CS 241: Systems Programming Lecture 2. Introduction to Unix and the Shell

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What is the shell?

Text-based interface to the operating system and to the file system

User enters commands

The shell runs the commands

Output appears on a terminal (terminal emulator)

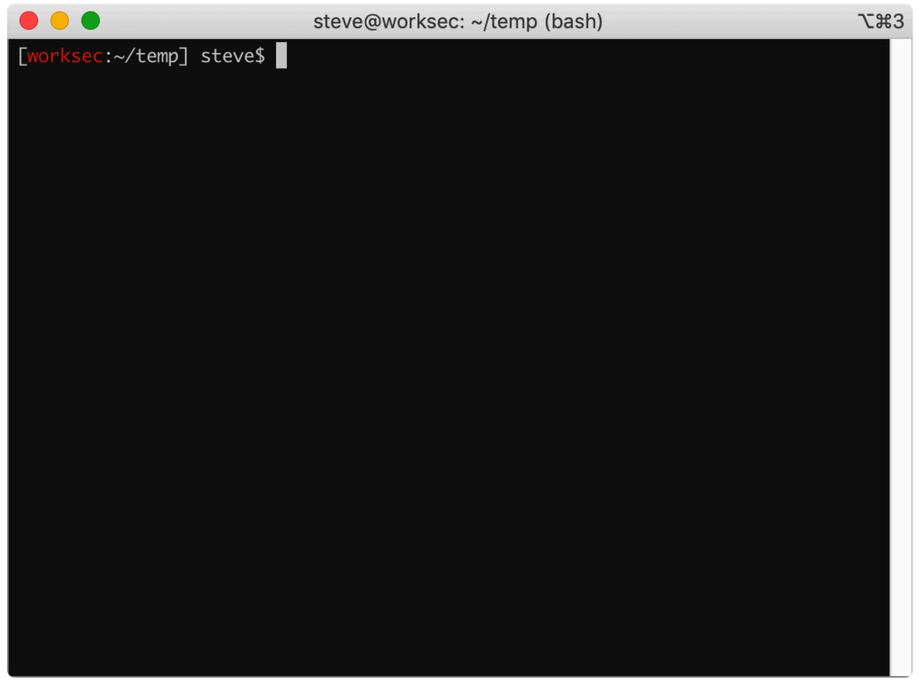
Commands can change files/directories on the file system

Terminals/terminal emulators

DEC VT100 terminal

https://upload.wikimedia.org/wikipedia/commons/6/6f/Terminal-dec-vt100.jpg

iTerm2 terminal emulator

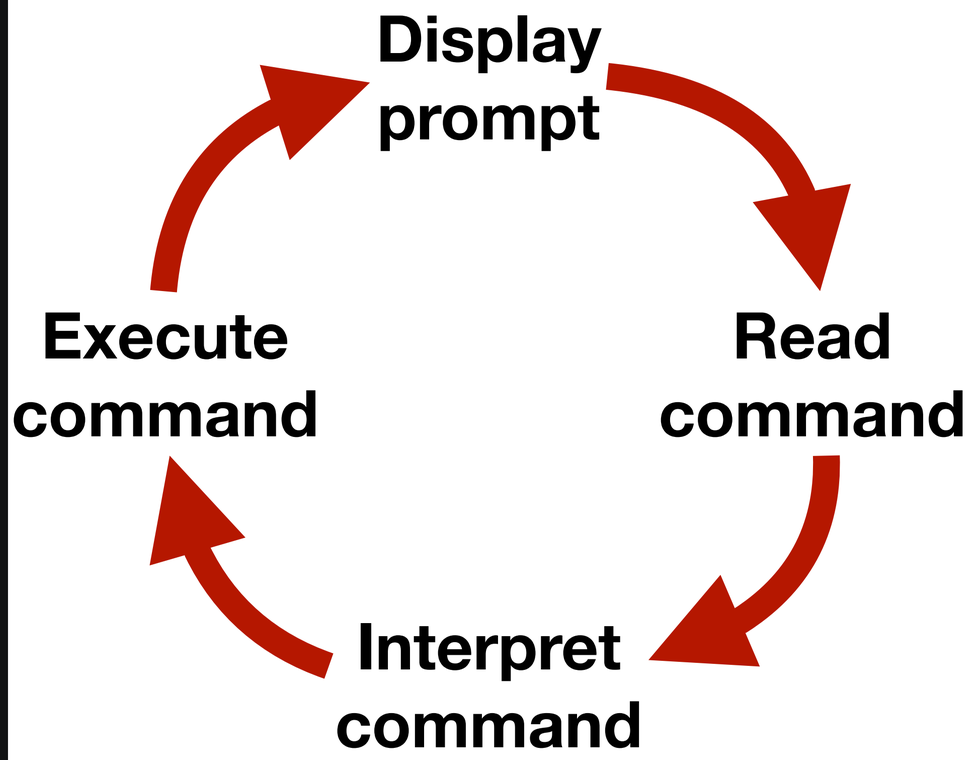


There are many shells

`sh`	Bourne shell
`bash`	Bourne again shell (the one we'll be using)
`dash`	Light-weight Bourne shell (often named `sh` on Linux)
`csh`	C shell
`tcsh`	An improved csh
`ksh`	Korn shell (sh-compatible, some csh features)
`zsh`	Z shell (incorporates aspects of tcsh, ksh, and bash, default for macOS)

Interpreter loop

```
[worksec:~/temp] steve$
```



Types of commands

Commands to print output to the screen

- `$ echo 'Hello world!'`

Commands to manipulate the file system

- `$ ls`
- `$ mv old_name.txt new_name.txt`

GUI programs

- `$ code lab1`
- `$ firefox`

Most commands run programs, some are shell builtins

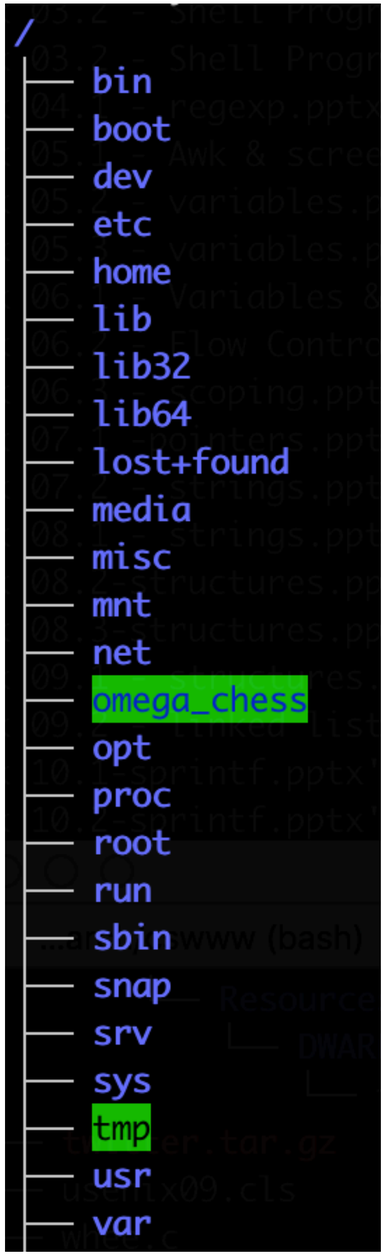
The file system

Structured as a single tree with root node: `/`

Directories hold files and directories

We name files (or directories) by giving a path through the tree

- Absolute path: `/usr/bin/ssh`
- Relative path (we'll come back to this)



Some important directories

`/`	The root directory
`/bin`	Holds programs used for essential tasks (e.g., `cp`, `mv`, `ls`)
`/sbin`	Superuser (administrator) binaries
`/etc`	System-wide configuration files
`/usr`	Holds programs and support files for user programs
`/usr/bin`	User binaries
`/home`	Holds users' home directories (this is configurable)

The current working directory

Every program on the system has its own current working directory

Not related to where the program lives in the file system

Programs can change their current working directory

The initial working directory of a running program is the current working directory of the parent—the program that launched the program

Bash's current working directory

The shell has a current directory (like every running program)

`cd` changes the current working directory

`pwd` prints the current working directory

We can name files using an absolute path or a relative path

- Absolute (starts with a `/`): `/usr/bin/ssh`
- Relative to the current working directory (doesn't start with a `/`)

Programs run by `bash` start with their initial working directory set to bash's current working directory

Accessing files via relative paths

Programs read (and write) files all the time

It would be painful to always give the full path

- “Edit file /home/mary/programming/neat-project/main.py”
- “Edit file /home/mary/programming/neat-project/drawing.py”
- “Run program /home/mary/programming/neat-project/main.py”

By changing the current directory to /home/mary/programming/neat-project

- “Edit file main.py”
- “Edit file drawing.py”
- “Run program main.py”

From relative to absolute paths

Constructing an absolute path from a relative path is easy:

- absolute_path = current_working_directory + “/” + relative_path

This happens automatically when accessing files via a relative path

Example of a relative path

```
mhogan@mcnulty:~$ pwd
/usr/users/noquota/faculty/mhogan
mhogan@mcnulty:~$ ls --color=auto /usr/bin/ssh
/usr/bin/ssh
mhogan@mcnulty:~$ cd /usr/
mhogan@mcnulty:/usr$ ls --color=auto bin/ssh
bin/ssh
mhogan@mcnulty:/usr$
```

Running bash from bash

When we open a terminal (emulator), it runs our shell, usually bash **[except newer macOS]**

In Lab 0, we will run

```
$ bash hello.sh
```

Two instances of bash will be running at the same time

- The interactive bash we type our commands in; and
- The noninteractive bash that runs the commands from inside hello.sh

`hello.sh` is a relative path to the file that the noninteractive bash tries to read

If bash's current working directory is your home directory and the script you want to run, `hello.sh`, is in the `programming` directory inside your home directory, which of the following commands would you use?

A. `$ bash hello.sh`

B. `$ bash programming hello.sh`

C. `$ bash programming\hello.sh`

D. `$ bash programming/hello.sh`

E. `$ bash programming:hello.sh`

Useful commands

- **ls** – list files
- **cd** – change directory
- pwd – print the working directory
- pushd, popd, dirs – use a stack to change directories
- **cp** – copy a file
- **man** – show the manual page
- **mv** – rename (move) a file
- **mkdir**, **rmdir** – make or delete a directory
- **rm** – delete a file
- chmod – change file permissions
- **cat** – concatenate files
- more, **less** – pagers
- head, tail – show first/last lines
- grep – match lines
- wc – count words
- tr – transform characters
- split, join, cut, paste
- sort, uniq

If we have three (poorly named) files with paths

```
/dir/file
/dir/dir/file
/dir/dir/dir/file
```

and we run the two commands

```
$ cd /dir
$ rm dir/file
```

which file is deleted by the `rm` command?

A. `/dir/file`

B. `/dir/dir/file`

C. `/dir/dir/dir/file`

D. All three files

E. None of them (e.g., because it's an error)

Two special directory entries

Each directory contains two special entries

- `.` the directory itself (pronounced "dot")
- `..` the directory's parent (pronounced "dot dot")

We can use these in paths

- These all refer to the same directory

  ```
  /usr/bin
  /usr/./bin/.
  /etc/../usr/bin
  ```

- `.` is usually only used at the start of a relative path as `./`

  ```
  ./foo
  ```

- `cd ..` takes us to the parent directory of the current directory
- `cd ../..` takes us to the current directory's parent's parent

Which directory is listed if we run the following two commands in the shell?

```
$ cd /usr
$ ls bin/../../bin
```

A. `/`

B. `/bin`

C. `/usr/bin`

D. /usr/bin/bin

E. Some other directory

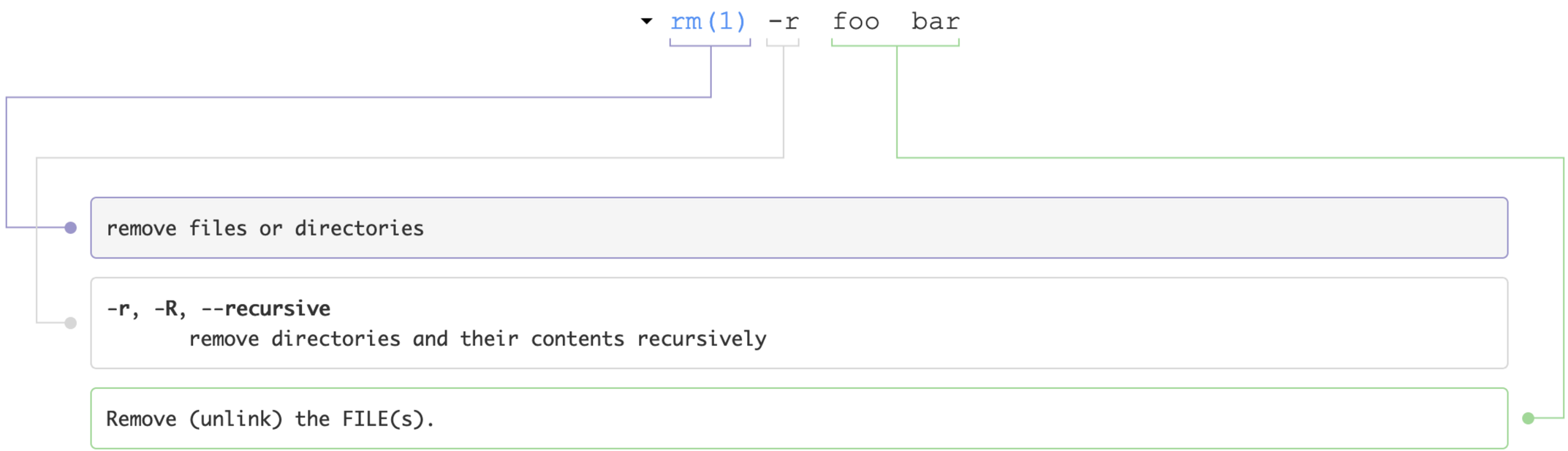
Commands

`⟨command⟩ ⟨options⟩ ⟨arguments⟩`

- `⟨command⟩` is the name of a command or a path to a program
- `⟨options⟩` are directives to the command to control its behavior
  - Usually start with one or two hyphens
- `⟨arguments⟩` are the things the command acts on
  - Often file paths or server names or URLs

Example: `rm -r foo bar`

Example meaning



Click to go to explainshell.com

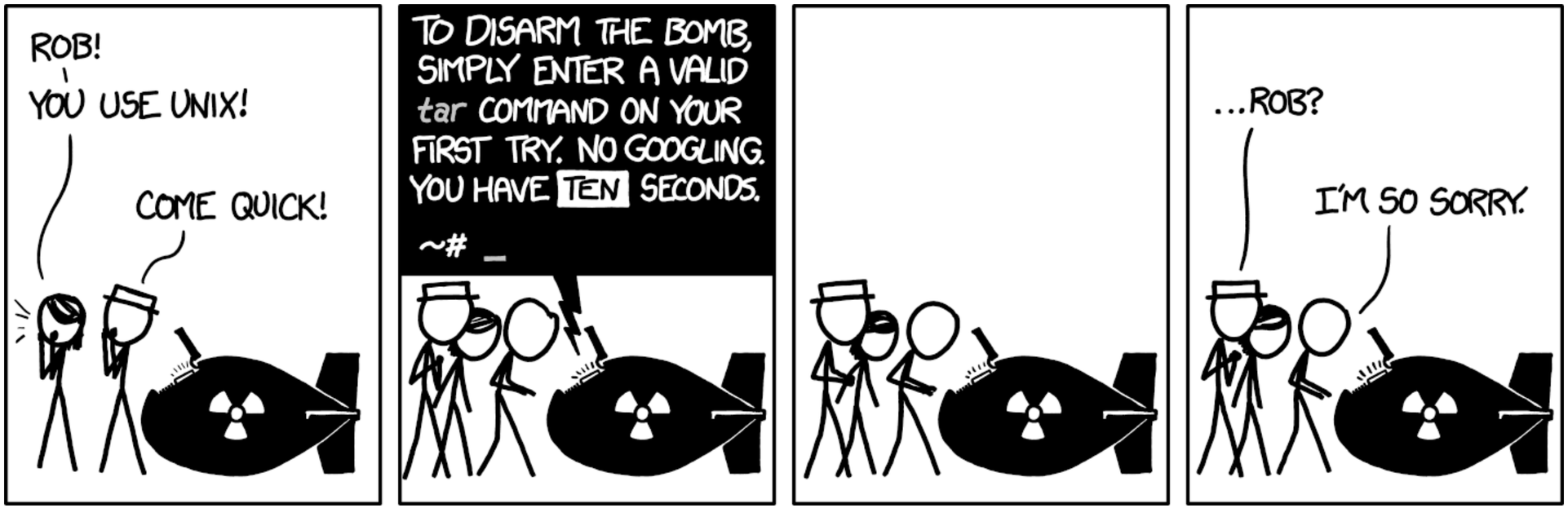
Option consistency

Related commands often have similar arguments:

- `$ cp -r` Copy directories recursively
- `$ rm -r` Remove directories recursively
- `$ grep -r` Search for text in files in directories recursively
- `$ zip -r` Zip directories recursively

But not always

- `$ ln -r` Create links relative to the link location (requires `-s`)
- `$ uname -r` Print the kernel version



https://xkcd.com/1168

Learning about arguments/options

Most programs respond to -h, --help, or -help

Many modern programs support commands in addition to arguments

- ⟨`program`⟩ ⟨`global-options`⟩ ⟨`command`⟩ ⟨`options`⟩ ⟨`arguments`⟩
- Examples:

  ```
  $ git commit
  $ cargo build
  ```
- These often support a `help` command like `git help`

Many programs have manual pages that can be accessed using man

- `$ man ls` Shows the manual page for `ls`
- `$ man cp` Shows the manual page for `cp`

Manual (man) pages

`man` is the system manual

- Use this to find out more about Unix programs
- `$ man cp`

`whatis` show just single line information

- also via `$ man -f cp`

`apropos` search for keyword, return single lines

- also via `$ man -k cp`

`whereis` locate binary, source, man page

- ```
  $ whereis cp
  cp: /bin/cp /usr/share/man/man1/cp.1.gz
  ```
  ```

Sections of the manual

Divided into sections

1. user commands (e.g., `cp(1)`, `ls(1)`, `cat(1)`, `printf(1)`)
2. system calls (e.g., `open(2)`, `close(2)`, `rename(2)`)
3. library functions (e.g., `printf(3)`, `fopen(3)`, `strcpy(3)`)
4. special files
5. file formats (e.g., `ssh_config(5)`)
6. games
7. overview, conventions, and miscellany section
8. administration and privileged commands (e.g., `reboot(8)`)

Use `man 3 printf` to get info from section 3

- You can use `man -a printf` to get all sections