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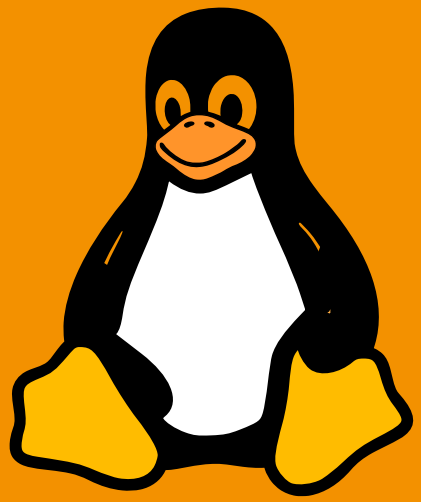
OS 5 – Process/Thread



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The lecture is based on the work and the documents of Prof. Dr. Ludwig Frank

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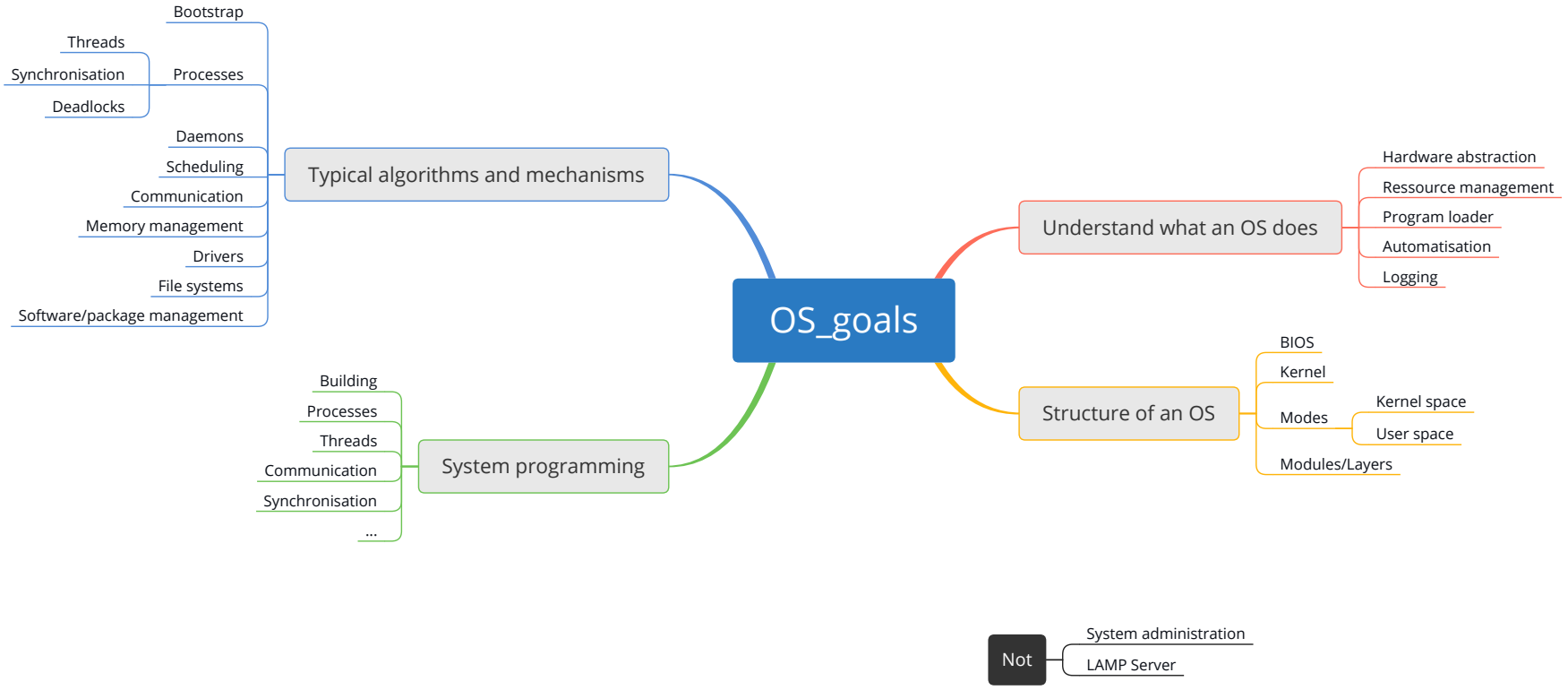
Goal



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Goal

OS::Process/Thread

- What is a process/thread
- Process hierarchy
- Processes management
- Thread management
- Parallelisation

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Intro

What is a process?

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Process definition

A process is an **instance of a computer program** that is being executed.

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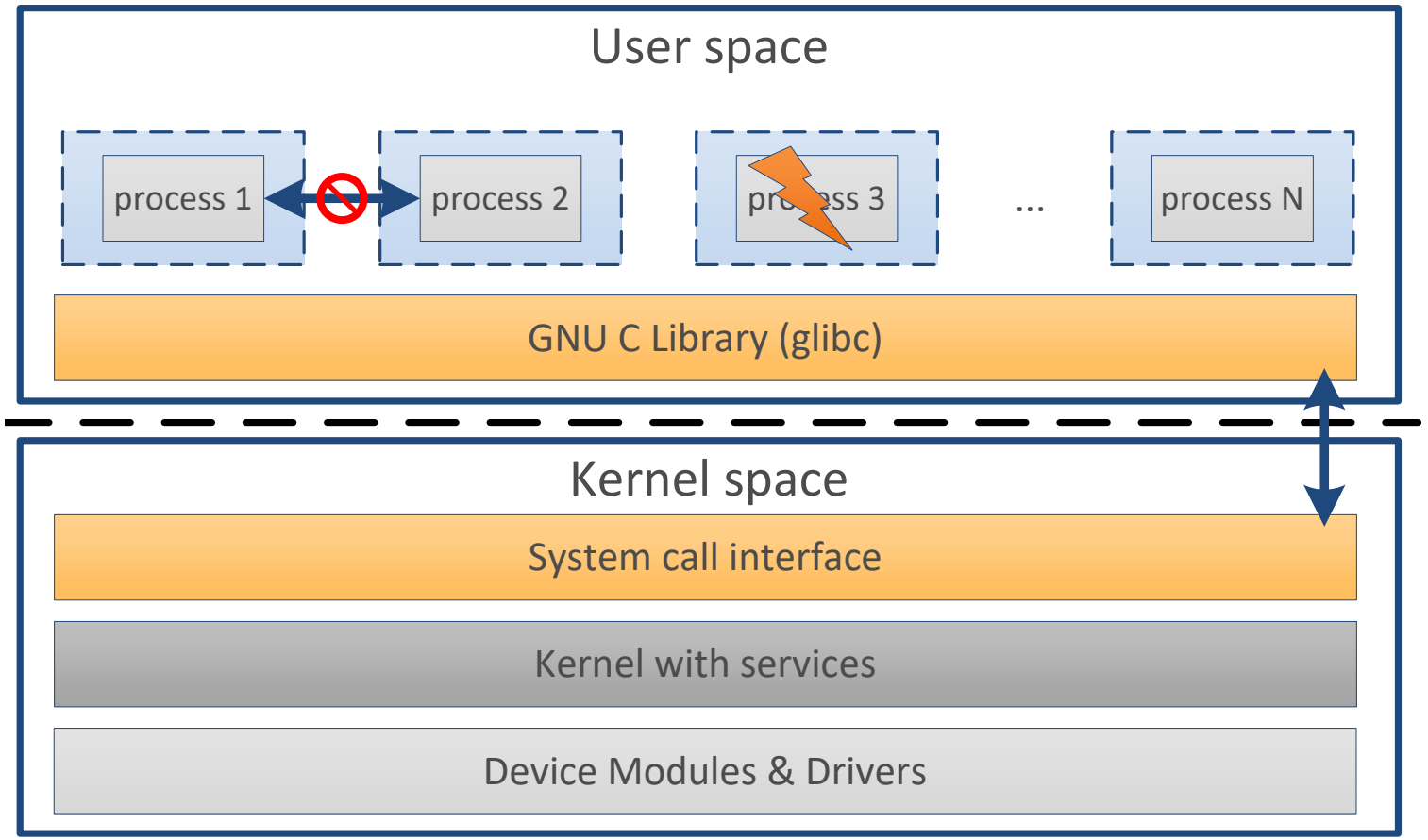
Process isolation



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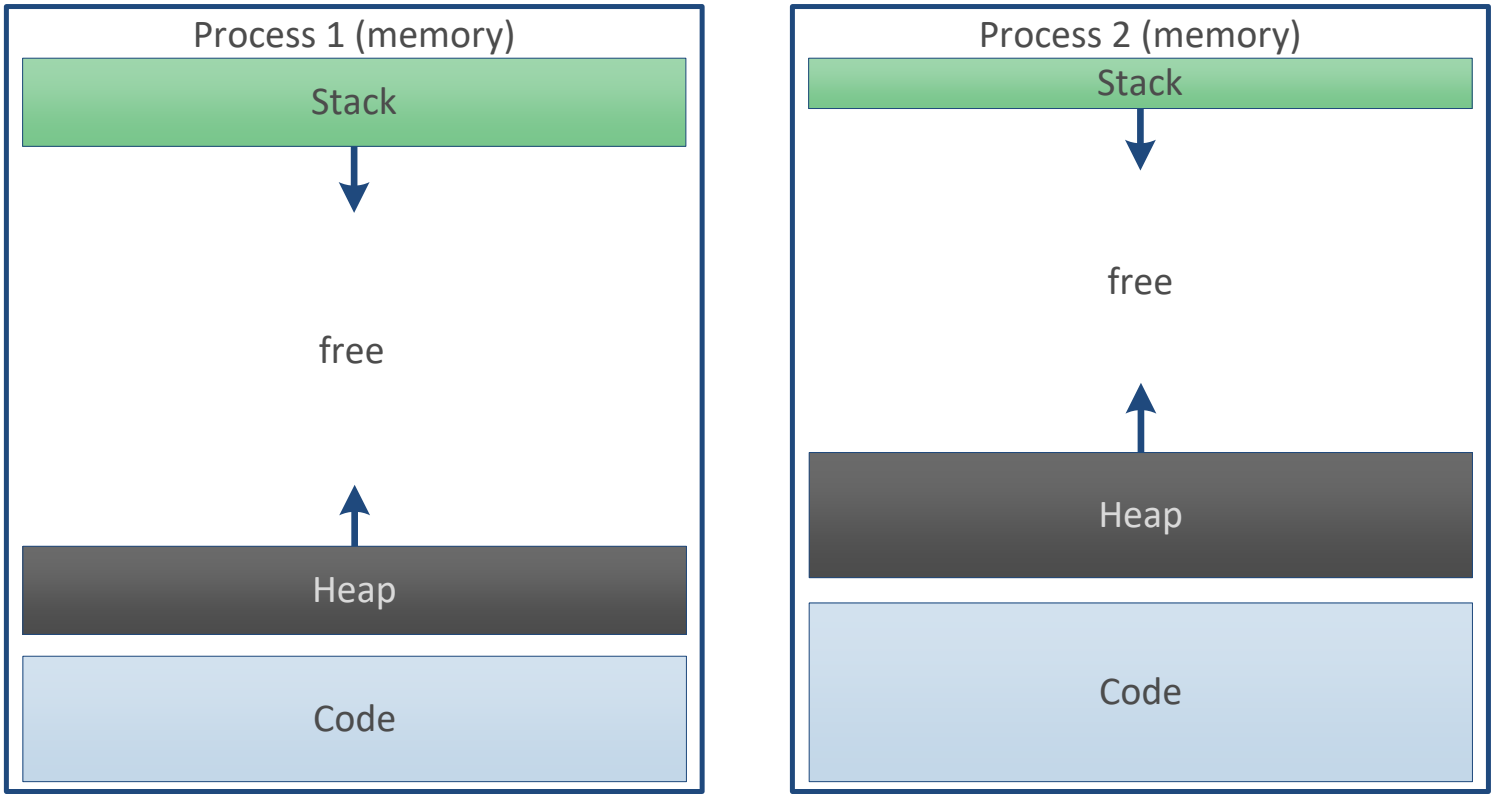
Process memory view



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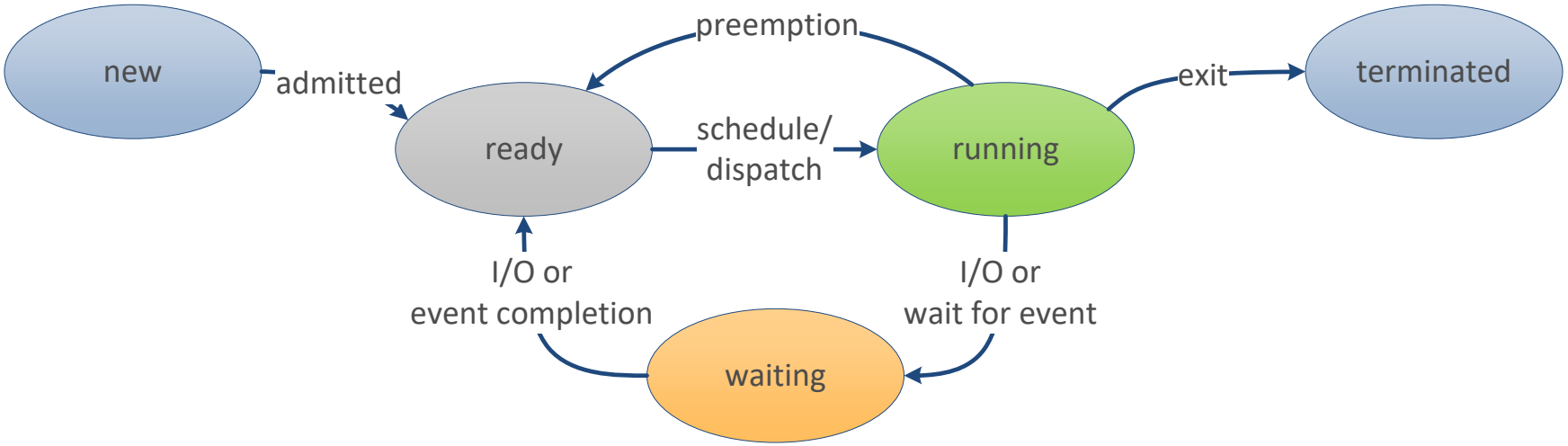
Process states



It is still a simplified view!

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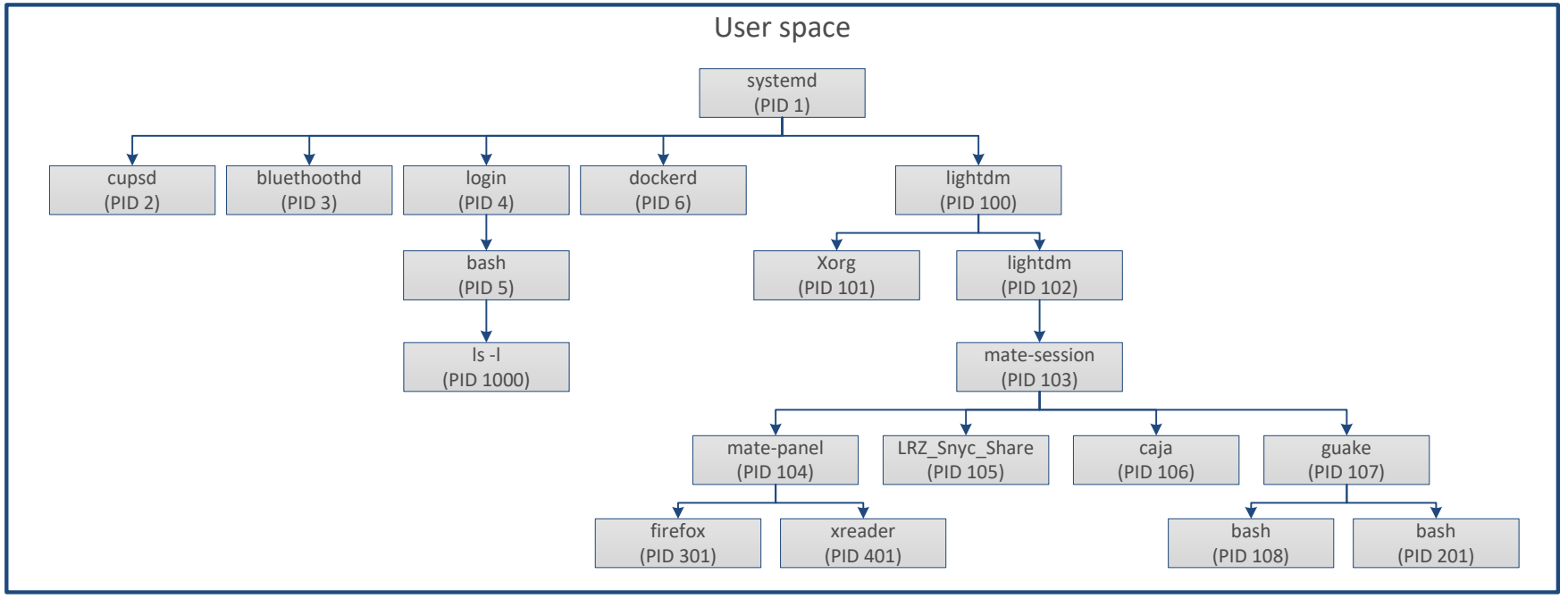
Process hierarchy



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Daemon: a special kind of a process

Daemon - disk and execution monitor (bacronym)

- A daemon is a process
- Operates in the background
- A daemons parent PID is 1 -> `systemd`
- Usually started from `systemd` as part of the boot procedure
- A daemon has no direct interaction (shell, keyboard, mouse) with the user
- Communication with a daemon: network, signals, pipes, shared memory, ...
- Working directory is /
- Usually uses a logfile to log events and errors

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Process specific properties

Process management

- Process id (PID)
- Parent (PID)
- State
- Register entries
- Priority
- Signals
- Start time

Process memory

- Code (pointer)
- Stack (pointer)
- Heap (pointer)

File management

- Root directory (/)
- Working directory
- File descriptors
- User id
- Group id

Advantages of multiple processes

- **Independent start** of different processes
- Can be **executed** in **parallel**
- If a process **crashes** the others can **continue** their work
- **No overwriting** of the memory
- Security: **No read** of another process memory possible
- **Independent development**!
- **Independent dependencies**!
- **Each user** can have its **own processes**.

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OS process table

Process control block (PCB)

- The **kernel manages** the different **processes**
- Each process has its own **process control block (PCB)**
  - Contains all **process specific properties**
  - The process table contains all PCBs
- In Linux: `struct task_struct {...}`
- `https://github.com/torvalds/linux/blob/master/include/linux/sched.h`

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Programmatic: execute a command

```c
#include <stdio.h>      //printf
#include <stdlib.h>     //EXIT_SUCCESS, system

int main(int argc, char** argv)
{
    //executes a command specified in command by calling /bin/sh -c command
    const char* const command = "ls -l /";
    int exit_status = system(command);

    if(exit_status == -1) {
        printf("%s can't be started.\n", command);
    } else {
        printf("%s exited with status: %d.\n", command, exit_status);
    }

    return EXIT_SUCCESS;
}
```

system (man): http://man7.org/linux/man-pages/man3/system.3.html

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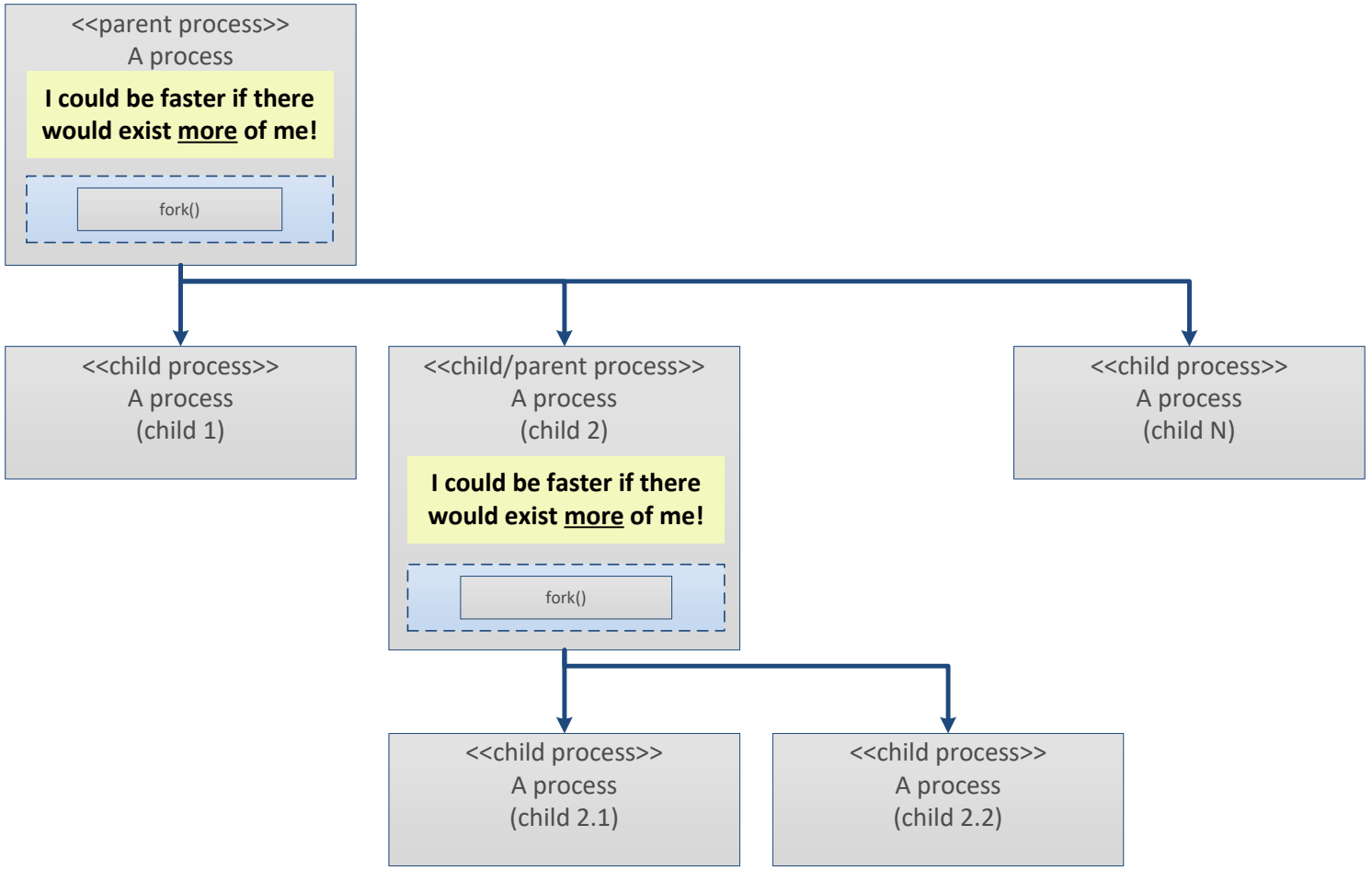
Programmatic: fork idea



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Programmatic: fork example

```c
#include <stdio.h>     //printf
#include <stdlib.h>    //EXIT_SUCCESS, system
#include <unistd.h>    //fork
#include <sys/wait.h>  //waitpid

int main(int argc, char** argv)
{
    pid_t pid = fork();

    switch(pid){
        case -1: //error
            printf("Error: fork failed.\n");
            exit(EXIT_FAILURE);
            break;
        case 0:  //child
            printf("Hi, I'm the fork with the PID %d!\n", getpid());
            break;
        default: //parent
            printf("Parent waits until child process with PID %d ends.\n", pid);
            waitpid(pid, NULL, 0);
            printf("Child process with PID %d exited.\n", pid);
            break;
    }

    return EXIT_SUCCESS;
}
```

fork (man): http://man7.org/linux/man-pages/man2/fork.2.html

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Processes management on shell

cmd	Description
`./command`	**Start** a process.
`kill`	**Stop** (exit) a process.
`wait`	**Wait** until a child process has stopped.
`ps aux`	**Show** information about started processes.
`top`	**Show live** information about processes.
`pstree`	**Show** the process **hierarchy**.
`renice`	**Change** the priority of the process.

Thread definition

A thread is an **entity within a process** that can be **scheduled independently** of other threads for execution.

In Linux: A thread is a **lightweight process**!

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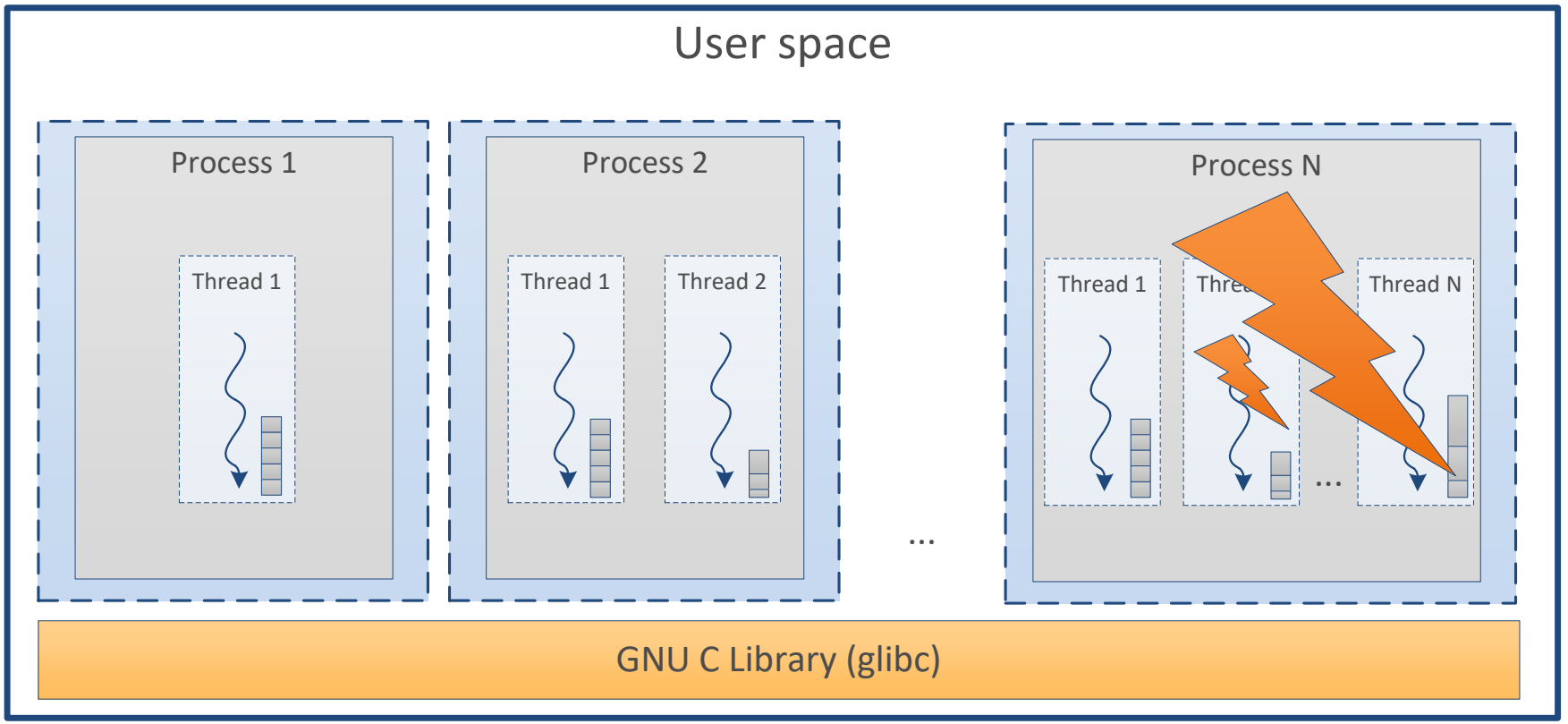
Thread illustration



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Thread properties

Properties for each thread

- Thread id (TID)
- State
- Register entries
- Stack (pointer)

Shared process properties

- Address space (code/heap)
- Global variables
- Opened files
- Child processes
- Signals
- Working directory

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OS thread/process table

Thread control block (TCB)

- The **kernel manages** the different **threads** (similar to a process)
- Each thread has its own **thread control block (TCB)**
  - Contains all **thread specific properties**
  - Each process knows the thread TCBs in its PCB
- In Linux:
  - `struct task_struct {...}`
  - It is **used** for **processes and threads**
  - This is the reason for the term: "**lightweight process**"
  - `https://github.com/torvalds/linux/blob/master/include/linux/sched.h`

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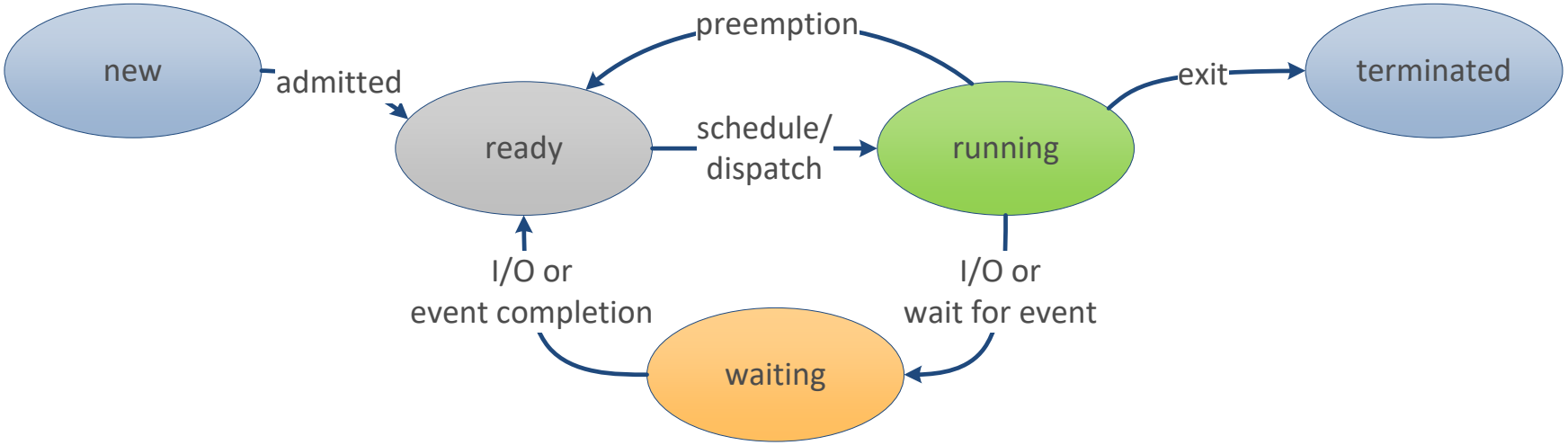
Thread states

Similar to the process states.



It is still a simplified view!

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Programmatic: pthread example

```c
#include <stdio.h>     //printf
#include <stdlib.h>    //EXIT_SUCCESS, system
#include <pthread.h>   //pthread_create, pthread_join

void* thread_work() {
    printf("Hi, I'm the thread with the TID %lu!\n", pthread_self());
    return NULL; //the thread ends here
}

int main(int argc, char** argv) {
    //create thread
    pthread_t thread_id;
    int thread_create_state = pthread_create(&thread_id, NULL, &thread_work, NULL);
    if( thread_create_state != 0) {
        printf("Failed creating thread\n");
        exit(EXIT_FAILURE);
    }

    //join thread (wait until the thread has finished)
    printf("Main thread waits until child thread with TID %lu ended.\n", thread_id);
    int thread_exit_state = pthread_join(thread_id, NULL);
    if(thread_exit_state != 0){
        printf("Thread exited with failure %d.\n", thread_exit_state);
    }

    printf("Child thread with TID %lu exited.\n", thread_id);
    return EXIT_SUCCESS;
}
```

pthreads (man): http://man7.org/linux/man-pages/man7/pthreads.7.html

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Process vs. thread

Quiz: When to use a process or a thread?

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Summary and outlook

Summary

- What is a process/thread
- Process hierarchy
- Processes management
- Thread management
- Parallelisation

Outlook

- Process synchronisation
- Semaphore
- Mutual exclusion