Transactions, Views, Indexes

Controlling Concurrent Behavior

Virtual and Materialized Views

Speeding Accesses to Data

Why Transactions?

- Database systems are normally being accessed by many users or processes at the same time.
  - Both queries and modifications.
- Unlike operating systems, which *support* interaction of processes, a DMBS needs to keep processes from troublesome interactions.

Example: Bad Interaction

- You and your domestic partner each take $100 from different ATM's at about the same time.
  - The DBMS better make sure one account deduction doesn't get lost.
- Compare: An OS allows two people to edit a document at the same time. If both write, one's changes get lost.

Transactions

- *Transaction* = process involving database queries and/or modification.
- Normally with some strong properties regarding concurrency.
- Formed in SQL from single statements or explicit programmer control.

ACID Transactions

- *ACID transactions* are:
  - *Atomic* : Whole transaction or none is done.
  - *Consistent* : Database constraints preserved.
  - *Isolated* : It appears to the user as if only one process executes at a time.
  - *Durable* : Effects of a process survive a crash.
- Optional: weaker forms of transactions are often supported as well.

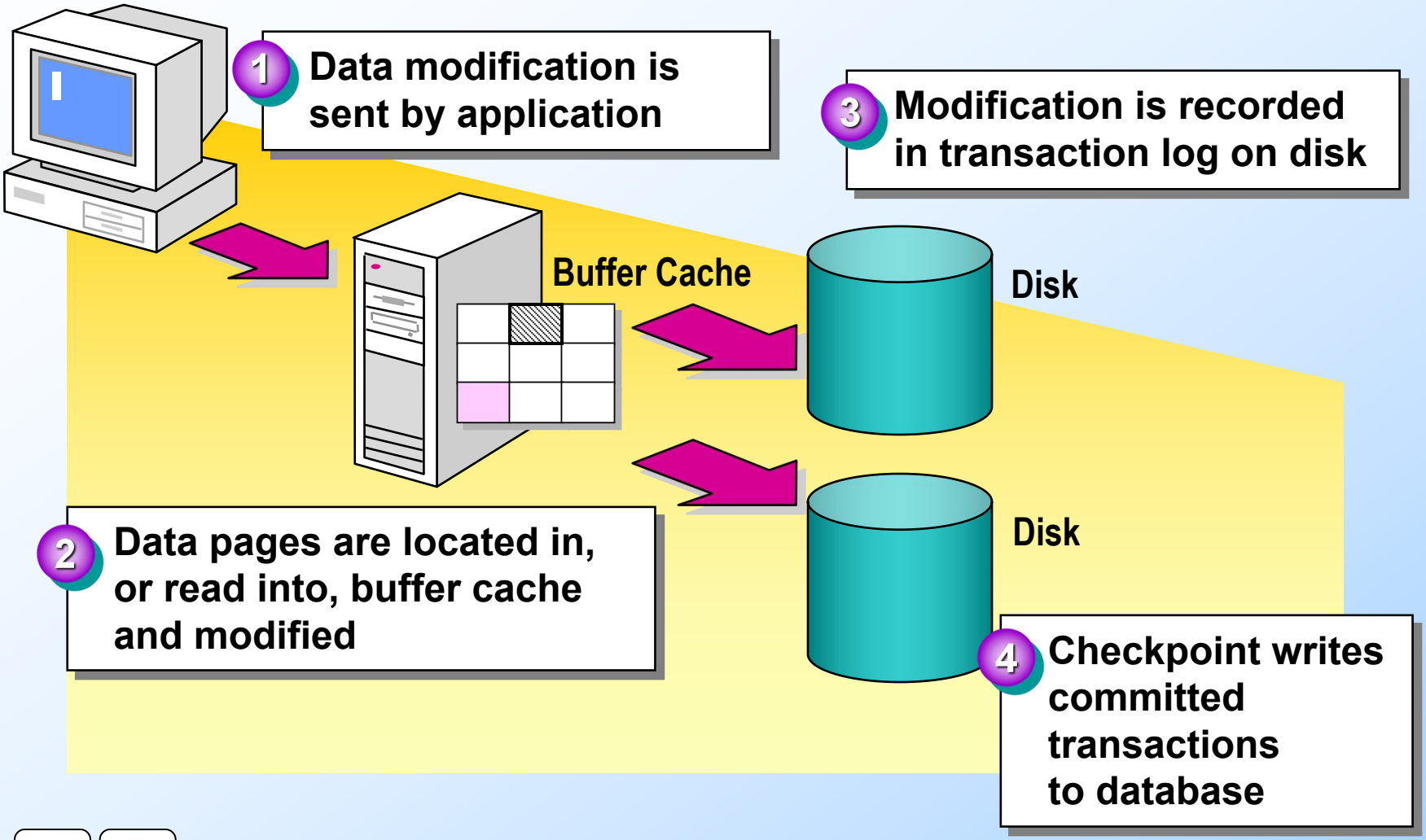
COMMIT

- The SQL statement COMMIT causes a transaction to complete.
  - It's database modifications are now permanent in the database.

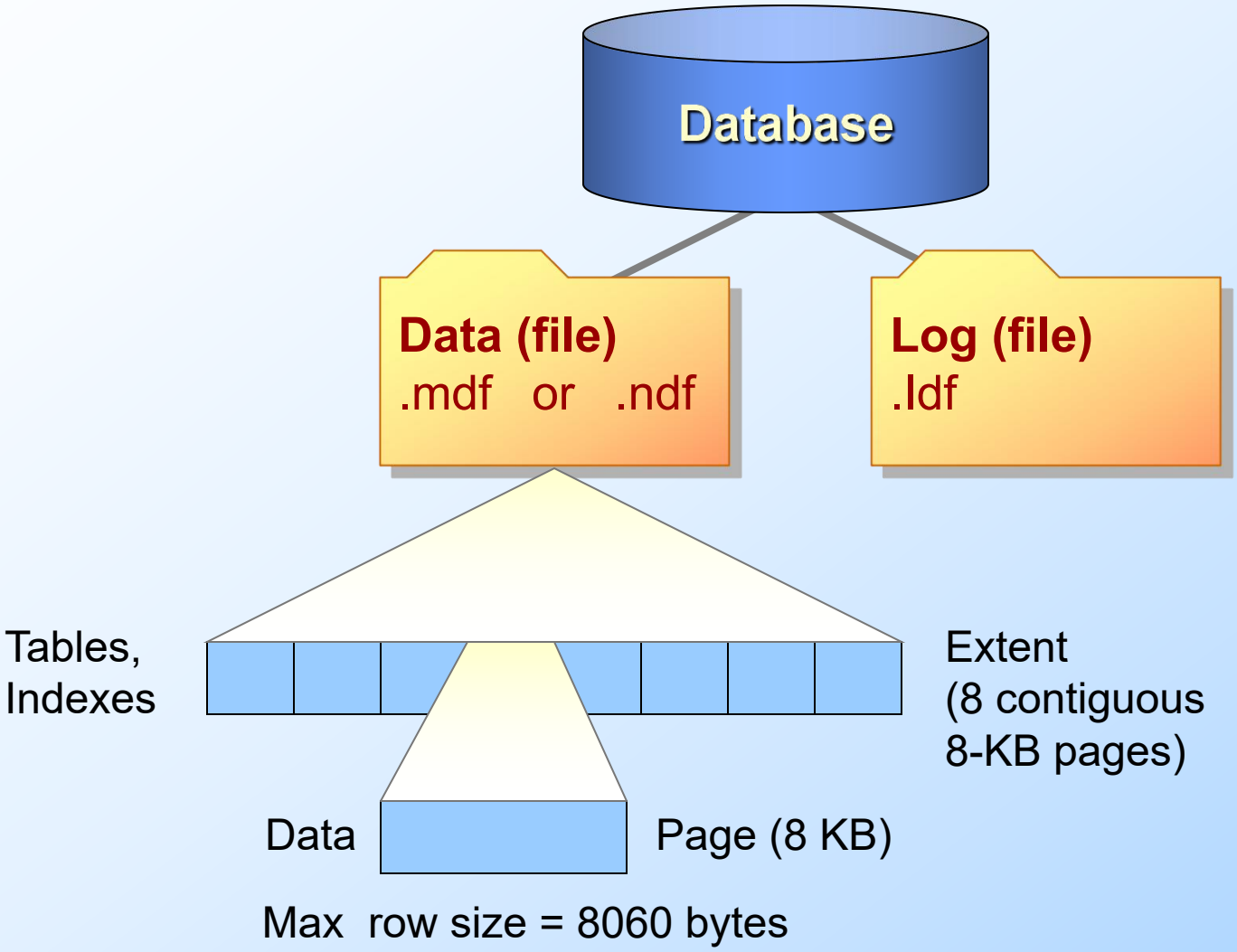
ROLLBACK

- The SQL statement ROLLBACK also causes the transaction to end, but by *aborting*.
  - No effects on the database.
- Failures like division by 0 or a constraint violation can also cause rollback, even if the programmer does not request it.

How the Transaction Log Works



How Data Is Stored



Example: Interacting Processes

- Assume the usual Sells(bar,beer,price) relation, and suppose that Joe's Bar sells only Bud for $2.50 and Miller for $3.00.
- Sally is querying Sells for the highest and lowest price Joe charges.
- Joe decides to stop selling Bud and Miller, but to sell only Heineken at $3.50.

Sally's Program

- Sally executes the following two SQL statements called (min) and (max) to help us remember what they do.

```
(max)   SELECT MAX(price) FROM Sells
        WHERE bar = 'Joe''s Bar';
(min)   SELECT MIN(price) FROM Sells
        WHERE bar = 'Joe''s Bar';
```

Joe's Program

- At about the same time, Joe executes the following steps: (del) and (ins).

```
(del)  DELETE FROM Sells
       WHERE bar = 'Joe"s Bar';
(ins)  INSERT INTO Sells
       VALUES('Joe"s Bar', 'Heineken', 3.50);
```

Interleaving of Statements

- Although (max) must come before (min), and (del) must come before (ins), there are no other constraints on the order of these statements, unless we group Sally's and/or Joe's statements into transactions.

Example: Strange Interleaving

- Suppose the steps execute in the order (max)(del)(ins)(min).

Joe's Prices:	{2.50,3.00}	{2.50,3.00}		{3.50}
Statement:	(max)	(del)	(ins)	(min)
Result:	3.00			3.50

- Sally sees MAX < MIN!

Fixing the Problem by Using Transactions

- If we group Sally's statements (max)(min) into one transaction, then she cannot see this inconsistency.
- She sees Joe's prices at some fixed time.
  - Either before or after he changes prices, or in the middle, but the MAX and MIN are computed from the same prices.

Another Problem: Rollback

- Suppose Joe executes (del)(ins), not as a transaction, but after executing these statements, thinks better of it and issues a ROLLBACK statement.
- If Sally executes her statements after (ins) but before the rollback, she sees a value, 3.50, that never existed in the database.

Solution

- If Joe executes (del)(ins) as a transaction, its effect cannot be seen by others until the transaction executes COMMIT.
  - If the transaction executes ROLLBACK instead, then its effects can *never* be seen.

Isolation Levels

- SQL defines four *isolation levels* = choices about what interactions are allowed by transactions that execute at about the same time.
- Only one level ("serializable") = ACID transactions.
- Each DBMS implements transactions in its own way.

Choosing the Isolation Level

- Within a transaction, we can say:

SET TRANSACTION ISOLATION LEVEL *X*

where *X* =

1. SERIALIZABLE
2. REPEATABLE READ
3. READ COMMITTED
4. READ UNCOMMITTED

Serializable Transactions

- If Sally = (max)(min) and Joe = (del)(ins) are each transactions, and Sally runs with isolation level SERIALIZABLE, then she will see the database either before or after Joe runs, but not in the middle.

Isolation Level Is Personal Choice

- Your choice, e.g., run serializable, affects only how *you* see the database, not how others see it.
- Example: If Joe Runs serializable, but Sally doesn't, then Sally might see no prices for Joe's Bar.
  - i.e., it looks to Sally as if she ran in the middle of Joe's transaction.

Read-Commited Transactions

- If Sally runs with isolation level READ COMMITTED, then she can see only committed data, but not necessarily the same data each time.
- Example: Under READ COMMITTED, the interleaving (max)(del)(ins)(min) is allowed, as long as Joe commits.
  - Sally sees MAX < MIN.

Repeatable-Read Transactions

- Requirement is like read-committed, plus: if data is read again, then everything seen the first time will be seen the second time.
  - But the second and subsequent reads may see *more* tuples as well.

Example: Repeatable Read

- Suppose Sally runs under REPEATABLE READ, and the order of execution is (max)(del)(ins)(min).
  - (max) sees prices 2.50 and 3.00.
  - (min) can see 3.50, but must also see 2.50 and 3.00, because they were seen on the earlier read by (max).

Read Uncommitted

- A transaction running under READ UNCOMMITTED can see data in the database, even if it was written by a transaction that has not committed (and may never).
- Example: If Sally runs under READ UNCOMMITTED, she could see a price 3.50 even if Joe later aborts.

Determining Which Type of Constraint to Use

Type of integrity	Constraint type
Domain	DEFAULT
	CHECK
	REFERENTIAL
Entity	PRIMARY KEY
	UNIQUE
Referential	FOREIGN KEY
	CHECK

DEFAULT Constraints

- Apply Only to INSERT Statements
- Only One DEFAULT Constraint Per Column
- Cannot Be Used with IDENTITY Property
  or rowversion Data Type
- Allow Some System-supplied Values

```
ALTER TABLE dbo.Customers
ADD
CONSTRAINT DF_contactname DEFAULT 'UNKNOWN'
FOR ContactName
```

CHECK Constraints

- Are Used with INSERT and UPDATE Statements
- Can Reference Other Columns in the Same Table
- Cannot:
  - Be used with the **rowversion** data type
  - Contain subqueries

```
ALTER TABLE dbo.Employees
ADD
CONSTRAINT CK_birthdate
CHECK (BirthDate > '01-01-1900' AND BirthDate <
getdate())
```

PRIMARY KEY Constraints

- Only One PRIMARY KEY Constraint Per Table
- Values Must Be Unique
- Null Values Are Not Allowed
- Creates a Unique Index on Specified Columns

```
ALTER TABLE dbo.Customers
ADD
CONSTRAINT PK_Customers
  PRIMARY KEY NONCLUSTERED (CustomerID)
```

UNIQUE Constraints

- Allow One Null Value
- Allow Multiple UNIQUE Constraints on a Table
- Defined with One or More Columns
- Enforced with a Unique Index

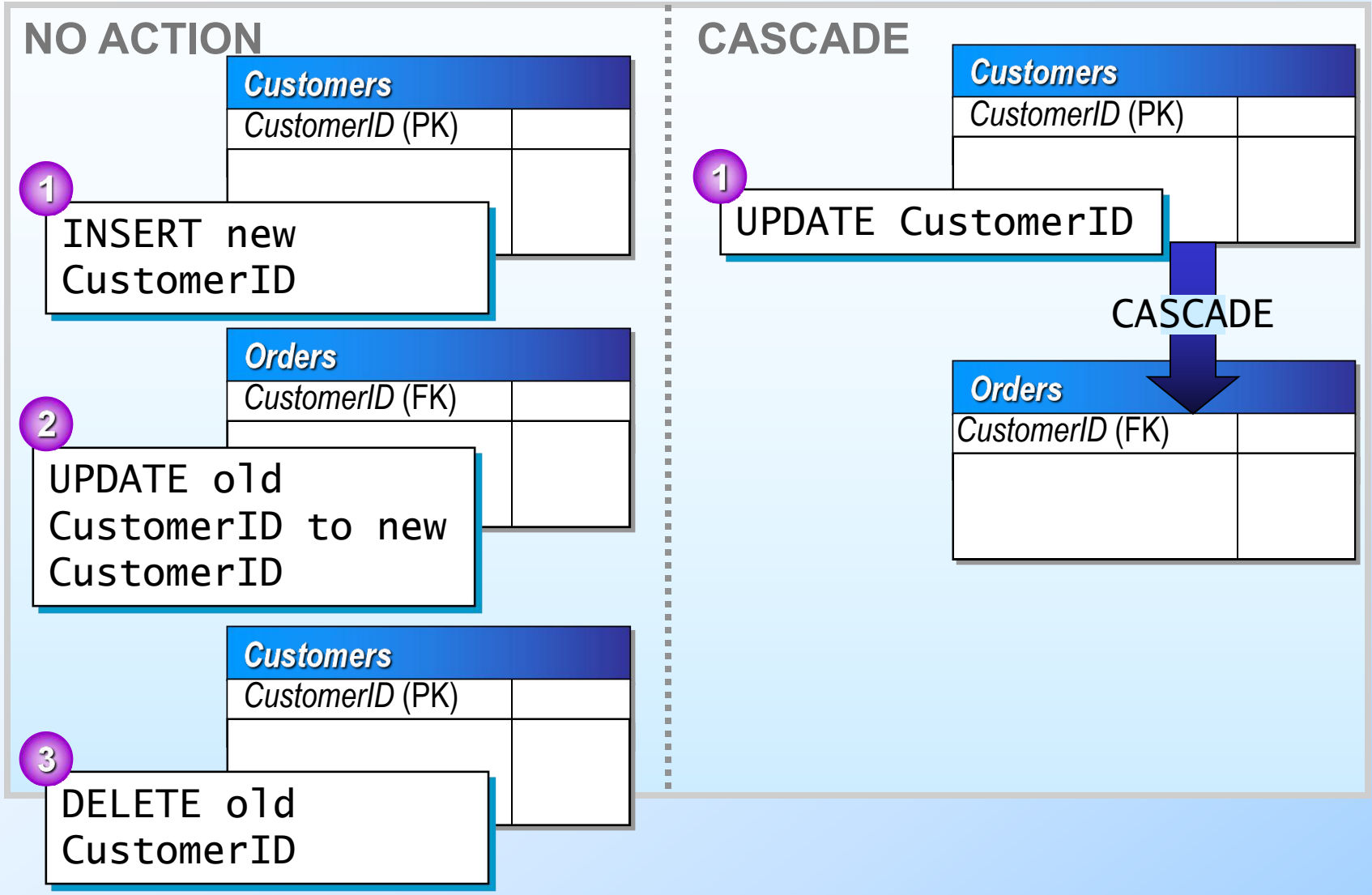
```
ALTER TABLE dbo.Suppliers
ADD
CONSTRAINT U_CompanyName
  UNIQUE NONCLUSTERED (CompanyName)
```

FOREIGN KEY Constraints

- Must Reference a PRIMARY KEY or UNIQUE Constraint
- Provide Single or Multicolumn Referential Integrity
- Do Not Automatically Create Indexes
- Users Must Have SELECT or REFERENCES Permissions on Referenced Tables
- Use Only REFERENCES Clause Within Same Table

```
ALTER TABLE dbo.Orders
ADD CONSTRAINT FK_Orders_Customers
  FOREIGN KEY (CustomerID)
  REFERENCES dbo.Customers(CustomerID)
```

Cascading Referential Integrity



Using Defaults and Rules

- As Independent Objects They:
  - Are defined once
  - Can be bound to one or more columns or user-defined data types

```
CREATE DEFAULT phone_no_default
  AS '(000)000-0000'
GO
EXEC sp_bindefault phone_no_default,
  'Customers.Phone'
```

```
CREATE RULE regioncode_rule
  AS @regioncode IN ('IA', 'IL', 'KS', 'MO')
GO
EXEC sp_bindrule regioncode_rule,
  'Customers.Region'
```

Deciding Which Enforcement Method to Use

Data integrity components	Functionality	Performance costs	Before or after modification
Constraints	Medium	Low	Before
Defaults and rules	Low	Low	Before
Triggers	High	Medium-High	After
Data types, Null/Not Null	Low	Low	Before

Views

- A *view* is a relation defined in terms of stored tables (called *base tables*) and other views.
- Two kinds:
  1. *Virtual* = not stored in the database; just a query for constructing the relation.
  2. *Materialized* = actually constructed and stored.

Declaring Views

- Declare by:

  CREATE [MATERIALIZED] VIEW
  <name> AS <query>;

- Default is virtual.

Example: View Definition

- CanDrink(drinker, beer) is a view "containing" the drinker-beer pairs such that the drinker frequents at least one bar that serves the beer:

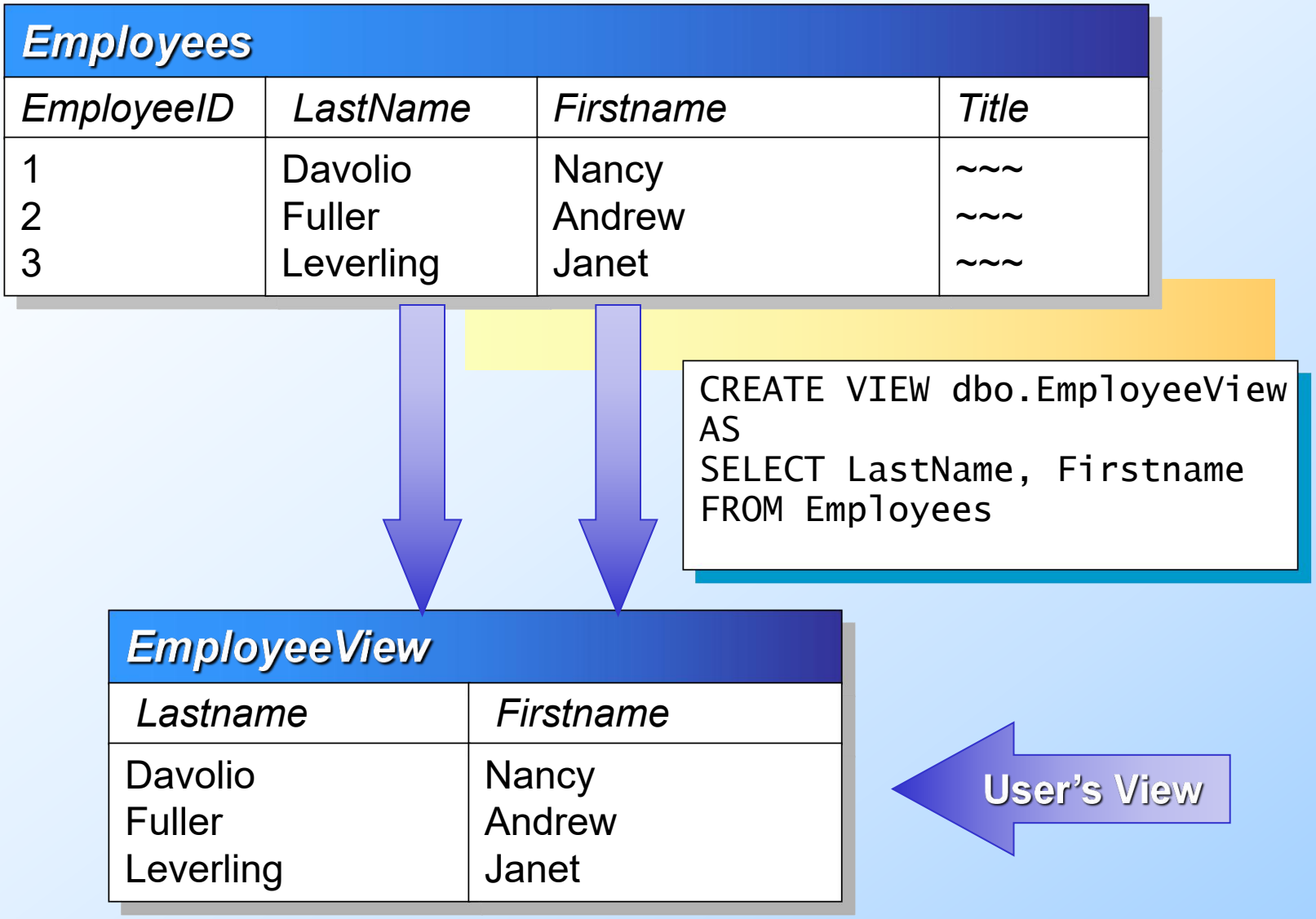
```
CREATE VIEW CanDrink AS
    SELECT drinker, beer
    FROM Frequents, Sells
    WHERE Frequents.bar = Sells.bar;
```

Example: Accessing a View

- Query a view as if it were a base table.
  - Also: a limited ability to modify views if it makes sense as a modification of one underlying base table.
- Example query:

```
SELECT beer FROM CanDrink
WHERE drinker = 'Sally';
```

Using Views


Employees
EmployeeID
LastName
Firstname
Title
1
2
3
Davolio
Fuller
Leverling
Nancy
Andrew
Janet
~~~
~~~
~~~
CREATE VIEW dbo.EmployeeView
AS
SELECT LastName, Firstname
FROM Employees
EmployeeView
Lastname
Firstname
Davolio
Fuller
Leverling
Nancy
Andrew
Janet
User's View
~~~

Example: View of Joined Tables

Orders

OrderID	CustomerID	RequiredDate	ShippedDate
10663	BONAP	1997-09-24	1997-10-03
10827	BONAP	1998-01-26	1998-02-06
10427	PICCO	1997-02-24	1997-03-03
10451	QUICK	1997-03-05	1997-03-12
10515	QUICK	1997-05-07	1997-05-23

Customers

CustomerID	CompanyName	ContactName
BONAP	Bon app'	Laurence Lebihan
PICCO	Piccolo und mehr	Georg Pipps
QUICK	QUICK-Stop	Horst Kloss

```
CREATE VIEW dbo.ShipStatusView
AS
SELECT OrderID, RequiredDate, ShippedDate,
       ContactName
FROM Customers c INNER JOIN Orders o
   ON c.CustomerID = O.CustomerID
WHERE RequiredDate < ShippedDate
```

ShipStatusView

OrderID	ShippedDate	ContactName
10264	1996-08-23	Laurence Lebihan
10271	1996-08-30	Georg Pipps
10280	1996-09-12	Horst Kloss

Advantages of Views

- Focus the Data for Users
  - Focus on important or appropriate data only
  - Limit access to sensitive data
- Mask Database Complexity
  - Hide complex database design
  - Simplify complex queries, including distributed queries to heterogeneous data
- Simplify Management of User Permissions
- Improve Performance
- Organize Data for Export to Other Applications

Triggers on Views

- Generally, it is impossible to modify a virtual view, because it doesn't exist.
- But an INSTEAD OF trigger lets us interpret view modifications in a way that makes sense.
- Example: View Synergy has (drinker, beer, bar) triples such that the bar serves the beer, the drinker frequents the bar and likes the beer.

Example: The View

Pick one copy of each attribute

```
CREATE VIEW Synergy AS
    SELECT Likes.drinker, Likes.beer, Sells.bar
    FROM Likes, Sells, Frequents
    WHERE Likes.drinker = Frequents.drinker
        AND Likes.beer = Sells.beer
        AND Sells.bar = Frequents.bar;
```

Natural join of Likes, Sells, and Frequents

Interpreting a View Insertion

- We cannot insert into Synergy --- it is a virtual view.
- But we can use an INSTEAD OF trigger to turn a (drinker, beer, bar) triple into three insertions of projected pairs, one for each of Likes, Sells, and Frequents.
  - Sells.price will have to be NULL.

The Trigger

```
CREATE TRIGGER ViewTrig
    INSTEAD OF INSERT ON Synergy
    REFERENCING NEW ROW AS n
    FOR EACH ROW
    BEGIN
        INSERT INTO LIKES VALUES(n.drinker, n.beer);
        INSERT INTO SELLS(bar, beer) VALUES(n.bar, n.beer);
        INSERT INTO FREQUENTS VALUES(n.drinker, n.bar);
    END;
```

Materialized Views

- Problem: each time a base table changes, the materialized view may change.
  - Cannot afford to recompute the view with each change.
- Solution: Periodic reconstruction of the materialized view, which is otherwise "out of date."

Example: Axess/Class Mailing List

- The class mailing list cs145-aut0708-students is in effect a materialized view of the class enrollment in Axess.
- Actually updated four times/day.
  - You can enroll and miss an email sent out after you enroll.

Example: A Data Warehouse

- Wal-Mart stores every sale at every store in a database.
- Overnight, the sales for the day are used to update a *data warehouse* = materialized views of the sales.
- The warehouse is used by analysts to predict trends and move goods to where they are selling best.

Indexes

- *Index* = data structure used to speed access to tuples of a relation, given values of one or more attributes.
- Could be a hash table, but in a DBMS it is always a balanced search tree with giant nodes (a full disk page) called a *B-tree*.

Using Clustered Indexes

- Each Table Can Have Only One Clustered Index
- The Physical Row Order of the Table and the Order of Rows in the Index Are the Same
- Key Value Uniqueness Is Maintained Explicitly
  or Implicitly

Using Nonclustered Indexes

- Nonclustered Indexes Are the SQL Server Default
- Existing Nonclustered Indexes Are Automatically Rebuilt When:
  - An existing clustered index is dropped
  - A clustered index is created
  - The DROP_EXISTING option is used to change which columns define the clustered index

Declaring Indexes

- No standard!
- Typical syntax:

```
CREATE INDEX BeerInd ON
  Beers(manf);
CREATE INDEX SellInd ON
  Sells(bar, beer);
```

Using Indexes

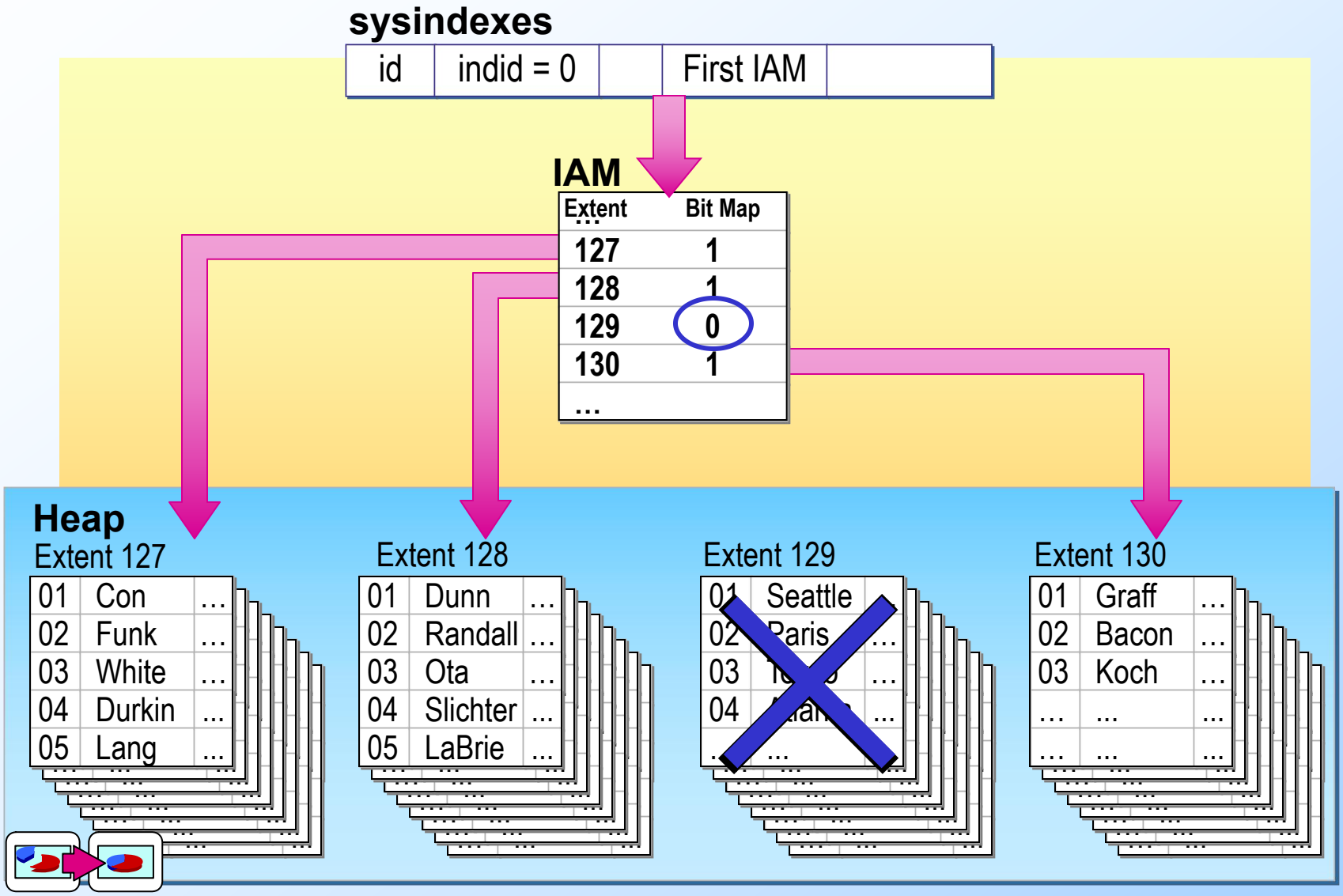
- Given a value *v*, the index takes us to only those tuples that have *v* in the attribute(s) of the index.
- Example: use BeerInd and SellInd to find the prices of beers manufactured by Pete's and sold by Joe. (next slide)

Using Indexes --- (2)

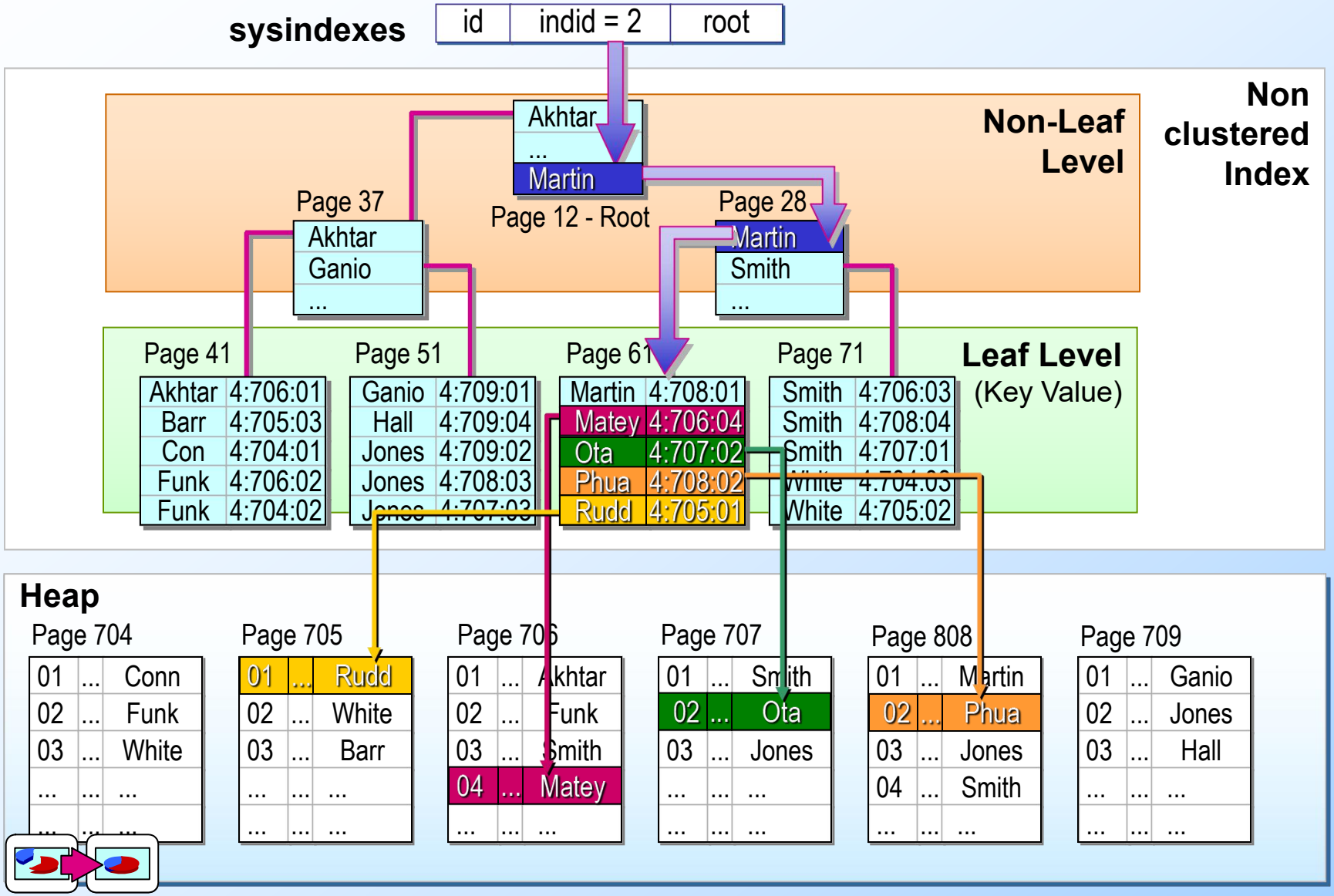
```
SELECT price FROM Beers, Sells
WHERE manf = 'Pete''s' AND
    Beers.name = Sells.beer AND
    bar = 'Joe''s Bar';
```

1. Use BeerInd to get all the beers made by Pete's.
2. Then use SellInd to get prices of those beers, with bar = 'Joe"s Bar'

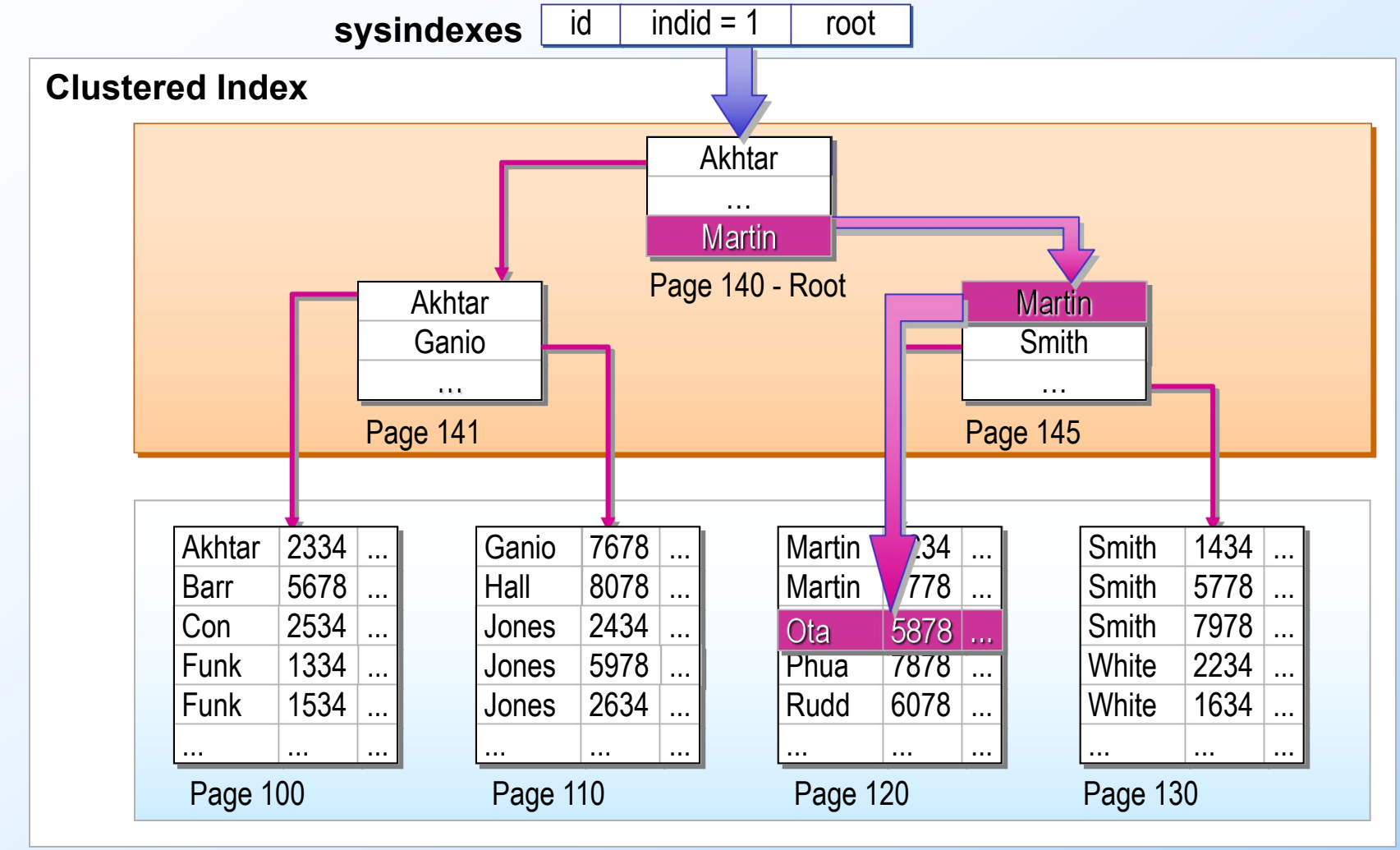
Finding Rows Without Indexes

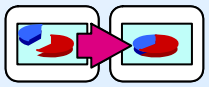


Finding Rows in a Heap with a Nonclustered Index

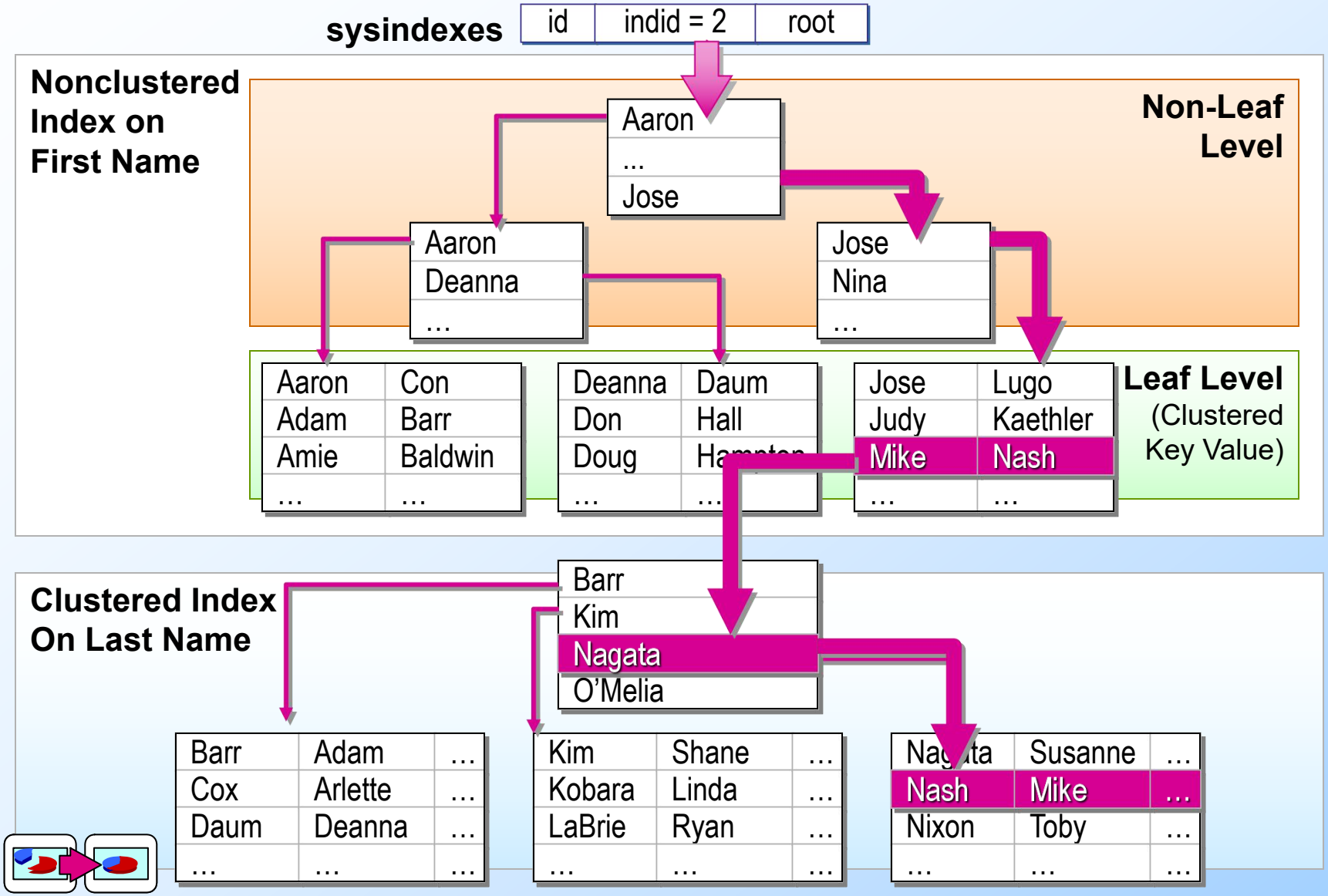


Finding Rows in a Clustered Index





Finding Rows in a Clustered Index with a Nonclustered Index



Database Tuning

- A major problem in making a database run fast is deciding which indexes to create.
- Pro: An index speeds up queries that can use it.
- Con: An index slows down all modifications on its relation because the index must be modified too.

Example: Tuning

- Suppose the only things we did with our beers database was:
  1. Insert new facts into a relation (10%).
  2. Find the price of a given beer at a given bar (90%).
- Then SellInd on Sells(bar, beer) would be wonderful, but BeerInd on Beers(manf) would be harmful.

Tuning Advisors

- A major research thrust.
  - Because hand tuning is so hard.
- An advisor gets a *query load*, e.g.:
  1. Choose random queries from the history of queries run on the database, or
  2. Designer provides a sample workload.

Tuning Advisors --- (2)

- The advisor generates candidate indexes and evaluates each on the workload.
  - Feed each sample query to the query optimizer, which assumes only this one index is available.
  - Measure the improvement/degradation in the average running time of the queries.