

Linux System Administration

Linux Professional Institute (LPI) Certification Level 1
Exam 101



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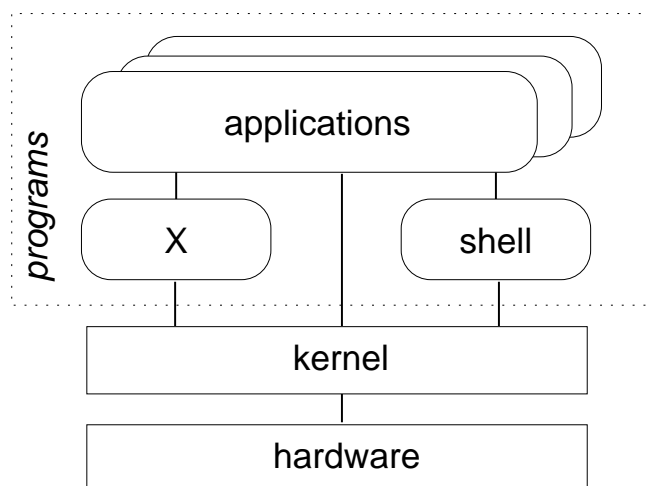
Module 1

Introduction

1. Unix and Linux

- Linux is based on Unix
 - ◆ Unix philosophy
 - ◆ Unix commands
 - ◆ Unix standards and conventions
- There is some variation between Unix operating systems
 - ◆ Especially regarding system administration
 - ◆ Often Linux-specific things in these areas

2. Unix System Architecture



- The shell and the window environment are programs
- Programs' only access to hardware is via the kernel

3. Unix Philosophy

■ Multi-user

- ◆ A **user** needs an **account** to use a computer
- ◆ Each user must **log in**
- ◆ Complete separation of different users' files and configuration settings

■ Small components

- ◆ Each component should perform a single task
- ◆ Multiple components can be combined and chained together for more complex tasks
- ◆ An individual component can be substituted for another, without affecting other components

4. What is Linux?

■ Linux kernel

- ◆ Developed by Linus Torvalds
- ◆ Strictly speaking, 'Linux' is just the kernel

■ Associated utilities

- ◆ Standard tools found on (nearly) all Linux systems
- ◆ Many GNU utilities
 - Written by the Free Software Foundation
 - Some claim the OS as a whole should be 'GNU/Linux'

■ Linux distributions

- ◆ Kernel plus utilities plus other tools, packaged up for end users
- ◆ Generally with installation program
- ◆ Distributors include: Red Hat, Debian, SuSE, Mandrake

5. Using a Linux System

- Login prompt displayed
 - ◆ When Linux first loads after booting the computer
 - ◆ After another user has logged out
- Need to enter a **username** and **password**
- The login prompt may be graphical or simple text
- If text, logging in will present a **shell**
- If graphical, logging in will present a **desktop**
 - ◆ Some combination of mousing and keystrokes will make a **terminal window** appear
 - ◆ A shell runs in the terminal window

6. Linux Command Line

- The shell is where commands are invoked
- A command is typed at a **shell prompt**
 - ◆ Prompt usually ends in a dollar sign (\$)
- After typing a command press `Enter` to invoke it
 - ◆ The shell will try to obey the command
 - ◆ Another prompt will appear

- Example:

```
$ date
Thu Jun 14 12:28:05 BST 2001
$
```

- ◆ The dollar represents the prompt in this course – do not type it

7. Logging Out

- To exit from the shell, use the `exit` command
- Pressing `Ctrl+D` at the shell prompt will also quit the shell
- Quitting all programs should log you out
 - ◆ If in a text-only single-shell environment, exiting the shell should be sufficient
 - ◆ In a window environment, the window manager should have a log out command for this purpose
- After logging out, a new login prompt should be displayed

8. Command Syntax

- Most commands take **parameters**
 - ◆ Some commands *require* them
 - ◆ Parameters are also known as **arguments**
 - ◆ For example, `echo` simply displays its arguments:

```
$ echo
```

```
$ echo Hello there
Hello there
```

- Commands are case-sensitive
 - ◆ Usually lower-case

```
$ echo whisper
whisper
$ ECHO SHOUT
bash: ECHO: command not found
```

9. Files

- Data can be stored in a **file**
- Each file has a **filename**
 - ◆ A label used to refer to a particular file
 - ◆ Permitted characters include letters, digits, hyphens (-), underscores (_), and dots (.)
 - ◆ Case-sensitive – *NewsCrew.mov* is a different file from *NewScrew.mov*
- The `ls` command lists the names of files

10. Creating Files with `cat`

- There are many ways of creating a file
- One of the simplest is with the `cat` command:

```
$ cat > shopping_list
cucumber
bread
yoghurts
fish fingers
```
- Note the greater-than sign (>) – this is necessary to create the file
- The text typed is written to a file with the specified name
- Press `Ctrl+D` after a line-break to denote the end of the file
 - ◆ The next shell prompt is displayed
- `ls` demonstrates the existence of the new file

11. Displaying Files' Contents with `cat`

- There are many ways of viewing the contents of a file
- One of the simplest is with the `cat` command:

```
$ cat shopping_list
cucumber
bread
yoghurts
fish fingers
```

- Note that no greater-than sign is used
- The text in the file is displayed immediately:
 - ◆ Starting on the line after the command
 - ◆ Before the next shell prompt

12. Deleting Files with `rm`

- To delete a file, use the `rm` ('remove') command
- Simply pass the name of the file to be deleted as an argument:

```
$ rm shopping_list
```

- The file and its contents are removed
 - ◆ There is no recycle bin
 - ◆ There is no 'unrm' command
- The `ls` command can be used to confirm the deletion

13. Unix Command Feedback

- Typically, succesful commands do not give any output
- Messages are displayed in the case of errors
- The `rm` is typical
 - ◆ If it manages to delete the specified file, it does so silently
 - ◆ There is no 'File shopping_list has been removed' message
 - ◆ But if the command fails for whatever reason, a message is displayed
- The silence can be off-putting for beginners
- It is standard behaviour, and doesn't take long to get used to

14. Copying and Renaming Files with `cp` and `mv`

- To copy the contents of a file into another file, use the `cp` command:

```
$ cp CV.pdf old-CV.pdf
```
- To rename a file use the `mv` ('move') command:

```
$ mv commitee_minutes.txt committee_minutes.txt
```

 - ◆ Similar to using `cp` then `rm`
- For both commands, the existing name is specified as the first argument and the new name as the second
 - ◆ If a file with the new name already exists, it is overwritten

15. Filename Completion

- The shell can making typing filenames easier
- Once an unambiguous prefix has been typed, pressing `Tab` will automatically 'type' the rest
- For example, after typing this:

```
$ rm sho
```

pressing `Tab` may turn it into this:

```
$ rm shopping_list
```

- This also works with command names
 - ◆ For example, `da` may be completed to `date` if no other commands start 'da'

16. Command History

- Often it is desired to repeat a previously-executed command
- The shell keeps a **command history** for this purpose
 - ◆ Use the `Up` and `Down` cursor keys to scroll through the list of previous commands
 - ◆ Press `Enter` to execute the displayed command
- Commands can also be edited before being run
 - ◆ Particularly useful for fixing a typo in the previous command
 - ◆ The `Left` and `Right` cursor keys navigate across a command
 - ◆ Extra characters can be typed at any point
 - ◆ `Backspace` deletes characters to the left of the cursor
 - ◆ `Del` and `Ctrl+D` delete characters to the right
 - Take care not to log out by holding down `Ctrl+D` too long

17. Exercise 1

- 1 Log in.
- 2 Log out.
- 3 Log in again. Open a terminal window, to start a shell.
- 4 Exit from the shell; the terminal window will close.
- 5 Start another shell. Enter each of the following commands in turn.
The dollar (\$) represents the prompt – do not type it.
 - \$ date
 - \$ whoami
 - \$ hostname
 - \$ uname
 - \$ uptime

18. Exercise 2

- 1 Use the `ls` command to see if you have any files.
- 2 Create a new file using the `cat` command as follows:

```
$ cat > hello.txt
Hello world!
This is a text file.
```

Press `Enter` at the end of the last line, then `Ctrl+D` to denote the end of the file.
- 3 Use `ls` again to verify that the new file exists.
- 4 Display the contents of the file.
- 5 Display the file again, but use the cursor keys to execute the same command again without having to retype it.

19. Exercise 3

- 1 Create a second file. Call it *secret-of-the-universe*, and put in whatever content you deem appropriate.
- 2 Check its creation with `ls`.
- 3 Display the contents of this file. Minimise the typing needed to do this:
 - Scroll back through the command history to the command you used to create the file.
 - Change that command to display *secret-of-the-universe* instead of creating it.

20. Exercise 4

After each of the following steps, use `ls` and `cat` to verify what has happened.

- 1 Copy *secret-of-the-universe* to a new file called *answer.txt*. Use `Tab` to avoid typing the existing file's name in full.
- 2 Now copy *hello.txt* to *answer.txt*. What's happened now?
- 3 Delete the original file, *hello.txt*.
- 4 Rename *answer.txt* to *message*.
- 5 Try asking `rm` to delete a file called *missing*. What happens?
- 6 Try copying *secret-of-the-universe* again, but don't specify a filename to which to copy. What happens now?

Module 2

Getting Started

1. Files and Directories

- A **directory** is a collection of files and/or other directories
 - ◆ Because a directory can contain other directories, we get a directory **hierarchy**
- The 'top level' of the hierarchy is the **root directory**
- Files and directories can be named by a **path**
 - ◆ The root directory is referred to as /
 - ◆ Other directories are referred to by name, and their names are separated by /
- If a path refers to a directory it can end in /
 - ◆ Usually an extra slash at the end of a path makes no difference

2. Examples of Absolute Paths

- An **absolute path** starts at the root of the directory hierarchy, and names directories under it
- In the root directory is a directory called *bin*, which contains a file called *ls*:

```
/bin/ls
```

- The following example will run the `ls` command, by specifying the absolute path to it:

```
$ /bin/ls
```

- We can use `ls` to list files in a specific directory by specifying the absolute path:

```
$ ls /usr/share/doc/
```

3. Current Directory

- Your shell has a **current directory** – the directory in which you are working
- Commands like `ls` use the current directory if none is specified
- Use the `pwd` command to see what your current directory is:

```
$ pwd
/home/fred
```

- Change the current directory with `cd`:

```
$ cd /mnt/cdrom
$ pwd
/mnt/cdrom
```

- Use `cd` without specifying a path to get back to your home directory

4. Making and Deleting Directories

- The `mkdir` command makes new, empty, directories
- For example, to make a directory for storing company accounts:

```
$ mkdir Accounts
```

- To delete an empty directory, use `rmdir`:

```
$ rmdir OldAccounts
```

- Use `rm` with the `-r` option to delete directories and all the files they contain:

```
$ rm -r OldAccounts
```

- Be careful – `rm` can be a dangerous tool if misused

5. Relative Paths

- Paths don't have to start from the root directory
 - ◆ A path which doesn't start with / is a **relative path**
 - ◆ It is relative to some other directory, usually the current directory
- For example, the following sets of directory changes both end up in the same directory:

```
$ cd /usr/share/doc

$ cd /
$ cd usr
$ cd share/doc
```
- Relative paths specify files inside directories in the same way as absolute ones

6. Special Dot Directories

- Every directory contains two special subdirectories which help making relative paths:
 - ◆ The directory `..` points to the parent directory, so to list the files in the directory which contains the current directory, use `ls ..`
 - ◆ For example, if we start from `/home/fred`:

```
$ cd ..
$ pwd
/home
$ cd ..
$ pwd
/
```
- The special directory `.` points to the directory it is in
 - ◆ So `./foo` is the same file as `foo`

7. Hidden Files

- The special `.` and `..` directories don't show up when you do `ls`

- ◆ They are **hidden files**

- Simple rule: files whose names start with `.` are hidden
- Make `ls` display even the hidden files, by giving the `-a` option:

```
$ ls -a
.      ..      .bashrc      .profile
```

- Hidden files are often used for configuration files
- You can still read hidden files – they just don't get listed by `ls` by default

8. Paths to Home Directories

- The symbol `~` is an abbreviation for your home directory

- ◆ So for user 'fred', the following are equivalent:

```
$ cd /home/fred/documents/
$ cd ~/documents/
```

- The `~` is expanded by the shell, so programs only see the expanded path
- You can get the paths to other users' home directories using `~`, for example:

```
$ cat ~alice/notes.txt
```

- The following are all the same for user 'fred':

```
$ cd
$ cd ~
$ cd /home/fred
```

9. Looking for Files in the System

- The command `locate` lists files which contain the text you give
- For example, to find files whose name contains the word 'mkdir':

```
$ locate mkdir
/usr/man/man1/mkdir.1.gz
/usr/man/man2/mkdir.2.gz
/bin/mkdir
...
```

- `locate` is useful for finding files when you don't know exactly what they will be called, or where they are stored
- For many users, graphical tools make it easier to navigate the filesystem
 - ◆ Also make file management simpler

10. Running Programs

- Programs under Linux are files, stored in directories like */bin* and */usr/bin*
- Programs are run from the shell, simply by typing their name
- Many programs take options, which are added after their name and prefixed with `-`, for example:

```
$ ls
Accounts  notes.txt  report.txt
$ ls -l
drwxrwxr-x    2 fred   users      4096 Jan 21 10:57 Accounts
-rw-rw-r--    1 fred   users         345 Jan 21 10:57 notes.txt
-rw-r--r--    1 fred   users      3255 Jan 21 10:57 report.txt
```

- Many programs accept filenames after the options
 - ◆ Specify multiple files by separating them with spaces

11. Specifying Multiple Files

- Most programs can be given a list of files

- ◆ For example, to delete several files at once:

```
$ rm oldnotes.txt tmp.txt stuff.doc
```

- ◆ To make several directories in one go:

```
$ mkdir Accounts Reports
```

- The original use of `cat` was to join multiple files together

- ◆ For example, to list two files, one after another:

```
$ cat notes.txt morenotes.txt
```

- If a filename contains spaces, or characters which are interpreted by the shell (e.g., *, ~), put single quotes around them:

```
$ rm 'Beatles - Strawberry Fields.mp3'  
$ cat '* important notes.txt *'
```

12. Finding Documentation for Programs

- Use the `man` command to read the manual for a program

- The manual for a program is called its **man page**

- ◆ Other things, like file formats and library functions also have man pages

- To read a man page, specify the name of the program to `man`:

```
$ man mkdir
```

- To quit from the man page viewer press `q`

- Man pages for programs usually have the following information:

- ◆ A description of what it does
- ◆ A list of options which it accepts
- ◆ Other information, such as the name of the author

13. Specifying Files with Wildcards

- Use the `*` wildcard to specify multiple filenames to a program:

```
$ ls -l *.txt
-rw-rw-r-- 1 fred users 108 Nov 16 13:06 report.txt
-rw-rw-r-- 1 fred users 345 Jan 18 08:56 notes.txt
```

- The shell expands the wildcard, and passes the full list of files to the program
- Just using `*` on its own will expand to all the files in the current directory:

```
$ rm *
```

- Names with wildcards in are called **globs**, and the process of expanding them is called **globbing**

14. Chaining Programs Together

- The `who` command lists the users currently logged in
- The `wc` command counts bytes, words, and lines in its input
- We combine them to count how many users are logged in:

```
$ who | wc -l
```

- The `|` symbol makes a **pipe** between the two programs
 - ◆ The output of `who` is fed into `wc`
- The `-l` option makes `wc` print only the number of lines
- Another example, to join all the text files together and count the words, lines and characters in the result:

```
$ cat *.txt | wc
```

15. Graphical and Text Interfaces

- Most modern desktop Linux systems provide a **graphical user interface** (GUI)
- Linux systems use the X window system to provide graphics
 - ◆ X is just another program, not built-in to Linux
 - ◆ Usually X is started automatically when the computer boots
- Linux can be used without a GUI, just using a command line
- Use `Ctrl+Alt+F1` to switch to a text console – logging in works as it does in X
 - ◆ Use `Ctrl+Alt+F2`, `Ctrl+Alt+F3`, etc., to switch between virtual terminals – usually about 6 are provided
 - ◆ Use `Ctrl+Alt+F7`, or whatever is after the virtual terminals, to switch back to X

16. Text Editors

- Text editors are for editing plain text files
 - ◆ Don't provide advanced formatting, like word processors
- The most popular editors are Emacs and Vim, both of which are very sophisticated, but take time to learn
- Simpler editors include `nano`, `pico`, `kedit` and `gnotepad`
- Some programs run a text editor for you
 - ◆ They use the `$EDITOR` variable to decide which editor to use
 - ◆ Usually it is set to `vi`, but it can be changed
 - ◆ Another example of the component philosophy

17. Exercise 1

- 1 Use the `pwd` command to find out what directory you are in.
- 2 If you are not in your home directory (*/home/USERNAME*) then use `cd` without any arguments to go there, and do `pwd` again.
- 3 Use `cd` to visit the root directory, and list the files there. You should see *home* among the list.
- 4 Change into the directory called *home* and again list the files present. There should be one directory for each user, including the user you are logged in as (you can use `whoami` to check that).
- 5 Change into your home directory to confirm that you have gotten back to where you started.

18. Exercise 2

- 1 Create a text file in your home directory called *shakespear*, containing the following text:

```
Shall I compare thee to a summer's day?  
Thou art more lovely and more temperate
```
- 2 Rename it to *sonnet-18.txt*.
- 3 Make a new directory in your home directory, called *poetry*.
- 4 Move the poem file into the new directory.
- 5 Try to find a graphical directory-browsing program, and find your home directory with it. You should also be able to use it to explore some of the system directories.
- 6 Find a text editor program and use it to display and edit the sonnet.

19. Exercise 3

- 1 From your home directory, list the files in the directory `/usr/share`.
- 2 Change to that directory, and use `pwd` to check that you are in the right place. List the files in the current directory again, and then list the files in the directory called `docs`.
- 3 Next list the files in the parent directory, and the directory above that.
- 4 Try the following command, and make sure you understand the result: `echo ~`.
- 5 Use `cat` to display the contents of a text file which resides in your home directory (create one if you haven't already), using the `~/` syntax to refer to it. It shouldn't matter what your current directory is when you run the command.

20. Exercise 4

- 1 Use the `hostname` command, with no options, to print the hostname of the machine you are using.
- 2 Use `man` to display some documentation on the `hostname` command. Find out how to make it print the IP address of the machine instead of the hostname. You will need to scroll down the manpage to the 'Options' section.
- 3 Use the `locate` command to find files whose name contains the text 'hostname'. Which of the filenames printed contain the actual `hostname` program itself?

21. Exercise 5

- 1 The `*` wildcard on its own is expanded by the shell to a list of all the files in the current directory. Use the `echo` command to see the result (but make sure you are in a directory with a few files or directories first)
- 2 Use quoting to make `echo` print out an actual `*` symbol.
- 3 If you created a *poetry* directory earlier, augment it with another file, *sonnet-29.txt*:

```
When in disgrace with Fortune and men's eyes,  
I all alone beweep my outcast state,
```

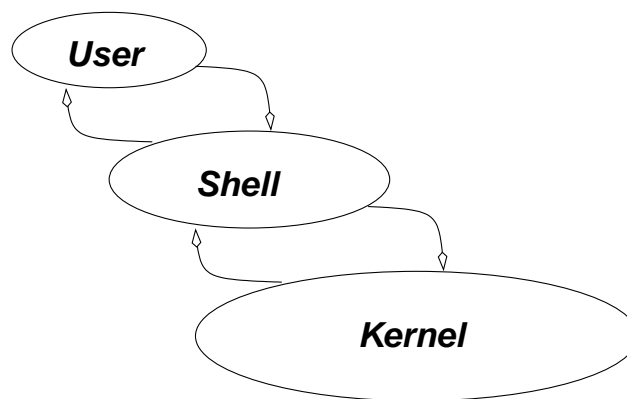
- 4 Use the `cat` command to display both of the poems, using a wildcard.
- 5 Finally, use the `rm` command to delete the *poetry* directory and the poems in it.

Module 3

Work Effectively on the Unix Command Line

1. Shells

- A **shell** provides an interface between the user and the operating system kernel
- Either a **command interpreter** or a graphical user interface
- Traditional Unix shells are **command-line interfaces** (CLIs)
- Usually started automatically when you log in



2. The Bash Shell

- Linux's most popular command interpreter is called `bash`
 - ◆ The **Bourne-Again Shell**
 - ◆ More sophisticated than the original `sh` by Steve Bourne
 - ◆ Can be run as `sh`, as a replacement for the original Unix shell
- Gives you a **prompt** and waits for a **command** to be entered
 - ◆ Traditionally, the prompt ends in `$`
 - ◆ Press Enter to run a command
- Although we concentrate on Bash, the shell `tcsh` is also popular
 - ◆ Based on the design of the older C Shell (`csh`)

3. Navigating the Filesystem

- Use the shell's builtin command `cd` to visit a directory
- The shell's `pwd` built-in command prints the current directory
 - ◆ These **builtins** are part of the shell
- For example:

```
$ pwd
/home/jeff
$ cd email
$ pwd
/home/jeff/email
```

- The commands entered consist of words
 - ◆ Separated by spaces (whitespace)
 - ◆ The first word is the command to run
 - ◆ Subsequent words are options or arguments to the command

4. Command-Line Arguments

- The words after the command name are passed to a command as a list of **arguments**
- Most commands group these words into two categories:
 - ◆ **Options**, usually starting with one or two hyphens
 - ◆ **Filenames**, directories, etc., on which to operate
- The options usually come first, but for most commands they do not need to
- There is a special option '--' which indicates the end of the options
 - ◆ Nothing after the double hyphen is treated as an option, even if it starts with -

5. Syntax of Command-Line Options

- Most Unix commands have a consistent syntax for options:
 - ◆ Single letter options start with a hyphen, e.g., `-B`
 - ◆ Less cryptic options are whole words or phrases, and start with two hyphens, for example `--ignore-backups`
- Some options themselves take arguments
 - ◆ Usually the argument is the next word: `sort -o output_file`
- A few programs use different styles of command-line options
 - ◆ For example, long options (not single letters) sometimes start with a single `-`, rather than `--`

6. Examples of Command-Line Options

- List all the files in the current directory:

```
ls
```
- List the files in the 'long format' (giving more information):

```
ls -l
```
- List full information about some specific files:

```
ls -l notes.txt report.txt
```
- List full information about all the `.txt` files:

```
ls -l *.txt
```
- List all files in long format, even the hidden ones:

```
ls -l -a  
ls -la
```

7. Where Programs are Found

- The location of a program can be specified explicitly:
 - ◆ `./sample` runs the `sample` program in the current directory
 - ◆ `/bin/ls` runs the `ls` command in the `/bin` directory
- Otherwise, the shell looks in standard places for the program
 - ◆ The variable called `$PATH` lists the directories to search in
 - ◆ Directory names are separated by colon, for example:

```
$ echo $PATH
/bin:/usr/bin:/usr/local/bin
```
 - ◆ Running `whoami` will run `/bin/whoami` or `/usr/bin/whoami` or `/usr/local/bin/whoami` (whichever is found first)

8. Setting Shell Variables

- **Shell variables** can be used to store temporary values
- Print out the value of a shell variable with the `echo` command:

```
echo $files
```
- Set a shell variable's value as follows:

```
files="notes.txt report.txt"
```

Note that the `$` *must* be omitted when setting a variable
- Shell variables are private to the shell, but **environment variables** are passed to programs run from the shell
 - ◆ In Bash, use `export` to put a shell variable in the environment:

```
files="notes.txt report.txt"
export files
```
- New values can be built from old ones: `PATH="$PATH:/sbin"`

9. Bash Configuration Variables

- Some variables contain information which Bash itself uses
 - ◆ The variable called `$PS1` (*Prompt String 1*) specifies how to display the shell prompt
- Use the `echo` command with a `$` sign before a variable name to see its value, e.g.

```
$ echo $PS1
[\u@\h \W]\$
```

- The special characters `\u`, `\h` and `\W` represent shell variables containing, respectively, your user/login name, machine's hostname and current working directory, i.e.,
 - ◆ `$USER`, `$HOSTNAME`, `$PWD`

10. Using History

- Previously executed commands can be edited with the `Up` or `Ctrl+P` keys
- This allows old commands to be executed again without re-entering
- Bash stores a **history** of old commands in memory
 - ◆ Use the builtin command `history` to display the lines remembered
 - ◆ History is stored between sessions in the file `~/.bash_history`
- Bash uses the `readline` library to read input from the user
 - ◆ Allows Emacs-like editing of the command line
 - ◆ `Left` and `Right` cursor keys, and `Delete` work as expected

11. Reusing History Items

- Previous commands can be used to build new commands, using **history expansion**

- Use `!!` to refer to the previous command, for example:

```
$ rm index.html
$ echo !!
echo rm index.html
rm index.html
```

- More often useful is `!string`, which inserts the most recent command which started with *string*

- ◆ Useful for repeating particular commands without modification:

```
$ ls *.txt
notes.txt  report.txt
$ !ls
ls *.txt
notes.txt  report.txt
```

12. Retrieving Arguments from the History

- The event designator `!$` refers to the last argument of the previous command:

```
$ ls -l long_file_name.html
-rw-r--r-- 1 jeff  users   11170 Oct 31 10:47 long_file_name.html
$ rm !$
rm long_file_name.html
```

- Similarly, `!^` refers to the first argument

- The pattern `^string^replacement^` replaces the first occurrence of *string* with *replacement* in the previous command, and runs it:

```
$ echo $HOSTNAME

$ ^TS^ST^
echo $HOSTNAME
tiger
```

13. Summary of Bash Editing Keys

- These are the basic editing commands, by default:
 - ◆ `Right` – move cursor to the right
 - ◆ `Left` – move cursor to the left
 - ◆ `Up` – previous history line
 - ◆ `Down` – next history line
 - ◆ `Ctrl+A` – move to start of line
 - ◆ `Ctrl+E` – move to end of line
 - ◆ `Ctrl+D` – delete current character
- There are alternative keys, as for the Emacs editor, which can be more comfortable to use than the cursor keys
- There are other, less often used keys, which are documented in the `bash` man page (section 'Readline')

14. Combining Commands on One Line

- You can write multiple commands on one line by separating them with `;`
- Useful when the first command might take a long time:

```
time-consuming-program; ls
```
- Alternatively, use `&&` to arrange for subsequent commands to run only if earlier ones failed:

```
time-consuming-potentially-failing-program && ls
```

15. Repeating Commands with `for`

- Run multiple commands on one line by separating them with `;`
- The same commands can be repeated using `for`
 - ◆ Syntax: `for varname in list; do commands...; done`
- For example, to rename all `.txt` files to `.txt.old`:

```
$ for file in *.txt;  
> do  
>   mv -v $file $file.old;  
> done  
barbie.txt -> barbie.txt.old  
food.txt -> food.txt.old  
quirks.txt -> quirks.txt.old
```

- The command above could also be written on a single line
- The value of the variable can be expanded by prefixing it with a dollar sign (e.g., `$file`)

16. Command Substitution

- **Command substitution** allows the output of one command to be used as arguments to another
- For example, use the `locate` command to find all files called `manual.html` and print information about them with `ls`:

```
ls -l $(locate manual.html)  
ls -l `locate manual.html`
```

- The punctuation marks on the second form are opening single quote characters, called **backticks**
 - ◆ The `$()` form is usually preferred, but backticks are widely used
- Newlines are stripped from the output before the substitution
- Another example: use `vi` to edit the last of the files found:

```
vi $(locate manual.html | tail -1)
```

17. Finding Files with `locate`

- The `locate` command is a simple and fast way to find files
- For example, to find files relating to the email program `mutt`:

```
locate mutt
```
- The `locate` command searches a database of filenames
 - ◆ The database needs to be updated regularly
 - ◆ Usually this is done automatically with `cron`
 - ◆ But `locate` will not find files created since the last update
- The `-i` option makes the search case-insensitive
- `-r` treats the pattern as a regular expression, rather than a simple string

18. Finding Files More Flexibly: `find`

- `locate` only finds files by name
- `find` can find files by any combination of a wide number of criteria, including name
- Syntax: `find directories criteria`
- Simplest possible example: `find .`
- Finding files with a simple criterion:

```
$ find . -name manual.html
```

Looks for files under the current directory whose name is *manual.html*
- The *criteria* always begin with a single hyphen, even though they have long names

19. `find` Criteria

- `find` accepts many different criteria; two of the most useful are:
 - ◆ `-name pattern`: selects files whose name matches the shell-style wildcard *pattern*
 - ◆ `-type d`, `-type f`: select directories or plain files, respectively
- You can have complex selections involving 'and', 'or', and 'not'

20. `find` Actions: Executing Programs

- `find` lets you specify an action for each file found; the default action is simply to print out the name
 - ◆ You can alternatively write that explicitly as `-print`
- Other actions include executing a program; for example, to delete all files whose name starts with *manual*:

```
find . -name 'manual*' -exec rm '{}' ';'
```
- The command `rm '{}'` is run for each file, with `'{ }'` replaced by the filename
- The `{ }` and `;` are required by `find`, but must be quoted to protect them from the shell

21. Exercise 1

- 1 Use the `df` command to display the amount of used and available space on your hard drive.
- 2 Check the man page for `df`, and use it to find an option to the command which will display the free space in a more human-friendly form. Try both the single-letter and long-style options.
- 3 Run the shell, `bash`, and see what happens. Remember that you were already running it to start with. Try leaving the shell you have started with the `exit` or `logout` commands.

22. Exercise 2

- 1 Try `ls` with the `-a` and `-A` options. What is the difference between them?
- 2 Write a `for` loop which goes through all the files in a directory and prints out their names with `echo`. If you write the whole thing on one line, then it will be easy to repeat it using the command line history.
- 3 Change the loop so that it goes through the names of the people in the room (which needn't be the names of files) and print greetings to them.
- 4 Of course, a simpler way to print a list of filenames is `echo *`. Why might this be useful, when we usually use the `ls` command?

23. Exercise 3

- 1 Use the `find` command to list all the files and directories under your home directory. Try the `-type d` and `-type f` criteria to show just files and just directories.
- 2 Use `locate` to find files whose name contains the string 'bashbug'. Try the same search with `find`, looking over all files on the system. You'll need to use the `*` wildcard at the end of the pattern to match files with extensions.
- 3 Find out what `find`'s `-iname` criterion does.

Module 4

Process Text Streams Using Text Processing Filters

1. Working with Text Files

- Unix-like systems are designed to manipulate text very well
- The same techniques can be used with plain text, or text-based formats
 - ◆ Most Unix configuration files are plain text
- Text is usually in the **ASCII** character set
 - ◆ Non-English text might use the ISO-8859 character sets
 - ◆ Unicode is better, but unfortunately many Linux command-line utilities don't (directly) support it yet

2. Lines of Text

- Text files are naturally divided into lines
- In Linux, a line ends in a **line feed** character
 - ◆ Character number 10, hexadecimal 0x0A
- Other operating systems use different combinations
 - ◆ Windows and DOS use a carriage return followed by a line feed
 - ◆ Macintosh systems use only a carriage return
 - ◆ Programs are available to convert between the various formats

3. Filtering Text and Piping

- The Unix philosophy: use small programs, and link them together as needed
- Each tool should be good at one specific job
- Join programs together with **pipes**
 - ◆ Indicated with the pipe character: |
 - ◆ The first program prints text to its **standard output**
 - ◆ That gets fed into the second program's **standard input**
- For example, to connect the output of `echo` to the input of `wc`:

```
$ echo "count these words, boy" | wc
```

4. Displaying Files with `less`

- If a file is too long to fit in the terminal, display it with `less`:

```
$ less README
```
- `less` also makes it easy to clear the terminal of other things, so is useful even for small files
- Often used on the end of a pipe line, especially when it is not known how long the output will be:

```
$ wc *.txt | less
```
- Doesn't choke on strange characters, so it won't mess up your terminal (unlike `cat`)

5. Concatenating Files with `cat`

- The `cat` filter concatenates the contents of all the files named on its command line
- More commonly used with just one file to quickly send its contents to the screen:

```
$ cat /etc/resolv.conf
domain gbdirect.co.uk
nameserver 127.0.0.1
nameserver 192.168.100.12
```

6. Counting Words and Lines with `wc`

- Count characters, words and lines in a file
- If used with multiple files, outputs counts for each file, and a combined total
- Options:
 - ◆ `-c` output character count
 - ◆ `-l` output line count
 - ◆ `-w` output word count
 - ◆ Default is `-clw`

- Examples: display word count for *essay.txt*:

```
$ wc -w essay.txt
```

- Display the total number of lines in several text files:

```
$ wc -l *.txt
```

7. Sorting Lines of Text with `sort`

- The `sort` filter reads lines of text and prints them sorted into order
- For example, to sort a list of words into dictionary order:

```
$ sort words > sorted-words
```
- The `-f` option makes the sorting **case-insensitive**
- The `-n` option sorts numerically, rather than lexicographically

8. Removing Duplicate Lines with `uniq`

- Use `uniq` to find unique lines in a file
 - ◆ Removes *consecutive* duplicate lines
 - ◆ Usually give it sorted input, to remove all duplicates
- Example: find out how many unique words are in a dictionary:

```
$ sort /usr/dict/words | uniq | wc -w
```
- `sort` has a `-u` option to do this, without using a separate program:

```
$ sort -u /usr/dict/words | wc -w
```
- `sort | uniq` can do more than `sort -u`, though:
 - ◆ `uniq -c` counts how many times each line appeared
 - ◆ `uniq -u` prints only unique lines
 - ◆ `uniq -d` prints only duplicated lines

9. Selecting Parts of Lines with `cut`

- Used to select columns or fields from each line of input
- Select a range of
 - ◆ Characters, with `-c`
 - ◆ Fields, with `-f`
- Field separator specified with `-d` (defaults to tab)
- A range is written as start and end position: e.g., 3-5
 - ◆ Either can be missed out
 - ◆ The first byte, character or field is numbered 1, not 0
- Example: select usernames of logged in users:

```
$ who | cut -d"_" -f1 | sort -u
```

10. Expanding Tabs to Spaces with `expand`

- Used to replace tabs with spaces in files
- Tab size (maximum number of spaces for each tab) can be set with `-t number`
 - ◆ Default tab size is 8
- To only change tabs at the beginning of lines, use `-i`
- Example: change all tabs in `foo.txt` to three spaces, display it to the screen (both of these are the same):

```
$ expand -t 3 foo.txt
$ expand -3 foo.txt
```

11. Using `fmt` to Format Text Files

- Arranges words nicely into lines of consistent length
- Use `-u` to convert to uniform spacing
 - ◆ One space between words, two between sentences
- Use `-w width` to set the maximum line width in characters
 - ◆ Defaults to 75
- Example: change the line length of *notes.txt* to a maximum of 70 characters, and display it on the screen:

```
$ fmt -w 70 notes.txt | less
```

12. Reading the Start of a File with `head`

- Prints the top of its input, and discards the rest
- Set the number of lines to print with `-n lines` or `-lines`
 - ◆ Defaults to ten lines
- View the headers of a HTML document called *homepage.html*:

```
$ head homepage.html
```

- Print the first line of a text file (two alternatives):

```
$ head -n 1 notes.txt  
$ head -1 notes.txt
```

13. Reading the End of a File with `tail`

- Similar to `head`, but prints lines at the end of a file
- The `-f` option watches the file forever
 - ◆ Continually updates the display as new entries are appended to the end of the file
 - ◆ Kill it with `Ctrl+C`
- The option `-n` is the same as in `head` (number of lines to print)
- Example: monitor HTTP requests on a webserver:

```
$ tail -f /var/log/httpd/access_log
```

14. Numbering Lines of a File with `nl`

- Add a line number to each line of the input
- There are options to finely control the formatting
- By default, blank lines aren't numbered
 - ◆ The option `-ba` numbers every line
 - ◆ `cat -n` also numbers lines, including blank ones

15. Dumping Bytes of Binary Data with `od`

- Prints the numeric values of the bytes in a file
- Useful for studying files with non-text characters
- By default, prints two byte words in octal
- Specify an alternative with the `-t` option
 - ◆ Give a letter to indicate base: `o` for octal, `x` for hexadecimal, `u` for unsigned decimal, etc.
 - ◆ Can be followed by the number of bytes per word
 - ◆ Add `z` to show ASCII equivalents alongside the numbers
 - ◆ A useful format is given by `od -t x1z` – hexadecimal, one byte words, with ASCII
- Alternatives to `od` include `xxd` and `hexdump`

16. Paginating Text Files with `pr`

- Convert a text file into paginated text, with headers and page fills
- Rarely useful for modern printers
- Options:
 - ◆ `-d` double spaced output
 - ◆ `-h header` change from the default header to *header*
 - ◆ `-l lines` change the default lines on a page from 66 to *lines*
 - ◆ `-o width` set ('offset') the left margin to *width*
- Example:

```
$ pr -h "My Thesis" thesis.txt | lpr
```

17. Dividing Files into Chunks with `split`

- Splits files into equal sized segments
- Syntax: `split [options] [input] [output-prefix]`
- Use `-l n` to split a file into *n*-line chunks
- Use `-b n` to split into chunks of *n* bytes each
- Output files are named using the specified output name with *aa*, *ab*, *ac*, etc., added to the end of the prefix
- Example: Split *essay.txt* into 30 line files, and save the output to files *short_aa*, *short_ab*, etc:

```
$ split -l 30 essay.txt short_
```

18. Using `split` to Span Disks

- If a file is too big to fit on a single floppy, Zip or CD-ROM disk, it can be split into small enough chunks
- Use the `-b` option, and with the *k* and *m* suffixes to give the chunk size in kilobytes or megabytes
- For example, to split the file *database.tar.gz* into pieces small enough to fit on Zip disks:

```
$ split -b 90m database.tar.gz zip-
```

- Use `cat` to put the pieces back together:

```
$ cat zip-* > database.tar.gz
```

19. `tac`: Backwards `cat`

- Similar to `cat`, but in reverse
- Prints the last line of the input first, the penultimate line second, and so on
- Example: show a list of logins and logouts, but with the most recent events at the end:

```
$ last | tac
```

20. Translating Sets of Characters with `tr`

- Translate one set of characters to another
- Usage: `tr [options] start-set end-set`
- Replaces all characters in *start-set* with the corresponding characters in *end-set*
- Cannot accept a file as an argument, but uses the standard input and output
- Options:
 - ◆ `-d` deletes characters in *start-set* instead of translating them
 - ◆ `-s` replaces sequences of identical characters with just one (squeezes them)

21. tr Examples

- Replace all uppercase characters in *input-file* with lowercase characters (two alternatives):

```
$ cat input-file | tr A-Z a-z
$ tr A-Z a-z < input-file
```

- Delete all occurrences of *z* in *story.txt*:

```
$ cat story.txt | tr -d z
```

- Run together each sequence of repeated *f* characters in *lullaby.txt* to with just one *f*:

```
$ tr -s f < lullaby.txt
```

22. sed – the Stream Editor

- sed uses a simple script to process each line of a file
- Specify the script file with *-f filename*
- Or give individual commands with *-e command*
- For example, if you have a script called *spelling.sed* which corrects your most common mistakes, you can feed a file through it:

```
$ sed -f spelling.sed < report.txt > corrected.txt
```

23. Substituting with `sed`

- Use the `s/pattern/replacement/` command to substitute text matching the *pattern* with the *replacement*
 - ◆ Add the `/g` modifier to replace every occurrence on each line, rather than just the first one
- For example, replace 'thru' with 'through':

```
$ sed -e 's/thru/through/g' input-file > output-file
```
- `sed` has more complicated facilities which allow commands to be executed conditionally
 - ◆ Can be used as a very basic (but unpleasantly difficult!) programming language

24. Put Files Side-by-Side with `paste`

- `paste` takes lines from two or more files and puts them in columns of the output
- Use `-d char` to set the delimiter between fields in the output
 - ◆ The default is tab
 - ◆ Giving `-d` more than one character sets different delimiters between each pair of columns
- Example: assign passwords to users, separating them with a colon:

```
$ paste -d: usernames passwords > .htpasswd
```

25. Performing Database Joins with `join`

- Does a database-style 'inner join' on two tables, stored in text files
- The `-t` option sets the field delimiter
 - ◆ By default, fields are separated by any number of spaces or tabs
- Example: show details of suppliers and their products:

```
$ join suppliers.txt products.txt | less
```
- The input files must be sorted!
- This command is rarely used – databases have this facility built in

26. Exercise 1

- 1 Type in the example on the `cut` slide to display a list of users logged in. (Try just `who` on its own first to see what is happening.)
- 2 Arrange for the list of usernames in `who`'s output to be sorted, and remove any duplicates.
- 3 Try the command `last` to display a record of login sessions, and then try reversing it with `tac`. Which is more useful? What if you pipe the output into `less`?
- 4 Use `sed` to correct the misspelling 'enviroment' to 'environment'. Use it on a test file, containing a few lines of text, to check it. Does it work if the misspelling occurs more than once on the same line?
- 5 Use `nl` to number the lines in the output of the previous question.

27. Exercise 2

- 1 Try making an empty file and using `tail -f` to monitor it. Then add lines to it from a different terminal, using a command like this:

```
$ echo "testing" >>filename
```

- 2 Once you have written some lines into your file, use `tr` to display it with all occurrences of the letters A–F changed to the numbers 0–5.
- 3 Try looking at the binary for the `ls` command (`/bin/ls`) with `less`. You can use the `-f` option to force it to display the file, even though it isn't text.
- 4 Try viewing the same binary with `od`. Try it in its default mode, as well as with the options shown on the slide for outputting in hexadecimal.

28. Exercise 3

- 1 Use the `split` command to split the binary of the `ls` command into 1Kb chunks. You might want to create a directory especially for the split files, so that it can all be easily deleted later.
- 2 Put your split `ls` command back together again, and run it to make sure it still works. You will have to make sure you are running the new copy of it, for example `./my_ls`, and make sure that the program is marked as 'executable' to run it, with the following command:

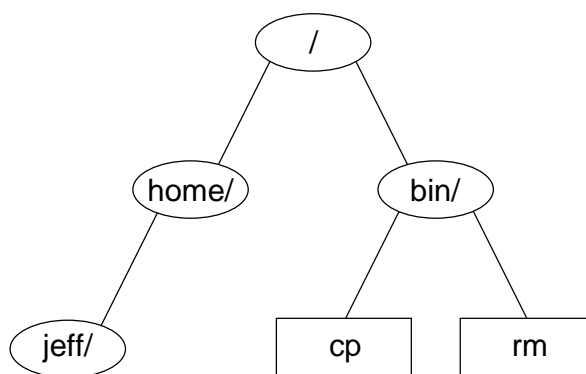
```
$ chmod a+rx my_ls
```

Module 5

Perform Basic File Management

1. Filesystem Objects

- A **file** is a place to store data: a possibly-empty sequence of bytes
- A **directory** is a collection of files and other directories
- Directories are organized in a hierarchy, with the **root directory** at the top
 - ◆ The root directory is referred to as `/`



2. Directory and File Names

- Files and directories are organized into a **filesystem**
- Refer to files in directories and sub-directories by separating their names with `/`, for example:

`/bin/ls`
`/usr/dict/words`
`/home/jeff/recipe`
- Paths to files either start at `/` (absolute) or from some 'current' directory

3. File Extensions

- It's common to put an **extension**, beginning with a dot, on the end of a filename

- The extension indicates the type of the file:

<code>.txt</code>	Text file
<code>.gif</code>	Graphics Interchange Format image
<code>.jpg</code>	Joint Photographic Experts Group image
<code>.mp3</code>	MPEG-2 Layer 3 audio
<code>.gz</code>	Compressed file
<code>.tar</code>	Unix 'tape archive' file
<code>.tar.gz</code> , <code>.tgz</code>	Compressed archive file

- On Unix and Linux, file extensions are entirely a matter of convention – the operating system itself ignores them
 - ◆ Only a few specific programs use extensions to guess what type a file is

4. Visiting Directories with `cd`

- Use `cd` to change the **current working directory**
 - ◆ If no argument is given, it changes to your home directory

- Use `pwd` to find out what the current directory is

- For example:

```
$ cd /usr/src
$ pwd
/usr/src
```

- To switch back to the previous directory: `cd -`

5. Going Back to Previous Directories

- The `pushd` command takes you to another directory, like `cd`
 - ◆ But also saves the current directory, so that you can go back later
- For example, to visit Fred's home directory, and then go back to where you started from:

```
$ pushd ~fred
$ cd Work
$ ls
...
$ popd
```

- `popd` takes you back to the directory where you last did `pushd`
- `dirs` will list the directories you can pop back to

6. Filename Completion

- Modern shells help you type the names of files and directories by completing partial names
- Type the start of the name (enough to make it unambiguous) and press `Tab`
- For an ambiguous name (there are several possible completions), the shell can list the options:
 - ◆ For Bash, type `Tab` twice in succession
 - ◆ For C shells, type `Ctrl+D`
- Both of these shells will automatically escape spaces and special characters in the filenames

7. Wildcard Patterns

- Give commands multiple files by specifying patterns

- Use the symbol `*` to match any part of a filename:

```
$ ls *.txt
accounts.txt  letter.txt  report.txt
```

- Just `*` produces the names of all files in the current directory

- The wildcard `?` matches exactly one character:

```
$ rm -v data.?
removing data.1
removing data.2
removing data.3
```

- Note: wildcards are turned into filenames by the shell, so the program you pass them to can't tell that those names came from wildcard expansion

8. Copying Files with `cp`

- Syntax: `cp [options] source-file destination-file`

- Copy multiple files into a directory: `cp files directory`

- Common options:

- ◆ `-f`, force overwriting of destination files
- ◆ `-i`, interactively prompt before overwriting files
- ◆ `-a`, archive, copy the contents of directories recursively

9. Examples of `cp`

- Copy */etc/smb.conf* to the current directory:

```
$ cp /etc/smb.conf .
```

- Create an identical copy of a directory called *work*, and call it *work-backup*:

```
$ cp -a work work-backup
```

- Copy all the GIF and JPEG images in the current directory into *images*:

```
$ cp *.gif *.jpeg images/
```

10. Moving Files with `mv`

- `mv` can rename files or directories, or move them to different directories

- It is equivalent to copying and then deleting

- ◆ But is usually much faster

- Options:

- ◆ `-f`, force overwrite, even if target already exists

- ◆ `-i`, ask user interactively before overwriting files

- For example, to rename *poetry.txt* to *poems.txt*:

```
$ mv poetry.txt poems.txt
```

- To move everything in the current directory somewhere else:

```
$ mv * ~/old-stuff/
```

11. Deleting Files with `rm`

- `rm` deletes ('removes') the specified files
- You must have write permission for the directory the file is in to remove it
- Use carefully if you are logged in as root!
- Options:
 - ◆ `-f`, delete write-protected files without prompting
 - ◆ `-i`, interactive – ask the user before deleting files
 - ◆ `-r`, recursively delete files and directories
- For example, clean out everything in `/tmp`, without prompting to delete each file:

```
$ rm -rf /tmp/*
```

12. Deleting Files with Peculiar Names

- Some files have names which make them hard to delete
- Files that begin with a minus sign:

```
$ rm ./-filename
$ rm -- -filename
```
- Files that contain peculiar characters – perhaps characters that you can't actually type on your keyboard:
 - ◆ Write a wildcard pattern that matches *only* the name you want to delete:

```
$ rm -i ./name-with-funny-characters*
```
 - ◆ The `./` forces it to be in the current directory
 - ◆ Using the `-i` option to `rm` makes sure that you won't delete anything else by accident

13. Making Directories with `mkdir`

- Syntax: `mkdir directory-names`
- Options:
 - ◆ `-p`, create intervening parent directories if they don't already exist
 - ◆ `-m mode`, set the access permissions to *mode*
- For example, create a directory called *mystuff* in your home directory with permissions so that only you can write, but everyone can read it:

```
$ mkdir -m 755 ~/mystuff
```
- Create a directory tree in */tmp* using one command with three subdirectories called *one*, *two* and *three*:

```
$ mkdir -p /tmp/one/two/three
```

14. Removing Directories with `rmdir`

- `rmdir` deletes empty directories, so the files inside must be deleted first
- For example, to delete the *images* directory:

```
$ rm images/*  
$ rmdir images
```
- For non-empty directories, use `rm -r directory`
- The `-p` option to `rmdir` removes the complete path, if there are no other files and directories in it
 - ◆ These commands are equivalent:

```
$ rmdir -p a/b/c  
$ rmdir a/b/c a/b a
```

15. Identifying Types of Files

- The data in files comes in various different formats (executable programs, text files, etc.)
- The `file` command will try to identify the type of a file:

```
$ file /bin/bash
/bin/bash: ELF 32-bit LSB executable, Intel 80386, version 1,
dynamically linked (uses shared libs), stripped
```

- It also provides extra information about some types of file
- Useful to find out whether a program is actually a script:

```
$ file /usr/bin/zless
/usr/bin/zless: Bourne shell script text
```

- If `file` doesn't know about a specific format, it will guess:

```
$ file /etc/passwd
/etc/passwd: ASCII text
```

16. Changing Timestamps with `touch`

- Changes the **access** and **modification** times of files
- Creates files that didn't already exist
- Options:
 - ◆ `-a`, change only the access time
 - ◆ `-m`, change only the modification time
 - ◆ `-t [YYYY]MMDDhhmm[.ss]`, set the timestamp of the file to the specified date and time
 - ◆ GNU `touch` has a `-d` option, which accepts times in a more flexible format
- For example, change the time stamp on *homework* to January 20 2001, 5:59p.m.

```
$ touch -t 200101201759 homework
```

17. Exercise 1

- 1 Just after you've logged in or opened a terminal window, what directory is your current directory? (The `pwd` command might be useful here.)
- 2 Change directory to `/etc` and then `/tmp`. Each time use `pwd` to check that you got to the right place, and `ls` to see what files are there.
- 3 From `/tmp`, use `cd ..` and see where you end up. Then try it again from your working directory.
- 4 Find out what files are in `/bin`, without changing your current directory. You should recognise the names of some of the programs stored there.
- 5 List the files in `/usr/bin` and `/usr/local/bin` (if it exists). Use the `Tab` key to save typing.

18. Exercise 2

- 1 Use `cd` to go to your home directory, and create a new directory there called `dog`.
- 2 Create another directory within that one called `cat`, and another within that called `mouse`.
- 3 Remove all three directories. You can either remove them one at a time, or all at once.
- 4 If you can delete directories with `rm -r`, what is the point of using `rmdir` for empty directories?
- 5 Try creating the `dog/cat/mouse` directory structure with a single command.

19. Exercise 3

- 1 Copy the file `/etc/passwd` to your home directory, and then use `cat` to see what's in it.
- 2 Rename it to `users` using the `mv` command.
- 3 Make a directory called `programs` and copy everything from `/bin` into it.
- 4 Delete all the files in the `programs` directory.
- 5 Delete the empty `programs` directory and the `users` file.

20. Exercise 4

- 1 The `touch` command can be used to create new empty files. Try that now, picking a name for the new file:

```
$ touch baked-beans
```
- 2 Get details about the file using the `ls` command:

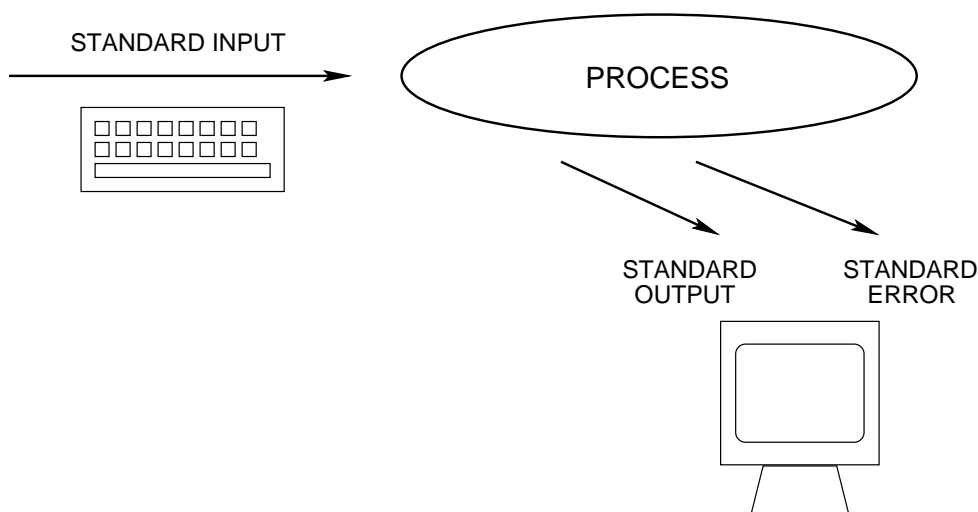
```
$ ls -l baked-beans
```
- 3 Wait for a minute, and then try the previous two steps again, and see what changes. What happens when we don't specify a time to `touch`?
- 4 Try setting the timestamp on the file to a value in the future.
- 5 When you're finished with it, delete the file.

Module 6

Use Unix Streams, Pipes and Redirects

1. Standard Files

- Processes are connected to three standard files



- Many programs open other files as well

2. Standard Input

- Programs can read data from their **standard input** file
- Abbreviated to **stdin**
- By default, this reads from the keyboard
- Characters typed into an interactive program (e.g., a text editor) go to stdin

3. Standard Output

- Programs can write data to their **standard output** file
- Abbreviated to **stdout**
- Used for a program's normal output
- By default this is printed on the terminal

4. Standard Error

- Programs can write data to their **standard error** output
- Standard error is similar to standard output, but used for error and warning messages
- Abbreviated to **stderr**
- Useful to separate program output from any program errors
- By default this is written to your terminal
 - ◆ So it gets 'mixed in' with the standard output

5. Pipes

- A **pipe** channels the output of one program to the input of another
 - ◆ Allows programs to be chained together
 - ◆ Programs in the chain run concurrently
- Use the vertical bar: |
 - ◆ Sometimes known as the 'pipe' character
- Programs don't need to do anything special to use pipes
 - ◆ They read from stdin and write to stdout as normal
- For example, pipe the output of `echo` into the program `rev` (which reverses each line of its input):

```
$ echo Happy Birthday! | rev
!yadhtriB yppaH
```

6. Connecting Programs to Files

- **Redirection** connects a program to a named file
- The `<` symbol indicates the file to read input from:
 - ◆ The file specified becomes the program's standard input
- The `>` symbol indicates the file to write output to:
 - ◆ The program's standard output goes into the file
 - ◆ If the file already exists, it is overwritten
- Both can be used at the same time:

```
$ filter < input-file > output-file
```

7. Appending to Files

- Use >> to append to a file:

```
$ date >> log.txt
```

- ◆ Appends the standard output of the program to the end of an existing file
- ◆ If the file doesn't already exist, it is created

8. Redirecting Multiple Files

- Open files have numbers, called **file descriptors**
- These can be used with redirection
- The three standard files always have the same numbers:

Name	Descriptor
Standard input	0
Standard output	1
Standard error	2

9. Redirection with File Descriptors

- Redirection normally works with stdin and stdout
- Specify different files by putting the file descriptor number before the redirection symbol:
 - ◆ To redirect the standard error to a file:

```
$ program 2> file
```
 - ◆ To combine standard error with standard output:

```
$ program > file 2>&1
```
 - ◆ To save both output streams:

```
$ program > stdout.txt 2> stderr.txt
```
- The descriptors 3–9 can be connected to normal files, and are mainly used in shell scripts

10. Running Programs with `xargs`

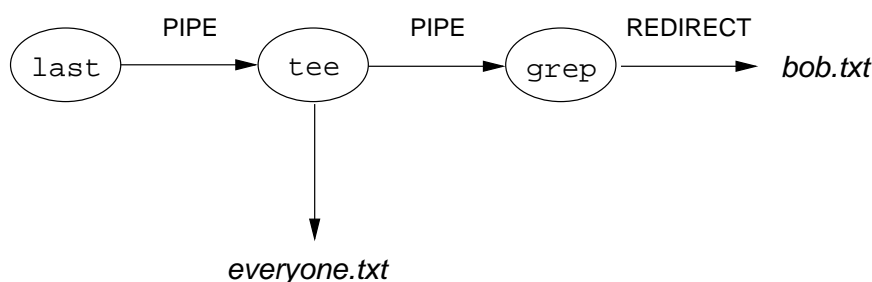
- `xargs` reads pieces of text and runs another program with them as its arguments
 - ◆ Usually its input is a list of filenames to give to a file processing program
- Syntax: `xargs command [initial args]`
- Use `-l n` to use *n* items each time the command is run
 - ◆ The default is 1
- `xargs` is very often used with input piped from `find`
- Example: if there are too many files in a directory to delete in one go, use `xargs` to delete them ten at a time:

```
$ find /tmp/rubbish/ | xargs -l10 rm -f
```

11. tee

- The `tee` program makes a 'T-junction' in a pipeline
- It copies data from `stdin` to `stdout`, and also to a file
- Like `>` and `|` combined
- For example, to save details of everyone's logins, and save Bob's logins in a separate file:

```
$ last | tee everyone.txt | grep bob > bob.txt
```



12. Exercise 1

- 1 Try the example on the 'Pipes' slide, using `rev` to reverse some text.
- 2 Try replacing the `echo` command with some other commands which produce output (e.g., `whoami`).
- 3 What happens when you replace `rev` with `cat`? You might like to try running `cat` with no arguments and entering some text.

13. Exercise 2

- 1 Run the command `ls --color` in a directory with a few files and directories. Some Linux distributions have `ls` set up to always use the `--color` option in normal circumstances, but in this case we will give it explicitly.
- 2 Try running the same command, but pipe the output into another program (e.g., `cat` or `less`). You should spot two differences in the output. `ls` detects whether its output is going straight to a terminal (to be viewed by a human directly) or into a pipe (to be read by another program).

Module 7

Search Text Files Using Regular Expressions

1. Searching Files with grep

- `grep` prints lines from files which match a pattern
- For example, to find the entries in the password file `/etc/passwd` relating to the user 'nancy':

```
$ grep nancy /etc/passwd
```

- `grep` has a few useful options:
 - ◆ `-i` makes the matching case-insensitive
 - ◆ `-r` searches through files in specified directories, recursively
 - ◆ `-l` prints just the names of files which contain matching lines
 - ◆ `-c` prints the count of matches in each file
 - ◆ `-n` numbers the matching lines in the output
 - ◆ `-v` reverses the test, printing lines which don't match

2. Pattern Matching

- Use `grep` to find patterns, as well as simple strings
- Patterns are expressed as **regular expressions**
- Certain punctuation characters have special meanings
- For example this might be a better way to search for Nancy's entry in the password file:

```
$ grep '^nancy' /etc/passwd
```

- ◆ The caret (^) anchors the pattern to the start of the line
- In the same way, `$` acts as an **anchor** when it appears at the end of a string, making the pattern match only at the end of a line

3. Matching Repeated Patterns

- Some regexp special characters are also special to the shell, and so need to be protected with quotes or backslashes
- We can match a repeating pattern by adding a modifier:

```
$ grep -i 'continued\.*'
```
- Dot (.) on its own would match any character, so to match an actual dot we escape it with \
- The * modifier matches the preceding character zero or more times
- Similarly, the + modifier matches one or more times

4. Matching Alternative Patterns

- Multiple subpatterns can be provided as alternatives, separated with |, for example:

```
$ grep 'fish\|chips\|pies' food.txt
```
- The previous command finds lines which match at least one of the words
- Use \(...\) to enforce precedence:

```
$ grep -i '\(cream\|fish\|birthday\) cakes' delicacies.txt
```
- Use square brackets to build a **character class**:

```
$ grep '[Jj]oe [Bb]loggs' staff.txt
```
- Any single character from the class matches; and ranges of characters can be expressed as 'a-z'

5. Extended Regular Expression Syntax

- `egrep` runs `grep` in a different mode
 - ◆ Same as `grep -E`
- Special characters don't have to be marked with `\`
 - ◆ So `\+` is written `+`, `\(...\)` is written `(...)`, etc
 - ◆ In extended regexps, `\+` is a literal `+`

6. `sed`

- `sed` reads input lines, runs editing-style commands on them, and writes them to stdout
- `sed` uses regular expressions as patterns in substitutions
 - ◆ `sed` regular expressions use the same syntax as `grep`
- For example, to use `sed` to put `#` at the start of each line:

```
$ sed -e 's/^/#/' < input.txt > output.txt
```
- `sed` has simple substitution and translation facilities, but can also be used like a programming language

7. Further Reading

- *Sed and Awk*, 2nd edition, by Dale Dougherty and Arnold Robbins, 1997
- The Sed FAQ,
<http://www.dbnet.ece.ntua.gr/~george/sed/sedfaq.html>
- The original user manual (1978),
<http://www.urc.bl.ac.yu/manuals/progunix/sed.txt>

8. Exercise 1

- 1 Use `grep` to find information about the HTTP protocol in the file `/etc/services`.
- 2 Usually this file contains some comments, starting with the `#` symbol. Use `grep` with the `-v` option to ignore lines starting with `#` and look at the rest of the file in `less`.
- 3 Add another use of `grep -v` to your pipeline to remove blank lines (which match the pattern `^$`).
- 4 Use `sed` (also in the same pipeline) to remove the information after the `/` symbol on each line, leaving just the names of the protocols and their port numbers.