Chapter 10: File System Interface

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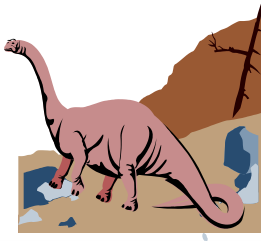
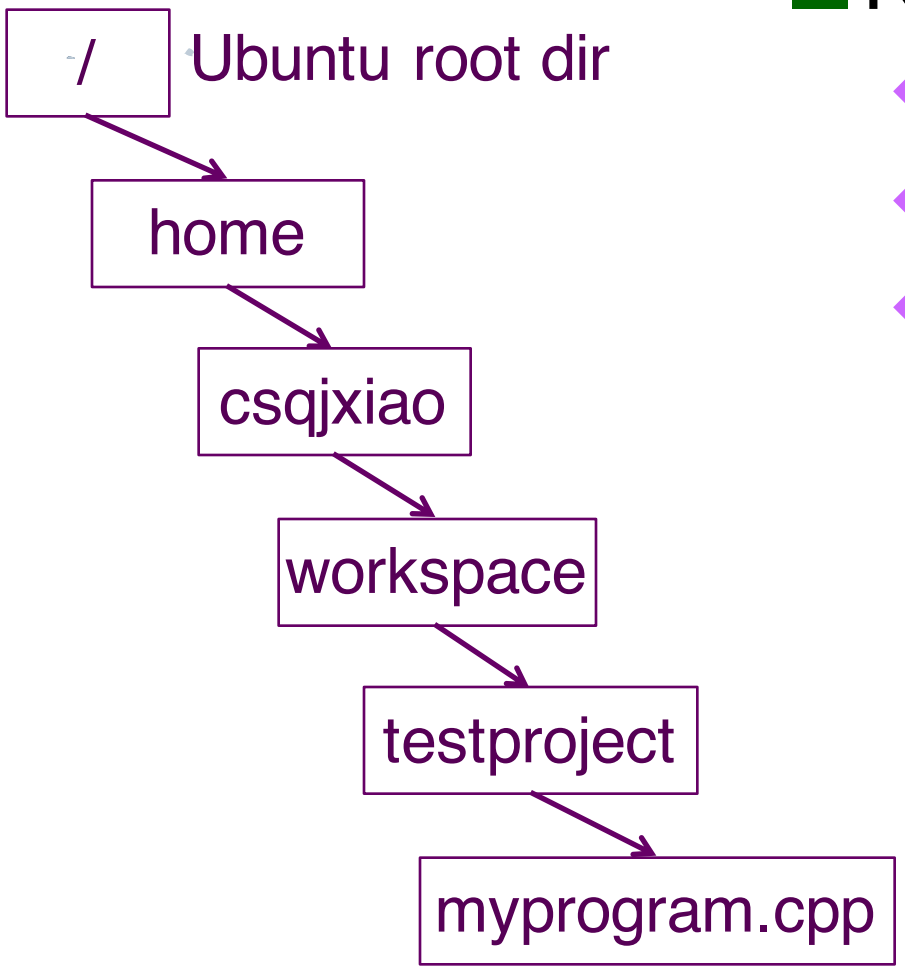
Chapter 10: File-System Interface

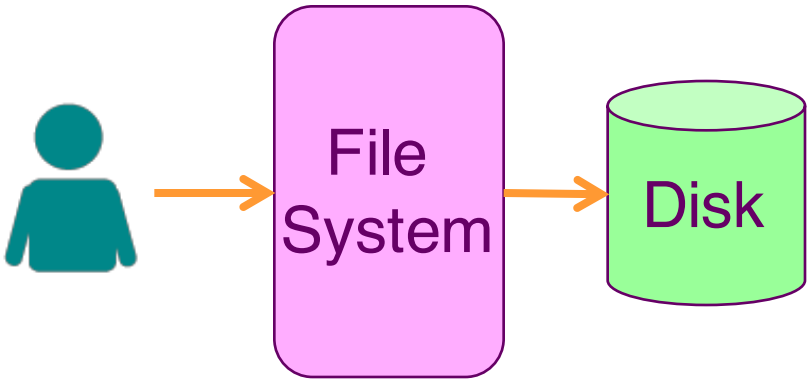
- File Concept
- Access Methods
- Directory Structure
- File System Mounting
- File Sharing
- Protection



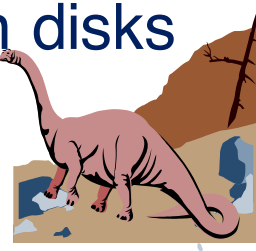
File System Concept



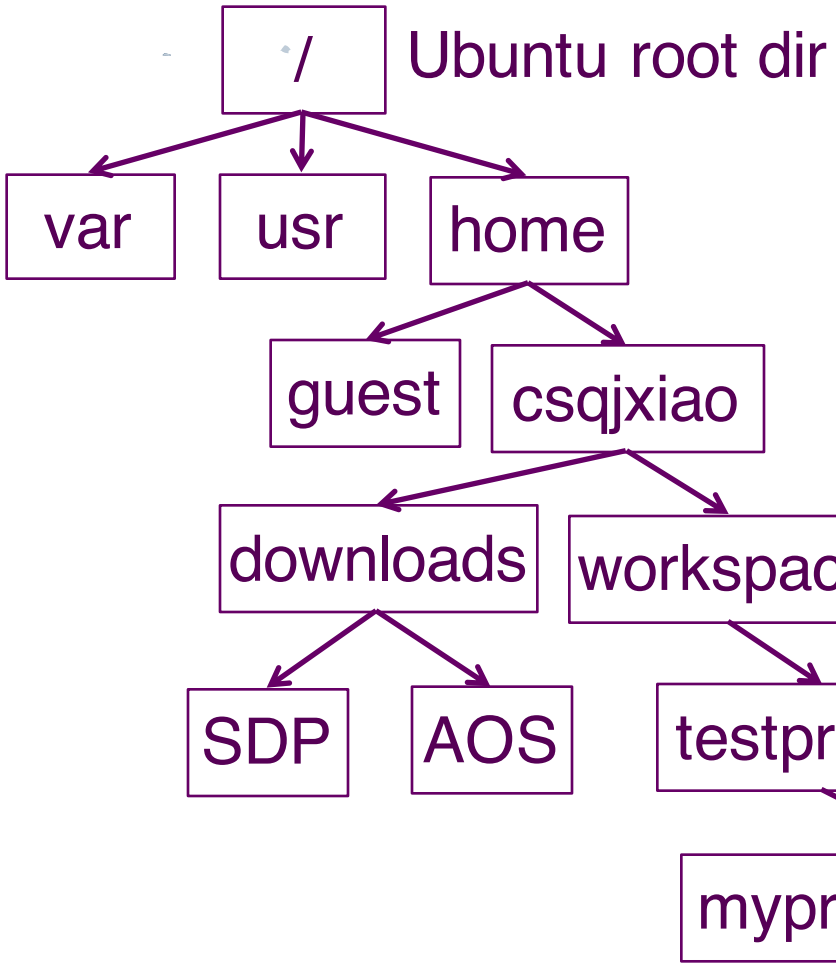
- Key Abstraction
  - File
  - Filename
  - Directory tree (folders)



Users do not access directly the file blocks on disks



File Path and Directory Tree



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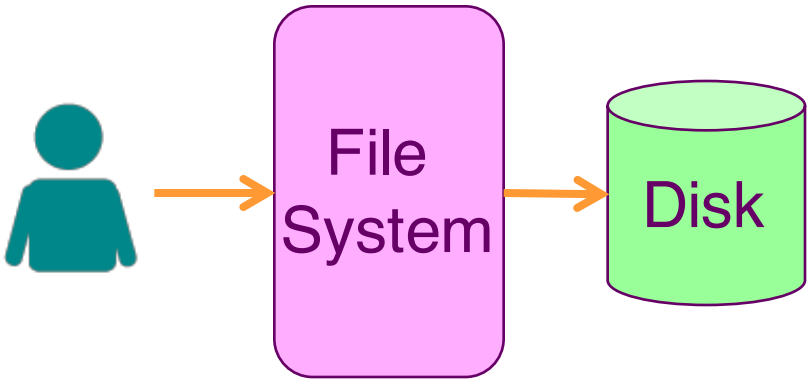

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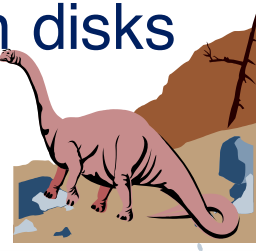
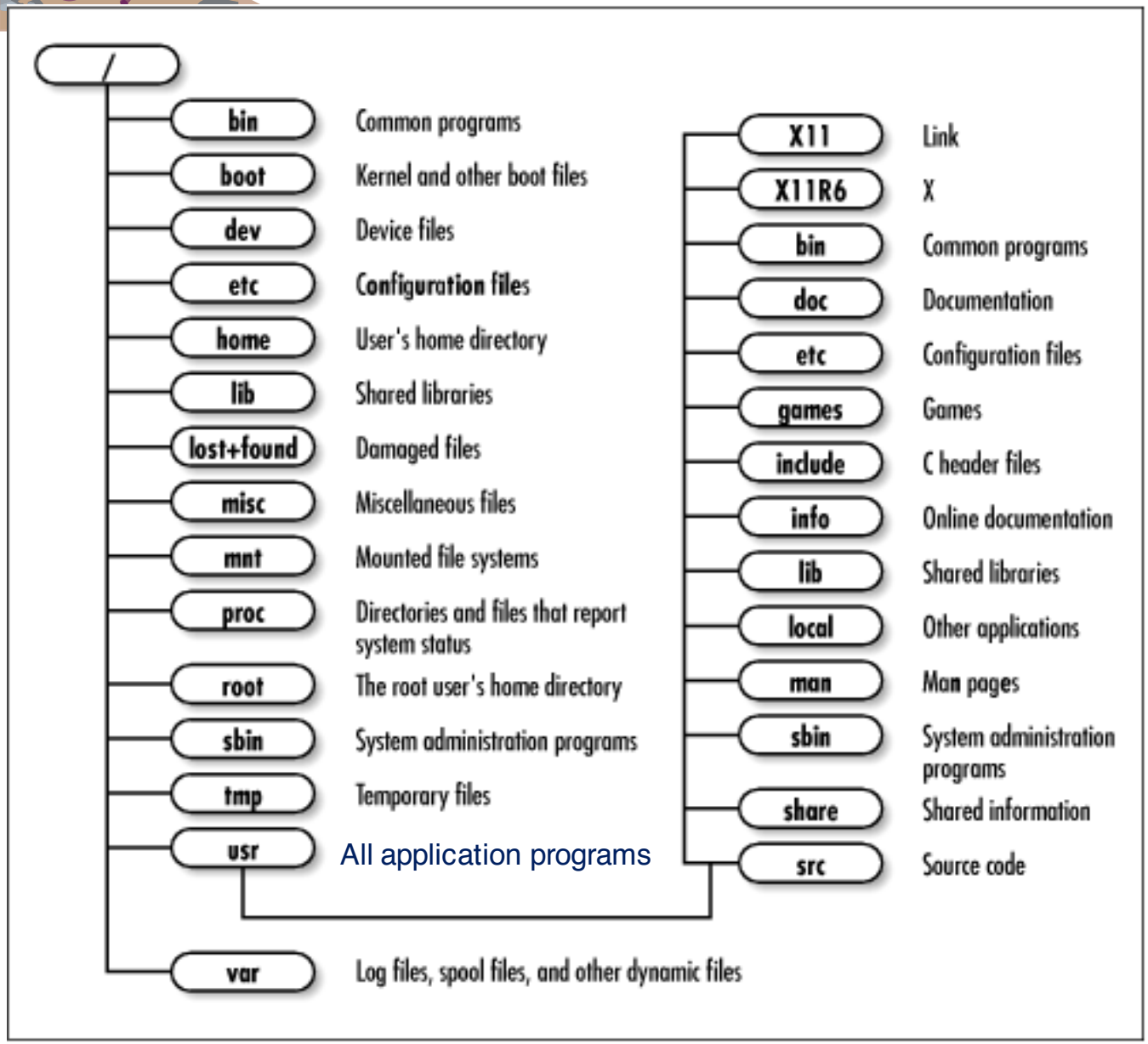


Debian GNU/Linux Directory Tree

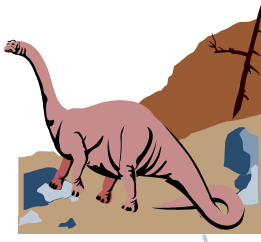


- /home (private): directories of users
- /dev: device files that represent hardware components
- /etc: important files for system configuration
- /bin: programs needed early in the boot process
- /usr: all application programs
- /var: log files, and other dynamic files
- /lib: shared libraries (for dynamically linked programs)

http://www.oreilly.com/openbook/debian/book/appa_01.html

File Concept

- Contiguous logical address space
- Types:
  - Data
    - ✓numeric
    - ✓character
    - ✓binary
  - Program

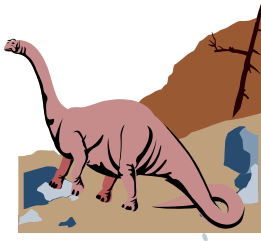


File Structure

- None - sequence of words, bytes
- Simple record structure
  - Lines
  - Fixed length
  - Variable length
- Complex Structures
  - Formatted document
  - Relocatable load file
- Can simulate last two with the first method by inserting appropriate control characters.
- Who decides the file structure?

File Attributes

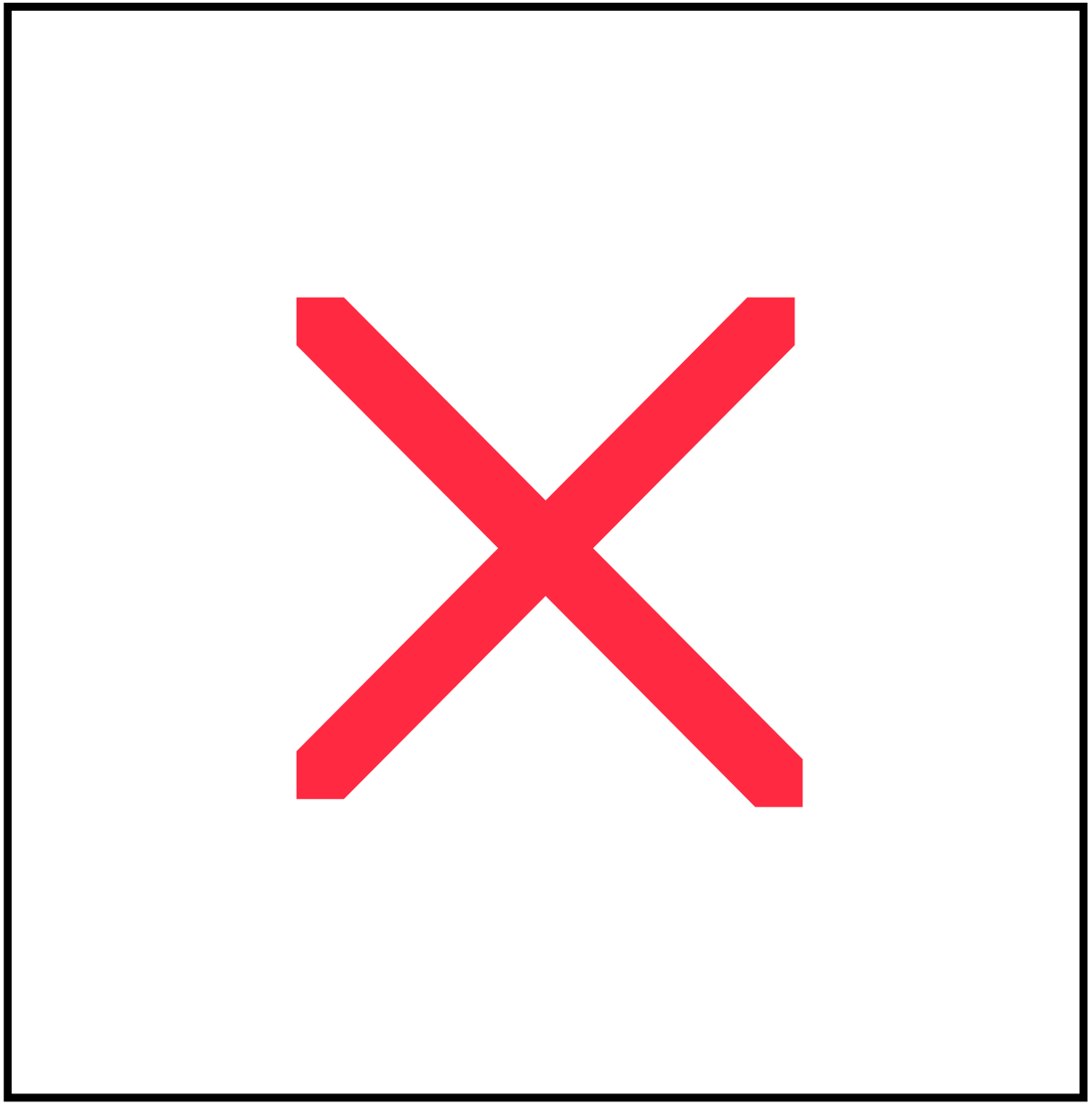
- **Name** – only information kept in human-readable form.
- **Type** – needed for systems that support different types.
- **Location** – pointer to file location on device.
- **Size** – current file size.

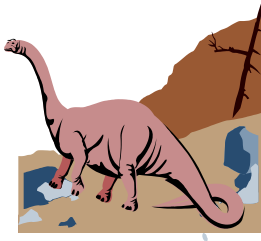


File Attributes (Cont.)

- **Protection** – controls who can do reading, writing, executing.
- **Time**, **date**, **and user identification** – data for protection, security, and usage monitoring.
- All these information about files are kept in the directory structure, which is maintained on the disk.

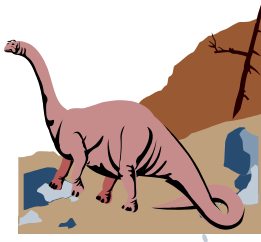
File Types – Name, Extension





File Operations from Developer's Perspective

- Create
- Write
- Read
- Reposition within file – file seek
- Delete
- Truncate

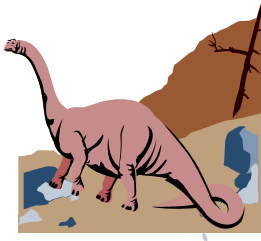


File Operations from Developer's Perspective (cont.)

- open(F_i) – search the directory structure on disk for entry F_i, and move the content of the entry from disk to memory.
- close(F_i) – persist the content of entry F_i in memory to directory structure on disk.

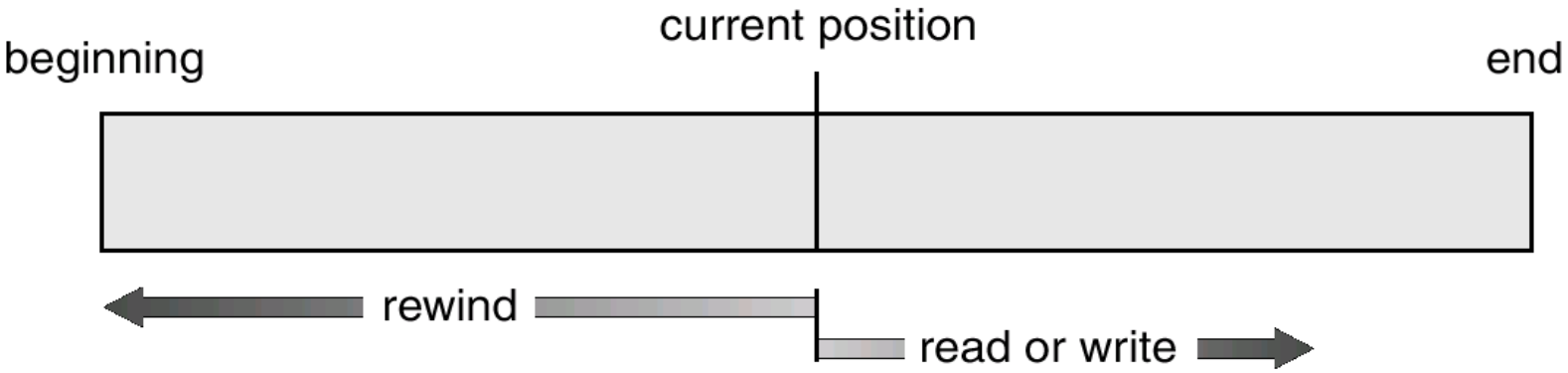
- read(F_i) – read the file content
- write(F_i) – write to the file

- fseek(F_i) – reposition the file cursor

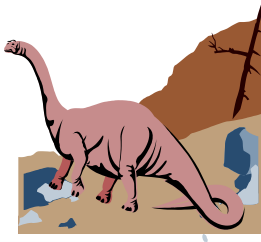


File Content Access Methods

- **Sequential Access**

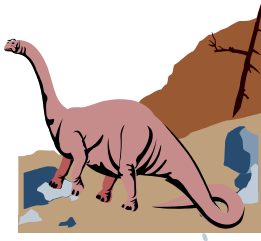


- **Direct Access**



Simulation of Sequential Access on a Direct-Access File

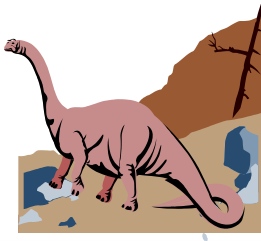
sequential access	implementation for direct access
reset	*cp* = 0;
read next	*read cp*; *cp* = *cp*+1;
write next	*write cp*; *cp* = *cp*+1;



Code Modifying a Key-Value Pair

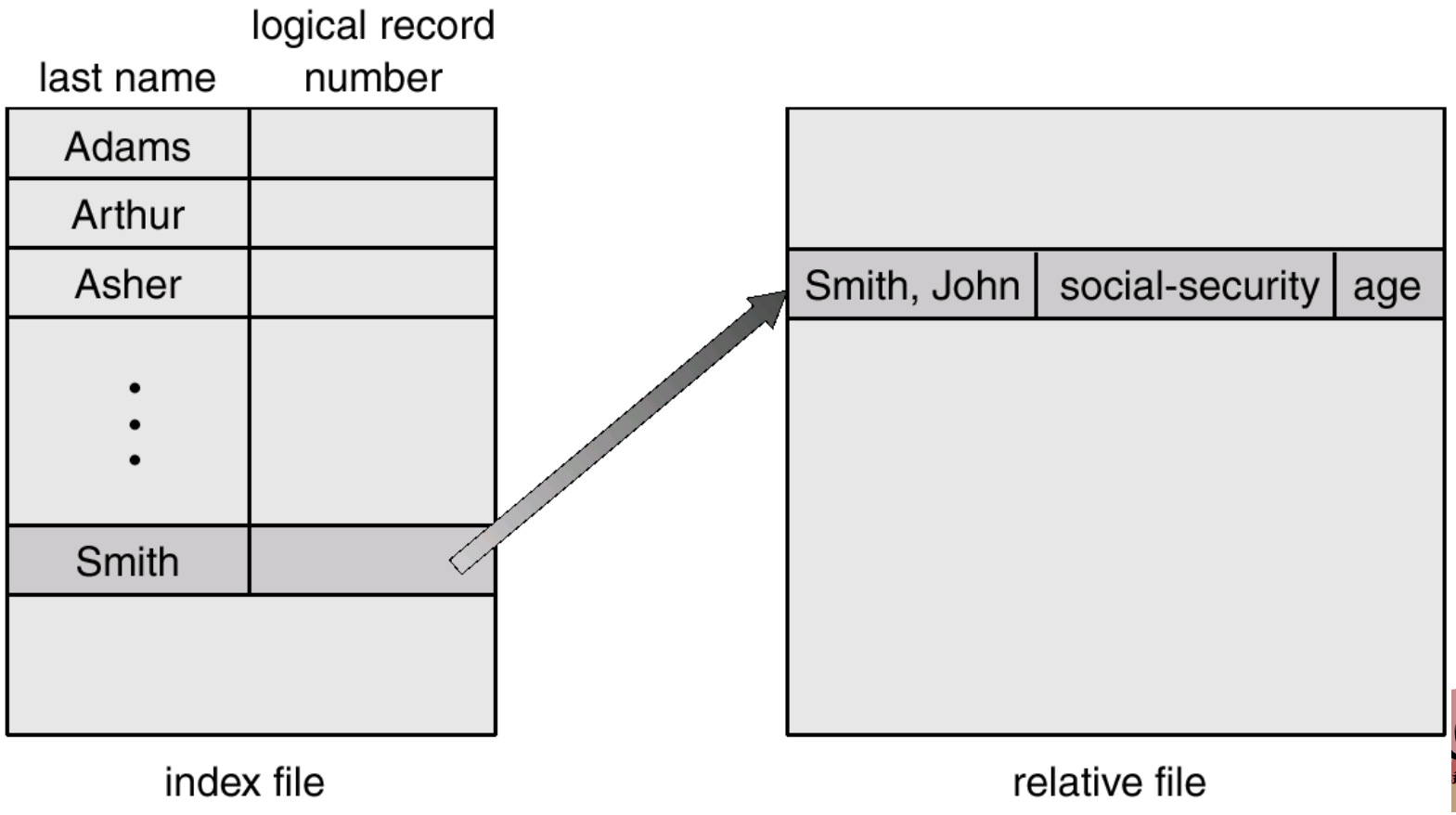
KEY	VALUE
integer	integer

```
ssize_t len;
char * filename;
int key, srch_key, new_value;
filename = argv[1];
srch_key = strtol(argv[2], NULL, 10);
new_value = strtol(argv[3], NULL, 10);
int fd = open(filename, O_RDWR);
while(sizeof(int) == read(fd, key, sizeof(int))) {
        if(key != srch_key)
                lseek(fd, sizeof(int), SEEK_CUR);
        else {
                write(fd, &new_value, sizeof(int));
                close(fd);
                return EXIT_SUCCESS;
        }
}
fprintf(stderr, "key not found!");
return EXIT_FAILURE;
```



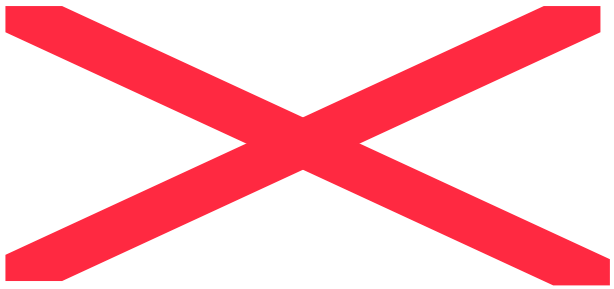
Example of Index and Relative Files

- Store keys in the index file
- Store values (or records) in the relative file
- How to quickly locate the record of John Smith



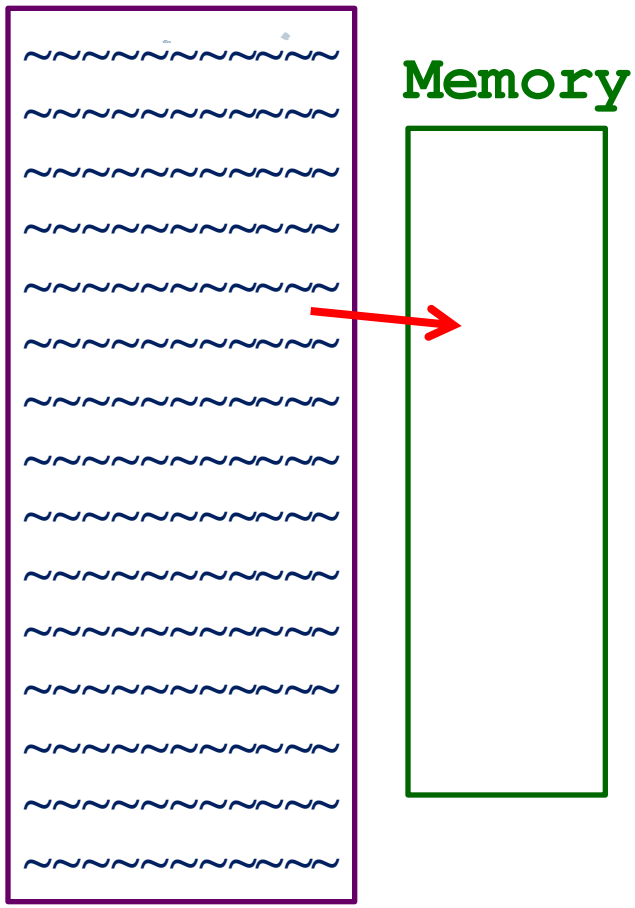
B+ Tree for Index File

- The primary value of a B+ tree is in storing data for efficient retrieval in a block-oriented storage context — in particular, filesystems. Unlike binary search trees, B+ trees have very high fanout (number of pointers to child nodes in a node, typically on the order of 100 or more), which reduces the number of I/O operations required to find an element in the tree.



https://en.wikipedia.org/wiki/B%2B_tree

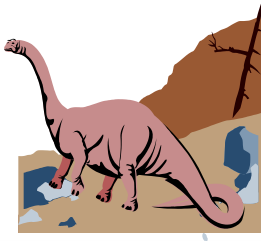
File Content Direct Access by Memory Mapped File



- **mmap**() creates a new mapping in the virtual address space of the calling process
- **munmap**() system call deletes the mappings for the specified address range, and causes further references to addresses within the range to generate invalid memory references

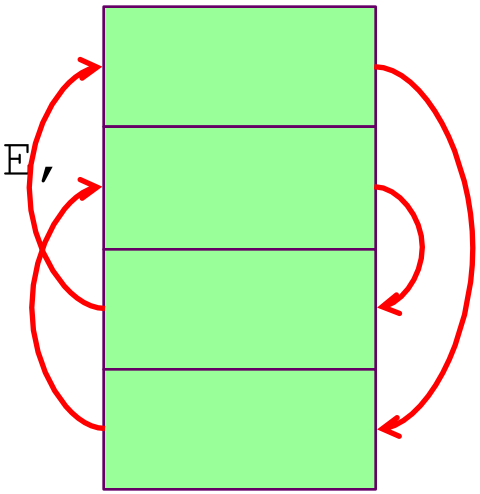
```
fd = open("file.txt", ….);
buffer = mmap(…, fd, …);

// manipulate the buffer

munmap(buf, …);
close(fd);
```

http://linux.die.net/man/2/mmap



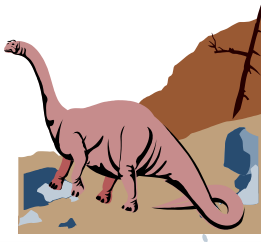
An Example of Memory Mapped File: Shuffle Blocks within a File

```
filename = argv[1];
card_size = strtol(argv[2], NULL, 10);
fd = open(filename, O_RDWR);
len = lseek(fd, 0, SEEK_END);
lseek(fd, 0, SEEK_SET);
buf = mmap(NULL, len, PROT_READ | PROT_WRITE,
           MAP_FILE | MAP_SHARED, fd, 0);
if( buf == (void*) -1) {
      fprintf(stderr, "mmap failed.\n");
      exit(EXIT_FAILURE);
}
memshuffle(buf, len, card_size);
munmap(buf, len);
close(fd);
return EXIT_SUCCESS;
```

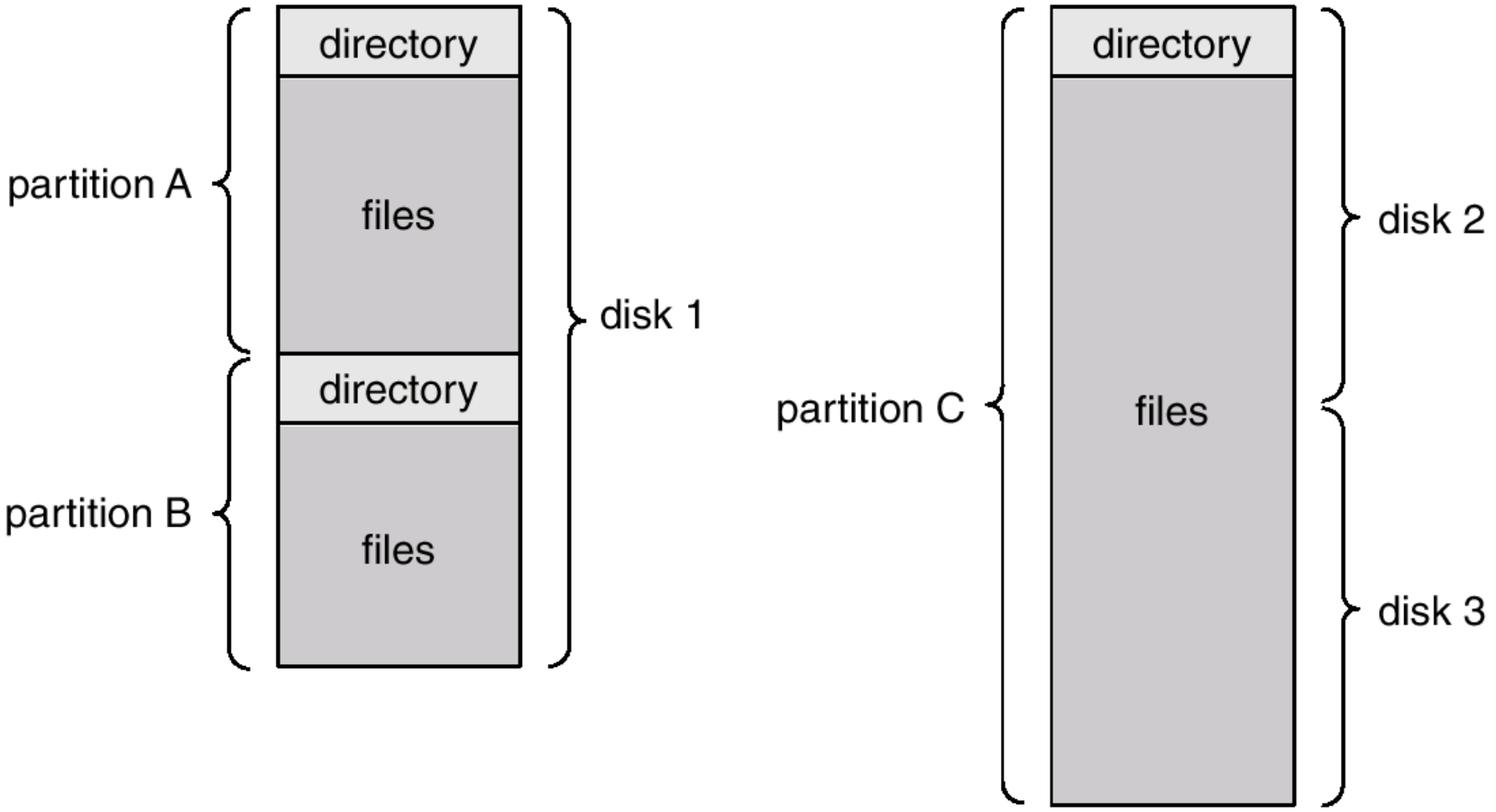


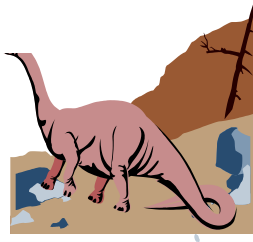
Directory Structure

- disks are split into one or more partitions.
- each partition contains information about files within it
- The information is kept in entries in a device directory or volume table of contents



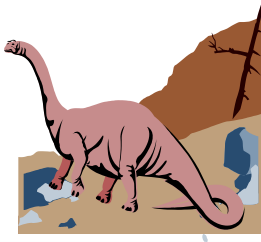
A Typical File-system Organization





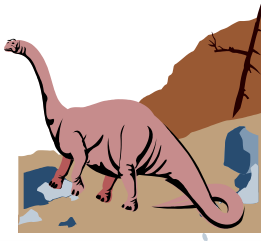
Operations Performed on Directory

- Search for a file
- Create a file
- Delete a file
- List a directory
- Rename a file
- Traverse the file system



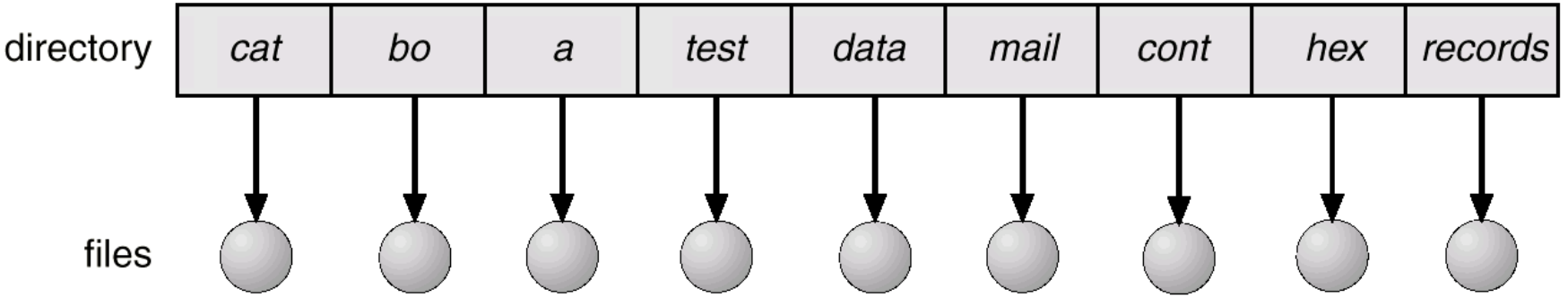
Organize the Directory (Logically) to Obtain

- **Efficiency** – locating a file quickly.
- **Naming** – convenient to users.
  - Two users can have the same name for different files.
  - The same file can have several different names.
- **Grouping** – logical grouping of files by properties, (e.g., all Java programs, all games, …)



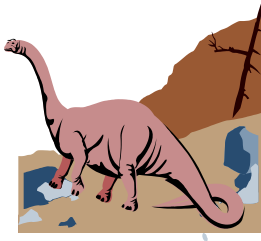
Single-Level Directory

- A single directory for all users.



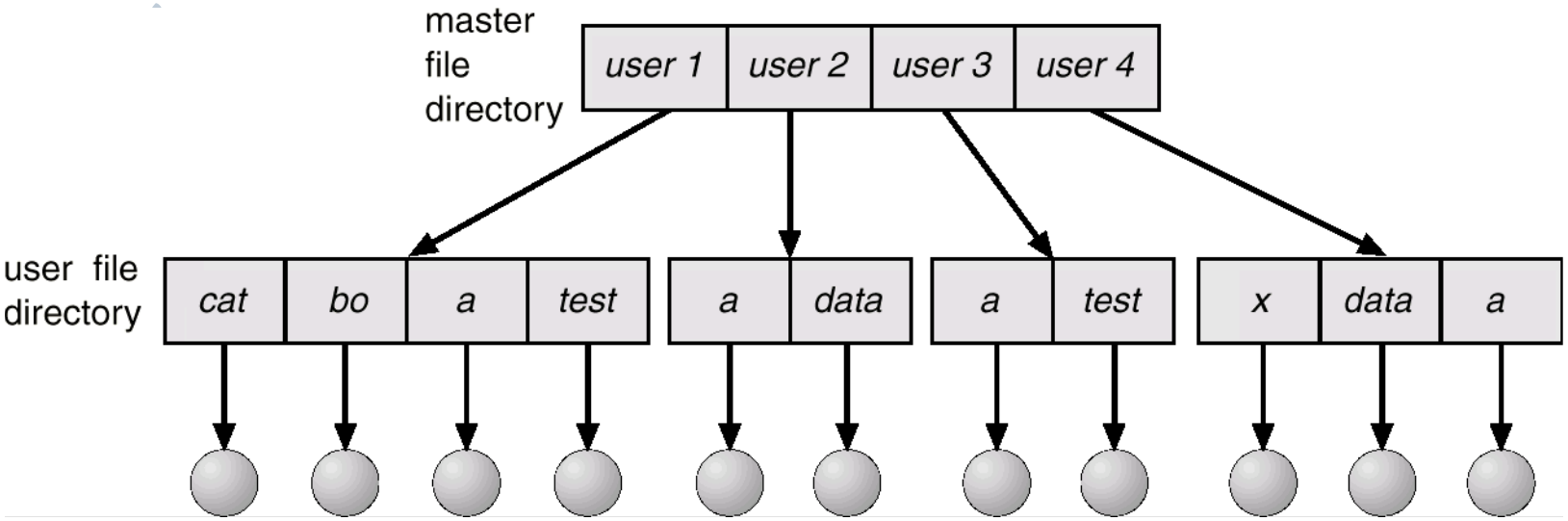
Naming problem

Grouping problem

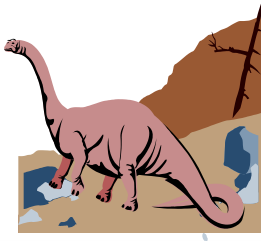


Two-Level Directory

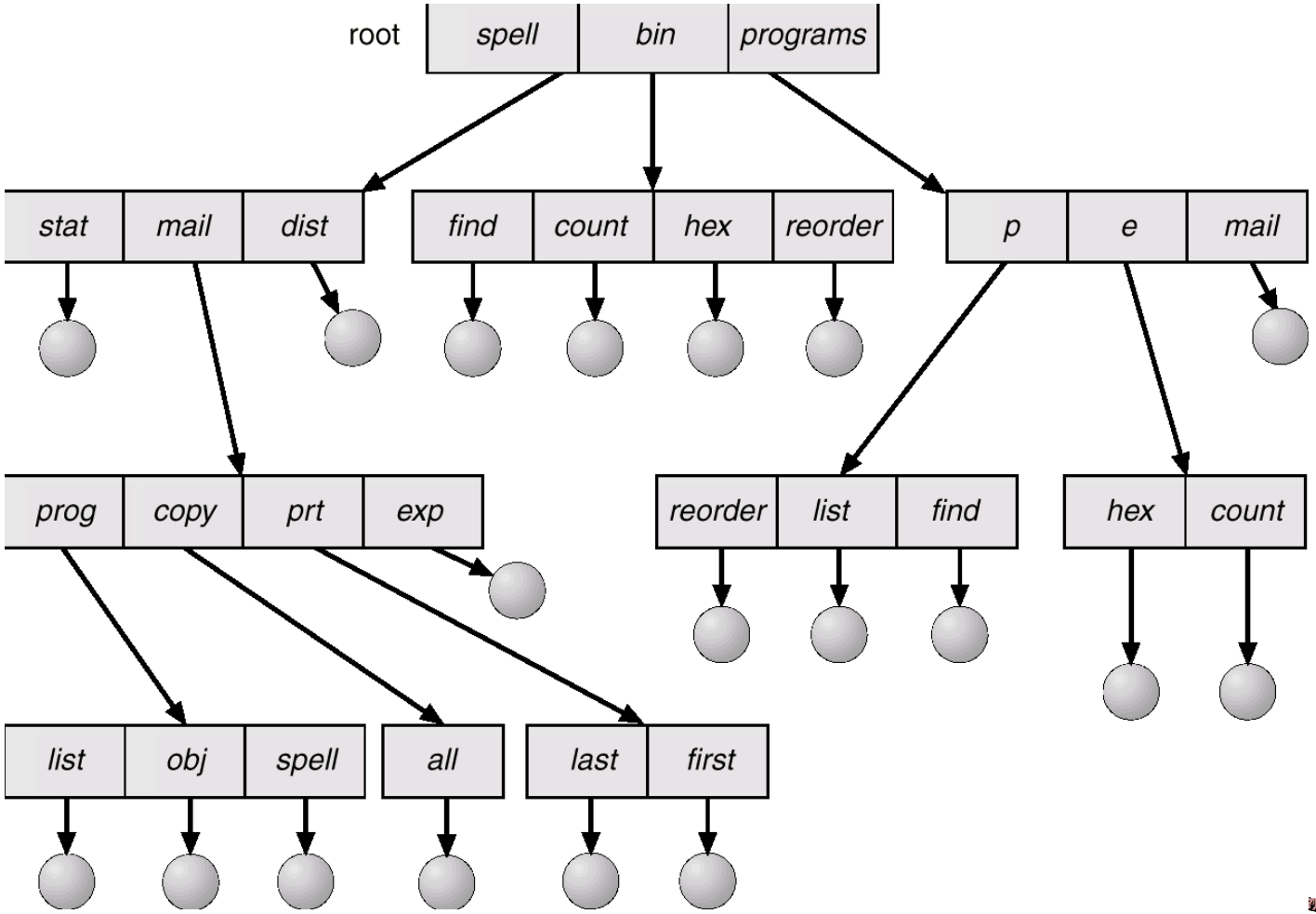
- Separate directory for each user.



- Efficient searching
- Support path name, so can have the same file name for different users
- No grouping capability

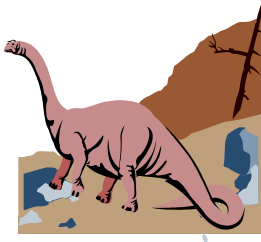


Tree-Structured Directories



Tree-Structured Directories (cont.)

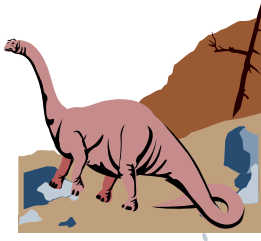
- Efficient searching
- Convenient naming
  - Two users can have the same name for different files.
- Grouping capability
- Current directory (working directory)
  - **cd** /spell/mail/prog
  - **type** list



Tree-Structured Directories (cont.)

- **Absolute** or **relative** path name
- Creating a new file can be done in current directory.
- Delete a file

  rm <file-name>



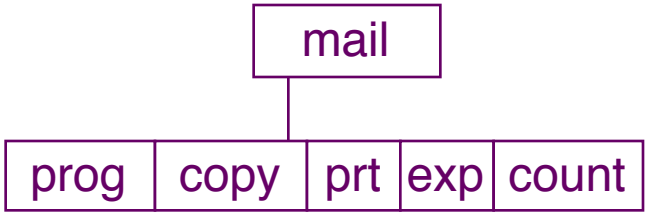
Tree-Structured Directories (cont.)

- Creating a new subdirectory is done in current directory.

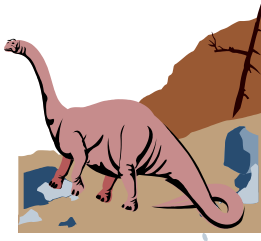
  mkdir <dir-name>

  Example: if in current directory **/mail**

  mkdir count



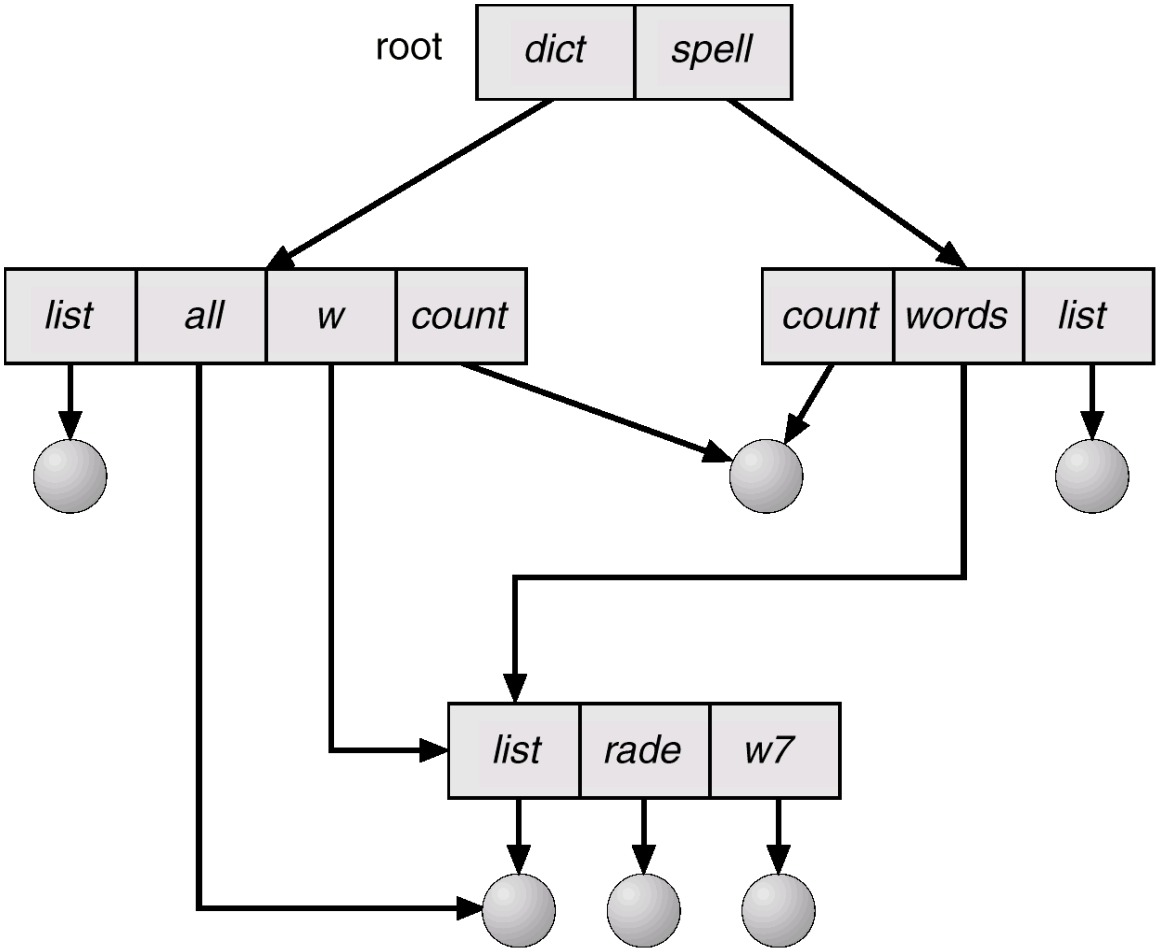
Deleting “mail” ⇒ deleting the entire subtree rooted by “mail”.

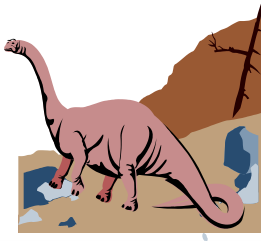


Acyclic-Graph Directories

- Have shared subdirectories and files.

The same file can have several different paths.

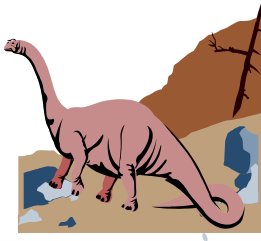




Acyclic-Graph Directories (cont.)

- Two different names (aliasing)
- If *dict* deletes *count* ⇒ dangling pointer.

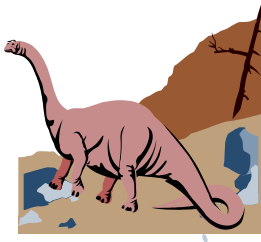
  Solutions:
  - Backpointers, so we can delete all pointers.
  - Entry-hold-count solution.
- These links we talked about are hard links in UNIX/Linus



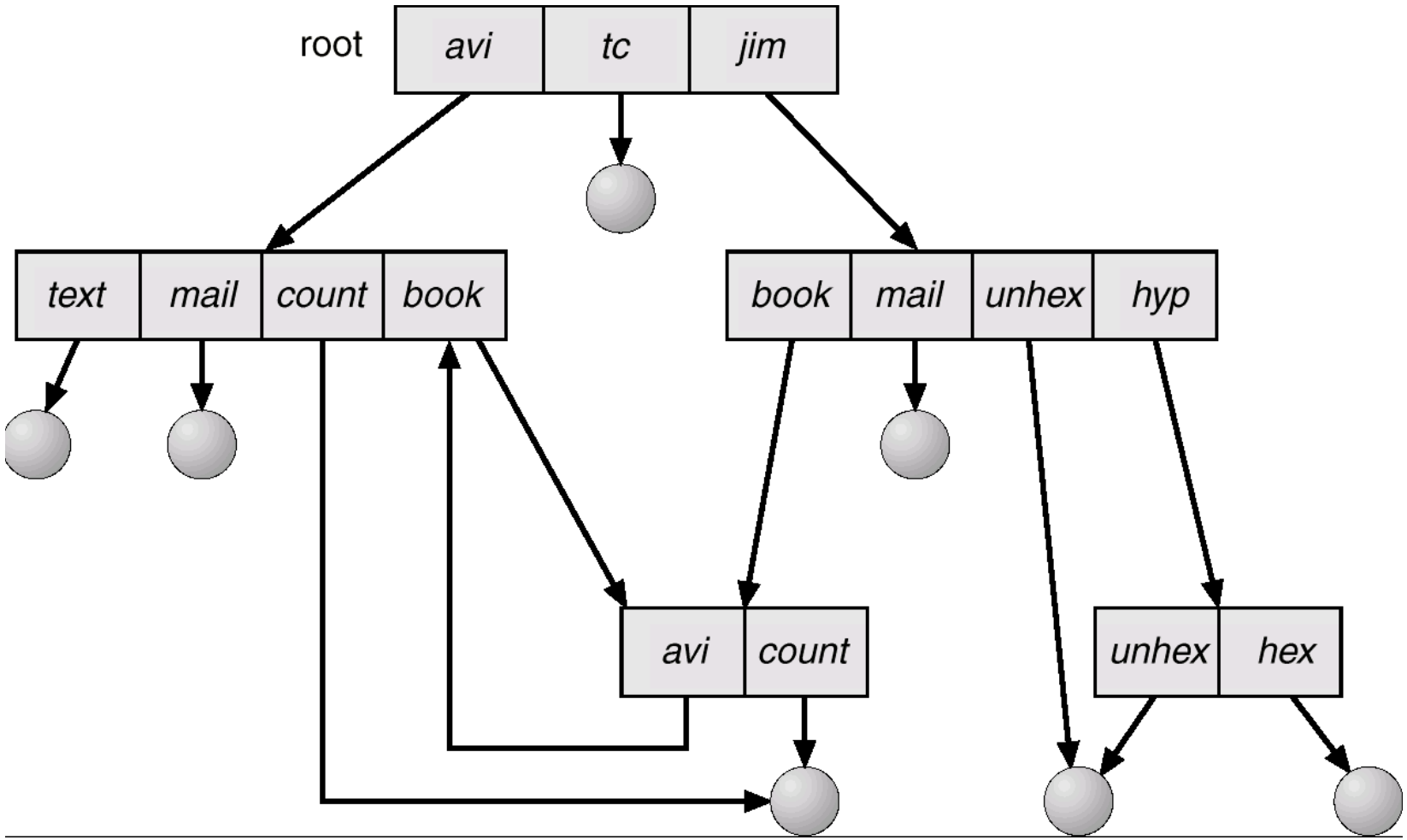
In Linux/Unix Shortcuts are knows as Link

- Soft Links (symbolic links)
  - You can make a link for either a file or a folder
  - You can create link (shortcut) on different partition
  - You got a different inode number from original.
  - If real copy is deleted the link will not work.
- Hard Links
  - For files only, and you cannot create a hard link on different partition (it should be on same partition)
  - You got the same inode number as original
  - If the real copy is deleted the link will work (because it act as original file)

https://askubuntu.com/questions/108771/what-is-the-difference-between-a-hard-link-and-a-symbolic-link

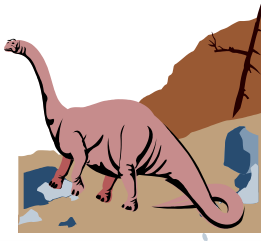


General Graph Directory



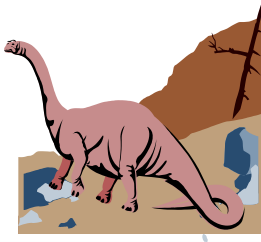
General Graph Directory (cont.)

- How do we guarantee no cycles?
  - Allow only links to file not subdirectories.
  - Garbage collection.
  - Every time a new link is added, use a cycle detection algorithm to determine whether it is OK.

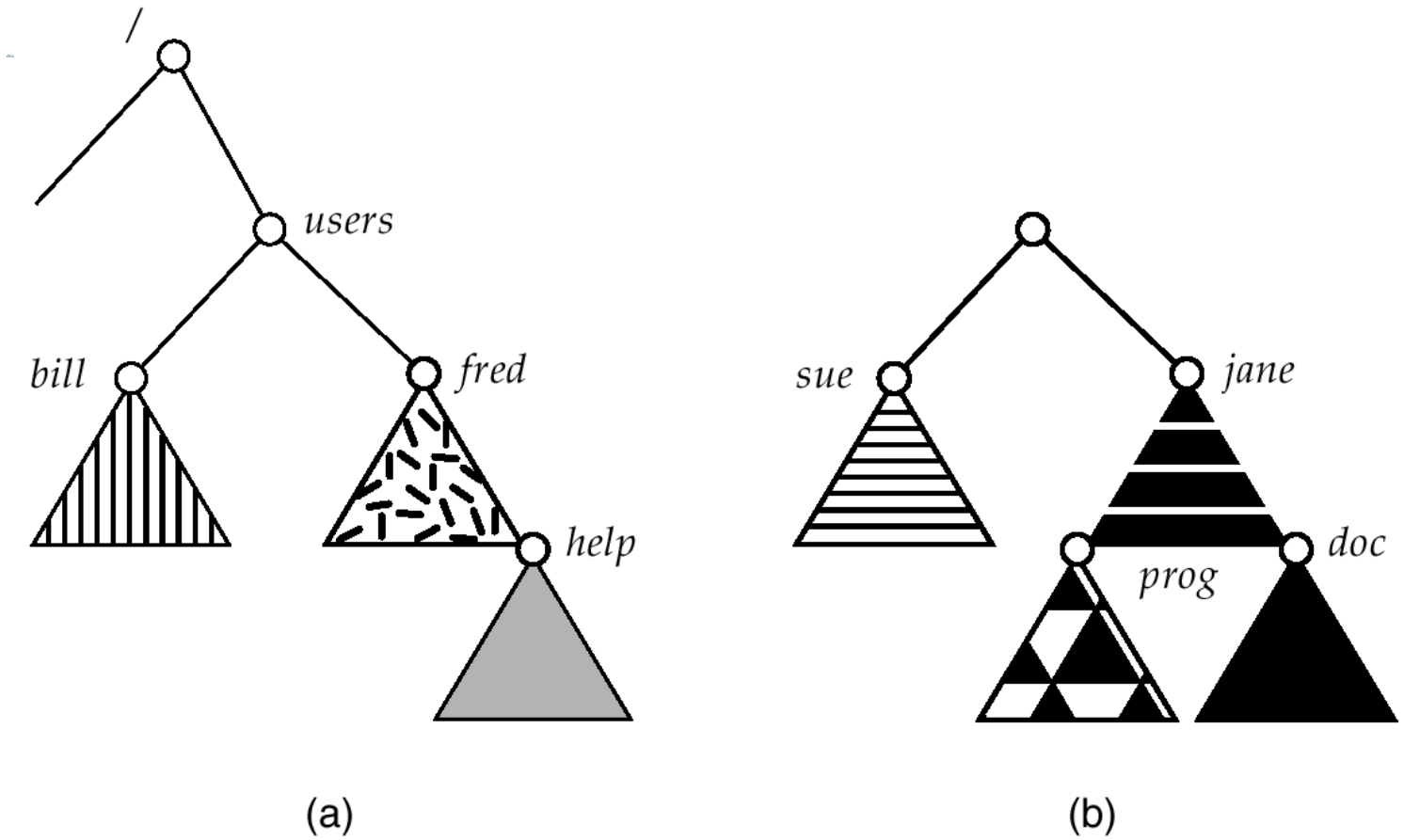


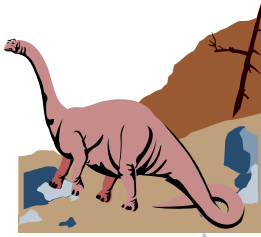
File System Mounting

- A file system must be **mounted** before it can be accessed.
- An unmounted file system (I.e. Fig. 11-11(b)) is mounted at a **mount point**.

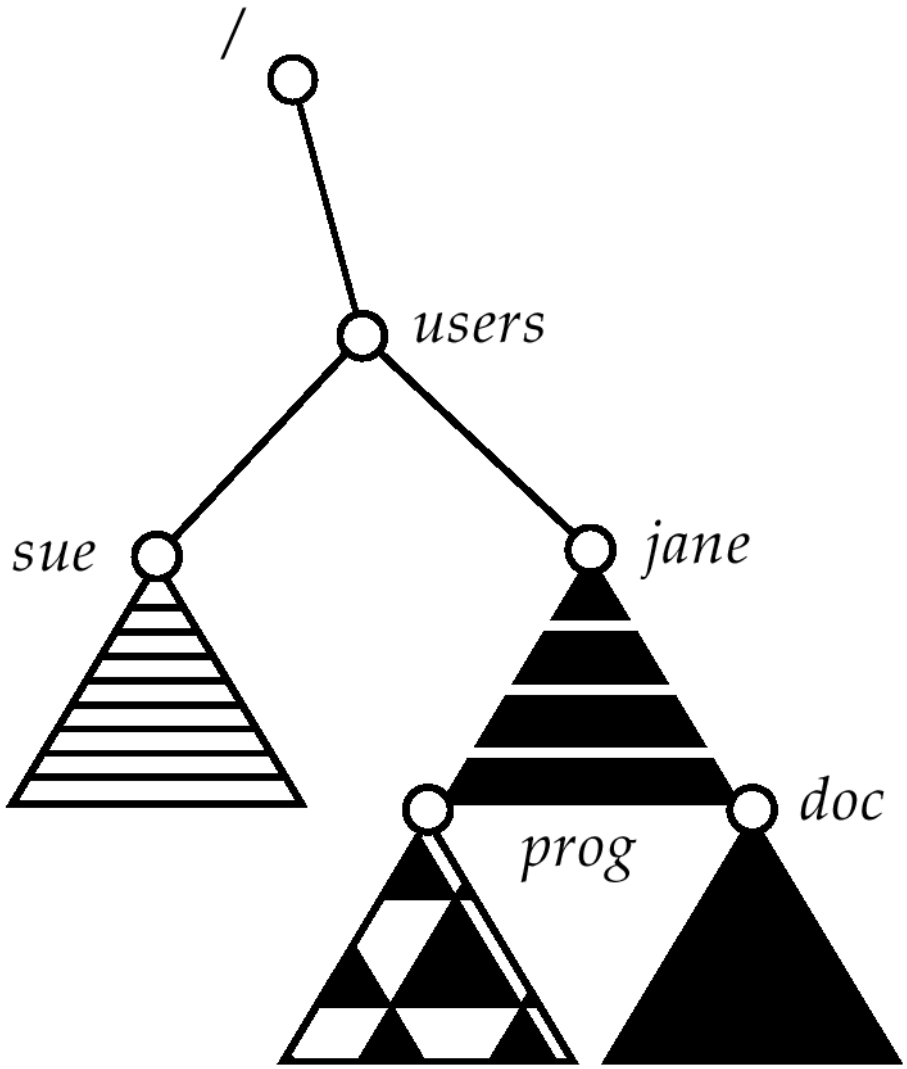


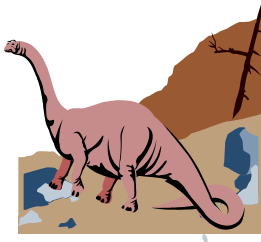
(a) Existing
(b) Unmounted Partition





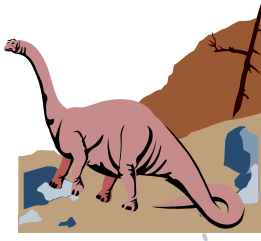
Mount Point





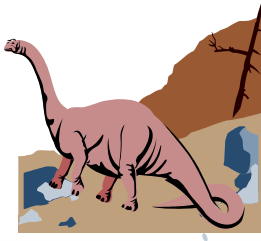
File Sharing

- Sharing of files on multi-user systems is desirable.
- Sharing may be done through a *protection* scheme.
- On distributed systems, files may be shared across a network.
- Network File System (NFS) is a common distributed file-sharing method.



Protection

- File owner/creator should be able to control:
  - what can be done
  - by whom
- Types of access
  - Read
  - Write
  - Execute
  - Append
  - Delete
  - List



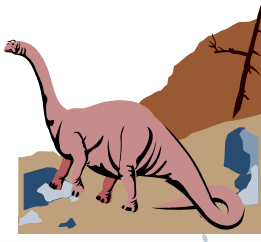
Access Lists and Groups

- Mode of access: read, write, execute
- Three classes of users RWX
  - a) **owner access** 7 ⇒ 1 1 1
  - b) **group access** 6 ⇒ 1 1 0
  - c) **public access** 1 ⇒ 0 0 1
- Ask manager to create a group (unique name), say G, and add some users to the group.
- For a particular file (say *game*) or subdirectory, define an appropriate access.

owner group public

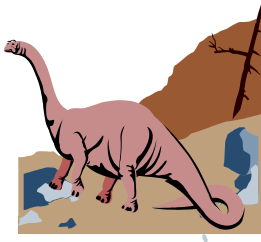
Attach a group to a file chmod 761 game

chgrp G game

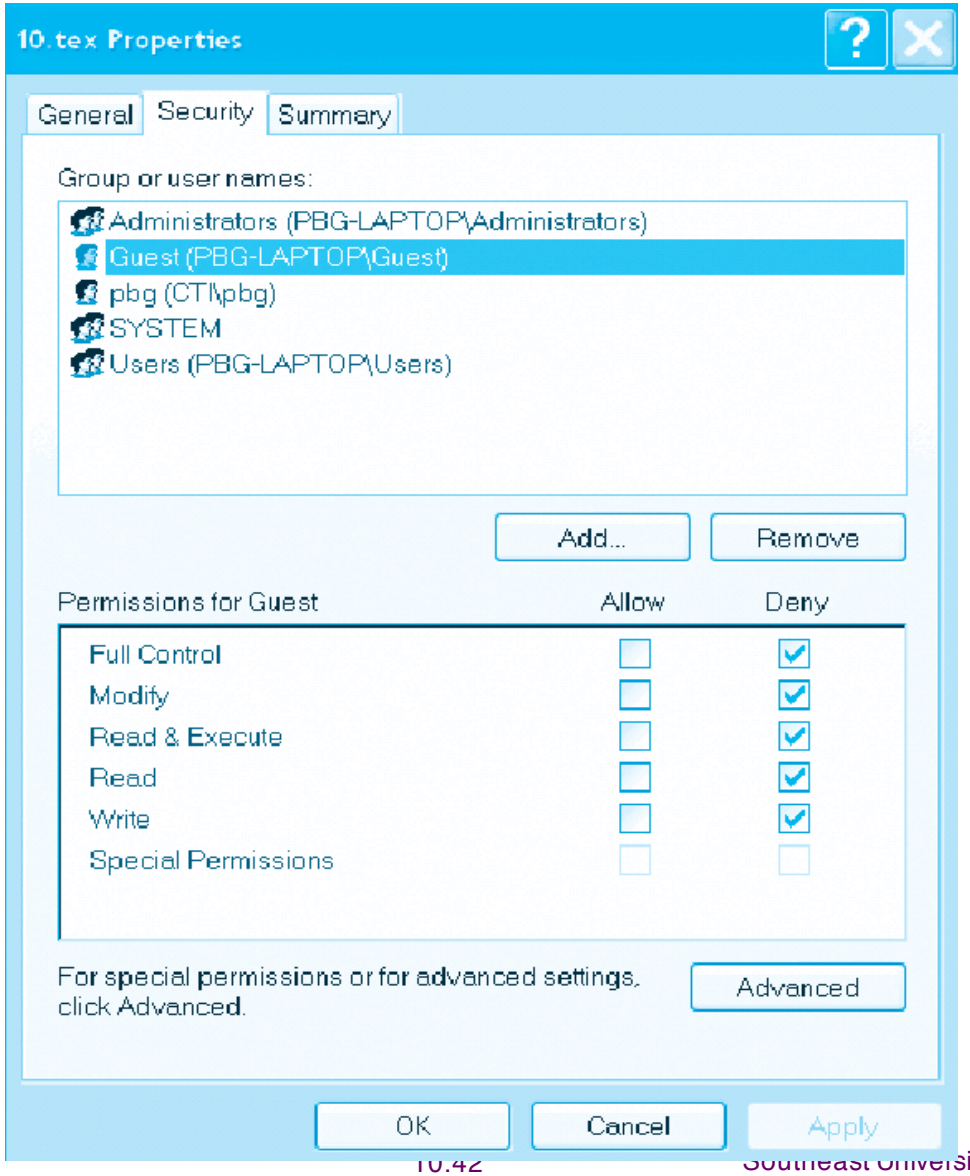


A Sample UNIX Directory Listing

-rw-rw-r--	1 pbg	staff	31200	Sep 3 08:30	intro.ps
drwx------	5 pbg	staff	512	Jul 8 09.33	private/
drwxrwxr-x	2 pbg	staff	512	Jul 8 09:35	doc/
drwxrwx---	2 pbg	student	512	Aug 3 14:13	student-proj/
-rw-r--r--	1 pbg	staff	9423	Feb 24 2003	program.c
-rwxr-xr-x	1 pbg	staff	20471	Feb 24 2003	program
drwx--x--x	4 pbg	faculty	512	Jul 31 10:31	lib/
drwx------	3 pbg	staff	1024	Aug 29 06:52	mail/
drwxrwxrwx	3 pbg	staff	512	Jul 8 09:35	test/



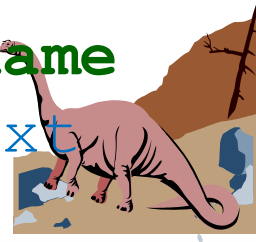
Windows XP Access-Control List Management



Question about File Access-Control

- Which of the following will generate a permission error?
  - cat foo.txt
  - cat dir/bar.txt
  - touch dir/new.txt

```
$ ls -l ./
Permission      user  group     ….   Filename
drw-r--r--      me    me              dir
-rw-r--r--      other other           foo.txt

$ sudo ls -l dir
Permission      user  group     ….   Filename
-rw-r--r--      me    me              bar.txt
```



Another Question

- Which of the following will generate a permission error?
  - cat foo.txt
  - cat dir/bar.txt
  - touch dir/new.txt

```
$ ls -l ./
Permission      user  group     ….   Filename
d--xr--r--      me    me              dir
-rw-r--r--      other other           foo.txt

$ sudo ls -l dir
Permission      user  group     ….   Filename
-rw-r--r--      me    me              bar.txt
```