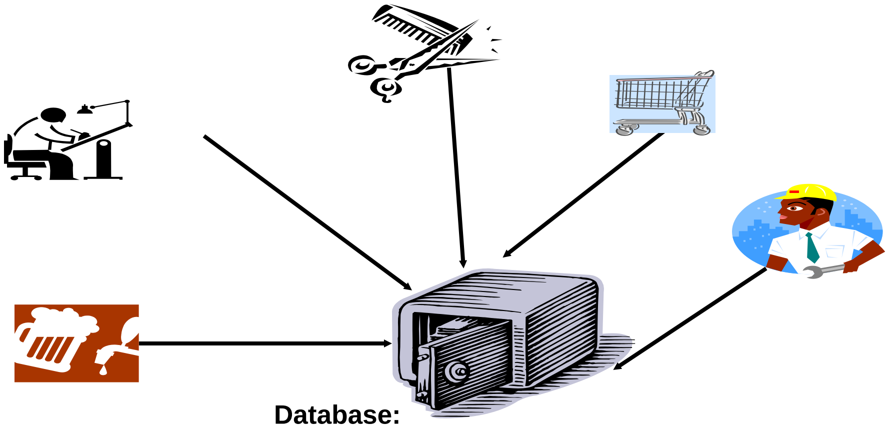
Databases

In this section of notes you will learn about: different types of databases, how information is stored in databases, the different types of relations that can exist within a database, how information can be retrieved via queries and how to normalize a database.

Purpose Of A Database

- To store information

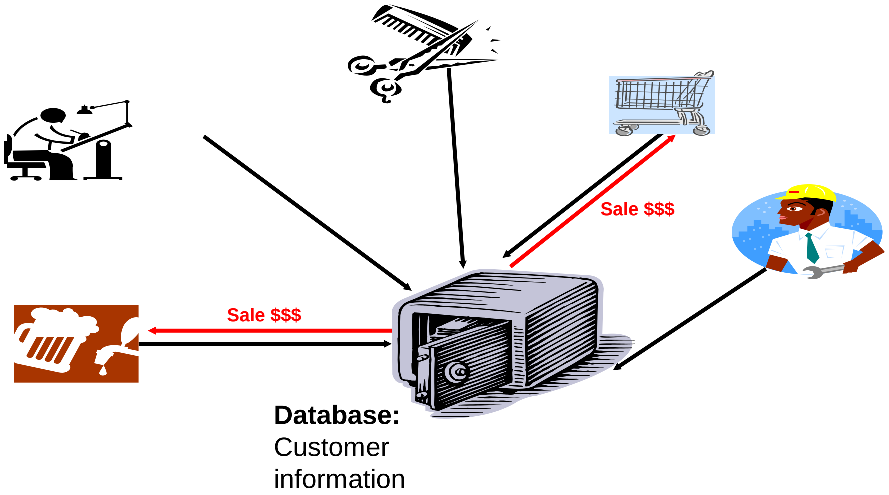


Francesco Rollandin/OpenClipart

Database: Customer information

Purpose Of A Database

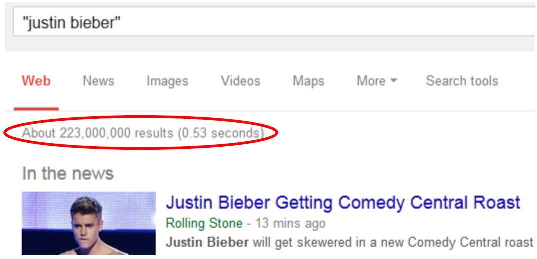
- To retrieve information information



Database:
Customer
information

Databases: Storing / Retrieving Information

- As you will see this isn't as easy as it seems.
- Information must be stored such that:
  - Information can be quickly retrieved



"justin bieber"

About 223,000,000 results (0.53 seconds)

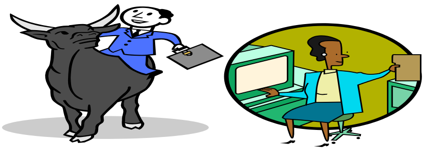
In the news

Justin Bieber Getting Comedy Central Roast
Rolling Stone - 13 mins ago
Justin Bieber will get skewered in a new Comedy Central roast

Databases: Storing / Retrieving Information (2)

- The database is designed to reduce problems during maintenance (additions, modifications, deletions)
  - Example: You will see this actual issue when we talk about database normalization.

Marketing Dept.
- Loren Coleman
- William McCloud



Finance & Accounting
- Victor Davion
- Ester Flowers

Databases: Storing / Retrieving Information (3)

- Minimizes redundancy:

Students data base table

ID	First Name	Last Name	Phone	Class 1	Class 2
123456	Jamie	Smyth	553-3992	CPSC 203, 01	PSYC 205, 03
123457	Stacey	Walls	790-3992	ACCT 321, 02	FNCE 353, 05
123458	Angel	Lam	551-4993	MATH 211, 02	MATH 251, 01

Classes data base table

ClassName	*ClassNumber*	*Lecture No*	ClassDescription
CPSC	*203*	*01*	Introduction to Computers
CPSC	*231*	*01*	Introduction to Computer Science I
CPSC	*233*	*01*	Introduction to Computer Science II

With Bother With Databases?

- Are used to store and retrieve information
- Why bother, use a simple file as an alternative?
  - E.g., tracking client information

MILES EDWARD O'BRIAN
DS9 Corp
Electrical engineering
2007 purchases: $10,0000,000
2006 purchases: $1,750,000

JAMIE SMYTHE
Cooperative services
Gasoline refining
2006 purchases: $5,000,0000
2005 purchases: $5,000,0000
2004 purchases: $5,000,0000
2003 purchases: $5,000,0000
2002 purchases: $5,000,0000

SCOTT BRUCE
Bryce Consulting
Investment analysis
2007 purchases: $500,000
2006 purchases: $1,500,000
2005 purchases: $2,500,000
2004 purchases: $500,000

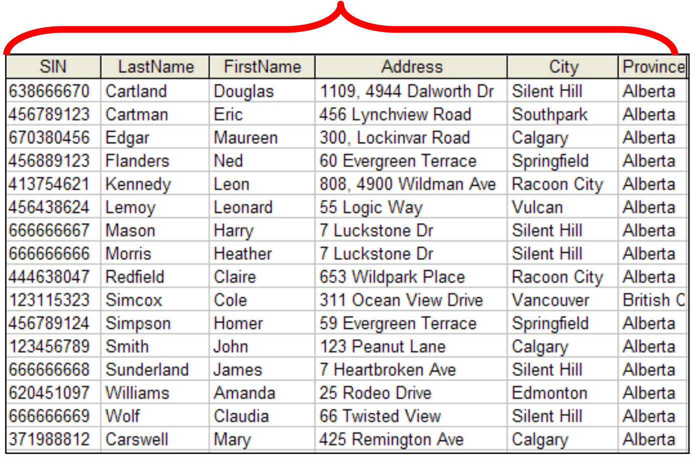
Etc.

- If the list is short then a simple text file may suffice
- As the list grows organizing and updating the information becomes more challenging (duplicates or inaccuracies?)
- Also searching the list according to specific criteria may become difficult
  - e.g., Show all clients whose purchases in 2007 were between one and five million dollars
  - e.g., Show all clients that made a year purchase exceeding 10 million dollars.

Storing Information In A Database

- Information is stored in tables:

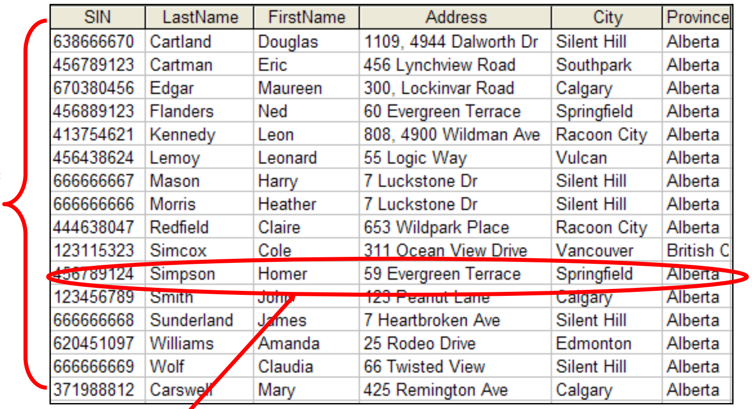
'Employees' table



SIN	LastName	FirstName	Address	City	Province
638666670	Cartland	Douglas	1109, 4944 Dalworth Dr	Silent Hill	Alberta
456789123	Cartman	Eric	456 Lynchview Road	Southpark	Alberta
670380456	Edgar	Maureen	300, Lockinvar Road	Calgary	Alberta
456889123	Flanders	Ned	60 Evergreen Terrace	Springfield	Alberta
413754621	Kennedy	Leon	808, 4900 Wildman Ave	Racoon City	Alberta
456438624	Lemoy	Leonard	55 Logic Way	Vulcan	Alberta
666666667	Mason	Harry	7 Luckstone Dr	Silent Hill	Alberta
666666666	Morris	Heather	7 Luckstone Dr	Silent Hill	Alberta
444638047	Redfield	Claire	653 Wildpark Place	Racoon City	Alberta
123115323	Simcox	Cole	311 Ocean View Drive	Vancouver	British C
456789124	Simpson	Homer	59 Evergreen Terrace	Springfield	Alberta
123456789	Smith	John	123 Peanut Lane	Calgary	Alberta
666666668	Sunderland	James	7 Heartbroken Ave	Silent Hill	Alberta
620451097	Williams	Amanda	25 Rodeo Drive	Edmonton	Alberta
666666669	Wolf	Claudia	66 Twisted View	Silent Hill	Alberta
371988812	Carswell	Mary	425 Remington Ave	Calgary	Alberta

Storing Information In A Database (2)

- Row = Record: An example instance of data within the table.
  - Employees Table: one row is an employee in the organization



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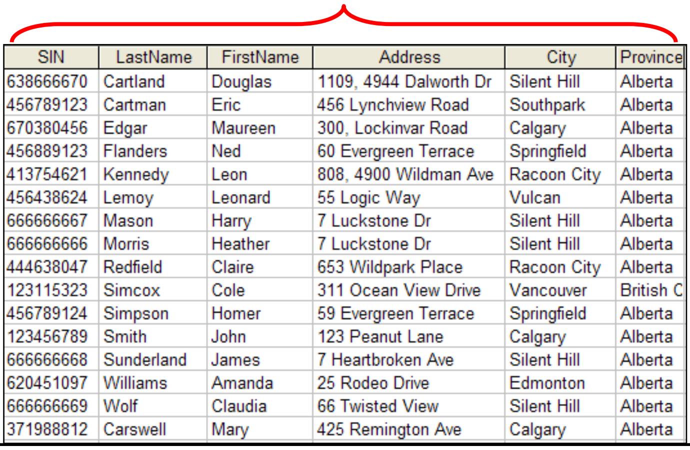
Records of the table

One record, ‘Simpson, Homer’

Storing Information In A Database (3)

- Column: are that attributes that we track for each record
  - Employees Table: each column specifies the information we store about employees in this database.

Attributes of each record



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456889123	Flanders	Ned	60 Evergreen Terrace	Springfield	Alberta
413754621	Kennedy	Leon	808, 4900 Wildman Ave	Racoon City	Alberta
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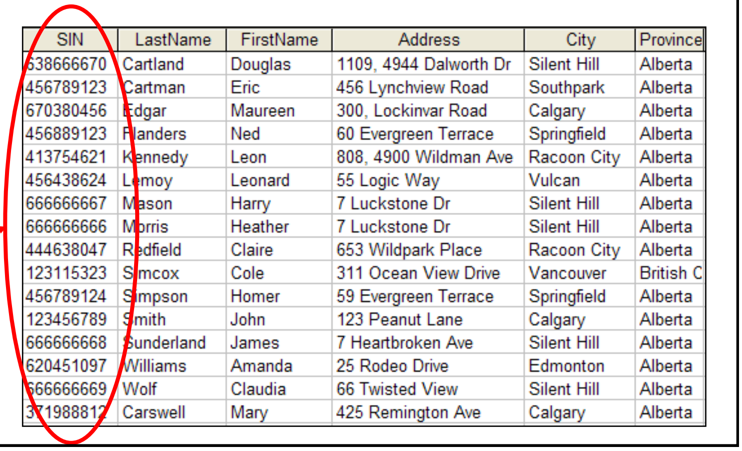
Primary Key

- Each table should typically have one field designated as the primary key:
  - The primary key must be guaranteed to be unique
  - It identifies one record from another



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Primary Key for table 'Employees' is the 'SIN' field

Choosing A Primary Key

- A primary key must be unique to each record because it is the one thing that distinguishes them.
- If there is at least one instance where records can have the same value for a field then that field cannot be a primary key. (When in doubt if this will ever be the case verify with your users).
- If a single key field cannot be found then several fields can be combined into a composite key. (Each field is still a separate field but together they form a unique primary key for each record).
  - E.g., Course name, course number, lecture section (CPSC 203 L01)
- If a unique primary key still cannot be found then 'invent' one.
  - E.g., `DepartmentID` from the `Departments` table

Example Problem: Tracking Employees

- You want to store employee and other information.
- Information we need to track for each employee:
  - Social insurance number
  - Last name
  - First name
  - Address
  - City
  - Province
  - Postal code
  - Home phone number
  - Date of birth
  - Hourly pay rate

Example Problem: Tracking Employee Pay

- Employees are paid hourly and may work for different departments. A job may cross department bounds
  - e.g., James Tam worked 25 hours on a chemical cleanup job on a chemical spill that occurred on the accounting and HR floor on Jan 15, 2015 to be billed to accounting and human resources.
- Information we need to track for pay
  - Employee to pay
  - Department to bill for the cost
  - Start date of the work
  - Hours worked
- Department information
  - Name of the department
  - Annual budget
  - Each department is assigned an ID code:
    - Human Resources = 1, Marketing = 2, Finance = 3, Management information systems = 4

Initial Database

- Three tables are required and start off with the following attributes:

EMPLOYEES

SIN	LName	FName	Address	City	Province	Postal code	Phone	Birth date	Hourly pay rate

TIMEBILLED

Employee info	Department	Start date	Hours worked

DEPARTMENTS

Department Code	Department Name	Budget

Refinements Needed: `Employees`

- Primary key?

EMPLOYEES

SIN	LName	FName	Address	City	Province	Postal code	Phone	Birth date	Hourly pay rate

Refinements Needed: Employees

- Primary key?

EMPLOYEES

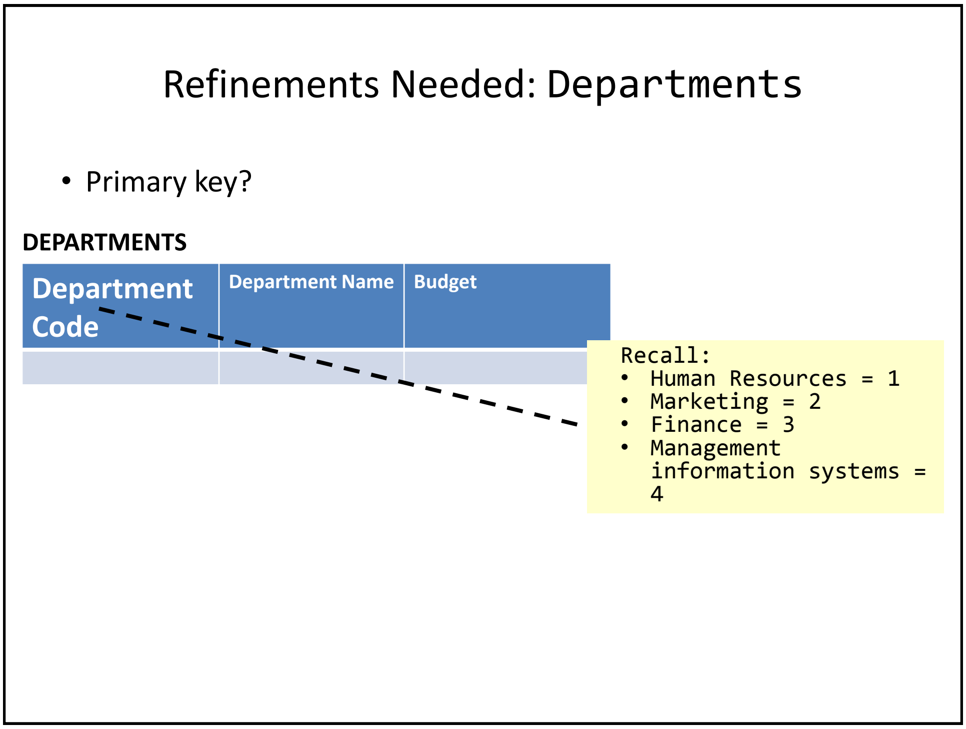
SIN	LName	FName	Address	City	Province	Postal code	Phone	Birth date	Hourly pay rate

Refinements Needed: Departments

- Primary key?

DEPARTMENTS

Department Code	Department Name	Budget



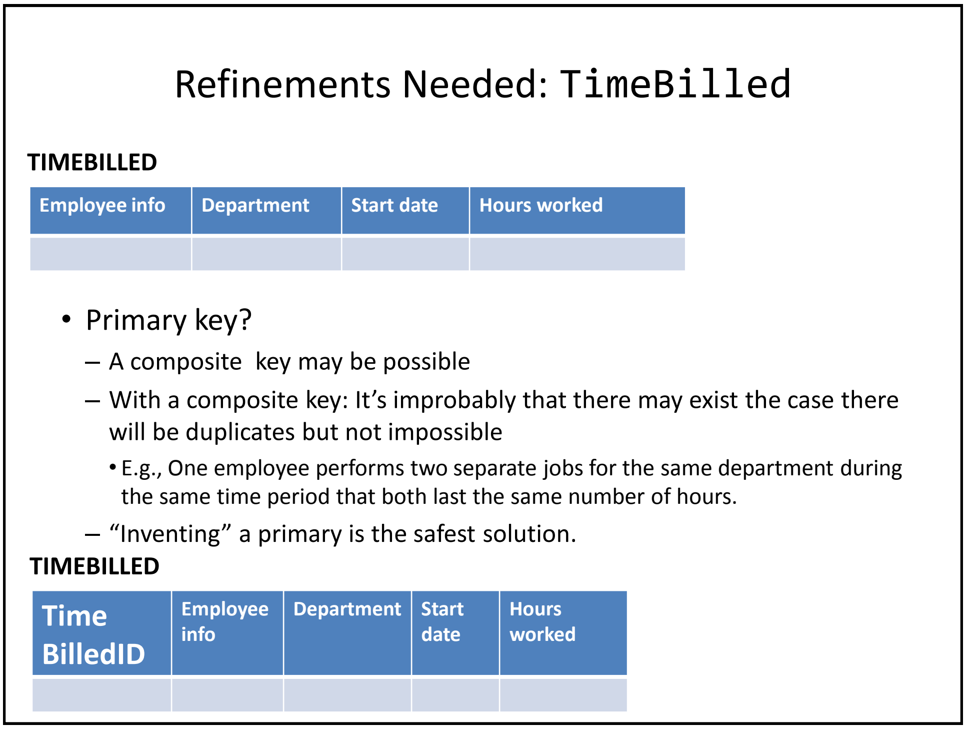
Refinements Needed: Departments

- Primary key?

DEPARTMENTS

Department Code	Department Name	Budget

Recall:
- Human Resources = 1
- Marketing = 2
- Finance = 3
- Management information systems = 4



Refinements Needed: TimeBilled

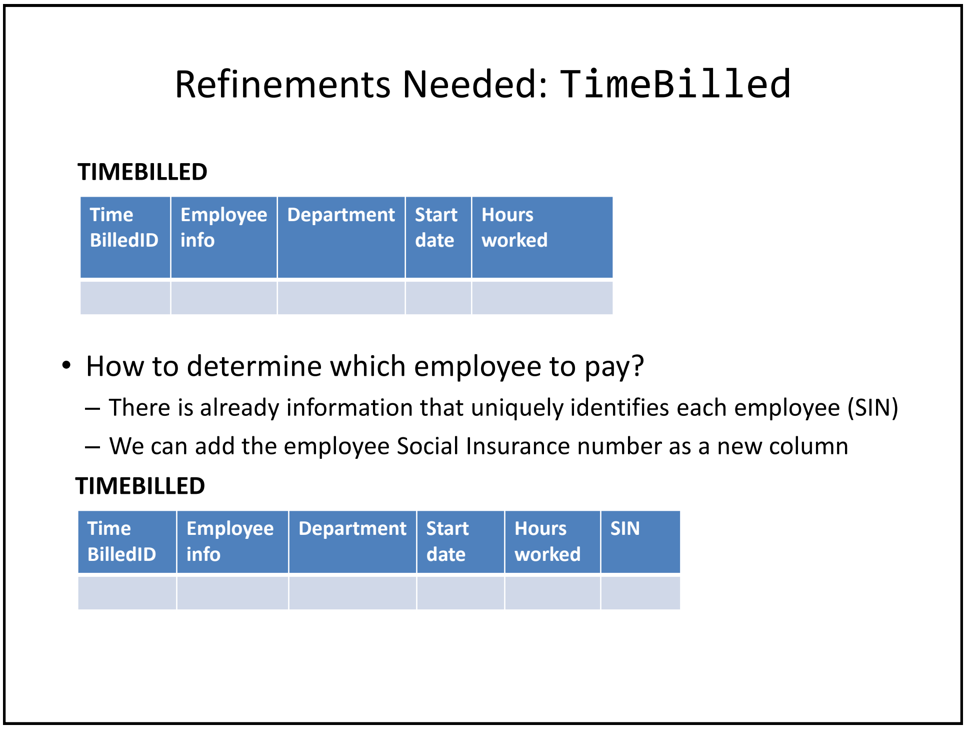
TIMEBILLED

Employee info	Department	Start date	Hours worked

- Primary key?
  - A composite key may be possible
  - With a composite key: It’s improbably that there may exist the case there will be duplicates but not impossible
    - E.g., One employee performs two separate jobs for the same department during the same time period that both last the same number of hours.
  - “Inventing” a primary is the safest solution.

TIMEBILLED

Time BilledID	Employee info	Department	Start date	Hours worked



Refinements Needed: TimeBilled

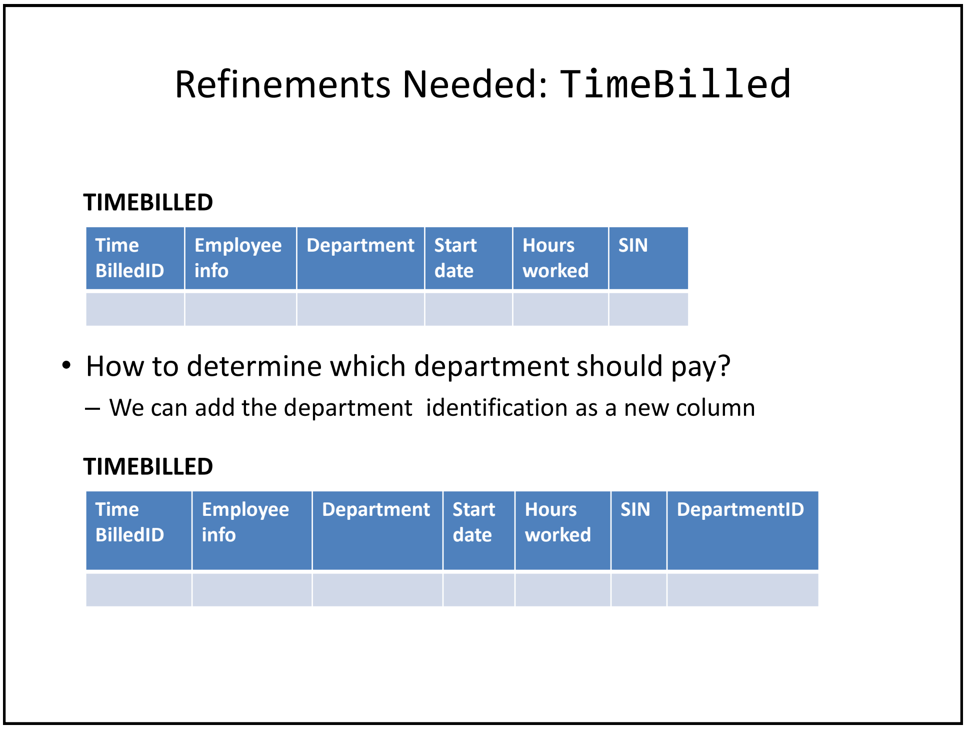
TIMEBILLED

Time BilledID	Employee info	Department	Start date	Hours worked

- How to determine which employee to pay?
  - There is already information that uniquely identifies each employee (SIN)
  - We can add the employee Social Insurance number as a new column

TIMEBILLED

Time BilledID	Employee info	Department	Start date	Hours worked	SIN



Refinements Needed: TimeBilled

TIMEBILLED

Time BilledID	Employee info	Department	Start date	Hours worked	SIN

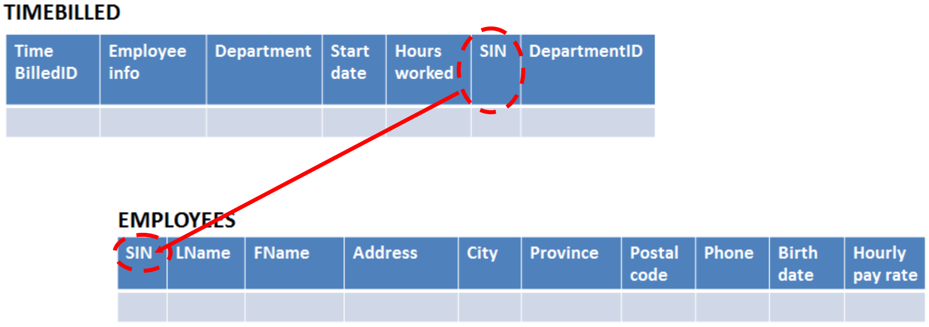
- How to determine which department should pay?
  - We can add the department identification as a new column

TIMEBILLED

Time BilledID	Employee info	Department	Start date	Hours worked	SIN	DepartmentID

Foreign Key

- A key in one table that refers to a key in another field:
  - E.g. SIN and DepartmentID field of the TimeBilled table



TIMEBILLED

Time BilledID	Employee info	Department	Start date	Hours worked	SIN	DepartmentID

EMPLOYEES

SIN	LName	FName	Address	City	Province	Postal code	Phone	Birth date	Hourly pay rate

MS-Access Tables Used In The Example

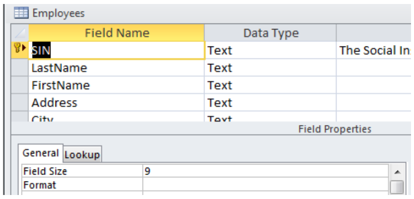
- **This example can be found online:**
  - http://pages.cpsc.ucalgary.ca/~tamj/203/topics/databases.html
- **Employees table (tracks information about individual employees)**
  - SIN
  - LastName
  - FirstName
  - Address
  - City
  - Province
  - PostalCode
  - HomePhone
  - BirthDate
  - PayRate

Tables Used In The Example (2)

- **Departments table (maps each department to a number e.g., Human Resources = 1, Marketing = 2)**
  - DepartmentID
  - DepartmentName
  - Budget
- **TimeBilled table (for each pay period information about how many hours each employee worked and how much they are owed is tracked with this table).**
  - TimeBilledID
  - SIN
  - DepartmentID
  - StartPayPeriod
  - HoursWorked

MS-Access: Views Of Your Database

- **Design view**



Employees

	Field Name	Data Type	
	SIN	Text	The Social In
	LastName	Text	
	FirstName	Text	
	Address	Text	
	City	Text	

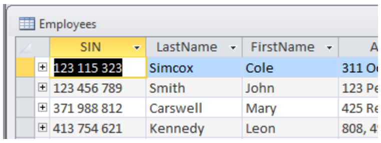
Field Properties

General Lookup

Field Size	9
Format	

  - Typically start with this view
  - Used to specify what fields that a table will consist of:
    - e.g., DepartmentID, DepartmentName
  - Used to specify the type and the format of the information in each field:
    - e.g., SIN is field with 9 characters that must be in the format 000 000 000

- **Datasheet view**



Employees

SIN	LastName	FirstName	A
123 115 323	Simcox	Cole	311 O
123 456 789	Smith	John	123 Pe
371 988 812	Carswell	Mary	425 Re
413 754 621	Kennedy	Leon	808, 4

- Once the fields have been specified in the Design view using the Datasheet view allows for each record to be entered.

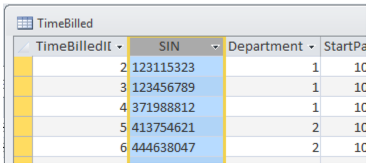
Types Of Tables

- **Data tables**
  - Stores data that provides information about the database
  - Dynamic, will likely be manipulated over the life the database (add, delete, modify)
  - E.g. `Employees`, `TimeBilled` tables (address and hours worked may change over time)
- **Validation tables**
  - Used to ensure data integrity (to ‘lookup’ values)
  - Typically it maps one value to another (e.g., product to product code, book to ISBN number)
  - Rarely (if ever) changes
  - E.g., `Departments` table

DepartmentID	DepartmentName
1	Human Resources
2	Marketing
3	Finance
4	Management Information Systems

Parent And Child Tables

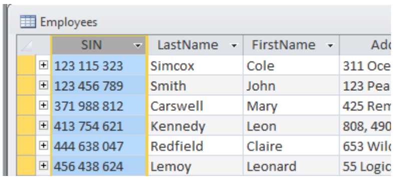
- A table whose primary key is the foreign key of another table is the parent table.
- The table whose foreign key is the primary key of another table is the child table.
- Example:



TimeBilled

TimeBilledI[	SIN	Department	StartPa
2	123115323	1	1C
3	123456789	1	1C
4	371988812	1	1C
5	413754621	2	1C
6	444638047	2	1C

SIN is a foreign key of the ‘TimeBilled’ table that corresponds to the SIN primary key of the ‘Employees’ table **(CHILD TABLE)**



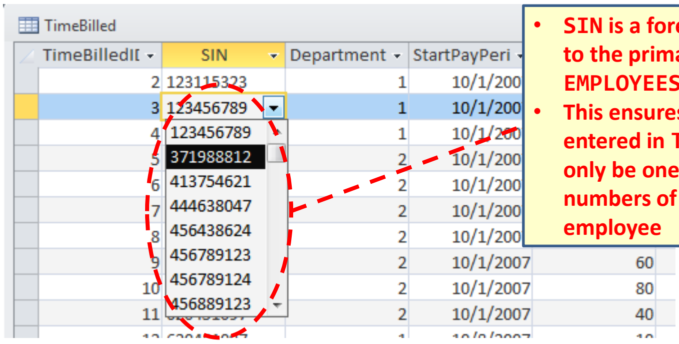
Employees

SIN	LastName	FirstName	Ad
123 115 323	Simcox	Cole	311 Oce
123 456 789	Smith	John	123 Pea
371 988 812	Carswell	Mary	425 Rem
413 754 621	Kennedy	Leon	808, 490
444 638 047	Redfield	Claire	653 Wil
456 438 624	Lemoy	Leonard	55 Logic

SIN: Primary key for ‘Employees’ table **(PARENT TABLE)**

Purpose Of Foreign Keys

- To ensure the integrity of the foreign key.
- (MS-Access: Ensure referential integrity): as new records are entered in a table with a foreign key as one of the fields, it will ensure that the record will only be entered with a foreign key value that is listed in the appropriate table.



TimeBilled

TimeBilledI	SIN	Department	StartPayPeri	
2	123115323	1	10/1/200	
3	123456789	1	10/1/200	
4		1	10/1/200	
5		2	10/1/200	
6		2	10/1/200	
7		2	10/1/200	
8		2	10/1/200	
9		2	10/1/2007	60
10		2	10/1/2007	80
11		2	10/1/2007	40

123456789
371988812
413754621
444638047
456438624
456789123
456789124
456889123

- SIN is a foreign key referring to the primary key of the EMPLOYEES table.
- This ensures that a SIN entered in TimeBilled will only be one of the SIN numbers of an actual employee

Null Values

- Refers to empty fields of a record
- Primary keys cannot be null but other fields may be null

Types Of Data Integrity In Databases

1. Table-level integrity (entity integrity):
   - Ensuring that no duplicate records exist.
   - Ensuring that no primary keys are null: MS-Access (automatic) indexed – no duplicates.
2. Relationship-level integrity (referential integrity):
   - Ensuring that relationship between a pair of tables is sound and the records in the tables are synchronized when data is entered into, updated in or deleted from either table (MS-Access: only partially implemented).
3. Field-level integrity (domain integrity):
   - Ensuring that the values in each field are valid and accurate.
   - In MS-Access this is done through input masks and validation rules.

Input Masks

- Ensures the proper format for the data entered into the database
- Example for A2: SIN number in the Employees table must be entered as:
  - <*three digits*> <space> <*three digits*> <space> <*three digits*>
- Invalid inputs:
  - Abc def ghi
  - 321 22 4234

Validation Rules

- Validation rules check the data that is entered that it is in the correct range.
- Examples for A2 (all employ the logical AND):
  - ‘Employees’: BirthDate
  - ‘Employees’: PayRate
  - ‘TimeBilled’: HoursWorked

Guidelines For Naming Tables

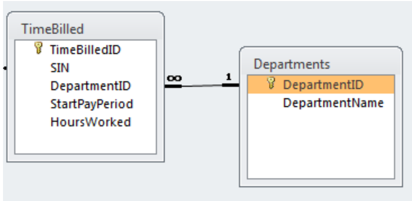
1. Create a unique and descriptive name.
   - “VehicleMaintenance” vs. “CarInfo”
2. Do not use words that convey physical characteristics or database terminology.
   - “File”, “Record”, “Table”
3. While names should be short avoid using acronyms and abbreviations unless they are well-known.
   - “SC” = ???
4. Consider using the plural form of a name.
   - “Employees” vs. “Employee”
5. Avoid the use of spaces in names.
   - “Undergraduate students” vs. “Undergraduate_Students”

Guidelines For Naming Fields

1. Select a unique and descriptive name (similar to tables).
2. Create a name that accurately, clearly and unambiguously identifies the characteristic that the field represents.
   – “`Mobile`” vs. “`CellPhone`” or “`MobilePhone`”
3. While names should be short avoid using acronyms and abbreviations unless they are well-known (similar to tables).
4. Use the singular form of a name.
5. Avoid the use of spaces in names (similar to tables).

Relationships Between Tables

- Relationships occur when a field of one table is a foreign key in another table.



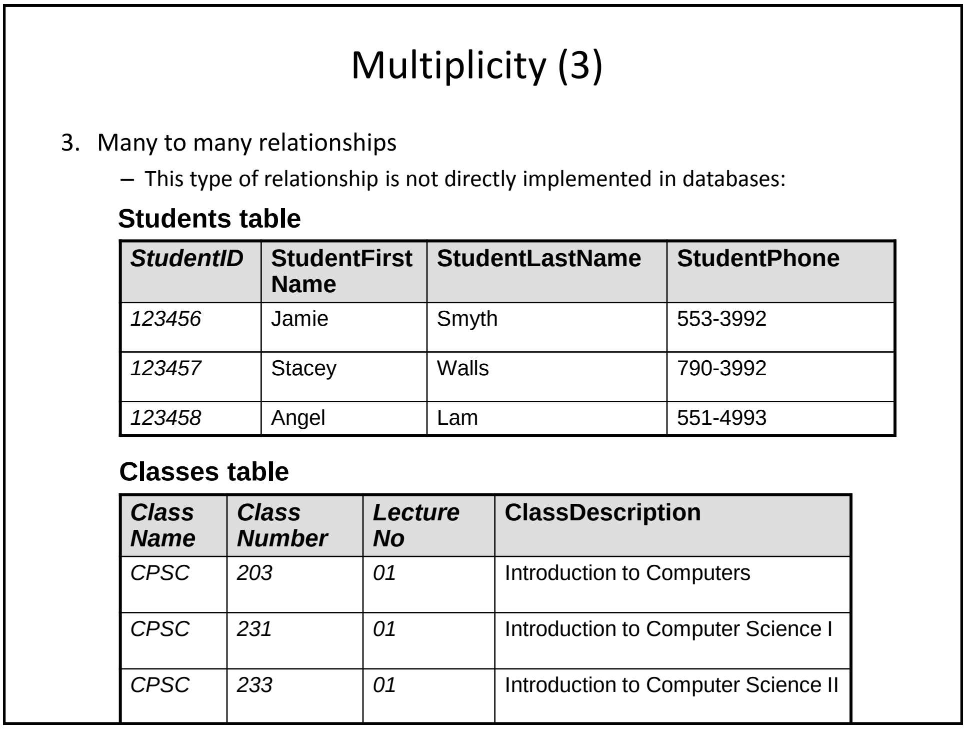
- Multiplicity: indicates how many instances of a particular item participates in the relationship:
  1. One to one
  2. One to many
  3. Many to many

Multiplicity

1. One to one relationships
   - One entity participates in the relationship from the ‘left’ and one entity participates in the relationship from the ‘right’.
   - Person : head
   - Worker : Social Insurance Number
   - This type of relationship is rare in databases
2. One to many relationships
   - On one side of the relationship one entity participates in the relationship while on the other side: zero or more entities may participate in the relationship.
   - Person : Hair
   - Employees : TimeBilled : Departments

Multiplicity (2)

3. Many to many relationships
   - On each side of the relationship zero or more entities may participate in the relationship.
   - Students : Classes



Multiplicity (3)

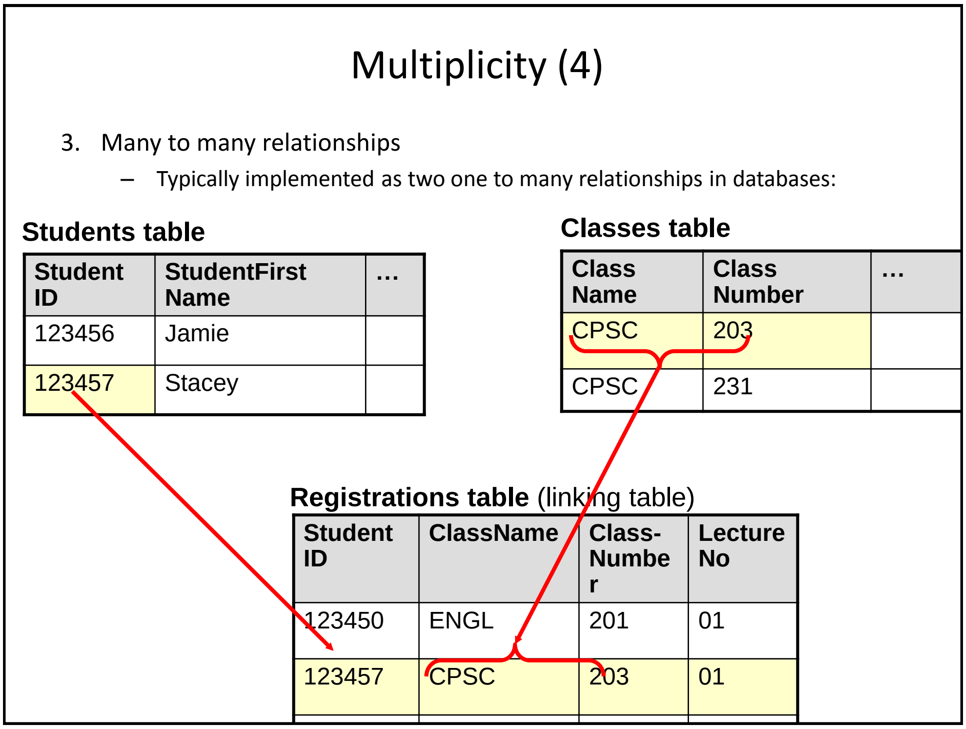
3. Many to many relationships
   - This type of relationship is not directly implemented in databases:

Students table

StudentID	StudentFirst Name	StudentLastName	StudentPhone
123456	Jamie	Smyth	553-3992
123457	Stacey	Walls	790-3992
123458	Angel	Lam	551-4993

Classes table

Class Name	*Class Number*	*Lecture No*	ClassDescription
CPSC	*203*	*01*	Introduction to Computers
CPSC	*231*	*01*	Introduction to Computer Science I
CPSC	*233*	*01*	Introduction to Computer Science II



Multiplicity (4)

3. Many to many relationships
   - Typically implemented as two one to many relationships in databases:

Students table

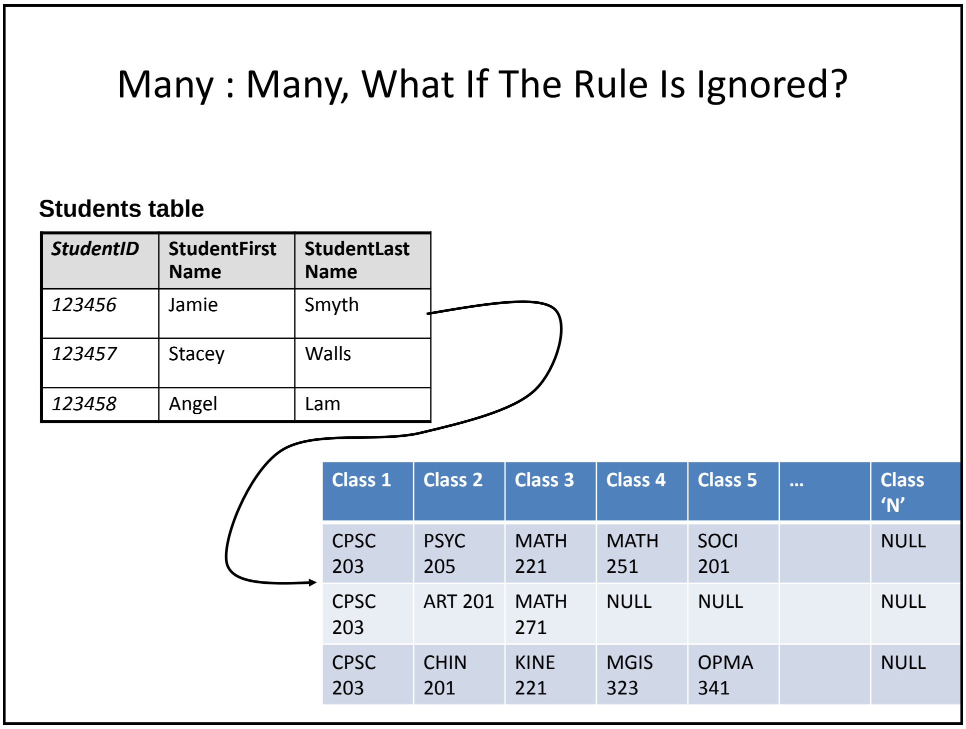
Student ID	StudentFirst Name	…
123456	Jamie	
123457	Stacey	

Classes table

Class Name	Class Number	…
CPSC	203	
CPSC	231	

Registrations table (linking table)

Student ID	ClassName	Class-Number	Lecture No
123450	ENGL	201	01
123457	CPSC	203	01

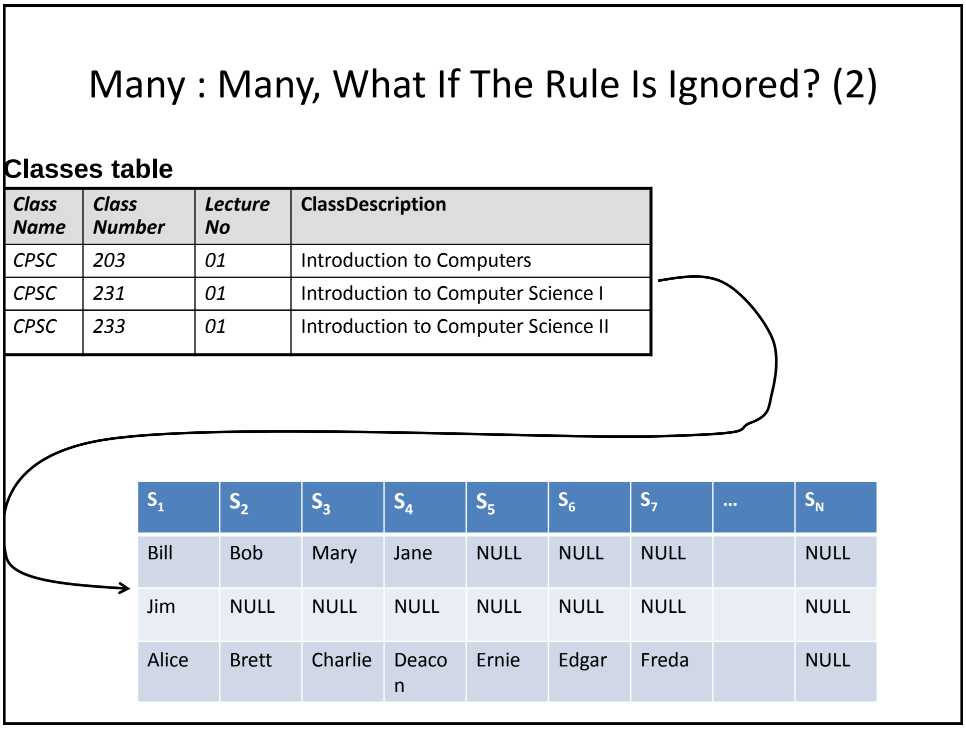


Many : Many, What If The Rule Is Ignored?

Students table

StudentID	StudentFirst Name	StudentLast Name
123456	Jamie	Smyth
123457	Stacey	Walls
123458	Angel	Lam

Class 1	Class 2	Class 3	Class 4	Class 5	…	Class 'N'
CPSC 203	PSYC 205	MATH 221	MATH 251	SOCI 201		NULL
CPSC 203	ART 201	MATH 271	NULL	NULL		NULL
CPSC 203	CHIN 201	KINE 221	MGIS 323	OPMA 341		NULL



Many : Many, What If The Rule Is Ignored? (2)

Classes table

Class Name	*Class Number*	*Lecture No*	ClassDescription
CPSC	*203*	*01*	Introduction to Computers
CPSC	*231*	*01*	Introduction to Computer Science I
CPSC	*233*	*01*	Introduction to Computer Science II

S_1	S_2	S_3	S_4	S_5	S_6	S_7	…	S_N
Bill	Bob	Mary	Jane	NULL	NULL	NULL		NULL
Jim	NULL	NULL	NULL	NULL	NULL	NULL		NULL
Alice	Brett	Charlie	Deaco n	Ernie	Edgar	Freda		NULL

Diagrammatically Representing Databases

- Entity-Relation diagrams (E-R Diagrams or E.R.D.'s): show the fields of a table.

Format

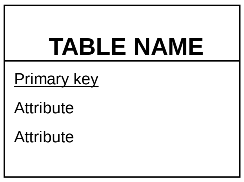


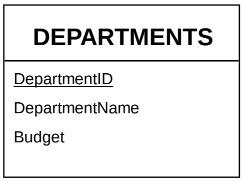
TABLE NAME

Primary key

Attribute

Attribute

Example



DEPARTMENTS

DepartmentID

DepartmentName

Budget

Primary : Foreign Keys Again

- When there is a one to many relationship the primary key of the 'one' side becomes a foreign key on the 'many' side.
- Examples:

1 **Many**

– `Employees` : `TimeBilled`

SIN: Primary key **SIN: Foreign key**

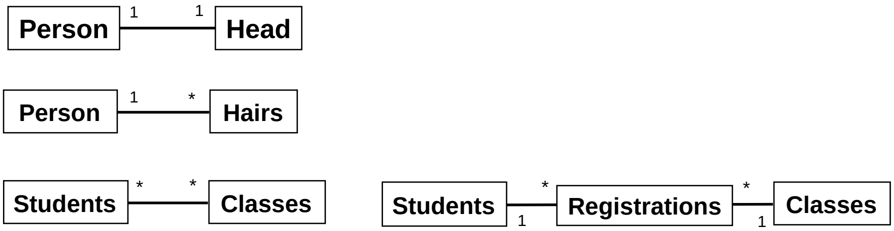
1 **Many**

– `Departments` : `TimeBilled`

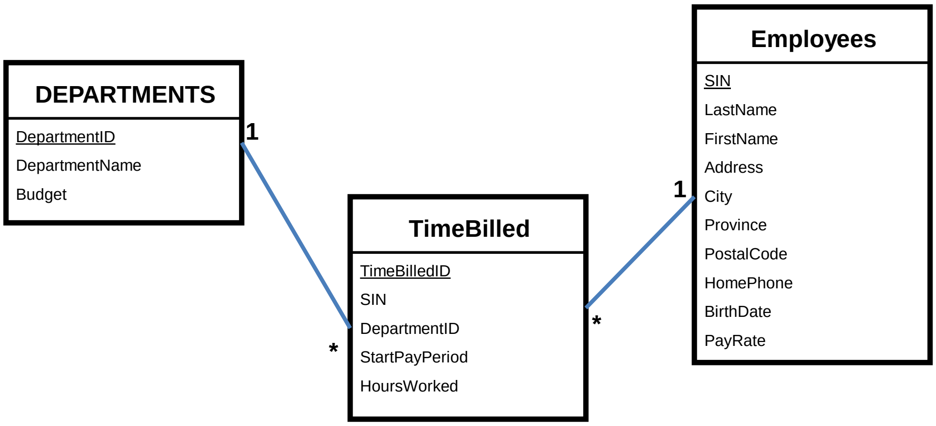
DepartmentID: Primary key **DepartmentID: Foreign key**

Diagrammatically Representing Relationships

- Graphically representing relationships between tables as well as any enforced rules on multiplicity:



The ERD For The Example Database



DEPARTMENTS

DepartmentID
DepartmentName
Budget

TimeBilled

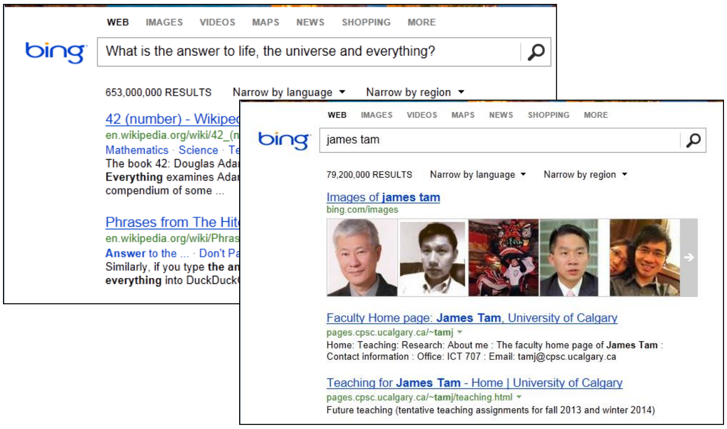
TimeBilledID
SIN
DepartmentID
StartPayPeriod
HoursWorked

Employees

SIN
LastName
FirstName
Address
City
Province
PostalCode
HomePhone
BirthDate
PayRate

Database Queries

- Queries are questions ‘asked’ of/to the database in order to retrieve information.



What is the answer to life, the universe and everything?

653,000,000 RESULTS Narrow by language Narrow by region

42 (number) - Wikiped
en.wikipedia.org/wiki/42_(n
Mathematics · Science · Te
The book 42: Douglas Adai
Everything examines Adai
compendium of some ...

Phrases from The Hit
en.wikipedia.org/wiki/Phras
Answer to the ... · Don't Pa
Similarly, if you type **the an**
everything into DuckDuck(

james tam

79,200,000 RESULTS Narrow by language Narrow by region

Images of **james tam**
bing.com/images

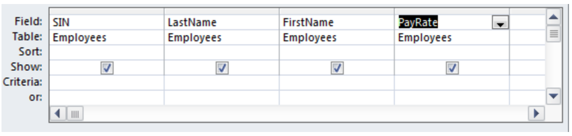
Faculty Home page: **James Tam**, University of Calgary
pages.cpsc.ucalgary.ca/~**tamj**
Home: Teaching: Research: About me : The faculty home page of **James Tam** :
Contact information : Office: ICT 707 : Email: tamj@cpsc.ucalgary.ca

Teaching for **James Tam** - Home | University of Calgary
pages.cpsc.ucalgary.ca/~**tamj**/teaching.html
Future teaching (tentative teaching assignments for fall 2013 and winter 2014)

Retrieving Data Via Queries

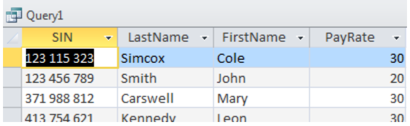
- Data retrieval occurs through the use of ‘queries’:
  - A query is a question asked of the data in the database.
  - Typically worded to show only the parts of the database for which the answer to the question is true.
  - Example: What is the SIN, name and pay rate of every employee in the Employees Table:

Query



Field:	SIN	LastName	FirstName	PayRate
Table:	Employees	Employees	Employees	Employees
Sort:				
Show:	☑	☑	☑	☑
Criteria:				
or:				

Result of the query



Query1

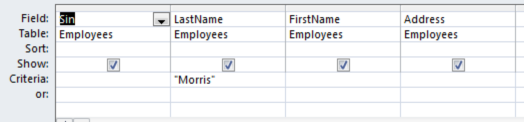
SIN	LastName	FirstName	PayRate
123 115 323	Simcox	Cole	30
123 456 789	Smith	John	20
371 988 812	Carswell	Mary	30
413 754 621	Kennedy	Leon	30

Retrieving Data Via Queries (2)

Query

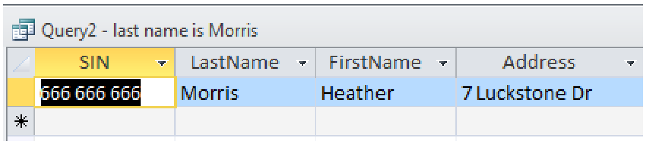
– Example: What is the SIN, name & address of all employees that have the last name of Morris?

Query



Field:	Sin	LastName	FirstName	Address
Table:	Employees	Employees	Employees	Employees
Sort:				
Show:	☑	☑	☑	☑
Criteria:		"Morris"		
or:				

Result of the query

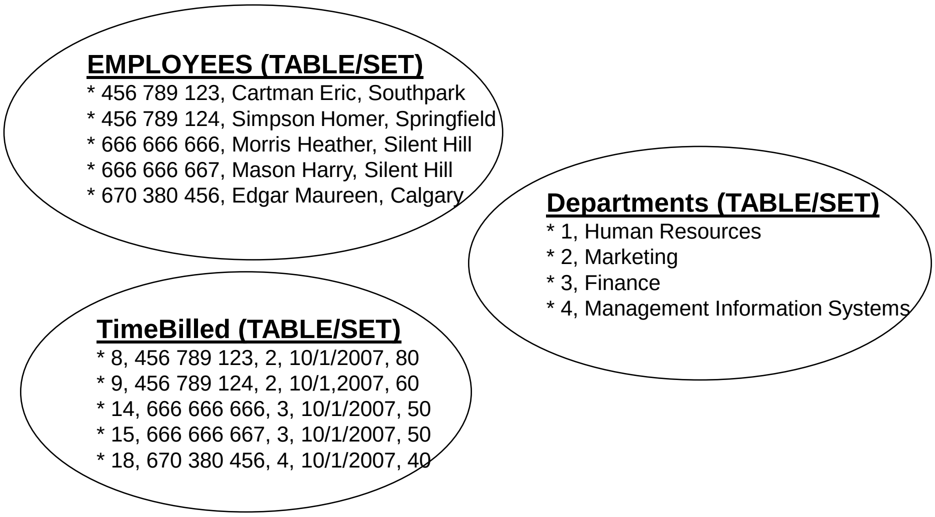


Query2 - last name is Morris

SIN	LastName	FirstName	Address
666 666 666	Morris	Heather	7 Luckstone Dr

Databases And Set Theory

- Each table can be viewed as a set of information.



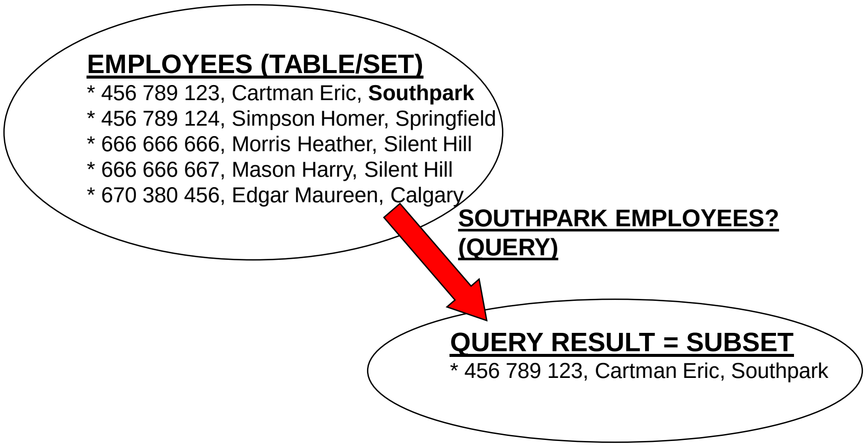
EMPLOYEES (TABLE/SET)
* 456 789 123, Cartman Eric, Southpark
* 456 789 124, Simpson Homer, Springfield
* 666 666 666, Morris Heather, Silent Hill
* 666 666 667, Mason Harry, Silent Hill
* 670 380 456, Edgar Maureen, Calgary

Departments (TABLE/SET)
* 1, Human Resources
* 2, Marketing
* 3, Finance
* 4, Management Information Systems

TimeBilled (TABLE/SET)
* 8, 456 789 123, 2, 10/1/2007, 80
* 9, 456 789 124, 2, 10/1,2007, 60
* 14, 666 666 666, 3, 10/1/2007, 50
* 15, 666 666 667, 3, 10/1/2007, 50
* 18, 670 380 456, 4, 10/1/2007, 40

Queries And Set Theory

- Queries retrieve a subset of the information:
  - Example: Which employees come from ‘Southpark’



EMPLOYEES (TABLE/SET)

* 456 789 123, Cartman Eric, **Southpark**
* 456 789 124, Simpson Homer, Springfield
* 666 666 666, Morris Heather, Silent Hill
* 666 666 667, Mason Harry, Silent Hill
* 670 380 456, Edgar Maureen, Calgary

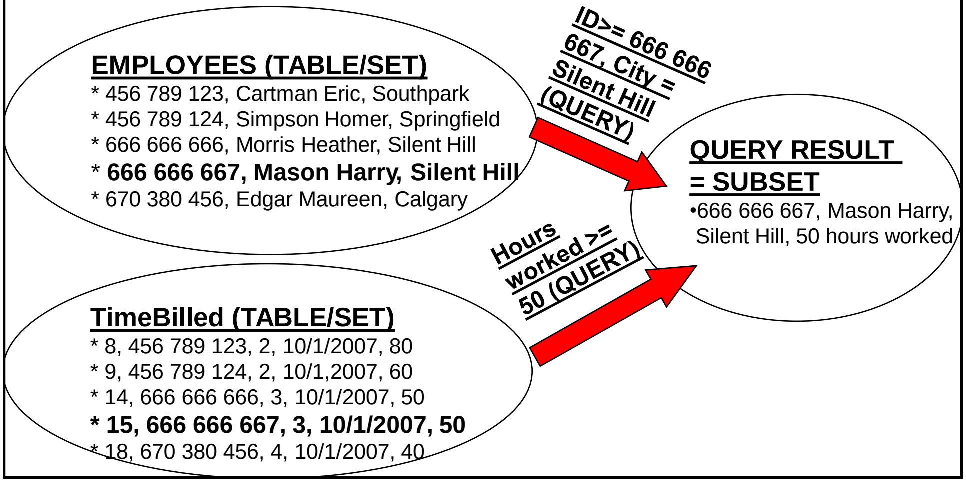
SOUTHPARK EMPLOYEES? (QUERY)

QUERY RESULT = SUBSET

* 456 789 123, Cartman Eric, Southpark

Queries And Set Theory (2)

- Queries can be asked of multiple tables
  - Example: Which employees come from ‘Silent Hill’, and have an employee number 666 666 667 or greater, and worked 50 or more hours?



EMPLOYEES (TABLE/SET)

* 456 789 123, Cartman Eric, Southpark
* 456 789 124, Simpson Homer, Springfield
* 666 666 666, Morris Heather, Silent Hill
*** 666 666 667, Mason Harry, Silent Hill**
* 670 380 456, Edgar Maureen, Calgary

ID>= 666 666 667, City = Silent Hill (QUERY)

QUERY RESULT = SUBSET

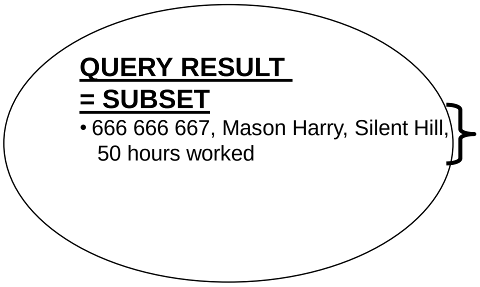
•666 666 667, Mason Harry, Silent Hill, 50 hours worked

Hours worked >= 50 (QUERY)

TimeBilled (TABLE/SET)

* 8, 456 789 123, 2, 10/1/2007, 80
* 9, 456 789 124, 2, 10/1,2007, 60
* 14, 666 666 666, 3, 10/1/2007, 50
*** 15, 666 666 667, 3, 10/1/2007, 50**
* 18, 670 380 456, 4, 10/1/2007, 40

Queries And Set Theory (3)



QUERY RESULT = SUBSET

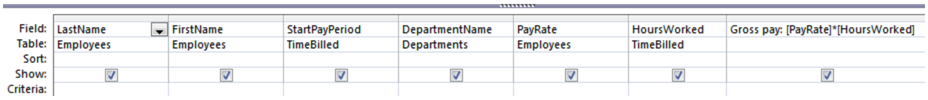
- 666 666 667, Mason Harry, Silent Hill, 50 hours worked

This is referred to as a 'join' because it combines data from multiple tables.

Multi-Table Queries

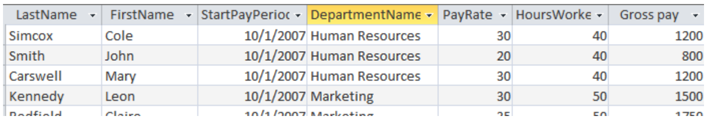
- Example: What is the full name, start pay period, name of the department billed and gross pay of employees in the organization (3 tables searched)?

Query



Field:	LastName	FirstName	StartPayPeriod	DepartmentName	PayRate	HoursWorked	Gross pay: [PayRate]*[HoursWorked]
Table:	Employees	Employees	TimeBilled	Departments	Employees	TimeBilled	
Sort:							
Show:	☑	☑	☑	☑	☑	☑	☑
Criteria:							

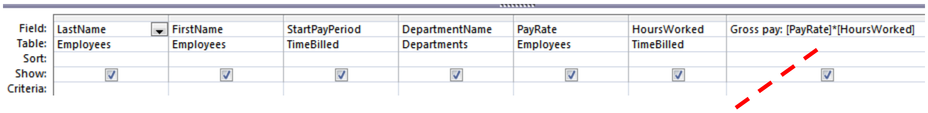
Result of the query



LastName	FirstName	StartPayPerioc	DepartmentName	PayRate	HoursWorke	Gross pay
Simcox	Cole	10/1/2007	Human Resources	30	40	1200
Smith	John	10/1/2007	Human Resources	20	40	800
Carswell	Mary	10/1/2007	Human Resources	30	40	1200
Kennedy	Leon	10/1/2007	Marketing	30	50	1500
Redfield	Claire	10/1/2007	Marketing	35	50	1750

Multi-Table Queries (2)

- Note in the previous example:
  - The result of one column was calculate from the columns of two tables.



Field:	LastName	FirstName	StartPayPeriod	DepartmentName	PayRate	HoursWorked	Gross pay: [PayRate]*[HoursWorked]
Table:	Employees	Employees	TimeBilled	Departments	Employees	TimeBilled	
Sort:							
Show:	☑	☑	☑	☑	☑	☑	☑
Criteria:							

A calculated value

`Gross pay: [PayRate] * [HoursWorked]`

Logical Operations

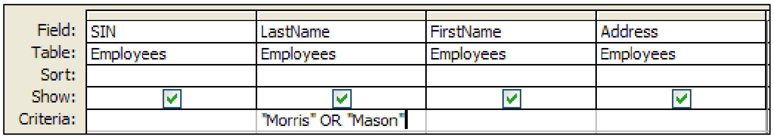
Operation	Description	MS-Access operator
AND	•All conditions must be true for the result to be true. •If any condition is false then the entire result is false.	And
OR	•All conditions must be false for the result to be false. •If any condition is true then the entire result is true.	Or

Logical Comparisons

Operator	Description
<	Less than
<=	Less than or equal to
>	Greater than
>=	Greater than or equal to
<>	Not equal to

Forming Queries

- Queries may be specified graphically:



Field:	SIN	LastName	FirstName	Address
Table:	Employees	Employees	Employees	Employees
Sort:				
Show:	☑	☑	☑	☑
Criteria:		"Morris" OR "Mason"		

- Also queries may be specified in the form of text descriptions of the question (SQL).

SQL (Structured Query Language)

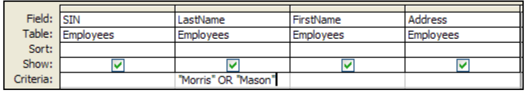
- It’s the universal language for querying a relational database (very widely used!)
- The statements are portable between different database programs.
- Queries are formed using text descriptions (can be more powerful but more complex than graphical queries):
  - **SELECT**: Specifies the fields/columns shown in the query results e.g., SIN field.
  - **FROM**: Lists the tables from which the data is to be selected e.g., look in the Employees table.
  - **WHERE**: Provides the conditions to determine if rows/records are shown by the query.
  - **ORDER BY**: Specifies the order in which rows are to be returned by the query.

Note: Capitalizing of the above four words is a standard SQL convention.

Using Logic While Forming Queries

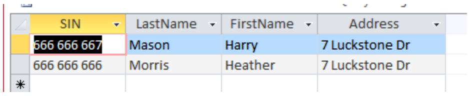
- Logical operators and logical comparisons can be performed during queries.
  - Examples: Which employees have the last name of ‘Morris’ or ‘Mason’?

Query



Field:	SIN	LastName	FirstName	Address
Table:	Employees	Employees	Employees	Employees
Sort:				
Show:	☑	☑	☑	☑
Criteria:		"Morris" OR "Mason"		

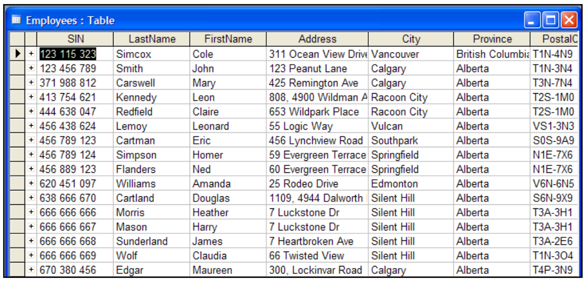
Result of the query



SIN	LastName	FirstName	Address
666 666 667	Mason	Harry	7 Luckstone Dr
666 666 666	Morris	Heather	7 Luckstone Dr
*			

SQL Equivalent

- **(Employees table):**



Employees : Table

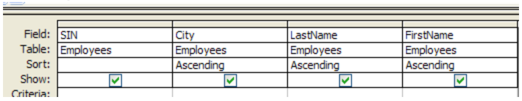
SIN	LastName	FirstName	Address	City	Province	PostalC
123 115 323	Simcox	Cole	311 Ocean View Drive	Vancouver	British Columbia	T1N-4N9
123 456 789	Smith	John	123 Peanut Lane	Calgary	Alberta	T1N-3N4
371 988 812	Carswell	Mary	425 Remington Ave	Calgary	Alberta	T3N-7N4
413 754 621	Kennedy	Leon	808, 4900 Wildman A	Racoon City	Alberta	T2S-1M0
444 638 047	Redfield	Claire	653 Wildpark Place	Racoon City	Alberta	T2S-1M0
456 438 624	Lemoy	Leonard	55 Logic Way	Vulcan	Alberta	VS1-3N3
456 789 123	Cartman	Eric	456 Lynchview Road	Southpark	Alberta	S0S-9A9
456 789 124	Simpson	Homer	59 Evergreen Terrace	Springfield	Alberta	N1E-7X6
456 889 123	Flanders	Ned	60 Evergreen Terrace	Springfield	Alberta	N1E-7X6
620 451 097	Williams	Amanda	25 Rodeo Drive	Edmonton	Alberta	V6N-6N5
638 666 670	Cartland	Douglas	1109, 4944 Dalworth	Silent Hill	Alberta	S6N-9X9
666 666 666	Morris	Heather	7 Luckstone Dr	Silent Hill	Alberta	T3A-3H1
666 666 667	Mason	Harry	7 Luckstone Dr	Silent Hill	Alberta	T3A-3H1
666 666 668	Sunderland	James	7 Heartbroken Ave	Silent Hill	Alberta	T3A-2E6
666 666 669	Wolf	Claudia	66 Twisted View	Silent Hill	Alberta	T1N-3O4
670 380 456	Edgar	Maureen	300, Lockinvar Road	Calgary	Alberta	T4P-3N9

```
SELECT Employees.SIN, Employees.LastName, Employees.FirstName,
Employees.Address
FROM Employees
WHERE (
( (Employees.LastName)="Morris" Or (Employees.LastName)="Mason")
)
```

Ordering Queries

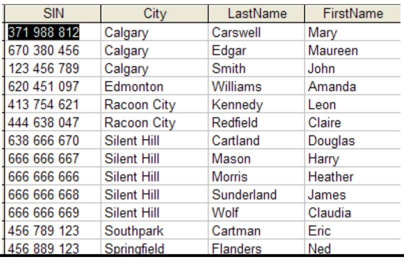
- Show the SIN, city, first name and last name of all employees in ascending order according to: city, last name and then first name.

Query



Field:	SIN	City	LastName	FirstName
Table:	Employees	Employees	Employees	Employees
Sort:		Ascending	Ascending	Ascending
Show:	☑	☑	☑	☑
Criteria:				

Query results



SIN	City	LastName	FirstName
371 988 812	Calgary	Carswell	Mary
670 380 456	Calgary	Edgar	Maureen
123 456 789	Calgary	Smith	John
620 451 097	Edmonton	Williams	Amanda
413 754 621	Racoon City	Kennedy	Leon
444 638 047	Racoon City	Redfield	Claire
638 666 670	Silent Hill	Cartland	Douglas
666 666 667	Silent Hill	Mason	Harry
666 666 666	Silent Hill	Morris	Heather
666 666 668	Silent Hill	Sunderland	James
666 666 669	Silent Hill	Wolf	Claudia
456 789 123	Southpark	Cartman	Eric
456 889 123	Springfield	Flanders	Ned

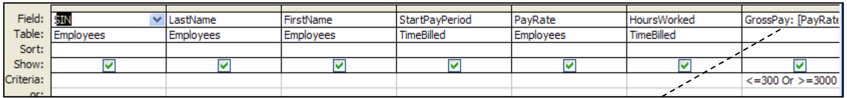
SQL Equivalent

- **SELECT** Employees.SIN, Employees.City, Employees.LastName, Employees.FirstName
- **FROM** Employees
- **ORDER BY** Employees.City, Employees.LastName, Employees.FirstName;

Queries With Ranges: Logical OR

- Ranges can be specified during the query.
  - Example: Which employees have a gross pay on their time card that’s less than $300 or greater than $3,000 (inclusive)?

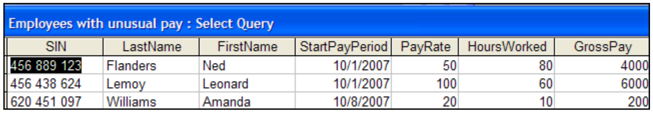
Query



Field:	SIN	LastName	FirstName	StartPayPeriod	PayRate	HoursWorked	GrossPay: [PayRate
Table:	Employees	Employees	Employees	TimeBilled	Employees	TimeBilled	
Sort:							
Show:	☑	☑	☑	☑	☑	☑	☑
Criteria:							<=300 Or >=3000
or:							

Calculated field
GrossPay: [PayRate]*[HoursWorked]

Result of the query



Employees with unusual pay : Select Query

SIN	LastName	FirstName	StartPayPeriod	PayRate	HoursWorked	GrossPay
456 889 123	Flanders	Ned	10/1/2007	50	80	4000
456 438 624	Lemoy	Leonard	10/1/2007	100	60	6000
620 451 097	Williams	Amanda	10/8/2007	20	10	200

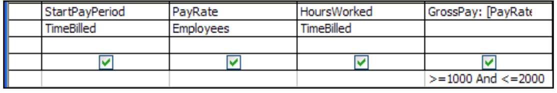
SQL Equivalent

```
• SELECT Employees.SIN, Employees.LastName,
  Employees.FirstName, TimeBilled.StartPayPeriod,
  Employees.PayRate, TimeBilled.HoursWorked,
  [PayRate]*[HoursWorked] AS GrossPay
• FROM Employees JOIN TimeBilled ON Employees.SIN =
  TimeBilled.SIN
• WHERE (
• (([PayRate]*[HoursWorked])<=300 Or
  ([PayRate]*[HoursWorked])>=3000)
• );
```

Queries With Ranges: Logical AND

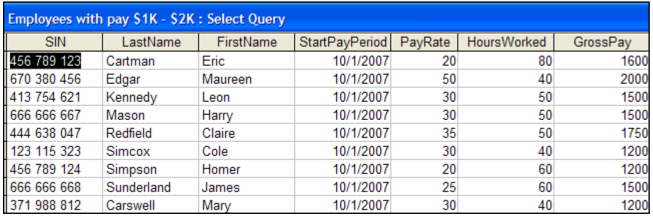
- Ranges can be specified during the query.
  - Example: Which employees have a gross pay within the range of $1,000 - $2000 (inclusive) on one of their timecards?

Query



	StartPayPeriod	PayRate	HoursWorked	GrossPay: [PayRate
	TimeBilled	Employees	TimeBilled	
	☑	☑	☑	☑
				>=1000 And <=2000

Result of the query



Employees with pay $1K - $2K : Select Query

SIN	LastName	FirstName	StartPayPeriod	PayRate	HoursWorked	GrossPay
456 789 123	Cartman	Eric	10/1/2007	20	80	1600
670 380 456	Edgar	Maureen	10/1/2007	50	40	2000
413 754 621	Kennedy	Leon	10/1/2007	30	50	1500
666 666 667	Mason	Harry	10/1/2007	30	50	1500
444 638 047	Redfield	Claire	10/1/2007	35	50	1750
123 115 323	Simcox	Cole	10/1/2007	30	40	1200
456 789 124	Simpson	Homer	10/1/2007	20	60	1200
666 666 668	Sunderland	James	10/1/2007	25	60	1500
371 988 812	Carswell	Mary	10/1/2007	30	40	1200

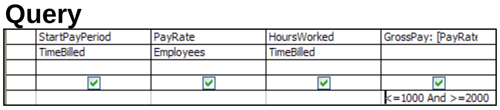
SQL Equivalent

- **SELECT** Employees.SIN, Employees.LastName, Employees.FirstName, TimeBilled.StartPayPeriod, Employees.PayRate, TimeBilled.HoursWorked, [PayRate]*[HoursWorked] AS GrossPay
- **FROM** Employees JOIN TimeBilled ON Employees.SIN = TimeBilled.SIN
- **WHERE** (
- (([PayRate]*[HoursWorked])>=1000 And ([PayRate]*[HoursWorked])<=2000)
-);

Empty Queries

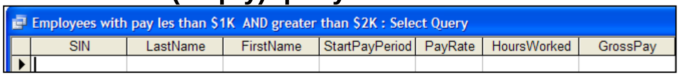
- Take care not to specify queries that can never be true!
- This will result in an “Empty Query”, a query that yields no results.
  - Example: Which employees have a gross pay lower than $1,000 AND higher than $2,000 (inclusive for both) on one of their time cards?

Query



	StartPayPeriod	PayRate	HoursWorked	GrossPay: [PayRate
	TimeBilled	Employees	TimeBilled	
	☑	☑	☑	☑
				<=1000 And >=2000

Result of the (empty) query



Employees with pay les than $1K AND greater than $2K : Select Query

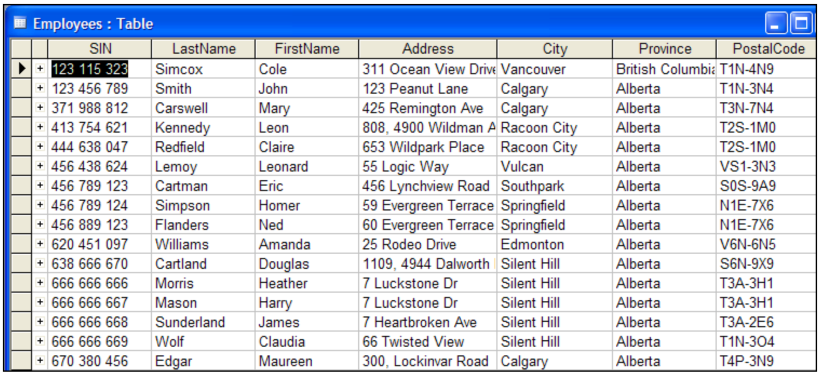
SIN	LastName	FirstName	StartPayPeriod	PayRate	HoursWorked	GrossPay

SQL Equivalent

- **SELECT** TimeBilled.StartPayPeriod, Employees.PayRate, TimeBilled.HoursWorked, [PayRate]*[HoursWorked] AS GrossPay
- **FROM** Employees JOIN TimeBilled ON Employees.SIN = TimeBilled.SIN
- **WHERE** (
- (([PayRate]*[HoursWorked])<=1000 And ([PayRate]*[HoursWorked])>=2000)
-);

Using The Wildcard In Queries

- The ‘wildcard’ character can stand for any number of characters in the position that the wildcard is positioned:
  - Example queries that follow will be in the Employees table:

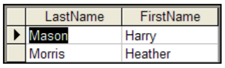


Employees : Table

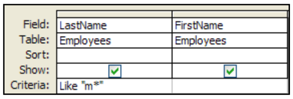
SIN	LastName	FirstName	Address	City	Province	PostalCode
123 115 323	Simcox	Cole	311 Ocean View Drive	Vancouver	British Columbi	T1N-4N9
123 456 789	Smith	John	123 Peanut Lane	Calgary	Alberta	T1N-3N4
371 988 812	Carswell	Mary	425 Remington Ave	Calgary	Alberta	T3N-7N4
413 754 621	Kennedy	Leon	808, 4900 Wildman A	Racoon City	Alberta	T2S-1M0
444 638 047	Redfield	Claire	653 Wildpark Place	Racoon City	Alberta	T2S-1M0
456 438 624	Lemoy	Leonard	55 Logic Way	Vulcan	Alberta	VS1-3N3
456 789 123	Cartman	Eric	456 Lynchview Road	Southpark	Alberta	S0S-9A9
456 789 124	Simpson	Homer	59 Evergreen Terrace	Springfield	Alberta	N1E-7X6
456 889 123	Flanders	Ned	60 Evergreen Terrace	Springfield	Alberta	N1E-7X6
620 451 097	Williams	Amanda	25 Rodeo Drive	Edmonton	Alberta	V6N-6N5
638 666 670	Cartland	Douglas	1109, 4944 Dalworth	Silent Hill	Alberta	S6N-9X9
666 666 666	Morris	Heather	7 Luckstone Dr	Silent Hill	Alberta	T3A-3H1
666 666 667	Mason	Harry	7 Luckstone Dr	Silent Hill	Alberta	T3A-3H1
666 666 668	Sunderland	James	7 Heartbroken Ave	Silent Hill	Alberta	T3A-2E6
666 666 669	Wolf	Claudia	66 Twisted View	Silent Hill	Alberta	T1N-3O4
670 380 456	Edgar	Maureen	300, Lockinvar Road	Calgary	Alberta	T4P-3N9

Using The Wildcard In Queries (Access)

- Examples:
  - Which employees have a last name that begins with ‘m’?

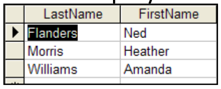


LastName	FirstName
Mason	Harry
Morris	Heather

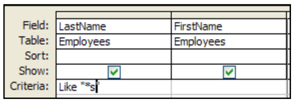


Field:	LastName	FirstName
Table:	Employees	Employees
Sort:		
Show:	☑	☑
Criteria:	Like "m*"	

  - Which employees have a last name ends with ‘s’?

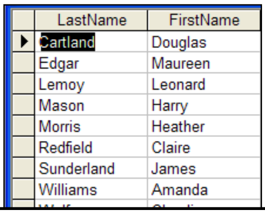


LastName	FirstName
Flanders	Ned
Morris	Heather
Williams	Amanda

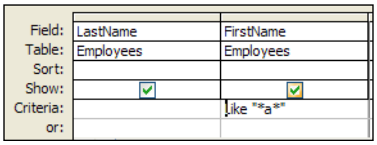


Field:	LastName	FirstName
Table:	Employees	Employees
Sort:		
Show:	☑	☑
Criteria:	Like "*s"	

  - Which employees have the letter ‘a’ anywhere in their first name?



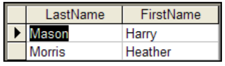
LastName	FirstName
Cartland	Douglas
Edgar	Maureen
Lemoy	Leonard
Mason	Harry
Morris	Heather
Redfield	Claire
Sunderland	James
Williams	Amanda



Field:	LastName	FirstName
Table:	Employees	Employees
Sort:		
Show:	☑	☑
Criteria:		Like "*a*"
or:		

Using The Wildcard In Queries (SQL)

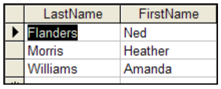
- Examples:
  - Which employees have a last name that begins with ‘m’?



LastName	FirstName
Mason	Harry
Morris	Heather

```
SELECT Employees.LastName,
Employees.FirstName
FROM Employees
WHERE (((Employees.LastName) Like "m*"));
```

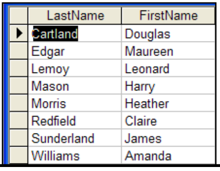
  - Which employees have a last name ends with ‘s’?



LastName	FirstName
Flanders	Ned
Morris	Heather
Williams	Amanda

```
SELECT Employees.LastName,
Employees.FirstName
FROM Employees
WHERE (((Employees.LastName) Like "*s"))
```

  - Which employees have the letter ‘a’ anywhere in their first name?

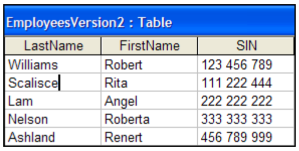


LastName	FirstName
Cartland	Douglas
Edgar	Maureen
Lemoy	Leonard
Mason	Harry
Morris	Heather
Redfield	Claire
Sunderland	James
Williams	Amanda

```
SELECT Employees.LastName,
Employees.FirstName
FROM Employees
WHERE (((Employees.FirstName) Like "*a*"))
```

Single Character Wildcard

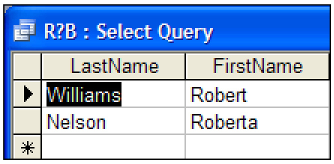
- The '?' stands for a single character wildcard:
  - Querying the following table



EmployeesVersion2 : Table

LastName	FirstName	SIN
Williams	Robert	123 456 789
Scalisce	Rita	111 222 444
Lam	Angel	222 222 222
Nelson	Roberta	333 333 333
Ashland	Renert	456 789 999

  - Which employees have the following string of characters in their first name: *<R> <any character> <B> <any number of characters>*



R?B : Select Query

LastName	FirstName
Williams	Robert
Nelson	Roberta

Database Design (And Redesign)

- The design-redesign process is referred to as "normalization"
- Each stage of redesign is referred to as a "form":
  - Stage 1: First normal form
  - Stage 2: Second normal form
  - Stage 3: Third normal form
  - (For the purposes of this course getting a database into third normal form is sufficient although there are other stages as well).

Why Is Normalization Necessary?

- Normalization is regarded as good style
- My database ‘works’ that’s “good enough” why bother?
- It also helps to prevent errors or problems which are caused by how the database is designed:
  - e.g., insertion anomalies: difficulties when adding new information
  - e.g., deletion anomalies: deleting information may result in the inadvertent loss of information

Example Database Table: Projects[1]

- This table shows:
  - ResearcherID: each professor working on a research project is given a computer generated login name.
  - Research project: name of the projects worked on in a particular department.
    - Professors can work on multiple projects
    - Research projects can be initiated without a professor
  - Location: room number of the research lab.

ResearcherID (PK)	Research projects (PK)	Location
aturing	Graph Coloring Traveling Salesman	QC-103 QC-201
rdescartes	Knapsack	QC-121
cbabbage	Traveling Salesman Knapsack	QC-201 QC-121
bowen	Knapsack	QC-121

[1] From “Database Development for Dummies” by Allen G. Taylor

Problem: Some Cells Can Contain Multiple Entries

- Queries can be awkward to form
  - E.g., Using the 'Like' operator is difficult because it must deal with special cases (or more entries in each cell).
  - Example:

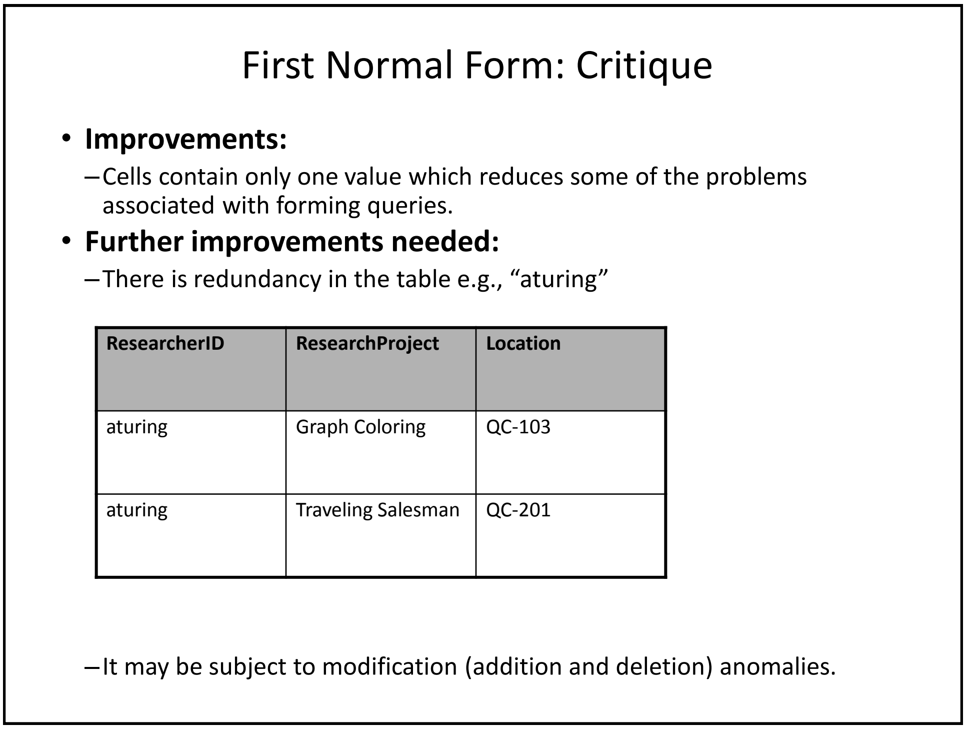
Research projects
Graph Coloring Traveling Salesman
Knapsack
Traveling Salesman Knapsack
Knapsack

With this format searching for projects under "Knapsack" won't work correctly (some labs show up with others will not).

Databases In First Normal Form

- **F.N.F.**: Each cell can contain *at most* one element (one value or a null value, the latter for non-primary key fields).
- The previous table in first normal form:

ResearcherID (PK)	Research project (PK)	Location
aturing	Graph Coloring	QC-103
aturing	Traveling Salesman	QC-201
rdescartes	Knapsack	QC-121
cbabbage	Traveling Salesman	QC-201
cbabbage	Knapsack	QC-121
bowen	Knapsack	QC-121

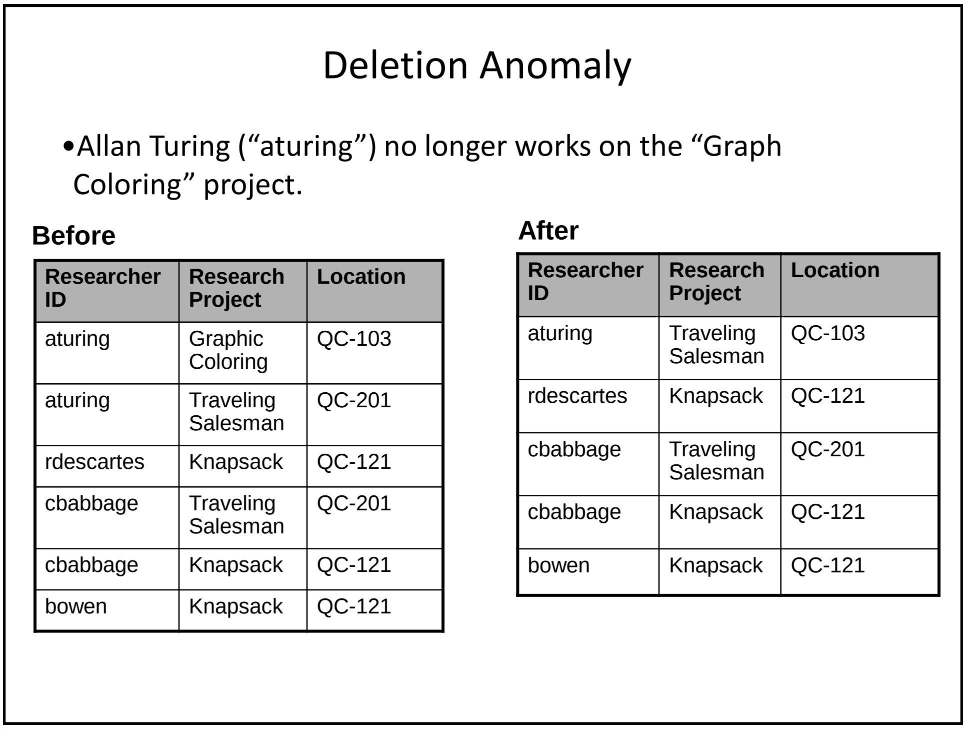


First Normal Form: Critique

- **Improvements:**
  - Cells contain only one value which reduces some of the problems associated with forming queries.
- **Further improvements needed:**
  - There is redundancy in the table e.g., “aturing”

ResearcherID	ResearchProject	Location
aturing	Graph Coloring	QC-103
aturing	Traveling Salesman	QC-201

  - It may be subject to modification (addition and deletion) anomalies.



Deletion Anomaly

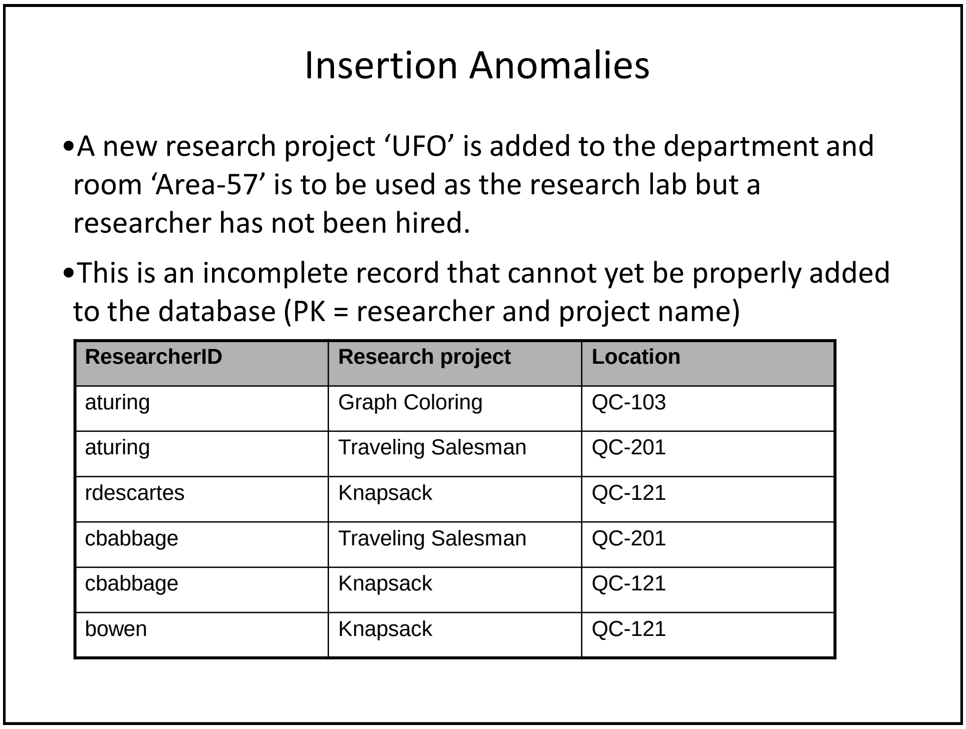
- Allan Turing (“aturing”) no longer works on the “Graph Coloring” project.

Before

Researcher ID	Research Project	Location
aturing	Graphic Coloring	QC-103
aturing	Traveling Salesman	QC-201
rdescartes	Knapsack	QC-121
cbabbage	Traveling Salesman	QC-201
cbabbage	Knapsack	QC-121
bowen	Knapsack	QC-121

After

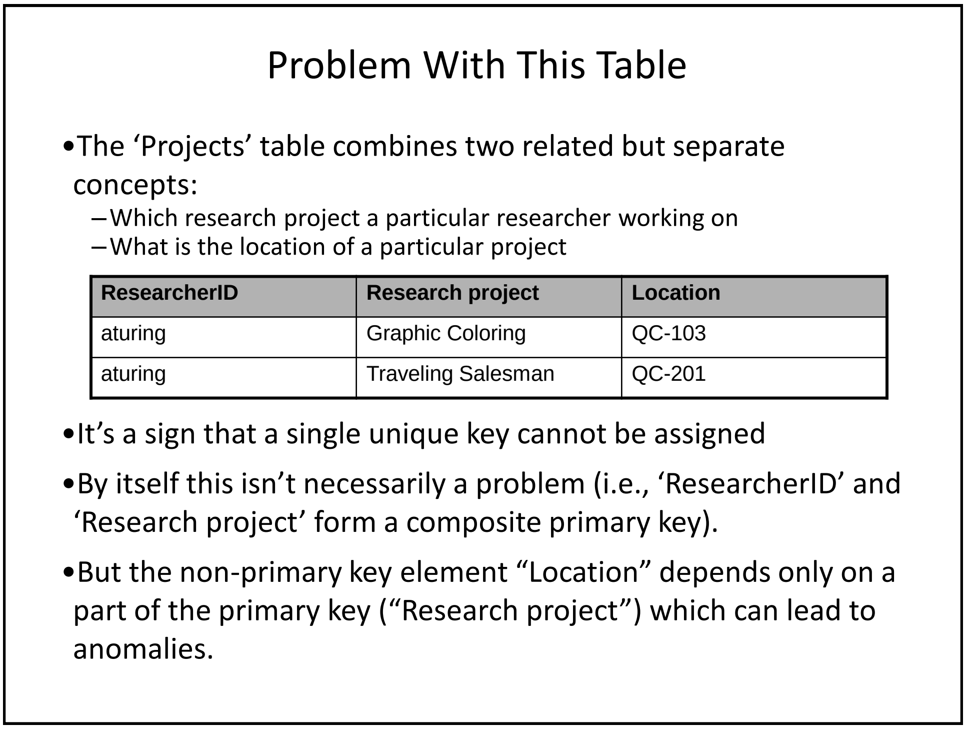
Researcher ID	Research Project	Location
aturing	Traveling Salesman	QC-103
rdescartes	Knapsack	QC-121
cbabbage	Traveling Salesman	QC-201
cbabbage	Knapsack	QC-121
bowen	Knapsack	QC-121



Insertion Anomalies

- A new research project ‘UFO’ is added to the department and room ‘Area-57’ is to be used as the research lab but a researcher has not been hired.
- This is an incomplete record that cannot yet be properly added to the database (PK = researcher and project name)

ResearcherID	Research project	Location
aturing	Graph Coloring	QC-103
aturing	Traveling Salesman	QC-201
rdescartes	Knapsack	QC-121
cbabbage	Traveling Salesman	QC-201
cbabbage	Knapsack	QC-121
bowen	Knapsack	QC-121

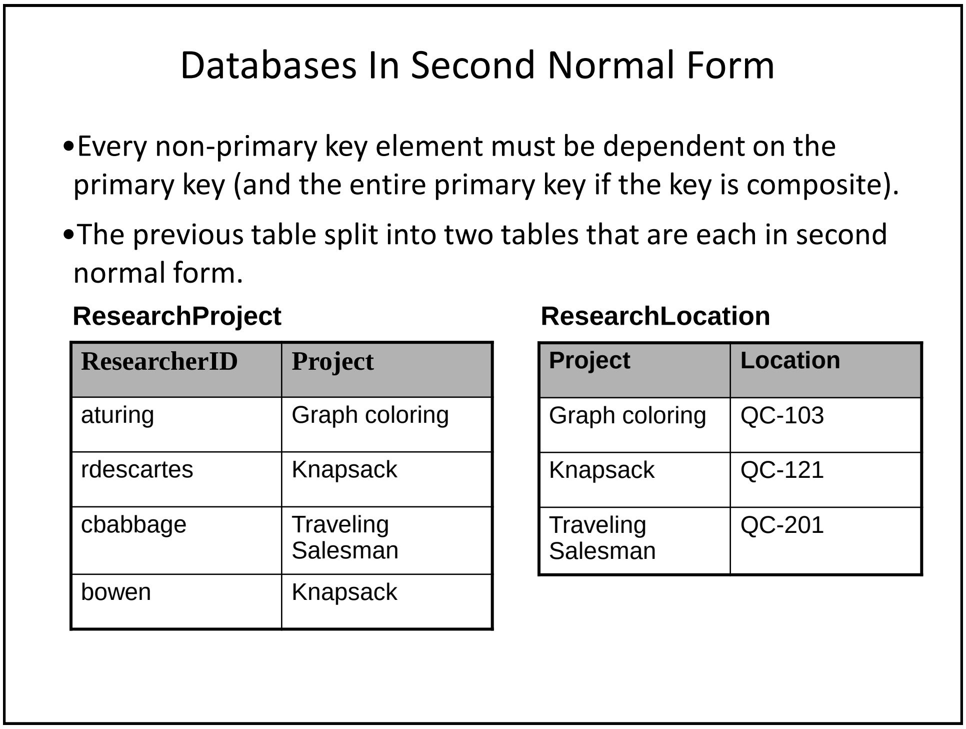


Problem With This Table

- The ‘Projects’ table combines two related but separate concepts:
  - Which research project a particular researcher working on
  - What is the location of a particular project

ResearcherID	Research project	Location
aturing	Graphic Coloring	QC-103
aturing	Traveling Salesman	QC-201

- It’s a sign that a single unique key cannot be assigned
- By itself this isn’t necessarily a problem (i.e., ‘ResearcherID’ and ‘Research project’ form a composite primary key).
- But the non-primary key element “Location” depends only on a part of the primary key (“Research project”) which can lead to anomalies.



Databases In Second Normal Form

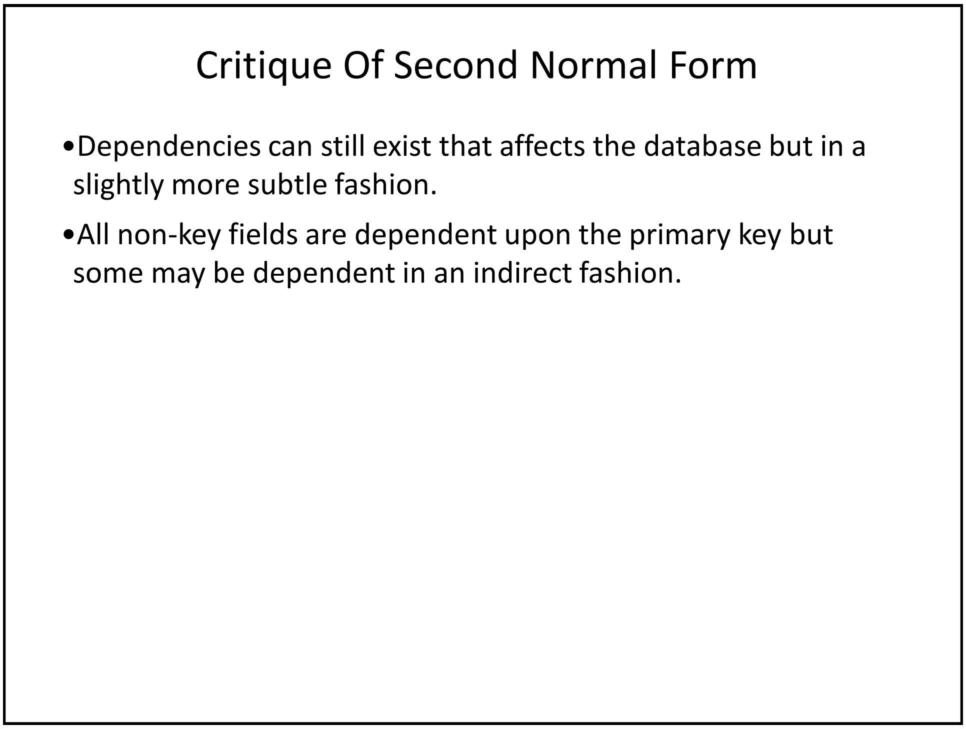
- Every non-primary key element must be dependent on the primary key (and the entire primary key if the key is composite).
- The previous table split into two tables that are each in second normal form.

ResearchProject

ResearcherID	Project
aturing	Graph coloring
rdescartes	Knapsack
cbabbage	Traveling Salesman
bowen	Knapsack

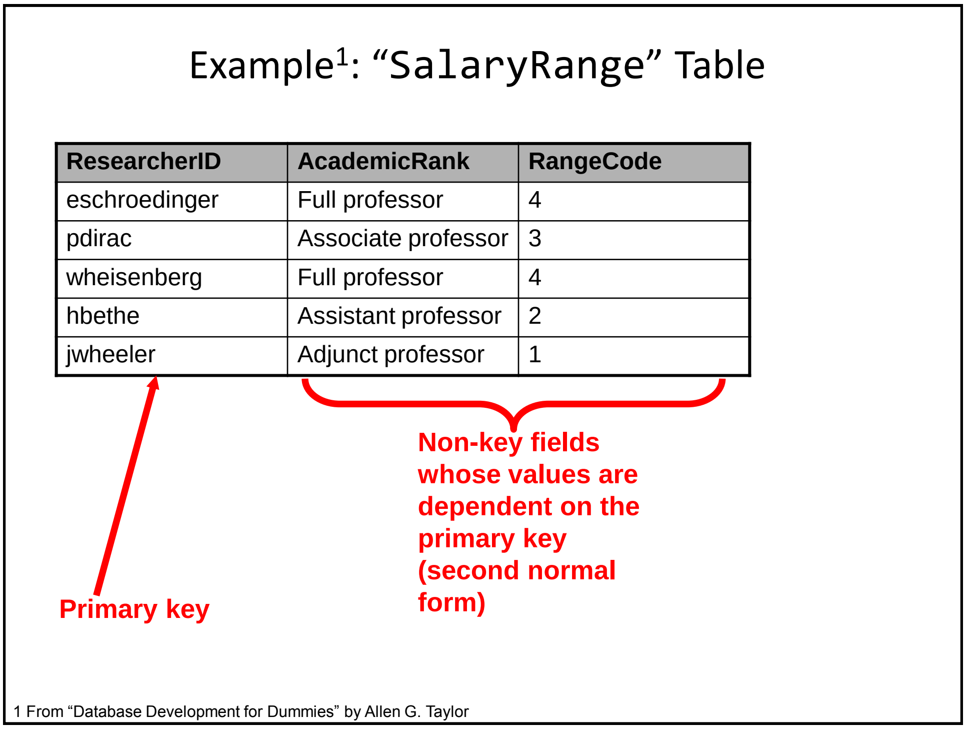
ResearchLocation

Project	Location
Graph coloring	QC-103
Knapsack	QC-121
Traveling Salesman	QC-201



Critique Of Second Normal Form

- Dependencies can still exist that affects the database but in a slightly more subtle fashion.
- All non-key fields are dependent upon the primary key but some may be dependent in an indirect fashion.



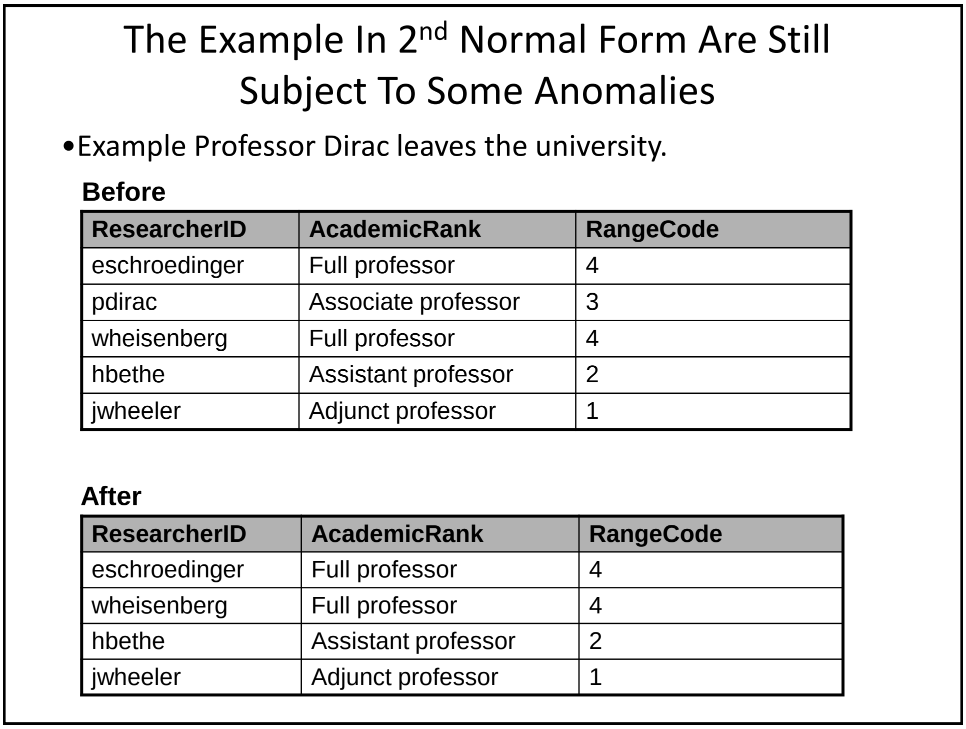
Example[1]: “SalaryRange” Table

ResearcherID	AcademicRank	RangeCode
eschroedinger	Full professor	4
pdirac	Associate professor	3
wheisenberg	Full professor	4
hbethe	Assistant professor	2
jwheeler	Adjunct professor	1

Non-key fields whose values are dependent on the primary key (second normal form)

Primary key

[1] From “Database Development for Dummies” by Allen G. Taylor



The Example In 2nd Normal Form Are Still Subject To Some Anomalies

- Example Professor Dirac leaves the university.

Before

ResearcherID	AcademicRank	RangeCode
eschroedinger	Full professor	4
pdirac	Associate professor	3
wheisenberg	Full professor	4
hbethe	Assistant professor	2
jwheeler	Adjunct professor	1

After

ResearcherID	AcademicRank	RangeCode
eschroedinger	Full professor	4
wheisenberg	Full professor	4
hbethe	Assistant professor	2
jwheeler	Adjunct professor	1

Problem With The Database (2nd Normal Form)

- While both non-key elements are dependent upon the primary key, with “RangeCode” that dependency is indirect.

ResearcherID	AcademicRank	RangeCode
eschroedinger	Full professor	4
pdirac	Associate professor	3

- “RangeCode” is dependent upon “AcademicRank” which is in turn dependent upon “ResearcherID”.
- This is referred to as a transitive dependency:

RangeCode → **AcademicRank** → **ResearcherID**

Third Normal Form

- A database in third normal form fulfills the requirements of second normal form and has no transitive dependencies.
- Previous example in third normal form:

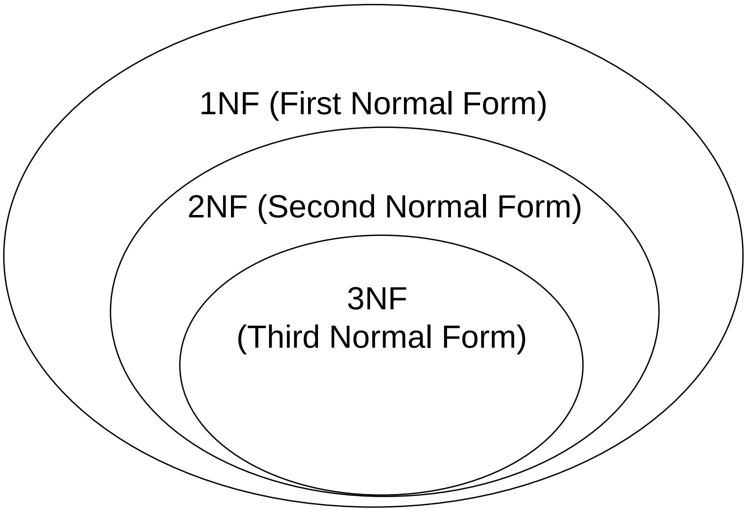
ResearcherRank

ResearcherID	AcademicRank
eschroedinger	Full professor
pdirac	Associate professor
wheisenberg	Full professor
hbethe	Assistant professor
jwheeler	Adjunct professor

RankRange

AcademicRank	Range Code
Full professor	4
Associate professor	3
Assistant professor	2
Adjunct professor	1

The Normal Forms Have A Nested Structure



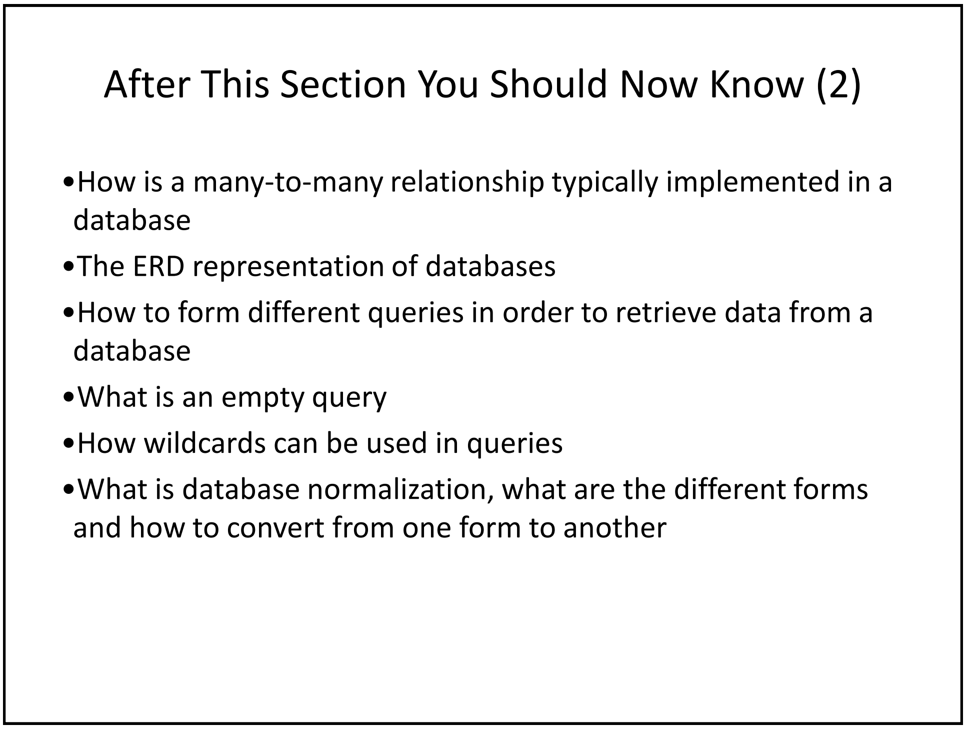
1NF (First Normal Form)

2NF (Second Normal Form)

3NF
(Third Normal Form)

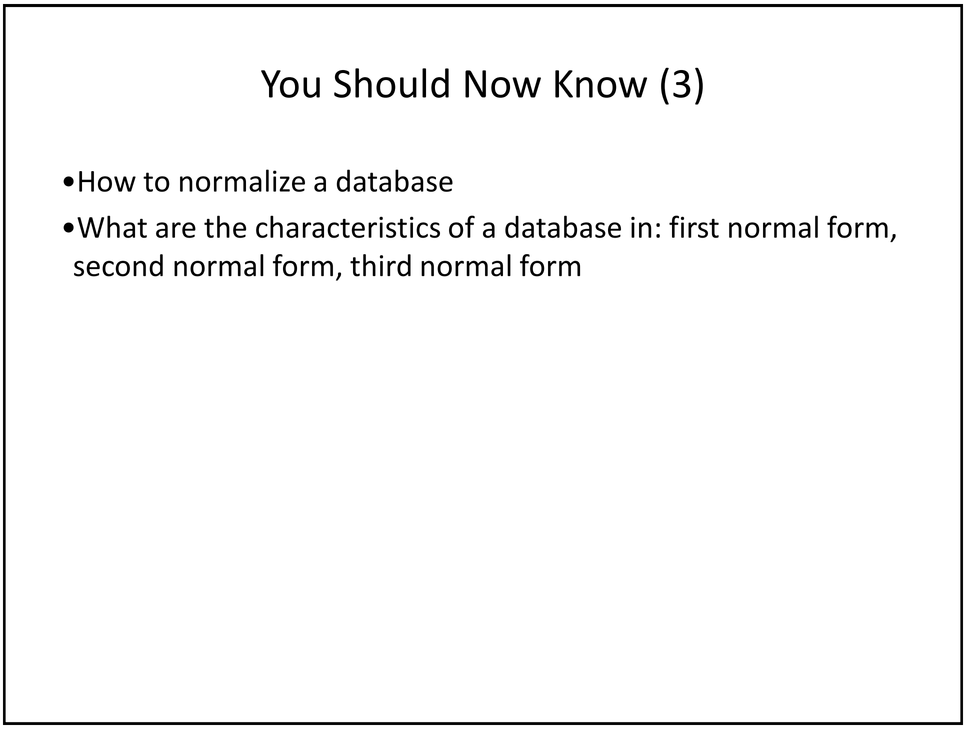
After This Section You Should Now Know

- How a database is broken down into tables and how tables are broken down into it's component parts
- What are the type of tables and the purpose of each
- What is the purpose of a primary key
- What is a foreign key
- When table are related what is the rule for determining which table contains the primary vs. foreign key
- What is a null value
- What are forms of data integrity in databases
- Guidelines for naming tables and the fields of the tables
- What are the three relationships that may exist between tables and how they differ



After This Section You Should Now Know (2)

- How is a many-to-many relationship typically implemented in a database
- The ERD representation of databases
- How to form different queries in order to retrieve data from a database
- What is an empty query
- How wildcards can be used in queries
- What is database normalization, what are the different forms and how to convert from one form to another



You Should Now Know (3)

- How to normalize a database
- What are the characteristics of a database in: first normal form, second normal form, third normal form