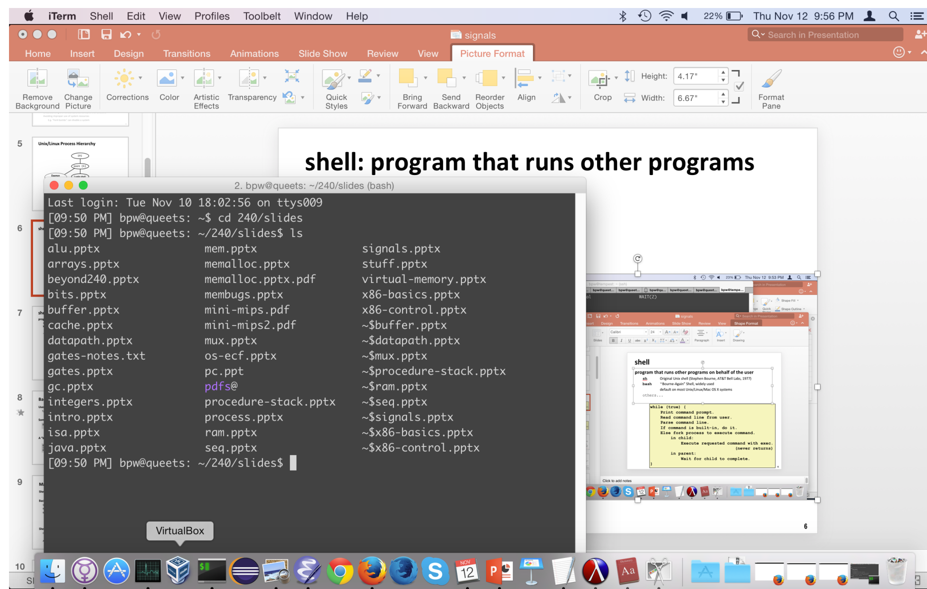
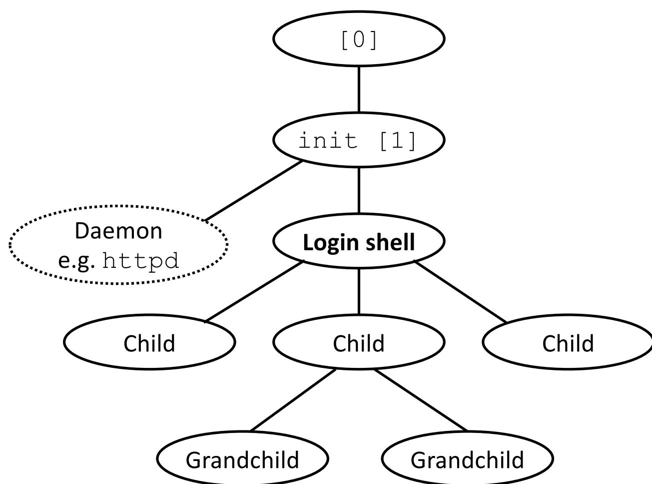
CS 240
Foundations of Computer Systems

Shells and Signals

shell: program that runs other programs



Shells and the process hierarchy



Shell logic

program that runs other programs on behalf of the user

sh Original Unix shell (Stephen Bourne, AT&T Bell Labs, 1977)

bash "Bourne-Again" Shell, widely used
default on most Unix/Linux/Mac OS X systems

many others...

```
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

User interface to shell and other programs.

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

Command-line terminal (emulator):

Input (keyboard)

Output (screen, sound)

To wait or not?

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.
```

don't do this with emacs unless using X windows version

*Also: 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)

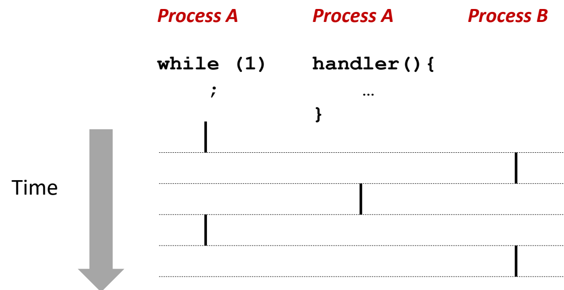
Catch the signal by executing a user-level function called *signal handler*

Like an impoverished Java exception handler

Signals handlers as concurrent flows

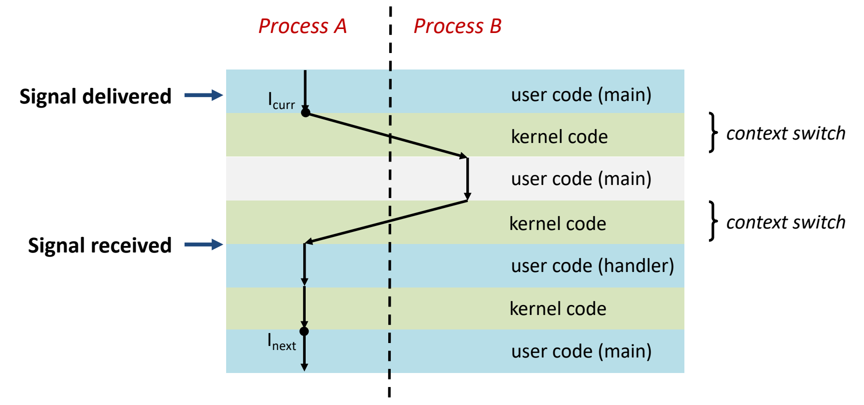
optional

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

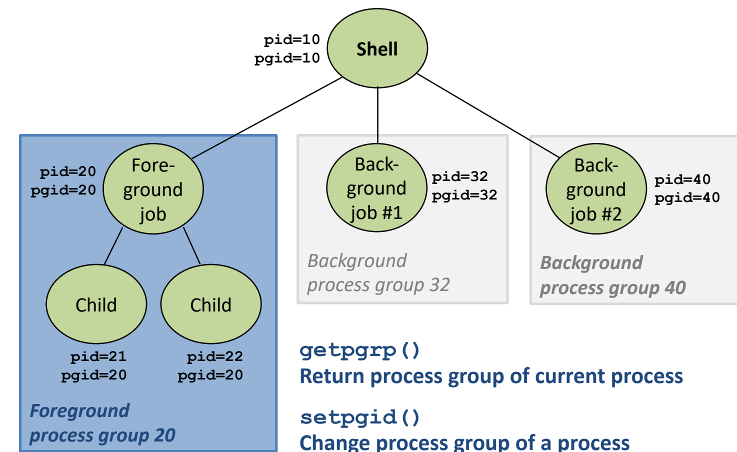
A pending signal is received at most once

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

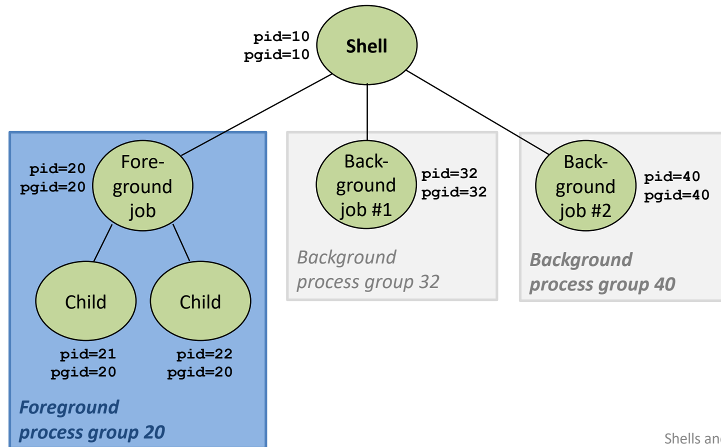
optional

Sending signals from the keyboard

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



optional

Signal demos

Ctrl-C

Ctrl-Z

kill

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


optional

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

```
#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

optional

A program that reacts to internally generated events

```
#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!
>
```

optional

Signal summary

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.