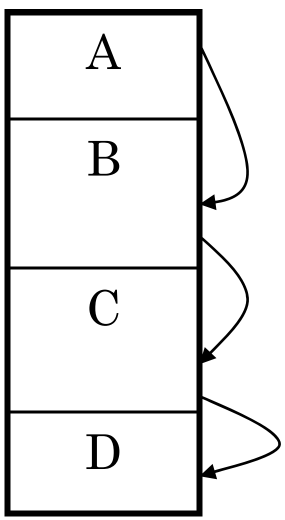
Processes and threads

Conceptual model

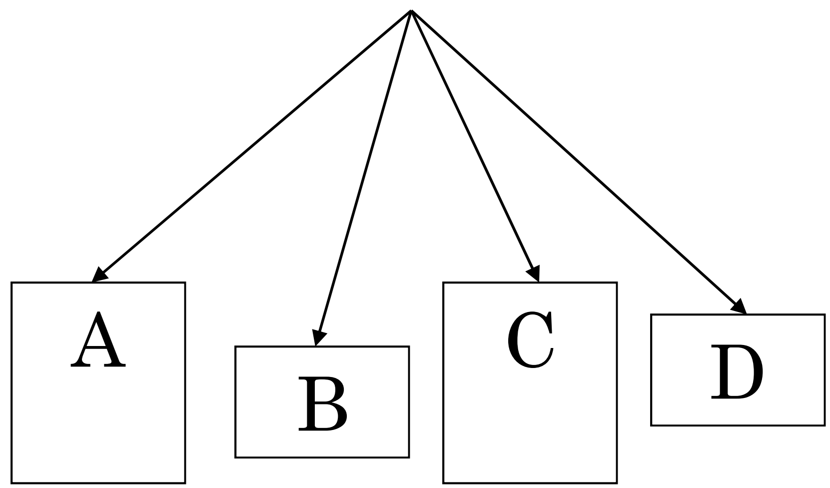
- Sequential process model
- Process → executing program
- Better think about “things” being executed in parallel rather than sequentially (too complicated)
- Switching back and forth of processes is called **multiprogramming**

Model

Reality



Our imagination



Processes

- Should not be designed with timing issues is mind since:
  - We don’t know when a context switch occurs

- Special actions need to be taken when timing is important

Process vs. Program

- Program: the instructions to be executed
  - The program is “unique”
- Process: the actual execution
  - There might be multiple instances (processes) of the same program

Process creation

- System initialization (boot time)
- Creation (by sys call) by a running process
- A user request (shell)
- Initiation of a batch job (or scheduled job)

Interactive vs. background

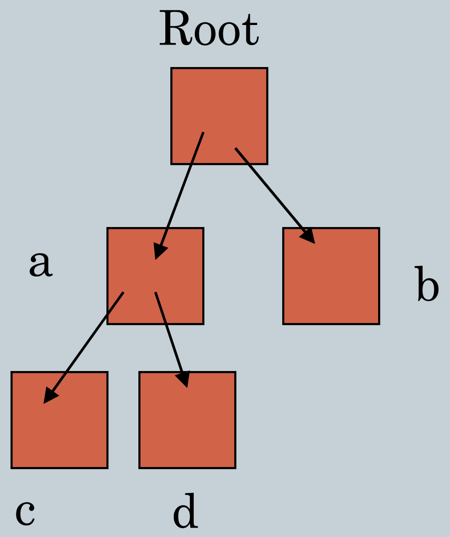
- Background processes
  - TSR (old DOS terminology)
  - Daemons (UNIX)
  - Services (Windows)
- Batch systems
  - When the system decides that there are enough resources it might start a new job. Users submit (possibly remotely) jobs to the system

Process creation/termination

- Creation
  - Unix: *fork()* $\rightarrow$ exact copy of the caller
  - Win32: CreateProcess() $\rightarrow$ a brand new one
- Termination
  - Voluntary: normal vs. error exit *exit()*
  - Involuntary: fatal error vs. killed *TerminateProcess()*

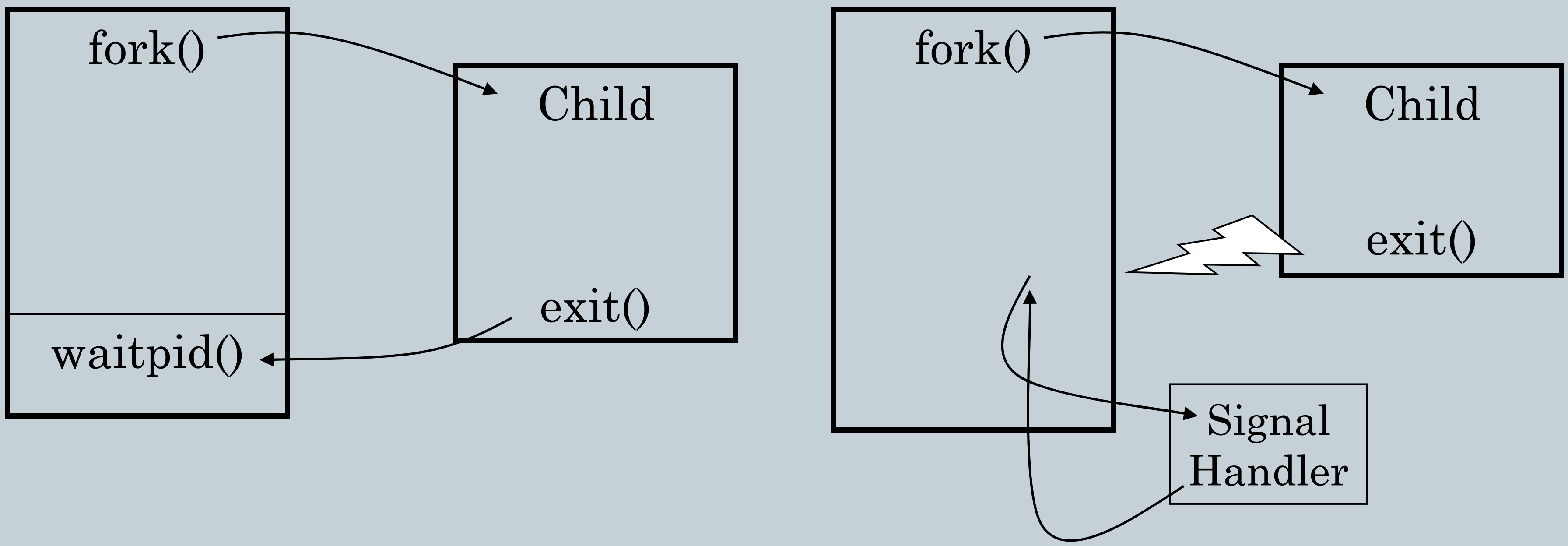
Process hierarchy

- Root → init
- a → login process
- c, d → shells
- b → background process



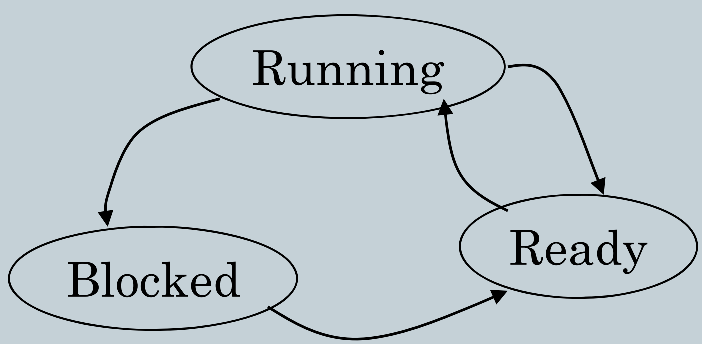
Wait for process termination

- Synchronous: *waitpid()*
- Asynchronous: SIGCHLD

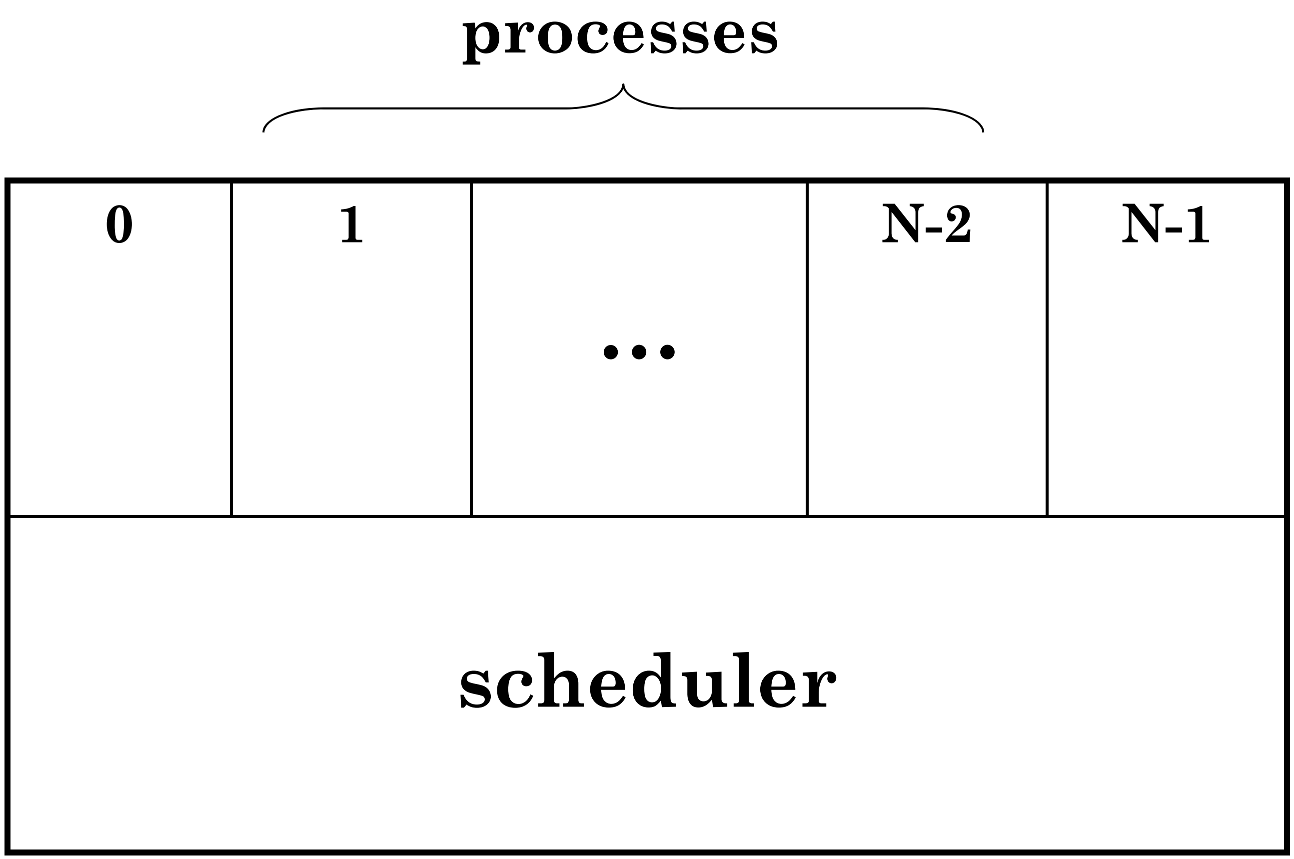


Process states

- Running (using the CPU)
- Ready (runnable)
- Blocked (temporarily stopped, waiting)



Scheduler



Processes

- Associated with each process:
  - Address space (program + data + stack)
  - Entry into the process table (a list of processes)
    - Set of registers (e.g. PC, PSW, etc.)
    - MMU status, registers
- Processes can be created, terminated, signaled (SW interrupt)
- They form a tree (a hierarchy) on some systems
- Process cooperation is obtained by means of IPC (inter-process communication) mechanisms
- Processes start with the privileges of the user who starts them

Implementation

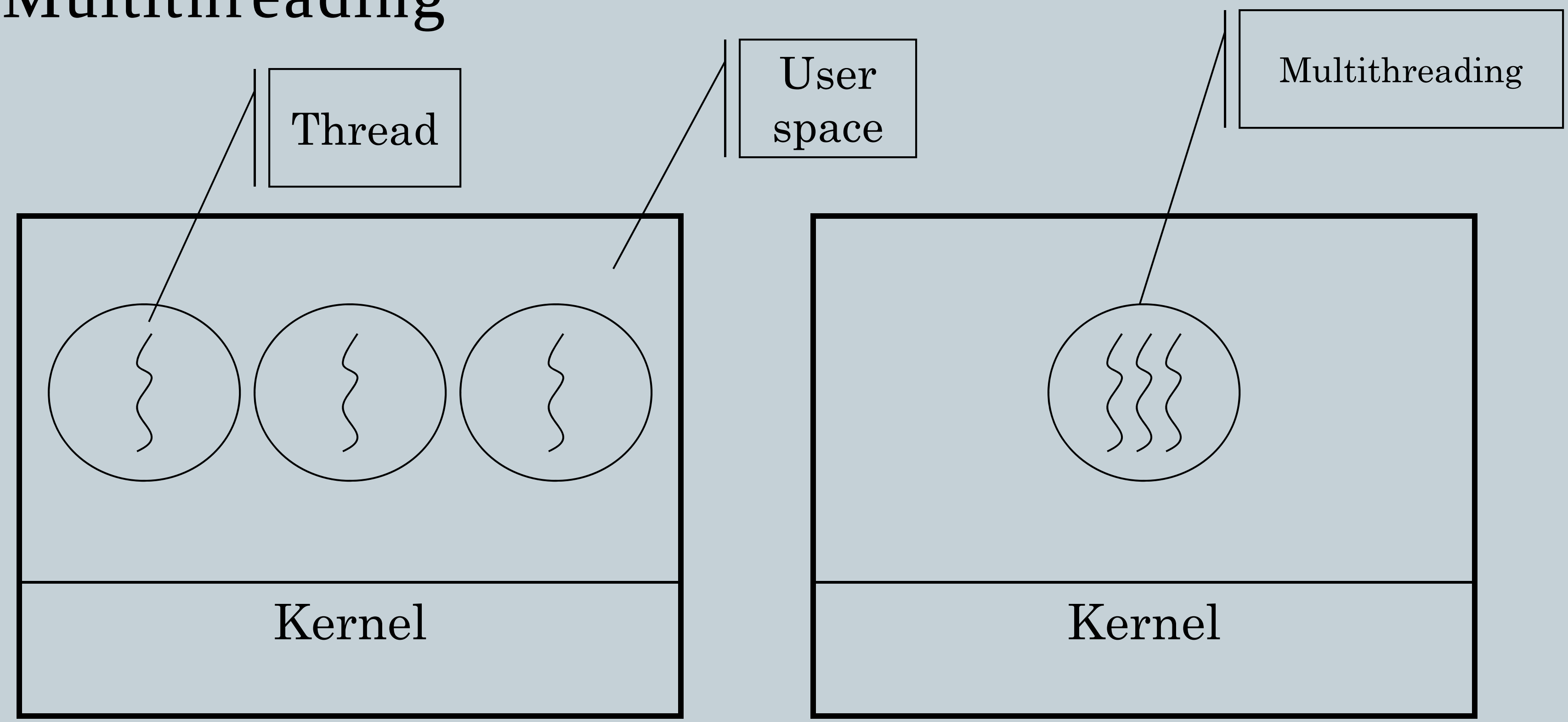
- Process table
- Scheduler is called when particular events occur (I/O interrupts, blocking calls, timers, etc.)

Threads

- Two concepts:
  - Shared resources: signal handlers, open files, memory, etc.
  - Thread of execution: PC, stack, etc.
- Decoupling the two concept:
  - Process: the container of the shared resources
  - Thread: the execution

Multiple threads

- Lightweight processes
- Multithreading



Threads (cntd.)

- Threads share the same **address space**
- No protection between thread
- A thread has a state (running, blocked, ready)
- A thread of execution is scheduled by the scheduler (depending on the implementation)

Needless to say…

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

Exemplar thread calls

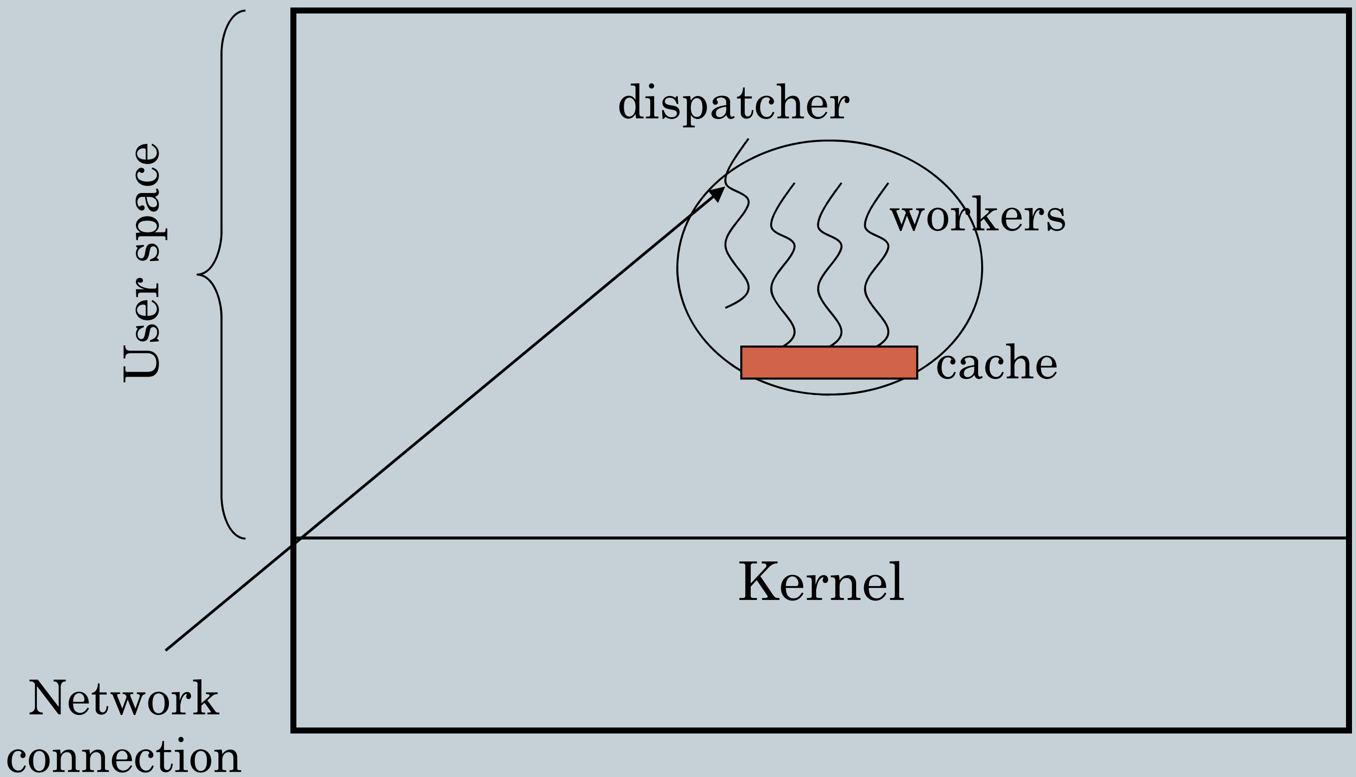
- *thread_create()*
- *thread_exit()*

- *thread_wait()*
  - Similar to *waitpid()*
- *thread_yield()*
  - Important, since there's no clock interrupt

Why?

- Simpler programming model:
  - If we need multiple quasi-parallel activities then it's better to provide a mechanism to support them
  - Background activity within an application
- Efficiency:
  - Keep the CPU busy
  - Multi-processor architectures

The web server



Many possibilities

- **Threads**: parallelism, blocking sys calls
- **Single-threaded process**: No parallelism, blocking sys calls
- **Finite state machine**: Parallelism, non-blocking sys calls (interrupt handling!)

Thread implementation

- User space
- Kernel space
- Hybrid

User space

- Each process maintain a thread table
- Threads are implemented by implementing library calls (user code, not kernel code)
- Efficient since there's no kernel trap to call the thread code
- Switching can be easy (thread switching)
- The kernel knows nothing of threads

Issues

- How do we implement blocking sys calls?
  - Change libraries: messy
  - Use *select()* to see if a prospective call would block, requires a "wrapper" to the library
- Page fault:
  - What should a thread do while waiting for a chunk of memory from disk?
- How do we switch from thread to thread?
  - User space threads do not have a timer clock

Kernel space threads

- Since the kernel knows everything about the system it can easily take care of managing threads
- Creating/destroying threads has a cost: a system call
  - Thread recycling in the kernel
- The kernel scheduler, schedules threads instead of whole processes

Making code multithreaded

- Access to global variables:
  - Thread local storage (TLS), library calls
  - Example: the *errno* variable
- Reentrant library calls:
  - The possibility of having a second call made while a previous call has not yet finished
  - E.g. *malloc* (maintains lists of memory chunks)
- Who should catch unspecific interrupts?
- Stack growth: how do we handle it?