Introduction to Unix

- A brief history of UNIX
- Why use UNIX?
- A model of the UNIX environment
- The UNIX file system (directories, commands)
- File attributes (permissions)
- ... and much more.

Embrace the mood of voluntary disorientation for the next few weeks.

A brief history of UNIX

- UNIX is a:
  - multi-user, multi-tasking operating system (or "OS")
  - architecture-independent operating system ("portable")
- the "UNIX" trademark:
  - owned by AT&T
  - passed to the "Unix System Laboratories" (USL)
  - passed to Novell
  - passed to X/Open Company, Ltd. (1993)
  - X/Open + Open Software Foundation (OSF) → The Open Group
  - The Open Group (1996), http://www.opengroup.org/
- So every manufacturer calls it something else!

A brief history of UNIX (2)

- AT&T / Bells Labs (was Lucent Technologies, now Avaya & Alcatel-Lucent)
  - Unix created by two researchers for their own personal use (Thomson & Ritchie, 1970)
  - academic/research operating system
  - Initially, pros: flexibility, extensibility, file sharing
  - Initially, cons: security, robustness, performance
  - easy to use (in comparison with contemporaneous OSes)
  - the first portable OS where "portable" == “recompilable and executable on another instruction set architecture”

A brief history of UNIX (3)

- Berkeley Standard Distribution (BSD)
  - freeware! (cheap for universities; only paid for distribution cost)
  - first UNIX to include standard network support
  - enhancements to interprocess communication (IPC), job control, security
- many flavours of UNIX in use today:
  - FreeBSD, NetBSD, XENIX, Solaris, SunOS, HP-UX, Linux, A/UX, AIX, macOS
- continues to evolve
  - e.g., Single UNIX Specification (derived from POSIX standard)
- Free Software Foundation and GNU Unix
- Ubuntu – arguably the most popular Linux distribution
- CentOS 7 – used in ELW B238

Android

- First introduced in 2008
  - Android 1.0
  - Running on device codenamed “Dream” (T-Mobile G1)
- Major versions have been released ever since
  - Current active release (October 12) is Android 12 (sadly: desserts no longer used for the names of releases)
- Other related variants have been released
  - Android TV
  - Wear OS (used to be Android Wear)
  - Android Auto

Wear OS by Google

Logos from: https://bit.ly/2vcPc7t, https://arris.ly/2LZKAst, https://bit.ly/2vhfJAf, https://bit.ly/2LVHRQG

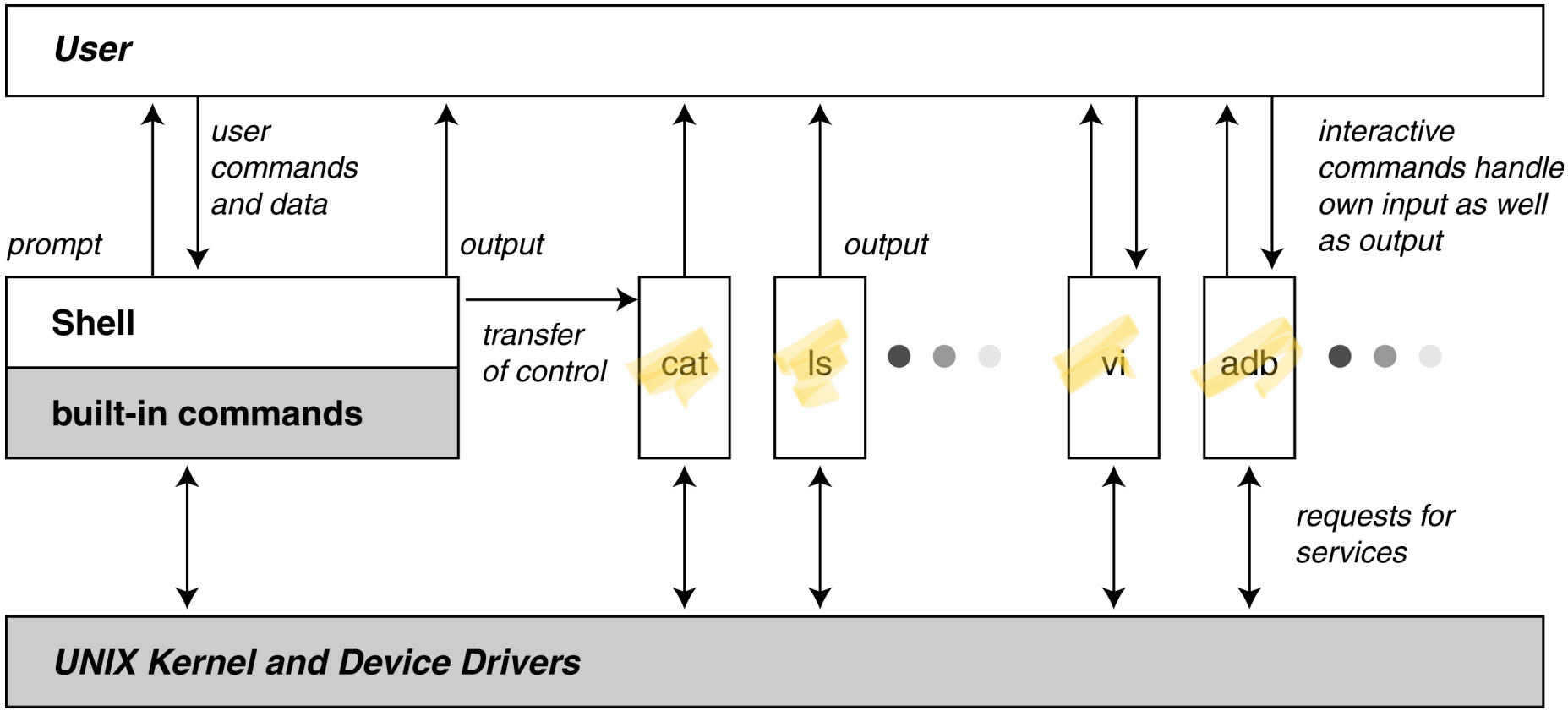
Aside 2: AOSP

- **Android Open Source Project**
  - `https://source.android.com`
- Code for a complete/full software stack
  - From web browser, media players, etc. ...
  - ... all the way down to USB, wifi, power management, etc.
- **Dependent upon the Linux kernel**
  - And much else besides (including Java)
- Note: The full AOSP distribution is much, much larger than the Android SDK
  - Takes around one hour to download
  - Just the source code is 100 gigabytes...
  - ... and to make one build you'll require another 150 gigabytes.
- Android uses Linux/Unix access controls and process isolation in very interesting & novel ways.

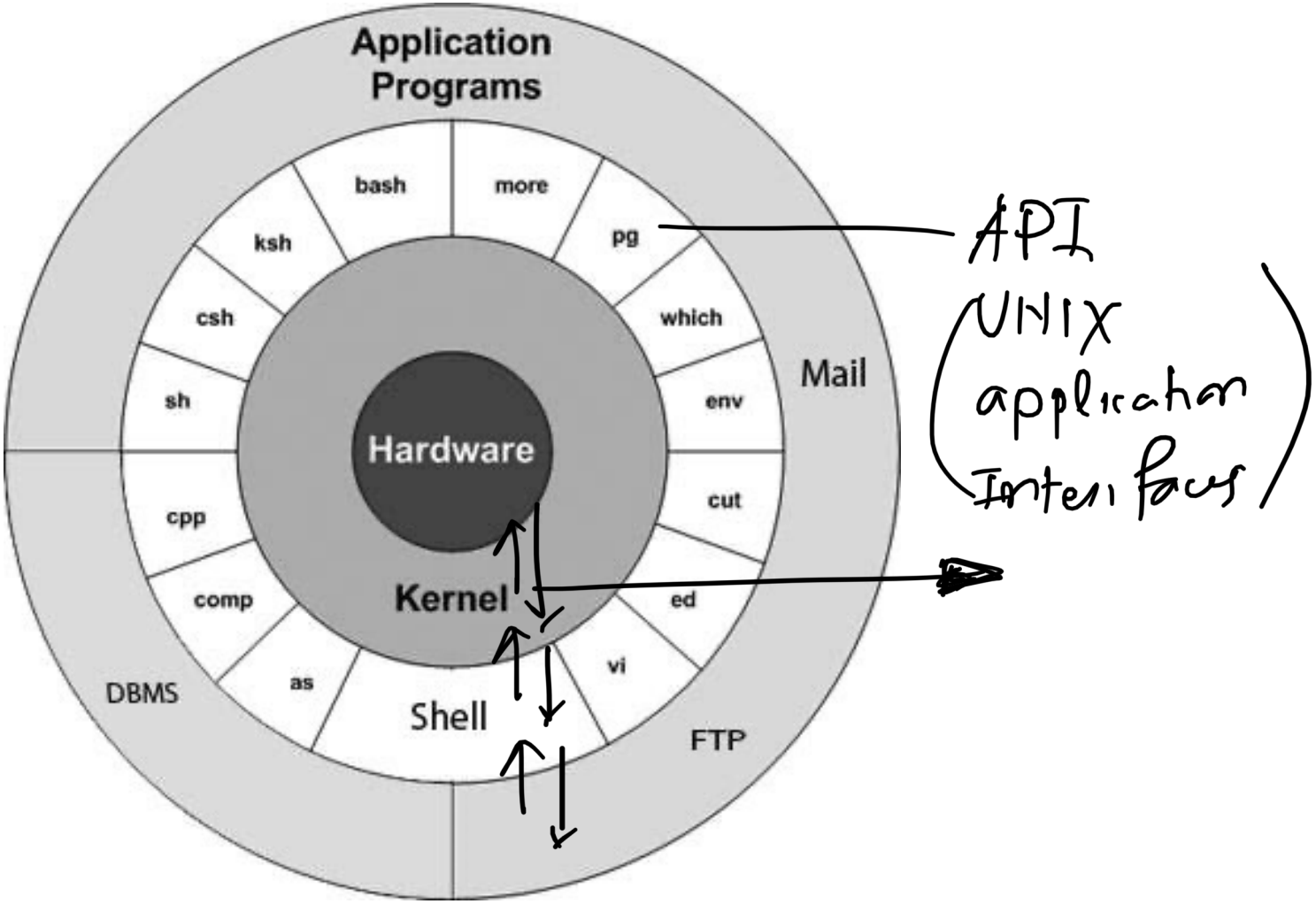
Why use UNIX?

- multiuser
- multitasking
- remote processing
- stable (some might even say "safe")
- highly modular
- some versions are free (open source → freedom to modify)
- large user community, extensive experience
- “tools are mature”

UNIX model of user interaction



UNIX model


Application Programs
bash
more
pg
ksh
csh
sh
which
env
Mail
Hardware
cut
cpp
comp
Kernel
ed
vi
as
DBMS
Shell
FTP
API
UNIX application Interfaces

shell

- responsible for communication between the user and kernel
- "shell" refers to its position in some diagrams of UNIX structure
  - These diagrams use concentric rings to show layering
- reads and interprets user commands at the console (or from within a "shell script")
- implements job control
- many shells have been developed:
  - `sh, csh, ksh, tcsh, zsh, bash` …
  - in this course we use the `bash` shell
  - `bash` extends `sh`, the Bourne shell

macOS
z shell / zee shell

Bash: Bourne Shell

Bash is a shell.

kernel

- the **kernel** is the **protected core** of the **OS**
- the kernel is itself a large and complex program
- clear demarcation between the “kernel” and a “user”
  - to access a computer’s hardware (via the OS), user's commands must go through kernel
  - that is, “user” must request the kernel to perform work on behalf of “user”
  - user/OS interaction mediated by a command shell (e.g., **bash**), or the system library (compiled application)
- main responsibilities
  - memory allocation
  - **file system**
  - loads and executes programs (assumes a process model)
  - communication with devices (input, output)
  - bootstraps the system

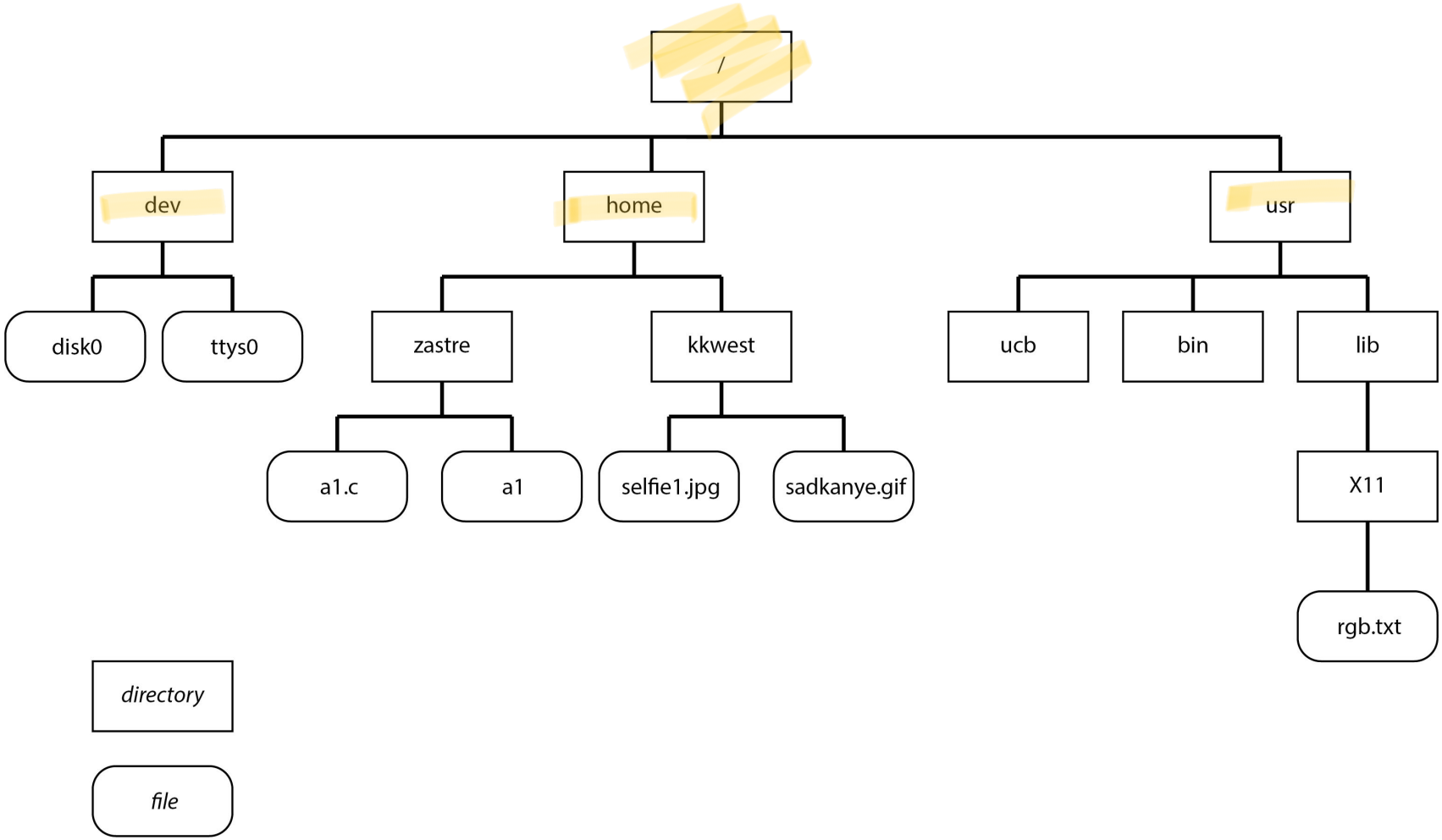
UNIX filesystem

- "file", "filesystem": **are key abstractions** of the UNIX computing model
- practically anything can be abstracted as a file (devices, programs, data, memory, IPC, etc.)
- mainly responsible for mapping blocks of data within **physical** storage devices (hard drive, flash memory) onto **logical** blocks that users can manipulate
  - maps filenames to block numbers
  - handles block allocations; chains units together
  - provides methods to access data
- facilitates the "multiuser" view of the OS

UNIX filesystem

- arranged as a hierarchy (tree-like structure)
  - organized as a collection of directories; think of a directory as a folder
  - forward slash "/" is used to separate directory and file components (cf., Windows uses "\")
- the root of the filesystem is represented by the **root-directory**, which we denote by a single "/"

Part of a (hypothetical) UNIX filesystem tree



Some properties of directories

- directories are actually “ordinary” files
- information contained in a directory file simply has a special format
- every directory contains two special directory entries
  - ".." refers to parent directory in hierarchy
  - "." refers to the current directory (itself)
- '~' is used to denote a **home directory**
  - `% cd /home/user` ≈ `cd ~user`
    `% cd` ≈ `cd ~`

Directory commands (ignore %)

- Example:

```
% cd /home
```

- listing directories

```
% ls
zastre keyboardcat
% ls keyboardcat
hi-rez.mp4 tinder-stuff.txt
```

- relative pathnames

```
% cd /home
% open keyboardcat/hi-rez.mp4
% open ./keyboardcat/hi-rez.mp4
% open ./keyboardcat/../keyboardcat/hi-rez.mp4
```

“working” vs. “home” directory

- “Working” directory is the directory the shell determines you are “in” at any point in time.
  - Eliminates the need to continuously specify full pathnames for files and directories
  - “Relative pathnames” are locations worked out in relation to (relative to) to the **working directory**.
- “Home” directory is (usually) configured to be your working directory upon logging into the system
  - Sometimes called the “login” directory
  - `/home/zastre` & `/home/seng265` are typical home directories

Directory commands (2)

- traversing directories

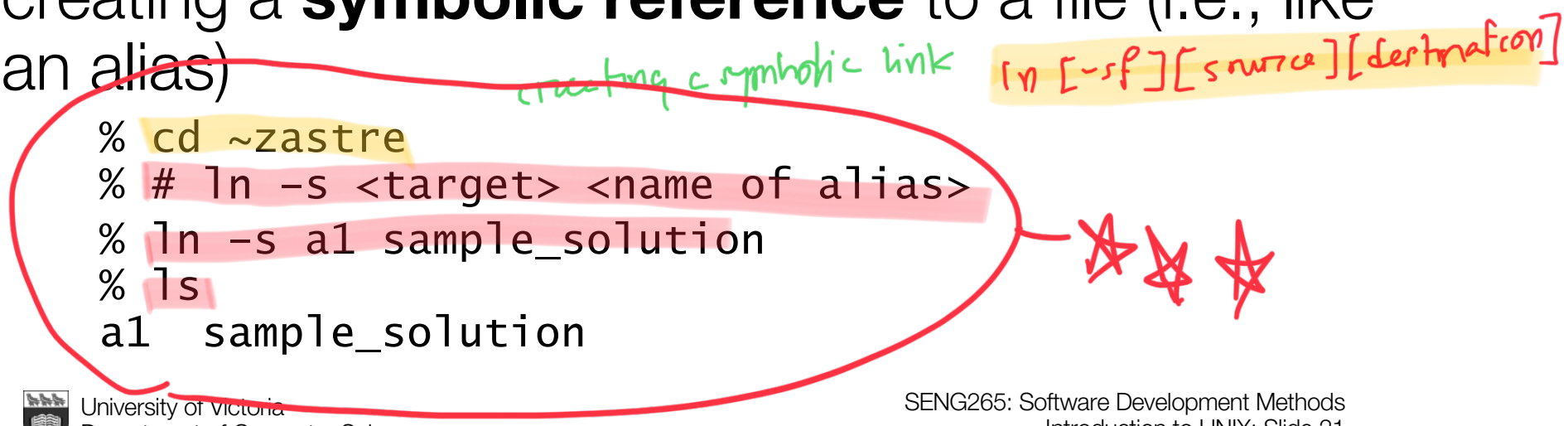
```
% cd /usr
% ls
ucb bin lib
```

- display the **current working directory**

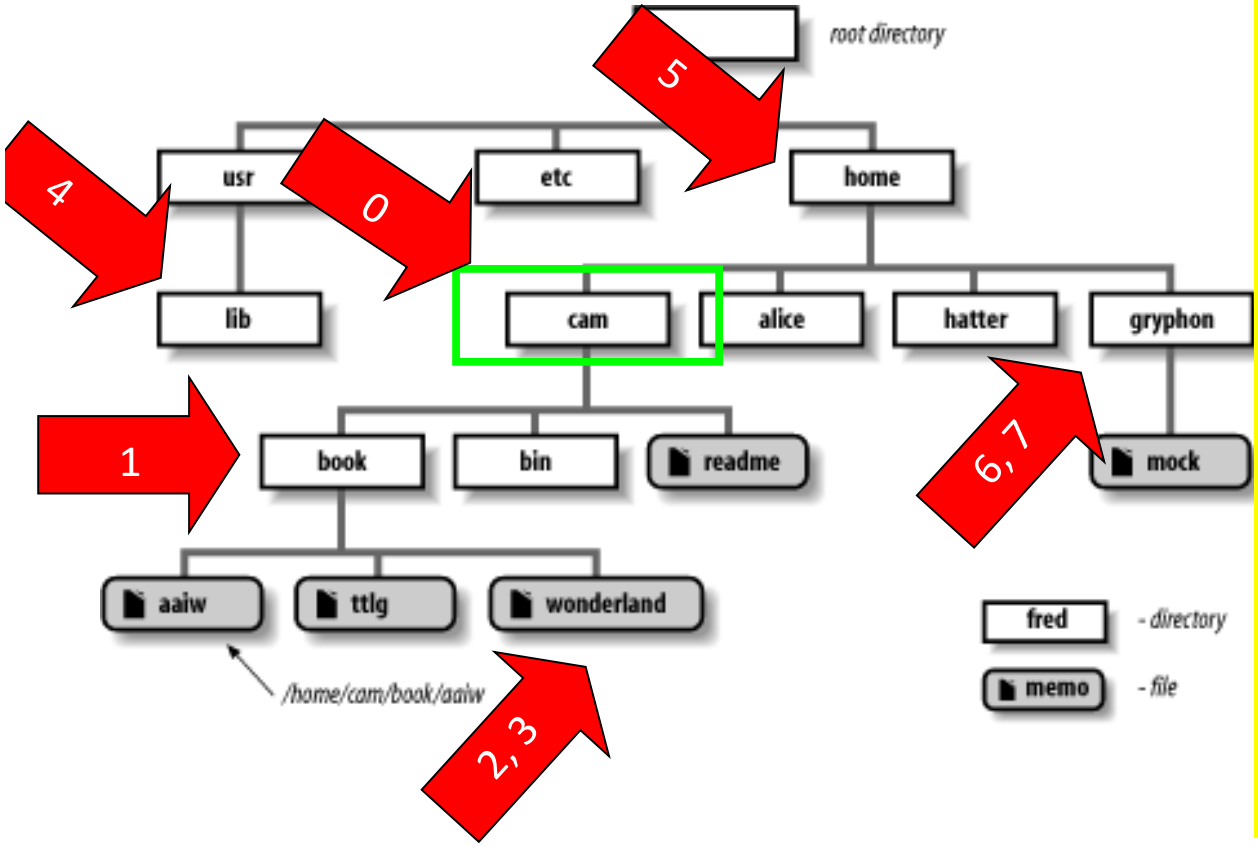
```
% pwd
/usr
```

- creating a **symbolic reference** to a file (i.e., like an alias)

```
% cd ~zastre
% # ln -s <target> <name of alias>
% ln -s a1 sample_solution
% ls
a1  sample_solution
```



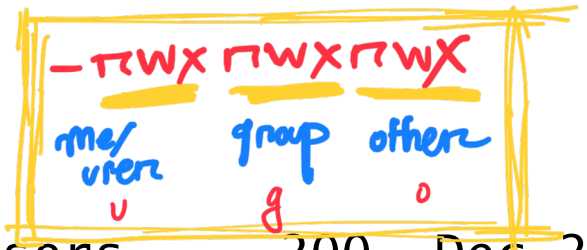
working directories




```
# "cam" is the logged-in user
#
# Each of the following commands
# starts in Cam's current directory
# /home/cam (i.e., every item
# below assumes we reference
# from at red-arrow 0).
% cd book                    #1
% vi book/wonderland         #2
% vi ~/book/wonderland       #3
% cd /usr/lib                #4
% cd ..                      #5
% cd ../gryphon              #6
% cd ~gryphon                #7
% cd alice                   # ??
```

File attributes

- every plain file and directory has a set of **attributes**, including:
  - user name (owner of file)
  - group name (for sharing)
  - file size (bytes)
  - creation time, modification time
  - file type (file, directory, device, link)
  - permissions




```
% ls -l unix.tex test
-rwxr-xr-x  1  joe  users     200  Dec 29  14:39  test
-rw-r--r--  1  dmg  users   21009  Dec 29  14:39  unix.tex
```

Who has permission?

- permissions can be set for
  - user ("u") `[-rwx------]`: the file owner
  - group ("g") `[----rwx---]`: group for sharing
  - other ("o") `[-------rwx]`: any other
  - all ("a"): user + group + other
- **user**: the owner of the file or directory; owner has full control over permissions
- **group**: a group of users can be given shared access to a file
- **other**: any user who is not the owner and does not belong to the group sharing a file

What kind of permissions?

- files:
  - **read (r)** : allows file to be read
  - **write (w)**: allows file to be modified (edit,delete)
  - **execute (x)**: tells UNIX the file is executable
  - **dash (-)** **:** owner/group/other have no permissions
- directories:
  - **read (r)**: allows directory contents to be read (listed)
  - **write (w)**: allows directory contents to be modified (create, delete)
  - **execute (x)**: allows users to navigate into that directory (e.g, with the **cd** command)
  - **dash (-)** : owner/group/other have no permissions

chmod: set file permissions

- there are several ways to use "chmod"
  - use letter symbols to represent "who" and "what"

```
% chmod o+rx ~/.www/ppt    # other can read and cd "ppt"
% chmod u+x run.pl         # script "run.pl" executable
% chmod go-rwx ~/private   # removing access group & other
% chmod u=rwx,g=rx,o=x foobar.txt  # all permissions
```

  - can also use "octal" (base 8) notation, representing each three-bit field with an octal digit; $r \in \{0,4\}$, $w \in \{0,2\}$, $x \in \{0,1\}$

```
% chmod 751 foobar.txt      # specify all permissions
```

  - the following are different ways of setting "read-only" permission for a file

```
% chmod =r file
% chmod 444 file
% chmod a-wx,a+r file
```

Various & Sundry

- UNIX file names are case-sensitive
  - assumption here: underlying file system is UNIX
  - e.g., `myFile` and `myfile` are two different names, and the `logout` command cannot be typed as `Logout`
- commands are available to change the **owner** and/or **group** of a file; e.g. `chown`, `chgrp`
- **pager** is a command (`less`, `more`) used to display a text file one page at a time

```
% less unix.txt
```

- quickly create a file (or update the timestamp of an existing file)

```
% touch unix.txt
% ls -l uxix.txt
-rw-r--r-- 1 zastre users  0  Aug 29 14:39  unix.tex
```

Introduction to UNIX (contd)

- The shell
- Basic command syntax
- Command types
- Getting help on commands
- I/O streams
- Redirection and pipelining
- Command sequences
- Console

the shell (again)

- The shell is **the** intermediary between you and the UNIX OS kernel
- It interprets your typed commands in order to do what you want
  - the shell reads the next input line
  - it interprets the line (expands arguments, substitutes aliases, etc.)
  - performs action
- There are two families of shells:
  - "sh" based shells, and "csh" based shells
  - they vary slightly in their syntax and functionality
  - we'll use "bash", the Bourne Again SHell (derivative of "sh", known as the "Bourne shell")
  - tip: you can find out what shell you are using by typing:
    ```
    echo $SHELL
    ```

basic command syntax

```
% cmd [options] [arguments]
```

- `cmd` represents here some builtin-shell or UNIX command
- `[options] = zero or many options`
- `[arguments] = zero or many arguments`

option	*example*
`opt`	`a`
`-opt`	`-v`
`--optname`	`--verbose`
`-opt arg`	`-s 5`
`--optname arg`	`--size 5`

basic command syntax (2)

- `opt` is a character in `{a..zA..Z0..9}`
- `optname` is an option name; e.g., `--size, --keep`
- `argument, arg` is one of the following:
  - file name
  - directory name
  - device name, e.g., `/dev/hdb2`
  - number, e.g., `10, 010, 0x1af, …`
  - string, e.g., `"*.c", "Initial release", …`
  - `…`

command types

- commands can be:
  - built into the shell (e.g., `cd, alias, bg, set,`…)
  - aliases created by the user or on behalf of the user (e.g., `rm='rm -i', cp='cp -i', vi='vim'`)
  - an executable file
    - binary (compiled from source code)
    - script (system-parsed text file)
- Use the `type` command to determine if a command is builtin, an alias, or an executable.

```
% type rm
rm is aliased to ‘rm -I’
```

some simple commands

% `cat [file1 file2 ...]`

- (catenate) copy the files to stdout, in order listed

% `less [filename]`

- browse through a file, one screenful at a time

% `date`

- displays current date and time

% `wc [filename]`

- (word count) counts the number of lines, words and characters in the input

% `clear`

getting help on commands

- You can ask for help in several ways.
- Display a description of a shell command (builtin)

```
% help times
```

- Display a long description of a command (from section *n* of manual)

```
% man [n] chmod
```

- Display a one line description of a command

```
% whatis gcc
gcc   gcc (1) - GNU project C and C++ compiler
```

- Use "info"

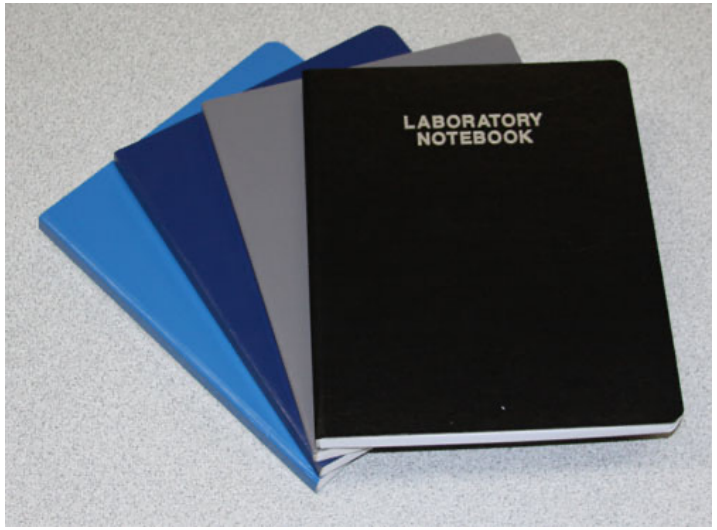
```
% info gcc
% info ls
```

somecommand = alias for any command

- Many commands provide their own help

```
% somecmd -h
% somecmd --help
```

Write it down!



input & output streams

- each UNIX program has access to three I/O "streams" when it runs:
  - **standard input** or **stdin**; defaults to the console keyboard
  - **standard output** or **stdout**; defaults to the console screen
  - **standard error** or **stderr**; defaults to the console screen
- the shell provides a mechanism for overriding this default behaviour (**stream redirection**)

stream redirection

- redirection allows you to:
  - take input from a file
  - save command output to a file
- redirecting from/to files using **bash** shell:
  - stdin:

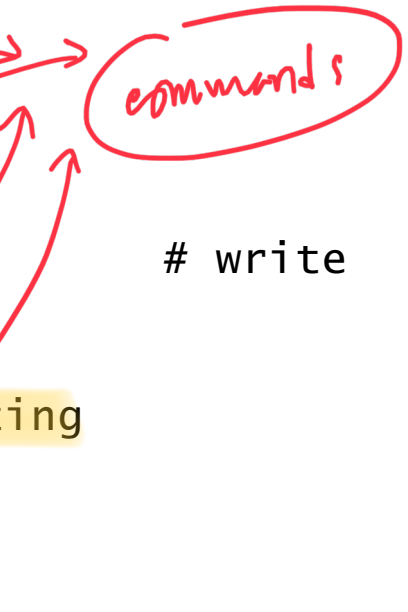
```
% cmd < file
% less < ls.1
```

  - stdout:

```
% cmd > file                    # write
% ls -la >dir.listing
% cmd >> file                   # append
% ls -la /home >>dir.listing
```

  - stderr:

```
% cmd 2> file                   # write
% cmd 2>> file                  # append
```



stream redirection (2)

- redirecting stdin and stdout simultaneously

```
% cmd < infile > outfile
% sort < unsorted.data > sorted.data
```

- redirecting stdout and stderr simultaneously

```
% cmd >& file
% grep 'hello' program.c >& hello.txt
% cmd 1>out.log 2>err.log
```

- UNIX gotchas:
  - symbols used for redirection depend on shell you are using
  - our work will be with the Bash shell (`bash, sh`)
  - slight differences from C-shell's (`csh, tcsh`)

pipes

- Pipes are considered by many to be one of the major Unix-shell innovations
  - excellent tool for creating powerful commands from simpler components,
  - does so in an effective, efficient way.
- Pipes route standard output of one command into the standard input of another command
- Allows us to build complex commands using a set of simple commands
- Motivation:
  - without pipes, lots of temporary files result

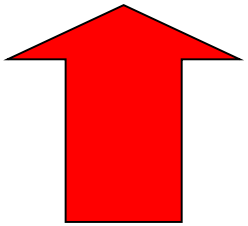
without pipes

- Example: How many different users are currently running processes on the server?

without pipes

- Example: How many different users are currently running processes on the server?

```
% ps aux > temp1.txt
% awk '{ print $1 }' temp1.txt > temp2.txt
% sort temp2.txt > temp3.txt
% uniq temp3.txt > temp4.txt
% wc -l < temp4.txt > temp5.txt
% cat temp5.txt
```



Off by one - need to mentally subtract one from the resulting number

with pipes

- Example: How many different users are currently running processes on the server?

I have no idea what this is!

```
% ps aux | awk '{ print $1 }' | sort | uniq | wc -l
```

Oh we didn't know when he was giving lecture

```
% ps aux | awk '{ print $1 }' | sort | uniq | wc -l | xargs expr -1 +
```

- Note the structure of the command:
  - "generator" command is at the head
  - successive "filter" commands transform the results
  - this is a very popular style of Unix usage

A bit more about pipes

- Pipes can save time by eliminating the need for intermediate files
- Pipes can be arbitrarily long and complex
- All commands are executed **concurrently**
- If any processing error occurs in a pipeline, the whole pipeline fails

command sequencing

- multiple commands can be executed sequentially, that is: `cmd1;cmd2;cmd3;…;cmdn`

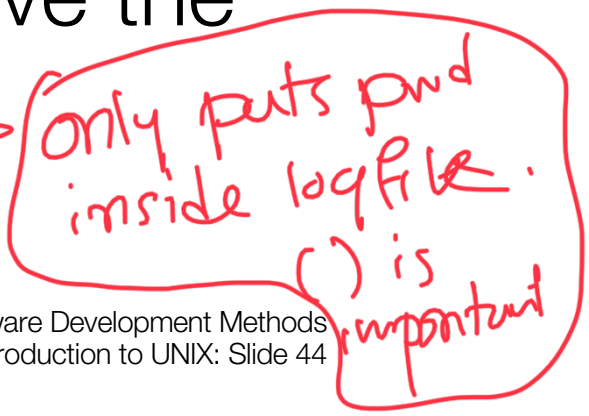
```
% date; who; pwd
```

- may group sequenced commands together and redirect output

```
% (date; who; pwd) > logfile
```

- note that the last line does not have the same effect as:

```
% date; who; pwd > logfile
```



Introduction to UNIX (contd)

- Filename expansion
- Command aliases
- Quoting and backslash escapes
- **bash** command history
- Job control
- Shell/environment variables
- Customizing your shell

filename expansion

- "shorthand" for referencing multiple **existing** files on a command line

`*`	any number of characters
`?`	exactly one of any character
`[abc]`	any character in the set `[abc]`
`[!abc]`	any character **not** in the set `[abc]`

- these can be combined together as seen on the next slide

filename expansion (2)

- examples:
  - count lines in all files having the suffix ".c"

```
% wc -l *.c
```

  - list detailed information about all files with a single character file extension

```
% ls -l *.?
```

  - send to the printer all files with names beginning in Chap* and chap* files

```
% lpr [Cc]hap*
```

filename expansion (3)

- * matches any sequence of characters (except those with an initial period)

```
% rm *.o          # remove all files ending in '.o'
% rm *            # remove all files in directory
% rm ../*-old*.c
```

- ? matches any single character (except an initial period)

```
% rm test.?       # remove test.c and test.o (etc.)
```

- So to delete a file of the form ".filename" you can't use wildcards

```
% rm .viminfo
```

How do we delete a file named *?

quoting

- controls bash's interpretation of certain characters
- what if you wanted to pass '>' as an argument to a command?
- **strong quotes** – All characters inside a pair of single quotes (') are preserved.
- **weak quotes** – Some characters ($,`) inside a pair of double quotes (") are expanded (interpreted) by the shell.
- **backquotes** – substitute result of evaluation as a command

quoting

```
% echo $SHELL *
/bin/bash file1 file2 file3

% echo '$SHELL' '*'
$SHELL *

% echo "$SHELL" "*"
/bin/bash *
```

prints out preserved words → strong Quotes

Weak Quotes → since $ exists, it's been interpreted by the shell

```
%echo `date`
Fri May 12 11:54:27 PDT 2017
```

backslash escaping

- Characters used by **bash** which may need to be escaped:

  ~, `, #, $, &, *, (,), \, [,], {, }, ;, ', ", <, >, /, ?, !

- single characters can be "protected" from expansion by prefixing with a backslash ("\")

  `cmd \*` is the same as typing `cmd '*'`

- protecting special characters in such a manner is an example of **backslash escaping**

```
% cp ~bob/junk \* # make copy of junk named '*'
% rm '*'                  # remove '*' (not "delete all files")
```

- Single quotes around a string turn off the special meanings of most characters

```
% rm 'dead letter'
% cp ~bob/junk '*' # same as up above
```

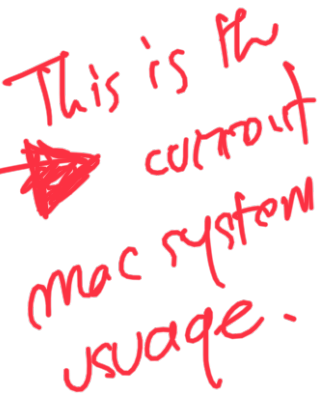
command substitution

- backquotes (`) are used to substitute the result of evaluating a command into a quoted string or shell variable:

```
% echo "Current date is: `date` "
Current date is: Fri May 12 11:54:27 PDT 2017
% BOOTTIME=`date`
% echo $BOOTTIME
Fri May 12 11:54:27 PDT 2017
```

- standards-compliant (i.e. POSIX) style avoids backticks:

```
% echo "Current date is: $(date)"
Current date is: Thu 15 Sep 2011 14:58:13 PDT
```



bash command history

- bash (and other shells like sh, tcsh, ksh, csh) maintain a history of executed commands
- uses the readline editing interface
- history will show list of recent commands

```
% history    # print your entire history
% history n # print most recent n commands
% history -c       # delete your history
```

- a common default size of the history is 500 commands
  - and the history is usually remembered across login sessions

Using history

- simple way: use up and down arrows
- using the "!" history expansion

```
% !!      repeat last command
% !n      repeat command number n
% !-n     repeat the command typed
          n commands ago
% !foo    last command that started with foo
```

shell variables

- a running shell carries with it a **dictionary** of variables with values
- some are **built in** and some are **user defined**
- used to customize the shell
- use `env` to display the values of your **environment variables**
- use `set` to display the values of your **environment + shell variables**

```
% env
PWD=/home/bgates
GS_FONTPATH=/usr/local/fonts/type1
XAUTHORITY=/home/dtrump/.Xauthority
TERM=ansi
HOSTNAME=c70
...
```

shell variables (2)

- many variables are automatically assigned values at login time
- variables may be re-assigned values at the shell prompt
- new variables may be added, and variables can be discarded
- assigning or creating a variable – and notice absence of spaces around the "=" symbol:

```
% somevar="value"
```

- to delete a variable:

```
% unset somevar
```

- To use the value of a shell variable use the `$` prefix:

```
% echo $somevar
```

PATH shell variable

- helps the shell find the commands you want to execute
- its value is a list of directories separated by ':' symbol
- when we intend to run a program, the directory of its executable should be in the PATH in order to be found quickly
- Example: assume that program `cmd` is located in directory "`/usr2/bin`"

```
% echo $PATH
PATH=/usr/bin:/usr/sbin:/etc
% cmd
 bash: cmd: command not found
% PATH="$PATH:/usr2/bin"
% echo $PATH
PATH=/usr/bin:/usr/sbin:/etc:/usr2/bin
% cmd
(... now runs ...)
```

- the shell searches sequentially in the order directories are listed

environment variables

- some shell variables are exported to every subshell
  - when executing a command, the shell often launches another instance of the shell; this is called a **subshell**

```
% (date ; who ; pwd) > logfile
```

  - the subshell executes as an entirely different process
  - the subshell "inherits" the environment variables of its "parent" (main shell)
- "exporting" shell variables (*var*) to the environment

```
% export var
% export var=value
```

- example:

```
% export EDITOR=vim
```

customizing the shell

- In your accounts there will be two files you can modify to customize the `bash` shell
- "`~/.bash_profile`" is evaluated by the shell each time you login to your account.
- by default, "`~/.bash_profile`" **sources** (reads and evaluates) a second file "`~/.bashrc`"
- **conventional wisdom** suggests that permanent shell/environment variables should be placed in "`~/.bash_profile`", and aliases should be placed in "`~/.bashrc`"
- system administrators, for very sound reasons, often prefer that we don't modify "`~/.bash_profile`", but instead customize the shell by modifying "`~/.bashrc`" (adding shell variables, aliasing, etc.)
- In both cases, the changes you make to these files will not take effect until you source the modified file

```
% source .bashrc
```

Use with caution!

job control

- the shell allows you to execute multiple programs in parallel
- starting a program in the background ...

```
% cmd &
  [1] 3141          # (jobid=1,pid=3141)
```

... and bringing it to the foreground

```
% fg %1
```

- placing a running program in the background

```
% cmd
      ^Z
% bg %1
```

job control (2)

- stopping and restarting a program:

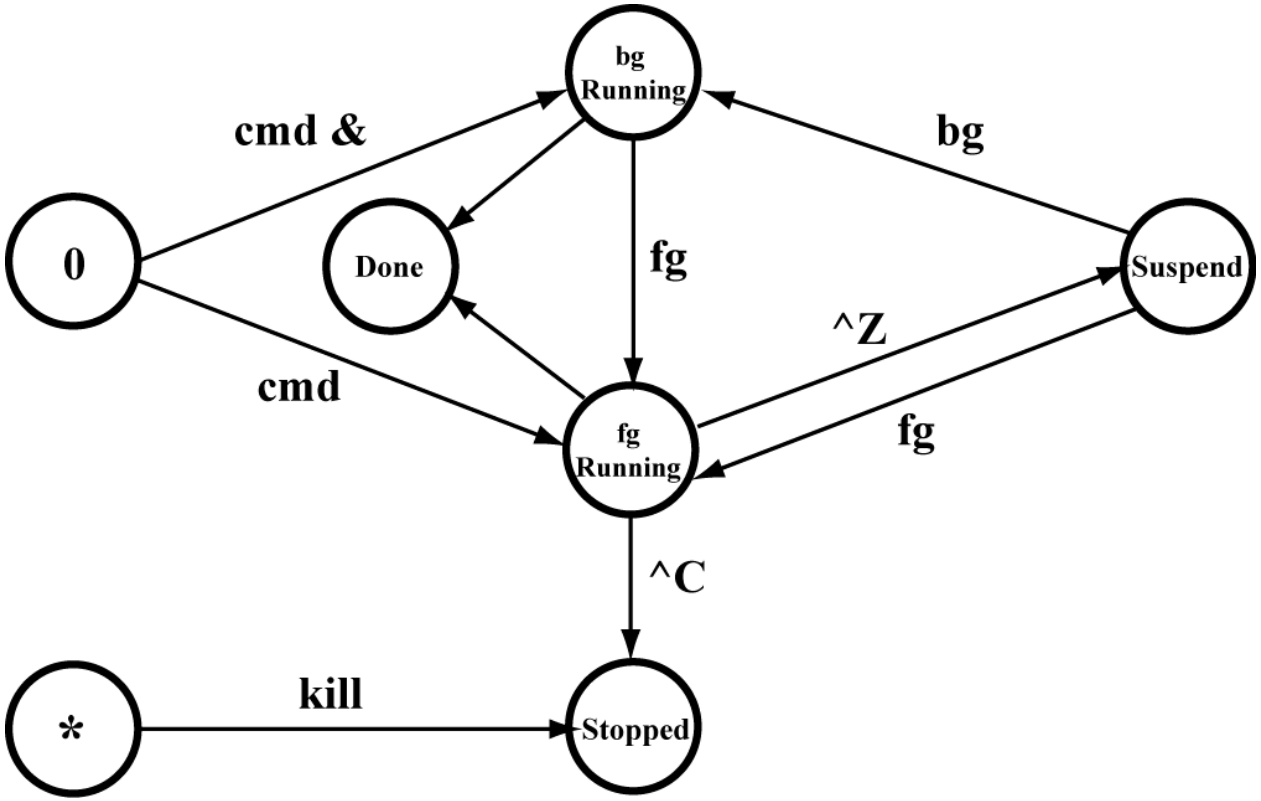
```
% vim hugeprog.c
^Z
[1]+ Stopped
% jobs
[1]+ Stopped  vim hugeprog.c
% gcc hugeprog.c -o hugeprog &
[2] 2435
% jobs
[1]- Stopped  vim hugeprog.c
[2]+ Stopped  gcc hugeprog.c -o hugeprog
% fg %1
[1]  vim hugeprog.c
```

- terminating (or “killing”) a job:

```
% kill %n  # use  kill -9 %n  if the job won't die!
% kill %cc # kill job that starts with cc
```

job control (3)

- job states



shell scripting

- Why write a shell script?
  - Sometimes it makes sense to wrap a repeated task into a command.
  - Sequences of operations can be placed in a script and executed like a command.
- Not everything is sensible for a script, though
  - For some problems it would make more sense for a full program
  - Instances: resource-intensive tasks, complex applications, mission critical apps, etc.

Some simple scripts

- For what appears below, ensure the file containing the script is executable

```
#!/bin/bash

echo 'Hello, world!'
```

hello.sh

```
#!/bin/bash

uptime
users
```

status.sh

- The very first line is called a "shebang" path
  - What follows the "#!" ("shebang") is the command that interprets everything else that follows.

Echoing command-line arguments

- Obtaining command-line argument is relatively straightforward

status.sh

```
#!/bin/bash

echo "First command-line arg" $1
echo "Second command-line arg" $2
```

- Notice that echo takes multiple strings
  - But these are not separated by commas
  - (Shell syntax is close enough to regular programming syntax to be confusing.)

Selection

- The numeric representation of true and false are inverted
  - True == 0
  - False == anything else
- Common tests involve file operators
- Note the spacing in the test expression!

```
#!/bin/bash

if [ -e /home/zastre/seng265/assign1 ] ; then
    echo 'Hooray! The file exists!'
else
    echo 'Boo! The file ain't yet there…'
fi

# Other tests:
# -f True if file is a regular file
# -d True if file is a directory
# -w True if file exists and is writable
# -O True if the account running script owns the file
```

String and arithmetic relationals

- String operators compare lexical order (i.e., dictionary order)
- Arithmetic operators only work on integers
- Note spacing variants…

```
#!/bin/bash

if [ "abc" != "ABC" ] ; then
    echo 'Case does matter here' ; fi

if [ 12 \< 2 ] ; then
    echo 'Why is 12 less than 2??!' ; fi

a=12
b=2
if [ "$a" -lt "$b" ]
then
    echo 'Something is wrong with numbers here...'
else
    echo "Ah ha! $a can be either a string or integer"
fi
```

More generate tests

- Sometimes we could use a good old logical OR or logical AND
- Some C-like expressive power is possible
- (Note slight syntax variation with the "if" statement)

```
#!/bin/bash

if [[ -e ~/.bashrc && ! -d ~/.bashrc ]]
then
    echo 'Definitely a config file to process'
fi
```

Arithmetic? Not so good…

- Bash usually treats variables as strings
- We can force bash to treat a variable's value as an integer

```
#!/bin/bash

x=1
x=$x+1
echo $x    # Still a string

y=1
(( y=y+1 ))
echo $y    # This gets it...
```

Iteration

- List-like values are common in the shell
  - Arguments passed to command
  - Files expanded by wildcards
- A list literal is simply spelled out

```
#!/bin/bash

for x in 1 2 a
do
    echo $x
done


for x in *
do
    echo $x
done
```

Iteration

- The output from commands may be used to create a list
  - Note that the text from the command will be tokenized into a sequence of individual words…
- We can also write old-style for loops
- Use "set –x" to have the shell print out commands as they are executed
  - Handy for debugging

```
#!/bin/bash

set -x

for i in $(date) ; do
    echo item: $i
done

for (( i=0; i<5; i++ )) ; do
    echo item: $i
    echo in$i.txt
done
```

Iteration

- Also: while loops
  - Recall: quantity in the square brackets is tested
  - Top-tested

```
#!/bin/bash

COUNTER=0
while [ $COUNTER -lt 5 ] ; do
    echo The counter is $COUNTER
    let COUNTER=COUNTER+1
done

COUNTER=8
until [ $COUNTER -lt 2 ] ; do
    echo COUNTER $COUNTER
    let COUNTER-=1
done
```

Lots more to shell scripting…

- … parameter expansion …
- … regular expressions …
- … but we have enough for now.
- Recall: selection and loops control by a test
  - If a program runs to completion without errors, it returns 0;
  - otherwise it should return something other than zero
  - This can be used to phrase a conditional (i.e., for driving a test plan involving sets of inputs and outputs)

endnotes

- This was a brief introduction to UNIX with a heavy emphasis on the use of the "bash" shell
- you should try out the concepts presented in these slides
- you should read man pages and/or other sources of information
  - books
  - online resources
- you can learn from others
  - rarely is there a single way to do the same thing
  - especially true when constructing large commands using pipes
- Slides on bash shell scripting based on lectures by Kurt Schmidt (Drexel University)