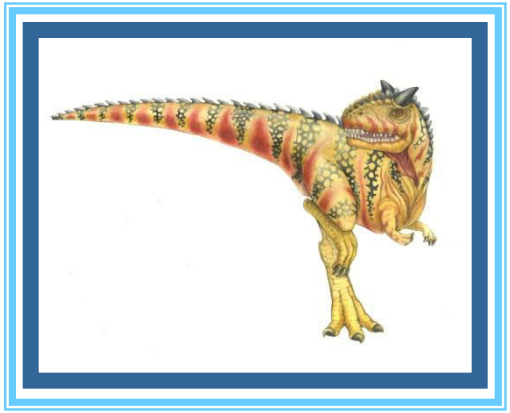
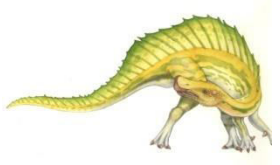
Chapter 13: File-System Interface



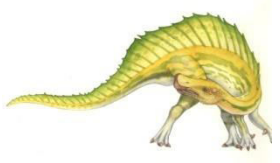
Chapter 13: File-System Interface

- File Concept
- Access Methods
- Disk and Directory Structure
- Protection



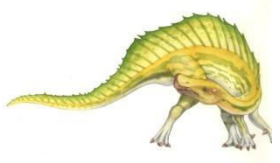
Objectives

- To explain the function of file systems
- To describe the interfaces to file systems
- To discuss file-system design tradeoffs, including access methods, file sharing, file locking, and directory structures
- To explore file-system protection



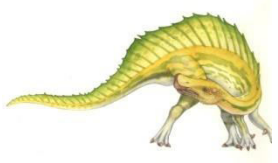
File Concept

- Contiguous logical address space
- Types:
  - Data
    - numeric
    - character
    - binary
  - Program
- Contents (many types) is defined by file's creator
  - text file,
  - source file,
  - executable file

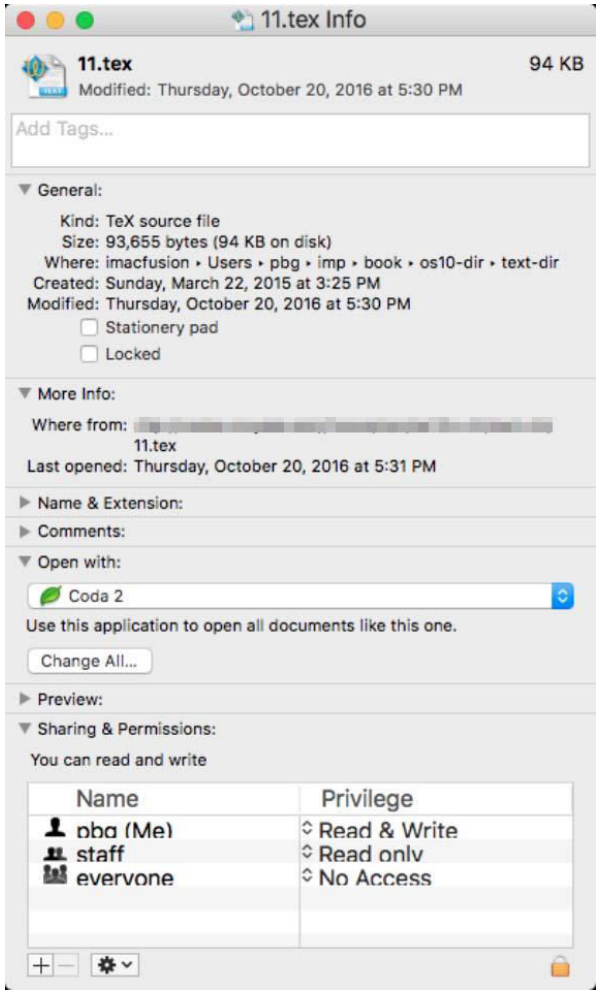


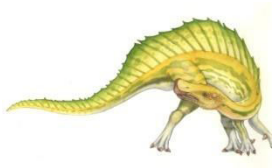
File Attributes

- **Name** – only information kept in human-readable form
- **Identifier** – unique tag (number) identifies file within file system
- **Type** – needed for systems that support different types
- **Location** – pointer to file location on the device (disk)
- **Size** – current file size
- **Protection** – controls who can do reading, writing, executing
- **Time, date, and user identification** – information kept for creation time, last modification time, and last use time.
  - Useful for data for protection, security, and usage monitoring
- Many variations, including extended file attributes such as file checksum
- Information kept in the directory structure (on disk), which consists of “inode” entries for each of the files in the system.



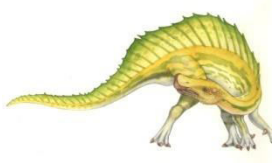
File info Window on Mac OS X





File Operations

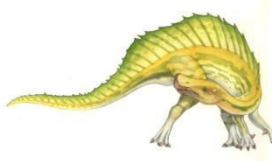
- **Create**
- **Write –** at **write pointer** location
- **Read –** at **read pointer** location
- **Reposition within file - seek**
- **Delete**
- **Truncate**
- ***Open*(F_i)** – search the directory structure on disk for inode entry F_i, and move the content of the entry to memory
- ***Close*** (F_i) – move the content of inode entry F_i in memory to directory structure on disk.



Open Files

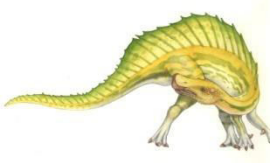
Several pieces of data are needed to manage open files:

- **Open-file table**: Keeps information (inode data) about all the open files
- **File pointer** : A pointer to last read/write location, per process that has the file open
- **File-open count**: A counter of the number of times a file is open – to allow removal of data from open-file table when last processes closes it
- **Disk location of the file**: Many file operations require the system to modify data within the file. The information needed to locate the file on disk is kept in memory so that the system does not have to read it from disk for each operation.
- **Access rights**: Per-process access mode information



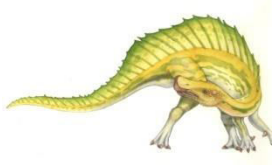
Open File Locking

- Provided by some operating systems and file systems
  - Similar to reader-writer locks
  - **Shared lock** similar to reader lock – several processes can acquire concurrently
  - **Exclusive lock** similar to writer lock
- Mediates access to a file according to the lock state.
- Access policy:
  - **Mandatory** – access is denied depending on locks held and requested
  - **Advisory** – processes can find status of locks and decide what to do



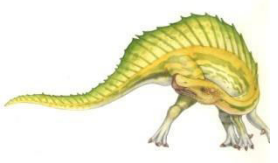
File Types – Name, Extension

file type	usual extension	function
executable	exe, com, bin or none	ready-to-run machine-language program
object	obj, o	compiled, machine language, not linked
source code	c, cc, java, pas, asm, a	source code in various languages
batch	bat, sh	commands to the command interpreter
text	txt, doc	textual data, documents
word processor	wp, tex, rtf, doc	various word-processor formats
library	lib, a, so, dll	libraries of routines for programmers
print or view	ps, pdf, jpg	ASCII or binary file in a format for printing or viewing
archive	arc, zip, tar	related files grouped into one file, sometimes compressed, for archiving or storage
multimedia	mpeg, mov, rm, mp3, avi	binary file containing audio or A/V information



File Structure

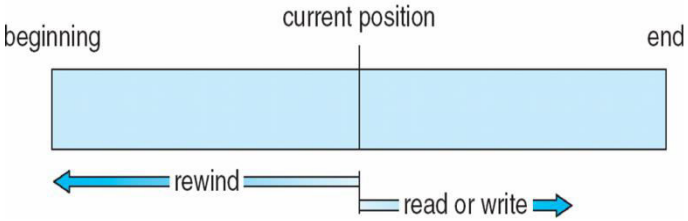
- None - sequence of words, bytes
- Simple record structure
  - Lines
  - Fixed length
  - Variable length
- Complex Structures
  - Formatted document
  - Relocatable load file
- Who decides?
  - Operating system
  - Program



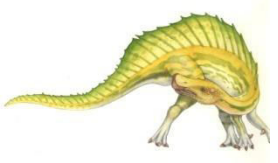
Access Methods

Sequential Access

- General structure



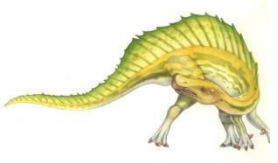
- Operations:
  - **re**ad_**next ()** – reads the next portion of the file and automatically advances a file pointer.
  - **write_next () –** append to the end of the file and advances to the end of the newly written material (the new end of file).
  - r**eset** – back to the beginning of the file.



Access Methods

Direct Access

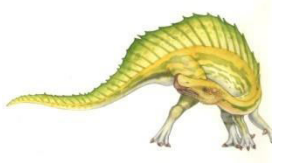
- File is made up of fixed-length logical records that allow programs to read and write records rapidly in no particular order.
- File is viewed as a numbered sequence of blocks or records. For example, can read block 14, then read block 53, and then write block 7.
- Operations:
  - **read(n)** – reads relative block number n.
  - **write(n)** – writes relative block number n.
- Relative block numbers allow OS to decide where file should be placed
  - See allocation problem in Ch 14



Simulation of Sequential Access on Direct-access File

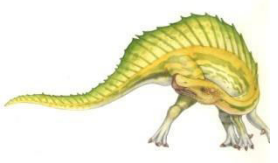
cp is a pointer to the next block to be read/written

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

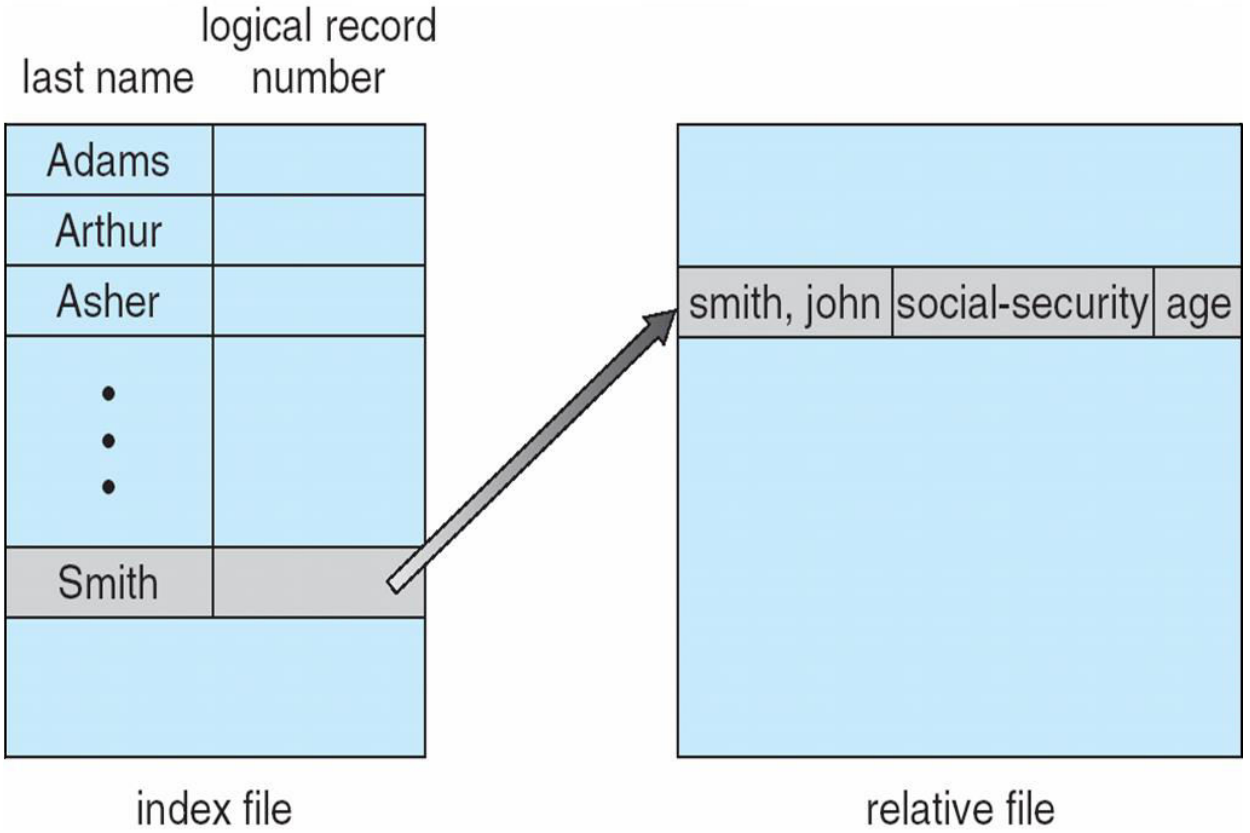


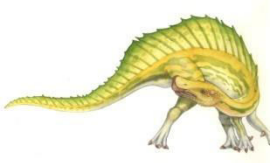
Other Access Methods

- Can be built on top of the base methods
- Generally -- involve creation of an index for the file
- Keep index in memory for fast determination of location of data to be operated on (consider UPC code plus record of data about that item)
- If too large, keep index (in memory) of the main index (on disk)
- IBM indexed sequential-access method (ISAM)
  - Small master index, points to disk blocks of secondary index
  - File kept sorted on a defined key
  - All done by the OS
- VMS operating system provides index and relative files as another example (see next slide)



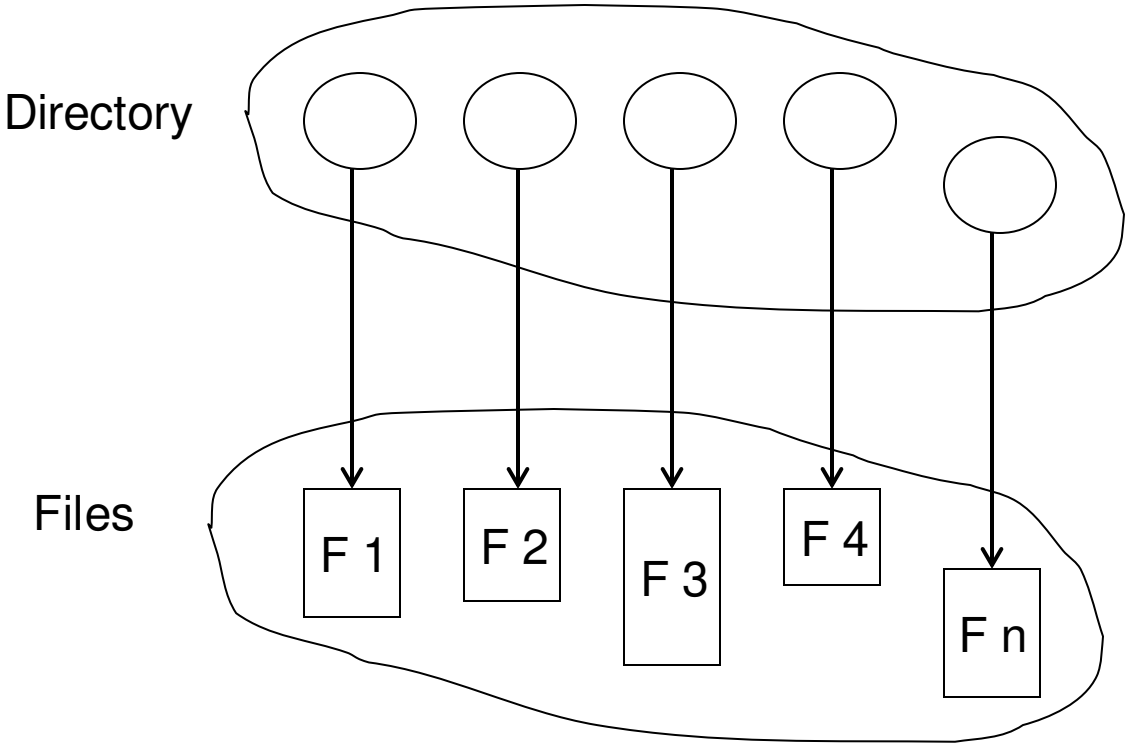
Example of Index and Relative Files



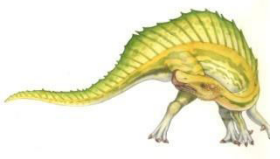


Directory Structure

A collection of nodes containing information about all files

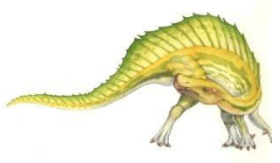


Both the directory structure and the files reside on disk



Operations Performed on Directory

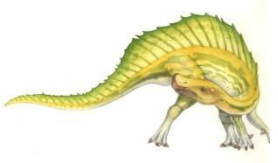
- Search for a file
- Create a file
- Delete a file
- List a directory
- Rename a file
- Traverse the file system



Directory Organization

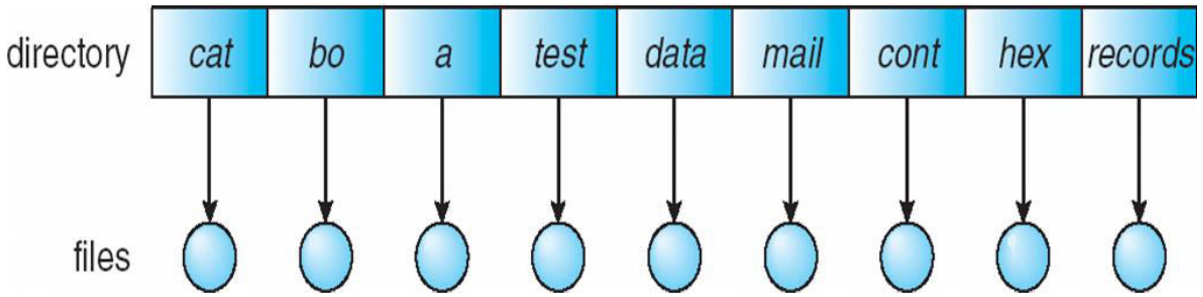
The directory is organized logically to obtain

- Efficiency – locating a file quickly
- Naming – convenient to users
  - Two users can have 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, …)

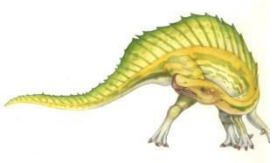


Single-Level Directory

- A single directory for all users

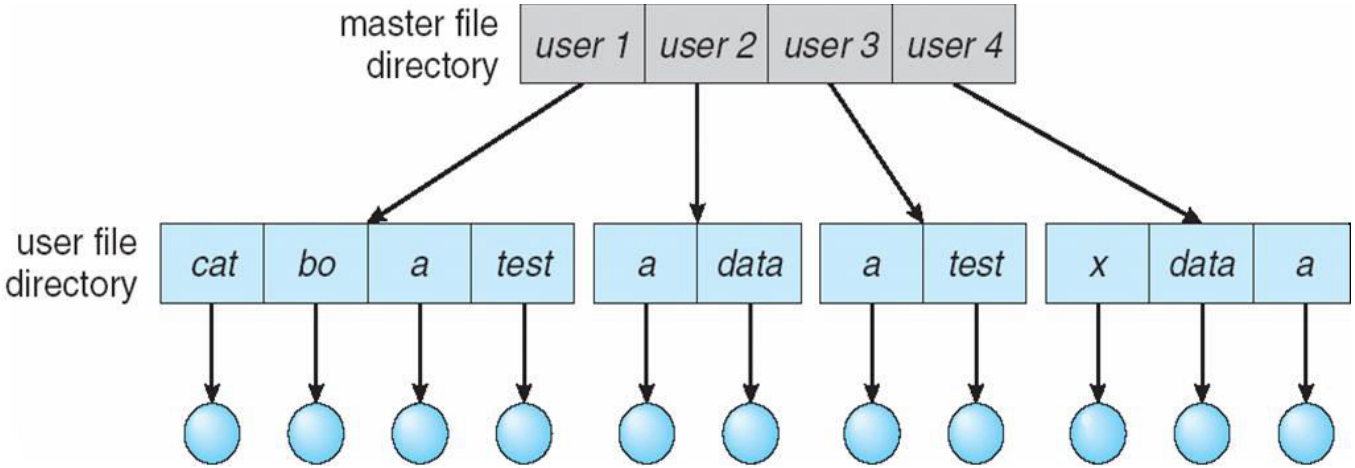


- Naming problem
- Grouping problem

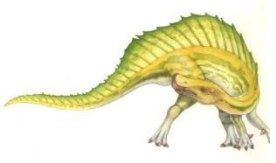


Two-Level Directory

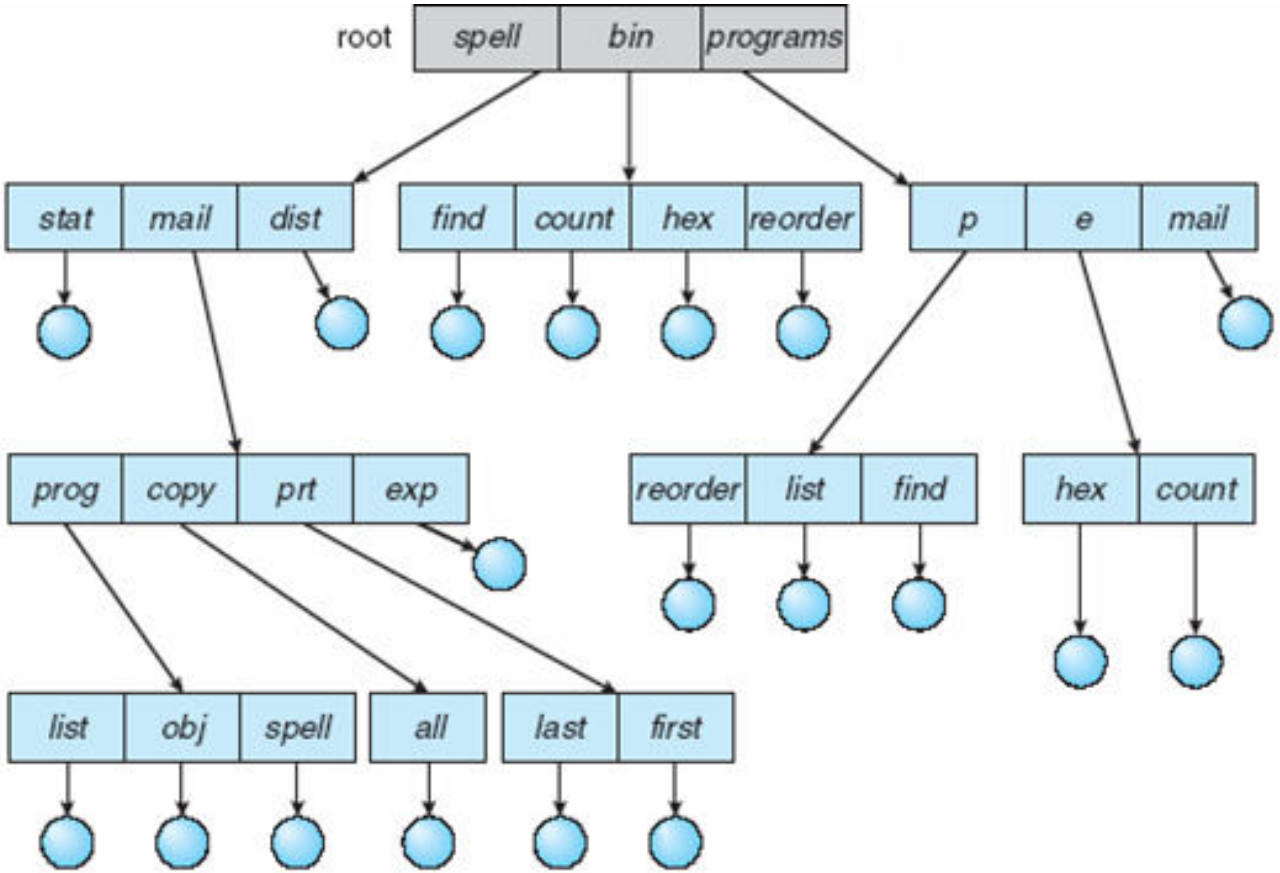
- Separate directory for each user

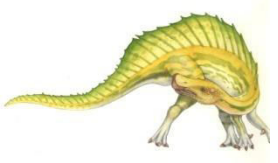


- Path name
- Can have the same file name for different user
- Efficient searching
- No grouping capability



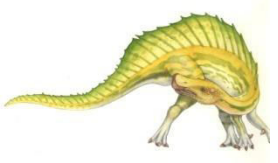
Tree-Structured Directories





Tree-Structured Directories (Cont.)

- Efficient searching
- Grouping Capability
- Current directory (working directory)
  - `cd /spell/mail/prog`
  - `type list`



Tree-Structured Directories (Cont)

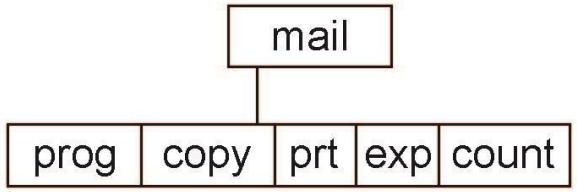
- **Absolute** or **relative** path name
- Creating a new file is done in current directory
- Delete a file

```
rm <file-name>
```

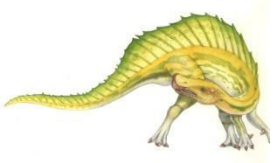
- Creating a new subdirectory is done in current directory

```
mkdir <dir-name>
```

- Example: Suppose the current directory is -- "**`/mail`**"
  - **`mkdir count`**

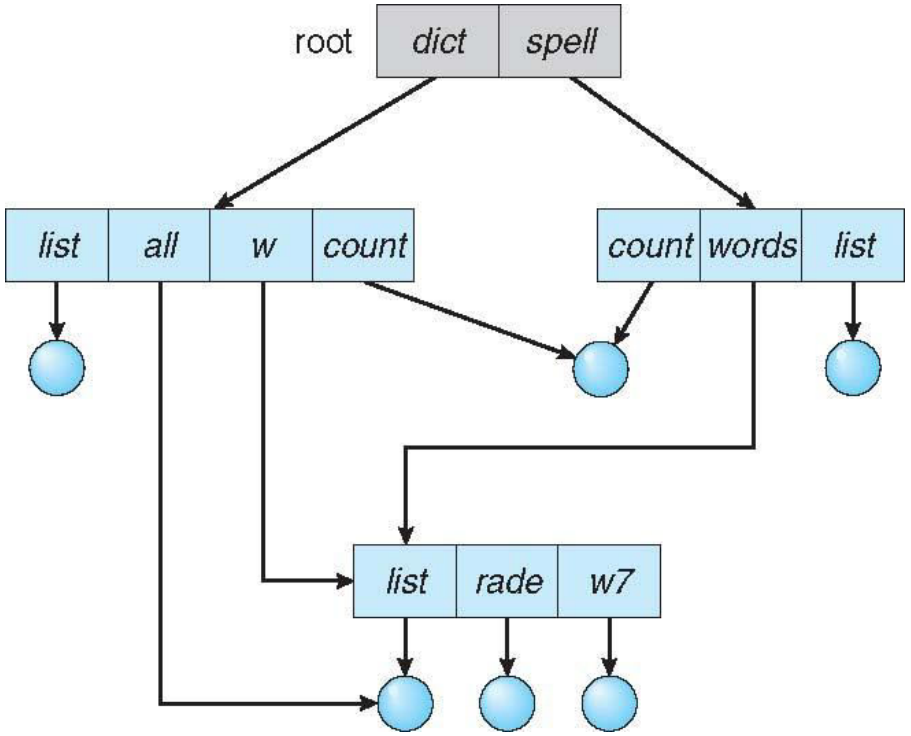


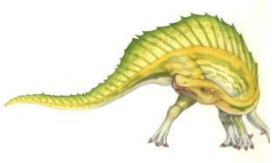
- Deleting "mail" ⇒ deleting the entire subtree rooted by "mail"



Acyclic-Graph Directories

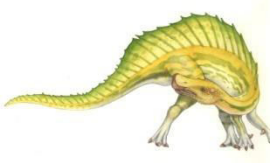
Have shared subdirectories and files





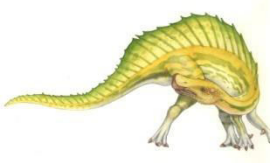
Acyclic-Graph Directories (Cont.)

- Files/subdirectories have two different names (aliasing)
  - Only one actual file exists, so any changes made by one person are immediately visible to the other.
- How do we implement shared files and subdirectories?
  - Can duplicate the *inode* information about the shared file/subdirectory in each of the subdirectories that "point' to the shared structure.
    - If some information changes about the file it had to be updated in several places.
  - Have a new directory entry type:
    - **Link** – another name (pointer) to an existing file or subdirectory.



Acyclic-Graph Directories -- Links

- A link may be implemented as an **absolute** or a **relative** path name.
- When a reference to a file is made, the directory is searched. If the directory entry is marked as a link, then the name of the real file is included in the link information.
- We **resolve** the link by using that path name to locate the real file.
- Links are easily identified by their format in the directory entry (or by having a special type on systems that support types) and are effectively indirect pointers.
- The operating system ignores these links when traversing directory trees to preserve the acyclic structure of the system.

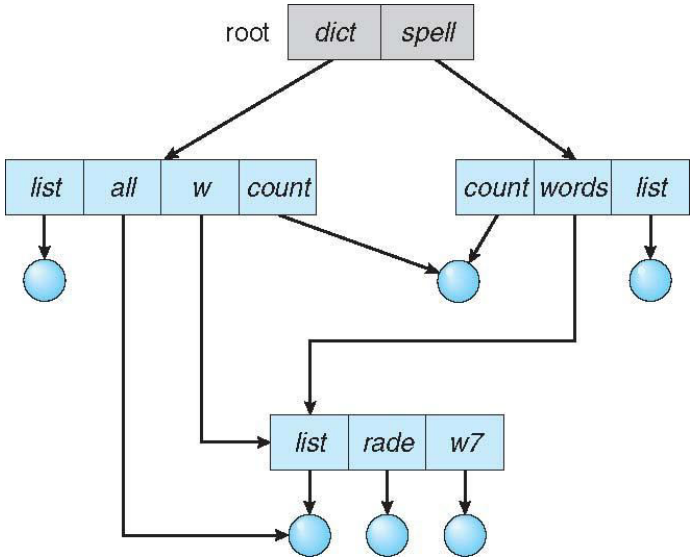


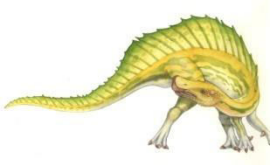
Acyclic-Graph Directories -- Deletion

- If ***dict*** / ***count*** is deleted ⇒ dangling pointer

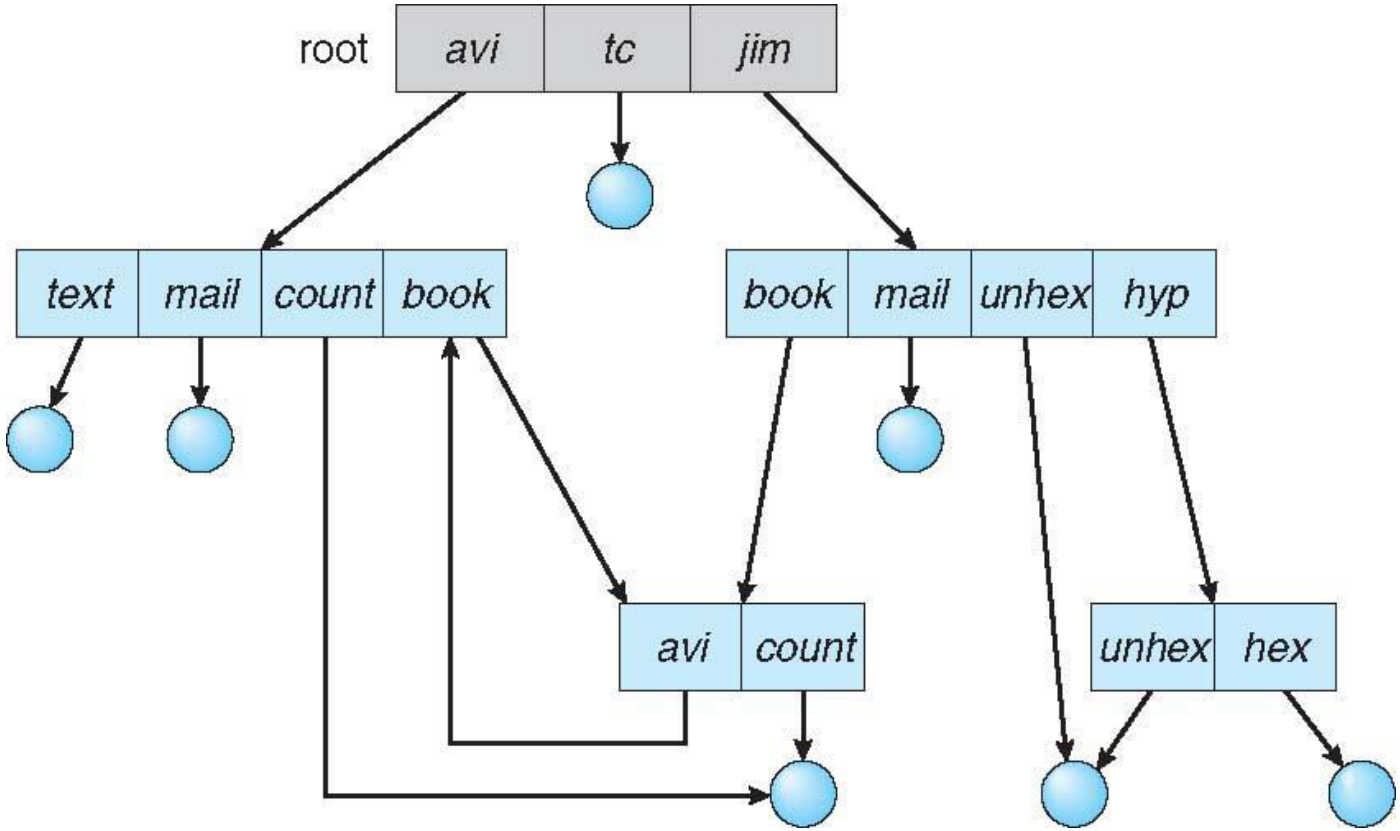
  Solutions:

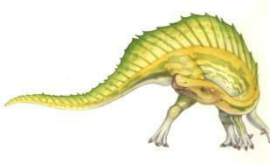
  - Backpointers -- so we can delete all pointers.
    - Variable size records a problem
  - Backpointers using a daisy-chain organization
  - Entry-hold-count solution





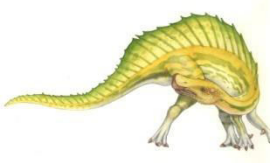
General Graph Directory





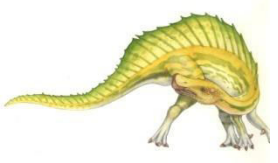
General Graph Directory (Cont.)

- 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



Protection

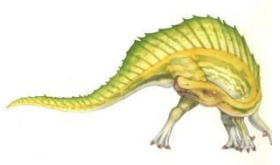
- File owner/creator should be able to control:
  - What can be done
  - By whom
- Types of access
  - **Read**
  - **Write**
  - **Execute**
  - **Append**
  - **Delete**
  - **List**



Access Control in Unix

- Mode of access: read, write, execute
- Three classes of users on Unix / Linux:
  - owner
  - group
  - public
- With each file and subdirectory we keep 9 protection bits, 3 for owner, 3 for group, 3 for public.

			RWX
a) **owner access**	7	⇒	1 1 1
b) **group access**	6	⇒	RWX 1 1 0
c) **public access**	1	⇒	RWX 0 0 1

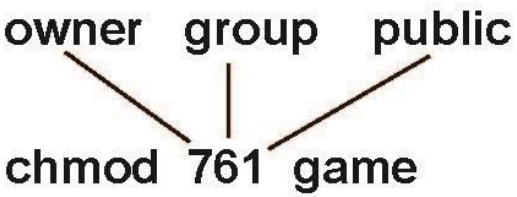


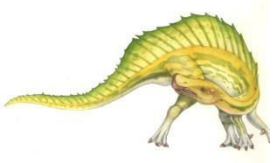
Access Control (Cont.)

- To create a group, ask the system manager to create a new group (unique name), say G, and to add some users to the group (say, Judi, Mark)
- For a particular file (or subdirectory), say *game*, define an appropriate access.
- Attach a group, say G, to a file , say game – using the command "chgrp"

```
chgrp  G game
```

- Set protection for file "game" -- using the command "chmod"



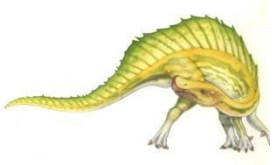


A Sample UNIX Directory Listing

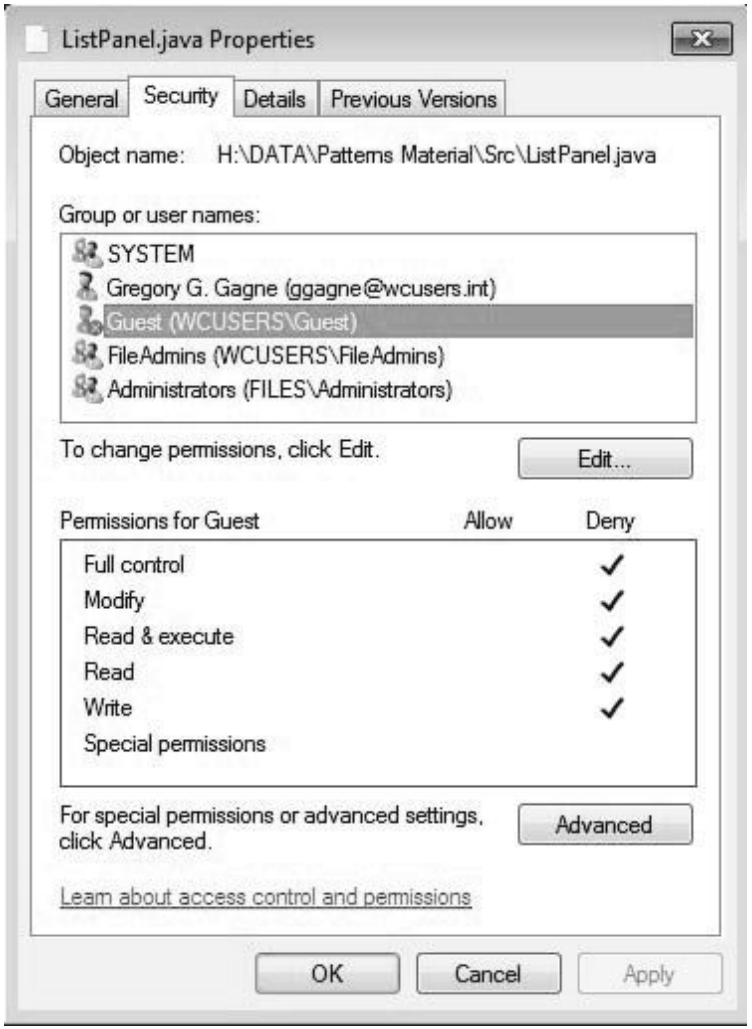
- Example:

-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/

- Explanation:
  - “into.ps” is a file owned by “pbg” with group ”staff”
  - “lib” is a subdirectory owned by “pbg” with group “faculty”



Windows 7 Access-Control List Management



End of Chapter 13