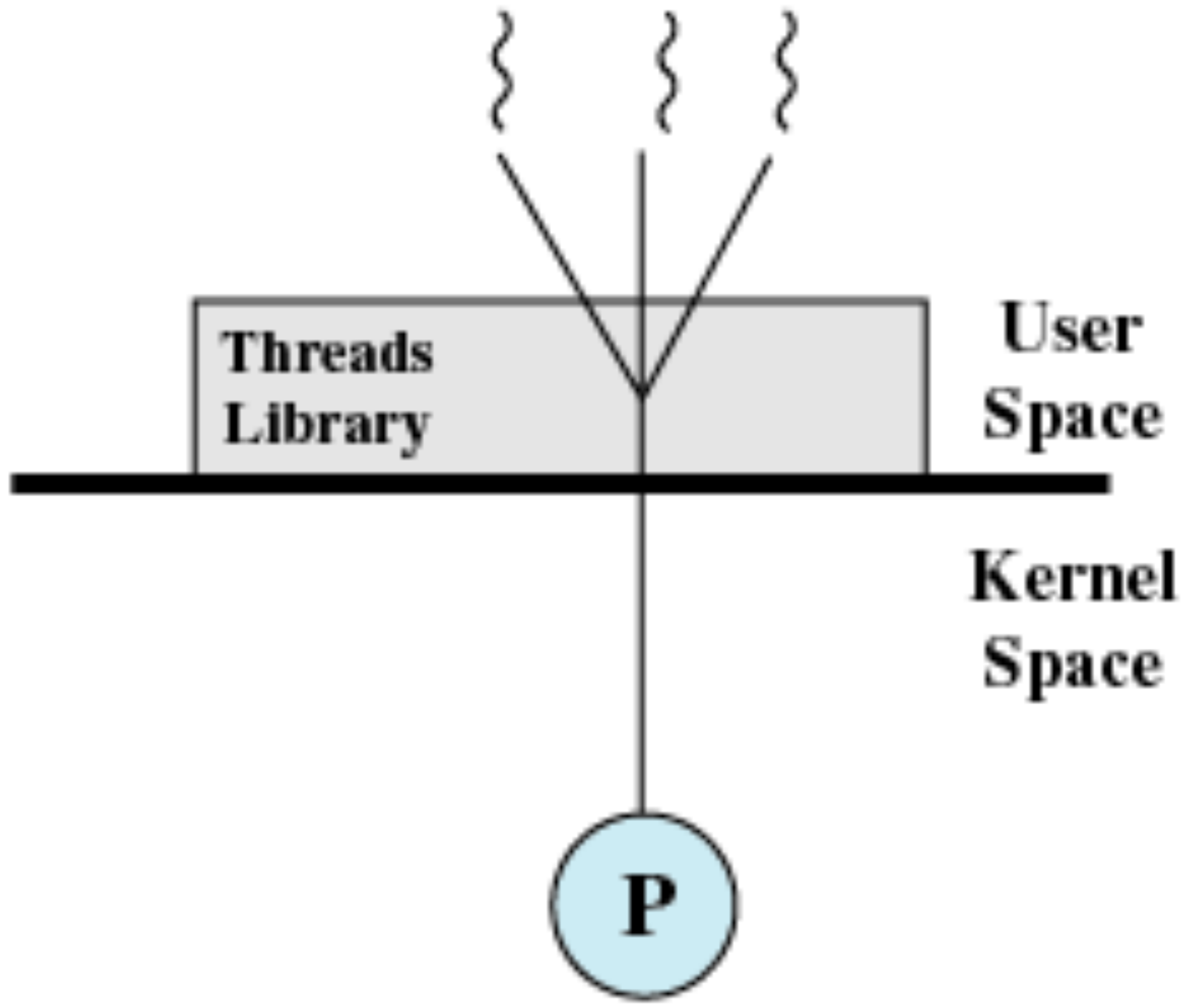
Basic questions

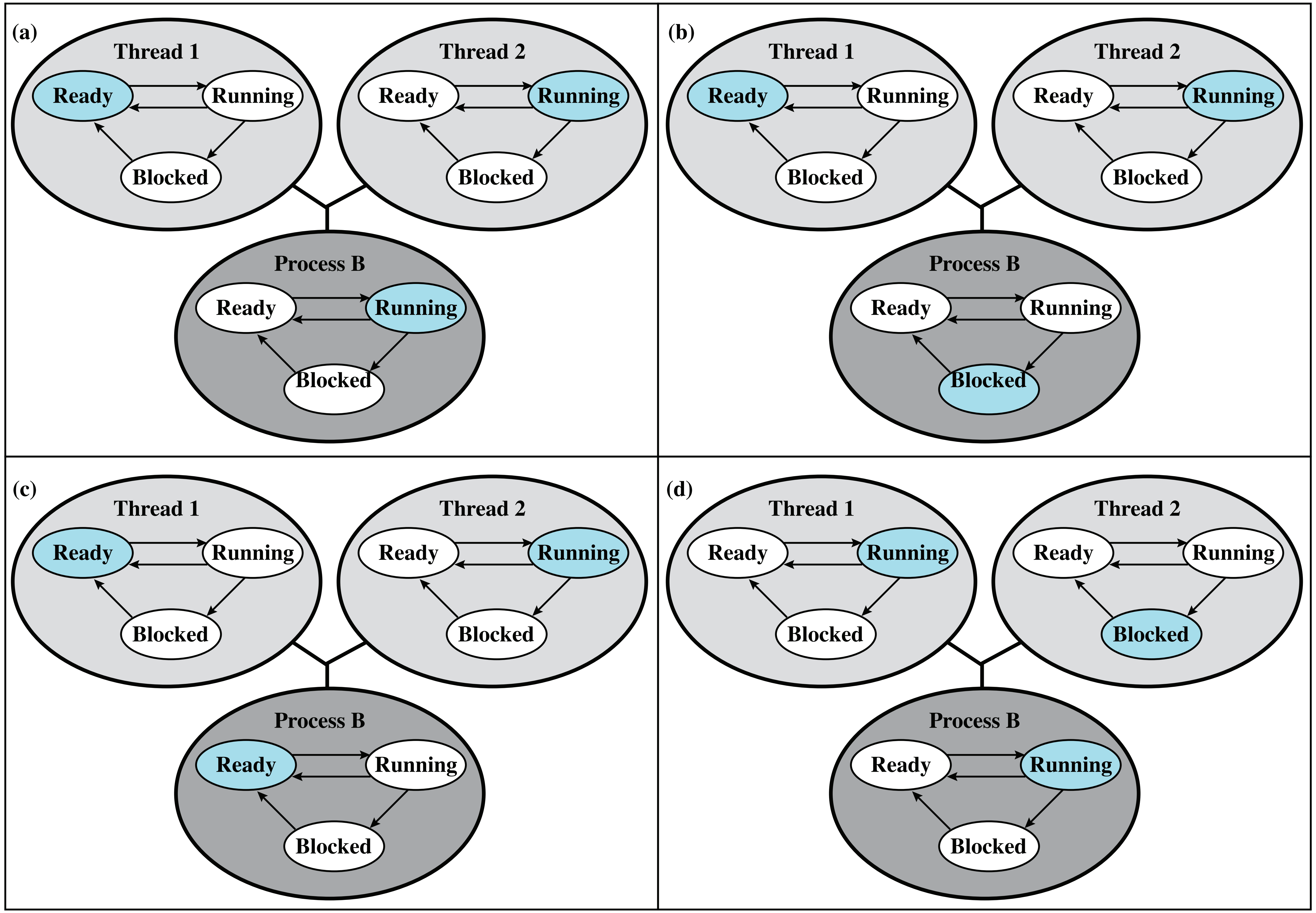
- What is the difference between this and multiprocessing?
  - kind of looks the same, or...?
- Is there a need to synchronize threads?
  - e.g. two threads insert an element into a linked structure

User-Level Threads (ULT)

- All thread management is done by the application
  - e.g. using threads library
- The kernel is not aware of the existence of threads

User-Level Threads





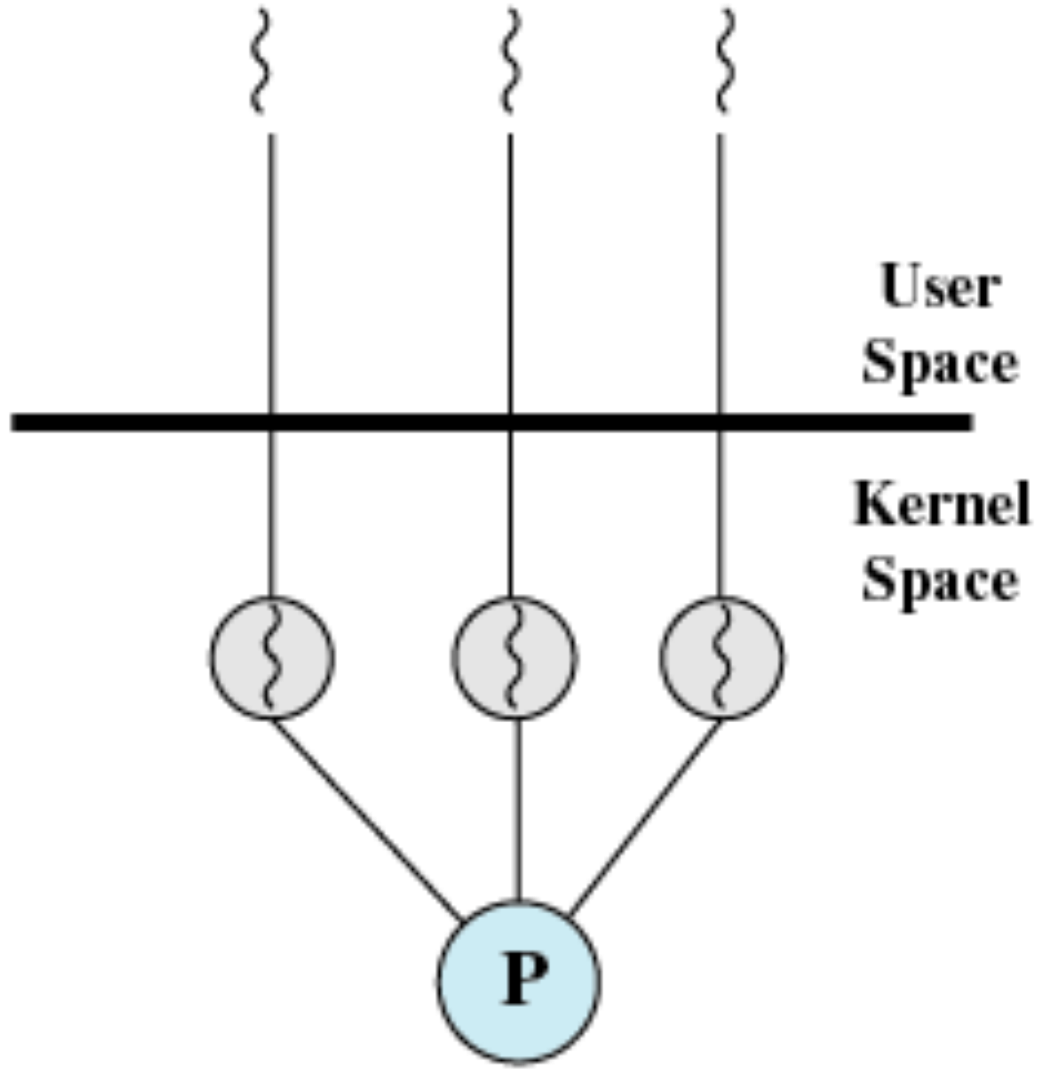
Colored state
is current state

Figure 4.6 Examples of the Relationships Between User-Level Thread States and Process States

Kernel-Level Threads (KLT)

- Often called *lightweight processes*
- Windows is an example of this approach
- Kernel maintains context information for the process and the threads
- Scheduling is done on a thread basis

Kernel-Level Threads



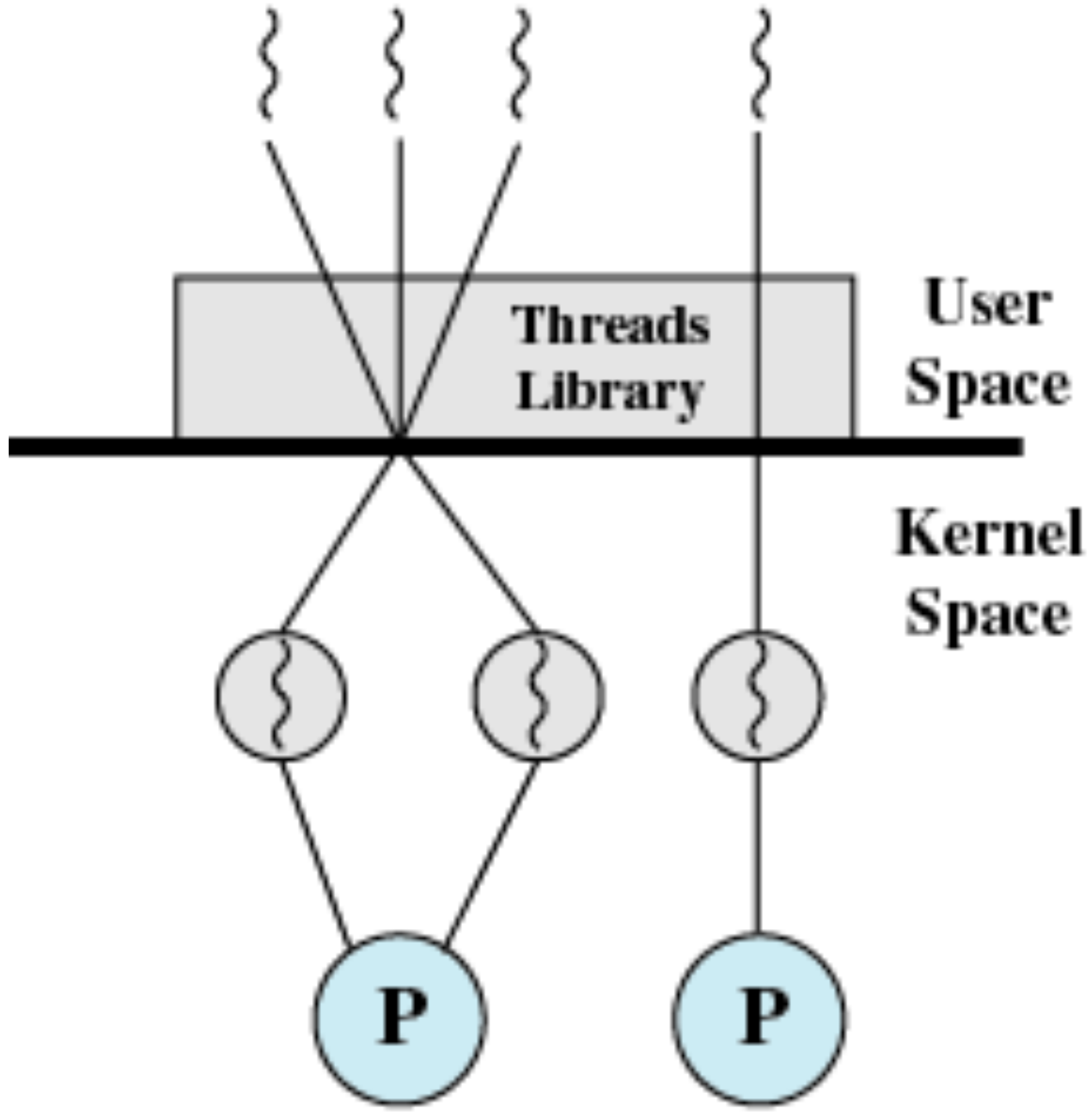
(b) Pure kernel-level

Combined Approaches

- Thread creation is done in user space
- Bulk of scheduling and synchronization of threads done within application

- Example is Solaris

Combined Approaches



(c) Combined

Relationship Between Threads and Processes

Table 4.2 Relationship Between Threads and Processes

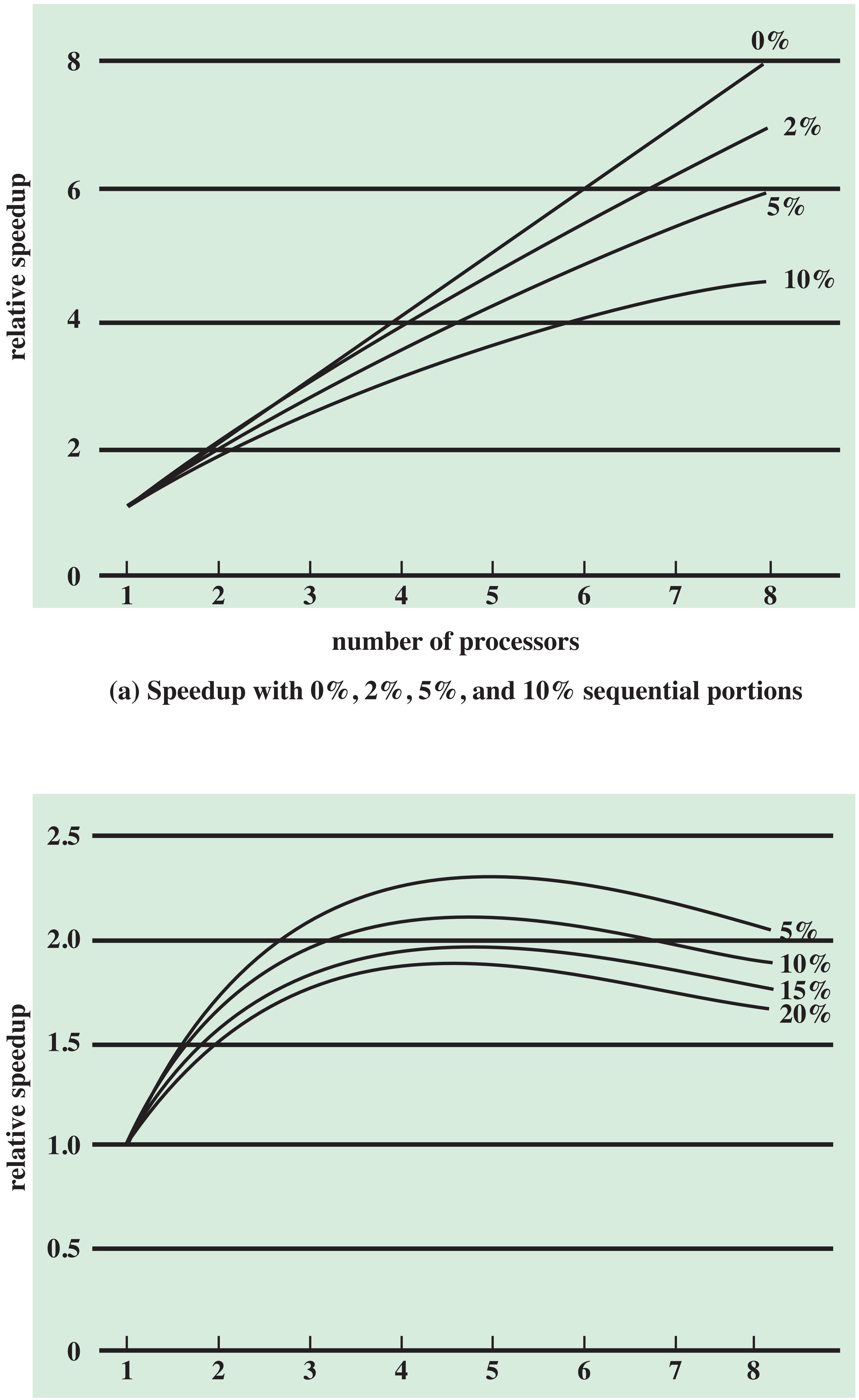
Threads:Processes	Description	Example Systems
1:1	Each thread of execution is a unique process with its own address space and resources.	Traditional UNIX implementations
M:1	A process defines an address space and dynamic resource ownership. Multiple threads may be created and executed within that process.	Windows NT, Solaris, Linux OS/2, OS/390, MACH
1:M	A thread may migrate from one process environment to another. This allows a thread to be easily moved among distinct systems.	Ra (Clouds), Emerald
M:N	Combines attributes of M:1 and 1:M cases.	TRIX

Advantages of ULT over KLT

- thread switching does not require kernel mode privileges
  - saves two mode switches (user-to-kernel and kernel-to-user)
- application specific scheduling
  - applications may prefer their own specific scheduling algorithm
- ULT can run on any OS

Disadvant. of ULT vs KLT

- Many OS system calls are blocking.
  - so if ULT executes such call all threads within its process are blocked
- In pure ULT strategy a multithreaded application cannot take advantage of multiprocessing
  - no concurrency



number of processors

(a) Speedup with 0%, 2%, 5%, and 10% sequential portions

number of processors

(b) Speedup with overheads

Figure 4.7 Performance Effect of Multiple Cores

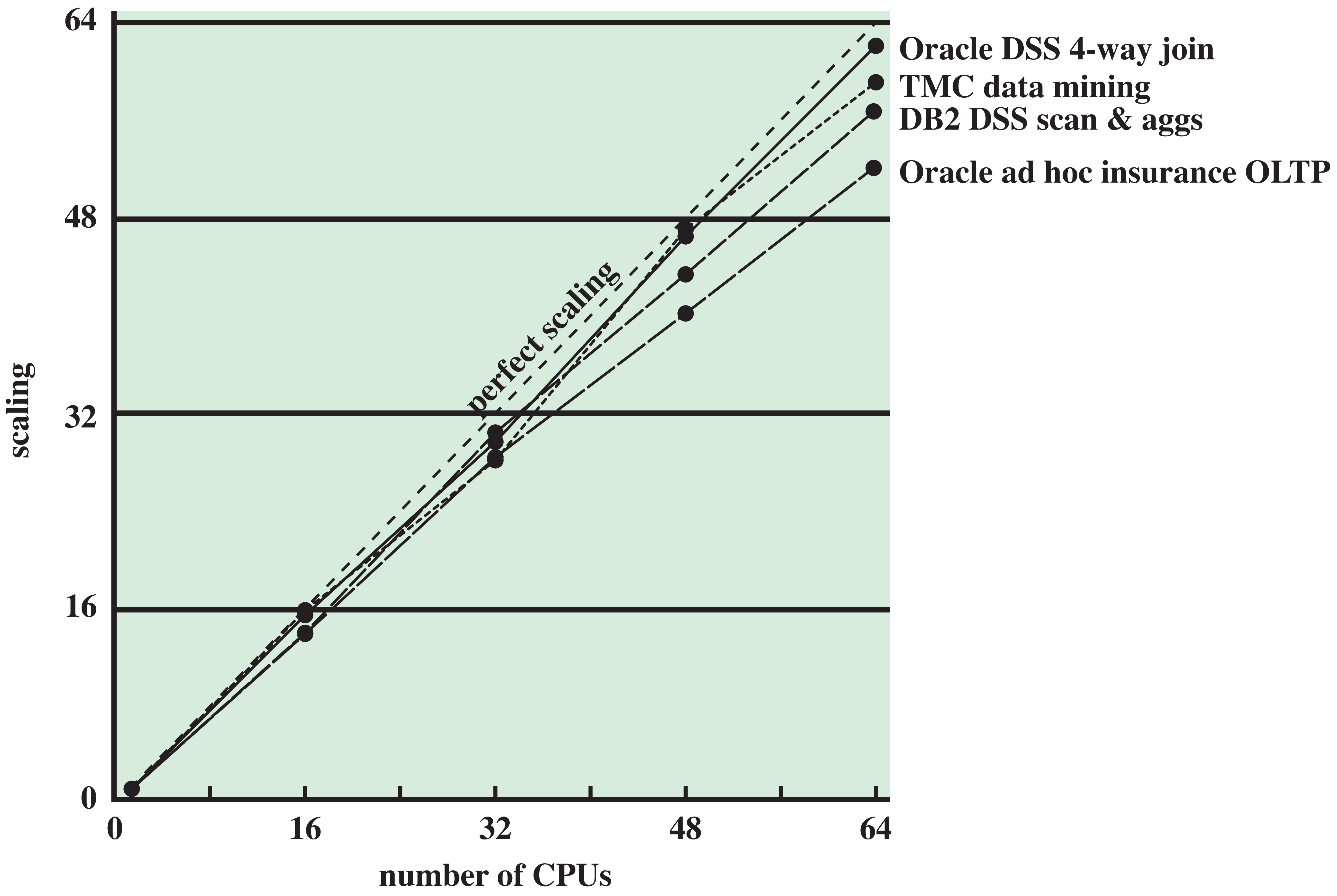


Figure 4.8 Scaling of Database Workloads on Multiple-Processor Hardware

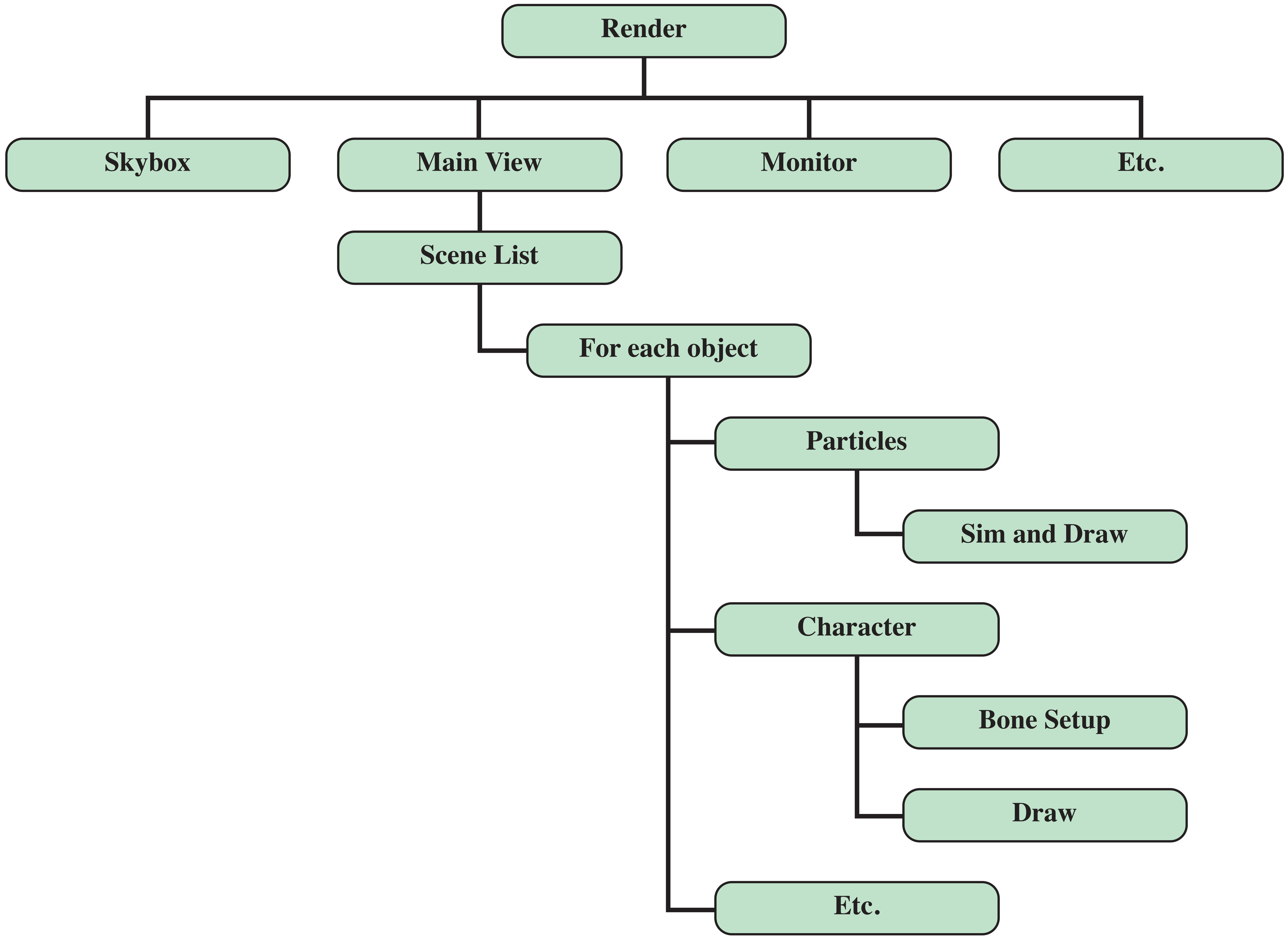


Figure 4.9 Hybrid Threading for Rendering Module

Windows Processes

- Implemented as objects
- An executable process may contain one or more threads
- Both processes and thread objects have built-in synchronization capabilities

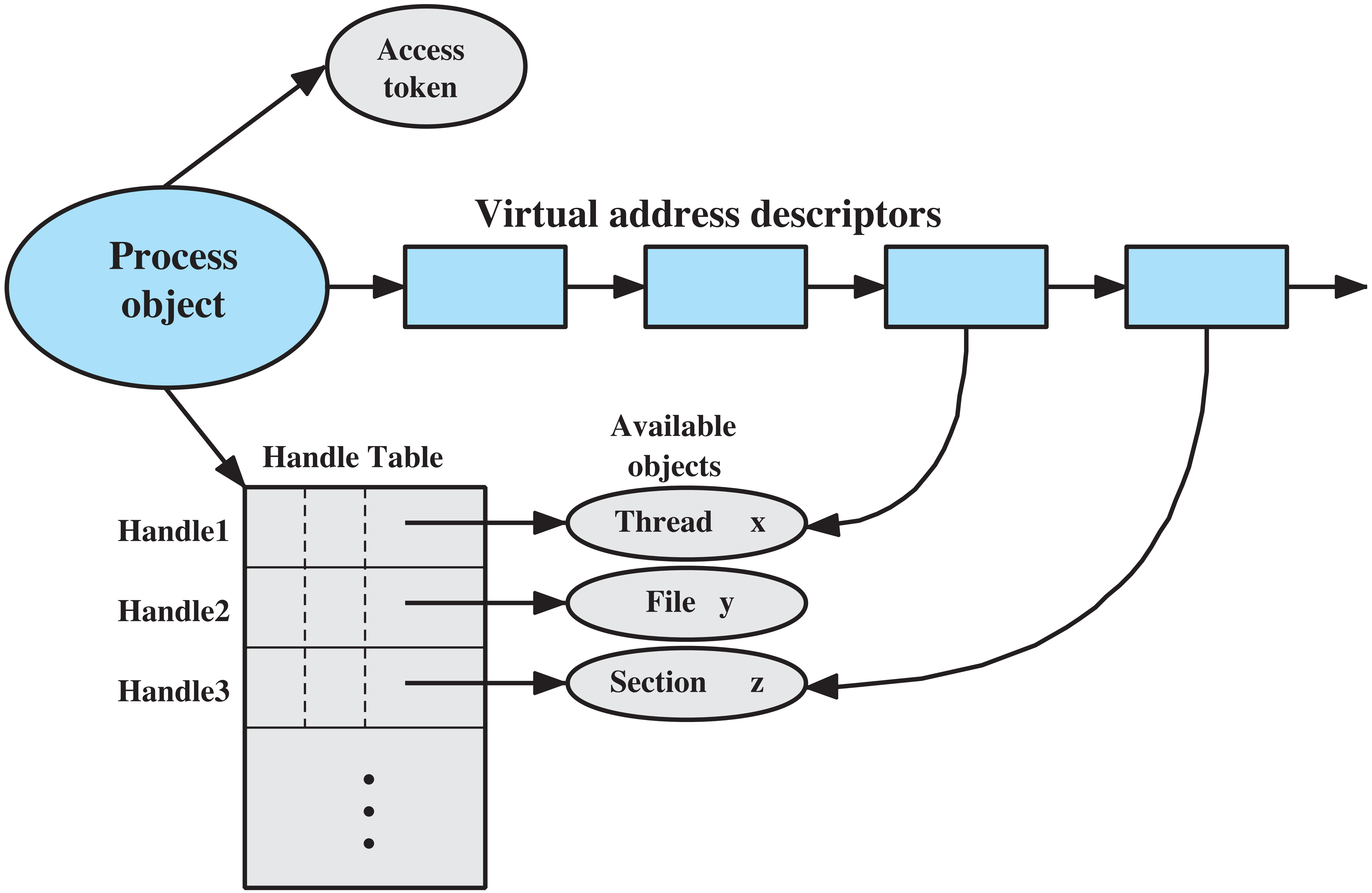
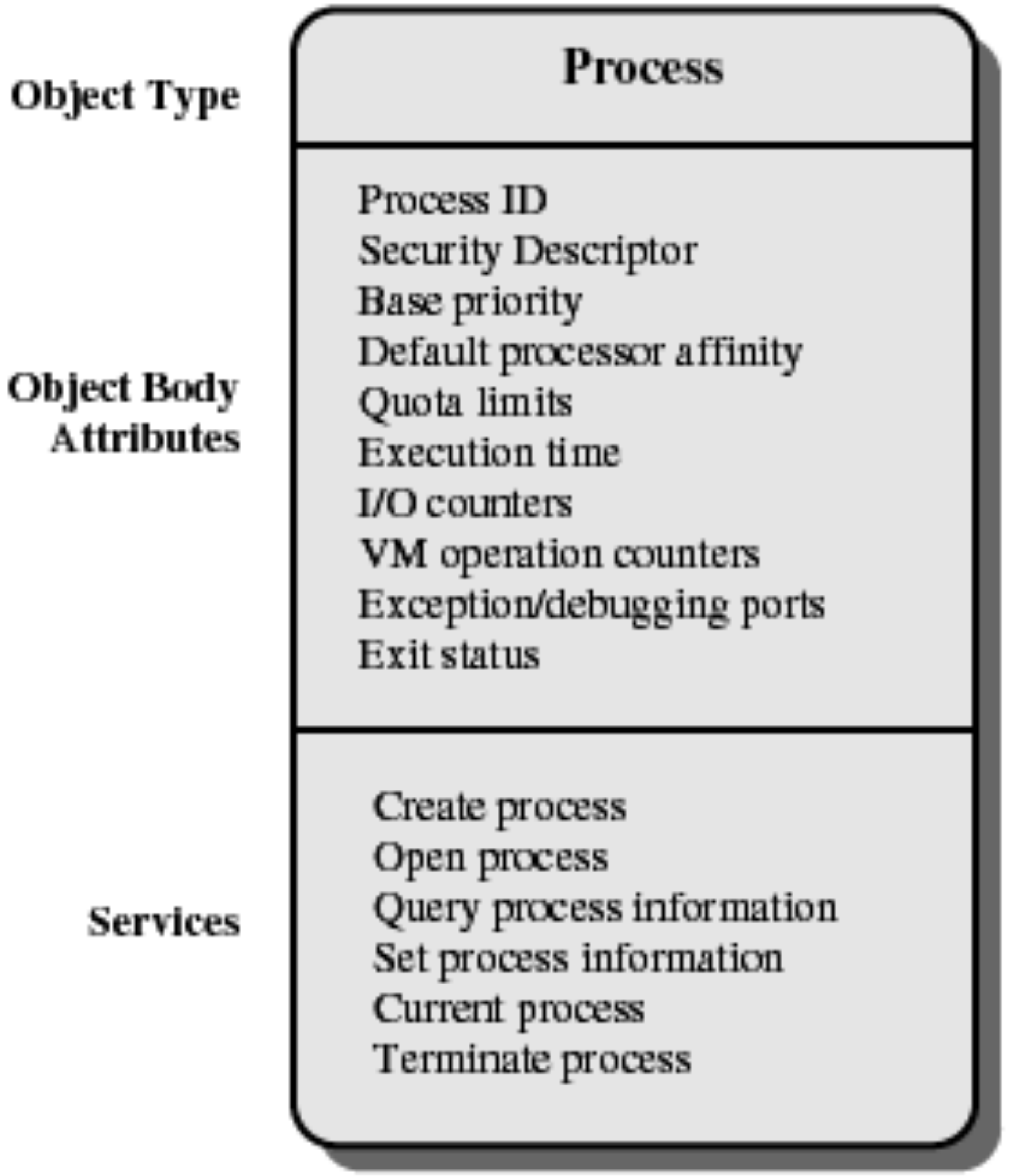


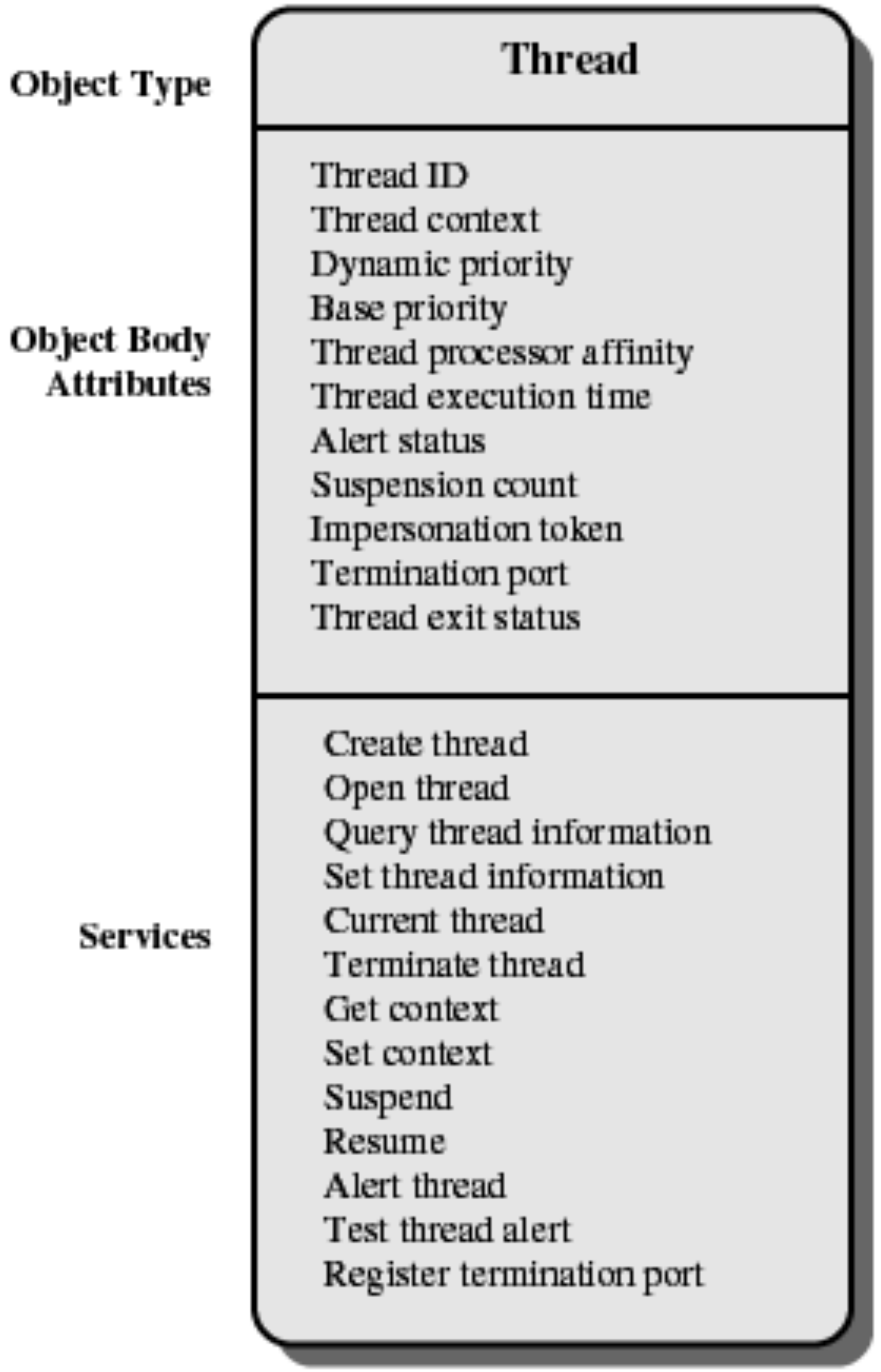
Figure 4.10 A Windows Process and Its Resources

Windows Process Object



(a) Process object

Windows Thread Object



(b) Thread object

Windows 2000 Thread States

- Ready
- Standby
- Running
- Waiting
- Transition
- Terminated

Windows 2000!@#$ …From the historical documents ☺

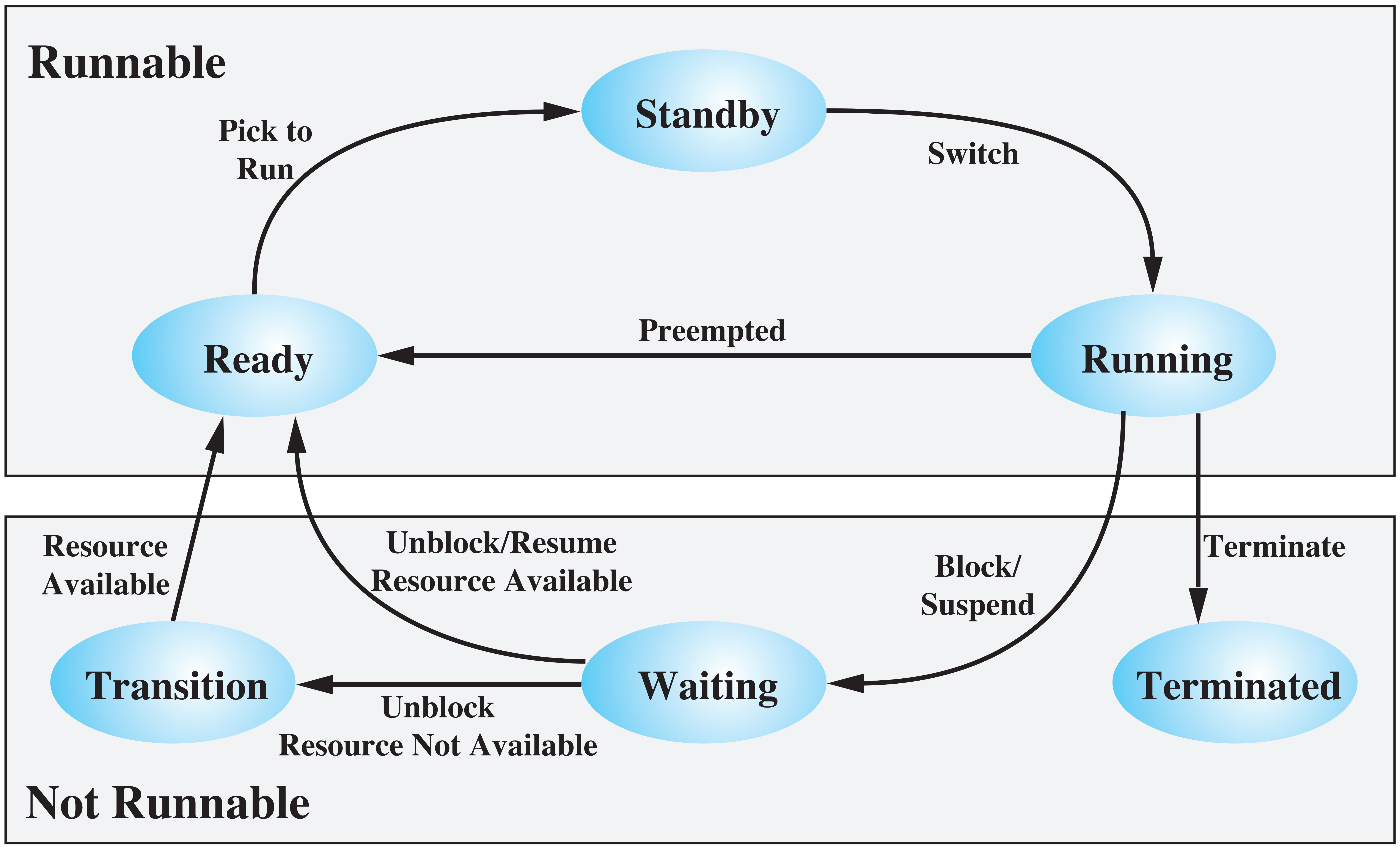


Figure 4.11 Windows Thread States

Solaris

- Process includes the user's address space, stack, and process control block
- User-level threads
- Lightweight processes (LWP)
- Kernel threads

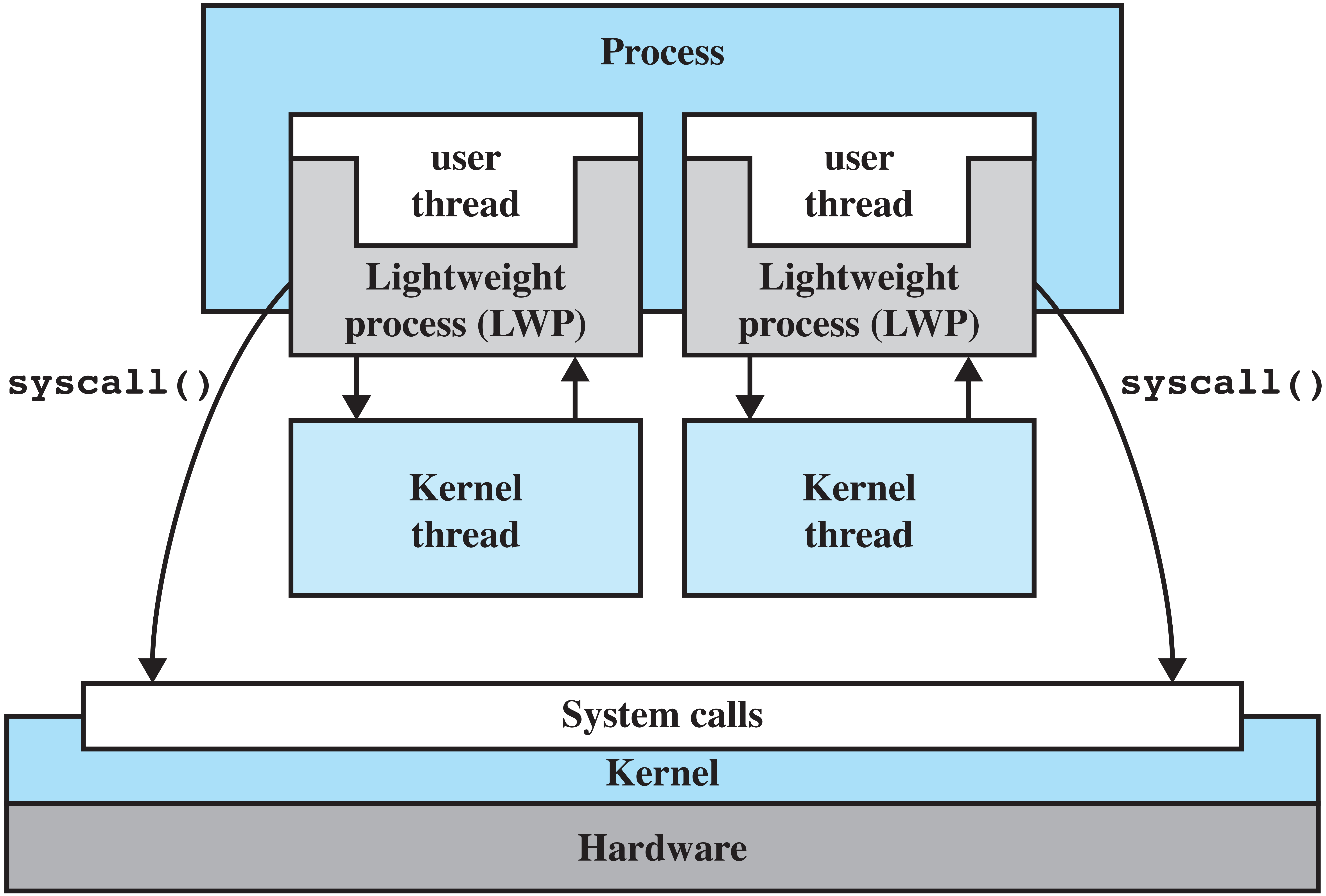


Figure 4.12 Processes and Threads in Solaris

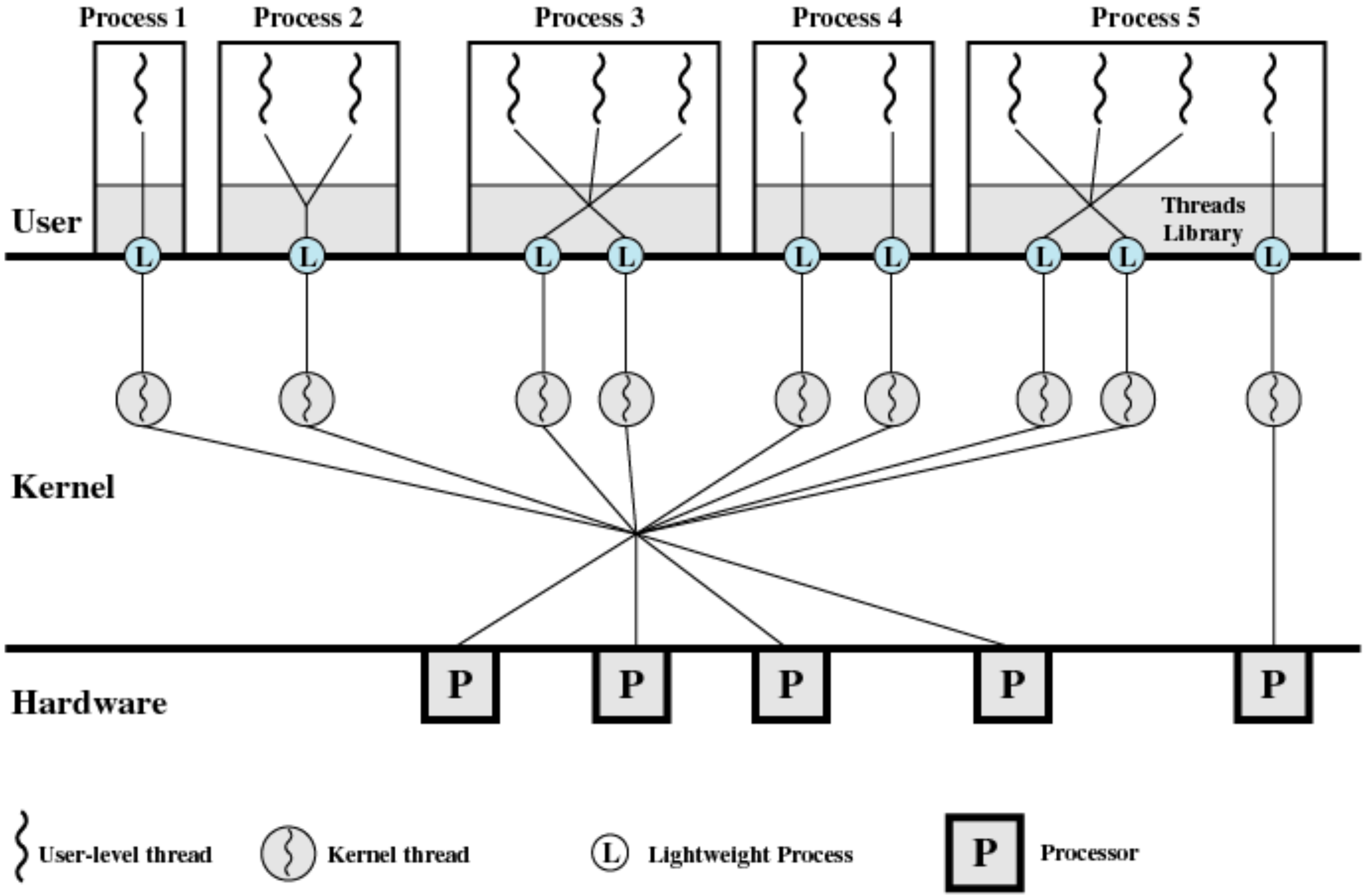


Figure 4.15 Solaris Multithreaded Architecture Example

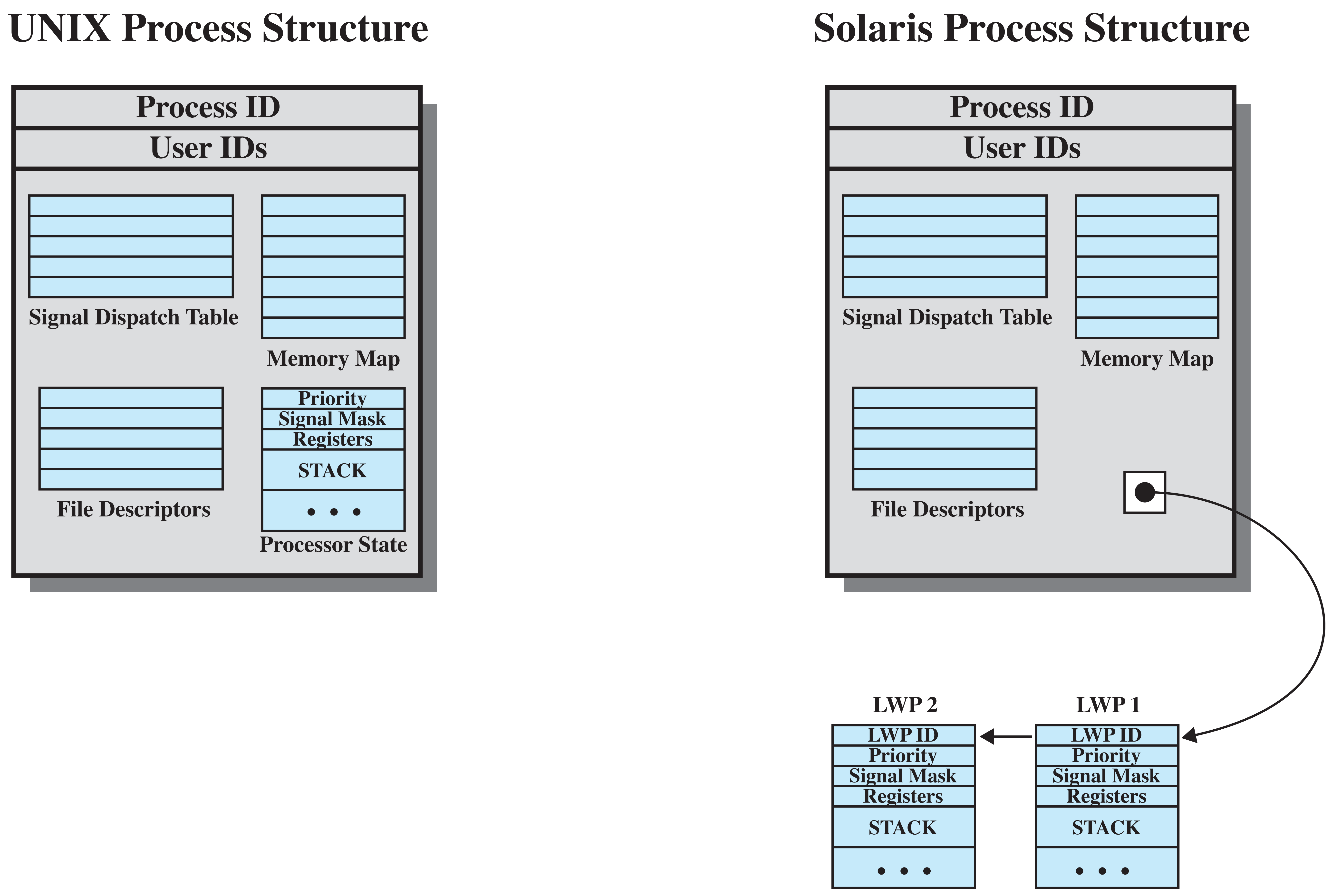


Figure 4.13 Process Structure in Traditional UNIX and Solaris [LEWI96]

Solaris Lightweight Data Structure

- Identifier
- Priority
- Signal mask
- Saved values of user-level registers
- Kernel stack
- Resource usage and profiling data
- Pointer to the corresponding kernel thread
- Pointer to the process structure

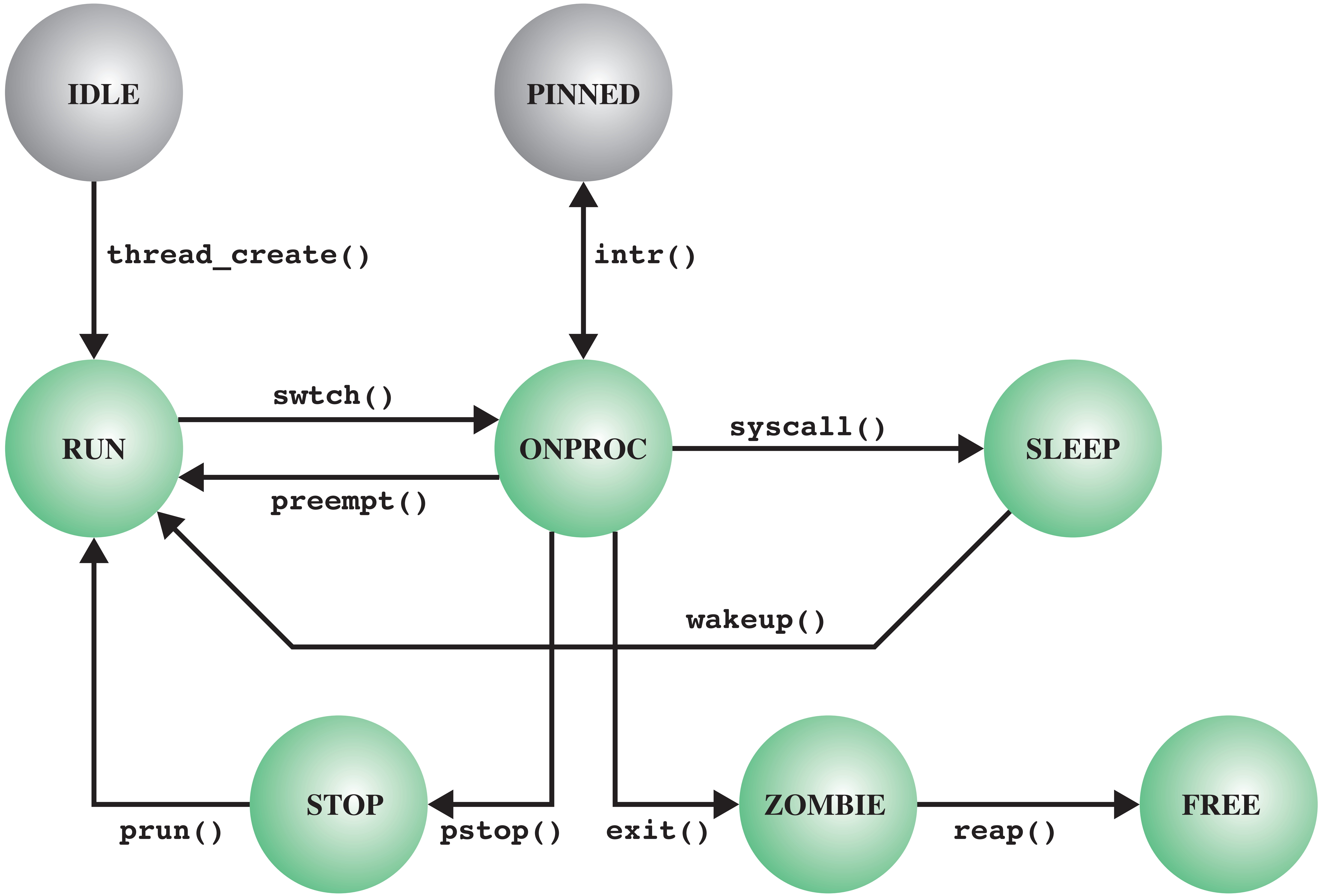


Figure 4.14 Solaris Thread States

Linux Task Data Structure

- State
- Scheduling information
  - normal or real-time, priorities
- Identifiers
- Interprocess communication
- Links
- Times and timers
- File system
- Address space
- Processor-specific context

Linux States of a Process

- Running
- Interruptable
- Uninterruptable
- Stopped
- Zombie

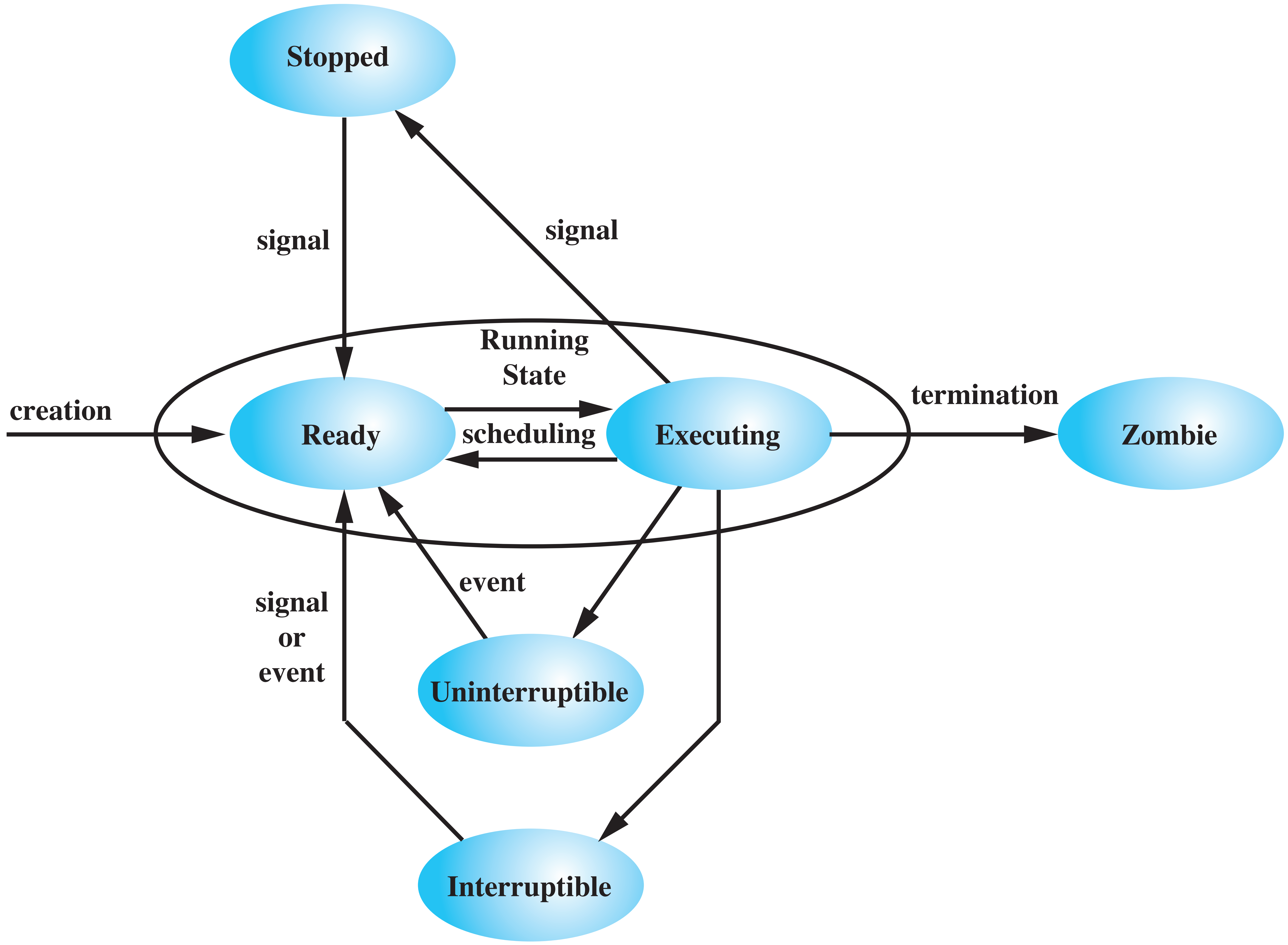


Figure 4.15 Linux Process/Thread Model