Pipes have two main benefits:

- they control same inter-process communication
- they are transparent (the program doesn't know they exist

How are they implemented?

```
int pipe(int pipefd[2]);
pipefd[0] = "read"
pipefd[1] = "write"
// these can be thought of like 0 = stdin and 1 = stdout
```

This builds a circular bounded buffer that can be used to communicate between processes BUT that introduces the case of a full buffer; what do we do?

- write what you can and return the size
- wait
- throw error

Pipes therefore have a third benefit—flow control!

```
$ du | sort -n
```

How do we use pipes?

```
int pipefd[2];
pid_t cpid;
char buf;
if (argc != 2) exit(EXIT_FAILURE);
if (pipe(pipefd) == -1) {perror("pipe"); exit(1);}
if ((cpuid = fork()) == 0) {
  close(pipefd[1];
  while(read(pipefd[0], &buf, 1) > 0) write(STDOUT_FILENO, &buf, 1);
  write(STDOUT_FILENO, "\n", 1);
  close(pipefd[0];
  _exit(0);
}
else { // parent
  close(pipefd[0]);
  write(pipefd[1], argv[1], strlen(argv[1]));
  close(pipefd[1]);
  wait(NULL);
  exit(0);
}
// note: the order of execution is not guaranteed
```

Pipes, as mentioned above, are not perfect; we have 4 major categories of pipe failure:

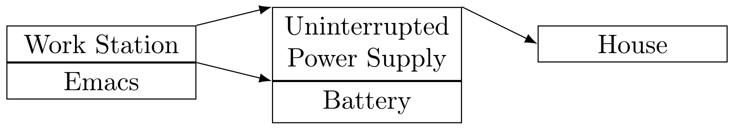
1. Reading from an empty pipe where the writer never writes $\implies$ hang indefinitely
2. Reading from an empty pipe with no writers $\implies$ return 0
3. Writing to a full pipe where the reader never reads $\implies$ suspend/hang indefinitely
4. Writing to a full pipe where the reader never reads
   - SIGPIPE since returning 0 would probably cause many people to retry
   - if SIGPIPE is ignored, write fails with ESPIPE

Note that the big mistakes and performance errors occur when we do not close pipes. For example, a named pipe can cause an fd leak, since it could be referenced by any program

A common issue:

```
while (condition) printf("%d\n", number);
// since this would run forever on write failure,
// we have an asynchronous signal SIGPIPE
// which kills a program if no readers remain
```

BUT sometimes there is a reader, who's not listening (plus closing has a delay). Take the setup:



What do we do if the power in the house goes out?

1. do nothing and lose work
2. OS saves a stack of running processes and state in the stack
3. End-to-End (processes are notified and can figure it out for themselves)

Since #2 can make clock-based apps go haywire, we consider #3; we have 3 ways of notifying processes that we have lost power

1. poll /dev/power
   this is annoying, since the burden is on the programmer

2. /dev/powering_off
   the kernel blocks this unless we have lost power (too complicated)

3. SIGNALS
   grab the attention of a program not designed to receive it