FunSQL:
A library for compositional construction of SQL queries

Find all patients born at or after 1950.

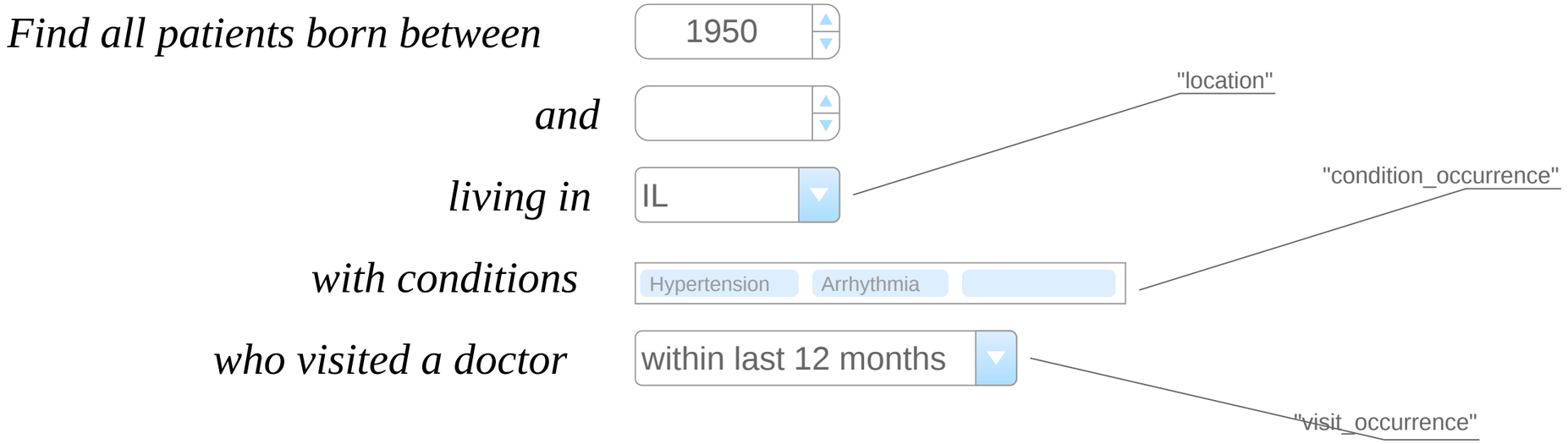
```
function find_patients(conn)
    sql = """
    SELECT person_id
    FROM patient
    WHERE year_of_birth >= 1950
    """
    DBInterface.execute(conn, sql)
end
```

- What is SQL? Data is often stored in relational databases, and to retrieve it, we write queries in SQL.
- Popular databases with SQL interface include MySQL, PostgreSQL, SQLite, Microsoft SQL Server, Redshift, BigQuery, and many others.
- Julia already has a number of libraries that let you interact with SQL databases.
- Why another tool?

Find all patients born between 1950

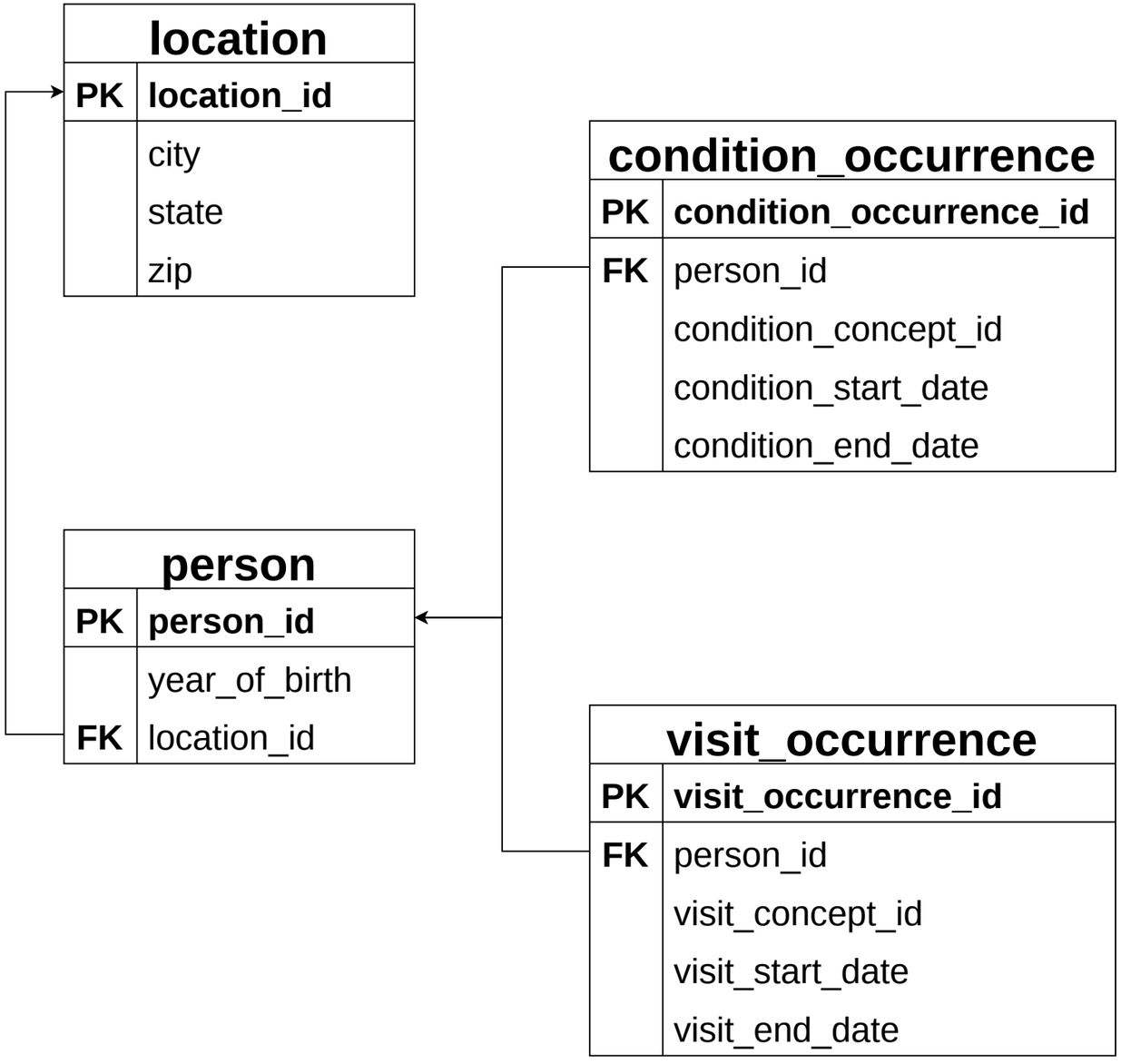
and

```
function find_patients(conn; start_year = nothing,
                             end_year = nothing)
    sql = """
    SELECT person_id
    FROM patient
    """
    conditions = String[]
    if start_year !== nothing
        push!(conditions, "year_of_birth >= $start_year")
    end
    if end_year !== nothing
        push!(conditions, "year_of_birth <= $end_year")
    end
    if !isempty(conditions)
        sql *= "\nWHERE " * join(conditions, " AND ")
    end
    DBInterface.execute(conn, sql)
end
```




```
function find_patients(conn; start_year = nothing,
                             end_year = nothing,
                             state = nothing,
                             conditions = []
                             last_visit = nothing)
    sql = """
    SELECT person_id
    FROM patient
    """
    ???
    DBInterface.execute(conn, sql)
end
```

- Clearly, a more systematic approach is necessary.

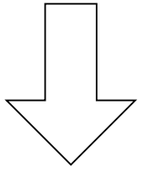


- A small diversion to introduce the database schema which we will use in subsequent examples.
- OMOP Common Data Model is a popular open-source used in healthcare of observational research.
- As typical in healthcare, the schema is patient-centric. The *person* table stores information about patients including basic demographic information. Their address is stored in a separate table called *location*.
- Most of the patient data consists of clinical events: encounters with healthcare providers, recorded observations, diagnosed conditions, performed procedures, etc.

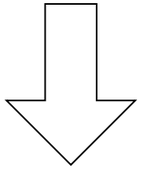
```
using FunSQL: SQLTable

const person =
    SQLTable(name = :person,
             columns = [:person_id, :year_of_birth, :location_id])

const location =
    SQLTable(name = :location,
             columns = [:location_id, :city, :state, :zip])

const condition_occurrence =
    SQLTable(name = :condition_occurrence,
             columns = [:condition_occurrence_id, :person_id,
                        :condition_concept_id,
                        :condition_start_date, :condition_end_date])

const visit_occurrence =
    SQLTable(name = :visit_occurrence,
             columns = [:visit_occurrence_id, :person_id,
                        :visit_concept_id,
                        :visit_start_date, :visit_end_date])
```

Find all patients born in 1970 or later.

```
FROM person p
```

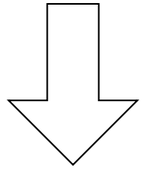


```
FROM person p
WHERE p.year_of_birth >= 1950
```

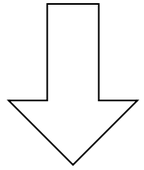


```
SELECT p.person_id
FROM person p
WHERE p.year_of_birth >= 1950
```

```
q = From(person)
```



```
q = From(person) |>
    Where(Get.year_of_birth .>= 1950)
```



```
q = From(person) |>
    Where(Get.year_of_birth .>= 1950) |>
    Select(Get.person_id)
```

```
sql = render(q, dialect = :postgresql)
```

- To introduce FunSQL, I will take several SQL queries and show how to express them in FunSQL.
- A SQL query starts with a FROM clause, where you choose the starting table.
- In FunSQL, we start building a query object using From constructor applied to a SQLTable object.
- What follows it is a sequence of operations that transform the data to the desired form.
- FunSQL provides a way to express SQL operations, and use chain operator for composing them.
- The final clause is always SELECT, which is written at the top, but is always performed last.
- In FunSQL, Select is not mandatory.

Bound References

```
q.year_of_birth        q.person_id

q1 = From(person)
q2 = q1 |> Where(q1.year_of_birth .>= 1950)
q3 = q2 |> Select(q2.person_id)
```

- Both bound and unbound references are supported.
- Bound references are created by taking an attribute of a query object.
- On the other hand, unbound references are not associated with a particular query object, and are resolved at render time.
- Unbound references make decomposition easier.

Unbound References

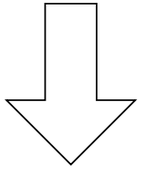
```
Get.year_of_birth      Get.person_id

q = From(person) |>
    Where(Get.year_of_birth .>= 1950) |>
    Select(Get.person_id)
```

```
BornInOrLater(y) =
    Get.year_of_birth .>= y

q = From(person) |>
    Where(BornInOrLater(1950)) |>
    Select(Get.person_id)
```

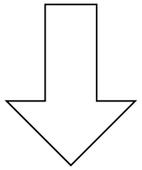
Show patients with their state of residence.

- The JOIN operator combines the output of two queries.
- Suppose we want to display patients with their state of residence. We need to combine the data from the table person, which store the patient record, and the table location, which stores information about addresses.

```
FROM person p
```

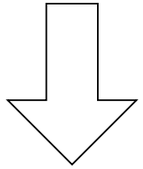


```
FROM person p
JOIN location l
  ON (p.location_id = l.location_id)
```

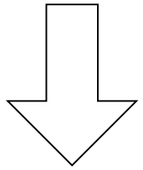


```
SELECT p.person_id, l.state
FROM person p
JOIN location l
  ON (p.location_id = l.location_id)
```

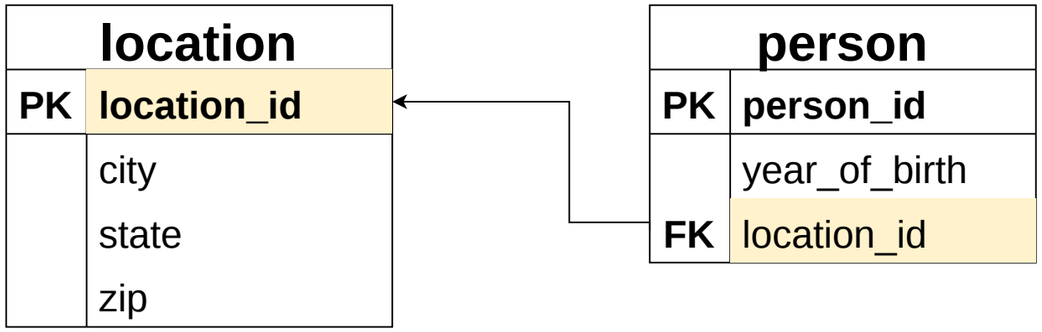
```
From(person)
```



```
person |>
Join(:location => location,
     Get.location_id .==
     Get.location.location_id)
```



```
person |>
Join(:location => location,
     Get.location_id .==
     Get.location.location_id) |>
Select(Get.person_id,
       Get.location.state)
```



- Joining two tables poses a challenge for unbound references.
- For instance, both person and location table have a column called location_id.
- This isn't a problem if you use bound references.
- To solve this problem, we introduce hierarchical references: As() constructor to introduce a level of hierarchy, which can be then traversed using Get.
- To clarify: although this operation is similar to SQL AS operator, it does not really affect the generated SQL.

```
q1 = From(person)
q2 = From(location)
q3 = q1 |> Join(q2, q1.location_id .== q2.location_id)
```

```
From(person) |>
Join(From(location) |>
     As(:location),
     on = Get.location_id .== Get.location.location_id)
```

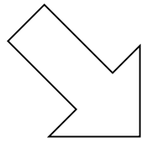
Find patients

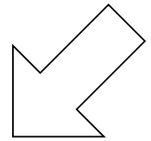
- *born in 1970 or later,*
- *living in Illinois*

- Recall that we want to find patients with certain constraints on date of birth and location.
- Suppose we are already assembled queries to find patients with appropriate age and locations in Illinois. Then we could use these queries as building blocks to construct a larger query.

```
From(person) |>
Where(Get.year_of_birth .>= 1970)
```

```
From(location) |>
Where(Get.state .== "IL")
```

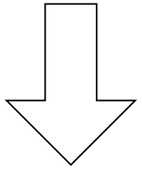




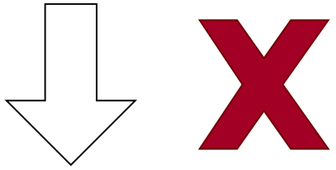
```
From(person) |>
Where(Get.year_of_birth .>= 1970)
Join(:location => From(location) |>
                  Where(Get.state .== "IL"),
     on = Get.location_id .==
          Get.location.location_id)
```

- However if you know SQL, you may be confused by this query. This is because it is not clear what is the corresponding SQL.

```
FROM person p
```

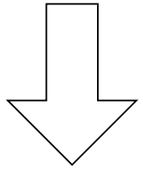


```
FROM person p
WHERE p.year_of_birth >= 1950
```

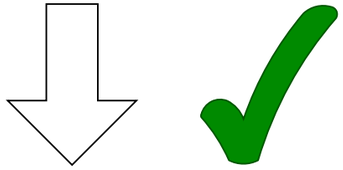


```
FROM person p
WHERE p.year_of_birth >= 1950
JOIN location l
  ON (p.location_id = l.location_id)
```

```
From(person)
```



```
From(person) |>
Where(Get.year_of_birth .>= 1950)
```



```
From(person) |>
Where(Get.year_of_birth .>= 1950) |>
Join(:location => location,
     Get.location_id .==
         Get.location.location_id)
```

- In fact, in SQL, the operations have rigid order, FROM followed by JOINs, then WHERE, GROUP BY, HAVING, ORDER BY.
- FunSQL, on the other hand, doesn't have this restriction. You can apply operations in any order required by the query logic. There is not syntactic restrictions.
- However, how does it work? We know that FunSQL must, at the end, render a SQL query. So what query does it generate?