

An Introduction to the Command Line

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Slides, code, lecture notes: <https://github.com/crahal/Teaching>

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- However: For a lot of classes, this isn't necessary, where a simple R (more often) or Python (less often) will be more than sufficient.
- The CLI will only be required for some classes, but practicing with it this week provides **invaluable** experience for HPCs (an integral part of genomics).

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- Control: Commands are often more powerful and precise, giving more control over the operations to be performed
- Software tools: A number of genetics software tools will only run in Linux/Mac environments.

Our Friend - ARCUS (or AWS)

- Why have this class at all? Our friend ARCUS provides some motivation:

WARNING

Finally, Linux assumes that the user knows what they are doing. On ARC systems users will not have escalated or 'root' privileges but will be able to delete or modify any files/data that resides in their own home account or project data directory. Where you are sharing data with other project members you need to be careful when using Linux commands as you may inadvertently delete or modify this data. Most Linux (UNIX) commands do not ask questions. They assume you know what you are typing and blindly execute the task as instructed.

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unfortunately, there is no decompressor available.'*
- However: **the potential is endless!**
- (and a Virtual Machine is the best way to learn).

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(a) Sleepy



(b) Curious

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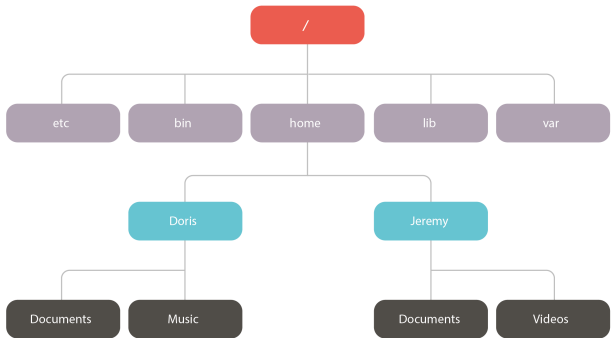
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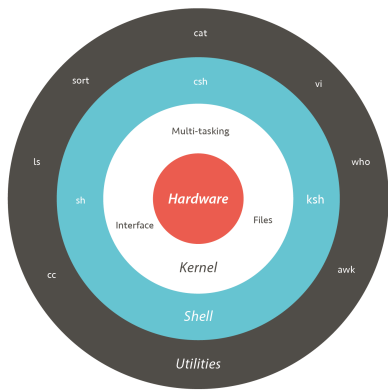
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The File Tree



You might also find `/opt`: optional software or `/tmp`: temporary space.

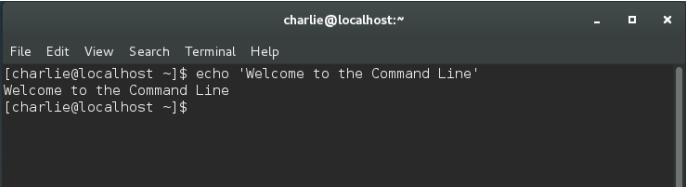
System Architecture



Importantly, the shell is a program that takes your commands from the keyboard and gives them to the operating system to perform.

The Terminal

The terminal is a program which lets you interact with the shell:



```
charlie@localhost:~  
File Edit View Search Terminal Help  
[charlie@localhost ~]$ echo 'Welcome to the Command Line'  
Welcome to the Command Line  
[charlie@localhost ~]$
```

If the last character of your shell prompt is `#` rather than `$`, you are operating as the superuser. This means that you have administrative privileges. This can be potentially dangerous, since you are able to delete or overwrite any file on the system. Unless you absolutely need administrative privileges, do not operate as the superuser (try `whoami` and `sudo whoami`).

Fundamental CLI Commands: `man`

- The `man` command shows the manual for a given page, including information on options and usage.
- This is the default resource for getting help on specific commands.

```
1 user@system:~$ man echo
2 ECHO(1) User Commands ECHO(1)
3
4 NAME
5     echo — display a line of text
6
7 SYNOPSIS
8 ...
```

- For example, the `man echo` command will display the manual for the `echo` command which we just saw.

Fundamental CLI Commands: `whatis`

- The `whatis` command gives a short summary description of the specific command, and command inputs can be stacked together.

```
1 user@system:~$ whatis echo ls
2 echo (1) – display a line of text
3 ls (1) – list directory contents
```

- Each manual page has a short description available within it – and `whatis` searches the manual page names.

Fundamental CLI Commands: `ls`

- `ls` is a Linux shell command that lists directory contents of files and directories.

```
1 user@system:~$ ls
2 Desktop Documents Downloads Music Pictures Public Videos
```

- The lists can also be sorted, accept wildcards, and pipe outputs to file.
- It can show hidden files, show file size, and has the option for a 'long' format.

Fundamental CLI Commands: `pwd`

- However, this isn't much use without knowing *where* we are in the file tree.

```
1 user@system:~$ pwd
2 /home/user
```

- In *nix-like operating systems, the `pwd` command (which stands for print working directory) writes the full path-name of the current working directory to the standard output.

Fundamental CLI Commands: `mkdir` and `cd`

- We should make a new directory (or folder – a container for other files) for the purposes of following along with these examples.

```
1 user@system:~$ mkdir nix
2 user@system:~$ ls
3 nixTextbookChapter
4 user@system:~$ cd nix
5 user@system:~/nix$ pwd
6 /home/user/nix
```

- This brings us to *absolute* and *relative* paths.
- From the documents folder above, we can navigate to the new folder (`nix`) through the relative path or through the absolute path.
- The `cd` command is used to change the current directory.
- There are multiple ways of identifying the same file path in the directory tree.

Fundamental CLI Commands: touch

- The `touch` command is the easiest way to create new, empty files...

```
1 user@system:~/nix$ touch testfile
2 user@system:~/nix$ ls
3 testfile
```

- `testfile` might seem unfamiliar to you for one obvious reason: the lack of an extension.
- In *nix-like systems, the extension is ignored, and the file type is determined automatically (and the command `file` can tell us additional information).

Fundamental CLI Commands: `rm`

- Now that we've learnt how to create files and directories, lets look at removing them:

```
1 user@system:~/nix$ cd ..
2 user@system:~/$ rm -ri nix
3 rm: remove directory 'nix'?
```

- This shows how we can stack options together, where `rm -ri` is the equivalent to `rm -r -i`.
- However, command line options are not universal between commands, and implementation across different operating systems may vary.
- We should also note the existence of `rmdir`, the negative equivalent to `mkdir`, which removes *empty* directories.

Fundamental CLI Commands: `mv` and `cp`

- It seems only natural that we now learn how to move, copy and rename files.

```
1 user@system:~/nix$ cp testfile ..
2 user@system:~/nix$ rm ../testfile
3 user@system:~/nix$ mv testfile ..
```

- We need not actually remove `testfile` after copying it and before moving it, as the `mv` command would simply overwrite it.
- To rename a file, we can just move it with a new name.

Other Basic Utilities

- We can `clear` the terminal screen.
- We can display all environmental variables with `env` (try `echo $LANG`).
- `find` and `locate` search for files and directories (with the latter being faster – performing on a database of indexed filenames).
- `date` displays or sets (with the option `-s`) the system time, and `cal` displays the calender.
- `history` and specifically - `history [NUM]` reports the last `[NUM]` commands.
- We can `exit` from the current terminal session, `logout` as a specific user, or `shutdown` the machine entirely.

Editors at the Command Line

- Lets introduce the use of text editors at the command line (vi, pico, nano and emacs). These are plain text editors – not word processing suites.
- Unlike many GUI based editors, the mouse does not move the cursor. Unlike PC editors, you cannot modify text by highlighting it with a mouse.
- Lets use nano to create a file which we will use for some examples later on: a list of all the fruits we can think of (call the file allfruits).

Introducing Text Editors at the CLI: nano allfruits

```
1 Apple
2 Apricot
3 Avocado
4 .
5 .
6 "allfruits" 90 lines, 846 characters
```

I/O Redirection

- Most command line programs output their results to the standard output (STDOUT): which, by default, is the display.
- We can redirect standard output to specific files using the `>` character, and append to a file using `>>`.
- Commands can also accept input from standard input (STDIN), which defaults to the keyboard: to redirect from STDIN, we use the `<` character.

```
1 user@system:~/nix$ ls > filelist.txt
2 user@system:~/nix$ sort < filelist.txt
```

- There is also a third stream which will go unexamined (standard error or STDERR) which is used for error messages and also defaults to the terminal.

Filters

filters are a class of programs which are extremely useful for I/O Redirection:

- `sort`: Sorts STDIN and outputs the sorted result on standard output.
- `uniq`: Given a sorted stream of data from STDIN, it removes duplicates.
- `grep`: Examines each line of data it receives from standard input and outputs every line that contains a specified pattern of characters.
- `head`: Outputs the first few lines of its input (defaults to first 10 lines).
- `cat`: Concatenates files and displays their contents, or just displays contents if given one input.
- `cut`: Divides a file into several columns.
- `nl`: prints the line number before data.
- `wc`: which prints the count of lines, words and characters.

The Pipe

- The pipe (`|`), which allows you to connect multiple commands together.
- The standard output of one command is fed into the standard input of another, enabling you to chain together individual commands to create something really powerful.
- The example below *pipes* the output from `ls` into the `head` command which takes the input `1` to show us the first 1 line of the `ls` output: we've chained the two commands together.

```
1 user@system:~/nix$ ls | head -1
2 allfruits
```

Wildcards

- Another more advanced concept is the 'wildcard': a set of tools that allow you to create a pattern which defines a specific set of files or directories.
- There are two simple types of wildcards:
 1. * represents zero or more characters
 2. ? represents a single character.

```
1 user@system:~/nix$ touch fileonea fileoneb filetwoa filetwob
2 user@system:~/nix$ ls file*a
3 fileonea filetwoa
4 user@system:~/nix$ ls filetwo?
5 filetwoa filetwob
```

- A regular expression (or 'regex') includes such functionality, but is a much more powerful pattern matcher beyond the scope of this introduction.

Users, Groups and Permissions

- Permissions specify what a user can and cannot do.
- Perhaps, for example, you want to lock your files so other people cannot change them or secure system files from damage.
- Permissions are split into three distinct categories which govern the ability to: Read: `r`, Write: `w` and Execute: `x`.
- For every file, we need to define permissions for potential users:
 - The user who created the file (`u`).
 - The group which owns the file (`g`).
 - Others (`o`).
- There are typically only two people who can manage the permissions of a given file or directory: the owner and the root user.
- To view the permissions associated with an individual file, we can use the `-l` option on the `ls` command:

```

1 user@system:~/nix$ ls -l allfruits
2 -rw-rw-r-- 1 user user 846 May 29 14:57 allfruits
  
```

Users, Groups and Permissions (Cont.)

- The first character determines whether it is a file (-) or a directory (d).
- We have information on the permissions for u, g and o.
- A - represents the omission of a permission.
- To change the permissions, use the `chmod`, including information on: 1.) Who are we changing the permission for? 2.) Are we giving (+) or taking permission (-)?, 3.) Which permissions are we setting?
- For example, lets take away read permissions from the group and others:

```

1 user@system:~/nix$ chmod og-r allfruits
2 user@system:~/nix$ ls -l allfruits
3 -rw----- 1 user user 846 May 29 15:09 allfruits

```

- Importantly, permissions are not inherited from the parent directory - and the recursive option (-R) for `chmod` can be especially useful.
- There are a range of 'short-hand' commands (e.g. `chmod 751 <filename>`).

Archiving

- Archiving in our context is similar to the familiar .zip extension in Windows.
- Introducing the tape archive – tar: extract with `-x`, create with `-c`..
- Typically compressed with gzip (Lempel-Ziv) or bzip2 (Burrows-Wheeler).

```

1 user@system:~/nix$ head -5 allfruits > top5fruits
2 user@system:~/nix$ ls -la
3 -rw----- 1 user user 846 May 30 13:32 allfruits
4 -rw-rw-r-- 1 user user 38 May 30 13:33 first5fruits
5 user@system:~/nix$ tar -cvf fruits.tar allfruits first5fruits
6 user@system:~/nix$ gzip fruits.tar
7 user@system:~/nix$ tar -cvf fruits.tar allfruits first5fruits
8 user@system:~/nix$ bzip2 fruits.tar
9 user@system:~/nix$ bzip2 ls -l
10 -rw----- 1 user user 10240 May 30 14:07 allfruits
11 -rw-rw-r-- 1 user user 38 May 30 13:33 first5fruits
12 -rw-rw-r-- 1 user user 214 May 30 14:13 fruitlists.tar.bz2
13 -rw-rw-r-- 1 user user 224 May 30 14:13 fruitlists.tar.gz

```

Bash Scripting: Introduction

- Bash scripting performs complex, repetitive tasks with minimal effort.
- A script is just a text file containing commands which could be ran directly.
- It is a convention (albeit unnecessary) to give bash scripts an extension of `.sh`.
- Lets create our first script (`myfirstscript.sh`) and describe how it works:

```
1 #!/bin/bash
2 echo Hello There! Welcome to Bash Scripting!
```

- The first line is called the ‘shebang’. We can run the file in two ways:

```
1 user@system:~/nix$ ./myfirstscript.sh
2 Hello There! Welcome to Bash Scripting!
3 user@system:~/nix$ bash myfirstscript.sh
4 Hello There! Welcome to Bash Scripting!
```

Bash Scripting: Variables

- Just like in other languages: variables are temporary methods of storing information.
- Setting them requires no \$, but reading them does.
- Lets pass variables to a script which accepts \$1 and \$2 as inputs:

```
1 #!/bin/bash
2 echo Hello $1! Message sent from $2!
```

and then execute it as before:

```
1 user@system:~/nix$ ./variables.sh Felix Charlie
2 Hello Felix! Message sent from Charlie!
```

- There are also a number of special variables: \$0, \$n, \$? etc.

Bash Scripting: User Input

- We can also ask the user for input using `read`:

```
1 #!/bin/bash
2 echo Hey, Buddy! What is your favorite color?
3 read favoritecolor
4 echo Wow! $favoritecolor is my favorite color too!
```

and then execute it as before:

```
1 user@system:~/nix$ ./readvariable.sh
2 Hey, Buddy! What is your favorite color?
3 Blue
4 Wow! Blue is my favorite color too!
```

Bash Scripting: Arithmetic

- We can also do simple arithmetic operations using `let` and `expr`: `let` stores the variable, but `expr` prints it out.
- We can utilize the standard operators of `+`, `-`, `*`, `/`.

```
1 #!/bin/bash
2 let "a = $1 + $2"
3 echo adding $1 and $2 together gives $a
4 echo multiplying $1 and $2 together gives $(expr $1 \* $2)
```

and then execute it as before:

```
1 user@system:~/nix$ ./arithmetic.sh 10 5
2 adding 10 and 5 together gives 15
3 multiplying 10 and 5 together gives 50
```

- Finally, we can also embed `if` statements just like in other languages (no indentation), and utilize various types of loops (`while`, `until` and `for`).

Python and R

- The lack of a GUI on HPCs requires us to submit our Python and R scripts through the command line rather than an IDE.
- This is as simple as writing your R or Python scripts locally and then transferring them (scp or rsync) or writing them using a CLI editor.
- Lets create an example file called `helloworld` which simply has the single line: `print("Hello World! How are you?")`.
- Assuming Py 2, we can execute `helloworld` with almost identical output:

```

1 user@system:~/nix$ python helloworld
2 Hello World! How are you?
3 user@system:~/nix$ Rscript helloworld
4 [1] "Hello World! How are you?"

```

- We can execute the files with `./` as above, but this requires a shebang! `#!/usr/bin/Rscript` for R and `#!/usr/bin/env python`.

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- Other courses use these ideas in their application to sociogenomics.
- We didn't really cover: alias-ing, networking, **ssh-ing**, scheduling, awk and sed. We didn't really consider control statements, or regex.

Conclusion

- We've gone through the main basic ideas behind the CLI, with the intention of providing some intuition.
- Other courses use these ideas in their application to sociogenomics.
- We didn't really cover: alias-ing, networking, **ssh-ing**, scheduling, awk and sed. We didn't really consider control statements, or regex.
- Hopefully you now feel as suave with the CLI as this guy:

