WORK

FEUP -- Distributed Systems

Today - Disclaimer

- May seem pretty "definitional"
  (Other lectures will have a lot more "how to do cool stuff")
  - We need clear, precise definitions to understand, communicate, and build systems.
- Analogy: A computer will do exactly what you tell it. But you have to know exactly how to express what you want...
  - **A device that you don't understand is not by definition intelligent**
  - So first, you have to *know* exactly what you want
- This happens everywhere - ugrad, grad school, and beyond. **Clear definitions** are necessary for **clear thought**.
- A challenge: **Systems contain subsystems that are themselves systems** -- aka, system decomposition is recursive.

Jobs: Chunks of work

* A *Job* (n): A task that is performed as if it was a single logical unit

  Remember, our definitions have to operate at multiple levels of abstraction

  Example:
  From the perspective of a password cracker server, cracking one password is a job. (Batch processing has similar views)

  From the client application's perspective, cracking a range is a job.

  From the OS kernel's perspective, a job is the granularity at which threads are scheduled (a burst of activity)

Let's examine representations of these from bottom-up

Tasks

* Set of instructions

* Usually, a “task” is more generic than a “process” or a “thread” (which have specific extra stuff with them)

Machine organisation

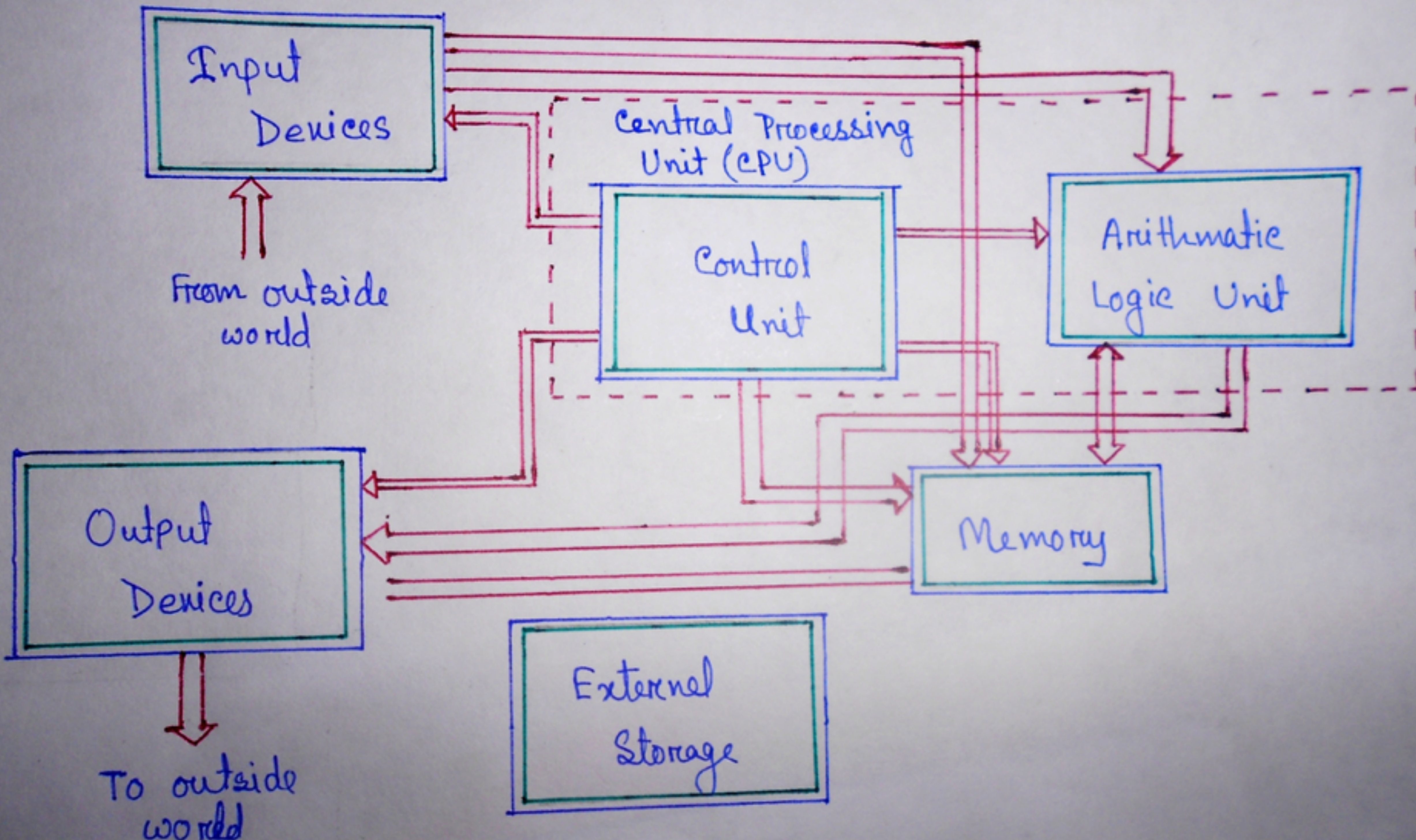


Fig: Basic Computer Organization

The CPU

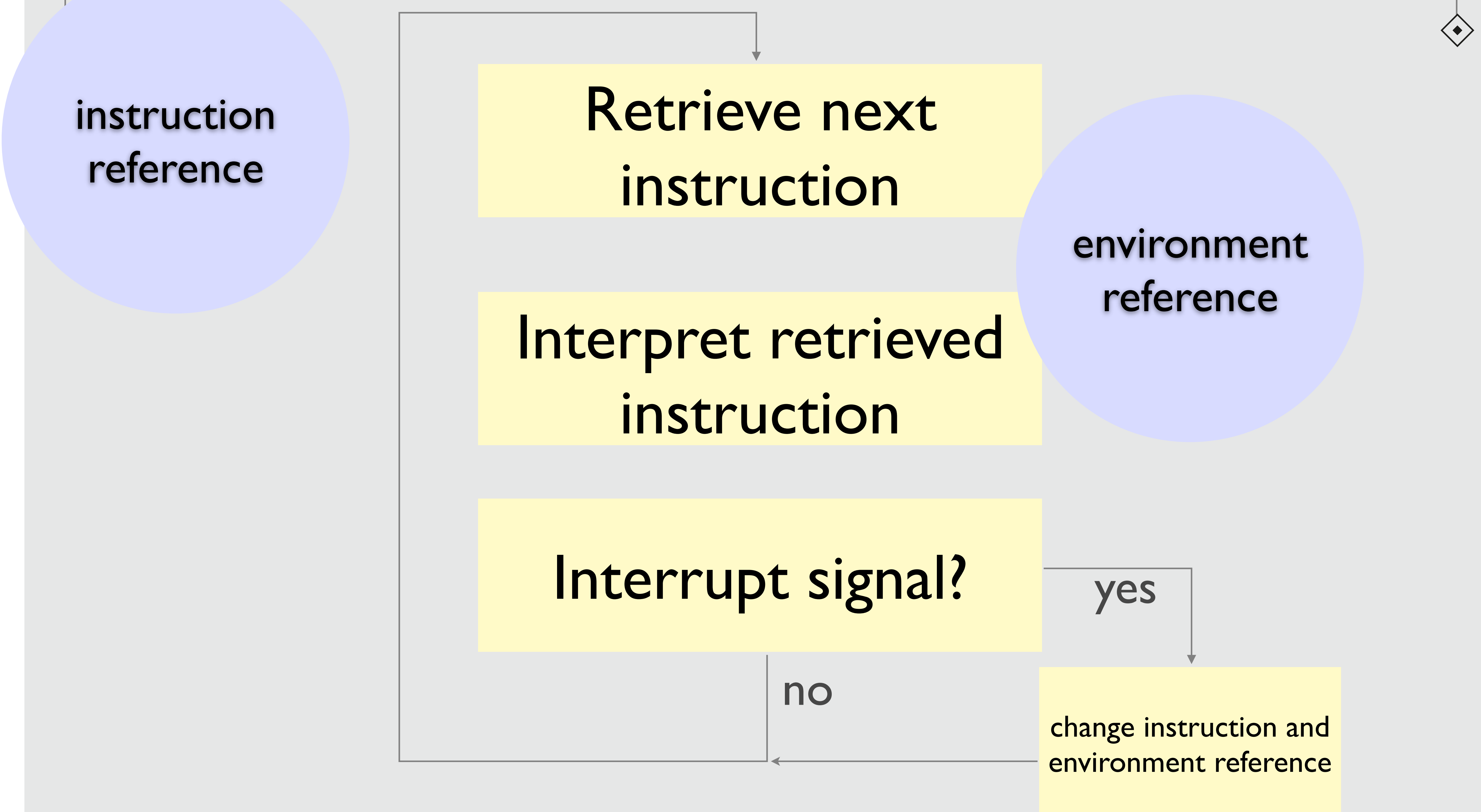
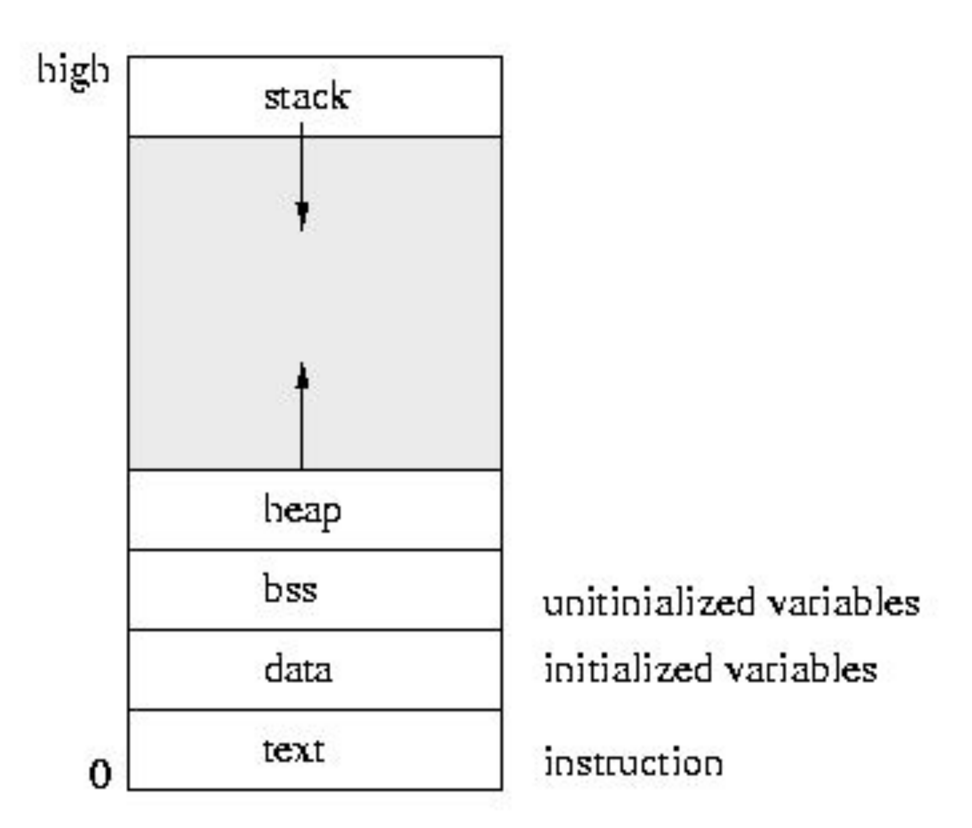


Diagram adapted from Saltzer & Kaashoek

At the hardware level

- The *program counter* is the instruction reference
  - A *program* is the instructions
  - contains address of memory location that stores next instruction
- Memory: Storage, the *stack*, the *page* table (virtual memory bindings), the registers



At the OS level

- A *process* is an instance of a program (code) in execution. In other words, it's … the same stuff on the previous slide, but applied to a single instance of a particular chunk of code running.
    - (You could have multiple processes running from the same program)
- Plus various operating system abstractions: open files, open sockets, etc.

Resource accounting and isolation!

Practical Stuff: Using processes

- Creating a new *process* (has its own memory): fork()
  - Makes an (almost) exact copy of calling process (PID changes, etc.)
  - How to tell difference? Return value is **0 in child**, child **PID in parent**. How?
  - Stack copied, but different value placed on top of each
- Executing a different *program*: exec()
  - Basically entirely **replaces** the process with a new one running the new program. But some things, maybe some file descriptors, *are* preserved.

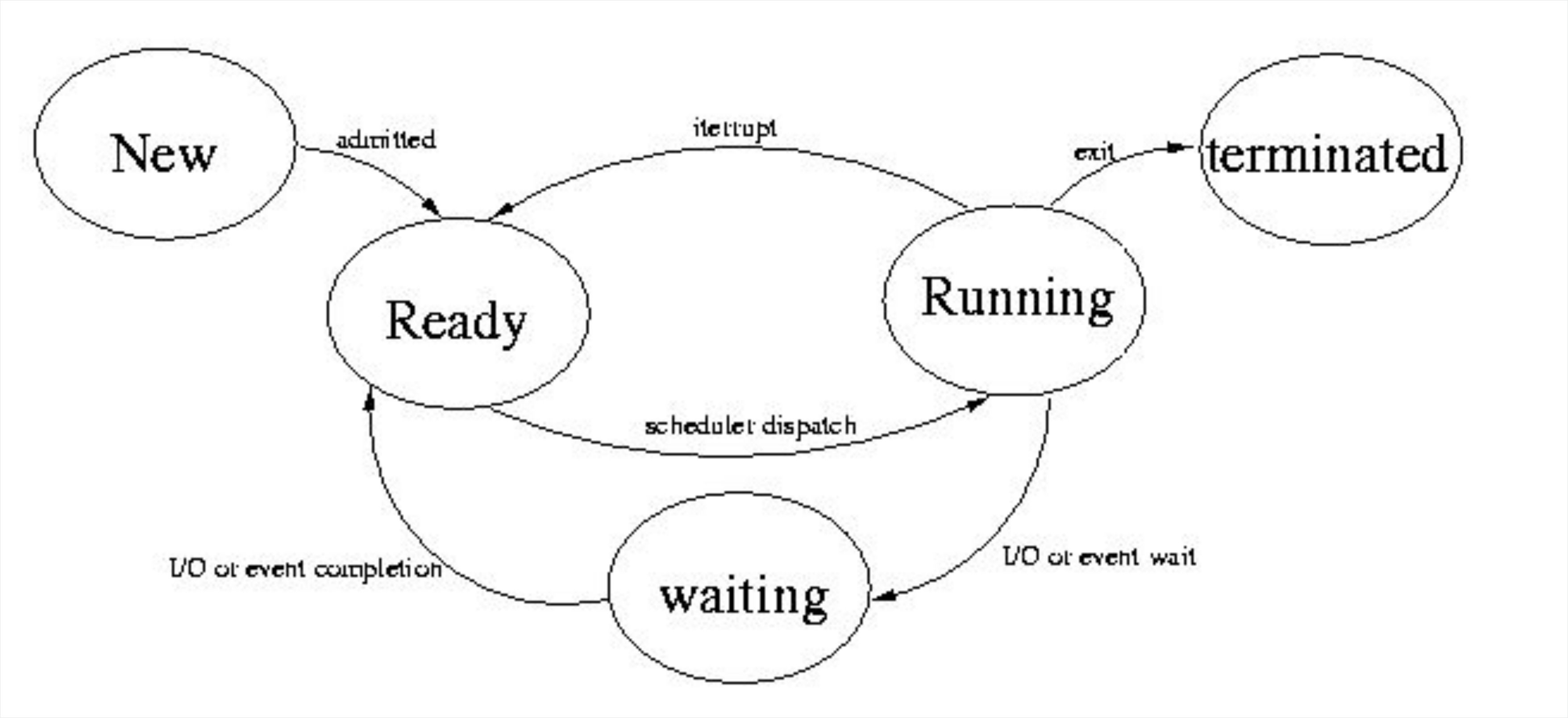
Cool internals: copy-on-write

- CoW is a useful, general technique that shows up all over in systems.
  - Mark parents' m
  - Have child *shar*
  - If either one wri … l raise an exception)
    - *Now* give the child its own copy of the page of memory someone was writing

```
std::string x("Hello");
std::string y = x;

fork();
printf(y);
 y += ", World!";
```

Tasks & Scheduling



Remember last time that a process "blocked" if it tried to send too much data to a TCP socket? "waiting"

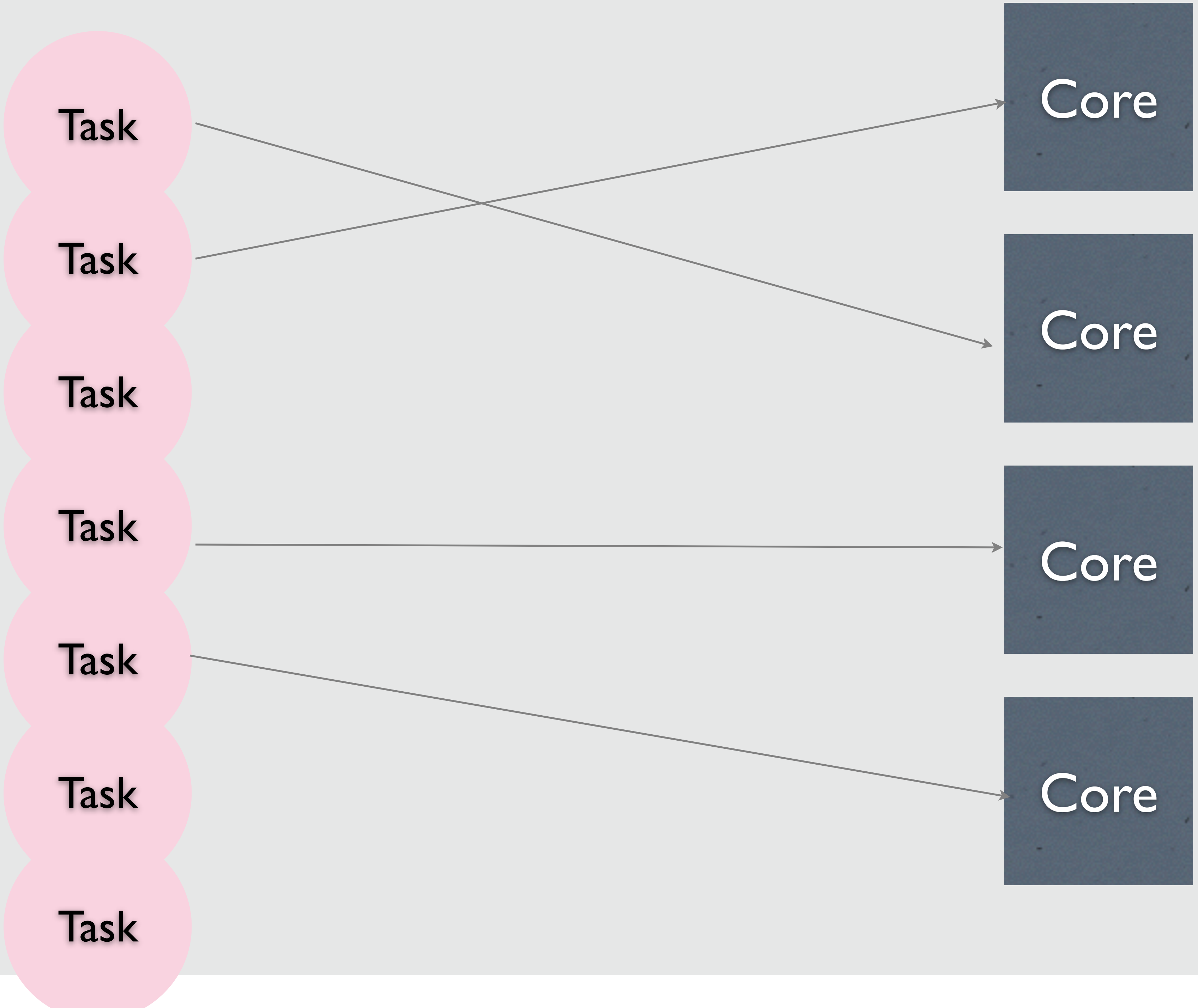
Resource sharing again!

Types of scheduling

MS Windows (< 95)
MAC OS (< MAC OS X)

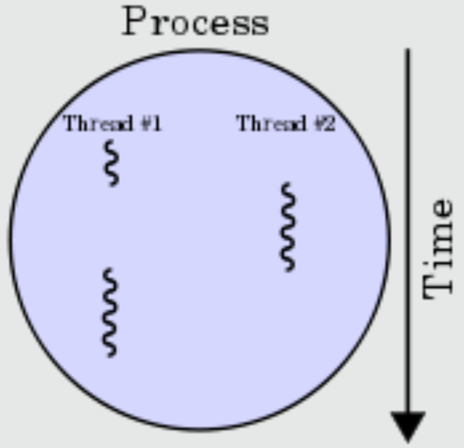
- Cooperative: one task explicitly *yields* to another
- Preemptive: some underlying management thingy (e.g., the OS) can forcibly switch which task is running. Prevents hogging, out of control tasks, etc.
- Food for thought:
  - Why would you ever want cooperative, then?
    - Think about real-time embedded systems (e.g., spacecrafts)

OS Scheduling



Threads

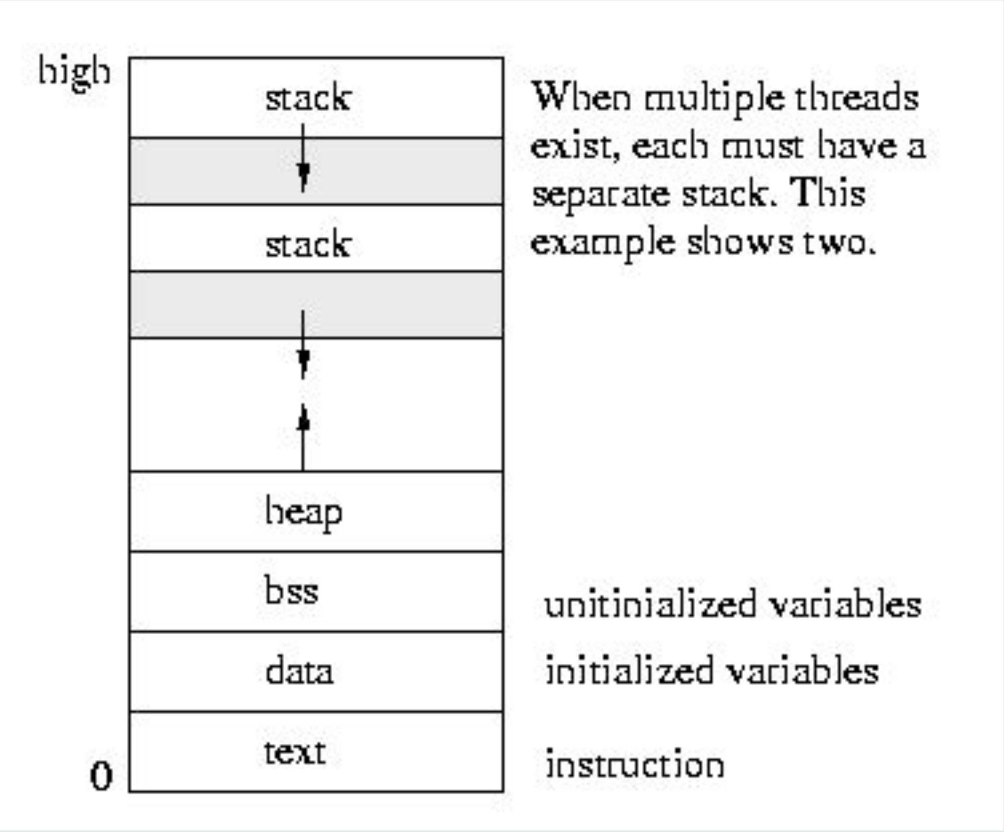
- A *thread* is, roughly, a task within a process
- There can be multiple threads within a single process
- A *process* is the unit of resource allocation (Threads don't have memory)



- Threads do have execution state, their own stack, etc.

figure from wikipedia

Threads in memory



Threads

- Threads share memory
- Handy! They can .. share stuff.
- Dangerous! They can .. muck stuff.

Why Threads?

- Switching between threads faster than switching between processes (don't have to change as much stuff around -- such as invalidating the page table cache)
- Creating and destroying is much cheaper than fork
- Provides convenient abstraction for chunking up work
  - Example: Assign a thread to handling an incoming request in a Web server
  - This use matches well to blocking semantics of posix
    - If we can't write to the socket, thread blocks, some other thread keeps running. That's cool - our thread doesn't *need* to do anything if it can't send to the client...
  - Though it isn't always the best way to do things, in practice

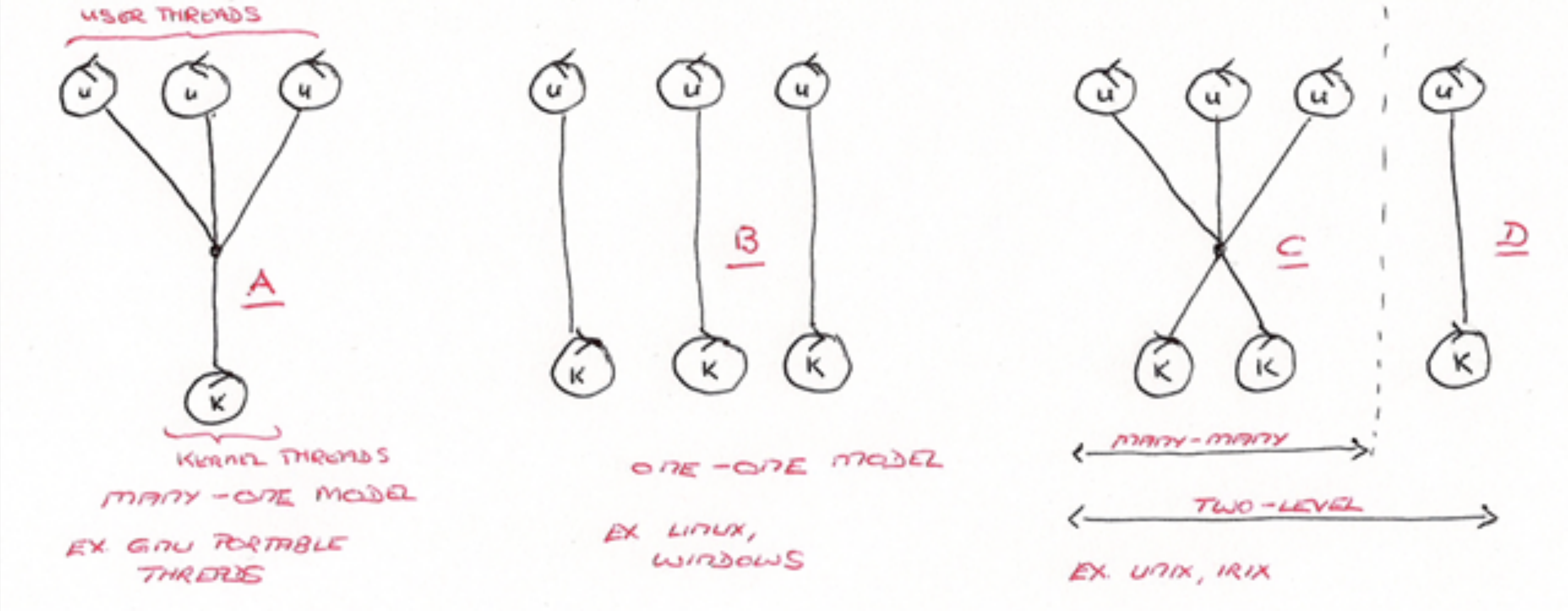
Why (at a higher abstraction)?

- Better responsiveness to users
- Resource sharing within the process
- Economy (less expensive than creating a process)
- Scalability
- make maximum use of new hardware platforms, such as multi cores

How threads?

- Well, that depends -- what do you want to accomplish?
- Early days: uniprocessor systems
  - Threads as a programming abstraction
  - This was source of many rollicking debates in system community about what abstraction was better. It got ridiculous and religious.
  - But no need for multicore foo like today, so…

User vs. Kernel threading models



MANY-ONE Model

- Maps user threads to one kernel thread
- Managed by a thread library in a user model
- If any thread makes a blocking system call, all other threads are blocked

ONE-ONE Model

- One user thread is mapped into one kernel thread

- Better concurrency and supporting for multiple blocking system calls

- Challenge is the high number of kernel threads, which can be taxing on the overall operating systems (scalability)

MANY-MANY Model

- The many-many model maps many user mode threads to a smaller or potentially equal number of kernel threads.
- The tax by kernel threads is lower
- Advantage of multiple system blocking calls is maintained in this mode

Hybrid Mode

- The model shown as D is a hybrid approach, based on the many-many model, but allowing user threads to directly hook to kernel threads

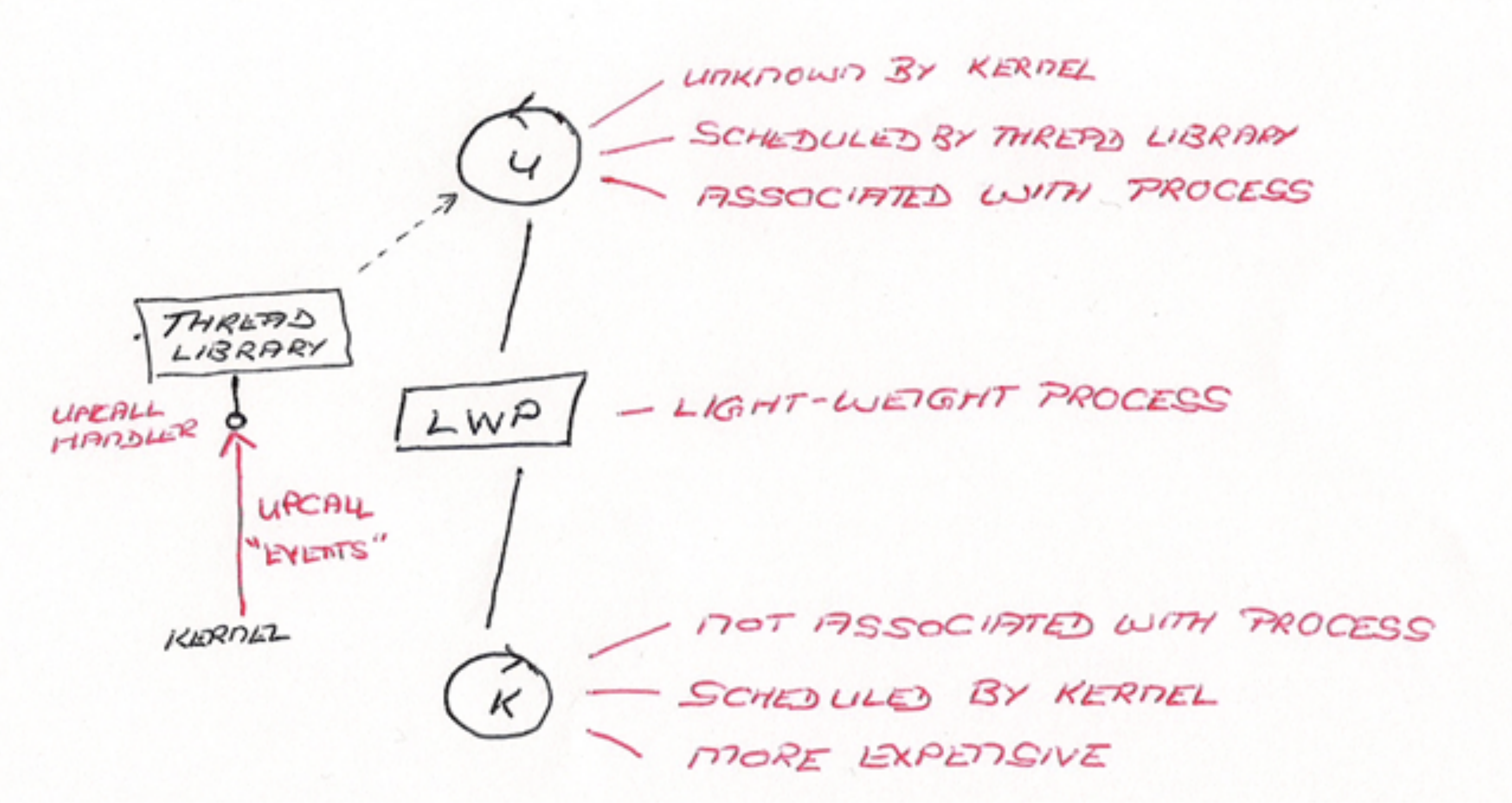
- Also referred as a two-level model

Advantages of User Threads

- Ridiculously fast thread switching.
  - Never even need to enter the kernel to switch threads.
- Provides a good abstraction.
- But…

- On an MP system, only one thread within a process can execute at the same time.
  - Even if the kernel can schedule multiple processes to run concurrently
- If any thread in a process makes a blocking system call, *all* threads will be blocked
  - Common example: Some DNS functions were not re-entrant, and some thread libs failed to mask them. A long DNS delay could hang process. Oops.
  - Not all system calls can be “checked” for blocking using *select*. Opening a file, e.g.
    - Why can this block???
    - Think about NFS… (revisit these slides after DFS)

Thread Scheduler



That said

- For simplicity, and as CPU gets cheaper and cheaper and the importance of maximally exploiting parallelism grows…
- more and more we’re seeing just kernel supported user threads
- But at other levels…
  - Many interpreted languages (ruby, python) provide user threads
  - Keeps things simpler (don’t have to write a parallel interpreter)
  - but you have to go multiple-process to use multicore.
  - (Sun wrote java and they’ve always liked SMP. Java uses native OS threads, so on sun, can use LWPs or user threads…)

Tasks in dist. systems

- May hear other terms:
  - "Workers" (*clients* that are assigned *jobs* by a *scheduler* of some sort)
  - "Master" (the node/task that hands out work)
- Mid-90s research looked at "remote fork" and similar primitives -- spawn a new task on some other computer. We'll look more at these abstractions later.