# External Sorting
# 外排序

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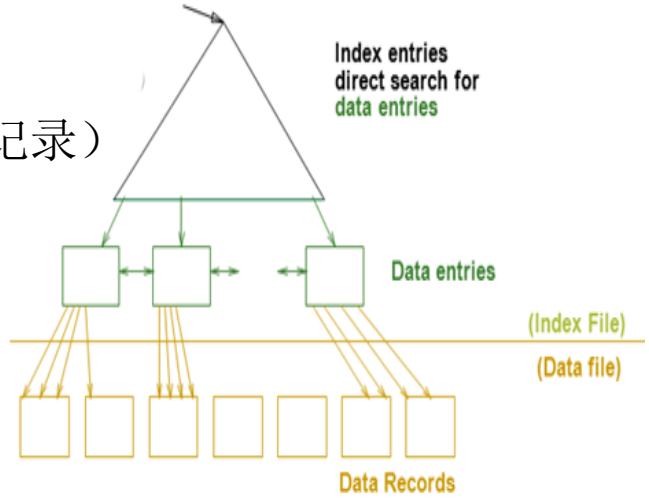
# Review

- Cost Model（代价模型）
  - 只关心磁盘块的IO次数
- 文件由页组成，而每个页包含一组记录
  - *Record id = <page id, slot #>*
- 索引文件由两部份组成
  1. 数据项部分
     - Data Entry(数据项) ⟺ data record（数据记录）
  2. 引导部份
     - 树索引技术
     - Hash索引
- 索引的 clustered？



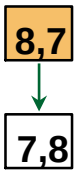
# Why External Sorting(外排序)?

- Problem: sort 100Gb of data with 1Gb of RAM.
  - why not virtual memory?

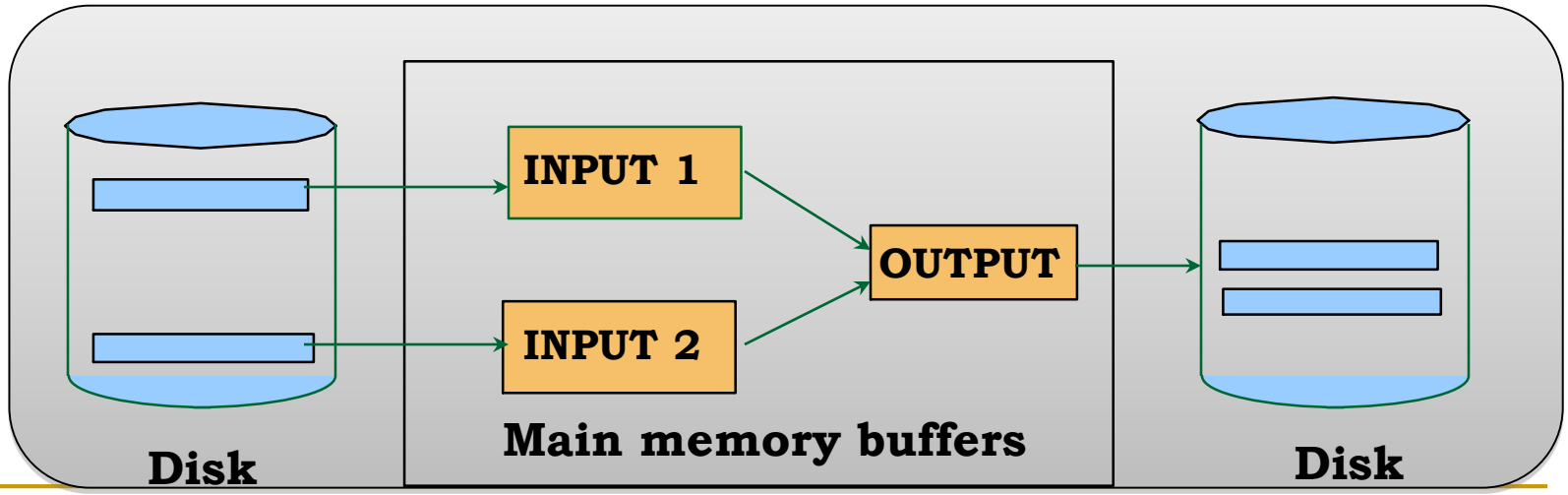
- Idea
  - 方法:对数据进行多遍处理,
  - 效果:从而可以使用较少内存排序庞大的数据集

# Two-Way External Merge Sort: Requires 3 Buffers
# 两路归并外排序

- Pass 0(生成有序段/子文件): Read a page, sort it, write it.
  - each sorted page (or subfiles) is called a run(有序段).
  - only 1 buffer page is used.




- Pass 1, 2, 3, …, etc.(合并有序段):
  - merge pairs of runs into runs twice as long 有序段长加倍
  - 3 buffer pages used




Merging Runs(合并有序段)

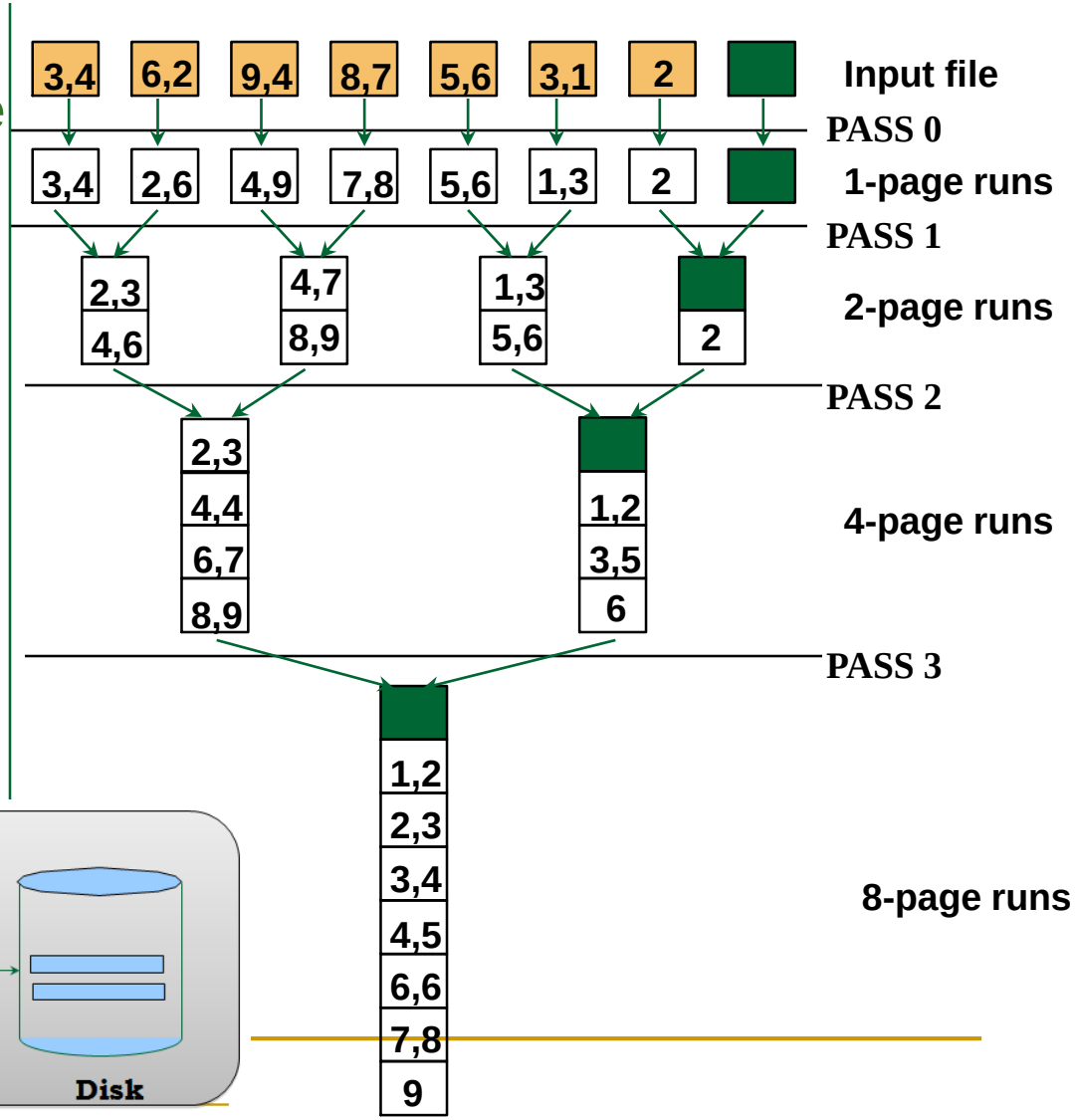
# Two-Way External Merge Sort: Requires 3 Buffers
# 两路归并外排序

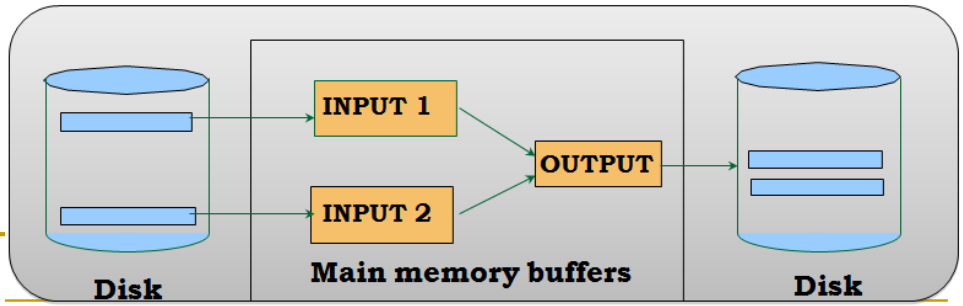
- Each pass(每遍) we read + write each page in file.
- N pages in the file => the number of passes

$$= \lceil \log_2 N \rceil + 1$$

- So total cost is:

$$2N\left(\lceil \log_2 N \rceil + 1\right)$$



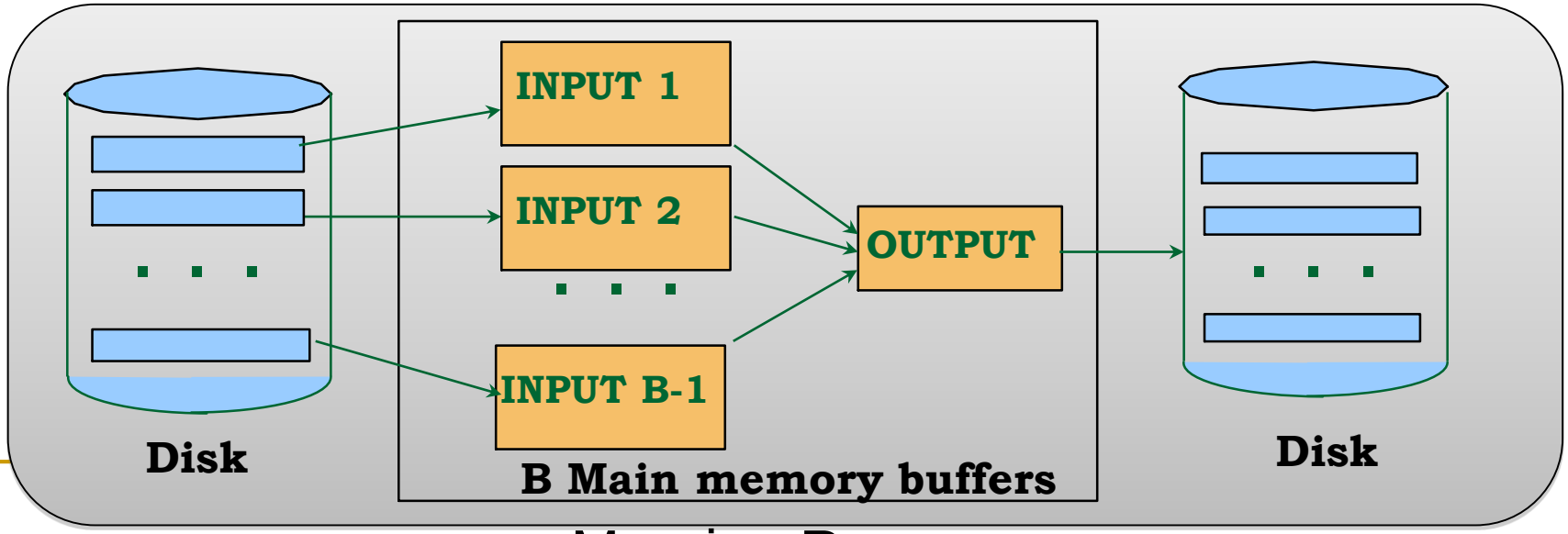

Merging Runs(合并有序段)

# General External Merge Sort
# 外归并排序

$2N\left(\lceil \log_2 N \rceil + 1\right)$

✉ ***More than 3 buffer pages. How can we utilize them?***

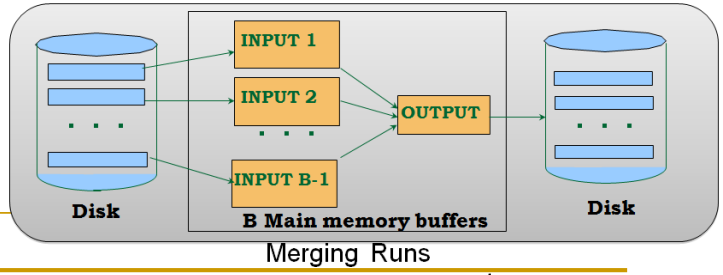
- To sort a file with *N* pages using *B* buffer pages:
  - Pass 0: use *B* buffer pages. Produce $\lceil N / B \rceil$ sorted runs of *B* pages each.
  - Pass 1, 2, …, etc.: merge *B-1* runs.




Merging Runs

# Cost of External Merge Sort $2N(\lceil \log_2 N \rceil + 1)$

- Number of passes: $1 + \lceil \log_{B-1} \lceil N / B \rceil \rceil$
- Cost = 2N * (# of passes)
- E.g., with 5 buffer pages, to sort 108 page file:
  - Pass 0: $\lceil 108 / 5 \rceil$ = 22 sorted runs of 5 pages each (last run is only 3 pages)
  - Pass 1: $\lceil 22 / 4 \rceil$ = 6 sorted runs of 20 pages each (last run is only 8 pages)
  - Pass 2: 2 sorted runs, 80 pages and 28 pages
  - Pass 3: Sorted file of 108 pages



Merging Runs

Formula check: $\lceil \log_4 22 \rceil = 3 \ldots + 1 \rightarrow$ 4 passes $\surd$

# Number of Passes of External Sort

$$1+\lceil \log_{B-1}\lceil N/B \rceil \rceil$$

- 缓冲区越多,处理遍数越少
- ( I/O cost is 2N times number of passes)

| N | B=3 | B=5 | B=9 | B=17 | B=129 | B=257 |
|---|---|---|---|---|---|---|
| 100 | 7 | 4 | 3 | 2 | 1 | 1 |
| 1,000 | 10 | 5 | 4 | 3 | 2 | 2 |
| 10,000 | 13 | 7 | 5 | 4 | 2 | 2 |
| 100,000 | 17 | 9 | 6 | 5 | 3 | 3 |
| 1,000,000 | 20 | 10 | 7 | 5 | 3 | 3 |
| 10,000,000 | 23 | 12 | 8 | 6 | 4 | 3 |
| 100,000,000 | 26 | 14 | 9 | 7 | 4 | 4 |
| 1,000,000,000 | 30 | 15 | 10 | 8 | 5 | 4 |

In practice, most files sorted in 2-3 passes

# Summary, cont.

- Choice of internal sort algorithm may matter:
  - Quicksort: Quick!
  - Heap/tournament(树形选择排序) sort
- Clustered B+ tree is good for sorting; unclustered tree is usually very bad.

- 要求:
  - 掌握外排序算法
  - 理解并记住外排序IO开销的基本公式 $1+\lceil \log_{B-1} \lceil N/B \rceil \rceil$

Cost = 2N * ( # of passes)