Shells and Signals

shell: program that runs other programs

avh — -zsh — 80×24

```
[avh ~ $ pwd
/Users/avh
[avh ~ $ echo "hello cs240"
hello cs240
[avh ~ $ sleep 1
[avh ~ $ sleep 1; echo "hello"
hello
[avh ~ $ (sleep 4; echo "hello")&
[1] 29371
avh ~ $ hello

[1]  + done       ( sleep 4; echo "hello"; )
[avh ~ $ (sleep 5; echo "hello")&
[1] 29577
[avh ~ $ (sleep 10; echo "hello")&
[2] 29648
avh ~ $ hello

[1]  - done       ( sleep 5; echo "hello"; )
avh ~ $ hello

[2]  + done       ( sleep 10; echo "hello"; )
avh ~ $
```

How many child threads are there at this point for this shell?

- 1 (foreground)
- 2 (1 foreground, 1 background)
- 3 (2 foreground, 1 background)
- 3 (1 foreground, 2 background)
- None of the above

How many child threads are there at this point for this shell?

1 (foreground) — 0%

2 (1 foreground, 1 background) — 0%

3 (2 foreground, 1 background) — 0%

3 (1 foreground, 2 background) — 0%

None of the above — 0%

How many child threads are there at this point for this shell?

1 (foreground) 0%

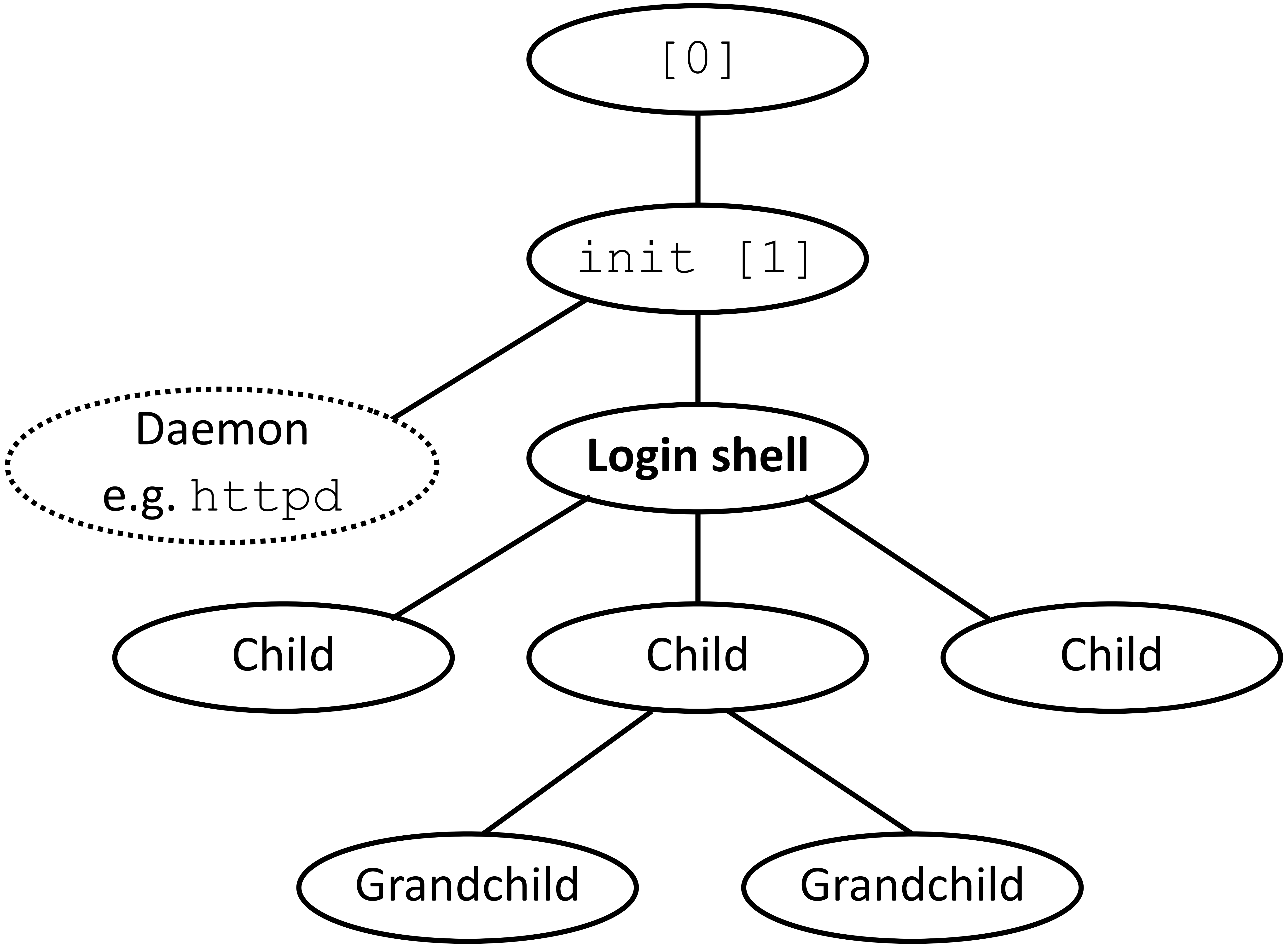
2 (1 foreground, 1 background) 0%

3 (2 foreground, 1 background) 0%

3 (1 foreground, 2 background) 0%

None of the above 0%

Shells and the process hierarchy

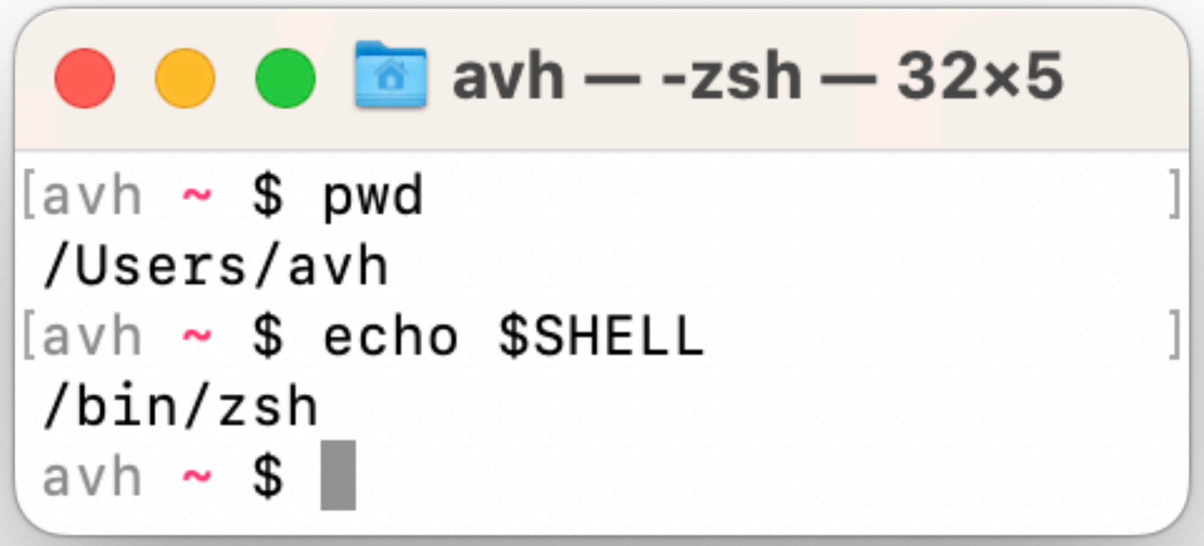


Shell summary

Program that runs other programs on behalf of the user

Typically via the "command line interface" (CLI)

Example: Mac (zsh)

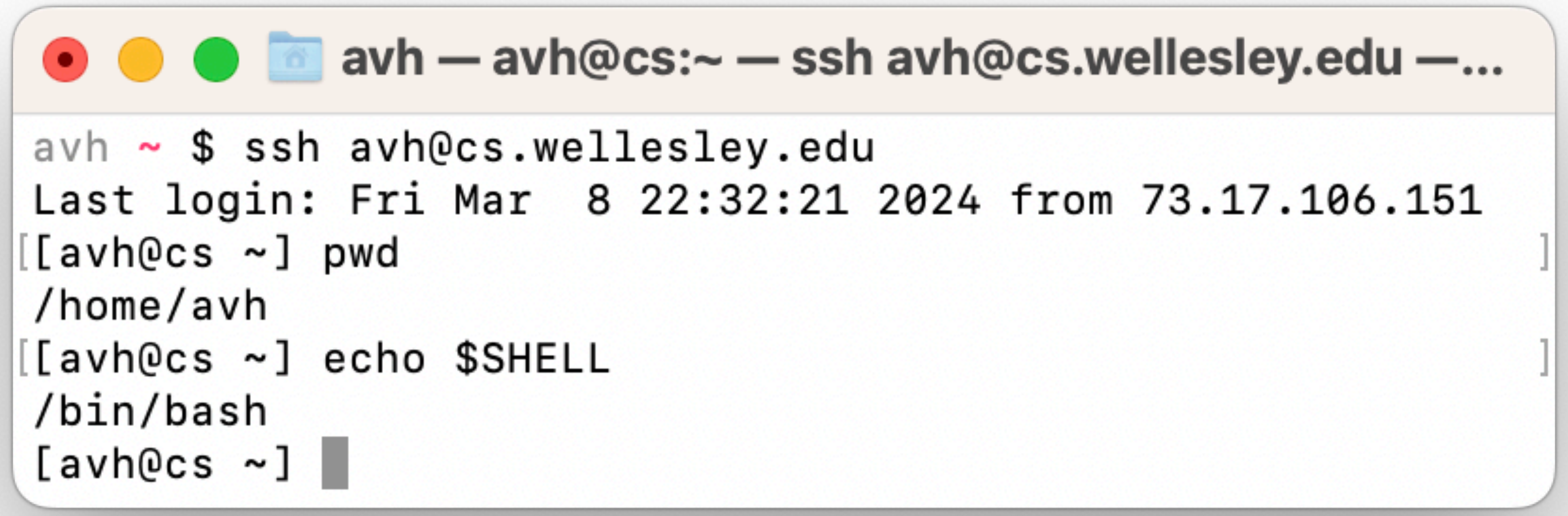


Example shells

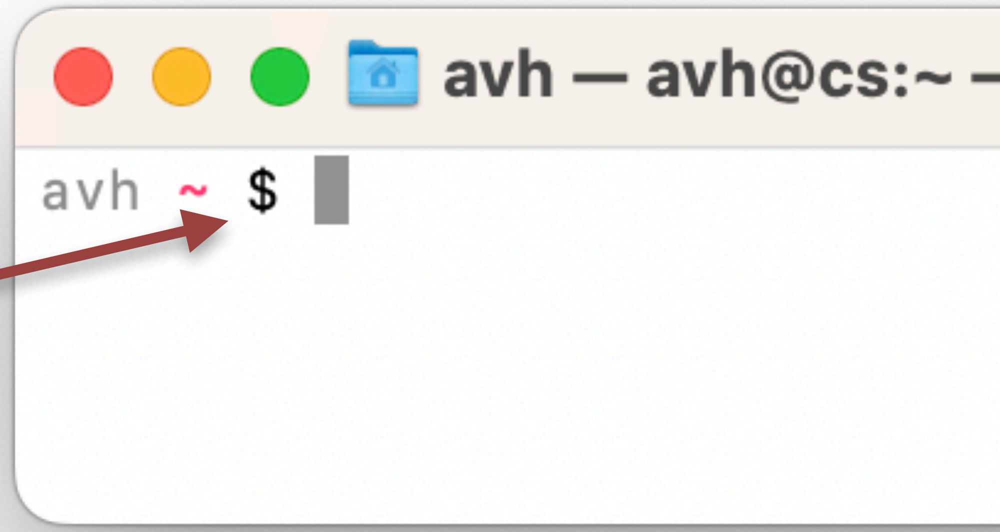
`sh`	Original Unix shell (Stephen Bourne, AT&T Bell Labs, 1977)
`bash`	"Bourne-Again" Shell, widely used, default on most Unix/Linux systems
`zsh`	Pronounced "z shell", newer, now default on newer Mac systems
`Windows Terminal`	Default on Windows systems

`many others…`

Example: CSLinux (bash)



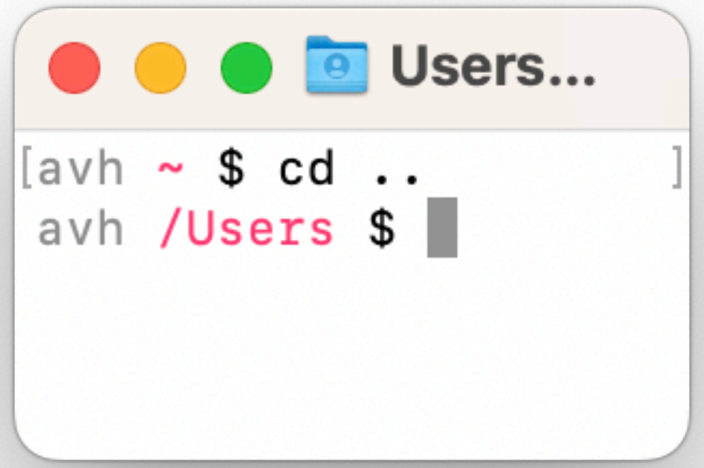
Shell implementation (Concurrency assignment)



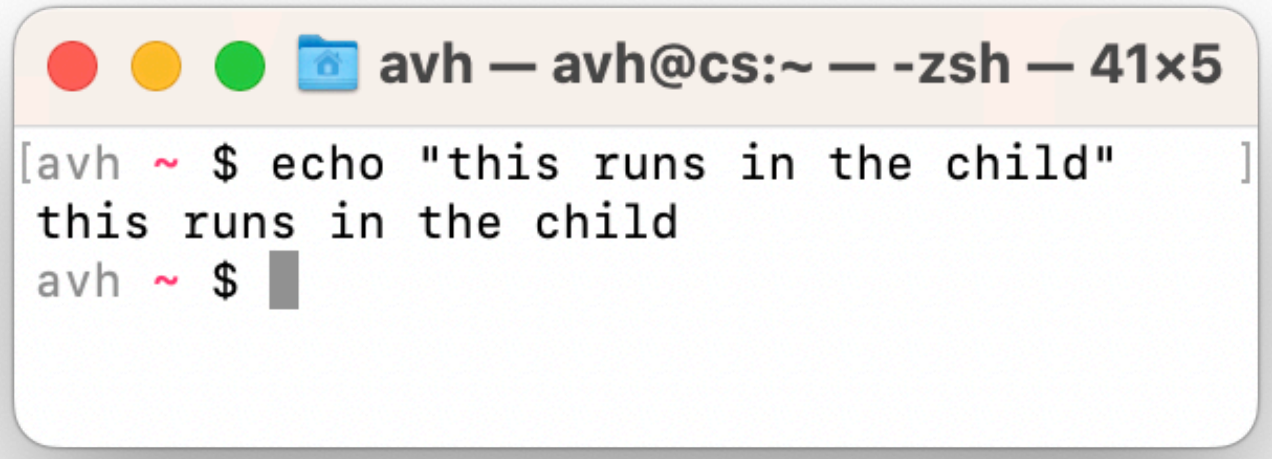
Shell high-level design:

1. Wait for input from the user. Print the "`command prompt`" to indicate readiness.
2. Read in a command from the user, parse it (`Pointers` assignment)
3. Execute the command, either by:
   1. If a built-in command, do it.
   2. Otherwise, create a child process to run the command (`fork` call)

cd is built-in



echo is not built-in



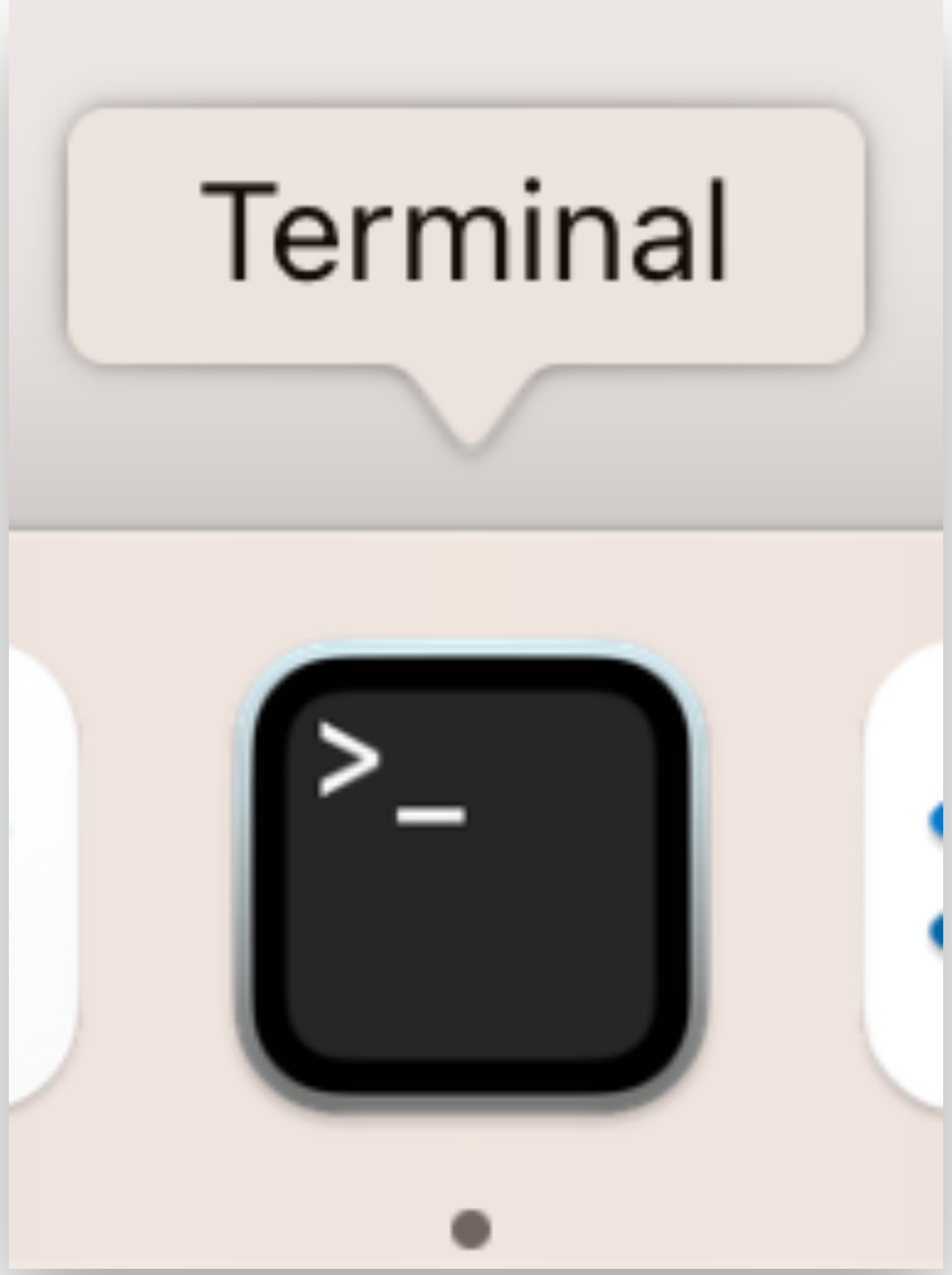
Pseudocode:

```
while (true)
    Print command prompt.
    Read command line from user.
    Parse command line.
    If command is built-in, do it.
    Else fork process to execute command.
        in child:
            Exec requested command (never returns)
        in parent:
            Wait for child to complete.
```

Terminal ≠ shell

Terminal is the user interface to shell and other programs.

Graphical (GUI) vs. command-line (CLI)



The shell itself does not control pixels, it manipulates strings

To wait or not to wait?

A *foreground* job is a process for which the shell waits.*

```
$ emacs fizz.txt  # shell waits until emacs exits.
```

A *background* job is a process for which the shell does not wait*… yet.

```
$ emacs boom.txt &   # emacs runs in background.
[1] 9073             # shell saves background job and is…
$ gdb ./umbrella     # immediately ready for next command.
```

Foregound jobs get input from (and "own") the terminal. Background jobs do not.

Signals

optional

Signal: small message notifying a process of event in system

like exceptions and interrupts

sent by kernel, sometimes at request of another process

ID is entire message

ID Name	*Corresponding Event*	*Default Action*	*Can Override?*
2 SIGINT	Interrupt (Ctrl-C)	Terminate	Yes
9 SIGKILL	Kill process (immediately)	Terminate	**No**
11 SIGSEGV	Segmentation violation	Terminate & Dump	Yes
14 SIGALRM	Timer signal	Terminate	Yes
15 SIGTERM	Kill process (politely)	Terminate	Yes
17 SIGCHLD	Child stopped or terminated	Ignore	Yes
18 SIGCONT	Continue stopped process	Continue (Resume)	No
19 SIGSTOP	Stop process (immediately)	Stop (Suspend)	**No**
20 SIGTSTP	Stop process (politely)	Stop (Suspend)	Yes

…

Sending/receiving a signal

optional

Kernel *sends* (delivers) a signal to a *destination process*
by updating state in the context of the destination process.

Reasons:

- **System event**, e.g. segmentation fault (SIGSEGV)
- **Another process used `kill`** system call:
  explicitly request the kernel send a signal to the destination process

Destination process *receives* signal when kernel forces it to react.

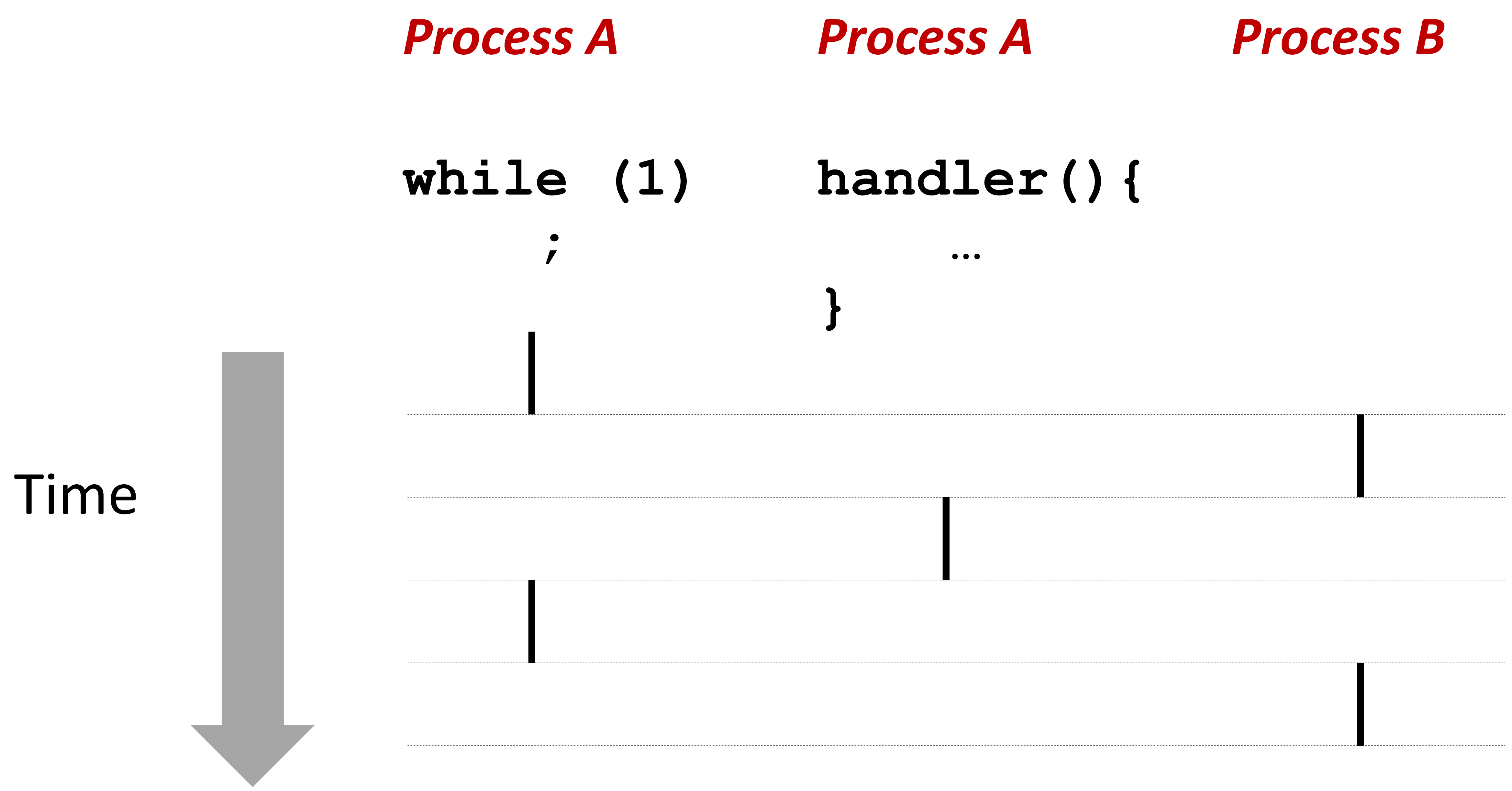
Reactions:

- ***Ignore*** the signal (do nothing)
- ***Terminate*** the process (with optional core dump)
- ***Catch*** the signal by executing a user-level function called *signal handler*
  - Like an impoverished Java exception handler

Signals handlers as concurrent flows

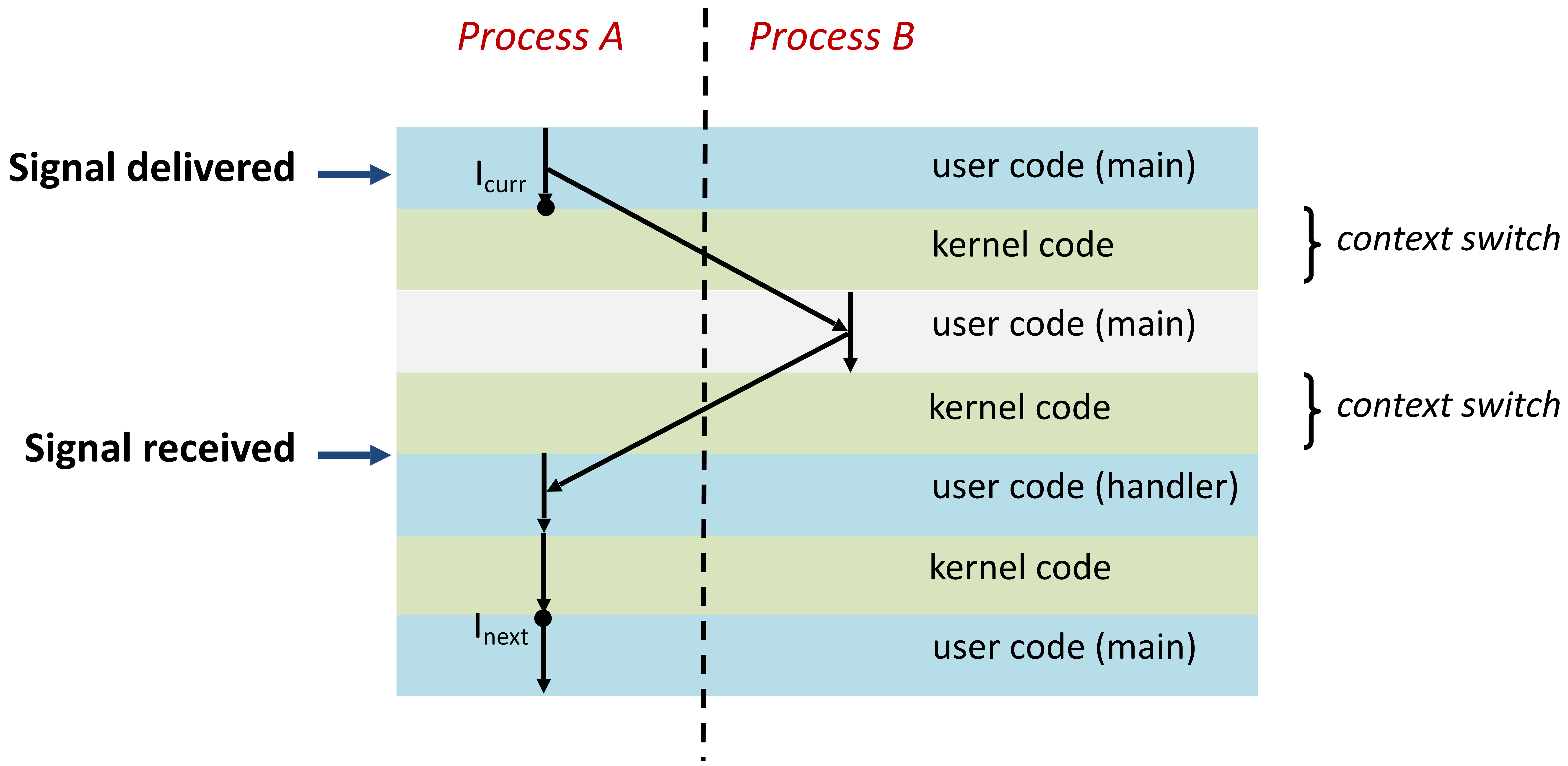
optional

Signal handlers run concurrently with main program (in same process).



Another view of signal handlers as concurrent flows

optional



Pending and blocked signals

optional

A signal is *pending* if sent but not yet received

<= 1 pending signal per type per process

No Queue! Just a bit per signal type.

Signals of type S discarded while process has S signal pending.

A process can *block* the receipt of certain signals

Receipt delayed until the signal is unblocked

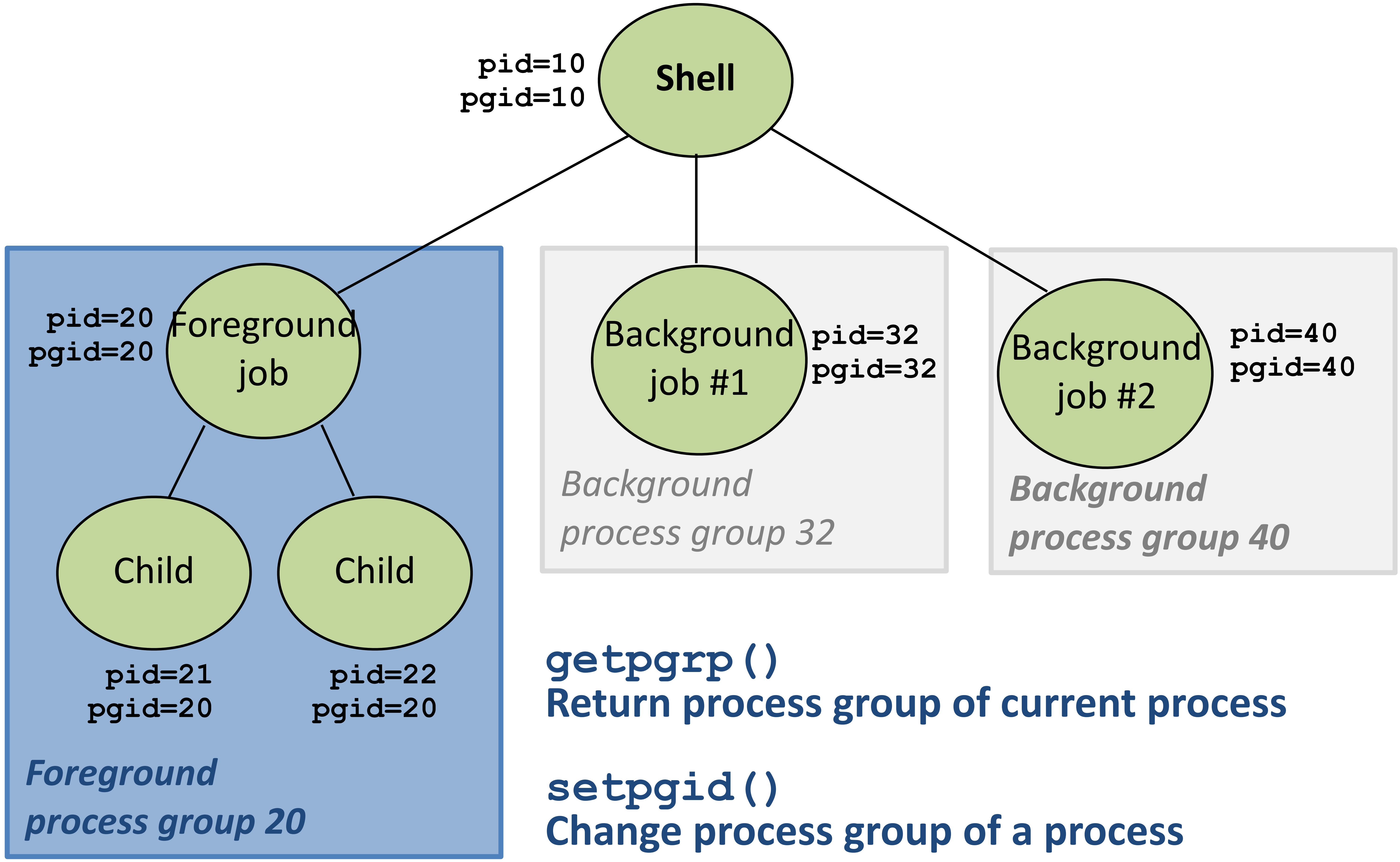
A pending signal is received at most once

Let's draw a picture...

Process Groups

optional

Every process belongs to exactly one process group (default: parent's group)



`getpgrp()`
Return process group of current process

`setpgid()`
Change process group of a process

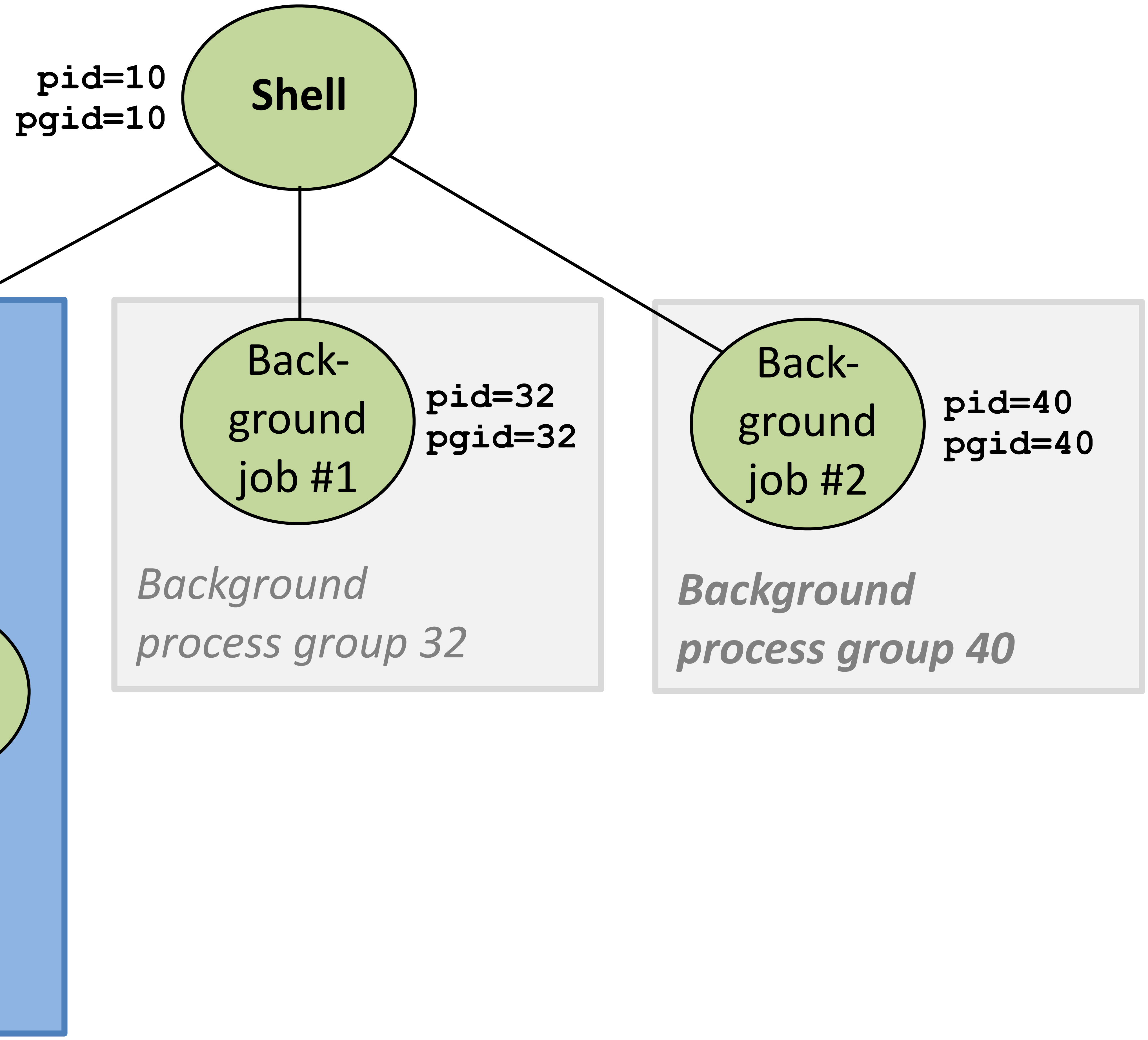
Sending signals from the keyboard

optional

Shell: Ctrl-C sends SIGINT (Ctrl-Z sends SIGTSTP)
to every job in the foreground process group.

SIGINT – default action is to terminate each process

SIGTSTP – default action is to stop (suspend) each process



Signal demos

optional

Ctrl-C

Ctrl-Z

kill

```
kill(pid, SIGINT);
```

A program that reacts to externally generated events (Ctrl-c)

optional

```
#include <stdlib.h>
#include <stdio.h>
#include <signal.h>

void handler(int sig) {
  safe_printf("You think hitting ctrl-c will stop me?\n");
  sleep(2);
  safe_printf("Well...");
  sleep(1);
  printf("OK\n");
  exit(0);
}

main() {
  signal(SIGINT, handler); /* installs ctrl-c handler */
  while(1) {
  }
}
```

```
> ./external
<ctrl-c>
You think hitting ctrl-c will stop me?
Well...OK
>
```

external.c

A program that reacts to internally generated events

optional

```
#include <stdio.h>
#include <signal.h>

int beeps = 0;

/* SIGALRM handler */
void handler(int sig) {
  safe_printf("BEEP\n");

  if (++beeps < 5)
    alarm(1);
  else {
    safe_printf("DING DING!\n");
    exit(0);
  }
}
```

internal.c

```
main() {
  signal(SIGALRM, handler);
  alarm(1); /* send SIGALRM in
               1 second */

  while (1) {

  }
}
```

```
> ./internal
BEEP
BEEP
BEEP
BEEP
BEEP
DING DING!
>
```

Signal summary

optional

Signals provide process-level exception handling

- Can generate from user programs
- Can define effect by declaring signal handler

Some caveats

- Very high overhead
  - >10,000 clock cycles
  - Only use for exceptional conditions
- Not queued
  - Just one bit for each pending signal type
- Many more complicated details we have not discussed.
  - Book goes into too much gory detail.

Conclusion of unit: Hardware-Software Interface (ISA)

Lectures

Programming with Memory
x86 Basics
x86 Control Flow
x86 Procedures, Call Stack
Representing Data Structures
Buffer Overflows
Processes Model
Shells

Labs

6: Pointers in C
7: x86 Assembly
8: x86 Stack
9: Data structures in memory
10: Buffer overflows
11: Processes

Topics

C programming: pointers, dereferencing, arrays, structs, cursor-style programming, using malloc
x86: instruction set architecture, machine code, assembly language, reading/writing x86, basic program translation
Procedures and the call stack, data layout, security implications
Processes, shell, fork, wait

Assignments

Pointers
x86
Buffer
Concurrency

Exam 2: ISA + Process/Shell
April 18
(1 week from today)