

Introduction to Unix and Unix-like systems (Linux and MacOS)

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UNIX
Where there is a shell, there is a way.

Unix history

- Started to be developed in the 60' at Bell Labs / AT&T for the PDP-7
- Coded mostly in C (also developed by AT&T)
- Modular philosophy (combine or “pipe” several small programs)
- Multi-tasking (resources are shared)
- Multiuser (can handle many users simultaneously)
- Initially, Unix was not open source
- The advent of Open Source
 - 1990s: GNU Open Source tools + kernel = Linux
- Today Unix is widely used used in:
 - Large supercomputers
 - Computer clusters & servers
 - Companies & organisations
 - MacOS (BSD-like)
 - Research (specially Bioinformatics)



Ken Thompson & Dennis Ritchie



PDP-7



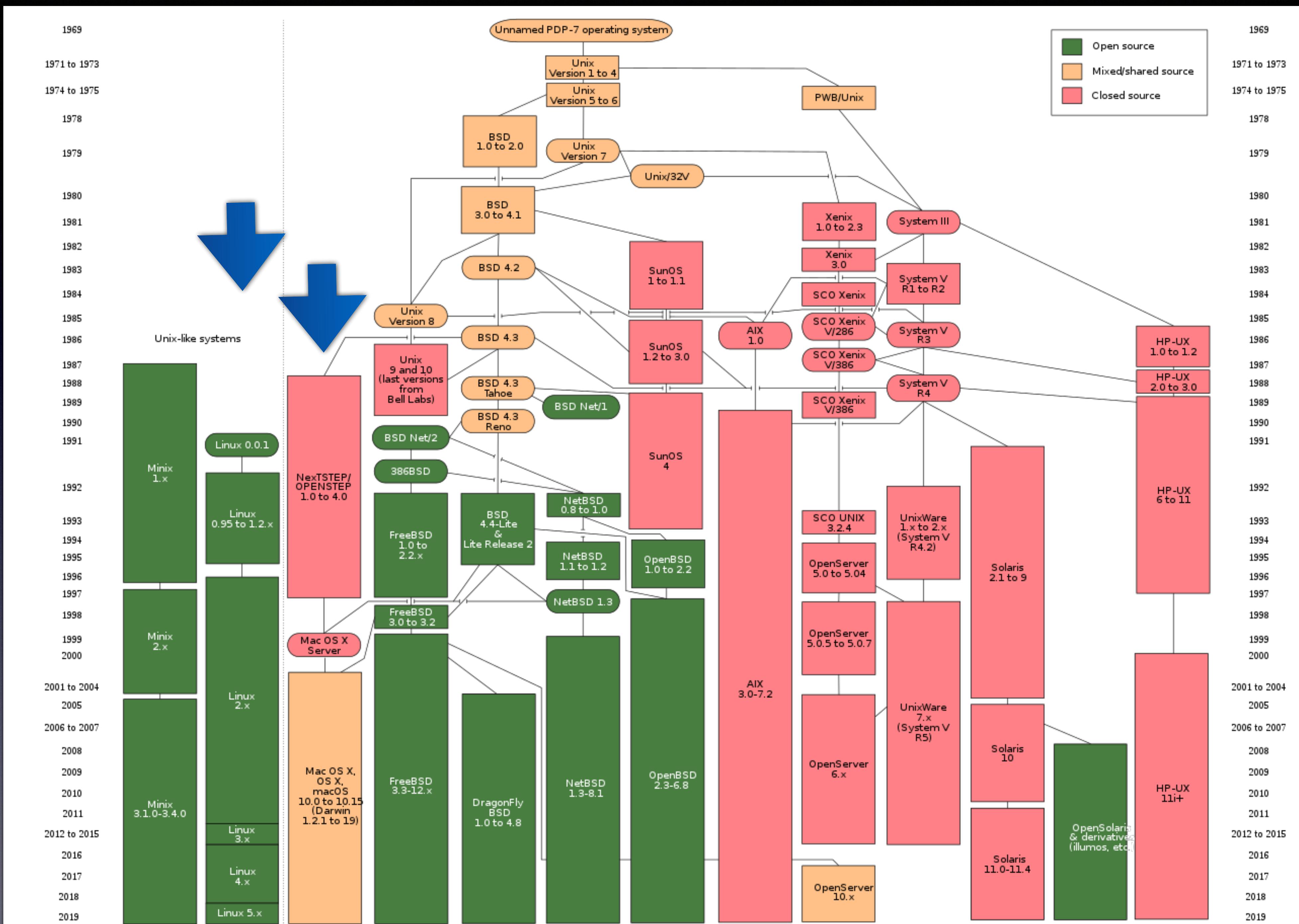
Richard Stallman



Linus Torvalds



Abbreviations.com

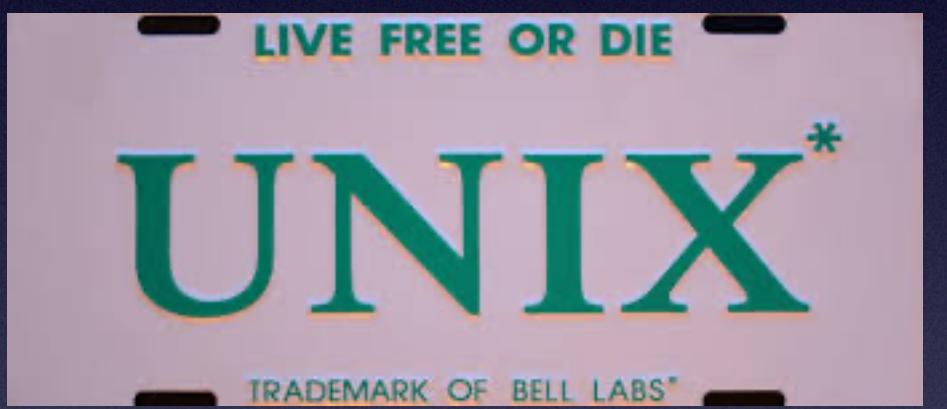


- **Advantages**

- Great stability
- Security
- Good control of users and processes
- Can handle large computing load
- Open Source FREE versions: Several options (Ubuntu, CentOS, Debian, etc.)
- Large community of developers
- Large amount of free software (specially for bioinfo)
- Excellent connectivity between computers

- **Disadvantages**

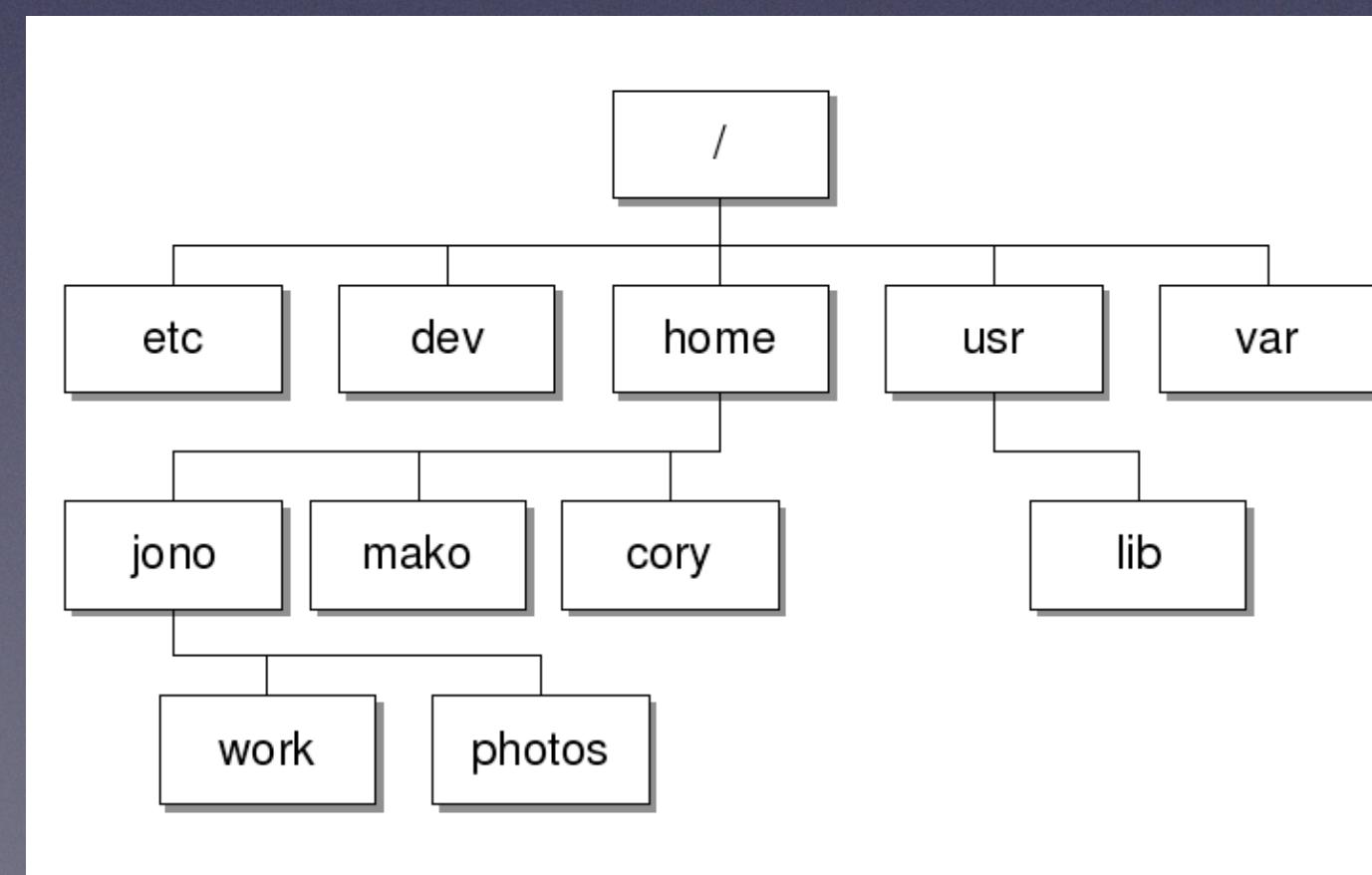
- Compatibility with popular tools
- Some hardware may not be supported
- Some applications may need more knowledge to use them



Basics

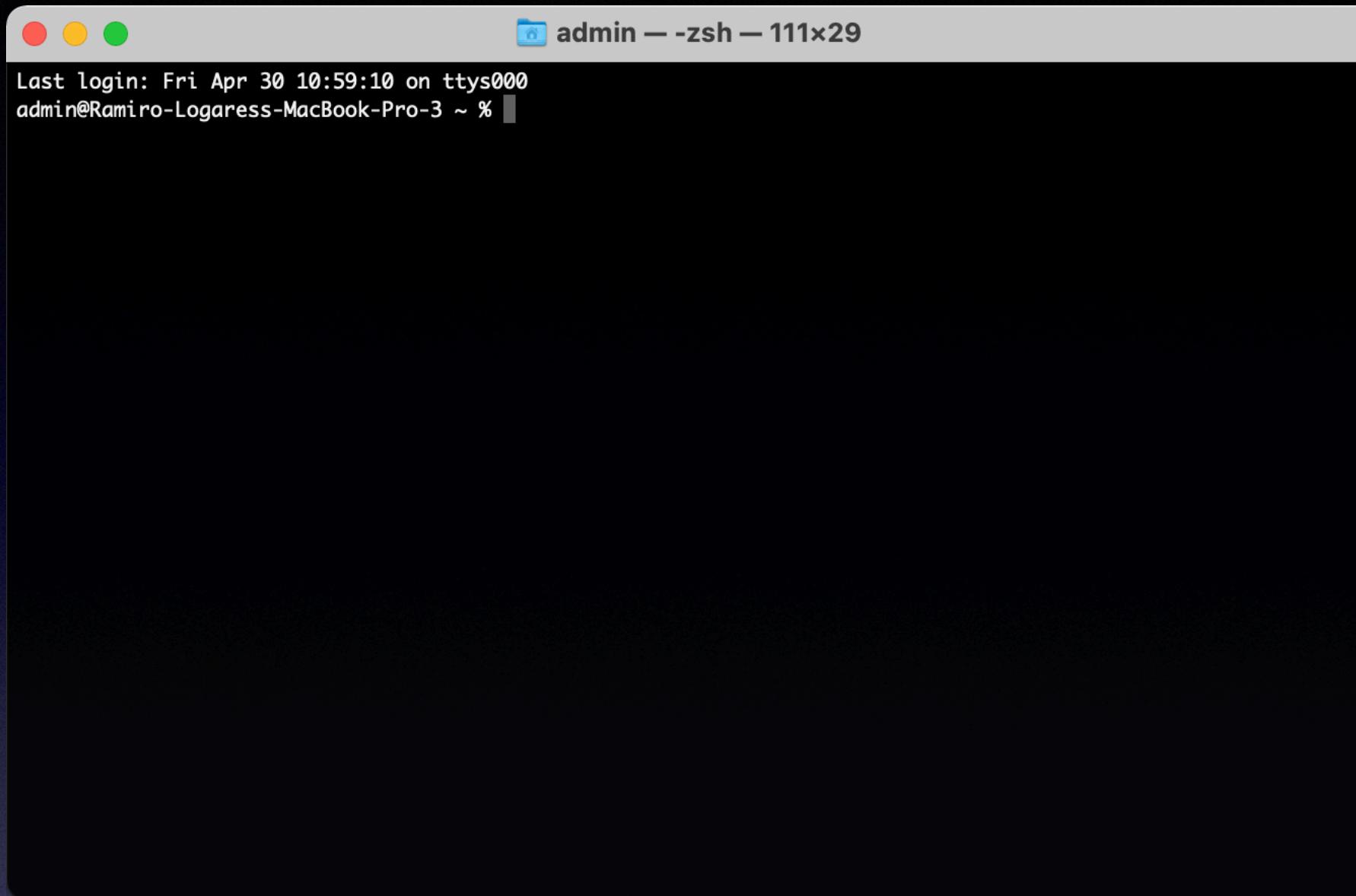
- User: performs several tasks, but has restricted access to specific functions (e.g. installing software)
- Has a “home” directory, where most operations are allowed (editing, generating files, deleting, etc.)
- Files belong to users and groups
- Root: super-user, can do everything, normally is the system administrator

Filesystem hierarchy



/ : root
/bin: or /usr/bin: files needed by Linux (binaries)
/boot: files needed for booting. Contains the kernel.
/etc: configuration files for Linux.
/dev: devices available (e.g. External Hard Drive)
/home: contain user homes
/lib: shared libraries
/usr: user applications
/var: variable data
/tmp: temporary files
/lost+found:files related to crashes
/opt: software and add-on packages (you may install software here)

Terminal



Mac

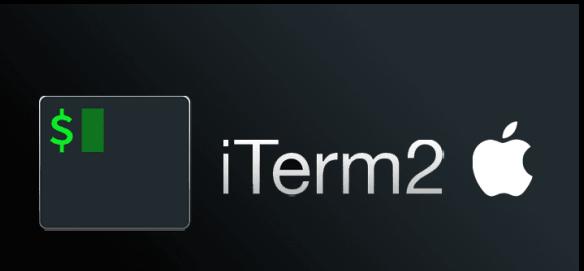
The homepage of the iTerm2 website. It features a large logo with a green dollar sign icon inside a white square. The text "iTerm2" is prominently displayed in a large, white, sans-serif font. Below the logo, it says "iTerm2 is a terminal emulator for macOS that does amazing things." A navigation bar at the top includes links for Home, News, Features, FAQ, Documentation, Downloads, and a red "Donate" button. The main content area contains sections for "What is iTerm2?", "Why Do I Want It?", and "How Do I Use It?", each with descriptive text and links. A large "Download" button is centered at the bottom of the page.

- Terminal available in:
- all Unix versions
 - MacOS
 - Windows emulators

Windows

Check list of linux emulators:
<https://www.fosslinux.com/43264/best-linux-emulator-windows.htm>

```
[rlogares@marbits ~]$ si
PARTITION HOSTNAMES AVAIL STATE CPU$ CPU_LOAD MEMORY FREE_MEM S:C:T REASON
main      c01       up   mix    48   3.67  773942  761589  2:12:2 none
main      c02       up   mix    48   29.44  773942  298384  2:12:2 none
main      c05       up   mix    48   24.75  257847  237107  2:12:2 none
main      c06       up   mix    48   27.04  257847  209366  2:12:2 none
main      c07       up   mix    48   24.51  257847  145737  2:12:2 none
main      c08       up   mix    48   7.90   257847  219942  2:12:2 none
main      c09       up   mix    48   8.10   257847  205758  2:12:2 none
main      c22       up   mix    24   7.02   80544   76375   2:6:2 none
main      c03       up   alloc   48   22.13  257847  185893  2:12:2 none
main      c04       up   alloc   48   39.53  257847  233318  2:12:2 none
main      c10      up   alloc   48   1.62   257847  229102  2:12:2 none
main      c13      up   alloc   24   1.16   112800  74372   2:6:2 none
main      c11      up   idle    24   0.01   80544   78076   2:6:2 none
main      c12      up   idle    24   0.01   80544   78103   2:6:2 none
main      c14      up   idle    24   0.01   80544   78179   2:6:2 none
main      c15      up   idle    24   0.01   80544   78176   2:6:2 none
main      c16      up   idle    24   0.01   80544   78195   2:6:2 none
main      c17      up   idle    24   0.01   80544   78195   2:6:2 none
main      c18      up   idle    24   0.01   80544   78199   2:6:2 none
main      c19      up   idle    24   0.01   64416   62251   2:6:2 none
main      c20      up   idle    24   0.01   62429   62224   2:6:2 none
main      c21      up   idle    24   0.01   80544   78101   2:6:2 none
```



```
[rlogares@marbits ~]$ logout
Connection to marbits.cmima.csic.es closed.
admin@Ramiro-Logares-MacBook-Pro-3 ~ %
```

```
nconsolata --style solarized-dark -W -J 150 -j 3 --syntax r | pbcopy
admin@Ramiro-Logares-MacBook-Pro-3 code.for.slides % highlight -0 rtf code.slide1.txt --line-numbers --font-size 24 --font I
nconsolata --style solarized-dark -W -J 150 -j 3 --syntax r | pbcopy
admin@Ramiro-Logares-MacBook-Pro-3 code.for.slides % highlight -0 rtf code.slide1.txt --line-numbers --font-size 24 --font I
nconsolata --style solarized-dark -W -J 150 -j 3 --syntax r | pbcopy
admin@Ramiro-Logares-MacBook-Pro-3 code.for.slides % highlight -0 rtf code.slide1.txt --line-numbers --font-size 18 --font I
nconsolata --style solarized-dark -W -J 150 -j 3 --syntax r | pbcopy
admin@Ramiro-Logares-MacBook-Pro-3 code.for.slides % highlight -0 rtf code.slide1.txt --line-numbers --font-size 18 --font I
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admin@Ramiro-Logares-MacBook-Pro-3 code.for.slides % highlight -0 rtf code.slide1.txt --line-numbers --font-size 22 --font I
nconsolata --style solarized-dark -W -J 150 -j 3 --syntax r | pbcopy
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nconsolata --style solarized-dark -W -J 150 -j 3 --syntax r | pbcopy
admin@Ramiro-Logares-MacBook-Pro-3 code.for.slides % highlight -0 rtf code.slide1.txt --line-numbers --font-size 12 --font I
nconsolata --style solarized-dark -W -J 150 -j 3 --syntax r | pbcopy
admin@Ramiro-Logares-MacBook-Pro-3 code.for.slides % highlight -0 rtf code.slide1.txt --line-numbers --font-size 14 --font I
nconsolata --style solarized-dark -W -J 150 -j 3 --syntax r | pbcopy
admin@Ramiro-Logares-MacBook-Pro-3 code.for.slides % highlight -0 rtf code.slide1.txt --line-numbers --font-size 13 --font I
nconsolata --style solarized-dark -W -J 150 -j 3 --syntax r | pbcopy
admin@Ramiro-Logares-MacBook-Pro-3 code.for.slides %
Session Contents Restored on 29 Apr 2021 at 22:49
Last login: Thu Apr 29 22:48:07 on console
admin@Ramiro-Logares-MacBook-Pro-3 code.for.slides %
Session Contents Restored on 30 Apr 2021 at 10:59
Last login: Fri Apr 30 10:58:54 on console
admin@Ramiro-Logares-MacBook-Pro-3 code.for.slides % highlight -0 rtf code.slide1.txt --line-numbers --font-size 18 --font I
nconsolata --style solarized-dark -W -J 150 -j 3 --syntax r | pbcopy
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code.slide1.txt
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nconsolata --style solarized-dark -W -J 150 -j 3 --syntax r | pbcopy
admin@Ramiro-Logares-MacBook-Pro-3 code.for.slides %
```

Some commands

```
1 # Working with directories & files
2
3 ls = "list files/folders"
4     ls or ll
5
6 cd = "change directory (move around)"
7     cd (home) ; cd dir (go to dir); cd .. (one level up); cd ../../ (two levels up)
8
9 pwd = "see working directory"
10
11 cp = "copy files"
12     cp /route/to/file/to/copy/file /new/location/of/file
13     cp -r /dir/to/copy/dir /location/for/dir/copy # Copy dir and its contents
14
15 mv = "move or rename files"
16     mv /old/location/for/my/file /new/location/for/my/file
17     mv old_name new_name
18
19 rm = "delete a file or directory"
20     rm /file/to/remove
21     rm -rf /remove/directory/and/all/contents (use carefully!!)
22
```

```
1 # Working with directories & files

22
23 rmdir = "delete a directory"
24
25 mkdir = make directory"
26
27 less/cat = "see what's inside a file"
28
29 head/tail = "see beginning / end of a file"
30         tail -n 300 file (see last 300 lines); head -n 300
31
32 cat = "concatenate files (also print files to the terminal)"
33         cat file1 file2 > new.cat.file"
34
35 # Permissions
36 chmod = "change permissions"
37         chmod a+x executable.file
38         chmod 755 file (owner:group:world permissions)"
39
40 chown = "change ownership of a file or directory"
41         chown user:group file # Assign file to a new user and group
```

File permissions

```
shum@sol:~ $ ls -l
total 20
drwx----- 2 shum    staff      4096 Jan 16 22:04 Mail
drwx----- 3 shum    staff      4096 Jan 16 14:15 csc128
drwxr-xr-x 2 shum    staff      4096 Jan 13 16:42 public
drwxr-xr-x 2 shum    staff      4096 Jan 16 14:07 public_html
-rw-r--r-- 1 shum    staff       628 Jan 15 20:04 verse
```

The diagram illustrates the structure of the `ls -l` output. It shows five entries with their respective permissions, owner, group, size, date modified, and filename. Arrows point from specific fields to their meanings:

- file type**: Points to the first character of each line (d for directory, - for file).
- user (owner) name**: Points to the second column.
- group name**: Points to the third column.
- size**: Points to the fourth column.
- date/time last modified**: Points to the fifth and sixth columns.
- filename**: Points to the final column.
- permissions**: Points to the first three characters of each line. A legend below defines:
 - r**: Read
 - w**: Write
 - x**: Execute
 - : No permission
- user permissions**: Points to the first character of the permission string.
- group permissions**: Points to the second character of the permission string.
- other (everyone) permissions**: Points to the third character of the permission string.
- readable**: Points to the first character of the permission string.
- writeable**: Points to the second character of the permission string.
- executable**: Points to the third character of the permission string.

drwxrwxrwx	7	rwx	111
d = Directory	6	rw-	110
r = Read	5	r-x	101
w = Write	4	r--	100
x = Execute	3	-wx	011
	2	-w-	010
	1	--x	001
	0	---	000

chmod 777

↓ ↓ ↓

rwx|rwx|rwx
Owner|Group|Others

```
1 # Processes & super user
2
3 top = "see running processes"
4
5 kill = "kill a process"
6
7 sudo = "request root access for a task (not always available)"
8
9 #Common Tools
10
11 emacs/vim/nano: "useful text editors"
12
13 grep = "search text for a pattern"
14     grep pattern file # search pattern in file
15     grep -c pattern file # count pattern in file
16
17 awk: "Powerful text editor"
18     awk '{print $1, $5}' table # Prints fields 1 and 5 from table
19
20 sed = "search and replace patterns in files"
21     sed "s/rat/cat/g" infile > outfile # Search "rat" and replace by "cat" in infile
22     sed "s/rat//g" infile > outfile # Remove "rat" from infile
23
```

```
1 # Processes & super user
2
3
4 #Combine commands with a pipe |
5 output | input
6     ll | grep -c pattern (count filenames with pattern)
7     ll | grep pattern > file
8     cut: "cuts characters from a file"
9     less file | cut -f 2 -d "-" # Bring the 2nd field from file, separated by "-"
10
11 sort = "sorts records"
12
13 uniq = "retrieves unique records"
14
15 Often used together as sort | uniq
16
17 wget (get files or directories from remote computers)
18 wget http://linux.come/file
19
20
21 #Connectivity
22 ssh = remote connection to a machine"
23     ssh user@machine (remote connection)
24     scp file.to.copy user@machine:/path/to/location/to/copy # copy to a remote computer
25     scp user@machine:/path/to/file . # copy from a remote location
```

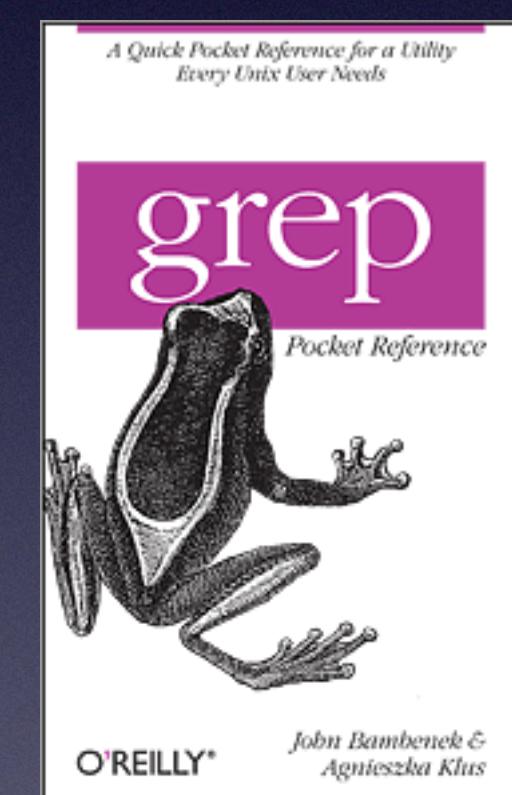
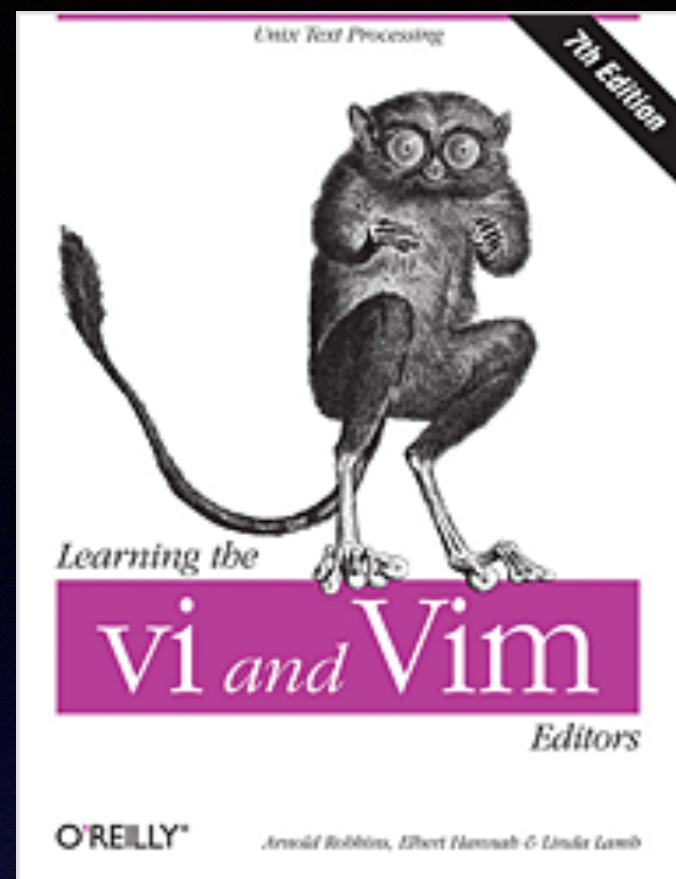
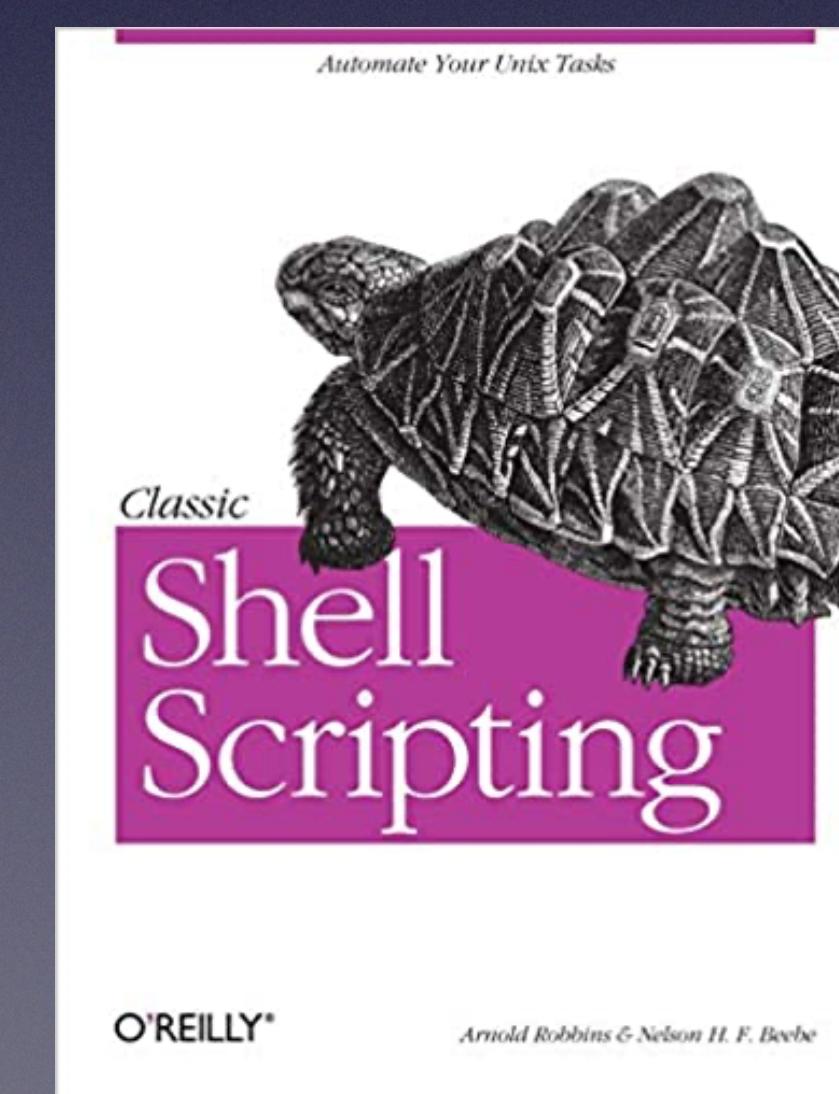
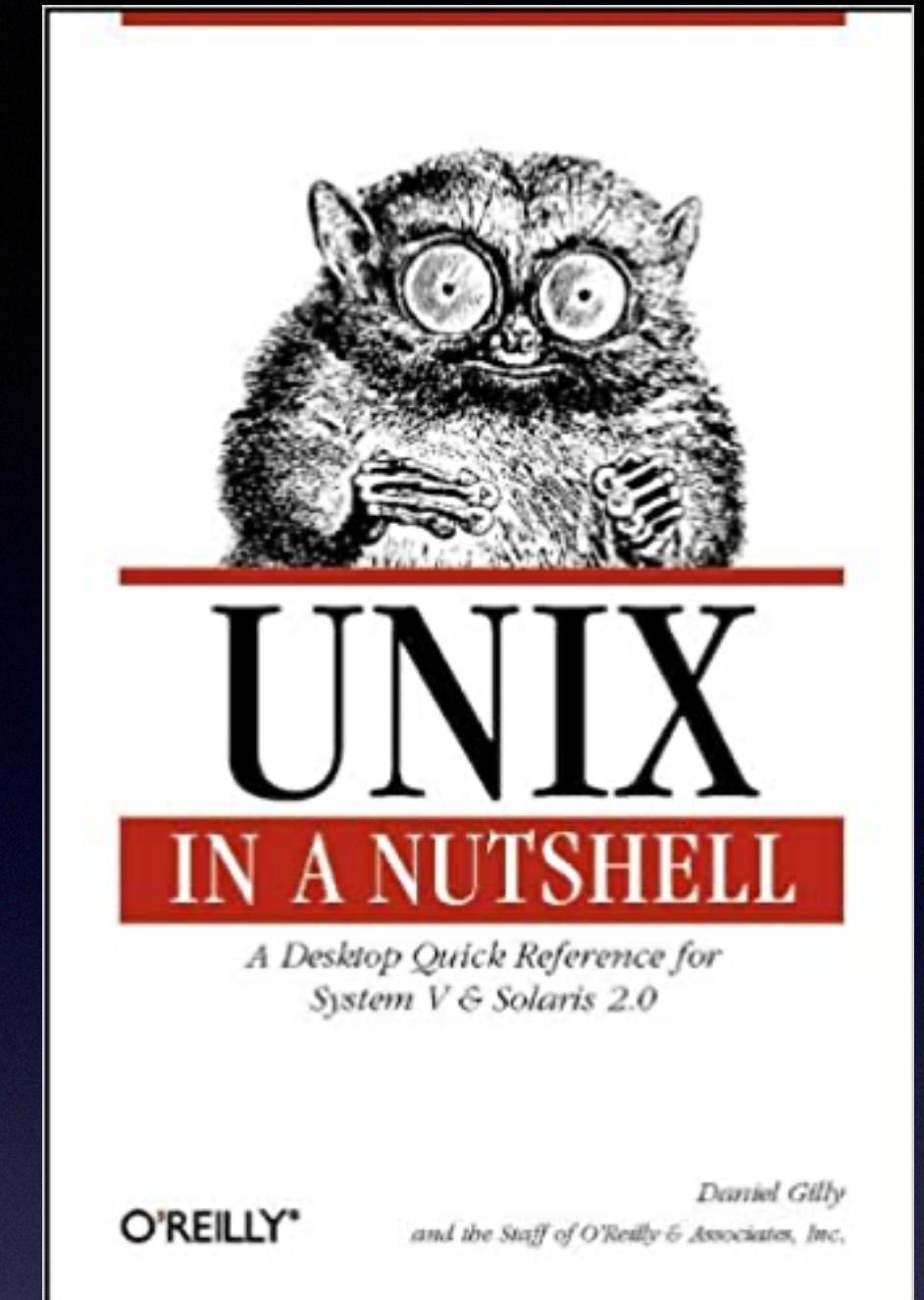
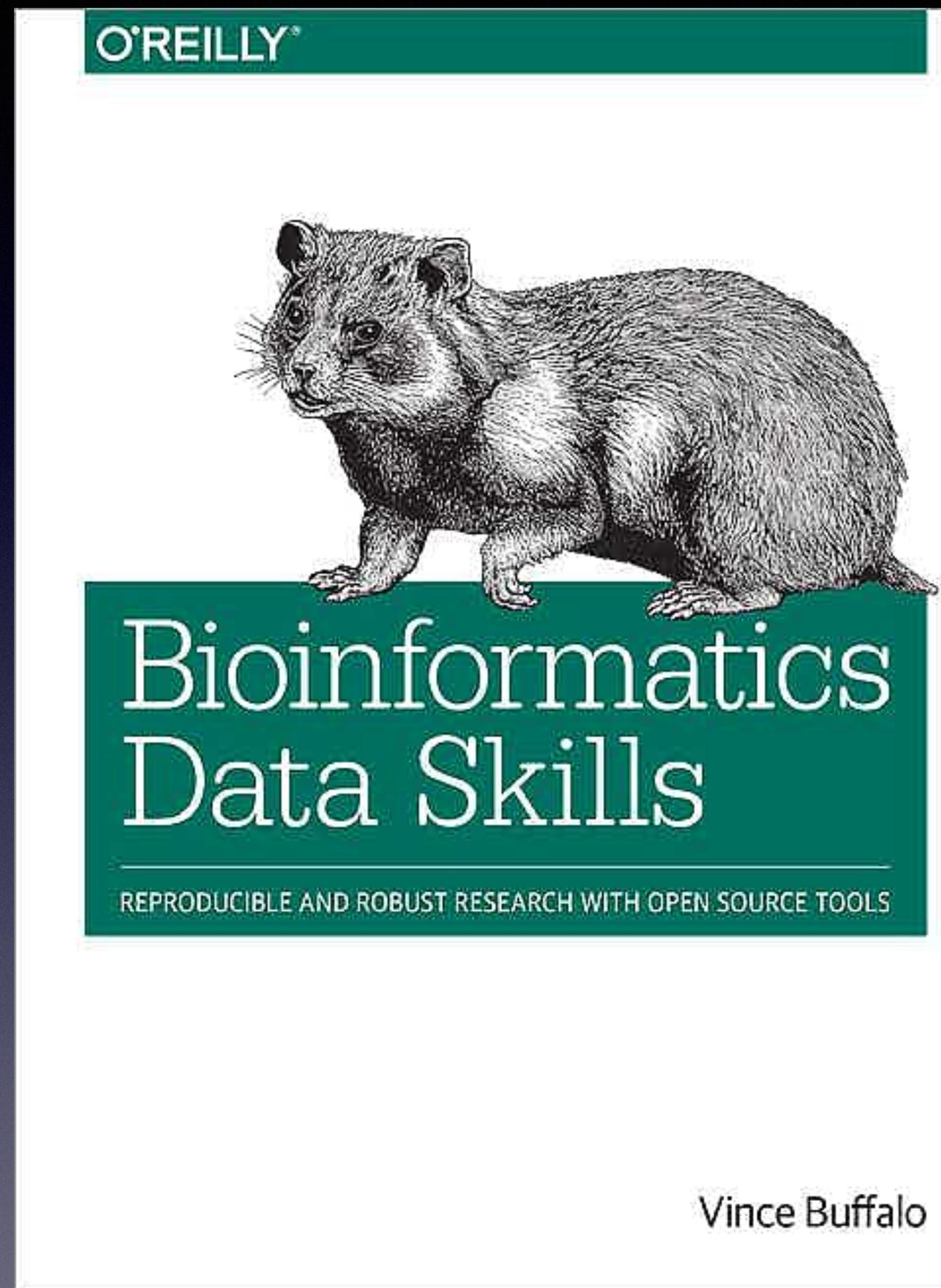
```
1 #Manual
2 man = documentation about a command (also program -h)
3     #Available for all core functions and programs
4
5 # Execute a program/script
6 ./executable
7
8 Add programs to your search path permanently
9
10 edit .bashrc # This is a file at your home with environmental variables
11 emacs .bashrc
12     export PATH=/path/to/file :$PATH
13
14
15 # Generate temporal variables
16
17 var1=/path/to/file # set up variable
18 ${var1} # calls variable
19
```

```
21 # Loops
22 Runs a function over several files
23
24 If you have: file1, file2, ..., filen
25 Then:
26     for i in $(ls); do cut -f 2 ${i} > ${i}.out; done
27     Cuts field 2 in each file and sends it to a corresponding output
28
29
30 # Execute functions in bashscripts
31 emacs my.bash.script.sh
32
33 #!/bin/bash
34 for i in $(ls); do cut -f 2 ${i} > ${i}.out; done
35
36 chmod a+x my.bash.script.sh # make script executable
37 ./my.bash.script.sh # execute script
38
```

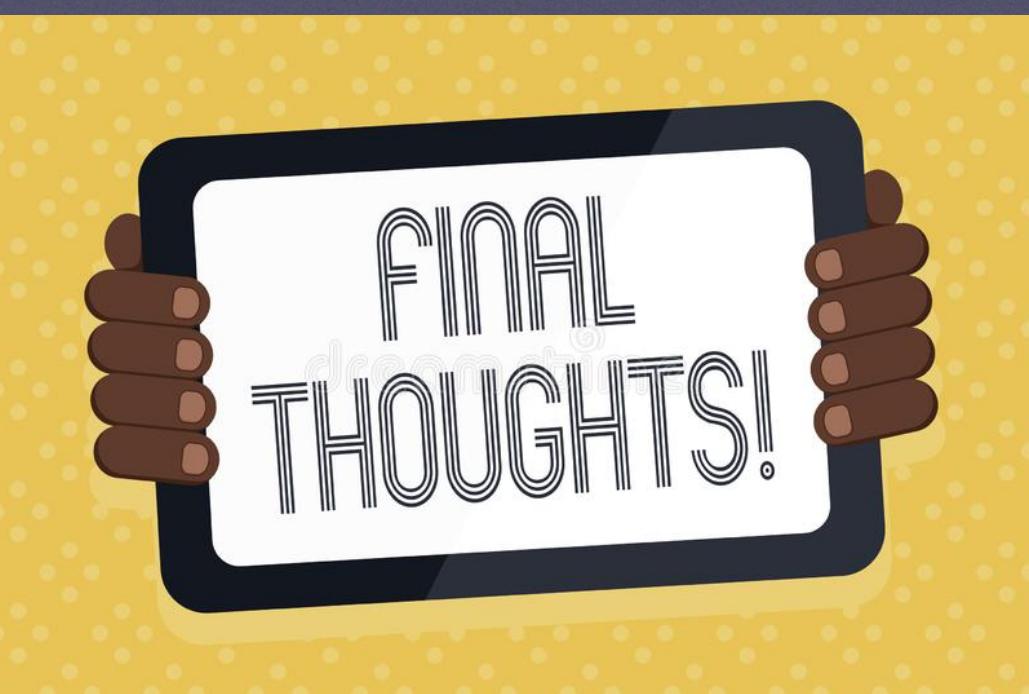
File Commands	System Info
<code>ls</code> - directory listing <code>ls -al</code> - formatted listing with hidden files <code>cd dir</code> - change directory to <i>dir</i> <code>cd ~</code> - change to home <code>pwd</code> - show current directory <code>mkdir dir</code> - create a directory <i>dir</i> <code>rm file</code> - delete <i>file</i> <code>rm -r dir</code> - delete directory <i>dir</i> <code>rm -f file</code> - force remove <i>file</i> <code>rm -rf dir</code> - force remove directory <i>dir</i> * <code>cp file1 file2</code> - copy <i>file1</i> to <i>file2</i> <code>cp -r dir1 dir2</code> - copy <i>dir1</i> to <i>dir2</i> ; create <i>dir2</i> if it doesn't exist <code>mv file1 file2</code> - rename or move <i>file1</i> to <i>file2</i> if <i>file2</i> is an existing directory, moves <i>file1</i> into directory <i>file2</i> <code>ln -s file link</code> - create symbolic link <i>link</i> to <i>file</i> <code>touch file</code> - create or update <i>file</i> <code>cat > file</code> - places standard input into <i>file</i> <code>more file</code> - output the contents of <i>file</i> <code>head file</code> - output the first 10 lines of <i>file</i> <code>tail file</code> - output the last 10 lines of <i>file</i> <code>tail -f file</code> - output the contents of <i>file</i> as it grows, starting with the last 10 lines	<code>date</code> - show the current date and time <code>cal</code> - show this month's calendar <code>uptime</code> - show current uptime <code>w</code> - display who is online <code>whoami</code> - who you are logged in as <code>finger user</code> - display information about <i>user</i> <code>uname -a</code> - show kernel information <code>cat /proc/cpuinfo</code> - cpu information <code>cat /proc/meminfo</code> - memory information <code>man command</code> - show the manual for <i>command</i> <code>df</code> - show disk usage <code>du</code> - show directory space usage <code>free</code> - show memory and swap usage <code>whereis app</code> - show possible locations of <i>app</i> <code>which app</code> - show which <i>app</i> will be run by default
Process Management	Compression
<code>ps</code> - display your currently active processes <code>top</code> - display all running processes <code>kill pid</code> - kill process id <i>pid</i> <code>killall proc</code> - kill all processes named <i>proc</i> * <code>bg</code> - lists stopped or background jobs; resume a stopped job in the background <code>fg</code> - brings the most recent job to foreground <code>fg n</code> - brings job <i>n</i> to the foreground	<code>tar cf file.tar files</code> - create a tar named <i>file.tar</i> containing <i>files</i> <code>tar xf file.tar</code> - extract the files from <i>file.tar</i> <code>tar czf file.tar.gz files</code> - create a tar with Gzip compression <code>tar xzf file.tar.gz</code> - extract a tar using Gzip <code>tar cjf file.tar.bz2</code> - create a tar with Bzip2 compression <code>tar xjf file.tar.bz2</code> - extract a tar using Bzip2 <code>gzip file</code> - compresses <i>file</i> and renames it to <i>file.gz</i> <code>gzip -d file.gz</code> - decompresses <i>file.gz</i> back to <i>file</i>
File Permissions	Network
<code>chmod octal file</code> - change the permissions of <i>file</i> to <i>octal</i> , which can be found separately for user, group, and world by adding: <ul style="list-style-type: none"> • 4 - read (r) • 2 - write (w) • 1 - execute (x) Examples: <code>chmod 777</code> - read, write, execute for all <code>chmod 755</code> - rwx for owner, rx for group and world For more options, see <code>man chmod</code> .	<code>ping host</code> - ping <i>host</i> and output results <code>whois domain</code> - get whois information for <i>domain</i> <code>dig domain</code> - get DNS information for <i>domain</i> <code>dig -x host</code> - reverse lookup <i>host</i> <code>wget file</code> - download <i>file</i> <code>wget -c file</code> - continue a stopped download
SSH	Installation
<code>ssh user@host</code> - connect to <i>host</i> as <i>user</i> <code>ssh -p port user@host</code> - connect to <i>host</i> on port <i>port</i> as <i>user</i> <code>ssh-copy-id user@host</code> - add your key to <i>host</i> for <i>user</i> to enable a keyed or passwordless login	Install from source: <code>./configure</code> <code>make</code> <code>make install</code> <code>dpkg -i pkg.deb</code> - install a package (Debian) <code>rpm -Uvh pkg.rpm</code> - install a package (RPM)
Searching	Shortcuts
<code>grep pattern files</code> - search for <i>pattern</i> in <i>files</i> <code>grep -r pattern dir</code> - search recursively for <i>pattern</i> in <i>dir</i> <code>command grep pattern</code> - search for <i>pattern</i> in the output of <i>command</i> <code>locate file</code> - find all instances of <i>file</i>	<code>Ctrl+C</code> - halts the current command <code>Ctrl+Z</code> - stops the current command, resume with <code>fg</code> in the foreground or <code>bg</code> in the background <code>Ctrl+D</code> - log out of current session, similar to <code>exit</code> <code>Ctrl+W</code> - erases one word in the current line <code>Ctrl+U</code> - erases the whole line <code>Ctrl+R</code> - type to bring up a recent command <code>!!</code> - repeats the last command <code>exit</code> - log out of current session



- In bioinformatics, Unix is your friend (using windows for bioinformatics is strongly discouraged)
- There's plenty of free resources online
- Solutions to many problems are already indicated in one of the many forums
- You can easily work in local and remote computers, and switch between them



- Even though most analyses that you'll see in this course are done in R, some steps are carried out in unix (e.g. initial sequence cleaning)
- Alternative analyses can be carried out using other tools, e.g. VSEARCH, that run in unix
- Normally, a substantial part of the bioinformatics work is done in clusters that run unix
- Moving between R and unix is normal (and easy)
- R runs smoothly in unix environments





```
1 # Unix tutorial
2
3 1. Open the terminal, go to your "home" folder or another chosen location
4
5 2. Create a directory called "biocourse" (use cd)
6
7 3. Go into the biocourse directory, and create the file "norwegian.black.metal.bands" (use nano, emacs, vi)
8     and write "windir, gorgoroth, emperor, abbath, urgehal"
9
10    If you have issues with the text editors, then run
11        echo "windir, gorgoroth, emperor, abbath, urgehal" > norwegian.black.metal.bands
12    What did we do in the line above?
13
14 4. Count how many words we have in the file norwegian.black.metal.bands (use wc -w)
15
16 5. Concatenate norwegian.black.metal.bands into a new file with repeated contents
17     cat norwegian.black.metal.bands norwegian.black.metal.bands > norwegian.black.metal.bands.x2
18
19 6. Open the new file norwegian.black.metal.bands.x2
20
21 7. Count again the number of words
22
23 8. See the unique words:
24     less norwegian.black.metal.bands.x2 | sort | uniq
25
26 9. Match the pattern "emperor" in the file norwegian.black.metal.bands.x2
27     grep --color "emperor" norwegian.black.metal.bands.x2
28     What do the results tell you?
29
```

```
1 # Unix tutorial
2
30 10. Paste the contents of norwegian.black.metal.bands.x2 next to each other
31     paste norwegian.black.metal.bands.x2 norwegian.black.metal.bands.x2 > norwegian.black.metal.bands.x4
32     See the contents and match the pattern "abbath"
33
34 11. Concatenate the contents of one file after the other
35     cat norwegian.black.metal.bands.x4 norwegian.black.metal.bands.x4 > norwegian.black.metal.bands.x8
36
37 12. Replace in the document the band "gorgoroth" by "norwegian.reggaeton"
38     sed "s/gorgoroth/norwegian.reggaeton/g" norwegian.black.metal.bands.x8 > norwegian.black.metal.bands.x8.v2
39
40 13. Let's change the order of bands with awk
41     less norwegian.black.metal.bands.x8.v2 | awk '{print$2,$1,$5,$3,$10,$6,$9,$8}' >norwegian.black.metal.bands.x8.v2.reordered
42     With "print" we indicate the order of the fields in the new file
43
44 14. We add the prefix bandname to each field
45     less norwegian.black.metal.bands.x8.v2.reordered | awk '{print "bandname", $0}'
46
47 15. Have a look to the permissions of the files that were created:
48     ls -l norwegian.black.metal.bands*
49     What do these permissions mean?
50
51 16. Change the permissions of one of the created files
52     chmod 777 norwegian.black.metal.bands
53     What permissions did we give to this file? What can group and other users can do with it?
54
55 17. Remove the file
56     rm norwegian.black.metal.bands
57
58 18. Go one level up from the directory biocourse. Try to remove it with:
59     rmdir biocourse
60     What is happening? how would you solve this? NB: no need to actually remove this directory unless you want to do it.
```