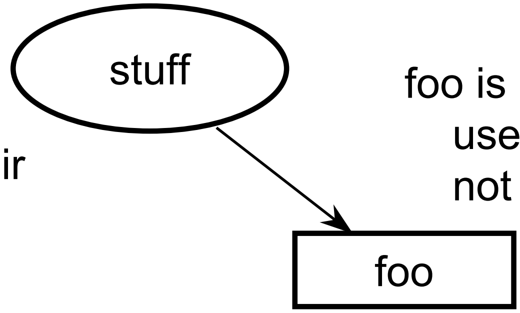
Announcements

- Reading Chapter 12
- Please see class web site for info on project submission format

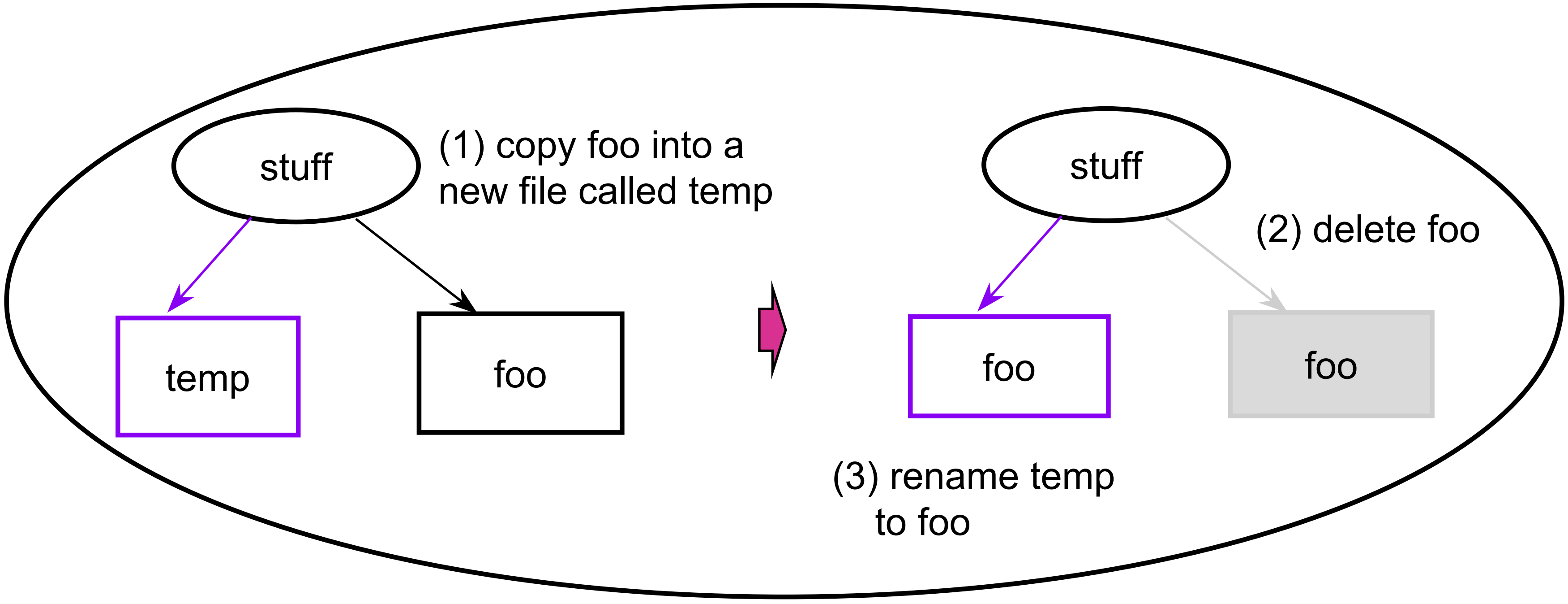
UNIX File Protection Example

Stuff is a directory:
user hollings has r/w/x on the dir



foo is a file:
user hollings has r, but
not write on this file

hollings can still write the file!



(1) copy foo into a new file called temp

(2) delete foo

(3) rename temp to foo

File Protection Example (AFS)

- Each Directory has an ACL
  - protection information applies to all files in a directory
  - file access types are:
    - read, write, lookup, delete, insert, lock (k), administer
  - an ACL may be for a user or a group
  - ACL may contain negative rights
    - everyone but Joe Smith may read this file
- Groups
  - are collections of users
  - each user can create up to a fixed number of groups
    - users can administrate their own groups
- Cells
  - collections of computers (e.g. wam)

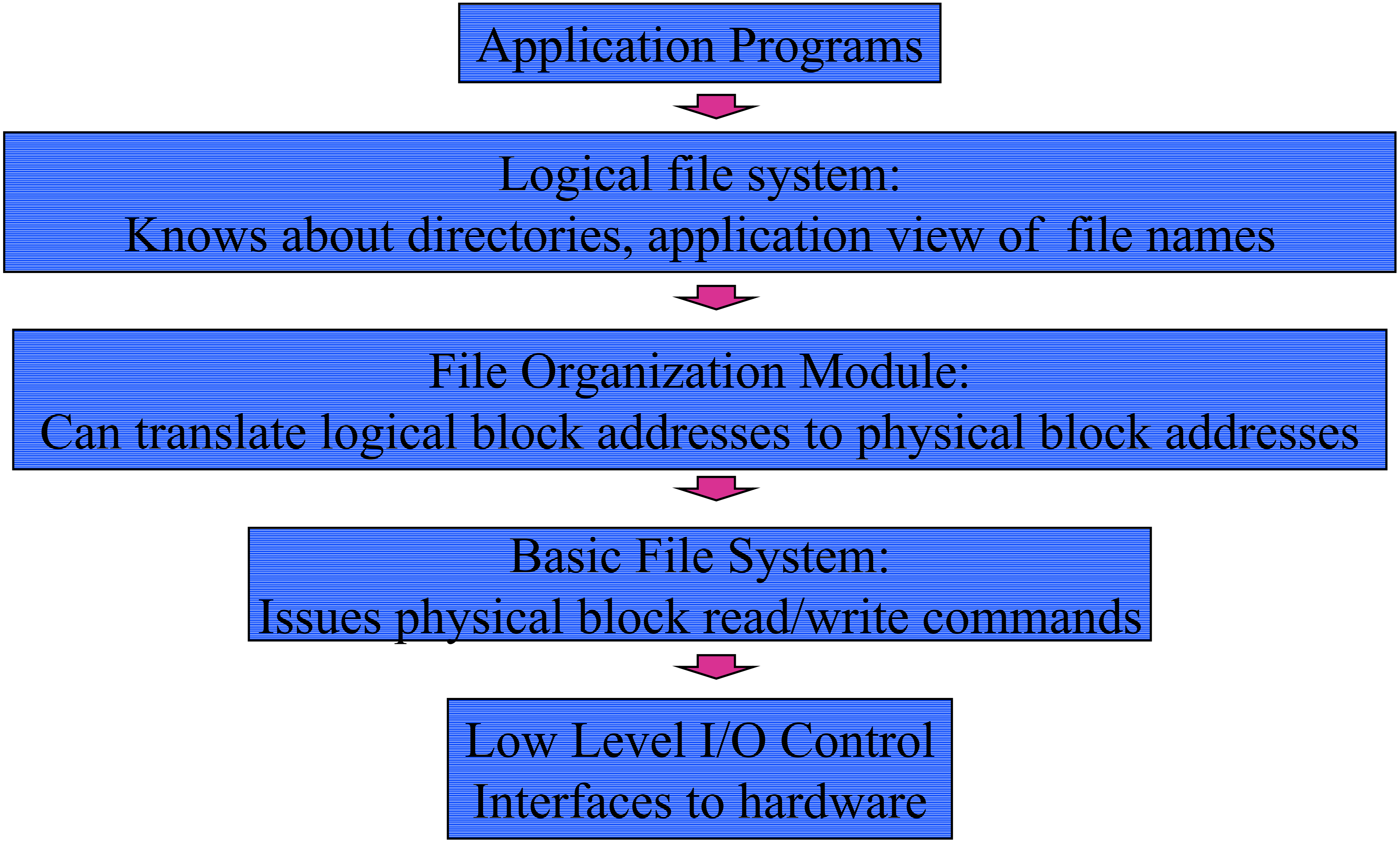
File Consistency semantics

- How do multiple processes see updates to files
- UNIX
  - writes are visible immediately
  - have a mode to permit processes to share file pointers
- AFS
  - open/close semantics
    - “copy” the file on open
    - write-back on close
- Immutable files
  - once made visible to the world, the file never changes
    - usually done by attaching a version # to the filename
  - new versions of the file must be given a new name

Filesystems

- Raw Disks can be viewed as:
  - a linear array of fixed sized units of allocation, called blocks
    - assume that blocks are error free (for now)
    - typical block size is 512 to 4096 bytes
  - can update a block in place, but must write the entire block
  - can access any block in any desired order
    - blocks must be read as a unit
    - for performance reasons may care about “near” vs. “far” blocks (but that is covered in a future lecture)
- A Filesystem:
  - provides a hierarchical namespace via directories
  - permits files of variable size to be stored
  - provides disk protection by restricting access to files based on permissions

File System Implementation



Application Programs

Logical file system:
Knows about directories, application view of file names

File Organization Module:
Can translate logical block addresses to physical block addresses

Basic File System:
Issues physical block read/write commands

Low Level I/O Control
Interfaces to hardware

Allocation Methods

- How do we select a free disk block to use?
- Contiguous allocation
  - allocate a contiguous chunk of space to a file
  - directory entry indicates the starting block and the length of the file
  - easy to implement, but
    - how to satisfy a given sized request from a list of free holes?
    - two options
      - first fit (find the first gap that fits)
      - best fit (find the smallest gaps that is large enough)
    - What happens if one wants to append to file?
  - from time to time, one will need to repack files

Linked Allocation

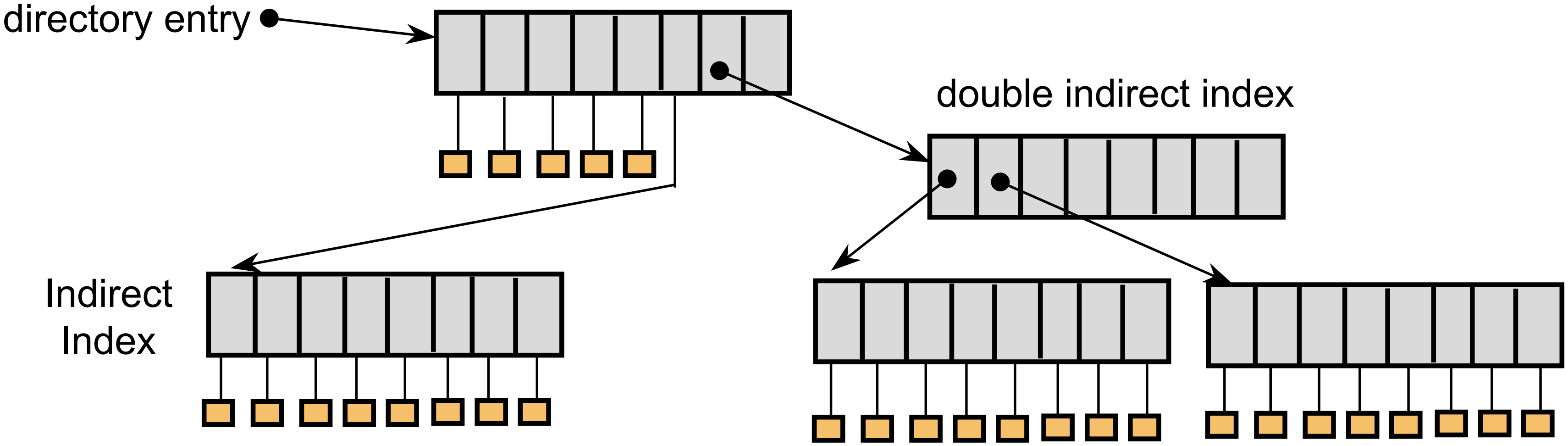
- Each file is a linked list of disk blocks, blocks can be located anywhere
  - Directory contains a pointer to the first and last block of a file
  - Each block contains a pointer to the next block
  - This is essentially a linked-list data structure
- Problems:
  - Best for sequential access data structures
    - requires sequential access whether you want to or not!
  - Reliability - one bad sector and all portions of your file downstream are lost
- Useful fix:
  - Maintain a separate data structure just to keep track of linked lists
  - Data-structure includes pointers to actual blocks

Indexed Allocation

- Bring all pointers together in an *index block*
  - Each file has its own index block - *i*th entry of index block points to *i*th block making up the file
- How large to make an index block?
  - To avoid a fixed maximum file size, index block must be extensible
- Linked scheme:
  - maintain a linked list of indexed blocks
- Multilevel index:
  - Index block can point to other index blocks (which point to index blocks ....), which point to files
- Hybrid multi-level index
  - first n blocks are from a fixed index
  - next m blocks from an indirect index
  - next o blocks from a double indirect index

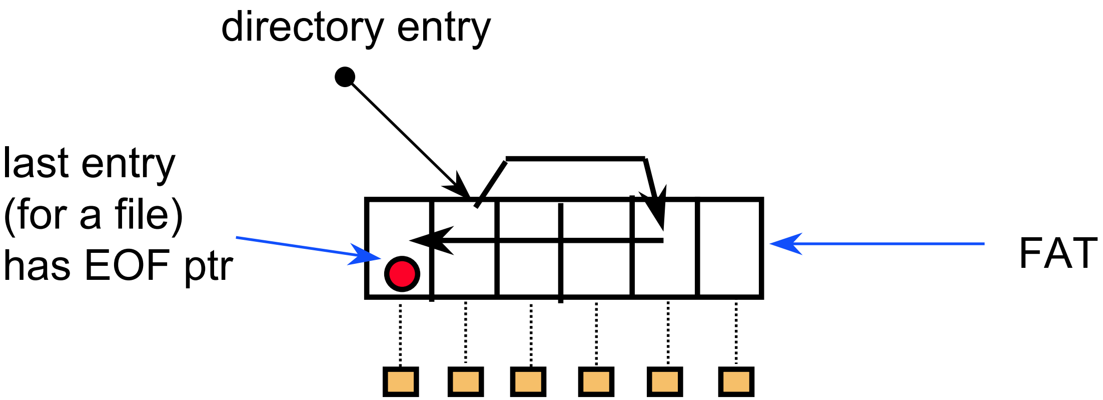
Hybrid Multi-level Index (UNIX)

- Observations
  - most files are small
  - most of the space on the disk is consumed by large files
- Want a flexible way to support different sized
  - assume 4096 byte block
  - first 12 blocks (48 KB) are from a fixed index
  - next 1024 blocks (4 MB) from an indirect index
  - next 1024^2 blocks (16 GB) from a double indirect index
  - final 1024^3 blocks (64 TB) from a triple indirect index



Modified Linked Allocation (FAT)

- Section of disk contains a table
  - called the file allocate table (FAT)
  - used in MS-DOS
- Directory entry contains the block number of the first block in the file
- Table entry contains the number of the next block in the file
- Last block has a end-of-file value as a table entry



directory entry

last entry
(for a file)
has EOF ptr

FAT

i^{th} block corresponds to the i^{th} FAT entry

Performance Issues

- FAT
  - ✔ simple, easy to implement
  - ✔ faster to traverse than linked allocation
  - – random access requires following links
  - – files can’t have holes in them
- Hybrid indirect
  - ✔ fast access to any part of the file
  - ✔ files can have holes in them
  - – more complex

Free Space Management

- How do we find a disk block to allocate?
- Bit Vectors
  - array of bits (one per block) that indicates if a block is free
  - compact so can keep in memory
    - 100 GB disk, 4K blocks -> 6MB per disk (0.003%)
  - easy to find long runs of free blocks
- Linked lists
  - each disk block contains the pointer to the next free block
  - pointer to first free block is keep in a special location on disk
- Run length encoding (called counting in book)
  - pointer to first free block is keep in a special location on disk
  - each free block also includes a count of the number of consecutive blocks that are free