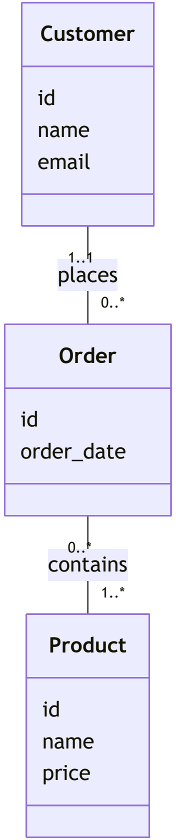
The relational model

- The learning objectives for this week are:
  - Knowing what is a **data model**
  - Knowing what is the **relational data model**
  - Knowing the core terminology of the relational model
  - Knowing what are the properties of database **relations**
  - Knowing what are **domain integrity**, **entity integrity**, and **referential integrity** rules
  - Knowing how to identify **candidate keys**, **primary keys**, **alternate keys**, and **foreign keys**
  - Knowing how to formulate **relation schemas** and **relational schemas**
  - Knowing how tables are used to represent data

Data Model



- A **data model** is a conceptual model that defines how data is structured, stored, and accessed in a system
- For example, **entity-relationship model** describes **entities** (things about which data is stored), **attributes** (details about each entity), and **relationships** (how entities are connected)
- In case of a simple online store, a "Customer" **entity** consists of **attributes** such as "name" and "email"
- The "Customer" entity could have a **relationship** with the "Order" entity, describing which orders a specfic customer has placed
- Data model **helps design the structure** of a database and **makes data requirements easier to understand**, ensuring that both technical and non-technical stakeholders share a common understanding of the data

Components of a data model

- A data model consists of three components:
    1. **Structural part**: what types of data exist and how they relate to each other. For example data model could consist of "Course implementation" and "Teacher" entities, and "Teacher" entity has a relationship with the "Course implementation" entity (the teacher teaching the course implementation)
    2. **Integrity part**: how the data can be used, validated, and maintained. For example "credits" attribute of a "Course" entity should be a number between 0 and 10
    3. **Manipulative part**: what can be done with the data (like creating, reading, updating, deleting)

The relational model

- When all data model’s data is logically structured within **relations**, the model is a **relational model**
- **Relation** (informally called a **table**) represents a data entity organized in a specific structure, such as "Course"
- Each relation consists of **attributes** (informally called **columns**) that define its properties, such as "name" and "credits"
- Attributes have a set of allowable values, which is referred to as the attribute’s **domain**. For example, "Course" relation’s "credits" attribute could be an integer value between 1 and 10
- The actual data is in relations’s **tuples** (informally called **rows**)
- **Relationships** between two relations are established using a **foreign key**, which references other relation’s unique **primary key**. For example "Course implementation" relation has a "teacherno" foreign key referencing the "Teacher" relation’s "teacherno" attribute

The relational model

code	name	credits	programmecode
HIS201	World History	5	HIS
MATH201	Calculus II	3	MATH
ENG150	Academic Writing	2	LING
CSC102	Introduction to Programming	5	CS

- The following data represents a "Course" **relation**
- The relation has four **attributes** "code", "name", "credits" and "programmecode"
- There a four **tuples** containing the actual data
- The "code" attribute is a **primary key**, which uniquely identifies each tuple (no two tuples have the same value for the attribute)

Properties of relations

- Each relation has a name that is **distinct from all other relation names**
- Each attribute of a relation has a **distinct name within the relation**
- Each relation has a **primary key** attribute, which **unique identifies each tuple** and makes sure, there’s no duplicate values. For example "code" primary key for "Course" relation and "studentnumber" primary key for "Student" relation
- Each attribute is **atomic**, meaning that each tuple’s cell contains exactly one value. For example, it is not possible to have a "emails" attribute representing multiple email addresses
- Values of an attribute are all **from the same domain**. For example, "name" attribute values are only text and "credits" attribute values are only numbers

Integrity constraints

order_id	customer_id	order_date	total_amount
❌ 1	102	2025-01-13	❌ -50.00
❌ 1	❌ NULL	2025-01-14	150.00
6	104	❌ 02.02.2025	200.00

- The quality of the data directly determines the quality of the whole database
- Therefore preventing entry of incorrect data is one of the most important functions of a DBMS
- **Integrity constraints** are different kind of rules used to control the legal database states enforcing database **integrity**
- If the database satisfies all the integrity constraints specified on the database schema, it is in a legal state

Superkey, candidate key and primary key

- A **superkey** is an attribute or group of attributes that **uniquely identifies** each tuple of a relation
- Superkey consisting of a group of attributes is called a **composite key**
- Relation can have multiple superkeys, for example in the "Course" relation the "code" attribute, and group of "code" and "name" attributes (composite key) are superkeys
- ❓ What other superkeys does the "Course" relation have?

code	name	credits	programmecode
CS102	Introduction to Programming	5	CS
MATH201	Calculus II	4	MATH
ENG150	Academic Writing	2	LING

Superkey, candidate key and primary key

- A composite **candidate key** is a superkey that satisfies the property of **minimality**
- Minimality is satisfied if an attribute can’t be removed from the composite key without breaking the uniqueness property
- In the "Course" relation the group of "code" and "name" attributes doesn’t satify minimality, so it isn’t a candidate key
- ❓ What other candidate keys does the "Course" relation have?

code	name	credits	programmecode
CS102	Introduction to Programming	5	CS
MATH201	Calculus II	4	MATH
ENG150	Academic Writing	2	LING

Entity integrity

- From the set of candidate keys for the relation, **exactly one** candidate key is chosen to be the **primary key**
- The other candidate keys become **alternate keys**
- Each tuple has a value for the primary key, **it can’t be missing**
- Primary key’s value **should not change**. For example person’s name or phone number might sound tempting options for a primary key but are actully subject to change
- **Primary key constraint** prevents duplicate tuples to exist for the relation
- Primary key constraints enforce **entity integrity**

Surrogate keys

- If there is initially no candidate key for a relation, then we cannot determine a **natural primary key**
- For example, the relation "Messages", representing email messages:

from	**to**	**title**	**body**
kalle.ilves@haaga-helia.fi	john.doe@gmail.com	Greeting	Hello John!
john.doe@gmail.com	kalle.ilves@haaga-helia.fi	Response	Hello Kalle!

Surrogate keys

- We have to take care of the situation by including an extra attribute in the relation to act as the primary key
- For example a "messageid" column that holds a unique number for each tuple:

messageid	from	to	title	body
1	kalle.ilves@haaga-helia.fi	john.doe@gmail.com	Greeting	Hello John!
2	john.doe@gmail.com	kalle.ilves@haaga-helia.fi	Response	Hello Kalle!

Surrogate keys

- Such primary key is called a **surrogate key**
- Surrogate key has no relationship to the real-world meaning of the data held in a tuple
- Surrogate keys are quite common and a natural key is often replaced with a surrogate key
- Surrogate keys are commonly generated by the DBMS once a tuple is inserted
- Automatically incremented numbers (1, 2, 3, …) and randomly generated values like UUID are common surrogate key values

Choosing a primary key

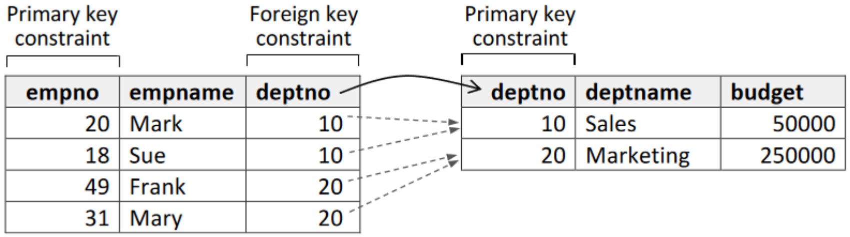
- Let’s consider a suitable primary key in the following cases:
  - ❓ Is "Student" relation’s "phonenumber" attribute a good option for a primary key? Why or why not?
  - ❓ A "Customer" relation has attributes "address", "name", "email" and "social_security_number". What would be suitable primery key for this relation and why?

social_security_number	**name**	**address**	**email**
123-45-6789	Alice Johnson	742 Evergreen Terrace	alicejohnson@gmail.com
987-65-4321	Bob Smith	221B Baker Street	bobthebot87@hotmail.com
555-12-3456	Carol Nguyen	1600 Pennsylvania Avenue	carolnguyen123@gmail.com

Referential Integrity

- **Foreign key** is a attribute or group attributes whose values are required to match those of the primary key of the referenced relation
- There can be several foreign keys in a relation
- Foreign-to-primary-key matching is the "glue" which holds the database together
- **Foreign key constraint** prevents foreign key not being matched by a primary key in the referenced relation
- Foreign key constraints enforce **referential integrity**

Referential Integrity



empno	empname	deptno
20	Mark	10
18	Sue	10
49	Frank	20
31	Mary	20

deptno	deptname	budget
10	Sales	50000
20	Marketing	250000

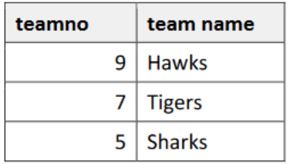
Employee (Referencing relation)

Department (Referenced relation)

- In this example we have two relations: "Employee" and "Department"
- Each employee belongs to one department, where they work in
- This relationship is established between entities by using a **foreign key** attribute "deptno" in the "Employee" relation, which is linked to the "Department" relation’s **primary key** attribute "deptno"
- ⚠ A general rule is, that foreign key **always references a primary key**

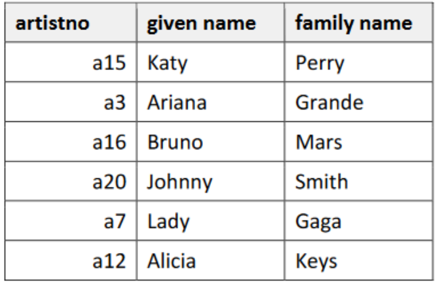
Example of primary and foreign keys

TEAM



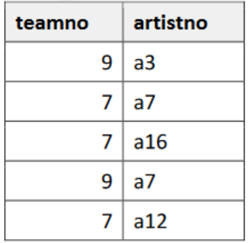
teamno	team name
9	Hawks
7	Tigers
5	Sharks

ARTIST



artistno	given name	family name
a15	Katy	Perry
a3	Ariana	Grande
a16	Bruno	Mars
a20	Johnny	Smith
a7	Lady	Gaga
a12	Alicia	Keys

TEAM_ARTIST



teamno	artistno
9	a3
7	a7
7	a16
9	a7
7	a12

- Let’s consider the following question related to these "Team", "Artist" and "Team_Artist" relations:
  - ❓ What are the **primary keys** for each table?
  - ❓ What are the **foreign keys** for each table?

Relation schema and relational schema

- To provide a textual presentation of relation or a collection related relations, we can use **relation schemas** and **relational schemas**
- **Relation schema** describes a single relation. It includes the name of the relation, the names of attributes and the **primary key** attribute underlined

```
Course (courseCode, courseName, credits)
```

- **Relational schema** describes a collection of relations (the logical structure of a relational database)

```
Course (courseCode, courseName, credits)
Student (studentNumber, familyName, givenName, birthdate)

CourseGrade (courseCode, studentNumber, grade)
 FOREIGN KEY (courseCode) REFERENCES Course (courseCode)
 FOREIGN KEY (studentNumber) REFERENCES Student (studentNumber)
```

Domain integrity

- A **domain constraint** specifies the set of allowable values for an attribute
- It includes attribute's **type-based restriction** (e.g. integer, string, or date) and further restrictions based on user-defined rules. For example:
  - Valid grade marks are integers between 0 and 5
  - Student's birth date is a valid date before today's date
  - Student's email should be a string in format `%@%.%`
- Domain constraints enforce **domain integrity**

Not null constraint

studentid	name	phonenumber	major
2001	Emma Thompson	(415) 555-0198	Computer Science
2002	Liam Martinez	⚠️ NULL	Computer Science
2003	Sophia Chen	(212) 555-0843	Psychology

- **Null** is a marker for a missing attribute value
- Null is not the same as e.g. blanks or zero. Null represents **absence of a value**
- The **not null constraint** is a restriction placed on an attribute, which enforces that in every tuple of data the attribute **must have a value**
- For example, it would make sense that in the "Employee" relation, the "deptno" attribute has a not null constraint, meaning that every employee belongs to a department

Database manipulation

- A **manipulation mechanism** is among the most important parts of a data model
- A manipulation mechanism allows the data to be retrieved and updated
- **Structured Query Language** (SQL) is the standard database language for relational databases. With SQL we can:
  - Create the database and relation structures
  - Perform insertion, modification, and deletion of data from the relations
  - Perform database queries
- Instead of using formal terms of relations, attributes, and tuples, the terms **tables**, **columns**, and **rows** are used in the SQL standard

SQL

- An **SQL query** is a single statement in which you describe what kind of data we want to **retrieve from the database** or **how we want to manipulate it** (insert, update, delete)
- While retrieving data, the query operates on tables and builds a result table from one or more tables in the database
- Here's an example of an SQL query and its result table:

```sql
SELECT code, name, credits
FROM course
WHERE name = 'Data Management and Databases';
```

code	name	credits
CS220	Data Management and Databases	5

Summary

- A **data model** consists of three components: the **structural part**, the **integrity part** and the **manipulative part**
- In the **relational model**, all data is logically structured within relations that have attributes and tuples
- **SQL** is the standard database language for relational databases
- **Integrity constraints** are rules which make sure that the database is in a legal state
- **Domain constraint** specifies the set of allowable values for an attribute
- **Primary key constraint** prevents duplicate tuples to exist for the relation
- **Foreign key constraint** prevents foreign key not being matched by a primary key in the referenced relation
- **Not null constraint** enforces that in every tuple of data the specified attribute **must have a value**