Signals (continued)

CS 241

April 9, 2012

University of Illinois

Signals

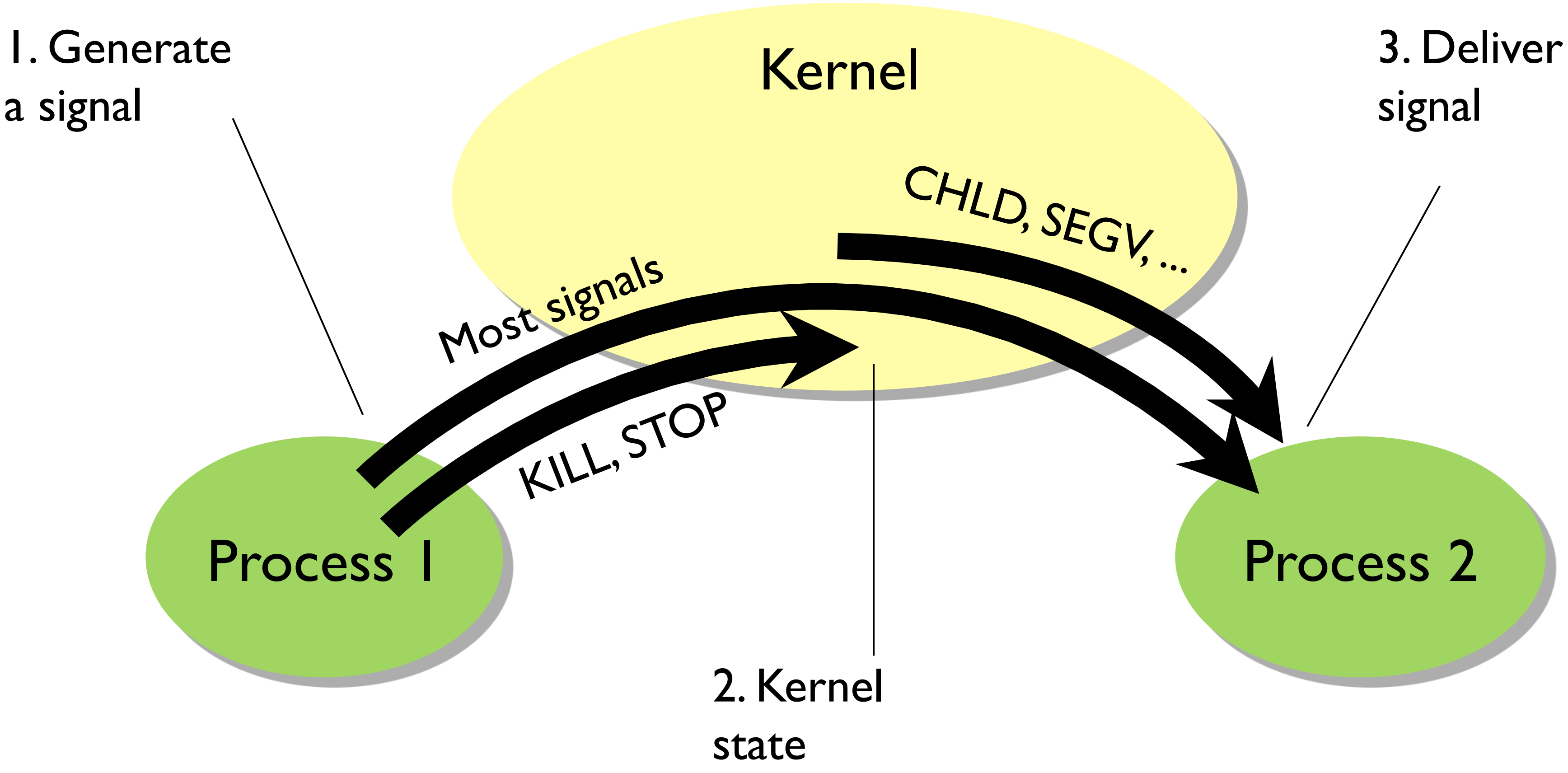
A signal is an asynchronous notification of an event

- Asynchronous: could occur at any time
- Interrupts receiving process; jumps to signal handler in that process
- A (limited) menu of event types to pick from

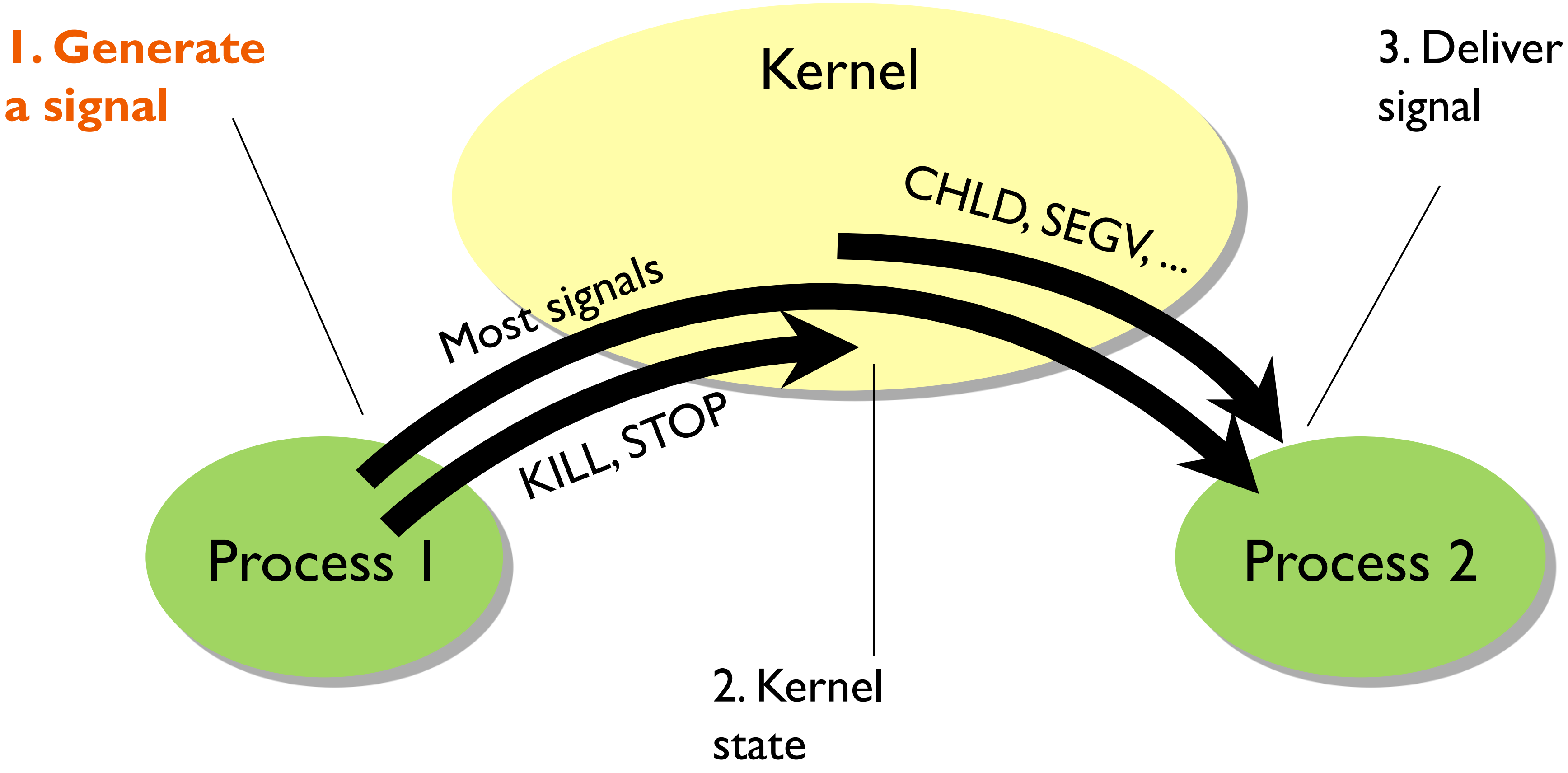
What events could be asynchronous?

- Email message arrives on my machine
  - Mailing agent (user) process should retrieve it
- Invalid memory access
  - OS should inform scheduler to remove process from the processor
- Alarm clock goes off
  - Process which sets the alarm should catch it

Signaling overview



Signaling overview



Generating a signal

Generated by a process with syscall `kill(pid, signal)`

- Sends `signal` to process `pid`
- Poorly named: sends any signal, not just SIGKILL

Generated by the kernel, when...

- a child process exits or is stops (SIGCHLD)
- floating point exception, e.g. div. by zero (SIGFPE)
- bad memory access (SIGSEGV)
- ...

Signals from the command line: kill

`kill -l`

- Lists the signals the system understands

`kill [-signal] pid`

- Sends signal to the process with ID `pid`
- Optional argument `signal` may be a name or a number (default is SIGTERM)

`kill -9 pid` or `kill -KILL pid` or `kill -SIGKILL pid`

- Unconditionally terminates process `pid`

Signals in the interactive terminal

Control-C is SIGINT

- Interactive attention signal

Control-Z is SIGSTOP

- Execution stopped – cannot be ignored

Control-Y is SIGCONT

- Execution continued if stopped

Control-\ is SIGQUIT

- Interactive termination: core dump

A program can signal itself

Similar to raising an exception

- `raise(signal)` or
- `kill(getpid(), signal)`

Or can signal after a delay

- `unsigned alarm(unsigned seconds);`
- Calls are not stacked
  - any previously set `alarm()` is cancelled
- `alarm(20)`
  - Send `SIGALRM` to calling process after 20 seconds
- `alarm(0)`
  - cancels current alarm

Example: What does this do?

```
int main(void) {
    alarm(10);
    while(1);
}
```

Example of program signaling itself

“Infinite” loop for 10 seconds

Then interrupted by alarm

- Doesn’t matter that `while` loop is still looping
- No signal handler set by program; default action: terminate

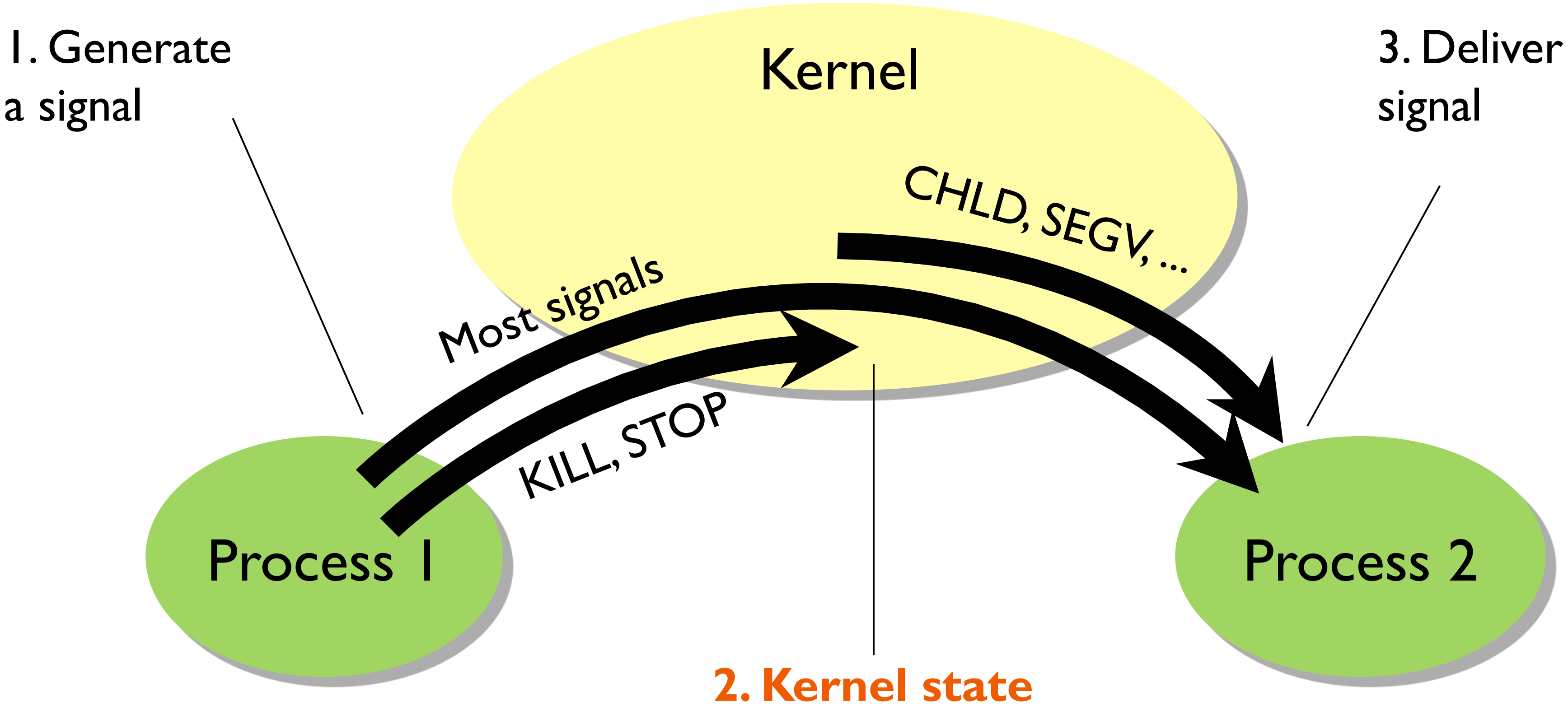
Morbid example

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

int main(int argc, char** argv) {
    while (1) {
        if (fork())
            sleep(30);
        else
            kill(getppid(), SIGKILL);
    }
}
```

What does this do?

Signaling overview



Kernel state

A signal is related to a specific process

In the process's PCB (process control block), kernel stores

- Set of pending signals
    - Generated but not yet delivered
- Set of blocked signals
    - Will stay pending
    - Delivered after unblocked (if ever)
- An action for each signal type
    - What to do to deliver the signal

Kernel signaling procedure

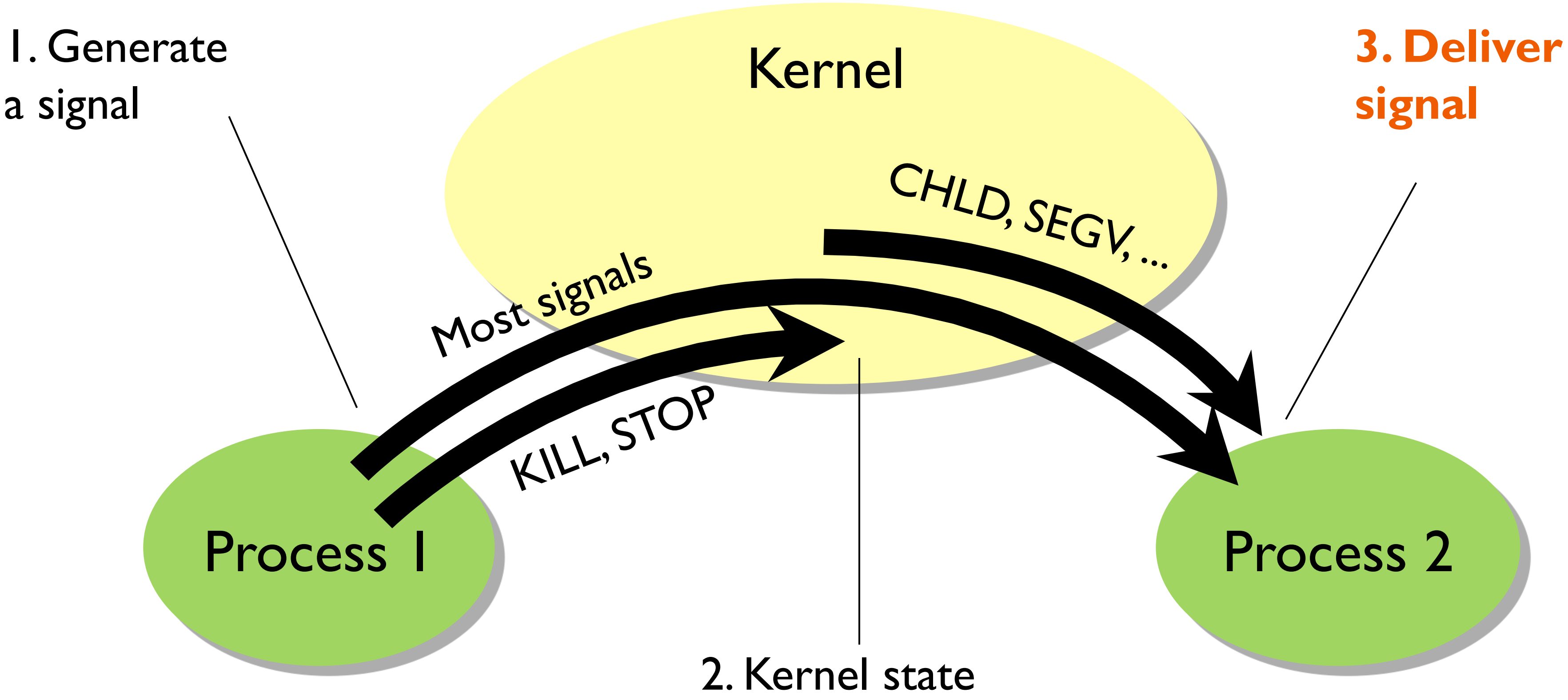
Signal arrives

- Set pending bit for this signal
- Only one bit per signal type!

Ready to be delivered

- Pick a pending, non-blocked signal and execute the associated action – one of:
  - Ignore
  - Kill process
  - Execute signal handler specified by process

Signaling overview



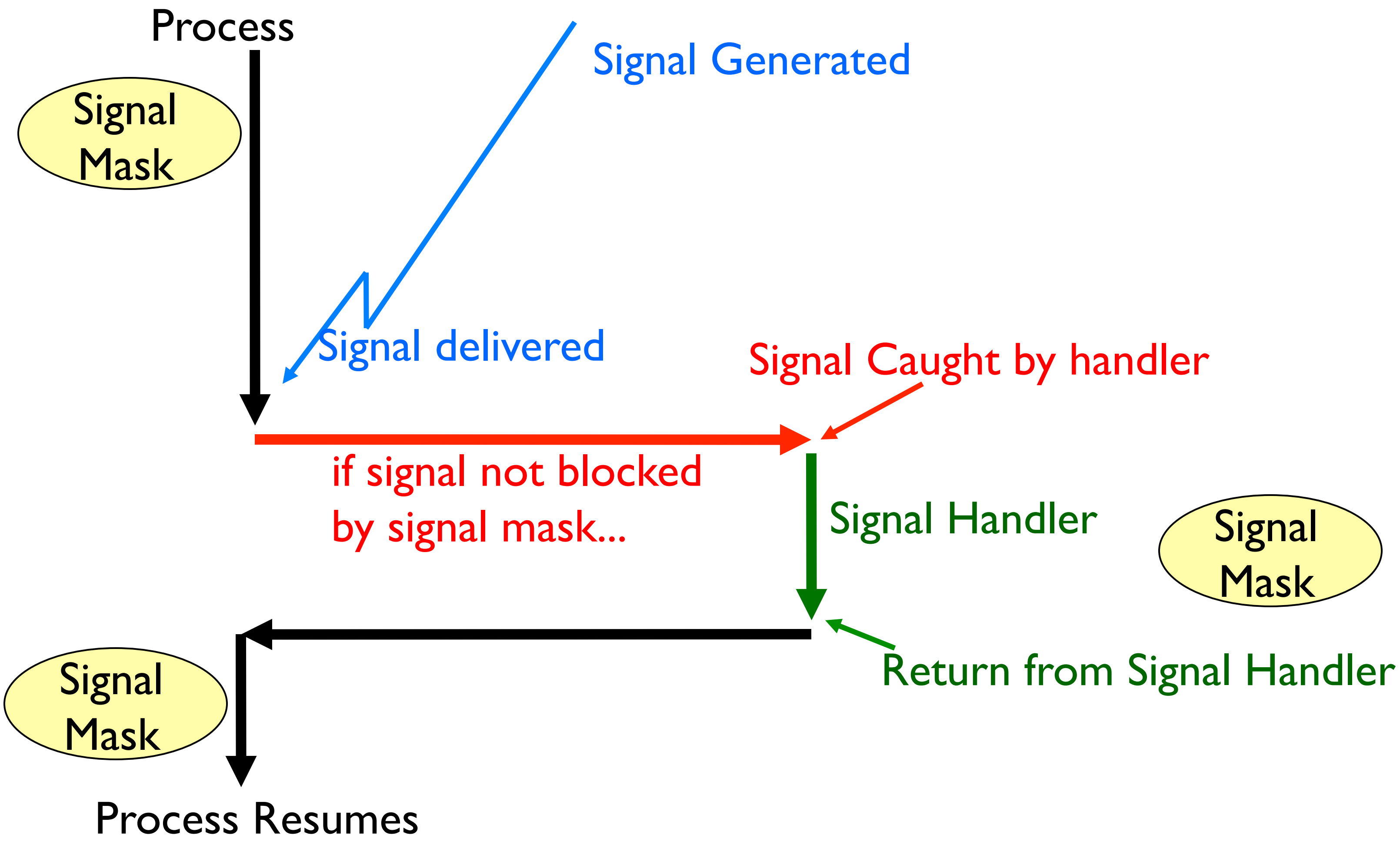
Delivering a signal

Kernel may handle it

- Not delivered to target program at all!
- SIGSTOP, SIGKILL
- Target process can’t handle these
- They are really messages to the kernel about a process, rather than messages to a process

But for most signals, target process handles it (if it wants)

If process handles the signal...



Signal mask

Temporarily prevents select types of signals from being delivered

- Implemented as a bit array
- Same as kernel’s representation of pending and blocked signals

SigInt	SigQuit	SigKill	…	SigCont	SigAbrt
1	0	1	…	1	0

Signal mask example

Block all signals:

```
sigset_t sigs;
sigfillset(&sigs);
sigprocmask(SIG_SETMASK, &sigs, NULL);
```

Instead of sigfillset, you might try:

- sigemptyset
- sigaddset
- sigdelset
- sigismember

If it's not masked, we handle it

Three ways to handle

- Ignore it
  - Different than blocking!
- Kill process
- Run specified signal handler function

One of these is the default

- Depends on signal type

Tell the kernel what we want to do: `signal()` or `sigaction()`

sigaction

```
#include <signal.h>

int sigaction(int                            signum,
              const struct sigaction *       act,
              struct sigaction *             oldact);
```

Changes the action taken by a process when it receives a specific signal

Notes

- `signum` is any valid signal except SIGKILL and SIGSTOP
- If `act` is non-null, new action is installed from `act`
- If `oldact` is non-null, previous action is saved in `oldact`

Example: Catch SIGINT

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

void handle(int sig) {
    char handmsg[] = "Ha! Handled!!!\n";
    int msglen = sizeof(handmsg);
    write(2, handmsg, msglen);
}

int main(int argc, char** argv) {
    struct sigaction sa;
    sa.sa_handler = handle;   /* the handler function!! */
    sa.sa_flags = 0;
    sigemptyset(&sa.sa_mask); /* block all signals during handler */

    sigaction(SIGINT, &sa, NULL);

    while (1) {
        printf("Fish.\n");
        sleep(1);
    }
}
```

Note: Need to check for error conditions in all these system & library calls!

Potentially unexpected behavior

Inside kernel, only one pending signal of each type at a time

- If another arrives while first one still pending, second is lost

What's an interesting thing that could happen during a signal handler?

- Another signal arrives!
- Need to either
  - Write code that does not assume mutual exclusion, or
  - Block signals during signal handler (signal() and sigaction() can do this for you)

How to catch without catching

Can wait for a signal

- No longer an asynchronous event, so no handler!

First block all signals

Then call `sigsuspend()` or `sigwait()`

- Atomically unblocks signals and waits until signal occurs
- Looks a lot like condition variables, eh?
  - cond_wait() unlocks mutex and waits till condition occurs

Puzzle:
Using signals to send a stream of data