Pipes (cont.)

Broken pipes

- A process waiting to read from a pipe with no writer gets an EOF (once all existing data has been read).
- A process writing to a pipe with no reader gets signalled.
- Writes are guaranteed to not be interleaved if they are smaller than the PIPE_BUF constant.
  This must be at least 512 bytes and is 65536 on Linux now.

Limitation

- Can only be used to communicate between related processes. (Named pipes or FIFO files can be used for unrelated processes.)
  - The file handles are just low integers which index into the file table for this process.
  - The same numbers only make sense in the same process (or in one forked from it).

Cond vars for A1

Condition variables

- A thread sometimes needs to wait before continuing.
- In the assignment you may want to wait until the main thread gives you more work to do.
- Rather than continually running checking on global variables we can check and if the state says you should wait then wait until the condition changes.
- That is what condition variables are used for.

```c
#include <pthread.h>
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>

pthread_mutex_t lock = PTHREAD_MUTEX_INITIALIZER;
pthread_cond_t cond = PTHREAD_COND_INITIALIZER;

void *work(void *arg) {
    pthread_mutex_lock(&lock);
    puts("waiting in the second thread");
    // usually a while loop to see if you should wait
    pthread_cond_wait(&cond, &lock);
    puts("finished waiting in the second thread");
    pthread_mutex_unlock(&lock);
    pthread_cond_signal(&cond);
    puts("second thread sent the signal");
}

int main(void) {
    pthread_t thread;
    pthread_create(&thread, NULL, work, NULL);

    getchar();
    pthread_cond_signal(&cond);
    puts("main thread sent the signal");

    pthread_mutex_lock(&lock);
    puts("waiting in the main thread");
    // it is possible for this wait to last forever, how?
    pthread_cond_wait(&cond, &lock);
    puts("finished waiting in the main thread");
    pthread_mutex_unlock(&lock);
}
```

Shared memory for A1

Shared memory

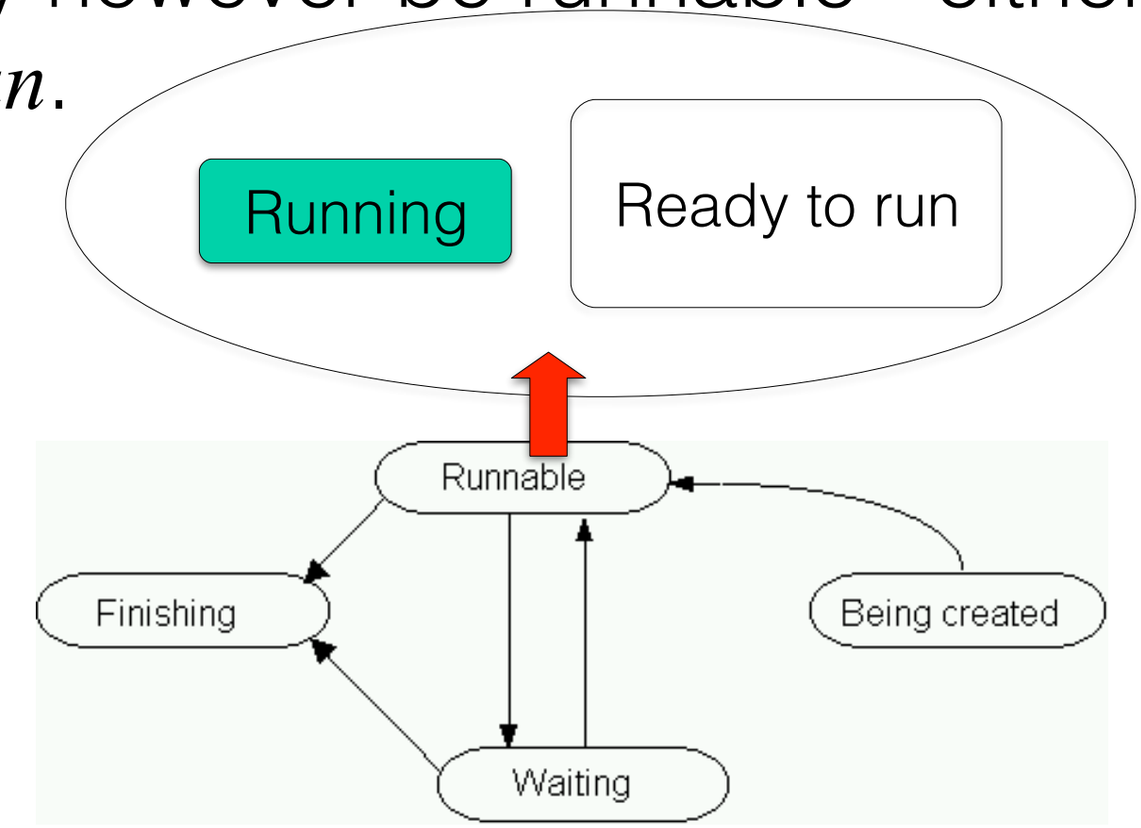
- Unlike threads, processes do not share memory (ignoring the code which is shared when a process calls fork).
- So we have to explicitly request areas of memory to be shared between processes.
- For A1 we can easily do this because one process forks the second.

```c
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <sys/mman.h>

int main(void) {
    int *data;
    data = (int *)mmap(NULL, sizeof(int), PROT_READ | PROT_WRITE,
            MAP_SHARED | MAP_ANONYMOUS, -1, 0);
    if (data == (int *)-1) {
        perror("unable to allocate shared data");
        exit(EXIT_FAILURE);
    }
    *data = 0;
    if (fork() == 0) { // child
        puts("changing the value of *data");
        *data = 1;
    } else {
        while (*data == 0) {
            printf(".");
        }
    }
    puts("I have finished.");
    return 0;
}
```

Runnable

- On a single core only one process/thread can run at a time. (Not actually true - Simultaneous Multithreading SMT)
  Many may however be runnable - either *running* or *ready to run*.



Preemptive multitasking

- A clock interrupt causes the OS to check to see if the current thread should continue
  Each thread has a time slice
  How is the time slice allocated?
- What advantages/disadvantages does preemptive multitasking have over cooperative multitasking?
- Advantages
  - control
  - predictability
- Disadvantages
  - critical sections
  - efficiency

Cooperative multitasking

- Two main approaches
  1. a process yields its right to run
  2. system stops a process when it makes a system call
- This does **NOT** mean a task will work to completion without allowing another process to run. e.g. Macintosh before OS X and early versions of Windows

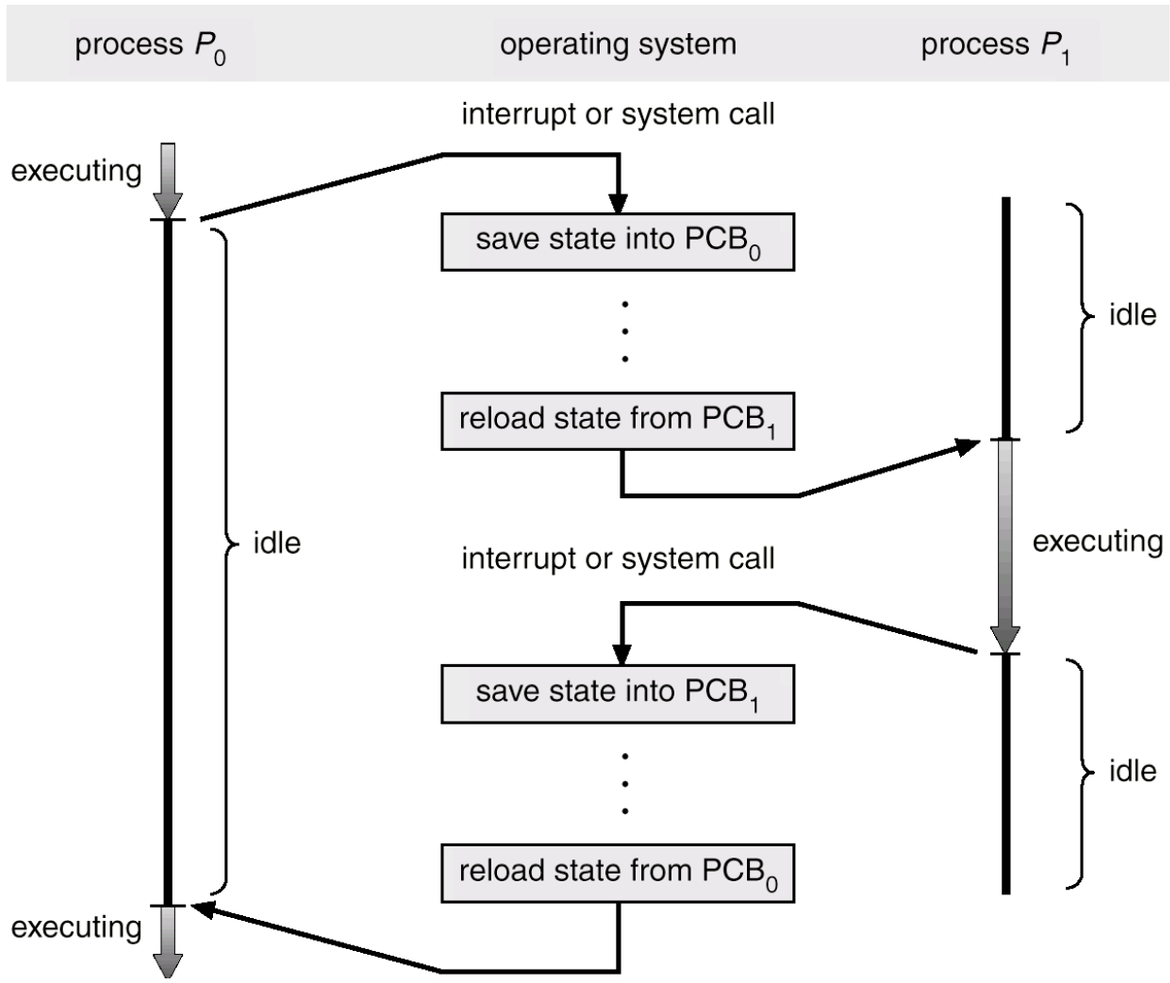
A mixture

- Older versions of UNIX (including versions of Linux before 2.6) did not allow preemptive multitasking when a process made a system call.

Context switch

- The change from one process running to another one running on the same processor is usually referred to as a "context switch".
- What is the context?
  - registers
  - memory - including dynamic elements such as the call stack
  - files, resources
  - but also things like caches, TLB values - these are normally lost
- The context changes as the process executes.
- But **normally** a "context switch" means the change from one process running to another, or from a process running to handling an interrupt. Whenever the process state has to be stored and restored.

Context switch (cont.)



Returning to running

State transition

- Must store process properties so that it can restart where it was.
- If changing processes the page table needs altering.
- Rest of environment must be restored.
- If changing threads within the same process simply restoring registers might be enough.
- Some systems have multiple sets of registers which means that a thread change can be done with a single instruction.

Waiting

- Processes seldom have all the resources they need when they start
  - memory
  - data from files or devices e.g. keyboard input
- Waiting processes must not be allowed to unnecessarily consume resources, in particular the processor.
  - state is changed to waiting
    - may be more than one type of waiting state
    - short wait e.g. for memory
    - long wait e.g. for an archived file (see suspended below)
  - removed from the ready queue
  - probably entered on a queue for whatever it is waiting for
- when the resource becomes available
  - state is changed to runnable
  - removed from the waiting queue
  - put back on the runnable queue

Suspended

- Another type of waiting
  - ctrl-z in some UNIX shells
- Operators or OS temporarily stopping a process – i.e. it is not (usually) caused by the process itself
  - allows others to run to completion more rapidly
  - or to preserve the work done if there is a system problem
  - or to allow the user to restart the process in the background etc.
- Suspended processes are commonly swapped out of real memory.
  - This is a state which affects the process not individual threads.

See **`infinite.c`** and use ctrl-z, then do **`ps`**
to resume you type **`fg`** (foreground), also play with the **`jobs`** command
ctrl-z sends the same signal as **`kill(pid, SIGSTOP)`**

Why we don't use Java suspend()

- If dealing with threads in Java we don't use these deprecated methods:
- `suspend()` freezes a thread for a while. This can be really useful.
- `resume()` releases the thread and it can start running again.
- But we can *easily(?)* get deadlock.
  - `suspend()` keeps hold of all locks gathered by the thread.
  - If the thread which was going to call `resume()` needs one of those locks before it can proceed we get stuck.

Java threads and “stop”

- Why we don’t use stop()
- `stop()` kills a thread forcing it to release any locks it might have.
  - We will see where those locks come from in later lectures.
- The idea of using locks is to protect some shared data being manipulated simultaneously.
- If we use `stop()` the data may be left in an inconsistent state when a new thread accesses it.

Waiting in UNIX

- A process waiting is placed on a queue.
- The queue is associated with the hash value of a kernel address
  - (waiting or suspended processes may be swapped out)
  - when the resource becomes available
    - originally used to scan whole process table
    - all things waiting for that resource are woken up
    - (may need to swap the process back in)
    - first one to run gets it
    - if not available when a process runs the process goes back to waiting
- a little like in Java

```
while (notAvailable)
  wait();
```

Finishing

- All resources must be accounted for
  - may be found in the PCB or other tables
    e.g. devices, memory, files
- reduce usage count on shared resources
  - memory, libraries, files/buffers
    (can this shared library be released from memory now?)
- if the process doesn't tidy up e.g. close files, then something else must
- accounting information is updated
- remove any associated processes
  - Was this a session leader? If so then should all processes in the same session be removed?
- remove the user from the system
- notify the relatives?

Two reasons to stop

Stopping normally

- must call an exit routine
- this does all the required tidying up
- What if it doesn't call exit and just doesn't have a next instruction?

Forced stops

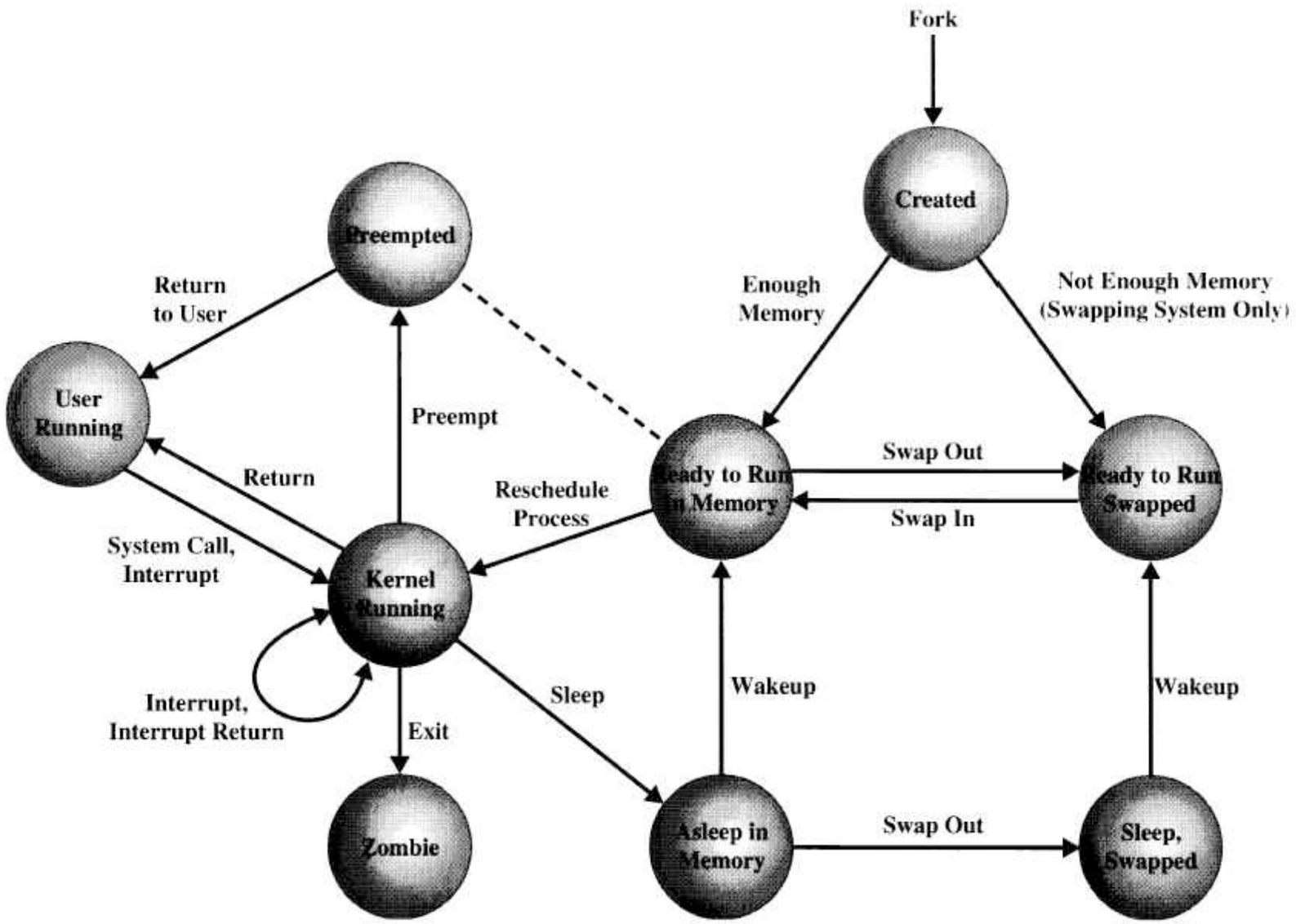
- Only certain processes can stop others
  - parents
  - owned by the same person
  - same process group
- Why do they do it?
  - work no longer needed
  - somehow gone wrong
  - user got bored waiting for completion
- OS also stops processes
  - usually when something has gone wrong
  - exceeded time
  - tried to access some prohibited resource
- Cascading termination

  Some systems don't allow child processes to continue when the parent stops

UNIX stopping

- Usually call `exit(termination status)`
- open files are closed - including devices
- memory is freed
- accounting updated
- state becomes "zombie"
- children get "init" as a step-parent
- parent is signalled (in case it is waiting or will wait)
- after the parent retrieves the termination status the PCB is freed

UNIX state diagrams



Info from a Linux process table

```
ps -e -o s,uid,pid,ppid,group,sess,c,pri,ni,rss,sz:7,wchan:30,tty,time,cmd
```

```
S   UID   PID  PPID GROUP      SESS  C PRI  NI   RSS      SZ WCHAN                          TT           TIME CMD
S     0     1     0 root          1  0  19   0  2684    6700 poll_schedule_timeout          ?        00:00:01 /sbin/init
S     0     2     0 root          0  0  19   0     0       0 kthreadd                       ?        00:00:00 [kthreadd]
S     0     3     2 root          0  0  19   0     0       0 smpboot_thread_fn              ?        00:00:00 [ksoftirqd/0]
S     0     5     2 root          0  0  39 -20     0       0 worker_thread                  ?        00:00:00 [kworker/0:0H]
S     0     7     2 root          0  0  39 -20     0       0 worker_thread                  ?        00:00:00 [kworker/u:0H]
S     0     8     2 root          0  0 139   -     0       0 cpu_stopper_thread             ?        00:00:00 [migration/0]
S     0     9     2 root          0  0  19   0     0       0 rcu_gp_kthread                 ?        00:00:00 [rcu_bh]
S     0    10     2 root          0  0  19   0     0       0 rcu_gp_kthread                 ?        00:00:00 [rcu_sched]
S     0    11     2 root          0  0 139   -     0       0 smpboot_thread_fn              ?        00:00:00 [watchdog/0]
S     0    12     2 root          0  0 139   -     0       0 smpboot_thread_fn              ?        00:00:00 [watchdog/1]
S     0    13     2 root          0  0  19   0     0       0 smpboot_thread_fn              ?        00:00:00 [ksoftirqd/1]
S     0    14     2 root          0  0 139   -     0       0 cpu_stopper_thread             ?        00:00:00 [migration/1]
S     0    16     2 root          0  0  39 -20     0       0 worker_thread                  ?        00:00:00 [kworker/1:0H]
S     0    17     2 root          0  0  39 -20     0       0 rescuer_thread                 ?        00:00:00 [cpuset]
S     0    18     2 root          0  0  39 -20     0       0 rescuer_thread                 ?        00:00:00 [khelper]
... lots of processes removed
S  1000  2098  1348 robert     1348  0  19   0 23636   97269 poll_schedule_timeout          ?        00:00:00 gnome-screensaver
S  1000  2121  1348 robert     1348  0  19   0 13932  129253 poll_schedule_timeout          ?        00:00:00 update-notifier
S  1000  2139     1 robert     1348  0   9  10 126180 160715 poll_schedule_timeout          ?        00:00:39 /usr/bin/python3 /usr/b
S  1000  2174     1 robert     1403  0  19   0  3760   69016 poll_schedule_timeout          ?        00:00:00 /usr/lib/libunity-webap
S  1000  2268     1 robert     1403  0  19   0  8988  253634 poll_schedule_timeout          ?        00:00:00 /usr/lib/gvfs/gvfsd-htt
S  1000  2278  2268 robert     1403  0  19   0   628    1110 wait                           ?        00:00:00 sh -c /usr/lib/x86_64-l
S  1000  2279  2278 robert     1403  0  19   0  3412   49887 poll_schedule_timeout          ?        00:00:00 /usr/lib/x86_64-linux-g
S  1000  2305  1348 robert     1348  0  19   0  4844  111973 poll_schedule_timeout          ?        00:00:00 /usr/lib/x86_64-linux-g
S  1000  2364     1 robert     1403  0  19   0  6068   60692 poll_schedule_timeout          ?        00:00:00 /usr/lib/geoclue/geoclu
S  1000  2368     1 robert     1403  0  19   0  7744   86212 poll_schedule_timeout          ?        00:00:00 /usr/lib/ubuntu-geoip/u
S  1000  2371  2368 robert     1403  0  19   0   624    1110 wait                           ?        00:00:00 sh -c /usr/lib/x86_64-l
S  1000  2372  2371 robert     1403  0  19   0  3412   49887 poll_schedule_timeout          ?        00:00:00 /usr/lib/x86_64-linux-g
S  1000  2917     1 robert     1348  0  19   0 25208  153503 poll_schedule_timeout          ?        00:00:11 gnome-terminal
S  1000  2925  2917 utmp       1348  0  19   0   844    3708 unix_stream_recvmsg            ?        00:00:00 gnome-pty-helper
S  1000  2926  2917 robert     2926  0  19   0  3016    6520 wait                           pts/2    00:00:00 bash
S  1000  2977  2926 robert     2926  0  19   0  1524    5582 wait                           pts/2    00:00:00 man ps
S  1000  2987  2977 robert     2926  0  19   0   992    3443 n_tty_read                     pts/2    00:00:00 pager -s
S  1000  2993  2917 robert     2993  0  19   0  3104    6520 wait                           pts/3    00:00:00 bash
S     0  3565     2 root          0  0  19   0     0       0 worker_thread                  ?        00:00:00 [kworker/1:2]
S     0  3671     2 root          0  0  19   0     0       0 worker_thread                  ?        00:00:00 [kworker/0:1]
R  1000  3688  2993 robert     2993  0  19   0  1300    5661 -                              pts/3    00:00:00 ps -e -o s,uid,pid,ppid
S   UID   PID  PPID GROUP      SESS  C PRI  NI   RSS      SZ WCHAN                          TT           TIME CMD
```

Before next time

Read from the textbook

- 6.1 Basic Concepts
- 6.2 Scheduling Criteria
- 6.3 Scheduling Algorithms
- 6.5 Multiple-Processor Scheduling