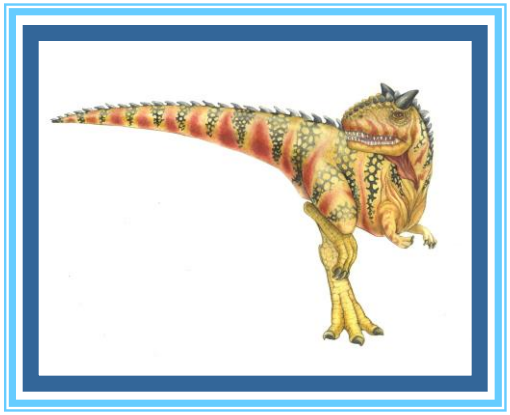
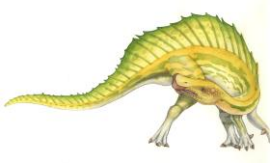
# Chapter 13: File-System Interface



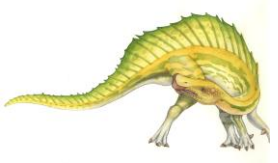
# Outline

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



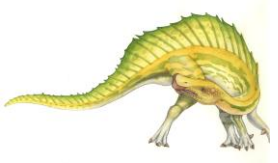
# Objectives

- 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



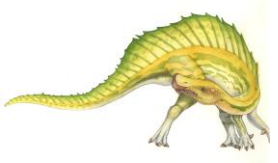
# File Concept

- Contiguous logical address space
- Types:
  - Data
    - Numeric
    - Character
    - Binary
  - Program
- Contents defined by file's creator
  - Many types
    - **text file,**
    - **source file,**
    - **executable file**



# File Attributes

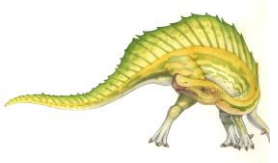
- **Name** – only information kept in human-readable form
- **Identifier** – unique tag (number) identifies file within file system
- **Type** – needed for systems that support different types
- **Location** – pointer to file location on device
- **Size** – current file size
- **Protection** – controls who can do reading, writing, executing
- **Timestamps and user identification** – data for protection, security, and usage monitoring
- Information about files are kept in the directory structure, which is maintained on the disk
- Many variations, including extended file attributes such as file checksum
- Information kept in the directory structure



# File info Window on Mac OS X

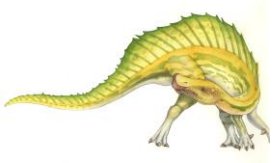
# File Operations

- **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 entry ***$F_i$***, and move the content of entry to memory
- ***Close*** **(*$F_i$*)** – move the content of entry ***$F_i$*** in memory to directory structure on disk



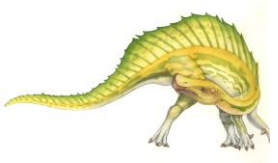
# Open Files

- Several pieces of data are needed to manage open files:
  - **Open-file table**: tracks open files
  - File pointer:  pointer to last read/write location, per process that has the file open
  - **File-open count**: counter of 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: cache of data access information
  - Access rights: per-process access mode information



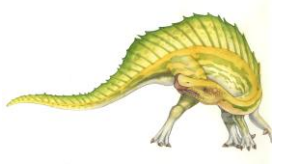
# File Locking

- 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
- Mandatory or advisory:
  - **Mandatory** – access is denied depending on locks held and requested
  - **Advisory** – processes can find status of locks and decide what to do



# File Locking Example – Java API

```
import java.io.*;
import java.nio.channels.*;
public class LockingExample {
    public static final boolean EXCLUSIVE = false;
    public static final boolean SHARED = true;
    public static void main(String arsg[]) throws IOException {
        FileLock sharedLock = null;
        FileLock exclusiveLock = null;
        try {
            RandomAccessFile raf = new RandomAccessFile("file.txt", "rw");
            // get the channel for the file
            FileChannel ch = raf.getChannel();
            // this locks the first half of the file - exclusive
            exclusiveLock = ch.lock(0, raf.length()/2, EXCLUSIVE);
            /** Now modify the data . . . */
            // release the lock
            exclusiveLock.release();
```

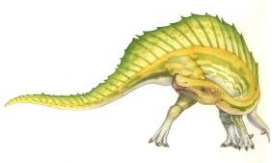


# File Locking Example – Java API (Cont.)

```
                    // this locks the second half of the file - shared
                    sharedLock = ch.lock(raf.length()/2+1, raf.length(),
                                         SHARED);
                    /** Now read the data . . . */
                    // release the lock
                    sharedLock.release();
            } catch (java.io.IOException ioe) {
                    System.err.println(ioe);
            }finally {
                    if (exclusiveLock != null)
                    exclusiveLock.release();
                    if (sharedLock != null)
                    sharedLock.release();
            }
    }
}
```

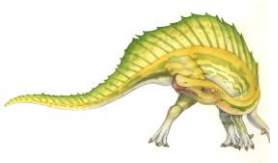
# File Types – Name, Extension

| 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 |



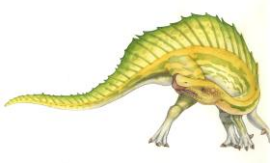
# File Structure

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



# Access Methods

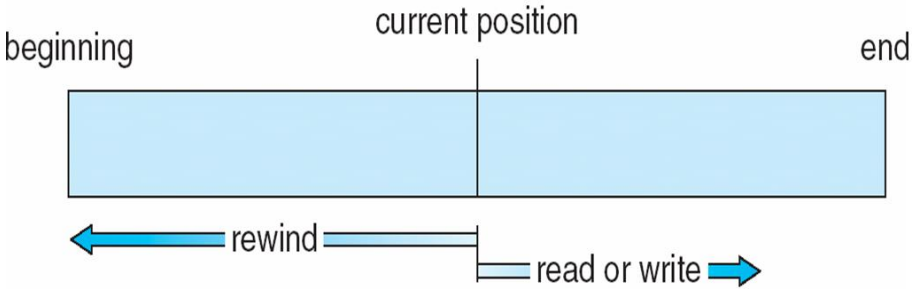
- A file is fixed length **logical records**
- **Sequential Access**
- **Direct Access**
- **Other Access Methods**

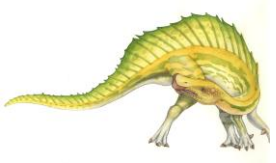


# Sequential Access

- Operations
  - **`read next`**
  - **`write next`**
  - **`Reset`**
  - no read after last write  (rewrite)

- Figure



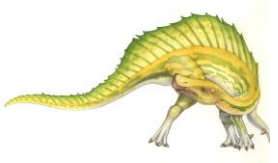



# Direct Access

- Operations
  - **`read n`**
  - **`write n`**
  - **`position to n`**
    - **`read next`**
    - **`write next`**
    - **`rewrite n`**

  *n* = **relative block number**

- Relative block numbers allow OS to decide where file should be placed



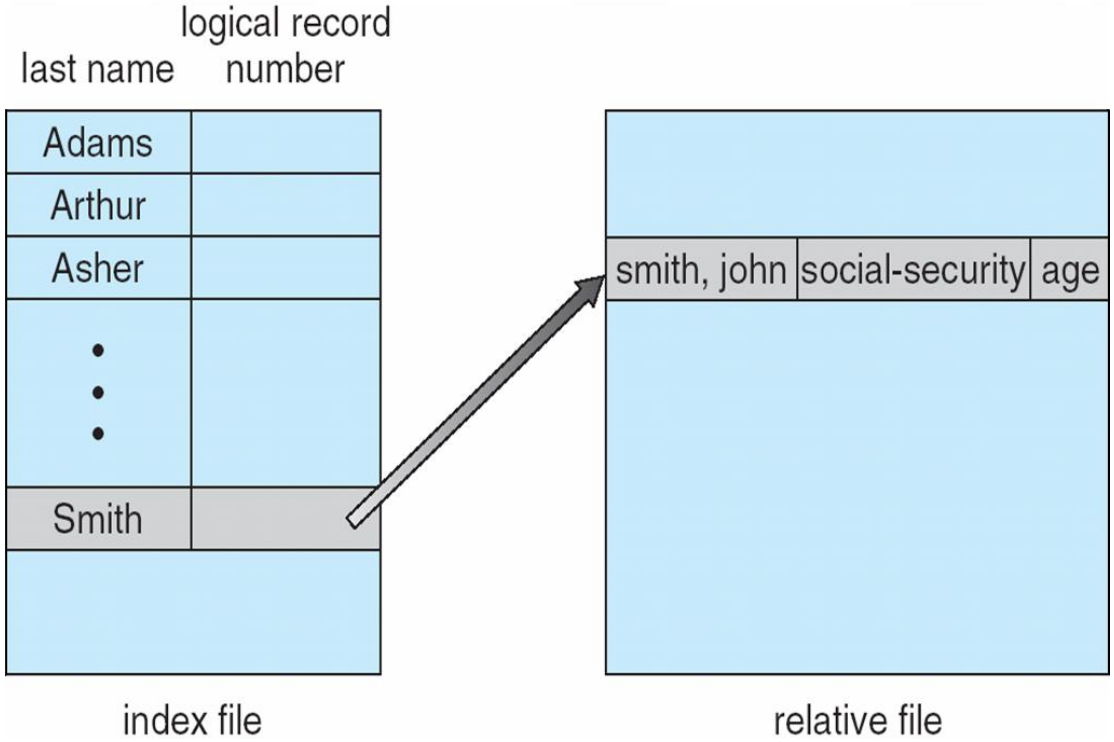
# Simulation of Sequential Access on Direct-access File

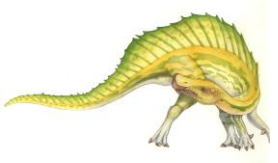
| sequential access | implementation for direct access |
|---|---|
| *reset* | $cp = 0;$ |
| *read next* | *read cp*;<br>$cp = cp + 1;$ |
| *write next* | *write cp*;<br>$cp = cp + 1;$ |

# Other Access Methods

- Can be other access methods built on top of base methods
- General involve creation of an **index** for the file
- Keep index in memory for fast determination of location of data to be operated on (consider Universal Produce Code (UPC code) plus record of data about that item)
- If the index is too large, create an in-memory index, which an index of a disk index
- 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)

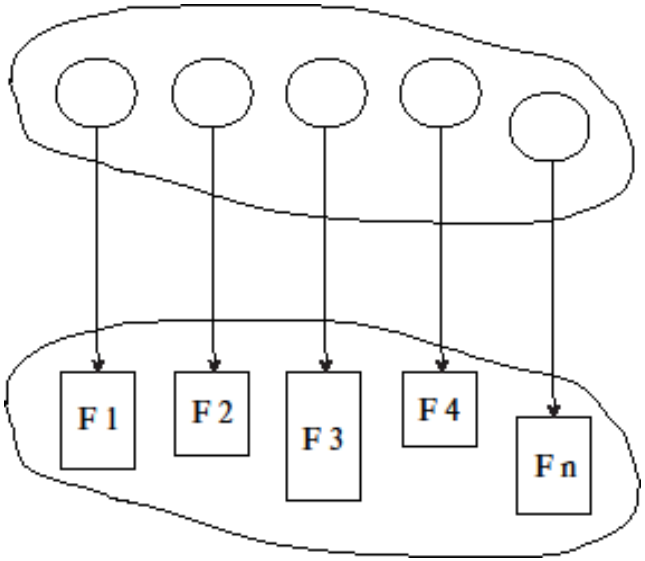
# Example of Index and Relative Files



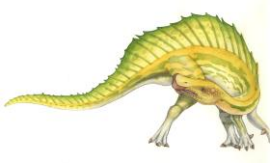



# Directory Structure

- A collection of nodes containing information about all files

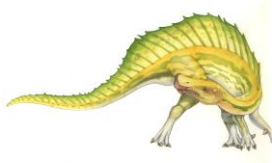



- Both the directory structure and the files reside on disk



# Operations Performed on Directory

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



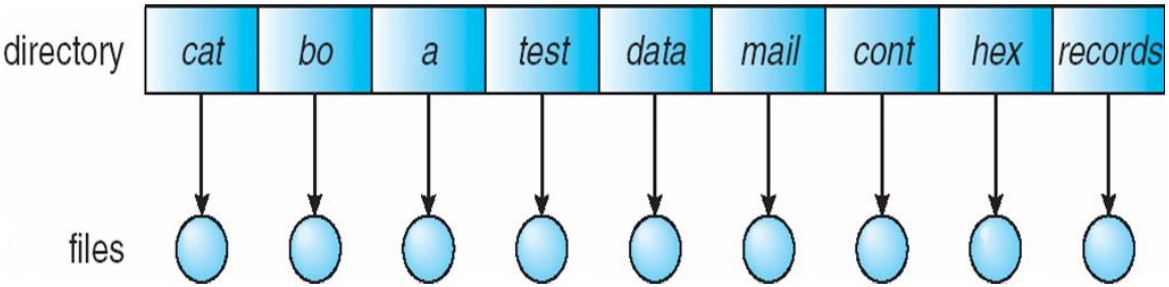
# Directory Organization

The directory is organized logically to obtain

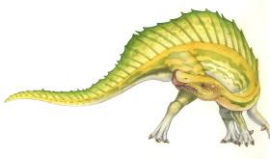
- Efficiency – locating a file quickly
- Naming – convenient to users
  - Two users can have same name for different files
  - The same file can have several different names
- Grouping – logical grouping of files by properties, (e.g., all Java programs, all games, …)

# Single-Level Directory

- A single directory for all users

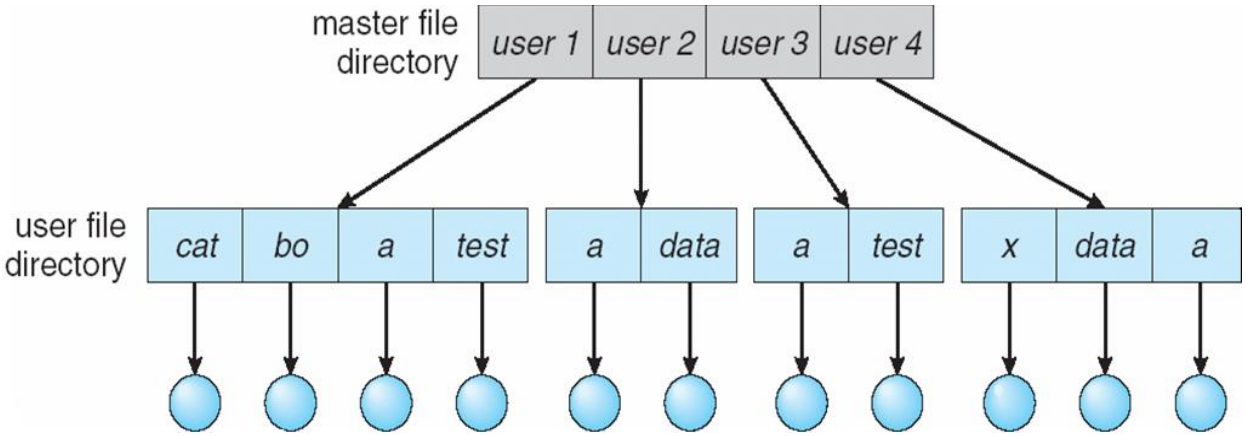



- Naming problem
- Grouping problem

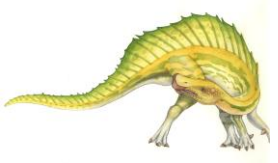


# Two-Level Directory

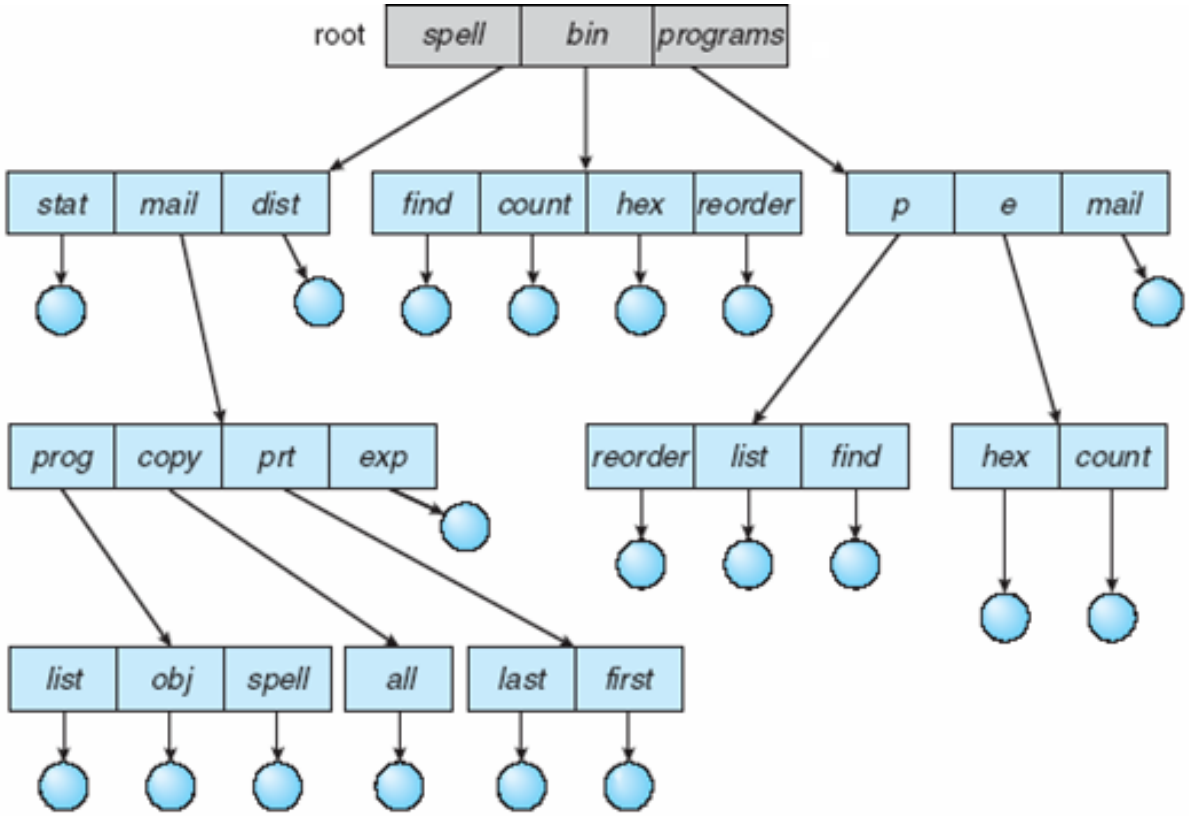
- Separate directory for each user

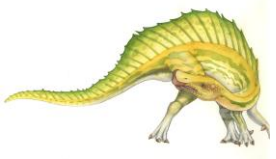



- Path name
- Can have the same file name for different user
- Efficient searching
- No grouping capability



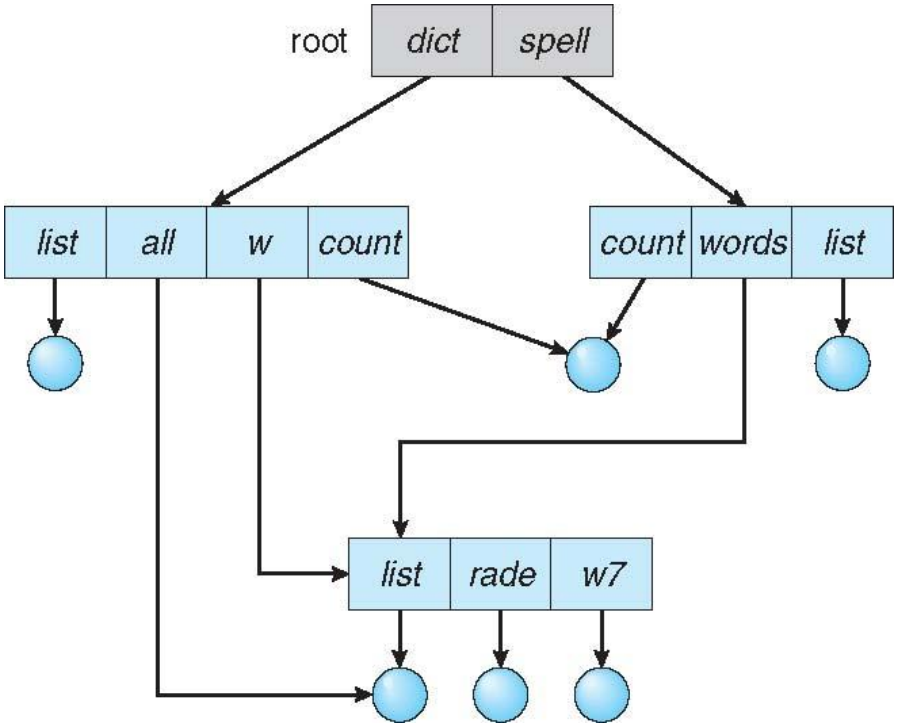
# Tree-Structured Directories

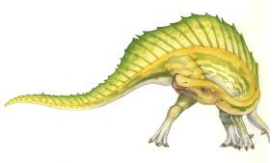


# Acyclic-Graph Directories

- Have shared subdirectories and files
- Example

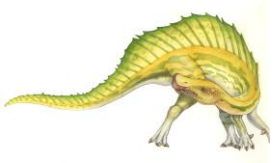


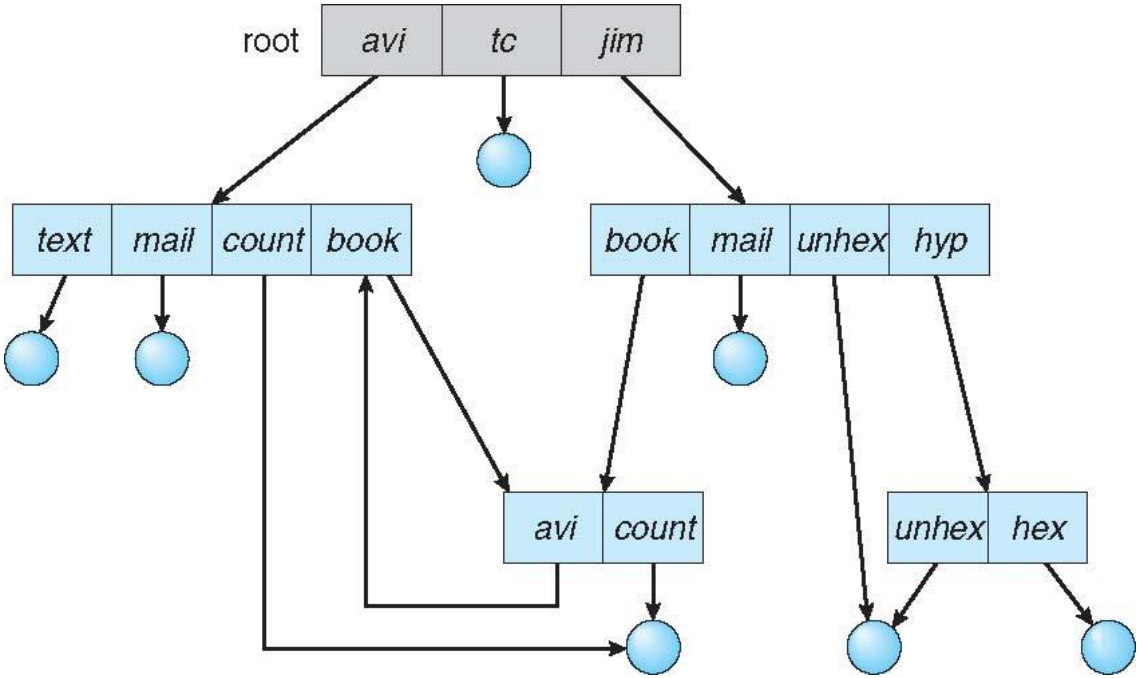
# Acyclic-Graph Directories (Cont.)

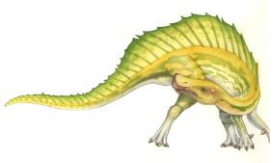
- Two different names (aliasing)
- If ***dict*** deletes **w/*list*** ⇒ dangling pointer

  Solutions:
  - Backpointers, so we can delete all pointers.
    - Variable size records a problem
  - Backpointers using a daisy chain organization
  - Entry-hold-count solution
- New directory entry type
  - **Link** – another name (pointer) to an existing file
  - **Resolve the link** – follow pointer to locate the file



# General Graph Directory



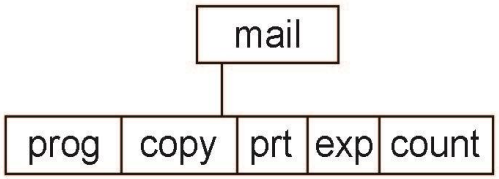
# General Graph Directory (Cont.)

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

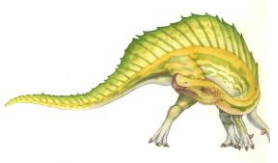
# Current Directory

- Can designate one of the directories as the current (working) directory
  - **`cd /spell/mail/prog`**
  - **`type list`**
- Creating and deleting a file is done in current directory
- Example of creating a new file
  - If in current directory is **`/mail`**
  - The command

    **mkdir <dir-name>**
  - Results in:




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



# Protection

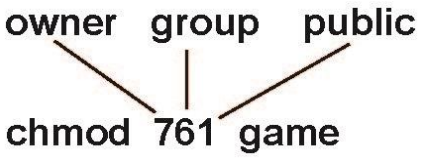
- File owner/creator should be able to control:
  - What can be done
  - By whom
- Types of access
  - **Read**
  - **Write**
  - **Execute**
  - **Append**
  - **Delete**
  - **List**

# Access Lists and Groups in Unix

- Mode of access: read, write, execute
- Three classes of users on Unix / Linux

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

- Ask manager to create a group (unique name), say G, and add some users to the group.
- For a file (say *game*) or subdirectory, define an appropriate access.



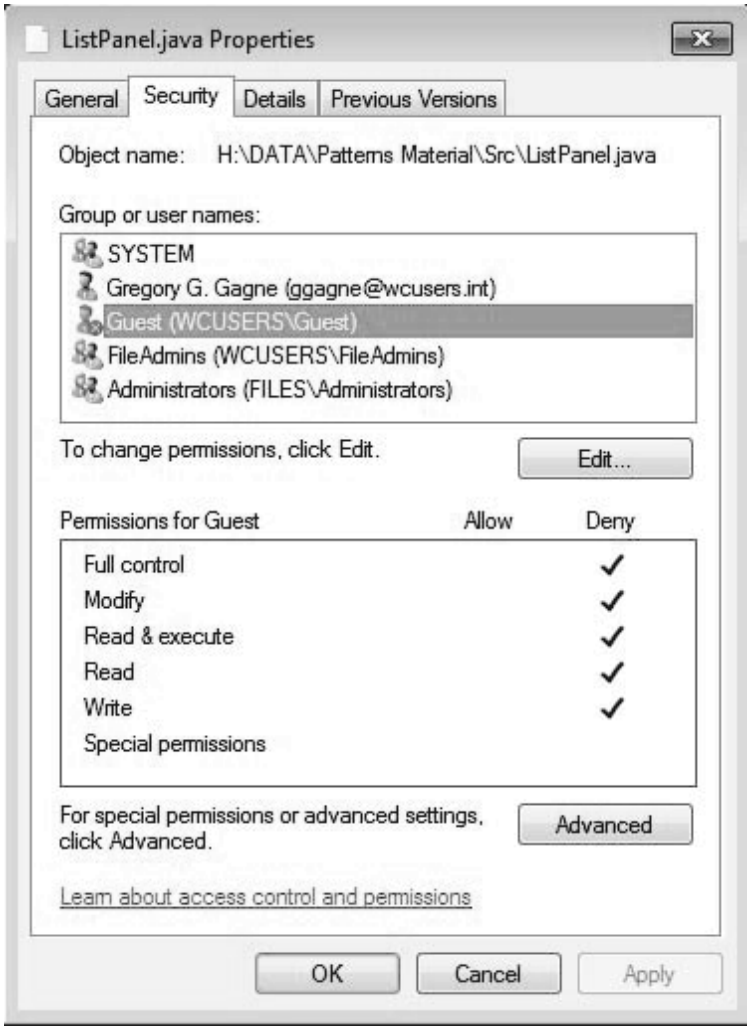

- Attach a group to a file

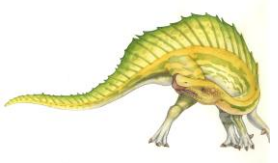
```
chgrp       G       game
```

# 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 7 Access-Control List Management



# End of Chapter 13