The Shell

```
Module Code: COMP1712

Module Name: Computer Architectures and Operating Systems

Credits: 15

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What is a shell?

- User interface for running commands
- Interactive language
- Scripting language

Shell Initialisation

The initialisation file sets up the “work environment” and “customizes” the shell environment for the user. The main agenda of Shell initialisation files are to persist common shell configuration, such as:

- `$PATH` and other environment variables
- shell prompt
  - `jovyan@jupyter-seb-20blair:~/AOS/Bash$`
- shell tab-completion
- aliases, functions
  - `alias glg = "git log --graph --oneline --decorate --all"`
- key bindings
  - `bindsym $mod+d exec $menu`

Shell modes

The shell can be run in three possible modes:

- Interactive login
- Interactive non-login
- Non-interactive

Operations for Different Shell Modes

- Login to a remote system via SSH : **Login**, **Interactive**
- User successfully login into the system, using `/bin/login`, after reading credentials stored in the `/etc/passwd` file: **Login**, **Interactive**
- Execute a script remotely and request a terminal, e.g. `ssh user@host -t 'echo $PWD'` : **Non-Login**, **Interactive**
- Start a new shell process, e.g. `bash`: **Non-Login**, **Interactive**
- Execute a script remotely, e.g. `ssh user@host 'echo $PWD` : **Non-Login**, **Non-Interactive**
- Run a script, `bash myscript.sh`: **Non-Login**, **Non-Interactive**
- Run an executable with `#!/usr/bin/env bash` shebang : **Non-Login**, **Non-Interactive**
- Open a new graphical terminal window/tab: **Non-Login**, **Interactive**

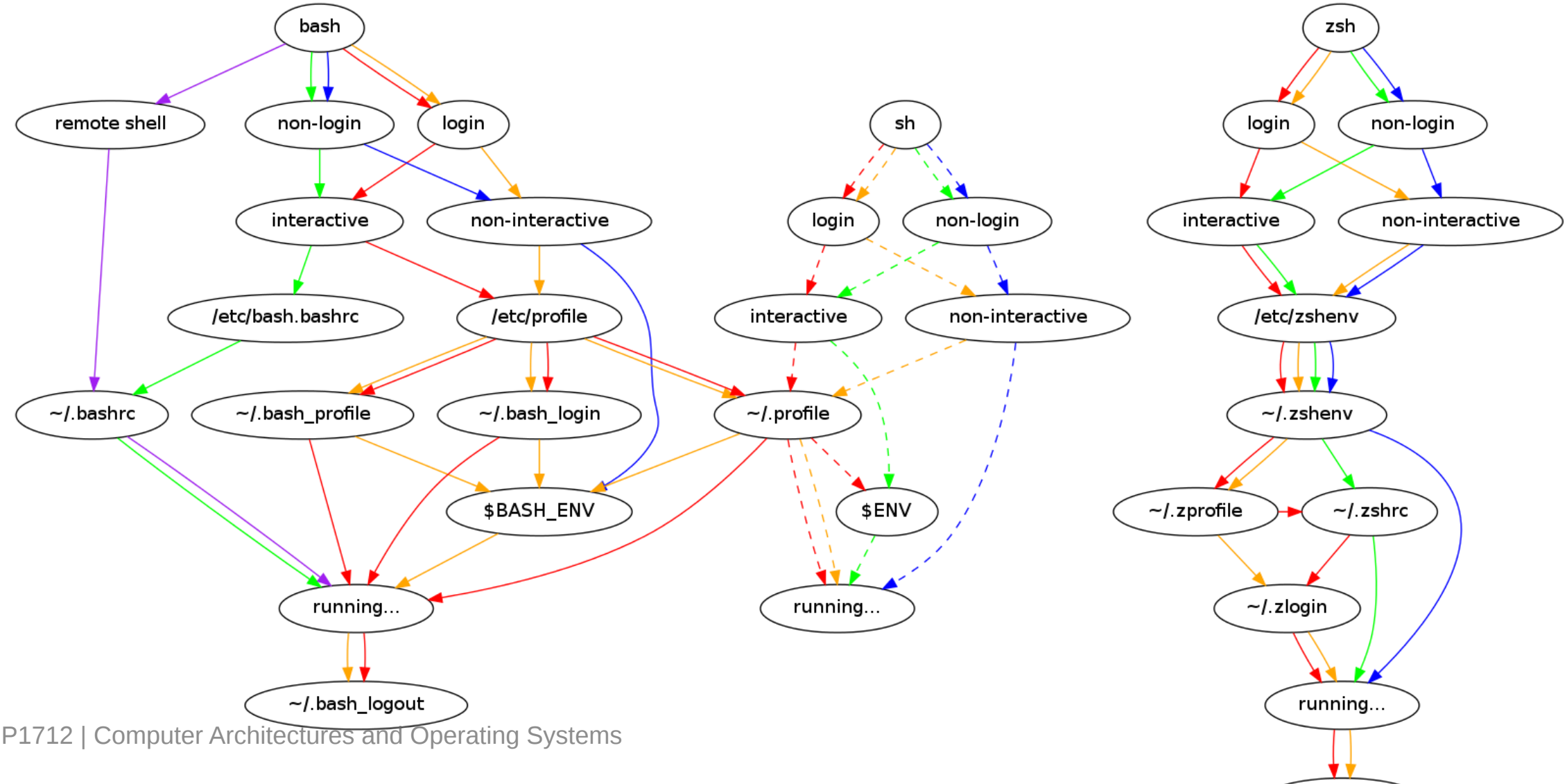
Shell Initialisation Files

1. System-wide startup files
    - whole system irrespective of a specific user
    - `/etc/profile` for system-wide environment configurations and startup programs for login setup
    - `/etc/bashrc` or `/etc/bash.bashrc` file contains system-wide functions and aliases including other configurations that apply to all system users

Shell Initialisation Files

2. User-specific startup files
    - files which contain configuration which applied to the specific user
    - `~/.bash_profile` file – Stores user-specific environment and startup programs configurations.
    - `~/.bashrc` file – Stores user-specific aliases and functions.
    - `~/.bash_login` file – Contains specific configurations that are normally only executed when you log in to the system.
    - `~/.bash_history` file – Bash maintains a history of commands that have been entered by a user on the system.
    - `~/.bash_logout` file – it's not used for shell startup, but stores user specific instructions for the logout procedure. It is read and executed when a user exits from an interactive login shell.

Order of Activation:



A Sea of Shells

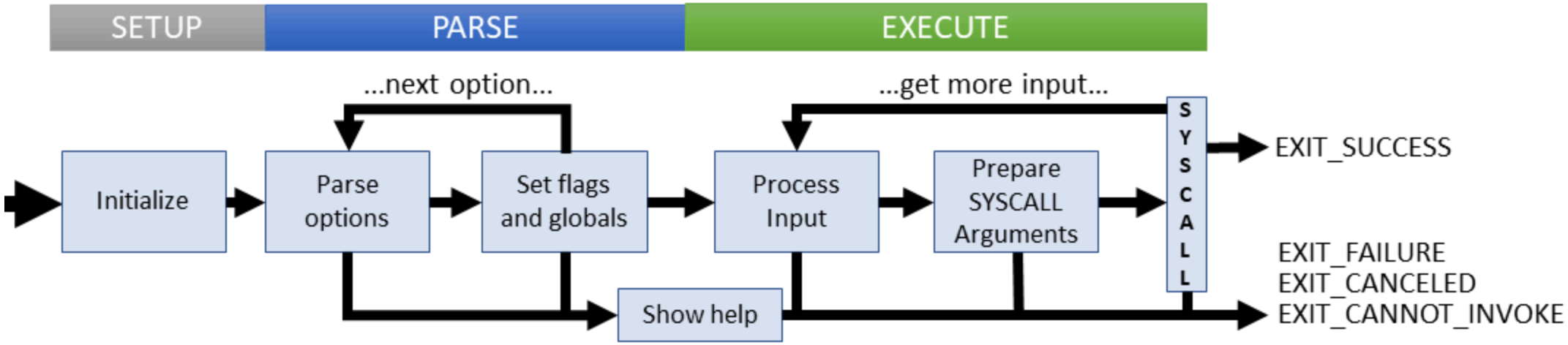
- There are 27+ Shells...
- Default is usaully Bash (**B**ourne **A**gain **Sh**ell) in Unix, powershell in Windows
- Others include:
  - sh (Bourne **Sh**ell)
  - ksh (**k**orn **sh**ell)
  - tcsh (**t**enex **c sh**ell)
  - zsh (**Z**hong Shao **Sh**ell)
  - fish

```
$ printenv SHELL
/bin/bash
```

Shell Command Applications

- Getting information
- Navigating and working with files and directories.
- Printing file and string contents.
- File compression and archiving. Performing network operations.
- Monitoring performance and status of the system, its components and applications.
- Running batch jobs, such as **E**xtract **T**ransform **L**oad (ETL) operations

Basic CLI Utilities Desgin



Getting Information

- `whoami` – which returns the user's username
- `id` – which returns the current user and group IDs,
- `uname` – returns the operating system name,
- `ps` – displays running processes and their IDs,
- `top` – displays running processes and resource usage including memory, CPU, and IO,
- `df` – shows information about mounted file systems,
- `man` – fetches the reference manual for any shell command,
- `date` – prints today's date.

Working with Files

- `cp` – copy file,
- `mv` – change file name or path,
- `rm` – remove file,
- `touch` – create empty file, update file timestamp,
- `chmod` – change/modify file permissions,
- `wc` – get count of lines, words, characters in file,
- `grep` – return lines in file matching pattern

Navigating & Working with Directories

- `ls` – lists the files and directories in the current directory,
- `find` – used to find files matching a pattern in the current directory tree,
- `pwd` – prints the current, or ‘present working,’ directory,
- `mkdir` – makes a new directory,
- `cd` – changes the current directory to another directory,
- `rmdir` – removes an entire directory

Printing File and String Contents

- `cat` – which prints the entire contents of a file,
- `more` – used to print file contents one page at a time,
- `head` – for printing just the first ‘N’ lines of a file,
- `tail` – for printing the last ‘N’ lines of a file,
- `echo` command – which 'echoes' an input string by printing it. It can also ‘echo’ the value of a variable.

Compression and Archiving

- `tar` – which is used to archive a set of files,
- `gzip` / `zip` – which compresses a set of files,
- `gunzip` / `unzip` – which extracts files from a compressed or zipped archive

Networking

`hostname` – prints the host name,

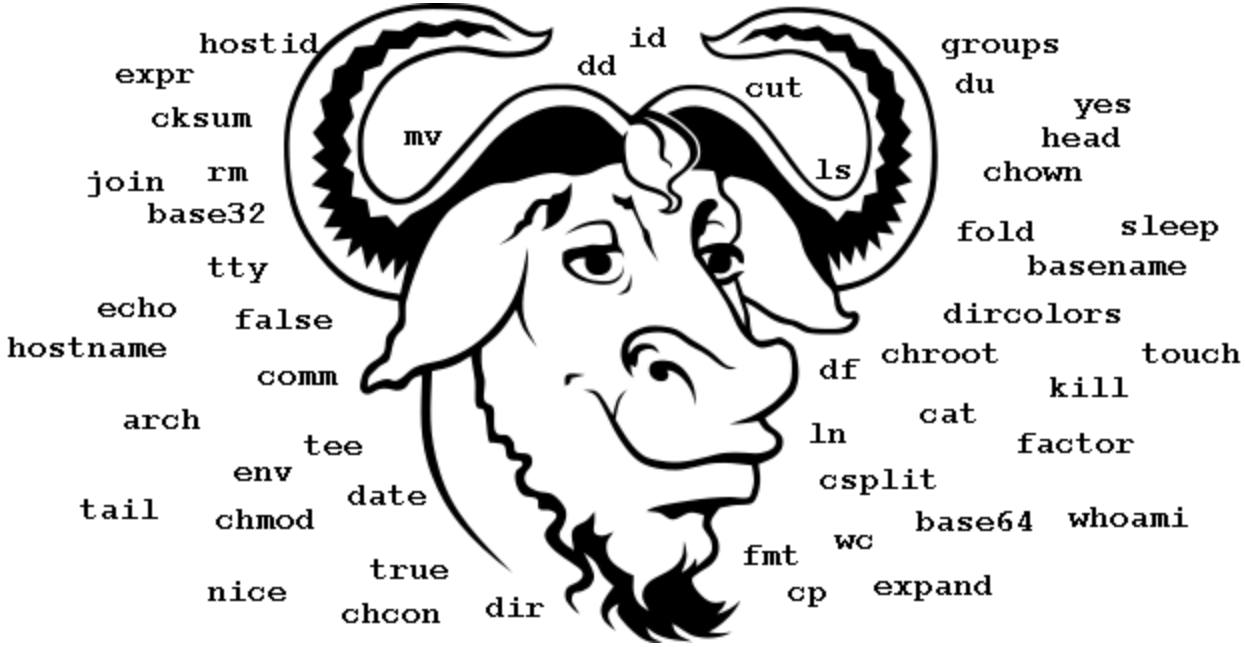
`ping` – sends packets to a URL and prints the response,

`ifconfig` – displays or configures network interfaces on the system,

`curl` – displays the contents of a file located at a URL, and the wget command can be used to download a file from a URL.

Coreutils

All of these commands and more that come shipped by default come from the `coreutils`



Portable Operating System Interface (POSIX)

- POSIX (Portable Operating System Interface) is a set of standard operating system interfaces based on the Unix operating system
- IEEE Std 1003.1-2017
  - defines a standard interface and environment that can be used by an operating system (OS) to provide access to POSIX-compliant application
- The standard also defines a command interpreter (**shell**) and common **utility** programs
- IEEE Std 1003.1
  - application programming interface in the C language
- IEEE Std 1003.2
  - standard shell and utility interface for the OS

Aliases

- The Open Group
  - The Open Group Base Specifications Issue 7, 2018 edition,
- ISO/IEC refer to it as ISO/IEC 9945:2009.
  - ISO/IEC adopted the standard in 2009 and added Technical Corrigendum 1 in late 2012 and Technical Corrigendum 2 in March 2017, putting it on par with IEEE Std 1003.1-2017.

POSIX.1 Sections

- **Base definitions**: Provides common definitions for the specifications, including information about terms, concepts, syntax, service functions and command-line
- **System interfaces**: Provides details about interface-related terms and concepts, and defines the functional interfaces available to applications accessing POSIX-conformant systems.
- **Shell and utilities**: Describes the commands and utilities available to applications accessing POSIX-conformant systems, including the command language used in those systems.
- **Rationale**: Includes historical information about the standard's contents and why certain features were added or removed.

C API

POSIX defines its standards in terms of the C language. Therefore, **programs are portable to other operating systems at the source code level**. Nonetheless, we can also implement it in any standardized language.

The POSIX C API adds more functions on top of the ANSI C Standard for a number of aspects:

- File operations
- Processes, threads, shared memory, and scheduling parameters
- Networking
- Memory management
- Regular expressions
- The complete description of the functions is defined in the POSIX headers.

File Formats

POSIX defines rules for formatting strings that we use in files, standard output, standard error, and standard input. As an example, let’s consider the description for an output string:

```
"<format>", <arg1>, ..., <argN>
```

The format can contain regular characters, escape sequence characters, and conversion specifications. The conversion specifications indicate the output format of the provided arguments and are prefixed by a percent symbol followed by argument type.

File Formats

As an example, let’s suppose we want to output a string that contains today’s date. We’ll use the printf utility because it follows the POSIX file format standard:

```
$ printf "Today's Date: %d %s, %d" 18 September 2021
Today's Date: 18 September, 2021
```

The format specifies three conversion specifications: `%d`, `%s`, and `%d`. The `printf` utility processes these conversion specifications and substitutes them with the arguments.

Environment Variables

- An environment variable is a variable that we can define in the environment file, which the login shell processes upon successful login.
- As a convention, the variable name should merely contain uppercase letters and an underscore.
- The name can also include a digit, although the POSIX standard doesn’t recommend putting the digit at the start of the name.

For instance, we can define the environment variable for our base user directory in the form of:

```
XDG_BASE_DIRECTORY="/home/user/"
```

Environment Variables

Any of your own implementation should respect the reserved environment variables:

- `COLUMN` defines the width of the terminal screen.
- `HOME` defines the pathname of the user's home directory.
- `LOGNAME` defines the user's login name.
- `LINES` defines the user's preferred lines on the terminal screen.
- `PATH` defines binary colon-separated paths for executables.
- `PWD` defines the current working directory.
- `SHELL` defines the current shell in use.
- `TERM` defines the terminal type.
- MORE HERE

Locale

A locale defines the language and cultural convention that is used in the user environment.

A program implementation shall conform to the POSIX locale, which is identical to the C locale.

- `LC_TYPE` for character classification
- `LC_COLLATE` defines the order for characters
- `LC_MONETARY` for monetary formatting
- `LC_NUMERIC` for formatting numbers
- `LC_TIME` for date and time formatting
- `LC_MESSAGES` for program messages such as information messages and logs

Character Set

- A character set is a collection of characters with codes and bit patterns for each character.
  - $010000001 \equiv 65 \equiv \text{A}$
- A standard character set is needed that conforms to the one defined by POSIX.
- POSIX recommends including at least one character set and a portable character set in implementations.
- The first eight entries in the character set should be control characters.
- The POSIX locale should include at least 256 characters from both portable and non-portable character sets.

Regular Expressions

- RE, is a string of characters that defines a search pattern for finding text:
  - `awk`, `sed`, `grep` are implemented
- Basic (BRE) and Extened (ERE)
- BRE and ERE should operate on a string of characters that ends with a NUL character.
- The literal escape sequence and newline character produce an undefined result. Therefore, our programs should treat them as ordinary characters.
- POSIX does not permit the use of an explicit NUL character in the REs or the text to be matched.
- Implementation should be able to perform a case-insensitive search by default.
- The length of our REs should not exceed 256 bytes in length.

Directory Structure

- Most major Linux distributions conform to the F**ilesystem Hierarchy Standard (FHS)**.
- FHS defines a configurable tree-like directory structure.
  - The first directory in the hierarchy is the **root directory**, and all the other directories, files, and special files branch out from it.

```
$ tree / -d -L 1
/
├── bin -> usr/bin
├── boot
├── dev
├── etc
├── home
├── lib64 -> usr/lib
├── mnt
├── opt
...
```

Utility Names

POSIX recommends that we implement the following argument syntax in our utility programs:

```
utility_name [-a][-b][-c option_argument]
    [-d|-e][-f[option_argument]][operand...] <parameter name>
```

- most utilities behave the same.
- For instance, we know that the `-h` option prints a help text for almost every UNIX/Linux utility.
- This consistency owes to the conventions described by POSIX.
- POSIX defines several conventions for programmers about how we should implement our utility programs.

OSs and POSIX Compliancy

- **Linux**
  - It’s certainly possible to create a Linux-based operating system that is entirely POSIX compliant. EulerOS is a good example of that. However, most modern programs, especially closed-source software, conform to the standard either partially or not at all.
  - As an example, the bash shell used to be completely POSIX compliant. The recent versions of bash, however, don’t conform to the POSIX standard by default. So, one can say that most Linux distributions are partially POSIX-compliant.

OSs and POSIX Compliancy

- **Darwin**
  - Darwin is the core set for Apple’s operating systems, such as macOS and iOS. It is partially POSIX compliant. However, the recent releases of macOS are completely POSIX compliant.
- **Windows NT**
  - Microsoft Windows doesn’t conform to the standard at all because its whole design is completely different than UNIX-like operating systems. However, we can set up a POSIX compliant environment by using the WSL compatibility layer or Cygwin.