Assignments

- Homework 2 is up. Meaning you send me your Overleaf email address in Slack and I share the homework document with you.

  - Goal – you compile some code, run it on different clusters, answer some questions and make a couple of plots in Overleaf Latex.

  - Along the way I know that you

1) Can compile C code with a makefile (you don't have to write anything)
2) You can setup a conda environment.
3) You can open a jupyter notebook and enter data into a plot
4) Upload that to overleaf so Nick and I can see your progress.

This will be the pattern for all homeworks and projects in this class.

Install Matplotlib with Conda

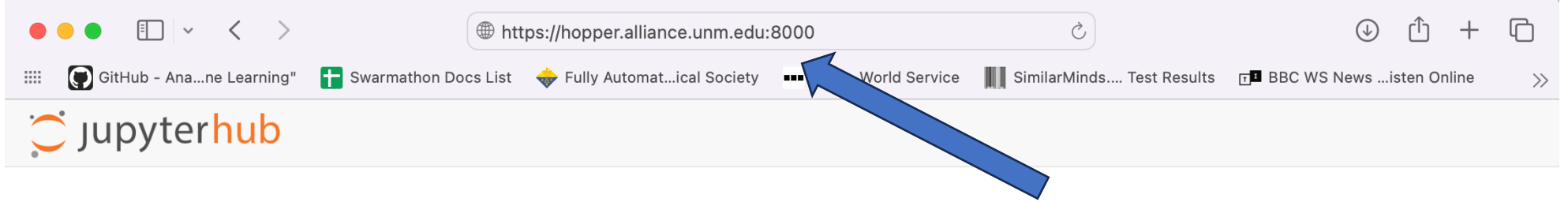
```
mfricke@hopper:~ $ module load miniconda3
mfricke@hopper:~ $ conda create --name plotting matplotlib ipykernel
```

Clone Homework Repository

```
mfricke@hopper:~ $ git clone https://github.com/gmfricke/SIMD_HW
```

Make addition benchmark code

```
mfricke@hopper:~ $ cd SIMD_HW
mfricke@hopper:~ $ make
```



https://hopper.alliance.unm.edu:8000

Sign in

Username:

Password:

Sign in

https://hopper.alliance.unm.edu:8000

GitHub - Ana...ne Learning" | Swarmathon Docs List | Fully Automat...ical Society | BBC - World Service | SimilarMinds.... Test Results | BBC WS News ...isten Online

jupyterhub

Logout | Control Panel

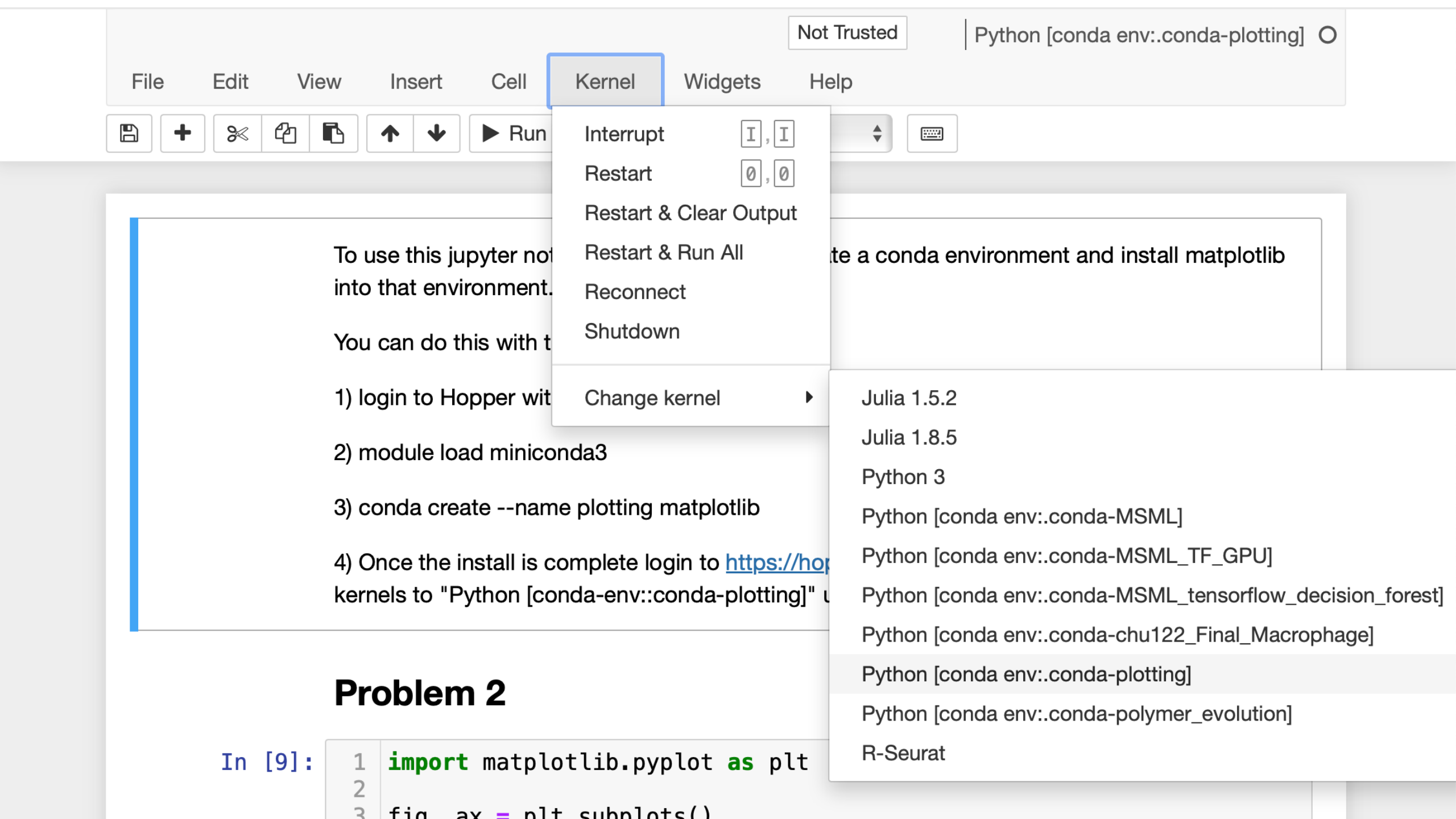
Files | Running | Clusters

Select items to perform actions on them.

Upload | New | 

0 / SIMD_HW

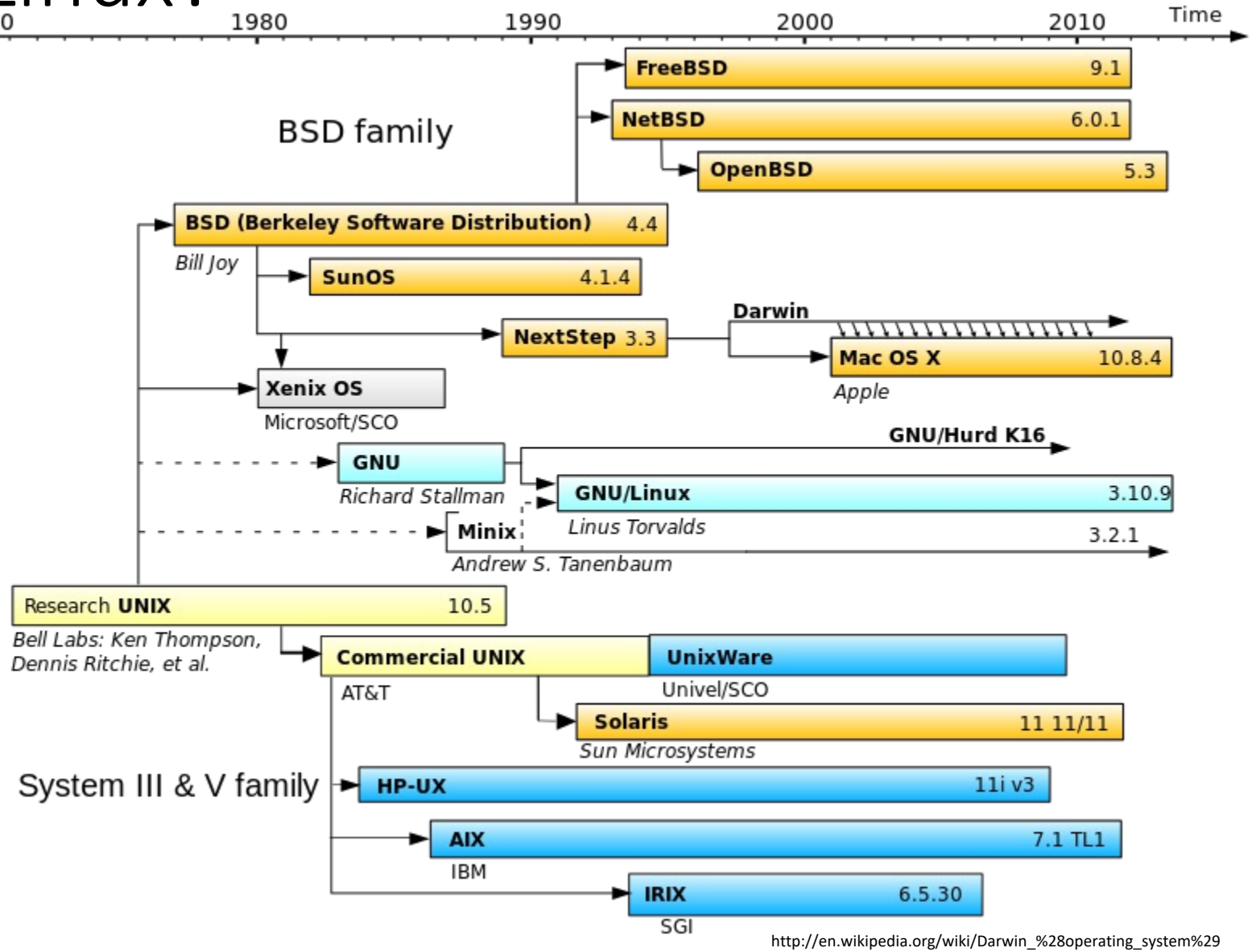
	Name	Last Modified	File size
..		seconds ago	
result_plots.ipynb		7 hours ago	121 kB
add.h		7 hours ago	424 B
add_benchmarks.c		7 hours ago	2.37 kB
add_main.c		7 hours ago	2.16 kB
Makefile		7 hours ago	1.06 kB
Readme.txt		7 hours ago	143 B
regular_add.c		7 hours ago	448 B
sse_add.c		7 hours ago	1.08 kB


Not Trusted
Python [conda env:.conda-plotting]
File
Edit
View
Insert
Cell
Kernel
Widgets
Help
Run
Interrupt I,I
Restart 0,0
Restart & Clear Output
Restart & Run All
Reconnect
Shutdown
Change kernel
Julia 1.5.2
Julia 1.8.5
Python 3
Python [conda env:.conda-MSML]
Python [conda env:.conda-MSML_TF_GPU]
Python [conda env:.conda-MSML_tensorflow_decision_forest]
Python [conda env:.conda-chu122_Final_Macrophage]
Python [conda env:.conda-plotting]
Python [conda env:.conda-polymer_evolution]
R-Seurat
To use this jupyter not
te a conda environment and install matplotlib
into that environment.
You can do this with t
1) login to Hopper wit
2) module load miniconda3
3) conda create --name plotting matplotlib
4) Once the install is complete login to https://hop
kernels to "Python [conda-env::conda-plotting]" u
Problem 2
In [9]:
1 import matplotlib.pyplot as plt
2
3 fig, ax = plt.subplots()

Lecture 4: Devices

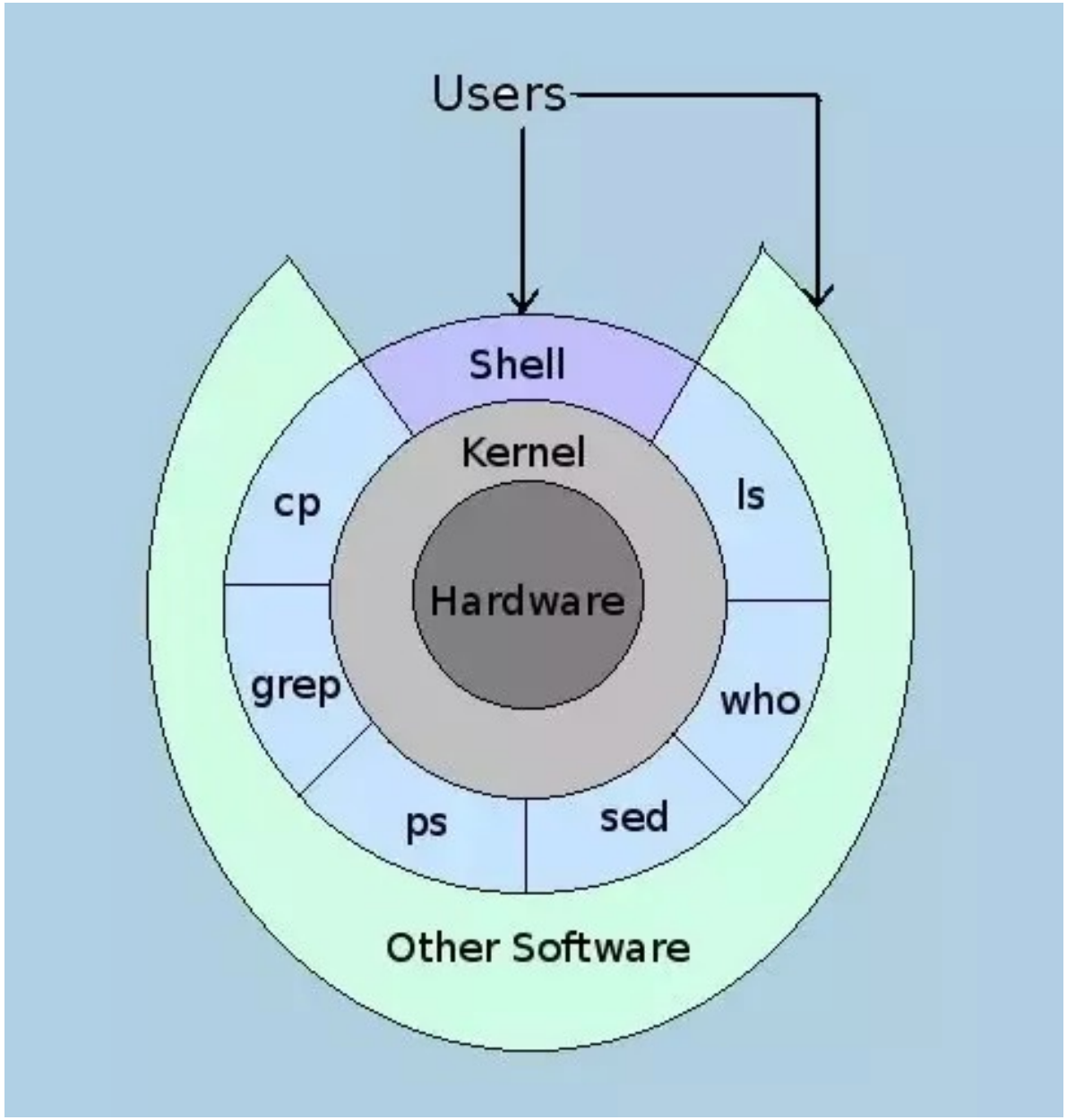
High Performance Computers

What is Linux?



http://en.wikipedia.org/wiki/Darwin_%28operating_system%29

The Kernel


Users
Shell
Kernel
Hardware
cp
ls
grep
who
ps
sed
Other Software

What is Linux?
Linux + GNU Utilities = Free Unix

TUX: Torvold's Linux

- Linux is an O/S core written by Linus Torvalds and others

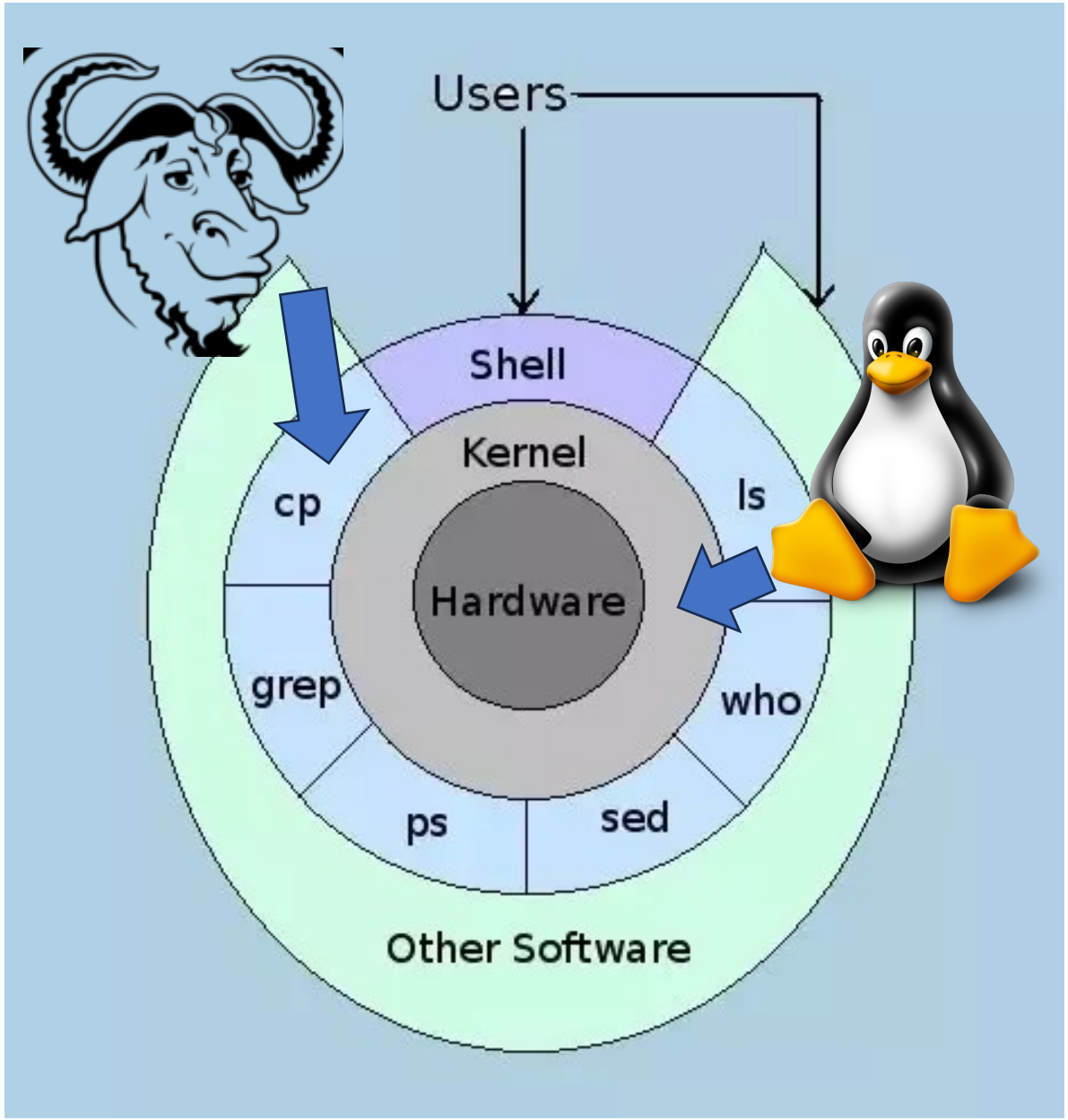
(Bitten by a Penguin)

- a set of programs written by Richard Stallman and others. They are the GNU utilities.

http://www.gnu.org/

GNU stands for GNU is Not Unix

GNU/Linux


Users
Shell
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cp
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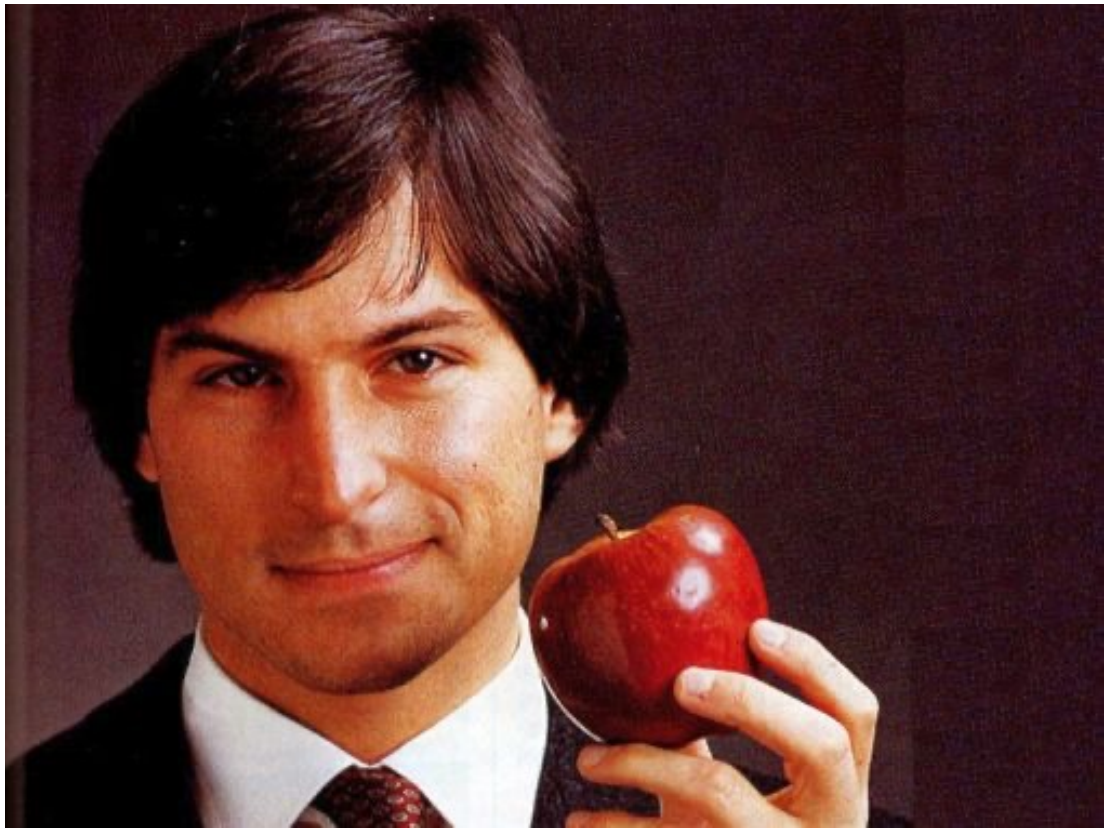
sed
Other Software

Mac OS X

- Darwin, the system on which Apple's Mac OS X is built, is a derivative of 4.4BSD-Lite2 and FreeBSD. In other words, the Mac is a Unix system!

- For X11 (graphics), see XQuartz

(http://xquartz.macosforge.org/landing/)



Udevd

- The udevd service monitors the kernel for hardware events:

Enter `systemctl status system-udevd`

And creates device files based on those events.

Device Files

- Most everything in Linux is a file.
- A file in Linux is anything that supports simple input and output including many devices.
- Interacting with a file is really just a way to ask the kernel to get or put data somewhere
- Device files are stored in the /dev directory

  Enter `ls /dev`

- Many device files point to a program that generates or consumes data

  Enter `head -n 1 /dev/urandom`

Device Files

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  Enter `head -n 1 /dev/urandom`

  Provides a stream of random output (e.g. for creating encryption keys)

  Enter `echo blah blah > /dev/null`

Sometimes a process will generate output we don't care about. We can send it to /dev/null where it is consumed and lost.

E.g. when some programs are run for days at a time and they sent informational output to standard out they can consume all available memory. Instead, we throw away the output.

Device Files - Types

Devices have permissions just like other files:

Enter `ls -l /dev`

- The type of device is given by the characters before the permission triplet:

- “b”: block – random access device
- “c”: character – data streams (e.g. /dev/null, /dev/urandom)
- “p”: pipe – a data stream from one process to another (unidirectional)
- “s”: socket – a data stream between two processes (bidirectional)

Devices without Files

- OK, not everything is a file. Network cards don’t have a device file.
- Device files have read and write functions that take bytes, but networks work on packets so their read and write functions are more complicated.
- Solaris systems did have device files for network cards btw

SysFS

- /dev provides a simple interface through the kernel to devices
- Downsides are that it is a bit too simple and the devices are named in the order that the kernel found them
- If you remove a device then the names the kernel gives everything else might change
- A more recent approach is to use sysfs to get information about hardware
- Devices files are kept in /sys/devices

    Enter `ls -l /sys/devices`

SysFS

- /dev provides a simple interface through the kernel to devices
- Devices files are kept in /sys/devices

  Enter `ls -l /sys/devices`
- Sysfs is used for managing and getting info about devices
- /dev is for reading and writing to them
- To find the sysfs file that corresponds to a /dev/ device file use this command:
- Enter `udevadm info --query all /dev/sda`

Is sda on Wheeler a spinning disk or SSD?

How about on your workstation?

Udev

- To monitor udev detected events live:

Enter `udevadm monitor`

After running udevadm monitor insert a usb device into your computer. You should see hardware events.

- Udev allows us to set rules for how hardware is handled:

Enter `cat /etc/udev/rules.d/60-ipath.rules`

dd command: Data Duplicator

- dd's function is to read and write block or stream data to device files.
- This makes it a powerful tool*

Enter `dd if=/dev/random of=/dev/stdout bs=128 count=1`

What do you see. What do you think /dev/stdout is?

*Nicknamed the disk destroyer

/dev/stdout

Let's take a closer look at /dev/proc/stdout

```
ls -l /dev/stdout
lrwxrwxrwx 1 root root 15 Aug 23 09:08 /dev/stdout -> /proc/self/fd/1
```

/proc contains a directory for every running process
(many listed by process ID)

/proc/self refers to the process reading the filesystem (your terminal)
Every process has a file descriptor (fd) so it can communicate.
fd 1 is the standard character stream to the screen (it's a socket)
fd 2 is standard error
When you write cout in C++ or print() in python you are sending a character stream to `/proc/self/fd/1`

dd command: Data Duplicator

You can also write block data.

dd if=/dev/urandom of=/dev/sdX bs=1M

Will write the stream of random characters from /dev/urandom to SCSI drive X in 1 MB chunks.

This will overwrite everything on drive X.

*Nicknamed the disk destroyer

Hard Disk Device Files /dev/sd*

- SCSI: Small Computer System Interface
- Linux uses SCSI protocols to talk to disks even SATA disks

You can list SCSI devices on the Wheeler and Hopper head nodes:

Enter `lsscsi`

Enter `cat /proc/scsi/scsi`

(Again “everything in Linux is a file”)

Virtual Disk Device Files /dev/xvd* /dev/vd*

- Some disks are optimized for virtual environments such as Amazon Web Services or VitualBox.

- Basically, a Virtual Disk Device allows virtual machines to communicate with the real disk faster.

Non-Volatile Memory Device Files /dev/nvme*

- NonVolatile Memory Express (NVME) is a protocol for talking to solid state drives (SSDs) and flash drives.

- SATA supports up to 6 Gbit/s, which was a lot faster than hard drives used to be (even older SSDs).
- SCSI devices support a queue of up to 2^8 commands at a time. SAS drives up to 2^8 so they can handle multiuser systems with lots of requests. SATA is intended for single user workstations and has a typical queue depth of 2^5 commands.

Enter `lsscsi -l` to see the queue depth

- PCI Express sockets are much faster than SATA connections with some capable of 32 Gbit/s since recent SSDs are capable of 25 Gbit/s speeds and support 2^{16} commands in the queue.

Device Mapper Device Files (LVM) /dev/dm* or /dev/mapper*

- A challenge with disk devices has always been that they are hard to change.
- When you partition a disk into filesystems (more later) it is hard to change the size of the partition when it fills up.
- Logical Volume Management (LVMs) solve that problem by abstracting the disk and allowing you to change the virtual disks size even while the OS is running.
- If you run out of space, you can just add another physical drive to the LVM and expand the partition.
- Enter `ls /dev/mapper*` and `df -h | grep mapper`

on wheeler to see that we use LVMs.

Terminal Device Files /dev/tty* /dev/pts*

- Terminals are devices that take character streams from processes and send them to and from Input/Output devices like this VT100 from 1978.
- Over the years physical terminals were replaced with terminal emulators but the protocols remained basically the same. It is always easier to reuse old code.
- The VT100 protocol is still used because is supports ANSI colors.
- You are typing and reading text in a virtual terminal whenever you use BASH.

Terminal Device Files /dev/tty* /dev/pts*

- Terminals that read directly from a local keyboard and write to a computer monitor are named /dev/tty*

- Terminals that connect to a remote program are called pseudoterminals and they are named /dev/pts*

Terminals that run over SSH are pseudoterminals.

Enter `tty` to get the path to the terminal to which you are connected. E.g. `/dev/pts/3`. Try it on hopper.

Now try writing to the terminal

Enter `echo Hello > /dev/pts/3`

Terminal Device Files /dev/tty* /dev/pts*

Let’s read from your terminal:

Enter `read data < /dev/pts/3`

This stores whatever character stream you enter next into the variable “data”.

We can display the contents of that variable:

Enter `echo $data`

TTY stands for tele-typewriter

Terminal Device Files /dev/tty* /dev/pts*

Open a new terminal and ssh into hopper (so you have two ssh sessions on Hopper).

Enter `tty` to get the device file path of your new SSH pseudoterminal.

From your first terminal

Enter `echo Hello > /dev/pts/#`

Where # is the device file for your second terminal.

Terminal Device Files /dev/tty* /dev/pts*

- Virtual terminals read and write to hardware connected directly to the computer (/dev/tty*)
- Many terminals have a getty process that waits for input on a terminal. Gettys guard access by asking for a login name and password.
- You can switch between virtual terminals with Alt-F# (F here is the function keys on your keyboard and # is the number of the device file).
- So to switch to Terminal 1 on your Linux machine enter Alt-F1.
- This is used all the time for troubleshooting. If the graphical terminal that comes up breaks and I want to login to Linux to fix it, I hit Alt-F1 to get a local text-based terminal so I can login.
- Try it on your Linux workstation.

Terminal Device Files /dev/tty* /dev/pts*

- Terminals can be text or graphical.
- If you installed a GUI with Linux then a graphical Greeter will be waiting for input from one of the TTY device files.
- Keep pressing Alt-F# incrementing # until you get to the graphical terminal.

Udev Overview

- Udev is responsible for creating device files, and does the following:

1. The kernel sends a uevent message to the systemd-udevd service.
2. Udev parses the uvent message
3. Udev applies all the rules in /etc/udev/rules.d and /lib/udev/rules.d to decide what to do about the hardware uevent message.

Take a look at the rules for handling mice by entering

`cat /lib/udev/rules.d/60-nvidia.rules`

The mknod command makes a device files named `/dev/nvidia*`

Enter `grep -R tty /lib/udev/rules.d/`

To see all the rules that create virtual terminals