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Introduction to Linux

Christopher Werner
Fionnuala Solomon

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What you will learn

- Introduction of Linux and the command line
- Navigating through files and directories
- Working with files and directories
- Useful tools
- Loops
- Bash scripting
- SSH keys

You can also follow along at https://ichec-learn.github.io/intro-to-linux/

Introduction to UNIX

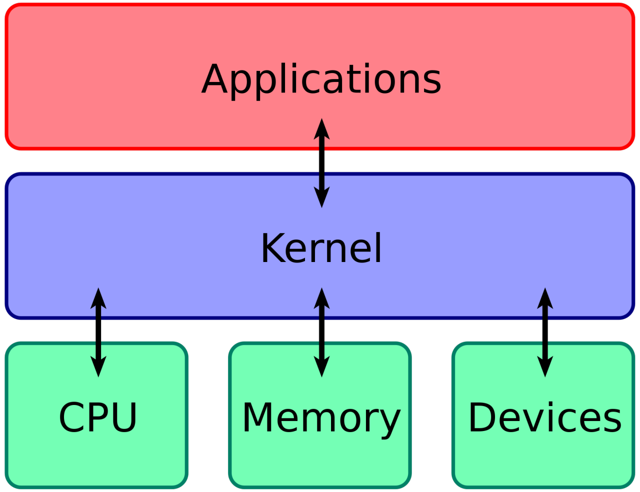
- Operating system
- Why UNIX?
    - Supercomputer operating system (100% of TOP500)
    - Reliable, more secure
    - Open source
    - Massive toolset for programming
    - Flexible
    - It's everywhere!
- UNIX systems also have GUIs
- Most popular varieties of UNIX are GNU/Linux, MacOS X

Starting a terminal

- Start up a terminal 💻
  - Mac users can use Terminal app
  - Windows use Git Bash or MobaXterm
  - NB: MobaXterm
    1. In Settings Tab → Terminal → Terminal features
       - Ensure "Paste using right click" is unticked
    2. In Settings Tab → General → Persistent home directory
       - Enter _ProfileDir_ into the box. Otherwise you may not be able to log into Kay for HPC course

Shell & Kernel

- **Shell** → Computer program that takes commands and gives them to OS to perform. It is the main interface between user and the Kernel
- **Kernel** → Computer program at the heart of the computer operating system
- Process for executing a command
  - Shell searches for program
  - Requests kernel to execute program
  - When process finishes, shell returns to prompt, waiting for further commands



Command line

“Prompt”

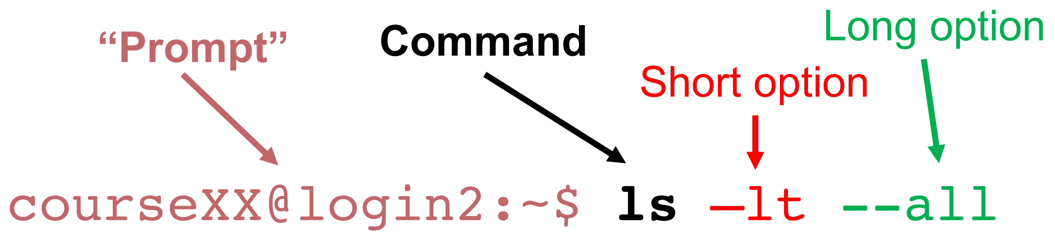
```
courseXX@login2:~$ █
```

Command line

“Prompt” Command

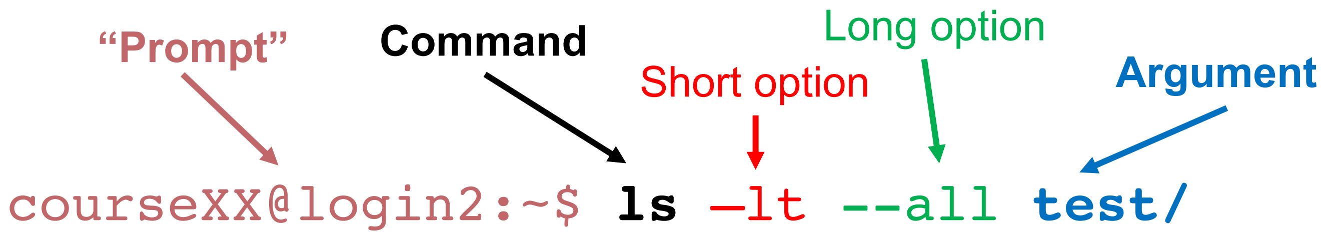
```
courseXX@login2:~$ ls
```

Command line



```
courseXX@login2:~$ ls –lt --all
```

Command line



```
courseXX@login2:~$ ls –lt --all test/
```

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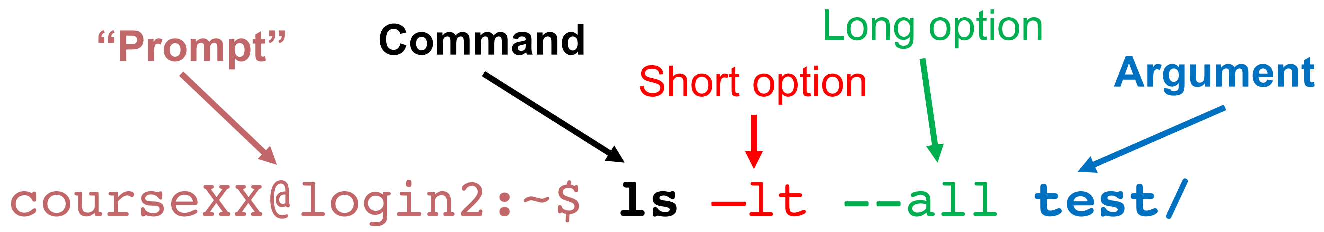
Command line

- Most command line programs need information on what they need to work on. These are command line arguments.
- Options come after a command, denoted with hyphen (-). These change the behaviour of the command
- They can be short (single letter) and grouped together or long form (full word)



```
courseXX@login2:~$ ls –lt --all test/
```

Command line

- Order matters! Which one(s) are correct? 💻

```
1.  la -s
2.  ls --a
3.  ls -
4.  ls -z
5.  -l ls
6.  ls -all --l prog/
7.  ls --all -l prog/
8.  ls -l all
9.  prog/ ls
10. ls -l --all prog/
11. ls -l--all prog/
```

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Command line: Errors & editing

- You will make mistakes, and the command line will tell you

```
cd: dir1: No such file or directory
```

- If you see a mistake at the beginning of a long command, don't worry you don't have to type it all out again.

Move to:	
left	`left-arrow`
right	`right-arrow`
Beginning of line	`ctrl-a`
End of line	`ctrl-e`
Previous command	`up-arrow`
Next command	`down-arrow`

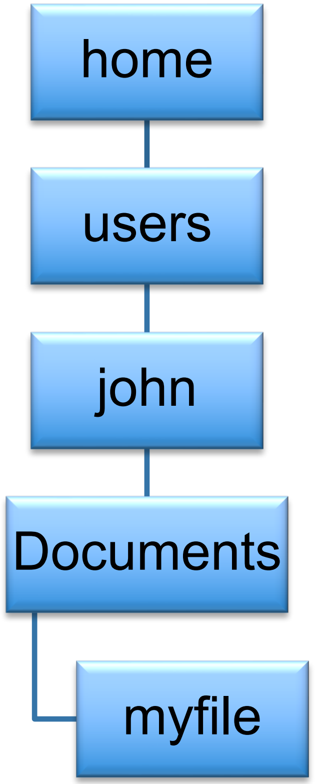
Delete:	
Previous character	`Backspace`
Previous word	`ctrl-w`
Next character	`ctrl-d`
Rest of line	`ctrl-k`

- Computers are not humans, so if a command is not **precisely** correct it will complain!

Navigating through files and directories

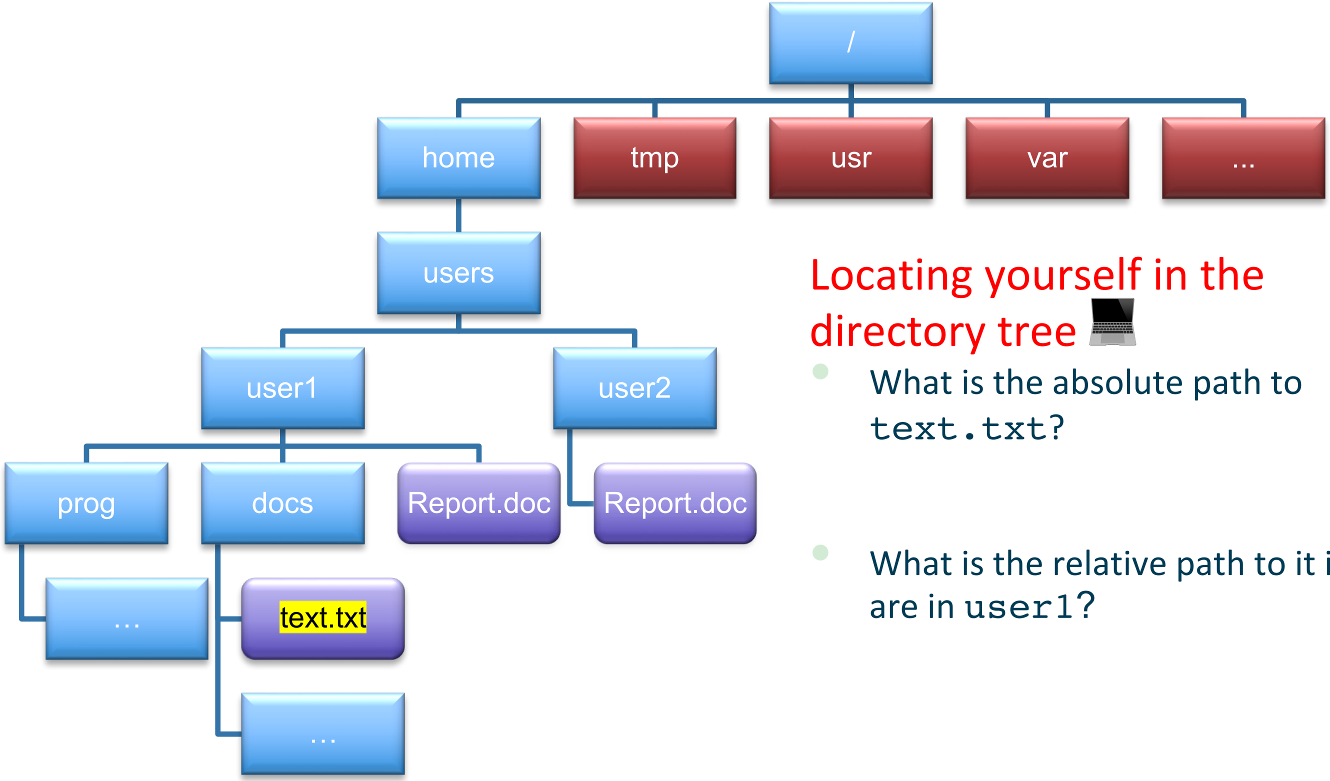
- What is the directory tree and what is a path?
- How do I move around?
- How can I see my files and directories (folders)
- How do I use ‘flags’?

The directory tree



- In Unix, everything is a file or a process, even directories
- / has 2 meanings, root or a separator between directories
- Every file has a unique id formed from the file name and list of directories
- So even files with the same name have unique identifier in the file system

The directory tree



Locating yourself in the directory tree 💻

- What is the absolute path to `text.txt`?

- What is the relative path to it if you are in `user1`?

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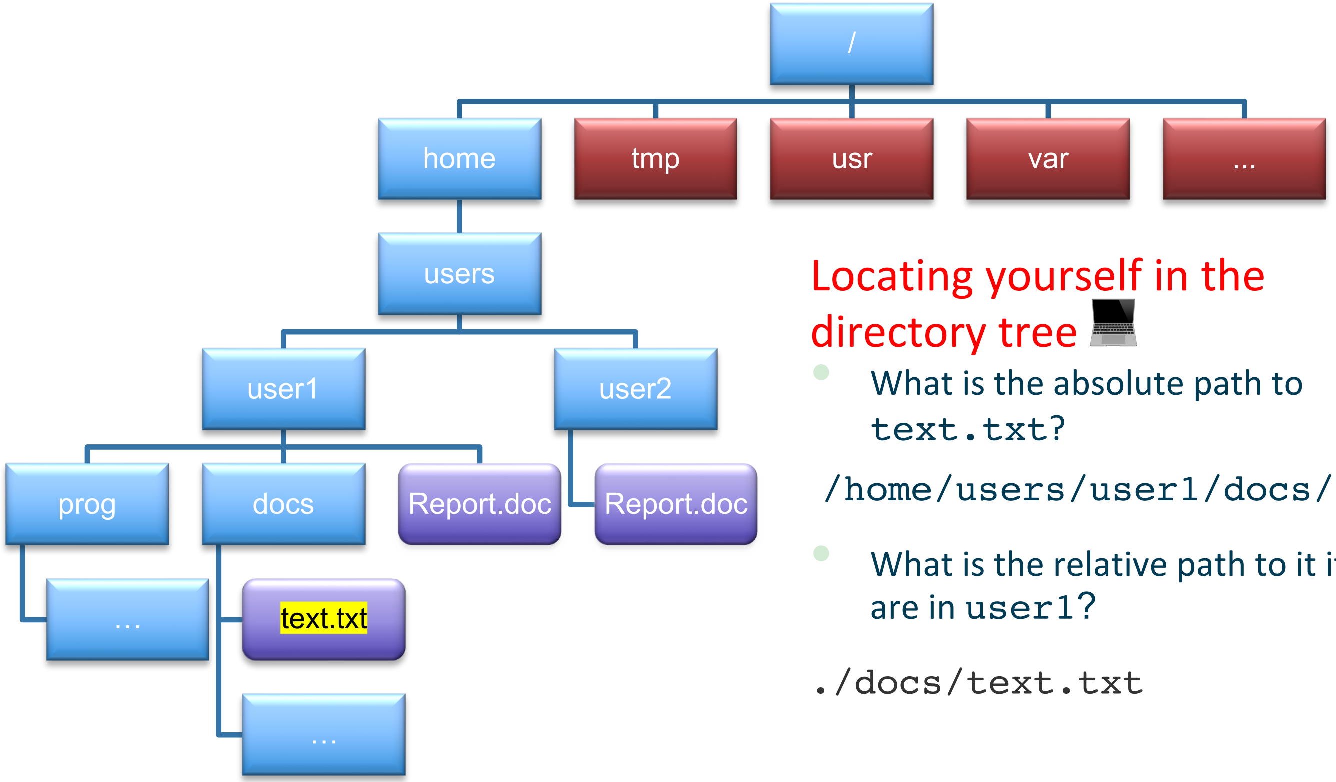
The directory tree



Locating yourself in the directory tree

- What is the absolute path to `text.txt`?

`/home/users/user1/docs/text.txt`

- What is the relative path to it if you are in `user1`?

`./docs/text.txt`

Nav commands; `pwd`, `ls`, `touch`

- `pwd` → Print working directory
  - Options:
    - `-L` = Symbolic path
    - `-P` = Actual path
- `touch` → Creates an empty file
    - `touch myfile.txt` = Creates an empty file called myfile.txt
- `ls` → list (files and directories)
  - Options:
    - `-a` = Show hidden files
    - `-t` = Sort by modification time
    - `-l` = Long, detailed list
    - `-d` = Express directory as file
    - `-h` = Human readable
  - Example: `ls –thl docs/`

Nav commands; cd

- `cd` → change directory
  - Operations

`cd mydir`	=	move into mydir directory
`cd ..`	=	move back 1 directory
`cd ../../`	=	move back 2 directories
`cd ~` OR `cd`	=	move to user home directory
`cd -`	=	move to previous directory
`cd /`	=	move to root directory

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Practice with `cd`

1. Use `cd` change plus the following and see what happens
   - `..`
   -
   - `.`
   - `new`
   - `../../`
   - `~`

Practice with cd

1. Match up the situations below with their expected output. Assume you are in a directory which contains a single directory, Documents

1	`cd`	Moves back one directory	A
2	`cd.`	No such file or directory	B
3	`cd Desktop`	Moves you back two directories	C
4	`cd ../..`	Moves you back into the "home" directory	D
5	`cd ..`	Does nothing, as you are already here	E
6	`cd Documents`	command not found	F
7	`cd ~`	Moves you back into the "home" directory	G
8	`cd .`	Moves you into Desktop	H

Practice with cd

1. Match up the situations below with their expected output. Assume you are in a directory which contains a single directory, Documents

1	`cd`	Moves you back into the “home” directory	D
2	`cd.`	command not found	B
3	`cd Desktop`	Moves you into Desktop	H
4	`cd ../..`	Moves you back two directories	C
5	`cd ..`	Moves back one directory	A
6	`cd Documents`	No such file or directory	F
7	`cd ~`	Moves you back into the “home” directory	G
8	`cd .`	Does nothing, as you are already here	E

Help commands;

- `man` → displays user manual of any command, including options
  - Example: `man ls` (press q to escape)
- `--help` → displays more info on how to use command. Similar to `man`. Only works in Linux itself
- `history` → shows last 500 commands entered
  - Pro tip: `!100` returns the 100th command in your history, great for complicated commands
  - ctrl-r shortcut to reverse search command in history

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Working with files and directories

- How do I create directories
- How can I copy and move files?

Clone a repo! 💻

```
git clone https://github.com/ICHEC-learn/intro-
to-linux.git
```

Making and removing; `mkdir`, `rm`

- `mkdir` → make a directory & `rmdir` → remove empty directory
  - Options:
    - `-m` = set permissions
    - `-p` = path name
  - Usage
    - `mkdir directory01/ directory02/`
    - `rmdir directory01/`

Creating and removing a directory 💻

- Create a new directory
- Change into the directory
- Create a new file
- Move back one directory
- Remove it

Making and removing; `mkdir`, `rm`

- `rm` → remove (files and directories): deleting is permanent
  - Options:
    - `-r` = delete directories and subdirectories
    - `-i` = prompt before use of rm (Y or N)
  - Usage
    - `rm test.txt file.pdf`

Using rm safely 💻

Create a new file using `touch newfile`, and then try and remove it using the `-i` flag.

Moving and copying; `mv`, `cp`

- `mv` → move files / change name of file/directory
  - Formats

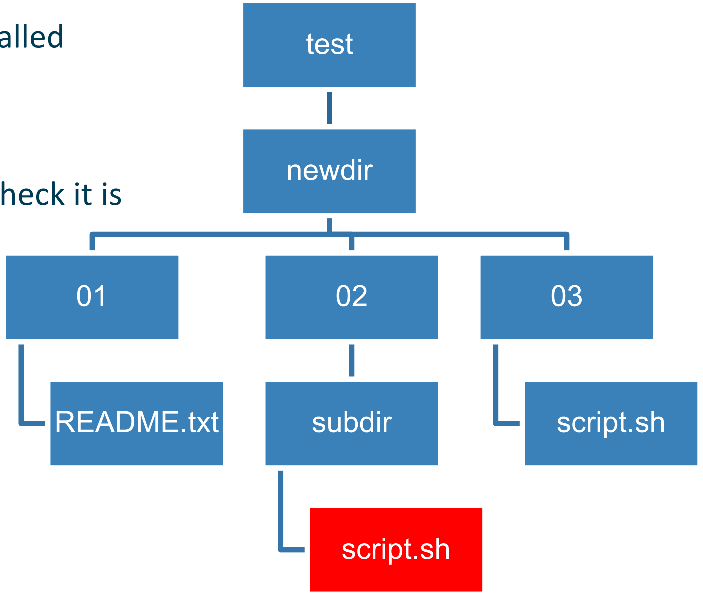
`mv test.txt dir/`	=	move test.txt into dir directory
`mv test.txt ../`	=	move test.txt back 1 directory
`mv test.txt test01.txt`	=	rename test.txt to test01.txt
`mv dir/ dir01/`	=	rename dir/ to dir01/
`mv -f 01.txt test.txt`	=	force renames 01.txt to test.txt
`mv –v 01.txt test.txt`	=	renames file, verbose option
`mv other/file.txt .`	=	move file.txt to current directory

- `cp` → copy files or directory
  - Examples:
    - `cp test.txt dir/test.txt = mv test.txt dir/test.txt`
    - `cp –r dir01/ dir02/` = copy directory (needs –r switch)

Creating a directory hierarchy

1. Navigate to your home directory, confirm it with `pwd`
2. List the files in this directory, then list all hidden files with the `—a` flag
3. Create a new directory called `01` and `cd` into it
4. Create a file called `README.txt`
5. Change back one directory to your home directory
6. Create 2 more directories `02` and `03`. In `02` create a new directory called `subdir`
7. In `03`, create a file called `script.sh`
8. Copy `script.sh` to the `02/subdir` folder, then move into it to check it is there
9. Remove the copied file using the `—i` flag for a confirmation prompt
10. Continue experimenting with navigating and working with files

- **Tips**: At every step use `pwd` and `ls` to confirm you know where you are and what files are located there
- **Commands**: `pwd, ls, touch, cd, mkdir, rm, mv, cp, man` *`command`*



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Useful Tools

- Writing to and viewing files
- Tar and zip files
- Wildcards
- Permissions
- Searching
- Sed and awk

Writing to and Viewing files

- `echo` → prints a message to the screen
  - Formats
    - `echo "Hello"` = prints "Hello" to the screen
    - `echo "Hello" > hello.txt` = writes "Hello" to a file called hello.txt
- `cat` → print contents of a file to the screen
  - eg:
    - `cat hello.txt` = prints out "Hello"
- `less` → prints contents of a file to a separate window
  - eg:
    - Less hello.txt = shows content
- `more` → Combines features of `cat` and `less`
- `head` → lists first 10 lines of a file
- `tail` → lists last 10 lines of a file

Familiarize yourself with the viewing commands 💻

File commands; `wc`, `diff`, `sort`

- `wc` → word count, as well as lines and characters
  - Usage: `wc text.txt` = number of lines, characters, words
  - Options:

`-c`	= number of bytes	`-m`	= number of characters
`-l`	= number of lines/rows	`-w`	= word count

- `diff` → used to view differences between files; (<) : file 1; (>) = file 2
  - Usage: `diff file1 file2`
  - Options:
    - `-a` = add
    - `-c` = change
    - `-d` = delete
  - The output will give instructions using a, c, d options to indicate which lines need changing to make the files identical.

- `sort` → sorts file but does not change file
  - Usage: `sort in.txt > out.txt` = puts sorted output to new file
  - Options

`-n`	= numerical sort	`-u`	= remove duplicates
`-r`	= reverse sort	`-o`	= write output
`-k 2n`	= sort based on 2nd col.	`-M`	= sort by month

Special file operations; `tar`

- The `tar` command creates maintains, modifies and extracts files archived in the tar (tape archive)
- Why tar? → Stores multiple files in one single file
  - Options:

`c`	= create archive file	`t`	= view file contents
`x`	= extract archive	`j`	= filter archive through bzip2
`v`	= show file progress	`z`	= filter archive through gzip
`f`	= filename	`r`	= append/update files to archive
		`W`	= verify archive file

  - Useful Commands (*works for `.gz`, `.bzip2` extensions)

`tar –cvf dir.tar dir/`	= create normal tar archive file
`tar –cvzf dir.tar dir/`	= create gzipped tar archive file
`tar –xvf dir.tar (-C /home/)`	= untar files (in other directory) (*)
`tar -tvf dir.tar`	= list content of archive (*)
`tar -rvf dir.tar`	= add text.txt to archive (*)
`tar –xvf dir.tar text.txt`	= extract text.txt from archive
`tar -zxvf dir.tar.gz –wildcards '*.txt'`	= extract group of files using wildcards

Special file operations; `gzip`

- The `gzip` command compresses files. Each single file is compressed into a single file
- Original file is deleted using `gzip`, use `–c` option to write compressed file to stdout
- The `gunzip` command unzips the file. You can also use `gzip –d`
  - Usage:

`gzip file`	= zips file, deleting it, creating `file.txt.gz`
`gzip –c file gzips/file`	= move `test.txt` back 1 directory
`gzcat file.txt.gz`	= view contents of `file.txt.gz`
`gunzip file.txt.gz`	= undo the effects of `gzip`
`gzip -d file.txt.gz`	= undo the effects of `gzip`
`gunzip –c a.txt | more`	= Write uncompressed content to stdout and pipe to `more` for an easy read

- If zipping a `tar` file, you can name `file.tar.gz` as `file.tgz` or use a specified `tar` command

`tar`-ing and `gzip`-ing a directory 💻

Use `tar` plus its flags to create a `.tar` archive of the `wildcards/` directory. Check the contents of the archive. Now zip the archive using `gzip`.

Finally, unzip and untar the archive.

Wildcards; *, ?, [ ]

- For a directory with: `001.txt  002.txt … nnn.txt other.dat`
- `*` → matches one or more occurrence of any character
  - Examples:

  -
    ```
    cp *.txt docs/txt_files       ls –l 0*
    ```
- `?` → matches single occurrence of any character
  - Examples:

  -
    ```
    cp 0?.txt docs/txt_files     ls –l 0?.txt
    ```
- `[ ]` → any character inside the square brackets
  - Examples:

  -
    ```
    cp 0[12]1.txt docs/txt_files ls –l [02468]1.txt
    ```
- `*?[ ]` → combining wildcards
  - Examples:

  -
    ```
    cp ??1* docs/txt_files        ls –l [1-6][4]?.txt
    ```
- Practice using the different wildcards to remove, or list out the different files in the wildcards directory 💻

Permissions

- All files have owners (machine user) and group owners (group on machine)
- The long listing format shows:

r	w	x	r	w	x	r	w	x
User			Group			Other		

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Permissions

- All files have owners (machine user) and group owners (group on machine)
- The long listing format shows:

r	w	x	r	w	x	r	w	x
	User			Group			Other	

- Create a file using touch and see its full details using `ls -l`
  - `r` → file can be opened for reading
  - `w` → file can be opened for writing
  - `x` → file can be opened for execution

Changing Permissions with chmod

- `chmod` (change mode) modifies permissions of user (u), group (g) and other (o) to read (r), write (w) and execute (x) the file
  - `chmod [ugo][+-][rwx] file`
- The same can be done with directories… eg home directory
  - `chmod go-rwx ~`

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- The same can be done with directories… eg home directory
  - `chmod go-rwx ~`
- There are also number notations, each one referring to u, g, o;

`0 == ---`	`2 == -w-`	`4 == r--`	`6 == rw-`
`1 == --x`	`3 == -wx`	`5 == r-x`	`7 == rwx`

- What's the equivalent numeric command?

```
OWNER   GROUP   OTHER
r w x   r w x   r w x
1 1 1   0 0 0   0 0 0
```

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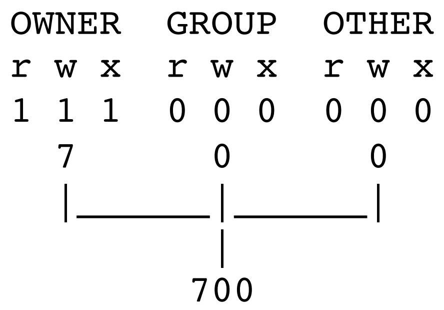
0 == ---	2 == -w-	4 == r--	6 == rw-
1 == --x	3 == -wx	5 == r-x	7 == rwx



- What's the equivalent numeric command?
  - `chmod 700 ~`
- Changing file permissions
  - Create a new file, add executable for user and group, remove reading permissions for other

Changing Permissions with chmod

Who has what permissions? 💻

```
1. rwxrwxr--
2. r--r--r--
3. 755
4. 700
5. rwxrw-r--
6. chmod u+x file
7. chmod go-wx file
```

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Pattern searching using `grep`

- One of the most commonly used and essential commands to master
- Used to find substrings in large bodies of text

```
grep 'int' main.c
```

finds all instances of `int` in the program `main.c` case sensitive

- Options

`-i`	= case insensitive
`-n`	= display line occurrence
`-v`	= omit unwanted strings
`-r`	= recursive (current/subdirectory)
`-l`	= all files which contain a string
`-C<num>`	= num of lines before and after match
`--color=auto`	= add colour display to selection

Pipes

Which is the best option for ease of use?

1 Tesla Roadster

10 Nissan Leafs

Better to combine smaller commands into a more powerful and useful one

Pipes (|) remove unnecessary temporary files, and send output of one command to the input of another. The syntax is;

```
command_1 | command_2 | … | command_n
```

Pipes – how do they work?

Which is more powerful and convenient?

```
$ cat -ns text.txt > newfile.txt
$ less newfile.txt

$ cat –ns text.txt | less
```

Not only is this cleaner, but there is less chance of overwriting important files

Very powerful tool particularly when combined with the `grep` command

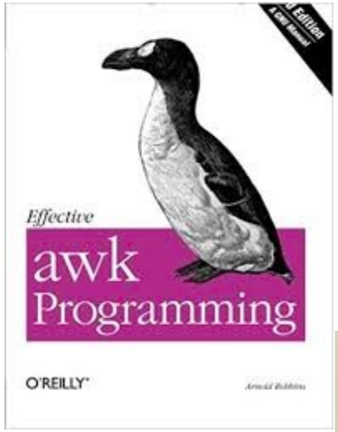
`sed` – UNIX's stream editor

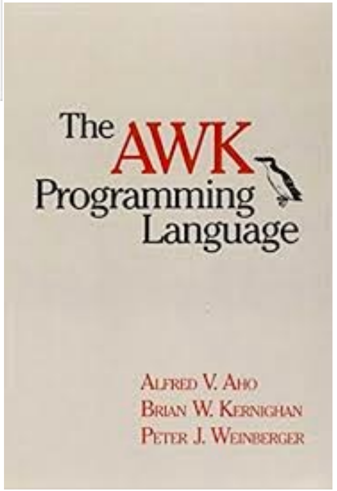
- `sed` is another handy tool in UNIX which can be used for;
  - Searching
  - find and replace
  - Insert / delete
- The format of the `sed` command is;
  - `sed 'opt/act/flag' file`

Replacing text:	`sed 's/string/replacements/' file`
Replace nth occurrence:	`sed 's/str/repl/2' file`
Print replaced lines:	`sed –n 's/str/repl/p' file`
Delete 5th line:	`sed '5d' file`

awk – language within UNIX

- So far you've learnt the language of UNIX, awk is its own language
- Enables users to write statement sized programs for data extracting and reporting
- Basics only covered here, plenty of commands in plenty of books.
- Awk program is a series of rules in the form;
  - `awk '(CONDITION) {ACTION}' file`





awk – language within UNIX

- awk can be used for anything from printing to complex mathematical statements
- It can also be used in bash scripting over multiple lines
- Examples include:

Command	Meaning
`awk '{print}' t.txt`	Prints out contents of t.txt. Works like cat
`awk '/example/ {print}' t.txt`	Searches for lines containing 'example'
`awk '{print $1,$3}' t.txt`	File split by whitespace delimiter $0 = whole line
`awk '{if ($1 > 100) print $1}' t.txt`	Prints any value greater than 100 in t.txt

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Loops and conditionals

- Variables
- Loops
- Conditionals

Environment Variables in bash

- System-wide variables inherited by all child processes and shells. `env` shows environment variables in your session
- Denoted with the ($) symbol. What happens when you type;
  - `echo $HOME`
- You can set a temporary environment variable for your current session;
  - export VARNAME="my value"
- You can set a permanent variable to future sessions, add it to `.bashrc`
- This process is also known as aliasing

Shell Variables in bash

- Shell variables are named symbols that represent strings or numeric value, and only apply to current shell instance
- Assigning/unassigning variables is easy (watch for whitespace)
  - `pi=3.142`
  - `echo $pi`
  - `unset pi`
- Crucial in bash scripting

Variables in bash

- Variables are not protected in longer strings
- From previous example;

```
$ pi=3.14
$ echo $pie              (won’t work, we didn’t declare pie!)
$ echo ${pi}e            (this will)
3.14e
```

- Arithmetic can also be performed using either `let` or `(())`

```
$ x=100; y=50
$ let x++; ((y--))
$ echo $x $y
101 49
```

- There is no floating point arithmetic in bash, but you can use `bc`

```
$ echo ‘100/3’ | bc –l
33.333
```

For loops in bash

- Allows code to be repeatedly executed, and particularly useful for dealing with lots of files
- The `seq –w` command allows us to produce equal width, i.e. sequential output (useful for filenames)

```
for i in a b c d e;
do
    echo $i
done

for x in $(seq -w 1 10);
do
    touch ${x}.txt
done
```

Functions in bash

- A function is a series of commands that can be called numerous times. It makes code more readable and user friendly
- Two formats

SCRIPT	

`function_name() {`
`Commands`
`}`
	`function func_name() {`
	`commands`
	`}`

COMMAND LINE	
`function_name``() {commands; }`	`function func_name() {commands; }`

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Comparison Operators

- Binary comparisons compare two variables or quantities. There are different operators for strings and integers

Integer Comparison		String Comparison
`-eq`		`= / ==`
`-ne`		`!=`
`-lt / <`		`<`
`-le / <=`		`<=`
`-gt / >`		`>`
`-ge / >=`		`>=`
	String is null	`-z`
	String not null	`-n`
`conditional [“$a” –lt “$b”] / ((“$a” < “$b”))`		

Conditional statements in bash

- Both `if` and `case` statements are supported. The case statement is for more complex use, and best saved for your actual code

```
if [ $x –gt 100 ]; then
    echo ‘greater than 100.’

elif [ $x == 100 ]; then
    echo ‘equal to 100.’
else
    echo ‘less than 100.’
fi
```

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Bash scripting

- Text editors
- Writing a bash script
- Conditionals

Scripting languages within UNIX

- A scripting language is a non-compiled programming language
- Usually written in text files and interactively on the command line
- Examples: `bash, csh, ksh, zsh, perl, python`
- Here we will look at `bash`, which is saved as a text file with `.sh` extension

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Text editors

- Trying to write a programming language like C or Fortran in the command line won't work!!
- Python can work in the command line, but not as a file!
- Use text editors for opening, viewing and editing files
- Depending on the coding language, different extensions are needed
- Examples include; gedit, vim, nano, emacs

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Text editors – Face-off

	nano	vim	emacs
Pros	• No learning curve • Easy to use • Good for simple edits	• Effective editing of text • Super powerful, complicated edits made easy • Highly effective, keyboard shortcuts for everything	• Customisable, extendable • Powerful edits • Edit files & browse web • Mature integration with tools
Cons	• Complicated edits difficult • No powerful features (macros, simultaneous multiple files)	• Overkill for simple edits • Steep(ish) learning curve (see vimtutor)	• Hard to customise using Lisp, steep learning curve • Not available everywhere
Verdict	• Great for beginners and simple edits.	• Ideal and go-to for programmers. Best choice when mastered.	• For those who want more than a text editor as Emacs can be an environment

* For commands for each see practical sheet

First bash script

- Run the following command;

  -
    ```
    echo 'hello from the command line'
    ```
- Create a file and use the text editor to edit

```
#!/bin/bash

# Comments denoted by hashtag

echo 'hello from bash'
```

- Run it using

```
bash ./test.sh
```

Running a file with a bash script

- Create a python “Hello world” file;

```
hello.py
```

```
print(“Hello world!”)
```

- Use your bash file to run the python file

```
test.sh
```

```
#!/bin/bash

# Comments denoted by hashtag

python hello.py
```

Running a file with a bash script

- Create a python “Hello world” file;

```
hello.py
```

```
print(“Hello world!”)
```

- Use your bash file to run the python file

```
test.sh
```

```
#!/bin/bash

module load conda/2
source activate python3

python hello.py
```

```
bash ./test.sh
```

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SSH Keys

- Text editors
- Writing a bash script
- Conditionals

Shell vs SSH (Secure Shell)

Shell

- Computer program that takes commands and gives them to OS to perform. It is the main interface between user and the Kernel
- Most Linux systems (incl. Kay) use bash as the default shell.

```
yourcomputer:dir username$ echo "Hello"
```

SSH (Secure Shell)

- The command `ssh` (secure shell) follows SSH protocol - a remote admin protocol that authenticates a remote user
- Easy in Mac/Linux, not as trivial in Windows

```
ssh {user}@{host}
```

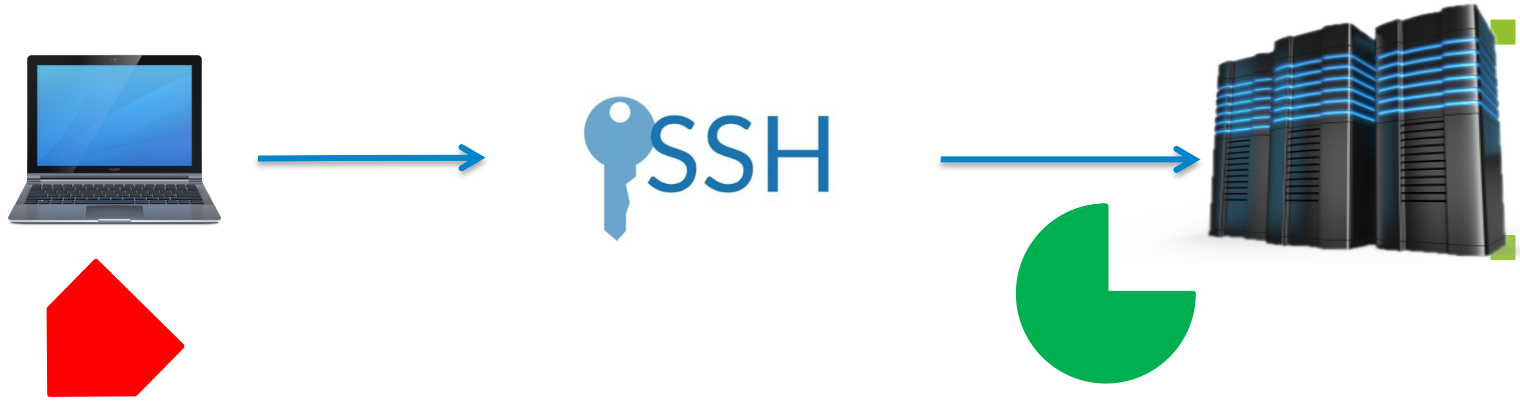
```
ssh yourusername@kay.ichec.ie
```

Public and Private Keys

Generate the ssh-key

Private: id_ed25519

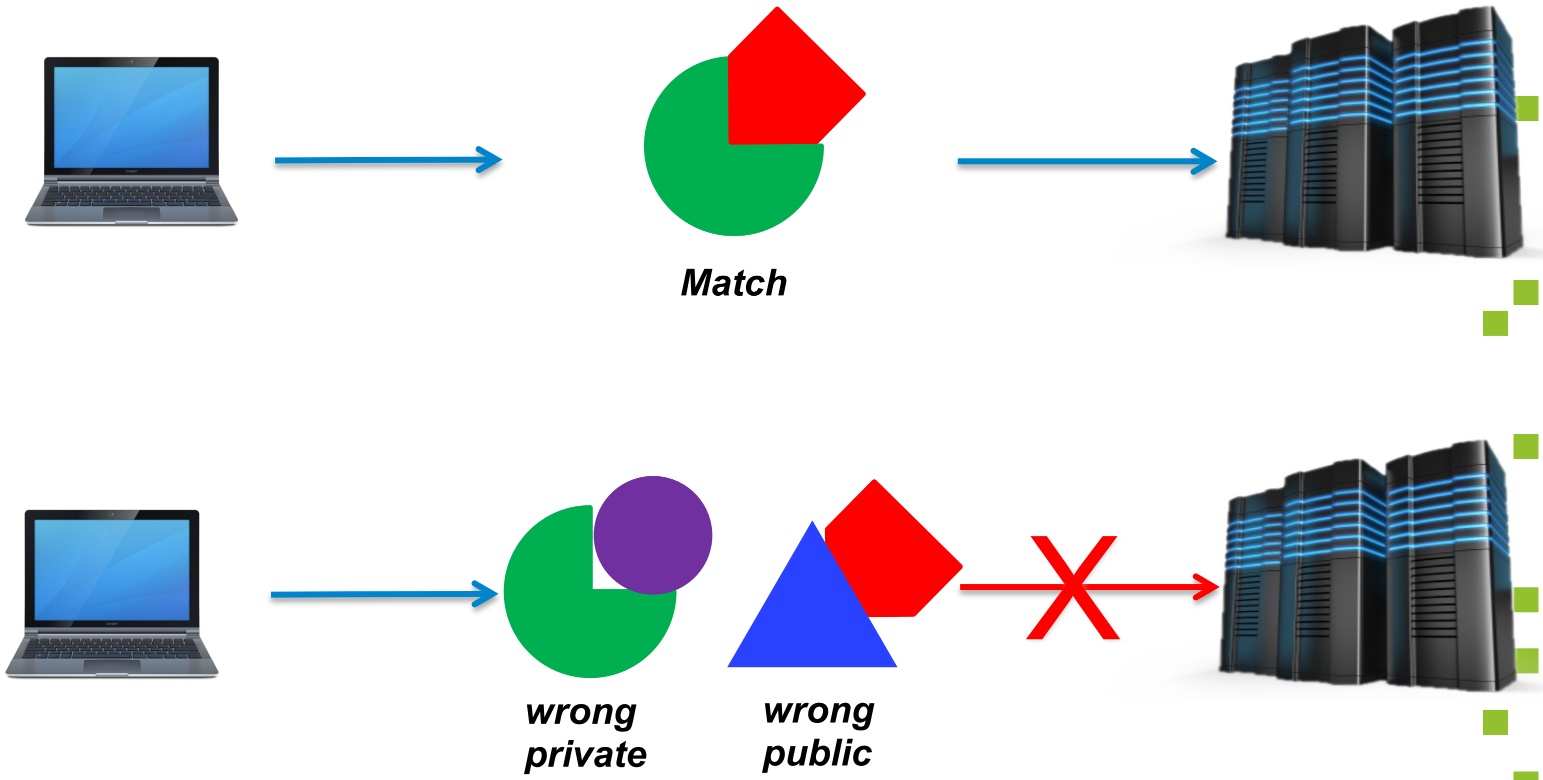
Public: id_ed25519.pub



$USER_PROFILE/.ssh/id_ed25519

$HOME/.ssh/authorized_keys

Public and Private Keys



Creating an SSH key-pair 💻

- Once an SSH key-pair has been generated, I need to…
  1. Submit my private key, as the account on the supercomputer will be private to me
  2. Submit my public key, as the account needs
  3. I don’t need to do anything, as I have both of them
  4. Submit both my public and private keys, as both will be needed for me to log in
  5. Generate a new SSH key pair in a different directory

Creating an SSH key-pair 💻

- Navigate to your home directory and type

```
ssh–keygen –t ed25519
```

- Choose a password you can remember

- Now try logging into Kay using your username in the document in the chat

```
ssh courseXXX@kay.ichec.ie
```

Summary

- Introduction to basic Linux commands
  - `pwd`, `cd`, `ls`, `mkdir`, `rmdir`, `rm`, `mv`, `cp` , `man`
- Navigation of directories
- Creating files and directories
- Pattern searching using `grep`
- Using `vim`, and creation of bash script
- Running a basic bash script
- Setting up ssh keys