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

Fall 2019

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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)

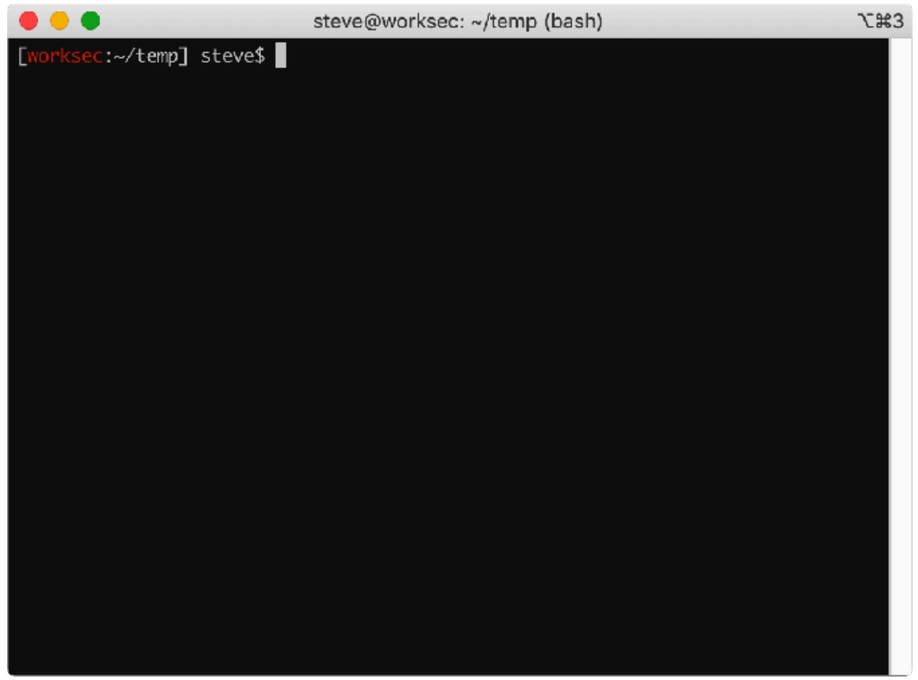
Commands can change files/directories on the file system

Terminals/terminal emulators

DEC VT100 terminal

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

iTerm2 terminal emulator

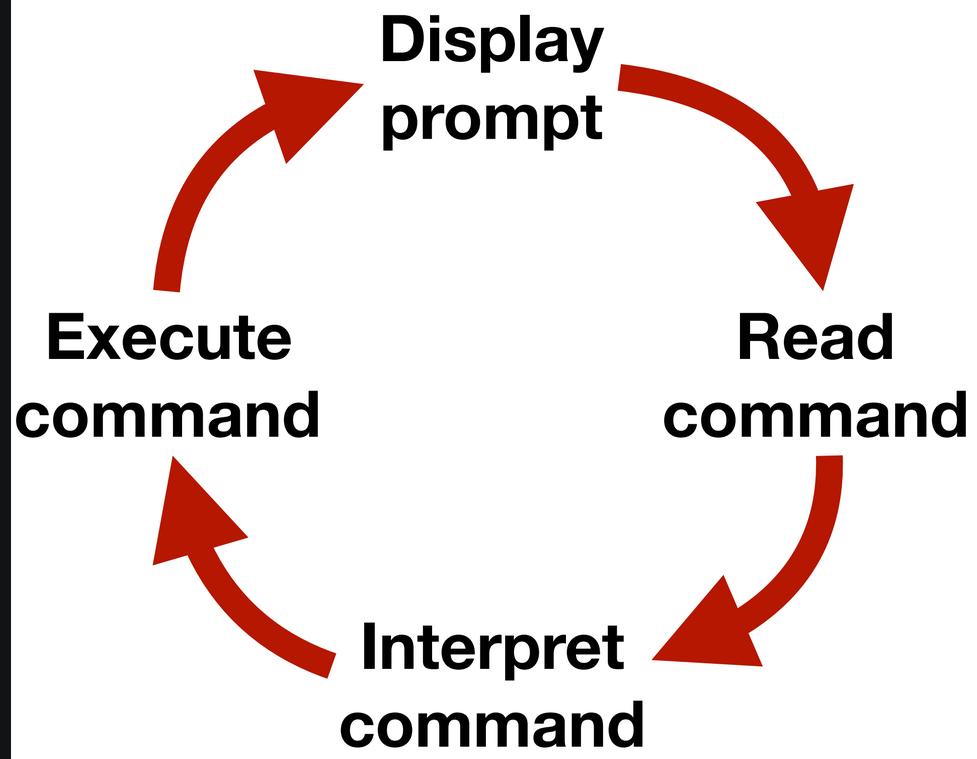


There are many shells

`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)

Interpreter loop

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



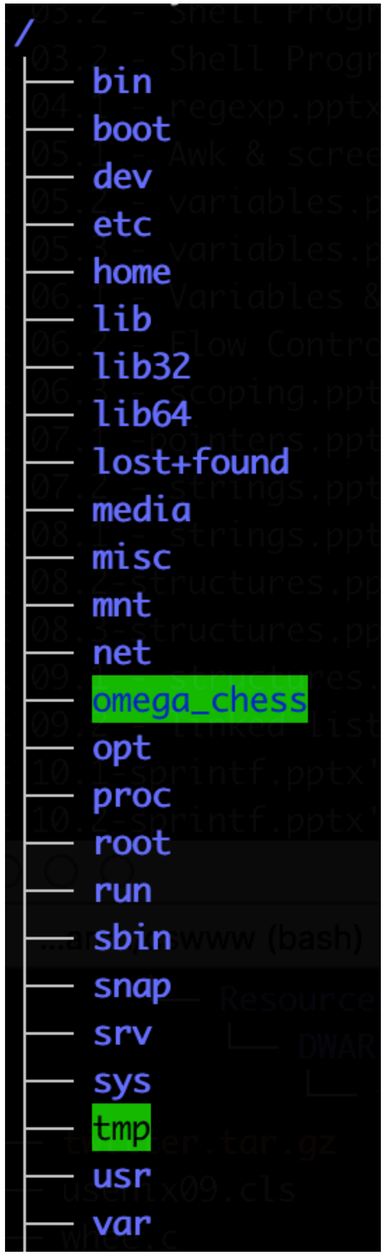
The file system

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 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

Recall that 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

Example of a relative path

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?

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

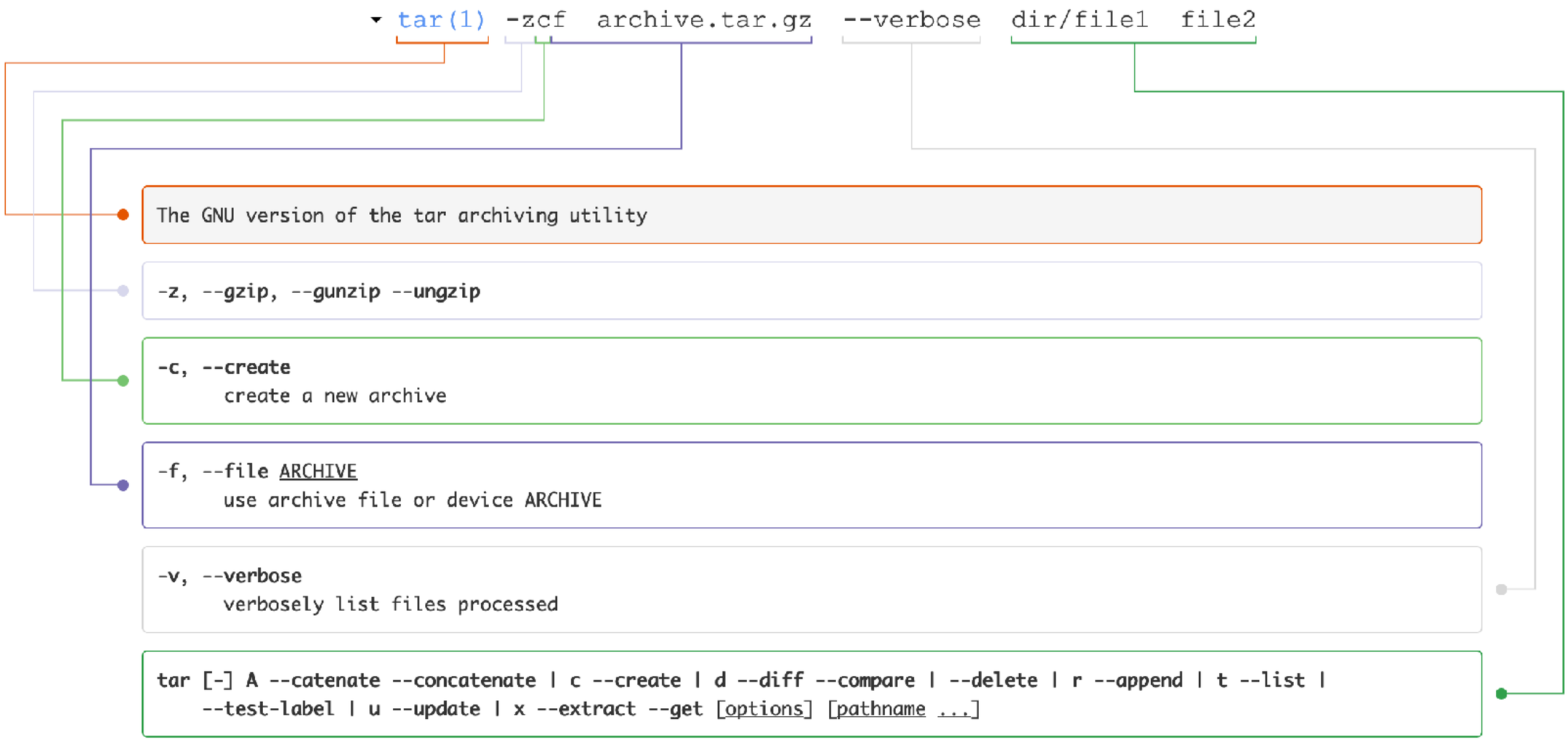
Anatomy of a single command

`⟨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
  - Short options are a hyphen and a letter: `-h`
  - Long options are (usually) two hyphens and multiple letters: `--help`
  - Multiple short options can be combined `-a -b -c` is the same as `-abc`
  - Options can take arguments: `-o file.txt` or `--output=file.txt`
- `⟨arguments⟩` are the things the command acts on
  - Often file paths or server names or URLs
  - When no arguments are given (or a single `-`), many commands read stdin

Example: `tar -zcf archive.tar.gz --verbose dir/file1 file2`

Example meaning



Click to go to explainshell.com

Shell commands

Shell builtins

- Functionality built into bash (all listed in the manual)
- E.g., `cd`, `alias`, `echo`, `pwd`

Shell functions

- User-defined functions (we'll get to these later)

Aliases

- E.g., `alias ls='ls --color=auto'`

Programs stored on the file system

- `/bin`, `/usr/bin`, `/usr/local/bin`, `/sbin`, `/usr/sbin`
- E.g., `ssh`, `cat`, `ls`, `rm`

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

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

Pathname expansion/globbing

Bash performs pathname expansion via pattern matching (a.k.a. globbing) on each unquoted word containing a wild card

Wild cards: `*`, `?`, `[`

- `*` matches zero or more characters
- `?` matches any one character
- `[…]` matches any single character between the brackets, e.g., `[abc]`
- `[!…]` or `[^…]` matches any character not between the brackets
- `[x-y]` matches any character in the range, e.g., `[a-f]`

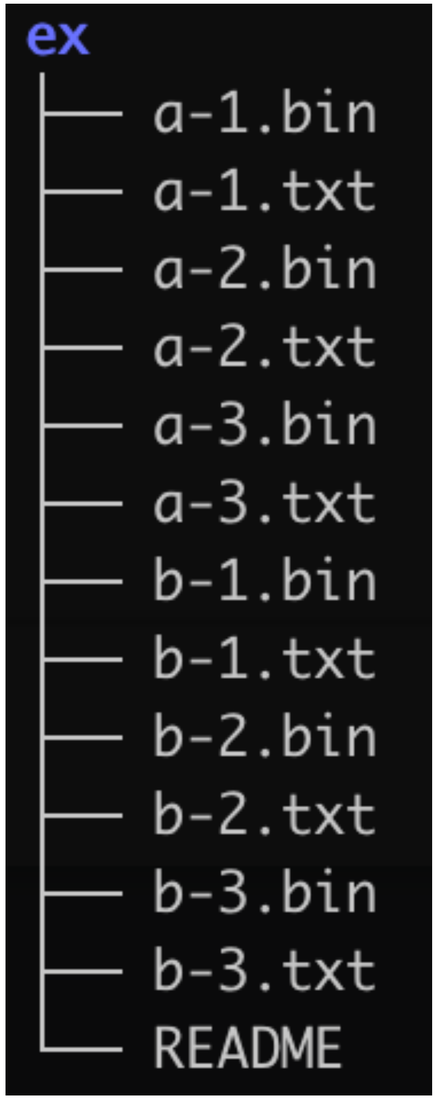
Example

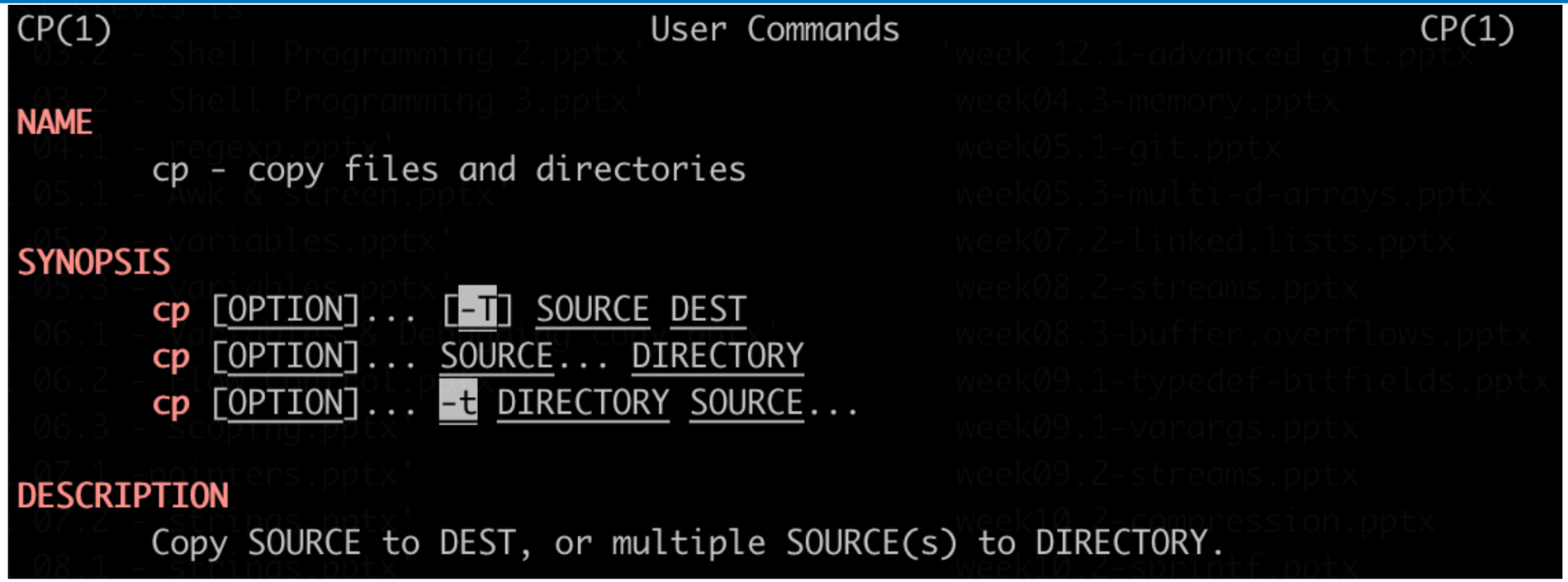
```
$ ls ex/*.txt
ex/a-1.txt  ex/a-2.txt  ex/a-3.txt  ex/b-1.txt
ex/b-2.txt  ex/b-3.txt

$ ls ex/?-3.*
ex/a-3.bin  ex/a-3.txt  ex/b-3.bin  ex/b-3.txt

$ ls ex/[^acd]-[0-9].b*in
ex/b-1.bin  ex/b-2.bin  ex/b-3.bin

$ ls "ex/*"
ls: cannot access 'ex/*': No such file or
directory
```





Which command copies all Java source files (those whose names end in `.java`) from the directory `a/b` to the directory `/tmp`?

A. `$ cp a/b/[a-z].java /tmp`

B. `$ cp a/*/*.java /tmp`

C. `$ cp a/b/*.java /tmp`

D. `$ cp a/b/?.java /tmp`

E. `$ cp a/b /tmp *.java`

In-class exercise

https://checkoway.net/teaching/cs241/2019-fall/exercises/Lecture-02.html

Grab a laptop and a partner and try to get as much of that done as you can!