



BASH Essentials

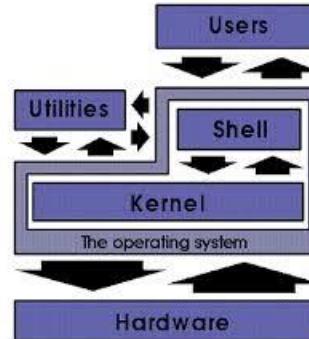
Ádám T. Kocsis

Friedrich-Alexander-Universität Erlangen-Nürnberg

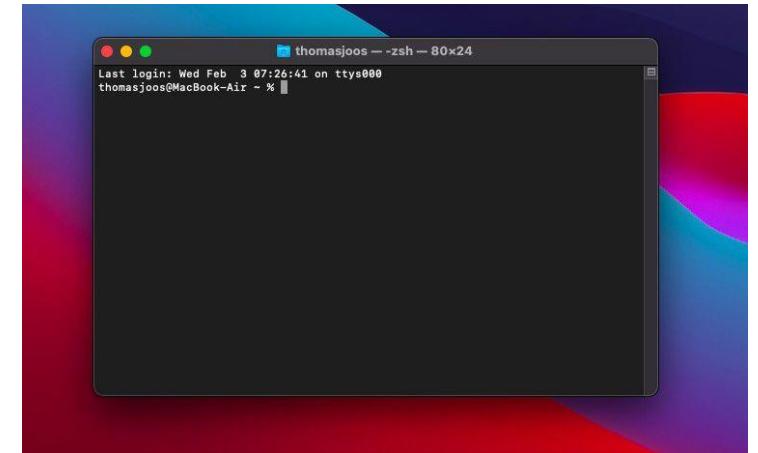
2025-10-10

Terminal emulators

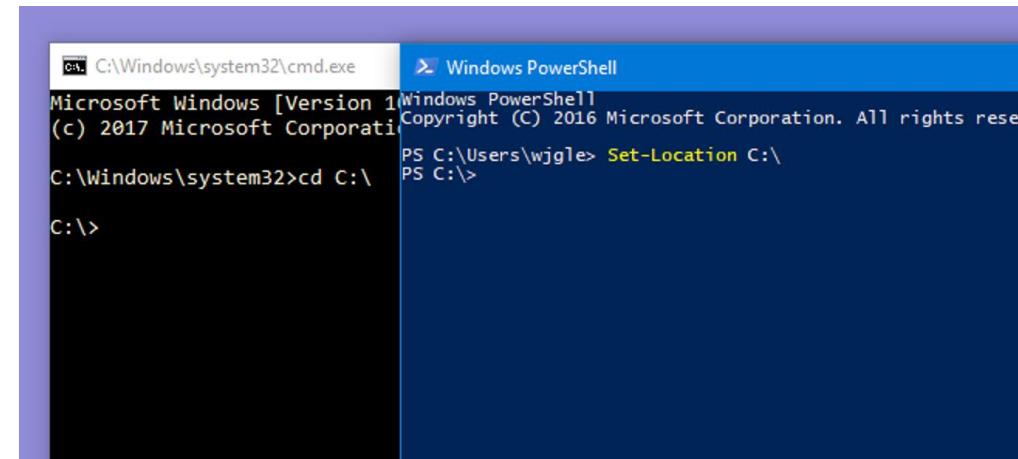
- Every OS has at least one
- Graphical applications that run a program called the “shell”: an interpreter program that translates instructions
- Console applications can be run with the shell
 - Automation
 - Program building
 - Scientific calculations
- Shells are programmable



Mac (zsh or bash)

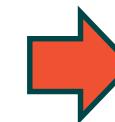


Windows (cmd and powershell)



The BASH shell

- Ubiquitous
- Most frequently used on servers and clusters
- UNIX-native: most programming systems use UNIX-like paths – even on Windows!
- Mac: have it, z shell (zsh) is almost the same
- Windows: a simplified version is available with git (git bash)



<https://git-scm.com>

BASH essentials

Most important functions and browsing directories

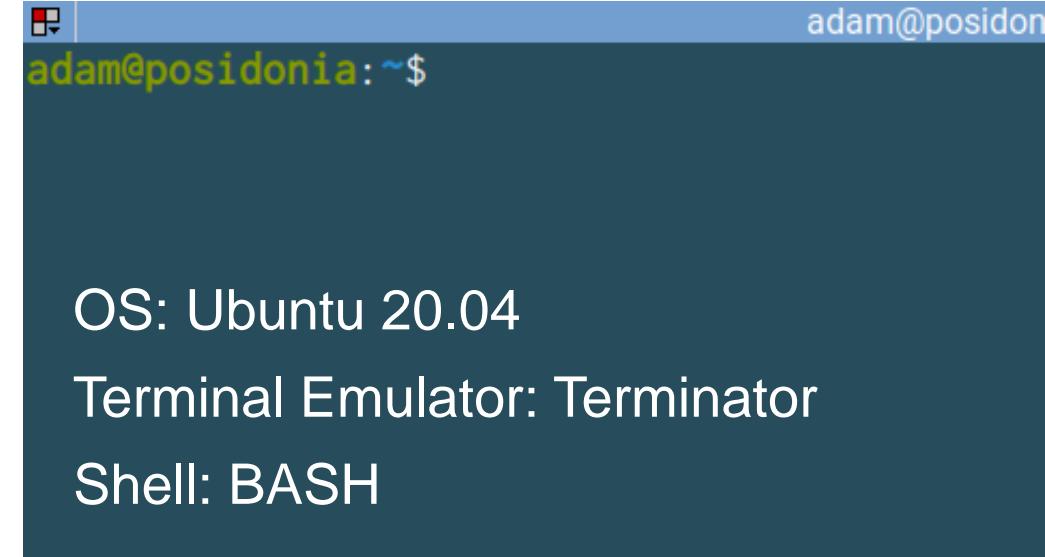
The prompt

- User input expected (typing)
- Looks different on all, but there are conventions:

user@host

~: is shorthand for user home

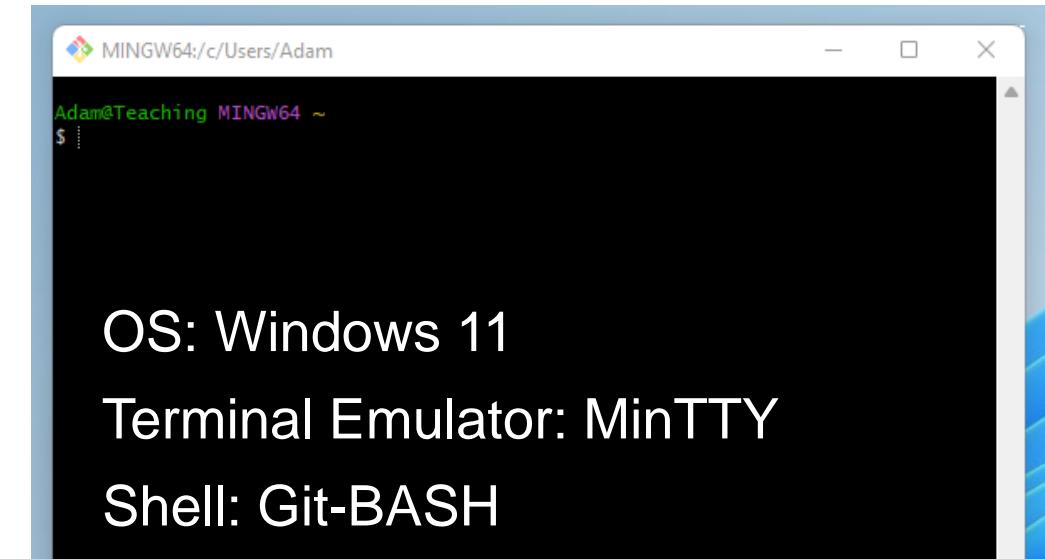
\$: means normal user mode



adam@positon:~\$

OS: Ubuntu 20.04
Terminal Emulator: Terminator
Shell: BASH

This screenshot shows a terminal window on an Ubuntu 20.04 system. The window title is 'adam@positon:~\$'. The terminal shows the user 'adam' is connected to a host named 'positon'. The prompt is 'adam@positon:~\$'. The text 'OS: Ubuntu 20.04' is displayed below the terminal window.



MINGW64:/c/Users/Adam

Adam@Teaching MINGW64 ~

\$

OS: Windows 11
Terminal Emulator: MinTTY
Shell: Git-BASH

This screenshot shows a terminal window on a Windows 11 system. The window title is 'MINGW64:/c/Users/Adam'. The terminal shows the user 'Adam' is connected to a host named 'Teaching'. The prompt is 'Adam@Teaching MINGW64 ~'. The text 'OS: Windows 11' is displayed below the terminal window.

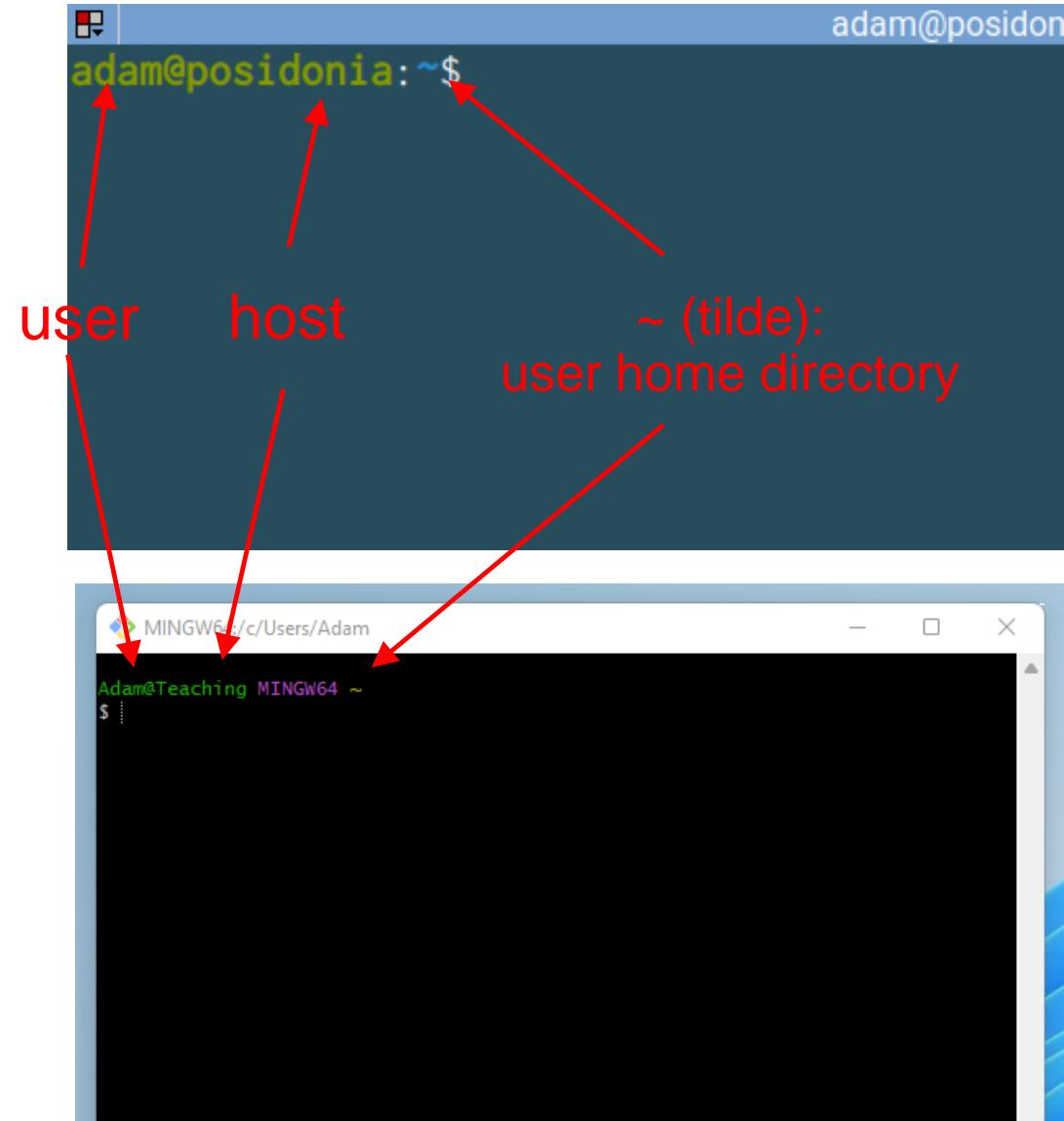
The prompt

- User input expected (typing)
- Looks different on all, but there are conventions:

user@host

~: is shorthand for user home

\$: means normal user mode



pwd

Return path to current directory

```
adam@positonia: ~ 50x28
adam@positonia: ~$ pwd
/home/adam
adam@positonia: ~$
```

`mkdir <name>`



space

Create a directory

- No output to the console: no error occurred (directory was created)



```
adam@positonia: ~ 50x28
adam@positonia: ~$ mkdir my_dir
adam@positonia: ~$
```

ls

List directory contents

- Returns a list of entries (both normal files and directories) – can be colored
- Note the quotes around entries with spaces in them!



```
adam@positonia: ~ 50x28
adam@positonia:~$ ls
01-network-manager-all.yaml      Programs
1_linktags.sh                    Public
Desktop                          random.conf
Documents                         report
Downloads                         snap
Edraw                            some.df
exercises                         Templates
gems                             temp.mbsync
Mail                             Videos
Music                            virtual
my_dir                           'VirtualBox VMs'
'NVIDIA Nsight Systems'          zen.json
Pictures                         Zotero
adam@positonia:~$
```

```
ls [-l]
```

List directory contents (with option l)

- Long output, includes attributes

d:directory

permissions

owner

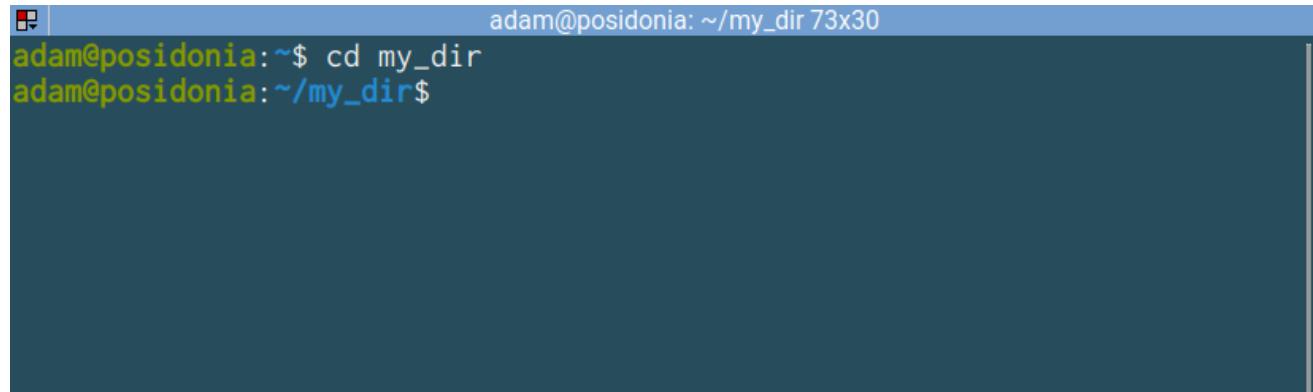
size (bytes) modification name

```
adam@positonia:~$ ls -l
total 112
-rw-r--r-- 1 adam adam 104 Sep 2 2020 01-network-manager-all.yaml
-rw-r--r-- 1 adam adam 224 Jul 2 13:34 1_linktags.sh
drwxr-xr-x 3 adam adam 4096 Jul 29 19:58 Desktop
drwxrwxr-x 2 adam adam 4096 Dez 16 2021 Documents
drwxr-xr-x 5 adam adam 16384 Aug 19 12:00 Downloads
drwxrwxr-x 3 adam adam 4096 Sep 5 2020 Edraw
drwxrwxr-x 3 adam adam 4096 Okt 14 2021 exercises
drwxrwxr-x 10 adam adam 4096 Aug 15 14:40 gems
drwxrwxr-x 7 adam adam 4096 Jan 24 2022 Mail
drwxr-xr-x 2 adam adam 4096 Sep 1 2020 Music
drwxrwxr-x 2 adam adam 4096 Aug 19 16:09 my_dir
drwxrwxr-x 2 adam adam 4096 Apr 21 15:34 'NVIDIA Nsight Systems'
drwxr-xr-x 2 adam adam 4096 Sep 1 2020 Pictures
drwxrwxr-x 4 adam adam 4096 Apr 28 2021 Programs
drwxr-xr-x 2 adam adam 4096 Sep 1 2020 Public
-rw-rw-r-- 1 adam adam 9 Aug 17 17:39 random.conf
drwxrwxr-x 3 adam adam 4096 Jun 2 12:36 report
drwx----- 5 adam adam 4096 Jun 4 2021 snap
drwxr-xr-x 2 adam adam 4096 Okt 23 2020 some.df
drwxr-xr-x 2 adam adam 4096 Sep 1 2020 Templates
-rw-rw-r-- 1 adam adam 0 Jan 24 2022 temp.mbsync
drwxr-xr-x 3 adam adam 4096 Mai 16 16:07 Videos
drwxrwxr-x 3 adam adam 4096 Jan 25 2019 virtual
drwxrwxr-x 5 adam adam 4096 Mai 30 10:38 'VirtualBox VMs'
-rw-rw-r-- 1 adam adam 154 Mär 16 13:11 zen.json
drwxr-xr-x 9 adam adam 4096 Aug 18 22:36 Zotero
adam@positonia:~$
```

```
cd <path_to_directory>
```

Go to a directory

- Can be relative or absolute!



```
adam@positonia: ~/my_dir 73x30
adam@positonia:~$ cd my_dir
adam@positonia:~/my_dir$
```

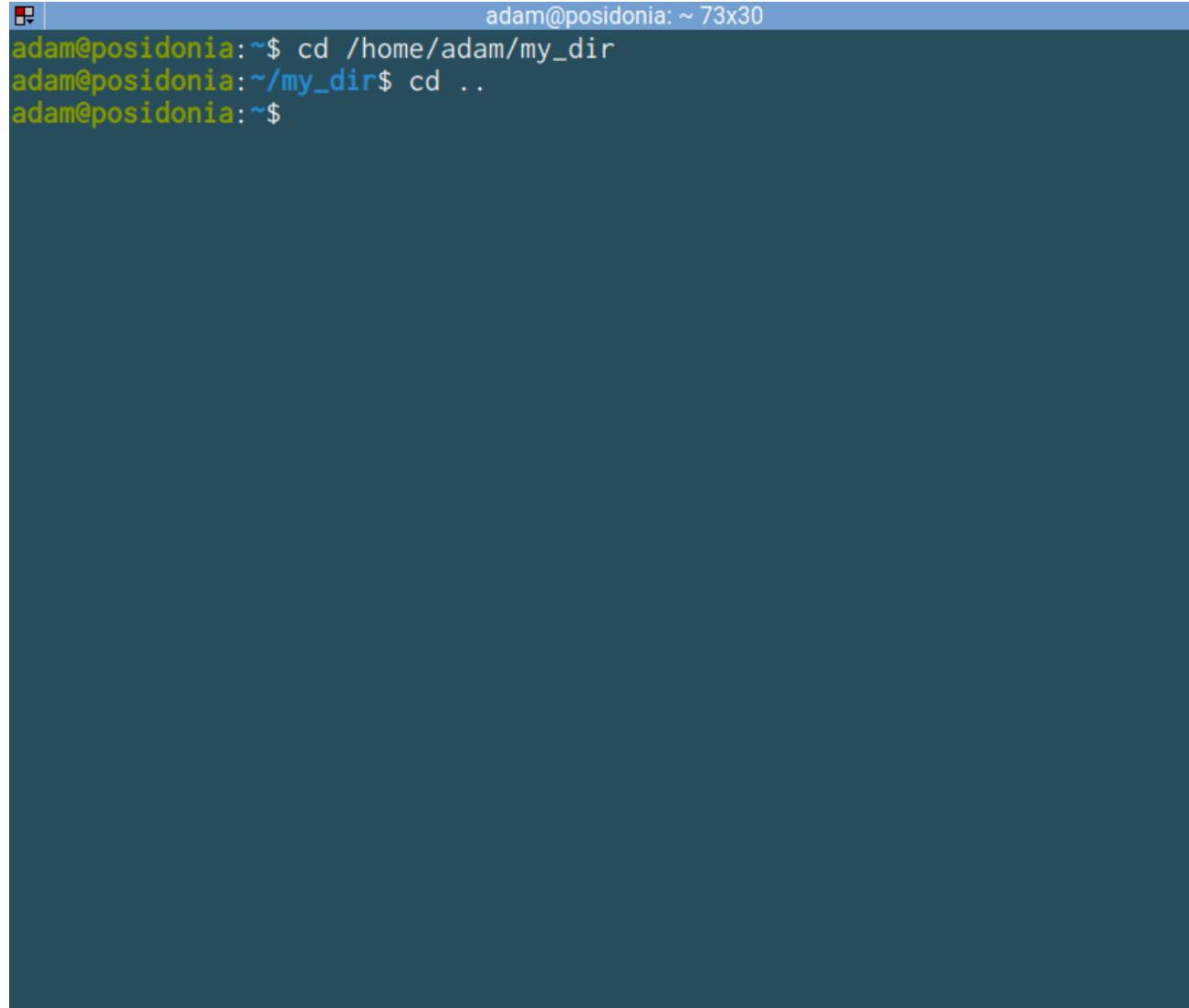


```
adam@positonia: ~/my_dir 73x30
adam@positonia:~$ cd /home/adam/my_dir
adam@positonia:~/my_dir$
```

cd ..

Go to parent directory

- .. (dot dot) is a placeholder for the parent of the current directory (one up in the hierarchy)



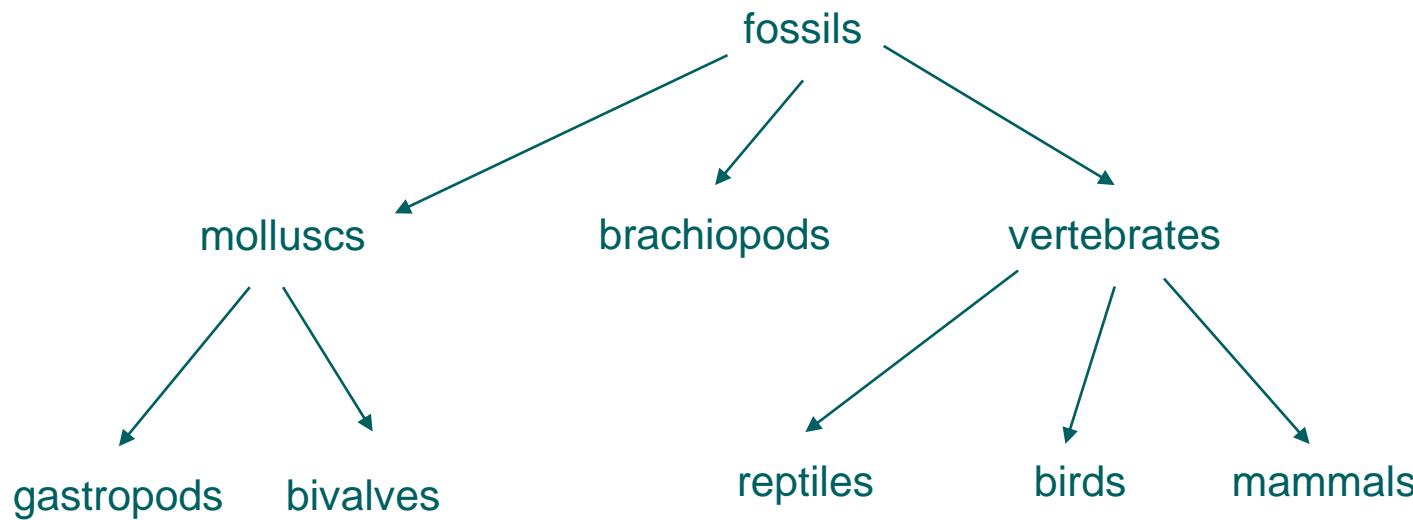
A screenshot of a terminal window titled 'adam@posidonia: ~ 73x30'. The window shows the following command sequence:

```
adam@posidonia:~$ cd /home/adam/my_dir
adam@posidonia:~/my_dir$ cd ..
adam@posidonia:~$
```

The terminal has a dark blue background with light blue text for the command and a dark grey background for the prompt. The window title is in white text at the top.

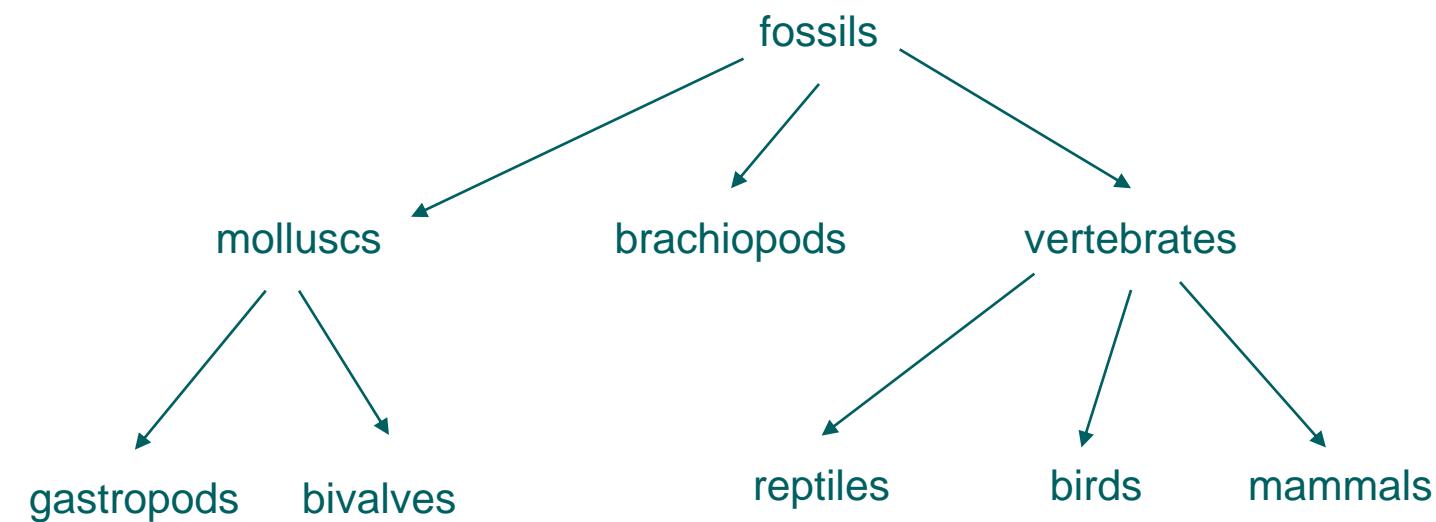
Exercise (5 minutes)

- Create this directory structure using the combinations of the previous commands!



Exercise (5 minutes)

- Create this directory structure using the combinations of the previous commands!

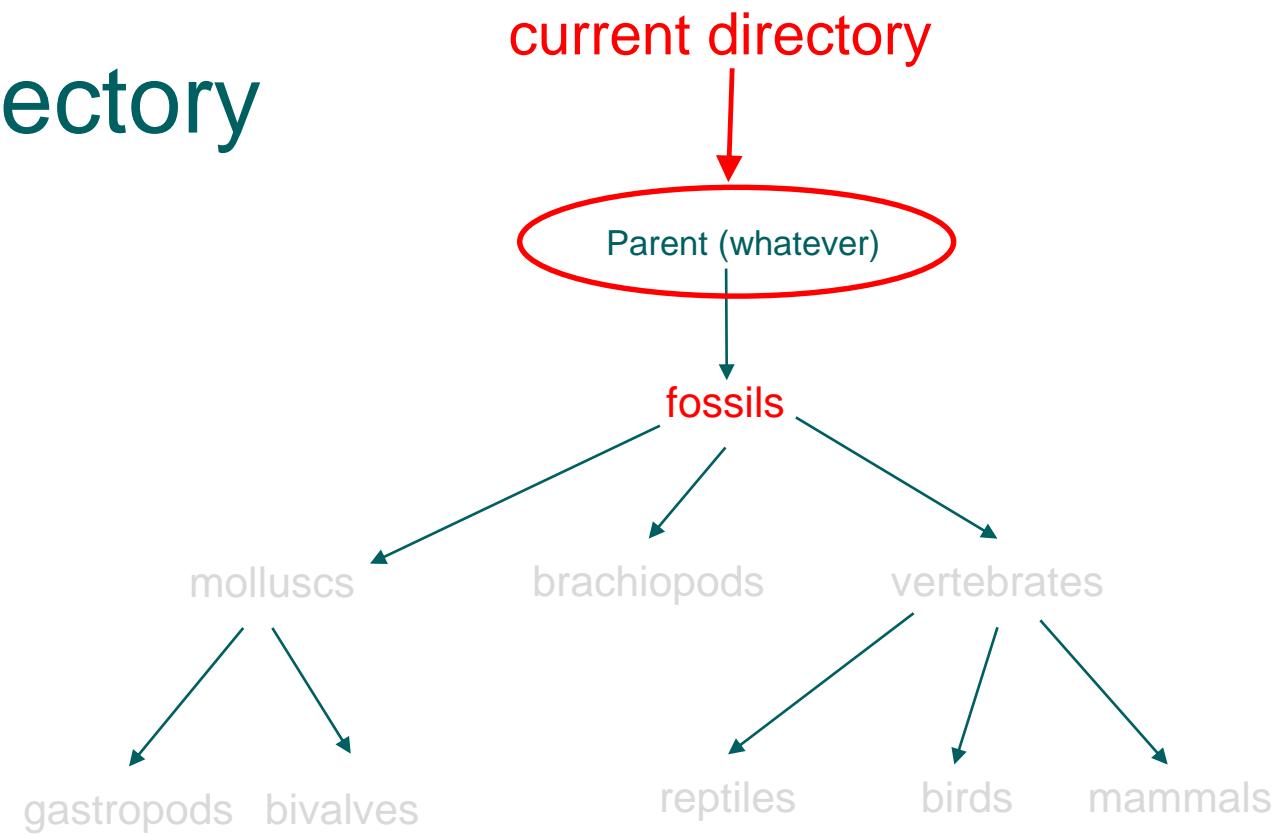


Hints

- use <TAB> completion (try <TAB> <TAB> to see multiple solutions)
- use <UP> and <DOWN> to search command history for already given commands

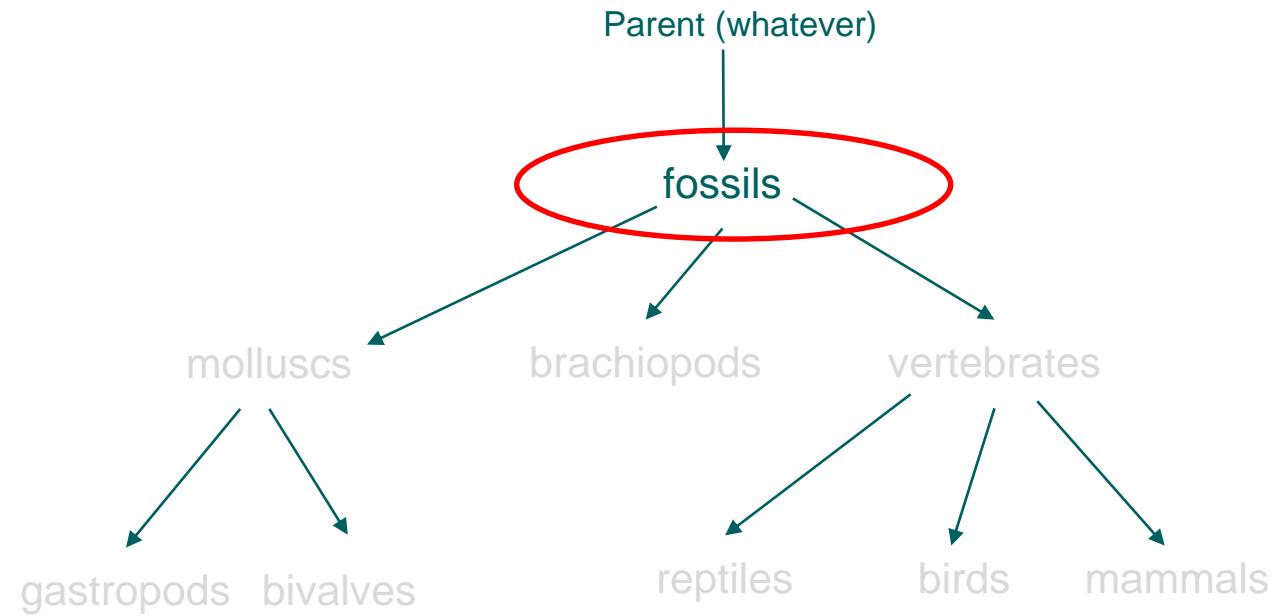
Solution 1 – changing directory

```
adam@posidonia:~/fossils/vertebrates 73x30
adam@posidonia:~$ mkdir fossils
adam@posidonia:~$ cd fossils
adam@posidonia:~/fossils$ mkdir molluscs
adam@posidonia:~/fossils$ mkdir brachiopods vertebrates
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adam@posidonia:~/fossils/molluscs$ mkdir gastropods bivalves
adam@posidonia:~/fossils/molluscs$ cd ..
adam@posidonia:~/fossils$ cd vertebrates
adam@posidonia:~/fossils/vertebrates$ mkdir reptiles birds mammals
adam@posidonia:~/fossils/vertebrates$
```



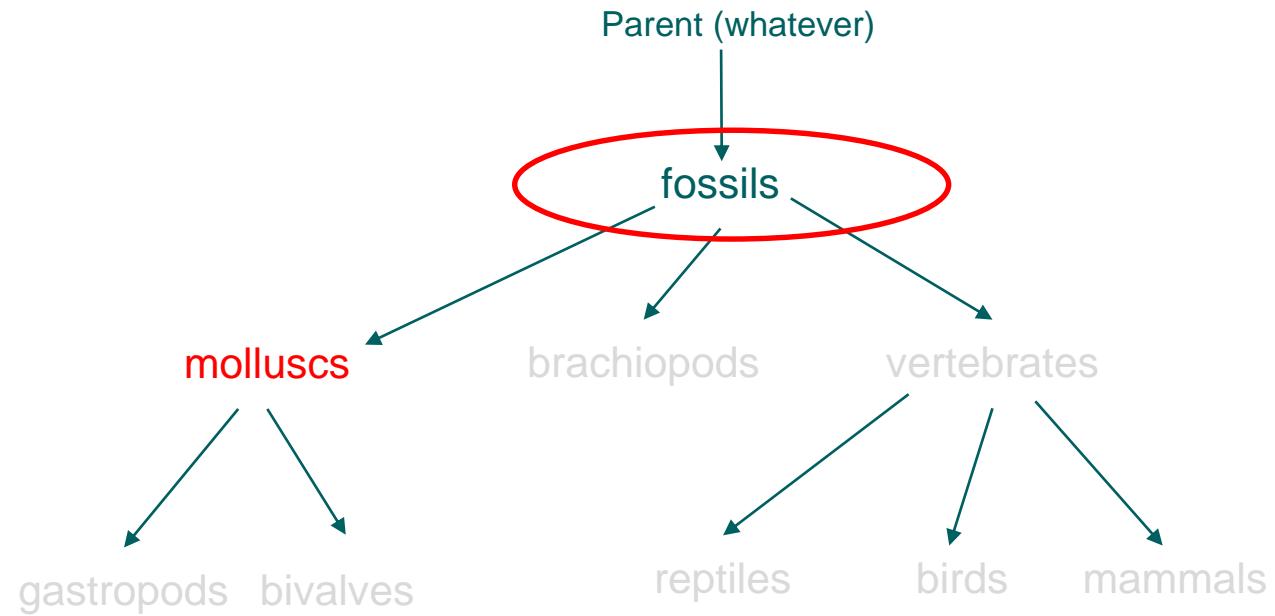
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```



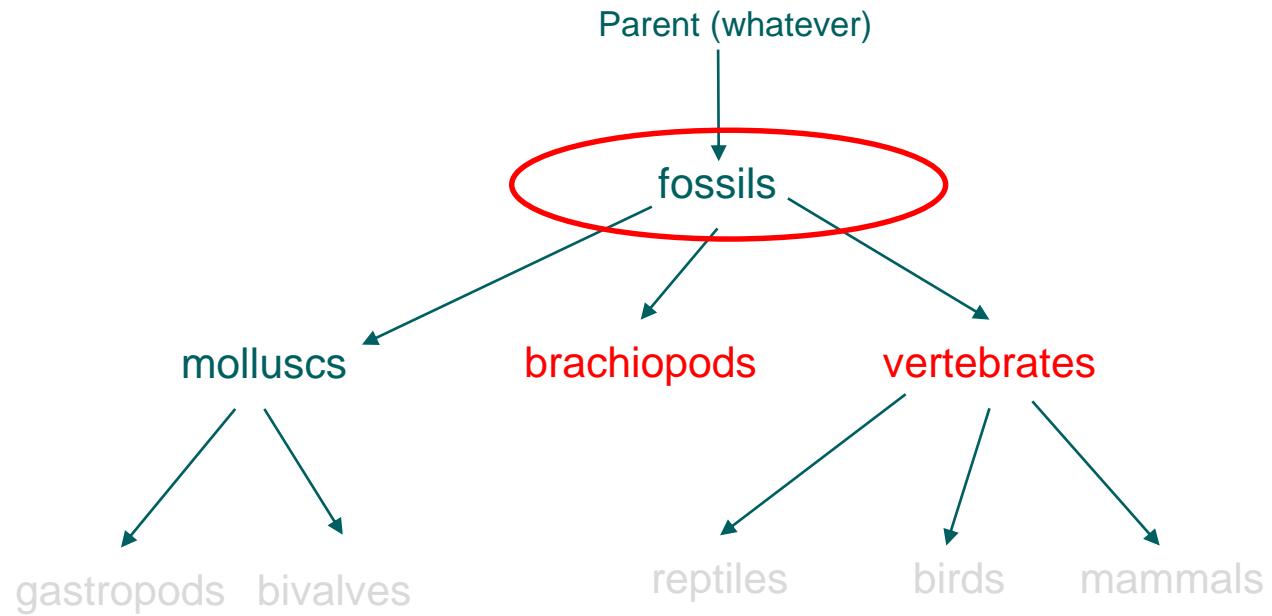
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adam@posidonia:~/fossils/vertebrates$
```



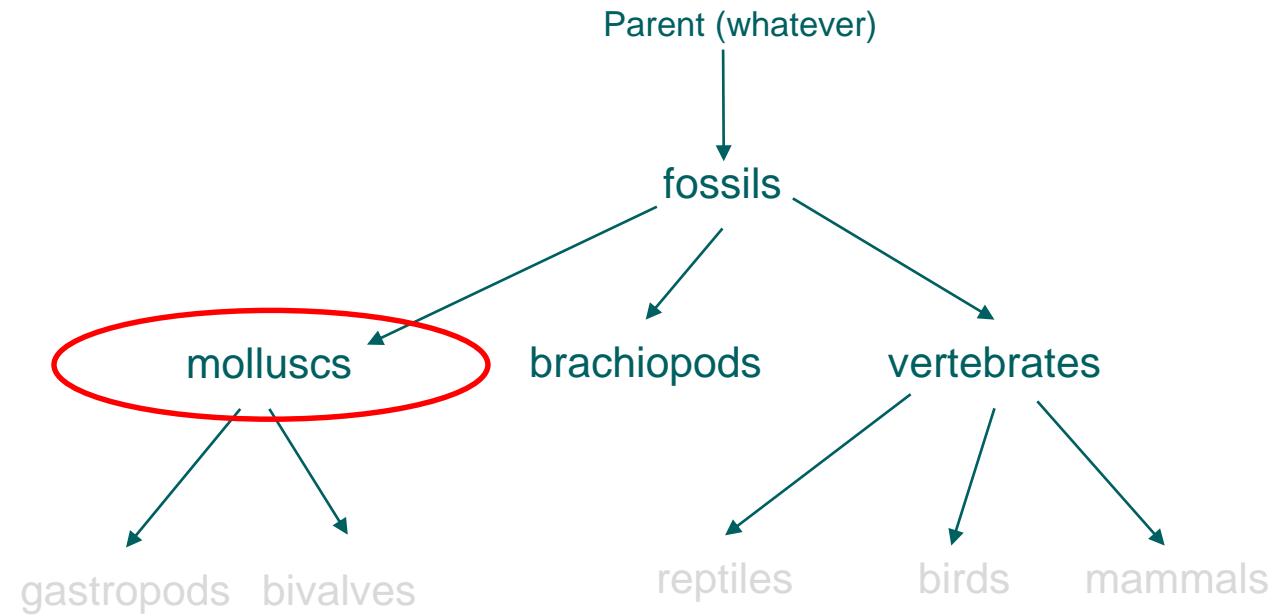
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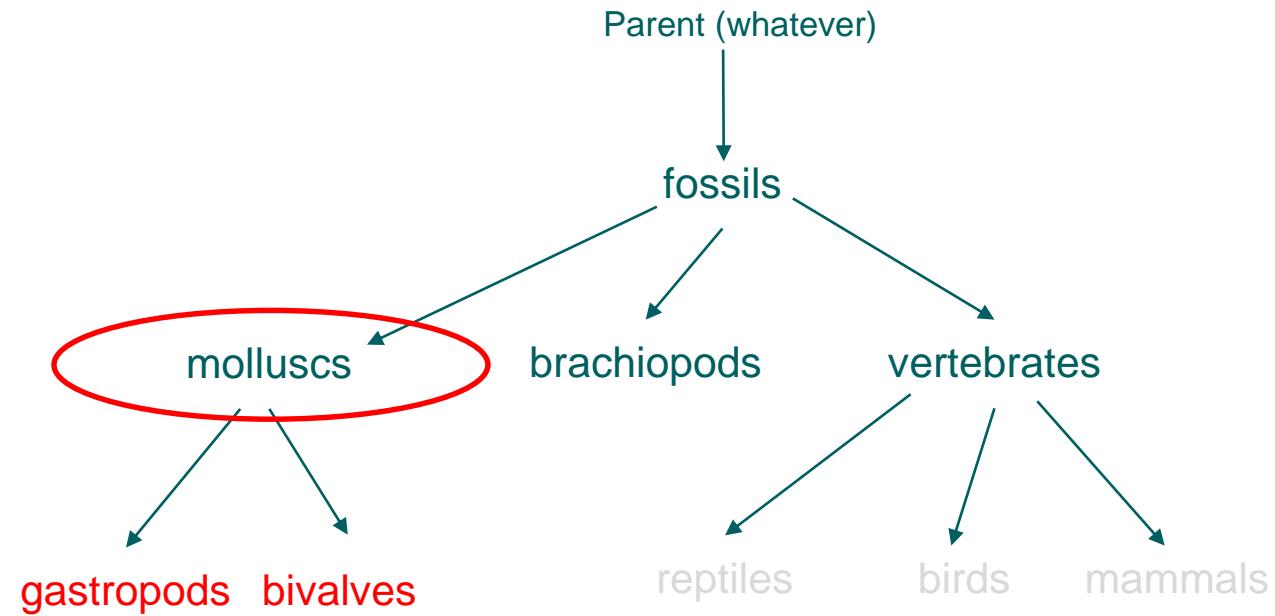
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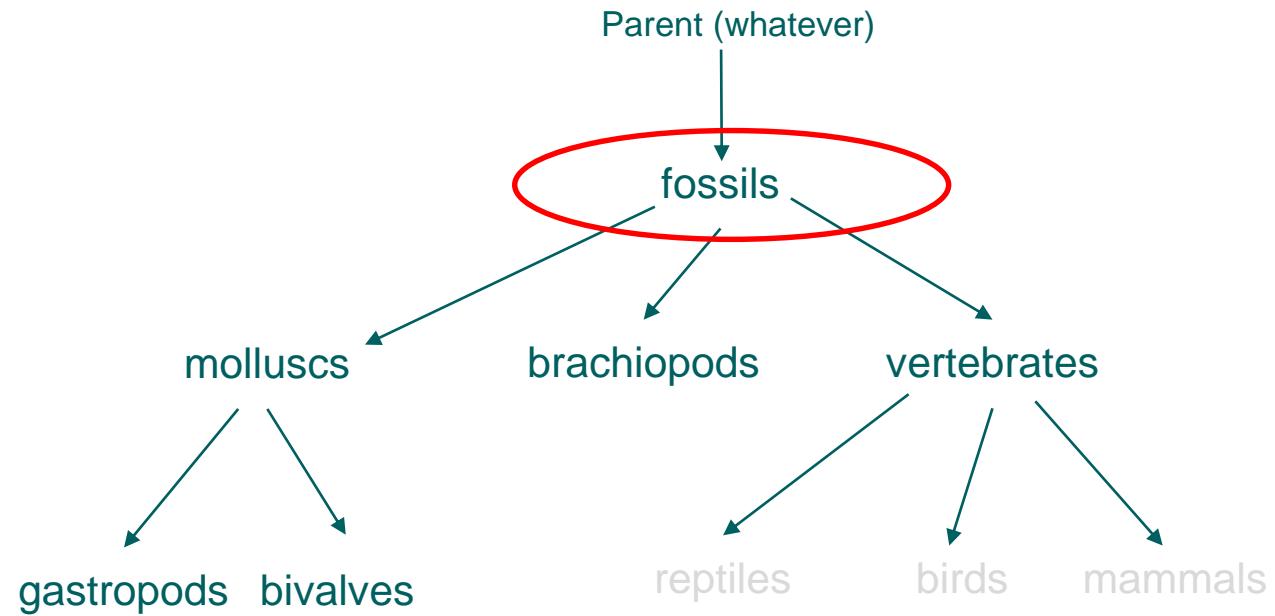
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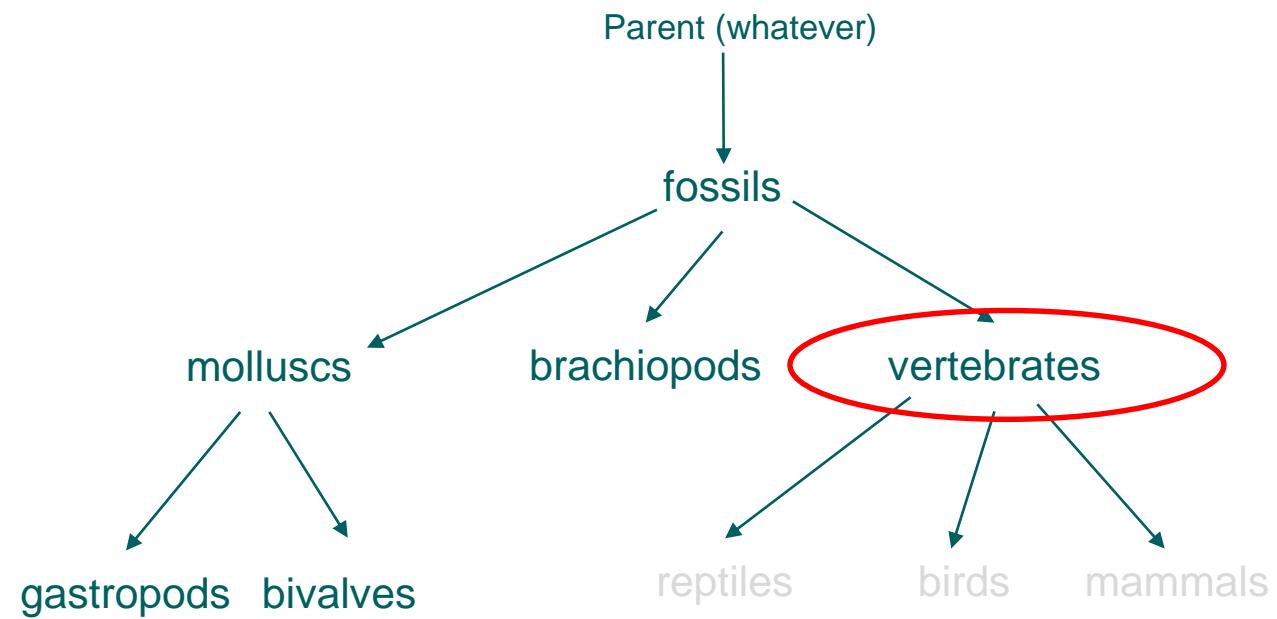
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```



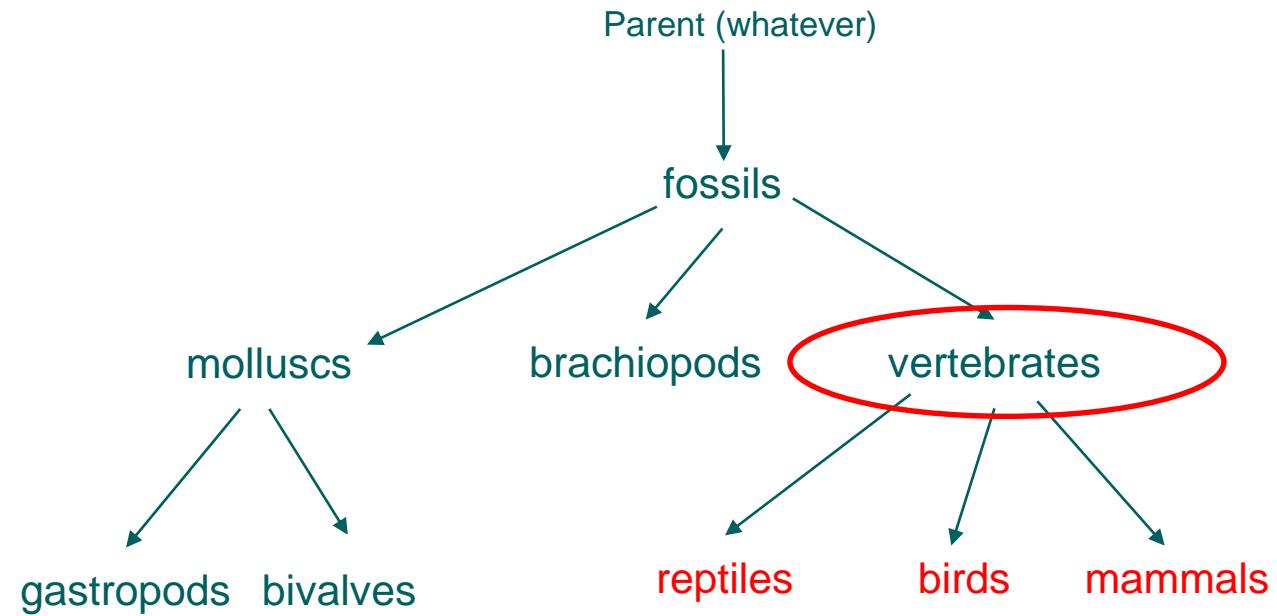
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```



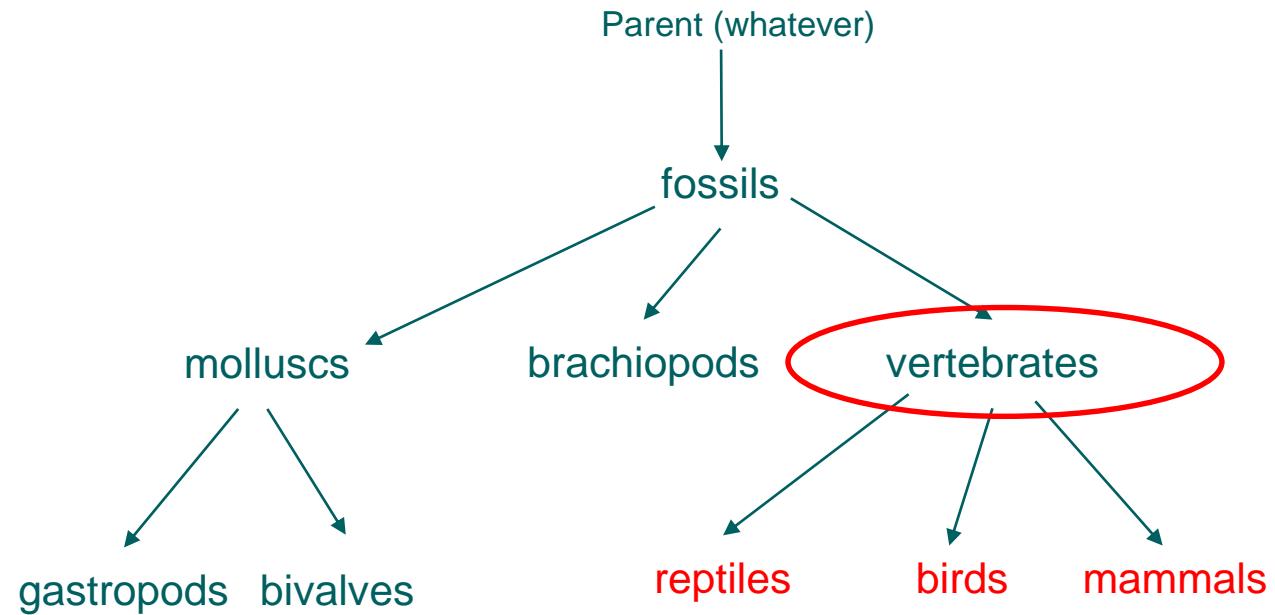
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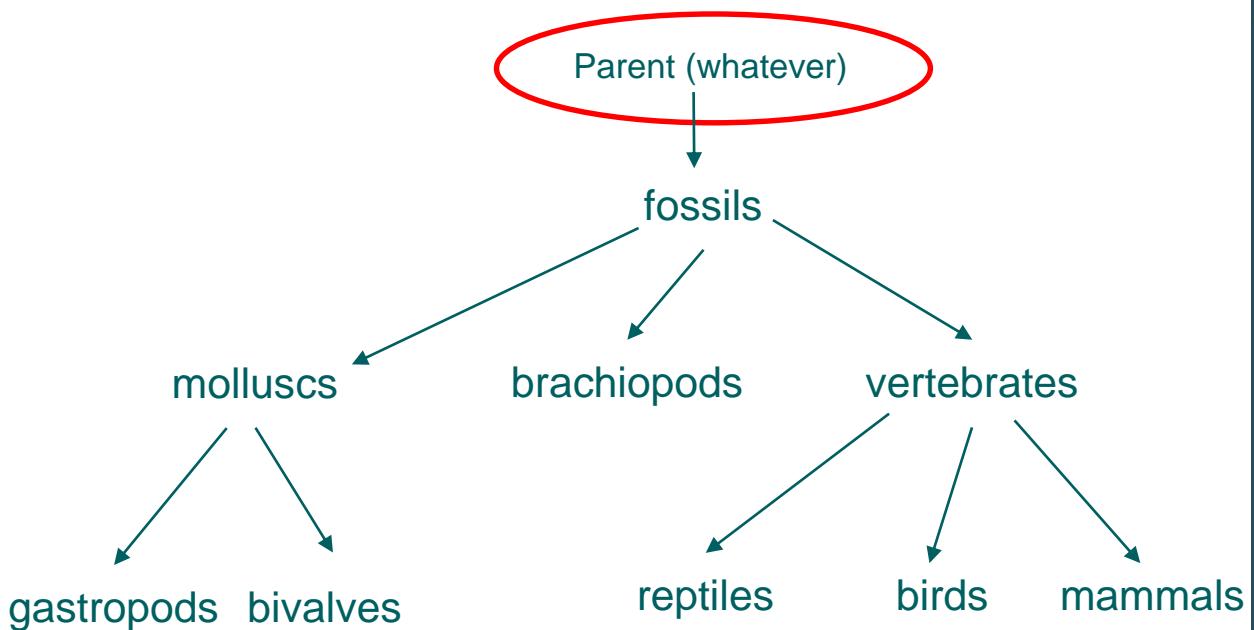


How to check?

find_<path to directory>

Recursive listing

- 1. Go back to the parent
- 2. Use find there!



```
adam@posidonia: ~/fossils/vertebrates$ cd ../../
adam@posidonia:~/fossils$ find fossils
fossils
fossils/molluscs
fossils/molluscs/gastropods
fossils/molluscs/bivalves
fossils;brachiopods
fossils/vertebrates
fossils/vertebrates/reptiles
fossils/vertebrates/birds
fossils/vertebrates/mammals
adam@posidonia:~$
```

parent of parent

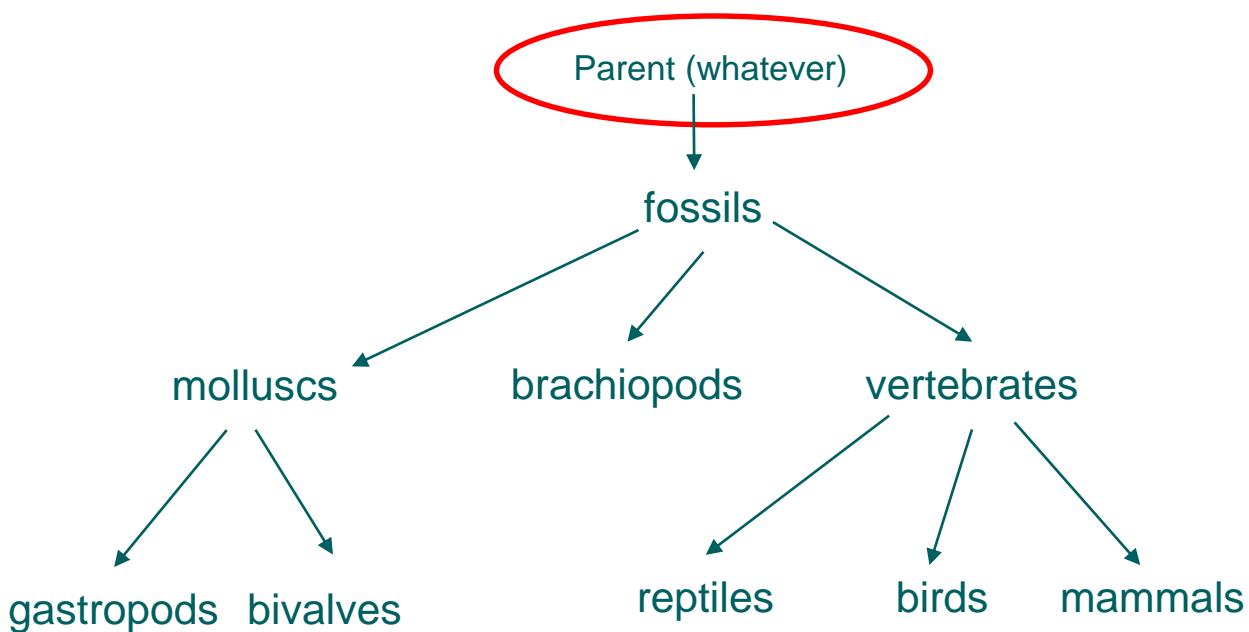
relative paths

Angled bracket or *chevron*

```
find_<path>_<path_to file>
```

Output redirection

- Whatever was output to the console is now in a new file!



```
adam@posidonia: ~/fossils/vertebrates$ cd ../..
adam@posidonia:~$ find fossils
fossils
fossils/molluscs
fossils/molluscs/gastropods
fossils/molluscs/bivalves
fossils;brachiopods
fossils/vertebrates
fossils/vertebrates/reptiles
fossils/vertebrates/birds
fossils/vertebrates/mammals
adam@posidonia:~$ find fossils > fossil_path.txt
adam@posidonia:~$
```

“>” Will overwrite existing files!

Suggested nomenclature

() : **Parenthesis** (open and close)

[] : **Bracket** (open and close)

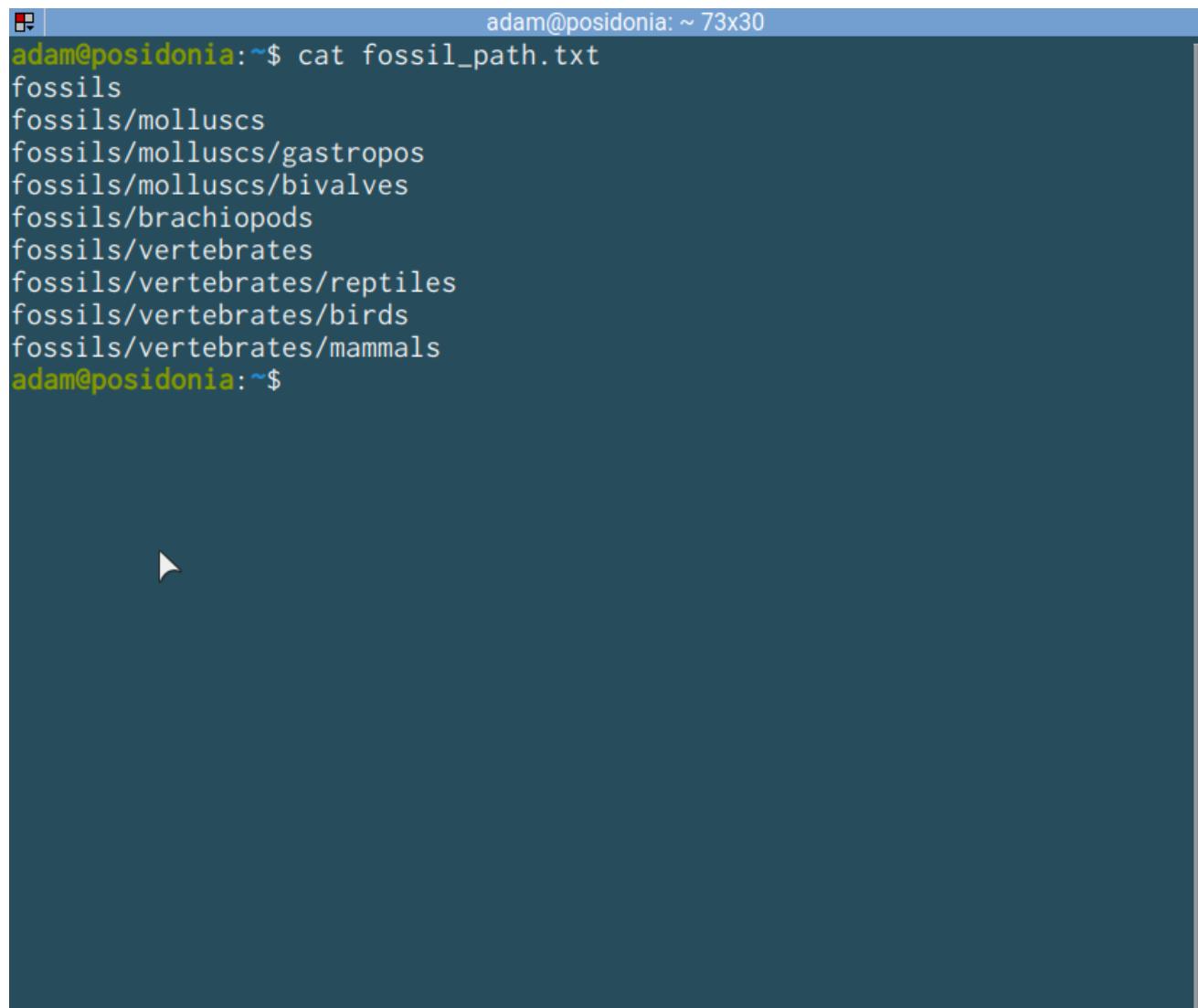
{ } : **Brace** (open and close)

< > : **Chevrons** (left and right)

cat [<path to file>]

Display contents of file

- Exactly as it was output to the console



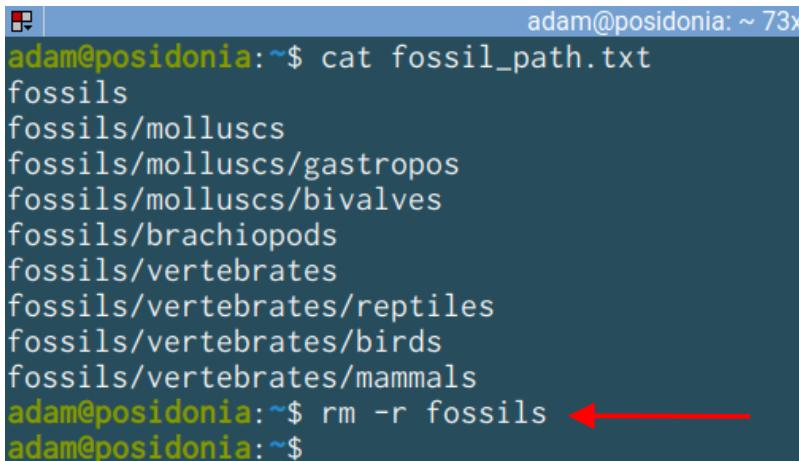
adam@posidonia: ~ 73x30

```
adam@posidonia:~$ cat fossil_path.txt
fossils
fossils/molluscs
fossils/molluscs/gastropods
fossils/molluscs/bivalves
fossils/brachiopods
fossils/vertebrates
fossils/vertebrates/reptiles
fossils/vertebrates/birds
fossils/vertebrates/mammals
adam@posidonia:~$
```

`rm [-r] <path to dir>`

Recursive deletion (-r)

- Deletes the content of the directory and the directory itself
- rmdir doesn't work! for the
- No output = success?!



```
adam@posidonia:~$ cat fossil_path.txt
fossils
fossils/molluscs
fossils/molluscs/gastropos
fossils/molluscs/bivalves
fossils/brachiopods
fossils/vertebrates
fossils/vertebrates/reptiles
fossils/vertebrates/birds
fossils/vertebrates/mammals
adam@posidonia:~$ rm -r fossils ←
adam@posidonia:~$
```

WARNING!
The results of rm
cannot be undone!

echo [<text>]

Print something

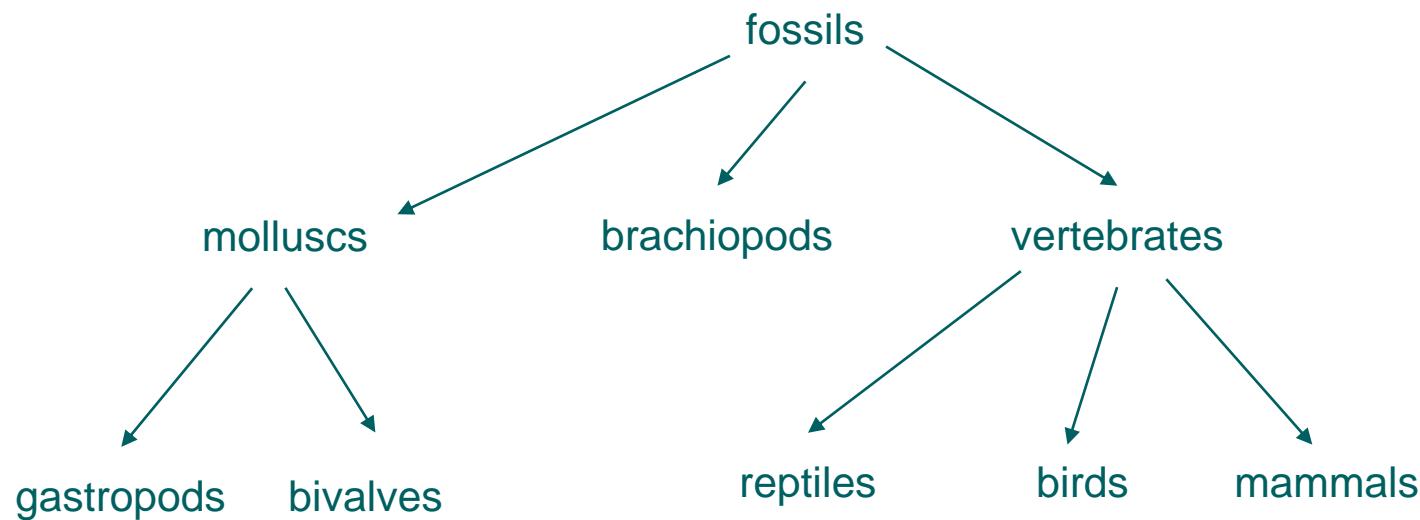
- Used to print things to the console (standard output)
- \$? Is a special symbol: the exit code of the last command:
 - 0: Success
 - Other: Failure

<https://www.redhat.com/sysadmin/exit-codes-demystified>

```
adam@positonia: ~$ cat fossil_path.txt
fossils
fossils/molluscs
fossils/molluscs/gastropos
fossils/molluscs/bivalves
fossils;brachiopods
fossils/vertebrates
fossils/vertebrates/reptiles
fossils/vertebrates/birds
fossils/vertebrates/mammals
adam@positonia: ~$ rm -r fossils
adam@positonia: ~$ echo $? ←
0
adam@positonia: ~$
```

Recreate the structure!

- Did you type things into the console?!



Hint 1. Use a general-purpose text editor!

Novice-friendly:

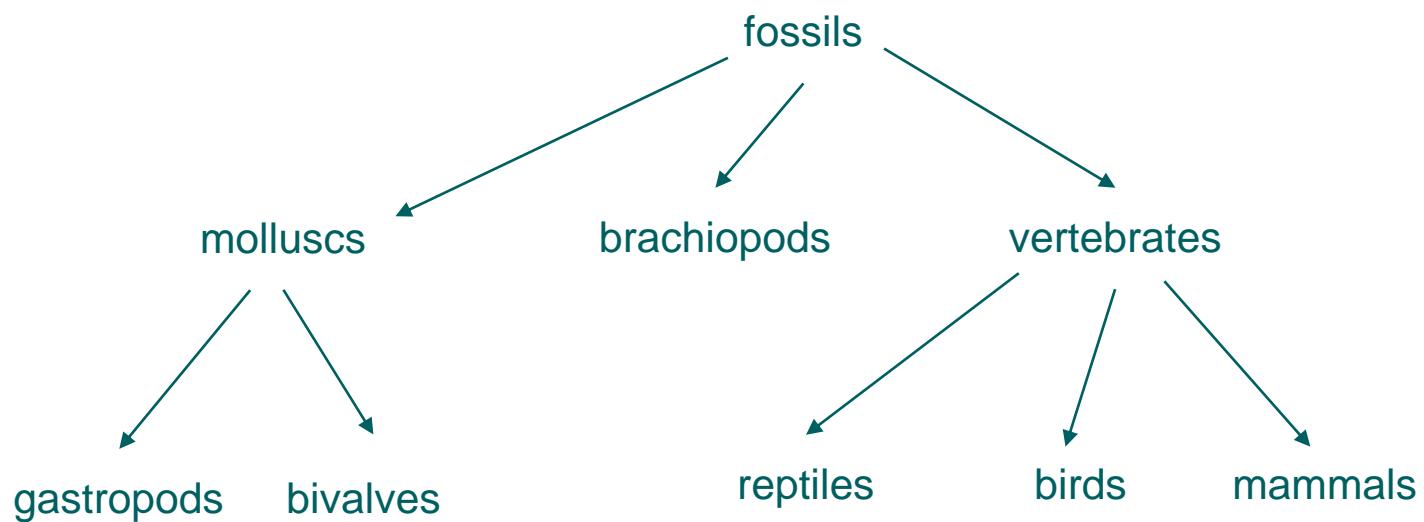
- Sublime Text 
- VS Code 
- Atom 

Expert-friendly:

- Vim 
- Emacs 

Solution 2

- Using the same reference directory



Hint 2. we can use the contents of fossil_path.txt

Add `mkdir` in front of every line, then copy and paste into the console!

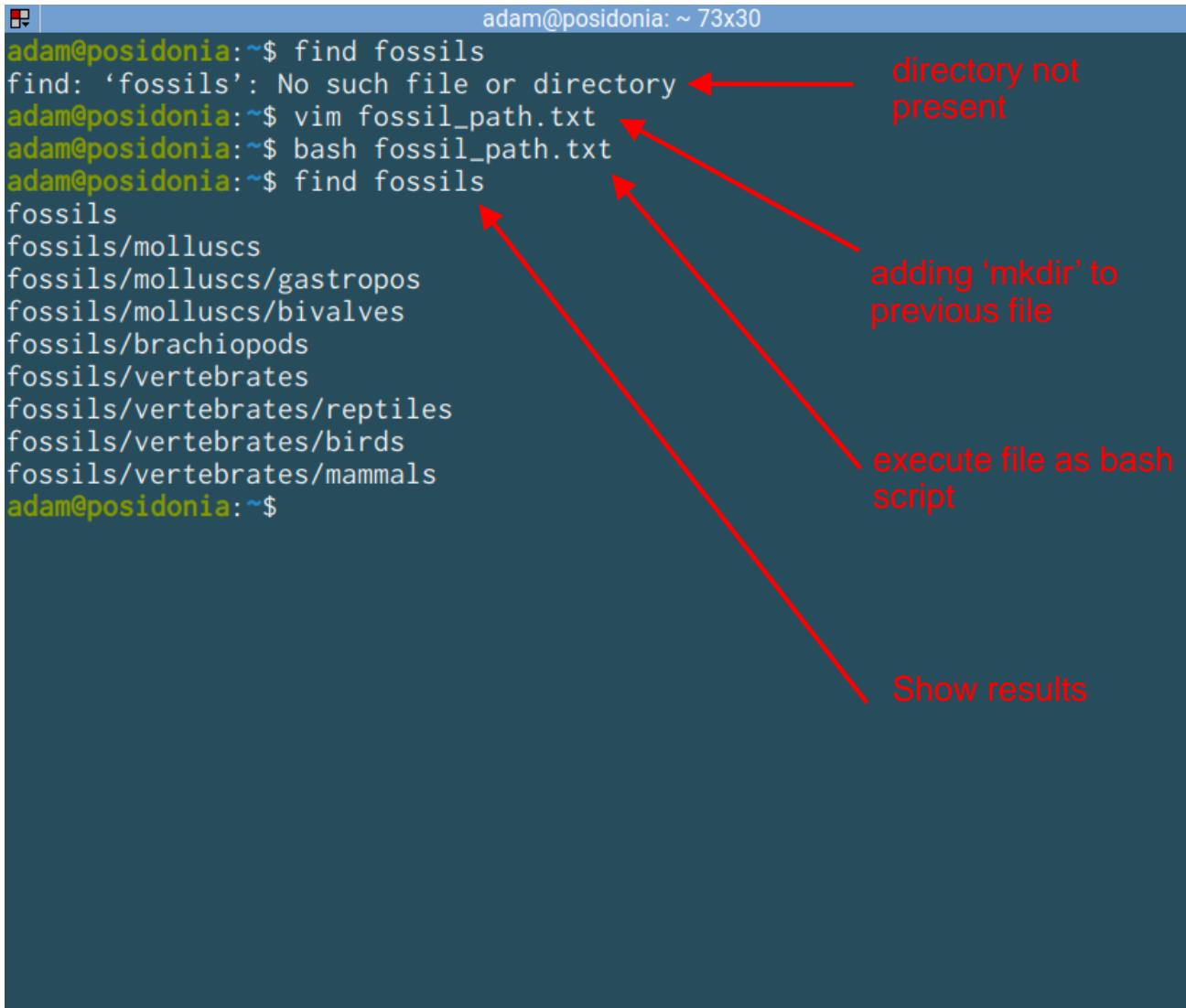
```
1 mkdir fossils
2 mkdir fossils/molluscs
3 mkdir fossils/molluscs/gastropods
4 mkdir fossils/molluscs/bivalves
5 mkdir fossils/brachiopods
6 mkdir fossils/vertebrates
7 mkdir fossils/vertebrates/reptiles
8 mkdir fossils/vertebrates/birds
9 mkdir fossils/vertebrates/mammals
```

bash_<path>

Executing shell scripts

- The text we created is actually a shell script
- The “bash” console application program can be used to execute it.

<https://www.redhat.com/sysadmin/exit-codes-demystified>



```
adam@positonia:~$ find fossils
find: 'fossils': No such file or directory
adam@positonia:~$ vim fossil_path.txt
adam@positonia:~$ bash fossil_path.txt
adam@positonia:~$ find fossils
fossils
fossils/molluscs
fossils/molluscs/gastropos
fossils/molluscs/bivalves
fossils/brachiopods
fossils/vertebrates
fossils/vertebrates/reptiles
fossils/vertebrates/birds
fossils/vertebrates/mammals
adam@positonia:~$
```

bash --version

Running console applications

- **--version**: ask for program version
- **--help**: display help for program

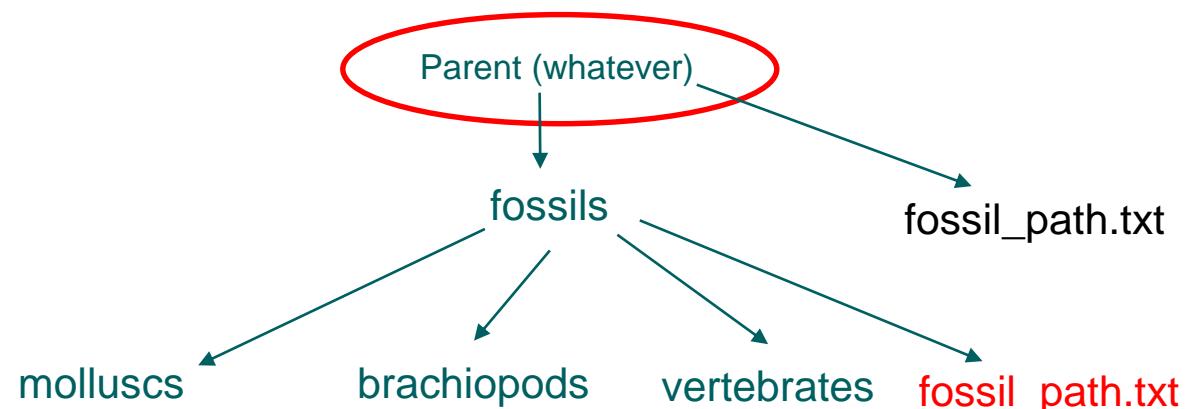
```
adam@positonia: ~ 73x30
adam@positonia:~$ bash --version
bash --version
GNU bash, version 5.0.17(1)-release (x86_64-pc-linux-gnu)
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tml>

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adam@positonia:~$
```

`cp_<what>_<where>`

Copying a file or directory

- Target directory or file
- If directory, the file will be put into it



```
adam@positonia: ~ 73x30
adam@positonia:~$ cp fossil_path.txt fossils
adam@positonia:~$ ls fossils
brachiopods  fossil_path.txt  molluscs  vertebrates
adam@positonia:~$
```

Red annotations on the screenshot:

- An arrow points to the 'fossil_path.txt' file in the 'ls' command output, with the text "New file".
- An arrow points to the 'molluscs' folder in the 'ls' command output, with the text "List contents of path!".

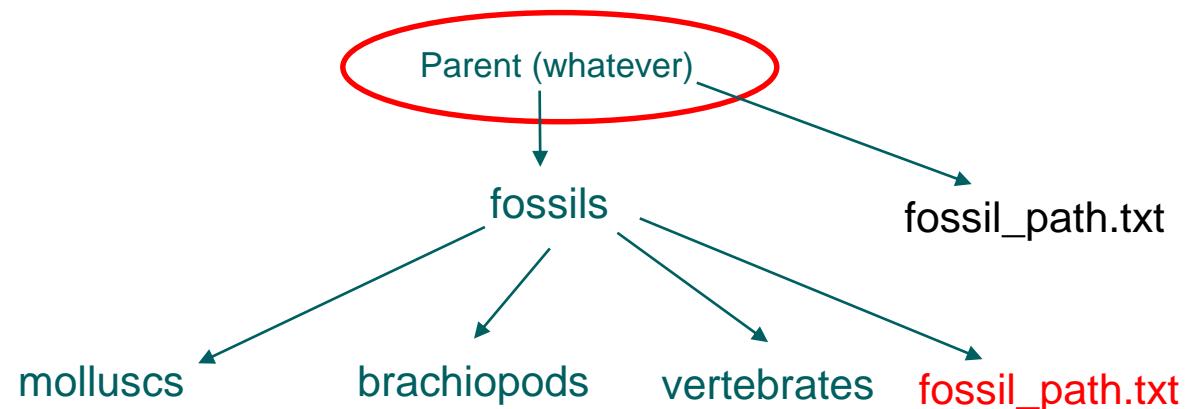
Red text at the bottom right of the screenshot:

One of the tools that we looked at can be used to delete the file that we have created. Try to delete it!

```
rm <path_file>
```

Without `-r` removes a single file

- As with `cp`, multiple files can be passed to this (separated by spaces)

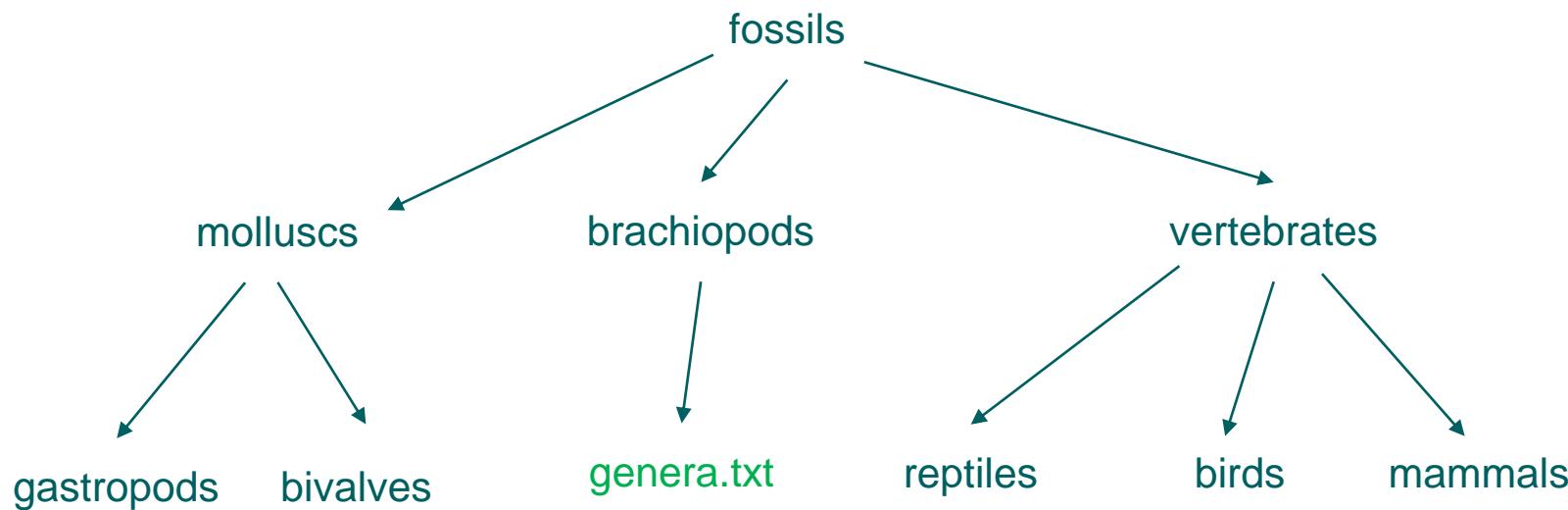


```
adam@posidonia:~$ cp fossil_path.txt fossils
adam@posidonia:~$ ls fossils
brachiopods fossil_path.txt molluscs vertebrates
adam@posidonia:~$ rm fossils/fossil_path.txt
adam@posidonia:~$ ls fossils
brachiopods molluscs vertebrates
adam@posidonia:~$
```

File disappeared

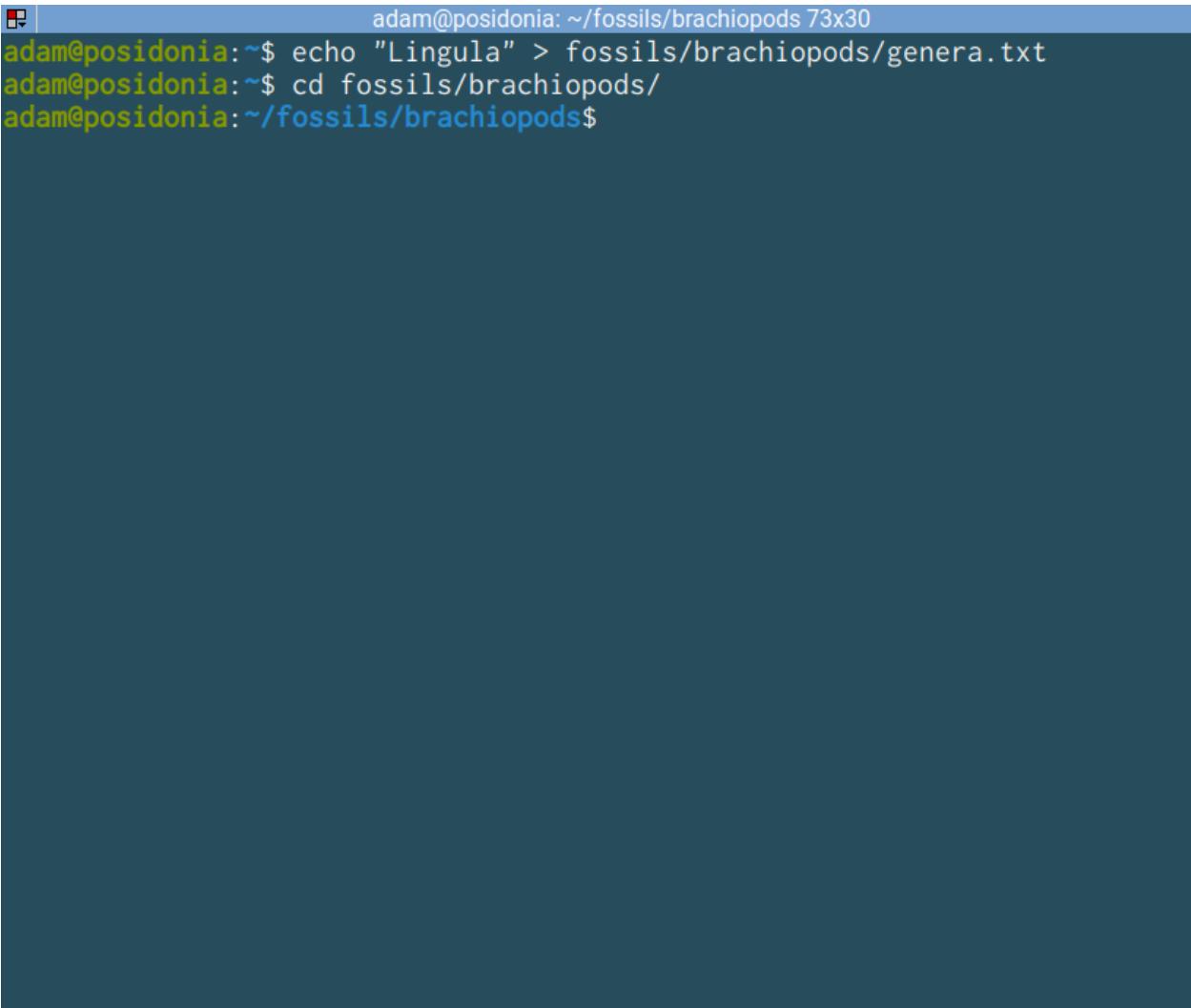
Exercise!

1. Use an echo statement to write the genus name “*Lingula*” into fossils/brachiopods/genera.txt!
2. Then change directory to brachiopods.



```
echo "Lingula" > fossils/brachiopods/genera.txt
```

- You can use the double chevron
 >> to append to an existing file



```
adam@positonia: ~/fossils/brachiopods 73x30
adam@positonia:~$ echo "Lingula" > fossils/brachiopods/genera.txt
adam@positonia:~$ cd fossils/brachiopods/
adam@positonia:~/fossils/brachiopods$
```

```
echo "Spiriferina" >> genera.txt
```

Appending to files

- You can use the double chevron
 `>>` to append to an existing file
- Added to new line!

```
adam@positonia: ~/fossils/brachiopods 73x30
adam@positonia:~$ echo "Lingula" > fossils/brachiopods/genera.txt
adam@positonia:~$ cd fossils/brachiopods/
adam@positonia:~/fossils/brachiopods$ echo "Spiriferina" >> genera.txt
adam@positonia:~/fossils/brachiopods$ cat genera.txt
Lingula
Spiriferina
adam@positonia:~/fossils/brachiopods$
```

Special characters

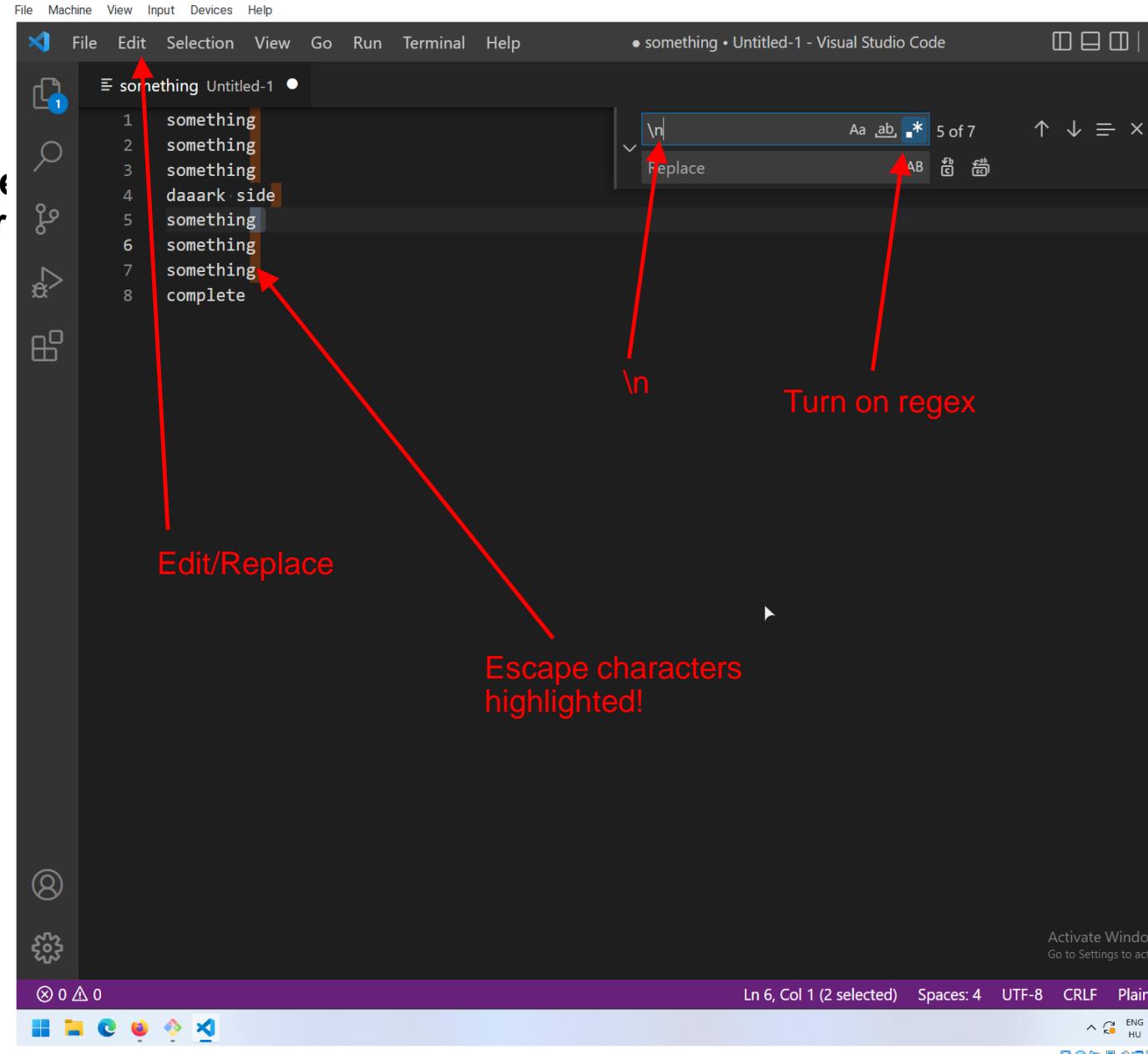
We use so called “escape characters to denote special symbols, that sometimes have other meanings.

\n: newline escape

\t : tab escape

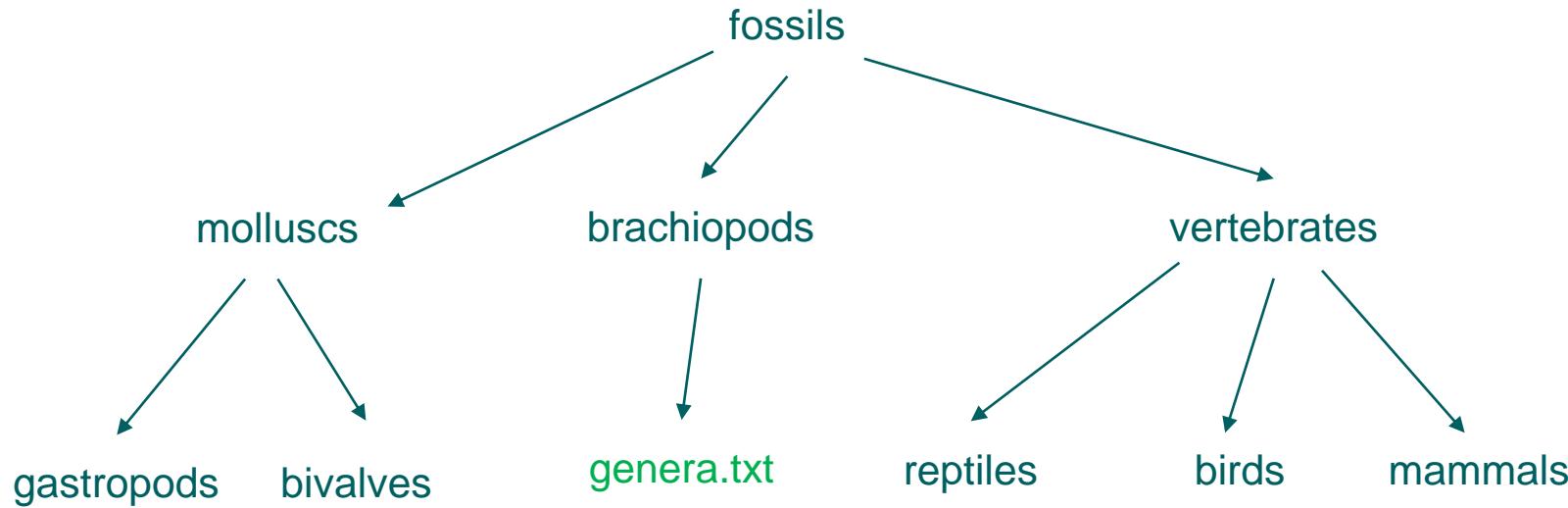
\" : double quote escape

\' : single quote escape



Exercise!

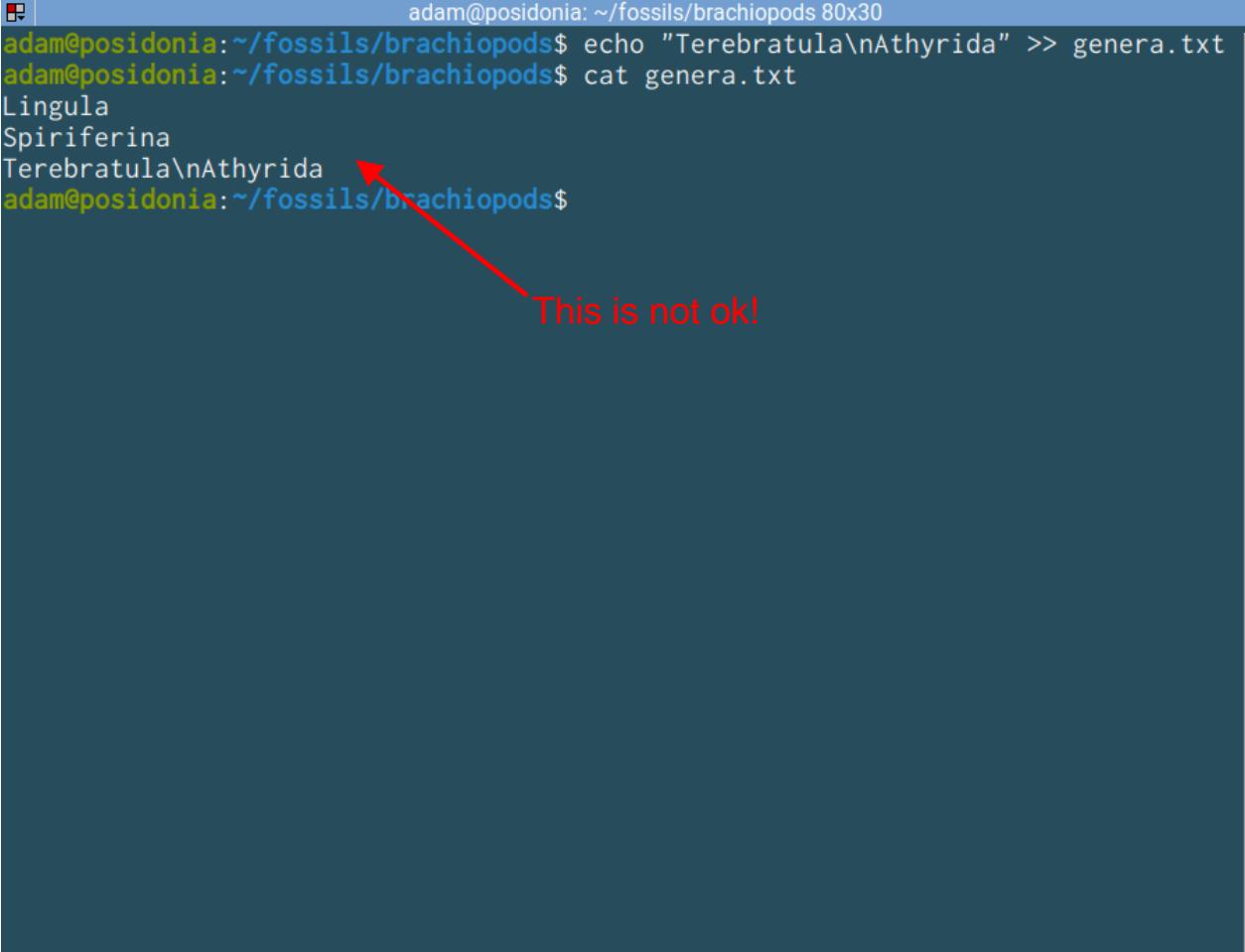
1. Use an echo statement to write the genus name “*Terebratula*” and “*Athyris*” into fossils/brachiopods/genera.txt, **use a newline escape between them!**
2. Then change directory to brachiopods.



```
echo "Terebratula\nAthyrida" >> genera.txt
```

Appending to files

- It doesn't seem to work!
- Echo needs to know to replace the combination `\n` with the newline character!



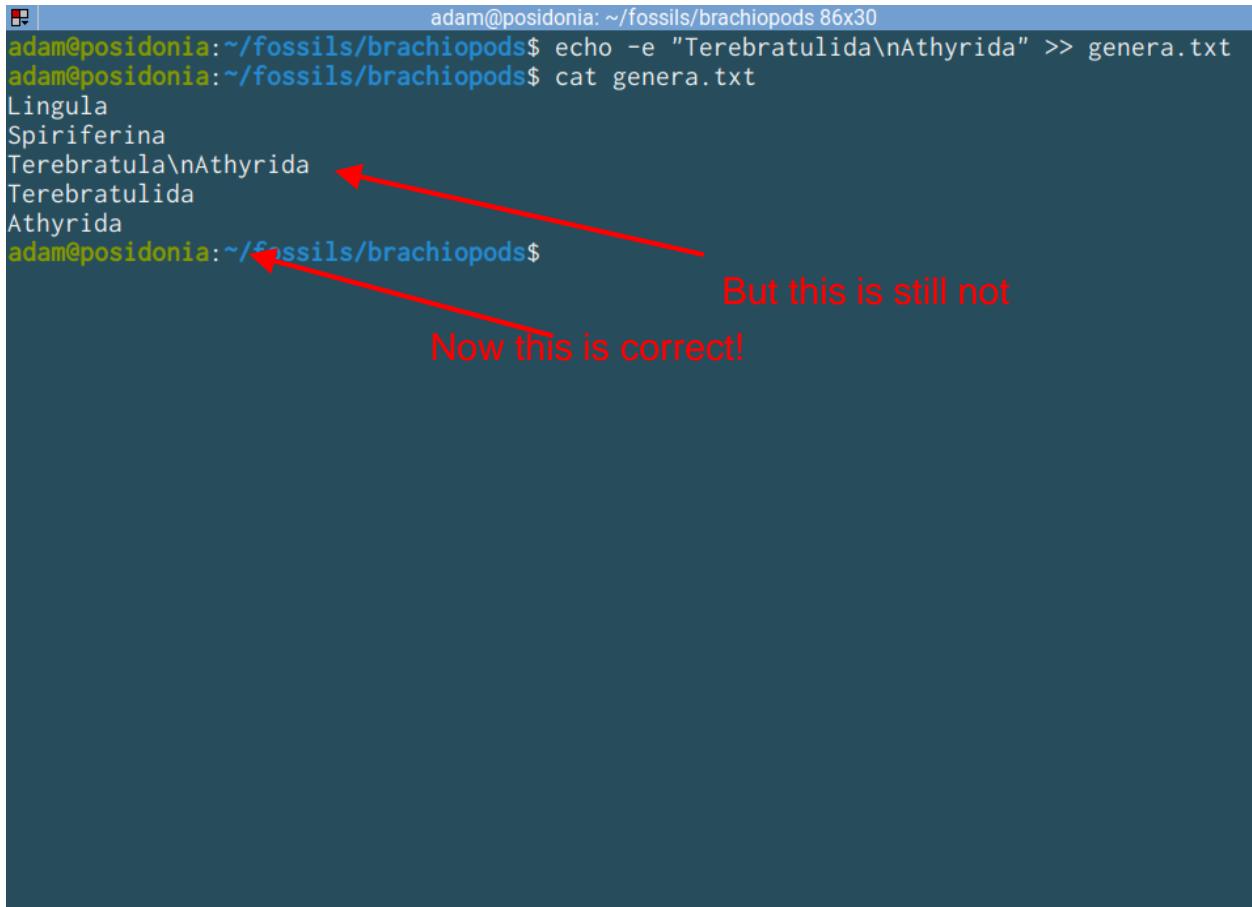
```
adam@positonia: ~/fossils/brachiopods 80x30
adam@positonia:~/fossils/brachiopods$ echo "Terebratula\nAthyrida" >> genera.txt
adam@positonia:~/fossils/brachiopods$ cat genera.txt
Lingula
Spiriferina
Terebratula\nAthyrida
adam@positonia:~/fossils/brachiopods$
```

This is not ok!

```
echo -e "Terebratula\nAthyrida" >> genera.txt
```

Appending to files

- Use the `-e` option!
- Our file is messed up. Options:
 - 1. Redo our file
 - 2. Use an editor to correct
- Delete the bad line!
- Better, next time: go back in time
e.g. use version control!



```
adam@positonia: ~/fossils/brachiopods 86x30
adam@positonia: ~/fossils/brachiopods$ echo -e "Terebratulida\nAthyrida" >> genera.txt
adam@positonia: ~/fossils/brachiopods$ cat genera.txt
Lingula
Spiriferina
Terebratula\nAthyrida
Terebratulida
Athyrida
adam@positonia: ~/fossils/brachiopods$
```

Now this is correct!

Joint Exercise

- Create the directory structure here!

