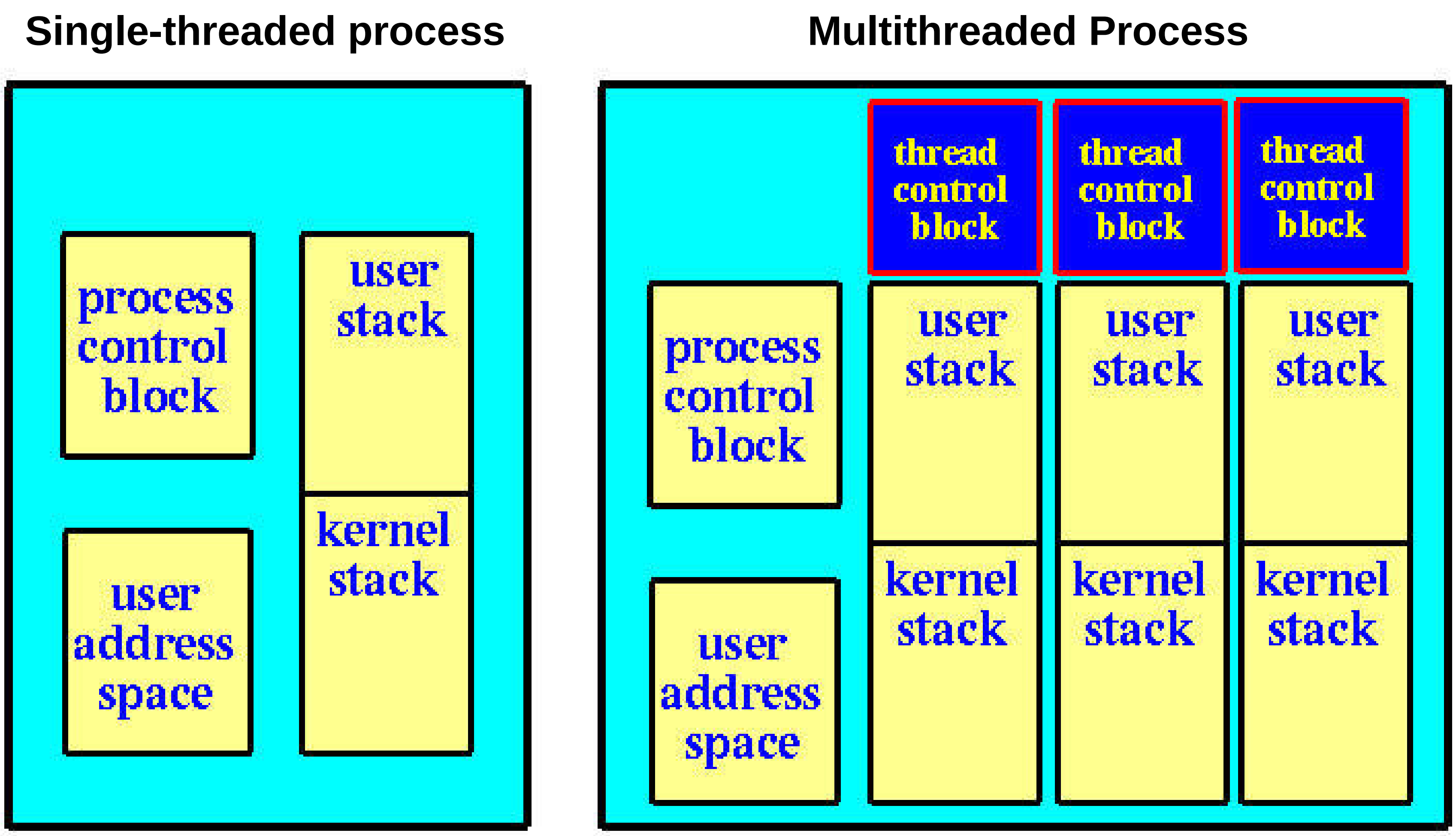
Part II
Process Management
Chapter 4: Threads

What Is a Thread?

- **A *thread*, also known as *lightweight process* (LWP), is a basic unit of CPU execution.**
- **A thread has a thread ID, a program counter, a register set, and a stack. Thus, it is similar to a process has.**
- **However, a thread *shares* with other threads in the *same* process its code section, data section, and other OS resources (*e.g.*, files and signals).**
- **A process, or heavyweight process, has a *single* thread of control.**

Single Threaded and Multithreaded Process



Benefits of Using Threads

- **Responsiveness: Other parts (*i.e.*, threads) of a program may still be running even if one part (*e.g.*, a thread) is blocked.**
- **Resource Sharing: Threads of a process, by default, share many system resources (*e.g.*, files and memory).**
- **Economy: Creating and terminating processes, allocating memory and resources, and context switching processes are very time consuming.**
- **Utilization of Multiprocessor Architecture: Multiple CPUs can run multiple threads of the same process. No program change is necessary.**

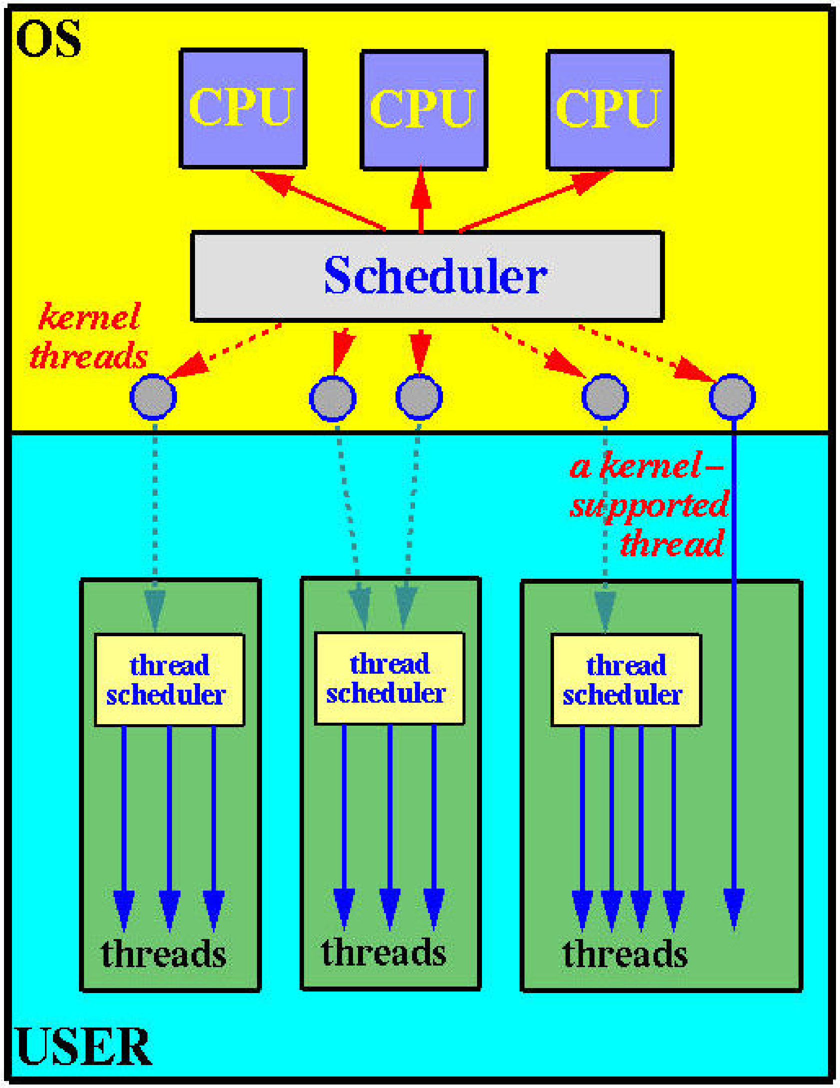
User and Kernel Threads: 1/3

- *User Threads*:
  - User threads are supported at the user level. The kernel is not aware of user threads.
  - A library provides all support for thread creation, termination, joining, and scheduling.
  - There is no kernel intervention, and, hence, user threads are usually more efficient.
  - Unfortunately, since the kernel only recognizes the containing process (of the threads), *if one thread is blocked, every other threads of the same process are also blocked* because the containing process is blocked.

User and Kernel Threads: 2/3

- ***Kernel threads*:**
  - **Kernel threads are directly supported by the kernel. The kernel does thread creation, termination, joining, and scheduling in kernel space.**
  - **Kernel threads are usually slower than the user threads.**
  - **However, *blocking one thread will not cause other threads of the same process to block*. The kernel simply runs other threads.**
  - **In a multiprocessor environment, the kernel can schedule threads on different processors.**

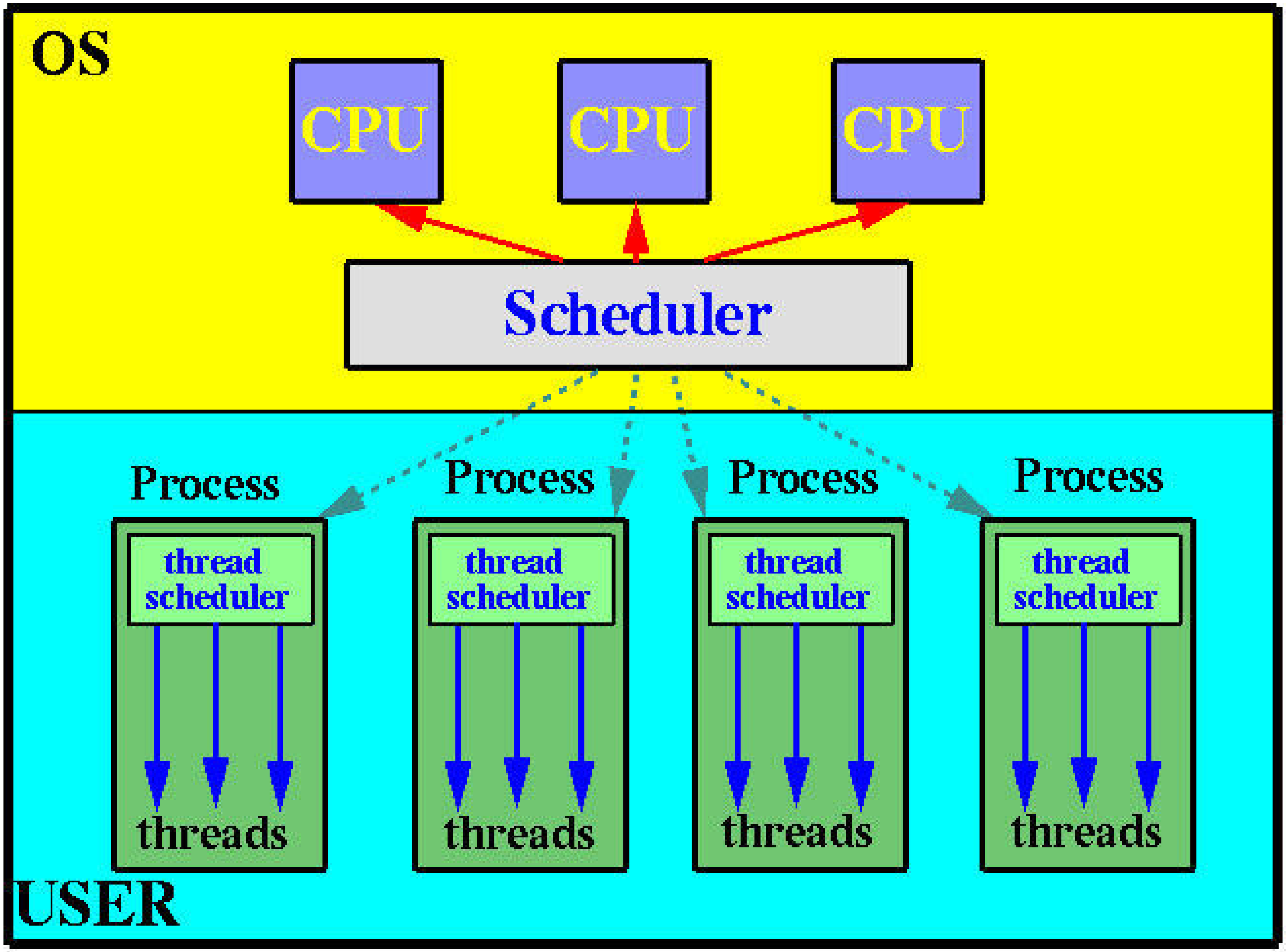
User and Kernel Threads: 3/3



Multithreading Models

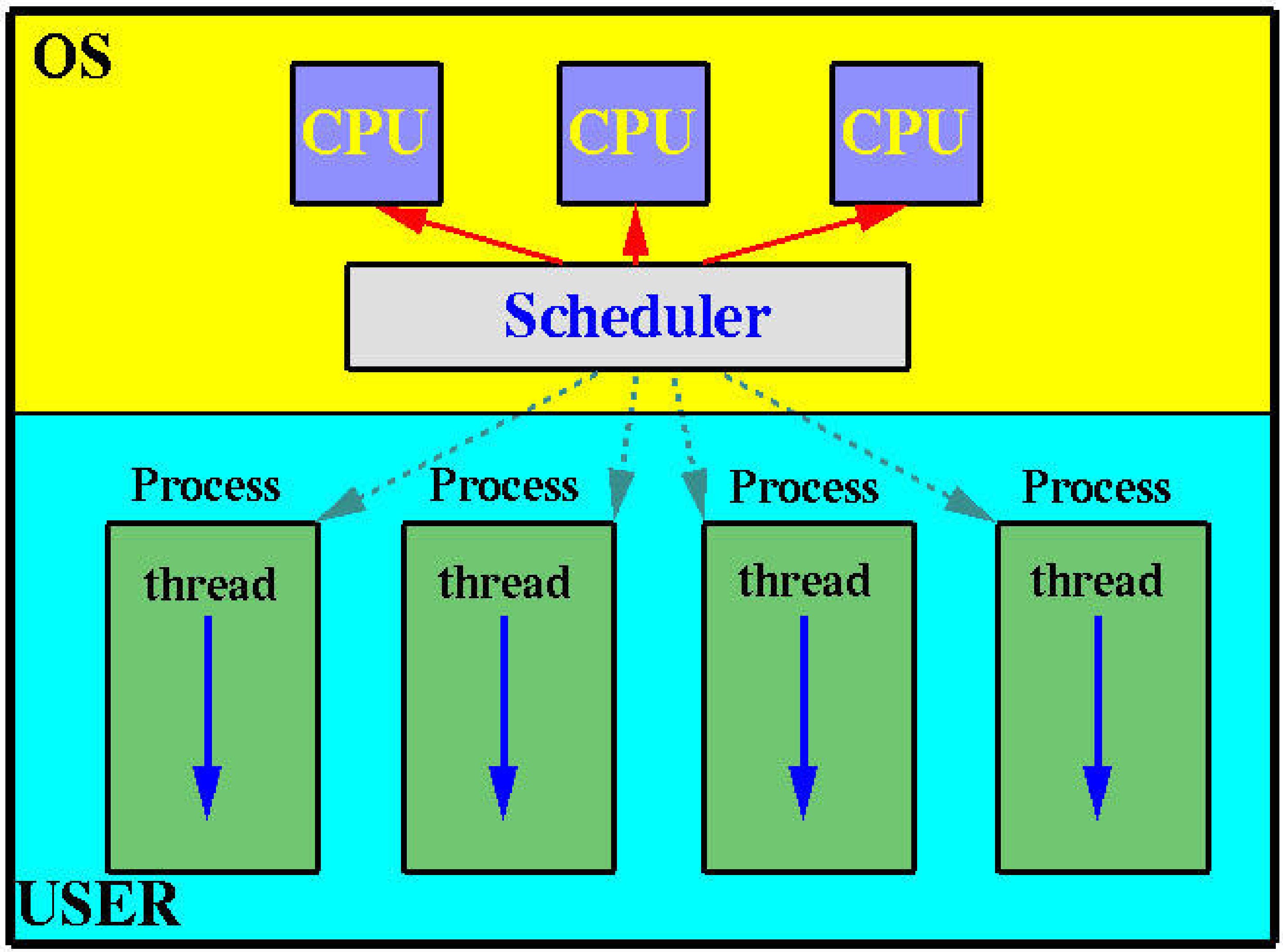
- **Different systems support threads in different ways. Here are three commonly seen thread models:**
  - ***Many-to-One Model*:One kernel thread (or process) has multiple user threads. Thus, this is a user thread model.**
  - ***One-to-One Model*: one user thread maps to one kernel thread (*e.g.*, Linux and Windows).**
  - ***Many-to-Many Model*: Multiple user threads maps to a number of kernel threads.**

Many-to-One Model

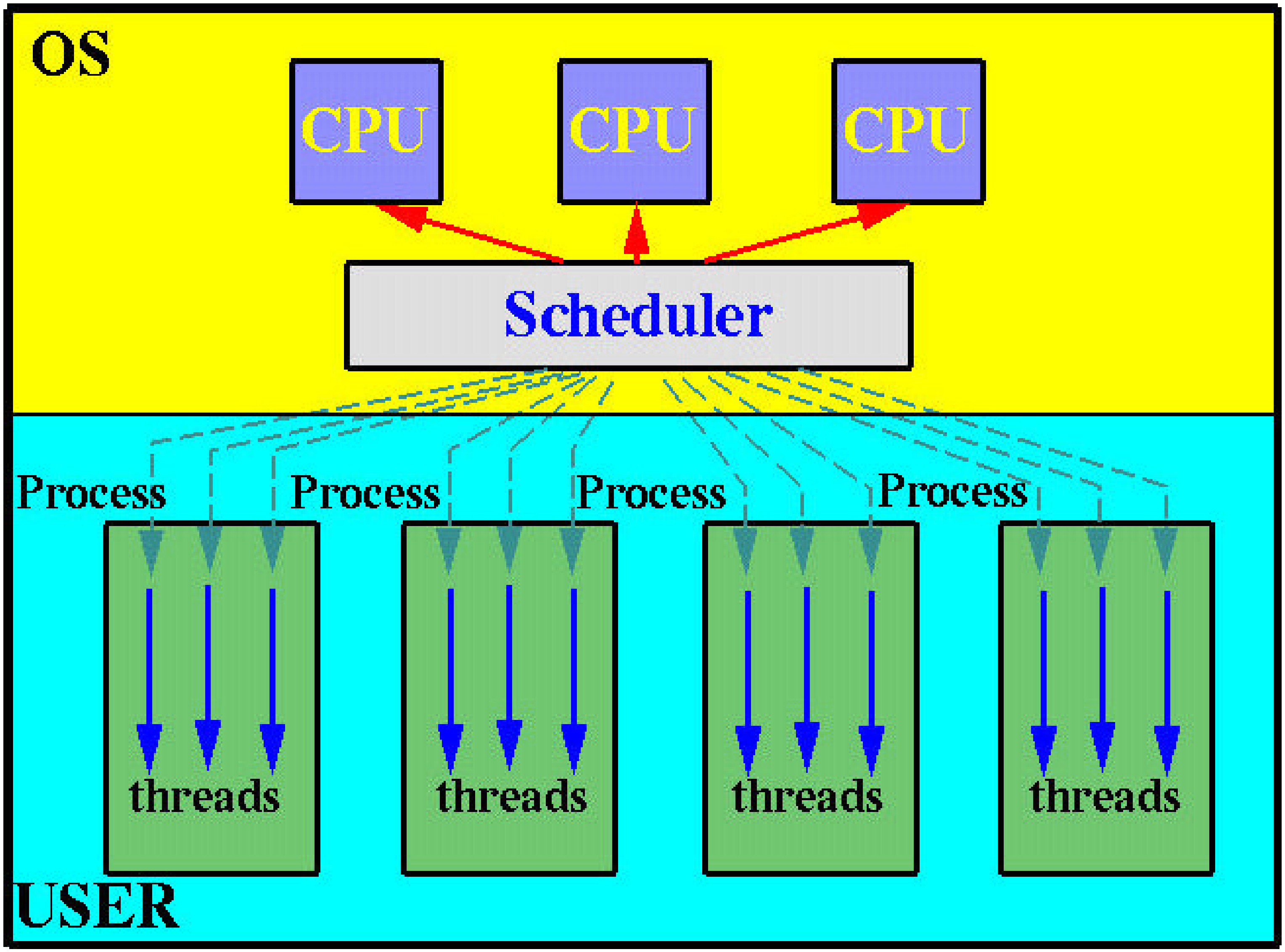


One-to-One Model: 1/2

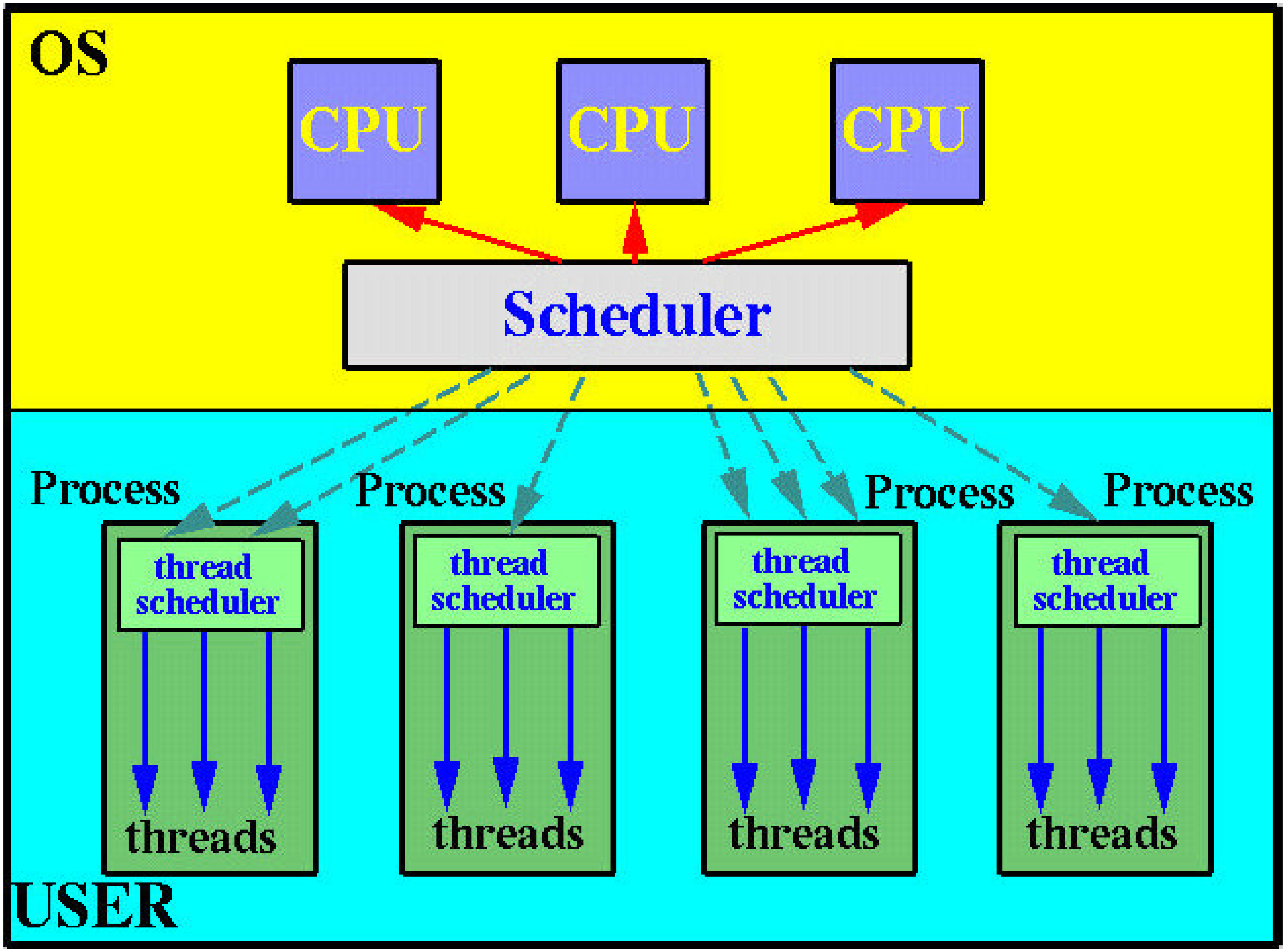
An Extreme Case: Traditional Unix



One-to-One Model: 2/2



Many-to-Many Model



Thread Issues

- **How Does a Thread Fork?**
- **Thread Cancellation**
- **Signal Handling**
- **Thread-Specific Data**
- **What Is Thread-Safe?**

How Does a Thread Fork?

- **If a thread forks, does the new process:**
  - **duplicate all threads?**
  - **contain only the forking thread (*i.e.*, single-threaded)?**
- **Some systems have two `fork` system calls, one for each case.**

Thread Cancellation: 1/2

- ***Thread cancellation*** **means terminating a thread before it has completed. The thread that is to be cancelled is the *target thread*.**
- **There are two types:**
  - ***Asynchronous Cancellation*: the target thread terminates immediately.**
  - ***Deferred Cancellation*: The target thread can periodically check if it should terminate, allowing the target thread an opportunity to terminate itself in an orderly fashion. The point a thread can terminate itself is a *cancellation point*.**

Thread Cancellation: 2/2

- **Problem: With asynchronous cancellation, if the target thread owns some system-wide resources, the system may not be able to reclaim all recourses owned by the target thread.**
- **With deferred cancellation, the target thread determines the time to terminate itself. Reclaiming resources is not a problem.**
- **Most systems implement asynchronous cancellation for processes (*e.g.*, use the `kill` system call) and threads.**
- **Pthread supports deferred cancellation.**

Signal Handling

- ***Signals*** **is a way the OS uses to notify a process that some event has happened.**
- **Once a signal occurs, who is going to handle it? The process, or one of the threads?**
- **This is a very complex issue and will be discussed later in this course.**

Thread-Specific Data/Thread-Safe

- **Data that a thread needs for its own operation are *thread-specific*.**
- **Poor support for thread-specific data could cause problem. For example, while threads have their own stacks, they share the heap.**
- **What if two `malloc()` or `new` are executed at the same time requesting for memory from the heap? Or, two `printf` or `cout` are run simultaneously?**
- **If a library can be used by multiple threads properly, it is a *thread-safe* one.**

Thread Pool

- **While we know that managing threads are more efficient than managing processes, creating and terminating threads are still not free.**
- **After a process is created, one can immediately create a number of threads and have them waiting.**
- **When a new task occurs, one can wake up one of the waiting threads and assign it the work. After this thread completes the task, it goes back to wait.**
- **In this way, we save the number of thread creation and termination.**
- **These threads are said in a *thread pool*.**