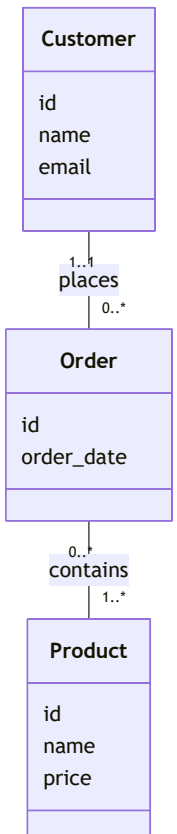
The relational model

- 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**
- These relations are informally referred to as **tables**
- The data is perceived by the users as tables
- Relation has named **attributes** (informally called **columns**)
- Attributes have a set of allowable values, which is referred to as the attribute's **domain**
  - For example, "Person" relation's "age" attribute could be an integer value larger or equal to zero
- 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

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 tuple's cell contains exactly one value
- Values of an attribute are all **from the same domain** (for example, numbers or text)
- The order of attributes has no significance
- There are no duplicate tuples
- The order of tuples has no significance

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

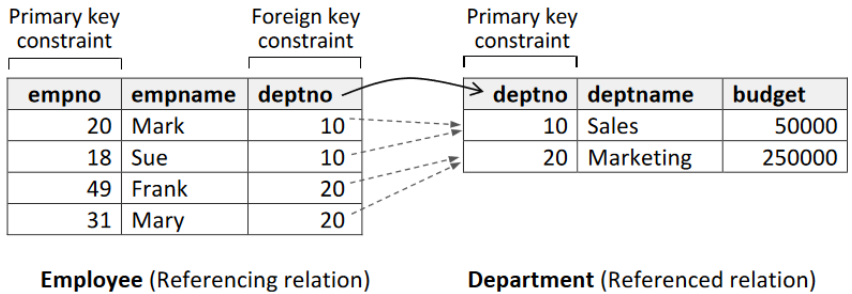
- Let’s consider a suitable primary key in the following cases:
  - ❓ Is "Student" relation’s "phonenumber" attribute a good option for a primary key? Why or why not?
  - ❓ A "Customer" relation has attributes "address", "name", "email" and "social_security_number". What would be suitable primery key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



- 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:

```
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**