



BASH Essentials

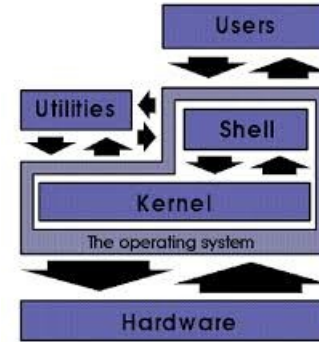
Ádám T. Kocsis

Friedrich-Alexander-Universität Erlangen-Nürnberg

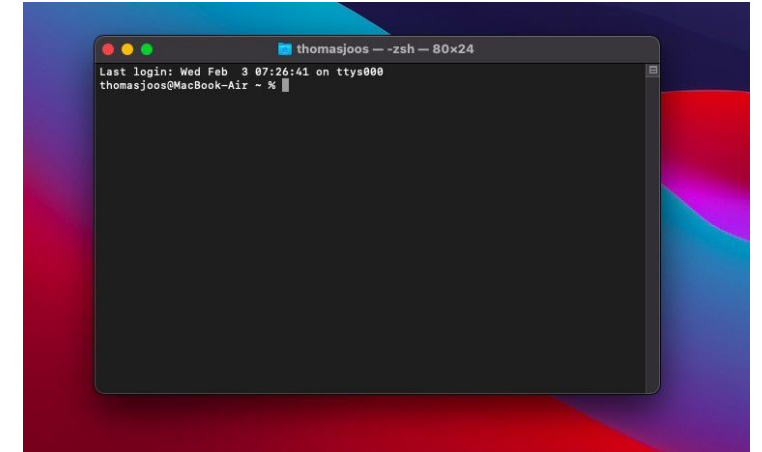
2023-10-09

Terminal emulators

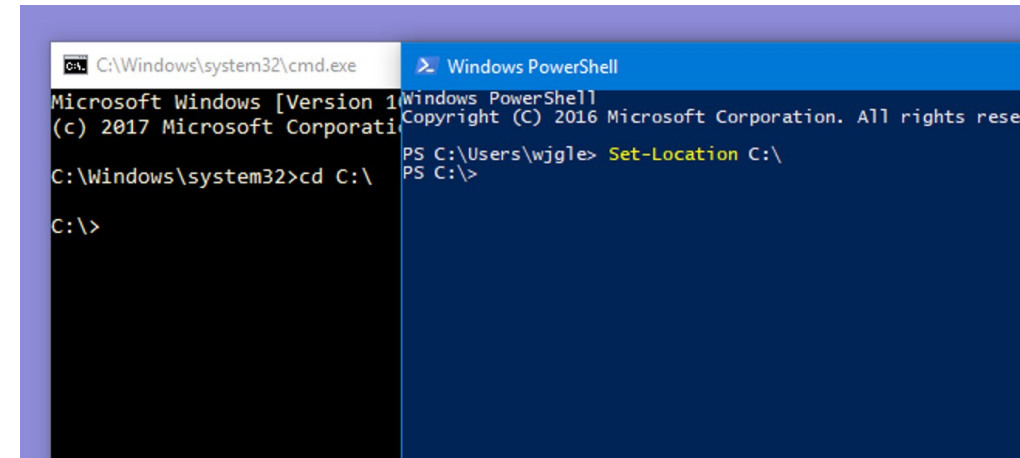
- Every OS has at least one
- Graphical applications that run a program called the “shell”: an interpreter program that translates instructions
- Console applications can be run with the shell
 - Automation
 - Program building
 - Scientific calculations
- Shells are programmable



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>

Installing git for Windows

If you use Mac OS: do nothing!

BASH essentials

Most important functions and browsing directories

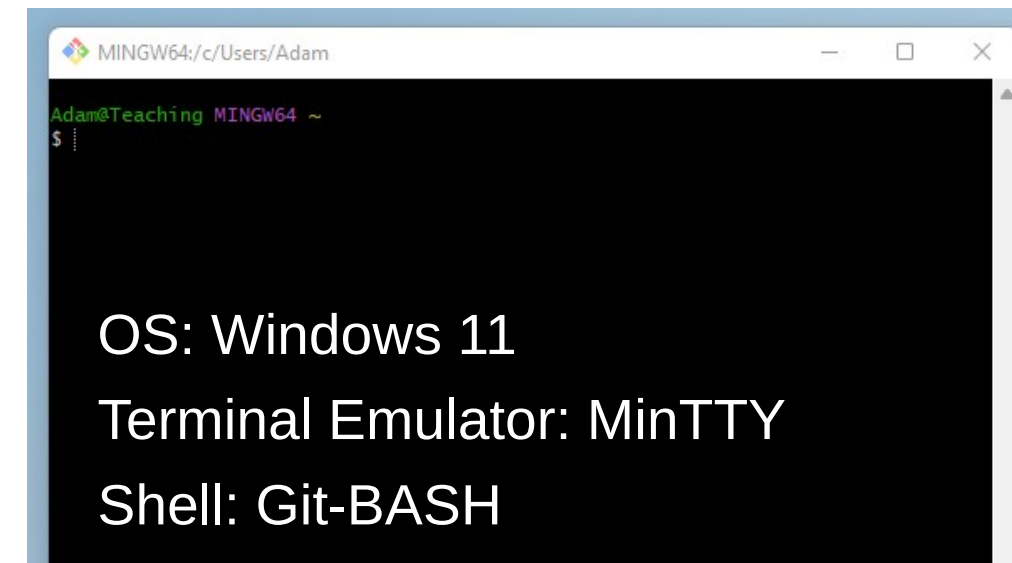
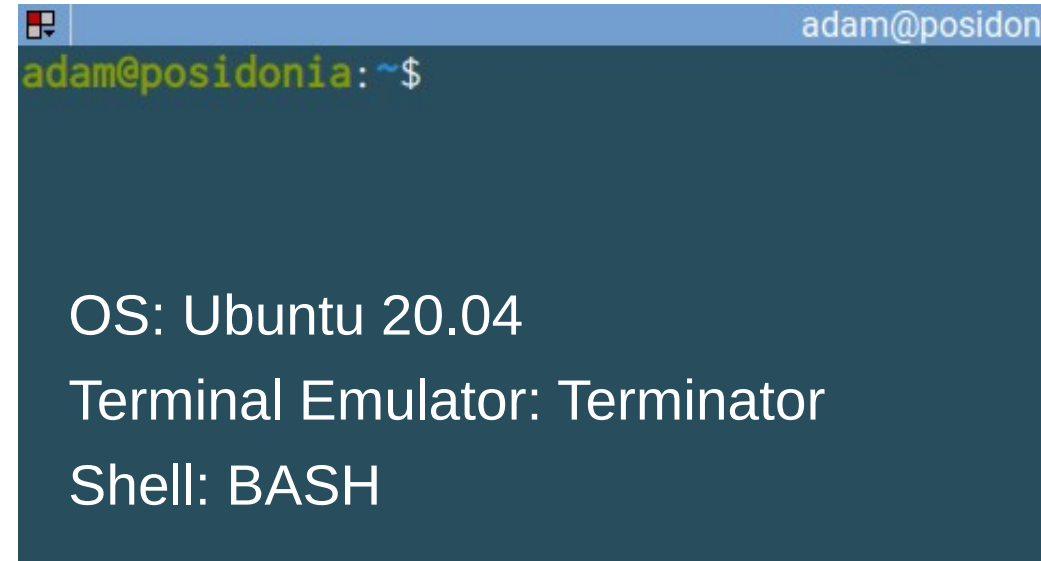
The prompt

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

user@host

~: is shorthand for user home

\$: means normal user mode



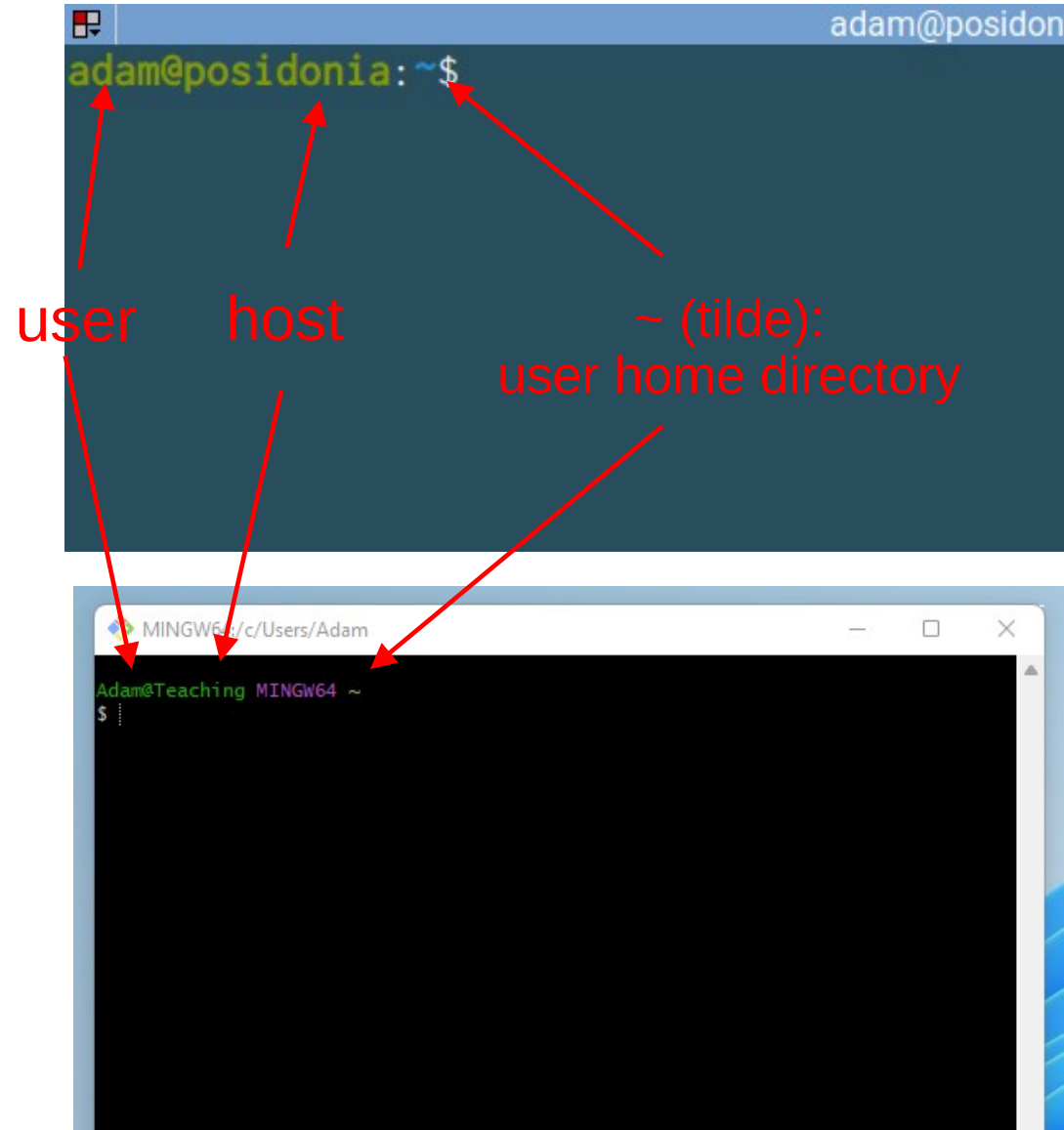
The prompt

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

user@host

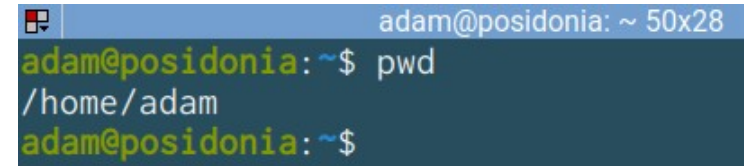
~: is shorthand for user home

\$: means normal user mode



pwd

Return path to current directory



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

A terminal window with a blue title bar containing the text "adam@posidonia: ~ 50x28". The terminal has a dark blue background. The command "pwd" is entered at the prompt "adam@posidonia:~\$". The output "/home/adam" is displayed on the next line. The prompt "adam@posidonia:~\$" appears again on the following line. A white mouse cursor is visible on the right side of the terminal window.

mkdir <name>

space

Create a directory

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

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

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@posidonia: ~ 50x28
adam@posidonia:~$ 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@posidonia:~$
```

ls -l

List directory contents (with option l)

- Long output, includes attributes

d:directory

permissions

owner

size (bytes)

modification

name

```
adam@posidonia: ~ 73x30
adam@posidonia:~$ 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@posidonia:~$
```

cd_<path_to_directory>

Go to a directory

- Can be relative or absolute!

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

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

cd_..

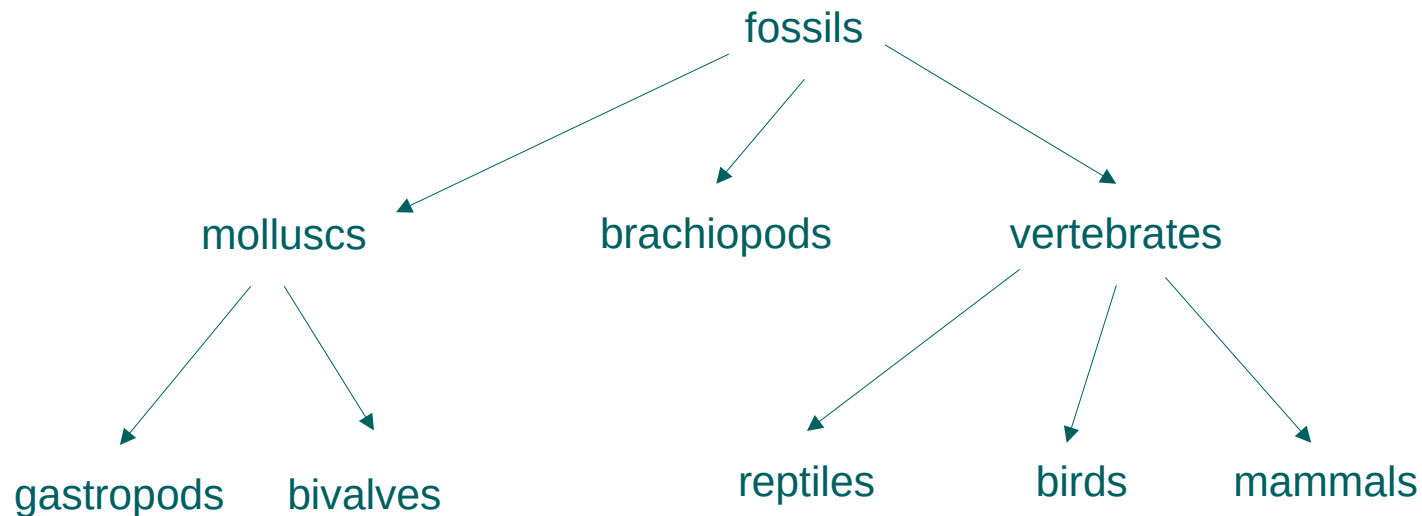
Go to parent directory

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

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

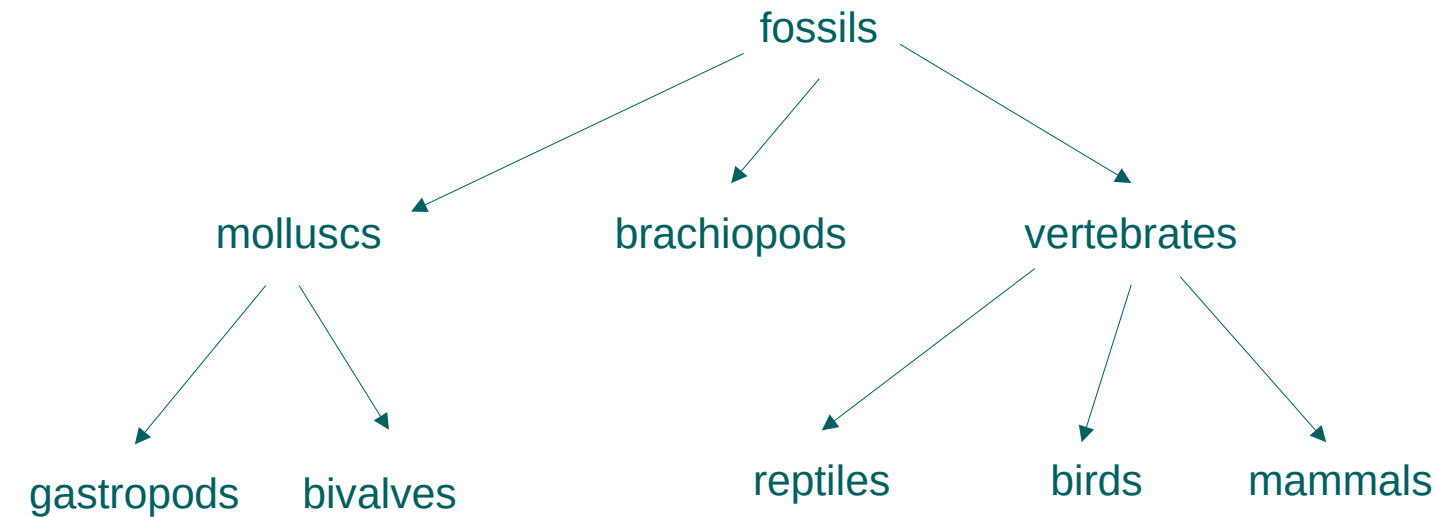
Exercise (5 minutes)

- 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!

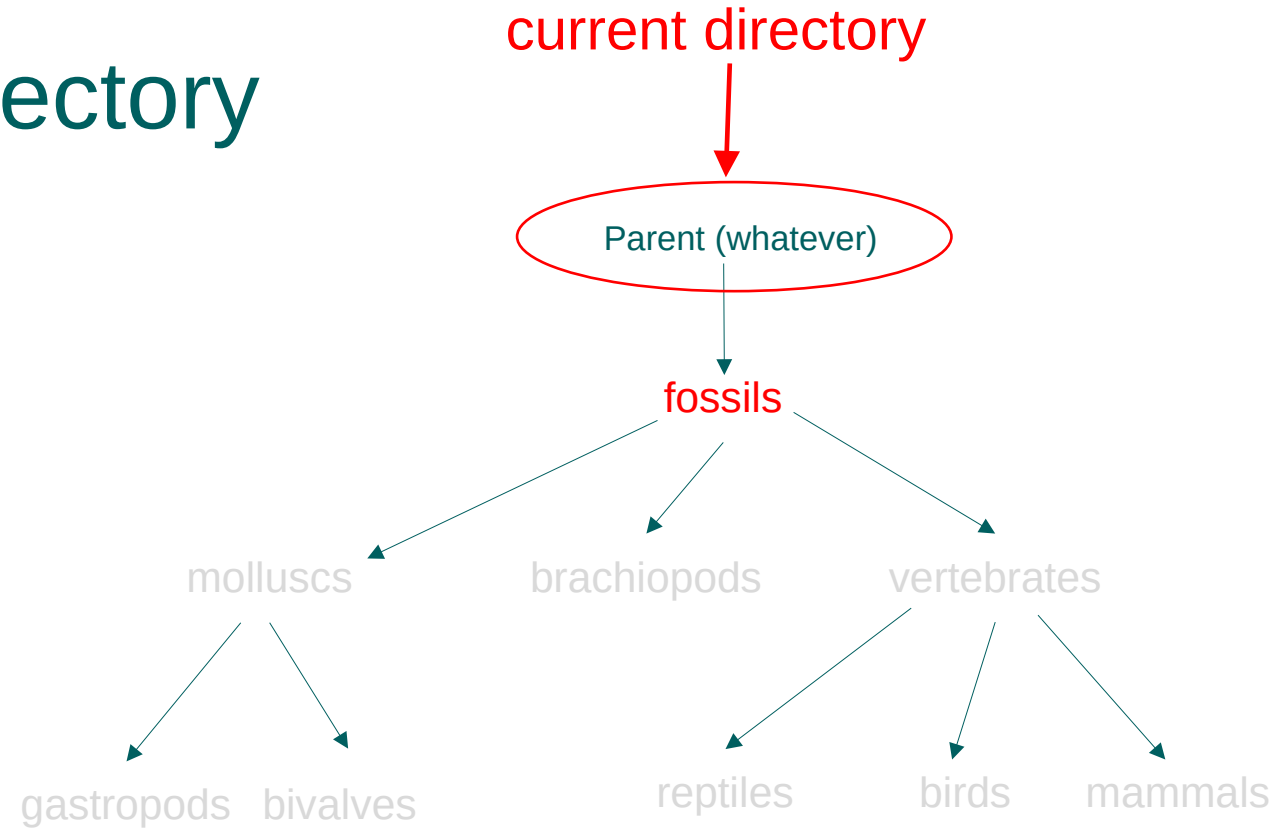


Hints

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

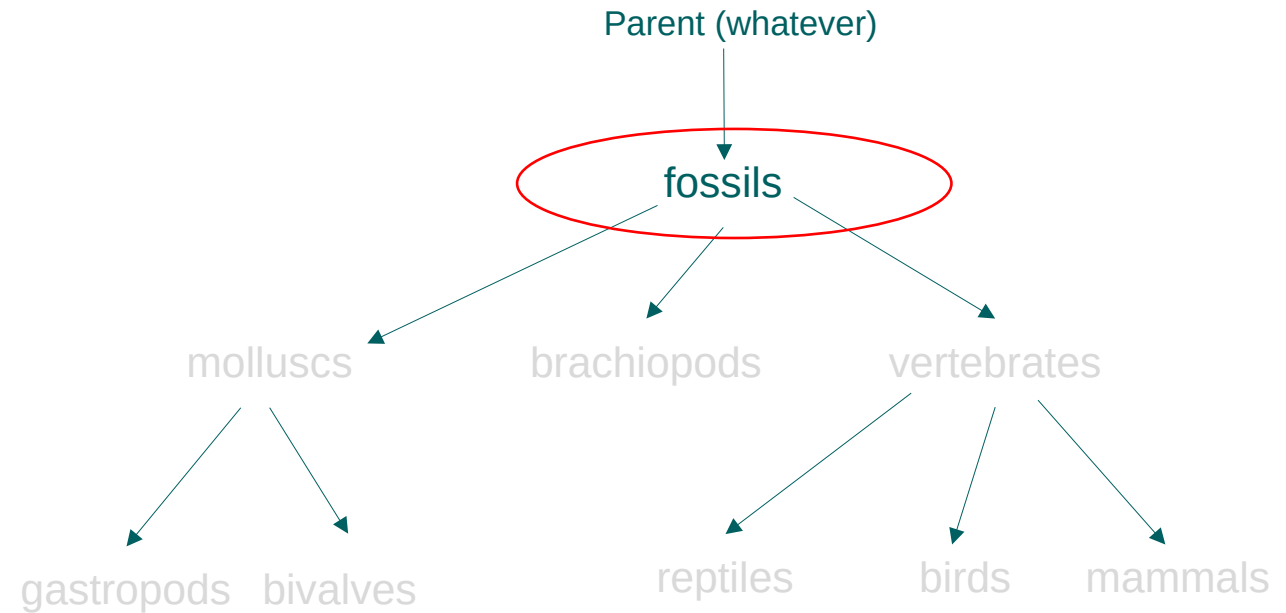
Solution 1 – changing directory

```
adam@posidonia: ~/fossils/vertebrates 73x30
adam@posidonia:~$ mkdir fossils
adam@posidonia:~$ cd fossils
adam@posidonia:~/fossils$ mkdir molluscs
adam@posidonia:~/fossils$ mkdir brachiopods vertebrates
adam@posidonia:~/fossils$ cd molluscs
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$
```



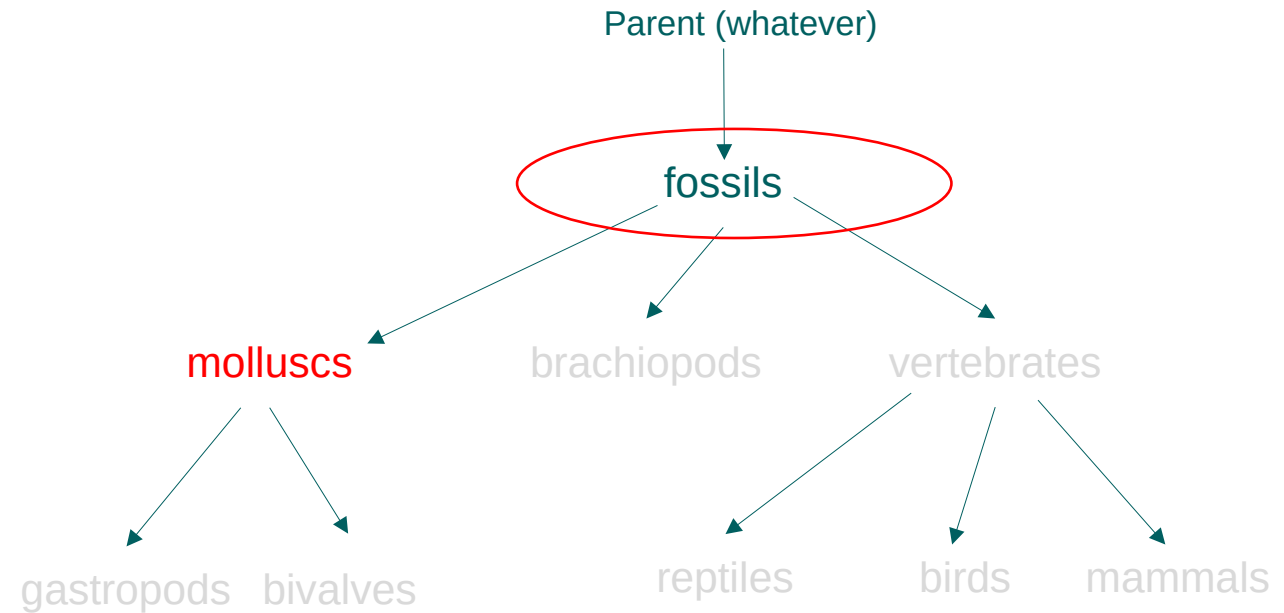
Solution 1 – changing directory

```
adam@posidonia: ~/fossils/vertebrates 73x30
adam@posidonia:~$ mkdir fossils
adam@posidonia:~$ cd fossils
adam@posidonia:~/fossils$ mkdir molluscs
adam@posidonia:~/fossils$ mkdir brachiopods vertebrates
adam@posidonia:~/fossils$ cd molluscs
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$
```



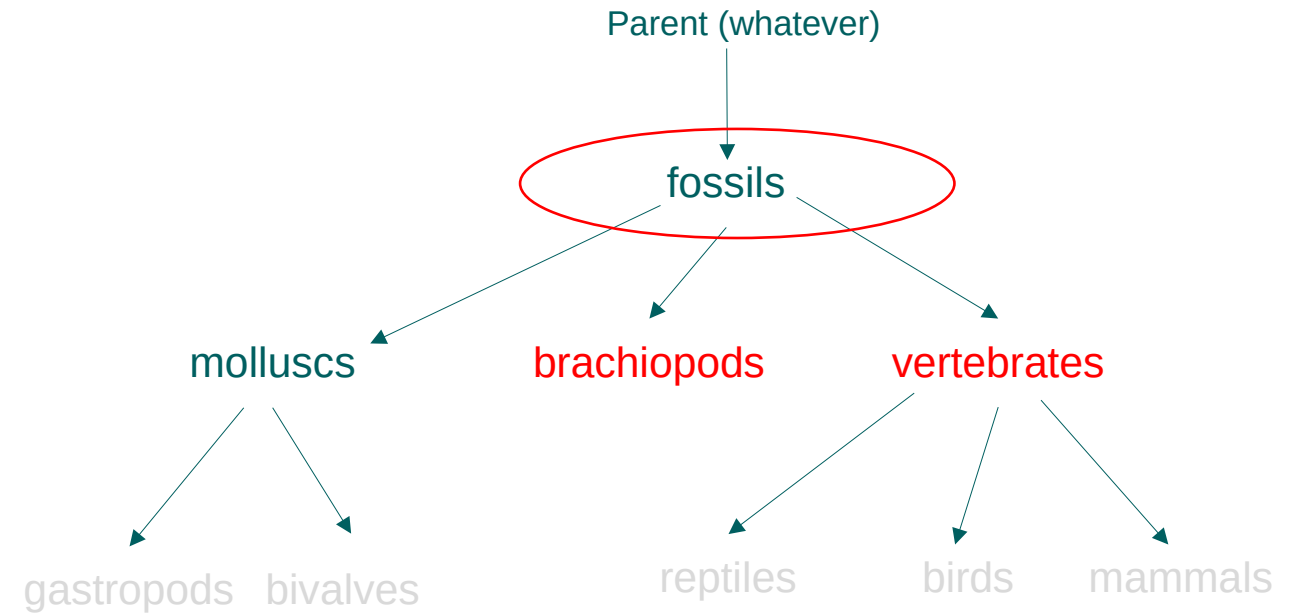
Solution 1 – changing directory

```
adam@posidonia: ~/fossils/vertebrates 73x30
adam@posidonia:~$ mkdir fossils
adam@posidonia:~$ cd fossils
adam@posidonia:~/fossils$ mkdir molluscs
adam@posidonia:~/fossils$ mkdir brachiopods vertebrates
adam@posidonia:~/fossils$ cd molluscs
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$
```



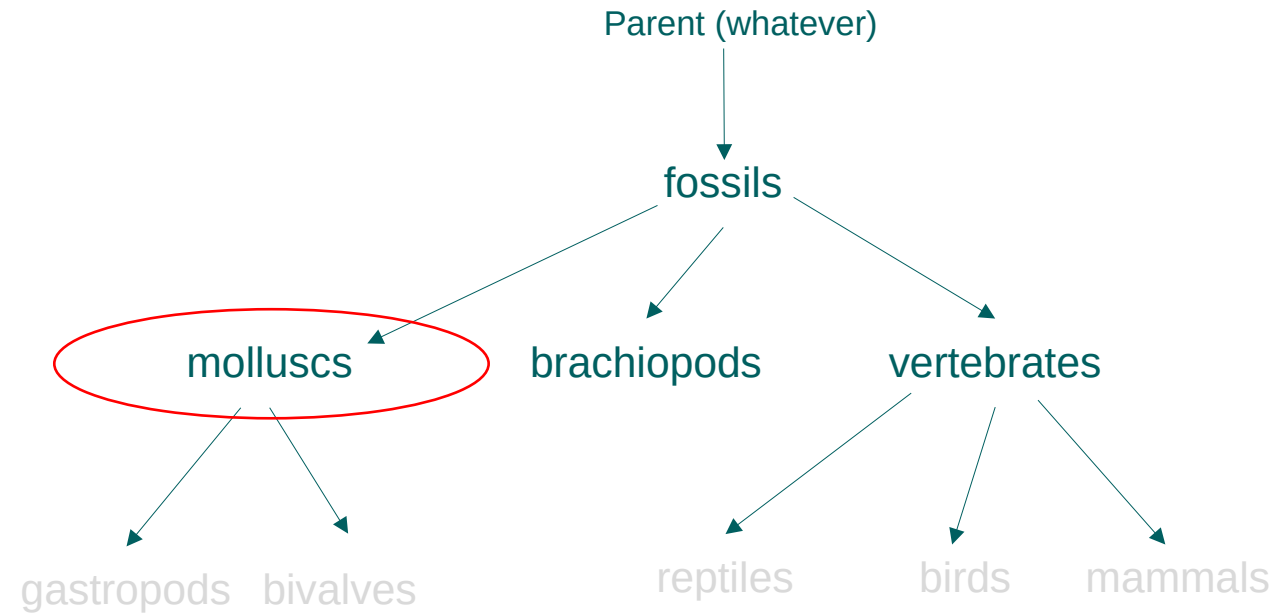
Solution 1 – changing directory

```
adam@posidonia: ~/fossils/vertebrates 73x30
adam@posidonia:~$ mkdir fossils
adam@posidonia:~$ cd fossils
adam@posidonia:~/fossils$ mkdir molluscs
adam@posidonia:~/fossils$ mkdir brachiopods vertebrates
adam@posidonia:~/fossils$ cd molluscs
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$
```



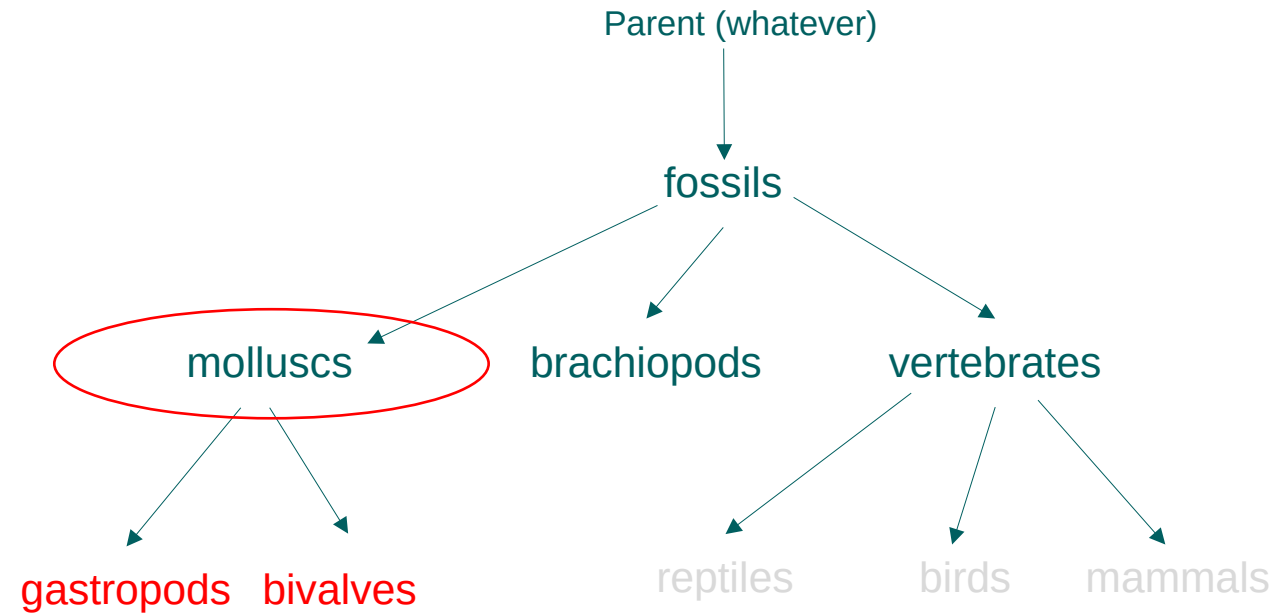
Solution 1 – changing directory

```
adam@posidonia: ~/fossils/vertebrates 73x30
adam@posidonia:~$ mkdir fossils
adam@posidonia:~$ cd fossils
adam@posidonia:~/fossils$ mkdir molluscs
adam@posidonia:~/fossils$ mkdir brachiopods vertebrates
adam@posidonia:~/fossils$ cd molluscs
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$
```



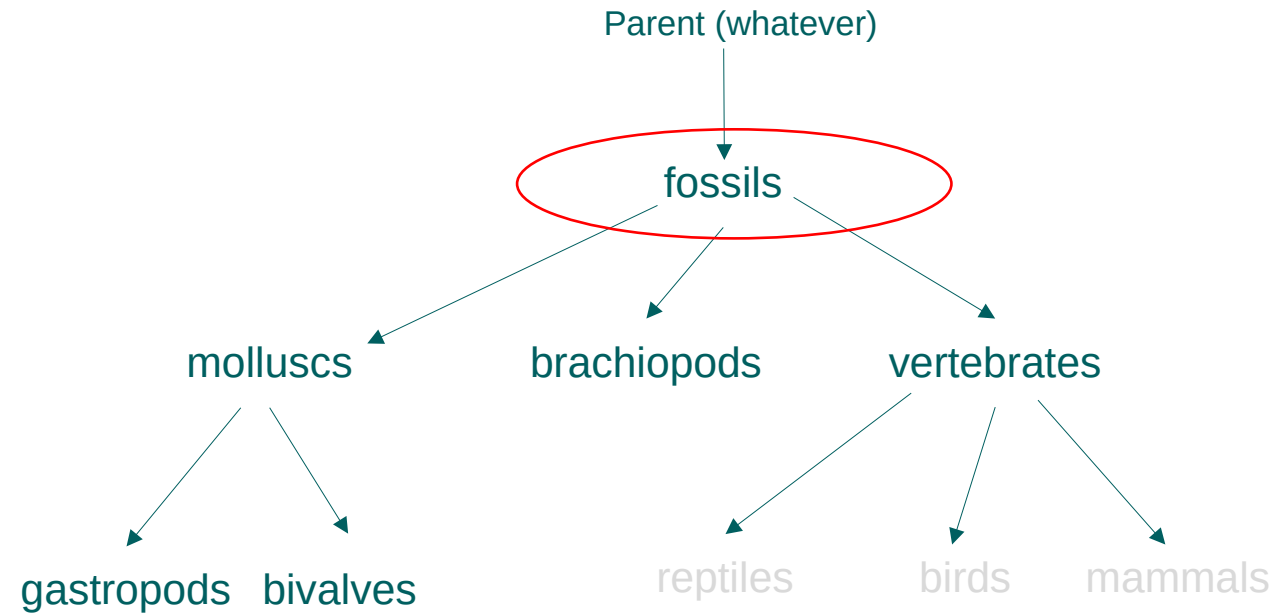
Solution 1 – changing directory

```
adam@posidonia: ~/fossils/vertebrates 73x30
adam@posidonia:~$ mkdir fossils
adam@posidonia:~$ cd fossils
adam@posidonia:~/fossils$ mkdir molluscs
adam@posidonia:~/fossils$ mkdir brachiopods vertebrates
adam@posidonia:~/fossils$ cd molluscs
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$
```



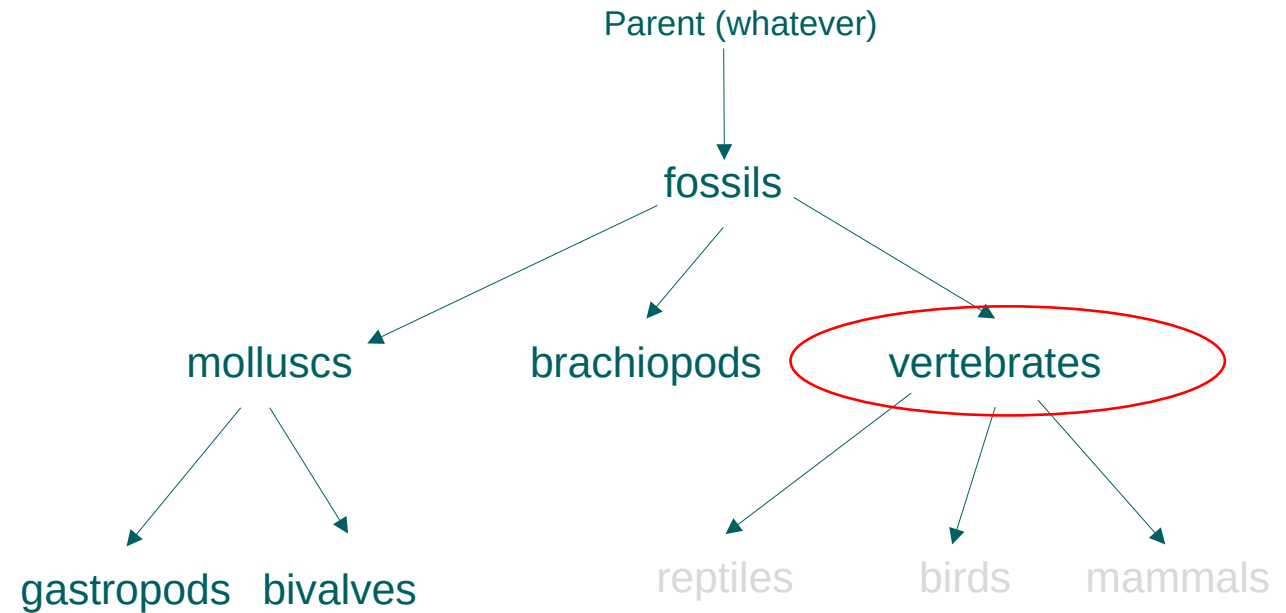
Solution 1 – changing directory

```
adam@posidonia: ~/fossils/vertebrates 73x30
adam@posidonia:~$ mkdir fossils
adam@posidonia:~$ cd fossils
adam@posidonia:~/fossils$ mkdir molluscs
adam@posidonia:~/fossils$ mkdir brachiopods vertebrates
adam@posidonia:~/fossils$ cd molluscs
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$
```



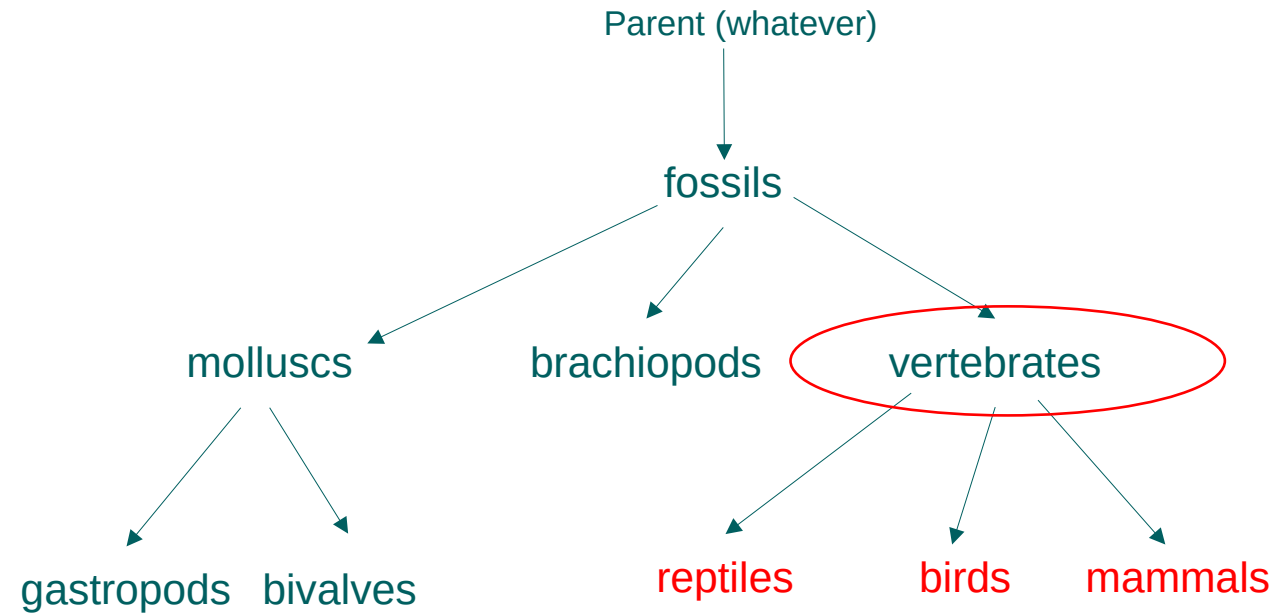
Solution 1 – changing directory

```
adam@posidonia: ~/fossils/vertebrates 73x30
adam@posidonia:~$ mkdir fossils
adam@posidonia:~$ cd fossils
adam@posidonia:~/fossils$ mkdir molluscs
adam@posidonia:~/fossils$ mkdir brachiopods vertebrates
adam@posidonia:~/fossils$ cd molluscs
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$
```



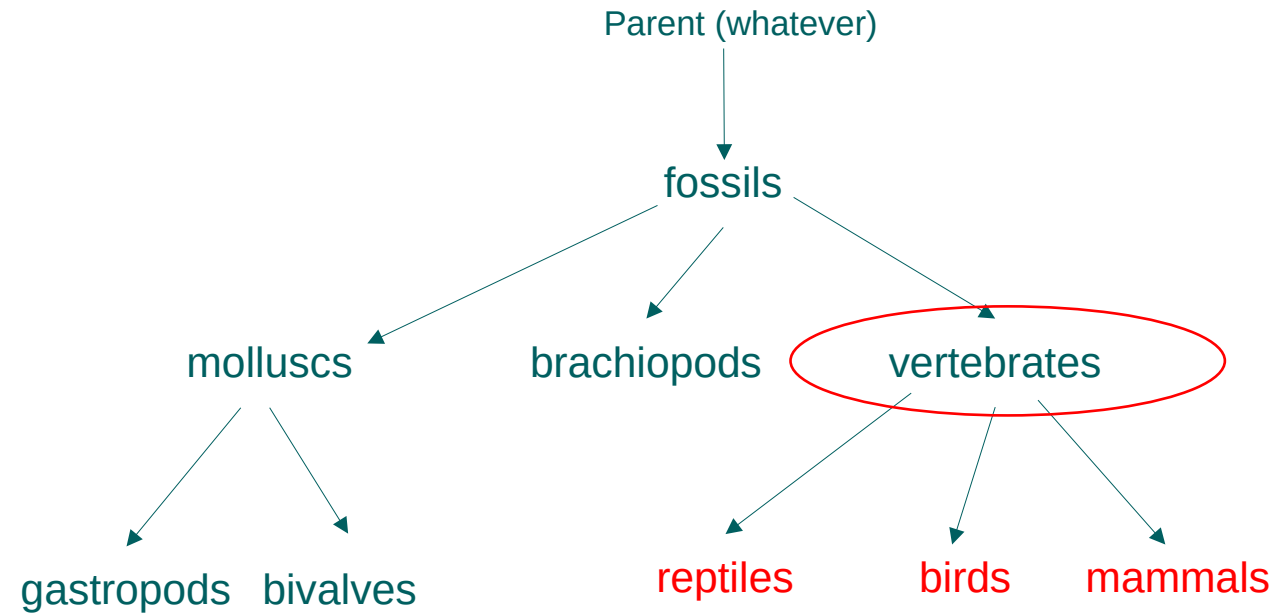
Solution 1 – changing directory

```
adam@posidonia: ~/fossils/vertebrates 73x30
adam@posidonia:~$ mkdir fossils
adam@posidonia:~$ cd fossils
adam@posidonia:~/fossils$ mkdir molluscs
adam@posidonia:~/fossils$ mkdir brachiopods vertebrates
adam@posidonia:~/fossils$ cd molluscs
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$
```



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
adam@posidonia:~/fossils$ cd molluscs
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$
```

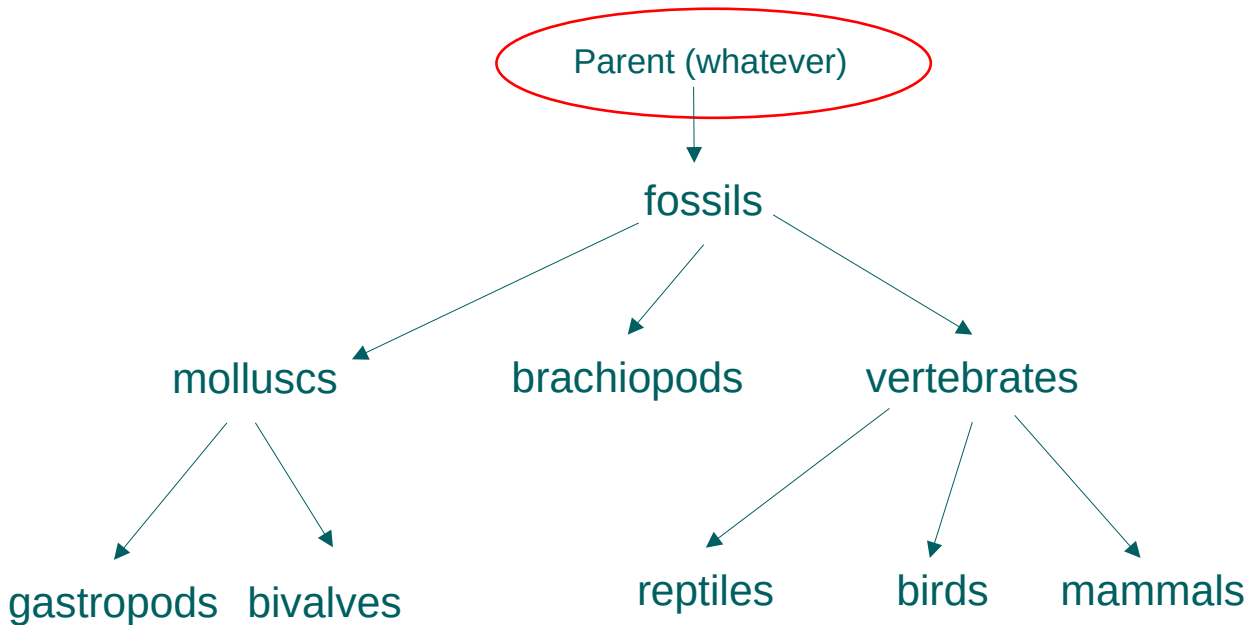


How to check?

find_<path to directory>

Recursive listing

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



```
adam@posidonia: ~ 73x30
adam@posidonia:~/fossils/vertebrates$ cd ../../
adam@posidonia:~$ 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@posidonia:~$
```

parent of parent

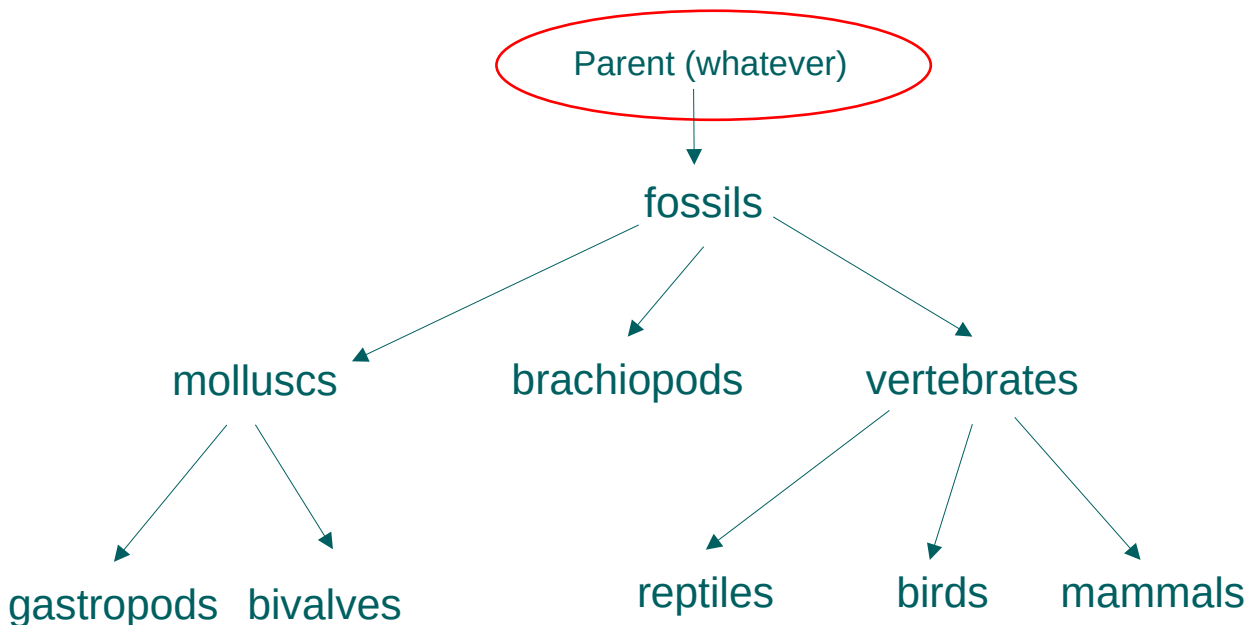
relative paths

`find` <path> > <path_to file>

Angled bracket or **chevron**

Output redirection

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



```
adam@posidonia: ~ 73x30
adam@posidonia:~/fossils/vertebrates$ cd ../../
adam@posidonia:~$ 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@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: ~ 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 fossils ←
adam@posidonia:~$
```

WARNING!
The results of rm
cannot be undone!

echo_<text>

Print something

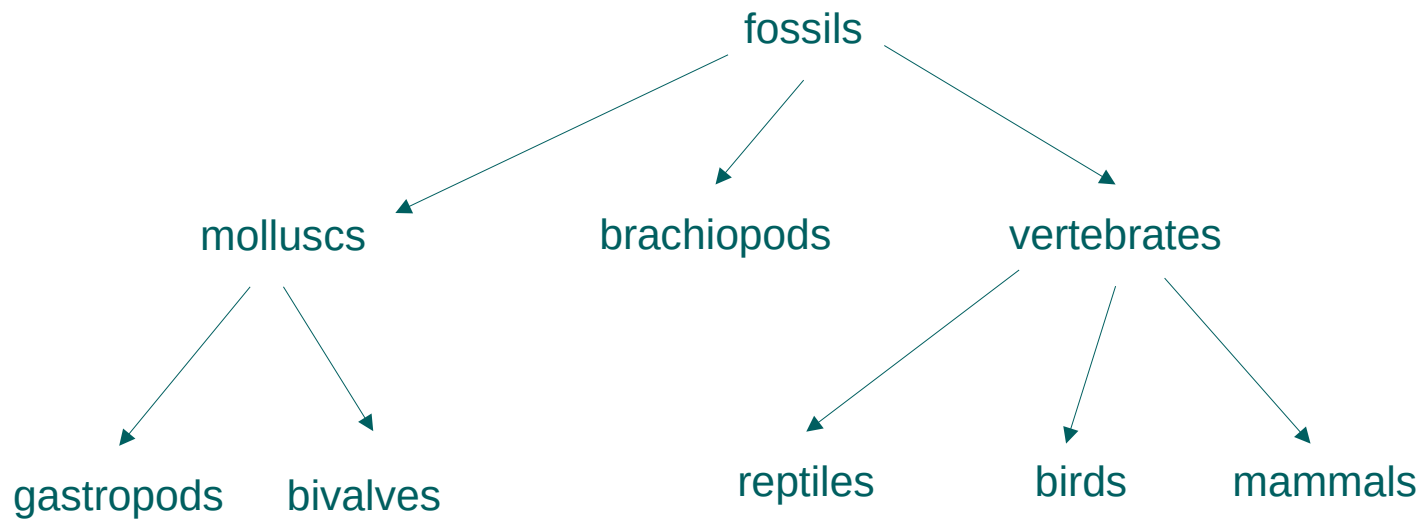
- Used to print things to the console (standard output)
- \$? Is a special symbol: the exit code of the last command:
 - 0: Success
 - Other: Failure

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

```
adam@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 fossils
adam@posidonia:~$ echo $? ←
0
adam@posidonia:~$
```

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

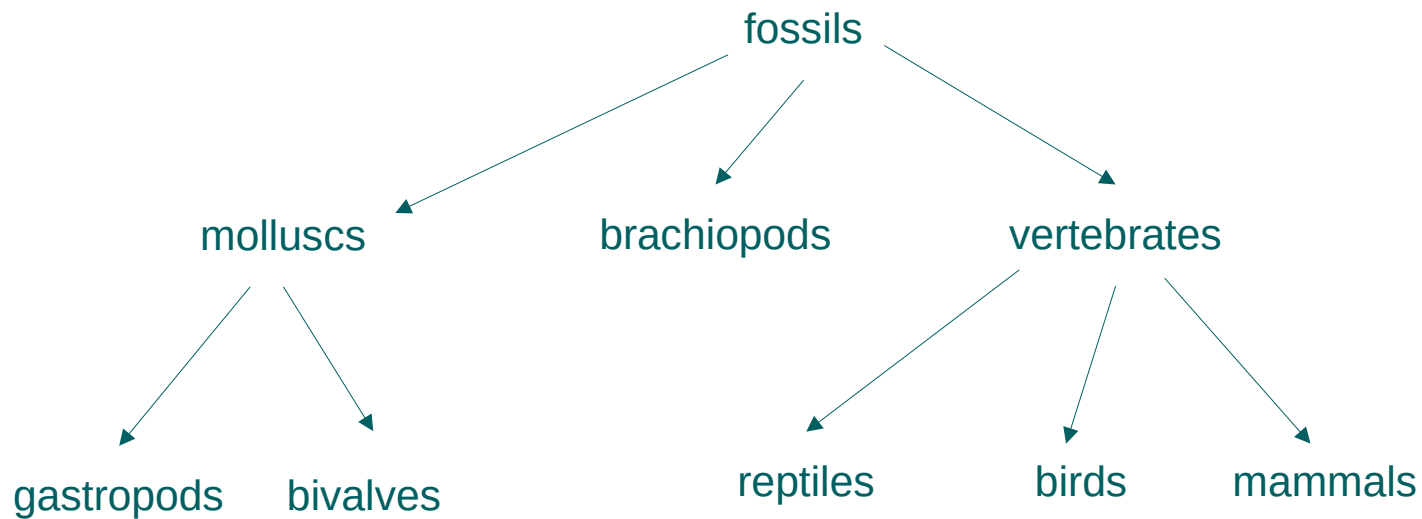


- Emacs



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!

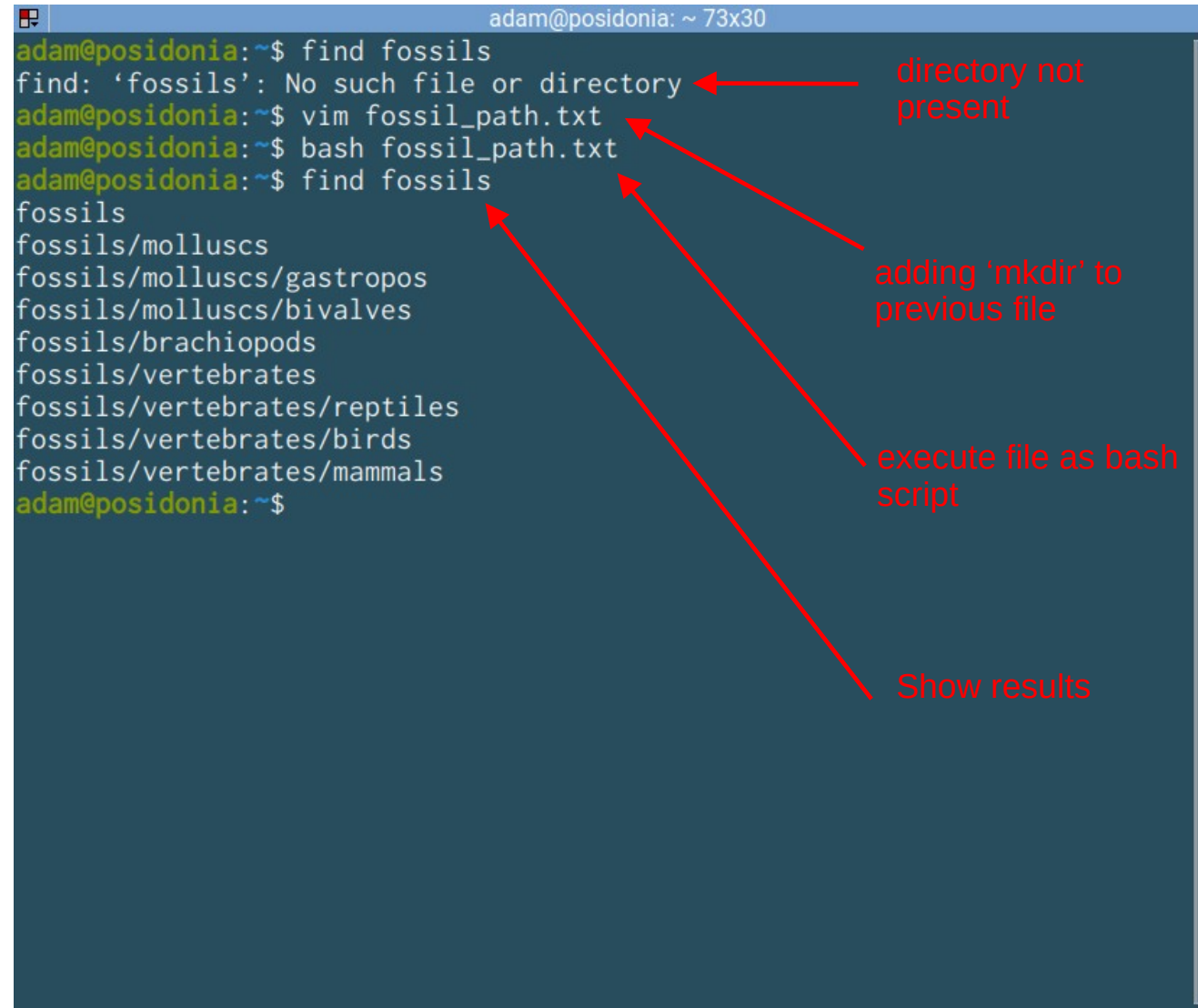
```
1 mkdir fossils
2 mkdir fossils/molluscs
3 mkdir fossils/molluscs/gastropods
4 mkdir fossils/molluscs/bivalves
5 mkdir fossils/brachiopods
6 mkdir fossils/vertebrates
7 mkdir fossils/vertebrates/reptiles
8 mkdir fossils/vertebrates/birds
9 mkdir fossils/vertebrates/mammals
```

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@posidonia: ~ 73x30
adam@posidonia:~$ find fossils
find: 'fossils': No such file or directory
adam@posidonia:~$ vim fossil_path.txt
adam@posidonia:~$ bash fossil_path.txt
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:~$
```

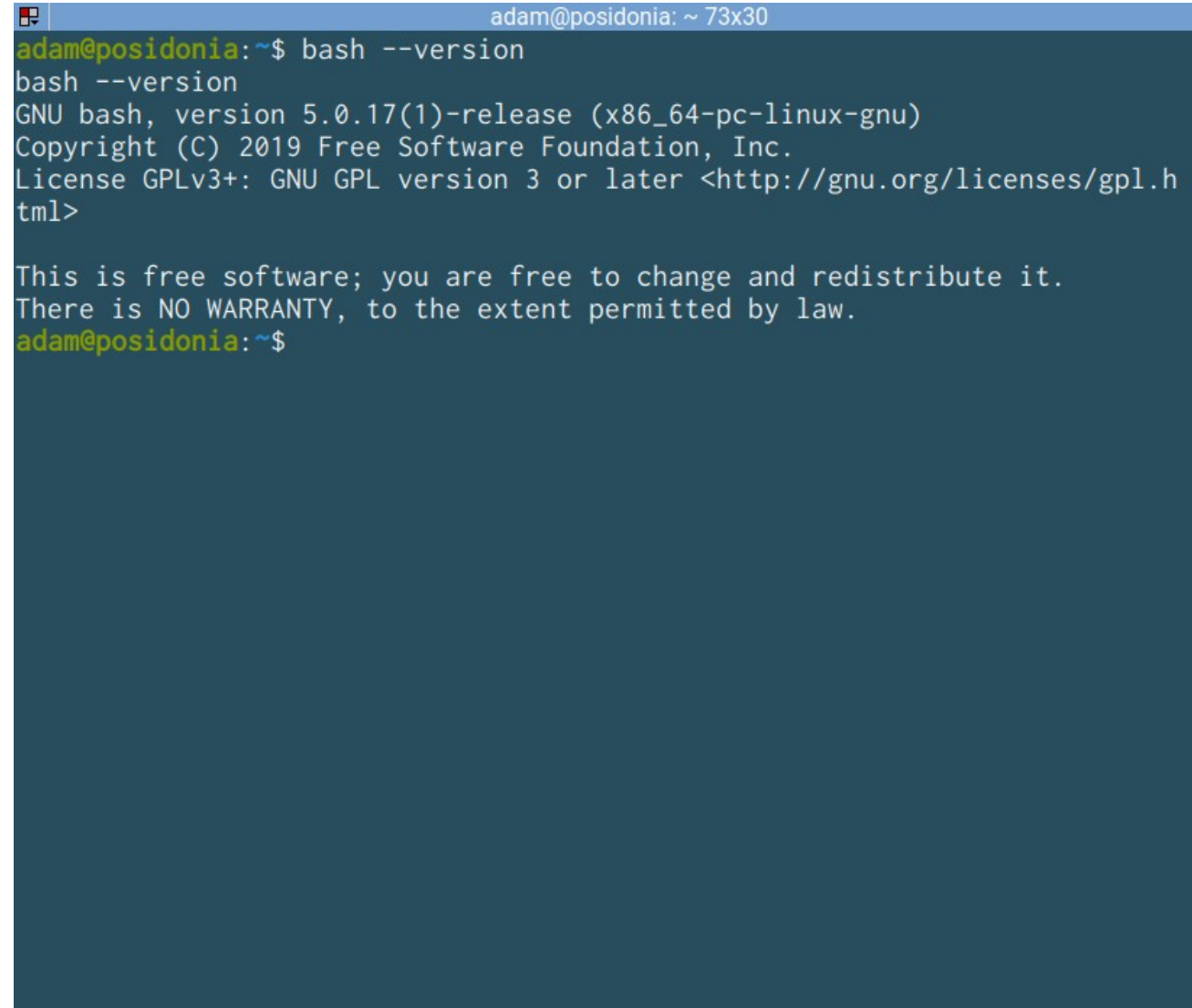
Annotations:

- directory not present (points to the error message)
- adding 'mkdir' to previous file (points to the `vim fossil_path.txt` command)
- execute file as bash script (points to the `bash fossil_path.txt` command)
- Show results (points to the output of the `find` command)

bash_--version

Running console applications

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

A terminal window with a blue title bar containing the text 'adam@posidonia: ~ 73x30'. The terminal has a dark blue background with white text. The command 'bash --version' has been entered and executed. The output shows the version of GNU bash as 5.0.17(1)-release for x86_64-pc-linux-gnu, along with copyright and license information. A disclaimer about free software and warranty is also displayed.

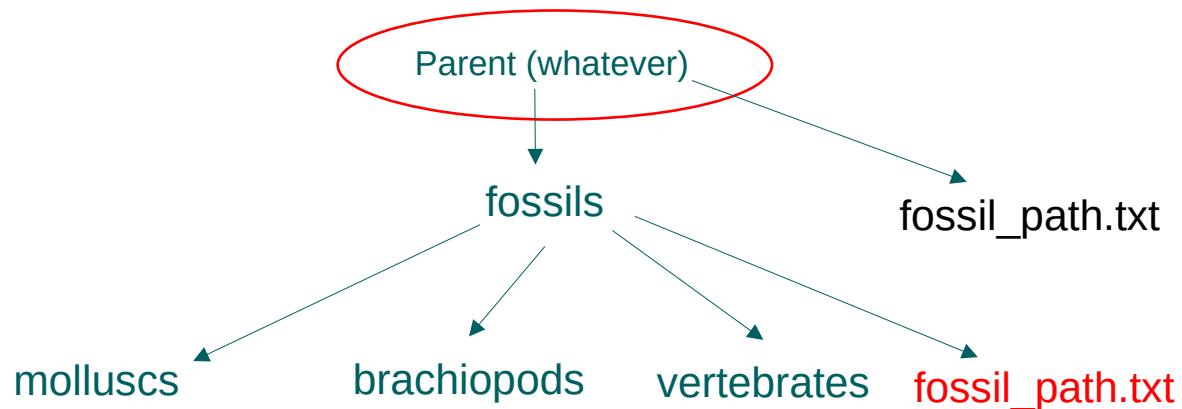
```
adam@posidonia:~$ bash --version
bash --version
GNU bash, version 5.0.17(1)-release (x86_64-pc-linux-gnu)
Copyright (C) 2019 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>

This is free software; you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law.
adam@posidonia:~$
```

cp_<what>_<where>

Copying a file or directory

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



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

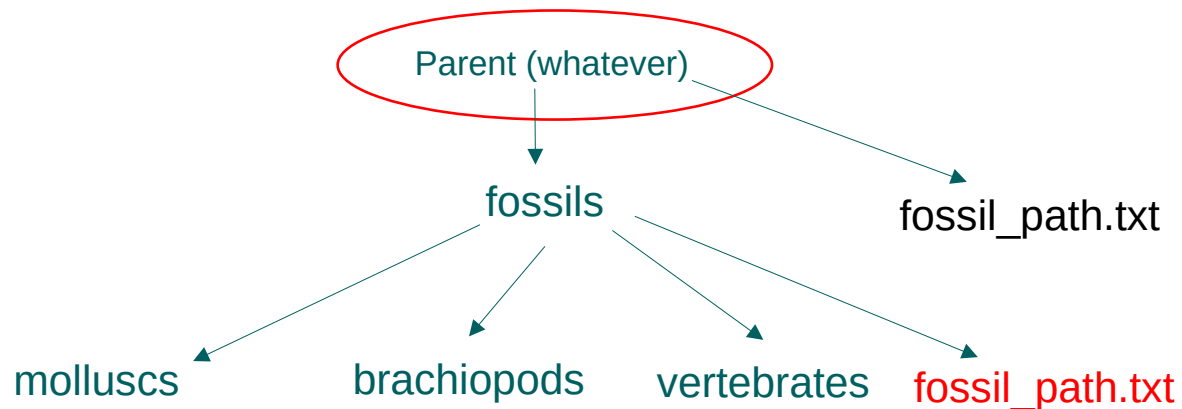
List contents of
path!
New file

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)

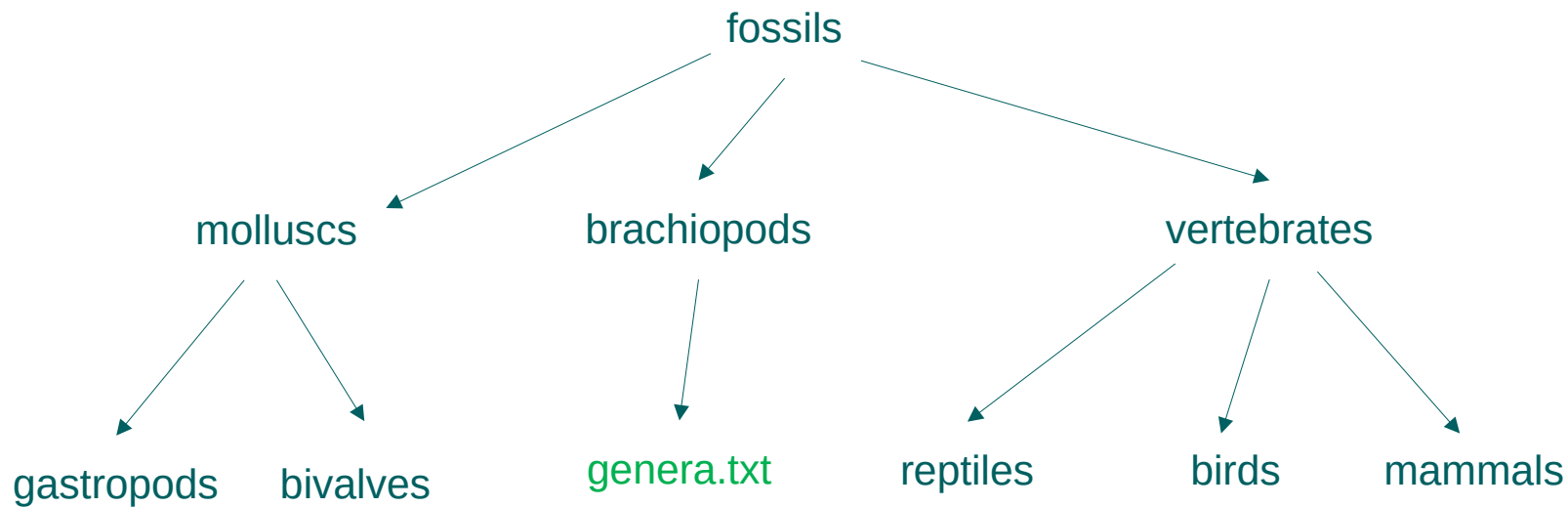


```
adam@posidonia: ~ 73x30
adam@posidonia:~$ cp fossil_path.txt fossils
adam@posidonia:~$ ls fossils
brachiopods fossil_path.txt molluscs vertebrates
adam@posidonia:~$ rm fossils/fossil_path.txt
adam@posidonia:~$ ls fossils
brachiopods molluscs vertebrates
adam@posidonia:~$
```

File disappeared

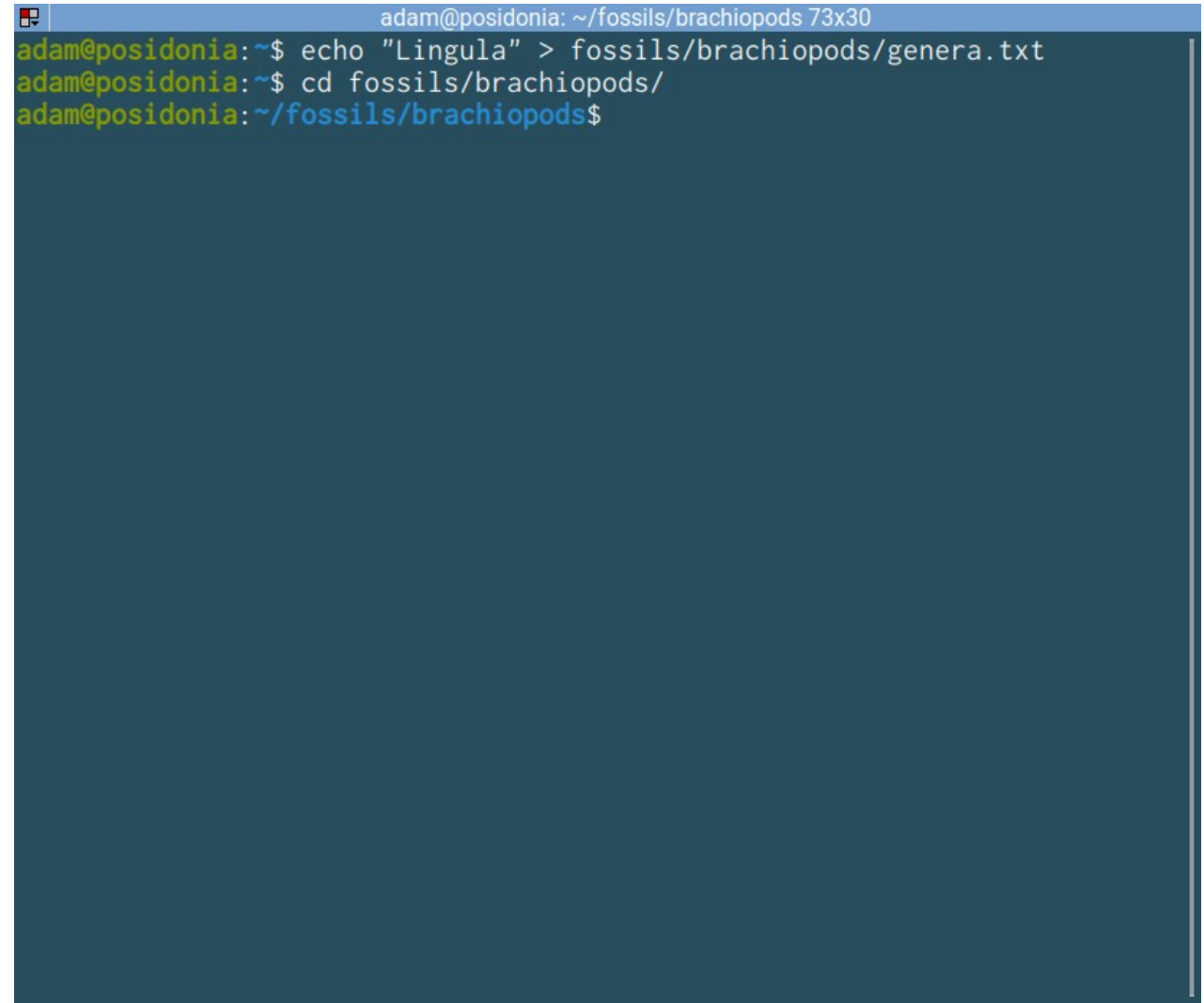
Exercise!

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

A terminal window with a dark blue background and a light blue title bar. The title bar contains the text 'adam@posidonia: ~/fossils/brachiopods 73x30'. The terminal shows three lines of text: a command to echo 'Lingula' to a file, a command to change the directory to 'fossils/brachiopods/', and the resulting prompt in the new directory.

echo "Spiriferina" >> genera.txt

Appending to files

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

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


Special characters

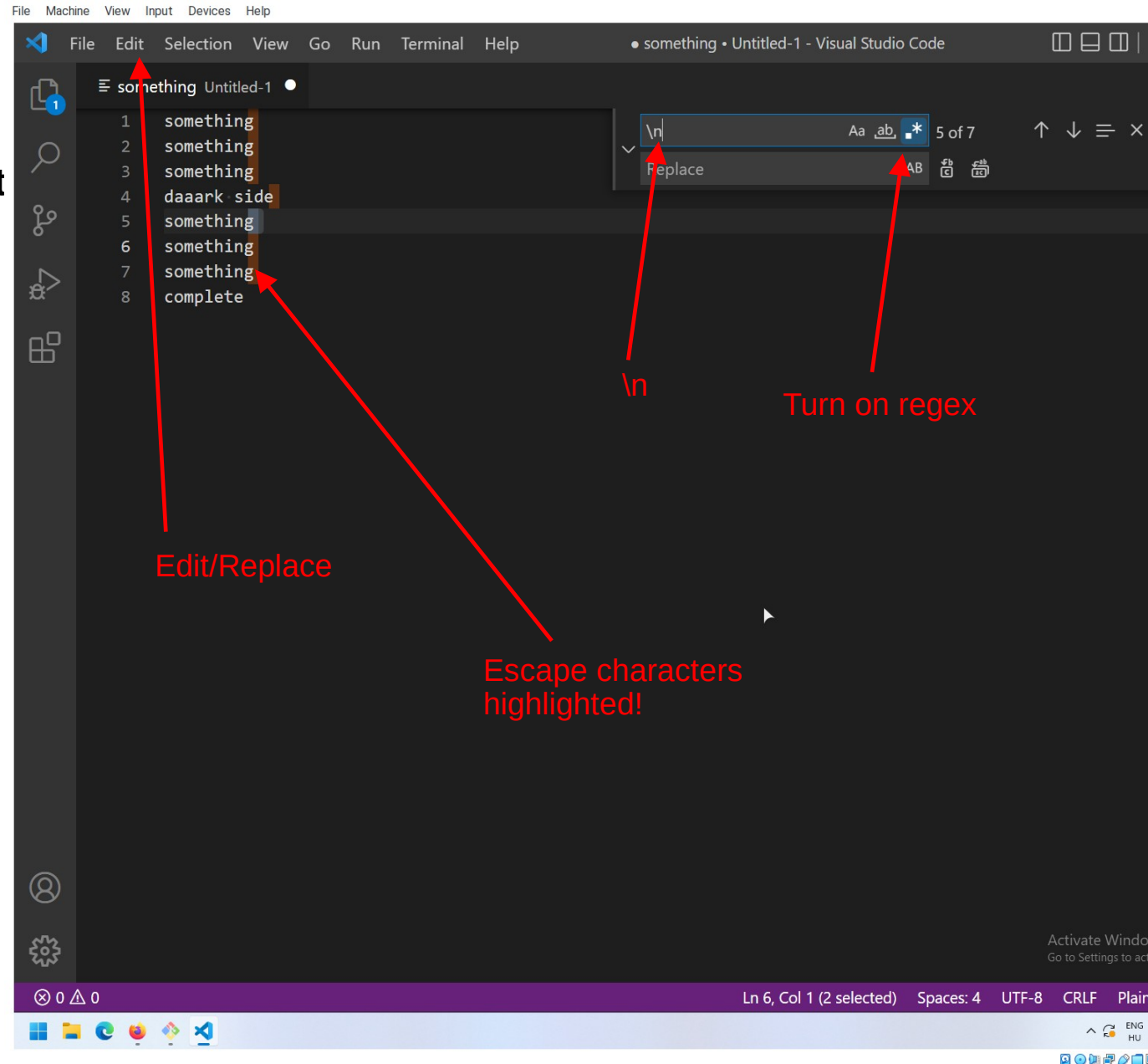
We use so called “escape characters to denote special symbols, that sometimes have other meanings.

`\n`: newline escape

`\t` : tab escape

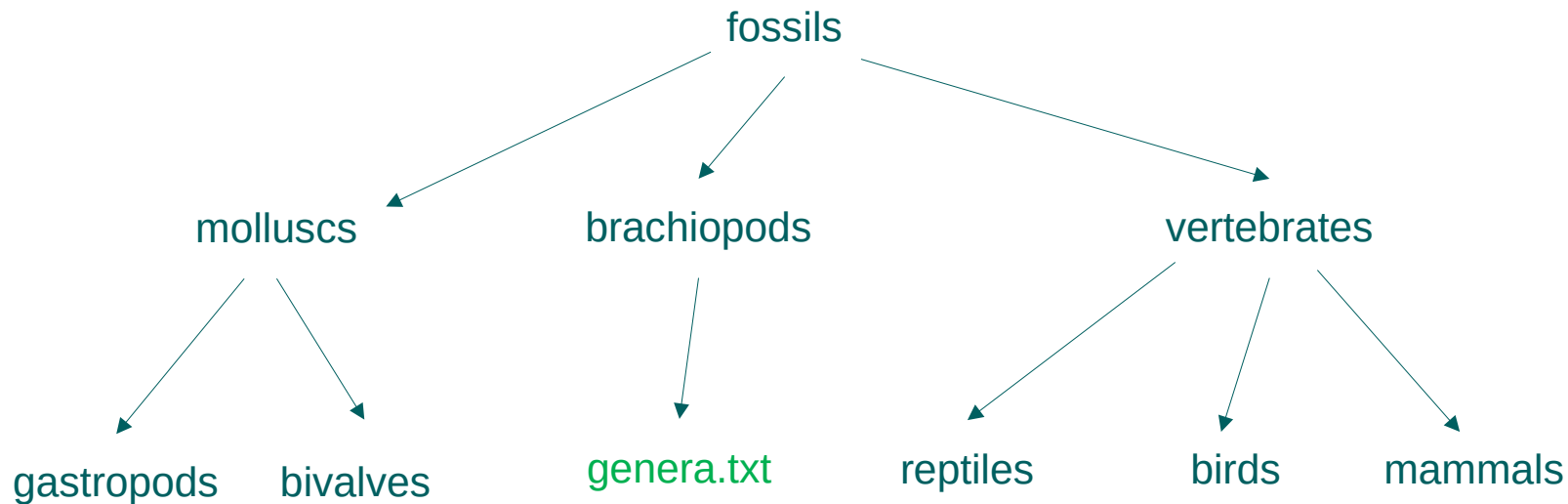
`\”` : double quote escape

`\’` : 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`.

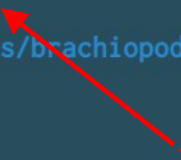


echo_"Terebratula\nAthyrida">>genera.txt

Appending to files

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

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

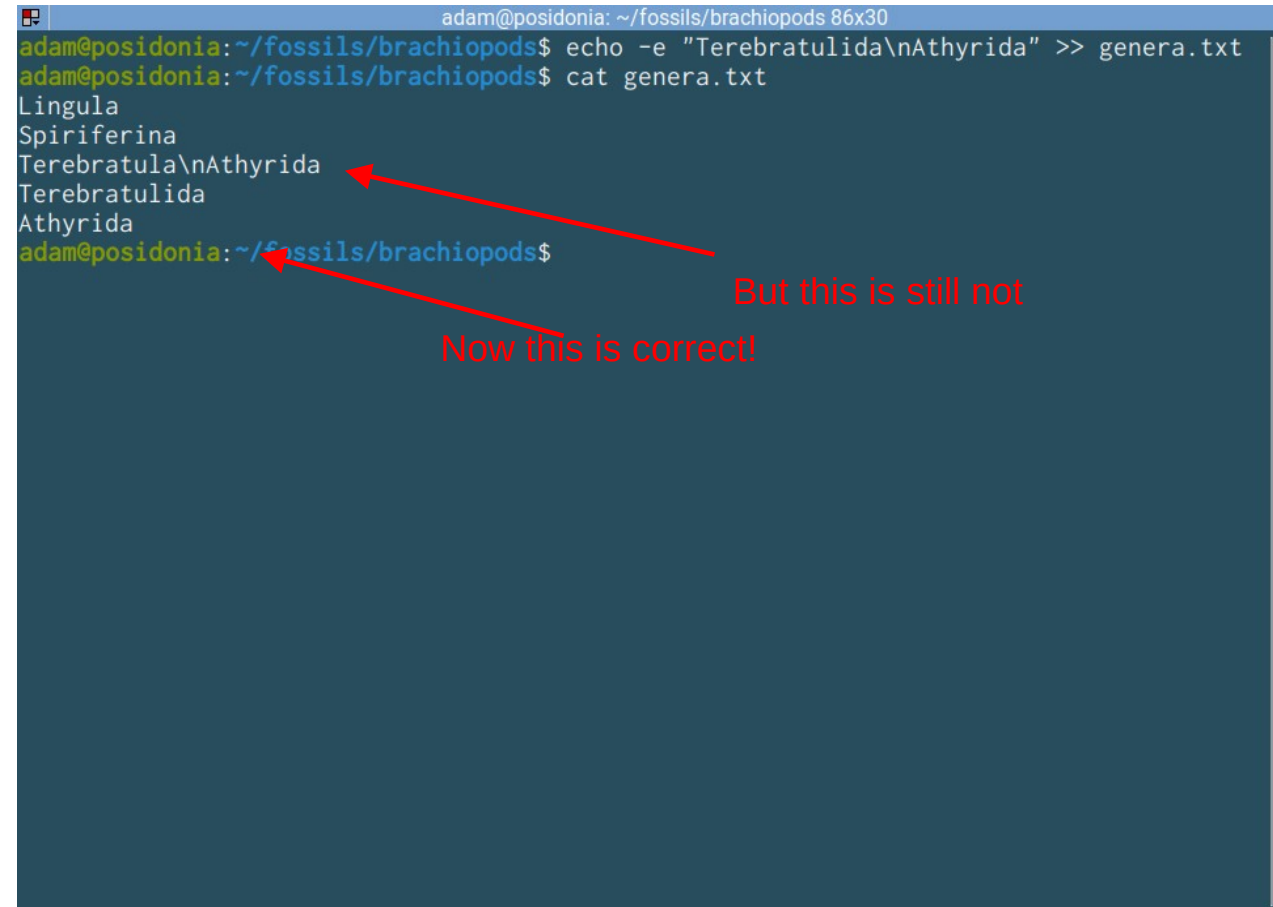


This is not ok!

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!



The terminal window shows the following commands and output:

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

Two red arrows point from text annotations to the output. The first arrow points to the line `Terebratula\nAthyrida` with the text "But this is still not". The second arrow points to the line `Athyrida` with the text "Now this is correct!".

Joint Exercise

Create the directory structure here!

