SQL

Introduction

Relational data model

Overview

1. Data models & the relational data model

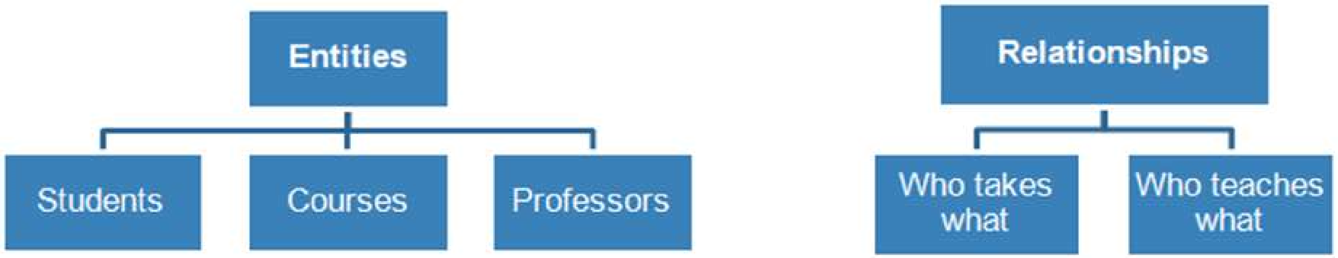
2. Schemas & data independence

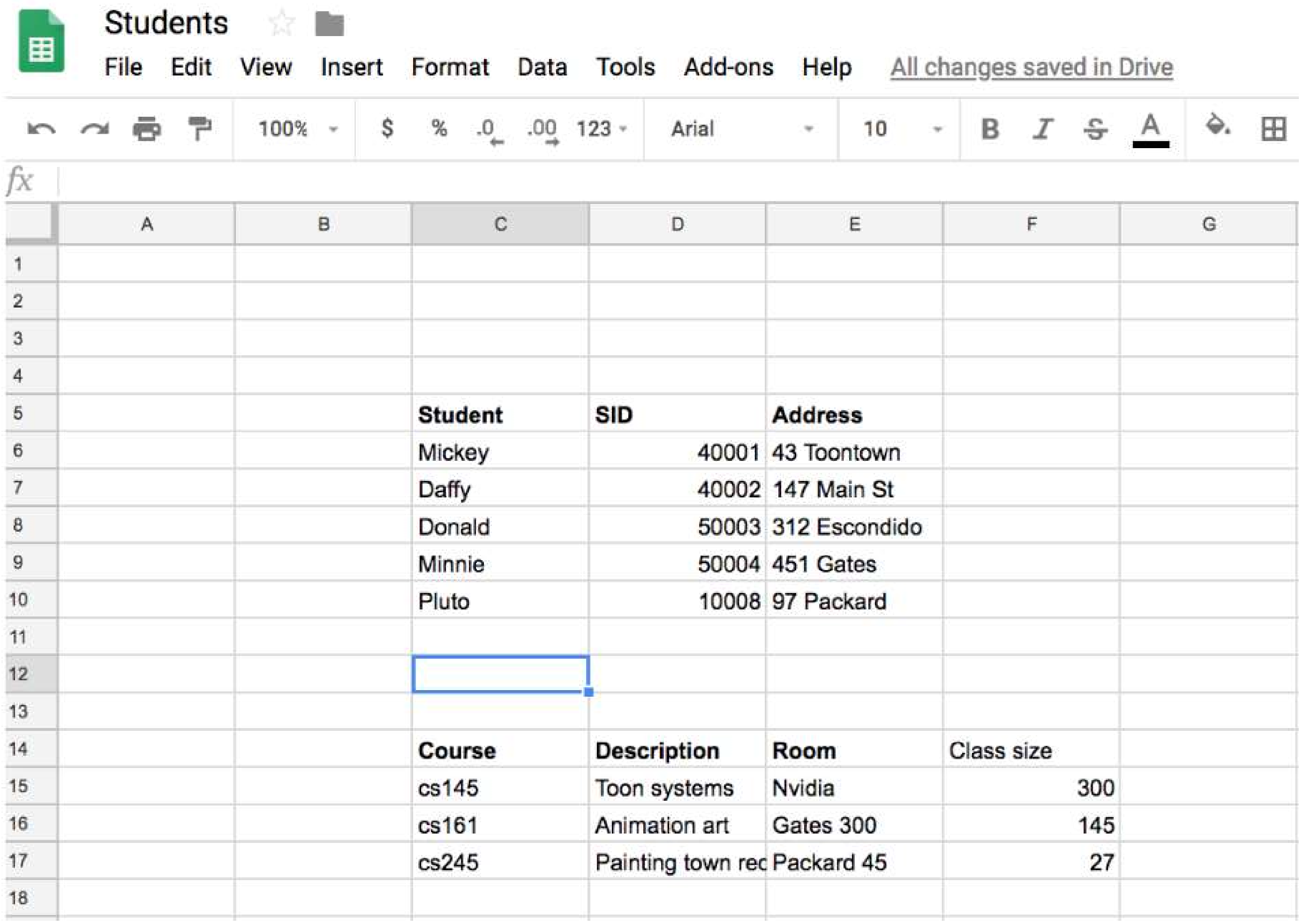
A Motivating, Running Example

Consider building a course management system (CMS):

Entities (e.g., Students, Courses)

Relationships (e.g., Alice is enrolled in 145)





	A	B	C	D	E	F	G
1							
2							
3							
4							
5			**Student**	**SID**	**Address**		
6			Mickey	40001	43 Toontown		
7			Daffy	40002	147 Main St		
8			Donald	50003	312 Escondido		
9			Minnie	50004	451 Gates		
10			Pluto	10008	97 Packard		
11							
12							
13							
14			**Course**	**Description**	**Room**	Class size	
15			cs145	Toon systems	Nvidia	300	
16			cs161	Animation art	Gates 300	145	
17			cs245	Painting town rec	Packard 45	27	
18							

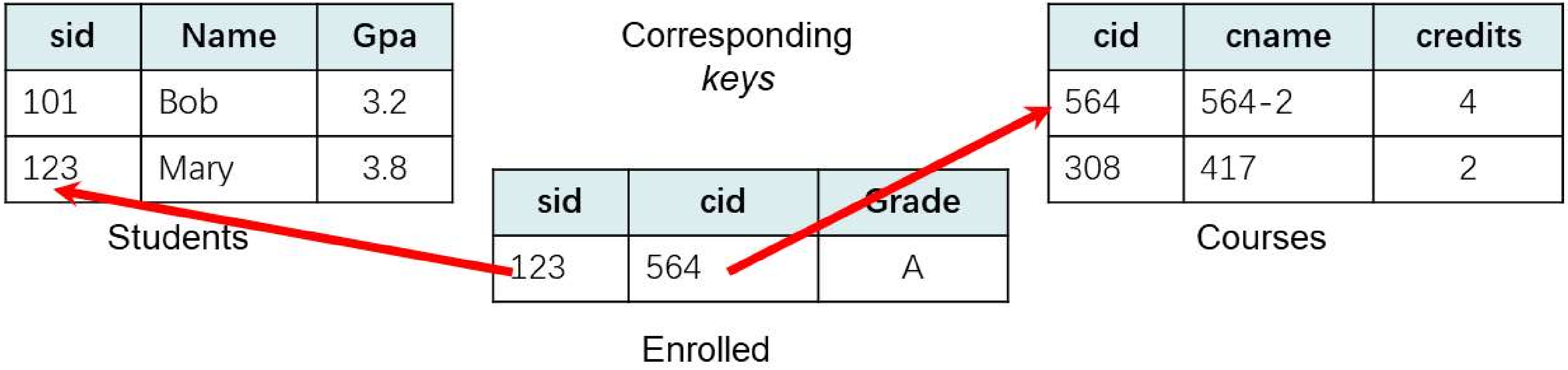
‘Modeling’ the CMS

Logical Schema

Students(sid: *string*, name: *string*, gpa: *float*)

Courses(cid: *string*, cname: *string*, credits: *int*)

Enrolled(sid: *string*, cid*:* *string*, grade*:* *string*)



sid	Name	Gpa
101	Bob	3.2
123	Mary	3.8

Students

Corresponding
keys

sid	cid	Grade
123	564	A

Enrolled

cid	cname	credits
564	564-2	4
308	417	2

Courses

Data model

Relational model (aka tables)

Simple and most popular

Elegant algebra (E.F. Codd et al)

Data model:

Organizing principle of data + operations

Schema:

Describes blueprint of table (s)

Key concept

Every relation has a schema

Logical Schema: describes types, names

Physical Schema: describes data layout

Virtual Schema (Views): derived tables

Data independence

Key concept

Logical Data Independence

Protection from changes in the Logical Structure of the data

i.e. Should not need to ask : Can we add a new entity or attribute without rewriting the application

Physical Data Independence

Protection from Physical Layout Changes

i.e. Should not need to ask : Which disks are the data stored on? Is the data indexed?

One of the most important reasons to use a DBMS

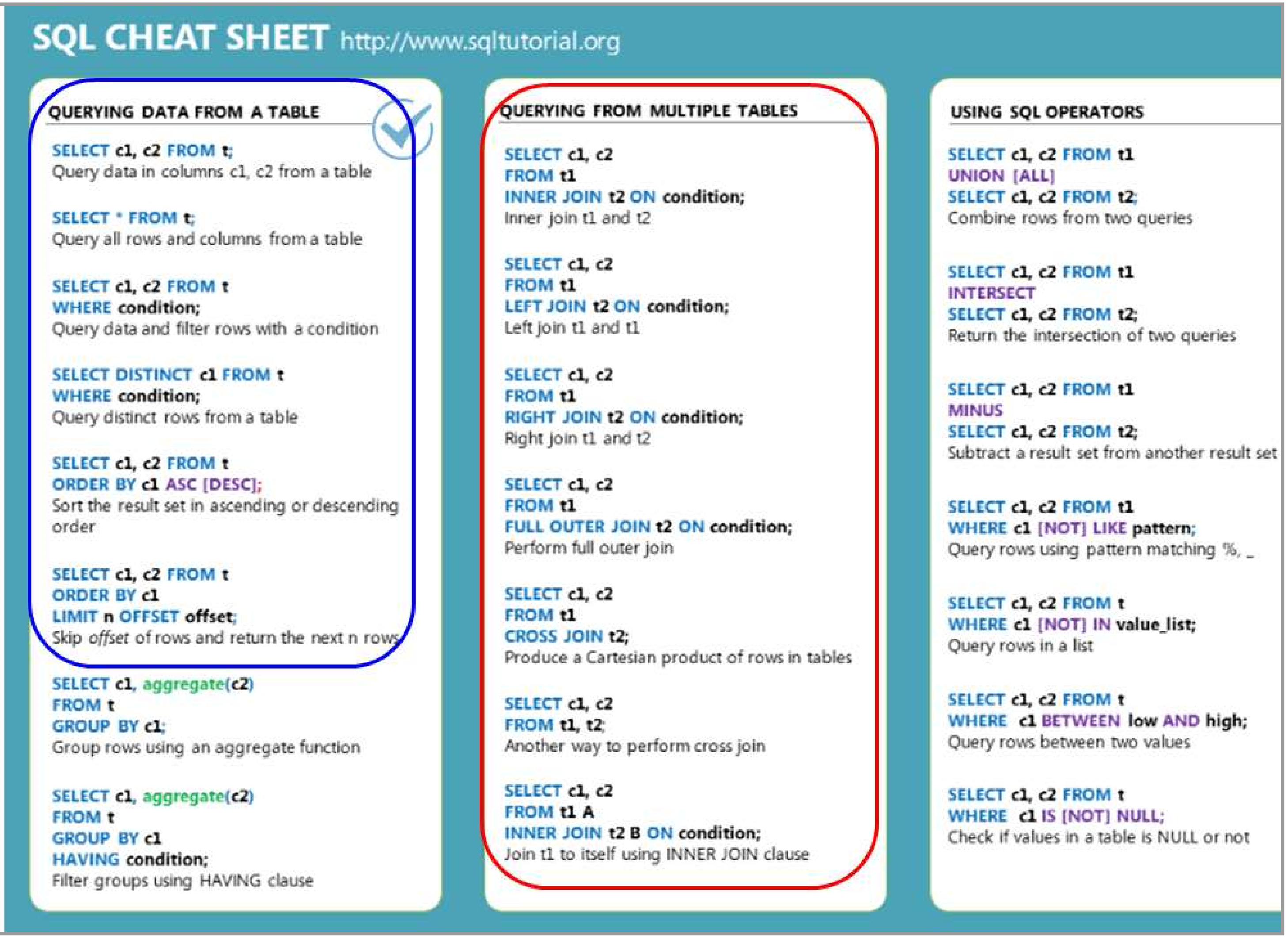
SQL language

preview

Preview

SQL queries

sqltutorial.org/sql-cheat-sheet



SQL CHEAT SHEET http://www.sqltutorial.org

QUERYING DATA FROM A TABLE

```
SELECT c1, c2 FROM t;
```
Query data in columns c1, c2 from a table

```
SELECT * FROM t;
```
Query all rows and columns from a table

```
SELECT c1, c2 FROM t
WHERE condition;
```
Query data and filter rows with a condition

```
SELECT DISTINCT c1 FROM t
WHERE condition;
```
Query distinct rows from a table

```
SELECT c1, c2 FROM t
ORDER BY c1 ASC [DESC];
```
Sort the result set in ascending or descending order

```
SELECT c1, c2 FROM t
ORDER BY c1
LIMIT n OFFSET offset;
```
Skip *offset* of rows and return the next n rows

```
SELECT c1, aggregate(c2)
FROM t
GROUP BY c1;
```
Group rows using an aggregate function

```
SELECT c1, aggregate(c2)
FROM t
GROUP BY c1
HAVING condition;
```
Filter groups using HAVING clause

QUERYING FROM MULTIPLE TABLES

```
SELECT c1, c2
FROM t1
INNER JOIN t2 ON condition;
```
Inner join t1 and t2

```
SELECT c1, c2
FROM t1
LEFT JOIN t2 ON condition;
```
Left join t1 and t1

```
SELECT c1, c2
FROM t1
RIGHT JOIN t2 ON condition;
```
Right join t1 and t2

```
SELECT c1, c2
FROM t1
FULL OUTER JOIN t2 ON condition;
```
Perform full outer join

```
SELECT c1, c2
FROM t1
CROSS JOIN t2;
```
Produce a Cartesian product of rows in tables

```
SELECT c1, c2
FROM t1, t2;
```
Another way to perform cross join

```
SELECT c1, c2
FROM t1 A
INNER JOIN t2 B ON condition;
```
Join t1 to itself using INNER JOIN clause

USING SQL OPERATORS

```
SELECT c1, c2 FROM t1
UNION [ALL]
SELECT c1, c2 FROM t2;
```
Combine rows from two queries

```
SELECT c1, c2 FROM t1
INTERSECT
SELECT c1, c2 FROM t2;
```
Return the intersection of two queries

```
SELECT c1, c2 FROM t1
MINUS
SELECT c1, c2 FROM t2;
```
Subtract a result set from another result set

```
SELECT c1, c2 FROM t1
WHERE c1 [NOT] LIKE pattern;
```
Query rows using pattern matching %, _

```
SELECT c1, c2 FROM t
WHERE c1 [NOT] IN value_list;
```
Query rows in a list

```
SELECT c1, c2 FROM t
WHERE c1 BETWEEN low AND high;
```
Query rows between two values

```
SELECT c1, c2 FROM t
WHERE c1 IS [NOT] NULL;
```
Check if values in a table is NULL or not

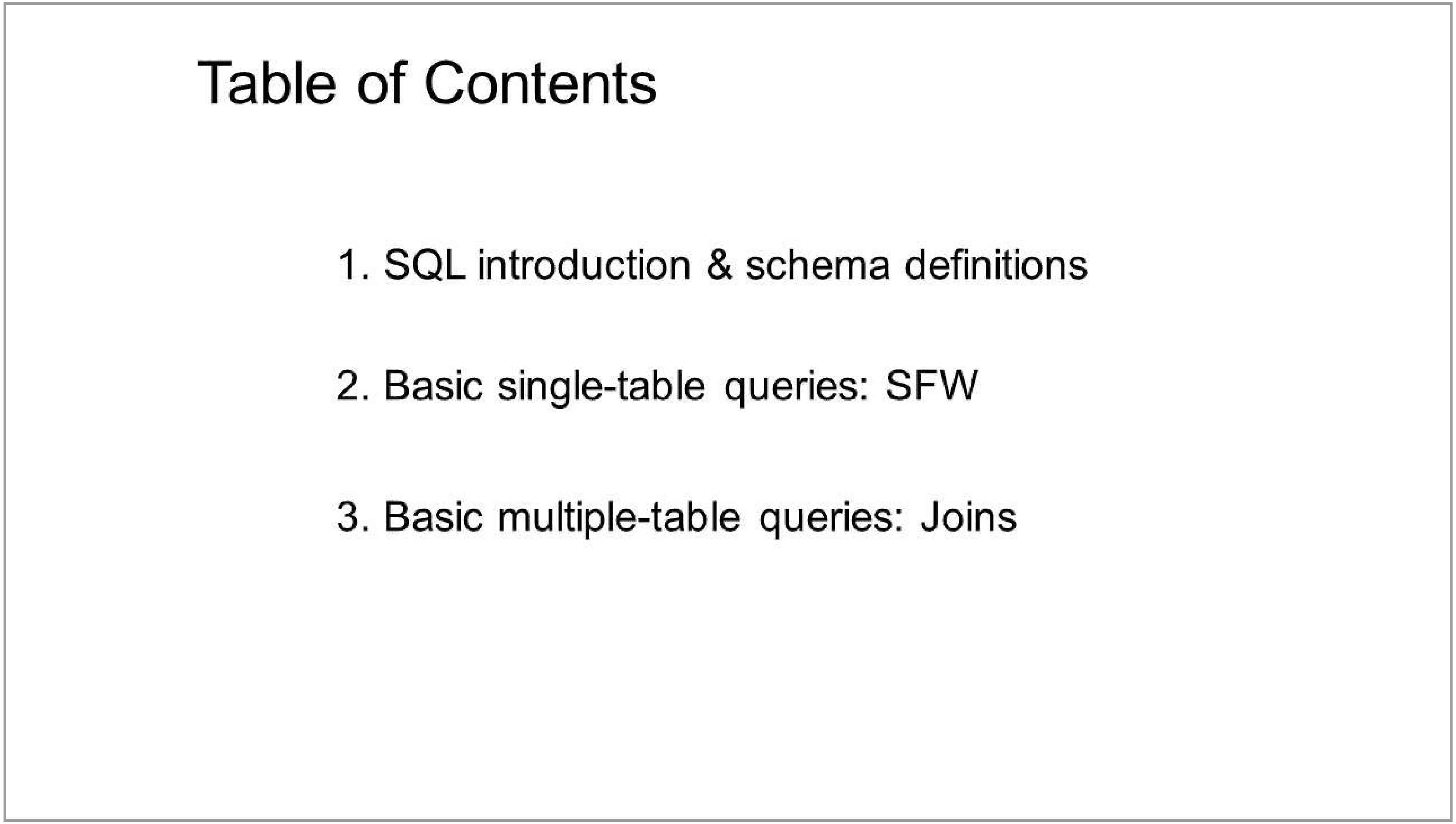


Table of Contents

1. SQL introduction & schema definitions

2. Basic single-table queries: SFW

3. Basic multiple-table queries: Joins

SQL Definitions

principles

What you will learn about in this section

1. What is SQL?
2. Basic schema definitions
3. Keys & constraints intro

SQL Introduction

- SQL is a standard language for querying and manipulating data

- SQL is a **very high-level** programming language

  This works because it is optimized well!

- Many standards out there:

  ANSI SQL, SQL92 (a.k.a. SQL2), SQL99 (a.k.a. SQL3), ….

SQL stands for
Structured
Query
Language

SQL is a…

- Data Manipulation Language (DML)
  - Query one or more tables
    - Insert/delete/modify tuples in tables

- Data Definition Language (DDL)
  - Define relational schemata
  - Create/alter/delete tables and their attributes

Set algebra

List: [1, 1, 2, 3]
Set: {1, 2, 3}
Multiset: {1, 1, 2, 3}

A **multiset** is an unordered list (or: a set with multiple duplicate instances allowed)

UNIONs

Set: {1, 2, 3} U { 2 } = { 1, 2, 3 }
Multiset: {1, 1, 2, 3} U { 2 } = { 1, 1, 2, 2, 3 }

Cross-product

{1, 1, 2, 3} * { y, z } =
{ <1, y>, <1, y>, <2, y>, <3, y>
<1, z>, <1, z>, <2, z>, <3, z>

i.e. no *next()*, etc. methods!

Tables in SQL

Product

PName	Price	Manuf
Gizmo	$19.99	GizmoWorks
Powergizmo	$29.99	GizmoWorks
SingleTouch	$149.99	Canon
MultiTouch	$203.99	Hitachi

A **relation** or **table** is a multiset of tuples having the attributes specified by the schema

Let's break this definition down

Tables in SQL

Product

PName	Price	Manuf
Gizmo	$19.99	GizmoWorks
Powergizmo	$29.99	GizmoWorks
SingleTouch	$149.99	Canon
MultiTouch	$203.99	Hitachi

An **attribute** (or **column**) is a typed data entry present in each tuple in the relation

*NB: Attributes must have an **atomic** type in standard SQL, i.e. not a list, set, etc.*

Tables in SQL

Product

PName	Price	Manuf
Gizmo	$19.99	GizmoWorks
Powergizmo	$29.99	GizmoWorks
SingleTouch	$149.99	Canon
MultiTouch	$203.99	Hitachi

A **tuple** or **row** is a single entry in the table having the attributes specified by the schema

*Also referred to sometimes as a **Record***

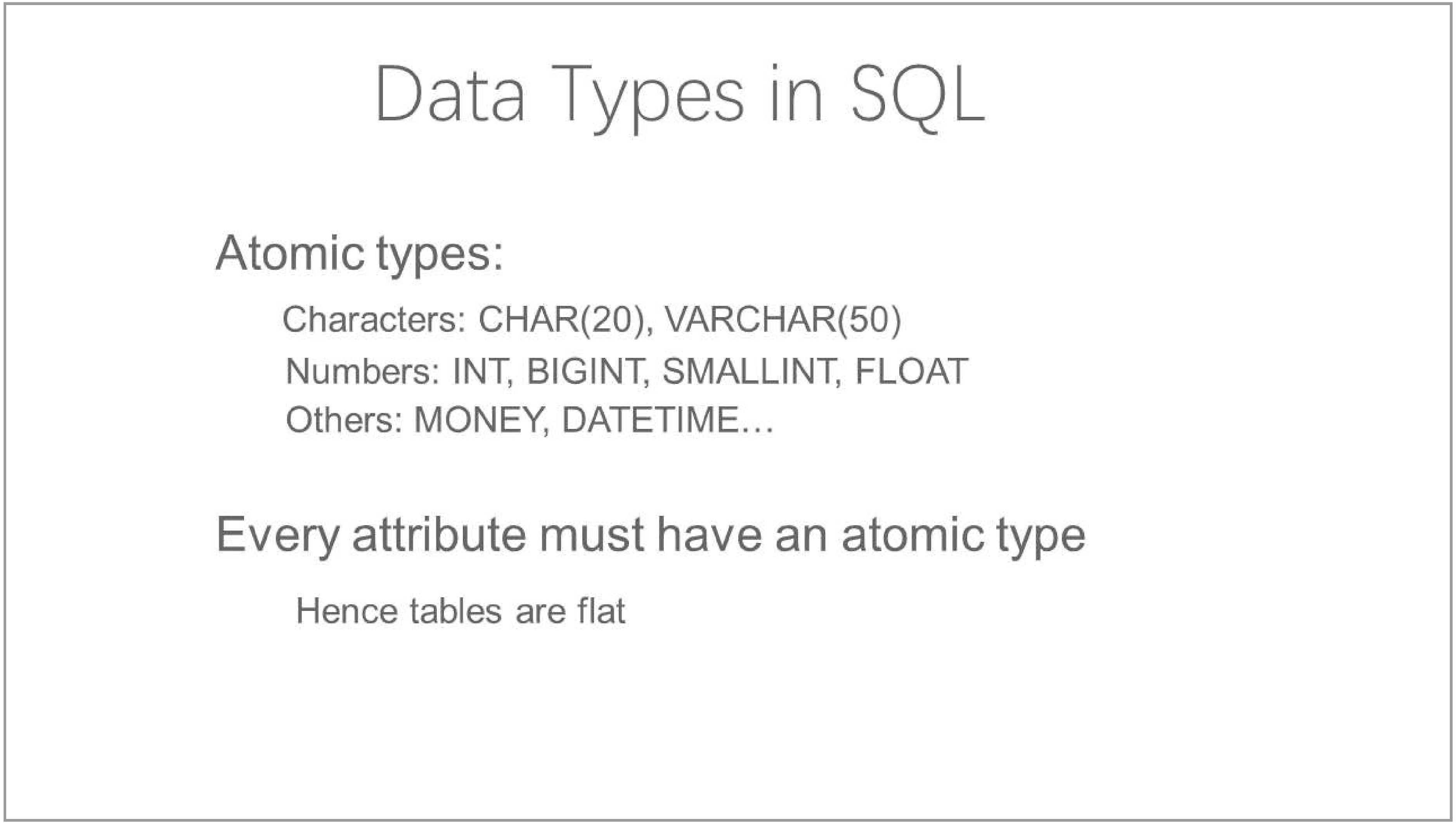
Tables in SQL

Product

PName	Price	Manuf
Gizmo	$19.99	GizmoWorks
Powergizmo	$29.99	GizmoWorks
SingleTouch	$149.99	Canon
MultiTouch	$203.99	Hitachi

The number of tuples is the **cardinality** of the relation

The number of attributes is the **arity** of the relation



Data Types in SQL

Atomic types:

- Characters: CHAR(20), VARCHAR(50)
- Numbers: INT, BIGINT, SMALLINT, FLOAT
- Others: MONEY, DATETIME…

Every attribute must have an atomic type

- Hence tables are flat

Table Schemas

The **schema** of a table is the table name, its attributes, and their types:

Product(Pname: *string*, Price: *float*, Category: *string*, Manufacturer: *string*)

A **key** is an attribute whose values are unique; we underline a key

Product(Pname: *string*, Price: *float*, Category: *string*, Manufacturer: *string*)

Key constraints

A **key** is a **minimal subset of attributes** that acts as a unique identifier for tuples in a relation

- A key is an implicit constraint on which tuples can be in the relation
- i.e. if two tuples agree on the values of the key, then they must be the same tuple!

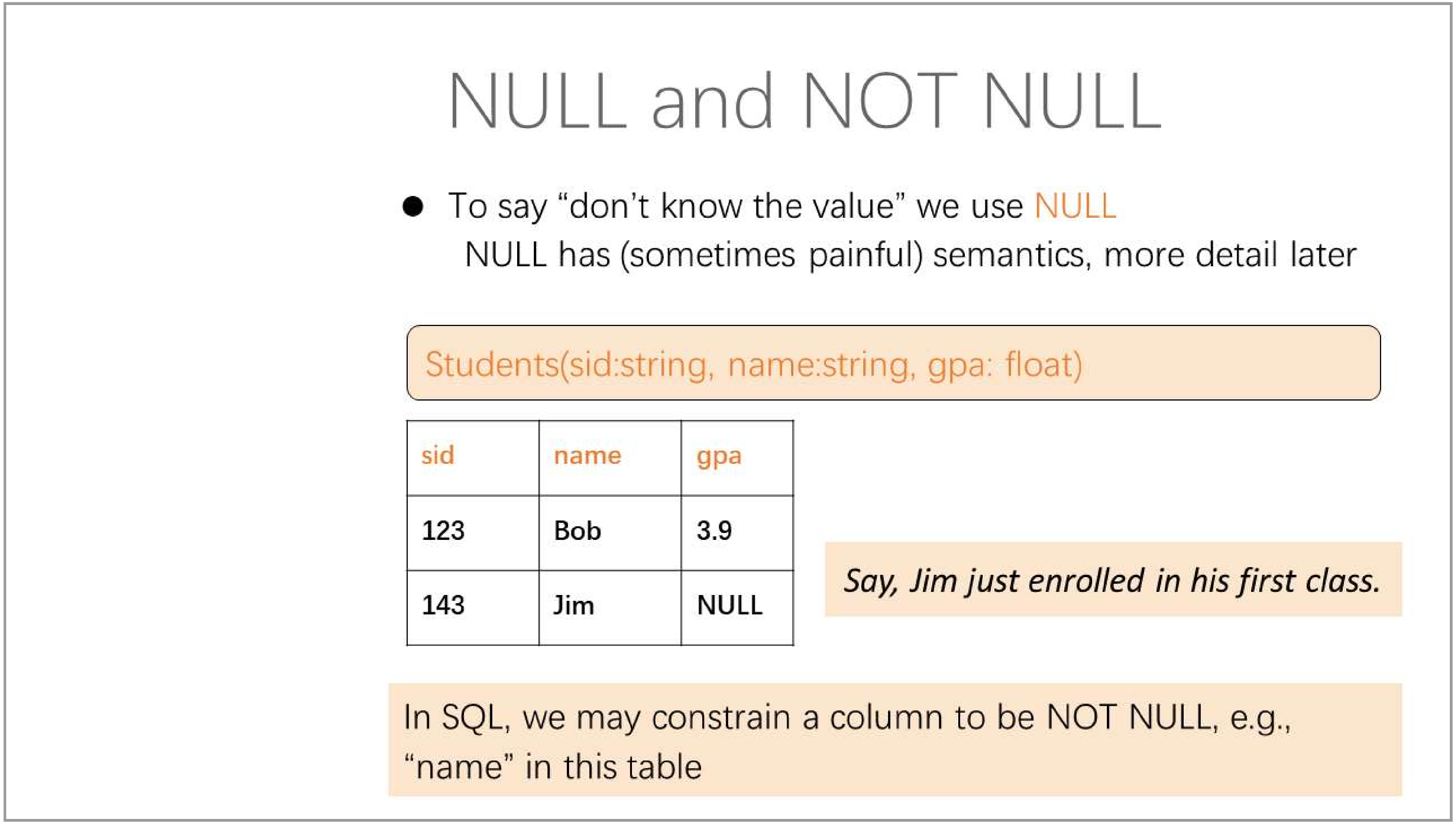
Students(sid:string, name:string, gpa: float)

1. Which would you select as a key?
2. Is a key always guaranteed to exist?
3. Can we have more than one key?

Declaring Schema

Students(sid: *string*, name: *string*, gpa: *float*)

```
CREATE TABLE Students (
  sid CHAR(20),
  name  VARCHAR(50),
  gpa  float,
  PRIMARY KEY (sid),
)
```



NULL and NOT NULL

- To say “don’t know the value” we use NULL
  NULL has (sometimes painful) semantics, more detail later

Students(sid:string, name:string, gpa: float)

sid	name	gpa
123	Bob	3.9
143	Jim	NULL

Say, Jim just enrolled in his first class.

In SQL, we may constrain a column to be NOT NULL, e.g., “name” in this table

多选题 1分

SQL查询依赖的是?

A 连表List

B 集合Set

[✓ C 多集MultiSet]

D 数组Array

2. Single - table queries

What you will learn about in this section

The SFW(Select-From-Where expression) query

Other useful operators: LIKE, DISTINCT, ORDER BY

SQL Query

- Basic form (there are many many more bells and whistles)

```
SELECT <attributes>

FROM   <one or more relations>

WHERE  <conditions>
```

Call this a **SFW** query.

Simple SQL Query: Selection

Selection is the operation of filtering a relation's tuples on some condition

```
SELECT *
FROM   Product
WHERE  Category = 'Gadgets'
```

PName	Price	Category	Manuf
Gizmo	$19.99	Gadgets	GWorks
Powergizmo	$29.99	Gadgets	GWorks
SingleTouch	$149.99	Photography	Canon
MultiTouch	$203.99	Household	Hitachi

⇩

PName	Price	Category	Manuf
Gizmo	$19.99	Gadgets	GWorks
Powergizmo	$29.99	Gadgets	GWorks

Simple SQL Query: Projection

Projection is the operation of producing an output table with tuples that have a subset of their prior attributes

PName	Price	Category	Manuf
Gizmo	$19.99	Gadgets	GWorks
Powergizmo	$29.99	Gadgets	GWorks
SingleTouch	$149.99	Photography	Canon
MultiTouch	$203.99	Household	Hitachi

```
SELECT Pname, Price, Manufacturer

FROM   Product

WHERE  Category = 'Gadgets'
```

PName	Price	Manuf
Gizmo	$19.99	GWorks
Powergizmo	$29.99	GWorks

Notation

Input Schema

Product(PName, Price, Category, Manufacturer)

```
SELECT Pname, Price, Manufacturer
FROM   Product
WHERE  Category = ‘Gadgets’
```

Output Schema

Answer(PName, Price, Manfacturer)

A Few Details

- SQL **commands** are case insensitive:

  Same: SELECT, Select, select

  Same: Product, product

- **Values** are **not:**

  Different: 'Seattle', 'seattle'

- Use single quotes for constants:

  'abc' - yes

  "abc" - no

LIKE: Simple String Pattern Matching

```
SELECT *
FROM   Products
WHERE  PName LIKE '%gizmo%'
```

- s **LIKE** p: pattern matching on strings
- p may contain two special symbols:
    - % = any sequence of characters
    - _ = any single character

DISTINCT: Eliminating Duplicates

```
SELECT DISTINCT Category
FROM   Product
```

Category
Gadgets
Photography
Household

Versus

```
SELECT Category
FROM   Product
```

Category
Gadgets
Gadgets
Photography
Household

ORDER BY: Sorting the Results

```
SELECT    PName, Price, Manufacturer
FROM       Product
WHERE     Category=‘gizmo’ AND Price > 50
ORDER BY Price, PName
```

Ties are broken by the second attribute on the ORDER BY list, etc.

Ordering is ascending, unless you specify the DESC keyword.

3. Multiple - table queries: JOIN

What you will learn about in this section

JOINs

Inner JOINs

Outer JOINs

Joins

Product(PName, Price, Category, Manufacturer)

Company(CName, StockPrice, Country)

Ex: Find all products under $200 manufactured in Japan; return their names and prices.

Joins

Product(PName, Price, Category, Manufacturer)

Company(CName, StockPrice, Country)

Several equivalent ways to write a basic join in SQL:

```
SELECT PName, Price
FROM    Product
JOIN     Company
ON         Manufacturer = Cname
WHERE  Price <= 200
              AND Country='Japan'
```

```
SELECT PName, Price
FROM     Product, Company
WHERE  Manufacturer = CName
            AND Country='Japan'
               AND Price <= 200
```

A few more later on

Joins

Product

PName	Price	Category	Manufacturer
Gizmo	$19	Gadgets	GizmoWorks
Powergizmo	$29	Gadgets	GizmoWorks
SingleTouch	$149	Photography	Canon
MultiTouch	$203	Household	Hitachi

Company

CName	Stock Price	Country
GizmoWorks	25	USA
Canon	65	Japan
Hitachi	15	Japan

```
SELECT PName, Price
FROM   Product, Company
WHERE  Manufacturer = CName
        AND Country='Japan'
              AND Price <= 200
```

PName	Price
SingleTouch	$149

Tuple Variable Ambiguity in Multi-Table

```
Person(name, address, worksfor)
Company(name, address)
```

```
SELECT DISTINCT name, address
FROM  Person, Company
WHERE    worksfor = name
```

Which “address” does this refer to?

Which name”s??

Tuple Variable Ambiguity in Multi-Table

```
Person(name, address, worksfor)
Company(name, address)
```

Both equivalent ways to resolve variable ambiguity

```
SELECT DISTINCT Person.name, Person.address
FROM           Person, Company
WHERE            Person.worksfor = Company.name
```

```
SELECT DISTINCT p.name, p.address
FROM           Person p, Company c
WHERE            p.worksfor = c.name
```

Semantics of JOINs

```
SELECT $x_1.a_1, x_1.a_2, \cdots, x_n.a_k$
FROM   $R_1$ AS $x_1$, $R_2$ AS $x_2$, $\cdots$, $R_n$ AS $x_n$
WHERE  Conditions($x_1, \cdots, x_n$)
```

Note:

This is a ***multiset*** union

```
Answer = {}
for $x_1$ in $R_1$ do
        for $x_2$ in $R_2$ do
        .....
        for $x_n$ in $R_n$ do
                if Conditions($x_1, \ldots, x_n$)
                then Answer = Answer $\cup$ {($x_1.a_1, x_1.a_2, \ldots, x_n.a_k$)}
return Answer
```

Semantics of JOINs

```
SELECT R.A
FROM   R, S
WHERE  R.A = S.B
```

- Take **cross product**

  X = R x S

- Apply **selections/conditions**

  Y = {(r, s) in X | r.A == s.B}

- Apply **projections** to get final output

  Z = (y.A) for y in Y

Recall: Cross product (A X B) is the set of all unique tuples in A,B

Ex: {a,b,c} X {1,2}

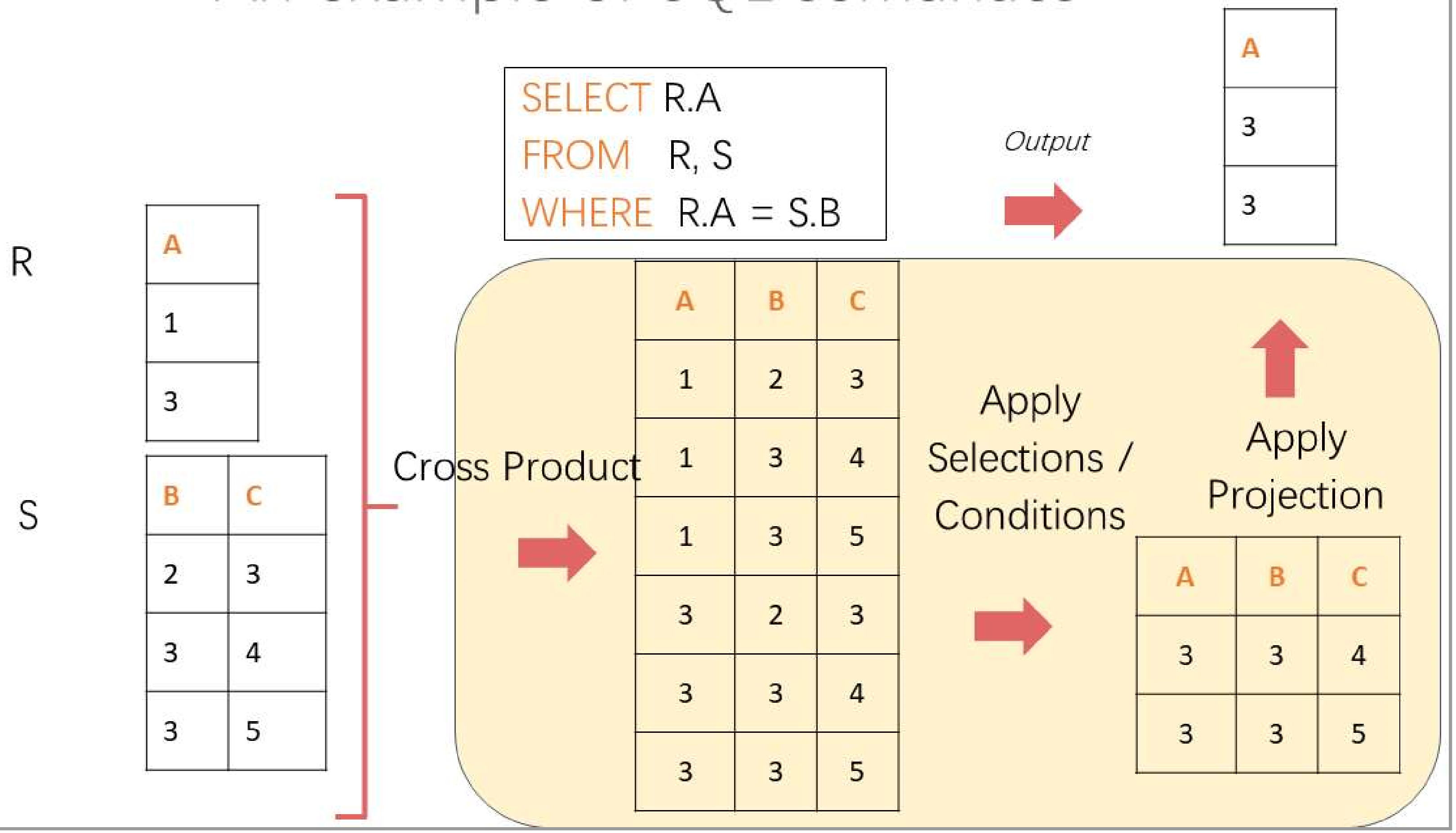
= {(a,1), (a,2), (b,1), (b,2), (c,1), (c,2)}

= Filtering!

= Returning only *some* attributes

Remembering this order is critical to understanding the output of certain queries (see later on…)

An example of SQL semantics



```
SELECT R.A
FROM   R, S
WHERE  R.A = S.B
```

R

A
1
3

S

B	C
2	3
3	4
3	5

Cross Product

A	B	C
1	2	3
1	3	4
1	3	5
3	2	3
3	3	4
3	3	5

Apply Selections / Conditions

A	B	C
3	3	4
3	3	5

Apply Projection

Output

A
3
3

Outer Joins

- Left outer join:
  - Include the left tuple even if there's no match
- Right outer join:
  - Include the right tuple even if there's no match
- Full outer join:
  - Include the both left and right tuples even if there's no match

RECAP: Inner Joins

By default, joins in SQL are **“inner joins”**:

```
Product(name, category)
Purchase(prodName, store)
```

1

```
SELECT Product.name, Purchase.store
FROM   Product
 JOIN Purchase ON Product.name = Purchase.prodName
```

2

```
SELECT Product.name, Purchase.store
FROM   Product, Purchase
WHERE  Product.name = Purchase.prodName
```

Both equivalent:
Both INNER JOINS!

INNER JOIN:

Product

name	category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

prodName	store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

3

```
SELECT Product.name,  Purchase.store
FROM   Product
 INNER  JOIN  Purchase
                    ON Product.name  =  Purchase.prodName
```

➡

name	store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

Note: another equivalent way to write an INNER JOIN!

LEFT OUTER JOIN:

Product

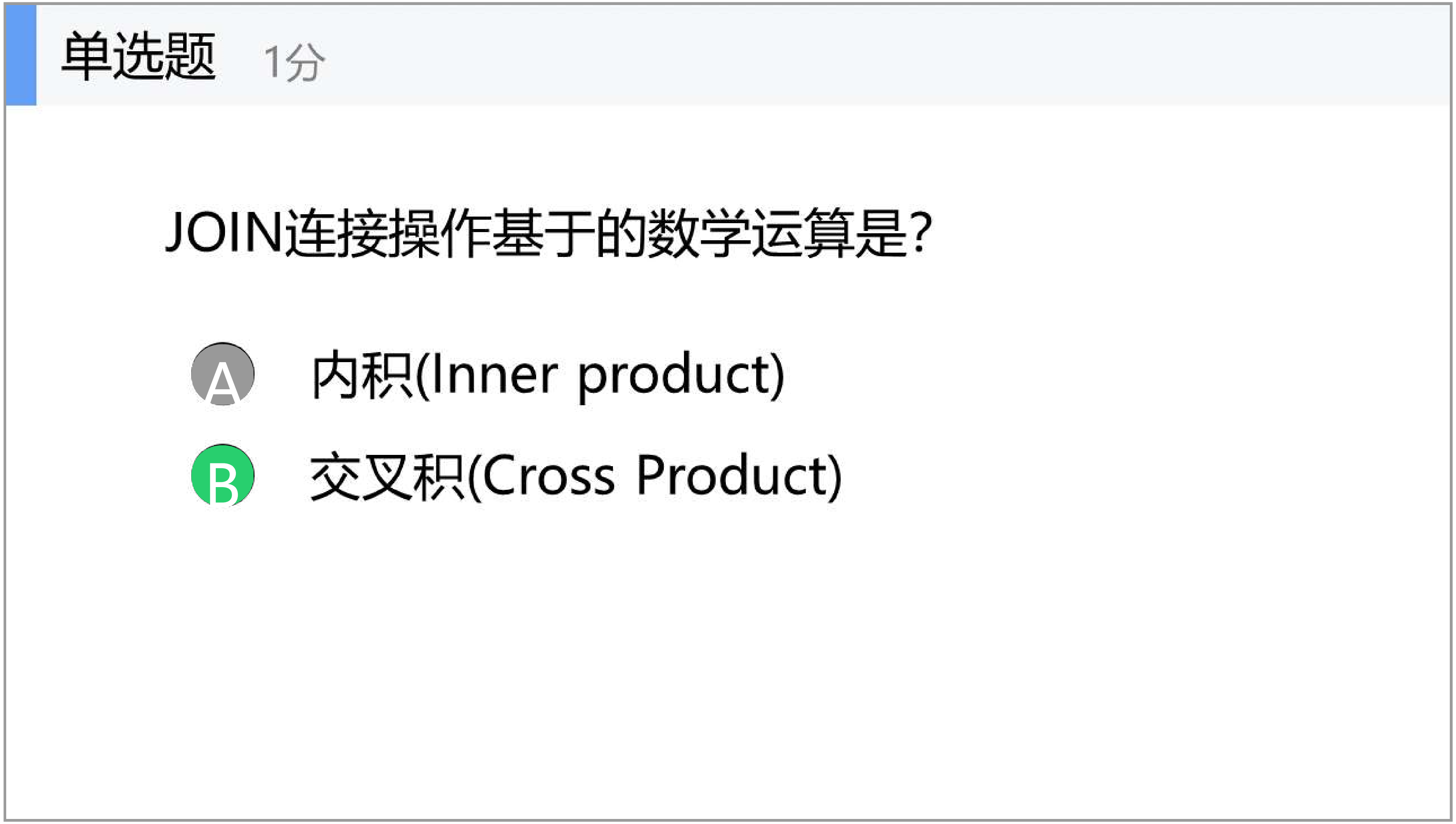
name	category
Gizmo	gadget
Camera	Photo
OneClick	Photo

Purchase

prodName	store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz

```
SELECT Product.name, Purchase.store
FROM   Product
 LEFT OUTER JOIN Purchase
              ON Product.name = Purchase.prodName
```

name	store
Gizmo	Wiz
Camera	Ritz
Camera	Wiz
OneClick	NULL



单选题 1分

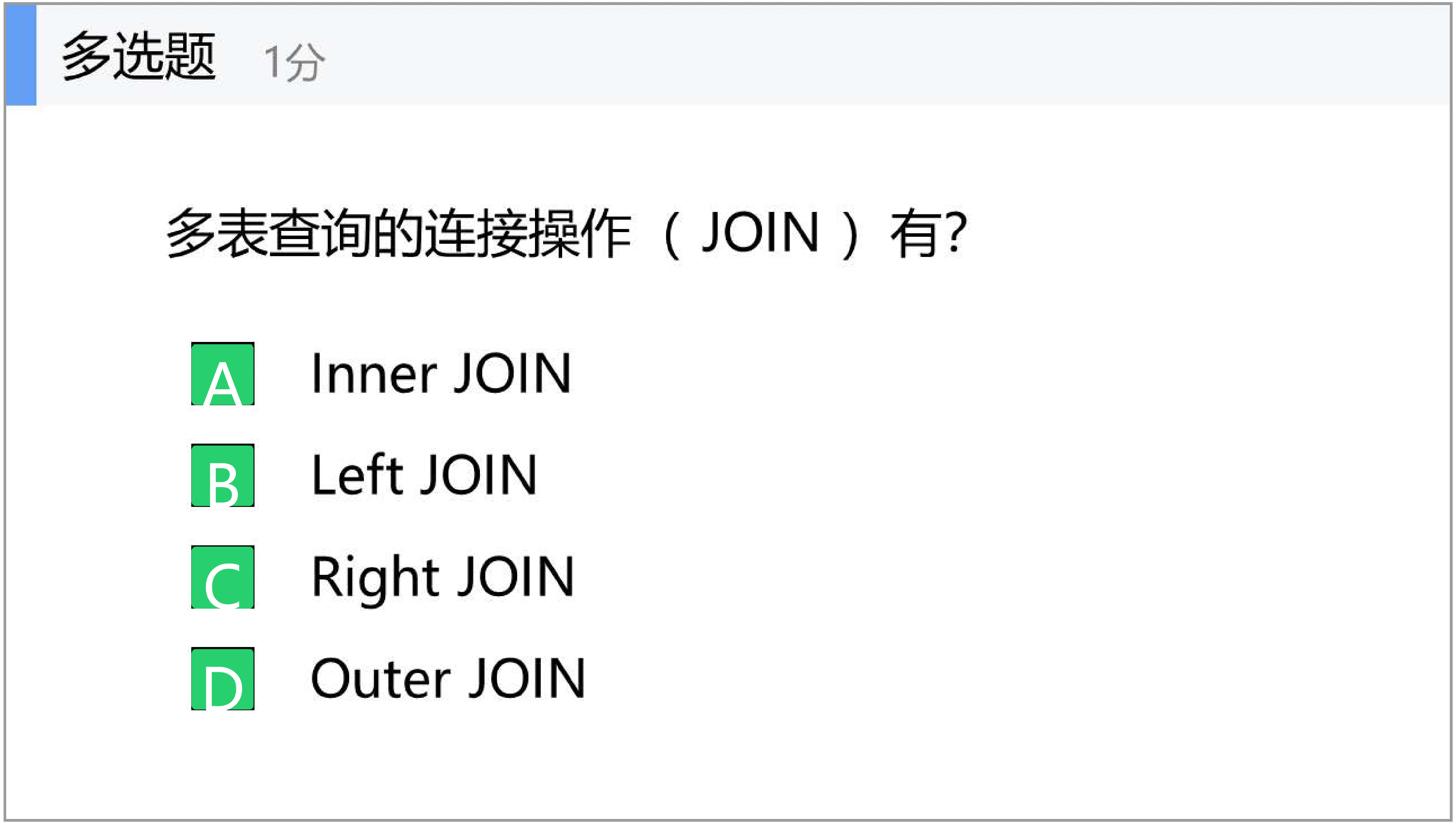
JOIN连接操作基于的数学运算是?

A 内积(Inner product)

[✓ B 交叉积(Cross Product)]

Outer Joins

- Left outer join:
  - Include the left tuple even if there’s no match
- Right outer join:
  - Include the right tuple even if there’s no match
- Full outer join:
  - Include the both left and right tuples even if there’s no match



多选题 1分

多表查询的连接操作（ JOIN ）有?

A Inner JOIN

B Left JOIN

C Right JOIN

D Outer JOIN

THANK YOU!