Housekeeping (Lecture 11 - 10/2/2013)

- Warmup #2 due at 11:45pm this Friday, 10/4/2013
  - if you have code from a previous semester, be very careful and *not copy any code from it*
    - it's best if you just get rid of it
- *Grading guidelines* is the *ONLY* way we will grade and we will grade on `nunki.usc.edu` in our grading account (which you don't have access to)
  - it's a good idea to run your code against the grading guidelines
- After submission, make sure you *Verify Your Submission*
- Have you installed *Ubuntu 11.10* on your laptop/desktop?
- Do you have partners for kernel assignments?
  - work with your potential partners for warmup 2
    - again, work at high level and must *not* share code

Housekeeping (Lecture 11 - 10/2/2013)

- Please do not address your post to the class Google Group to me (or the TA or the course producer)
  - if you post to the class Google Group, I will assume that it's not addressed to us (even if you copy us in the e-mail)
- We will not respond to posts to the class Google Group about the kernle assignments immediately
  - we will wait for at least 2 hours
    - this gives your classmates an opportunity to earn extra credits

Kernel Programming Assignments

Bill Cheng

http://merlot.usc.edu/cs402-f13

Kernel Programming Assignments

- Tom Doeppner's *weenix* source and binary code
  - provided as `weenix-assignment-1.0.7.tar.gz`
  - incomplete
  - contains code like:

```
NOT_YET_IMPLEMENTED("PROCS: bootstrap");
```

assignment name → PROCS

function name → bootstrap

    - your job is to implement these functions by replacing these lines with your code
      - please replace them *in-place*
  - to look for such code:

```
grep PROCS: kernel/*.c
grep PROCS: kernel/*/*.c
grep PROCS: kernel/*/*/*.c
grep PROCS: kernel/*/*/*/*.c
```

Download and Setup

```
% gunzip -c weenix-assignment-1.0.7.tar.gz | \
        tar xvf -
% cd weenix-assignment-1.0.7/weenix
% make clean
% make
% ./weenix -n
```

- if all goes well, you should see tons of stuff fly by and the following at the bottom of the console:

```
Not yet implemented: PROCS: bootstrap, file
    main/kmain.c, line 127
panic in main/kmain.c:129 bootstrap():
    weenix returned to bootstrap()!!! BAD!!!

Kernel Halting.
```

- Make sure you have tried the above this weekend
  - any problem, let us know ***NOW***

Documentation

- The `weenix` documentation is in `doc/latex/documentation.pdf`
  - introduces `weenix` to you
  - detailed instructions on assignments
  - you must read it thoroughly
- We are doing three of the assignments
  - *Processes and Threads (PROCS)*
  - *Virtual File System (VFS)*
  - *Virtual Memory (VM)*
- We are *not* doing two of the assignments
  - Drivers (DRIVERS)
  - System V File System (S5FS)
  - these are done for you and they are compiled and provided as libraries
    - `kernel/libdrivers.a` and `kernel/libs5fs.a`

Compilation and Configuration

- `Config.mk` controls what gets compiles and configured into the kernel
  - for PROCS, use the original `Config.mk`
    - set `DRIVERS` to 1 to complete this assignment
  - for VFS, set `DRIVERS` and `VFS` to 1
  - for VM, set `DRIVERS`, `VFS`, `S5FS`, and `VM` to 1
    - set `VM` to 0 at the beginning to get `kernel/mm/pframe.c` working
    - then set `VM` to 1 to work on the rest of the assignment
    - set `DYNAMIC` to 1 in the end if everything is working

- Modify `Config.mk` first, then do:

```
% make clean
% make
% ./weenix -n
```

- Use the debugger *right away*!

```
% ./weenix -n -d gdb
```

Debugging

- Use the debugger *right away*!

```
% ./weenix -n -d gdb
```

  - unfortunately, when you do the above, you won't see kernel debugging messages

```
% ./weenix -n -d gdb
```

- To see kernel debugging messages AND debug the kernel, do:
  - set `GDB_WAIT` to 1 in `Config.mk` then recompile kernel
  - run `weenix` under gdb with:

```
% ./weenix -n -d gdb -w
```

  - unfortunately, if you want to run *without gdb*, `weenix` will *hang*
    - you have to set `GDB_WAIT` back to 0 and recompile if you want to run `weenix` without gdb
    - you should set `GDB_WAIT` back to 0 when you submit your assignment for grading

Submissions

- Electronic submissions only with `bsubmit`
- Processes and Threads (PROCS)
  - need to fill out `procs-README.txt`, it's your assignment documentation
    - this is where you should include
      1) how to split the points (in terms of percentages and must sum to 100%)
      2) brief justification about the split

```
% make procs-submit
tar cvzf procs-submit.tar.gz \
        Config.mk \
        procs-README.txt \
        ...
```

    - your must add the required information about what you have implement in `procs-README.txt` as well
  - `scp` or `sftp` `procs-submit.tar.gz` to `nunki/aludra` and run `bsubmit` there

Submissions

- Virtual File System (VFS)
  - need to fill out `vfs-README.txt`

```
% make vfs-submit
...
```

- Virtual Memory (VM)
  - need to fill out `vm-README.txt`

```
% make vm-submit
...
```

- Submit source code only
  - we will deduct 2 points if you submit binary files
  - we will deduct 2 points if you submit unmodified files
  - we will deduct 2 points if you do not keep the same directory structure

Verify Your Submission

- Assume that in your home directory, you have
  - a *pristine* `weenix-assignment-1.0.7.tar.gz`
  - your submission file, e.g., `procs-submit.tar.gz`
- Do the following to verify your submission

```
% rm -rf /tmp/xyzzy
% mkdir /tmp/xyzzy
% cd /tmp/xyzzy
% gunzip -c ~/weenix-assignment-1.0.7.tar.gz | \
          tar xvf -
% cd weenix-assignment-1.0.7/weenix
% gunzip -c ~/procs-submit.tar.gz | tar xvf -
% make clean
% make
% ./weenix -n
```

Grading Guidelines

- For *every function* you need to implement, you need to think about its pre-conditions and post-conditions
  - you need to add `dbg()` and `KASSERT()` statements to show:
    1) you understand what a function is suppose to do
    2) what the important pre-conditions and post-conditions are
  - see grading guidelines for required `KASSERT()` statements
    - right after `KASSERT()`, prefix string in `dbg()` with `"(GRADING# X.Y)"`, where X and Y are from grading guidelines and # is the kernel assignment number
- You need to show us that you have thoroughly verified that your code works
  - turn in additional code or procedure and document how to enable/use these tests
  - it's okay if this is similar to our test code
- Run your code with additional test code from us
  - we will make suggestions in the grading guidelines

Backing Up Your Work & Collaboration

- You *have to* have a plan to *backup your code* and backup routinely
  - if you lose your work, there's nothing we can do
- Ubuntu 11.10 comes with "Ubuntu One"
  - free (up to 5GB) personal cloud
  - set one up for your group
    - all group members can sync with Ubuntu One
    - create a directory called `cs402backup` under `~/Ubuntu One`
- One simple way to backup your work
  - at the end of each day, do (for example, if today is 10/01/13):

```
% make procs-submit
% mv procs-submit.tar.gz procs-100213.tar.gz
% cp procs-100213.tar.gz ~/Ubuntu\ One/cs402backup
```

  - make sure only one person does this, or you will wipe out your partner's backup
  - can do backups more often if you'd like
    - `procs-100213-[time].tar.gz`

Backing Up Your Work & Collaboration

- You should use `git` to collaborate among project partners
  - read "Pro Git" (a free online book, one of our textbooks)
- But you need a shared repository in the cloud
  - there are free `git` repositories on the web
    - unfortunately, most of the free ones are required to be visible by the world - you must ***not*** use these
    - if you can find one that can be setup such that only you and your partners can see it, then you can use it
  - may be you can use ***Ubuntu One*** as your repository
    - the course producers will share their experience
- If you have two people working on the same file and then update the repository one after another
  - `git` will attempt to merge the changes, but it may not be what you want
  - may be it's best to ***coordinate*** and not have two pepole modifying the same file

Early and Late Policies

- Similar to warmup projects

Extra Credit

- You can get extra credit for posting good, useful, and insightful answers to the class Google Group in response to questions posted by other students regarding ***kernel*** programming assignments
  - the maximum number of extra credit points you can get is ***10*** points for each of the kernel assigments (on a 100-point scale)

How Do You Start?

- Definitely start with the documentation
- Read code, read lots and lots of code
  - try things out and see what happens (debugging statements)
  - you need to *absorb* other people's code, make sense of it
  - that's what OS hacking (in the good sense) is all about
    - it's *not* about "implementing an OS"
- It's the *process* that matters
  - *not* the *answers*
  - it's about learning how to figure out *which* 2 or 3 lines (or 20 or 30 lines) of code to insert and *where*
- So, it needs to be experienced
  - you should not expect quick/straight answers
  - this is not an OS hacking class
- Learning to write OS code is like...

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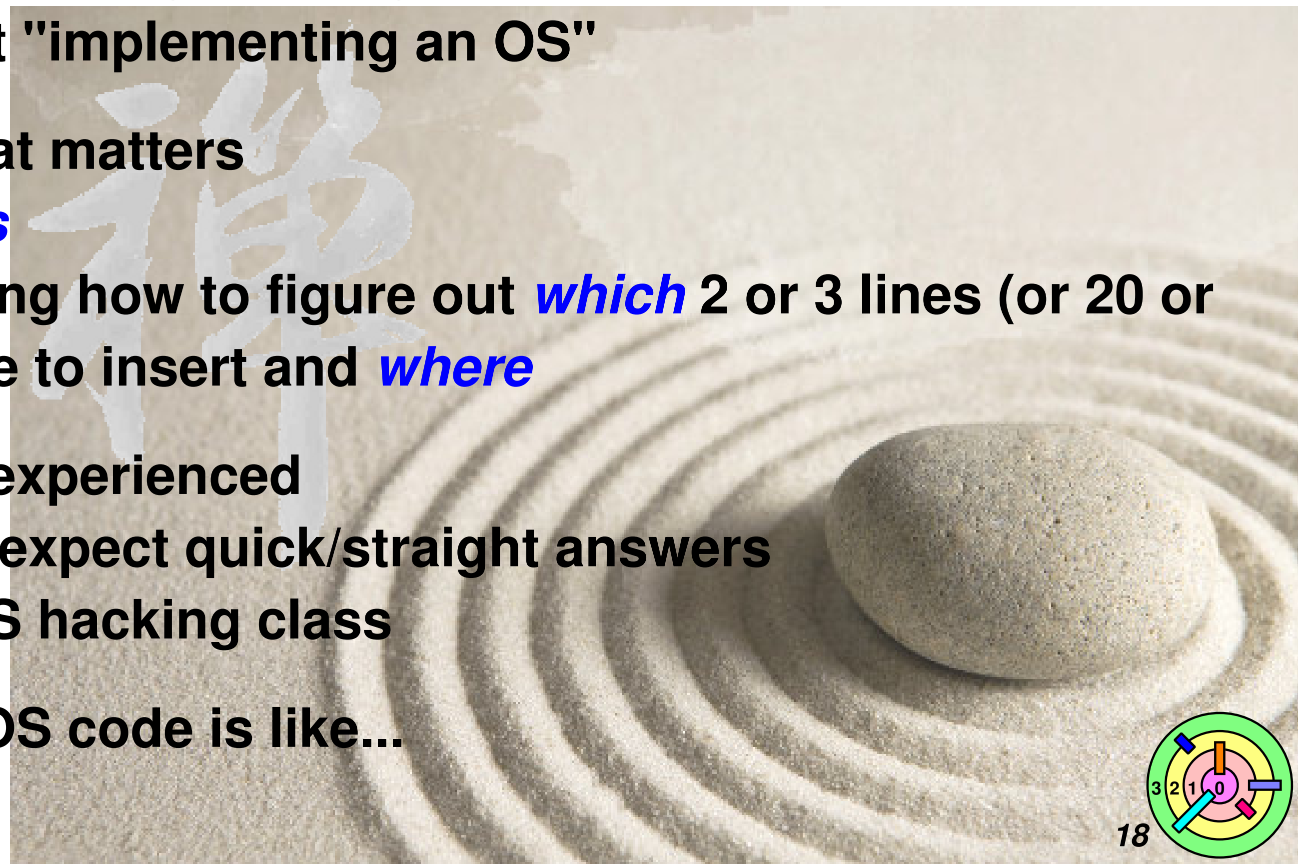
  - this is not an OS hacking class
- Learning to write OS code is like...
  - *Zen*



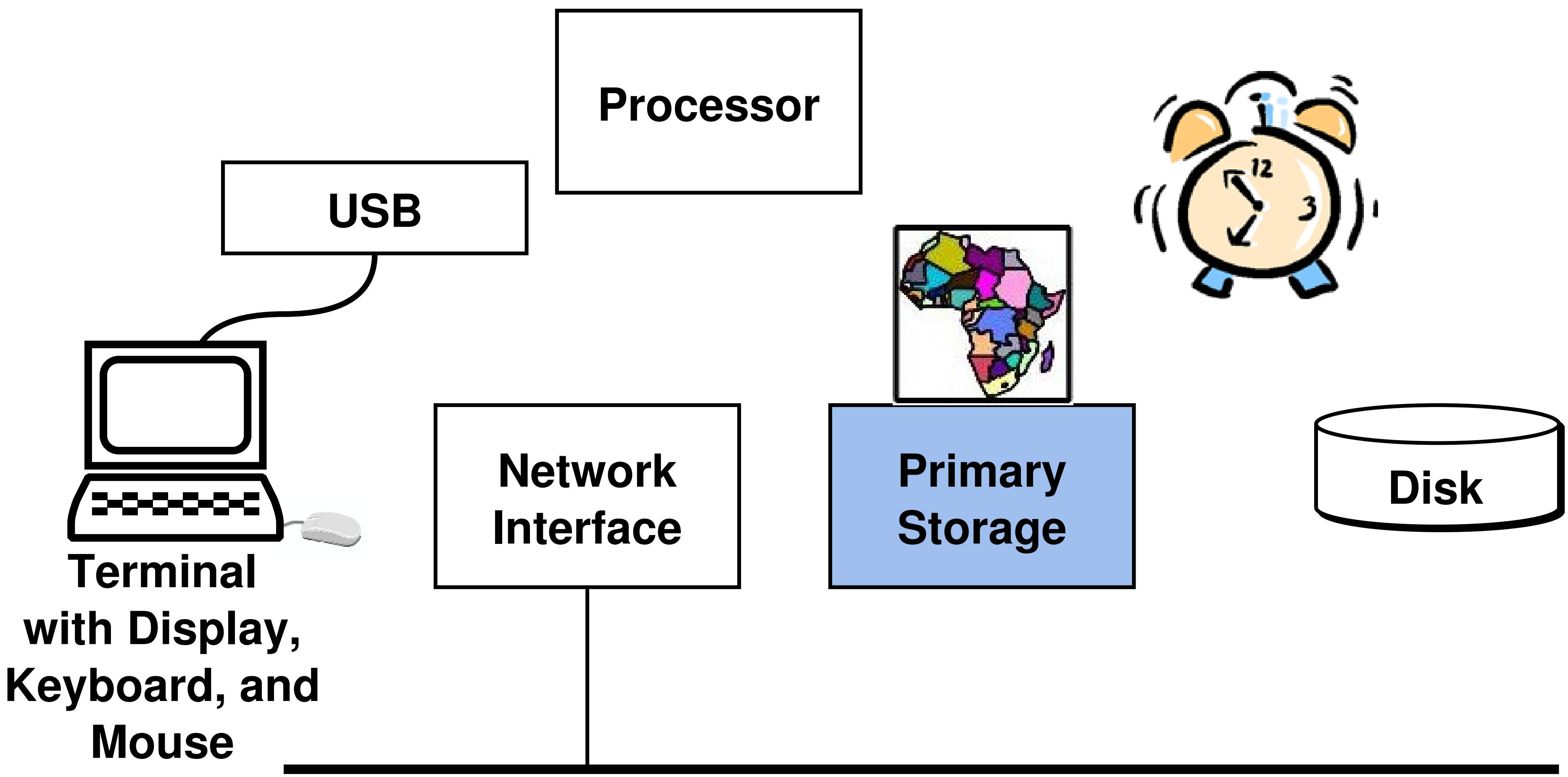
Getting Help

- If you have questions about the kernel assignments
  - read documentation, textbook, lecture slides, read more code
  - post your questions to the class Google Group
    - we will not immediately answer these questions to give your classmates an opportunity to earn extra credit points
      - we will wait 2 hours
    - if you send us questions about the assignments directly, we may simply forward your post to the class Google Group

OS Design Issues

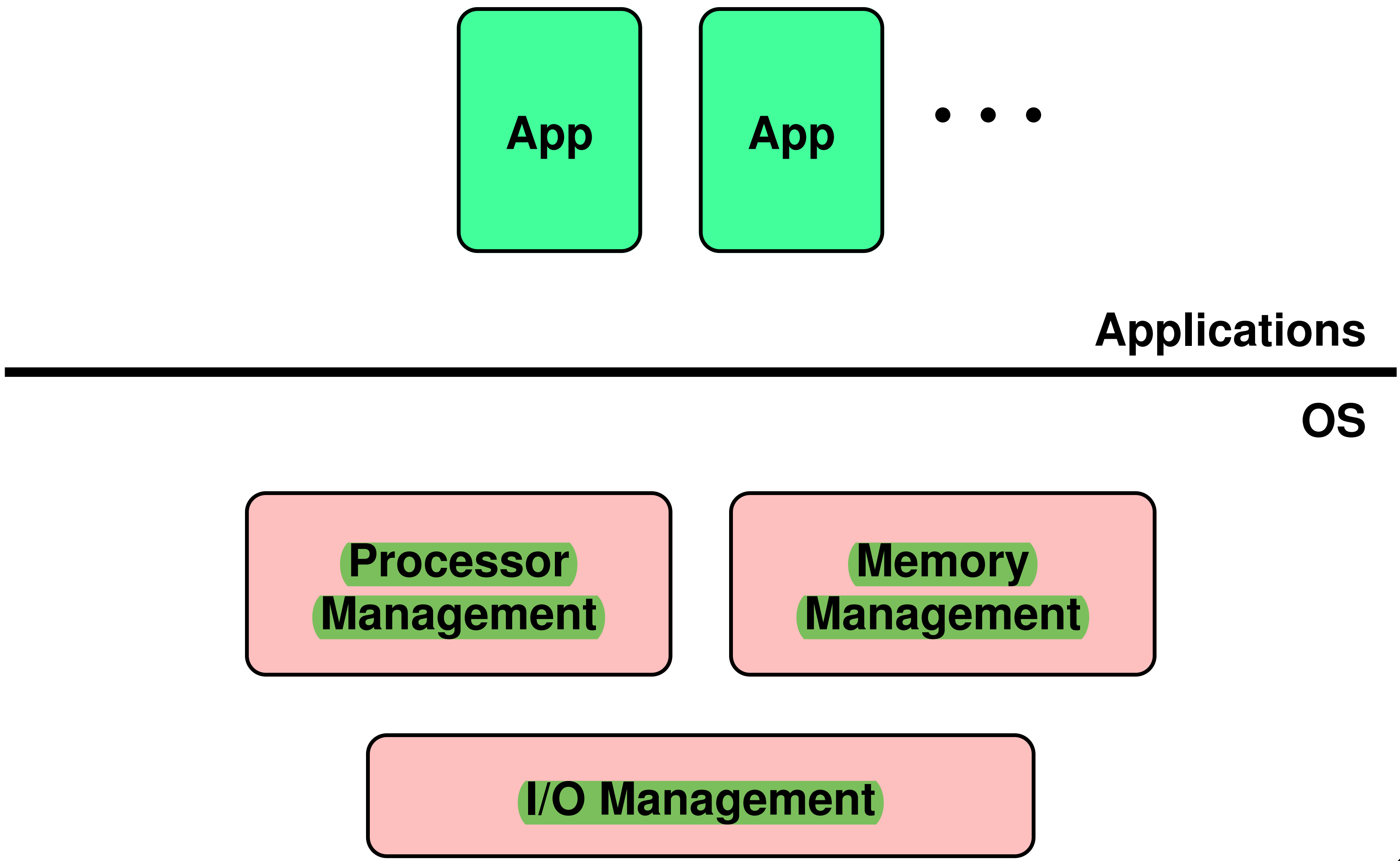
- **Performance**
  - efficiency of application
- **Modularity**
  - tradeoffs between modularity and performance
- **Device independence**
  - for new devices, don’t need to write a new OS
- **Security/Isolation**
  - isolate OS from application

Simple Configuration

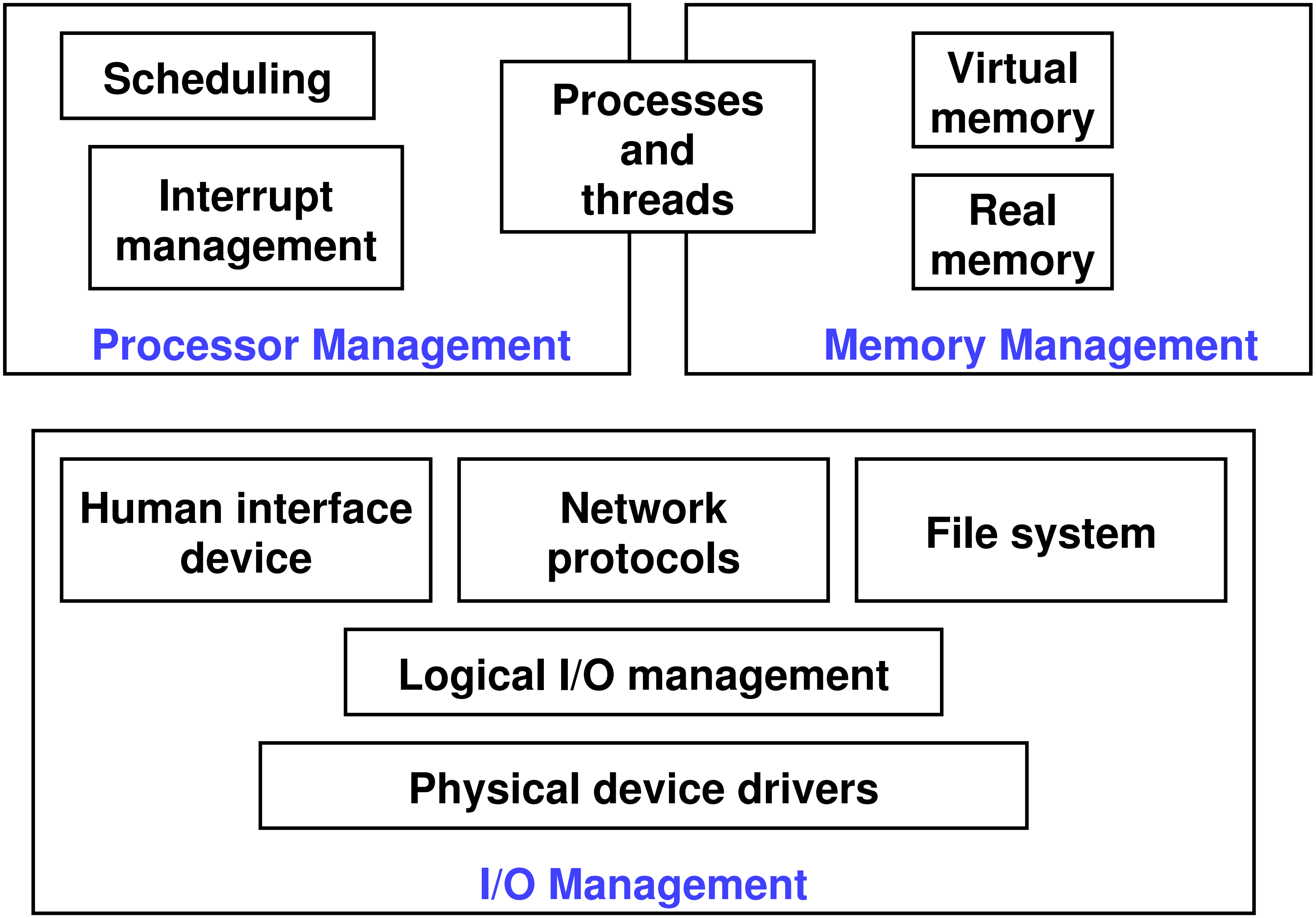


- Early 1980s OS, so we can focus on the basic OS issues
  - no support for bit-mapped displays and mice
  - generally less efficient design

OS Components



OS Components



OS Components

Scheduling

Interrupt management

Processes and threads

Processor Management

Virtual memory

Real memory

Memory Management

Human interface device

Network protocols

Logical I/O management

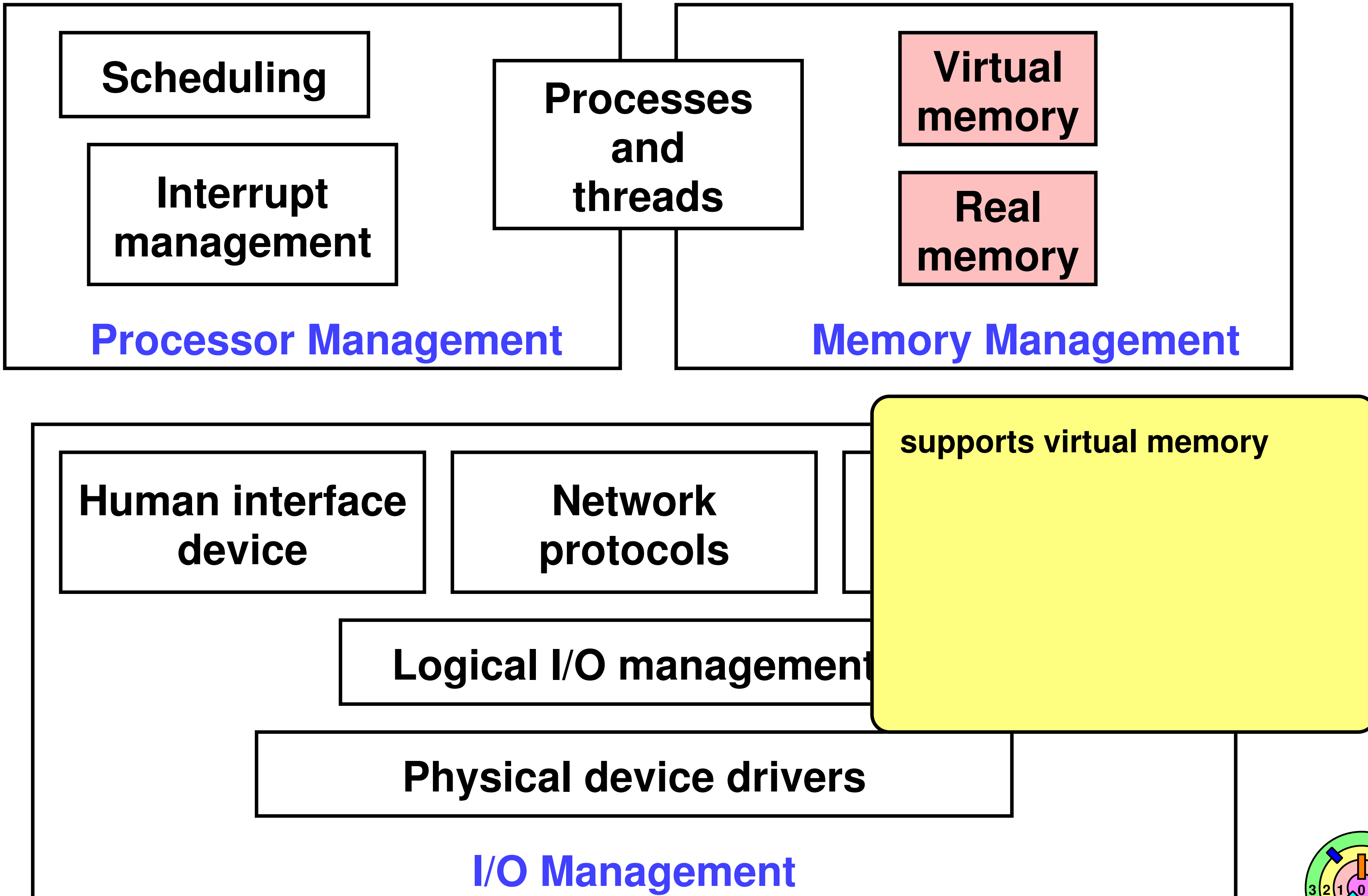
Physical device drivers

I/O Management

supports multithreaded processes

- each process has its own address space

OS Components



OS Components

Scheduling

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Physical device drivers

I/O Management

theads executing is multiplexed on a single processor

- by a simple time-sliced scheduler

OS Components

has a file system
- layered on disks

Processes and threads

...ent

Virtual memory

Real memory

Memory Management

Human interface device

Network protocols

File system

Logical I/O management

Physical device drivers

I/O Management

OS Components

Scheduling

Interrupt management

Processes and threads

Processor Management

Me

user interacts over a terminal

- text interface (typically 24 80-character rows)
- every character typed on the keyboard is sent to the processor

Human interface device

Network protocols

File system

Logical I/O management

Physical device drivers

I/O Management

OS Components

Scheduling

Interrupt management

Processes and threads

Processor Management

communication over Ethernet using TCP/IP

Me

Human interface device

Network protocols

File system

Logical I/O management

Physical device drivers

I/O Management

Applications

- How does an *application* view these OS components?
- From an application program's point of view, our system has:
  - processes with threads
  - a file system
  - terminals (with keyboards)
  - a network connection
- Need more details on these components... Need to look at:
  - how applications use them
  - how this affects the design of the OS

Processes And File Systems

- The purpose of a *process*
  - holds an *address space*
  - holds a group of *threads* that execute within that address space
  - holds a collection of references to *open files* and other *"execution context"*
- *Address space:*
  - set of addresses that threads of the process can usefully reference
  - more precisely, it's the content of these addressable locations
    - text, data, bss, dynamic, stack regions and what's in them

Processes And File Systems

- **Design issue:**
  - how should the OS *initialize* these address space regions?
- **Simple approach: copy their contents from the file system to the process address space (as part of the *exec* operation)**
  - quite wasteful (both in space and time) for the text region since it's read-only data
    - should *share* the text region
  - what about data regions? they can potentially be written into
    - can also *share* a portion of a data region if that portion is never modified

Remember This?

- ***Virtual Memory*** **(using *memory maps*)**

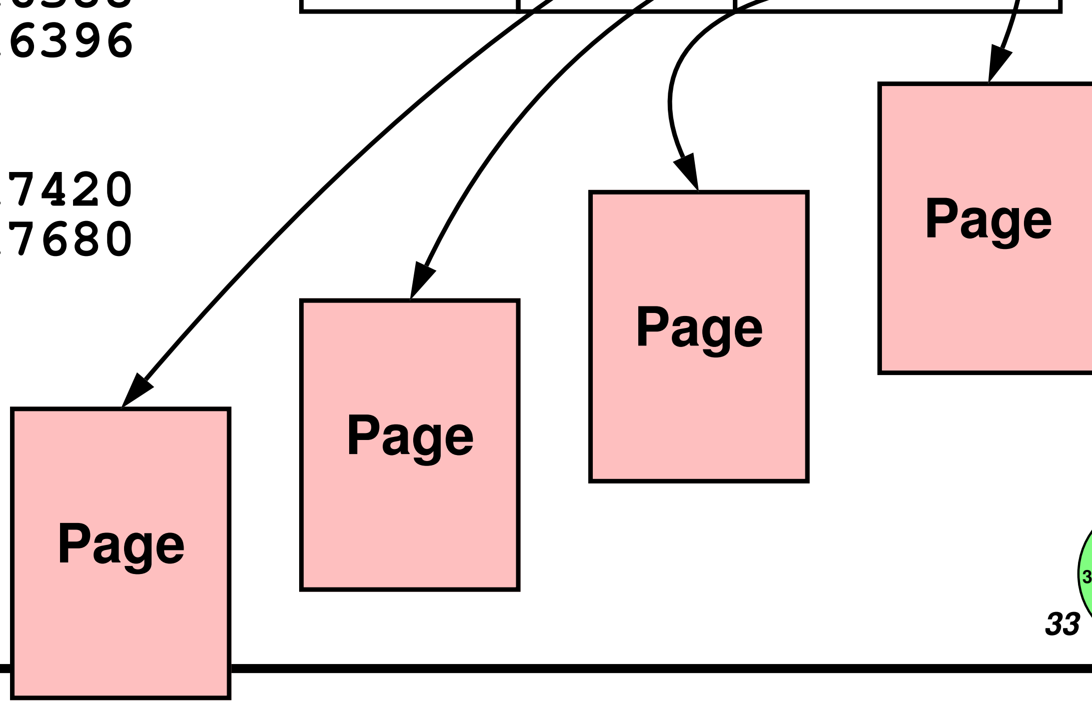
```
Text
   main           4096
   subr           4132
   printf         4156
   write         16156
   startup       16172

Data
   aX            16384
   printfargs    16388
   StandardFiles 16396

BSS
   X             17420
   errno         17680
```

Page Table

Start	*Access*	*Physical Addr*
0	-	-
4096	R	•
8192	R	•
12288	R	•
16384	R/W	•



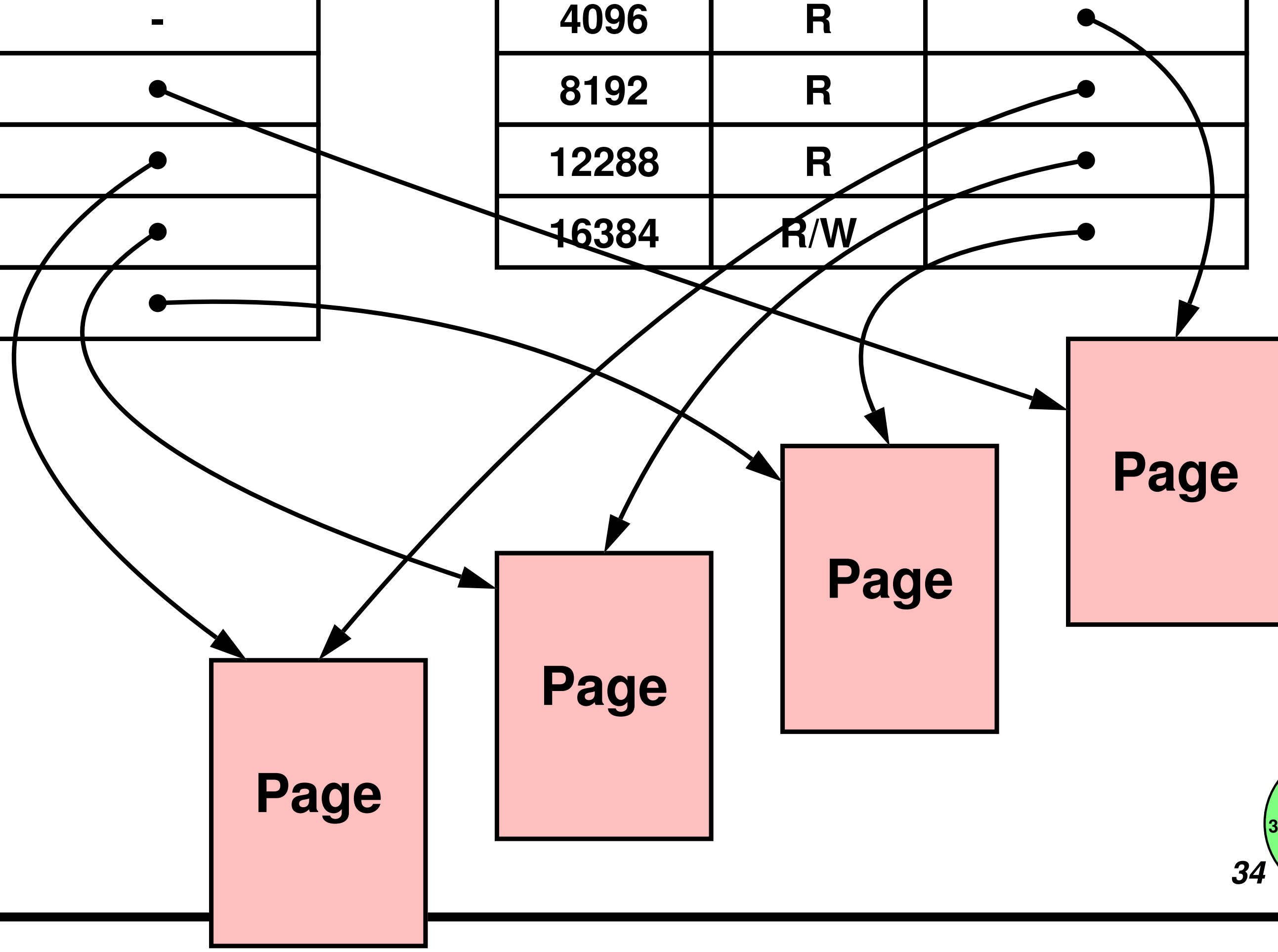
Processes Can Share Memory Pages

Process 2 Page Table

Start	*Access*	*Physical Addr*
0	-	-
4096	R	•
8192	R	•
12288	R	•
16384	R/W	•

Process 1 Page Table

Start	*Access*	*Physical Addr*
0	-	-
4096	R	•
8192	R	•
12288	R	•
16384	R/W	•



Processes And File Systems

- **For the text region, why bother copying the executable file into the address space in the first place?**
  - can just *map* the file into the address space (Ch 7)
    - *mapping* let the OS *tie* the regions of the address space to the file system
    - address space and files are divided into pieces, called *pages*
    - if several processes are executing the same program, then at most one copy of that program's text page is in memory at once
  - *text regions* of all processes running this program are setup, using hardware address translation facilities, to share these pages

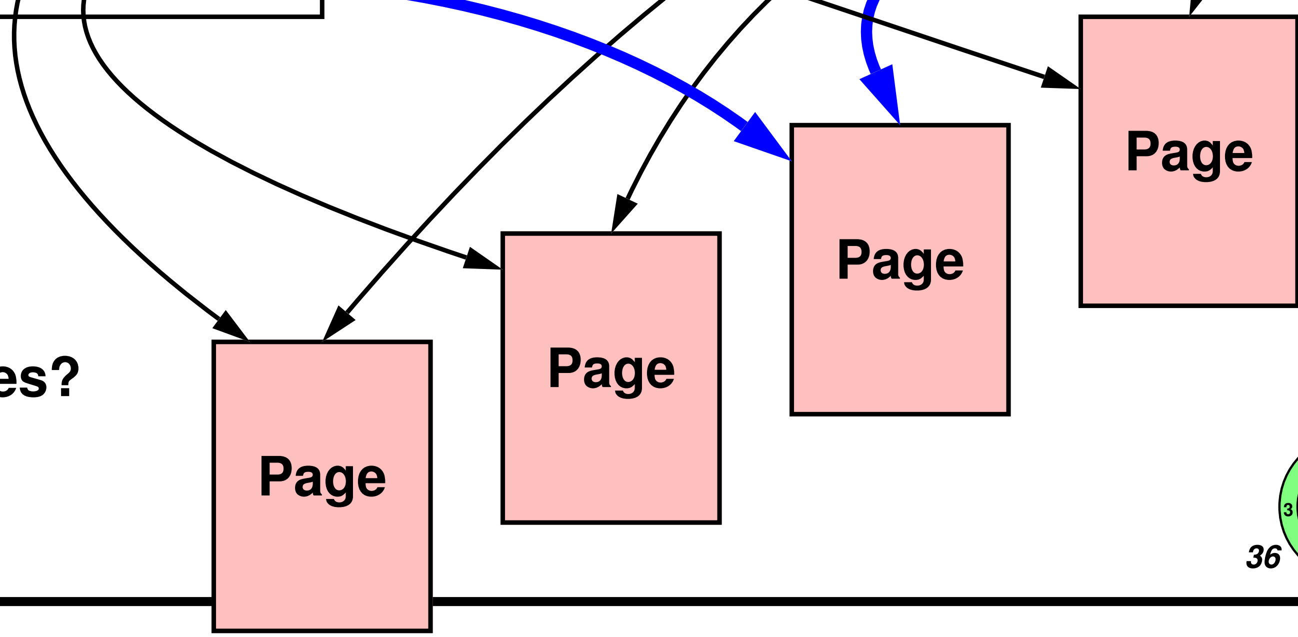
Processes Can Share Memory Pages

Process 1 Page Table

Start	*Access*	*Physical Addr*
0	-	-
4096	R	•
8192	R	•
12288	R	•
16384	R/W	•

Process 2 Page Table

Start	*Access*	*Physical Addr*
0	-	-
4096	R	•
8192	R	•
12288	R	•
16384	R/W	•



- can we really share ***data segment*** pages?

Processes And File Systems

- *Data regions* of all processes running this program *initially* refer to pages of memory containing a copy of the *initial* data region
  - this type of mapping is *private mapping*
    - when does each process really need a private copy of such a page?
    - when data is *modified* by a process, it gets a *new* and *private* copy of the initial page

Processes And File Systems

- *Copy-on-write (COW)*:
  - a process gets a *private* copy of the page after a thread in the process performs a *write* for the first time
    - the basic idea is that only those pages of memory that are modified are copied
- The BSS and stack regions use a special form of private mapping
  - their pages are initialized, with zeros; *copy-on-write*
    - known as *anonymous objects* in `weenix`
- If a bunch of processes share a file
  - we can also map the file into the address space
  - in this case, the mapping is *shared*
  - when one process modifies a page, no private copy is made
    - instead, the original page itself is modified
    - everyone gets the changes
    - and changes are written back to the file
      - more on issues in Ch 6

Block I/O vs. Sequential I/O

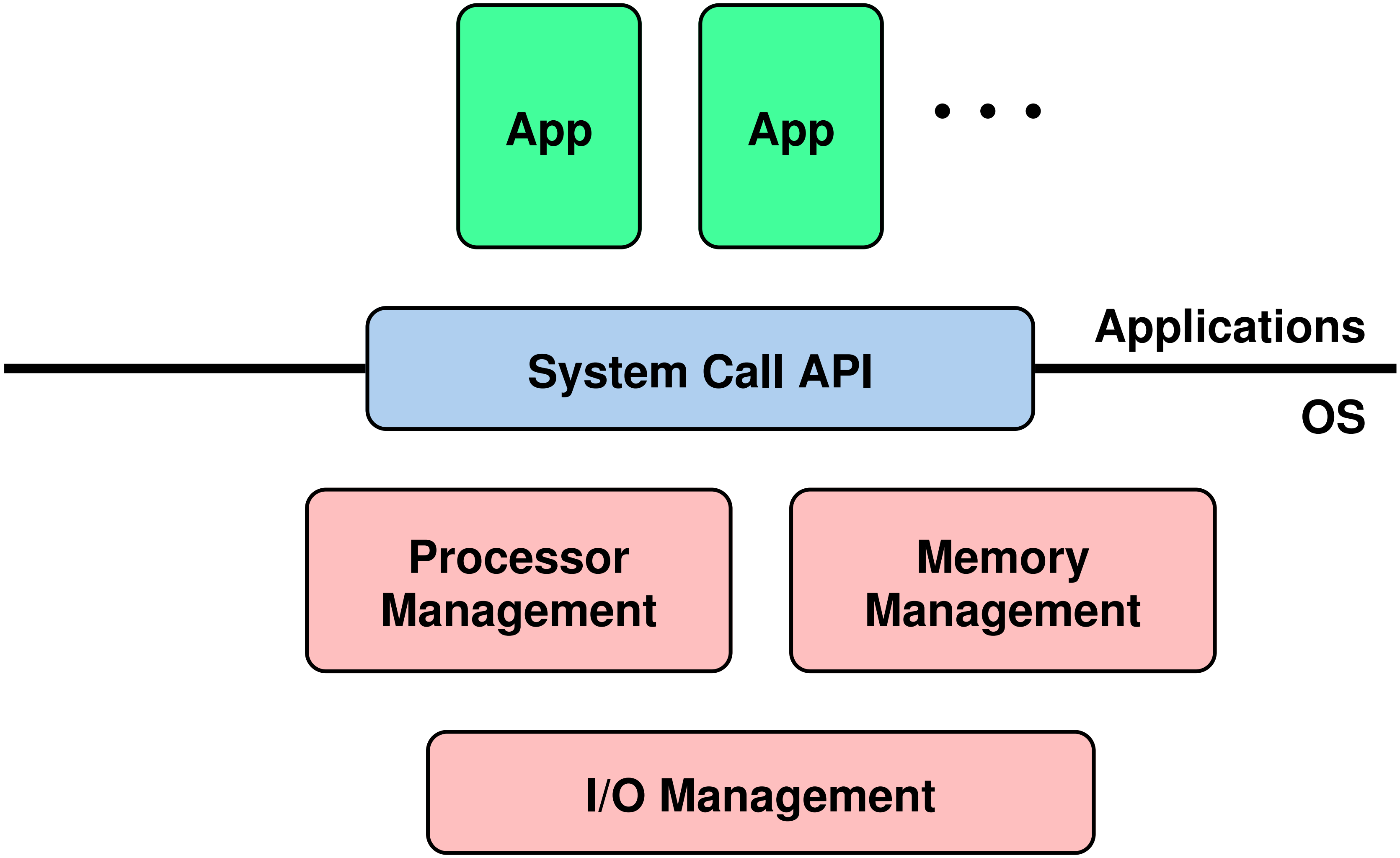
- Mapping files into address space is one way to perform I/O on files
  - block/page is the basic unit
  - this is referred to as *block I/O*
- Some devices cannot be mapped into the address space
  - e.g., receiving characters typed into the keyboard, sending a message via a network connection
  - need a more traditional approach using explicit system calls such as `read()` and `write()`
  - this is referred to as *sequential I/O*
- It also makes sense to be able to read a file like reading from the keyboard
  - similarly, a program that produces lines of text as output should be able to use the same code to write output to a file or write it out to a network connection
  - makes life easier! (and make code more robust)

A Simple System: To Be Discussed

- What is the functionality of the components?
- What are the key data structures?
- How is the system broken up into modules?
- To what extent is the system extensible?
- What parts run in the OS kernel in privileged mode? What parts run as library code in user applications? What parts run as separate applications?
- In which execution contexts do the various activities take place?
  - e.g., thread context vs. interrupt context

System Call API

- Backwards compatibility is an important issue
  - try not to change it much (to make the developers happy)



4.1 A Simple System (Monolithic Kernel)

- *A Framework for Devices*
- Processes & Threads
- Storage Management
- Low-level Kernel (will come back to talk about this after Ch 7)

Computer Terminal

- VT100

A "tty"

Devices

- Challenges in supporting devices
  - device independence
  - device discovery

- Device naming
  - two choices
    - independent name space (i.e., named independently from other things in the system)
    - devices are named as files

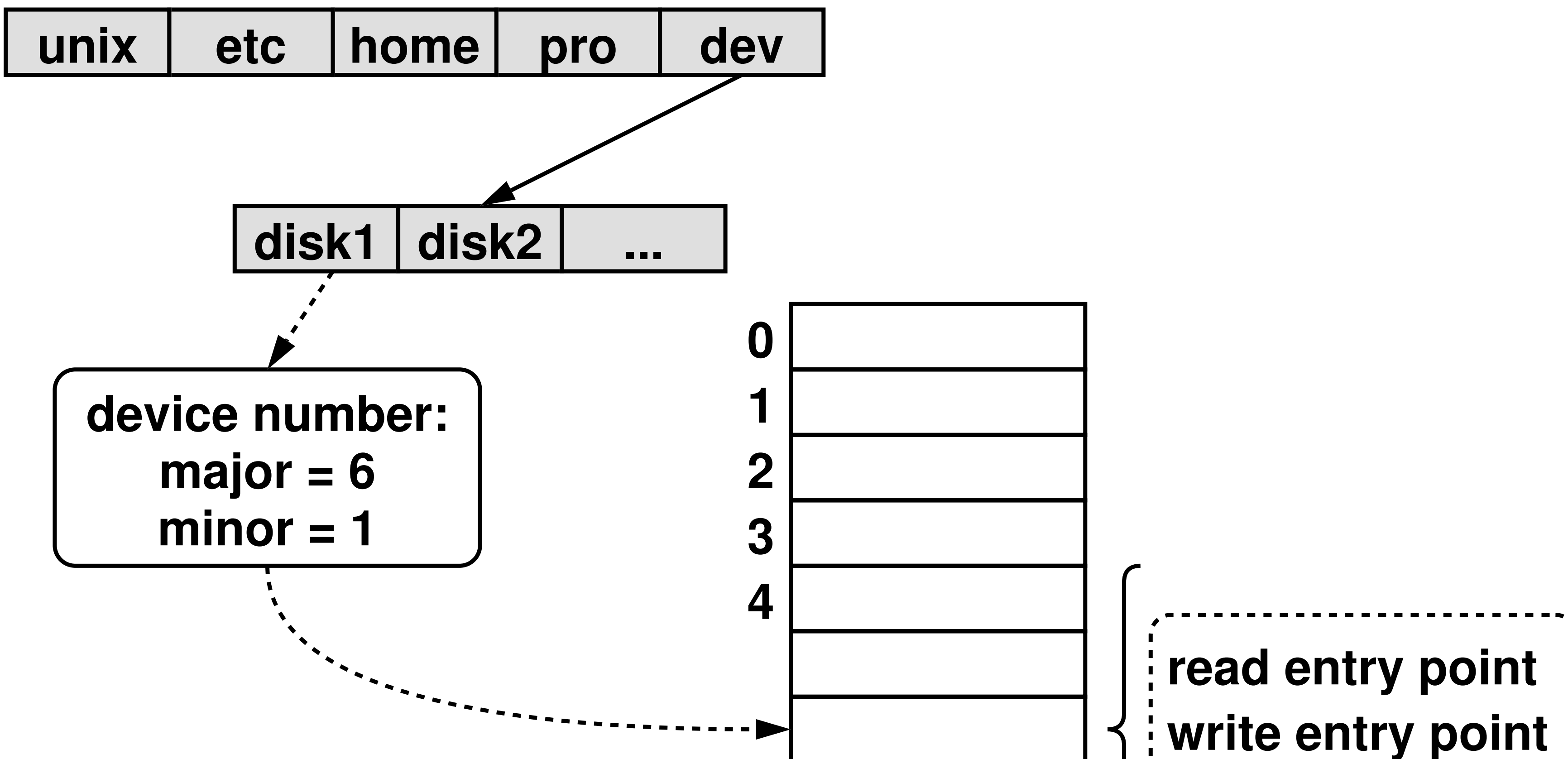
A Framework for Devices

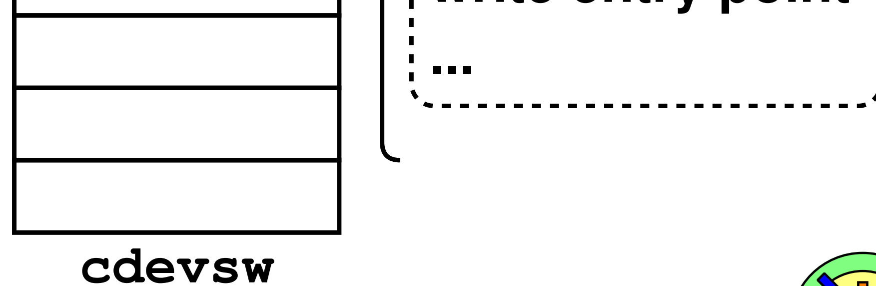
- Device driver:
  - every device is identified by a device "number", which is actually a pair of numbers
    - a *major device number* - identifies the device driver
    - a *minor device number* - device index for all devices managed by the same device driver

- Special entries were created in the file system to refer to devices
  - usually in the `/dev` directory
    - e.g., `/dev/disk1`, `/dev/disk2` each marked as a *special file*
      - a *special file* does not contain data
      - it refers to devices by their major and minor device numbers
      - if you do "`ls -l`", you can see the device numbers

- Data structure in the early Unix systems
  - statically allocated array in the kernel called `cdevsw` (character device switch)

Finding Devices





- entries in `cdevsw` contains addresses of the device driver entry points
  - a device driver maintains its own data structure

Device Drivers in Early Unix Systems

- The kernel was statically configured to contain device-specific information such as:
  - interrupt-vector locations
  - locations of device-control registeres on whatever bus the device was attached to
- Static approach was simple, but cannot be easily extended
  - a kernel must be custom configured for each installation

Device Probing

- First step to improve the old way
  - allow the devices to to be found and automatically configured when the system booted
  - (still require that a kernel contain all necessary device drivers)
- Each device driver includes a *probe routine*
  - invoked at boot time
  - probe the relevant buses for devices and configure them
    - including identifying and recording interrupt-vector and device-control-register locations
- This allowed one kernel image to be built that could be useful for a number of similar but not identical installations
  - boot time is kind of long
  - impractical as the number of supported devices gets big

Device Probing

- What's the right thing to do?
  - Step 1: discover the device without the benefit of having the relevant device driver in the kernel
  - Step 2: find the needed device drivers and dynamically link them into the kernel
  - but how do you achieve this?

- Solution: use meta-drivers
  - a meta-drive handles a particular kind of bus
  - e.g., USB (Universal Serial Bus)
    - a USB meta-driver is installed into the kernel
    - any device that goes onto a USB (Universal Serial Bus) must know how to interact with the USB meta-driver via the *USB protocol*
    - once a connected device is identified, system software would select the appropriate device driver and load into the kernel
    - what about applications? how can they reference dynamically discovered devices?

Discovering Devices

- So, you plug in a new device to your computer on a particular bus
  - OS would notice
  - find a device driver
    - what kind of device is it?
    - where is the driver?
  - assign a name, but how is it chosen?
  - multiple similar devices, but how does application choose?

- In some Linux systems, entries are added into `/dev` as the kernel discovers them
  - lookup the names from a database of names known as `devfs`
    - downside of this approach is that device naming conventions not universally accepted
    - what's an application to do?
  - some current Linux systems use `udev`
    - user-level application assigns names based on rules provided by an administrator

Discovering Devices

- What about the case where different devices acted similarly?
  - e.g., touchpad on a laptop and USB mouse
  - how should the choice be presented to applications?
- Windows has the notion of *interface classes*
  - a device can register itself as members of one or more such classes
  - an application can *enumerate* all currently connected members of such a class and choose among them (or use them all)

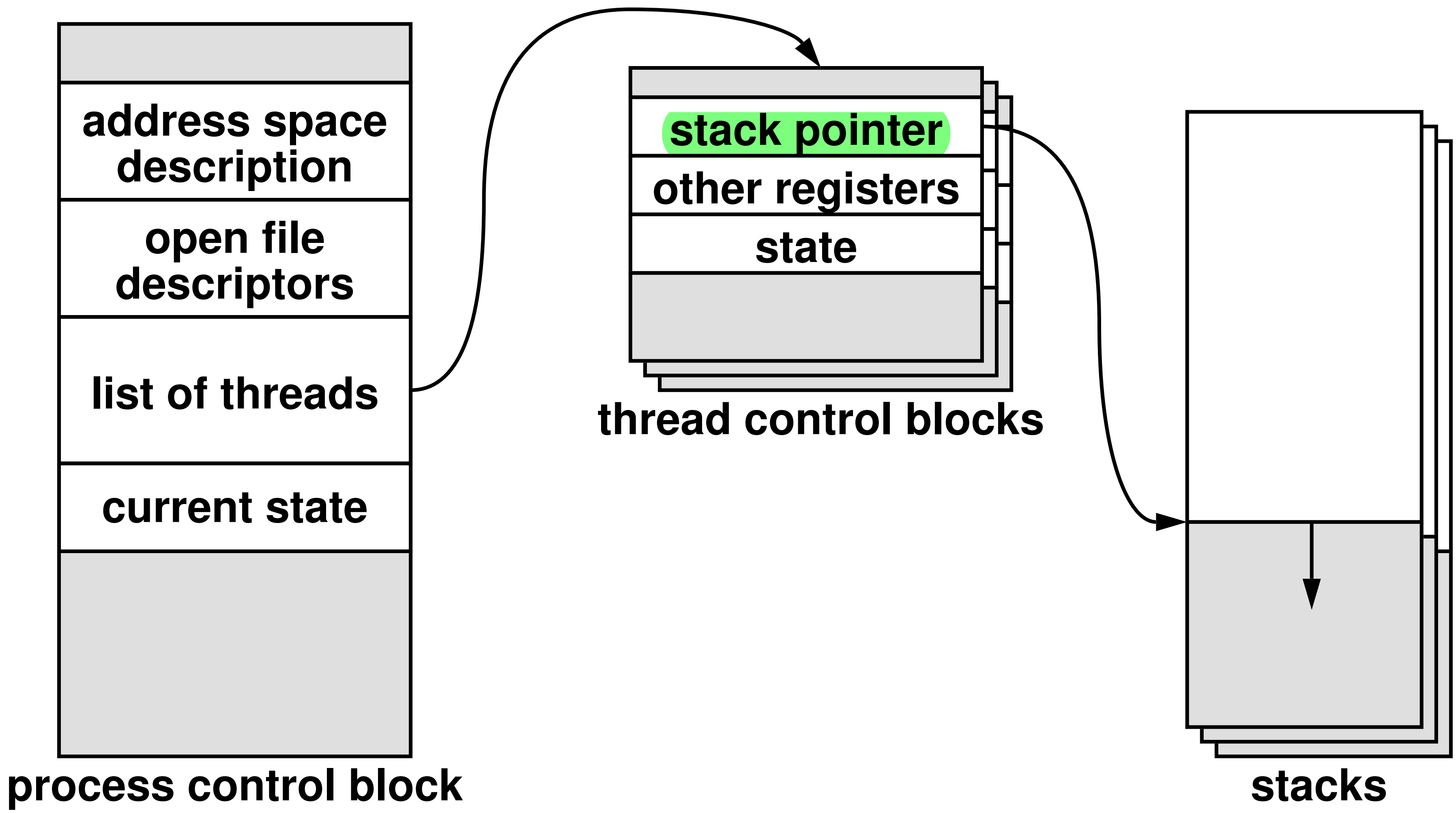
4.1 A Simple System (Monolithic Kernel)

- **A Framework for Devices**
- ***Processes & Threads***
- **Storage Management**
- **Low-level Kernel (will come back to talk about this after Ch 7)**

Processes and Threads

- **A process is:**
  - a holder for an *address space*
  - a collection of other information shared by a set of *threads*
  - a collection of references to *open files* and other "execution context"
- **As discussed in Ch 1, processes related APIs include**
  - `fork()`, `exec()`, `wait()`, `exit()`

Processes and Threads



Note: all these are relevant to your Kernel Assignment 1