Introduction to Linux

Bash and Basic GNU/Linux and Unix Concepts

BIOWULF
HIGH PERFORMANCE COMPUTING AT THE NIH

This class will….

- Get your toes wet. Unix and Linux are gargantuan topics that only come into focus with experience.
- Provide some basic concept information for users familiar with MacOS or Windows.
- Get you familiar with Linux commands.
- Get you started in understanding command line interfaces.

Class outline

- History of Linux
- Kernel and shells
- The bash shell
- Files and directories
- File ownership and permissions
- Essential Linux commands with exercises
- File transfer
- Processes
- Compressing files
- cron

History

Late 60's through 1980's

- Unix is the result of Bell Labs research (Dennis Ritchie, Brian Kerningham, Ken Thompson, et al). Originally written in assembly language.
- Unics (Unix) was named in contrast to MIT's Multics operating system.
- Berkeley Software Distribution (BSD), or Berkeley Unix derived from Bell Labs' work in part due to government monopoly agreements.
- Unix led to the BSD family of operating systems in the 1990's.

Bell Laboratories

History

Richard Stallman, in 1983

- Started the GNU (GNU's Not Unix!) project
- Open-sourced versions of standard suite of Unix utilities found in BSD
- GNU is also a software license – allows for code modifications as long as they are shared
- Utilities used in Linux, BSD-derived and proprietary Unix operating systems
- All commands in this lesson are from GNU

History

Linus Torvalds, in 1991

- Released the first version of his Linux kernel.
- Started as a study in processor architectures while at the University of Helsinki, Finland, and to this day still has the authority on what gets included in the Linux kernel
- In 1992 adopted the GNU license and rapidly gathered developers
- Combined the GNU suite of utilities with a new operating system kernel (GNU/Linux)

History

- By the mid 1990's/early 2000's GNU/Linux starts to gather main-stream adoption, especially in research and academic circles due to structural similarities with Unix and BSD
- Gains large market share of commercial servers
- Becomes usable for desktop adoption
- Present on gadgets (e.g. Android smartphones, home routers, car information systems, etc)

Popular Linux Distributions

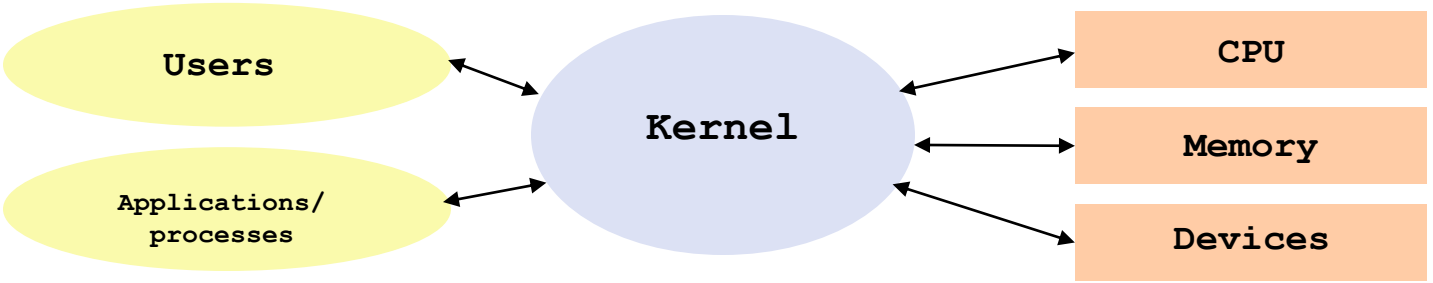
- Red Hat Enterprise Linux
- CentOS
- Fedora
- Debian
- Ubuntu
- Suse Linux
- Linux Mint

Linux in Science (why?)

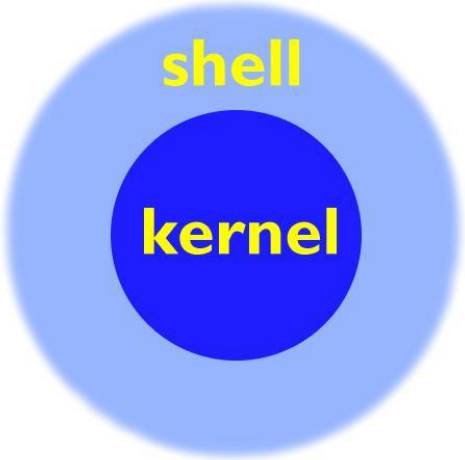
- Popular due to shared functional legacy with Unix systems associated with research (Irix, SunOS/Solaris, etc.)
- Source code availability and semi-liberal licensing made it easy for researchers to adjust the kernel as needed.
- Community backing and "perfect- storm" of enthusiasm for the project led to critical mass of development (in contract to the BSD family)
- Licensing and well known Unix-style APIs make it easy for vendors of HPC equipment to write drivers for their hardware.
- Wide range of tools available for users (compilers, scientific libraries, debuggers, etc).
- **Performance, functionality and portability**

Concepts: Kernel

- Operating system "kernel" is the core software used to "talk" to computer hardware
- It's a core and modular system of drivers used to create a standardized environment for interfacing with hardware
- Resource manager for allocating memory and time to system and user processes as well as interacting with files (I/O)
- Kernel operates in its own memory or "kernel-space"



Your Shell



- On user log-in, the system runs a *shell*
- A shell is the environment within which you will interface with the kernel via commands
- It determines the syntax for complex command-line operations and shell scripting
- The shell you're using is called "bash," the successor to the venerable "Bourne Shell" called "sh"
- BASH: "Bourne Again SHell"

Various Shells

- sh – the original UNIX shell (Bourne shell)
- bash – written as a replacement/extension of sh
- csh – C shell based on the C programming language developed in the late 1970s
- tcsh – enhanced version of C shell
- ksh – Korn shell developed in the early 1980's, backward compatible with sh, but with some features of csh
- zsh – extended version of sh, developed in 1990
- dash – developed as replacement for ash in Debian

Linux accounts

- To access a Linux system, you need to have an account
- A Linux account includes the following:

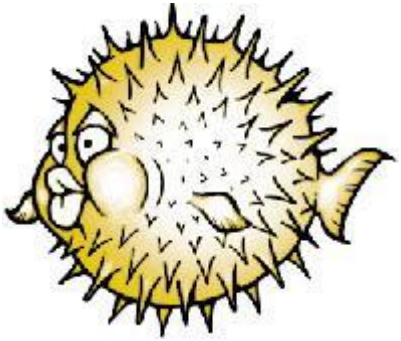
- username and password

- uid and gid

- a home directory, which is where you are placed by default when you log in

- a default shell

Using SSH to log in:



But First! Introducing OpenSSH:

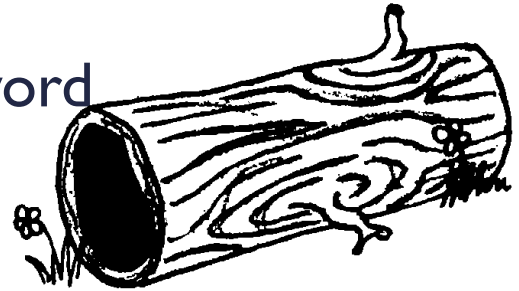
- SSH is the "Secure SHell"
- All traffic over SSH is encrypted
- Developed as a secure alternative to RSH and Telnet
- SSH supports a file-transfer subsystem - SCP
- SSH can act as an encryption layer for arbitrary network connections

Logging in

- MacOS:
  - Finder -> Applications -> Utilities -> Terminal
  - Now type: "`ssh username@helix.nih.gov`"
  - At the prompt, enter the account password

- Windows:
  - Launch PuTTY. Under "Host Name (or IP address), type:

    `username@helix.nih.gov`
  - …and click "Open"
  - At the prompt, enter the account password



Logging out

DON'T run this now, but to log out of a ssh session on a Linux system, you would type exit:

```
$ exit
```

More on shells

- What shell am I in? Typing "echo $SHELL" will show you!
- You should see '/bin/bash'
- Typing "echo $0" will also show your shell
- $SHELL and $0 are shell variables…more about variables later
- List of available shells on the system can be displayed by typing "chsh --list-shells"
- The chsh command can be used to change your default shell as well, but on Biowulf & Helix never change it to a shell that ends in LOCKED, SUSPENDED, DISABLED – you will lock yourself out of your account!

Shell preferences

- When you login, startup scripts are run to setup your environment
- For bash, you can customize your environment by adding or modifying environment variables and aliases in the **.bashrc** file in your home directory.
- Examples:

```
alias ls='ls -rtl'
alias bwulf='ssh $USER@biowulf.nih.gov'
PATH=$PATH:/data/myusername
EDITOR=/usr/bin/vim
PS1="[\u@\h   \w   \# ]"
set -o noclobber
```

Summary of Linux commands

awk	allows manipulation of text
bg	place suspended job into background
cal	display calendar
cat	view contents of a file
cd	change directory
chmod	change permissions on a file/directory
cp	copy a file
cut	extract a field of data from text output
diff	compare files line by line
echo	output text to the terminal or to a file
emacs	text editor
fg	bring suspended job to foreground
file	display file type
find	search for files
grep	search a file or command output for a pattern
head	view beginning of file
history	display list of most recent commands
less	scroll forward or back through a file
ln	create a link to a file
ls	list files in a directory
man	view information about a command
mkdir	make directory
more	scroll through file a page at a time
mv	change the name of a file (move)
nano/pico	text editors
printenv	display shell variables
ps	show current process information
pwd	print current working directory
rm	delete or remove a file
rmdir	delete or remove a directory
sed	stream editor
sleep	pause
sort	perform a sort of text
tail	view end of the file
touch	create an empty file or update timestamps
tr	character substitution tool
uniq	remove identical, adjacent lines
vi/vim	text editor
wc	print number of lines, words or characters
which	shows full path of a command
whoami	displays username

Our cast! (of characters)

Character	Name/Location
\	Backslash (above the enter key)
/	Slash (left of right shift key)
`	Back-tick (left of the number 1, above the tab key)
|	Pipe (shift-\)
[and]	Brackets (left of the backslash)
{ and }	Braces or "curly" brackets (shift-[and shift-])
< and >	Angle brackets (left of the right shift key)
~	Tilde (shift-~)
!, @, #, $, %, ^, &, *, (,)	(!) Bang/exclamation mark, (@) at sign, (#) hash, ($) dollar/string, (%) percent, (^) caret, (&) ampersand, (*) asterisk/start, and the left and right parenthesis.

Linux Command Basics

- Linux commands are case-sensitive

ls is not the same as LS

- Linux commands may have options that come after the command that start with a "–" and followed by a letter or "- -" and a word:

$ ls –r

$ ls --reverse

- Linux commands may allow for arguments:

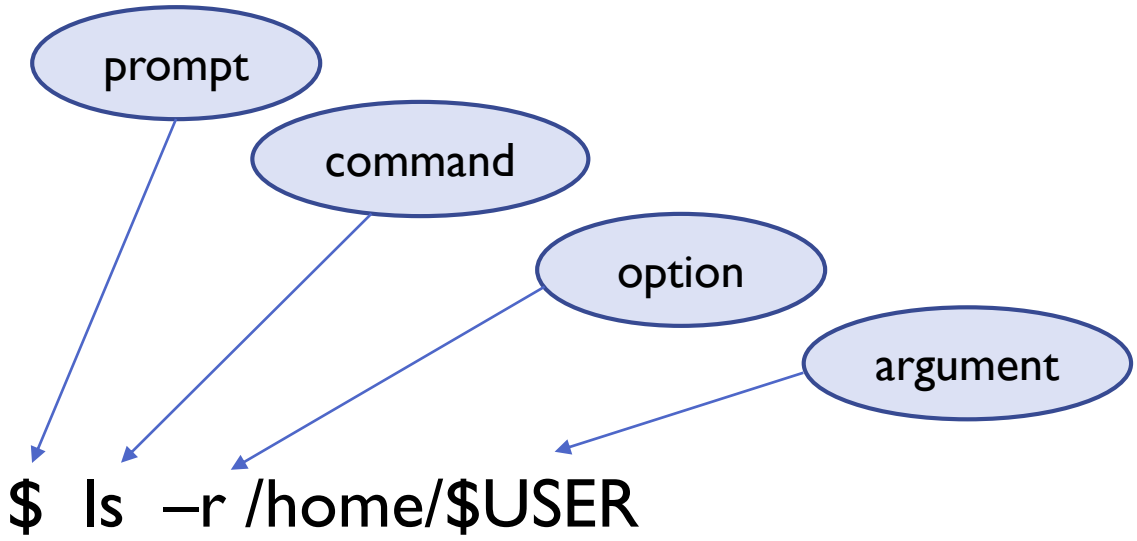
$ ls /tmp

- You can run more than one command on the same line by separating the commands with a semicolon (;)

$ ls;date

- Most Linux commands have a manual page or help to describe how they can be used….more about this later!

Linux Command Example



Exercise #1: First commands

```
[username@helix ~]$
```

- Type "**whoami**", press Enter – who are you?
- Type "**pwd**", press Enter – where are you?

- Type "echo $HOME" – what does it show?
- Type "echo $USER" – what does it show?
- Type "echo $PWD" – what does it show?

- $HOME, $USER and $PWD are three more examples of shell variables as we saw earlier with $SHELL

Concepts: Files and Processes

In Unix, and by extension, Linux, everything is either a file or a process. Meaning everything can be interfaced via the file system(s).

- Files: text, data, documents, traditional files
- Directories: directories are special text files that contain a bunch of other files
- Devices: all disks, video hardware, audio hardware, processors, memory, USB ports – all hardware can be interfaced via files (usually in /dev)
- Processes: all running processes can be "seen" via the file system (in /proc) – each has a unique identifier (PID)

More on Files

- Each file (and directory) has a name
- The filename can contain letters, numbers and special characters – best to start with name or number
- Every file has a unique path to its location

  Example: /home/student2/read-write.txt
- A filename MUST be unique within a directory…though files with the same filename can exist in different directories
- Like Linux commands, filenames are case sensitive so a file named "myfile" and "Myfile" can co-exist in the same directory – the names are different.
- Filenames can be lengthy

More on Directories

- A directory is a special type of file that can hold other files – often referred to as a folder in Windows or MacOS
- The "working directory" is the directory with which your shell is currently associated…where you currently are! When you first login, you will normally be in your home directory, /home/username

- Use the '**pwd**' command to print working directory

- Special directory notations:
- . refers to the current working directory
- .. refers to the parent directory (one level back – the parent directory of /home/username would be /home)

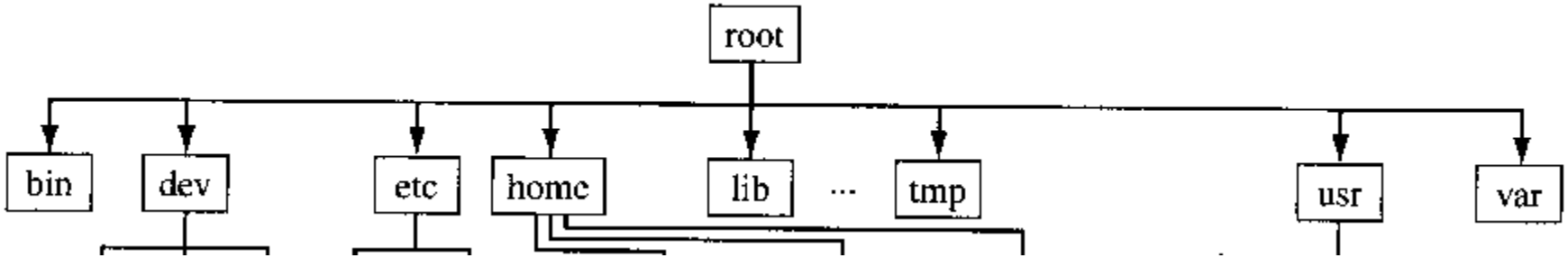
Pathname

- Every file has a unique path to its location…for example:

/home/student2/Projects/docs/final_report.doc

- '/home/student2' is the home directory for student2
- 'Projects' is a directory in /home/student2 - student2 is the parent directory of Projects
- 'docs' is a directory in 'Projects' – docs is a subdirectory or child directory of Projects
- 'final_report.doc' is a file in 'docs'

Concepts: The File System



- Linux and Unix-like file systems are arranged in a tree structure, all with the same bottom level, called "root" (/).
- Unlike Windows there are no drives, drive letters or any separate conceptual "space" for storage hardware.
- New hardware will come in the form of a "file system" attached (mounted) to some arbitrary point in the directory structure.

Linux Directory Structure

- `/` root
- `/bin` bare essential commands
- `/boot` OS Kernels
- `/dev` hardware devices
- `/etc` system files, configuration
- `/home` home directories
- `/lib` Libraries needed by the system
- `/opt` 3rd party applications
- `/proc` Running processes
- `/sbin` administrative commands
- `/tmp` temporary space
- `/usr` operating system applications
- `/var` Logs, databases and other variable length stuff

cd and ls commands

- The "cd" command is used to change directory location. Without an argument, "cd" takes you to your home directory
- The "ls" command is used to list the files in a directory. Like many Linux commands, it can take a number of "flags" as options to change the behavior of the command

```
$ cd /home/$USER
$ ls
$ cd /etc
$ pwd
$ ls
$ ls -l
$ ls -rl
$ cd
$ pwd
```

Exercise #2: "cd" and "ls" commands

- Type "`cd /data/classes/linux`"
- Try "`ls -l`"
- Try "`ls -a`"
- Try "`ls -la`"
- How are the above outputs different?
- Type "`ls -lt`"
- How is this output ordered?
- Type "`ls -l /tmp`"

The above shows how providing an argument to the 'ls' command displays the contents of a directory without first changing to the directory

- Type "`cd /home/$USER`" to change to your home directory
- Now type "`cd -`"
- To what directory did that take you?
- Now type "`cd ..`"
- To what directory dis that take you?
- Type "`cd /home/$USER`" to get back to your home directory

Finding your way home!

- The "~" is a special character that is short-hand for "`/home/username`"
- The shell variable $HOME also stores the path of "`/home/username`"
- Several ways to get to your home directory:

```
$ cd  ~
$ cd  $HOME
$ cd  /home/username
$ cd /home/$USER
$ cd
```

- But you can also use the "~" and $HOME as arguments with other commands:

```
$ ls  ~/tmp
$ ls  $HOME/LinuxClass
```

Absolute and Relative paths

- The starting "/" in the directory argument explicitly spells out a pathname – specifying an absolute or full path
- No leading "/" means you are specifying a path that is relative to the current working directory.
- "cd /tmp" is different from "cd tmp"

```
$ cd  /home/username

# Absolute path:
$ cd  /home/username/tmp

# Relative path:
$ cd  tmp

# Using ~

These do the same:
$ cd  ~/tmp
$ cd  /home/username/tmp
```

Help!

- Many commands provide a '--help' option which will display information on the various options and there means. For example:

$ ls --help

- There is also the "man" command, which will provide a manual listing on the use of standard Linux commands such as ls one page at a time

$ man ls

- One can scroll forward or back one line at a time using the up & down arrow keys and scroll forward or back one page at a time by hitting the 'f' or 'b' keys, respectively.
- Exit out of a man page by typing 'q'
- Try both of the above commands

Users and Groups

- Users are associated with a unique user identification (UID) number that the system uses internally
- Users can be real people
- Users can be system entities
- Users can be herded via groups
- Groups also are associated with a unique group identification (GID) number by the system
- Groups allow multiple users to access/share the same files

Ownership & Permissions

- Linux systems are multi-user environments that allow users to create files, run programs and share data.
- Files and directories have two types of ownership – the user and group. A Linux group consists of one or more users.

- Files and directories have three types of access permissions:

read permission (r)

write permission (w)

execute permission (x)

- Every file and directory has permissions for three levels or entities of permissions:

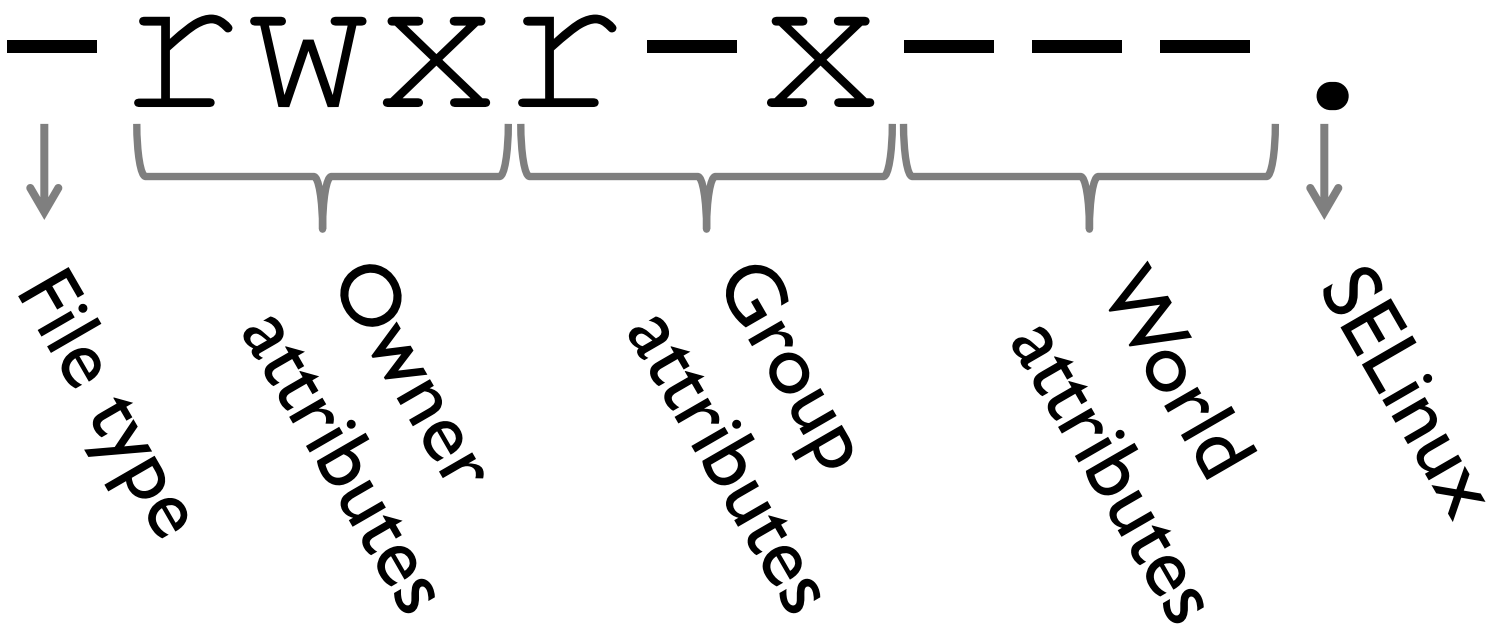
a) user or owner (denoted by u)

b) group (one or more users – denoted by g)

c) others or world (denoted by o)

Permissions triplets

Each triplet indicates the access permissions for that level – in the example below, the user/owner has read, write & execute permission, other group members only have read and execute permissions and all others have no access permissions.



Long List Output Explained (a little)

- From left to right:
  - Unix permissions
  - Hard links
  - Owner
  - Group ownership
  - File size in bytes
  - Modification date
  - Name of file

```
$ ls -la
drwxrwx---  104 mark      staff   110592 Aug 17 13:02 .
drwxr-xr-x 2510 root      root    196608 Aug 17 12:58 ..
-rw-r--r--    1 mark      mark      1051 May  8  2016 ad-week
-rwxr--r--    1 mark      staff      239 May 11  2013 alias.pl
-rw-r-----    1 mark      staff     1185 Jun 22  2014 bp.txt
-rwxr-xr-x    1 root      root     27320 Mar 29  2015 getpass.awk
-rw-rw-r--    1 david     staff    20529 Aug  7  2017 httpd.conf
-rwxr--r--    1 root      staff   136236 Sep 10  2017 memcon
drwxr-x---    2 mark      staff     4096 Jun 24  2017 misc
drwx------    3 mark      staff     4096 Jun 24  2017 test
-rwx------    1 mark      staff      493 Feb 10  2016 unlock
-rw-r-----    1 mark      staff       38 Oct 20  2017 world.c
-rwxr-x---    1 mark      staff     6703 Jan  8  2017 world.exe
-rwxrwx---    1 mark      staff     2350 May 22  2017 year.pl
lrwxrwxrwx    1 mark      staff        7 Aug 16 15:30 year2 -> year.pl
```

Special Directories:

- . is the current working directory
- . . is the "parent" directory, one level "back"

Permissions described:

File Type:

- "-" regular file
- "d" directory
- "l" symlink
- "b" block device
- "c" character device
- "p" named pipe
- "s" socket

Permissions

- "r" read
- "w" write
- "x" execute

Special values:

- "s" or "t": executable and setuid/setgid/sticky
- "S" or "T": setuid/setgid or sticky, but not executable.

Changing Permissions and Ownership

- Use '**chmod**' to change the file permissions:

chmod [ugoa][+/-][rwx] filename

where u=user, g=group, o=others or world and a=all three

For example, to provide group read access to a file:

$ chmod g+r myfile

Or to remove file access to another than the owner or group members (in other words, others):

$ chmod o-rwx myfile

- The '**chown**' command is used to change file ownership and the '**chgrp**' command can change group ownership of a file. **As a regular user, you can not change the ownership of a file, but you can change the group ownership if you are a member of the group to which you are changing the group ownership**

- You can use the –R argument on any of the above to recursively make changes on a directory of files

Exercise #3 pre-exercise

- We'll talk about some of these commands shortly, but you each need to make a copy of files needed for the rest of class.

- First go to your home directory

```
$ cd  /home/$USER
```

- Make a 'LinuxClass' directory using the 'mkdir' command & go into that directory:

```
$ mkdir  LinuxClass
$ cd  LinuxClass
```

- Copy the files from the exercise file to your directory using 'cp':

```
$ cp  –r  /data/classes/linux/*  .
$ ls  -l
```

- Create a shell variable to your class directory:

```
$ class=$PWD
$ cd  $class
```

Exercise #3: File Permissions

Read Permissions

```
The cat command displays
contents of a file

$ cd /home/$USER/LinuxClass
$ cat  read-write.txt

Change the read permission
$ chmod  u-r  read-write.txt
$ cat  read-write.txt

What happened? Now restore the
read permission

$ chmod  u+r  read-write.txt
$ cat  read-write.txt
```

Execute Permissions

```
$ cd /home/$USER/LinuxClass
Run the myhostname file to see the
system name
$ ./myhostname

Remove the execute permission for the
user on the myhostname file:

$ chmod  u-x  myhostname
$ ./myhostname
What happened?
$ chmod  u+x  myhostname
$ ./myhostname

Change permissions on the directory
dir-perms:

$ chmod  u-x  dir-perms
$ ls dir-perms
$ ls -l dir-perms

What happened and why?
```

Wildcards

- With many Linux commands, you can use wildcards to match characters

- The '*' can be used to match **zero or more** characters

Examples:

```
$ ls  bear*
bears  bears7  bears_chicago
$ ls  *bear*
bears bears7 bears_chicago polarbears
```

- The '?' can be used to match **EXACTLY one** character

```
$ ls  bears?
bears7
```

Special Keys

Tab Key allows for command auto-completion

Single Quote vs Back Tick

Arrow keys allow you to:

a) Move horizontally along the command to make changes without deleting and retyping everything

b) Move vertically through your history of previously run commands

Ctrl-c, ESC & command line editing

- If you get into a situation where you can't seem get back to a command line prompt, try hitting the Ctrl-C combination or the Esc key – often one of those will abort whatever you are currently doing.
- The Ctrl character is often represented by the ^

- Use Ctrl-a to go to the beginning of the line
- Use Ctrl-e to go to the end of the line

What is that file?

file

The "file" command tells us what type of file it might be - text, executable, PDF, jpg, gzip, tar, directory, etc.

```
$ file read-write.txt

$ file world.exe

$ file examples

$ file Linux_slides.pdf
```

cat and echo

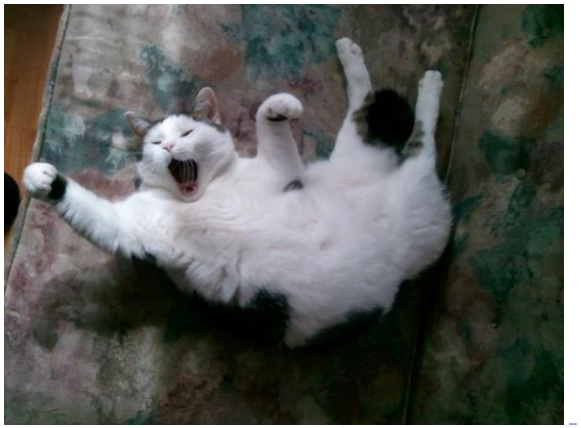
Use cat to display file contents to the terminal:

```
$ cat bears
$ cat bears7
$ cat bears bears7
```

"cat" is short for concatenate. The "cat" command takes one or more files and concatenates their contents to standard output.

echo is used to output arbitrary text to the terminal:

```
$ echo 'Hello World!'
$ echo without single quotes
$ echo 'Hello World!' > MyWorld
```



Output Redirection to Files

Redirect output (>):

```
$ cat bears > Teddybears
$ cat Teddybears
$ cat bears bears7 > bothbears
$ cat bothbears
$ cat bears* > allbears

$ echo 'Hi there!' > greeting
$ cat greeting
```

Append files (>>):

```
$ echo 'Hi yourself!' >> greeting
$ cat Teddybears >> greeting
$ cat greeting
```

Exercise #4: cat and echo

cat a file to view contents

```
$ pwd
$ cd  /home/$USER/LinuxClass
$ cat  lions
$ cat  tigers
$ cat  bears
$ cat  lions tigers > animals
$ cat  animals
$ cat  bears >> animals
$ cat  animals
```

Using echo

```
$ echo my name is Chris
$ echo "my name is $USER" > myname
$ cat myname
$ echo Hello $USER >> myname
$ cat myname
```

Symbolic links

Allows you to reference same file with different name or path – a symbolic link is a another file type.

```
$ ln  -s  <existing_file>  <file_link>
$ cat Capitals
$ ln  -s  Capitals  CapCities
$ ls  -l  Cap*
$ cat CapCities
```

```
Example:
$ ln  -s /home/$USER/LinuxClass/examples/tmp/colors color-pairs
$ ls -la color-pairs
$ cat /home/$USER/LinuxClass/examples/tmp/colors
$ cat color-pairs
```

Creating files/directories

Using touch and mkdir

```
To create an empty file, use the touch command:
$ touch  my_data_file

You can also create a file using an editor such as pico,
nano, vi or emacs:
$ nano  Music

To create a directory:
$ mkdir  Mydirectory
$ mkdir  2017
$ mkdir  -p  2018/Jan/stats
```

Deleting files/directories

Using rm and rmdir

```
To remove a file:
$ rm my_data_file
$ touch myFile
$ chmod  u-rwx  myFile
$ rm myFile
$ rm -f myFile

To remove a directory:
$ rmdir Mydirectory
$ rm -r 2017
```

rmdir only works if the directory is empty!

Dangerous:

```
$ rm  -rf  *
```

Exercise #5: Creating and deleting files

Creating a file, directory & symbolic link

$ cd /home/$USER/LinuxClass

$ echo 'I love genomic research!' > science

Now create a file named science_project and a directory named scienceclass (hint: use touch & mkdir)

$ ls –ld science*

$ ln –s "/home/$USER/LinuxClass/examples/tmp/ice_cream" Ice_cream

$ ls –la Ice_cream

$ cat Ice_cream

Deleting a file and directory

$ rm science*

$ ls –ld science*

What happened?

$ rmdir scienceclass

Displaying Portions of a File

"more" or "less"

```
$ more  mascots.txt
$ less  mascots.txt
- each prints out a page of a file at a time
```

"head" or "tail"

```
$ head  mascots.txt
 - prints out the first 10 lines by default.  Can use the
-n argument to change the default number of lines

$ tail  -20  mascots.txt
 - prints out the last 20 lines
```

Text editors

Good simple editors:

- pico (pine composer)
- nano (pico clone)

Advanced editors with more features:

- “vim” (vi-improved)
- “emacs” (Editor MACroS)

nano – a simple editor

$ nano filename

The essentials:

- Just start typing – can use arrow keys to position, backspace or delete key to delete characters to the left
- Keystrokes for basic commands at bottom of the screen
- ^G – help screen (^C to exit help)
- ^O – save the file
- ^W – search for a string
- ^X – exit nano

$ nano --help

Exercise #6: Editing a file using nano

$ cd /home/$USER/LinuxClass

$ nano bashrc

1) Using the RIGHT arrow key, position the cursor at the end of the first line,
2) Use the Backspace key to remove **<HOMEDIRECTORY>** from the first line and then type **$HOME** after the colon
3) Hit Ctrl-W (to search), type **NANOPATH** and hit Enter – this should place you on the last line
4) Hit Ctrl-E to get to the end of the line
5) Use the Backspace key to remove everything after the '=' sign and type **'/bin/nano'**
6) Use the up & the right arrow keys to get to the @ on the 2nd line
7) Backspace to remove **<USERNAME>** and type **your username**
8) Use the down arrow key to get to the 3rd line
9) Hit Ctrl-K to cut the 3rd line
10) Hit the Up arrow to get to the 1st line & Ctrl-A to get to the start of the line
11) Hit Ctrl-U to paste the text – the 3rd line should now be the first
12) Hit Ctrl-X to exit – type Yes to save the file when prompted and hit Enter when prompted for the name

$ cat bashrc

mv - moving files/directories

mv - move one or more files or rename a file (some Linux versions have a 'rename' command, but not all):

Syntax: mv source destination

```
$ touch football
$ touch footballgame
$ ls -l football*
$ mv footballgame footballtee
$ ls -l football*
$ mkdir sports
$ mv sports Sports
$ ls -ld *ports*
$ touch footballtee2
$ mv footballtee* Sports
$ ls -la Sports
```

cp - copying files/directories

cp - copy one or more files or directories

Syntax: cp source destination

```
$ cp football football2
$ cp -p football football3
$ ls -la football*
$ cp -p Sports/footballtee .
$ mkdir -p Sports/fall
$ cp -p football2 Sports/fall
$ cd Sports/fall
$ cp -p football2 ../football4
$ cd ..
$ ls -R Sports
```

Archival copy:

```
$ cp -a Sports Sports2017
$ cp -pr Sports Sports2018
```

Exercise #7: Moving/Copying Files

Move (mv)

```
$ cd  /home/$USER/LinuxClass
$ touch Raspberry
$ mv  Raspberry raspberry
$ echo blueberry > blueberry
$ ls  -la *berry
```

Now create a directory path using mkdir with the -p option:

```
$ mkdir  -p  Berries/All/B
```

Use mv to move the **blueberry file** *into* **Berries/All/B** *directory:*

```
$ mv blueberry Berries/All/B
$ touch Berries/All/B/blackberry
$ mv Berries/All/B/blackberry .
$ mv  Berries BERRIES
$ ls  -Rl  Berries
$ ls  -Rl  BERRIES
```

Copy (cp)

```
$ cp raspberry strawberry
$ cp -p raspberry cranberry
$ ls -la *berry
```

*How do the four *berry files differ?*

```
$ mkdir -p BERRIES/Others
$ cp -p *berry BERRIES/Others
$ mv *berry BERRIES
$ ls -la BERRIES
$ cp -pr BERRIES/Others BERRIES/More
$ ls  -Rla  BERRIES

$ cp  BERRIES NewBerries
```

What did you see?

```
$ cp  -pr  BERRIES NewBerries
```

Archival copy:

```
$ cp  -a  BERRIES Berries-save
```

wc - what's in that file?

"wc" (word count)

```
$ wc  mascots.txt
 345  955 7342 mascots.txt
Output shows the number of lines, words and characters in
the file

Can use argument to only get one of the three values:

$ wc  -l  mascots.txt
$ wc  -w  mascots.txt
$ wc  -m  mascots.txt

$ wc  -help
```

grep – pattern matching search of a file

"grep" – global/ regular expression/ print

```
$ grep  cat  nonsense.txt
$ grep  dog  nonsense.txt
$ grep  -i  dog  nonsense.txt  # case insensitive
$ grep  -v  dog  nonsense.txt  # exclude 'dog'
$ grep -A1 cat nonsense.txt    # include line after match
$ grep -B1 cat nonsense.txt    # include line after match
$ grep  oc  nonsense.txt
$ grep -c oc nonsense.txt      # count of matching lines
$ grep  ^oc  nonsense.txt      # ^ -starts line with oc
$ grep  oc$  nonsense.txt      # $ - ends line with oc
```

grep is a powerful tool. Use it (as well as egrep...extended grep)

```
$ grep  --help
$ man  grep
```

Exercise #8: Using grep

- Make sure you are in the class directory:

```
$ cd ~/LinuxClass
$ pwd
```

- Using the 'grep' utility with the file **mascots.txt**, determine the following:

- find the lines that have the letters 'cat' (*just lowercase letters*) as part of the mascot name

- find the lines that have the letters 'cat' **regardless of case** as part of the mascot name

- find which colleges that **start** with the word "Saint" and redirect the output to a file named **Saints –** how many?

find – where are my darn files?

find - used to locate files based on various criteria

- $ find [path_to_search] [expression/options]
- $ find . –name "*.txt"
- $ find /home/$USER/LinuxClass –iname "capital*"
- $ find /home/$USER/LinuxClass –type f -mmin 40
- $ find /home/$USER/LinuxClass –type f -mmin -40
- $ find /home/$USER/LinuxClass –type f -mmin +40
- $ find /home/$USER/LinuxClass –type f –mtime 1
- $ find /home/$USER/LinuxClass –name "*.bak" –delete
- $ find . –name "*.txt" –exec ls \-la {} \;
- $ man find

Exercise #9: Using find

- Let's use the find utility to look for files in your home directory
- Make sure you are in your class directory:

```
$ cd ~/LinuxClass
$ pwd
```

- Using 'find', locate the file named 'colors'
- Using 'find', locate the files whose name **contains** the word 'bear' where the match is **case insensitive** (hint: **-iname** option)
- Using 'find', locate the files that were modified LESS than 45 minutes ago (hint: -mmin option)
- How many files did you find for each?

uniq – show or remove duplicate lines

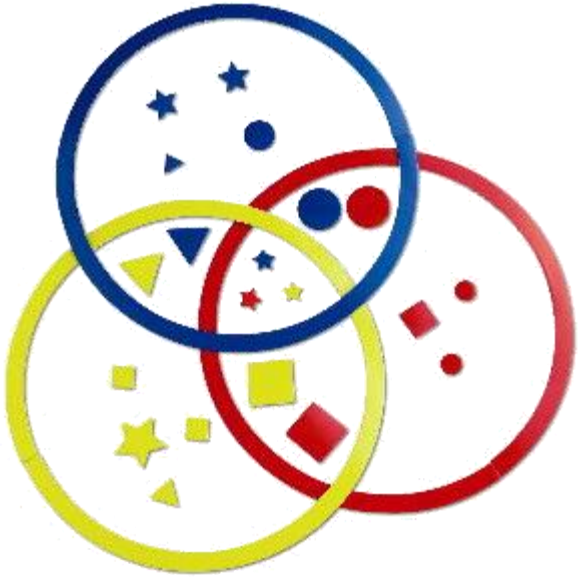
- uniq – show either unique or duplicate **consecutive** lines in a file or output. Default behavior is to merge adjacent matching lines into one, but can be used to print just the matching lines or provide a count of matching lines…most effective with the sort command

```
$ uniq  bears      # will show all unique lines
$ uniq  -d  bears  # show only duplicate lines
$ uniq  -c  bears  # show a count of each unique line
```

Sorting

sort command

"sort" can be used to read a file, sort the contents and output to the terminal



```
$ cat  grades.txt
$ sort  grades.txt
$ sort  -r  grades.txt
$ sort  -k2 grades.txt
$ sort  -b  -k2  grades.txt
$ sort  -bn  -k2  grades.txt
$ sort  -bnr -k2  grades.txt
$ sort  -help
```

Pipes (redirect to other processes)

Much like you can write output to files, you can write or "pipe" output to other commands using pipes "|"

```
$ cat college1 | sort | uniq
$ cat college2 | sort | uniq
$ cat college1 college2 | sort | uniq  -c
```

Write to a file at the end:

```
$ cat college1 college2 | sort | uniq |grep  ^C > Colleges
```

Exercise #10: sort, pipes and redirection

- cd /home/$USER/LinuxClass
- Look at the contents of two files, grocery1 and grocery2 (use cat command)
- Combine the two files using the cat command and then use the sort and uniq commands to get a list of sorted, unique items for the grocery list
- Now redirect the output to a file named grocery3
- Use the wc command to determine how many unique items are on the list (in the grocery3 file).
- Use grep and wc to determine how many items in the grocery3 list start with the letter 'c'

Exercise #10 continued

- $ cat grocery1
- $ cat grocery2
- $ cat grocery1 grocery2 | sort | uniq
- $ cat grocery1 grocery2 | sort | uniq | wc –l

You should have 32 items

- $cat grocery1 grocery2 | sort | uniq > grocery3
- $ grep ^c grocery3

7 items start with the letter c

Other useful commands

- history – displays a history of commands which allows for an easy way of running a command again without having to type it out again
- alias – list aliases or create a new one for another cmd

```
Example:
$ alias hist="history 20"
```

- cut – print out selected fields

```
Example:
$ cat famousdogs | cut -f1,4 -d:
```

- diff – find the differences between two files:

```
$ diff numbers1 numbers2
```

date & cal

- date – prints the current date and time

```
$ date
Wed Sep 12 15:08:17 EDT 2018
$ date +"%D %T"
  09/12/18 15:08:18
```

- cal – print the calendar for the current month or entire year

```
$ cal 2018
```

Input, Output and Error

- Commands can have an input and output
- STDIN or 'standard input' is input from the keyboard though we can have redirected input from a file
- STDOUT or 'standard output' is output going to the screen. We've already seen where we can 'redirect' the output of a command to a file or pipe it as the input to another command
- Commands may also produce errors such as 'Permission denied'
- STDERR or 'standard error' is error output that goes to the screen by default

Input, Output and Error (cont)

- STDIN, STDOUT and STDERR have handles or numbers associated with each:

	Handle	
STDIN	0	Standard input
STDOUT	1	Standard output
STDERR	2	Standard error

Let's change permissions on dogs2 to be unreadable:

```
$ cd $HOME/LinuxClass
$ chmod  ugo-r  dogs2
```

- Can redirect the STDERR to a file:

```
$ grep  dog  dogs*   2>  errors
$ grep  dog  dogs*   2>  /dev/null
```

- Can redirect BOTH the STDOUT and STDERR to a same file:

```
$ grep  dog  dogs*  >  out_plus_errs  2>&1
```

or to different files:

```
$ grep  dog  dogs*  > OUTPUT  2> ERRORS
```

Putting it all together

Read in from a file with input redirection, do some stuff and output to another file:

```
$ sort < Colleges.txt | grep -i ^C > C-colleges
```

- Program first, then arguments, then any file I/O
- Most programs will read from standard input (stdin) if no file is specified in arguments

awk – text manipulation

- In awk, lines are split into fields by whitespace by default, which are represented by variables $1, $2, $3, etc
- 'print $1' will print the first field
- Let's look at an example:

$ cat hare_tortoise

The hare beat the tortoise handily.

- We can change the ordering of words using awk:

$ awk '{print $1,$5,$3,$4,$2,$6}' hare_tortoise

The tortoise beat the hare handily.

- You do NOT have to use all of the fields – can pick and choose as needed

sed – stream editor for pattern matching and modification

- In sed, one can do text pattern matching and modification

$ cat hare_tortoise

The hare beat my tortoise handily.

- If we want to change the word 'beat' with the word 'defeated':

$ sed 's/beat/defeated/g' hare_tortoise

The hare defeated the tortoise handily.

- The trailing '/g' at the end of that command indicates that the change is to be done globally…without it, only the first occurrence of the word in the file will be changed.

- We can use both awk & sed on the same command line:

$ awk '{print $1,$5,$3,$4,$2,$6}' hare_tortoise |
sed 's/beat/defeated/g'

The tortoise defeated the hare handily.

tr – allows character substitution or translation

- With tr, characters can used to translated – perhaps to change the case of letters:

```
$ echo 'Let's Go Caps!!!' | tr "a-z" "A-Z"
LET'S GO CAPS!!!
```

- Or to replace a new line character (\n) with a space or comma:

```
$ cat numbers2 | tr "\n" " "
 1 2 3 4 5 6 7 8
$ cat jobs
$ cat jobs|awk '{print $1}'|tr "\n" ","
```

More Linux Command Basics…Quotes

- Linux treats single, double and back quotes in commands differently
- Contents of a set of single quotes are treated as a string:

```
$ echo '$USER'
$USER
```

- Contents of a set of double quotes will have any included variables replaced:

```
$ echo "The home directory of $USER is $HOME"
The home directory of username is /home/username
```

- Contents of a set of back quotes or back ticks (on the upper left of the keyboard) are treated as a command and the output can be assigned to a variable:

```
$ NOW=`date`; echo $NOW
Mon Jul 30 15:08:56 EDT 2018
```

Your PATH

Execution path

In BASH, execution of a program happens when you enter the program name. Your PATH variable keeps you from having to enter the full path to the program

```
$ echo $PATH


$ which date
$ which whoami
$ which perl
```

Modifying your PATH

```
$ echo $PATH
$ PATH=$PATH:/data/$USER
$ echo $PATH


To path changes permanent, need
to modify the .bashrc file in
your home directory.
```

Shell Variables

Variable assignment

Arbitrary assignment

```
$ MYWORLD="Hello World"
$ echo $MYWORLD
$ MY_PI=3.14
$ echo $MY_PI
```

With program output

```
$ RIGHTNOW=`date`
$ echo $RIGHTNOW
Mon Jul 30 15:08:56 EDT 2018
```

From a file

```
$ FILE=`cat jobs`
$ echo $FILE

$ echo $FILE | awk \
'{print $1}'|sort | uniq
```

Shell Variables

Show all currently assigned variables

```
$ printenv
HOSTNAME=biowulf.nih.gov
TERM=xterm
SHELL=/bin/bash
HISTSIZE=500
SSH_CLIENT=165.112.93.227
49886 22
OLDPWD=/home/mark
HISTFILESIZE=500
USER=mark
…
```

Useful predefined and important variables

- `$HOSTNAME` System hostname
- `$USER` Your Username
- `$SHELL` Your shell
- `$HOME` Home directory
- `$PWD` Current directory
- `$PATH` Command paths

Loops

"For" loops allow for iteration based on flow control criteria

```
$ for n in 1 2 3 4 5 6 7
> do
> echo The value of n is $n
> done

$ for n in {1..7}
> do
> echo The value of n is $n
> done

$ for n in `cat Capitals`
> do
> echo $n|tr "a-z" "A-Z"
> done
```

Perform math using the seq command:

```
$ seq 1 10

$ t=0
$ for n in `seq 1 10`; do
> t=`expr $t + $n`
> echo $t
> done
$ echo $t
55

$ t=1
$ for n in `seq 1 10`; do
> t=`expr $t \* $n`
> done
```

Loops, part 2

Let's combine contents of many named files into one

```
$ cd /home/$USER/LinuxClass/loops
$ cat nih1
.
.
$ cat nih9

We can combine the contents of the 9 nih named files into
one using a loop:
$ for i in `seq 1 9`
> do cat nih$i >> NIH-ALL
> done
$ cat NIH-ALL
```

Logic tests

Equality: if, then, else, fi

```
$ TRUE="good"
$ if [ "$TRUE" = "good" ]
> then
> echo "it's true"
> fi

$ if [ "$TRUE" = "no good" ]
> then
> echo "true statement"
> else
> echo "false statement"
> fi
```

Existence

```
$ if [ -e $HOME/.bashrc ]
> then
> echo true
> fi

$ if [ -d $HOME/LinuxClass ]
> then
> echo true
> fi
```

File Transfer

SCP, SFTP and clients

- SCP and SFTP are file transfer protocols that run over SSH, the same protocol that you used to log in
- They are very secure and encrypt both the log-in and content of any transfer

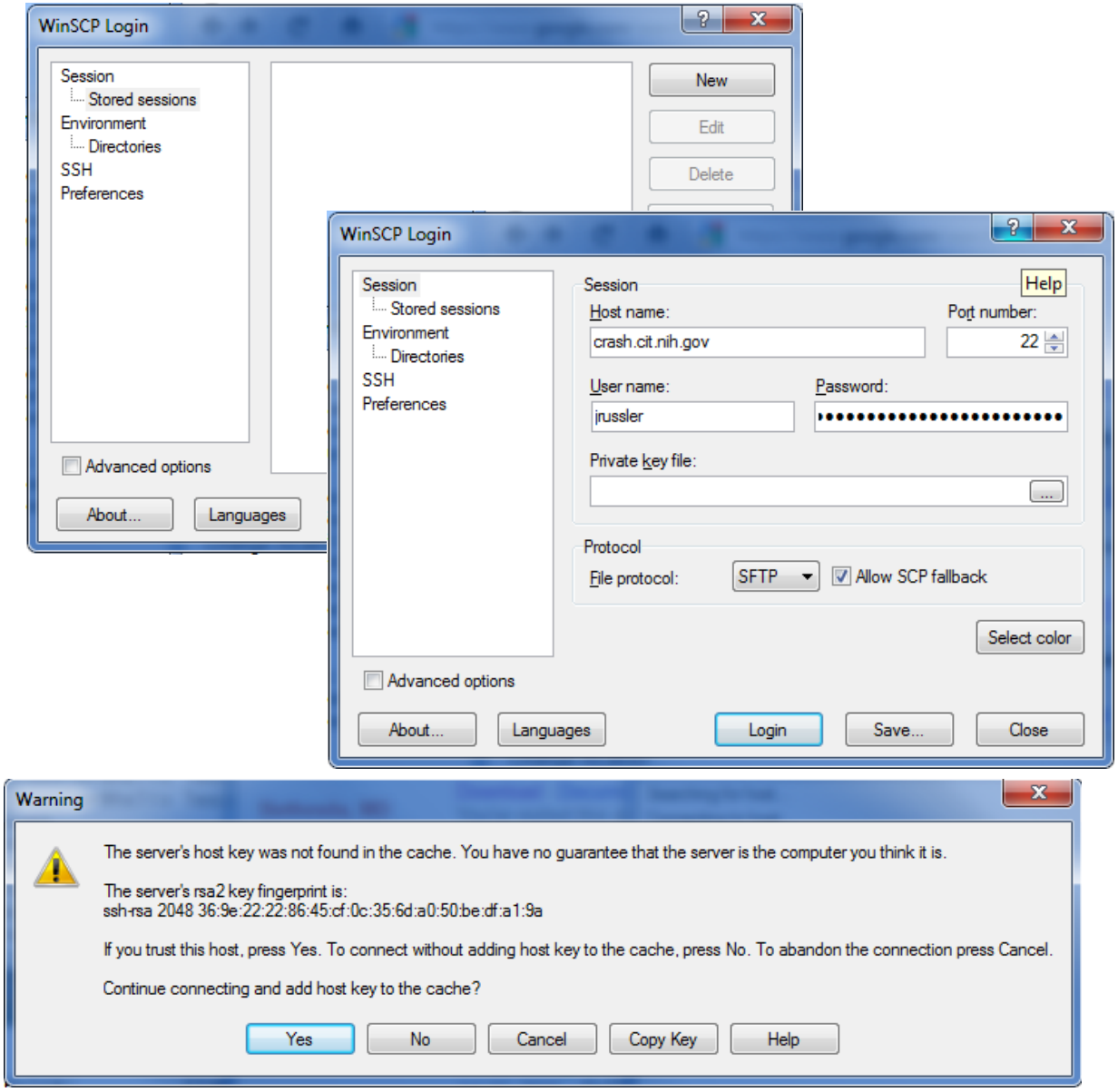
Clients

Linux/MacOS:

- "scp" secure copy
- "sftp" secure FTP
- "fuze-ssh" (Linux only)

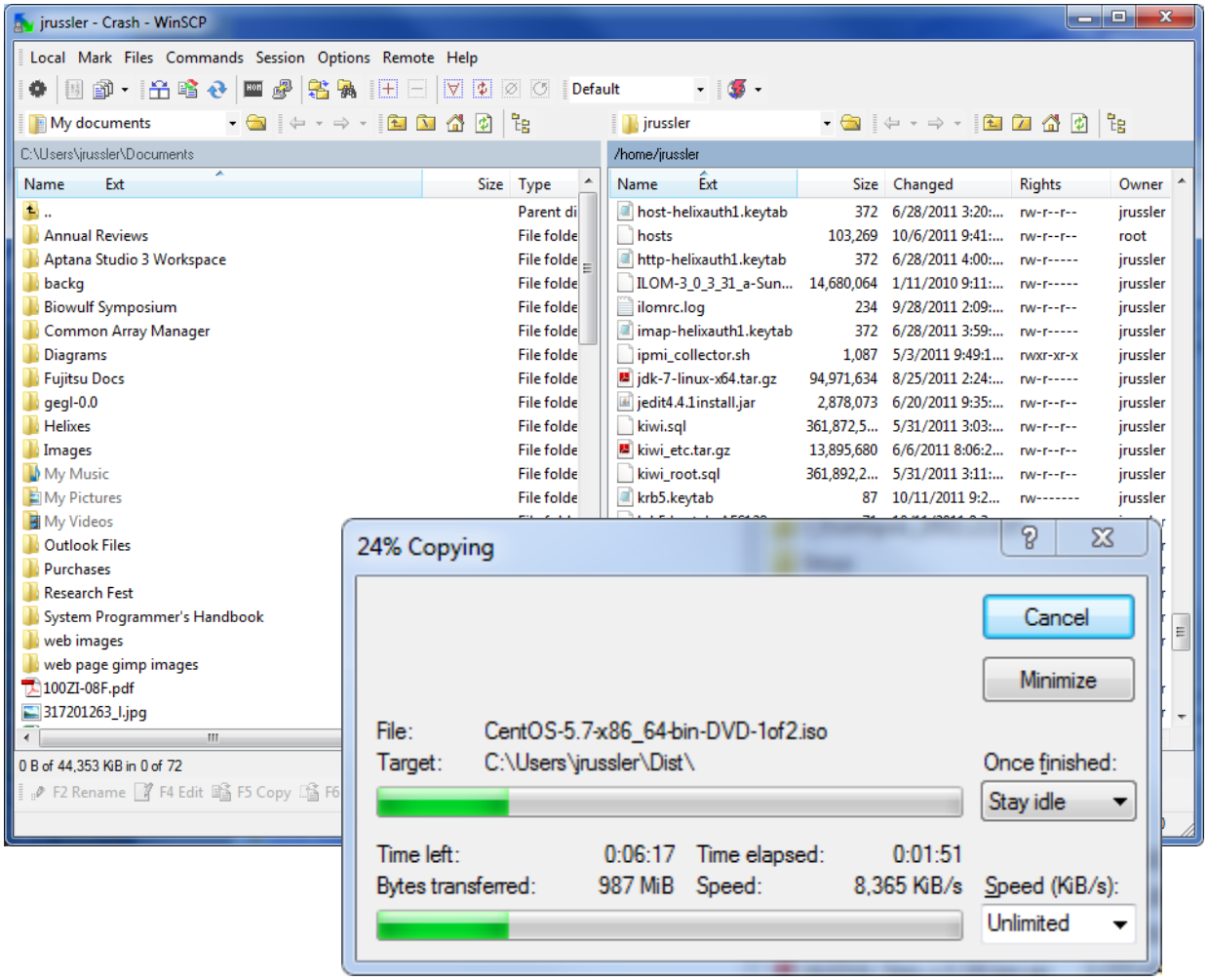
Windows:

- WinSCP
- Filezilla
- Swish



WinSCP

- Start WinSCP
- Click "New"
- Enter the host name (i.e.: helix.nih.gov)
- Fill in user name
- Leave password blank
- Click Login
- If this is the first time you've connected to this host, you'll have to accept the host's key



WinSCP Interface

- Left window is your local workstation, right window is the remote host
- Drag and drop files
- Navigate like a traditional explorer interface

Using OpenSSH (Unix/Linux/MacOS)

SCP files via command line:

Transfer a file:

```
$ scp helix.nih.gov:/tmp/file ~
```

Recursive transfer (whole directory)

```
$ scp -r helix.nih.gov:/tmp/dir ~
```

Preserve time stamps of the file being transferred:

```
$ scp -p helix.nih.gov:/tmp/file ~
```

From local host to remote.

```
$ scp ~/file helix.nih.gov:/tmp/
```

As usual

```
$ scp --help
$ man scp
```

Using SFTP

```
$ sftp helix.nih.gov
sftp> cd /tmp
sftp> get file
Fetching /tmp/file to file
/tmp/file  100% 2048KB   2.0MB/s   00:00
sftp> put file newfile
Uploading file to /tmp/file
file  100% 2048KB   2.0MB/s   00:00
sftp> exit

$ man sftp
```

File Transfer via HPCdrive

Network drive (Windows)

HPCdrive is available to users with NIH HPC (Helix/Biowulf) accounts:

- Open “Computer” from the start menu
- Click “Map Network Drive”
- Folder: hpcdrive.nih.gov/username
- Click Finish
- If prompted, enter NIH username and password

Network Drive (MacOS)

- Menu Bar -> Go -> Connect to Server
- Server Address: smb://hpcdrive.nih.gov/username
- Click “Connect”
- Check “Registered User”
- If prompted, enter NIH username and password

Globus

- Globus is a service that allows one to transfer large amounts of data in & out of systems. It will manage the file transfers, monitor performance, retry failures, recover from faults automatically when possible, and report the status of your data transfer.

- Requires an endpoint at source & destination. You can install Globus Connect on your local Windows, Mac or Linux system to create personal endpoint. NIH users can authenticate using their NIH username & password.

- The HPC (Biowulf/Helix) endpoint is nihhpc#globus. More information regarding Globus can be found at:

  https://hpc.nih.gov/storage/globus.html

Exercise #11: Using scp

- Type 'exit' to log off from Helix and get back to your local system:

$ exit

- Use scp to copy the file read-write.txt from Helix to your local system – **NOTE the trailing space & period in each command!**

$ scp username@helix.nih.gov:/data/classes/linux/read-write.txt .

- Now copy a whole directory:

$ scp -pr username@helix.nih.gov:/data/classes/linux/examples .

- Reconnect to helix via ssh once the file transfer has been completed

Processes

Show processes

Show your processes:

```
$ ps
$ ps -f
```

sleep is a delay or pause for specified number of seconds

```
$ sleep 5

$ sleep 25 &
$ ps -f
$ ps -f --forest
```

Show all processes:

```
$ ps -e
$ ps -ef --forest
$ man ps
```

More on Processes

Background and Foreground processes

- A command/job can be run in the background by adding '&' to end of the command:

```
$ sleep 50 &
[1]+ Done       sleep 50
```

- **ctrl-z** suspends a running job/process
- **bg** allows you to resume a suspended job in the background and returns you to the command prompt
- **fg** allows you to resume a suspended job in the foreground until it completes
- **ctrl-c** interrupts or kills the currently running process

- **Warning:** Backgrounded processes will die when you log out of your session unless you use something like nohup or screen.

More on Processes

Detach and Reattach processes

Ctrl-z suspends an active job

```
$ sleep 300
```

[ctrl-z] (process is suspended)

```
$ bg
$ ps -f
$ fg
```

Killing a process

```
$ sleep 300
[ctrl-Z]
$ bg
$ ps
  PID TTY          TIME CMD
 6686 pts/0    00:00:03 bash
 8298 pts/0    00:00:00 sleep
 8299 pts/0    00:00:00 ps
```

(find the PID of the process you want to kill)

```
$ kill 8298
```

Processes: kill them

"kill" only requests that the program exit. Use a signal 9 to force it to exit

```
$ sleep 300
[ctrl-Z]
$ ps
  PID TTY          TIME CMD
 6686 pts/0    00:00:03 bash
 8298 pts/0    00:00:00 sleep
 8299 pts/0    00:00:00 ps
```

(find the PID of the process you want to kill)

```
$ kill -9 8298
```

- The kill command is slightly misnamed, what it actually does is send a *signal* to a process
- Most signals are interpreted by the application being signaled and thus behavior is consistent only by convention
- Using signal 9 is dangerous if used indiscriminately

Exercise #12: Using 'kill' on a process

- First start a 'sleep' process that will run in the background for 300 seconds:

$ sleep 300

- Type '**Ctrl-z**' (the Ctrl and z keys together) to suspend the 'sleep' process
- Type '**bg**' to unsuspend the 'sleep' process and have it run in the background.
- Check that the process is running by using the '**ps**' command and note the pid, process identification number
- Using the '**kill**' command with the pid of the sleep process from the previous step, terminate the sleep process
- How can you check that the sleep process is gone?

uptime

- **uptime** shows a summary of the system status

```
$ uptime
 14:39:46 up 14 days,  7:00, 305 users,  load average: 39.18, 40.68, 38.68
```

- Numbers shown from left to right:

- Current time
- Amount of the time the system has been up
- Number of users currently logged on
- The average system load for the past 1, 5 and 15 minutes
- The load is the usage of the system's CPUs – a load of 1 corresponds to a full load of 1CPU

Who is doing what…using top

By default, top will produce continuous output about running processes

```
$ top
top - 16:19:54 up 28 days,  9:07, 255 users,  load average: 32.18, 32.79, 33.22
Tasks: 4749 total,   8 running, 4733 sleeping,   7 stopped,   1 zombie
Cpu(s):  9.6%us,  5.8%sy,  6.0%ni, 78.2%id,  0.2%wa,  0.0%hi,  0.2%si,  0.0%st
Mem:  1058656848k total, 955041356k used, 103615492k free,    79064k buffers
Swap: 67108856k total,   547376k used, 66561480k free, 89619996k cached

   PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  COMMAND
120202 johanesb  39  19  235m 180m 1432 R 96.4  0.0 170:21.86 merlin
252158 liqingli  39  19 58496  26m  756 S 95.0  0.0  17141:15 moe
170176 bozser    33  13  407m 117m 2588 S 60.1  0.0  62:30.33 ascp
218983 jrussler  20   0 18532 4704  872 R 22.3  0.0   0:00.38 top
127988 elliottm  39  19  223m 3544 1064 S 16.8  0.0 782:02.42 sshd
198816 wenxiao   20   0  4280  792  416 D 14.0  0.0  24:50.19 gzip
```

Hit ‘q’ to quit out of top

Looking at file system (disk) Space

To see local file system space:

$ df -l

```
Filesystem           1K-blocks      Used Available Use% Mounted on
/dev/mapper/vg_helix-root
                      51403396   8502228  40289968  18% /
tmpfs                529355640      2216 529353424   1% /dev/shm
/dev/sda2               495844    180879    289365  39% /boot
/dev/sda1               204580     33228    171352  17% /boot/efi
/dev/mapper/vg_helix-tmp
                      51606140    973788  48010912   2% /tmp
/dev/mapper/vg_helix-var
                      32253856  19349996  11265460  64% /var
```

To see numbers in human readable format:

$ df -lh

```
Filesystem            Size  Used Avail Use% Mounted on
/dev/mapper/vg_helix-lv_root
                       50G  8.9G   38G  19% /
tmpfs                 505G  5.6M  505G   1% /dev/shm
/dev/sda2             485M  142M  318M  31% /boot
/dev/sda1             200M  256K  200M   1% /boot/efi
/dev/mapper/vg_helix-lv_tmp
                       50G  613M   47G   2% /tmp
```

All filesystems, including network file systems:

$ df -h

Directory size

Estimate file space use (du)

```
$ cd /home/$USER
```

Estimate a file size:

```
$ du LinuxClass/Linux_slides.pdf
```

Summary:

```
$ du -s LinuxClass
```

Summary in human-readable format:

```
$ du -sh LinuxClass
```

Default behavior:

```
$ du
```

Checking Quotas on Helix/Biowulf

"checkquota"

- The **checkquota** command will query all network storage devices to find the applicable quota(s) for your user
- This command is specific to Helix and Biowulf and is not available to Linux in general since it relies on information that is site-specific to this infrastructure.

```
$ checkquota
Mount                    Used       Quota   Percent     Files
/data:                 94.2 GB   200.0 GB    47.12%     70424
/home:                  5.2 GB    16.0 GB    32.50%    133607
```

tar & gzip

- The **tar** command allow users to compress and archive files – does not remove the original files by default

Syntax for tar to create an archive:

$ tar –czvf <output file> <files to be archived>

where c is to create

z is to compress using gzip

v is verbose output (lists files as they are tar'd)

f indicates that the next argument is the output filename

Syntax to extract files from an archive:

$ tar –xzvf <filename>

Syntax to list the files in a tar file:

$ tar –tzvf tarfile.tar.gz

- The **gzip** command is similar, but the original file is removed unless you specify to keep it with the '-c' option.
- Example:

$ gzip files.gz

Cron

Cron: run a job whenever you want

- crontab -l
- crontab -e

```
--
15 3 * * * ~/script.sh >> ~/output 2> ~/error.log—
```

Runs "script.sh" at 3:15AM every day of every week of every month of every year.

```
* * * * *
```

- First number is the minute at which to run (0-59)
- Second is the hour (0-23)
- Third is the day of the month (1-31)
- Fourth is the month (1-12)
- Fifth is the day of the week (0-6), 0 is Sunday

Review

- History – Linux Torvalds, 1991
- Why Linux? Performance, functionality and portability
- Bash shell & shell variables
- Files and directories – permissions & ownership
- Linux file system
- Paths to files/directories
- Basic Linux commands to create & access files & directories
- nano editor
- sort, grep & find
- pipe & file redirection
- awk, sed, & tr text manipulation utilities
- transferring data to & from a Linux system
- processes
- cron

Resources

- Linux Documentation Project: `http://www.tldp.org`
  - **Introduction to Linux - A Hands on Guide:**

`http://www.tldp.org/LDP/intro-linux/html/index.html`

  - **Bash Guide for Beginners:**

`https://www.tldp.org/LDP/Bash-Beginners-Guide/html/`

  - **Linux Tutorial at the Texas Advanced Computing Center (TACC):**

`https://portal.tacc.utexas.edu/-/linux-unix-basics-for-hpc`

- NIH HPC Web Site: `https://hpc.nih.gov/training`

Questions? Comments?

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