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THE UNIVERSITY OF MELBOURNE

INFO 90002 Database Systems & Information Modelling

Week 03

Data Modelling and SQL (2)

Today's Session…

- More relationship types
  - Many to Many
    - Associative entity
  - One to One
  - Recursive / Unary relationships
    - One-to-one, One-to-many, Many-to-Many
  - Multiple One to Many Relationships
    - between the same pair of entities
- More SQL
  - Referential and Data Field Integrity
  - Rules for FK's – CASCADE, RESTRICT etc.
  - Nested/Sub queries

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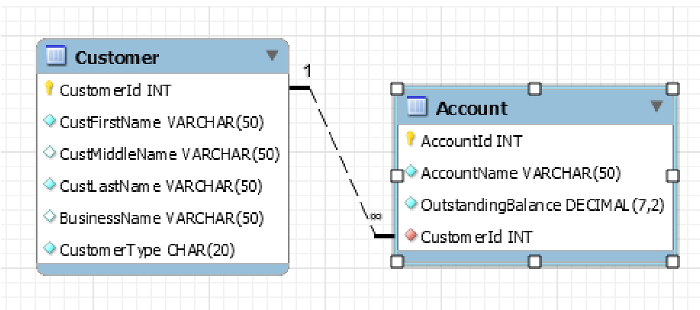
Recap: one-to-many relationships

- Data are spread across 2 tables
- Inner join = Join rows where FK value = PK value

CustID	CustFirstName	CustMiddleName	CustLastName	BusinessName	CustType
1	Peter		Smith		Personal
2	James		Jones	JJ Enterprises	Company



AccountID	AccountName	OutstandingBalance	CustID
01	Peter Smith	245.25	1
05	JJ Ent.	552.39	2
06	JJ Ent. Mgr	10.25	2

```
SELECT *
FROM Customer INNER JOIN Account
ON Customer.Customerid = Account.Customerid;
```


CustomerId	CustFirstName	CustMiddleName	CustLastName	BusinessName	CustomerType	AccountId	AccountName	OutstandingBalance	CustomerId
1	Peter	NULL	Smith	NULL	Personal	1	Peter Smith	245.25	1
2	James	NULL	Jones	JJ Enterprises	Company	5	JJ Ent.	552.39	2
2	James	NULL	Jones	JJ Enterprises	Company	6	JJ Ent. Mgr	10.25	2

Data Integrity Constraints

- Domain Integrity
  - Valid values and domain
    - selection of data type constrains possible data values
  - Default value
    - takes this value if no explicit value is given on Insert
  - Null value control
    - allows or prohibits empty fields
  - Check constraint
    - limits range of allowable values (not available in MySQL)
- Entity Integrity Constraints
  - Primary key cannot be null
  - No component of a composite key can be null
  - Primary key must be unique

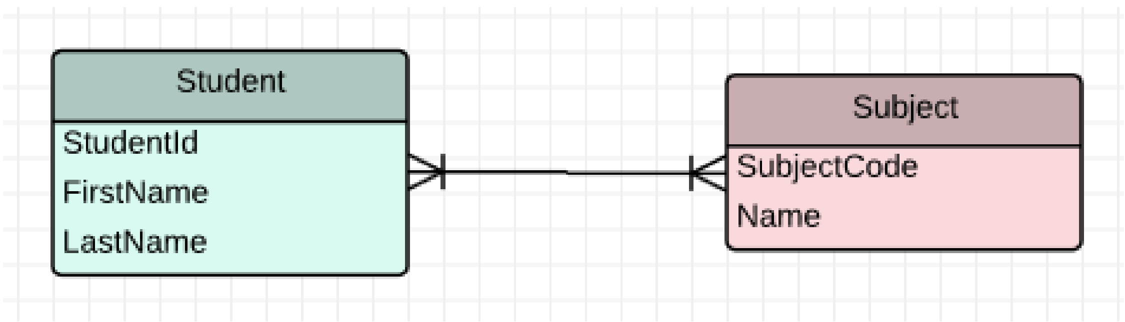
Referential Integrity

- Each non-null FK value must match a PK value
  - Rules for update and delete (SQL CREATE statement)
    - RESTRICT
      - Don't allow deletes or updates of the parent table if related rows exist in the child table
    - CASCADE
      - Automatically delete/update the child table if related rows are deleted/updated in the parent table
    - SET NULL
      - Set the foreign key to NULL in the child table if deleting/updating the key in parent table

```
CONSTRAINT `fk_StudentSubject_Student`
  FOREIGN KEY (`StudentId`)
  REFERENCES `Student` (`StudentId`)
  ON DELETE NO ACTION
  ON UPDATE NO ACTION,
CONSTRAINT `fk_StudentSubject_Subject1`
  FOREIGN KEY (`SubjectCode`)
  REFERENCES `Subject` (`SubjectCode`)
  ON DELETE NO ACTION
  ON UPDATE NO ACTION)
```

Many to Many relationships

- Example: we need to design a Student Records database
- Each student will take more than one subject,
  and each subject will be taken by more than one student
- Where do we record who took what subject and their result?

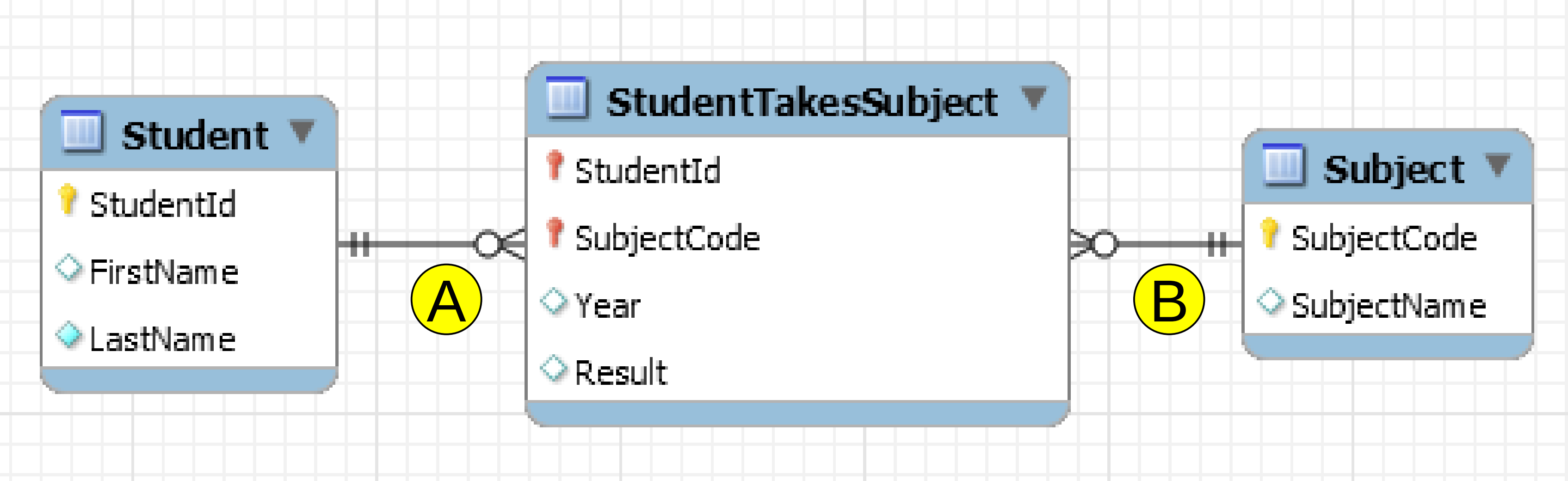


StudentId	FirstName	LastName
11111	John	Lennon
22222	Paul	McCartney
33333	George	Harrison

SubjCode	Name
INFO90002	Database
ISYS90026	Fundamentals
ISYS90081	Organisational

Problems modelling Many-Many…

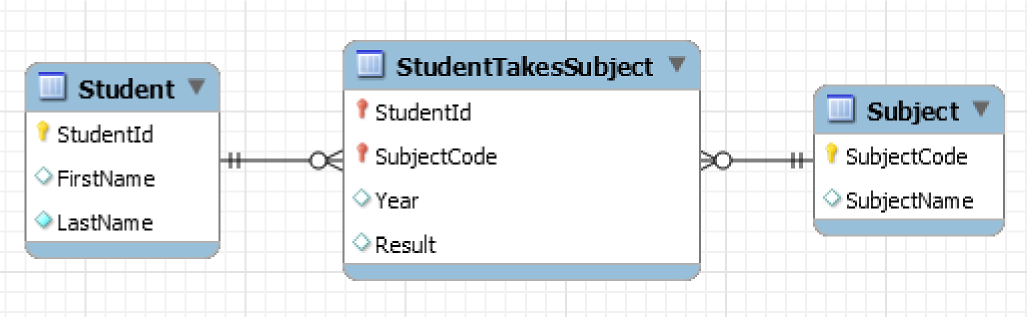
- Relational database doesn't directly support M-M…
  - so we create an Associative Entity between the other 2 entities (when converting Conceptual to Logical model)
  - each of these 2 relationships is like any 1-M relationship



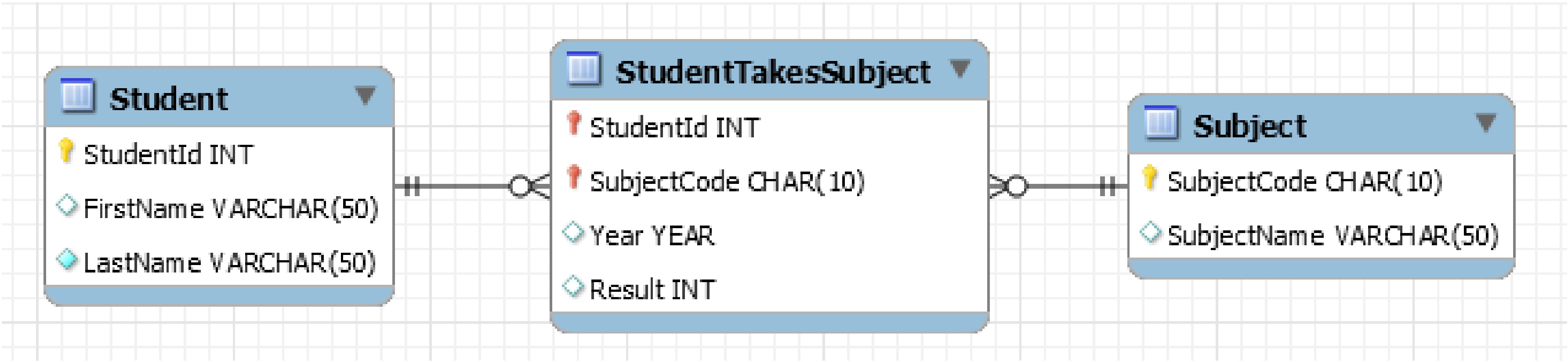
- We can add attributes to the associative entity to record when the student took the subject and the result they got.
- Associate Entities are also called 'Join Tables' and many other names, see https://en.wikipedia.org/wiki/Junction_table

Associative Entities

- When to create
  - when going from Conceptual to Logical phase of design
  - to implement a Many-to-Many relationship
  - to implement a Ternary relationship
- The associative entity
  - has an independent meaning
  - has a unique identifier, usually a combination of FKs
  - may have attributes other than the FKs
  - may participate in other relationships



Many-Many Physical Model



- Choose data types
- Example decisions:
  - are results integers or floating point?
  - are StudentIds number or strings?
  - how long are people's names?

Many-Many CREATE statements

- Order of creation is important!
  - so is order of deletion…
- Create tables *without* foreign keys first
  - *drop* tables without foreign keys *last*

```
-- -----------------------------------------------
-- Table `Student`
-- -----------------------------------------------
CREATE TABLE IF NOT EXISTS `Student` (
  `StudentId` INT NOT NULL,
  `FirstName` VARCHAR(50) NULL,
  `LastName` VARCHAR(50) NULL,
  PRIMARY KEY (`StudentId`))
ENGINE = InnoDB;


-- -----------------------------------------------
-- Table `Subject`
-- -----------------------------------------------
CREATE TABLE IF NOT EXISTS `Subject` (
  `SubjectCode` CHAR(10) NOT NULL,
  `SubjectName` VARCHAR(50) NULL,
  PRIMARY KEY (`SubjectCode`))
ENGINE = InnoDB;
```

Many-Many CREATE statements

- Order of creation is important!
  - so is order of deletion…
- Create tables *with* foreign keys last
  - *drop* tables with foreign keys *first*

```
-- -----------------------------------------------------
-- Table `StudentTakesSubject`
-- -----------------------------------------------------
CREATE TABLE IF NOT EXISTS `StudentTakesSubject` (
  `StudentId` INT NOT NULL,
  `SubjectCode` CHAR(10) NOT NULL,
  `Year` YEAR NULL,
  `Result` INT NULL,
  PRIMARY KEY (`StudentId`, `SubjectCode`),
  INDEX `fk_StudentSubject_Subject1_idx` (`SubjectCode` ASC),
  CONSTRAINT `fk_StudentSubject_Student`
   FOREIGN KEY (`StudentId`)
   REFERENCES `Student` (`StudentId`)
   ON DELETE NO ACTION
   ON UPDATE NO ACTION,
  CONSTRAINT `fk_StudentSubject_Subject1`
   FOREIGN KEY (`SubjectCode`)
   REFERENCES `Subject` (`SubjectCode`)
   ON DELETE NO ACTION
   ON UPDATE NO ACTION)
ENGINE = InnoDB;
```

Adding data to a M-M relationship

- Insert into the join table *last*

```
-- ------------------------------------------------------------
-- Data for table `Student`
-- ------------------------------------------------------------
INSERT INTO `Student` VALUES (11111, 'John', 'Lennon');
INSERT INTO `Student` VALUES (22222, 'Paul', 'McCartney');
INSERT INTO `Student` VALUES (33333, 'George', 'Harrison');
INSERT INTO `Student` VALUES (44444, 'Ringo', 'Starr');
-- ------------------------------------------------------------
-- Data for table `Subject`
-- ------------------------------------------------------------
INSERT INTO `Subject` VALUES ('INFO90002', 'Database Systems and Information Modelling'
INSERT INTO `Subject` VALUES ('ISYS90026', 'Fundamentals of Information Systems');
INSERT INTO `Subject` VALUES ('ISYS90081', 'Organisational Processes');
INSERT INTO `Subject` VALUES ('ISYS90048', 'Managing ICT Infrastructure');
INSERT INTO `Subject` VALUES ('ISYS90045', 'Professional ICT Consulting');
-- ------------------------------------------------------------
-- Data for table `StudentTakesSubject`
-- ------------------------------------------------------------
INSERT INTO `StudentTakesSubject` VALUES (11111, 'INFO90002', 2014, 85);
INSERT INTO `StudentTakesSubject` VALUES (11111, 'ISYS90026', 2015, 77);
INSERT INTO `StudentTakesSubject` VALUES (22222, 'INFO90002', 2014, 90);
```

How to read complete student results

- Three table join

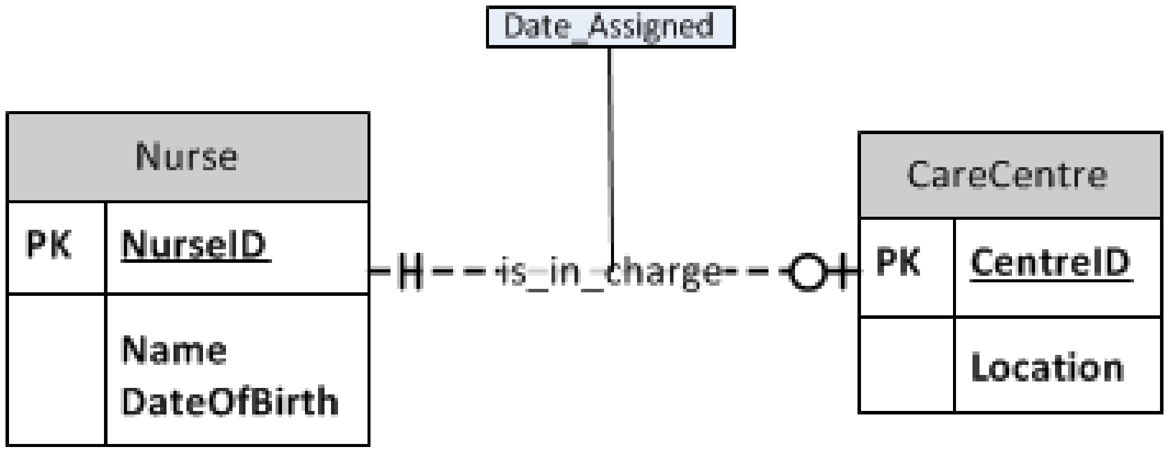
```
SELECT *
FROM Student NATURAL JOIN StudentTakesSubject
NATURAL JOIN Subject;
```

Result Grid | Filter Rows: | Export: | Wrap Cell Content:

SubjectCode	StudentId	FirstName	LastName	Year	Result	SubjectName
INFO90002	11111	John	Lennon	2014	85	Database Systems and...
ISYS90026	11111	John	Lennon	2015	77	Fundamentals of Info...
INFO90002	22222	Paul	McCartney	2014	90	Database Systems and...

Binary One-One Relationship

- Given this example… How do we implement it…

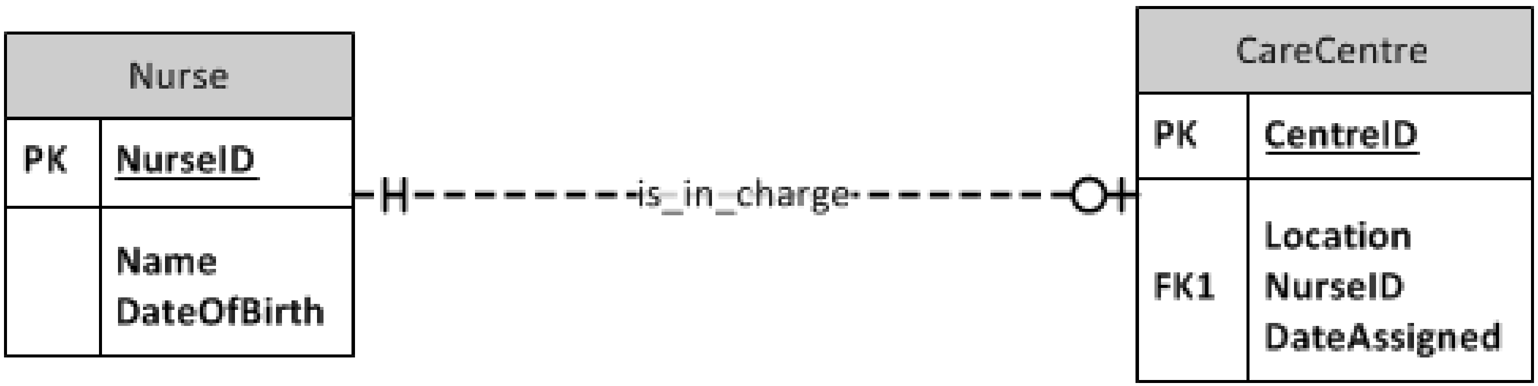


- Note: Date_assigned is an attribute of the relationship

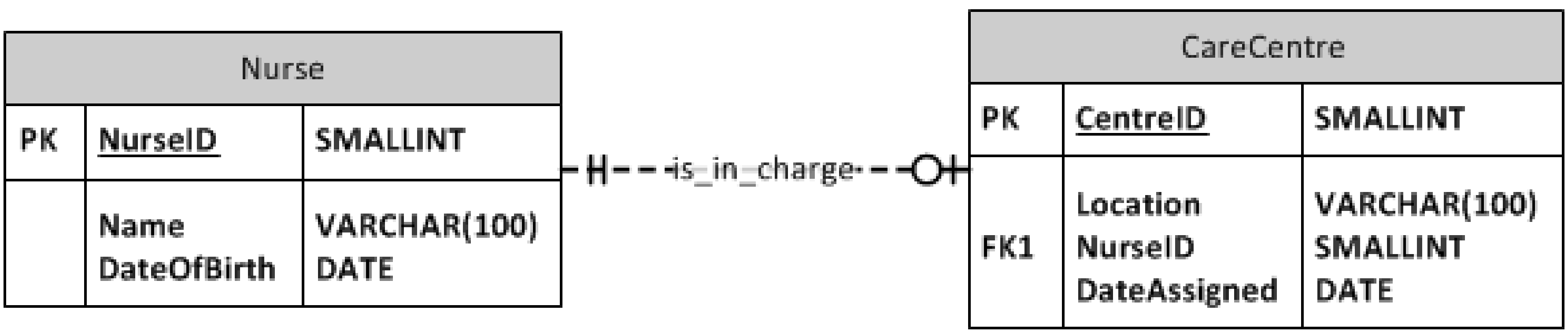
- Need to decide whether to put the foreign key inside Nurse or CareCentre (in which case you would have the Date_Assigned in the same location)
  - Where would the least NULL values be?
  - The rule is the OPTIONAL side of the relationship gets the foreign key

Binary One-One Relationship – Logical and Physical

- Logical
  - Nurse = (NurseID, Name, DateOfBirth)
  - CareCentre = (CentreID, Loction, NurseID, DateAssigned)



- Physical



1-1 Implementation in SQL

```sql
CREATE TABLE Nurse (
  NurseID                smallint,
  Name                   varchar(100)    NOT NULL,
  DateOfBirth            varchar(100)    NOT NULL,
  PRIMARY KEY  (NurseID)
) ENGINE=InnoDB;


CREATE TABLE CareCentre (
  CentreID                 smallint,
  Location                 varchar(150)  NOT NULL,
  NurseID                  smallint      NOT NULL,
  DateAssigned             DATE          NOT NULL,
  PRIMARY KEY  (CentreID),
  FOREIGN KEY (NurseID) REFERENCES Nurse(NurseID)
        ON DELETE RESTRICT
        ON UPDATE CASCADE
) ENGINE=InnoDB;
```

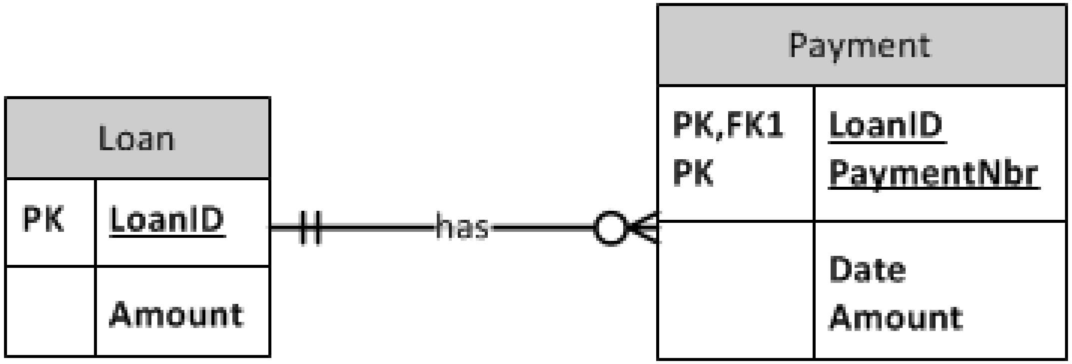
- have to insert into Nurse 1st, then into CareCentre
- query it by joining the Nurse and CareCentre tables

Summary of Binary Relationships

- One-to-Many
  – primary key on ONE side becomes foreign key on MANY side
- Many-to-Many
  – create an Associative Entity (a new table) with a compound primary key consisting of 2 FKs that refer to the other 2 tables
  – you then have two One-to-Many joins
- One-to-One
  – decide in which table to put the foreign key
  – foreign key on the optional side refers to primary key on the mandatory side

1-M special case – "Identifying Relationship"

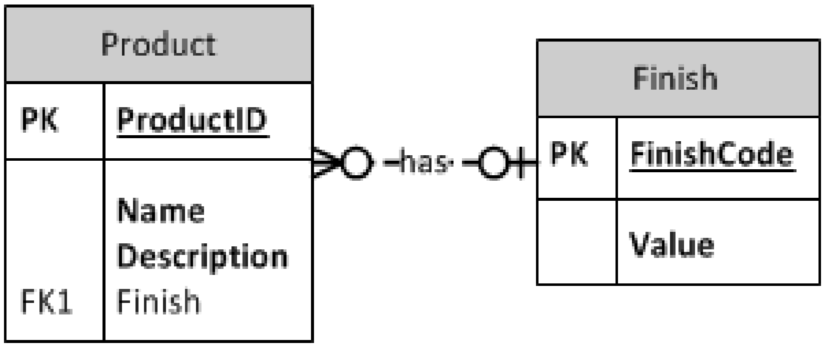
- How to deal with an Identifying relationship
  - i.e. a relationship between weak child and strong parent tables
  - Foreign Key defines the relationship at the crows foot end.
  - and FK becomes part of the Primary Key



  - Logical Design
    - Loan = (<u>LoanID</u>, Amount)
    - Payment = (<u>LoanID</u>, <u>PaymentID</u>, Date, Amount)
  - Physical Design = normal one-to-many relationship

1-M special case – "Lookup table"

- Consider the following logical design



ProductID	Nam	…	Finish
1	Chai		A
2	Desk		C
3	Tabl		B
4	Book		A

Code	Value
A	Birch
B	Maple
C	Oak

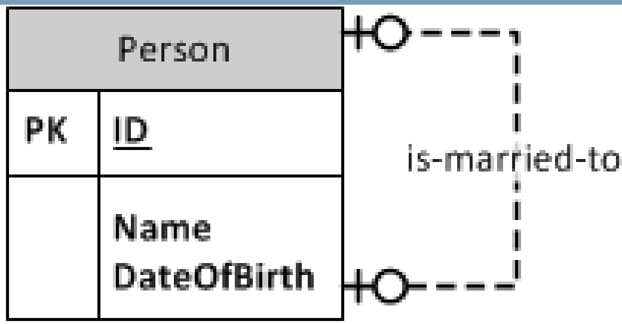
- Physical design decision
  - Implement as 2 tables or one? trade-off = speed vs data integrity

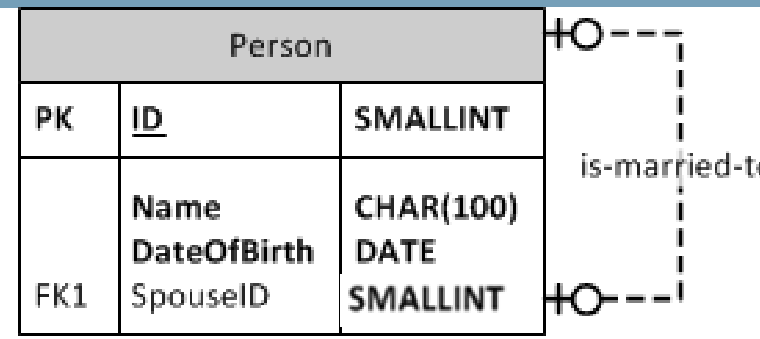
ProductID	Name	…	Finish
1	Chair		Birch
2	Desk		Oak
3	Table		Maple
4	Bookcase		Birch

Unary Relationships

- Operate in the same way exactly as binary relationships
  - One-to-One
    - put a Foreign key in the entity
  - One-to-Many
    - put a Foreign key in the entity
  - Many-to-Many
    - create an extra table - Associative Entity
    - put two Foreign keys in the Associative Entity
      - the two FKs need different names
      - the FKs become the combined PK of the Associative Entity

Unary – One-to-One





Logical Design

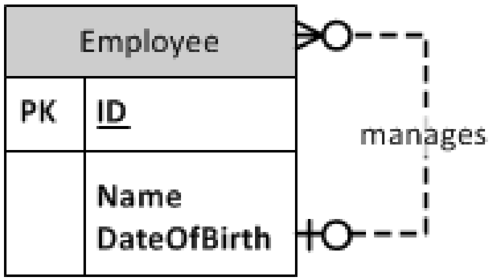
Physical Design

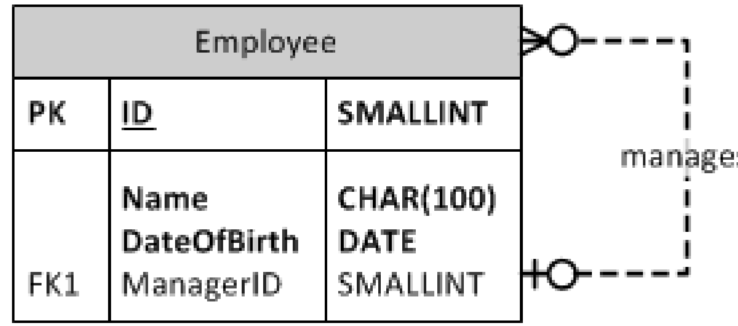
(ID, Name, DateOfBirth, SpouseID)

ID	Name	DOB	SpouseID
1	Ann	1969-06-12	3
2	Fred	1971-05-09	
3	Chon	1982-02-10	1
4	Nancy	1991-01-01	

```sql
CREATE TABLE Person (
  ID                smallint,
  Name              varchar(150)  NOT NULL,
  DateOfBirth       DATE          NOT NULL,
  SpouseID          smallint      ~~NOT NULL~~,
  PRIMARY KEY  (ID),
  FOREIGN KEY (SpouseID) REFERENCES Person(ID)
        ON DELETE RESTRICT
        ON UPDATE CASCADE
) ENGINE=InnoDB;
```

Unary – One-to-Many





Logical Design

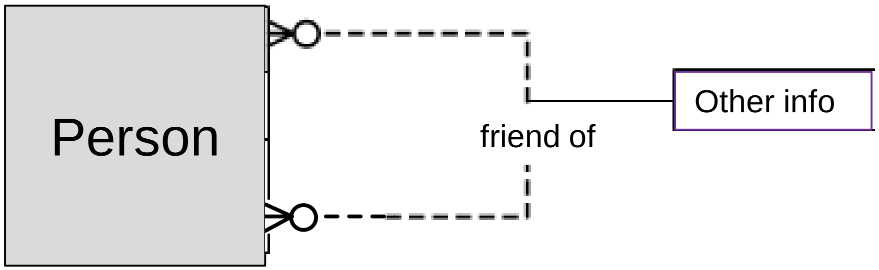
Physical Design

(<u>ID</u>, Name, DateOfBirth, <u>ManagerID</u>)

```
CREATE TABLE Employee (
    ID                  smallint,
    Name                varchar(150)  NOT NULL,
    DateOfBirth         DATE          NOT NULL,
    ManagerID           smallint      NOT NULL,
    PRIMARY KEY  (ID),
    FOREIGN KEY (ManagerID) REFERENCES Employee(ID)
           ON DELETE RESTRICT
           ON UPDATE CASCADE
) ENGINE=InnoDB;
```

ID	Name	DOB	MngrID
1	Ann	1969-06-12	
2	Fred	1971-05-09	1
3	Chon	1982-02-10	1
4	Nancy	1991-01-01	1

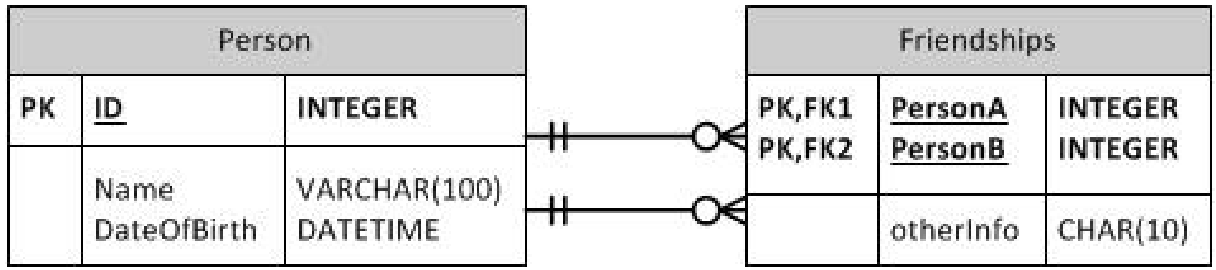
Unary – Many-to-Many



- Logical Design
  - Set up Associative Entity as for any M-M relationship
    - Person = (<u>ID</u>, Name, DateOfBirth)
    - Friendship = (<u>PersonA, PersonB,</u> otherInfo)

Unary – Many-to-Many

- Physical Design



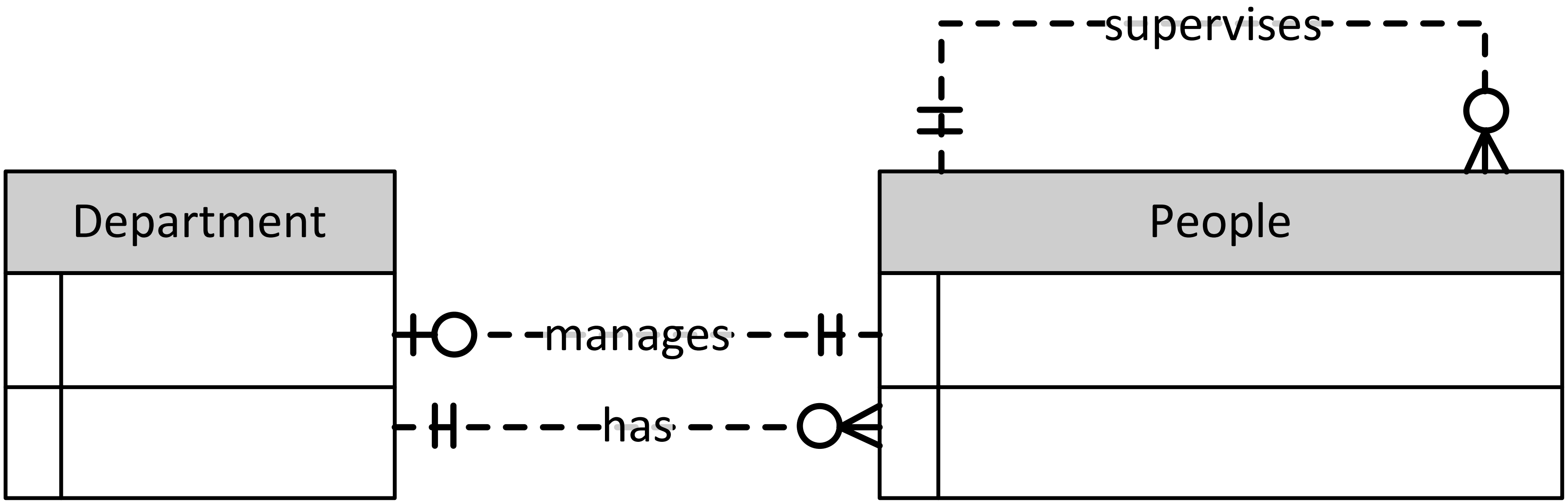
- Implementation

```
-- -----------------------------------------------------
-- Table `mydb`.`Person`
-- -----------------------------------------------------
CREATE TABLE IF NOT EXISTS `mydb`.`Person` (
  `ID` INT NOT NULL,
  `Name` VARCHAR(50) NULL,
  `DateOfBirth` DATE NULL,
  PRIMARY KEY (`ID`))
ENGINE = InnoDB;
```

```
-- -----------------------------------------------------
-- Table `mydb`.`Friendship`
-- -----------------------------------------------------
CREATE TABLE IF NOT EXISTS `mydb`.`Friendship` (
  `PersonA` INT NOT NULL,
  `PersonB` INT NOT NULL,
  `otherInfo` CHAR(10) NULL,
  PRIMARY KEY (`PersonA`, `PersonB`),
  INDEX `fk_Friendship_Person1_idx` (`PersonB` ASC),
  CONSTRAINT `fk_Friendship_Person`
    FOREIGN KEY (`PersonA`)
    REFERENCES `mydb`.`Person` (`ID`)
    ON DELETE NO ACTION
    ON UPDATE NO ACTION,
  CONSTRAINT `fk_Friendship_Person1`
    FOREIGN KEY (`PersonB`)
    REFERENCES `mydb`.`Person` (`ID`)
    ON DELETE NO ACTION
    ON UPDATE NO ACTION)
ENGINE = InnoDB;
```

Multiple Relationships

- Entities can be related in several ways simultaneously



- Treat this the same was as any other One-to-Many, One-to-One relationship

SQL

SQL – Subqueries / nested queries

- Select allows you to nest *sub-queries* inside the main or "outer" query
- A nested query is simply another Select query you write to produce a table of data
  - remember that all select queries return a "table"
- A common use of sub-queries is to perform tests
  - set membership, set comparisons
- Often there is an equivalent Join query
- Put the subquery inside round brackets

```
SELECT DISTINCT saleId FROM Sale
WHERE departmentid IN
    (SELECT departmentId FROM Department
    WHERE floor = 2);
```

(3, 7)

Comparison Operators for SubQueries

- IN / NOT IN
  - is the value a member of the set returned by the Subquery?
- ALL
  - true if all values returned meet the condition
- WHERE [NOT] EXISTS
  - true if the subquery yields any [/ no] results

Set Comparison examples

- auction example: Buyer, Seller, Artefact, Offer tables

ID	Name	Description
1	Vase	Old Vase
2	Knife	Old Knife
3	Pot	Old Pot

SellerID	Name	Phone
1	Abby	0233232232
2	Ben	0311111111
3	Carl	0333333333

BuyerID	Name	Phone
1	Maggie	0333333333
2	Nicole	0444444444
3	Oleg	0555555555

SellerID	ArtefactID	BuyerID	Date	Amount	Acceptance
1	1	1	2012-06-20	81223.23	N
1	1	2	2012-06-20	82223.23	N
2	2	1	2012-06-20	19.95	N
2	2	2	2012-06-20	23.00	N

Set queries

- which Artefacts *don't have* offers made on them?

```
SELECT * FROM Artefact
    WHERE ID NOT IN
        (SELECT ArtefactID FROM Offer);
```

ID	Name	Description
3	Pot	Old Pot

- which Buyers *haven't* made a bid for Artefact 3?

```
SELECT * FROM Buyer
    WHERE BuyerID NOT IN
        (SELECT BuyerID FROM Offer
            WHERE ArtefactID = 3);
```

BuyerID	Name	Phone
1	Maggie	0333333333
2	Nicole	0444444444
3	Oleg	0555555555

- which Buyers *haven't* made a bid for the "Pot" Artefact?

```
SELECT * FROM Buyer
    WHERE BuyerID NOT IN
        (SELECT BuyerID FROM Offer
            WHERE ArtefactID IN
                (SELECT ID FROM Artefact
                    WHERE Name = "Pot"));
```

BuyerID	Name	Phone
1	Maggie	0333333333
2	Nicole	0444444444
3	Oleg	0555555555

Multiple subquery

- which Buyers have made a bid for the “Knife” Artefact?

```
SELECT * FROM Buyer
    WHERE BuyerID IN
        (SELECT BuyerID FROM Offer
            WHERE ArtefactID IN
                (SELECT ID FROM Artefact
                    WHERE Name = "Knife"));
```

BuyerID	Name	Phone
1	Maggie	0333333333
2	Nicole	0444444444

There is often an equivalent Join that will achieve the same result. The above is equivalent to:

```
SELECT Buyer.*
FROM Buyer NATURAL JOIN Offer NATURAL JOIN Artefact
WHERE Artefact.name = 'Knife' ;
```

Aggregate functions

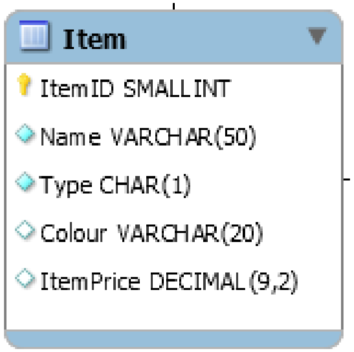
These functions operate on a set of values (e.g. in a column of a table) and return a single value

- AVG()
  - Average value
- MIN()
  - Minimum value
- MAX()
  - Maximum value
- COUNT()
  - Number of values
- SUM()
  - Sum of values

- and there are others …
  - http://dev.mysql.com/doc/refman/5.7/en/group-by-functions.html
- These ignore null values, and return null if all values are null.
- But COUNT(*) counts the rows not the values,
  and thus even if the value is NULL it is still counted.

Finding above average

- Consider the Item table in our labs database
- Which items have a price that is higher than the average?




```
SELECT * FROM Item
WHERE itemPrice >
    (SELECT AVG(itemPrice) FROM Item);
```

234.766400

itemID	Name	Type	Colour	itemPrice
1	Boots Riding	C	Brown	235.00
2	Horse saddle	R	Brown	1895.00
12	Gortex Rain Coat	C	Green	249.75
19	Tent - 2 person	F	Khaki	399.95
20	Tent - 8 person	F	Khaki	785.96
21	Tent - 4 person	F	Blue	638.95
24	Boots - Womens Goretex	C	Grey	289.95
25	Boots - Mens Hiking	C	Grey	299.95

Finding a maximum

- Which item has the highest cost?

Item
- ItemID SMALLINT
- Name VARCHAR(50)
- Type CHAR(1)
- Colour VARCHAR(20)
- ItemPrice DECIMAL(9,2)

```
SELECT * FROM Item
WHERE itemPrice =
    (SELECT MAX(itemPrice) FROM Item);
```

1,895

```
SELECT * FROM Item
ORDER BY itemprice DESC
LIMIT 1;
```

itemID	Name	Type	Colour	itemPrice
2	Horse saddle	R	Brown	1895.00
NULL	NULL	NULL	NULL	NULL

- Will these two methods always give the same answer?

Finding a maximum

- another method

```
SELECT * FROM Item
WHERE itemPrice >= ALL
    (SELECT itemPrice FROM Item);
```

- and another: a “correlated subquery”

```
SELECT * FROM Item A
WHERE itemPrice > ALL
    (SELECT itemPrice FROM Item B
    WHERE A.itemId != B.itemId);
```