Operating System Concepts

Lecture 31: File System Implementation

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MWF 12:00-12:50 VVC 2 215

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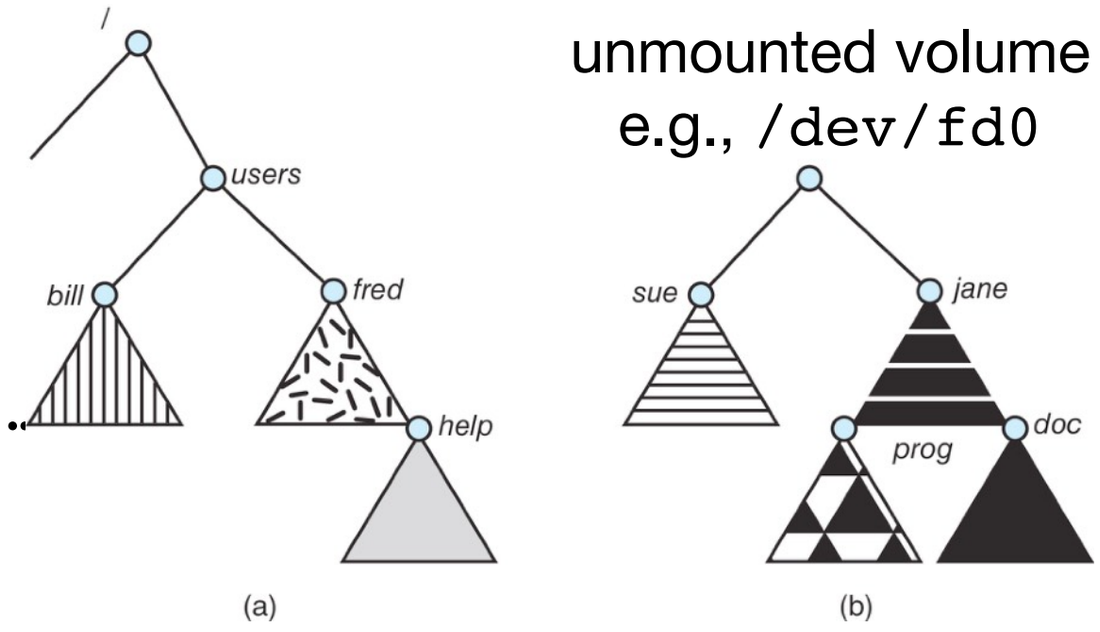
  - so if `/dev/sdb` mounted over `/home` contains a directory called `userx` its full path name will be `/home/userx`
- mount point is usually an empty directory
  - but what if it is not empty?
    - disallow the mount
    - obscure the directory's existing files until the file system is unmounted

Mounting over a nonempty directory

the existing file system, e.g.,
root partition containing the OS

unmounted volume
e.g., `/dev/fd0`



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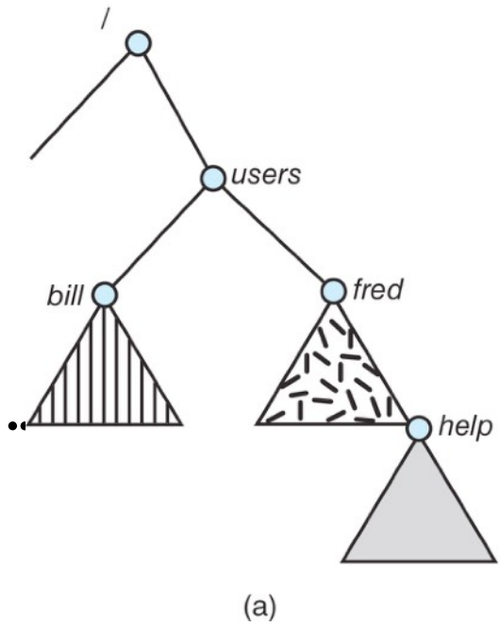

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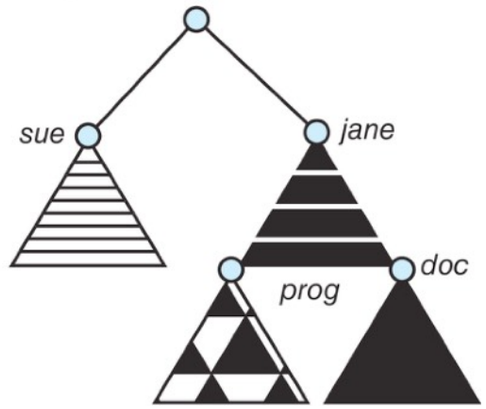

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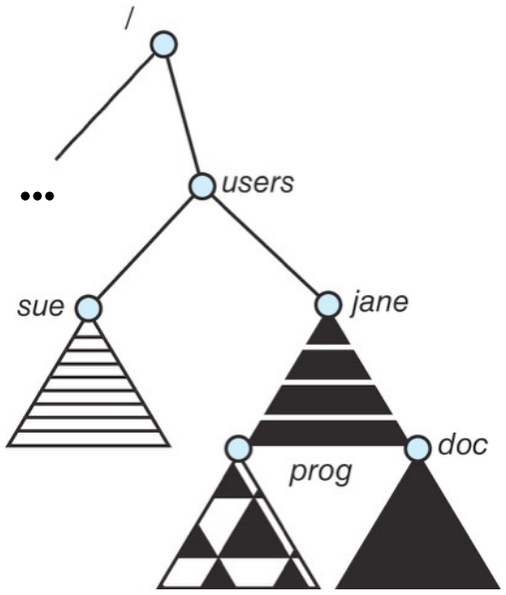
mounting over `/users`



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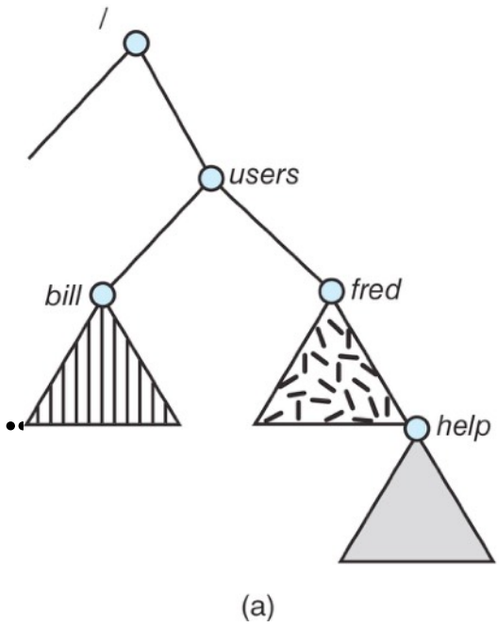

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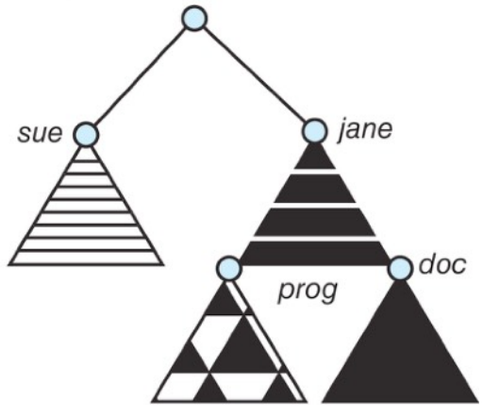

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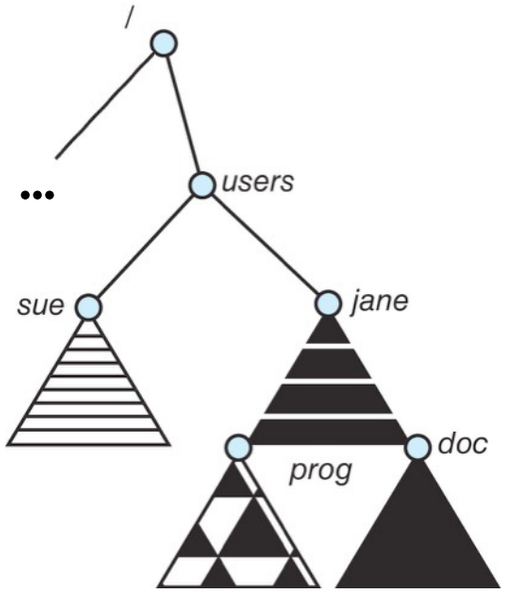

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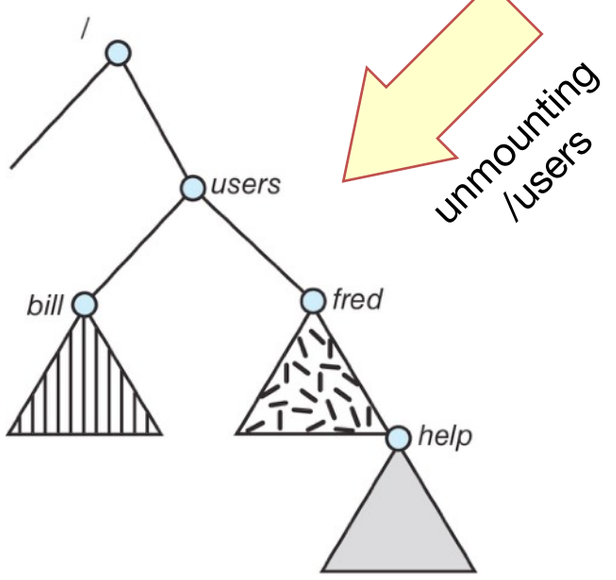

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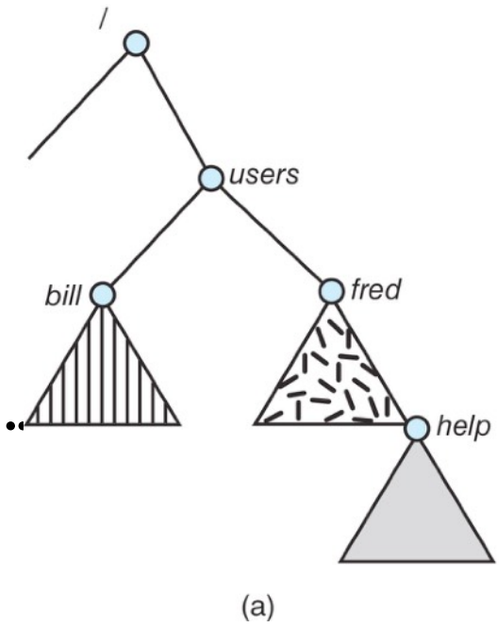

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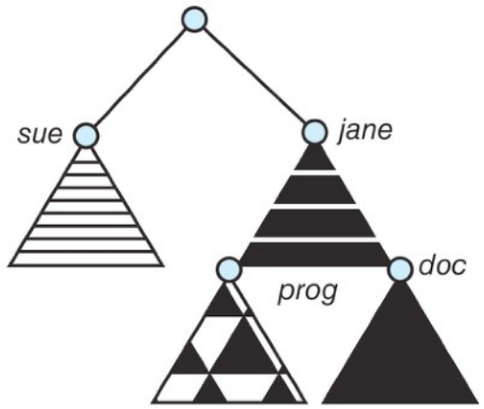

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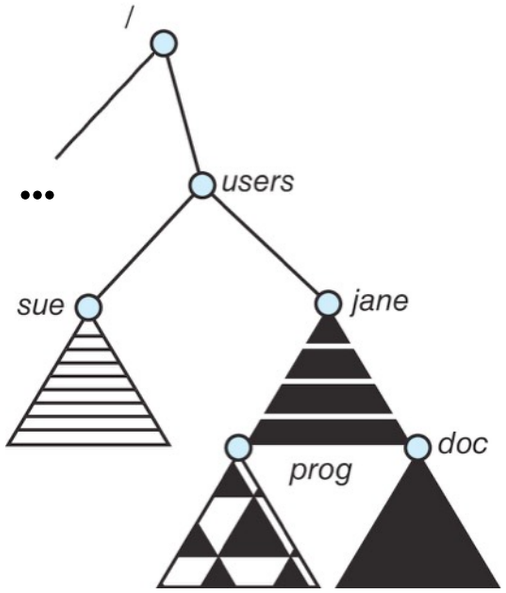

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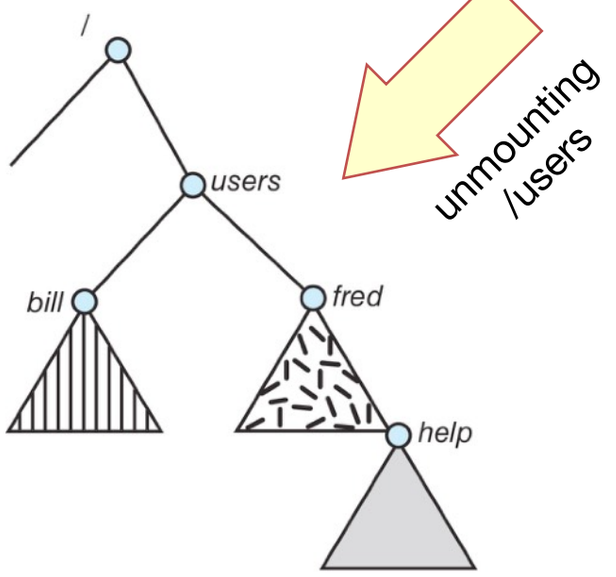


(a)

see `man mount` in Linux

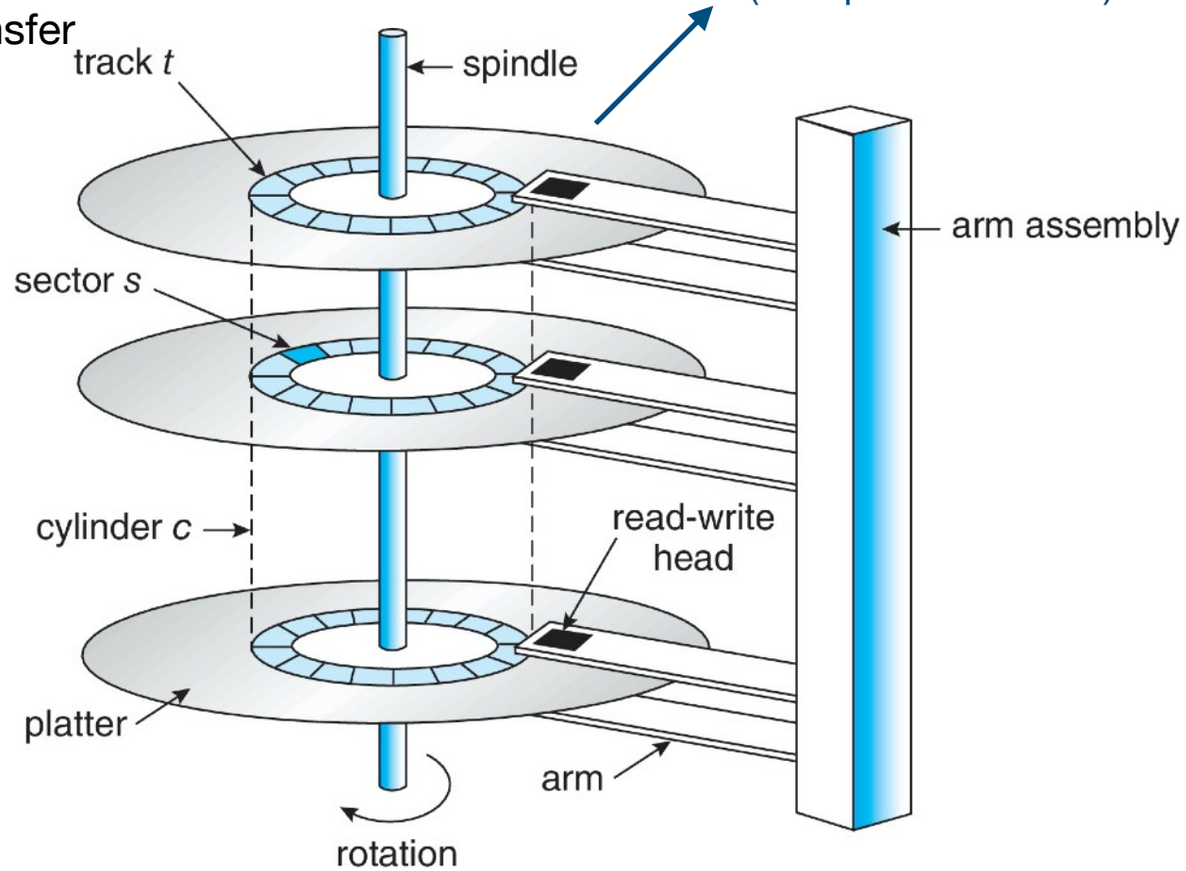
Today's class

- How file system requests disk I/O and how it is handled?
- How disk blocks are allocated to files?
  - contiguous allocation
  - linked allocation
  - indexed allocation
  - multilevel indexed allocation

Disk structure

- disks come organized in disk pack consisting of a stack of circular platters
  - each platter has two sides where each side has its own read-write head (above and below the platter)
- tracks are concentric rings on disk platter (bits are laid out serially on tracks)
  - the first track is the outer-most track on each platter
- a cylinder is a set of vertically-aligned tracks on all platters
- each track is divided into a number of sectors
  - a sector/block defines the minimum unit of data transfer
  - a sector has a specific physical address, commonly expressed as a CHS (cylinder-head-sector) tuple
    e.g., cylinder 45, head 6, sector 10

both sides of platters are used (except on the ends)



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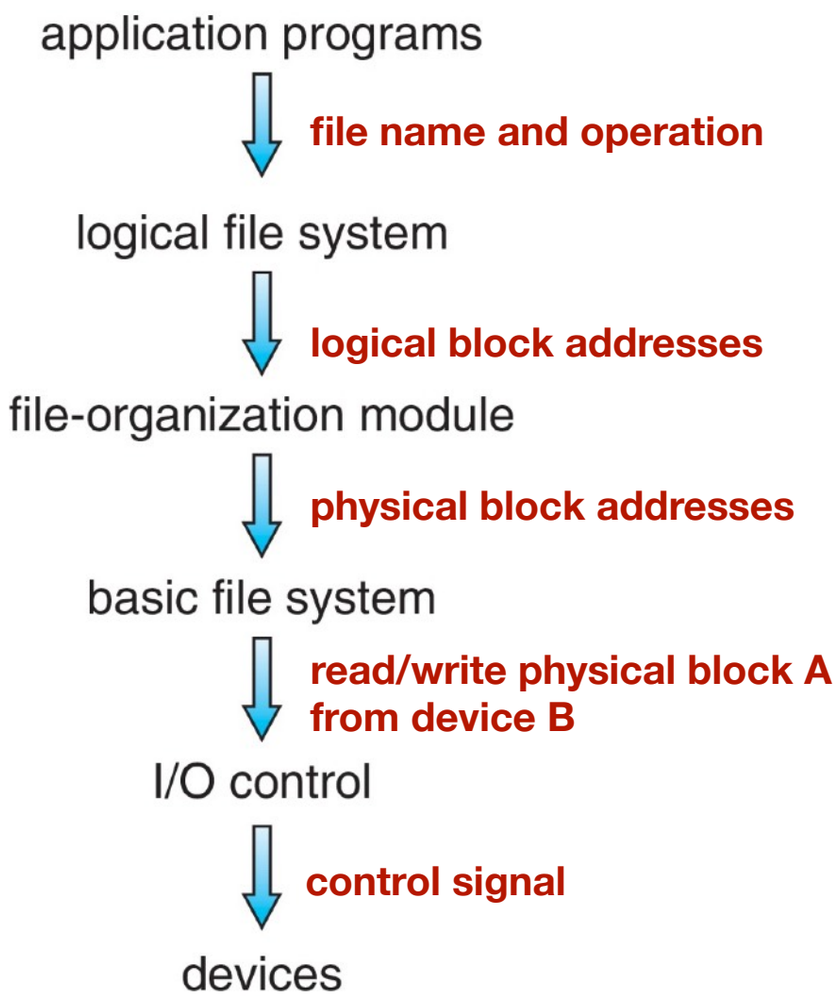
- a block in the file system memory buffer is allocated before the transfer of a disk block starts

Disk latency and bandwidth

- I/O latency: time to initiate a disk transfer of 1 byte to memory
  - seek time: time to position the head over the correct cylinder
  - rotational latency: the time for the correct sector to rotate under the head
- bandwidth: the rate of I/O transfer once it starts

Layered file system



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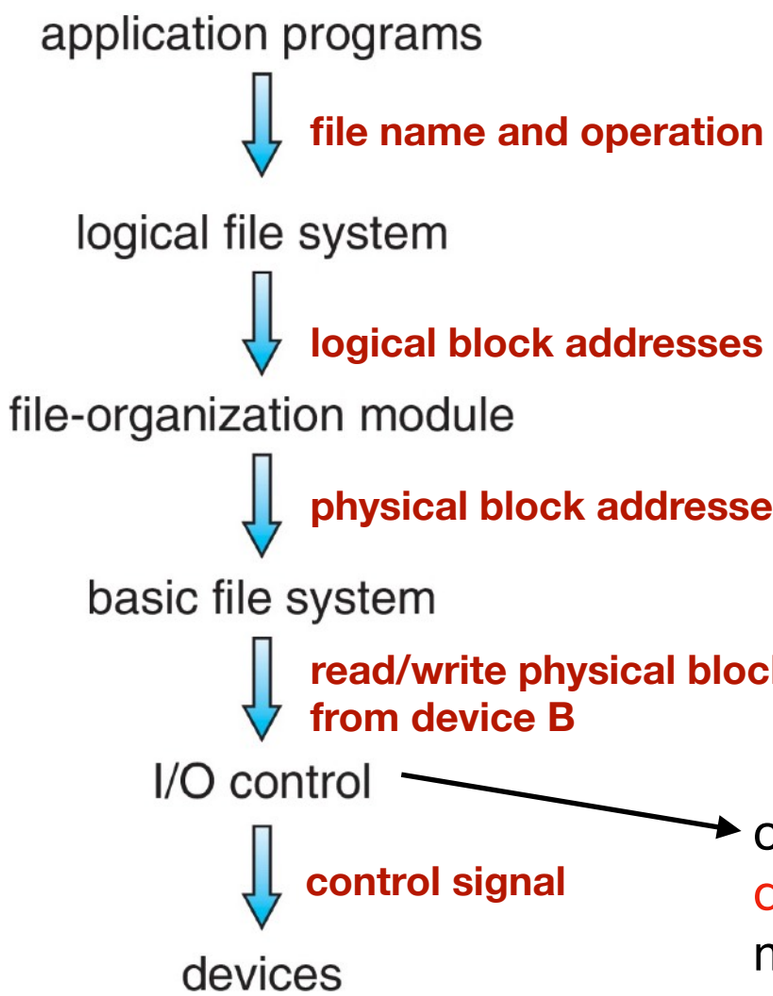

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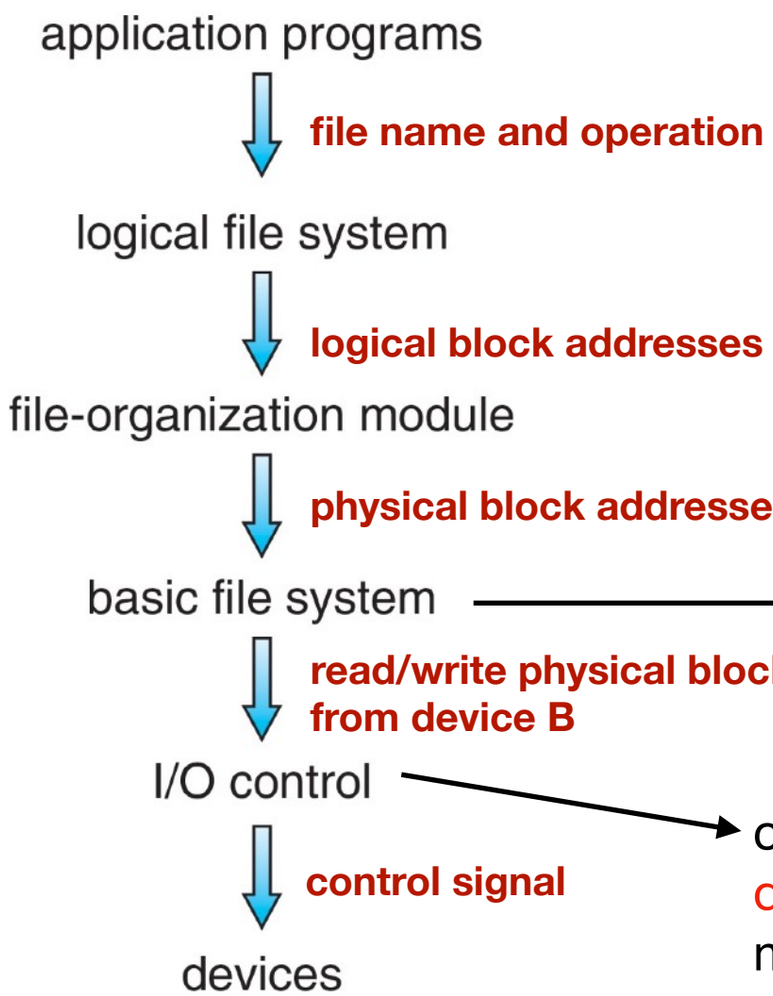

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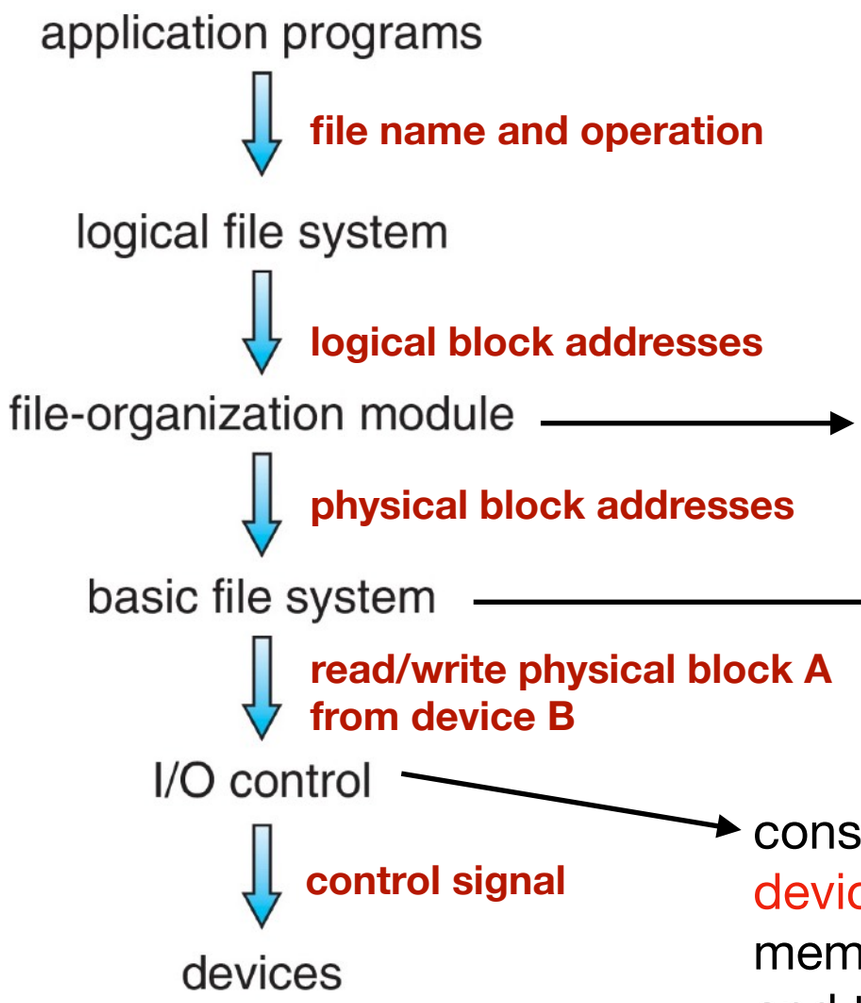

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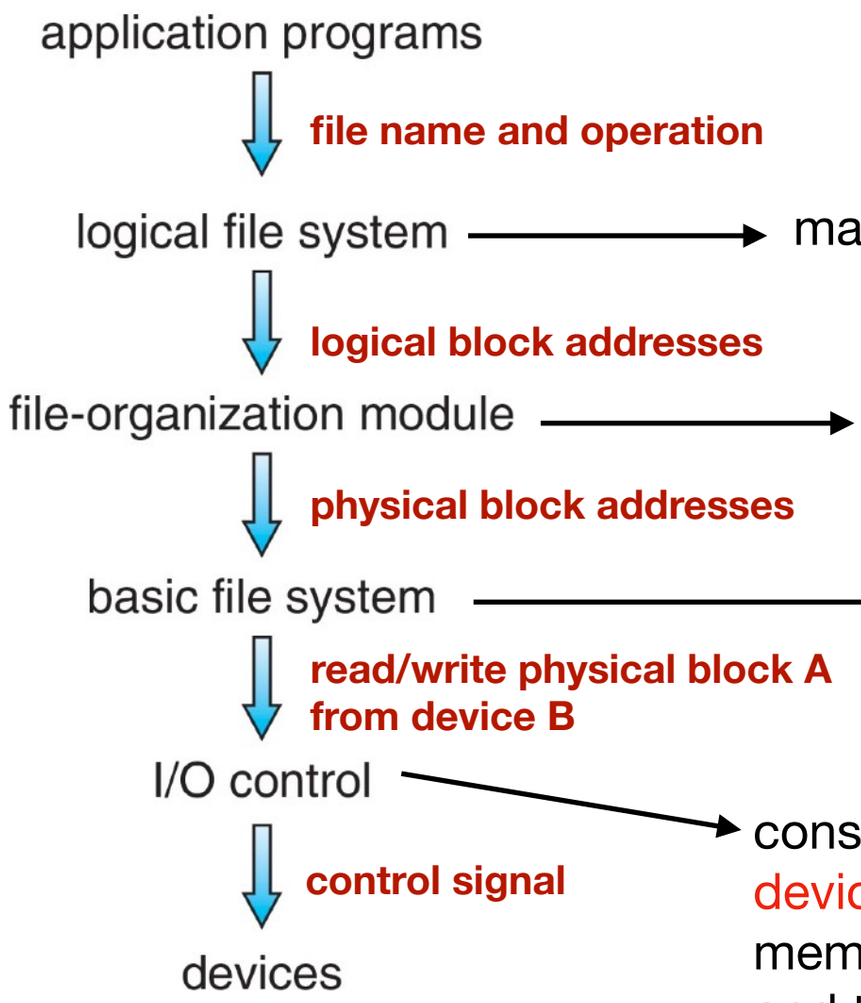

maintains directory structure and file metadata (in FCB)

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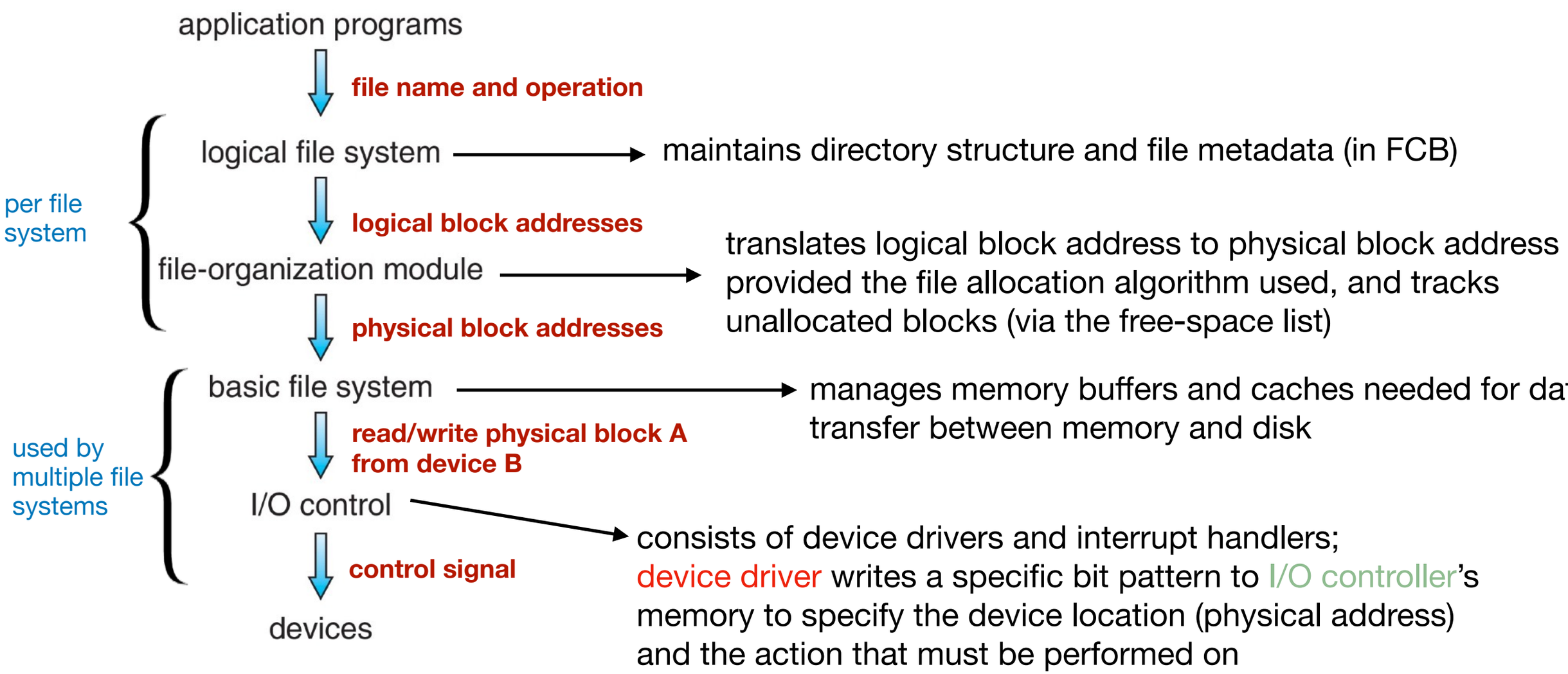

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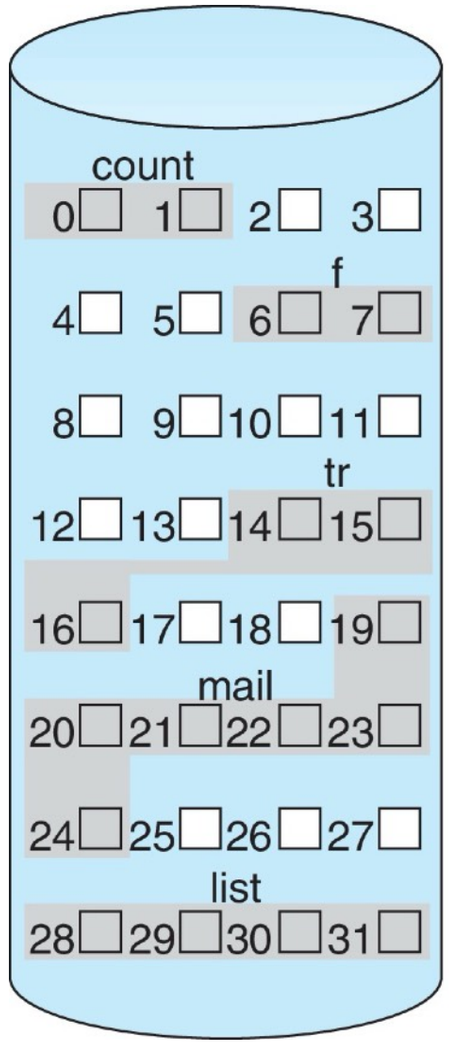

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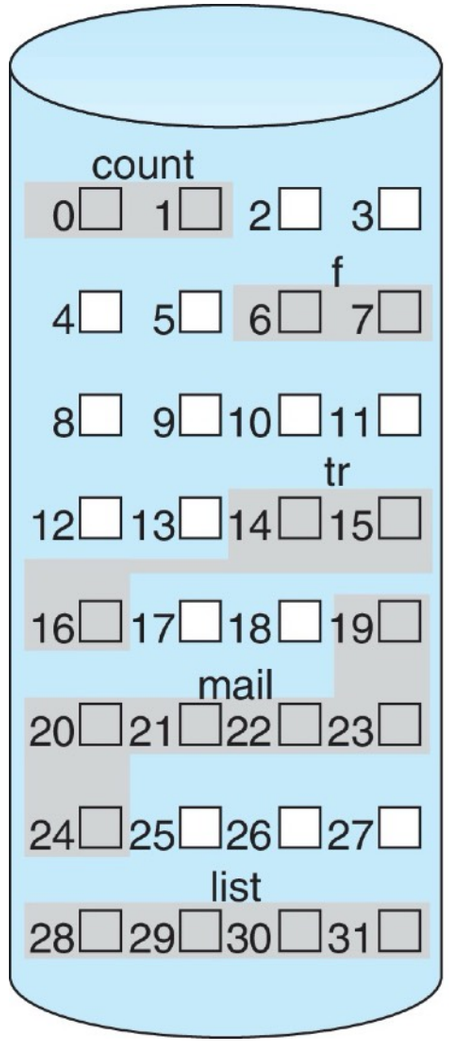

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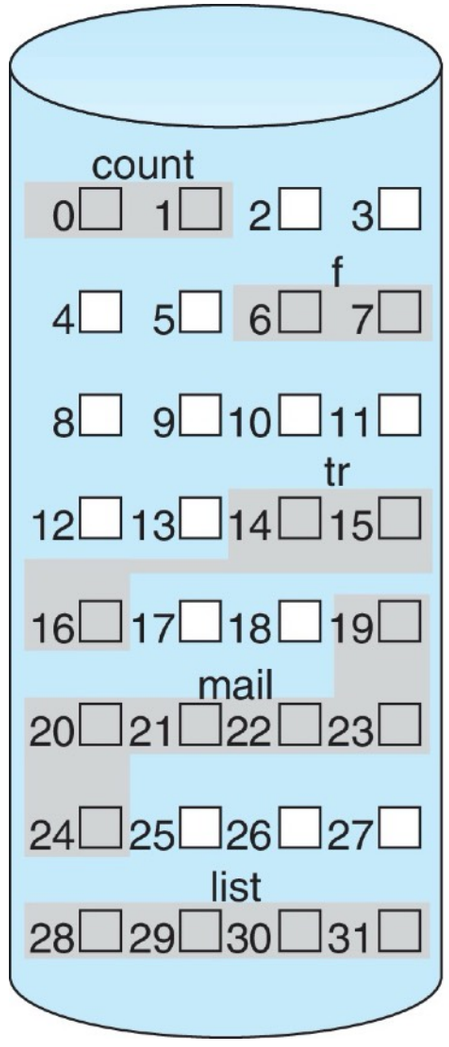

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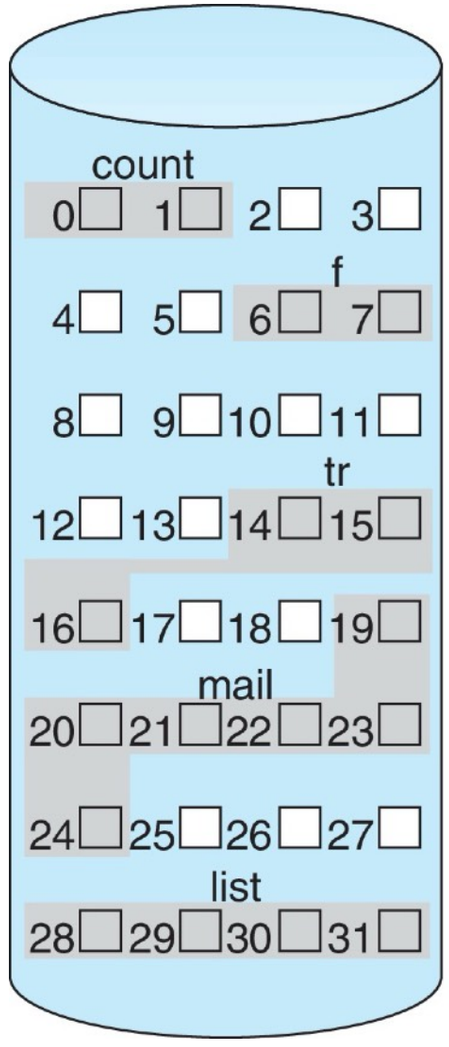
- ideal for write-once read-many (WORM) devices, like CD-R and DVD-R (**why?**)



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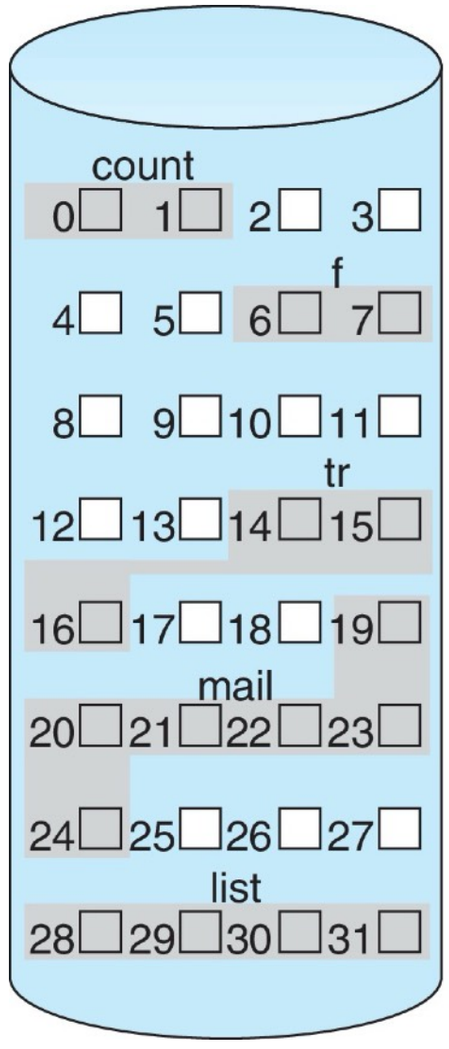

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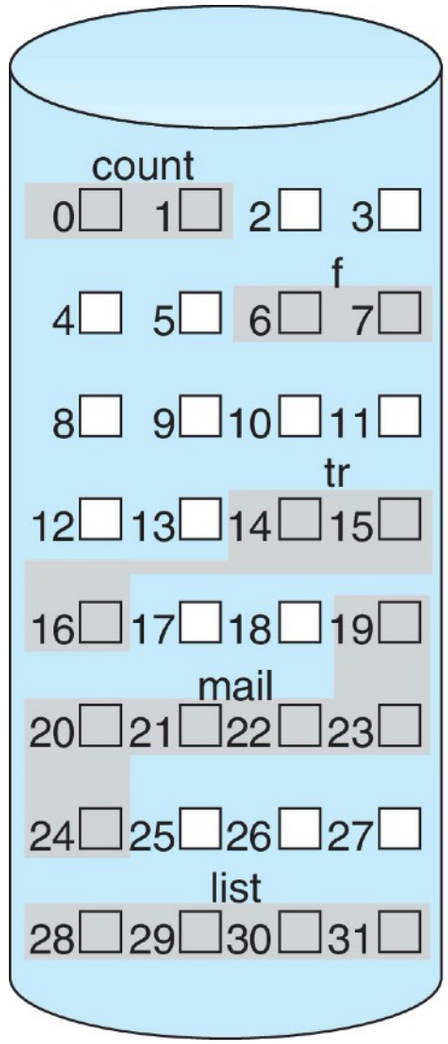

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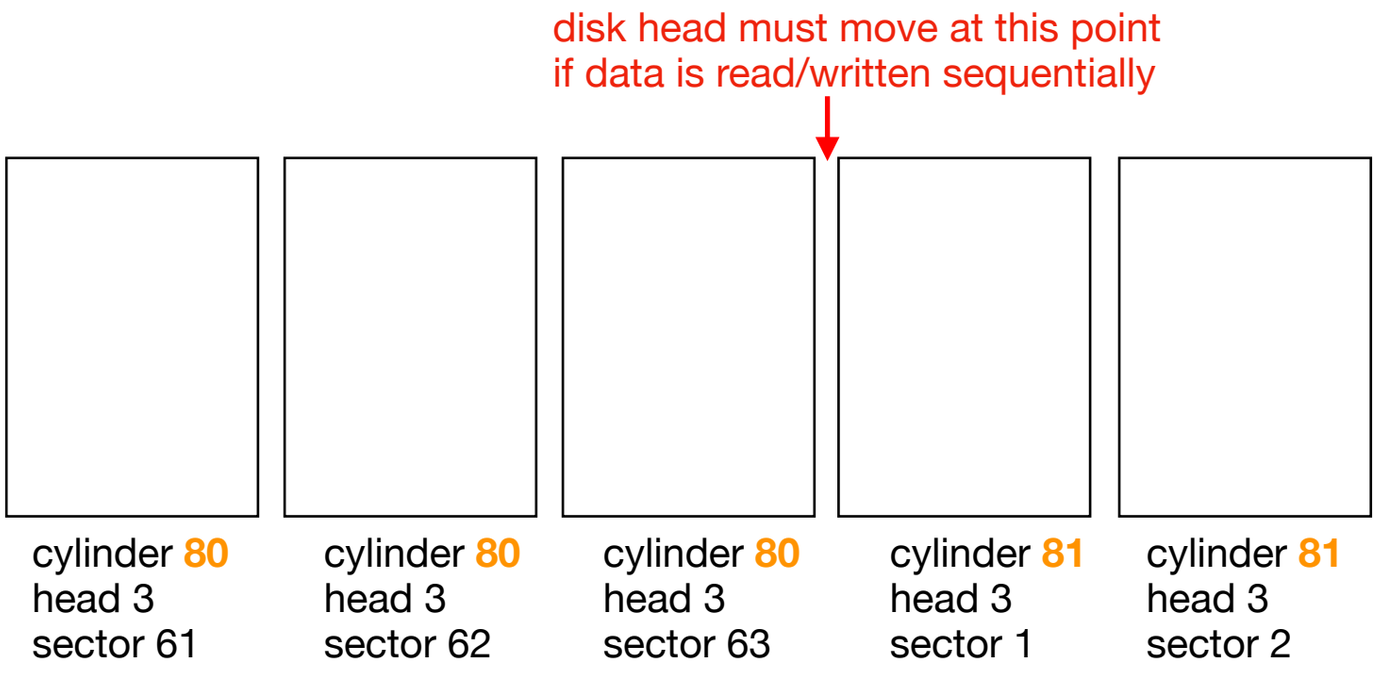

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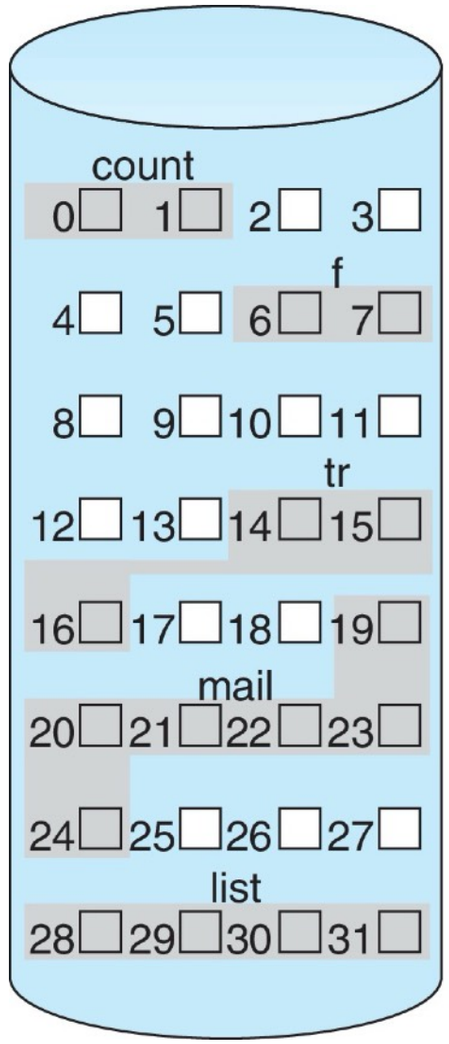

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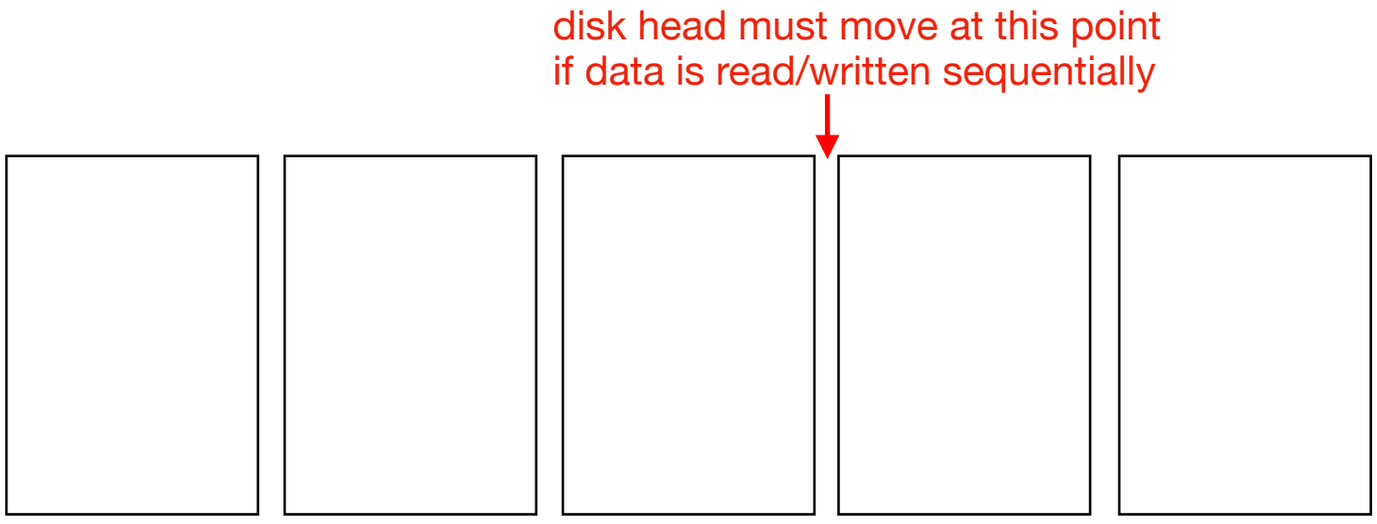

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How to do this translation?

logical disk block n → cylinder i, head j, sector k

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  - so a file consists of multiple extents, each being a contiguous chunk of space
- keep a link to the first block of the next extent allocated to this file in addition to recording the start block and length of each extent
- how to set the extent size?
  - large extent sizes cause internal fragmentation
  - using variable-size extents contributes to external fragmentation

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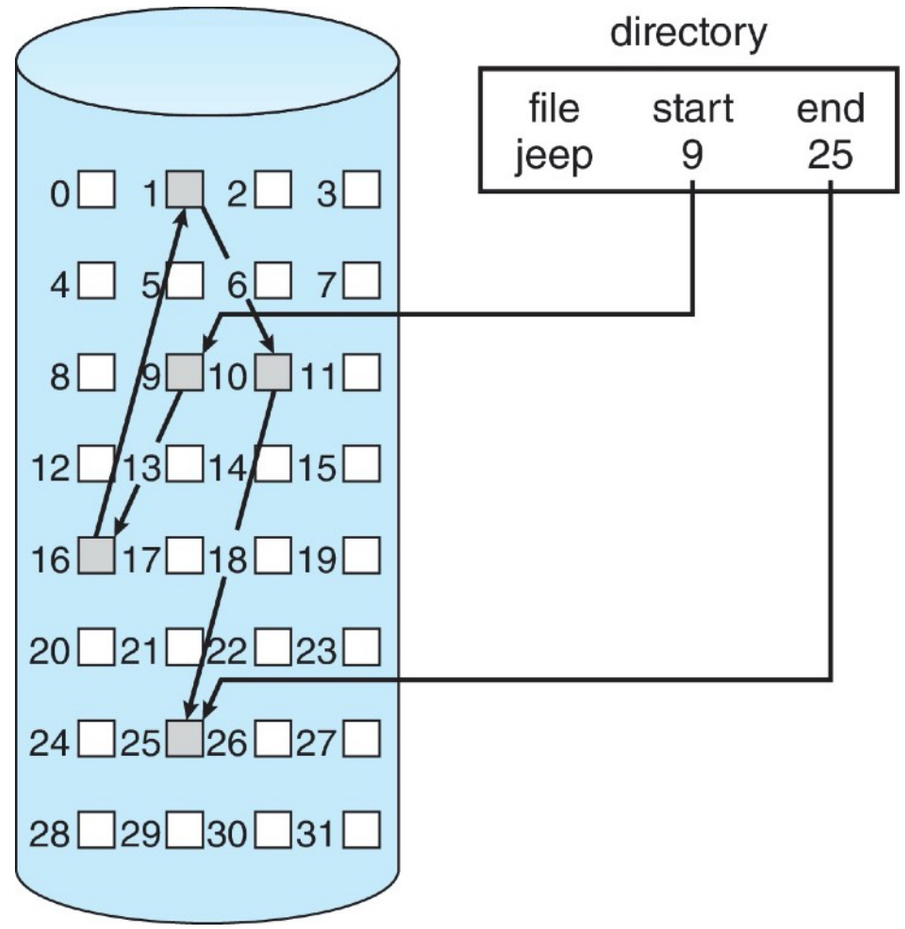

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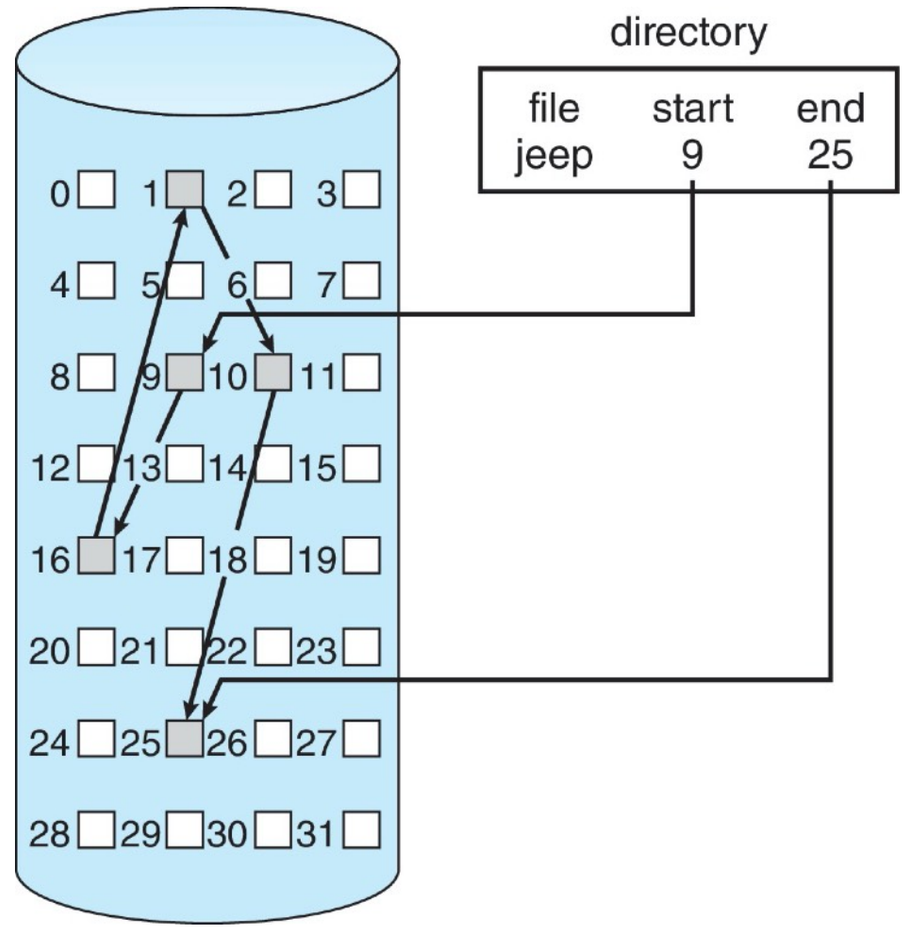

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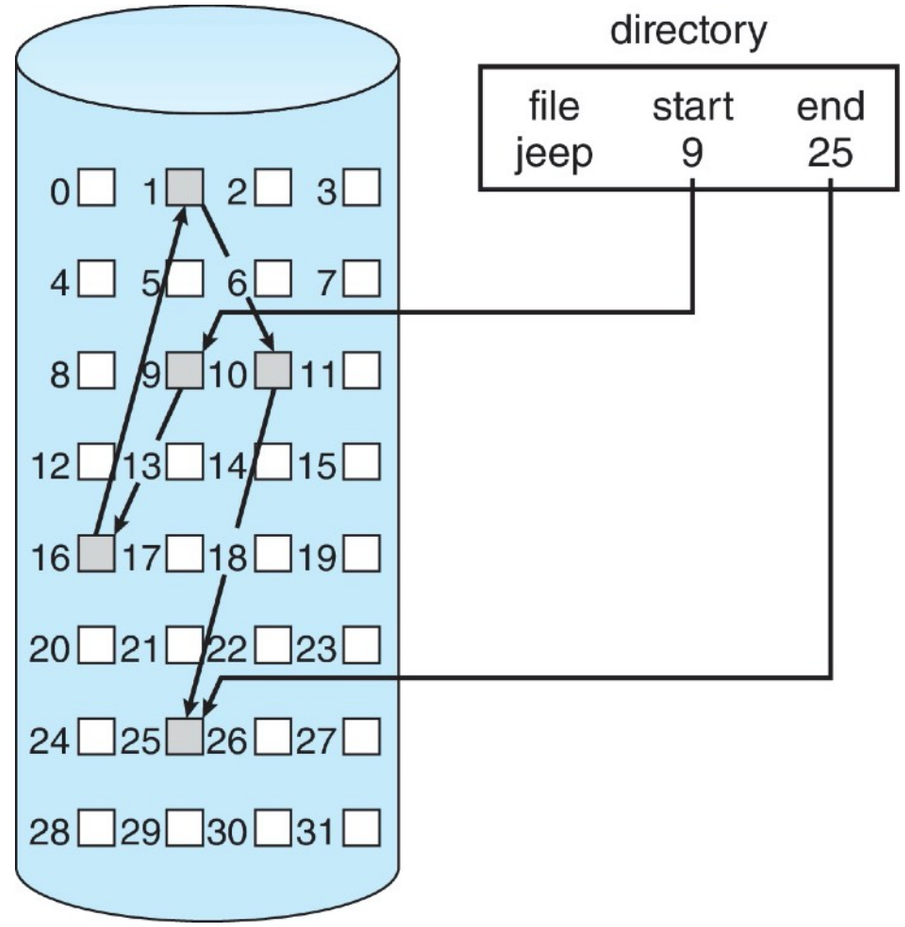

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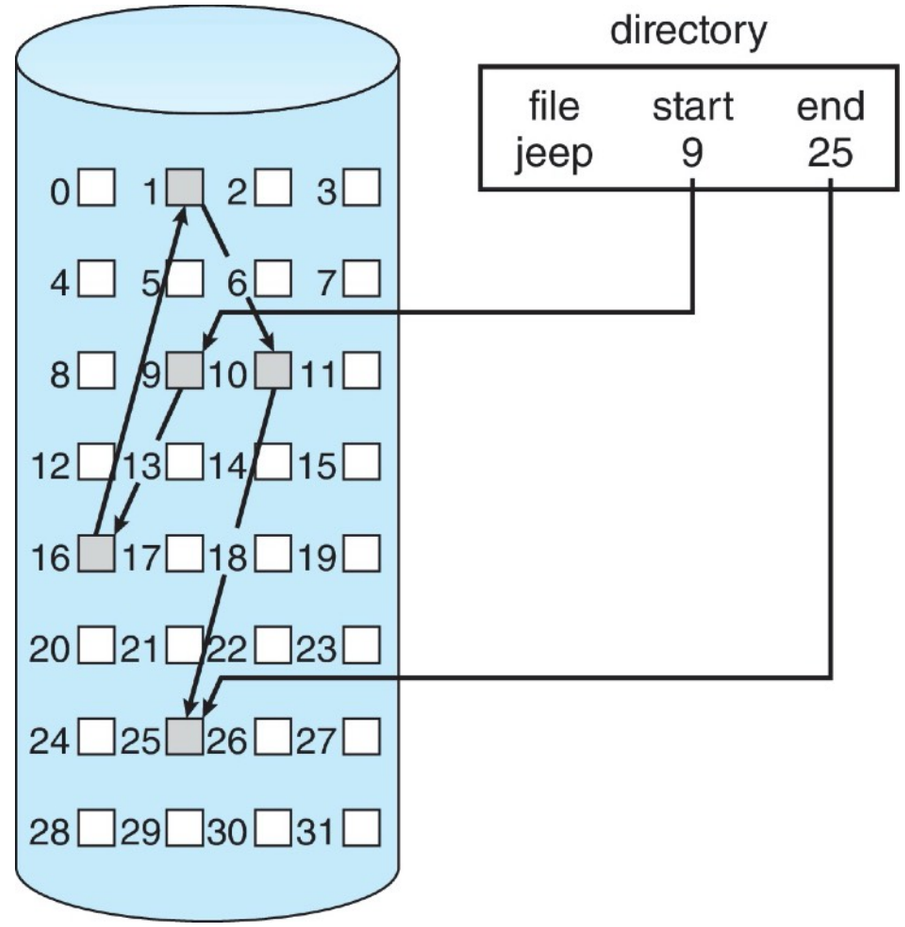
  - if each block is 512 bytes and a pointer to the next block needs 4 bytes (assuming 32-bit address space), only 508 bytes from each block are available to user; so 0.78% of disk space is wasted



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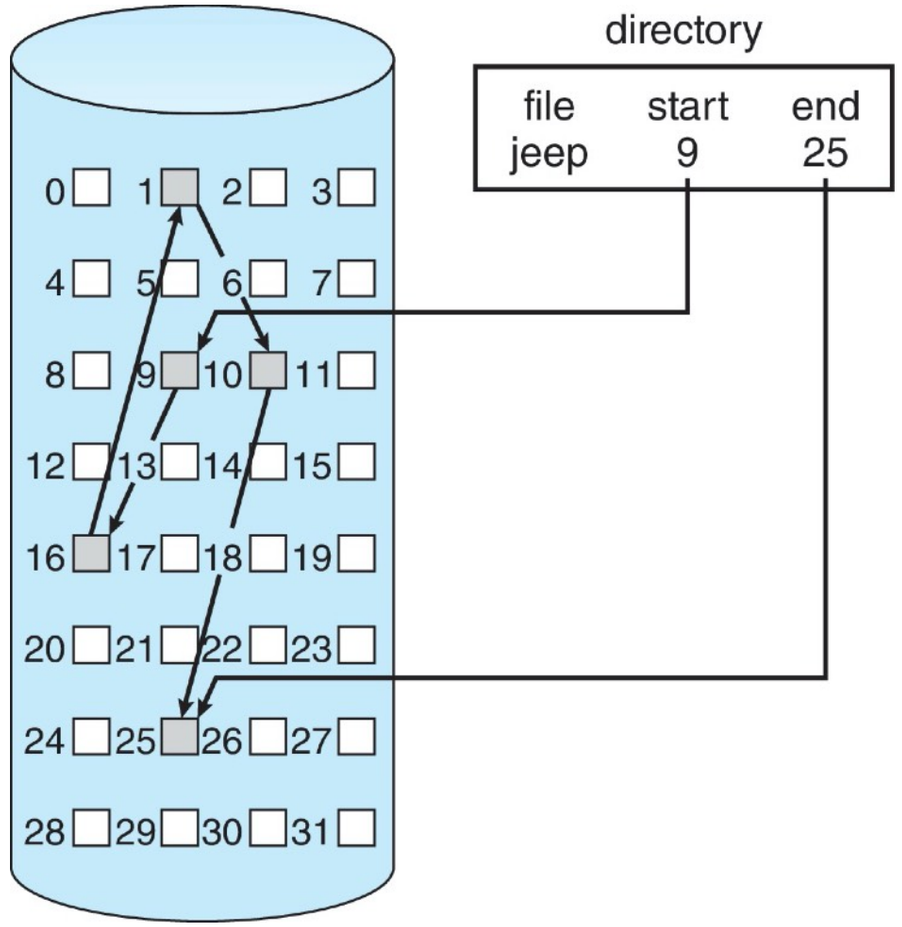
- each file a linked list of blocks scattered on disk
  - each block contains pointer to next block;
    last block contains a null pointer
- advantages:
  - no external fragmentation; no need for compacting disk
- disadvantages:
  - random access is inefficient (locating a block may require many disk reads and seeks)
  - if each block is 512 bytes and a pointer to the next block needs 4 bytes (assuming 32-bit address space), only 508 bytes from each block are available to user; so 0.78% of disk space is wasted
    - **can improve efficiency by collecting multiple blocks into clusters and using a pointer per cluster at the cost of increasing internal fragmentation**



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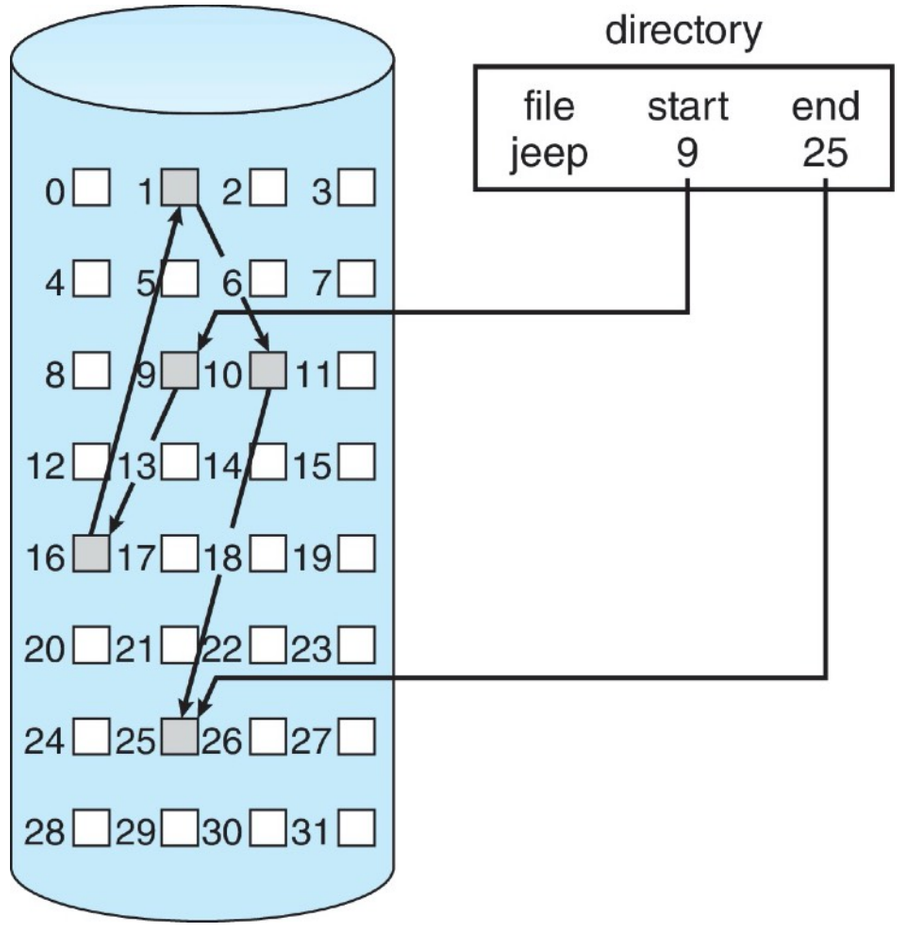

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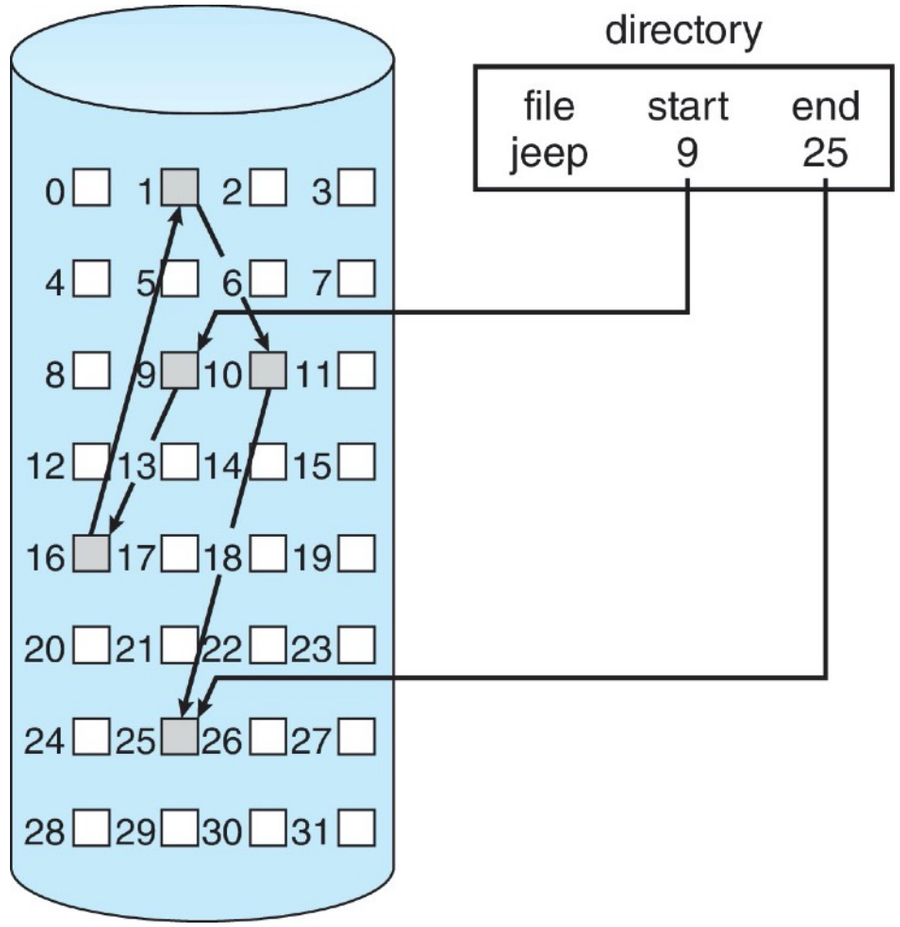

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  - divide the logical file address by block size - p (where p is the size of the next-block pointer); let the quotient be `i` and the remainder be `r`
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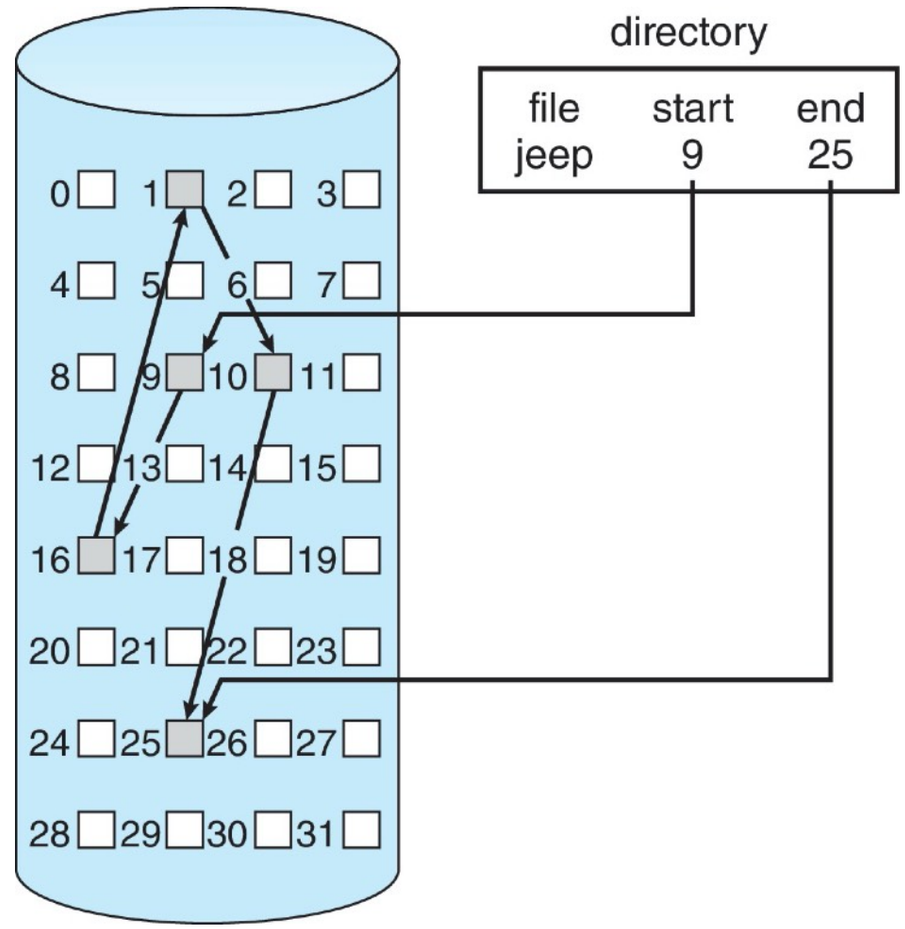

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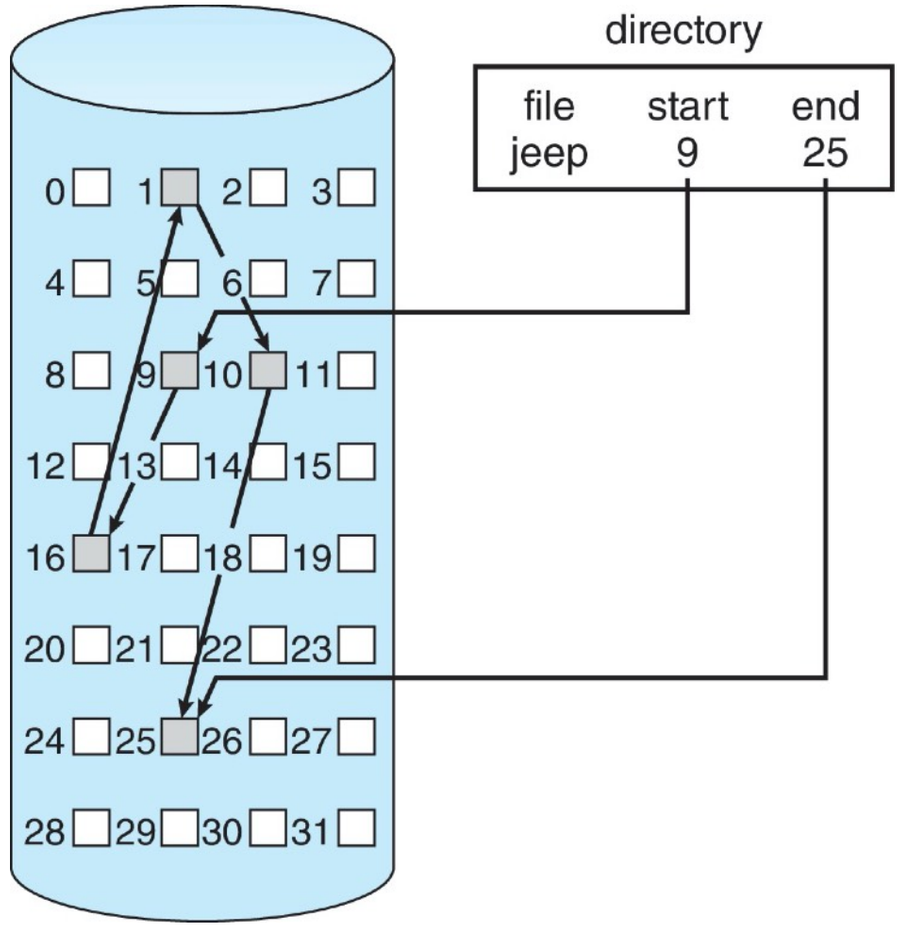

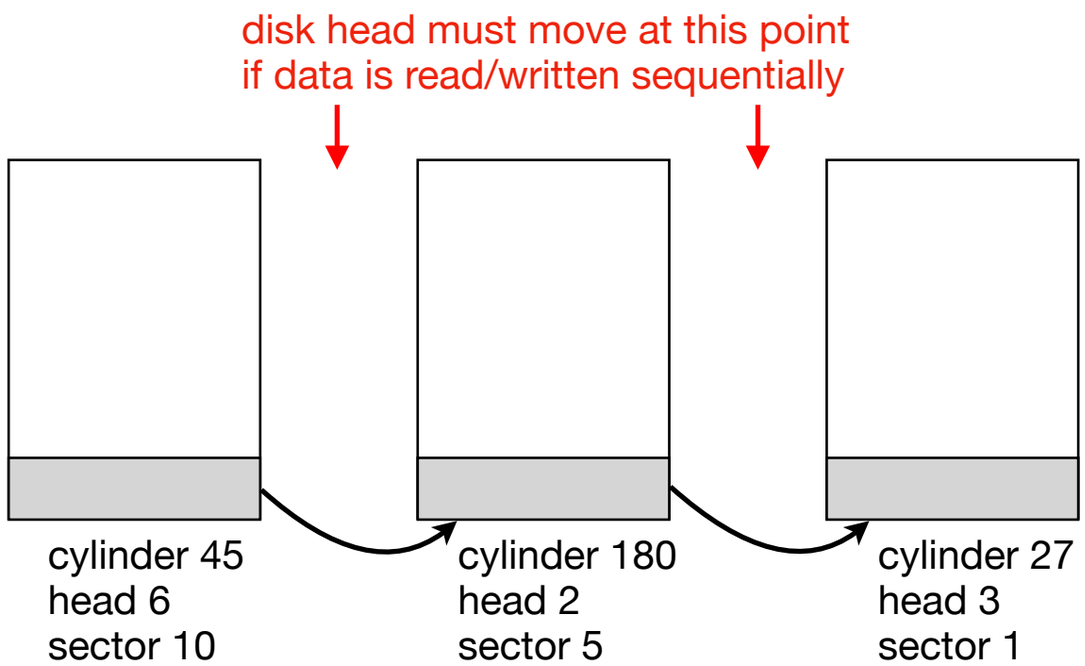

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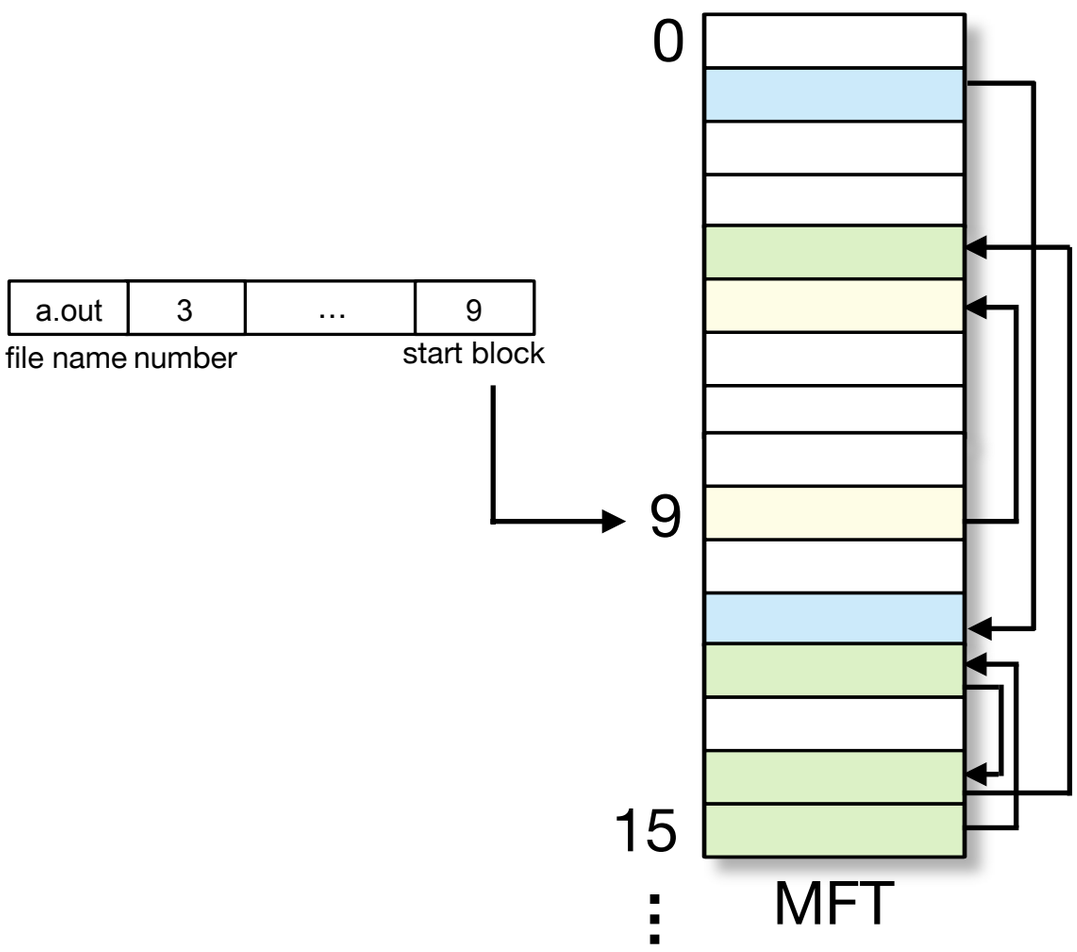
  - master file table (MFT) contains an entry for each data block; this entry holds the pointer to the entry containing the next data block of the file



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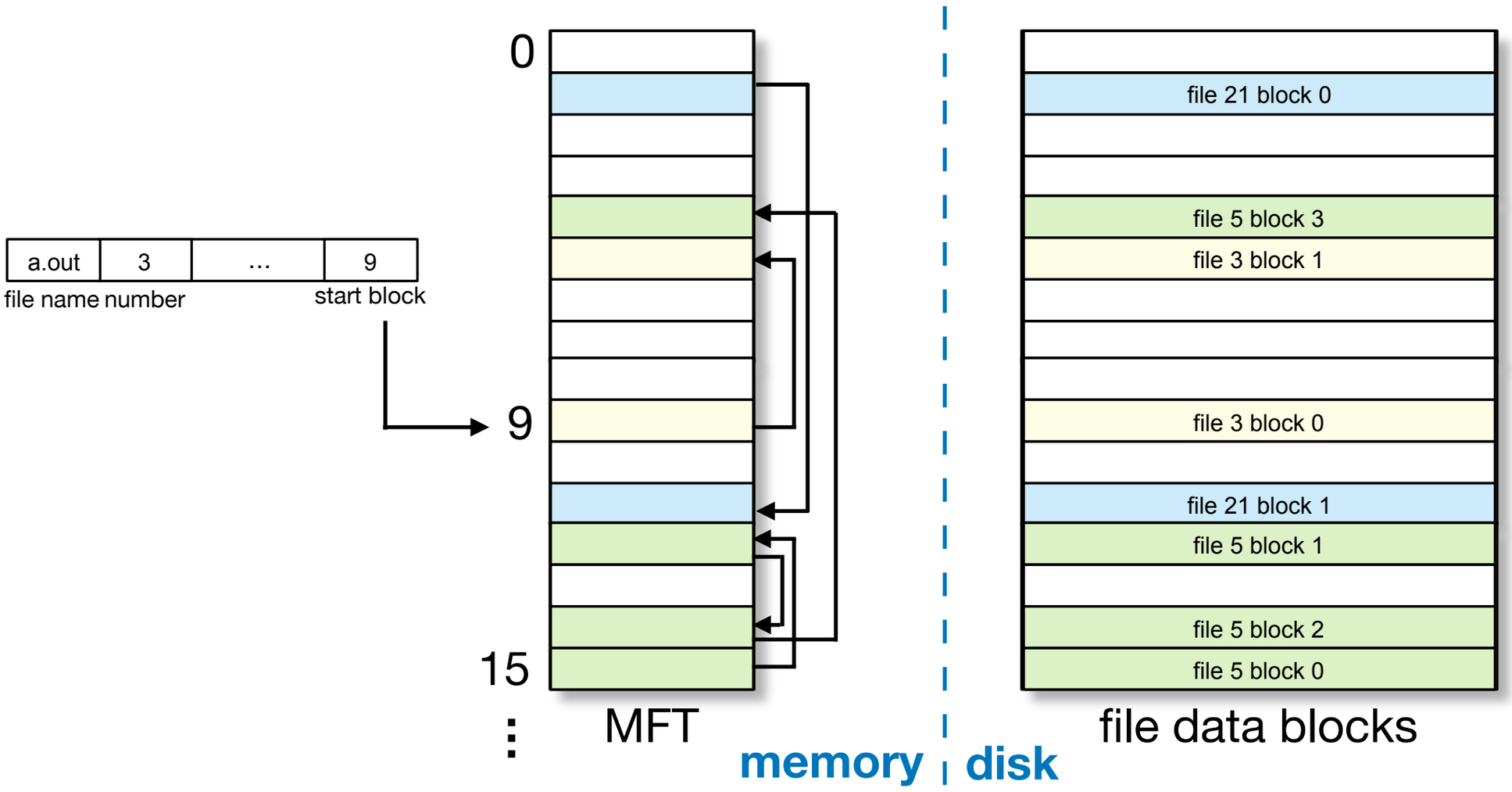

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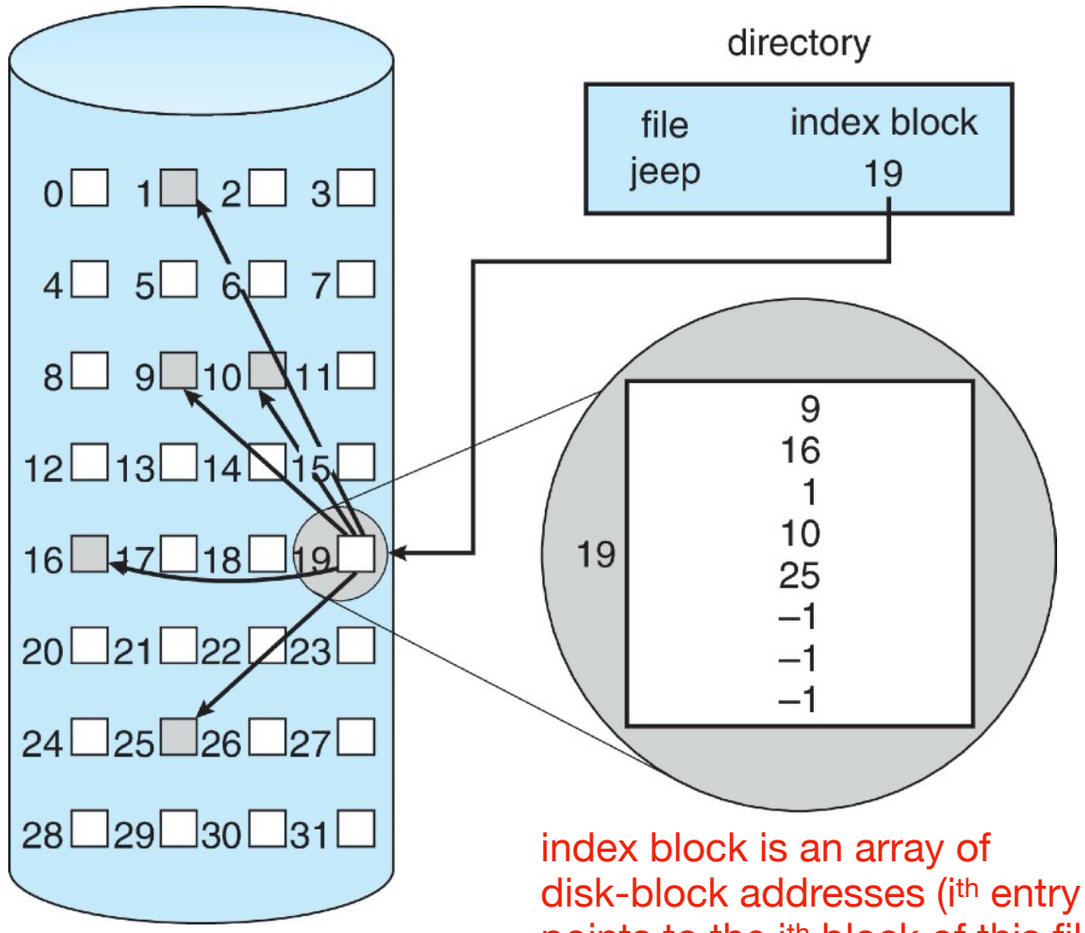

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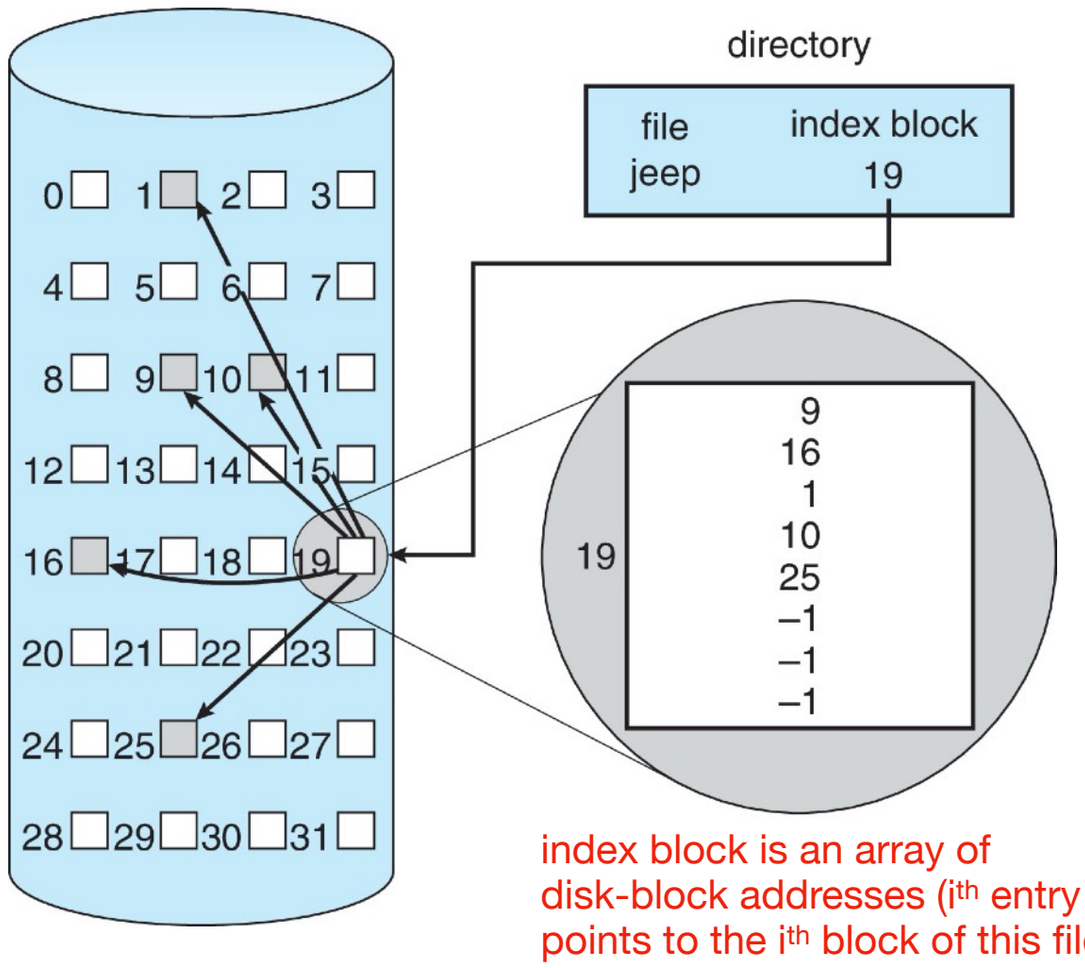

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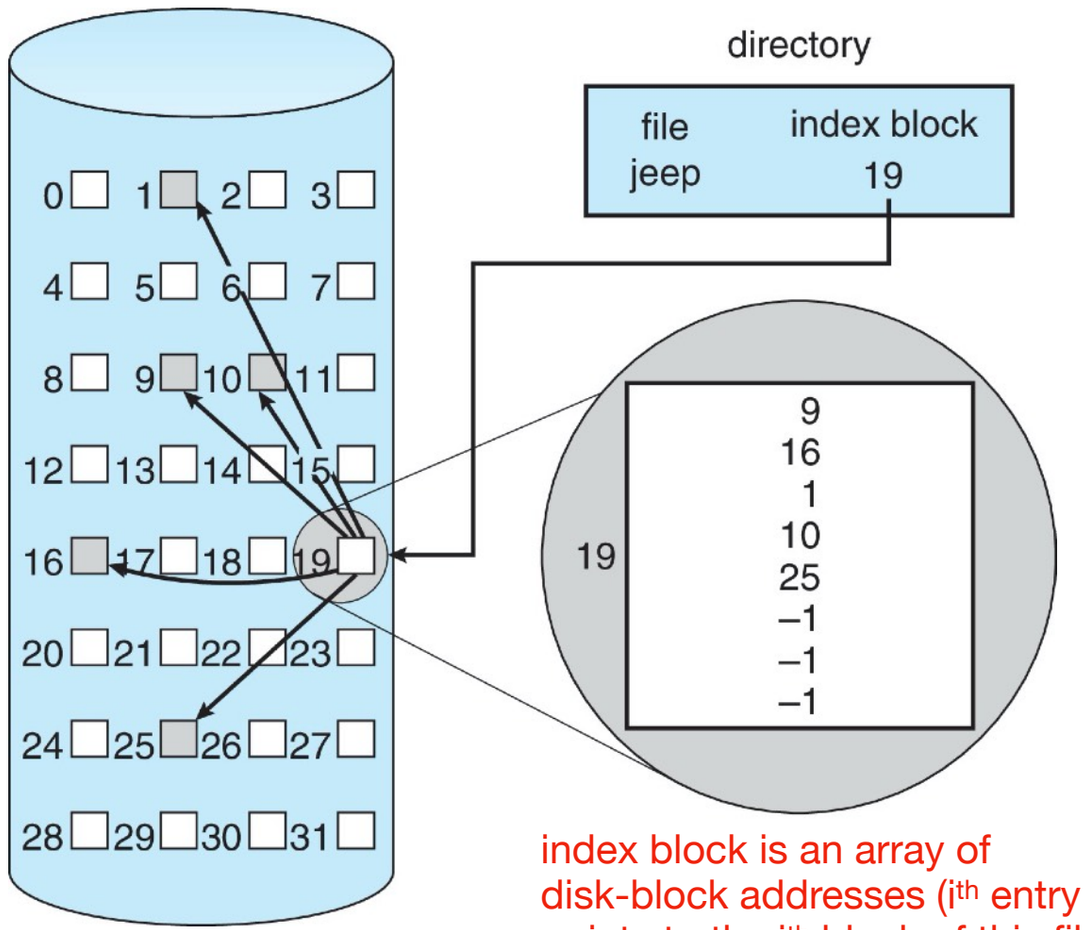

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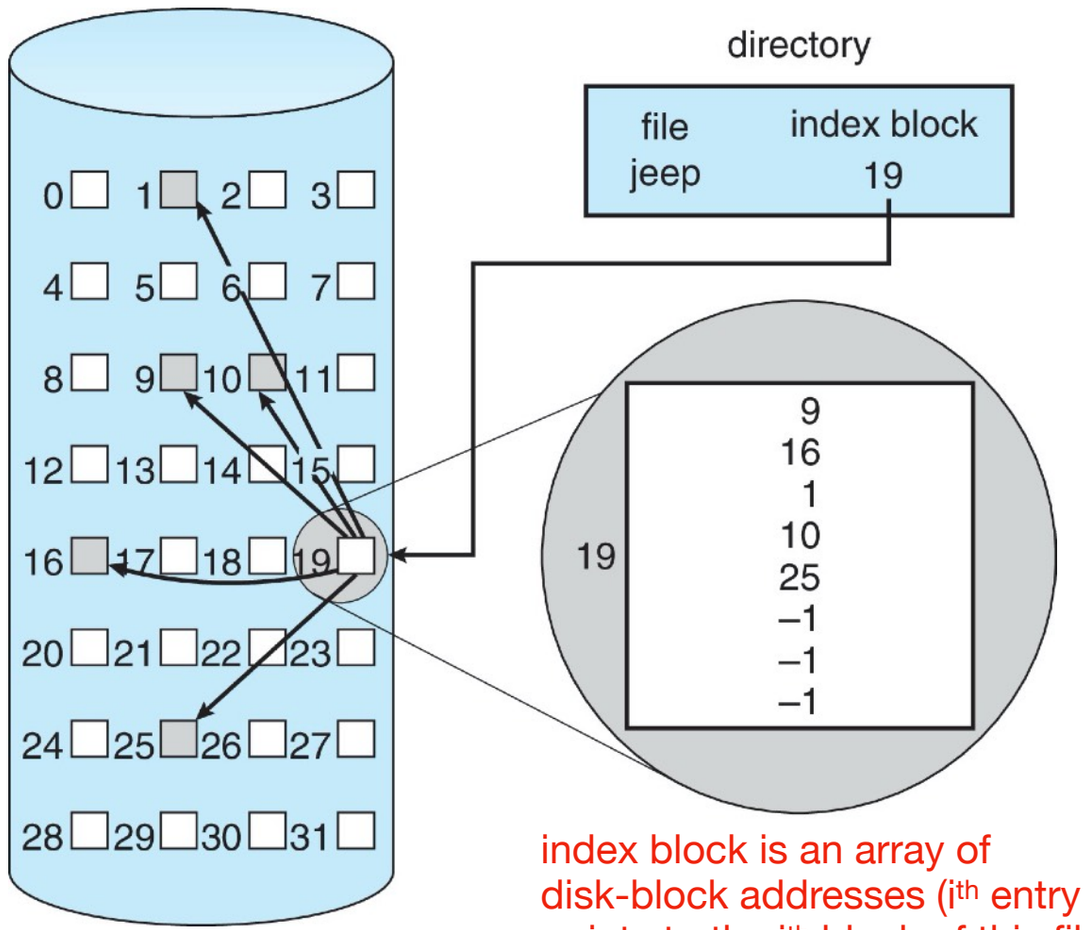
- how to relax the constraint on the maximum file size?
  - index blocks can be chained if needed, i.e., a pointer to the next index block is stored in each index block
  - index block can be indexed itself



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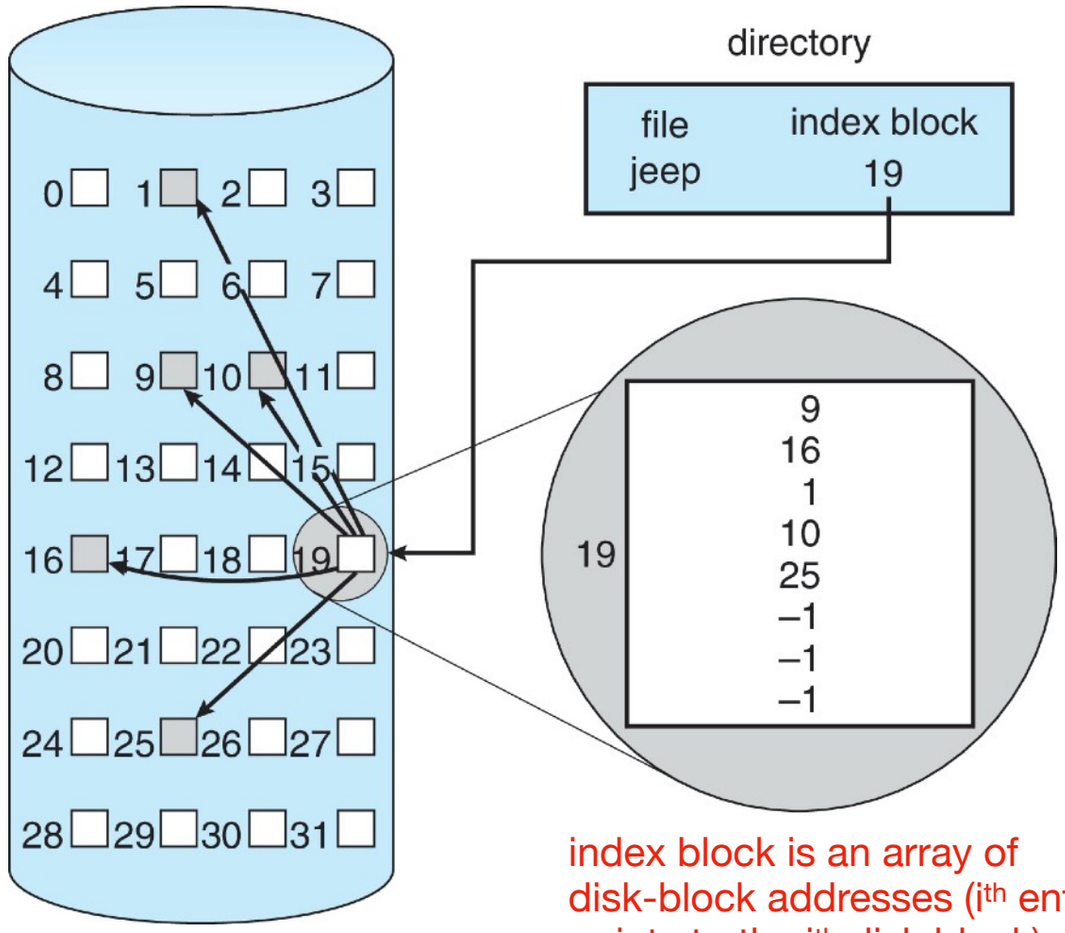

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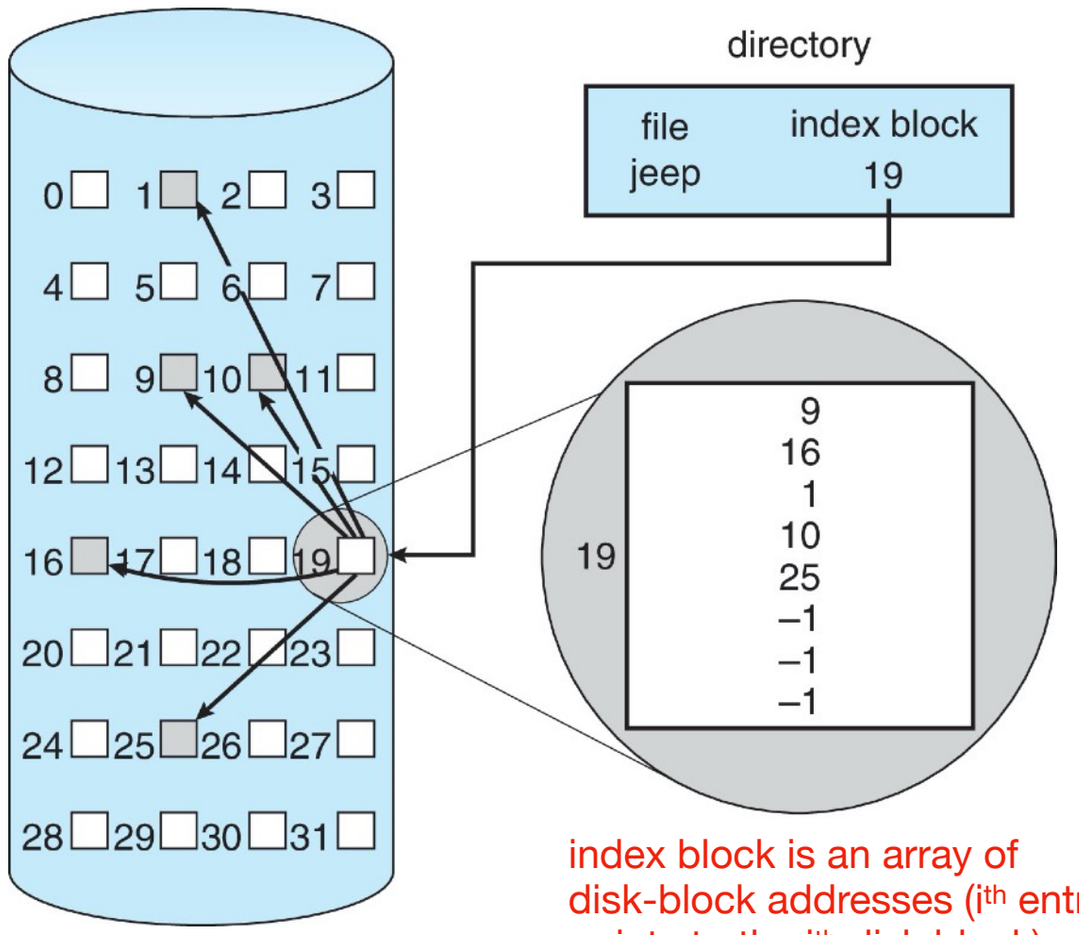

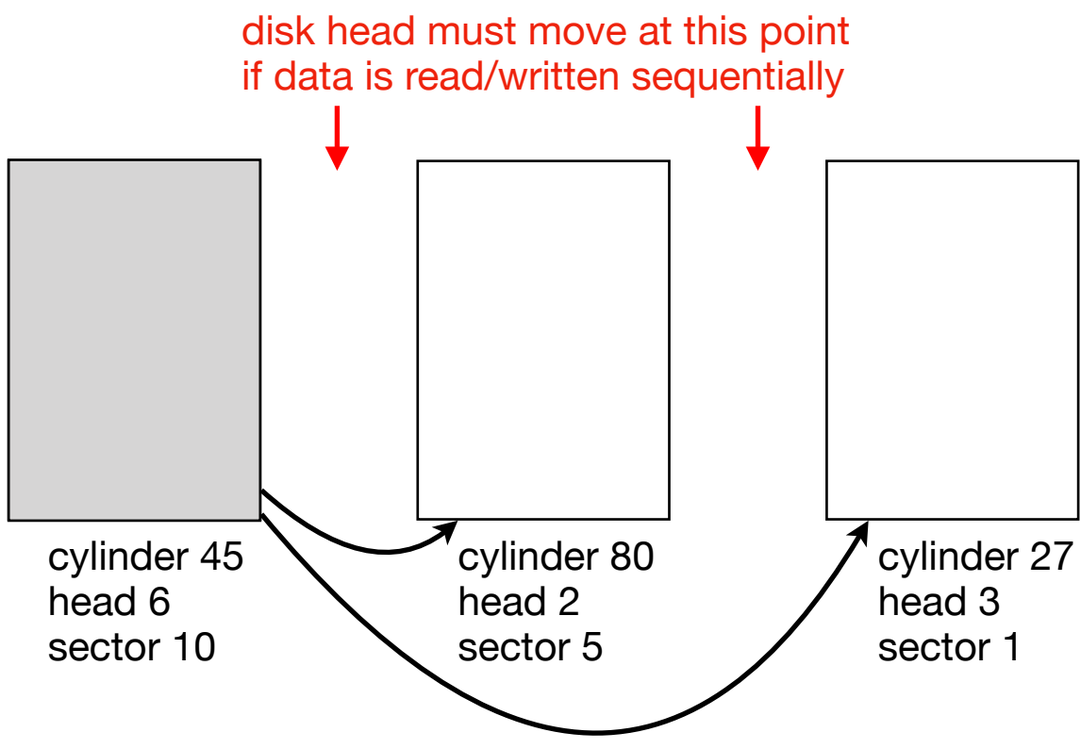

Hybrid multi-level approach

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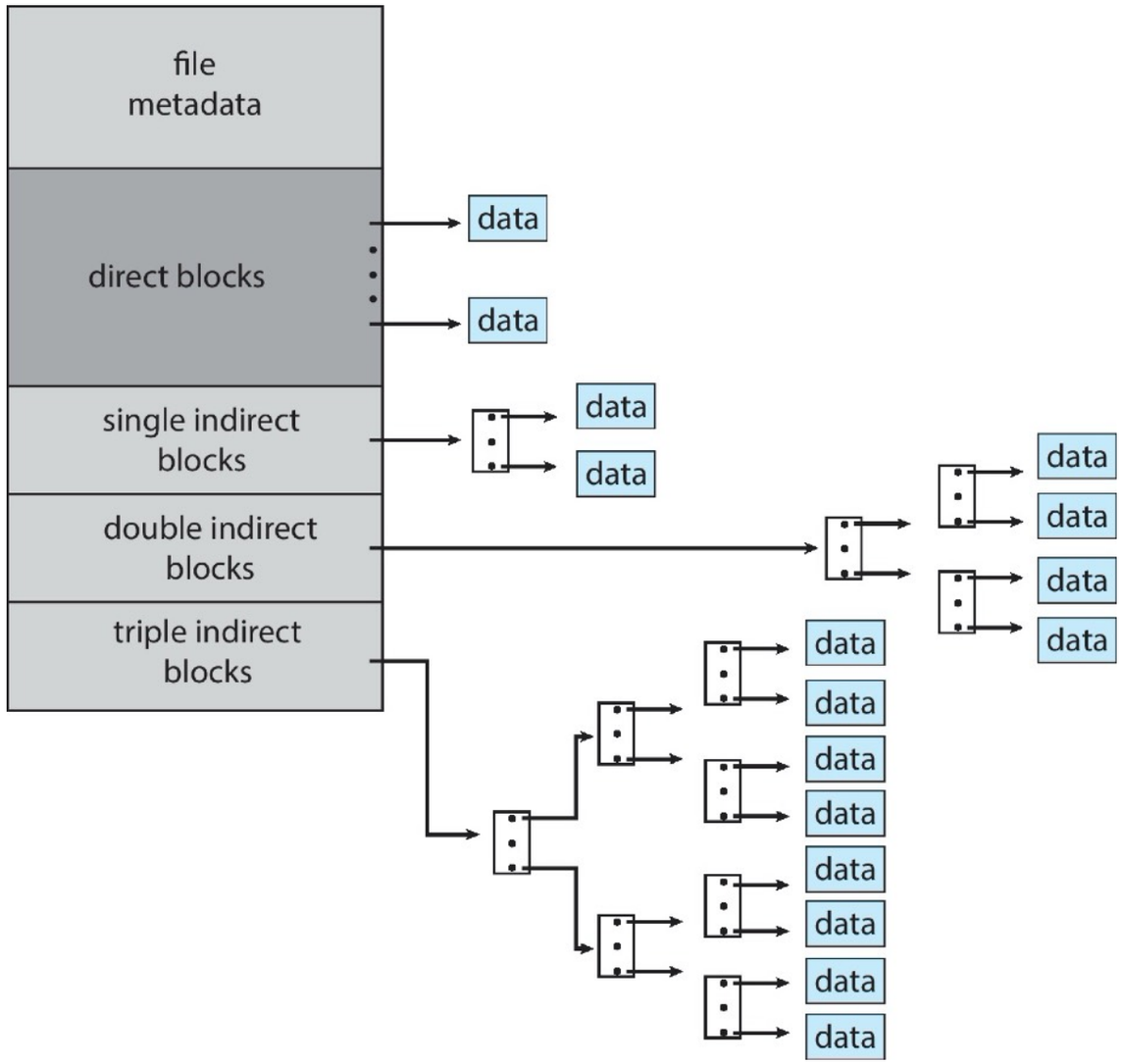

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- each inode contains 13 block pointers
  - the first 10 pointers point to 4KB data blocks (direct pointers)
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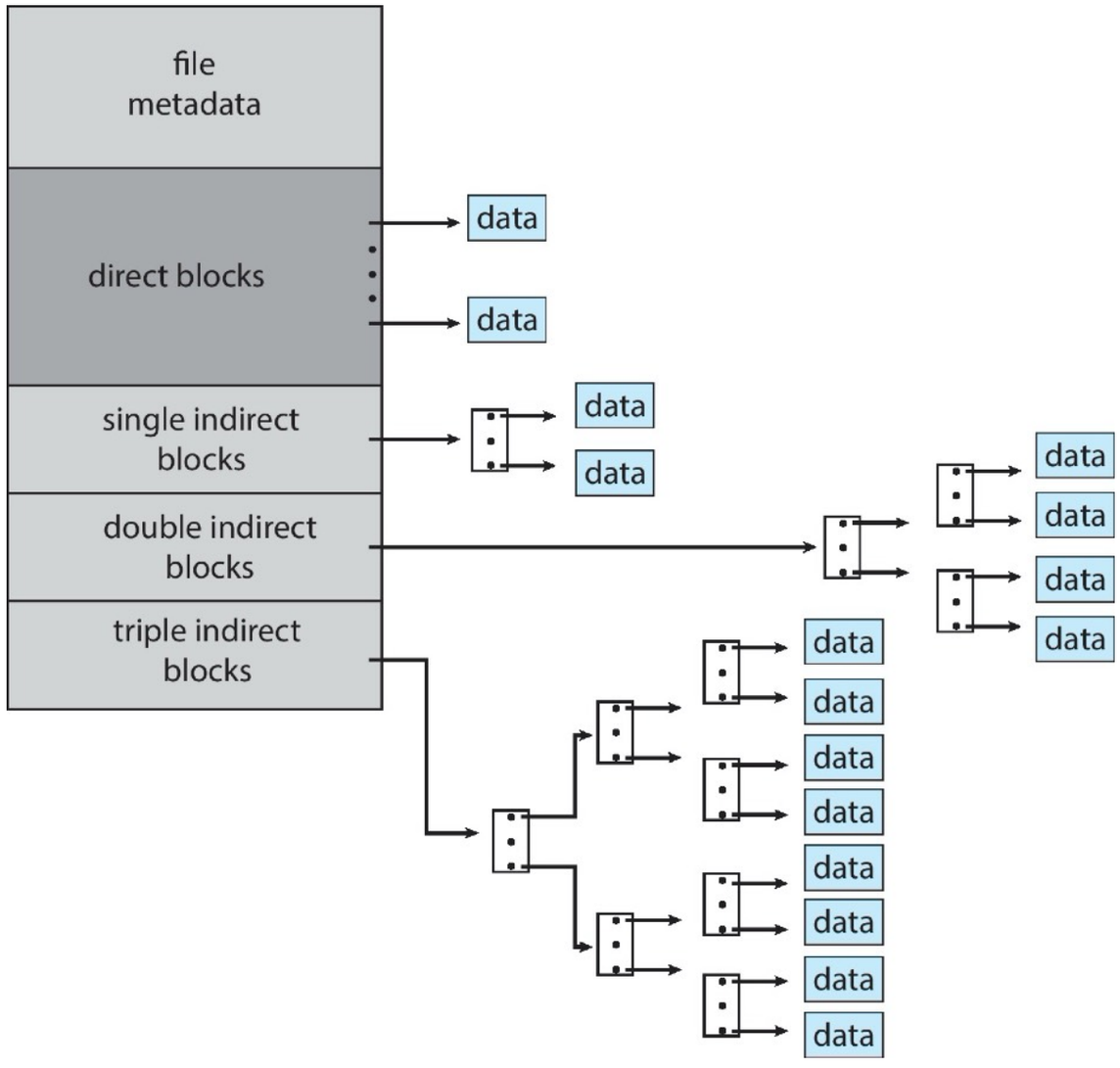

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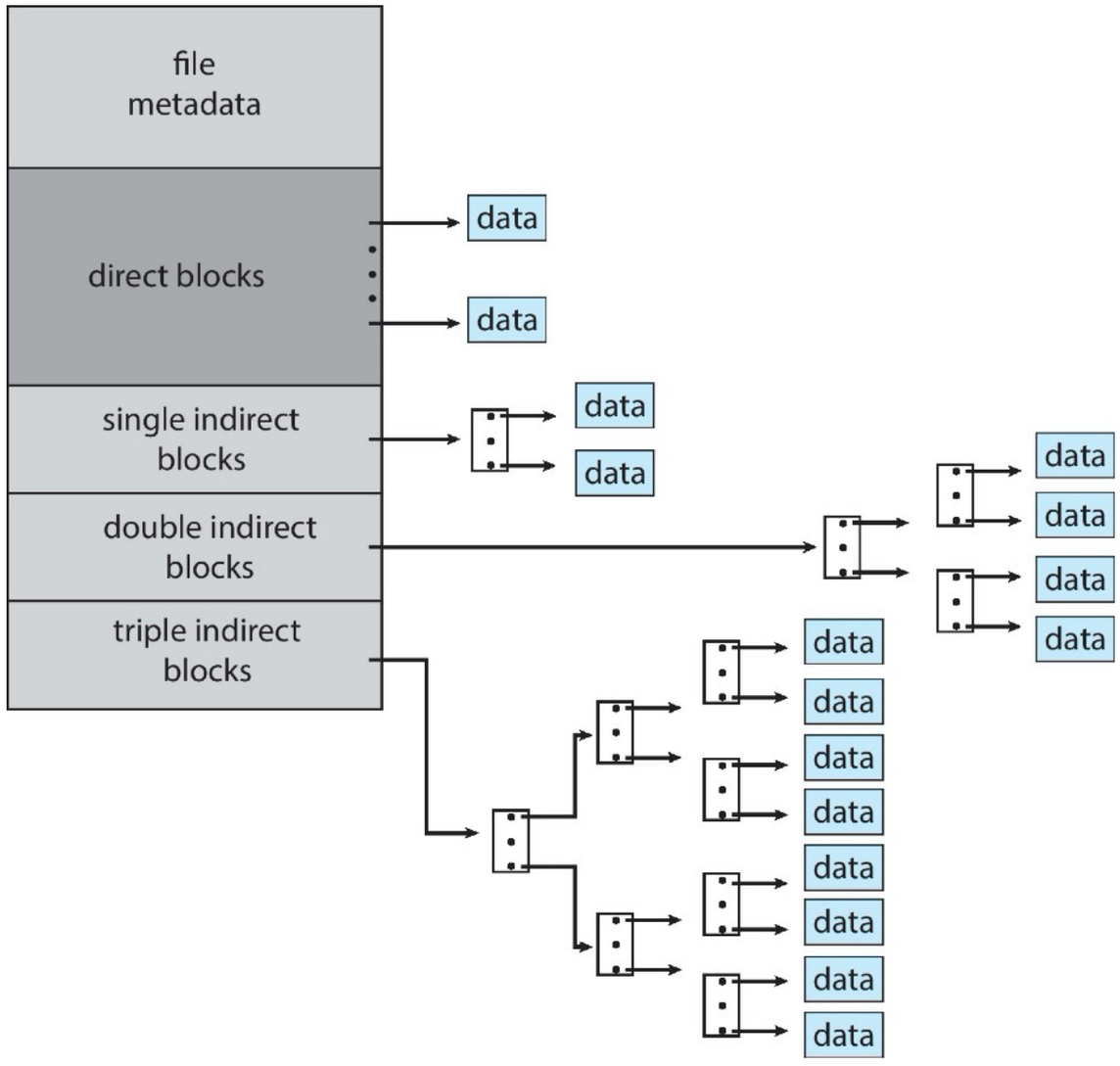

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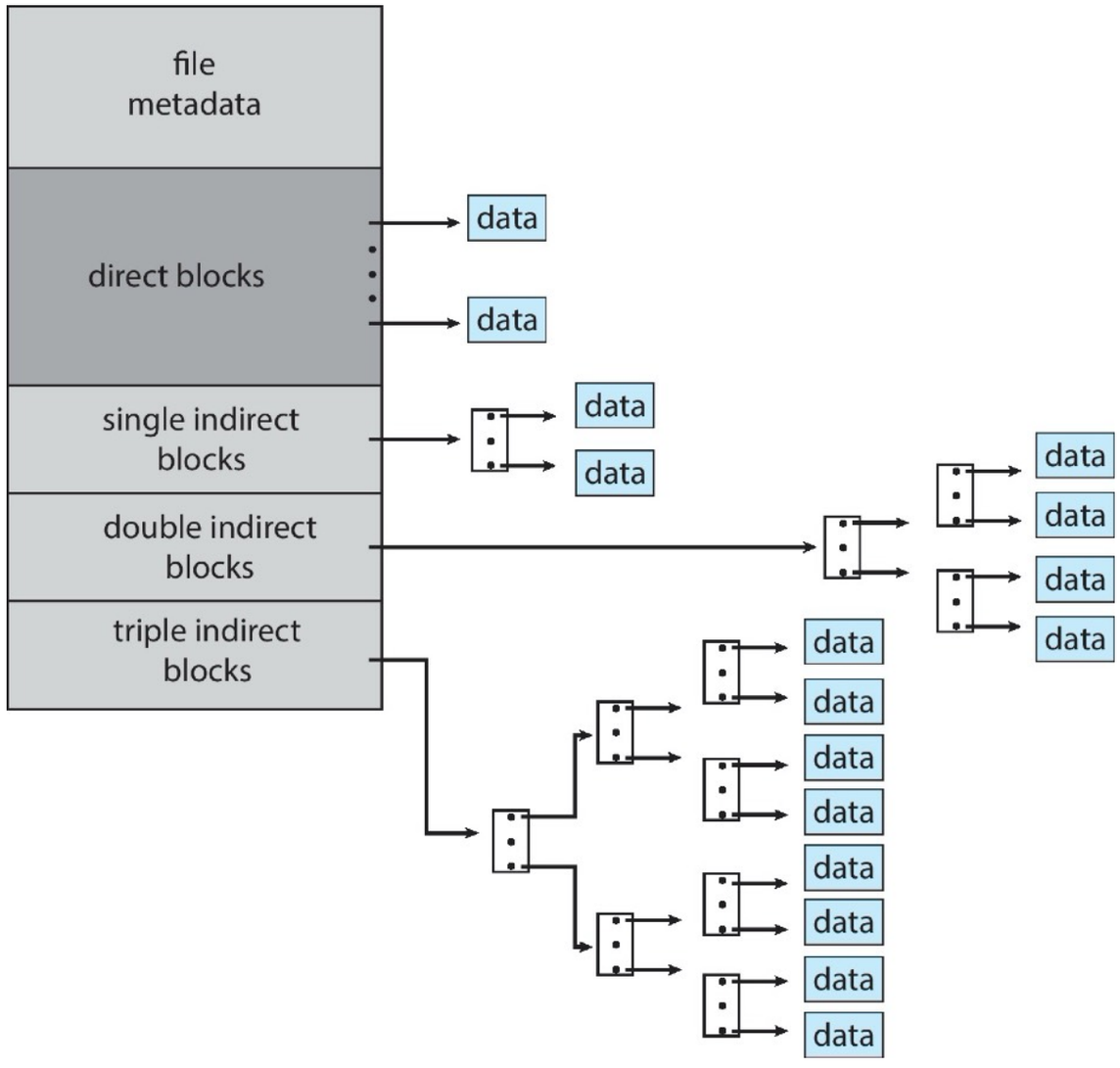
  - several levels of indirection is inefficient for random access to very large files, accessing file data needs many disk seeks (especially for large files)



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  - single block access could require 2 index block reads followed by a data block read
- how about a hybrid approach?
  - small files (up to 3 or 4 blocks) are contiguously allocated; indexed allocation is used when file grows large
  - works well since most files are small!