

# CSE 333

## Section 3

POSIX I/O and Directories

# Logistics

- Homework 1
  - Due **Thursday (7/7) @ 11:59pm (Tonight!)**
  - Reminder that you can use up-to 2 late days on an assignment
  - Weekend counts as 1 late day (Sunday is the last day to submit)
- Exercise 4
  - Due **Wednesday (7/13) @ 11:00am**

**POSIX**



# POSIX (Portable Operating System Interface)

A family of IEEE standards that maintains compatibility across variants of Unix-like operating systems for basic I/O (*file*, terminal, and *network*) and for *threading*.

Why might a POSIX standard be beneficial (e.g., from an application perspective or vs. the C stdio library)?

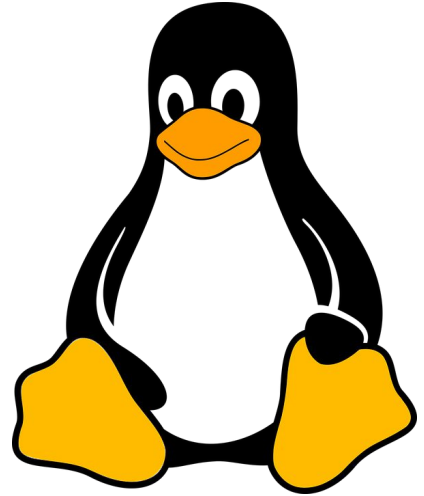
- More explicit control since read and write functions are system calls and you can directly access system resources.
- POSIX calls are unbuffered so you can implement your own buffer strategy on top of read()/write().
- There is no standard higher level API for network and other I/O devices

# What's Tricky about (POSIX) File I/O?

- Communication with input and output devices doesn't always work as expected
  - Some details might be unknown (*e.g.*, size of a file)
  - May not process all data or fail, necessitating read/write *loops*
- Different system calls have a variety of different failure modes and error codes
  - Look up in the documentation and use pre-defined constants!
  - Lots of error-checking code needed
    - Need to handle resource cleanup on *every* termination pathway

# I/O Analogy – Messy Roommate

- The Linux kernel (**Tux**) now lives with you in room #333
- There are N pieces of trash in the room
- There is a single trash can, **char bin[N]**
  - (For some reason, the trash goes in a particular order)
- You can tell your roommate to pick it up, but they are unreliable



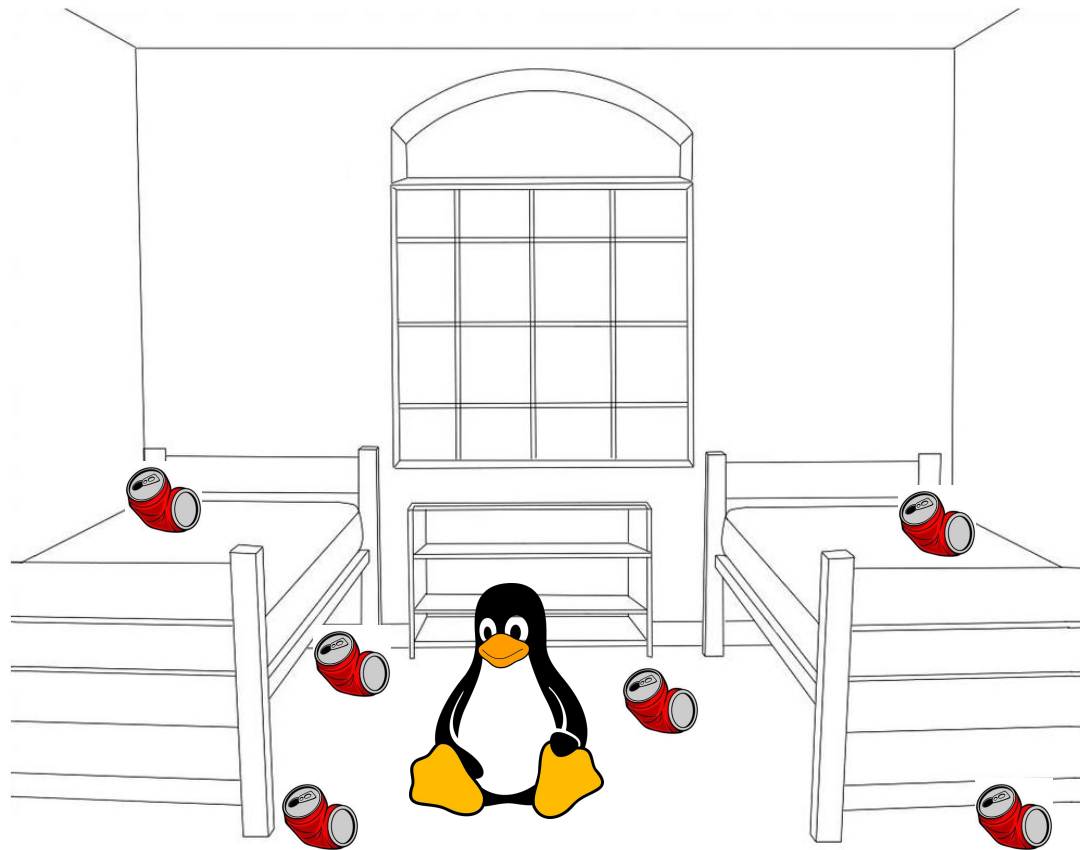
# I/O Analogy – Messy Roommate

NumTrash pickup(roomNum, trashBin, Amount)

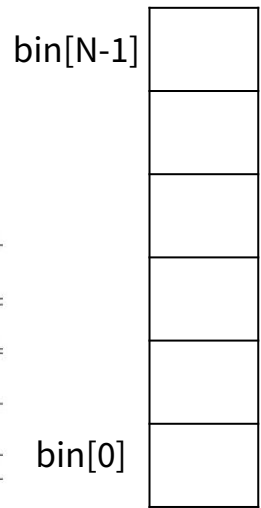
<i>“I tried to start cleaning, but something came up” (got hungry, had a midterm, room was locked, etc.)</i>	NumTrash == -1 errno == excuse
<i>“You told me to pick up trash, but the room was already clean”</i>	NumTrash == 0
<i>“I picked up some of it, but then I got distracted by my favorite show on Netflix”</i>	NumTrash < Amount
<i>“I did it! I picked up all the trash!”</i>	NumTrash == Amount

NumTrash pickup(roomNum, trashBin, Amount)

# How do we get room 333 clean?



NumTrash == -1, errno == excuse
NumTrash == 0
NumTrash < Amount
NumTrash == Amount



What do we do in the following scenarios?

NumTrash pickup(roomNum, trashBin, Amount)

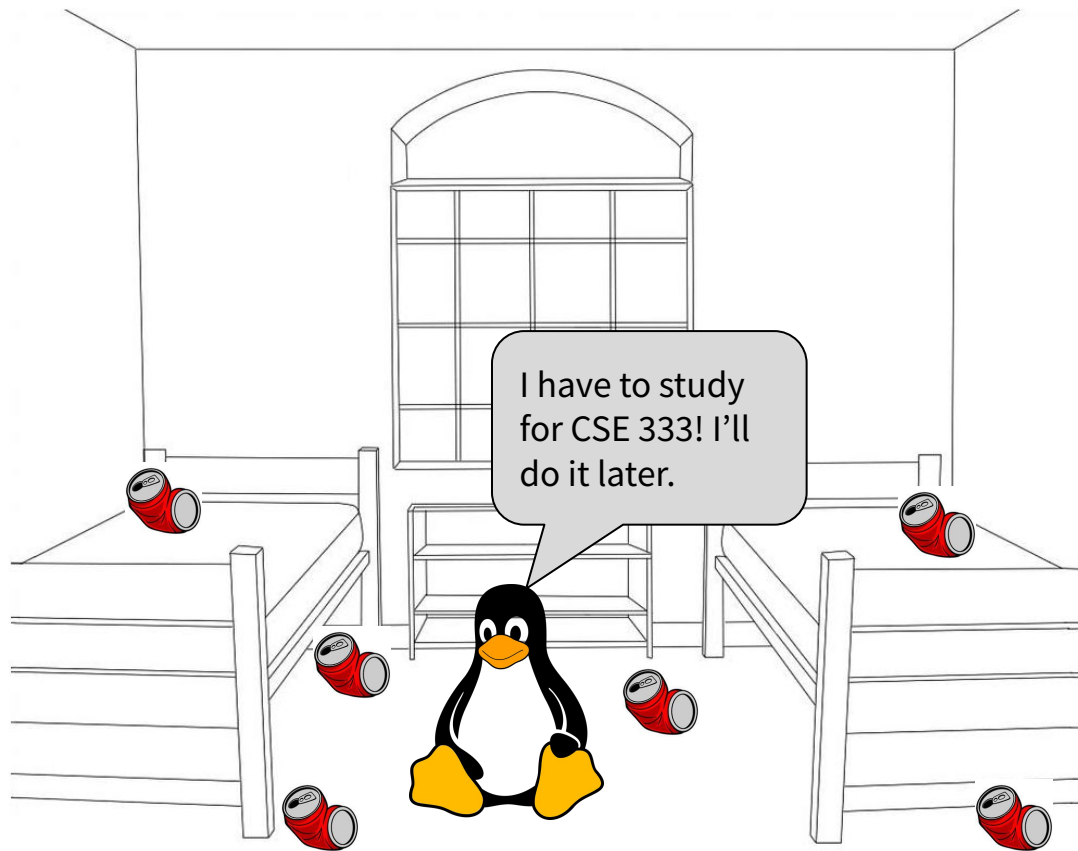
# How do we get room 333 clean?

NumTrash == -1, errno == excuse

NumTrash == 0

NumTrash < Amount

NumTrash == Amount



bin[N-1]

bin[0]

Decide if the excuse is reasonable, and either let it be or ask again.

NumTrash pickup(roomNum, trashBin, Amount)

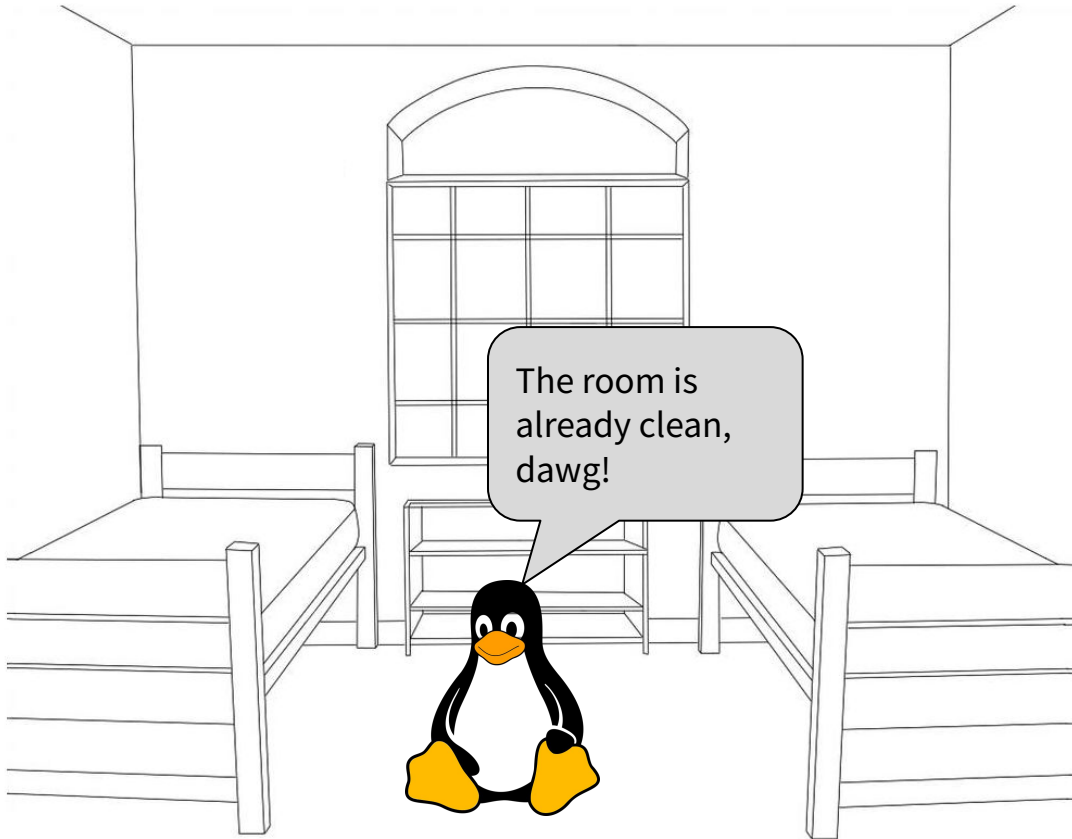
# How do we get room 333 clean?

NumTrash == -1, errno == excuse

NumTrash == 0

NumTrash < Amount

NumTrash == Amount



bin[N-1]

bin[0]

Stop asking  
them to clean  
the room!  
There's  
nothing to do.

NumTrash pickup(roomNum, trashBin, Amount)

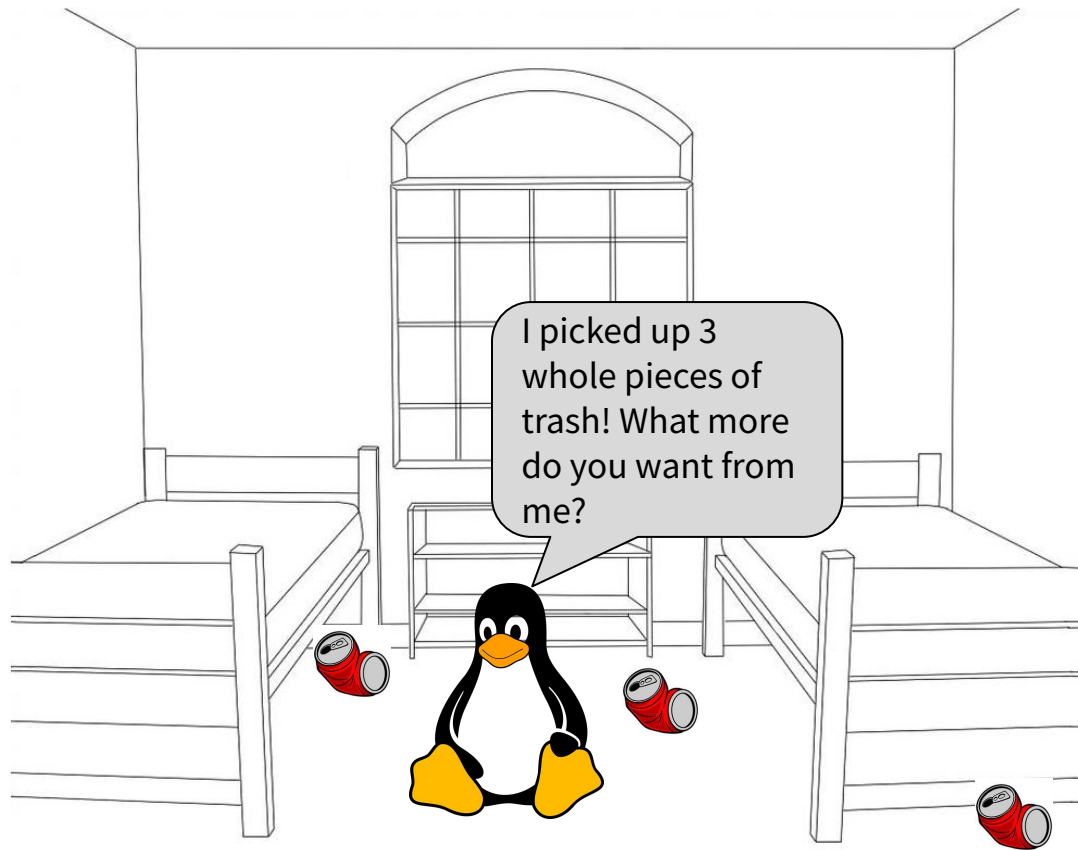
# How do we get room 333 clean?

NumTrash == -1, errno == excuse

NumTrash == 0

NumTrash < Amount

NumTrash == Amount



bin[N-1]



Ask them again to pick up the rest of it.

NumTrash pickup(roomNum, trashBin, Amount)

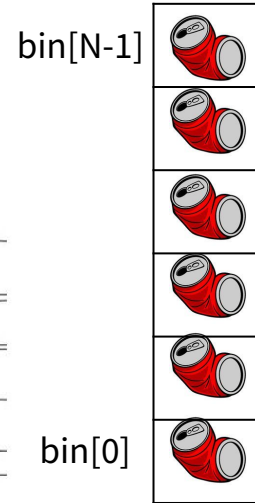
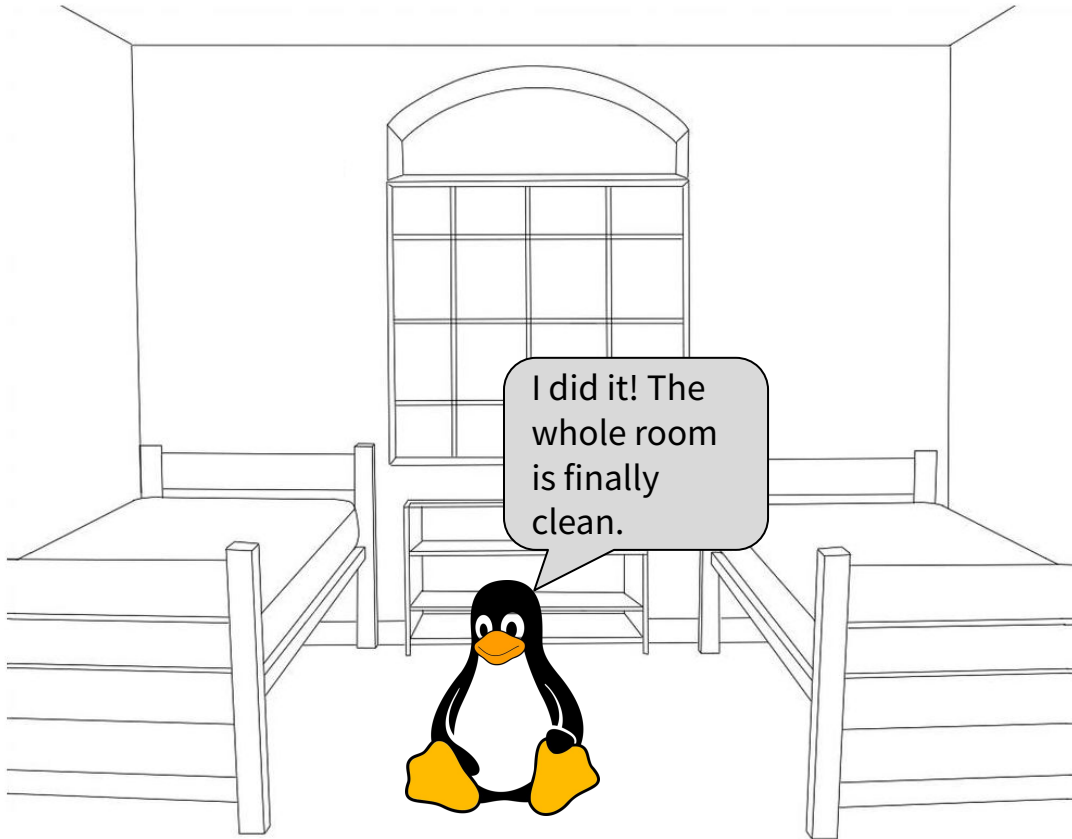
# How do we get room 333 clean?

NumTrash == -1, errno == excuse

NumTrash == 0

NumTrash < Amount

NumTrash == Amount



They did what you asked, so stop asking them to pick up trash.

NumTrash Pickup(roomNum, trashBin, Amount)

# How do we get room 333 clean?

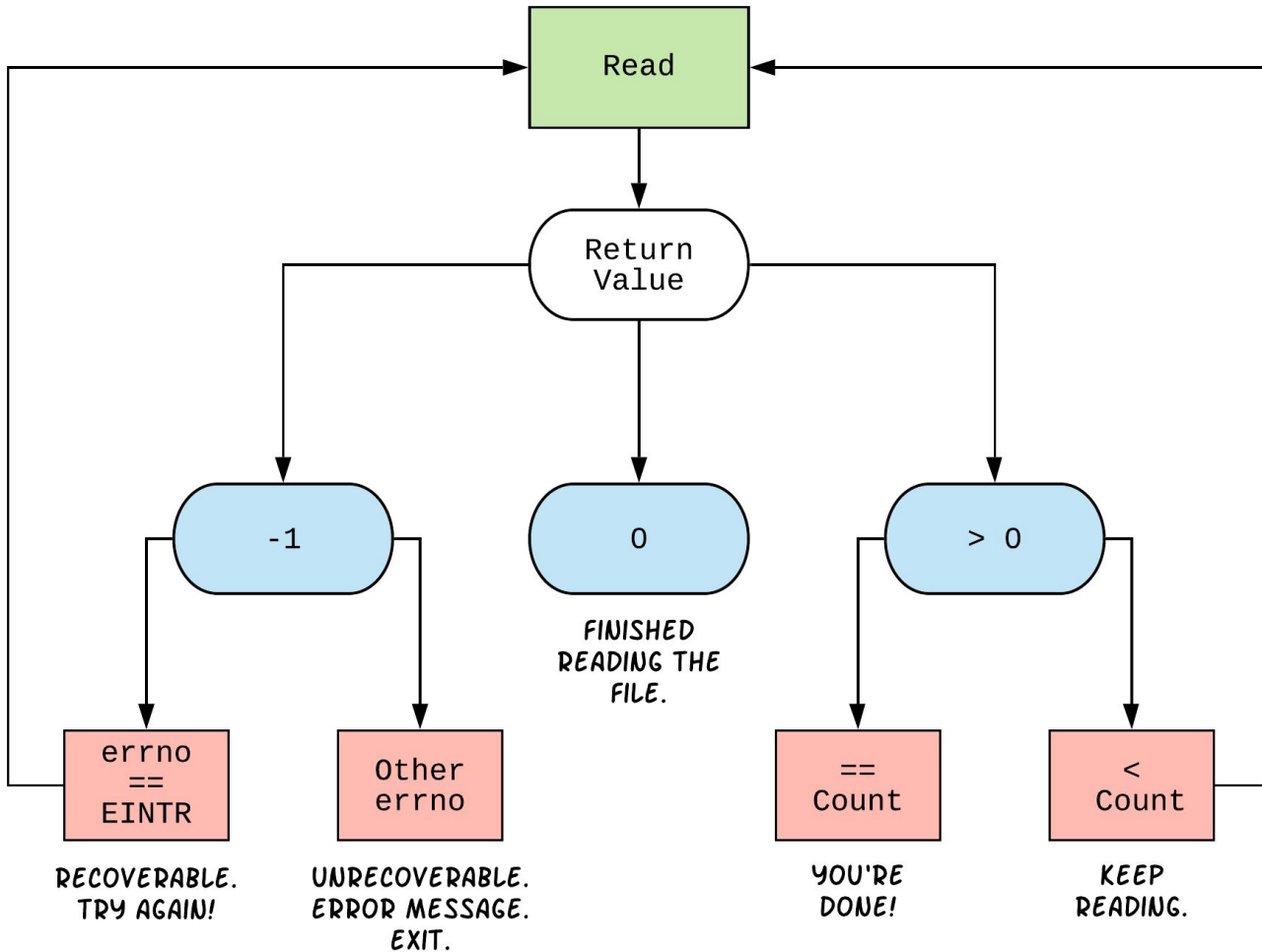
```
int picked_up = 0;
while ( picked_up < N ) {
    NumTrash = Pickup( 333, bin + picked_up, N - picked_up )
    if ( NumTrash == -1 ) {
        if ( excuse not reasonable )
            ask again
        stop asking and handle the excuse
    }
    if ( NumTrash == 0 ) // we over-estimated the trash
        stop asking since the room is clean
    add NumTrash to picked_up
}
```

NumTrash == -1, errno == excuse
NumTrash == 0
NumTrash < Amount
NumTrash == Amount

# Review from Lecture – POSIX Read

```
ssize_t read(int fd, void *buf, size_t count);
```

An error occurred	result = -1 errno = error
Already at EOF	result = 0
Partial Read	result < count
Success!	result == count



# Exercise 1

```
int open(char *name, int flags);
```

- *name is a string representing the name of the file. Can be relative or absolute.*
- *flags is an integer code describing the access. Some common flags are listed below:*
  - ◆ *O\_RDONLY – Open the file in read-only mode.*
  - ◆ *O\_WRONLY – Open the file in write-only mode.*
  - ◆ *O\_RDWR – Open the file in read-write mode.*
  - ◆ *O\_APPEND – Append new information to the end of the file.*
- ★ *Returns an integer which is the file descriptor. Returns -1 if there is a failure.*

```
ssize_t read(int fd, void *buf, size_t count);
```

```
ssize_t write(int fd, const void *buf, size_t count);
```

- *fd is the file descriptor (as returned by open()).*
- *buf is the address of a memory area into which the data is read or written.*
- *count is the maximum amount of data to read from or write to the stream.*
- ★ *Returns the actual amount of data read from or written to the file.*

```
int close(int fd);
```

```

int fd = open("333.txt", O_WRONLY); // open 333.txt
int n = ...;
char *buf = ...; // Assume buf initialized with size n
int result;

char *ptr = buf; // initialize variable for loop

... // code that populates buf happens here

while ( ptr < buf + n ) {
    result = write(fd, ptr, buf + n - ptr);

    if (result == -1) {
        if (errno != EINTR && errno != EAGAIN) {
            // a real error happened, return an error result
            close(fd); // cleanup
            perror("Write failed");
            return -1;
        }
        continue; // EINTR or EAGAIN happened, so loop and try again
    }
    ptr += result; // update loop variable
}
close(fd); // cleanup

```

**(i) This is just ONE possible way to solve this exercise!**

# POSIX Analysis

1. Why is it important to store the return value from `w r i t e`?  
Why don't we check for a return value of `0` like `r e a d`?

`w r i t e` may not actually write all the bytes specified in `count`.

The `0` case for reading was EOF, but writing adds length to your file and we know exactly how much we are trying to write.

2. Why is it important to remember to call `c l o s e` once you have finished working on a file?

In order to free resources (*i.e.*, locks on those files, file descriptor table entries).

# There is No One True Loop!!!

You will need to tailor your POSIX loops to the specifics of what you need.

Some design considerations:

- Read data in fixed-sized chunks or all at once?
  - Trade-off in disk accesses versus memory usage.
- What if we don't know N (how many bytes to read) ahead of time?
  - Keep calling **read** until we get 0 back (EOF).
  - Can determine N dynamically by tracking the number of bytes read and using **malloc/realloc** to allocate more space as we go.
  - This case comes up when reading/writing to the network (later in 333)!

# Directories



# Directories

- A directory is a special file that stores the names and locations of the related files/directories
  - This includes itself (`.`), its parent directory (`..`), and all of its children (*i.e.*, the directory's contents)
  - Take CSE 451 to learn more about the directory structure
- Accessible via POSIX (`dirent.h` in C/C++)
- Why might we want to work with directories in a program?  
List files, find files, search files, recursively traverse directories, etc.

# POSIX Directory Basics

- POSIX defines operations for directory *traversal*
  - `DIR*` is not a file descriptor, but used similarly
  - `struct dirent` describes a directory entry
  - `readdir()` returns the ‘next’ directory entry, or NULL at end
- Error values (they also set `errno`):
  - `DIR* opendir(const char* name); // NULL`
  - `struct dirent* readdir(DIR* dirp); // NULL`
  - `int closedir(DIR* dirp); // -1`

# struct dirent

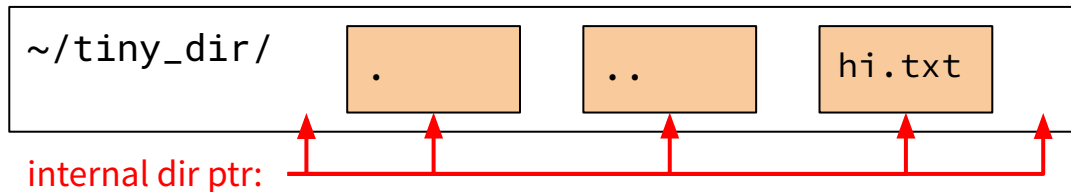
- Returned value from **readdir**
  - Does *not* need to be “freed” or “closed” 🎉
- Fields are “unspecified” (depends on your file system)
  - glibc specifies:

```
struct dirent {
    ino_t      d_ino;
    off_t      d_off;
    unsigned short d_reclen;
    unsigned char d_type;
    char        d_name[256];
};
```

} directory entry  
metadata stored in  
integer types

Null-terminated directory entry name  
(what we care about in 333)

# readdir Example



```
➔ DIR* dirp = opendir("~/tiny_dir"); // opens directory
➔ struct dirent* file = readdir(dirp); // gets ptr to "."
➔ file = readdir(dirp); // gets ptr to ".."
➔ file = readdir(dirp); // gets ptr to "hi.txt"
➔ file = readdir(dirp); // gets NULL
➔ closedir(dirp); // clean up
```

# Exercise 2



Given the name of a directory, write a C program (`./dirdump`) that is analogous to `ls`, i.e. prints the names of the entries of the directory to stdout. Handle any errors!

```
int main(int argc, char** argv) {
    /* 1. Check to make sure we have a valid command line arguments */
    if (argc != 2) {
        fprintf(stderr, "Usage: ./dirdump <path>\n");
        return EXIT_FAILURE;
    }
    /* 2. Open the directory, look at opendir() */
    DIR* dirp = opendir(argv[1]);
    if (dirp == NULL) {
        fprintf(stderr, "Could not open directory\n");
        return EXIT_FAILURE;
    }
    ...
}
```

Given the name of a directory, write a C program (./dirdump) that is analogous to **ls**, i.e. prints the names of the entries of the directory to stdout. Handle any errors!

...

```
/* 3. Read through/parse the directory and print out file names  
    Look at readdir() and struct dirent */
```

```
struct dirent *entry;  
entry = readdir(dirp);  
while (entry != NULL) {  
    printf("%s\n", entry->d_name);  
    entry = readdir(dirp);  
}
```

```
/* 4. Clean up */  
closedir(dirp);
```

```
return EXIT_SUCCESS;
```

```
}
```