Terminal Control & Proj1 demo

Computer Operating Systems, Fall 2023

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- How was project 0?
  Are you excited for more C and project 1? ☺

Administrivia

- Peer Evaluation: out now, due Friday 9/22 @ 11:59 pm
  - Please do it, it shouldn't take long
  - Mostly completion, don't just say "this is fine" for everything

- Project 1 is out now
  - The milestone is due Wed 9/27 @ 11:59 pm
    late deadline: 11:59 pm on Sun, Oct 01
  - Project is due 11:59 pm on Wed, Oct 11
    late deadline 11:59 pm on Sun, Oct 15
  - Demo of project 1 in the last half of this class
  - After this class, should have everything needed to complete the project

Administrivia

- Recitation 3
  - After lecture today, going over pipes and redirection
  - Should help with finishing the project milestone
- Partner sign up
  - If you do not have a partner, we will begin random pairing the remaining students sometime tonight
- Check-in Quiz 3 Due in ~1 week

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- Any questions, comments or concerns from last lecture?

Lecture Outline

- **Process Groups Revisited**
  - `setpgid()`
- Terminal Control
  - `tcsetpgrp()`
- Project 1: Synch vs Asynch wait
  - `SIGCHLD`
- Project 1 Demo & Q&A

Process Groups

- Processes are associated together into Process Groups.
  - A process always is in a process group
- Allows for convenient process & signal management:
  - If ctrl + C (SIGINT) is sent to a process via the keyboard, it is also sent to all processes within its group
- When we create a process with fork(), the child belongs to the same process group as the parent
- Shell has the notion of a **job**: "commands" started interactively. All processes in a job are in the same group
- Relevant for proj1: **`penn-shell`**

Process Group ID

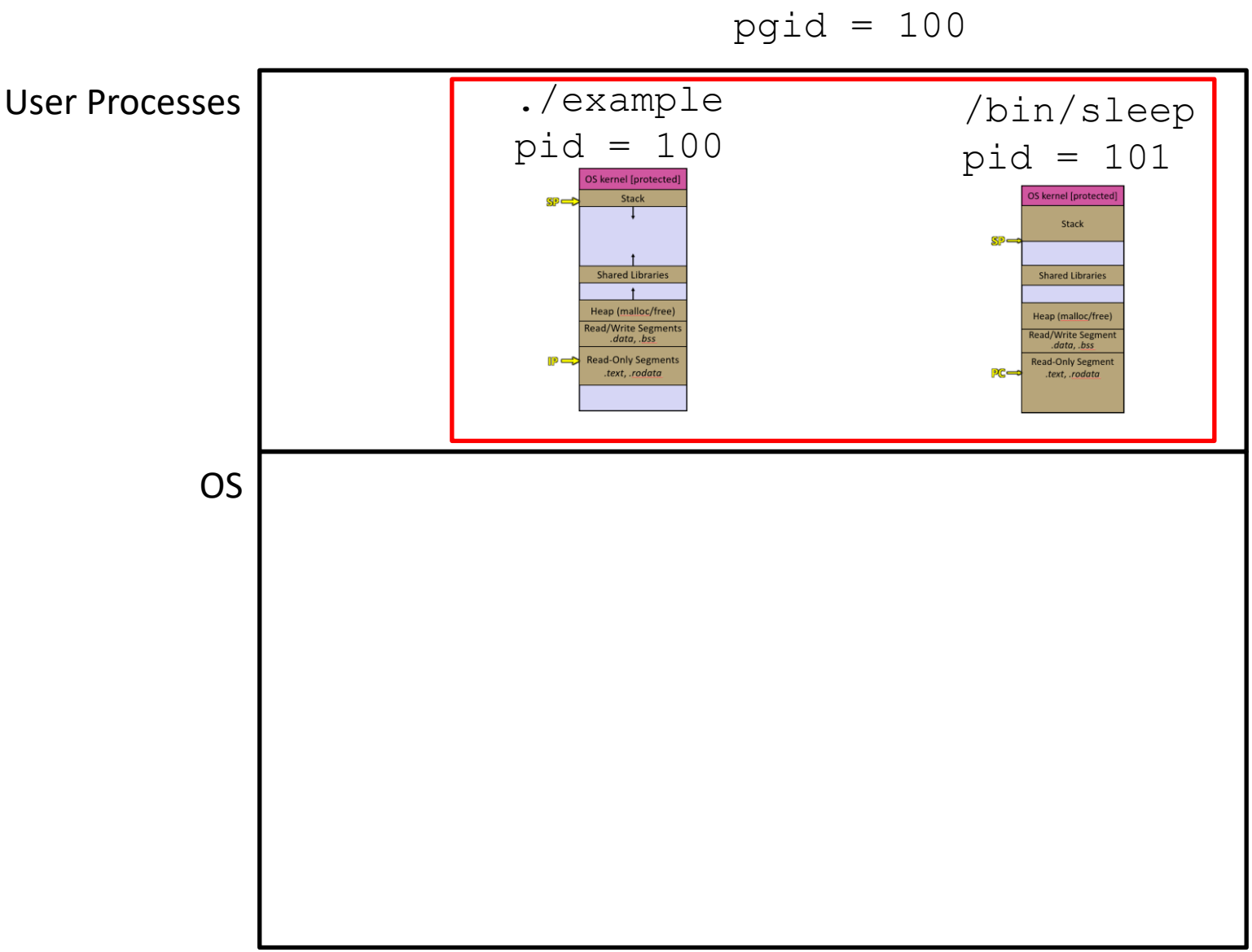
- The process group ID is equal to a process ID
  - The process ID of the first process to exist in the group
  - If a process group "leader" terminates, can its process ID be reused by another process? Even if the old group is still going?
  - Answer: no, that process ID will be reserved until the group is done

- ```
  int setpgid(pid_t pid, pid_t pgid);
  ```
- Sets page group id of the specified process to the new value
  - Only works if pgid specifies an existing process group
  - Or if pgid == pid, creates a new process group of that id
  ```

Process Group ID

- ```
  pid_t getpgid(pid_t pid);
  ```
- Gets the process group id of the specified process
- If `0` is passed in, get the group ID of the calling process
- `-1` returned on error
  ```

CTRL +C, same group

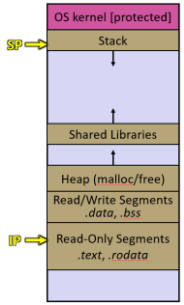


CTRL +C, same group

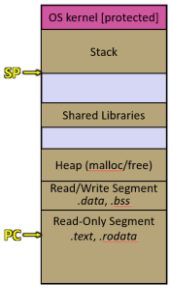
pgid = 100

User Processes

./example
pid = 100



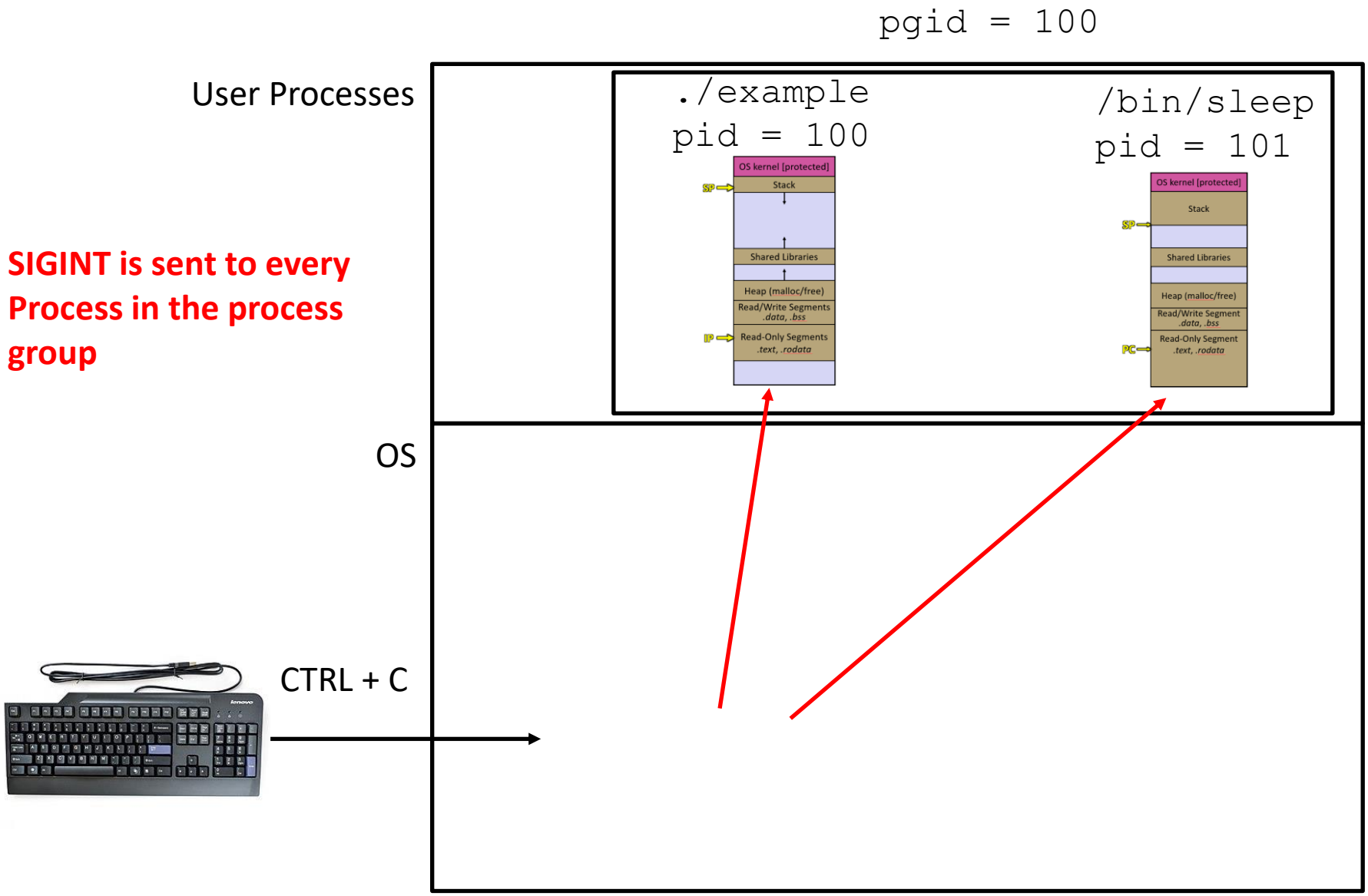
/bin/sleep
pid = 101



OS

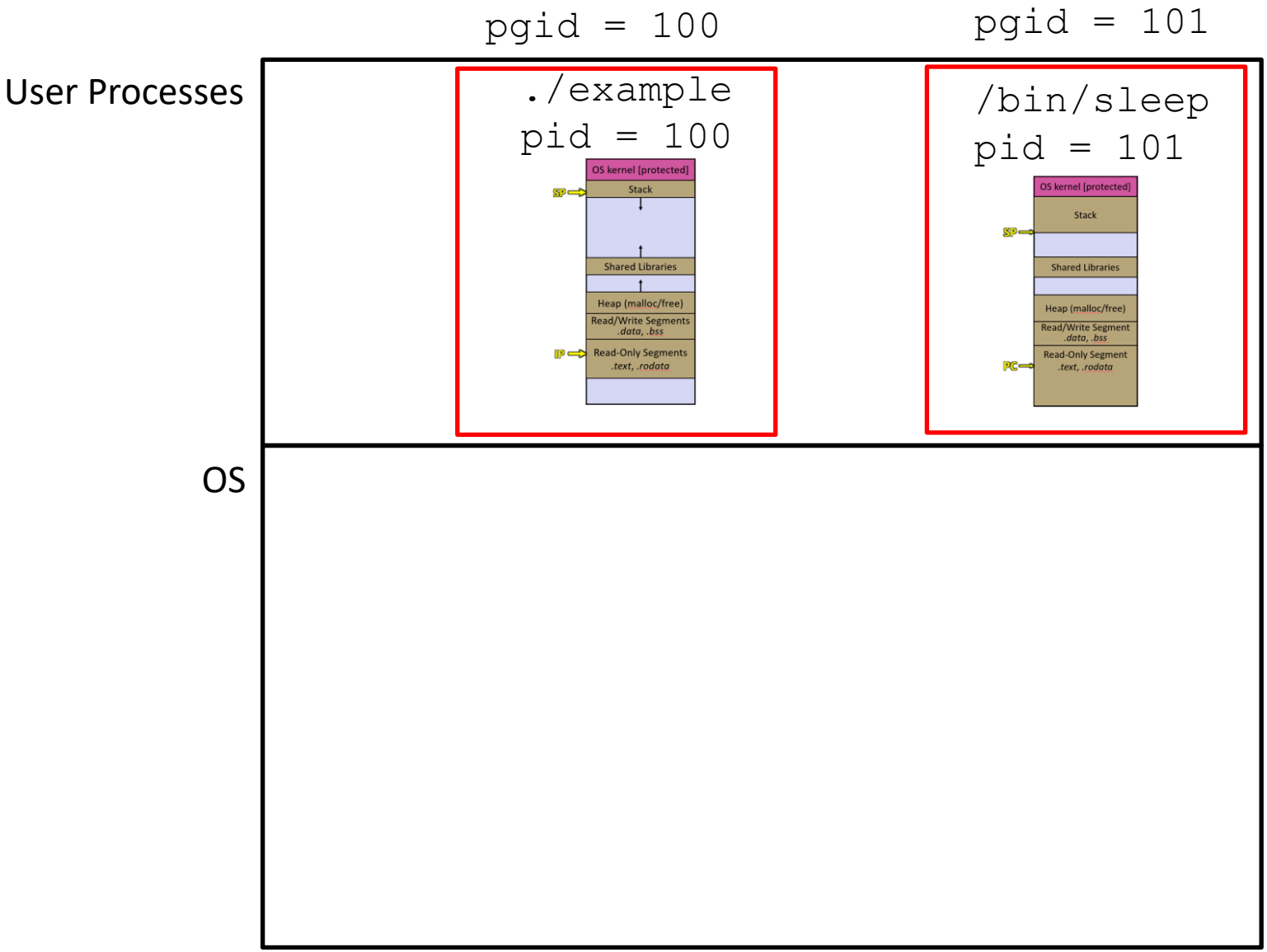
CTRL + C

CTRL +C, same group

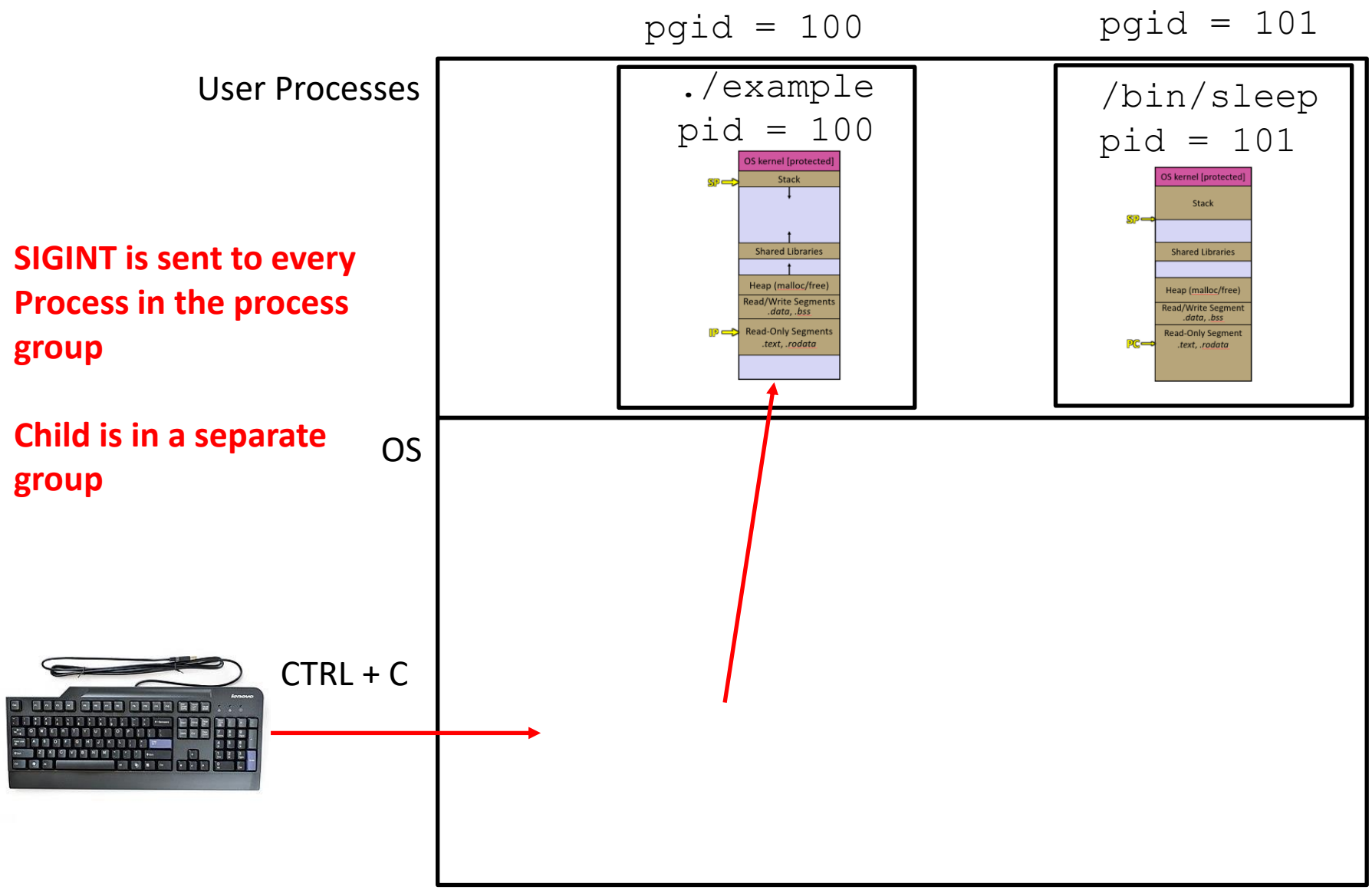


GAP SLIDE: MOVING ON TO DIFFERENT EXAMPLE

CTRL +C, different group



CTRL +C, different group



GAP SLIDE: MOVING ON TO DIFFERENT EXAMPLE

Process Groups: utility

- Can pass in **`-PGID`** (negative PGID) to **`kill()`** and **`waitpid()`**
- Doing so for **`kill()`** will send the signal to all processes in the group
- Doing so for **`waitpid()`** will wait for any process in the group
- You may find this useful for proj1: **`penn-shell`**

Diagram: signals between process groups

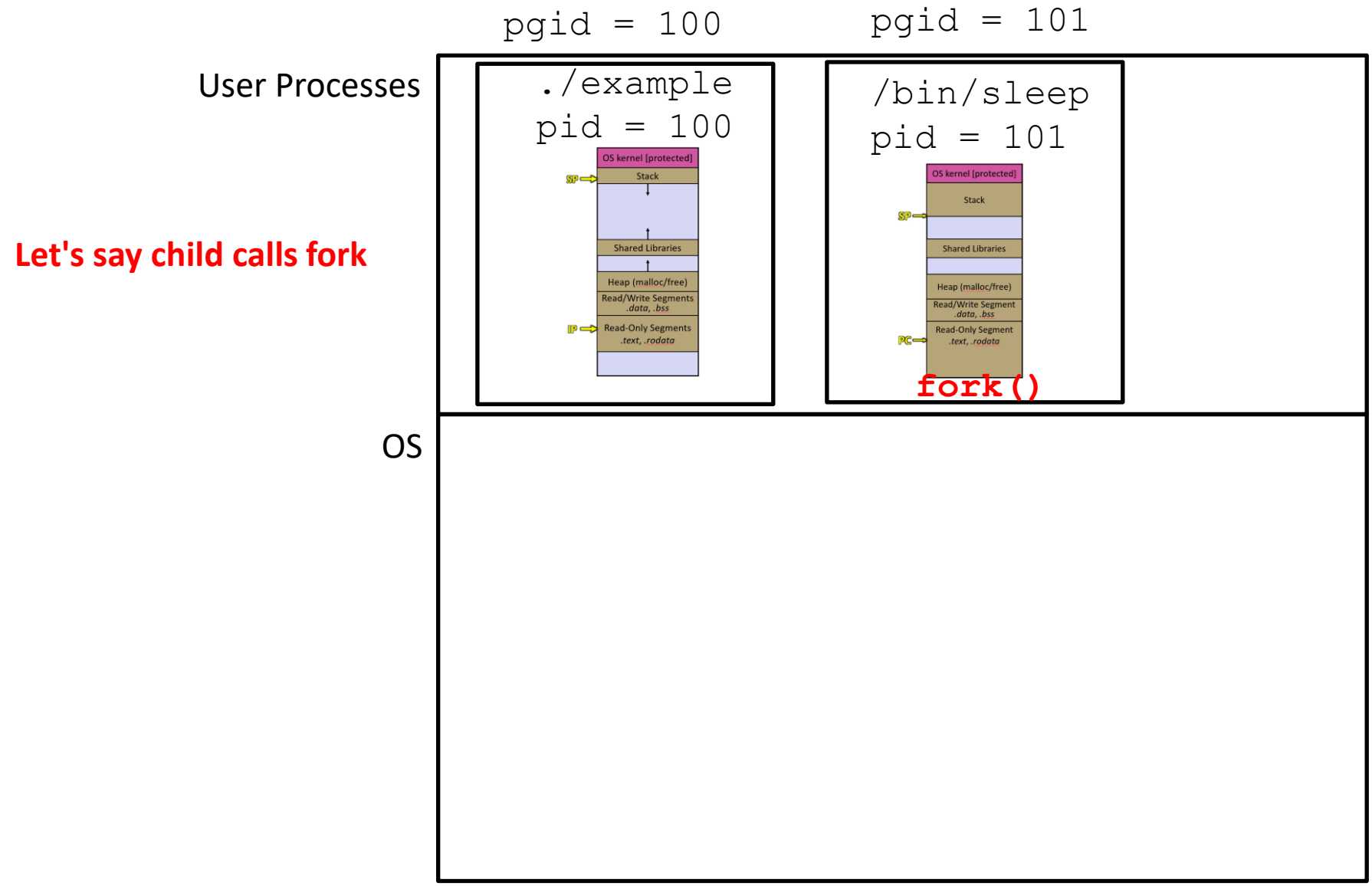
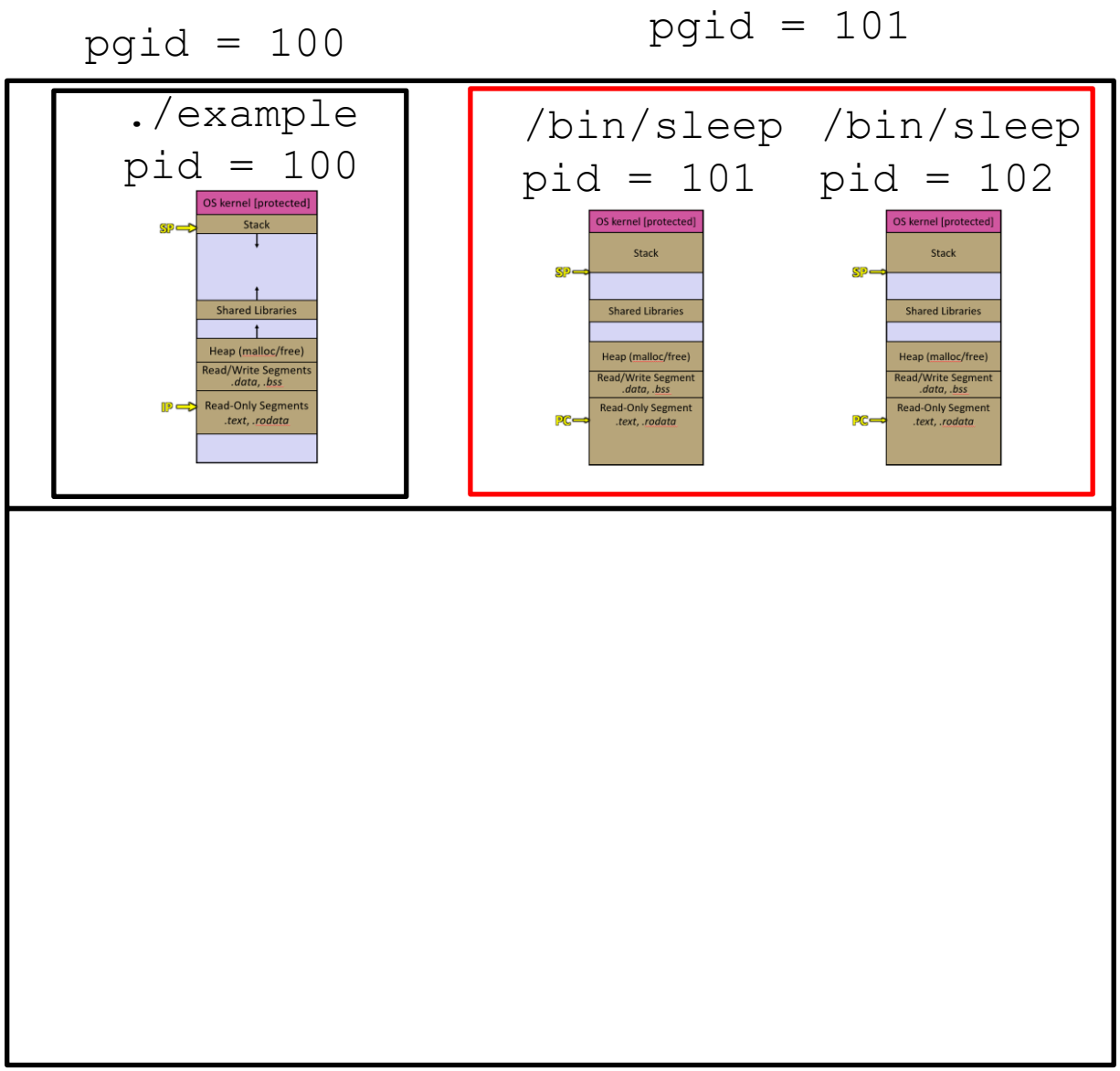


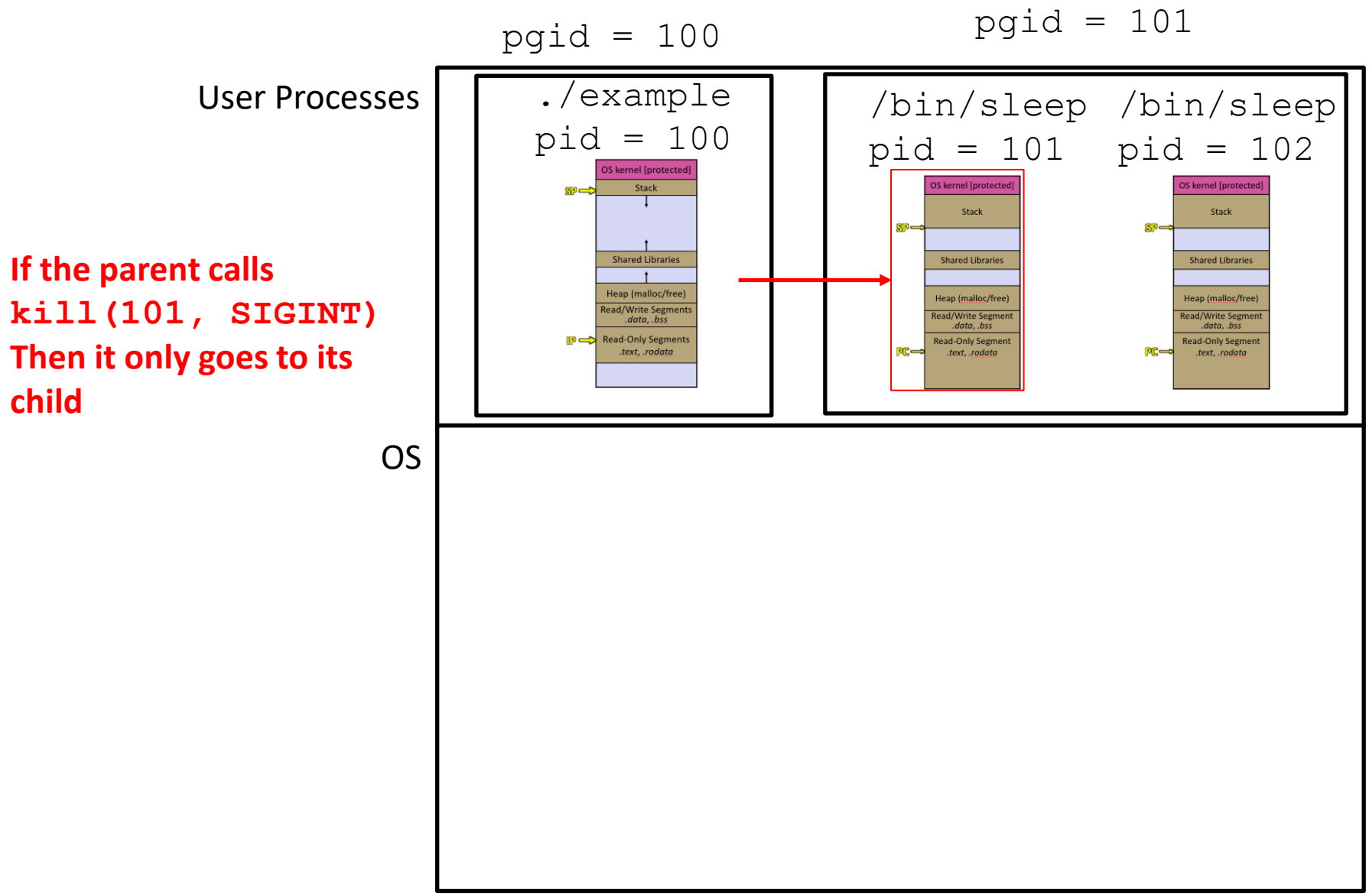
Diagram: signals between process groups



Let's say child calls fork

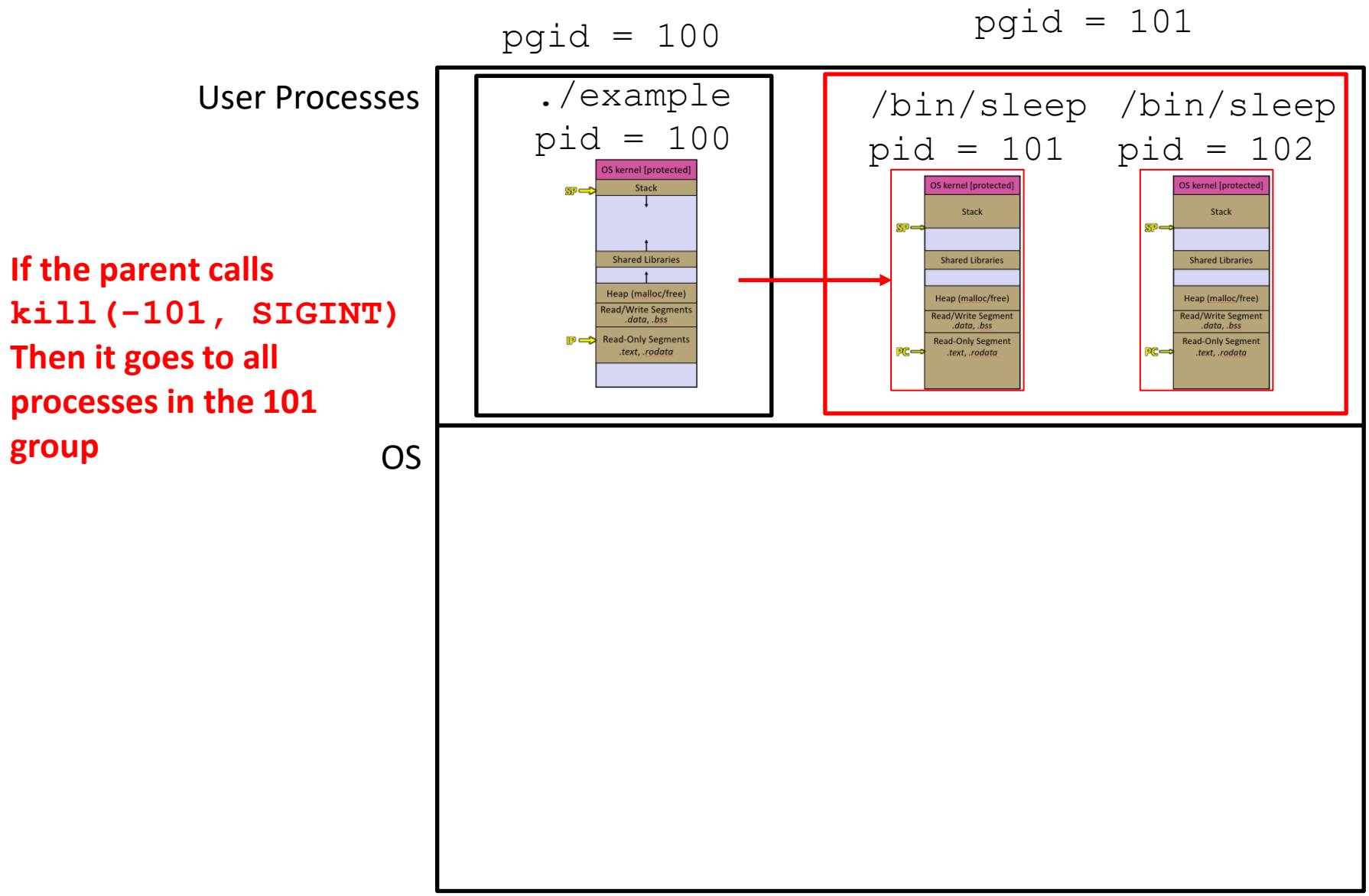
New child (grandchild of initial process) would be in the child's group

Diagram: signals between process groups



If the parent calls `kill(101, SIGINT)` Then it only goes to its child

Diagram: signals between process groups



Demo: pgrpg_signals.c

- See code demo: `pgrp_signals.c`
  - Handler registered for SIGINT in both child and parent
  - Parent puts child in its own group
  - CTRL + C is input -> parent signal handler is invoked -> parent relays the signal to the child

  - What happens if we don't call kill in parent handler?
  - What happens if we then don't put child in its own group?

Lecture Outline

- Process Groups Revisited
  - `setpgid()`
- **Terminal Control**
  - `tcsetpgrp()`
- Project 1: Synch vs Asynch wait
  - `SIGCHLD`
- Project 1 Demo & Q&A

What if the child tried to use the terminal?

- Demo!
  - Modify the `pgrp_signals.c` so that the child does “cat” (read from stdin, echo it to stdout until EOF)
  - it does not work?

Sessions

- A **Session** is a collection of process groups
  - A session can be attached to a controlling terminal
  - Or not attached to any terminal (daemon's)
- You can think of a session as mostly associated with a "login" or instance of a terminal application. Each login/terminal is a session
- Within a session (that has a controlling terminal) there are
  - Background processes
  - Foreground processes

Foreground Process Groups

- Foreground process groups (i.e., Foreground Jobs) can read from STDIN and the processes in that group receive the signals from the keyboard (e.g., CTRL + C)

- A foreground group can make another group the foreground with the function:
- ```
  int tcsetpgrp(int fd, pid_t pgrp);
  ```
  - **`fd`** is a file descriptor associated with the terminal (stdin)
  - Sets the process group specified by **`pgrp`** to be the foreground process group
  - `-1` returned on error, `0` when successful
  ```

Background Process

- If a background process tries to read from `stdin`, it gets sent the signal `SIGTTIN`

- If a background process tries to take control of the terminal with `tcsetgpgrp`, then the group gets sent `SIGTTOU`, which will stop the process group

- Writing to `stdout` from the background is ok, but can be configured so that background processes get `SIGTTOU`

Demo: tc.c

- See code demo: `tc.c`
  - Fixed our process group code so that it can run cat ☺
  - Parent can print to stdout even if has given away the terminal
  - How can we make the parent take back the terminal control?

Poll Everywhere

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- What is the intention of this code? Does it do what it intends to do? How can we fix it?

```
13 int main() {
14   while (true) {
15     fprintf(stderr, "give command: ");
16     char c;
17     ssize_t bytes  = read(STDIN_FILENO, &c, 1);
18     if (bytes == -1) {
19       perror("read\n");
20       exit(EXIT_FAILURE);
21     } else if (bytes == 0) {
22       break;
23     }
24
25     if (c == 'c') {
26       pid_t pid = fork();
27
28       if (pid == 0) {
29         // child
30         // reads from the terminal and
31         // prints what it reads until EOF
32         char* args[] = {"cat", NULL};
33         execvp(args[0], args);
34         exit(EXIT_FAILURE);
35       }
36       // parent
37
```

```
36       // parent
37
38       // put the child in its own process group
39       if (setpgid(pid, pid) == -1) {
40         perror("setpgid\n");
41         exit(EXIT_FAILURE);
42       }
43
44       // give terminal to the child
45       if(tcsetpgrp(STDIN_FILENO, pid) == -1) {
46         perror("tcsetpgrp\n");
47         exit(EXIT_FAILURE);
48       }
49       printf("starting to wait\n");
50
51       int wstatus;
52       waitpid(pid, &wstatus, 0);
53     } else if (c == 's') {
54       printf("sleeping...\n");
55       sleep(5);
56       printf("awake\n");
57     } else if (c == 'p') {
58       printf("HOWDY\n");
59     }
60   }
```

Demo: tc_loop.c

- See code demo: `tc_loop.c`
  - The code from the poll
  - Let's try to fix it…

  - How can we make the parent take back the terminal control?

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- **Project 1: Synch vs Asynch wait**
  - **`SIGCHLD`**
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Background in the shell

- To start a background job in the shell (and in penn-shell) run the command with a & at the end.
  - `sleep 10 &`

- While a command is running in the background, we can run other commands in the shell

- Can use the `jobs` command to see the status of the jobs we have started

Penn-shell

- Part of what you do in HW1 (after the milestone) is to make a shell that manages process groups in the foreground and background
- This means your code will have to handle multiple process groups at once, keeping track of the state of all of them.
- Need to maintain a linked list of the current jobs to handle job control

"Normal" approach Pseudo Code

- Discuss: what does this do?

- Is there a flaw in this? Not in correctness but maybe
  - Responsiveness
  - Resource utilization
  - etc.

```
int main(int argc, char* argv[]) {
  while(...) {
    printf(PROMPT);

    getline(&user_input);

    pid = fork_exec(user_input);

    waitpid(pid, &wstatus, 0);

    for (pid_t p : background) {
       // check status of background
       waitpid(p, &wstatus, WNOHANG);
       // if there is an update,
       // need to update the lists…
    }
    // re-prompt user
  }
}
```

Analysis: "Normal"

- The “normal”: check background processes before re-prompting the user
  - may not be responsive to background processes finishing
  - Consider we have many background processes then the user runs **`sleep 1000000`** in the foreground...
  - those background processes will not be reaped until foreground finishes

"Polling" approach Pseudo Code

- Discuss: what does this do?
- How does this compare to the previous attempt?

```
int main(int argc, char* argv[]) {
  while(...) {
    printf(PROMPT);
    getline(&user_input);
    pid = fork_exec(user_input);

    while (waitpid(pid, &wstatus, WNOHANG) == 0) {
      for (pid_t p : background) {
        // check status of background
        waitpid(p, &wstatus, WNOHANG);
        // if there is an update,
        // need to update the lists…
      }
    }
    // re-prompt user
  }
}
```

Analysis: Polling

- Polling is a term used to describe when we check to see if something is ready, but do not block if it is not ready

- This approach is more responsive than the previous one…
- but it busy waits… consuming CPU cycles…

Aside: SIGCHLD

- This approach registers `SIGCHLD` as a handler, `SIGCHLD` is a signal that is sent when a child process stops or is terminated
  - Is ignored by default

"async" approach Pseudo Code

- Discuss: what does this do?
- How does this compare to the previous attempt?

```
void handler(int signo) {
  for (pid_t p : background) {
    // check status of background
    waitpid(p, &wstatus, WNOHANG);
    // if there is an update,
    // need to update the lists…
  }
}
int main(int argc, char* argv[]) {
  signal(SIGCHLD, handler);
  while(...) {
    printf(PROMPT);
    getline(&user_input);
    pid = fork_exec(user_input);
    waitpid(pid, &wstatus, 0);
    // re-prompt user
  }
}
```

Analysis: Async

- This approach registers `SIGCHLD` as a handler, `SIGCHLD` is a signal that is sent when a child process stops or is terminated
  - Is ignored by default

- This allows us to respond quickly to the background children terminating
- No busy waiting! Main process instead is mostly blocked waiting on the foreground job
- Must use signal handlers and handle critical sections ;_;
- Handling this ASYNC is your extra credit

pass the normal autograder first PLEASE

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- **Project 1 Demo & Q&A**