Object-Relational Modeling

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Purpose of this Lecture

Introduce Object-Relational-Mapping

- Understand the problem it solves
- Understand the problems it does not solve
- Understand the problems it creates
- Learn about the implementations

Understand how ORM work

- Be able to manually perform the mapping
  - There are multiple ways of doing it – understand the tradeoffs
- Be able to create a class system for a relational schema

Normalization

Unnormalized Data - Everything goes

The Schema

```
OrderedBooks(Number, CustomerID, Customer, ShippingAddress,
  Titles, Authors)
```

OrderedBooks

Number	CustID	Customer	ShippingAddress	Titles	Authors
1	1	Holger	180 Queens Gate	Database Management Systems; A Game of Thrones	Ramakrishnan & Gehrke; Martin
2	2	Sam	32 Vassar Street	Database Management Systems	Ramakrishnan & Gehrke
3	3	Peter	180 Queens Gate	Distributed Systems	van Steen & Tanenbaum

Fix it by breaking the Schema

The Schema

```
OrderedBooks(Number, Customer, ShippingAddress, Title 1, Title 2,
  Author 1, Author 2)
```

The Data

Number	CustID	Customer	ShippingAddress	Title 1	Title2	Author 1	Author 2
1	1	Holger	180 Queens Gate	Database Management Systems	A Game of Thrones	Ramakrishnan & Gehrke	Martin
2	2	Sam	32 Vassar Street	Database Management Systems		Ramakrishnan & Gehrke	
3	3	Peter	180 Queens Gate	Distributed Systems		van Steen & Tanenbaum	

First Normal Form

The Schema

```
OrderedBooks(OrderNumber, Customer, ShippingAddress, BookNumber)
Books(Number, Title, Author)
```

OrderedItem

Number	CustomerID	Customer	ShippingAddress	BookNumber
1	1	Holger	180 Queens Gate	1
1	2	Holger	180 Queens Gate	2
2	2	Sam	32 Vassar Street	1
3	3	Peter	180 Queens Gate	3

Book

Number	Title	Author
1	Database Management Systems	Ramakrishnan & Gehrke
2	A Game of Thrones	Martin
3	Distributed Systems	van Steen & Tanenbaum

Second Normal Form

The Schema

```
Orders(OrderNumber, Customer, ShippingAddress)
OrderedBooks(OrderNumber, BookNumber)
Books(Number, Title, Author)
```

Order

Number	CustomerID	Customer	ShippingAddress	OrderNumber
1	1	Holger	180 Queens Gate	1
2	2	Sam	32 Vassar Street	2
3	3	Peter	180 Queens Gate	3

OrderedItem

OrderNumber	BookNumber
1	1
1	2
2	1
3	3

Book

Number	Title	Author
1	Database Management Systems	Ramakrishnan & Gehrke
2	A Game of Thrones	Martin
3	Distributed Systems	van Steen & Tanenbaum

Third Normal Form

The Schema

```
Customers(ID, Customer, ShippingAddress)
Orders(OrderID, CustomerID)
OrderedBooks(OrderID, BookID)
Books(ID, Title, Author)
```

Customer

ID	Customer	ShippingAddress
1	Holger	180 Queens Gate
2	Sam	32 Vassar Street
3	Peter	180 Queens Gate

Order

ID	CustomerID
1	1
2	2
3	3

OrderedItem

OrderId	BookID
1	1
1	2
2	1
3	3

Book

ID	Title	Author
1	Database Management Systems	Ramakrishnan & Gehrke
2	A Game of Thrones	Martin
3	Distributed Systems	van Steen & Tanenbaum

Object-Relational Mapping

What do we want from a DBMS?

Persistence!!

- When do we want it?
  - All the time!
- Databases are persistent
- Processes are not

Object-Oriented Databases

Programs work with objects, not tuples

- Granularity
  - Reconstruction overhead (Data navigation)
- Inheritance
- Identity vs. Equality
  - Identity is an inherent property
  - Equality has to be defined
- Associations

Why OO DBMSs failed

A couple of factors

- No standardized interface (for a long time)
- No real story for OLAP
- Non-technical reasons: IBM and Oracle backed relations
- Conincidence

ORMs are a compromise

- Given the illusion of an OODBMS
- On top of an RDBMS

Some Nomenclature

Wording

ORM	Object-Relational Mapping
Relation	A set of tuples (i.e., the relational sense)
Class	A template for object creation (i.e., the object-oriented sense)
Association	A rule defining the relationship between the objects of two classes (i.e., the object-oriented sense)

A Note on Entity-Relationship Modeling

This part of the class used to be about ER-Modelling

- Very related to ORM
- Popular in the 90s as a higher-level modeling paradigm
  - (Something management would understand)
- Rarely used today because it did not catch on in programming languages...
  - ...which is why we cover ORM instead
- ORMs are actually quite popular in pracice

Functionality of an ORM

Must have

- Mapping
  - Abstraction of syntax/oddities
  - Integrity Constraints
- Querying
- Schema
- Inserts

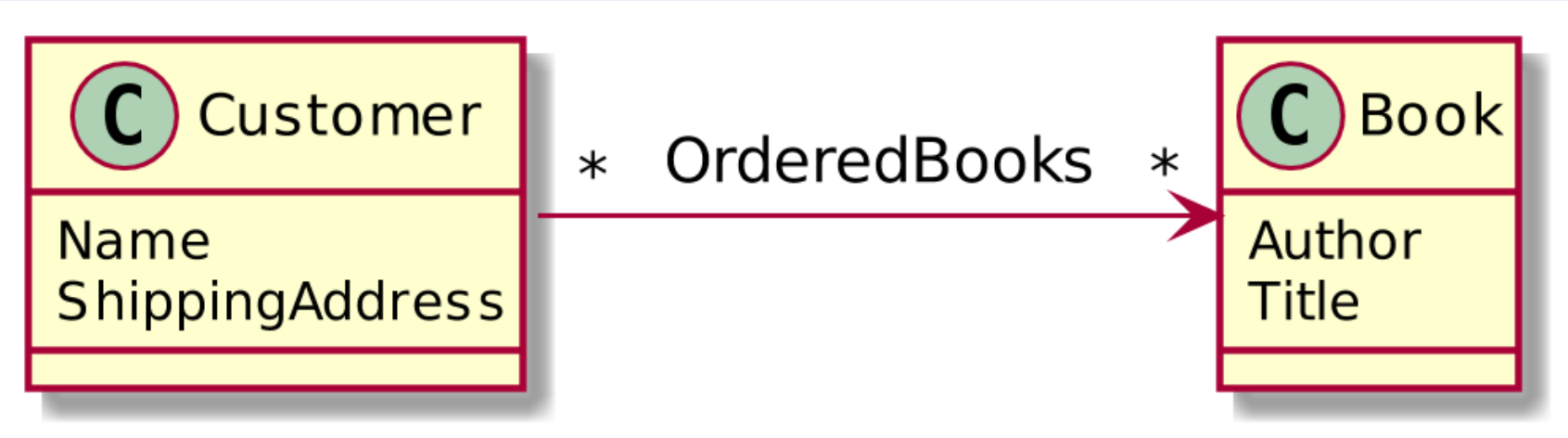
Nice to have

- Non-Intrusive
- Version control
- Faithfulness: object-oriented semantics should be represented

Let's dive into it

Classes

Classes in UML



- Poll: Is anybody seing this for the first time?

Classes

Classes in UML

```
class Customer{
std::string name;
std::string shipping_address;
std::set<std::shared_ptr<Customer>> orderedBooks;
}
class Book {
std::string author;
std::string title;
}
```

- Poll: Is anybody seing this for the first time?

Classes

Classes in UML

```
class Customer{
std::string name;
std::string shipping_address;
std::set<std::shared_ptr<Customer>> orderedBooks;
}
class Book {
std::string author;
std::string title;
}
```

- Poll: Is anybody seing this for the first time?
- Question: Why are there no IDs here?

Worksheet: Object-Oriented Modeling

Develop an object-oriented model to describe the following domain

Domain

The payroll system for *BIG Inc* records the salaries, status, joining date, name, and payroll number for all of the corporation's 30,000 employees. Each employee works for one division, and each division has an account number for paying its staff. We identify divisions by their name, and record the address where the division's HQ is located.
For employees sent abroad by *BIG Inc*, we record the address, country and telephone number of the foreign tax office that will handle the employee. It is assumed that each country has one central tax office that we have to deal with. All other employees have their tax affairs dealt with by the Inland Revenue.

Worksheet: Object-Oriented Modeling

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Mapping Classes

Mapping Rules

- Every class is mapped to a table
- Every scalar attribute is mapped to an attribute

Relations

```
Customer(Name, ShippingAddress)
Book(Title, Author)
```

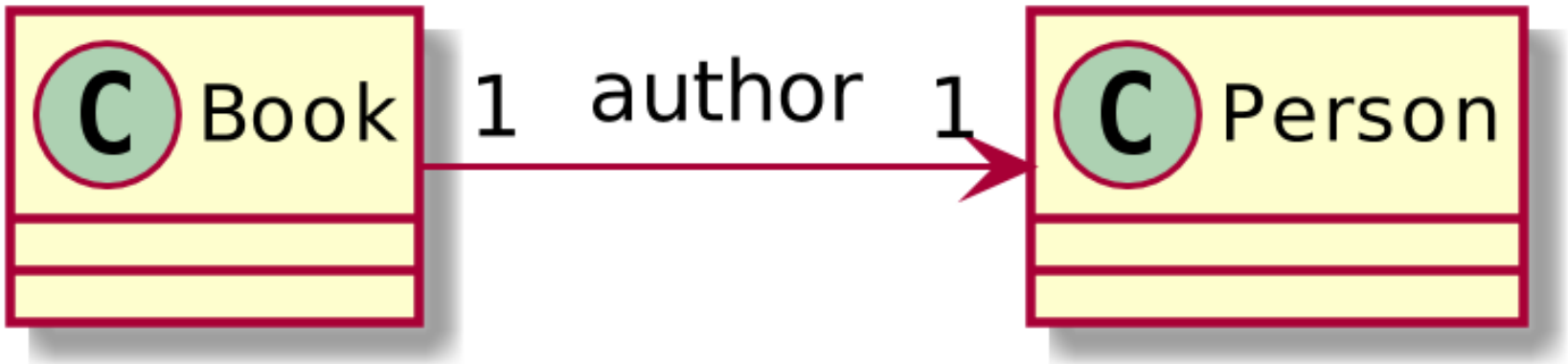
Mapping Relations

Multiplicities

- One-to-One
- One to Many
- Many to Many

One-to-One

In UML



In C++

```
class Person {
}
class Book {
Person author;
}
```

One-to-One

Translation rules

- Both classes get mapped into one (i.e., the same) relation
- Attributes of the relation is the concatenation of both
  - Conflicts can be resolved using, e.g., prefixing with class name

A note on One-to-One

- This is a very rare case
  - Two entities that are intricately linked but still semantically different
- Many practical frameworks do not treat one-to-one properly
  - Often modeled the same as One-to-Many

One-to-Many

In UML

In C++

```
class Book {
Person* author; // <- This is optional
// Don't play with raw pointers, children!
}
class Person {
set<Book> authoredBooks;
}
```

- Question: could a vector be used instead of a set?

One-to-Many

Translation rules

- Each class gets mapped into one (i.e., its own) relation
- The *many*-side receives a foreign-key attribute referencing the *one*-side

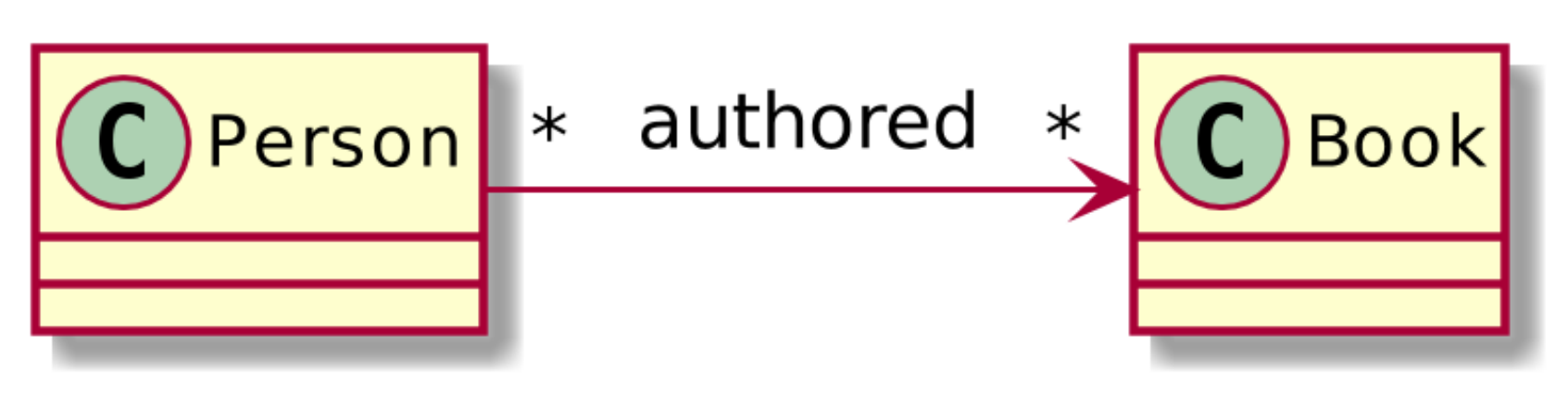
Example

```
create table Person(
id int;
...
primary key(id);
)

create table Book(
Person_id int not null;
foreign key (Person_id) references Person(id);
)
```

Many-to-Many

In UML



In C++

```
class Book {
set<Person*> authors; // <- Both are needed
}
class Person {
set<Book*> authoredBooks; // <- Both are needed
}
```

Many-to-Many

Translation rules

- Each class gets mapped into one (i.e., its own) relation
- A third table is created containing the mapping
  - It contains two columns, each of which is a foreign key

Example

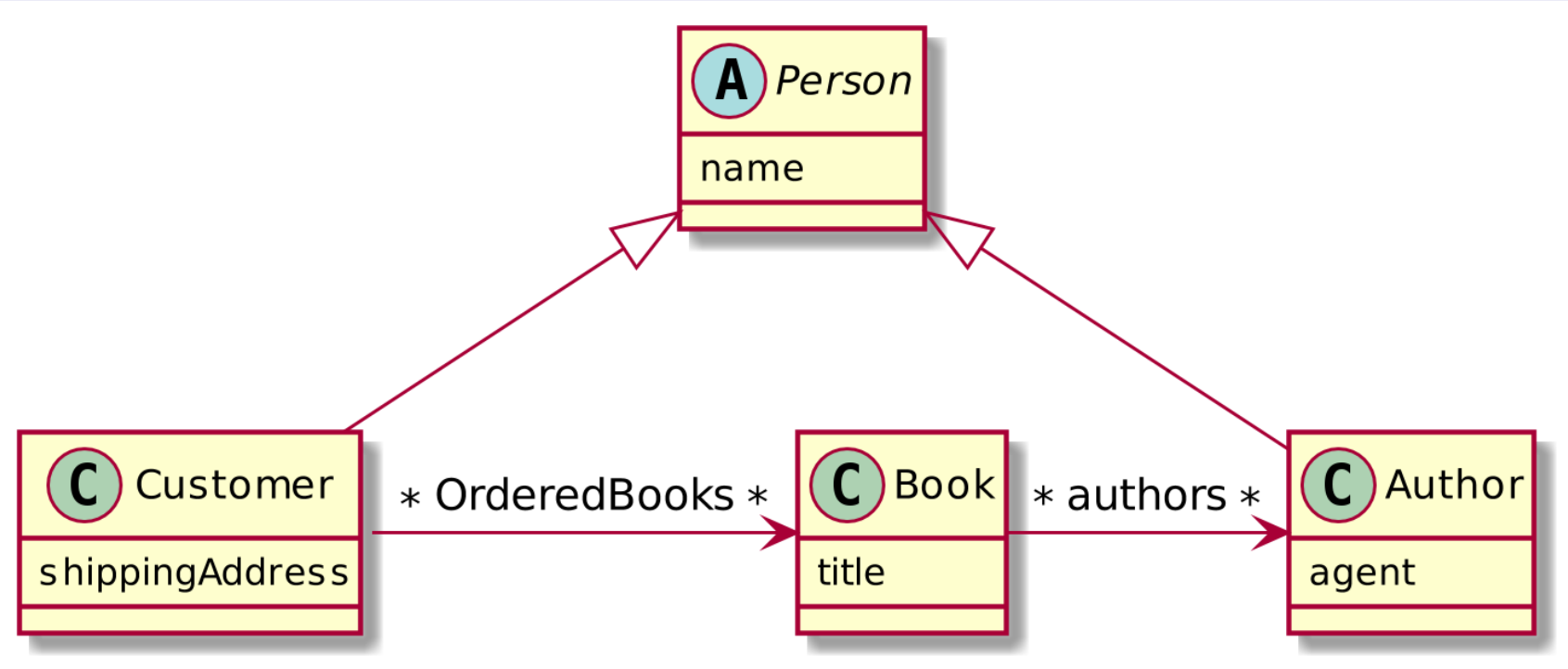
```
create table Person(
  id int; primary key(id);
)
create table Book(
  id int; primary key(id);
)

create table Book_to_Person(
Person_id int not null; foreign key (Person_id) references Person(id)
Book_id int not null; foreign key (Book_id) references Book (id);
)
```

Mapping Inheritance

Here comes the mismatch

An Example



Questions:

- How do we map this to a relation?
- Why would this be a problem?

Resolving inheritance

Let's give it a shot

- Every class maps to a relation
  - `Person, Customer, Author, Book`
- The associations are all many-to-many
  - How do we map those?
- What about the inheritance
  - Lets say we create foreign keys
  - Is the schema in 3NF?
  - Is the schema faithful? Are the object-oriented semantics represented?

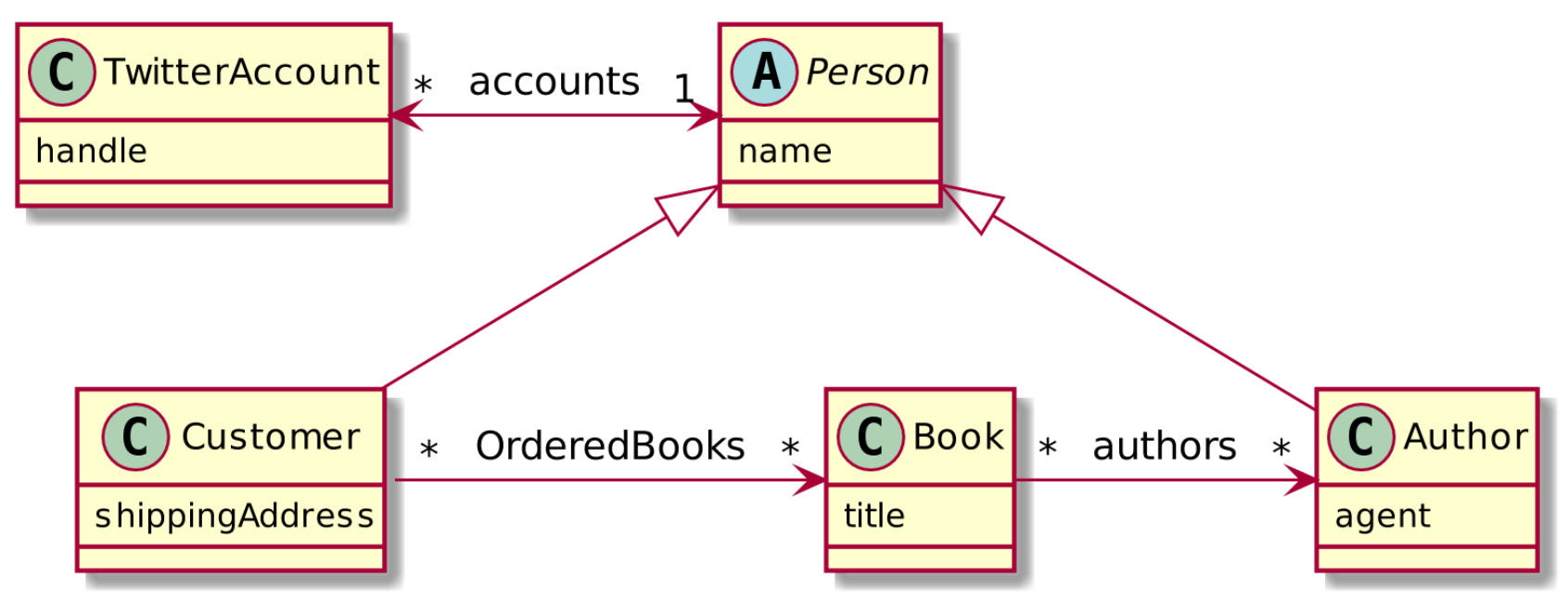
Resolving inheritance 2

Let's give it another shot

- Every concrete class maps to a relation
  - `CustomerWithPerson, AuthorWithPerson, Book`
- The associations are all many-to-many
  - How do we map those?
- What about the inheritance
  - Is the schema in 3NF?
  - Is the schema faithful? Are the object-oriented semantics represented?

Resolving inheritance 2

Let's complicate the example



Question

- Is there a problem here?

Resolving inheritance 3

Let's give it a last shot

- Every class hierarchy maps to a relation
  - `CustomerWithCustomerWithPerson, Book, TwitterAccount`
- The associations are all many-to-many
  - How do we map those?
- What about the inheritance
  - Is the schema in 3NF?
  - Is the schema faithful? Are the object-oriented semantics represented?

Conclusion

Three methods

- table per class (abstract or concrete)
- table per concrete class
- Single table per hierarchy

None are perfect

- Per class tables break object-oriented semantics
- Per concrete class table may break foreign-key constraints
- Single table per hierarchy violates normal form (produces sparse tables)

Worksheet: ORM

Continuing the previous example

- Map your previously defined class hierarchy to a relational schema

Reverse-engineering the OO model

Relatively simple rules

- Every relation is mapped to a class
  - Exception: relations with only two foreign-key columns
- Every non-foreign key attribute is mapped to an attribute
- Every PK/FK constraint gets mapped to
  - a collection on the PK side
  - a reference/pointer on the FK side

Question:

- Is ORM mapping/reverse-mapping a bijective process?
- Let's find out!

Worksheet: Reverse-ORM

Continuing the previous example

- Reverse-Map your previously defined class hierarchy to a relational table

Null-Semantics in relational DBMSs

Quiz

Unknown	We don't know the value of this attribute, may not even have one
Missing	The value exists but has not been entered into the system
Uncertain	The value exists but I have conflicting information about what it is
Invalid	The value that was entered in the system does not conform to the rules
Not an option	This column is here for technical reasons but is not to be set

Implementations

Java: Hibernate/JPA

Example

```
@Entity
public class User {
    @Id
    int id;
    String Name = null;
    String Login = null;
    String Password = null;
}
```

C++: ODB

Example

```
#include <memory>
#include <set>
#include <string>
#include <vector>

// never do this:
using namespace std;

class Author;

#pragma db object
class Book {
public:
#pragma db id
  int id;
  string title;
  Author* author;
};
```

...

```
#pragma db object
class Person {
public:
#pragma db id
  int id;
  string name;
  set<shared_ptr<Book>> orderedBooks;
};

#pragma db object
class Author {
 public:
#pragma db id
  int id;
  string name;
#pragma db inverse(author)
  set<Book*> authoredBooks;
};
```

C++: ODB

Querying

```
transaction ct2(db.begin());
auto folks = db.query<Person>(odb::query<Person>::name == "holger");
for(auto& person : folks)
  for(auto& book : person.orderedBooks)
    cout << book->title;
ct2.commit();
```

The end