

LINUX

- Plan for today:
 - (1) What is Linux?
 - (2) How to use a shell
 - (3) Navigating the file system
 - (4) Working with files
 - (6) Running programs & file permissions

What is Linux?

- Just another operating system
- Linux is open source
- Linux is a variant of Unix

So is Mac OS X, so much of this tutorial applies to Macs as well

Why Linux?

- Linux is **free**
- It's fully **customizable**
- It's **stable** (i.e. it almost never crashes)
- But: People are used to Windows/Mac! So why should they bother?

So why Linux?

- When working with sequencing data you don't really have another choice
- It is possible to handle extremely **large files** without problems
- Most of the **software** is developed/optimized for Linux
- It is easy to run programs on **remote machines**

Several ways to use Linux

- MACOS

```
Last login: Fri Aug 16 11:40:54 on ttys000
[liang@iMBP:~$ echo hello world!
hello world!
liang@iMBP:~$ ]
```

Several ways to use Linux

- Windows 10

Google windows 10 linux subsystem

All News Videos Images Books More Settings Tools

About 5,690,000 results (0.56 seconds)

Enabling the Windows Subsystem for Linux in the Windows 10 Fall Creators Update and Later

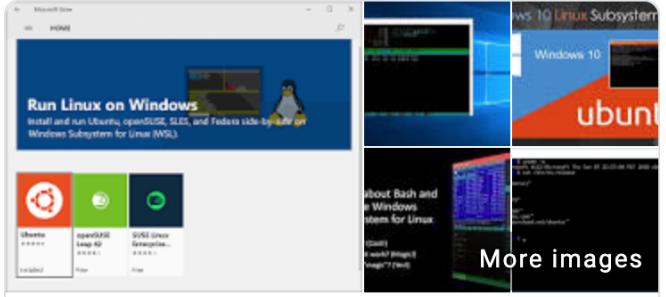
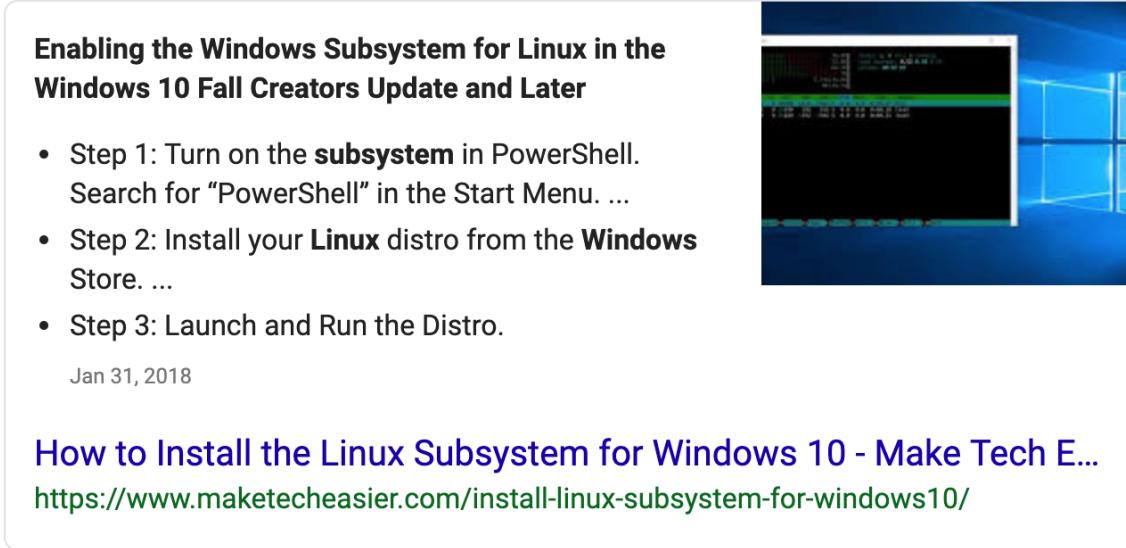
- Step 1: Turn on the **subsystem** in PowerShell. Search for “PowerShell” in the Start Menu. ...
- Step 2: Install your **Linux** distro from the **Windows Store**. ...
- Step 3: Launch and Run the Distro.

Jan 31, 2018

How to Install the Linux Subsystem for Windows 10 - Make Tech E...
<https://www.maketecheasier.com/install-linux-subsystem-for-windows10/>

About Featured Snippets Feedback

Install Windows Subsystem for Linux (WSL) on Windows 10 | Micr...
<https://docs.microsoft.com/en-us/windows/wsl/install-wsl1#on>



Windows Subsystem for Linux

Windows Subsystem for Linux is a compatibility layer for running Linux binary executables natively on Windows 10 and Windows Server 2019. In May 2019, WSL 2 was announced, introducing important changes such as a real Linux kernel, through a subset of Hyper-V features. [Wikipedia](#)

Several ways to use Linux

- Buy a second hand computer and install Linux

The screenshot shows a Taobao product page for a ThinkPad laptop. At the top, the URL is item.taobao.com/item.htm?spm=a230r.1.14.28.409733568scDK7&id=571046339342&ns=1&abbucket=4#detail. Below the URL is a horizontal bar with various application icons.

ThinkPad 经典商务黑

ThinkPad T450 /T440S商务T460办公T430联想X250笔记本 X240电脑i5

价格 ￥1520.00 161 累计评论
淘宝价 ￥1444.00 狂欢大促 47 交易成功

配送 上海至北京 快递 免运费 72小时内发货

颜色分类

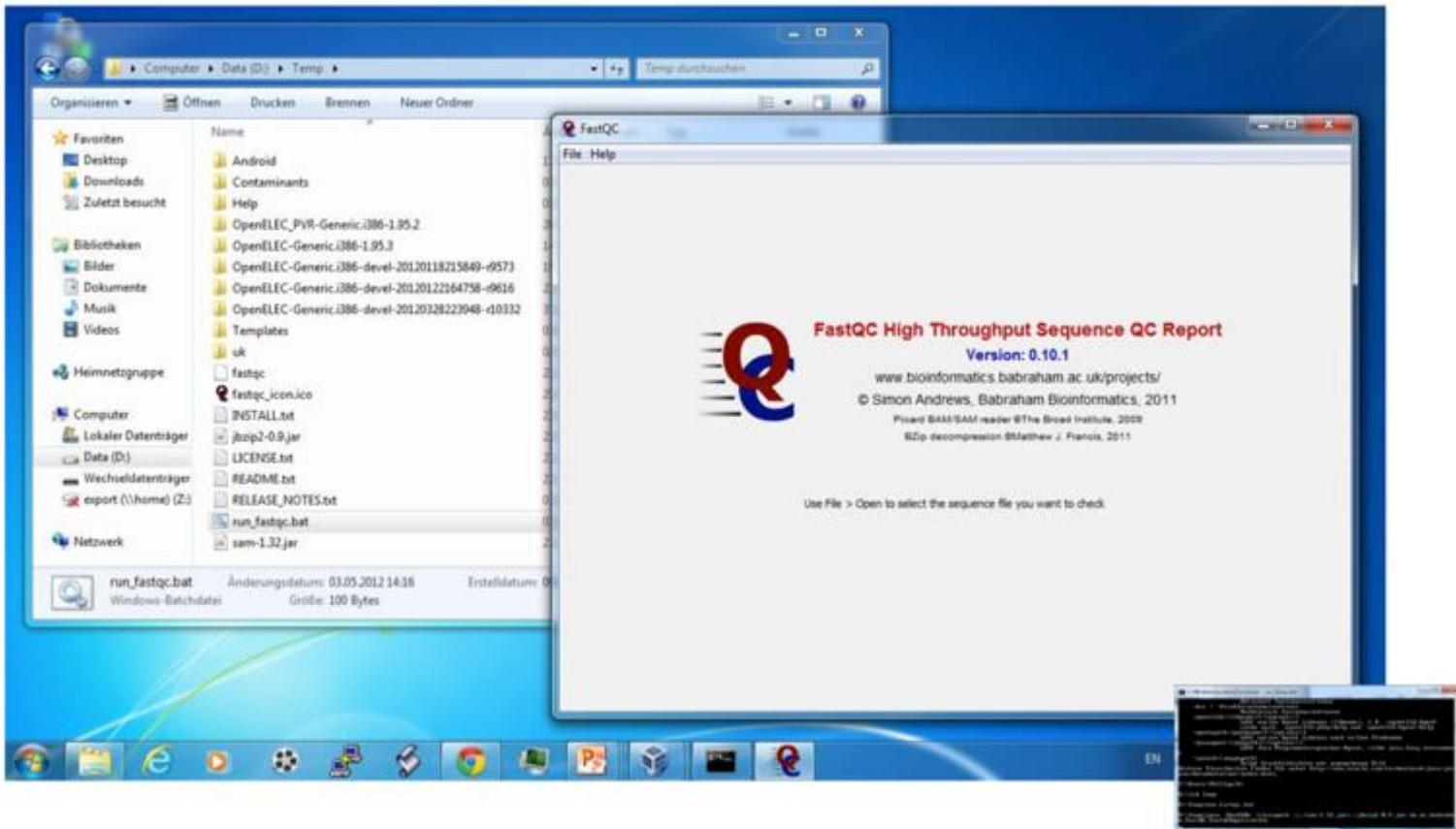
- A 【 T430 i5-3320M 】 (highlighted with a red border)
- B 【 T440/T440S 】
- C 【 T450/T450S 】
- D 【 T450 i5-五代 】
- E 【 T460 i5-六代 】
- F 【 X230 i5-3320M 】
- B 【 X240 i5-4300U 】
- C 【 X250 i5-5200U 】
- D 【 X260 i5-6300U 】
- F 【 S2银色13.3英寸】

套餐类型

- 套餐一 (highlighted with a red border)
- 套餐二
- 套餐三
- 套餐四

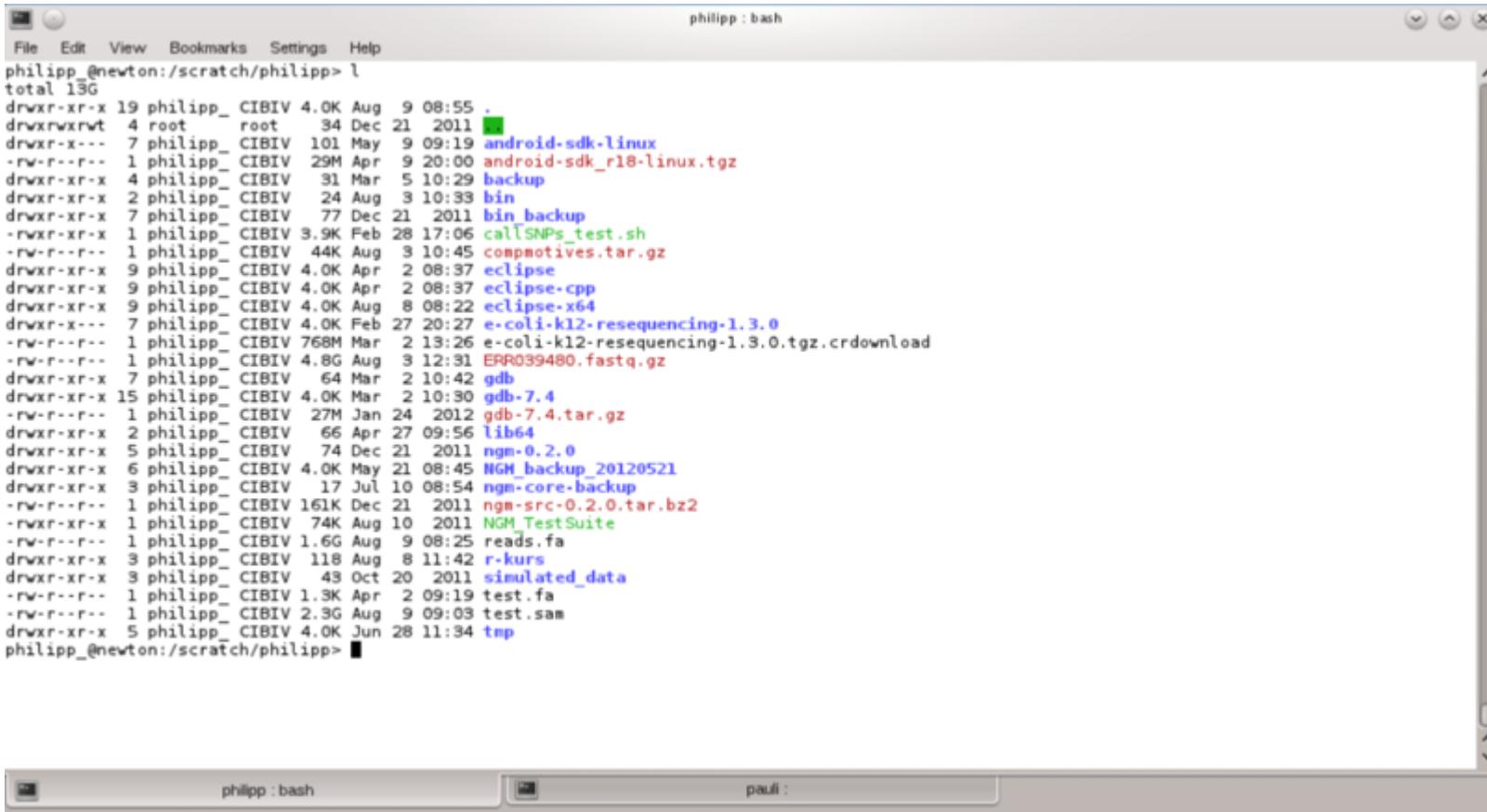
优惠中 分期免息 强劲性能，商务游戏两不误

GUI vs. Shell: Windows



- Windows: focus on graphical user interface

GUI vs. Shell: Linux



```
philipp : bash
philipp @_newton:/scratch/philipp> l
total 13G
drwxr-xr-x 19 philipp_ CIBIV 4.0K Aug  9 08:55 .
drwxrwxrwt  4 root   root  34 Dec 21  2011 █
drwxr-x---  7 philipp_ CIBIV 101 May  9 09:19 android-sdk-linux
-rw-r--r--  1 philipp_ CIBIV 29M Apr  9 20:00 android-sdk_r18-linux.tgz
drwxr-xr-x  4 philipp_ CIBIV 31 Mar  5 10:29 backup
drwxr-xr-x  2 philipp_ CIBIV 24 Aug  3 10:33 bin
drwxr-xr-x  7 philipp_ CIBIV 77 Dec 21  2011 bin_backup
-rwxt-r-x-  1 philipp_ CIBIV 3.9K Feb 28 17:06 callSNPs_test.sh
-rw-r--r--  1 philipp_ CIBIV 44K Aug  3 10:45 compmatives.tar.gz
drwxr-xr-x  9 philipp_ CIBIV 4.0K Apr  2 08:37 eclipse
drwxr-xr-x  9 philipp_ CIBIV 4.0K Apr  2 08:37 eclipse-cpp
drwxr-xr-x  9 philipp_ CIBIV 4.0K Aug  8 08:22 eclipse-x64
drwxr-x---  7 philipp_ CIBIV 4.0K Feb 27 20:27 e-coli-k12-resequencing-1.3.0
-rw-r--r--  1 philipp_ CIBIV 768M Mar  2 13:26 e-coli-k12-resequencing-1.3.0.tgz.crdownload
-rw-r--r--  1 philipp_ CIBIV 4.8G Aug  3 12:31 ERR039480.fastq.gz
drwxr-xr-x  7 philipp_ CIBIV 64 Mar  2 10:42 gdb
drwxr-xr-x 15 philipp_ CIBIV 4.0K Mar  2 10:30 gdb-7.4
-rw-r--r--  1 philipp_ CIBIV 27M Jan 24  2012 gdb-7.4.tar.gz
drwxr-xr-x  2 philipp_ CIBIV 66 Apr 27 09:56 lib64
drwxr-xr-x  5 philipp_ CIBIV 74 Dec 21  2011 ngm-0.2.0
drwxr-xr-x  6 philipp_ CIBIV 4.0K May 21 08:45 NGM_backup_20120521
drwxr-xr-x  3 philipp_ CIBIV 17 Jul 10 08:54 ngm-core-backup
-rw-r--r--  1 philipp_ CIBIV 161K Dec 21  2011 ngm-src-0.2.0.tar.bz2
-rw-r--r--  1 philipp_ CIBIV 74K Aug 10  2011 NGM_TestSuite
-rw-r--r--  1 philipp_ CIBIV 1.6G Aug  9 08:25 reads.fa
drwxr-xr-x  3 philipp_ CIBIV 118 Aug  8 11:42 r-kurs
drwxr-xr-x  3 philipp_ CIBIV 43 Oct 20  2011 simulated_data
-rw-r--r--  1 philipp_ CIBIV 1.3K Apr  2 09:19 test.fa
-rw-r--r--  1 philipp_ CIBIV 2.3G Aug  9 09:03 test.sam
drwxr-xr-x  5 philipp_ CIBIV 4.0K Jun 28 11:34 tmp
philipp @_newton:/scratch/philipp> █
```

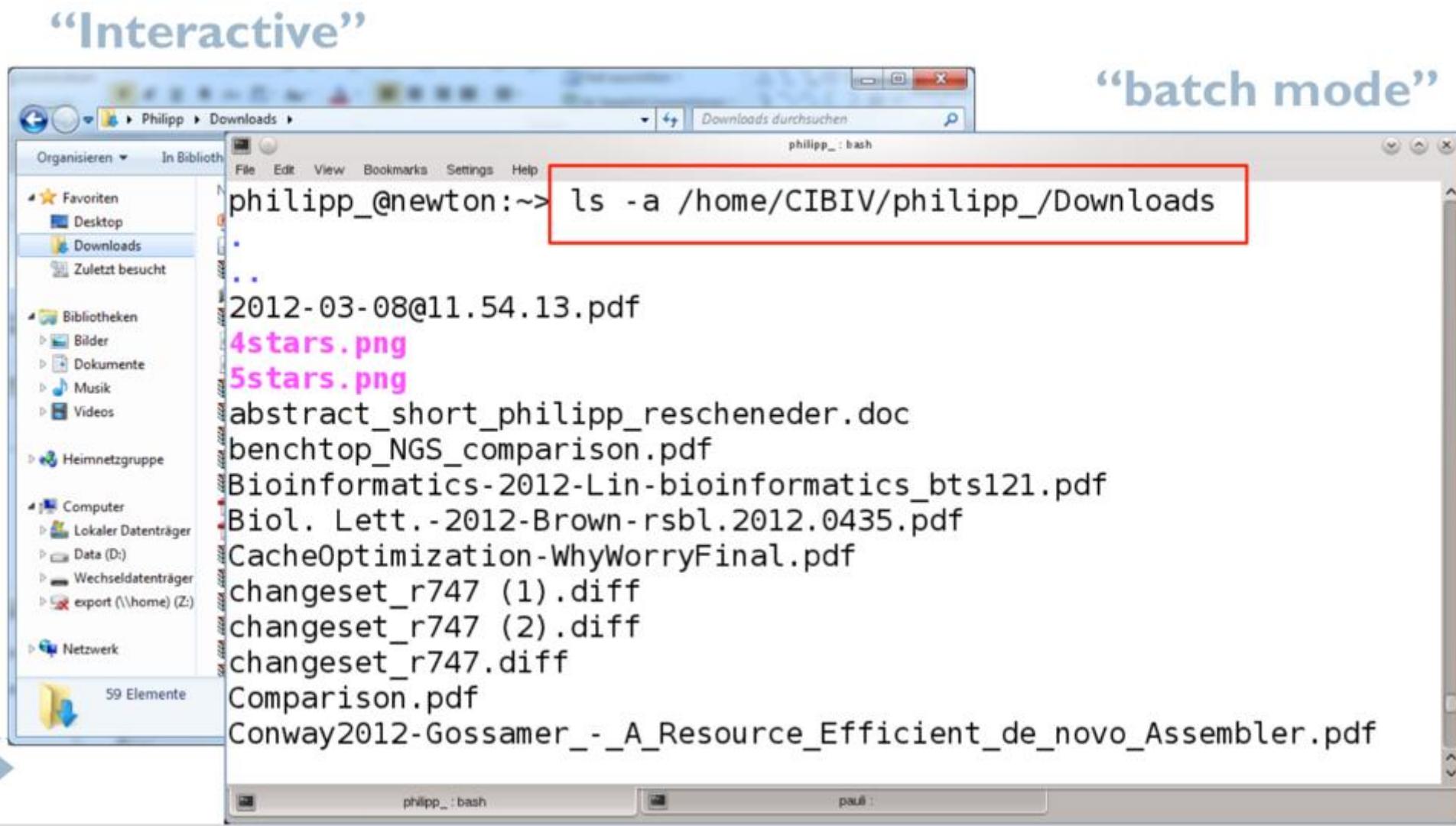
philipp : bash

pauli :

- Linux: focus on command line interface (GUI just an “Addon”)

GUI vs. Shell

- Show (hidden) files in Download folder

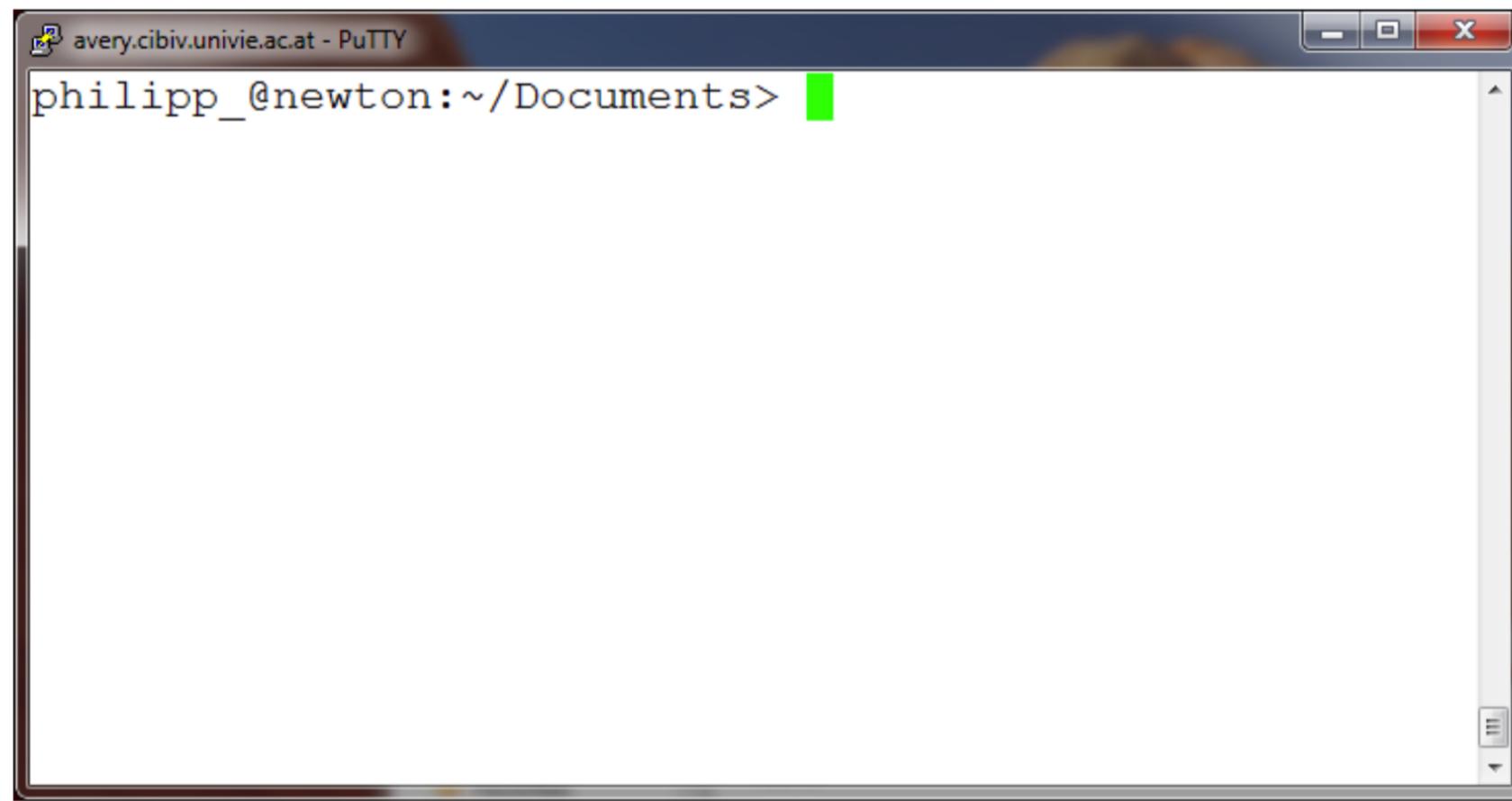


What exactly is a "shell"?

- ▶ The shell interprets commands the user types and manages their execution
 - ▶ The shell communicates with the internal part of the operating system called the **kernel**
 - ▶ The most popular shells are: tcsh, csh, korn, and **bash**
 - ▶ The differences are most times subtle
 - ▶ For this tutorial, we are using bash
- ▶ Shell commands are **CASE SENSITIVE!**

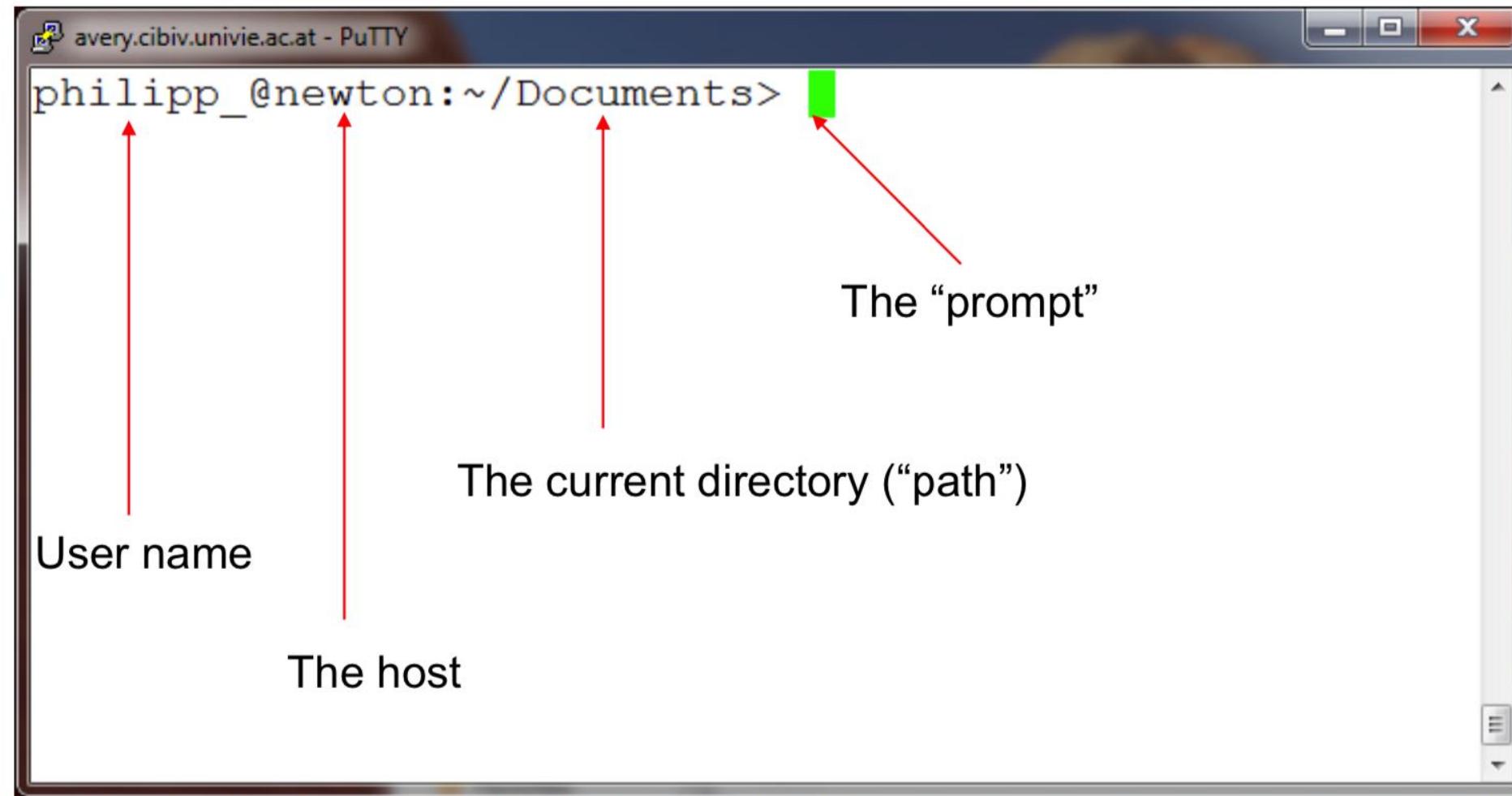
Connecting to a Unix/Linux system

- ▶ Open up a terminal:

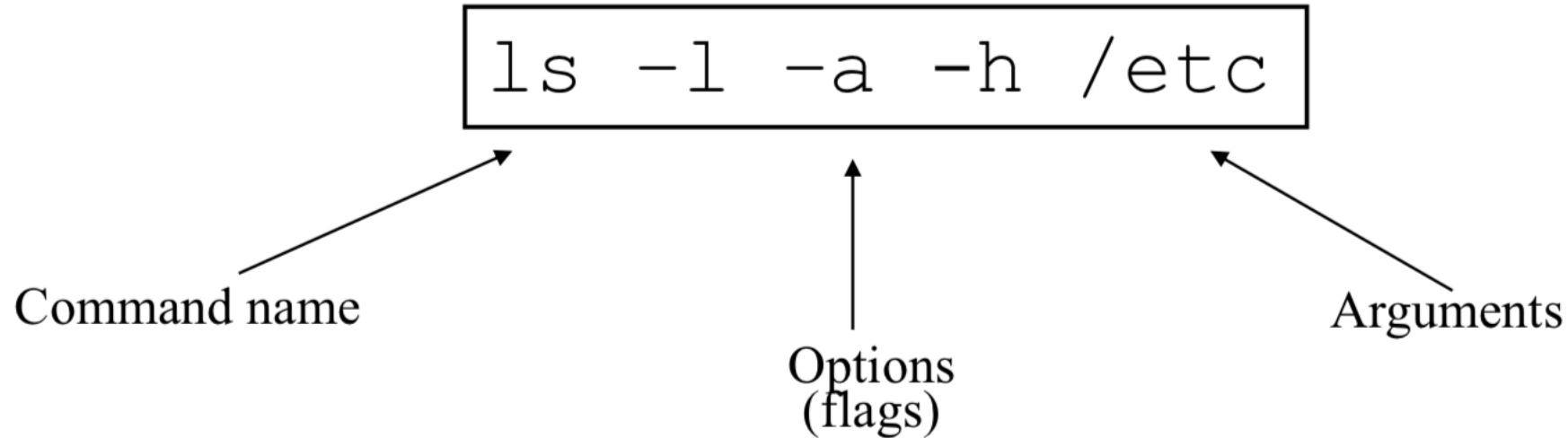


Connecting to a Unix/Linux system

- ▶ Open up a terminal:



Executing a command



- ▶ **Combine options:**

```
ls -lah /etc
```

- ▶ **Long options:**

```
ls -l --all --human-readable /etc
```

Terminating a running command



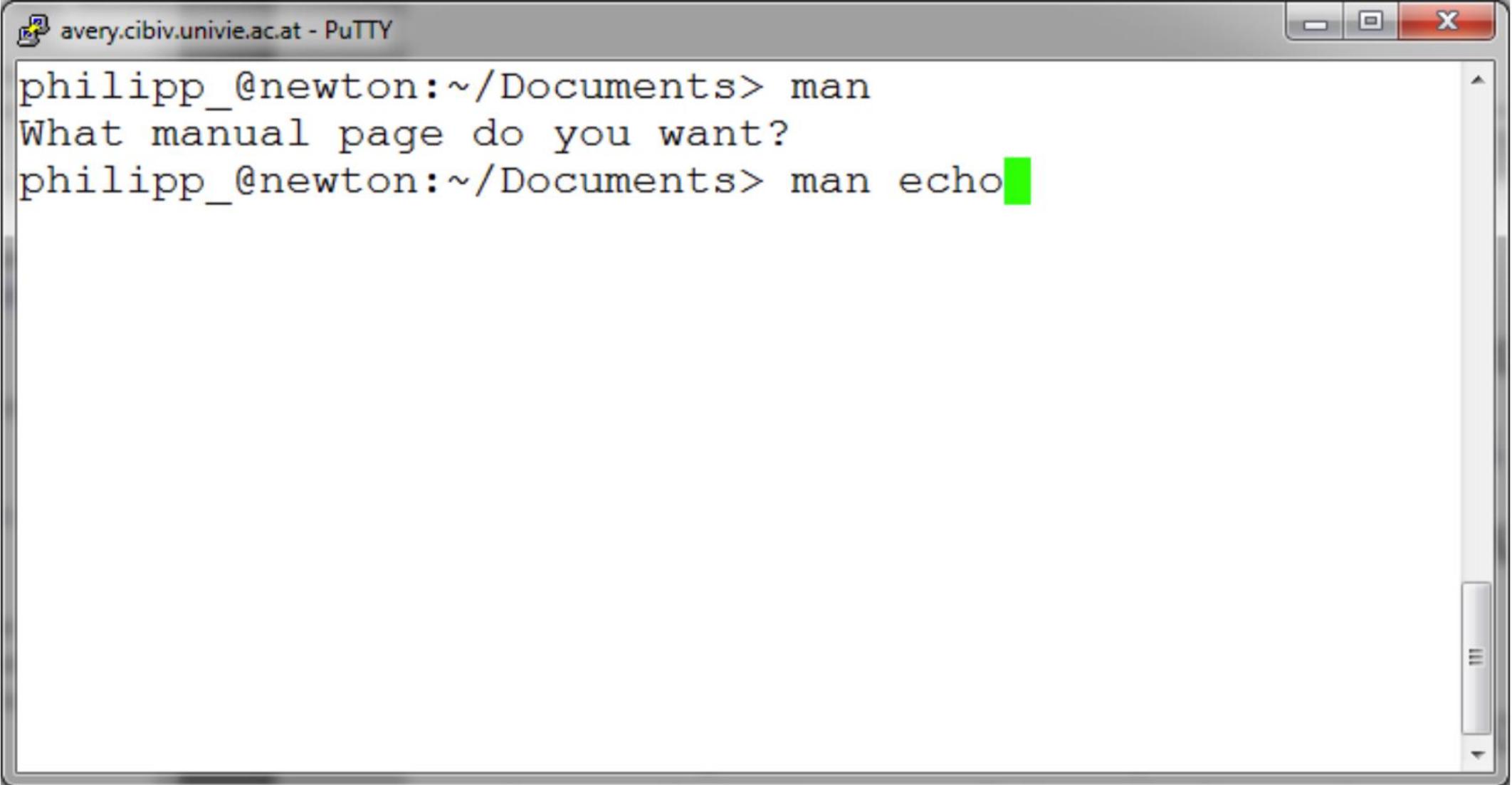
The screenshot shows a PuTTY terminal window titled "avery.cibiv.univie.ac.at - PuTTY". The command entered is "grep \"ATG\" - c test.fq". The output shows several lines of text: "ls", "as", "ASF", "cc", and "^C". The cursor is positioned at the end of the command line, just after the closing quote of the grep command.

- Press Ctrl-C to terminate the command!

Help!

- ▶ Endless number of commands/programs and parameters
- ▶ But: “*You never walk alone*”
- ▶ Whenever you need help with a command:
 - ▶ run the command with –h or –help as parameter
 - ▶ type “man” and the command name
 - ▶ ask Google!!

Help!



The screenshot shows a PuTTY terminal window titled "avery.cibiv.univie.ac.at - PuTTY". The session path is "philipp_@newton:~/Documents". The user has run the command "man" followed by "echo". The response from the manual system asks "What manual page do you want?". The word "echo" is highlighted with a green rectangular selection bar.

```
avery.cibiv.univie.ac.at - PuTTY
philipp_@newton:~/Documents> man
What manual page do you want?
philipp_@newton:~/Documents> man echo
```

Help!

```
avery.cibiv.univie.ac.at - PuTTY
ECHO(1)          User Commands          ECHO(1)

NAME
echo - display a line of text

SYNOPSIS
echo [SHORT-OPTION]... [STRING]...
echo LONG-OPTION

DESCRIPTION
Echo the STRING(s) to standard output.

-n        do not output the trailing newline

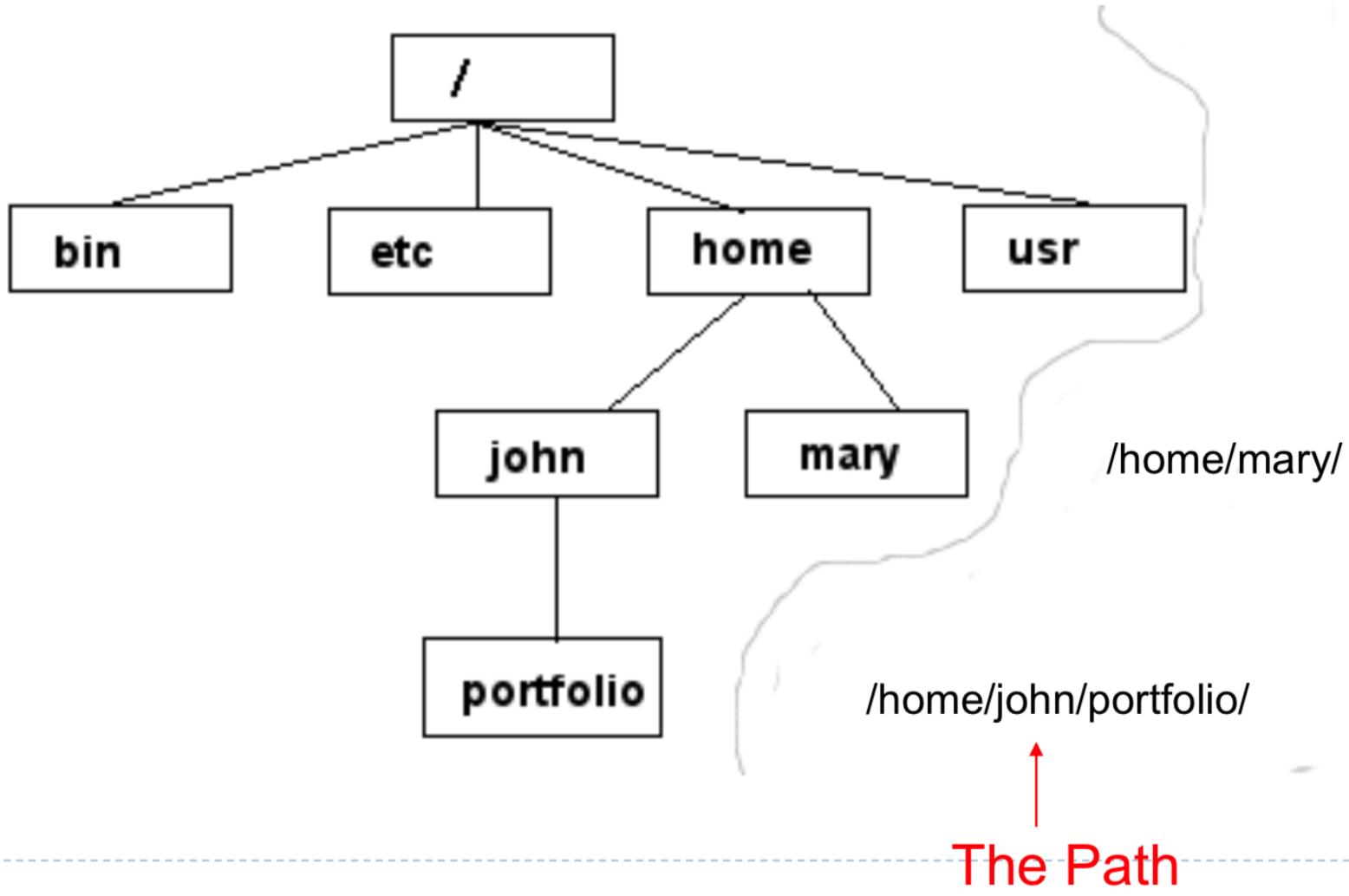
-e        enable interpretation of backslash
Manual page echo(1) line 1
```

 avery.cibiv.univie.ac.at - PuTTY

```
philipp_@newton:~/Documents> echo 'Hello World!'
Hello World!
philipp_@newton:~/Documents> █
```

Unix/Linux File System

NOTE: Unix file names
are **CASE SENSITIVE!**



File System

- ▶ **Absolute path**

- ▶ `ls /home/john/portfolio`

- ▶ **Relative path**

- ▶ `ls portfolio` or `ls ./portfolio`

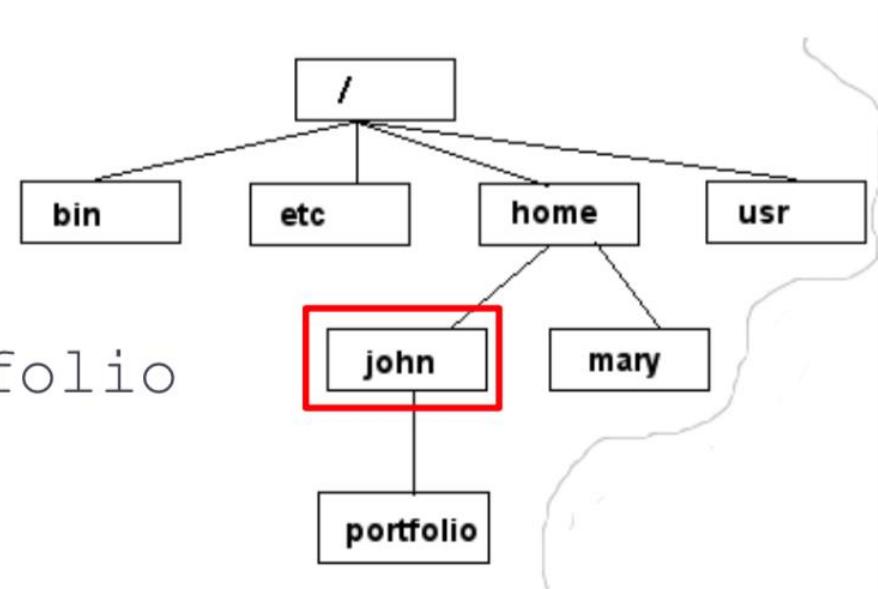
- ▶ **Shortcuts**

- ▶ Parent directory `(..)`, home directory `(~)`, last directory `(-)`

- ▶ **Wildcards**

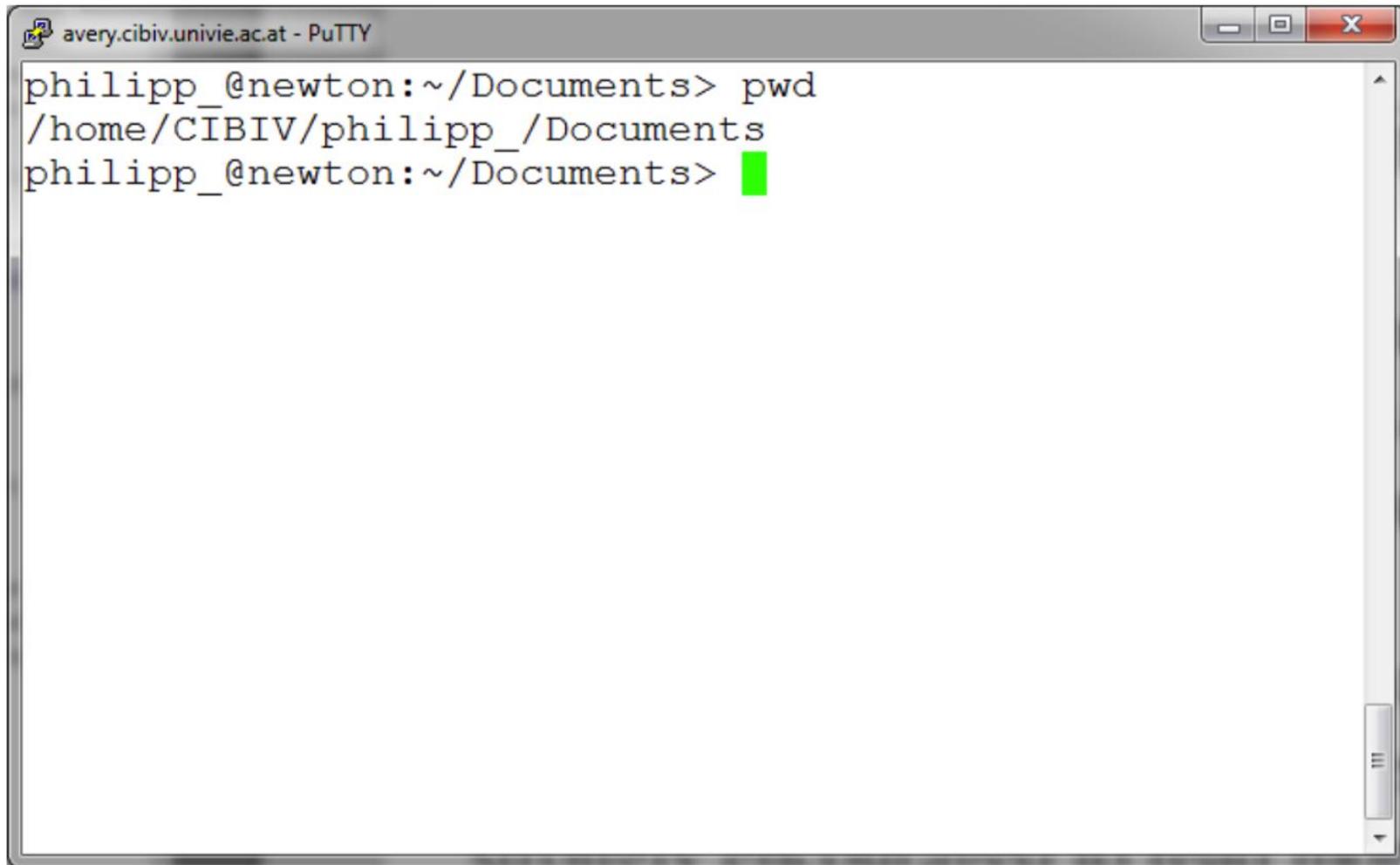
- ▶ Zero or more characters `(*)`, exactly one character `(?)`

- ▶ **Use tab-completion and avoid spaces in file names**



Command: pwd (print working directory)

- ▶ To find your current path use “pwd”

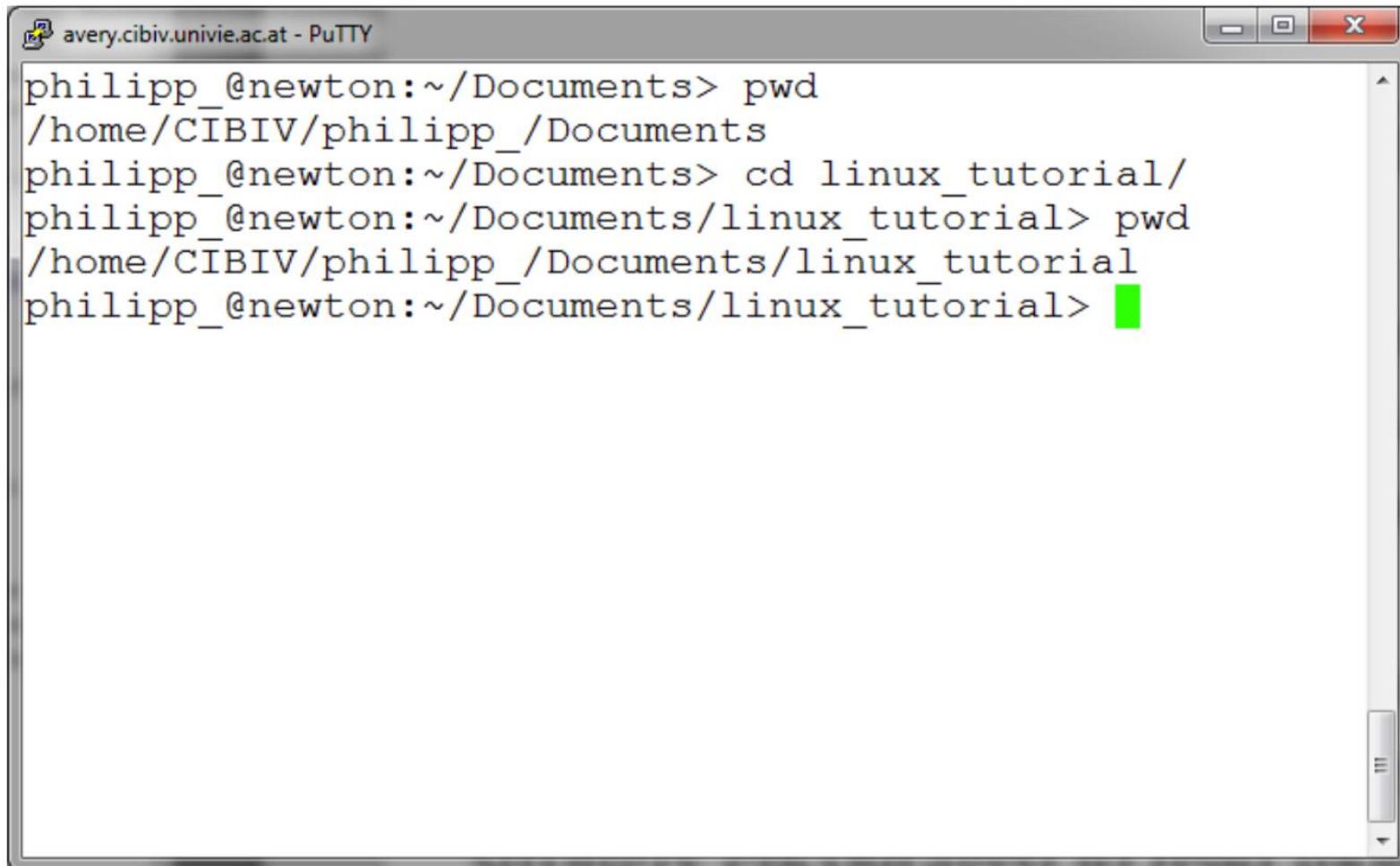


The image shows a screenshot of a PuTTY terminal window titled "avery.cibiv.univie.ac.at - PuTTY". The window displays a command-line session. The user, "philipp_@newton", is in their home directory, "~/Documents". They have run the "pwd" command, which outputs the full path "/home/CIBIV/philipp_/Documents". The session ends with a prompt "philipp_@newton:~/Documents>". A small green square cursor is visible at the end of the prompt line.

```
avery.cibiv.univie.ac.at - PuTTY
philipp_@newton:~/Documents> pwd
/home/CIBIV/philipp_/Documents
philipp_@newton:~/Documents>
```

Command: cd (change directory)

- ▶ To change to a specific directory use “cd”



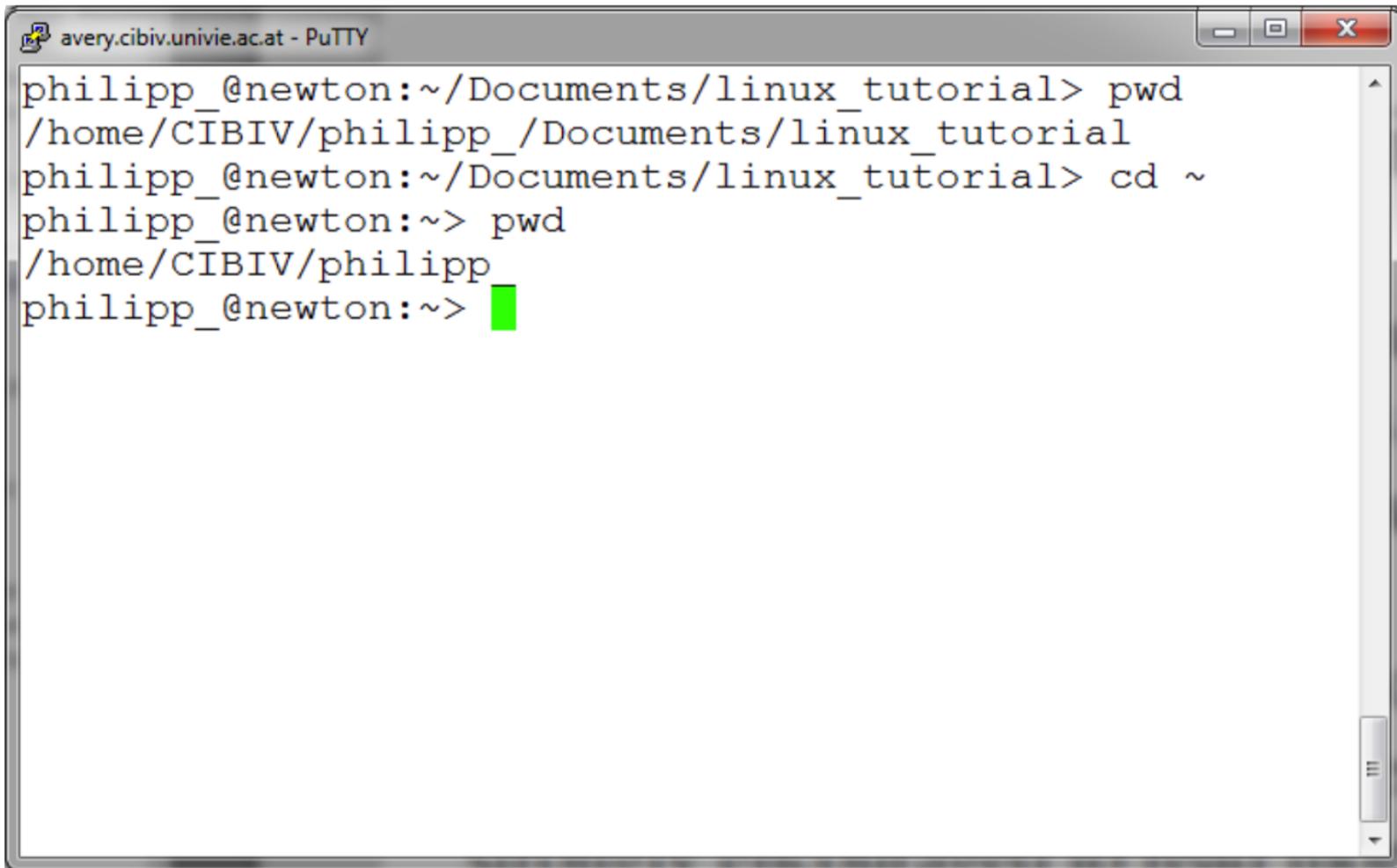
The screenshot shows a PuTTY terminal window titled "avery.cibiv.univie.ac.at - PuTTY". The session is connected to a user named philipp_ on a host named newton. The terminal displays the following sequence of commands:

```
philipp_@newton:~/Documents> pwd  
/home/CIBIV/philipp/_Documents  
philipp_@newton:~/Documents> cd linux_tutorial/  
philipp_@newton:~/Documents/linux_tutorial> pwd  
/home/CIBIV/philipp/_Documents/linux_tutorial  
philipp_@newton:~/Documents/linux_tutorial>
```

A green cursor is visible at the end of the last command line.

Command: cd

- ▶ “~” is the location of your home directory



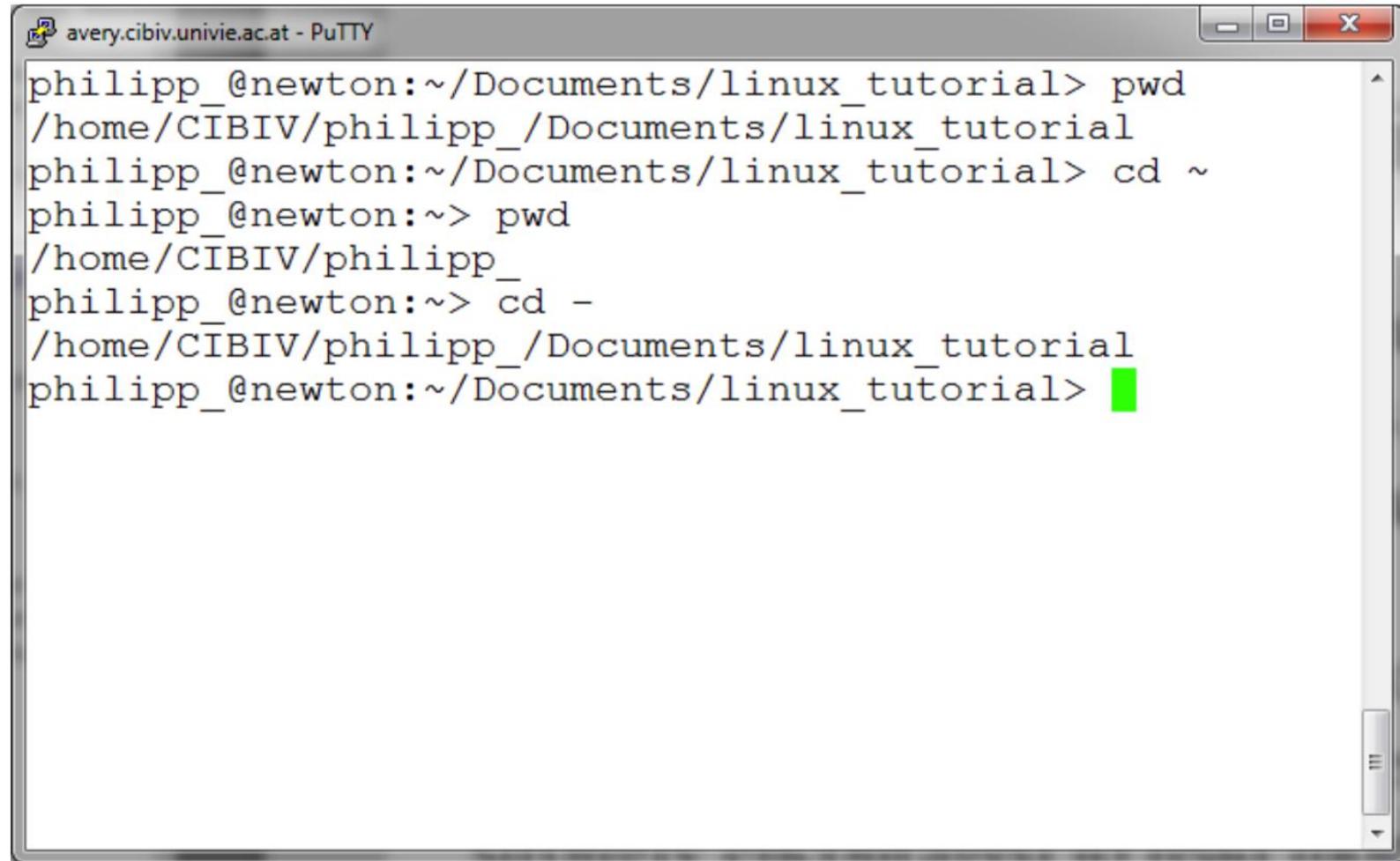
The screenshot shows a PuTTY terminal window titled "avery.cibiv.univie.ac.at - PuTTY". The session ID is "philipp_@newton". The terminal displays the following command-line session:

```
philipp_@newton:~/Documents/linux_tutorial> pwd  
/home/CIBIV/philipp/_Documents/linux_tutorial  
philipp_@newton:~/Documents/linux_tutorial> cd ~  
philipp_@newton:~> pwd  
/home/CIBIV/philipp  
philipp_@newton:~>
```

A green cursor is visible at the end of the last command line.

Command: cd

- ▶ “-” is the location of the last directory



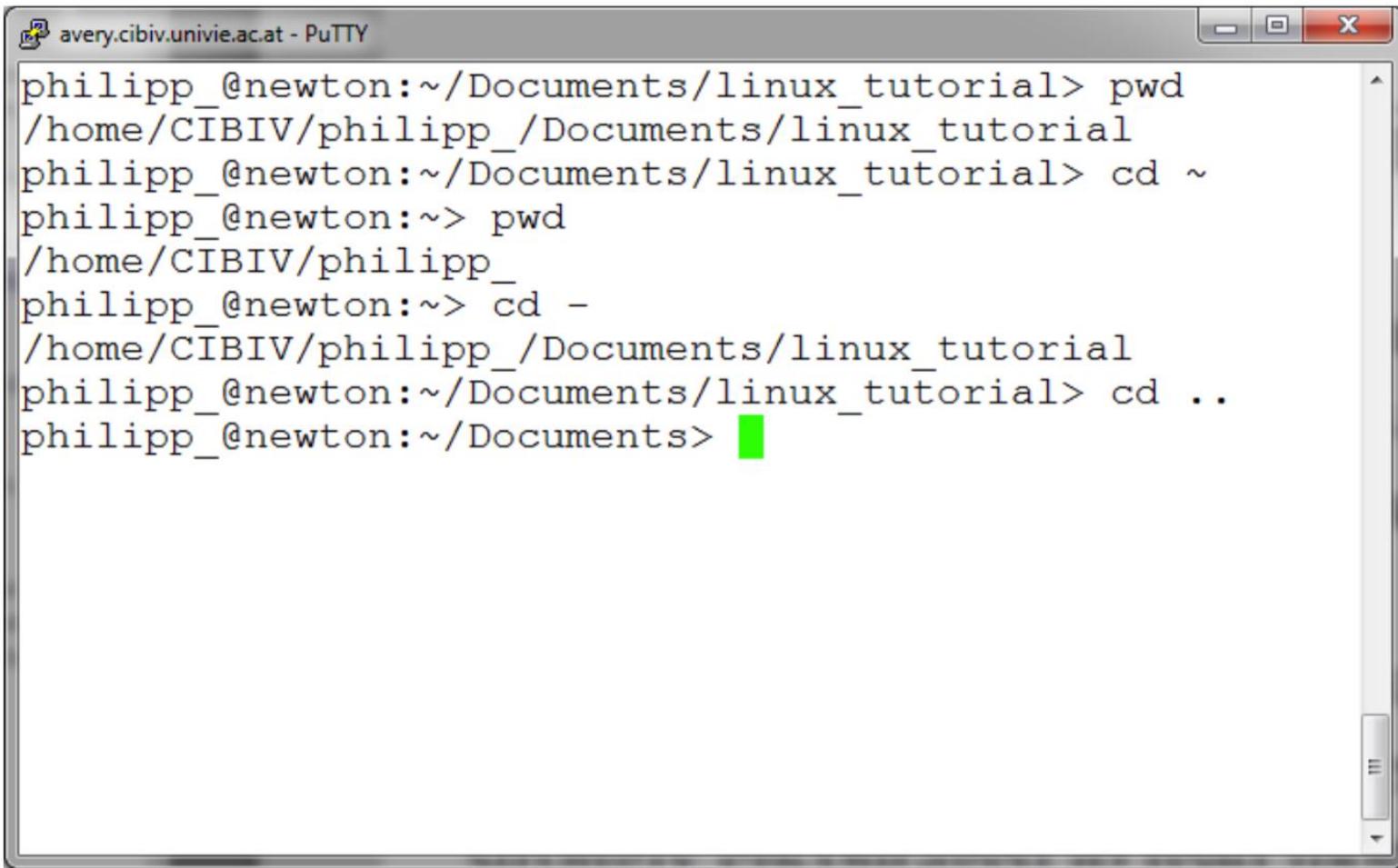
The screenshot shows a PuTTY terminal window titled "avery.cibiv.univie.ac.at - PuTTY". The session ID is "philipp_@newton". The terminal displays the following Linux shell session:

```
philipp_@newton:~/Documents/linux_tutorial> pwd
/home/CIBIV/philipp_/Documents/linux_tutorial
philipp_@newton:~/Documents/linux_tutorial> cd ~
philipp_@newton:~> pwd
/home/CIBIV/philipp_
philipp_@newton:~> cd -
/home/CIBIV/philipp_/Documents/linux_tutorial
philipp_@newton:~/Documents/linux_tutorial>
```

A green rectangular highlight is placed over the final command "cd -".

Command: cd

- ▶ “..” is the location of the parent directory



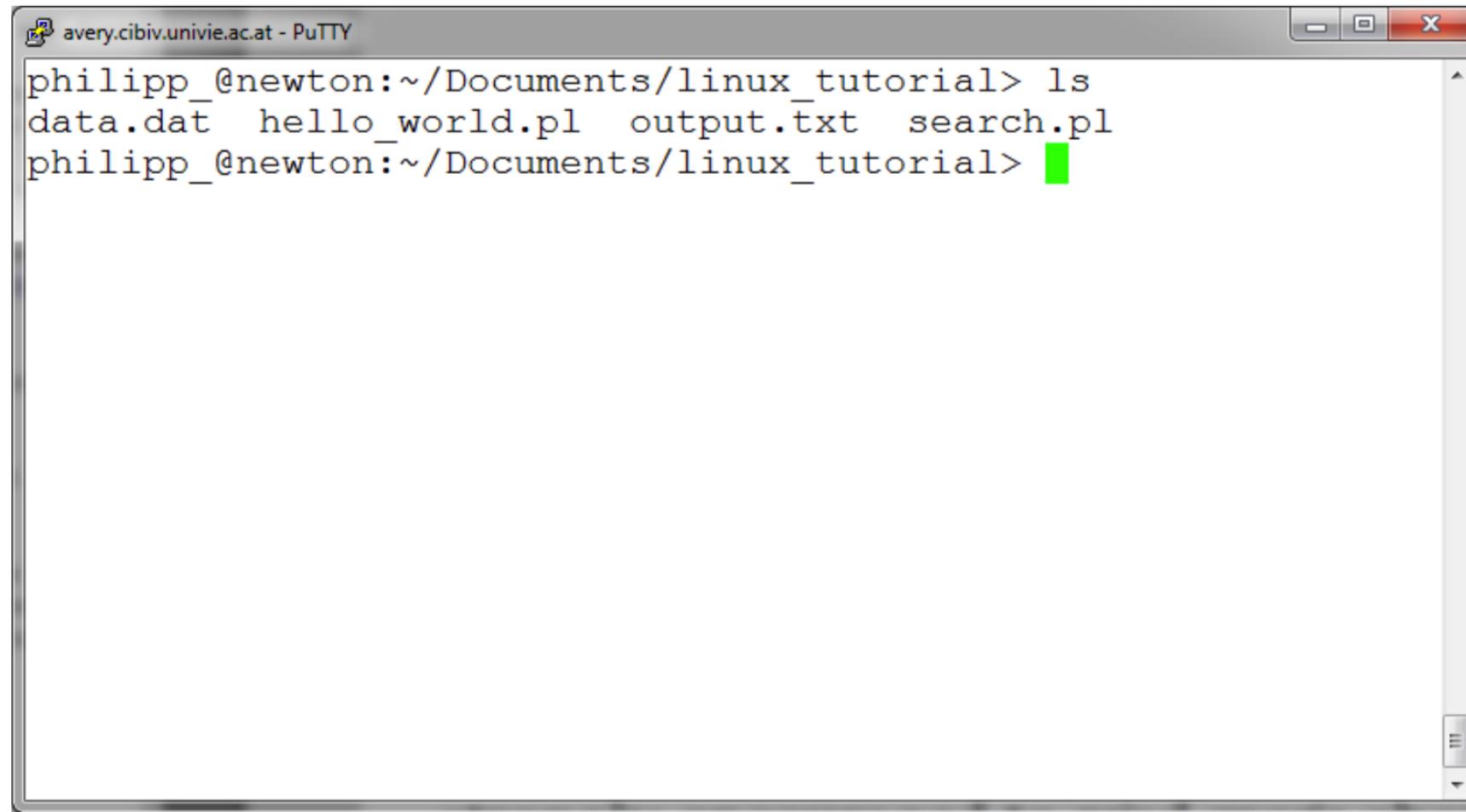
The screenshot shows a PuTTY terminal window titled "avery.cibiv.univie.ac.at - PuTTY". The session window displays a series of Linux shell commands and their outputs:

```
philipp_@newton:~/Documents/linux_tutorial> pwd  
/home/CIBIV/philipp_/Documents/linux_tutorial  
philipp_@newton:~/Documents/linux_tutorial> cd ~  
philipp_@newton:~> pwd  
/home/CIBIV/philipp_  
philipp_@newton:~> cd -  
/home/CIBIV/philipp_/Documents/linux_tutorial  
philipp_@newton:~/Documents/linux_tutorial> cd ..  
philipp_@newton:~/Documents>
```

A green rectangular highlight is placed over the final command "cd .." and its resulting prompt, indicating the current state of the terminal.

Command: ls

- ▶ To list the files in the current directory use “ls”



The screenshot shows a PuTTY terminal window titled "avery.cibiv.univie.ac.at - PuTTY". The window displays the following text:

```
philipp_@newton:~/Documents/linux_tutorial> ls
data.dat  hello_world.pl  output.txt  search.pl
philipp_@newton:~/Documents/linux_tutorial>
```

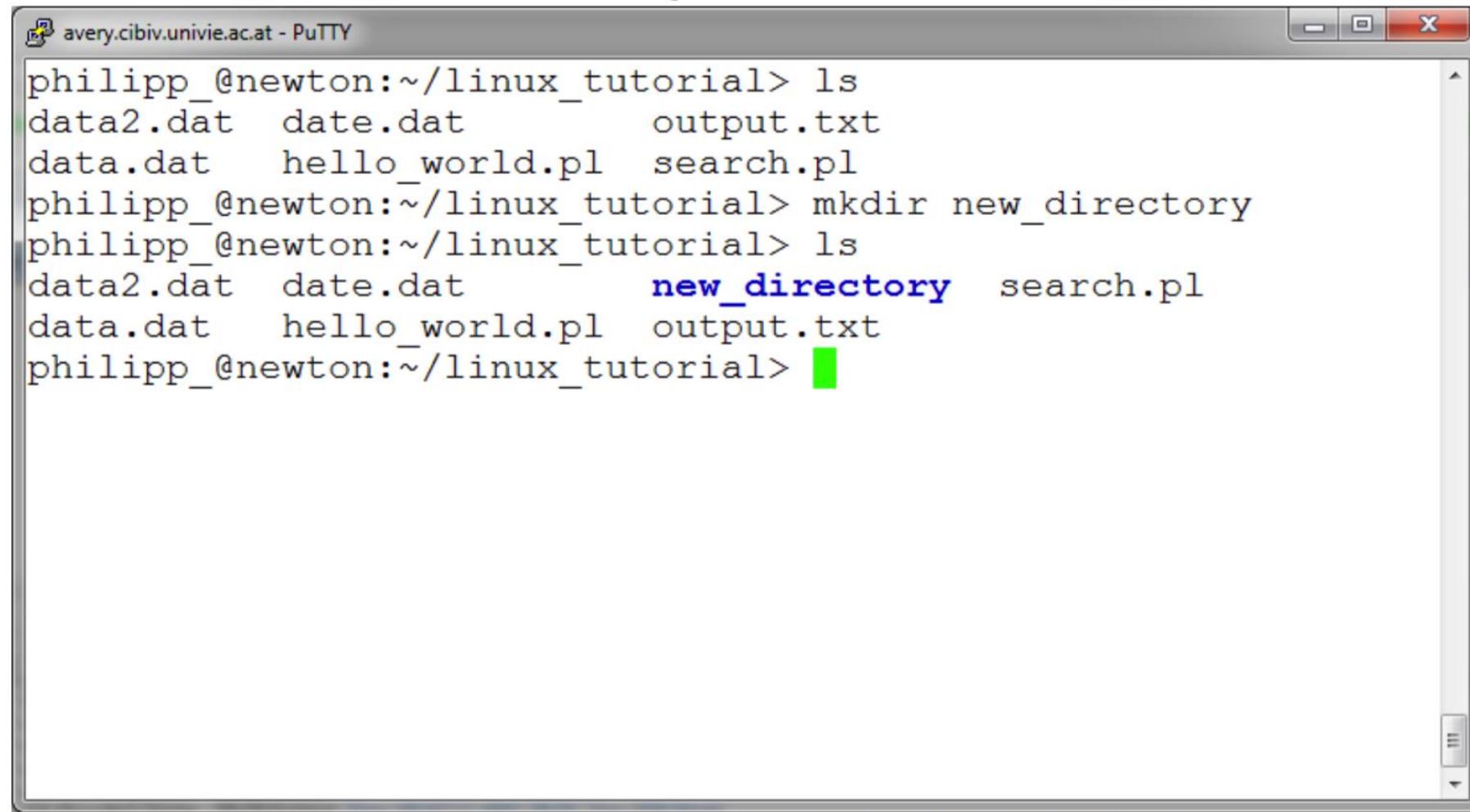
The terminal window has a standard Windows-style title bar with minimize, maximize, and close buttons. The main area of the window shows the command-line interface with the user's name, the host name, the current directory (~/Documents/linux_tutorial), the command entered (ls), the resulting file list, and the command prompt again.

Command: ls

- ▶ **ls has many options**
 - ▶ -l long list (displays lots of info)
 - ▶ -t sort by modification time
 - ▶ -S sort by size
 - ▶ -h list file sizes in human readable format
 - ▶ -r reverse the order
- ▶ “man ls” for more options
- ▶ Options can be combined: “ls -ltr”

Command: mkdir

- ▶ To create a new directory use “mkdir”



The screenshot shows a PuTTY terminal window titled "avery.cibiv.univie.ac.at - PuTTY". The session is connected to a Linux system where the user "philipp" is logged in. The user runs the command "ls" to list files in the current directory, which contains "data2.dat", "date.dat", "output.txt", "data.dat", "hello_world.pl", and "search.pl". Then, the user runs the command "mkdir new_directory" to create a new directory. After creating the directory, the user runs "ls" again, and the newly created "new_directory" is listed among the files. The terminal window has a standard Windows-style title bar and scroll bars.

```
avery.cibiv.univie.ac.at - PuTTY
philipp_@newton:~/linux_tutorial> ls
data2.dat  date.dat          output.txt
data.dat   hello_world.pl   search.pl
philipp_@newton:~/linux_tutorial> mkdir new_directory
philipp_@newton:~/linux_tutorial> ls
data2.dat  date.dat          new_directory  search.pl
data.dat   hello_world.pl   output.txt
philipp_@newton:~/linux_tutorial>
```

Displaying a file

- ▶ Various ways to display a file in Unix
 - ▶ cat
 - ▶ less
 - ▶ head
 - ▶ tail

Input / Output Redirection (“piping”)

- ▶ Programs can output to other programs
- ▶ Called “piping”
- ▶ “program_a | program_b”
 - ▶ program_a’s output becomes program_b’s input
- ▶ “program_a > file.txt”
 - ▶ program_a’s output is written to a file called “file.txt”
- ▶ “program_a < input.txt”
 - ▶ program_a gets its input from a file called “input.txt”

Command: cat

- ▶ Dumps an entire file to standard output
- ▶ Good for displaying short, simple files and for concatenating files
- ▶ Example: Concatenate three FASTQ files

```
cat SRA0001.fq SRA0002.fq SRA0003.fq > SRA000_all.fq
```

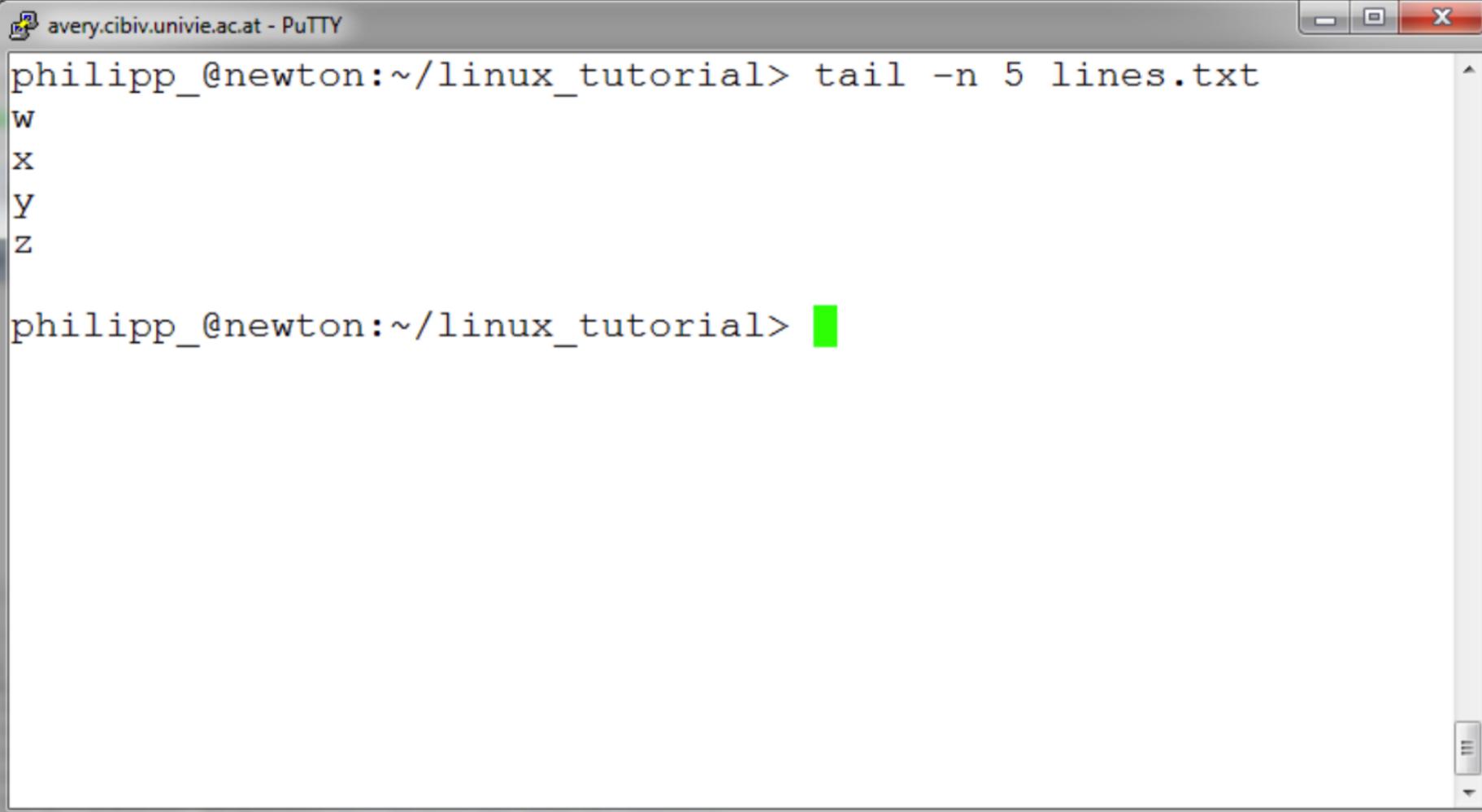
Command: head

- ▶ “head” displays the top part of a file
 - ▶ By default it shows the first 10 lines
 - ▶ -n option allows you to change that
-
- ▶ Example: Display the first 10 sequences of the dataset

```
head -n 40 SR012310.fq
```

Command: tail

- ▶ Same as head, but shows the last lines



The screenshot shows a PuTTY terminal window titled "avery.cibiv.univie.ac.at - PuTTY". The session path is "philipp_@newton:~/linux_tutorial>". The command entered was "tail -n 5 lines.txt". The output displayed is "w", "x", "Y", and "z", which are the last four lines of the file "lines.txt". The terminal window has a standard Windows-style title bar and scroll bars.

```
avery.cibiv.univie.ac.at - PuTTY
philipp_@newton:~/linux_tutorial> tail -n 5 lines.txt
w
x
Y
z

philipp_@newton:~/linux_tutorial>
```

Creating and editing files in Unix/Linux

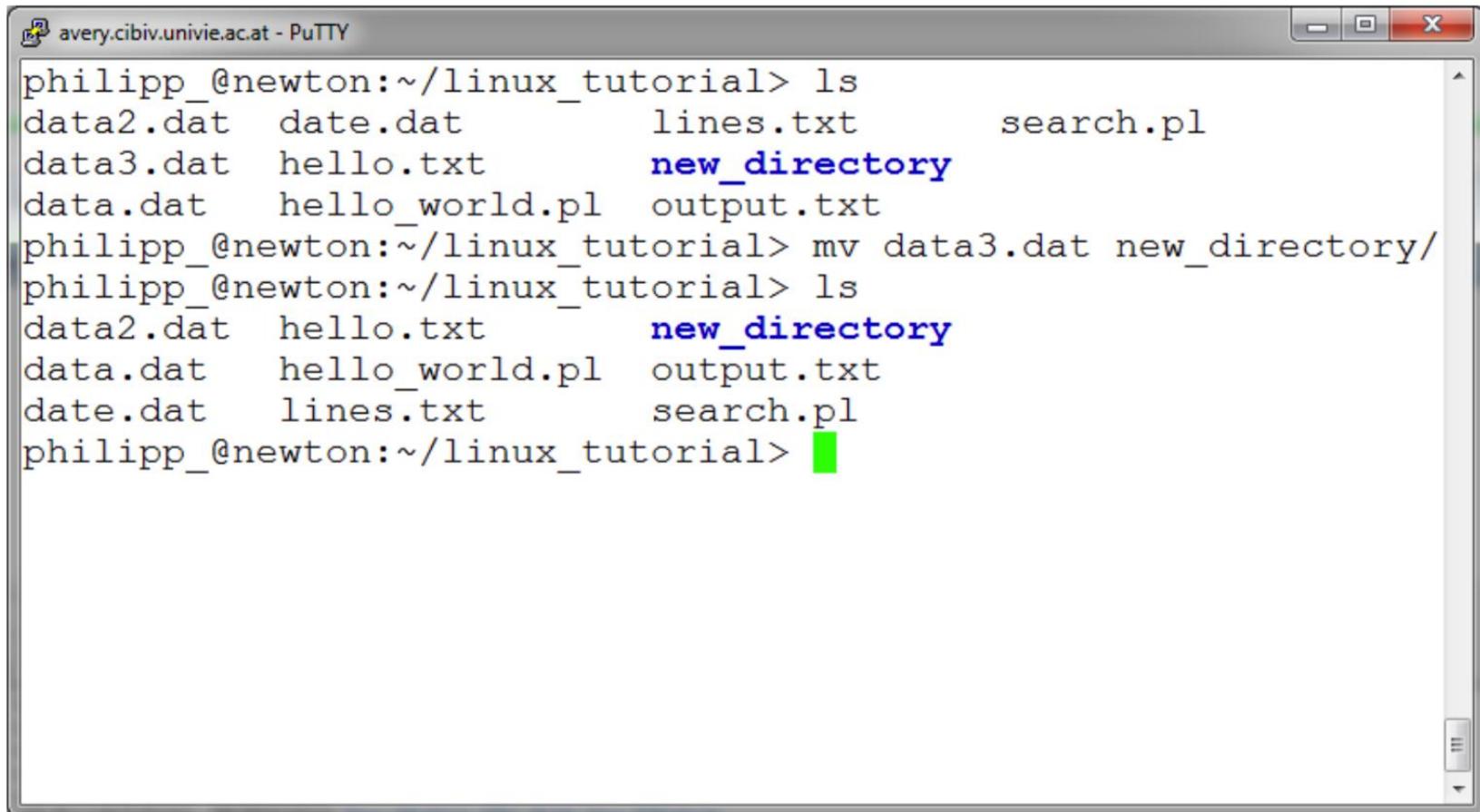
- ▶ Requires the use of an Editor
- ▶ Various Editors:
 - 1) nano / pico
 - 2) vi
 - 3) emacs

File Commands

- ▶ Copying a file: `cp`
- ▶ Move or rename a file: `mv`
- ▶ Remove a file: `rm`

Command: mv

- ▶ To move a file to a different location use “mv”

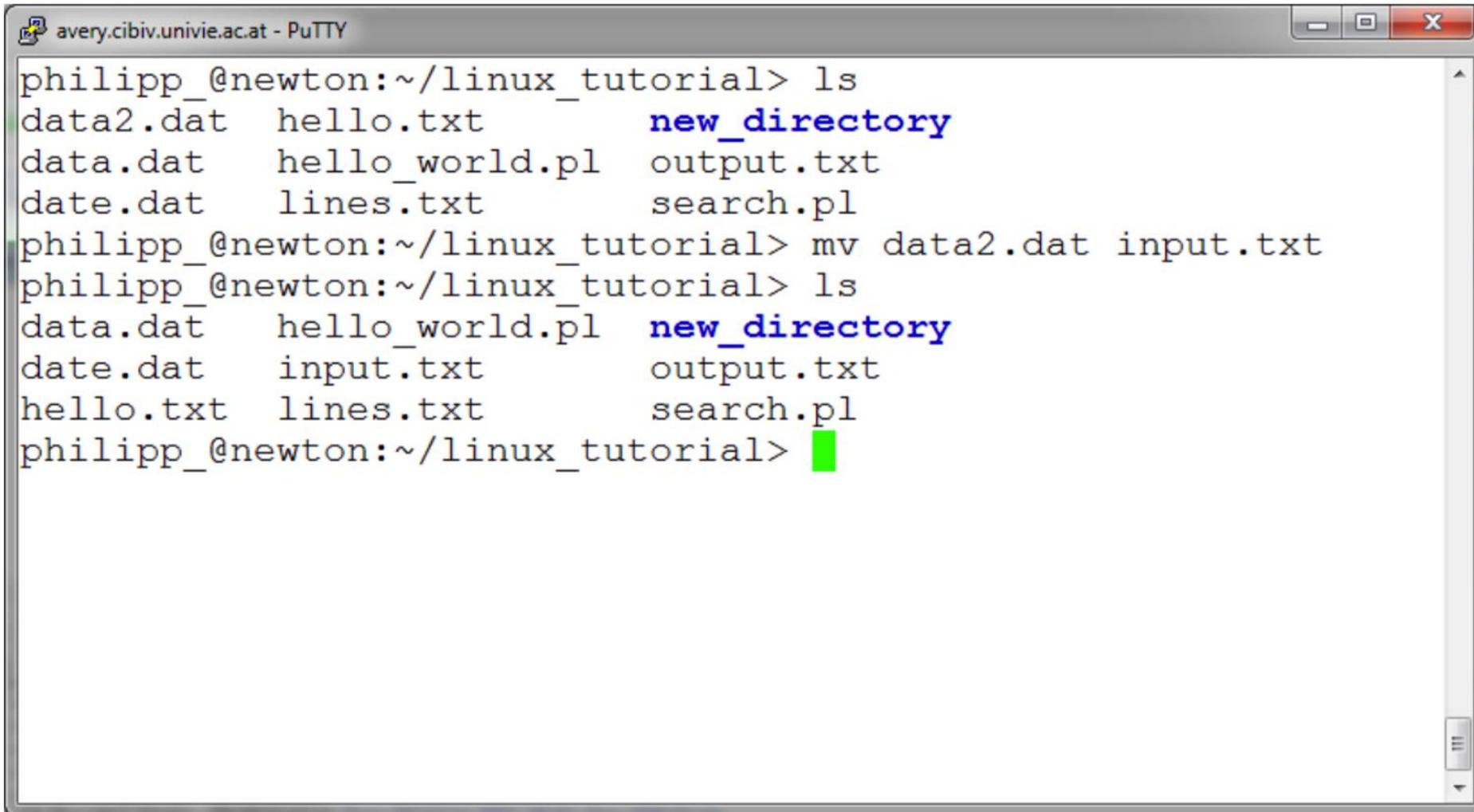


The screenshot shows a PuTTY terminal window titled "avery.cibiv.univie.ac.at - PuTTY". The session path is "philipp_@newton:~/linux_tutorial>". The user runs an "ls" command, which lists several files: data2.dat, date.dat, lines.txt, search.pl, data3.dat, hello.txt, data.dat, hello_world.pl, and output.txt. The "hello.txt" file is highlighted in blue and labeled "new_directory". The user then runs the "mv" command: "mv data3.dat new_directory/". After the move, another "ls" command is run, showing that the "data3.dat" file has been moved and is no longer listed. The "hello.txt" file remains in the directory and is also labeled "new_directory". The terminal prompt ends with a green cursor.

```
avery.cibiv.univie.ac.at - PuTTY
philipp_@newton:~/linux_tutorial> ls
data2.dat  date.dat      lines.txt      search.pl
data3.dat  hello.txt    new_directory
data.dat   hello_world.pl  output.txt
philipp_@newton:~/linux_tutorial> mv data3.dat new_directory/
philipp_@newton:~/linux_tutorial> ls
data2.dat  hello.txt    new_directory
data.dat   hello_world.pl  output.txt
date.dat   lines.txt      search.pl
philipp_@newton:~/linux_tutorial>
```

Command: mv

- ▶ mv can also be used to rename a file



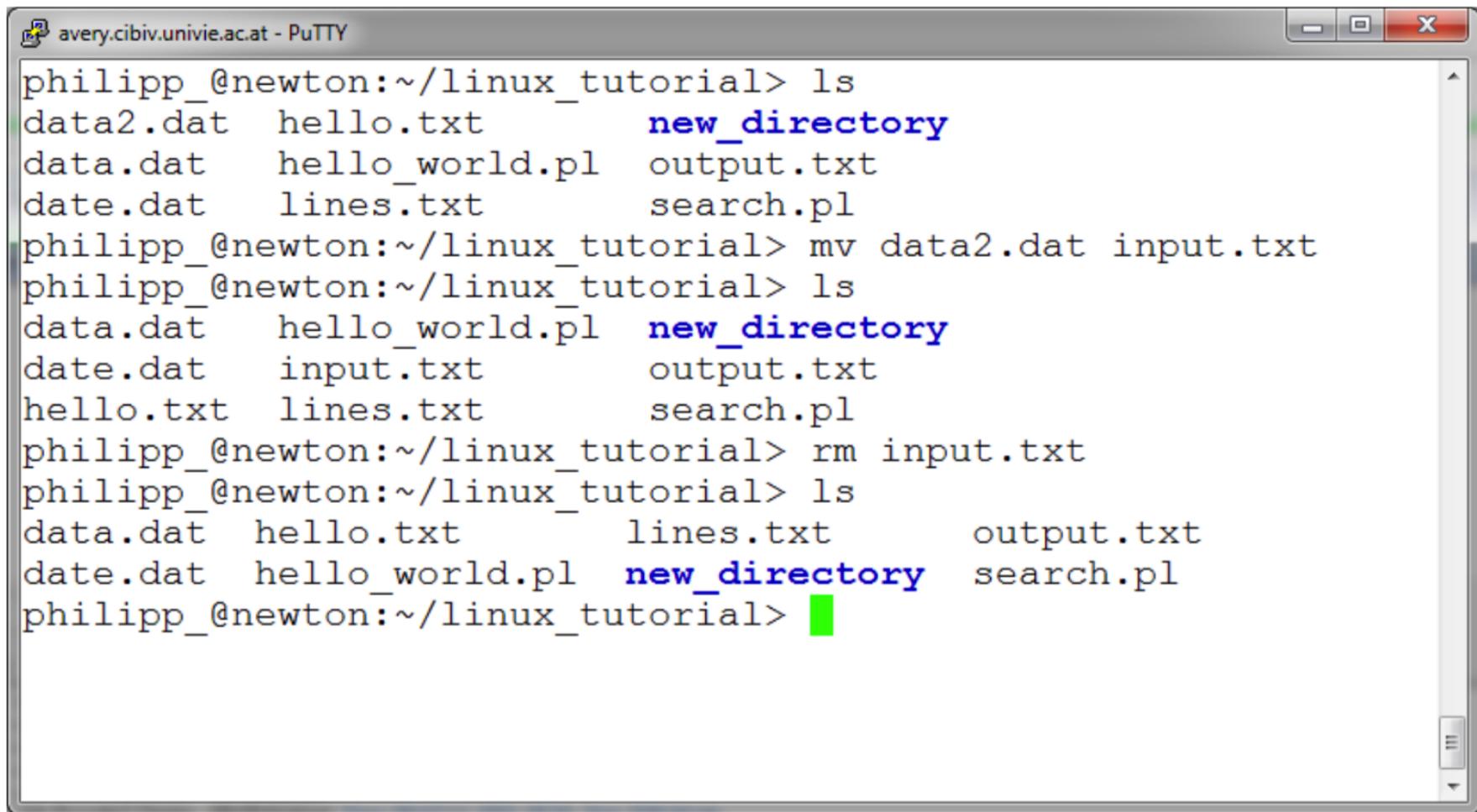
The screenshot shows a PuTTY terminal window titled "avery.cibiv.univie.ac.at - PuTTY". The session is connected to the user philipp_@newton in the directory ~/linux_tutorial. The terminal displays the following sequence of commands and their results:

```
philipp_@newton:~/linux_tutorial> ls
data2.dat  hello.txt      new_directory
data.dat   hello_world.pl  output.txt
date.dat   lines.txt       search.pl
philipp_@newton:~/linux_tutorial> mv data2.dat input.txt
philipp_@newton:~/linux_tutorial> ls
data.dat   hello_world.pl  new_directory
date.dat   input.txt       output.txt
hello.txt  lines.txt       search.pl
philipp_@newton:~/linux_tutorial>
```

In the first 'ls' command, there is a file named 'new_directory'. In the second 'ls' command, this file has been renamed to 'input.txt'. The 'mv' command was used to move the file 'data2.dat' to the new name 'input.txt'. The word 'new_directory' is highlighted in blue in both instances where it appears in the terminal output.

Command: rm

- ▶ To remove a file use “rm”



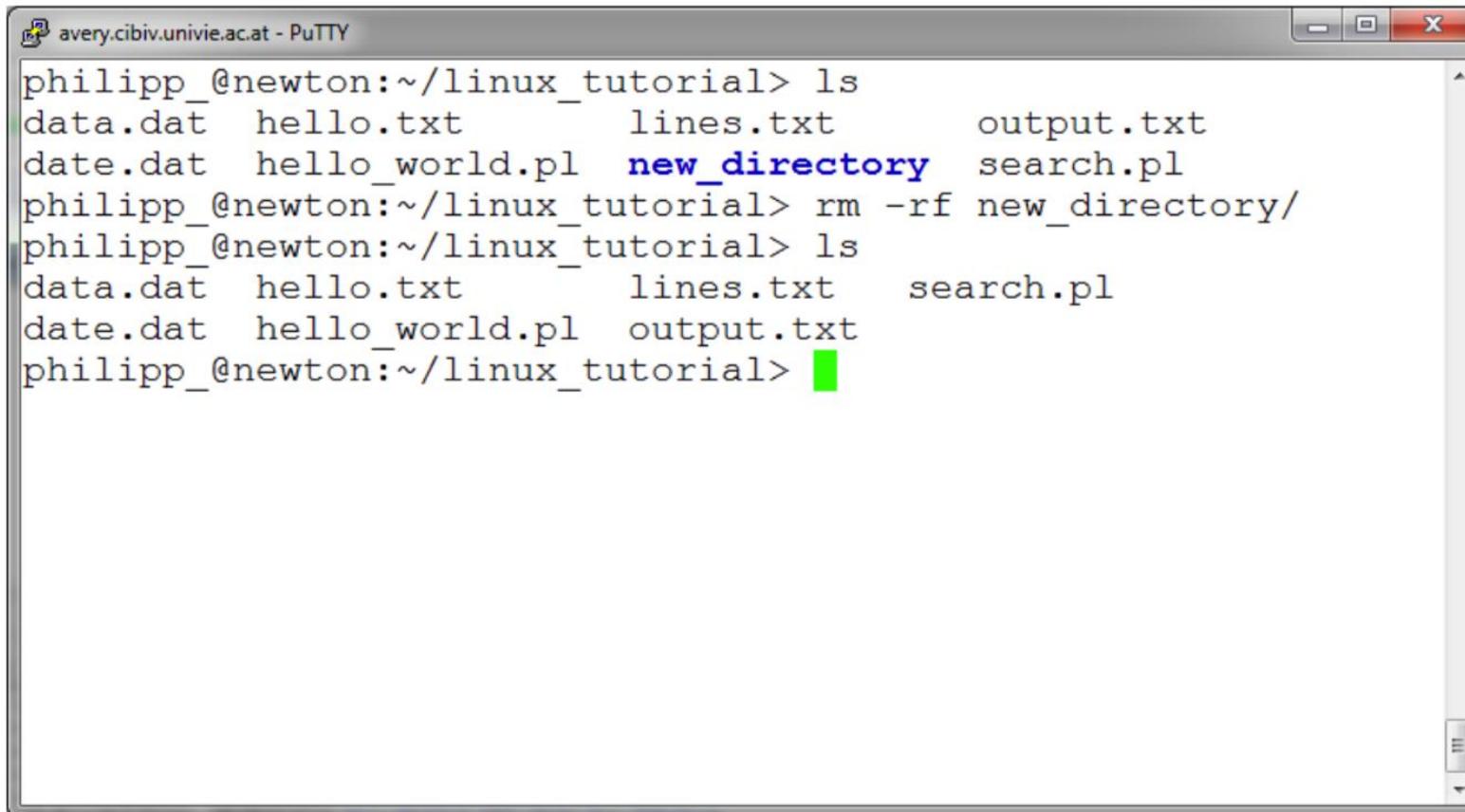
The screenshot shows a PuTTY terminal window titled "avery.cibiv.univie.ac.at - PuTTY". The session path is "philipp_@newton:~/linux_tutorial". The terminal displays the following sequence of commands and their results:

```
philipp_@newton:~/linux_tutorial> ls
data2.dat  hello.txt      new_directory
data.dat   hello_world.pl  output.txt
date.dat   lines.txt       search.pl
philipp_@newton:~/linux_tutorial> mv data2.dat input.txt
philipp_@newton:~/linux_tutorial> ls
data.dat   hello_world.pl  new_directory
date.dat   input.txt       output.txt
hello.txt  lines.txt       search.pl
philipp_@newton:~/linux_tutorial> rm input.txt
philipp_@newton:~/linux_tutorial> ls
data.dat   hello.txt       lines.txt       output.txt
date.dat   hello_world.pl  new_directory  search.pl
philipp_@newton:~/linux_tutorial>
```

The word "new_directory" appears in blue, indicating it is a link or a specific file name. The "input.txt" file is deleted in the third command, and its name is replaced by a green square cursor.

Command: rm

- ▶ To remove a file “recursively”: `rm -r`
- ▶ Used to remove all files and directories



The screenshot shows a PuTTY terminal window titled "avery.cibiv.univie.ac.at - PuTTY". The session is connected to a Linux system where the user "philipp" is in the directory "/linux_tutorial". The terminal output is as follows:

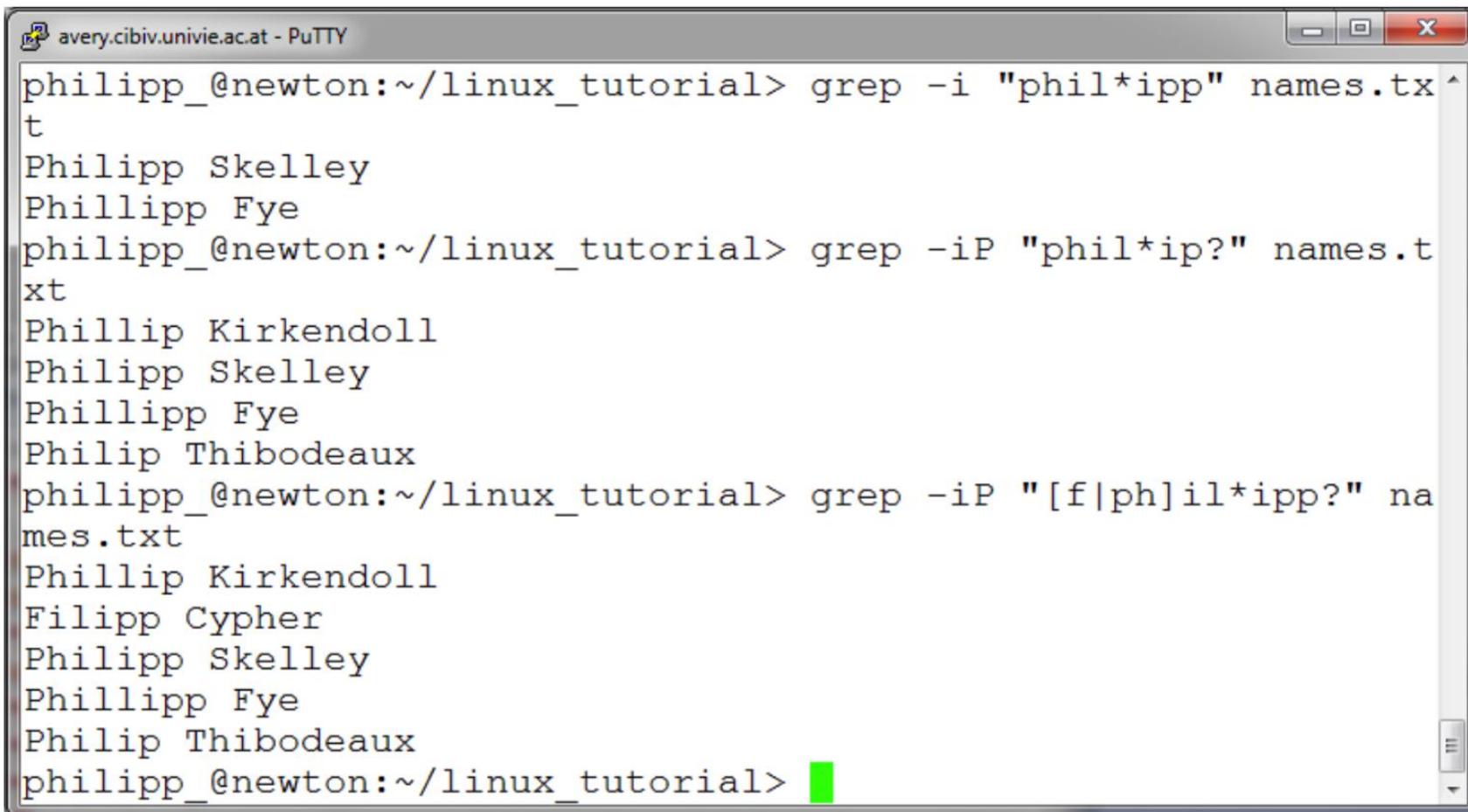
```
philipp_@newton:~/linux_tutorial> ls
data.dat  hello.txt      lines.txt      output.txt
date.dat  hello_world.pl  new_directory  search.pl
philipp_@newton:~/linux_tutorial> rm -rf new_directory/
philipp_@newton:~/linux_tutorial> ls
data.dat  hello.txt      lines.txt      search.pl
date.dat  hello_world.pl  output.txt
philipp_@newton:~/linux_tutorial>
```

A green rectangular box highlights the text "new_directory" in the second line of the first "ls" command, indicating it is the target of the deletion.

- ▶ Be very careful, deletions are **permanent** in Unix/Linux

Command: grep

- ▶ To search files for a specific string use “grep”

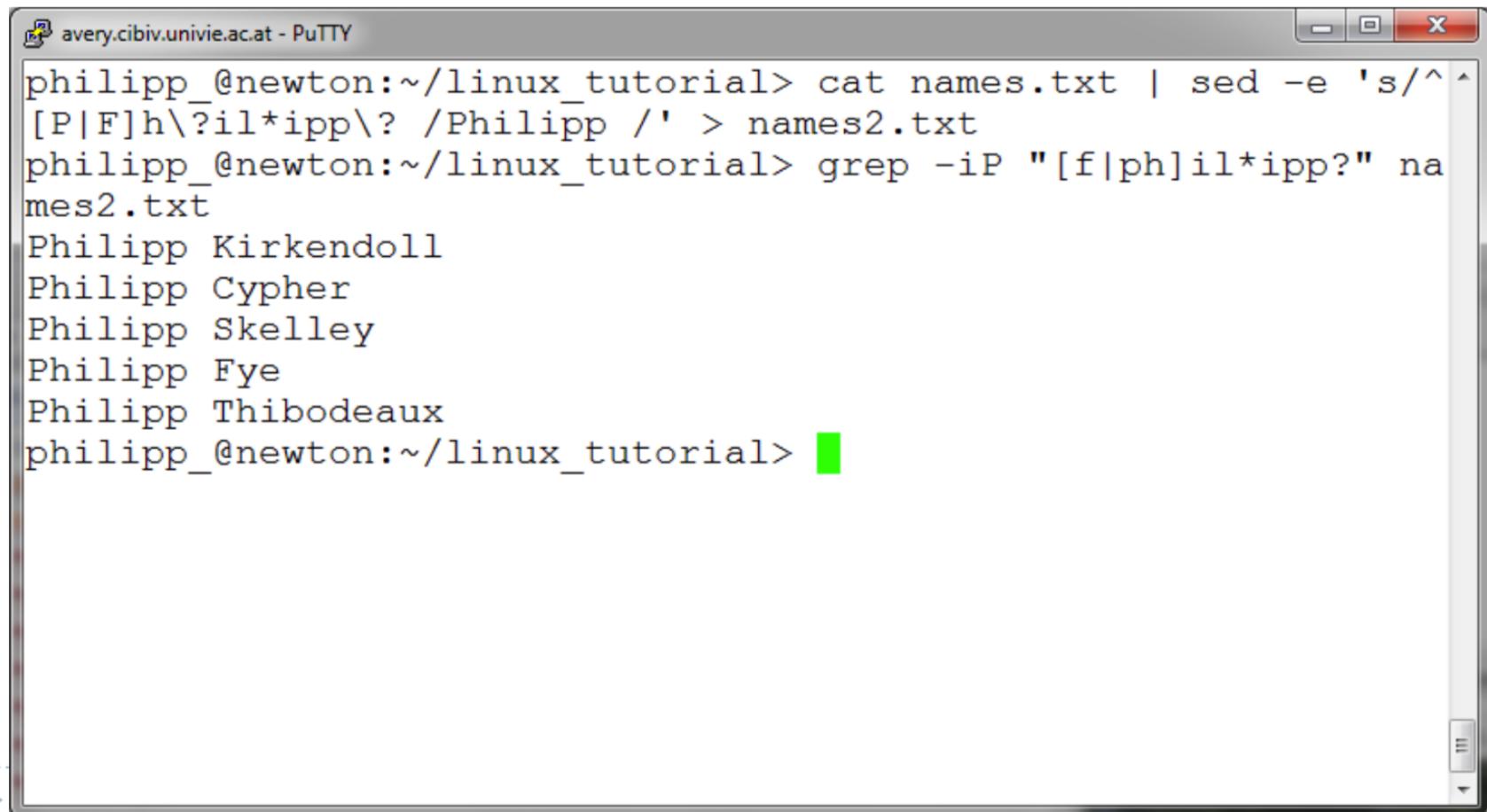


The screenshot shows a PuTTY terminal window titled "avery.cibiv.univie.ac.at - PuTTY". The user, philipp, is in their home directory (~) under the "linux_tutorial" folder. They run three grep commands to search for names starting with "phil". The first command uses a wildcard (*), the second uses a question mark (?), and the third uses a character class ([f|ph]).

```
philipp_@newton:~/linux_tutorial> grep -i "phil*ipp" names.txt
Philipp Skelley
Phillipp Fye
philipp_@newton:~/linux_tutorial> grep -iP "phil*ip?" names.txt
Phillip Kirkendoll
Philipp Skelley
Phillipp Fye
Philip Thibodeaux
philipp_@newton:~/linux_tutorial> grep -iP "[f|ph]il*ipp?" names.txt
Phillip Kirkendoll
Filipp Cypher
Philipp Skelley
Phillipp Fye
Philip Thibodeaux
philipp_@newton:~/linux_tutorial>
```

Command: sed

- ▶ sed is a stream editor for filtering and transforming text
- ▶ Powerful but complicated => useful for substitution



The screenshot shows a PuTTY terminal window titled "avery.cibiv.univie.ac.at - PuTTY". The session log contains the following commands and their output:

```
philipp_@newton:~/linux_tutorial> cat names.txt | sed -e 's/^P|Fh\?il*ipp\? /Philipp /' > names2.txt
philipp_@newton:~/linux_tutorial> grep -iP "[f|ph]il*ipp?" names2.txt
Philipp Kirkendoll
Philipp Cypher
Philipp Skellee
Philipp Fye
Philipp Thibodeaux
philipp_@newton:~/linux_tutorial>
```

Syntax:

\$ sed 'nd' filename.txt

Example:

\$ sed '5d' filename.txt

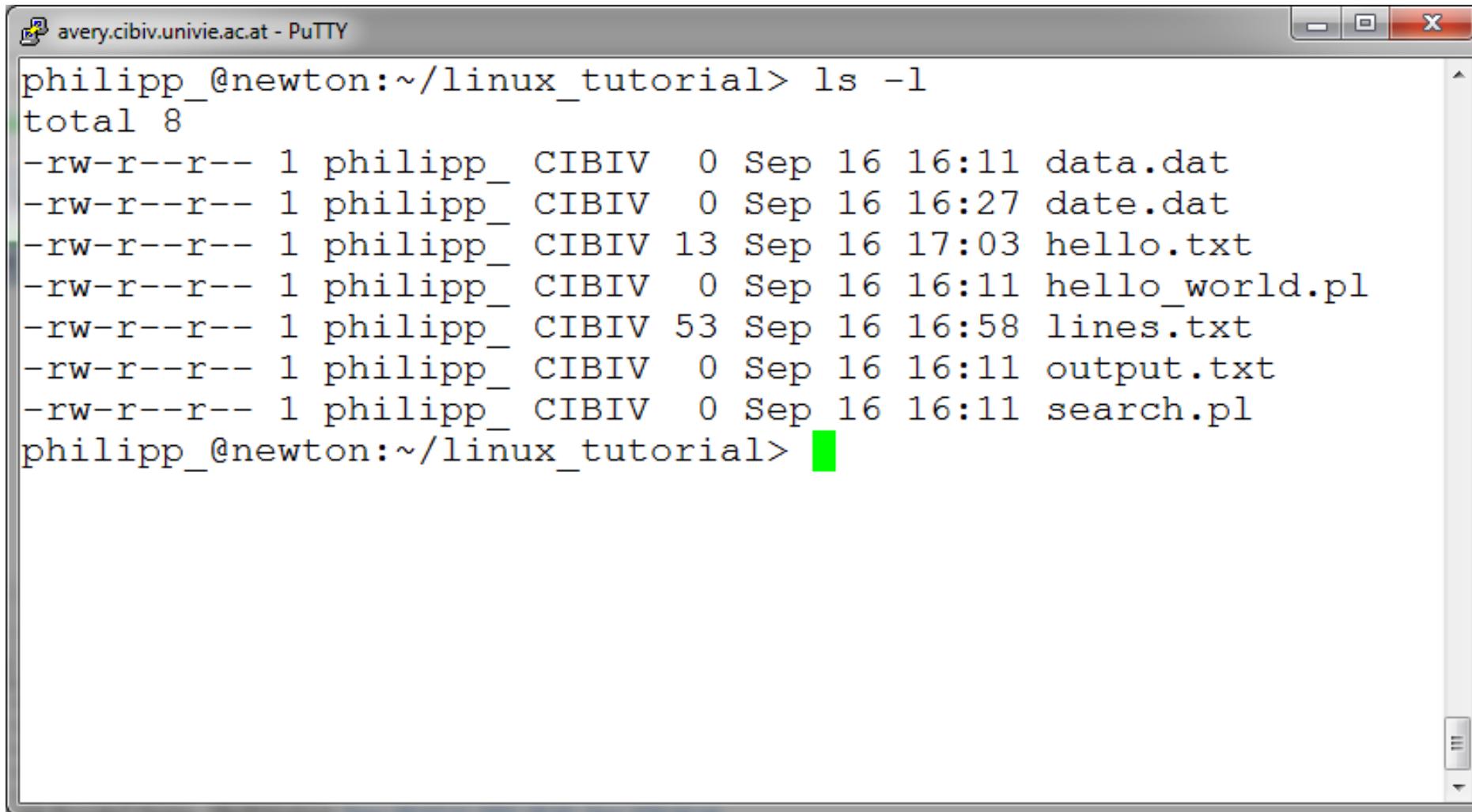
File permissions

- ▶ Each file in Unix/Linux has an associated permission level
- ▶ This allows the user to prevent others from reading/writing/executing their files or directories
- ▶ Use “`ls -l filename`” to find the permission level of that file

Permission levels

- ▶ “r” means “read only” permission
- ▶ “w” means “write” permission
- ▶ “x” means “execute” permission
 - ▶ In case of directory, “x” grants permission to list directory contents

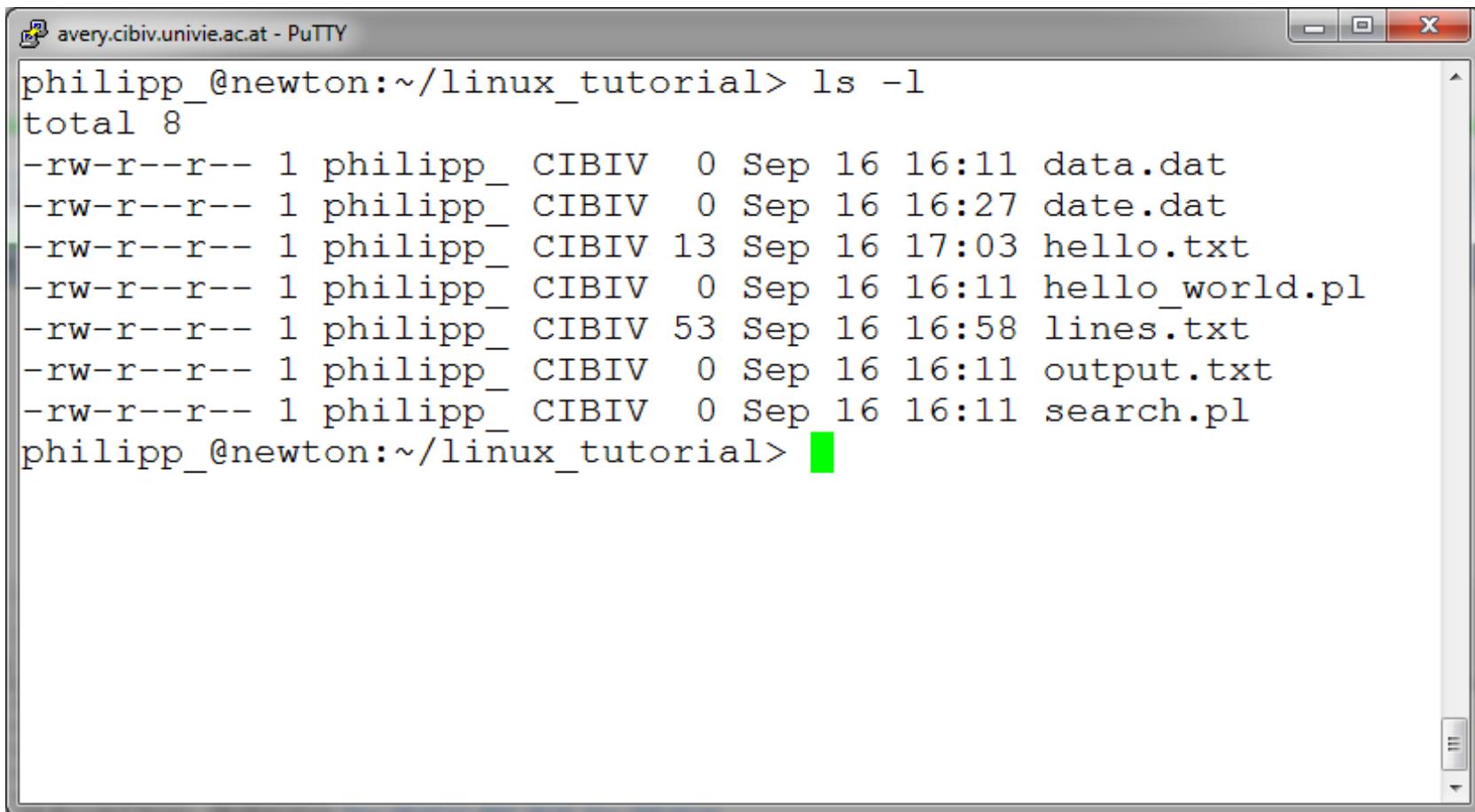
File Permissions



The screenshot shows a PuTTY terminal window titled "avery.cibiv.univie.ac.at - PuTTY". The command "ls -l" is run in the directory "/linux_tutorial". The output lists eight files with their permissions, owner, group, modification time, and names. A red box highlights the first file, "data.dat".

```
philipp_@newton:~/linux_tutorial> ls -l
total 8
-rw-r--r-- 1 philipp_ CIBIV 0 Sep 16 16:11 data.dat
-rw-r--r-- 1 philipp_ CIBIV 0 Sep 16 16:27 date.dat
-rw-r--r-- 1 philipp_ CIBIV 13 Sep 16 17:03 hello.txt
-rw-r--r-- 1 philipp_ CIBIV 0 Sep 16 16:11 hello_world.pl
-rw-r--r-- 1 philipp_ CIBIV 53 Sep 16 16:58 lines.txt
-rw-r--r-- 1 philipp_ CIBIV 0 Sep 16 16:11 output.txt
-rw-r--r-- 1 philipp_ CIBIV 0 Sep 16 16:11 search.pl
philipp_@newton:~/linux_tutorial>
```

File Permissions

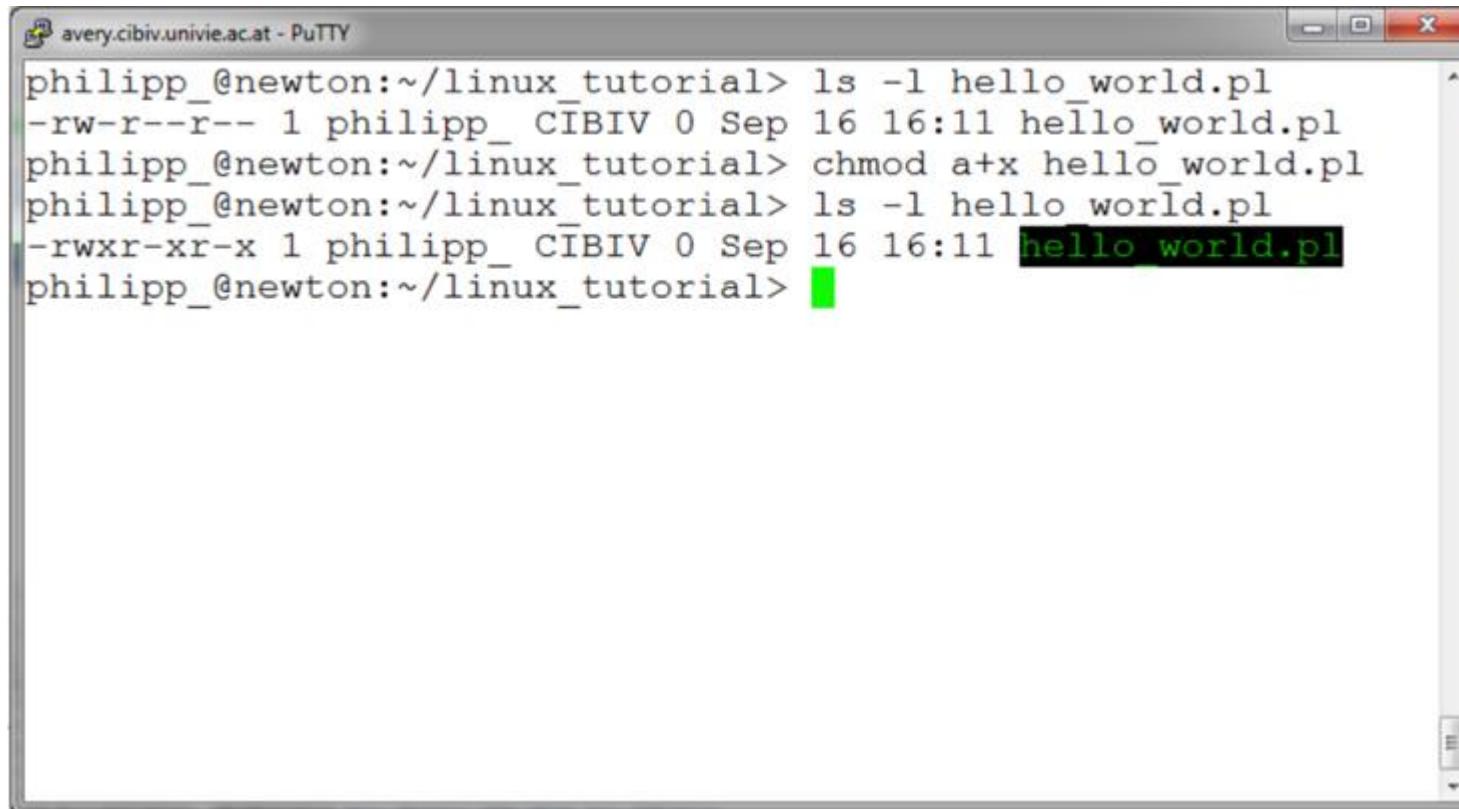


The screenshot shows a PuTTY terminal window titled "avery.cibiv.univie.ac.at - PuTTY". The command "ls -l" is run in the directory "/linux_tutorial". The output lists eight files with their permissions, owner, group, size, date, and name. A green rectangular highlight is placed over the command "ls -l" and its resulting output.

```
philipp_@newton:~/linux_tutorial> ls -l
total 8
-rw-r--r-- 1 philipp_ CIBIV 0 Sep 16 16:11 data.dat
-rw-r--r-- 1 philipp_ CIBIV 0 Sep 16 16:27 date.dat
-rw-r--r-- 1 philipp_ CIBIV 13 Sep 16 17:03 hello.txt
-rw-r--r-- 1 philipp_ CIBIV 0 Sep 16 16:11 hello_world.pl
-rw-r--r-- 1 philipp_ CIBIV 53 Sep 16 16:58 lines.txt
-rw-r--r-- 1 philipp_ CIBIV 0 Sep 16 16:11 output.txt
-rw-r--r-- 1 philipp_ CIBIV 0 Sep 16 16:11 search.pl
philipp_@newton:~/linux_tutorial>
```

Command: chmod

- If you own the file, you can change it's permissions with “chmod”
 - Syntax: chmod [User/Group/Others/all]+[permission] [file(s)]
 - Below we grant execute permission to all:



The screenshot shows a PuTTY terminal window titled "avery.cibiv.univie.ac.at - PuTTY". The user "philipp_@newton" is in their home directory (~) under the "linux_tutorial" folder. They first run the command "ls -l hello_world.pl" which shows the file has only read and write permissions for the owner. Then they run "chmod a+x hello_world.pl" to add execute permission for all users. Finally, they run "ls -l hello_world.pl" again, and the output shows that the file now has execute permission for all users (rwxr-xr-x).

```
philipp_@newton:~/linux_tutorial> ls -l hello_world.pl
-rw-r--r-- 1 philipp_ CIBIV 0 Sep 16 16:11 hello_world.pl
philipp_@newton:~/linux_tutorial> chmod a+x hello_world.pl
philipp_@newton:~/linux_tutorial> ls -l hello_world.pl
-rwxr-xr-x 1 philipp_ CIBIV 0 Sep 16 16:11 hello_world.pl
philipp_@newton:~/linux_tutorial>
```

Running a program (a.k.a. a job)

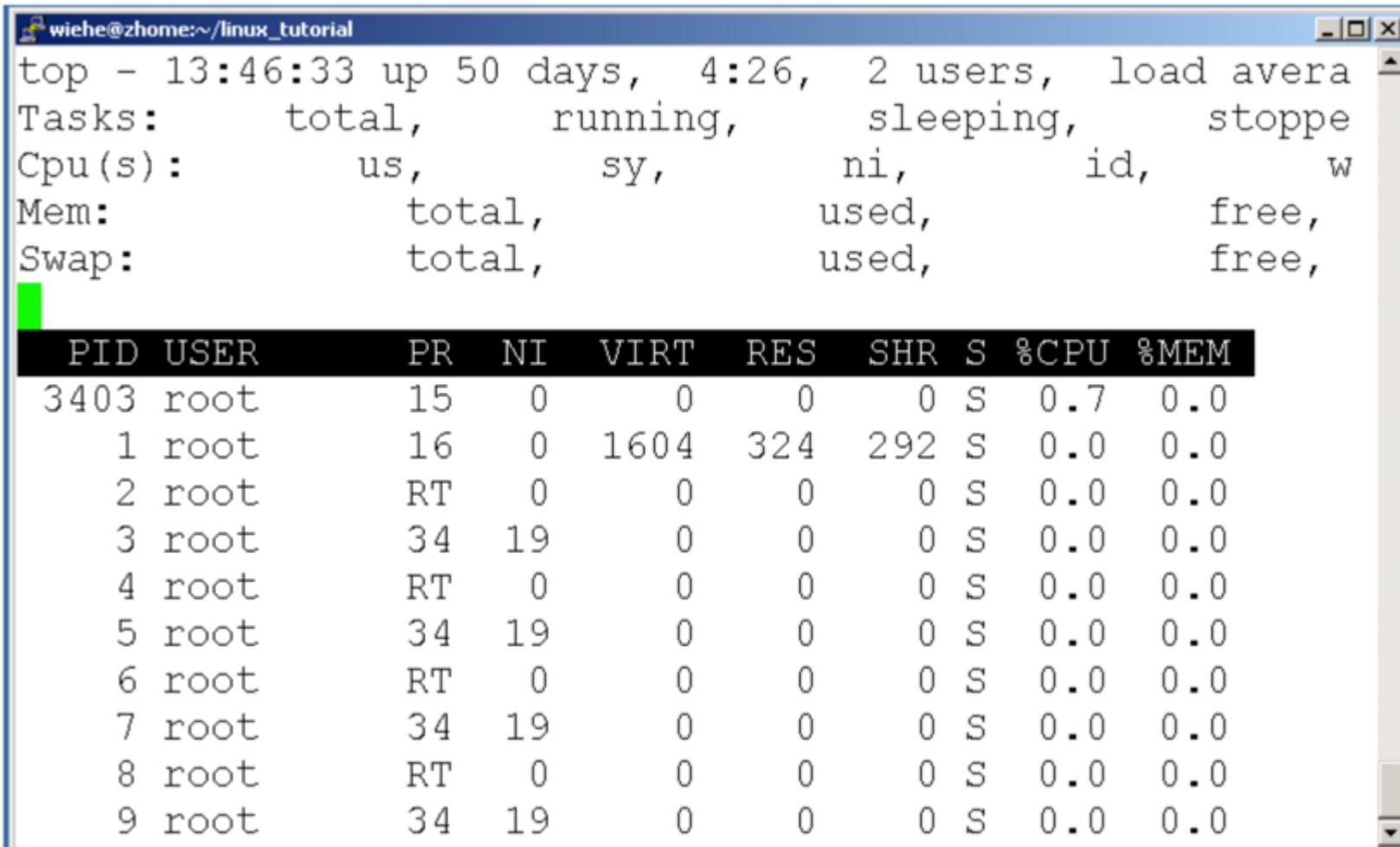
- ▶ Make sure the program has executable permissions
- ▶ Use “./” to run the program

Command: wc

- ▶ To count the characters, words, and lines in a file use “wc”
- ▶ The first column in the output is lines, the second is words, and the last is characters

Command: top

- To view the CPU usage of all processes:



The screenshot shows a terminal window titled "wiehe@zhome:~/linux_tutorial" displaying the output of the "top" command. The window title bar includes standard window controls (minimize, maximize, close) and scroll bars on the right side.

The top command output provides system statistics and a process list. The statistics include:

- System uptime: 13:46:33 up 50 days, 4:26, 2 users, load average (partially visible).
- Task counts: total, running, sleeping, stopped.
- CPU usage: us, sy, ni, id, w.
- Memory usage: total, used, free.
- Swap space: total, used, free.

The process list table has the following columns:

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM
3403	root	15	0	0	0	0	S	0.7	0.0
1	root	16	0	1604	324	292	S	0.0	0.0
2	root	RT	0	0	0	0	S	0.0	0.0
3	root	34	19	0	0	0	S	0.0	0.0
4	root	RT	0	0	0	0	S	0.0	0.0
5	root	34	19	0	0	0	S	0.0	0.0
6	root	RT	0	0	0	0	S	0.0	0.0
7	root	34	19	0	0	0	S	0.0	0.0
8	root	RT	0	0	0	0	S	0.0	0.0
9	root	34	19	0	0	0	S	0.0	0.0

Misc Command Line Cheat Sheet

Type	Command	Function
File Dir Info	ls	Directory listing
File Dir Info	ls -l	Directory listing with option
File Dir Info	pwd	Show the current directory
File Dir Info	rm <i>file</i>	Delete <i>file</i>
File Dir Info	rm -rf <i>dir</i>	Remove <i>dir</i>
File Dir Info	cp <i>file1 file2</i>	Copy <i>file1</i> to <i>file2</i>
File Dir Info	mv <i>dir1 dir2</i>	Rename <i>dir1</i> to <i>dir2</i>
File Dir Info	ln -s <i>file link</i>	Create a symbolic link <i>link</i> to <i>file</i>
File Dir Info	touch <i>file</i>	Create or touch <i>file</i> (update timestamp)
File Dir Info	cat <i>file</i>	Print contents of <i>file</i>
File Dir Info	less <i>file</i>	Browse contents of <i>file</i> using VIM short cuts
File Dir Info	grep <i>pattern files</i>	Search for a <i>pattern</i> in <i>files</i>
File Dir Info	<i>command1 command2</i>	Pipe results of <i>command1</i> to <i>command2</i>
File Dir Info	tail <i>file</i>	Print last 5 lines of <i>file</i>
File Dir Info	tar cfz <i>file.tar.gz file1 file2</i>	Combind files into a single <i>file.tar</i>
File Dir Info	tar xzf <i>file.tar.gz</i>	Uncompresses and unzip <i>file.tar.gz</i>
File Dir Info	find . -name "*.bam"	finds all filies matching *.bam under the current directory
File Dir Info	chmod 755 <i>file</i>	Change the permissions of <i>file</i> to make readable,writable, and executable to user, readable and executable to group and world
File Dir Info	tail -f <i>file</i>	Continually print last 5 lines of <i>file</i>
Processes	ps	Display your processes & their <i>pid</i>
Processes	top	Display all running process
Processes	kill <i>pid</i>	Kill Process id <i>pid</i>
Processes	Ctrl+c	Halts current command
Processes	Ctrl+z	Stop current command, suspending command
Processes	fg	Puts suspended command in foreground
Processes	bg	Puts suspended command to run in background
Processes	disown	Disowns process in background to remain running after logout
Net	ping <i>host</i>	Ping <i>host</i> and output timing
Net	wget <i>file</i>	Download <i>file</i>
Drive Info	du	Show directory space usage
Drive Info	df	Show disk usage
Info	man <i>command</i>	Show manual for <i>command</i>
Info	whereis <i>command</i>	Show the full path of <i>command</i>
Info	which <i>app</i>	Show the location of which <i>app</i> is being used
Net	ssh davidwcr@itg.usc.edu	ssh into itg.usc.edu as davidwcr
Net	rsync -avz --progress myfile davidwcr@itg.usc.edu:~/.	rsync <i>myfile</i> to itg.usc.edu in home directory
Dir Nav	cd <i>dir</i>	Change directory to <i>dir</i>
Dir Nav	.	Current directory
Dir Nav	..	Up one directory
Dir Nav	~	User home directory
Edit	vim <i>myfile.txt</i>	Edit a file
Misc	echo 'Message' mail -s 'subject' davidwcr@usc.edu	

Last but not least: install bwa

- **mkdir soft_download, soft**
- Bing (google) *bwa install*

国内版 国际版

bwa install

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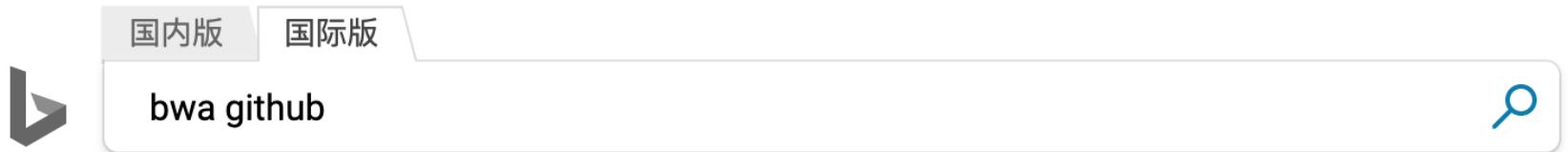
[Burrows-Wheeler Aligner - SourceForge](#)
bio-bwa.sourceforge.net ▾

BWA is a software package for mapping low-divergent sequences against a large reference genome, such as the human genome. It consists of three algorithms: BWA-backtrack, BWA-SW and BWA-MEM. The first algorithm is designed for Illumina sequence reads up to 100bp, while the rest two for longer sequences ranged from 70bp to 1Mbp.

[Browse Files at SourceForge](#)
BWA is a program for aligning sequencing reads against a large reference genome ...

[See results only from bio-bwa.sourceforge.net](#)

[SF Project Page](#)
Download Burrows-Wheeler Aligner for free.
BWA is a program for aligning sequencing ...



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bwa

<https://github.com/lh3/bwa>



Burrow-Wheeler Aligner for short-read alignment (see minimap2 for long-read alignment)

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v0.7.17

9f26bfc

BWA-0.7.17 (r1188)

lh3 released this on 24 Oct 2017 · 13 commits to master since this release

This release adds option -q to preserve the mapping quality of split alignment with a lower alignment score than the primary alignment. Option -5 automatically applies -q as well. BWA outputs identical alignments to the previous version unless option -5 is used.

(0.7.17: 23 October 2017, r1188)

▼ Assets 3

[bwa-0.7.17.tar.bz2](#)

186 KB

[Source code \(zip\)](#) [Source code \(tar.gz\)](#)

<https://github.com/lh3/bwa/releases/download/v0.7.17/bwa-0.7.17.tar.bz2>

- **cd** soft_download
- **wget** <https://github.com/lh3/bwa/releases/download/v0.7.17/bwa-0.7.17.tar.bz2>
- **cp** bwa-0.7.17.tar.bz2 .../soft
- **cd** .../soft
- **tar** jxvf bwa-0.7.17.tar.bz2
- **cd** bwa-0.7.17
- **make**
- **./bwa**

```
liang@iMBP:soft_download$ wget https://github.com/lh3/bwa/releases/download/v0.7.17/bwa-0.7.17.tar.bz2
[- 2019-09-10 17:31:11 -- https://github.com/lh3/bwa/releases/download/v0.7.17/bwa-0.7.17.tar.bz2 ]]
Resolving github.com... 52.74.223.119
Connecting to github.com|52.74.223.119|:443... connected.
HTTP request sent, awaiting response... 302 Found
Location: https://github-production-release-asset-2e65be.s3.amazonaws.com/1253014/14fe9d96-b7f4-11e7-8c34-ef5aa796dccc?X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIAIWNJYAX4CSVEH53A%2F20190910%2Fsus-east-1%2Fsaws4_request&X-Amz-Date=20190910T093113Z&X-Amz-Expires=300&X-Amz-Signature=6a40abce377cc3f221abc59be1c32cb99a88d7f48766061e475769ca276c33b9&X-Amz-SignedHeaders=host&actor_id=0&response-content-disposition=attachment%3B%20filename%3Dbwa-0.7.17.tar.bz2&response-content-type=application%2Foctet-stream [following]
--2019-09-10 17:31:12 -- https://github-production-release-asset-2e65be.s3.amazonaws.com/1253014/14fe9d96-b7f4-11e7-8c34-ef5aa796dccc?X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIAIWNJYAX4CSVEH53A%2F20190910%2Fsus-east-1%2Fsaws4_request&X-Amz-Date=20190910T093113Z&X-Amz-Expires=300&X-Amz-Signature=6a40abce377cc3f221abc59be1c32cb99a88d7f48766061e475769ca276c33b9&X-Amz-SignedHeaders=host&actor_id=0&response-content-disposition=attachment%3B%20filename%3Dbwa-0.7.17.tar.bz2&response-content-type=application%2Foctet-stream
Resolving github-production-release-asset-2e65be.s3.amazonaws.com... 52.216.160.75
Connecting to github-production-release-asset-2e65be.s3.amazonaws.com|52.216.160.75|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 190908 (186K) [application/octet-stream]
Saving to: 'bwa-0.7.17.tar.bz2'

bwa-0.7.17.tar.bz2 100%[=====] 186.43K 145KB/s in 1.3s

2019-09-10 17:31:15 (145 KB/s) - 'bwa-0.7.17.tar.bz2' saved [190908/190908]

liang@iMBP:soft_download$
```

```
[liang@iMBP:soft$ cp ./bwa-0.7.17.tar.bz2\r\=https%3A%2F%2Fsourceforge.net%2Fprojects%2Fbio-bwa%2Ffiles%2Fbwa-0.7.17.tar.bz2%2Fdownload ./
[liang@iMBP:soft$ mv bwa-0.7.17.tar.bz2\r\=https%3A%2F%2Fsourceforge.net%2Fprojects%2Fbio-bwa%2Ffiles%2Fbwa-0.7.17.tar.bz2 bwa-0.7.17.tar.bz2
[liang@iMBP:soft$ ls
bwa-0.7.17.tar.bz2
liang@iMBP:soft$ tar jxvf bwa-0.7.17.tar.bz2
x bwa-0.7.17/
x bwa-0.7.17/bntseq.c
x bwa-0.7.17/utils.c
x bwa-0.7.17/bwt.h
x bwa-0.7.17/bwamem.h
x bwa-0.7.17/bwtsw2_core.c
x bwa-0.7.17/bwase.h
x bwa-0.7.17/bwt.c
x bwa-0.7.17/bwt_lite.h
x bwa-0.7.17/README.md
x bwa-0.7.17/khash.h
x bwa-0.7.17/main.c
x bwa-0.7.17/bwtsw2.h
x bwa-0.7.17/bwt_lite.c
x bwa-0.7.17/ksort.h
x bwa-0.7.17/bwtgap.h
x bwa-0.7.17/NEWS.md
x bwa-0.7.17/bwa.1
x bwa-0.7.17/rle.c
x bwa-0.7.17/bwtaln.c
x bwa-0.7.17/bwamem_extra.c
x bwa-0.7.17/bwtaln.h
x bwa-0.7.17/rope.c
x bwa-0.7.17/rle.h
x bwa-0.7.17/kopen.c
x bwa-0.7.17/kthread.c
x bwa-0.7.17/bamlite.h
x bwa-0.7.17/bwtsw2_chain.c
x bwa-0.7.17/is.c
```

```
[liang@iMBP:soft$ cd bwa-0.7.17
liang@iMBP:bwa-0.7.17$ make
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS utils.c -o utils.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS kthread.c -o kthread.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS kstring.c -o kstring.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS ksw.c -o ksw.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwt.c -o bwt.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bntseq.c -o bntseq.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwa.c -o bwa.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwamem.c -o bwamem.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwamem_pair.c -o bwamem_pair.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwamem_extra.c -o bwamem_extra.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS malloc_wrap.c -o malloc_wrap.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS QSufSort.c -o QSufSort.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwt_gen.c -o bwt_gen.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS rope.c -o rope.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS rle.c -o rle.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS is.c -o is.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwtindex.c -o bwtindex.o
ar -csru libbwa.a utils.o kthread.o kstring.o ksw.o bwt.o bntseq.o bwa.o bwamem.o bwamem_pair.o bwamem_extra.o malloc_wrap.o QSufSort.o bwt_gen.o rope.o rle.o is.o bwtindex.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwashm.c -o bwashm.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwase.c -o bwase.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwaseqio.c -o bwaseqio.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwtgap.c -o bwtgap.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwtaln.c -o bwtaln.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bamlite.c -o bamlite.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwape.c -o bwape.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS kopen.c -o kopen.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS pemerge.c -o pemerge.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS maxk.c -o maxk.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwtsw2_core.c -o bwtsw2_core.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwtsw2_main.c -o bwtsw2_main.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwtsw2_aux.c -o bwtsw2_aux.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwt_lite.c -o bwt_lite.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwtsw2_chain.c -o bwtsw2_chain.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS fastmap.c -o fastmap.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwtsw2_pair.c -o bwtsw2_pair.o
gcc -c -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS main.c -o main.o
gcc -g -Wall -Wno-unused-function -O2 -DHAVE_PTHREAD -DUSE_MALLOC_WRAPERS bwashm.o bwase.o bwaseqio.o bwtgap.o bwtaln.o bamlite.o bwape.o kopen.o pemerge.o maxk.o bwtsw2_core.o bwtsw2_main.o bwtsw2_aux.o bwt_lite.o bwtsw2_chain.o fastmap.o bwtsw2_pair.o main.o -o bwa -L. -lbwa -lm -lz -lpthread
liang@iMBP:bwa-0.7.17$
```

```
[fastmap.o bwtswz_parr.o main.o -o bwa -L -lbwaz -lpthread]
```

```
[liang@iMBP: bwa-0.7.17$ ./bwa
```

Program: bwa (alignment via Burrows-Wheeler transformation)

Version: 0.7.17-r1188

Contact: Heng Li <lh3@sanger.ac.uk>

Usage: bwa <command> [options]

Command:	index	index sequences in the FASTA format
	mem	BWA-MEM algorithm
	fastmap	identify super-maximal exact matches
	pemerge	merge overlapping paired ends (EXPERIMENTAL)
	aln	gapped/ungapped alignment
	samse	generate alignment (single ended)
	sampe	generate alignment (paired ended)
	bwasw	BWA-SW for long queries
	shm	manage indices in shared memory
	fa2pac	convert FASTA to PAC format
	pac2bwt	generate BWT from PAC
	pac2bwtgen	alternative algorithm for generating BWT
	bwtupdate	update .bwt to the new format
	bwt2sa	generate SA from BWT and Occ

Note: To use BWA, you need to first index the genome with `bwa index'.

There are three alignment algorithms in BWA: `mem', `bwasw', and `aln/samse/sampe'. If you are not sure which to use, try `bwa mem' first. Please `man ./bwa.1' for the manual.

```
liang@iMBP: bwa-0.7.17$
```