

Database Development and Design (CPT201)





Lecture 3a: Indexing Techniques

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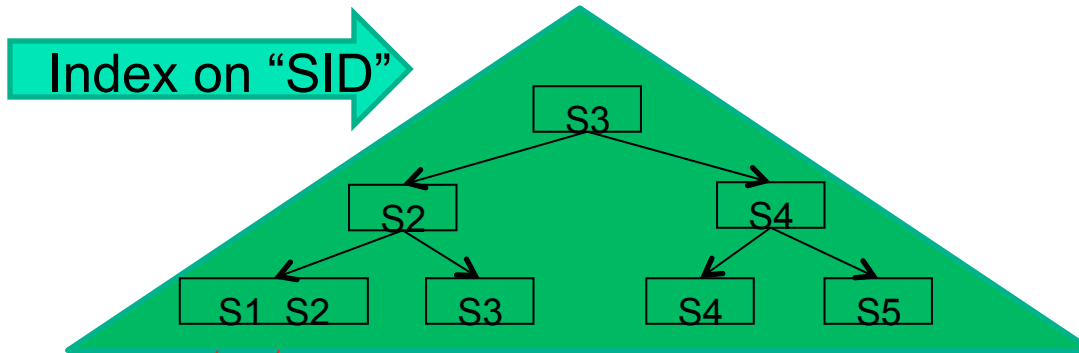
Learning Outcomes

- The Structure of Index
- Ordered Index
- Primary Index vs. Secondary Index
- Dense Index vs. Sparse Index
- Multilevel index

Motivation: Search Records

- To scatter records of a relation to different blocks is not efficient. 
- `SELECT * FROM C;`
 - problem: search all the blocks on the disk
 - solution: keep records of a certain relation on adjacent cylinders 
- `SELECT * FROM C WHERE age=10;`
 - problem: search all the blocks and check the condition on the disk
 - solution: create indices on some attributes 
- **Indexing** mechanisms used to **speed up** access to the desired data. 

Index



Athens	
London	
London	
Paris	
Paris	

SID	Name	Age	Address
S1	Smith	20	London
S2	Jones	10	Paris
S3	Blake	30	Paris
S4	Clark	20	London
S5	Adams	30	Athens


	10
	20
	20
	30
	30

Index on "Address"



Index on "Age"

The Structure of Index









- **Data file**: collection of blocks holding records on disk
- **Index file**: an data structure allowing the DBMS to find particular records in a data file more efficiently. 
 - An **index file** consists of records (called **index entries**) of the form:



search-key	pointer
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- **Search Key**: one or set of attributes used to look up records in a file. 
- **Relationship**: a search key K in the index file is associated with a **pointer** to a data-file record that has search key K. 




Index Evaluation Metrics

- Access types (supported) 
 - records with a specified **value** in the attribute or
 - records with an attribute value falling in a specified **range**. 
- Access time 
- Insertion time 
- Deletion time 
- Space overhead 

Indexing Techniques

- Depending on the organisation of index file, an index can be: 
 - an **ordered** Index where index entries are sorted on the search key value.
 - a **hashing** Index where hashing technique is employed to organise index entries. 

Ordered Indices

- Ordered index: index entries in the index are sorted on the search key value. 
- An ordered index can be:
 - **Dense** index: index record appears for every search-key value in the file. 
 - **Sparse** Index: contains index records for only some search-key values. 




Dense Index vs. Sparse Index

- Index size
 - Sparse index is smaller
- Requirement on data file
 - The data file must be sequential file
- Lookup
 - Sparse index is smaller and may fit in memory
 - Dense index can directly tell if a record exists.
- Update
 - Sparse index requires less space and maintenance for insertion and deletion.
- Good tradeoff: sparse index with an index entry for every block in file, corresponding to least search-key value in the block.

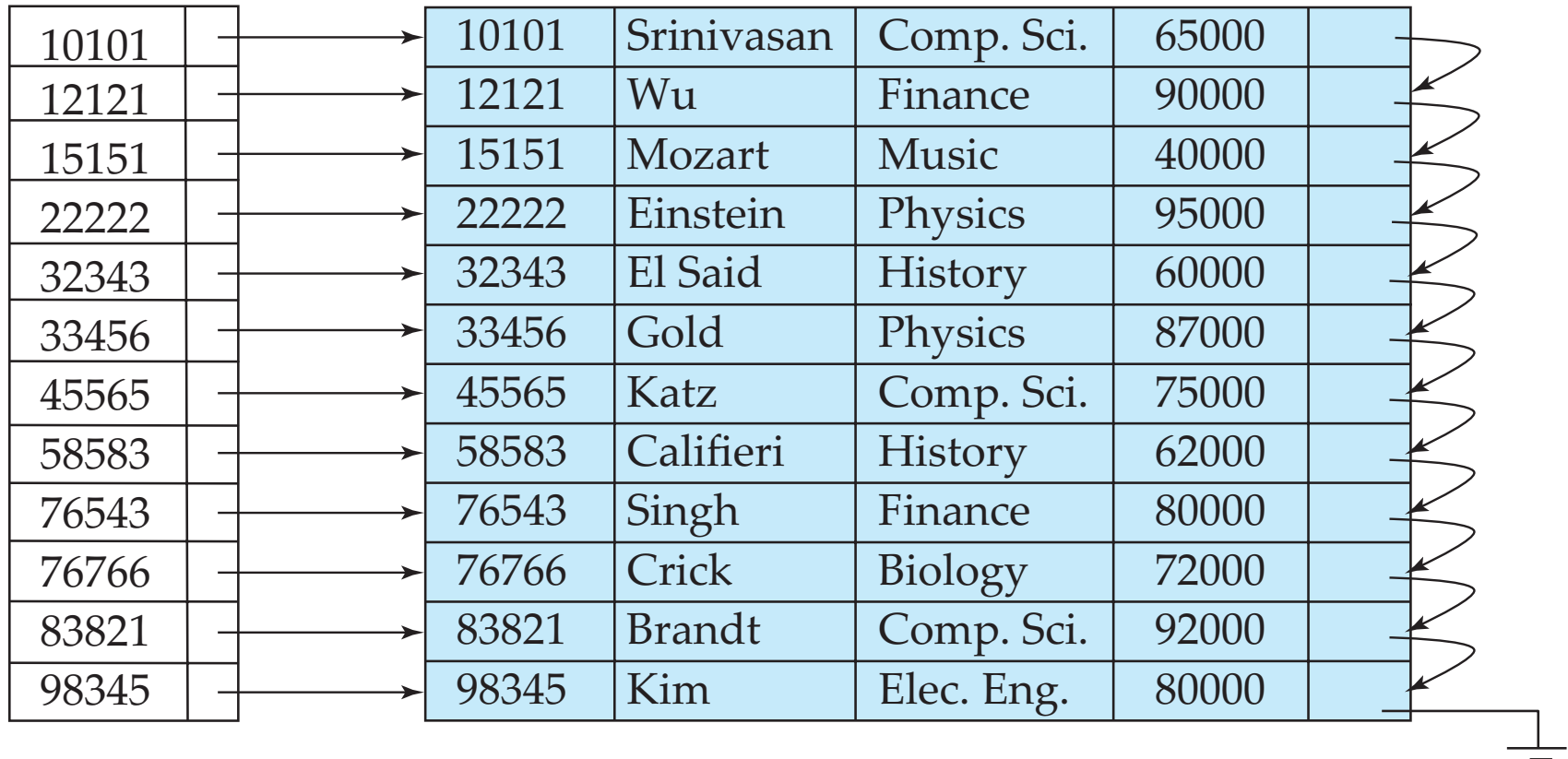
Brighton		A-217	Brighton	750	
Downtown		A-101	Downtown	500	
Mianus		A-110	Downtown	600	
Perryridge		A-215	Mianus	700	
Redwood		A-102	Perryridge	400	
Round Hill		A-201	Perryridge	900	
		A-218	Perryridge	700	
		A-222	Redwood	700	
		A-305	Round Hill	350	

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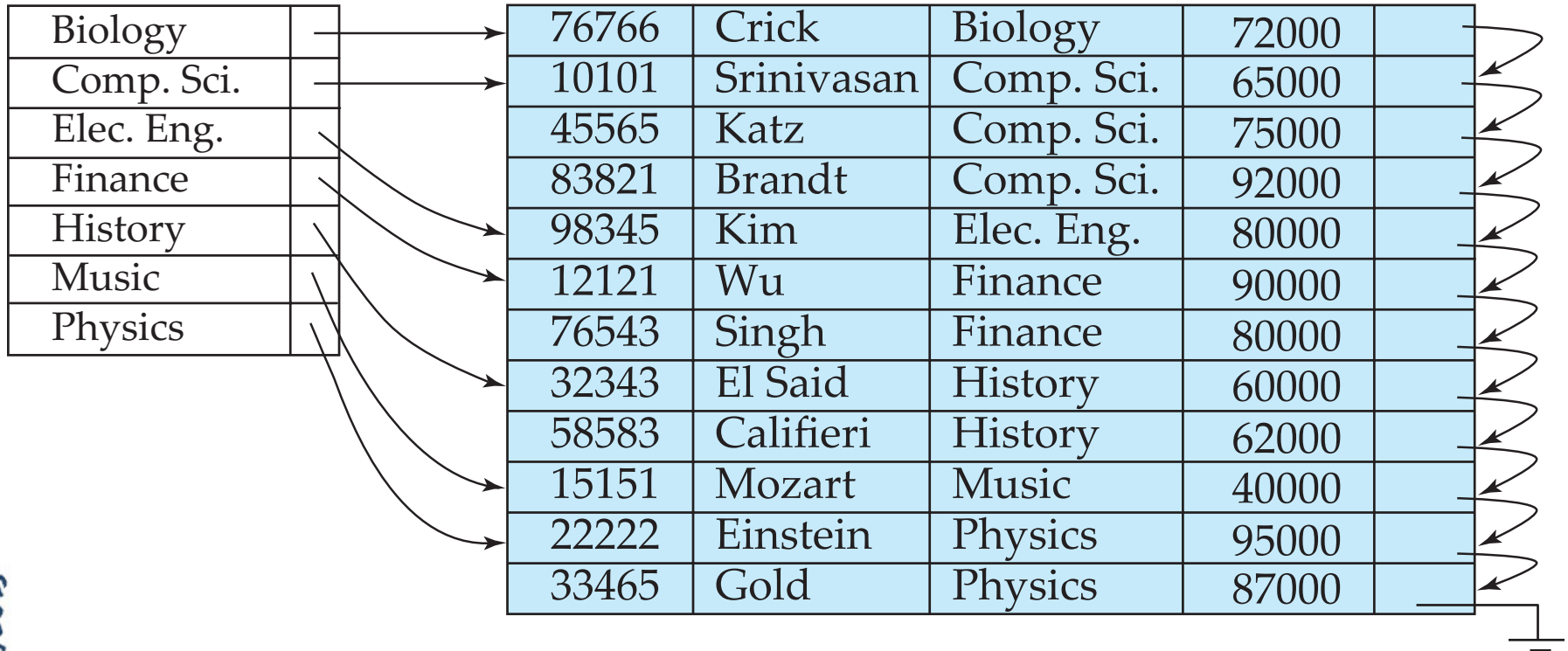
Ordered Indices cont'd

- An ordered index can also be:
 - **Primary** index: an index whose search key specifies the sequential order of the file. 
 - Also called **clustering** index. The search key of a primary index is usually but not necessarily the primary key. 
 - Can be **sparse**
 - **Secondary** index: an index whose search key specifies an order different from the sequential order of the file. 
 - Also called **non-clustering** index.
 - Can **not** be sparse
- Index-sequential file: ordered sequential file with a primary index.

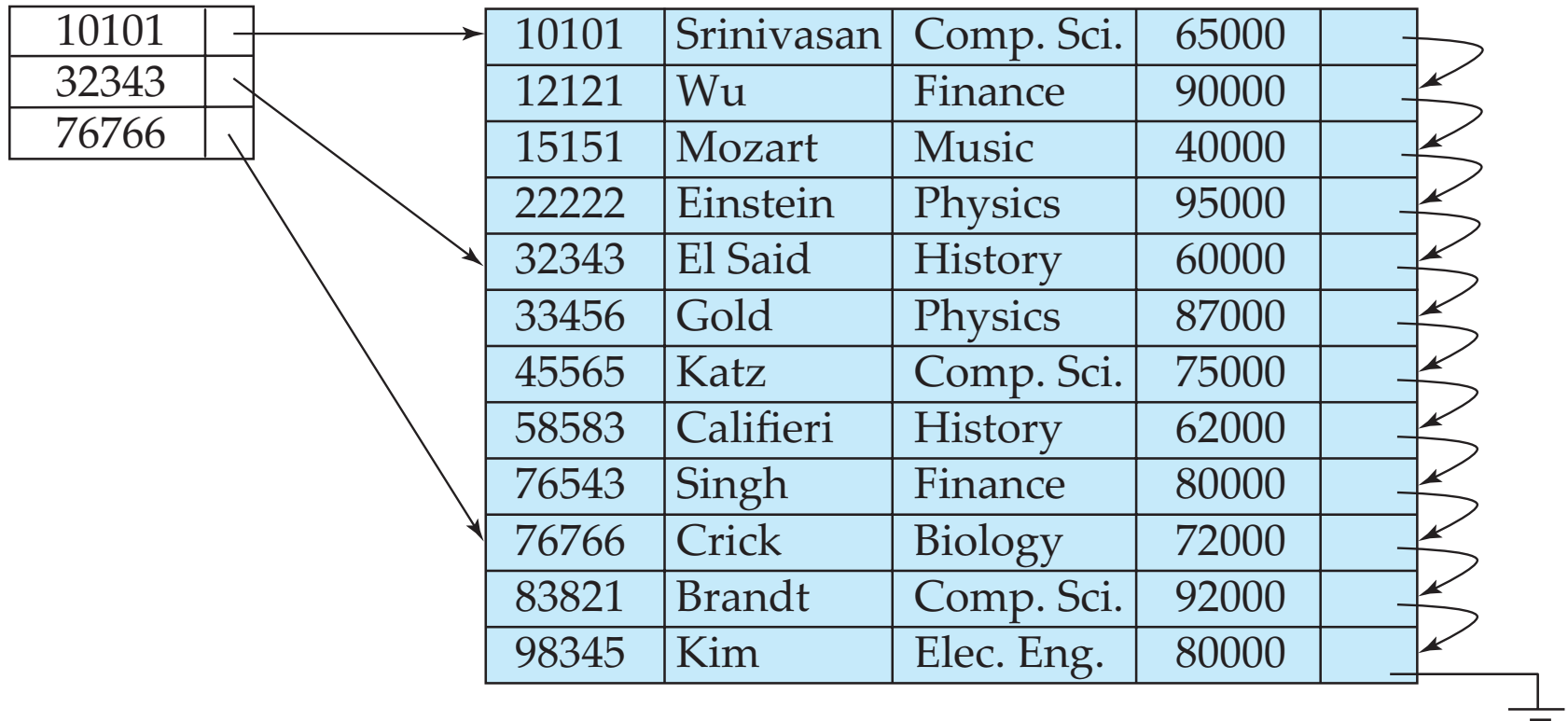
Dense Index Files



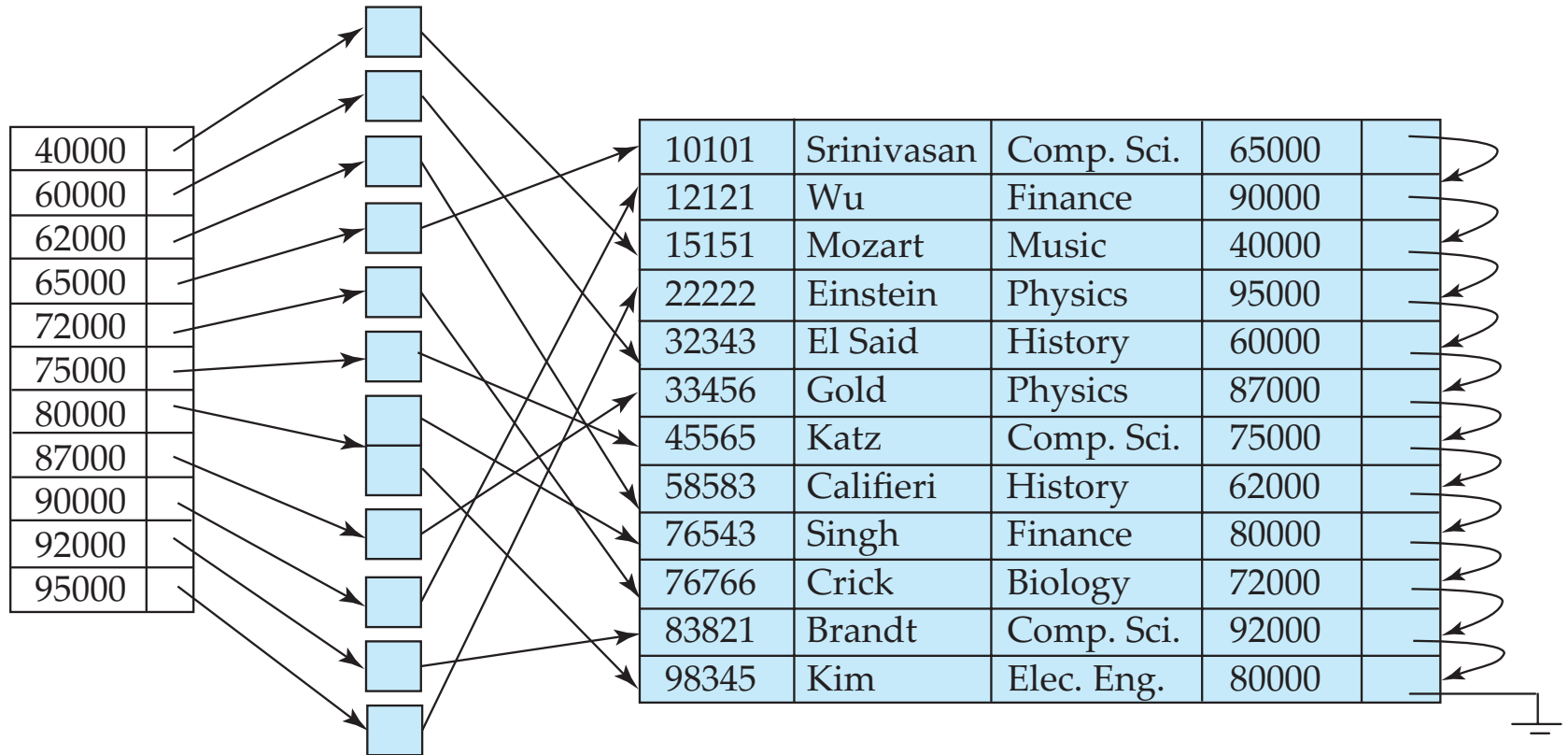
Dense Index Files cont'd



Sparse Index Files



Secondary Index



- Index record points to a **bucket** that contains **pointers** to all the actual records with that particular search-key value.
- Secondary indices have to be **dense**

Primary and Secondary Indices

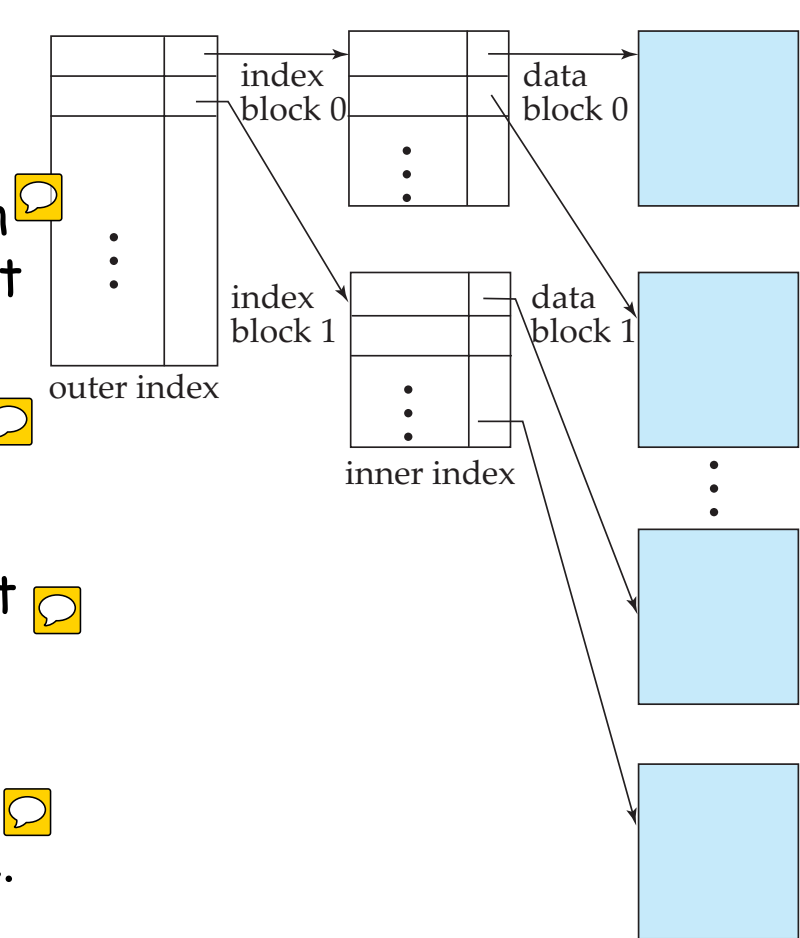


- Indices offer substantial benefits when searching for records.
- But **updating** indices imposes overhead on database modification - when a file is modified, every index on the file must be updated
- Sequential scan using primary index is efficient
- But a sequential scan using a secondary index is expensive
 - Each record access may fetch a new block from disk
 - Block fetch requires about 5 to 10 milliseconds; versus about 100 nanoseconds for memory access




Multilevel Index (Index on index)

- If primary index does not fit in memory, access becomes expensive.
- Solution: treat primary index kept on disk as a sequential file and construct a sparse index on it.
 - outer index - a sparse index of primary index
 - inner index - the primary index file
- If even outer index is too large to fit in main memory, yet another level of index can be created, and so on.
- Indices at all levels must be updated on insertion or deletion from the file.



Index Definition in SQL

- Create an index 
 - **create index** <index-name> **on** <relation-name> (<attribute-list>)
 - E.g.: **create index** b-index **on** branch(branch_name)
- To drop an index
 - **drop index** <index-name>
- Most database systems allow specification of type of index.

End of Lecture

■ Summary

- The Structure of Index
- Ordered Indices
- Primary index vs. Secondary index
- Dense index vs. sparse index
- Multilevel index

■ Reading

- Database System Concepts, 6th edition, chapter 11.1, 11.2
- Database System Concepts, 7th edition, chapter 14.1, 14.2