Functions in PGPLSQL

functions in psql
create or replace function funcName()
return s returntype as **$$**
begin
raise notice 'Hello Birb!';
end;
$$ language langName
The two $ are always necessary. Also note the returns with an s and the language at the end.
Which **MUST** be a **PROCEDURAL LANGUAGE**, so c++ doesn't work here.

Parameters are handled like in any language
func(x bigint, y bigint)
you can also define multiple return types
func(variadic a numeric[])
or a generic return
func(param anyelement)

Variable Declaration:
returns void as $$
DECLARE
x bigint; y bigint;
BEGIN ....

Variable manipulation: x := 6 + 4

if: IF n = 0 THEN RETURN 1;
(optional)ELSE RETURN 2; END IF;
ELSIF also possible (note elsif not elseif)

case x when 1, 2 then msg := 'one or two'; end case;
essentially this checks if x is 1 **OR** 2

case when x between 0 and 10 then ....
similar but with a range, both can be simulated by if else.

Exceptions: BEGIN z:= x / y;
EXCEPTION WHEN division-by-zero
THEN z:= 0; (or error rather) END;
if you want to catch all: WHEN others THEN
often used after exception: RAISE; (show error)

For Loop: For var IN query LOOP
statements END LOOP;
for r in SELECT * FROM ang LOOP
RETURN NEXT r; END LOOP; RETURN; END;
note that the return next doesn't return
you store it in a buffer
and return it at the end of the function.
for infinite loops: FOR i IN 1..__max LOOP;

update and insert: INSERT INTO ANG VALUES(...);
UPDATE ang set salary = salary + 500
where name = 'dashie';
interestingly, after the where name = 'dashie'
you can use if not found then (handle error)
this allows for easier error handling.

queries: **execute** 'SELECT * from ang'
|| into result; return result; END;

comments are done by either – or /* */ for multiline

anonymous function: you can omit
the name and just write do $$ ...

cursor: declare curs CURSOR FOR query;
BEGIN OPEN curs; LOOP do something CLOSE curs; END;
Cursors are essentially just iterables.
cursors can also be unbound curs1 refcursor
or they can be parameterized curs3 cursor(arg)

- **PL/pgSQL: Datentypen**
  - Boolean:
  - Zahlen: int, integer, number
  - Strings, Datum, etc.
  - Arrays: alle Datentypen gefolgt von „[]“, z.B. int[]
  - Weitere: JSON, etc.
- ... ergänzt mit zusätzlichen Datentypen:
  - var5 angestellter.id%type; -- abgeleiteter col.-Typ
  - var6 angestellter%rowtype; -- abgeleitet von Tabelle
  - var7 record; -- generischer Record
  - var8 anyelement; -- generischer Typ gemäss Fn.-Argument, vgl. nachfolgend
  - curs1 refcursor; curs2 cursor ...; -- vgl. nachfolgend

This is a simple entry inside a qurey aka 1 person

arrays: SELECT '1,2,3'::int[]
or SELECT ARRAY[1,2,3]
var int[] only in variable declaration.
!!arrays start with 1 in psql !!

return types: all of the above AND void,
SETOF type (array of a type), TABLE, Trigger

Arrays: Accessoren

```
create table tictactoe as
  (select 1 as id,
          array[ ['z1 k1', 'z1 k2','z1 k3'],
                 ['z2 k1', 'z2 k2','z2 k3'],
                 ['z3 k1', 'z3 k2','z3 k3']
               ] as board);
```

Index Query: intuitiv wie eine Koordinate ("1-basiert": Start mit 1 nicht 0):
`select board[1][1] from tictactoe;`
`-- z1 k1`

Slice Query: "Untergrenze:Obergrenze" für jede Dimension:
`select board[2:3][1:1] from tictactoe;`
`-- {{z2 k1},{z3 k1}}`

Max-Bound-Abkürzung "[2]" **vermeiden** (Verwechslungsgefahr), besser [1:2]
`select board[2:3][2] from tictactoe;  -- [2]=>[1:2]`
`-- {{z2 k1,z2 k2},{z3 k1,z3 k2}}`

Suche mit **ANY**:
`select * from tictactoe where 'z2 k2' = any(board);`
`-- 1;{{z1 k1,z1 k2},{z2 k1,z2 k2},{z3 k1,z3 k2}}`

Arrays: Operatoren

- «Is equal»: **=**
  - SELECT ARRAY[1,2,3] = ARRAY[1,2,3]; true
  - SELECT ARRAY[3,2,1] = ARRAY[1,2,3]; false
- «Contains»: **@>**
  - SELECT ARRAY[1,7,4,2,6] @> ARRAY[2,7];
- «Is contained by»: **<@**
  - SELECT ARRAY[2,7] <@ ARRAY[1,7,4,2,6];
- «Overlaps»: **&&**
  - SELECT ARRAY[1,4,3] && ARRAY[2,1]

hstore / map:
Create und Insert:

```
CREATE TABLE test (id integer, col2 hstore, col3 text);

INSERT INTO test VALUES (1, 'a=>123, b=>foo, c=>bar'::hstore, NULL);

SELECT * FROM test;
id| col2                                | col3
--+-------------------------------------+-----
1 | "a"=>"123", "b"=>"foo", "c"=>"bar"| null
(1 row)
```

Queries:
- List all keys
  SELECT akeys(mykvpfield) FROM ...
- Get all key-value pairs
  SELECT each(mykvpfield) FROM ...
- Get key value (as text)
  SELECT mykvpfield->'name' FROM ...
- Test if left hstore is contained in right hstore:
  ... WHERE mykvpfield @> 'tourism=>zoo'; -- or hstore('tourism','zoo')

Operatoren:
- "->" get value for key : SELECT 'a=>x, b=>y'::hstore -> 'a'
- „@>“, etc. ... ähnlich wie Array-Operator

hstore supports GIST/GIN indexing

	FUNCTION	PROCEDURE
Use in an expression	✔	✘
Return a value	✔	✘
Return values as OUT parameters	✔ (PG Spezialität)	✔ (PG v14)
Return a single result set	✔ (as table fn.)	✔
Return multiple result sets	✘	✔
Contain transactions	✘	✔
Make it run using ...	EXECUTE	CALL

also note that type%rowtype is used like this:
r ang%rowtype -> for r in select * from ang;

important to know, you can always use these functions to manipulate queries, for example
select upper(name) from ang;
depending on the function you can also
select generatetab(1,10)

- Es gibt zusätzlich IN, OUT, INOUT
  `create function foo(IN p1 type)` ...
  - IN: call by value; Variablen oder Ausdrücke als Argument
  - OUT: call by reference; nur Variablen als Argument
  - INOUT: beides

cast: cast(input as type);
cast(record.id as text);

stored procedures are nothing but a chaining of functions:
- Schritt 1 in PL/pgSQL: siehe Beispiel 3 (SP-Funktion mit in/out –Parametern)
- Schritt 2: Deklaration in Java/JPA (aka Registrierung in JPA):

```
@NamedStoredProcedureQuery(
  name = "MySum", -- JPA-Objekt
  procedureName = "mysum", -- Name der SP-Fn. (DB-Objekt)
  parameters = {
    @StoredProcedureParameter(mode = ParameterMode.IN, type = Double.class, name =
"x"),
    @StoredProcedureParameter(mode = ParameterMode.IN, type = Double.class, name =
"y"),
    @StoredProcedureParameter(mode = ParameterMode.OUT, type = Double.class, name =
"sum")
  }
)
```

- Schritt 3: Call it!

```
StoredProcedureQuery query = this.em.createNamedStoredProcedureQuery("MySum");
query.setParameter("x", 1.23d);
query.setParameter("y", 4.56d);
query.execute();
Double sum = (Double) query.getOutputParameterValue("sum");
```

some good to know things: plain SQL is more efficient.
write variables lower case for sql
use cast over typename -> not select date '2022-06-07'

Triggers

- sind DB-Objekte und immer einer Tabelle zugeordnet
- werden in Stored Procedures programmiert
- haben keine Parameter
- können nicht direkt aufgerufen werden
- werden vom DBMS beim Eintreten eines Events aufgerufen
- haben bei der Ausführung die Rechte ihres Owners

- Trigger can pass parameters to function
- FOR EACH [statement | row]
- Events: INSERT, UPDATE, DELETE, TRUNCATE, INSTEAD OF
- Function executes BEFORE or AFTER changes

statement is once, row means once per row, aka for the entire table.

- Before triggers can change contents of new row
- After triggers can only respond to what has happened e.g. Foreign Keys
- Return values of AFTER triggers will be ignored
- Triggers execute in alphabetical order

The INSTEAD Trigger can be use to avoid crashes:
-> INSTEAD OF UPDATE
-> ON UPDATE DO INSTEAD
for example, trying to update a read-only view -> INSTEAD OF UPDATE

- DDL für Triggers

```
CREATE | DROP | ALTER TRIGGER
  mytrigger …
  ON mytable …
```

- Syntax-Beispiel CREATE TRIGGER:

```
CREATE TRIGGER mytrigger
  AFTER INSERT OR UPDATE
  ON mytable
  FOR EACH ROW
  EXECUTE PROCEDURE mytriggerfn();
```

PL/pgSQL: Trigger-Fn.-Variablen

- TG_NAME — Name des Triggers (TG)
- TG_WHEN — BEFORE oder AFTER
- TG_LEVEL — ROW od. STATEMENT
- TG_OP — INSERT, UPDATE, DELETE, (TRUNCATE)
- TG_RELID — OID der Tabelle
- TG_RELNAME — Name der Tabelle
- TG_TABLE_SCHEMA — Schema der Tabelle

Syntax-Beispiel Trigger-Fn. passend zu Trigger:

```
CREATE FUNCTION mytriggerfn()
RETURNS TRIGGER --
AS $$
  <<body>>
$$ language plpgsql;
```

- Eine Trigger-Fn. hat keine Fn.-Parameter
- Diese werden über Trigger-Fn.-Variablen übergeben, u.a.:
  - TG_NARGS Anzahl Parameter
  - TG_ARGV[] Array von Parametern als TEXT

```
CREATE OR REPLACE FUNCTION dt_trigger_func()
  RETURNS TRIGGER AS $$
BEGIN
  IF (TG_OP = 'INSERT') THEN
    NEW.creation_date := now();
  ELSIF (TG_OP = 'UPDATE') THEN
    NEW.modification_date := now();
  END IF;
  RETURN NEW;
END
$$ LANGUAGE plpgsql;

CREATE TRIGGER dt_trigger
BEFORE INSERT OR UPDATE
ON mytable
FOR EACH ROW
EXECUTE PROCEDURE dt_trigger_func();
```

BEFORE-Trigger: Falls RETURN null → wird Operation abgebrochen

Return types: RETURN NEW -> returns a new table/row
RETURN OLD -> returns the old table/row
(but could change other rows!)
RETURN NULL -> cancel operation.

running order: before statement, before row, after row, after statement ->
and of course alphabetically.

inside the Trigger functions you can use the variables that don't matter aka can be ANY -> user
or the entered user from the trigger -> NEW.user
or explicitly the old one -> OLD.user
and last user defined stuff like -> SELECT 'I'
which just places an I as the variable
or something like now() for timestamps.

Triggers make the database slower and harder to maintain.
some databases therefore let you disable them if you want.
On a table basis.
Also watch out for cascading effects of triggers
they might cause something else to be deleted.

Stored Procedures are really helpful for security
They have all the prviliges, but only
allow the user to do what the
creator has predefined.

User defined types in SQL

CREATE DOMAIN ...
- erstellt einen benutzerdefinierten Datentyp
- für Datenschema und Stored Procedures
- mit Constraints wie NOT NULL, CHECK

```
create domain contact_name as
  varchar(255) not null
    check (value !~ '\s');
```

CREATE TYPE ...
- erstellt einen zusammengesetzten Datentyp
- Für Datenschema und Stored Procedures
- Auch für ENUM Type verwendet
- Keine Constraints-Angaben

```
create type easteregg as (
  outer: text,
  inner: text,
);
create type traffic_light_t as
  enum('red', 'yellow', 'green');
```

One is a completely new type, the other is just a type that is made up of already known types.
Essentially the right one is a class or struct.
The left is a completely new thing, that is not yet implemented.

Optimization and indexing

The basics of indexing is that is saves
time on queries, but it uses more space,
and needs to be redone on udpate/insert.

Data stored in Pages / Heap (Collection of Pages)
Indexing on either can be possible.
ex: Page index -> Primary key index
ex: Heap Index -> index on tables
PSQL does table cluster indexing
instead of integrated indexing -> key value (both indexed)

B-Tree: the default, can index multiple entries (only btree!)
CREATE UNIQUE INDEX name ON table (column [1,2...])

Hash Index: just like hashmap in programming
good for single or small multiple queries
bad for entire tables etc -> collision
hashing might take a long time with a lot of data.
B-tree almost always better!

GiST: balanced/treelike , Range/neighbor/fulltext search
used for geometric datatypes. SP-Gist for unbalanced trees.

GIN: General Inverted Index "list of words
that point to documents" wtf?. Good for duplicates.
Good for hstore,Json,Arrays
Vergleich zu GiST:
- Ca. 3x schnellerer Zugriff
- Ca. 2 – 3x mehr Diskplatz
- Ca. 2 – 3x länger bis Index erstellt ist
- Ca. 10x langsamer bei Update

Bitmap indexing: Bitmap -> 0 1 stores Booleans/Enums
very fast read / slow update
in postgres **only implicit** use Brin instead.

BRIN: Block Range Index, stores min/max values as blocks
good for range search, sorted data, small disk usage
data is naturally sorted, address next to postal code.

Bloom Index -> equality search,
Trigram Index -> Full text search
RUM , non-default-GIN jsonb-path-ops

creating index:
CREATE INDEX <indexname> ON <table(attribute)>;
and: DROP INDEX <indexname>;

default index order for psql is btree,ASC,NULL first

Index-Variationen

- Zusammengesetzter Index — query on phone return phone and name
  - Bsp.: CREATE INDEX idx_addr ON addr(phone,name); kann für Queries auf phone und "phone AND name" genutzt werden, sowie für bestimmte Q. auf name; jedoch nicht für Suffix-Q. "... LIKE %name;"
- Index mit INCLUDE — similar
  - Bsp.: CREATE INDEX idx_addr ON addr(phone) INCLUDE (name) ;

Index-Variationen ff.

- Partieller Index — index if(condition)
  - Bsp.: CREATE INDEX idx_addr ON addr(status) WHERE status='active';
- Indexe mit Funktionen / Ausdrücke ("Funktionaler I.") — index on function()
  - Bsp.: CREATE INDEX idx_addr ON addr(lower(name));
- Nicht nur PostgreSQL!

PG planner join strategies: Nested Loop,Merge,Hash
-Nested Loop: for r in right row r == for l in left row....
good for small tables, easy to setup
-Merge: Merge rows one after the other
higher starting cost, good for bigger tables
-Hash: Hash the row then compare to other row
equality check only , high starting cost, low execution cost

PG planner scans: Full,Index,Index Only, Bitmap
-full scans the entire table
-index scans index and more (if necessary)
-index only only scans index
-Bitmap scans the bitmap generated by an index.

The steps of optimization

1. generate the plan of transaction
2. reform the term to optimize performance
without knowledge of the internal structure.
-> all values are considered equal
3. optimization based on: available indexes, analysis & costs
4. generate all possible plans to calculate cost
5. analyze said plans -> how many tuples, what kind...
6. profit?

selectivety this is the ratio of tuples a query returns
low selectivety would mean high number of rows
an example is select * from table where sex='Male'
the opposite would be high selectivety.

density this is the ratio of duplicates a query returns
the more duplicates the higher the density.
you can therefore also make graphs about the distribution of density -> names a-c low g-l high

best practices: index only when selectivety over 10%
numeric comparison over text, join over subquery,
use short attributes, understand the query -> user,
don't select * from, don't use cross products.

distributed database systems

the advantages and disadvantages are obvious:
+ better performance – more complex
+better reliability + better management

homogeneous database system:
> all nodes have identical software
> all nodes know about each other and work together
> shows itself to the user as one big system

heterogeneous database system:
> nodes can have different software
> as well as different schemas -> can lead to problems
> nodes might NOT know about each other.

heterogeneous systems can be federated or unfederated
> unfederated -> no local users
> federated -> either tightly coupled with global schema or loosely coupled using export schema

fragmentation: this is the splitting of schemas
into multiple Nodes -> table 1 in node1
table 2 in node 2.

In Psql the horizontal fragmentation happens in 3 ways:
> 1 or more attributes for "partitioning key"
> "list" explicit designation
> hash function (ex: Modulo)

In Graph stores this would be called "sharding"
an example for this is the MongoDB
horizontal partitioning and allocation within a single node

replication: this is the duplication of data in schemas
this means table 1 might be on node1 and 2.
vertical -> splitting of columns
row1 in node1, row2 in node2
horizontal -> splitting of rows
part of column in node1 part of column in node2

unidirectional: Single-Master

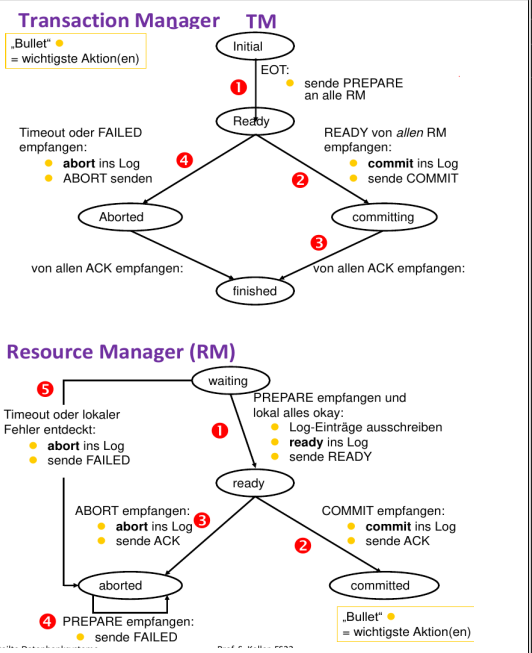
bidirectional: Multi-Master

synchronous OR asynchronous

allocation: this is the distribution of work to the nodes
node1 might handle query or part of query1
while node2 handles something else.

as already stated above, the user doesn't see anything about
fragmentation or similar, the user simply interacts
with the schema and executes transactions.
these **transactions are always local**
This means that the user will talk to **Transaction Manager**
that will handle the transaction and call the necessary
functions on the **Resource Managers** (inside nodes).

Two Phase Commit Protocol



case TM failed/restart:
> if the TM crashes before the commit message -> abort
> if the TM crashes after RM respond ready -> block RM
this is one of the main problems btw…

case RM failed/restart:
> if no entry in log, RM aborts
> if READY-Entry available -> RM asks TM what to do.
> if COMMIT-Entry available -> RM redoes transaction

case message dropped:
> if the prepare statement gets lost,
or the RM doesn't respond, then the TM
simply aborts the transaction for all.
> if RM doesn't get a response in READY state
then the RM will remind the TM until it gets one.

There are different 2PC protocols, PSQL, MYSQL, X/Open,
Java Transaction API, Orace Transaction Manager, Microtroll
+ often used / proven system + guarantees ACID
– slow – blocks transactions often
!!only use this when the complexity calls for it!!

Query handling:
there are 3 ways of handling a queries distributed databases:
> Ship Whole -> run query locally and remove duplicates
> Push Down -> split query when needed
> Fetch-as-needed -> Send join attributes to the correct node

NoSQL: Key/Value Stores

Why even NoSQL? -> fast, lots of data, web-based, scalable
RDBMS -> relational has the problem of complexity
it doesn't integrate seamlessly into programming languages
it therefore doesn't make sense to use this as
something like a webstore. -> !!! OR MAPPING !!!

attributes of NoSQL:
> easy to use API (http) > made for big volumes of data
> provided as cloud storage > not relational, schema free
> BASE instead of ACID > no query norm (other than SQL)

The Cap Theorem
The CAP theorem dicates, that you can only have
2 of 3 desired traits of a database, these include
consistency, **parition tolerance** and **availability**.
traditional databases have the **ACID** philosophy which is both
consistent and tolerant, however it often blocks transactions.
here comes **NoSQL with the BASE** philosophy
it is both **available** at all times and **tolerant**,
however it is **NOT consistent during transactions**.
Only after those have stopped will the system get consistent.
>tolerance means the system will work despite partial outage<

BASE THEOREM
» **Basically Available:**
The database will not block transactions
any and all requests will be responded to (can still fail though!)
» **Soft state:**
The state of the system can change even without input,
therefore we consider this to be a soft (not fixed) state
» **Eventual consistency:**
The system will become consistent after end of transactions.

Key-Value Database

- A simple hash table accessible only through its primary key
- Basically a table with two columns: ID and VALUE
- The value is a blob that the data store just stores: it can be text, JSON, XML, and anything else.
- Operations:
  - get the value for the key
  - put a value for a key (if the key already exists the corresponding value is overwritten)
  - delete a key from the data store

notable examples: Riak, Redis, Memcached, Berkeley DB
HamsterDB , Amazon DynamoDB, Project Voldemort

Key/Value Stores are usually used for this:
» Storing Session Information
» User Profiles, Preferences, Configs
» Shopping carts (LMAO)
They are **NOT** to be used in these cases:
« relationship among data , multioperation transactions
« query by data, operation by sets

NoSQL Aggregation database

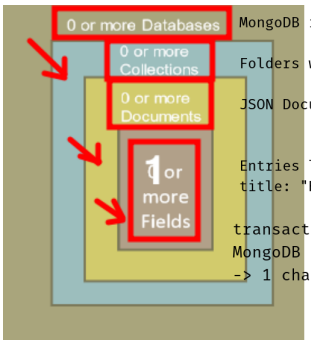
> Arrays (Array Store)
> Dictionaries (Key/Value Stores)
> nested Structures(Document-databases)

NoSQL Document Store

» Maps a key to a structured Document
» flexible schema , Document stored in **JSON** or BSON
» Examples: **MongoDB**, CouchDB
term comparison to RDBMS
instance -> instance/database, table -> collection
row -> Document , rowid -> _id/objectId

MongoDB

» JSON, partitioning via sharding, FOSS :)
» own query language, Document Store (no Schema)




```
var class = {
  _id: ObjectId ("509980df3"),
  course: {code: "Dbs2",
           title: "Advanced DB"},
  year: 2016,
  students: ["Peter", "Manuel",...],
  no_of_st: 34
}
```

- The document contains values of varying types
  - The primary key is _id and it is of the ObjectId type,
  - The field course is a subdocument, and
  - students is an array of strings

The documents are actually stored as BSON
the binary version of JSON with a bit more data.
Also there are certain restriction on naming…

_id

- The field _id is reserved for use as a document's primary key
  - Its value must be unique in the collection,
  - It is immutable,
  - May be of any type other than an array or a regular expression type
  - MongoDB creates a unique index on the _id field during the creation of a collection.
  - It is always the first field in the documents
- The following are common options for storing values for _id:
  - Use an ObjectId,
  - Use a natural unique identifier, if available
    - This saves space and avoids an additional index,
  - Generate an auto-incrementing number
- **ObjectId** is a 12-byte BSON type, constructed using:
  - A 4-byte value representing the seconds since the Unix epoch,
  - A 3-byte machine identifier,
  - A 2-byte process id, and
  - A 3-byte counter, starting with a random value
- ObjectIds are small, most likely unique, and fast to generate
- MongoDB uses ObjectIds as the default value for the _id field if the _id field is not specified by a client
- Additional benefits of using ObjectIds for the _id field:
  - In the mongo shell, you can access the creation time of the ObjectId, using the getTimestamp() method,
  - Sorting on ObjectId values is roughly equivalent to sorting by creation time.

MongoDB Queries

- Expressed via JSON with simple constructs

```
// in orders
{ "orderId":99,
  "customerId":"883c2c5b4e5b",
  "orderDate":"2014-04-23",
  "orderItems":[
   { "product": {"id":27, "name":"NoSQL Distilled"}, "price": 32.45 }
   { "product": {"id":55, "name":"Java 4 all"}, "price": 41.33 }
  ], }
db.orders.find()
db.orders.find({"customerId":"883c2c5b4e5b"})
db.order.find({customerId:"883c2c5b4e5b"},
{orderId:1,orderDate:1}) db.orders.find({"orderItems.product.name":/NoSQL/})
```

sharding

horizontal fragmentation into nodes
reduces IO due to outsourcing to other servers

The shard key -> fragmentation key should be:
» distributed equally in the data
» is a field/function or a combination of fields
should be not unique, but can be a hash on PK?….
default is hash on _id aka PK
shards can usually not be changed -> redo database.

MongoDB only offers few constraints like
the unique index constraint.

advantages:
» simple query language, » no schema
disadvantages:
» no constraints
» no real joins (workaround with lookup)
» slow/questionable transactions -> BASE
» security -> default open in the web

MongoDB Transactions

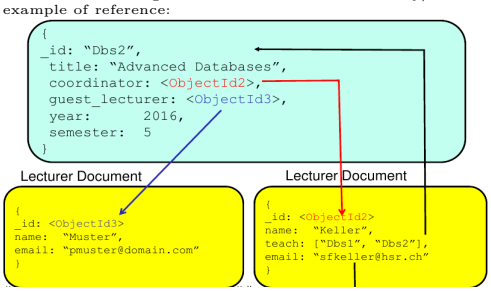
updates work similar to increasing an array
it even automatically pushes it to a new document
if the current one is too big!
however you can avoid relocation by using
referencing instead of embedding.

Performance hindering features:
» Atomicity of writes | » Document Growth
» Sharding | » Indexes and Capped Collections

MongoDB works with **Replica Sets**
child node has the data as well
in case of outage you can still get your data
due to the nature of MongoDB this happens
without having a specific distributed database.
Also the nodes will pick a new Master if the
old one goes down.

embedded: ALL IN ONE FILE
Preferred for » ONE-TO-ONE
» ONE-TO-MANY without many overlaps
Warning with this method, uncontrolled growth of document

referenced: Stored in multiple files
Preferred when dealing with complex relationships
this is the advantage Document stores have over key/value!
example of reference:



- MongoDB use one of two methods for relating documents:
  - Manual references where you save the _id field of one document in another document as a reference
    - These references are simple and sufficient for most use cases
  - The other method is to use DBRefs
- MongoDB documentation recommends using manual references

and here how to create it:

```
use mydb
var coordinator_id = ObjectId()
var guest_lec_id = ObjectId()

db.class_ref.insert({
  _id: "Dbs2",
  title: "Advanced Databases",
  coordinator: coordinator_id,
  guest_lecturer: guest_lec_id,
  year:       2016,
  semester:   5
})
```

in general, only use references for things that make sense,
for example don't make a reference for a blog post
or for a persons gender etc.
embed the small stuff, reference the big stuff

- MongoDB automatically creates a unique index on the _id field
- Indexes on fields (other than _id) that appear often in queries improve performance for common queries
- Indexes are built as BTrees (facilitating range queries)

createIndex() or ensureIndex()

- `db.collection.createIndex(keys, options)`
- Parameters:
  - `keys` of the type document:
  - For each field to index, a key-value pair with the field and the index order: `1` for ascending or `-1` for descending
  - `options` of the type `document` (optional)
- The most important options:
  - `unique` of the type `Boolean`:
    - The default value is false
  - `name` of the type `string`:
    - If unspecified, MongoDB generates an index name

```
db.collection.ensureIndex(
{_id: 1, year: -1}, {unique: true}
)
```

Capped Collection (*)

- Capped collections are fixed-size collections that support those high-throughput operations that insert and retrieve documents based on insertion order
- Capped collections work in a way similar to circular buffers: once a collection fills its allocated space, it makes room for new documents by overwriting the oldest documents in the collection

MongoDB CRUD

MongoDB Read Operation

- The read operation is defined from within the mongo shell
- It uses `db.collection.find()` method
- The method accepts: selection criteria, projection list, and modifiers as its arguments
- Selection ctiteria:
  - Comparison,
  - Existence,
  - Logical junctions (and, or,...),
  - Regular expressions,
  - Array selection objects
- Projection list contains either a:
  - List of fields to return, or
  - List of fields not to return,
  - The only exception is _id field that may be marked as not to return among the list of fields to return
- The read operation returns a cursor to matching documents
  - In mongo shell, up to 20 first documents are displayed on the standard output
- Cursor can be used to write handy scripts

MongoDB Aggregation

- Three ways to do aggregation:
  - Pipeline (preferred),
  - Map Reduce, and
  - Single purpose
- Aggregation Pipeline consists of stages
- Stage operators:
  - `$match, $group, $project, $sort, $skip,...`
- Each stage operator contains expression(s) that specify transformations of documents
- Expression operators:
  - Boolean, Arithmetic, Comparison, String, Set, Date, Accumulator,...
- Expressions in the `$group` and `$project` stages use field path to access fields in the input documents
- Examples show use cases

Lookup mit Aggregation (= aka Joins!)

- Lookup mit Aggregation (= aka Joins!) ab Version 3.2!

```
db.absences.aggregate([ {
    $lookup: {
      from: "holidays",
      pipeline: [
        { $match: { year: 2018 } },
        { $project: { _id: 0, date: { name: "$name", date: "$date" } } },
        { $replaceRoot: { newRoot: "$date" } } ],
      as: "holidays"
    }
  } ])
```

- Entspricht Left Join mittels Subquery:

```
SELECT *, holidays
FROM absences
WHERE holidays IN (SELECT name, date FROM holidays
WHERE year = 2018);
```

- Siehe MongDB Docs $lookup

MongoDB Write Operation

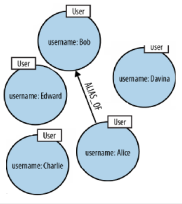
- There are three classes of write operations in MongoDB:
  - Insert that adds a new document to a collection,
  - Update that modifies an existing document, and
  - Remove that deletes an existing document from a collection.
  - The update and remove operations allow specifying criteria or conditions that identify documents (to be modified, or removed)
    - The syntax of the criteria is the same as in find() method
- For all inserts and updates, MongoDB modifies each document in isolation
  - Clients never see documents in an intermediate state
- For multi-document operations, MongoDB does not provide any multi-document transactions or isolation

- The method `db.collection.insert()` writes a document into a collection
  - If there is no `_id` field specified in the document, MongoDB generates it
- The method `db.collection.update()` modifies an existing document, or may upsert a new one
- The `update()` method can also rename or delete a field
- The methods `db.collection.remove()` and `drop()` are used to delete `just` documents or both documents and indices of a collection, respectively

NoSQL Graph Stores

made for compact objects with typed aggregations
sometimes without schema -> implicit schema
or not uniform data
The idea of this database is that everything is an aggregation, -> hence graphs.
Notable examples are: **Neo4J**, FlockDB, InfiniteGraph
biggest gaining database system right now!

Neo4J
java.... ok fuck this trash
GPL3, embedded, disk based
transaction based on MVCC, scalable
delarative, SQL like, pattern matching (SPARQL)
Collection like Haskell/Python

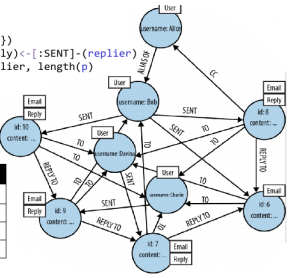



```
CREATE (alice:User {username:'Alice'}),
       (bob:User {username:'Bob'}),
       (charlie:User{username:'Charlie'}),
       (davina:User {username:'Davina'}),
       (edward:User {username:'Edward'}),
       (alice)-[:ALIAS_OF]->(bob)
MATCH (bob:User {username:'Bob'}),
      (charlie:User {username:'Charlie'}),
      (davina:User {username:'Davina'}),
      (edward:User {username:'Edward'})
CREATE (bob)-[:EMAILED]->(charlie),
       (bob)-[:CC]->(davina),
       (bob)-[:BCC]->(edward)
```

Path assignment

```
MATCH p = (email:Email {id:'6'})
      <-[:REPLY_TO*1..4]-(:Reply)<-[:SENT]-(replier)
RETURN replier.username AS replier, length(p)
 - 1 AS depth
ORDER BY depth
```

replier	depth
Davina	1
Bob	1
Charlie	2
Bob	3



after we match to a variable called email
we check for a chain of "replied_to"
aka we check at least one and max 4
then we get the person who sent
the mail and return the depth - 1
also note that the arrow moves to the left
meaning the relation is towards the matching node
–> away from node <– towards node

Node:
» set of labels (usually 1)
» set of properties

Edge:

» Name , » Node->Node direction

» set of properties

Property: key/value of primitive types "name:Dashie"

types: Node, Edge, path, map, list, integer, floating point

boolean and string

syntax:
(var:Node)-[var:edge]->(var:Node)
(var:Node)<-[var:Edge]-(var:Node)
var may be empty but the ':' has to be written!!
-> [:ALIAS_OF]
you also get the properties of a node by just
typing in a variable name -> (varsInsideNode)
could be 1 variable, could be a list

Joins: Because we can match multiple 'queries'
we don't have joins, instad we just
MATCH (query1) , (query2) <-Note the comma.

uses for Neo4J: connected data, routing, dispatch,
location based services and recommendation engines.
when not to use: few egdes/interactions, update on all nodes
big data.. ??nice word

NoSQL Column 'Family' store

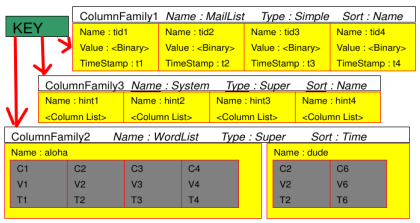
These databases store a full row, within
a single cell of a column
|1 | Dashie | 85 | f| -> |1|name:Dashie level:85 sex:f

the | symbol is to seperate columns

Notable column family stores:
BigTable (Google), HBase (Apache), Hypertable,
Cassandra (Apache) PNUTS (Yahoo)

Cassandra

» Keyspace: aka database within a Node
» Node: data storage -> like document for MongoDB
» Data Center: Collection of nodes
» Cluster: collection of data centers



Cassandra Column

- Column: basic unit of storage in Cassandra
- A name-value pair; always stored with a timestamp

(used to resolve write conflicts, deal with stale data, etc.)

- Example of a "simple column":

```
{
    name: "fullName",
    value: "Martin Fowler",
    timestamp: 12345667890
}
```

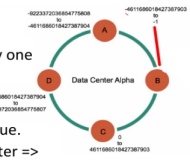
Cassandra "Column Family"

- A row is a collection of columns linked to a key
- A "column family" is a collection of grouped rows
- Example:

```
//column family
{
  //row
  "pramod-sadalage" : {
    firstName: "Pramod",
    lastName: "Sadalage",
    lastVisit: "2012/12/12" },
  //row
  "martin-fowler" : {
    firstName: "Martin",
    lastName: "Fowler",
    location: "Boston" }
}
```

Partitioning

- Consistent Hashing Algorithm
- Logical Ring of hash values
- Each node is given a position on this ring
- Each node is responsible for a LEFT range of hashes
- Each data item's RIGHT neighbor is responsible for storage and replication
- Nodes communicate about ranges so any one node knows the locations which should contain data for a particular key
- Each node in the cluster is responsible for a range of data based on the hash value.
- Example: Hash values in a four node cluster =>



Indexing

- You can index columns other than the keys for the column family

```
UPDATE COLUMN FAMILY Customer
WITH comparator = UTF8Type
AND column_metadata = [{
    column_name: city,
    validation_class: UTF8Type,
    index_type: KEYS}];
GET Customer WHERE city = 'Boston';
```

Cassandra Query Language (CQL)

-
```
CREATE COLUMNFAMILY Customer (
    KEY varchar PRIMARY KEY,
    name varchar,
    city varchar,
    web  varchar);
```
-
```
INSERT INTO Customer (KEY,name,city,web) VALUES
('mfowler', 'Martin Fowler', 'Boston',
'www.martinfowler.com');
```
-
```
SELECT * FROM Customer;
SELECT name, web FROM Customer;
SELECT name, web FROM Customer WHERE city='Boston';
```

Use cases:
» Event logging (ex: error logging)
good since cassandra scales with writes.
» Content management systems, Blogging platforms
-> good for handling post entries.
» counters in web applications (ex: count visitors)

when not to use:
» ACID requirement
» no aggregate functions available
» prototypes, query changes can take time.

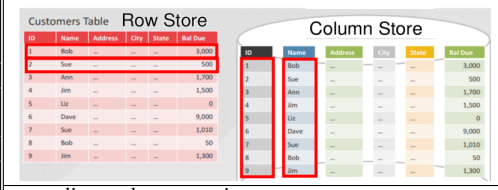
Column Store

OLTP: Online Transaction Processing
» low data volume | » High volume of transactions
» Typically normalized data | » ACID compliance
» high availability || » **relational db (psql)**
» data management optimized

OLAP: Online Analytical Processing
» high data volume | » low transaction volume
» denormalized data | » **not necessarily** ACID compliant
» usually don't need high availability

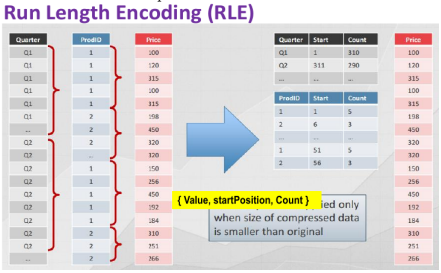
» read optimized system

Usually these two are separated, but recently there
have been efforts to combine those two
just like BASE and ACID are getting closer.

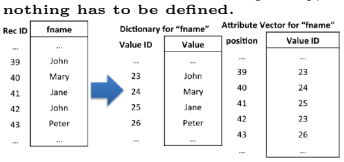


encoding and compression
in databases it is the default to
compress data when you have high selectivety
-> male / female
instead of storing male/female in every column or row
we can instead compress this attribute in order to save space

Run Length Encoding (RLE)



the way this is done is by storing
the possibilities, aka male/female in another table.
This means that we can then reference the id of male or female.
Note that this is all done implicitly,
nothing has to be defined.



Column store advantages:
» better compression | » less disk usage
» automatic indexing | » late materialization
Column stores disadvantages:
» bad writes | » **!!! don't Select * from !!!** | » **OLAP**

Row stores advantages:
» easy partitioning and parallization
» good writes | » seq row scans
Row stores disadvantages:
» column read == read all rows... | » more storage
» early materialization | **OLTP**

late vs early materialization
early means that everything has to be read first
while late means that we wait until the end of the query.
return just the column with nothing else.

NoSQL In Memory Stores (IMDB)

this database stores its values **inside the RAM**
However, it still stores **regular Snapshots** of its system
on the regular disk, in order to prevent data loss.
It also creates logs, to restore previous
states in case of a shutdown. Small note: the **pagefile**
is also loaded from the disk on startup

advantages: » fast read | » ACID
» indexing on the fly
» no buffer for write to disk -> happens with snapshots
less power requirement due to less software
disadvantages: » small storage...
» the values are compressed to save storage -> slow writes

MonetDB and NoSQL end

IMDB examples: SAP HANNA, Oracle TimesTen, IBM SoliDB, **MonetDB**

» **Column oriented Database** | » FOSS, written in C
» **SQL,C,R scripts on database itself**
» supports (application): C,C++,Java,Javascript, Perl,PHP,Python,R,Rust
» **used for Data mining, analysis and text search**
» every column mapped to 1 file | » columns are compressed
» columns are automatically indexed
» multi-core parallel execution of queries
» data-manipulation language SQL 2003, sql Explain, Xquery XML
» **OLAP** | » no secondary indexes (only automatic ones)
» **ACID/Optimistic Concurrency Control** -> OCC
» 100x faster than psql in TPC-H benchmark -> readonly

so then, why not use NoSQL all the time?
!NoSQL lacks multimodel databases!
always just one -> document, key/value, graph, etc

Database benchmarking: » TPC.org, pgbench (psql)
» timing | » data usage | » query types | » data amount..

execution models:
» **volcano execution model:** row by row -> ex:psql
vectorized execution model: value by value ->MonetDB

Database as a Service (DBAAS)

Providers: Amazon AWS, Microsoft Azure, Google Cloud, ..

Pagnation Paging

this is essentially just an offset -> where x > 10000

GraphQL

» declarative query language over the web
» schema with types | » description of data via API
» one endpoint for interaction
» easy to develop API | » clients can request data
» **Query and Data manipulation language (DML)**
» **Data-Type-System (DDL)**
» **supported by all big databases (psql)**
» results represent JSON docs but uses edges and nodes

In the end GraphQL handles input from the user
towards a database like PSQL or others
it is in itself not a database!!

GraphQL: Schema Definition Language (SDL)

- Datentypen «Scalar Types»:
  - Int (32-bit integer); Float (signed double-precision); String (UTF-8), Boolean
  - ID: unique identifier
  - Custom scalar types, e.g. Date type: scalar Date
- Weitere Typen: Enum, List , Union, Interface, ...
- Schema:
  - «Object type» mit «Fields»: Beispiel type abteilung { abtnr: Int! name: String }
  - „Query type" (=READ) und
  - optional je einen „Mutation type" für CREATE, UPDATE und DELETE,
  - die «Input Types» verlangen

schema-first vs code-first:
schema first allows for better and faster integration
however it is obviously more complicated to execute.

PostGraphile: GraphQL and PSQL

» library for integrating PSQL into GraphQL
» PSQL database, NodeJS http-server, GraphQL webAPI
» integrates GraphiQL (GUI tool to write queries)
schema first!

```
CREATE TABLE app_public.users (
  id serial PRIMARY KEY,
  username citext NOT NULL unique,
  name text NOT NULL,
  about text,
  organization_id int NOT NULL
    REFERENCES app_public.organizations ON DELETE CASCADE,
  is_admin boolean NOT NULL DEFAULT false,
  created_at timestamptz NOT NULL DEFAULT now(),
  updated_at timestamptz NOT NULL DEFAULT now()
);
```

table: create type -> User (CamelUpperCase)
attributes : organization_id,name,about -> originizationId (camelCase)
creates nodeId if PK exists
creates aggregationField (variable name) for FK -> userByOrganizationId
it also creates createUser, updateUser,deleteUser for CRUD compliance

for queries:
tablename: app_public.users -> allUsers name from above with all and s
unique constraints: for all unique constraint attributes it will create:
name -> userByName
a foo(nodeid: ID!) is obligatory -> ! denotes obligatory

and here the query as an example:

```
# «query» kann weggelassen werden:
query {
  allAngestelltersList(first: 5, offset: 0) {
    name
    persnr
    abtnr
    chef
  }
}
```

```
{
  "data": {
    "allAngestelltersList": [
      {
        "name": "Marxer, Markus",
        "persnr": 1001,
        "abtnr": 1,
        "chef": null
      },
      {
        "name": "Widmer, Anna",
        ...
```

```
query {
  allAngestellters {
    totalCount  # Info
    pageInfo {  # Paginierung
      startCursor
      endCursor
    }
    nodes {
      name
      persnr
      abtnr
      chef
    }}}
```

```
{
  "data": {
    "allAngestellters": {
      "totalCount": 23,
      "pageInfo": {
        "startCursor": "WyJwcmltYXJ5X2tleV9hc…=",
        "endCursor": "WyJwcmltYXJ5X2tleV9hc2M…="
      },
      "nodes": [
        {
          "name": "Marxer, Markus",
          "persnr": 1001,
          "abtnr": 1,
          "chef": null}, ...
```

» the default creation of createUser etc can be disabled
you can also redefine what the table returns on query
ex: user , userByRowId, allUsers, allUsersList
keep in mind that the first 2 return 1 user
the other return a list
the third one can also be used to
get more info about the nodes and egdes
see "pagnierung above"

best practices: » don't create nullable fields
» use mutations -> convert long types to mutations

GraphQL vs SQL » GrapQL is very limited
» controlled | » expandable

here an example for CRUD functions

```
mutation MyDeleteAbteilung99 {
    deleteAbteilungByAbtnr(input: {abtnr: 99}) {
        # clientMutationId
        # deletedAbteilungId
        abteilung {
            abtnr
            name }}}
```

Legende: rot=Metadaten (hier auskommentiert); grün: Rückgabedaten

OR MAPPER

Application -> Persistance API -> JPA Provider -> JDBC API -> JDBC Driver -> Database

» start with @ entity | » inheritance and interfaces possible
» can be astract | » no constructor arguments (unless private)
» needs primary key |» class may not be final
» fields should be private or protected | » Read commited!

```
@Entity
@Table(name = "account")
public class BankAccount {
  @Id
  @Column(name = "accountid")
  private long id;
  private double balance;

  @Column(name = "description")
  private String explanation;
  @Temporal(TemporalType.TIMESTAMP)
  private Calendar creationDate;

  @Enumerated(EnumType.STRING)
  private Currency curr;
  @Transient
  private String tempComments;
```

Name der DB-Tabelle
Name der DB-Column
Automatisch 1:1 Namens-Mapping
DATE/TIME-Typ bzw. Enum für das Datentyp-Mapping
Nicht persistent (nicht in DB)

the red line are optional, if the names in the java object and in the db are the same !!
supported datatypes: primitive types, wrapper types strings, enums, date, serializable classes
supported relations: collection, set, list, map of entities

execute statements

Base:

Name der Persistence Unit in persistence.xml

```
EntityManagerFactory factory =
  Persistence.createEntityManagerFactory("Bank");
EntityManager em = factory.createEntityManager();
```

Action or query insert / delete update / query

```
em.close();
```

!!this is the base, we always need to call this!!
note that entity managers are independent
comparing the same result from 2 entity managers will not be considered equal

insert

```
BankAccount account = new BankAccount();
account.setName("Bill");
em.persist(account);
em.getTransaction().commit();
```

delete

```
BankAccount account = em.find(BankAccount.class, 1L);
account.incBalance(100);
```

update

```
BankAccount account = em.find(BankAccount.class, 1L);
em.remove(account);
```

query

```
Query query = em.createQuery("SELECT a FROM BankAccount a");

List<BankAccount> list = query.getResultList();
for (BankAccount account : list) {
  System.out.println(account);
}
```

further type details can be specified as such:

```
@Column(name="ssn", unique=true, nullable=true)
private long ssn;
@Column(name="l_name", length=200)
private String lastName;
@Column(name="salary", scale=10, precision=2)
private BigDecimal salary;
@Column(name="s_time", columnDefinition="TIMESTAMPTZ")
private Calendar startDate;
```

Field Access & Property Acess
in OR mapping you don't need to specify setId or get Id they are automatically created. -> Field Access
Should you still create them -> Property Access
for field access the @id must be above the variable declaration
for the property access must to be above the getID() function.

order of mapping:
XML / user defined mapping / default mapping

One-To-One

BankCustomer 1..1 — 0..1 Address

```
@Entity
@Table(name = "bankcustomer")
public class BankCustomer {
  @OneToOne(optional = true)
  @JoinColumn(name = "customer_addressid") // FK
  private Address address;
```

default true
Nullable

Bi-One-To-One
this is an **optional ADDITION** to above
it just creates a manual mapping for the bankcustomer

```
@Entity      Bi == Bidirectional
@Table(name = "address")
public class Address {
  @OneToOne(mappedBy = "address",
            optional = false)
  private BankCustomer customer;
```

Inverse One-To-One

BankCustomer 0..1 — 1..1 Address

```
@Entity
@Table(name = "address")
public class Address {
  @OneToOne
  @JoinColumn(name = "addressid",
              referencedColumnName = "customer_addressid",
              insertable = false, updatable = false)
  private BankCustomer customer;
```

Read-Only, wenn Addressid schon @Id

For all many to x

```
private Collection<BankAccount> accounts = new …
```

instead of private something = new ..

Many-To-One -> change the @OneToOne with @ManyToOne

Bi-Many-To-One
-> change the second @OneToOne with @OneToMany

Many-To-Many

BankManager 0..* — 0..* BankCustomer

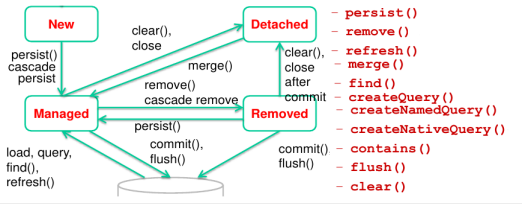
```
@Entity
@Table(name = "bankmanager")
class BankManager {
  @ManyToMany
  @JoinTable(name = "customer_manager",
    joinColumns =  {@JoinColumn(name = "managerref")},
    inverseJoinColumns = {@JoinColumn(name = "customerref")})
  private Collection<BankCustomer> customers = …
```

both inverse join and join needed

Bi-Many-To-Many -> Bi-OneToOne with @ManyToMany

Fetch Types
Eager -> default OneToOne/ManyToOne entity loaded directly
Lazy -> default OneToMany/ManyToMany load only on access
@relation(fetch = FetchType.LAZY/EAGER for override)

O/R Mapping Variants
» Top Down Code first | » Bottom up DB first
» Inside-out Mapping first | » Outside in DB Code together



Generated Ids

```
@Id
@GeneratedValue(strategy = GenerationType.IDENTITY)
private long accountId;
```

This is the same as SERIAL in SQL

```
@Id
@GeneratedValue(strategy = GenerationType.SEQUENCE,
                generator = "BankCustGen")
@SequenceGenerator(name = "BankCustGen",
                   sequenceName = "customeridseq",
                   allocationSize=1) // nur einmal ausführen
private long customerId;

@Id
@GeneratedValue(strategy = GenerationType.TABLE,
      generator ="CustomerGen")
@TableGenerator(name = "CustomerGen", table = "keytable",
       pkColumnName = "keyname",
       valueColumnName = "keyvalue",
       pkColumnValue = "customerkey")
private long customerId;
```

There is also the option for cascade, both persist and delete

```
@OneToMany(cascade = CascadeType.PERSIST, …) CascadeType.Remove)
```

Aggregation and Composition

BankCustomer 0..* — BankAccount

```
@OneToMany(cascade = CascadeType.PERSIST, …)
private Collection<BankAccount> accounts = new ArrayList<>();
```

BankCustomer 0..* — BankAccount

```
@OneToMany(cascade = { CascadeType.PERSIST, CascadeType.REMOVE }, …)
private Collection<BankAccount> accounts = new ArrayList<>();
```

for bidirectional relation,**MANUALLY sync ANY updates**. they are NOT automatic!!

inheritance strategy

Single Table

```
@Entity
@Inheritance(strategy = InheritanceType.SINGLE_TABLE)
@DiscriminatorColumn(name = "type")
public abstract class BankCustomer {
  @Id private String name;}
```

Joined Table

```
@Entity
@Inheritance(strategy = InheritanceType.JOINED)
@DiscriminatorColumn(name = "type")
public abstract class BankCustomer {
  @Id private int customerId;
  private String name;}
```

Multi Table

```
@Entity
@Inheritance(strategy = InheritanceType.TABLE_PER_CLASS)
public abstract class BankCustomer {
  @Id private int customerId;
  private String name;}
```

child tables (multi table without discriminator)

```
@Entity
@DiscriminatorValue("Private")
public class PrivateBankCustomer extends BankCustomer {
  private String eliteOffer;}
```

JPQL Query language optimized for OR

essentially the same other than this

Positional Parameters

```
select a from BankAccount a where
a.customer.name like ?1 and a.balance >= ?2
```

Named Parameters

```
select a from BankAccount a where
a.customer.name like :name and a.balance >= :lower
```

dynamic queries:

```
Query query = em.createQuery(
 "SELECT c FROM BankCustomer c WHERE c.name LIKE :customerName"
);
query.setParameter("customerName", name);
query.setMaxResults(1000);
List<BankCustomer> list = query.getResultList();
```

Predefined query

```
@NamedQuery(name = "CustomerSearch", query =
 "SELECT c FROM BankCustomer c WHERE c.name LIKE :customerName")
@Entity
public class BankCustomer { … }
Query query = em.createNamedQuery("CustomerSearch");
query.setParameter("customerName", name);
```

Locktype: either pessimistic or optimistic

```
BankAccount account = em.find(…);
em.lock(account, LockModeType.PESSIMISTIC_WRITE);
account.incBalance(100);
```

merge, add to existing or create new

```
public Customer storeUpdatedCustomer(Customer cust) {
    return entityManager.merge(cust);}
```

refresh entity manager

```
em.refresh(customer);
```

JSON to PSQL in seperate file. OPTIONAL!