Lecture 2 & 3

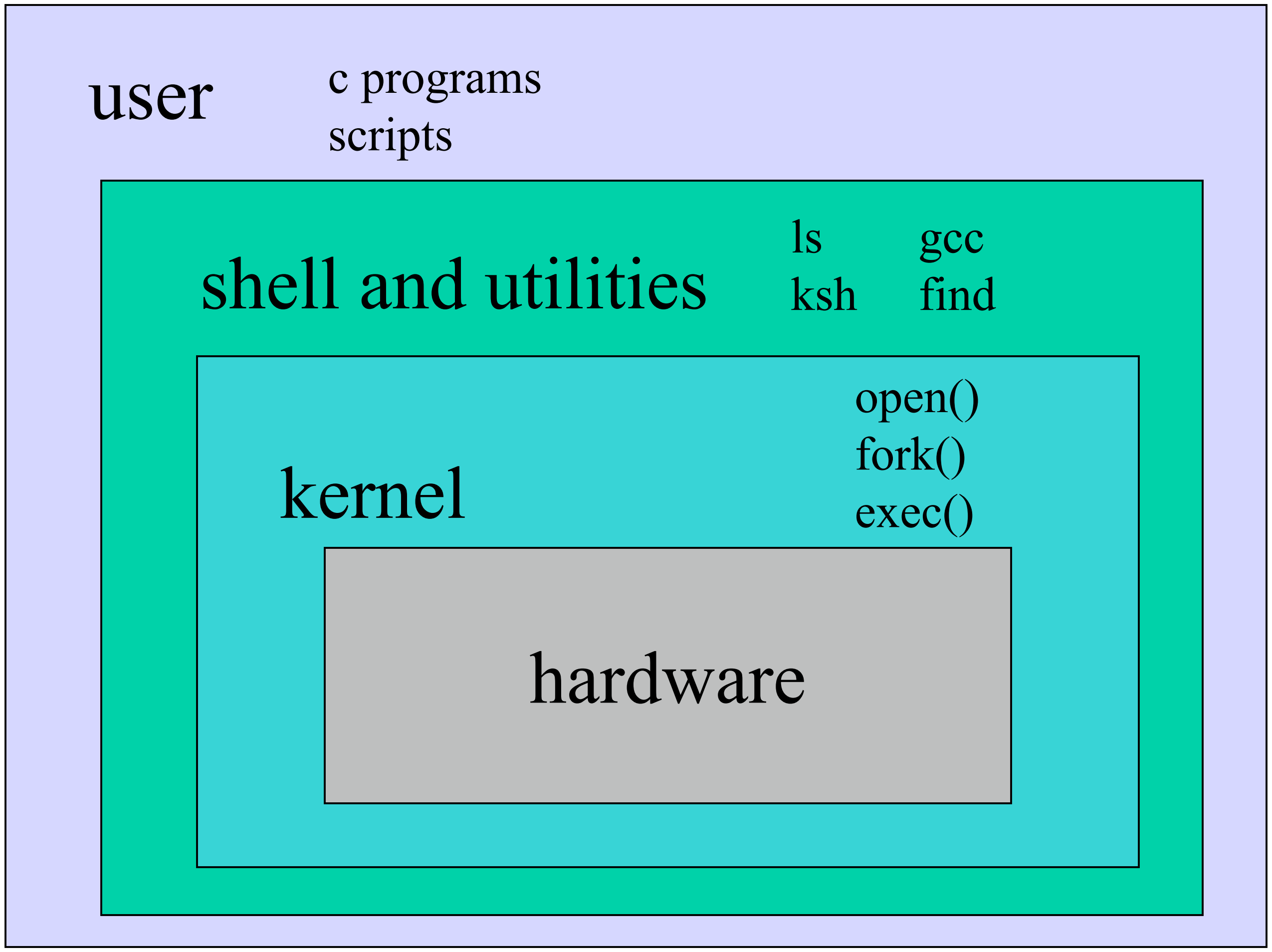
UNIX Basics

The UNIX Filesystem

On the last episode of UNIX Tools...

- Course Info
- History of UNIX
- Highlights of UNIX
- The UNIX Philosophy
- System organization

Unix System Structure



Kernel Subsystems

- File system
  - Deals with all input and output
    - Includes files and terminals
    - Integration of storage devices
- Process management
  - Deals with programs and program interaction
    - How processes share CPU, memory and signals
    - Scheduling
    - Interprocess Communication
    - Memory management
- UNIX variants have different implementations of different subsystems.

What is a shell?

- The user interface to the operating system
- Functionality:
  - Execute other programs
  - Manage files
  - Manage processes
- A program like any other
- Executed when you log on

Most Commonly Used Shells

– /bin/sh	The Bourne Shell / POSIX shell
– /bin/csh	C shell
– /bin/tcsh	Enhanced C Shell
– /bin/ksh	Korn shell
– /bin/bash	Bourne-Again Shell - Free ksh clone

Basic form of shell:

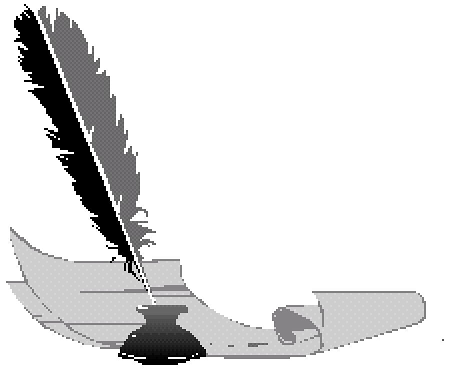
```
while (read command) {
 parse command
 execute command
}
```

Shell Interactive Use

When you log in, you interactively use the shell:

- Command history
- Command line editing
- File expansion (tab completion)
- Command expansion
- Key bindings
- Spelling correction
- Job control

Shell Scripting



- A set of shell commands that constitute an executable *program*
- A shell script is a regular text file that contains shell or UNIX commands
- Very useful for automating repetitive task and administrative tools and for storing commands for later execution

Simple Commands

- ***simple command***: sequence of non blanks arguments separated by blanks or tabs.
- 1st argument (numbered zero) usually specifies the name of the command to be executed.
- Any remaining arguments:
  - Are passed as arguments to that command.
  - Arguments may be filenames, pathnames, directories or special options (up to command)
  - Special characters are interpreted by shell

A simple example

```
$ ls -l /bin
-rwxr-xr-x   1 root   sys      1065112 Apr 24  2006 bash
-r-xr-xr-x   1 root   sys        34848 Jan 13  2006 cat
-r-xr-xr-x   1 root   sys        52476 Jan 13  2006 chmod
-r-xr-xr-x   1 root   sys        43796 Jun 28  2006 cp
-r-xr-xr-x   2 root   sys       654400 Jan 13  2006 csh
-r-xr-xr-x   1 root   sys        43632 Jan 13  2006 date
```

prompt *command* *arguments*

- Execute a basic command
- Parsing into command in arguments is called *splitting*

Types of Arguments

```
$ tar -c -v -f archive.tar main.c main.h
```

- Options/Flags
  - Convention: -*X* or --*longname*
- Parameters
  - May be files, may be strings
  - Depends on command

Getting Help on UNIX

- **man**: display entries from UNIX online documentation
- **whatis**, **apropos**
- Manual entries organization:
  - 1. Commands
  - 2. System calls
  - 3. Subroutines
  - 4. Special files
  - 5. File format and conventions
  - 6. Games

http://en.wikipedia.org/wiki/Unix_manual

Example Man Page

ls (1) **USER COMMANDS** **ls (1)**

NAME

ls - list files and/or directories

SYNOPSIS

ls [*options] [file ...]*

DESCRIPTION

For each directory argument **ls** lists the contents; for each file argument the name and requested information are listed. The current directory is listed if no file arguments appear. The listing is sorted by file name by default, except that file arguments are listed before directories.

.

OPTIONS

-**a**, --**all**
List entries starting with **.**; turns off **--almost-all**.

-**F**, --**classify**
Append a character for typing each entry.

-**l**, --**long|verbose**
Use a long listing format.

-**r**, --**reverse**
Reverse order while sorting.

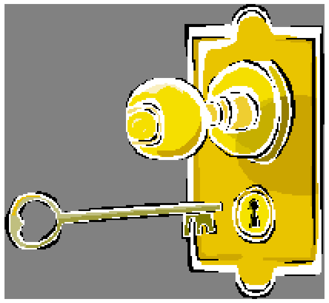
-**R**, --**recursive**
List subdirectories recursively.

SEE ALSO

chmod(1), find(1), getconf(1), tw(1)

Today

- Discuss several commands relating to:
  - Security
  - File system



Fundamentals of Security

- UNIX systems have one or more users identified with a number and name.

- A set of users can form a group. A user can be a member of multiple groups.
  - A special user (id 0, name **root**) has complete control.
  - Each user has a primary (default) group.

How are Users & Groups used?

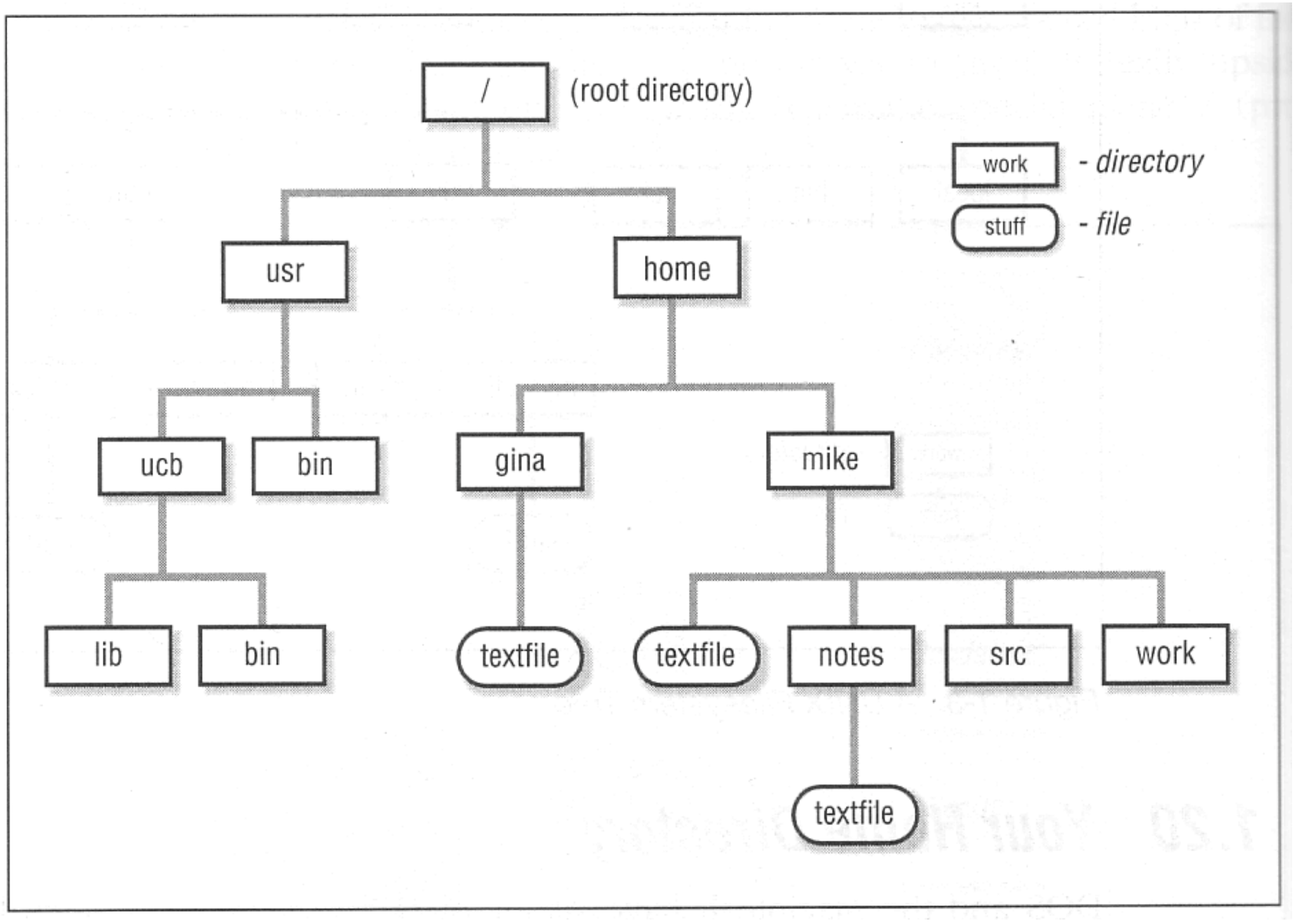
- Used to determine if file or process operations can be performed:
  - Can a given file be read? written to?
  - Can this program be run?
  - Can I use this piece of hardware?
  - Can I stop a particular process that’s running?

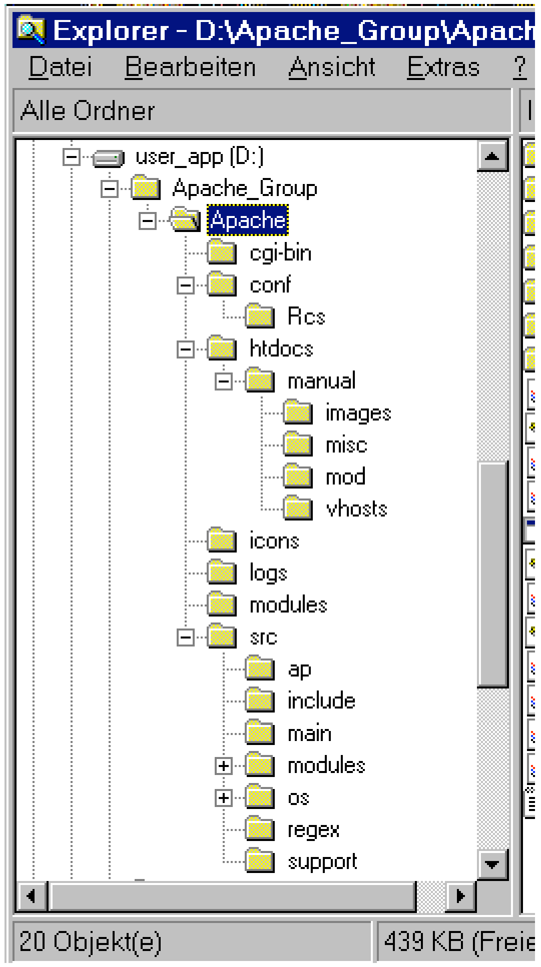
A simple example

```
$ ls -l /bin/date
-rwxr-xr-x  1 root   sys   43234 Jan 13  2006 /bin/date
$
```

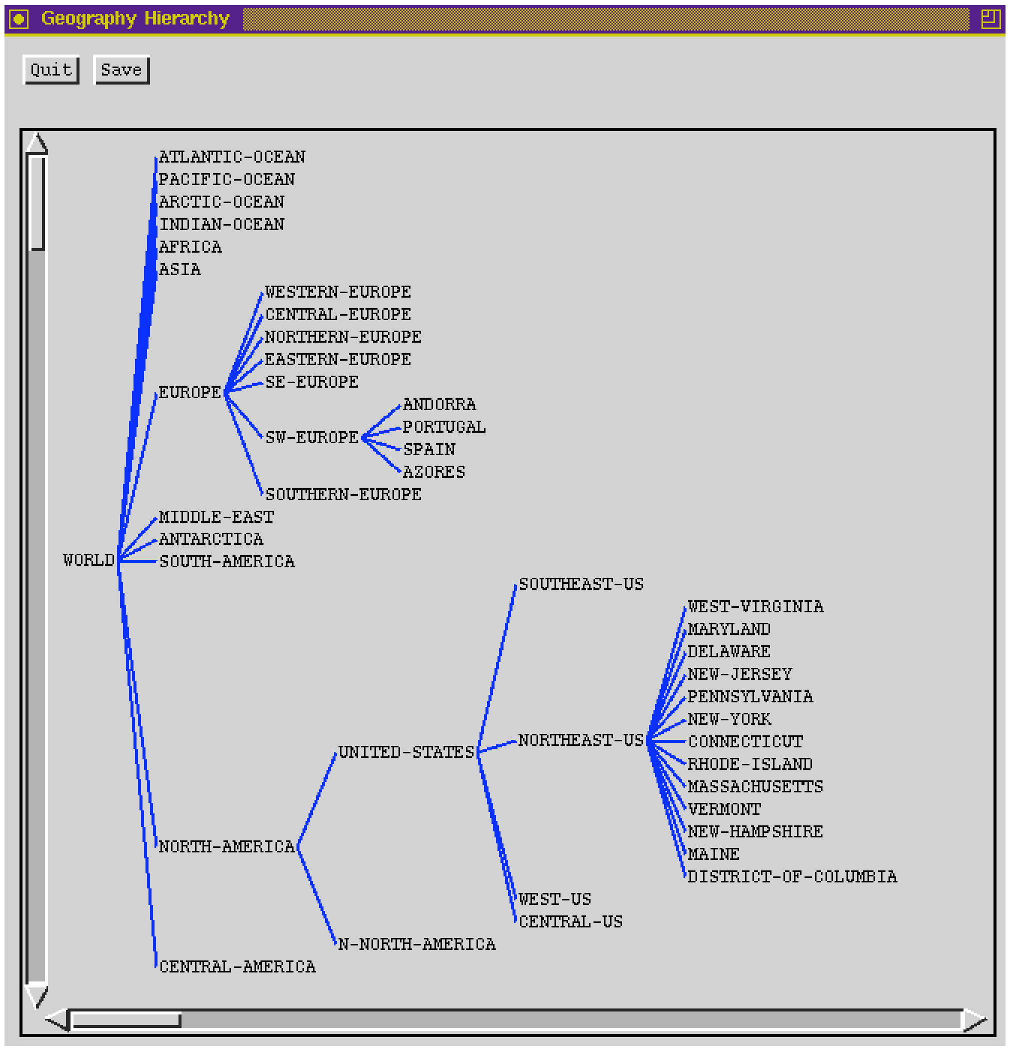
read *write* *e**x**ecute*

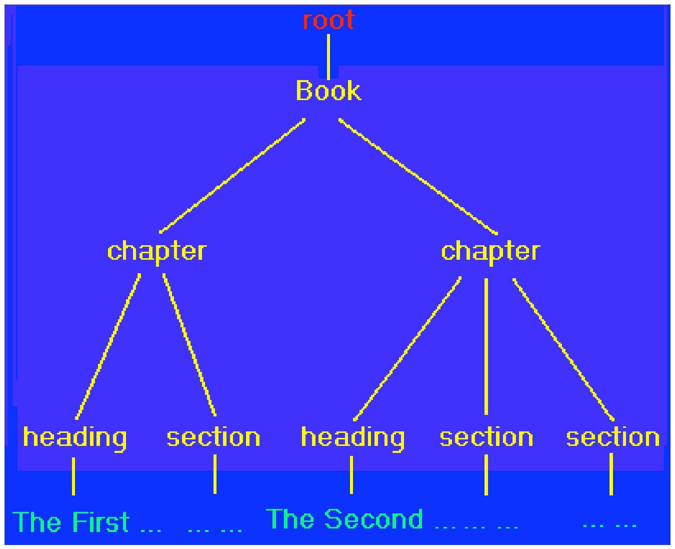
The UNIX File Hierarchy





Hierarchies are Ubiquitous

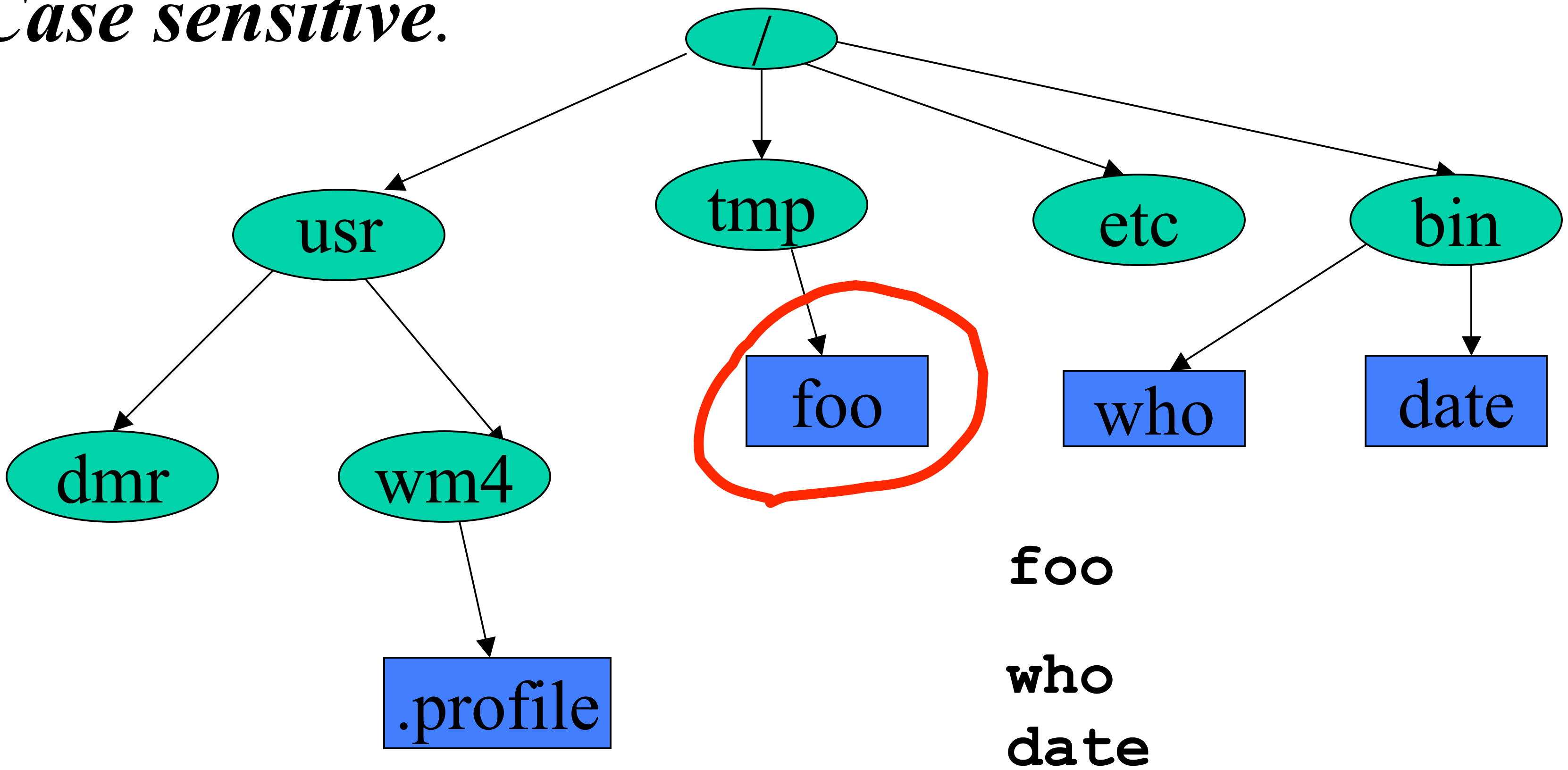




Definition: Filename

A sequence of characters other than slash.

Case sensitive.



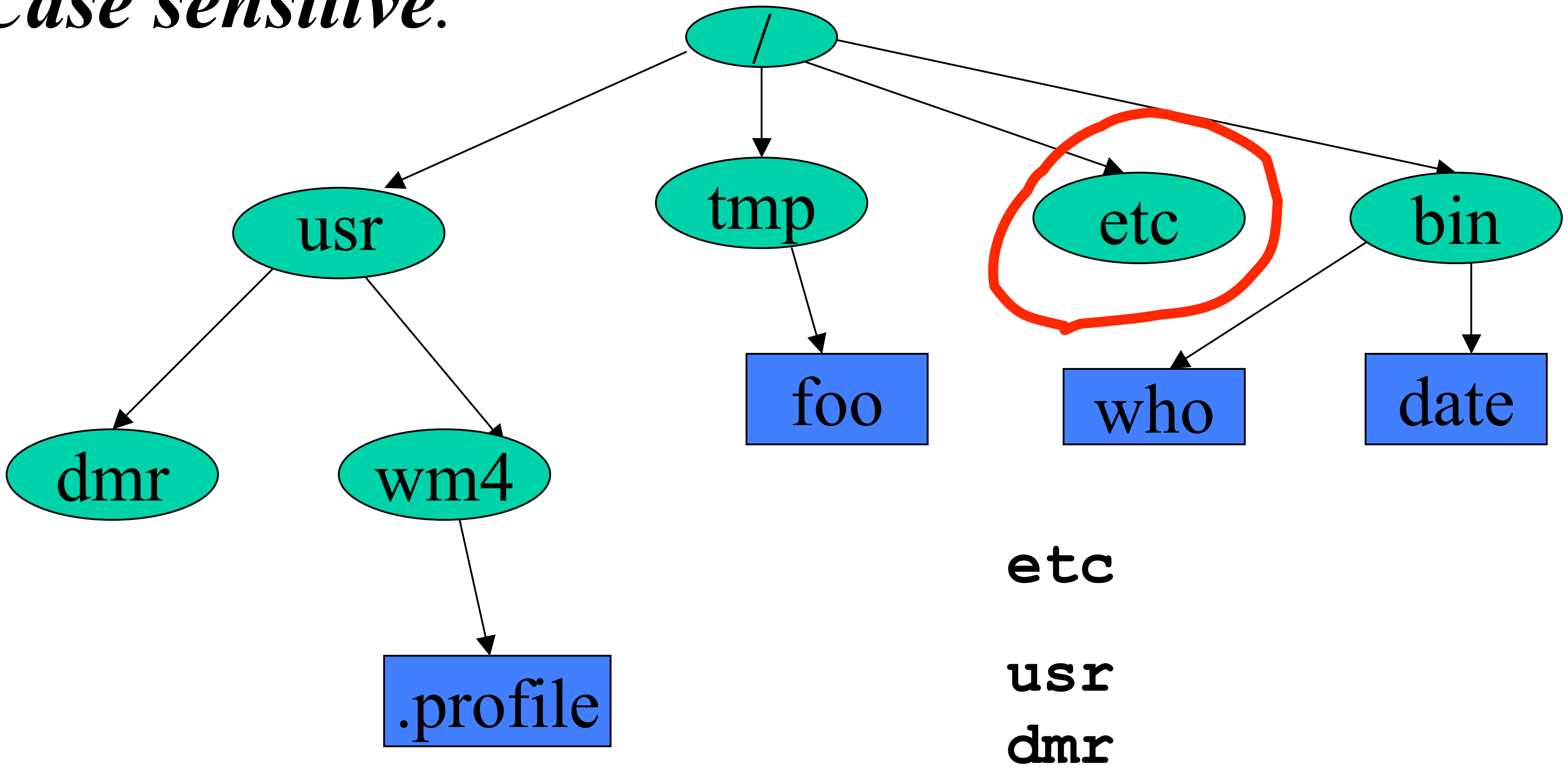
```
foo

who
date
.profile
```

Definition: Directory

Holds a set of files or other directories.

Case sensitive.

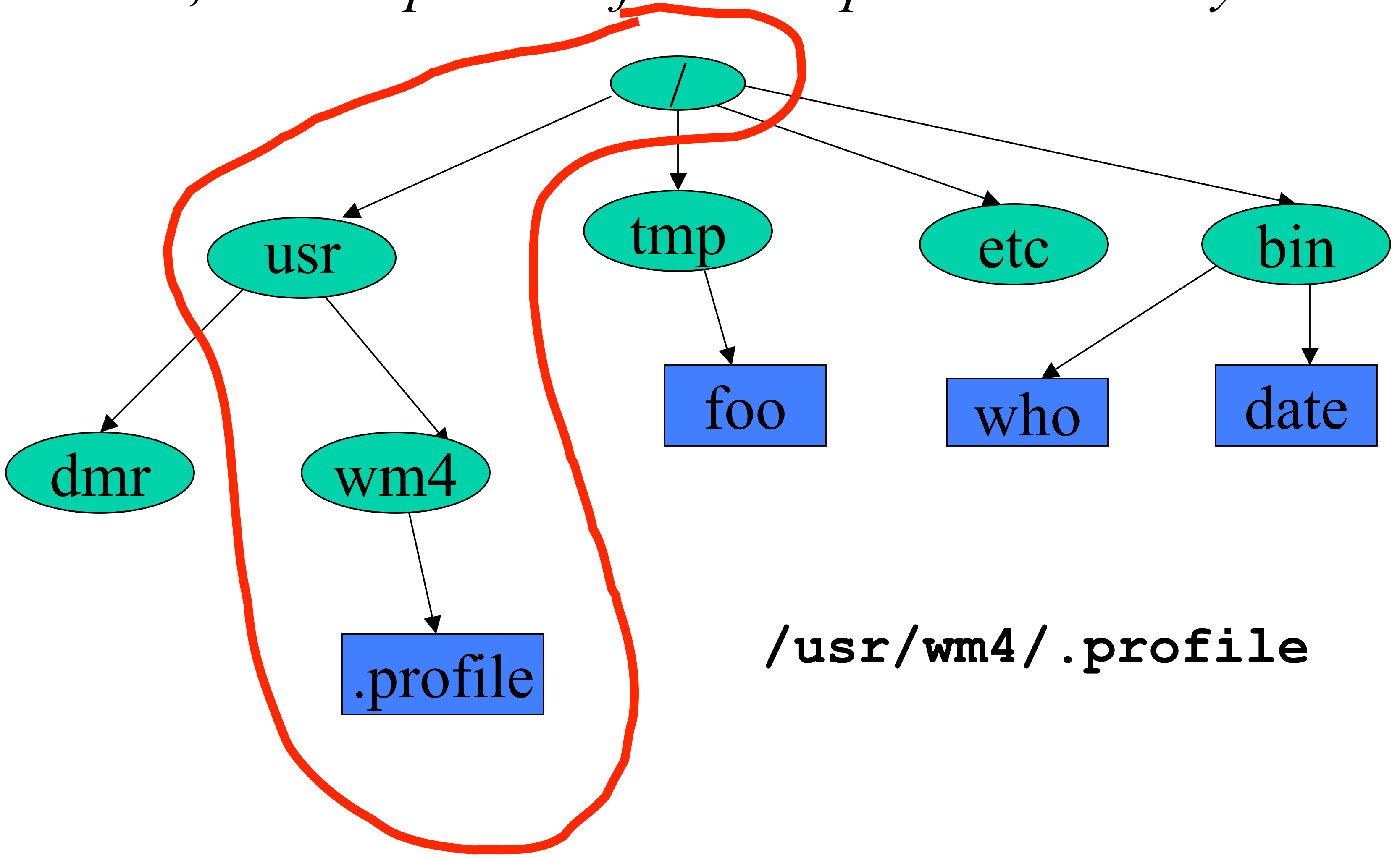


```
etc

usr
dmr
bin
```

Definition: Pathname

A sequence of directory names followed by a simple filename, each separated from the previous one by a /

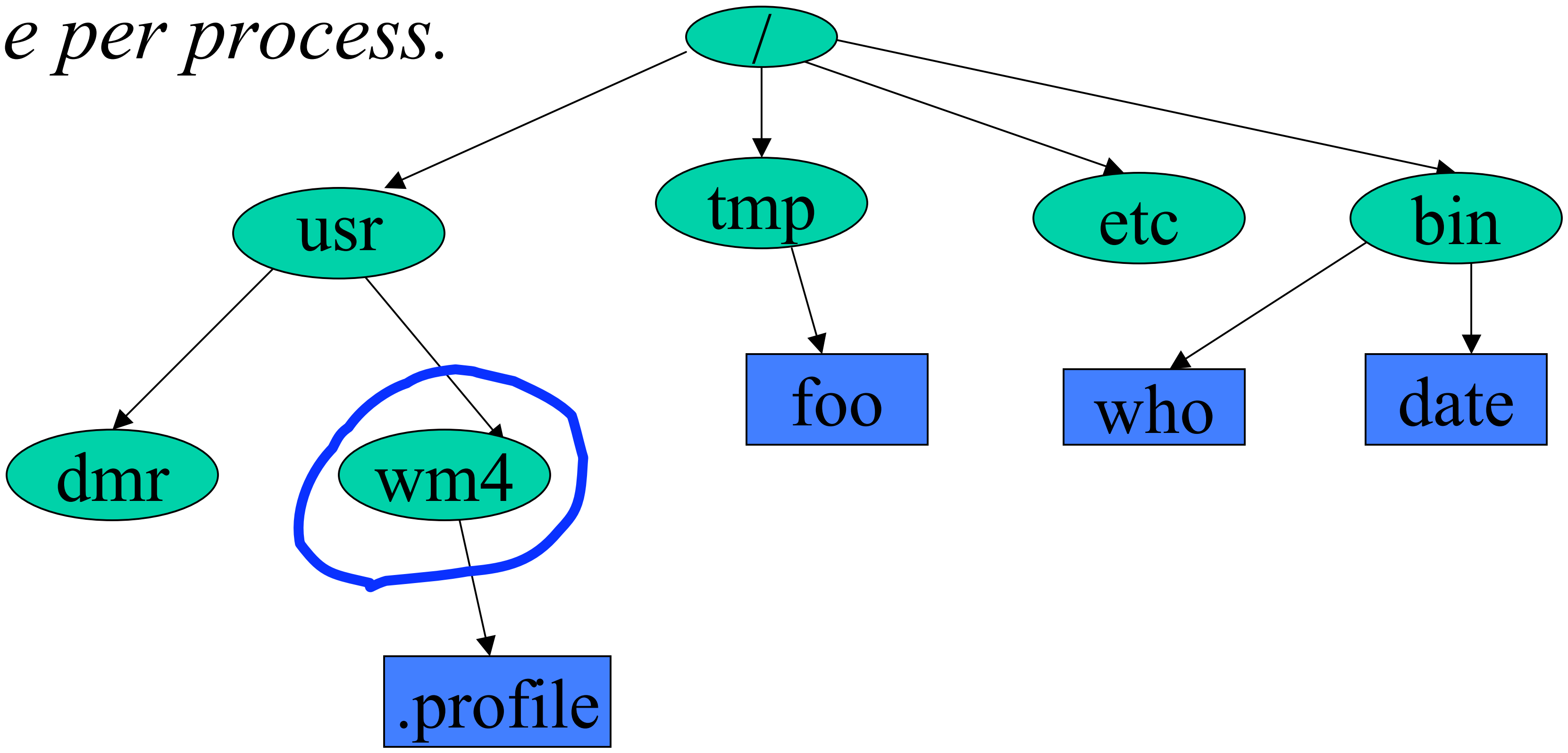


```
/usr/wm4/.profile
```

Definition: Working Directory

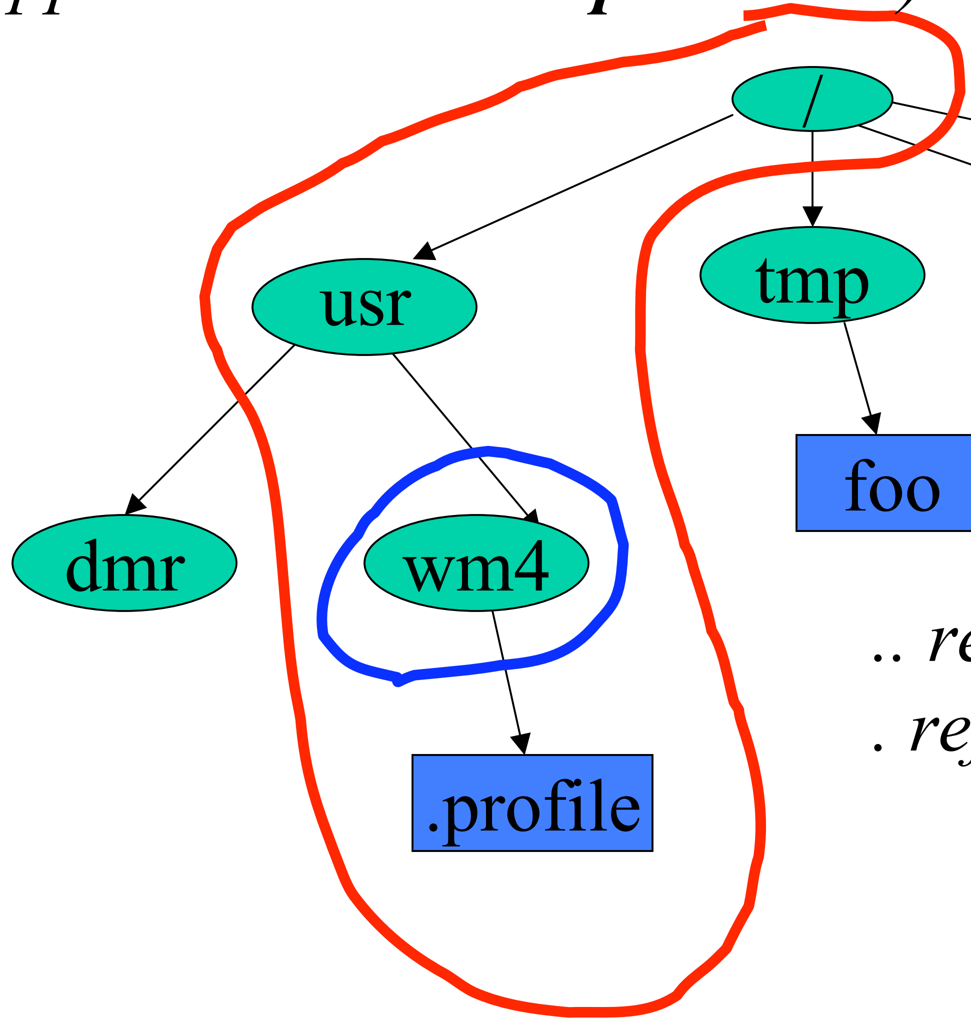
A directory that file names refer to by default.

One per process.



Definition: Relative Pathname

A pathname relative to the working directory (as opposed to ***absolute pathname****)*



.. refers to parent directory

. refers to current directory

```
.profile
./.profile
../wm4/.profile
```

Files and Directories

- Files are just a sequence of bytes
  - No file types (data vs. executable)
  - No sections
  - Example of UNIX philosophy
- Directories are a list of files and status of the files:
  - Creation date
  - Attributes
  - etc.

Tilde Expansion

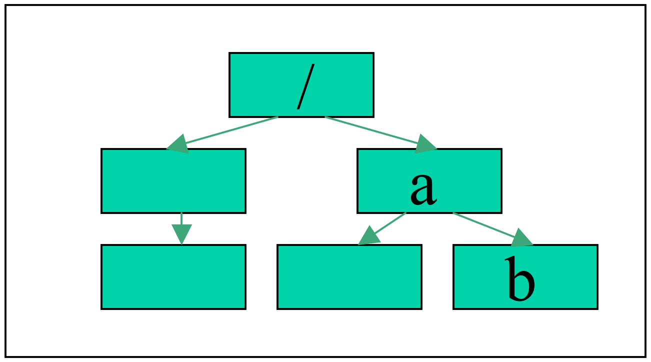
- Each user has a *home* directory
- Most shells (ksh, csh) support **`~`** operator:
  - **`~`** expands to my home directory
    - **`~/myfile`** → **`/home/mohri/myfile`**
  - **`~user`** expands to user's home directory
    - **`~unixtool/file2`** → **`/home/unixtool/file2`**
- Useful because home directory locations vary by machine

Mounting File Systems

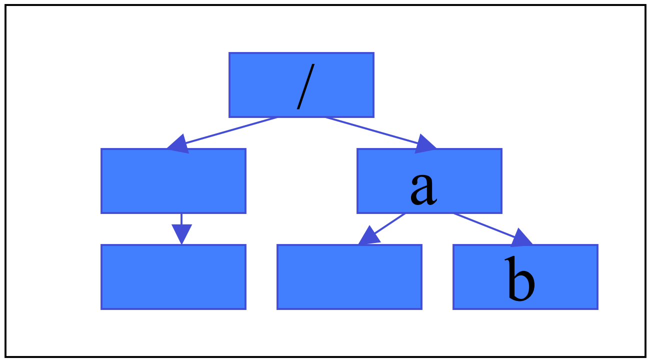
- When UNIX is started, the directory hierarchy corresponds to the file system located on a single disk called the *root device*.
- *Mounting* allows root to splice the root directory of a file system into the existing directory hierarchy.
- File systems created on other devices can be attached to the original directory hierarchy using the mount mechanism.
- Commands **mount** and **umount** manage

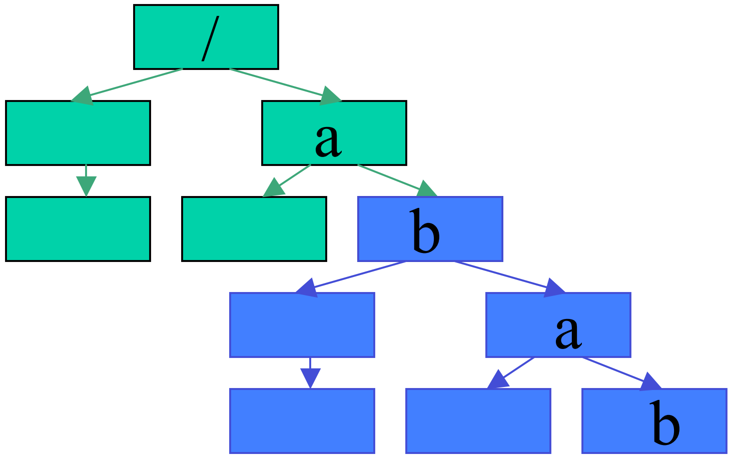
Mounting File Systems

root device



external device





Device	Mount Point
🟩	`/`
🟦	`/a/b`

Mount table

Printing File Contents

- The `cat` command can be used to copy the contents of a file to the terminal. When invoked with a list of file names, it con**cat**enates them.
- Some options:

`-n`	**n**umber output lines (starting from 1)
`-v`	display control-characters in **v**isible form (e.g. ^C)

- Interactive commands **more** and **less** show a page at a time

Common Utilities for Managing files and directories

• **pwd**	print process working dir
• **ed, vi, emacs**…	create/edit files
• **ls**	list contents of directory
• **rm**	remove file
• **mv**	rename file
• **cp**	copy a file
• **touch**	create an empty file or update
• **mkdir** and **rmdir**	create and remove dir
• **wc**	counts the words in a file
• **file**	determine file contents
• **du**	directory usage

File Permissions

- UNIX provides a way to protect files based on users and groups.
- Three **types** of permissions:
    - read, process may read contents of file
    - write, process may write contents of file
    - execute, process may execute file
- Three **sets** of permissions:
    - permissions for owner
    - permissions for group (1 group per file)
    - permissions for other

Directory permissions

- Same types and sets of permissions as for files:
  - **read**: process may read the directory *contents* (i.e., list files)
  - **write**: process may add/remove files in the directory
  - **execute**: process may open files in directory or subdirectories

Utilities for Manipulating file attributes

• **chmod**	change file permissions
• **chown**	change file owner
• **chgrp**	change file group
• **umask**	user file creation mode mask

- only owner or super-user can change file attributes
- upon creation, default permissions given to file modified by process **umask** value

Chmod command

- Symbolic access modes `{u,g,o}` / `{r,w,x}`
  - example: `chmod +r` *file*
- Octal access modes

octal	**read**	**write**	**execute**
0	no	no	no
1	no	no	yes
2	no	yes	no
3	no	yes	yes
4	yes	no	no
5	yes	no	yes
6	yes	yes	no
7	yes	yes	yes

File System Internals

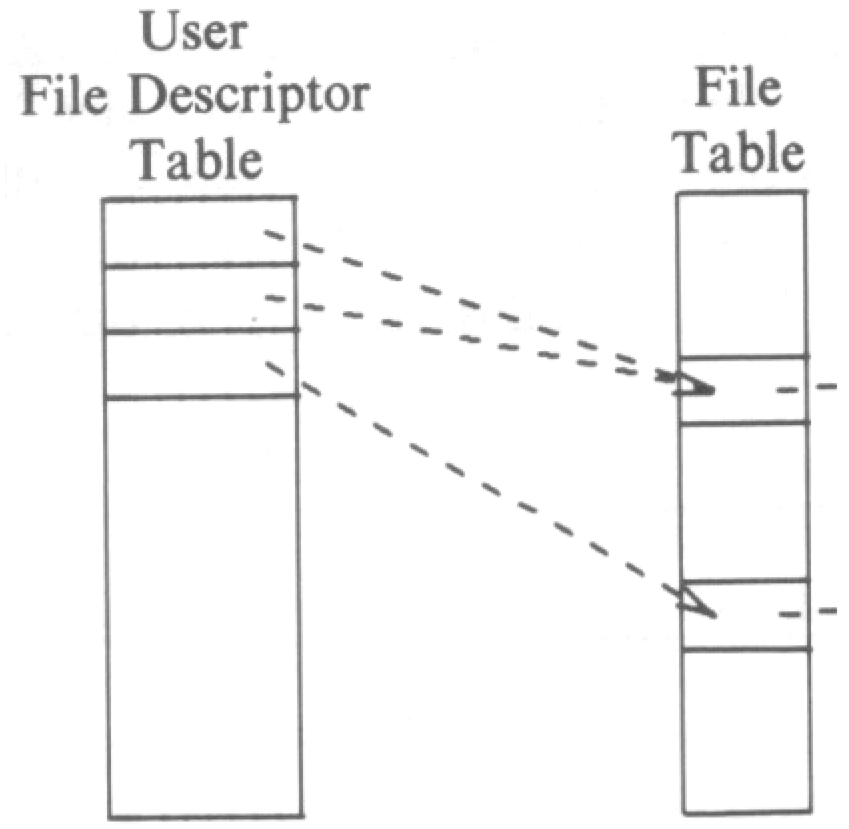
The Open File Table

- I/O operations are done on files by first **opening** them, reading/writing/etc., then **closing** them.
- The kernel maintains a global table containing information about each open file.

Inode	Mode	Count	Position
1023	read	1	0
1331	read/write	2	50
		…	

The File Descriptor Table

- Each process contains a table of files it has opened.
- Inherits open files from parent
- Each open file is associated with a **number** or **handle**, called **file descriptor**, **(fd)**.
- Each entry of this table points to an entry in the open file table.
- Always starts at 0

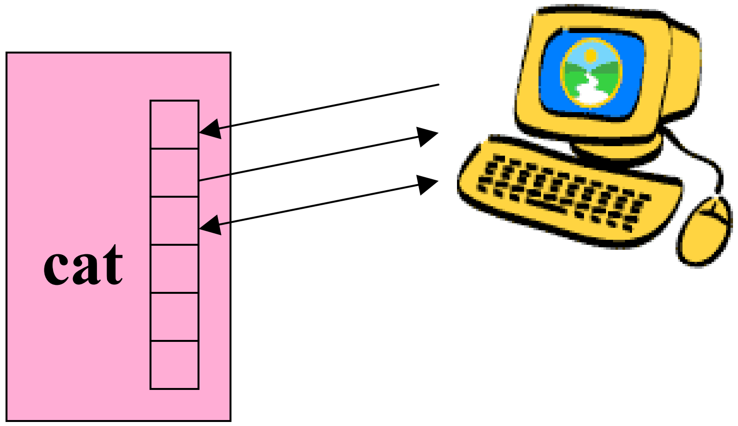


Why not directly use the open file table?

- Convenient for kernel
  - Indirection makes security easier
- Numbering scheme can be local to process (0 .. 128)
- Extra information stored:
  - Should the open file be inherited by children? (*close-on-exec* flag)

Standard in/out/err

- The first three entries in the file descriptor table are special by convention:

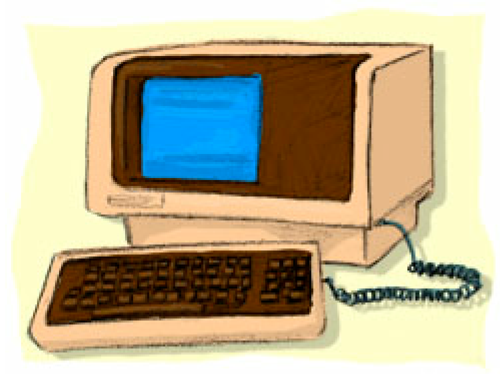
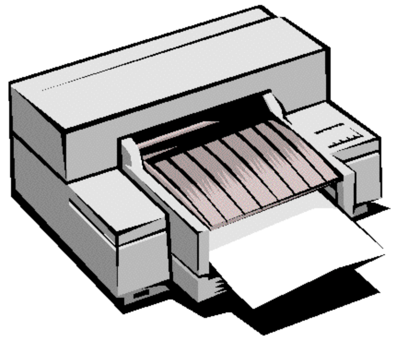


  - Entry 0 is for input
  - Entry 1 is for output
  - Entry 2 is for error messages

- What about reading/writing to the screen?

Devices

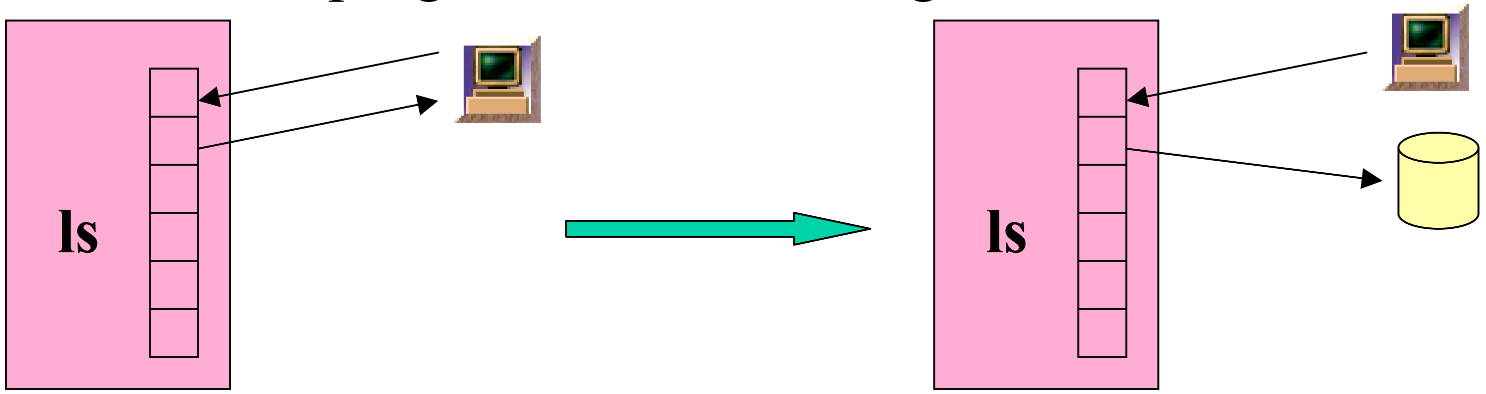
- Besides files, input and output can go from/to various hardware devices

- **UNIX innovation**: Treat these just like files!
  - **`/dev/tty, /dev/lpr, /dev/modem`**
- By default, standard in/out/err opened with **`/dev/tty`**

Redirection

- Before a command is executed, the input and output can be changed from the default (terminal) to a file
  - Shell modifies file descriptors in child process
  - The child program knows nothing about this



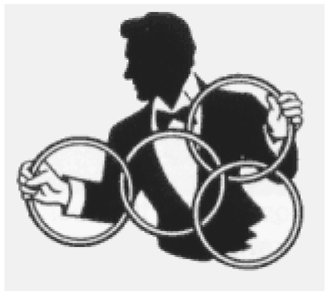
Redirection of input/ouput

- Redirection of output: >
  - example: `$ ls > my_files`
- Redirection of input: `<`
  - example: `$ mail mohri <input.data`
- Append output: >>
  - example: `$ date >> logfile`
- Bourne Shell derivatives: *fd*>
  - example: `$ ls 2> error_log`

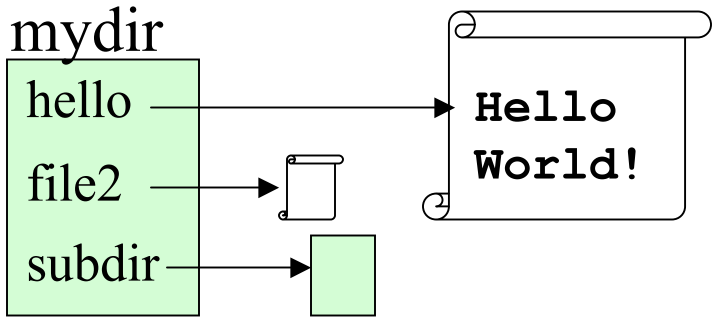
Using Devices

- Redirection works with devices (just like files)
- Special files in **`/dev`** directory
  - Example: **`/dev/tty`**
  - Example: **`/dev/lp`**
  - Example: **`/dev/null`**
    - **`cat big_file > /dev/lp`**
    - **`cat big_file > /dev/null`**

Links

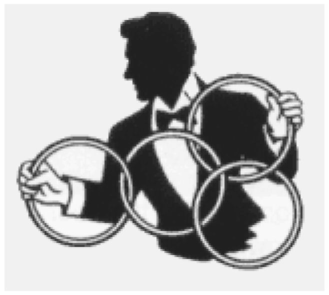


- Directories are a list of files and directories.
  - Each directory entry *links* to a file on the disk



  - Two different directory entries can link to the same file
    - In same directory or across different directories
  - Moving a file does not actually move any data around.
    - Creates link in new location
    - Deletes link in old location
- **ln** command

Links



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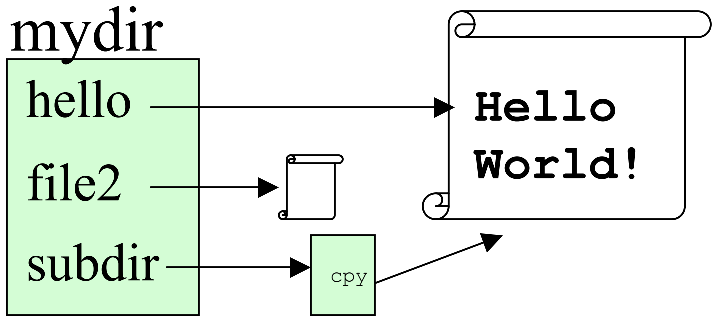

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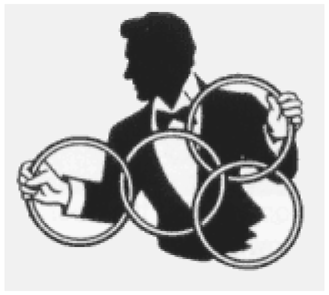

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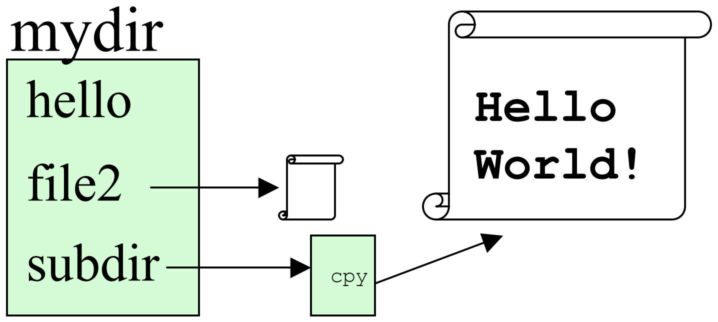

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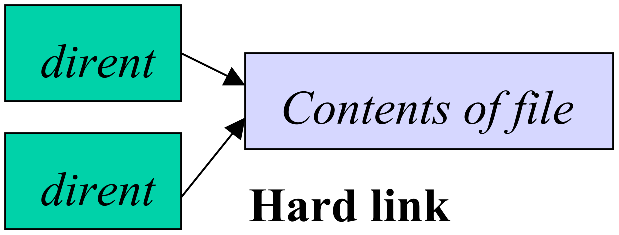
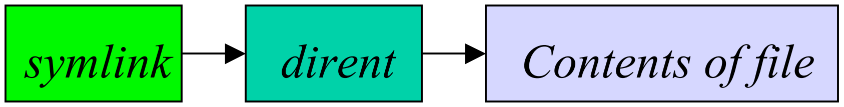
Symbolic links

- **Symbolic** links are different than regular links (often called **hard links**). Created with **ln -s**
- Can be thought of as a directory entry that points to the ***name*** of another file.
- Does not change link count for file
  - When original deleted, symbolic link remains
- They exist because:
  - Hard links don't work across file systems
  - Hard links only work for regular files, not directories

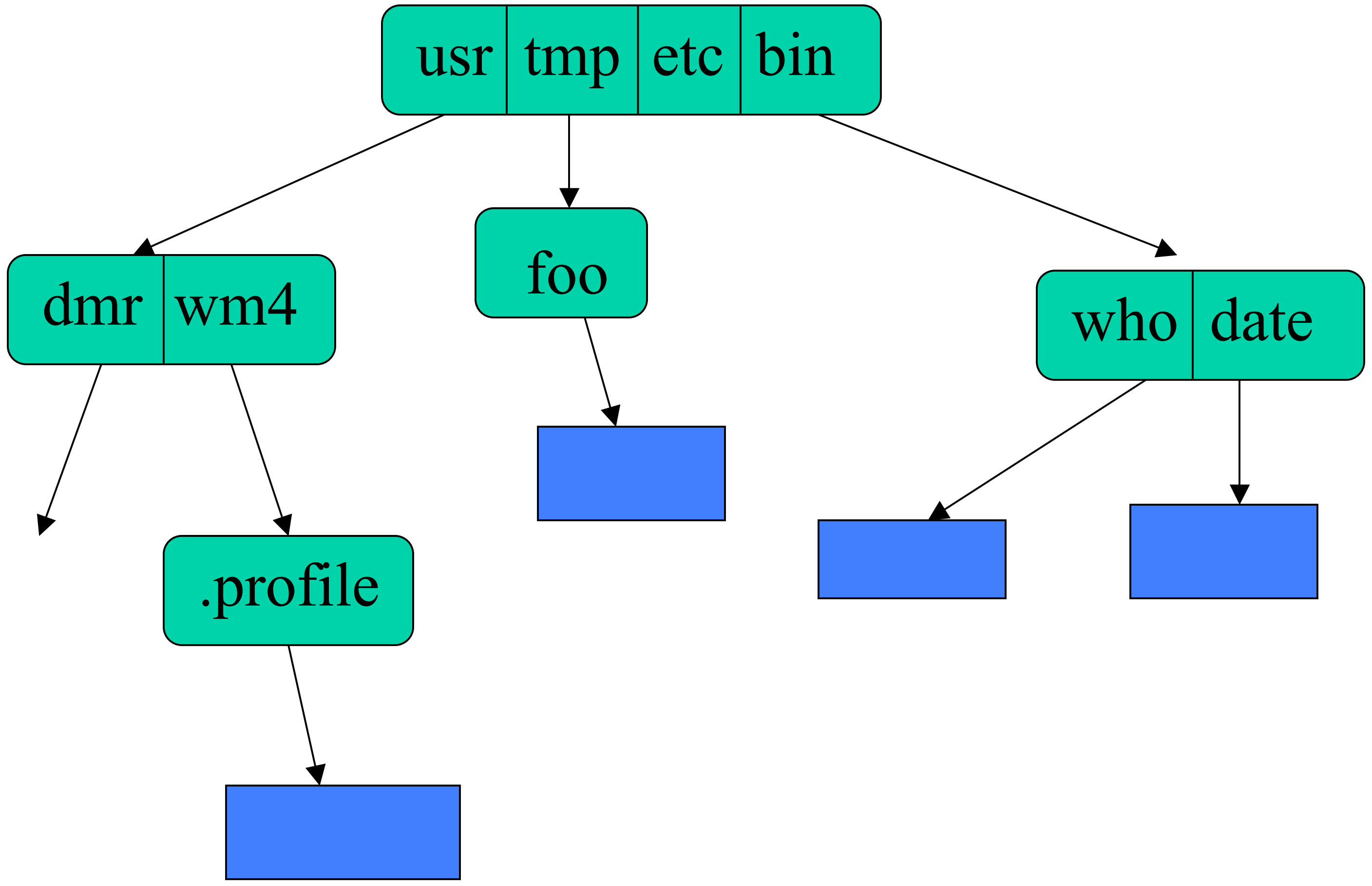


Hard link

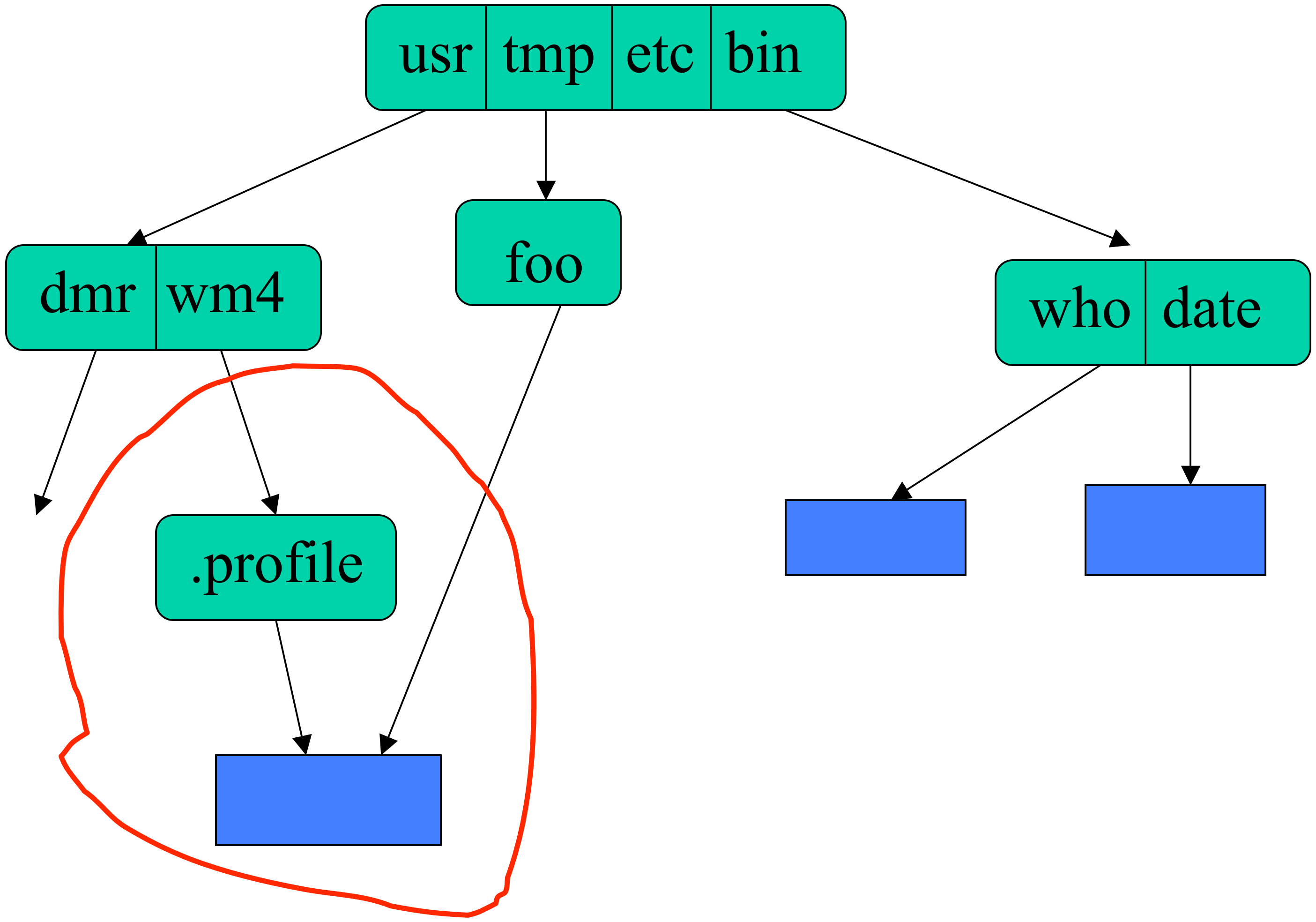


Symbolic Link

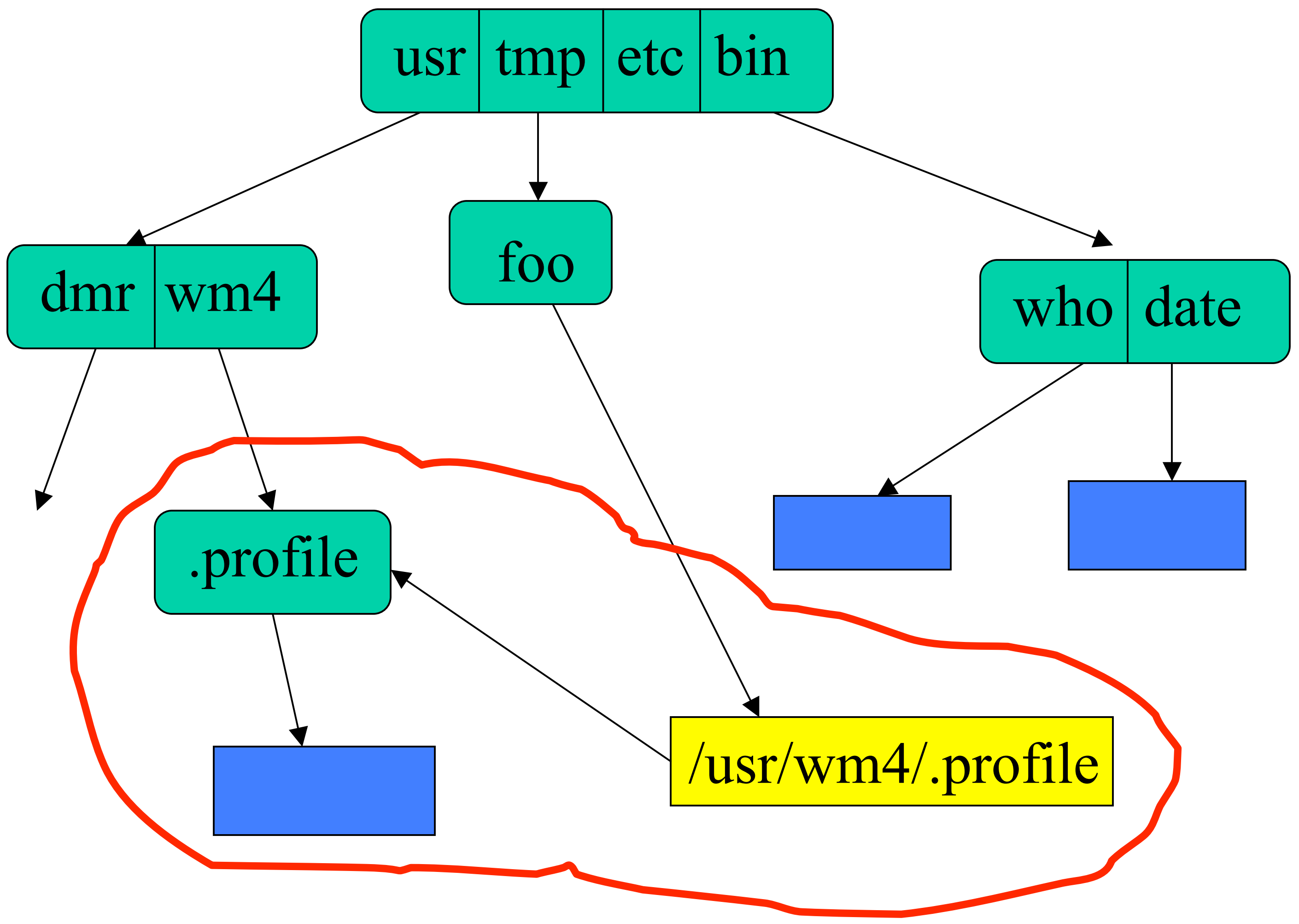
Example



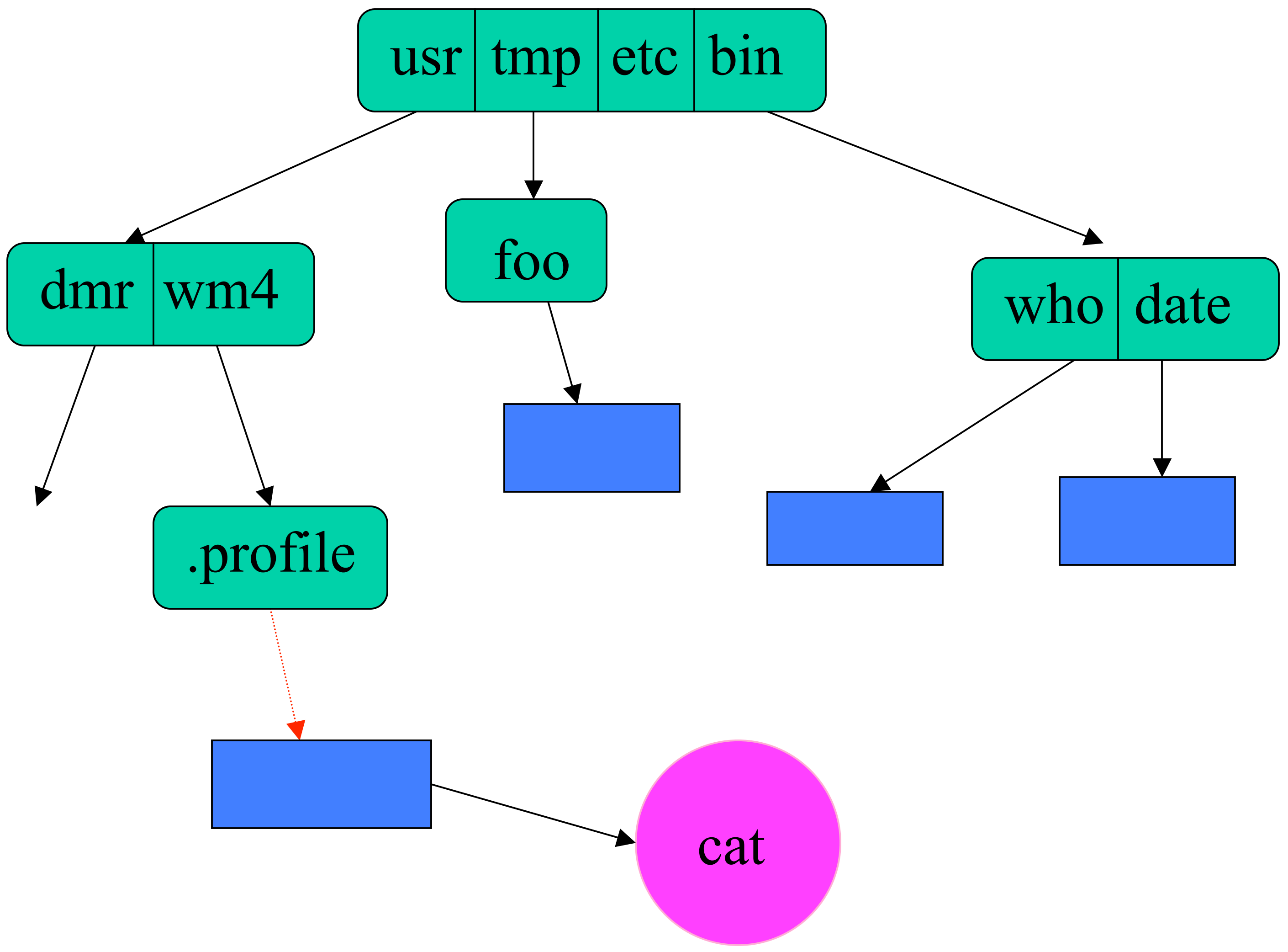
Hard Link



Symbolic Link



Can a file have no links?



Tree Walking

- How can we find a *set* of files in the hierarchy?
- One possibility:
  - `ls -l -R /`
- What about:
  - All files below a given directory in the hierarchy?
  - All files since Jan 1, 2001?
  - All files larger than 10K?

find utility

- **find** *pathlist expression*
- **find** recursively descends through *pathlist* and applies *expression* to every file.
- *expression* can be:
  - **`-name`** *pattern*
    - *true* if file name matches pattern. Pattern may include shell patterns such as *, must be in quotes to suppress shell interpretation.
  - Eg: **`find / -name '*.c'`**

find utility (continued)

- **`-perm`** [+-]*mode*
  - Find files with given access mode, mode must be in octal. Eg: **`find . 755`**
- **`-type`** *ch*
  - Find files of type *ch* (*c*=character, *b*=block, *f* for plain file, etc..). Eg: **`find /home -type f`**
- **`-user`** *userid*/*username*
  - Find by owner *userid* or *username*
- **`-group`** *groupid*/*groupname*
  - Find by group *groupid* or *groupname*
- **`-size`** *size*
  - File size is at least *size*
- *many more…*

find: logical operations

• **`!`** *expression*	returns the logical negation of expression
• *op1* **`-a`** *op2*	matches both patterns *op1* and *op2*
• *op1* **`-o`** *op2*	matches either *op1* or *op2*
• **`( )`**	group expressions together

find: actions

- `-print` prints out the name of the current file (default)
- `-exec` *cmd*
  - Executes *cmd*, where *cmd* must be terminated by an escaped semicolon (`\;` or `';'`).
  - If you specify `{}` as a command line argument, it is replaced by the name of the current file just found.
  - `exec` executes *cmd* once per file.
  - Example:
    - `find -name "*.o" -exec rm "{}" ";"`

find Examples

- Find all files beneath home directory beginning with f
  - `find ~ -name 'f*' -print`
- Find all files beneath home directory modified in last day
  - `find ~ -mtime 1 -print`
- Find all files beneath home directory larger than 10K
  - `find ~ -size 10k -print`
- Count words in files under home directory
  - `find ~ -exec wc -w {} \; -print`
- Remove core files
  - `find / -name core –exec rm {} \;`

diff: comparing two files

- **diff**: compares two files and outputs a description of their differences
  - Usage: **diff** [*options*] *file1 file2*
  - **`-i`**: ignore case

```
apples
oranges
walnuts
```

```
apples
oranges
grapes
```

```
$ diff test1 test2
3c3
< walnuts
---
> grapes
```

Other file comparison utilities

- **cmp**
  - Tests two files for equality
  - If equal, nothing returned. If different, location of first differing byte returned
  - Faster than **diff** for checking equality
- **comm**
  - Reads two files and outputs three columns:
    - Lines in first file only
    - Lines in second file only
    - Lines in both files
  - Must be sorted
  - Options: fields to suppress ([-123])