

SQL -> Graql

Created by: Brandon Ferguson

Agenda

- **Setup Grakn**
- **What is a graph?**
- **Why use graphs?**
- **Are hypergraphs useful?**
- **How do I model a graph?**
- **Introducing Grakn**
 - Ontology & Knowledge Model
 - Hierarchies & Relations
 - Modeling Tips
- **Introducing Graql**
 - Defining Schemas
 - Writing Data
 - Reading Data
 - Deleting/Modifying Data
- **Exercises**

Setup Grakn

Setup Grakn & Grakn Workbase

- Download grakn-core-all-* from <https://github.com/graknlabs/grakn/releases/tag/1.6.2>
- Extract grakn-core-all, open terminal/CMD, and CD into extracted directory
- Run `./grakn server start` (or `.\grakn.bat server start` on Windows)
- Download grakn-workbase-* from <https://github.com/graknlabs/workbase/releases/tag/1.2.7>
- Extract grakn-workbase, open terminal, and CD into extracted directory
 - On Windows, double-click the .exe to install
- Run `./grakn-workbase`
 - On Windows, run installed Grakn Workbase app

Download/Clone Training Data

<https://github.com/BFergerson/sql-to-graql>

Executing Graql Files

- On Linux/mac:
 - `./grakn console -f /path/to/file.gql`
- On Windows:
 - `.\grakn.bat console -f C:\path\to\file.gql`

Notice:

- Files under "graql" are standalone and can be executed separately or together in any order
- Files under "answers/exercise" are standalone and can be executed separately or together in any order
- Files under "answers/fill-in-the-blank" must be executed in the order they appear in this presentation

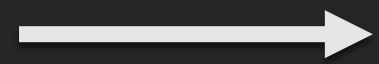
What is a graph?

What is a graph?

An abstract representation of a set of objects where some pairs are connected by links.



Vertex (Node, Point, Instance)



Edge (Link, Line, Arc, Relation)

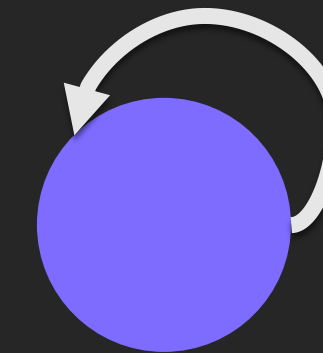
Undirected



Directed



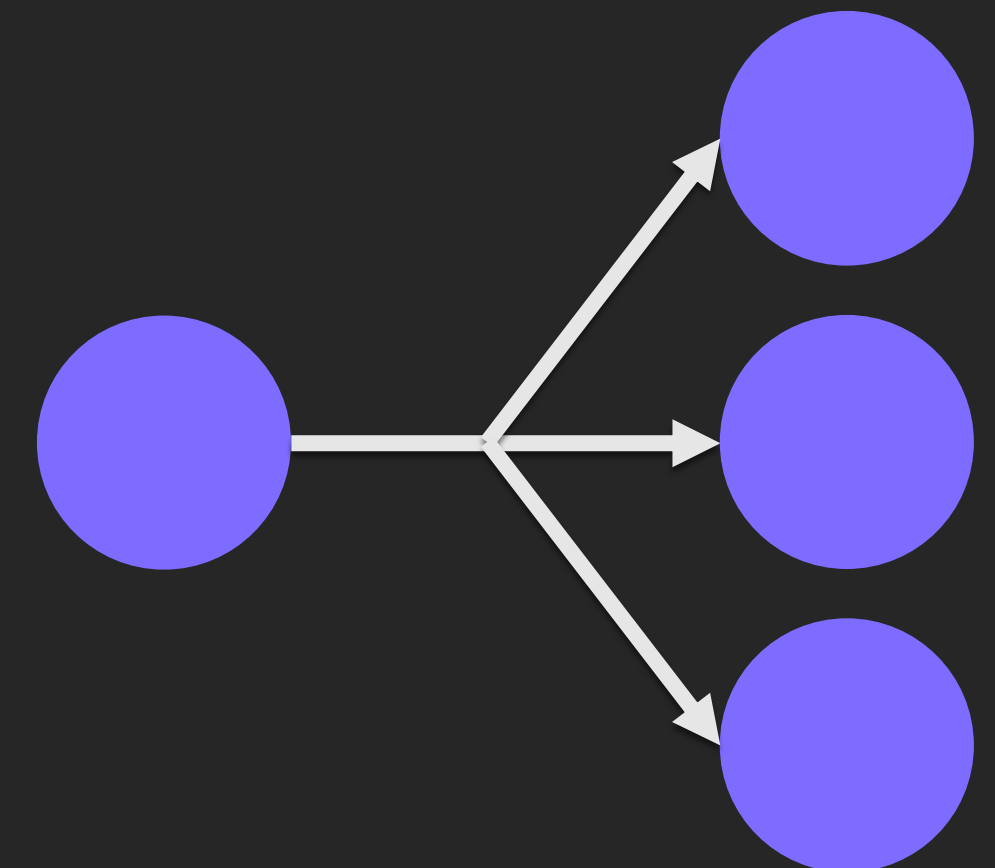
Pseudo



Multi

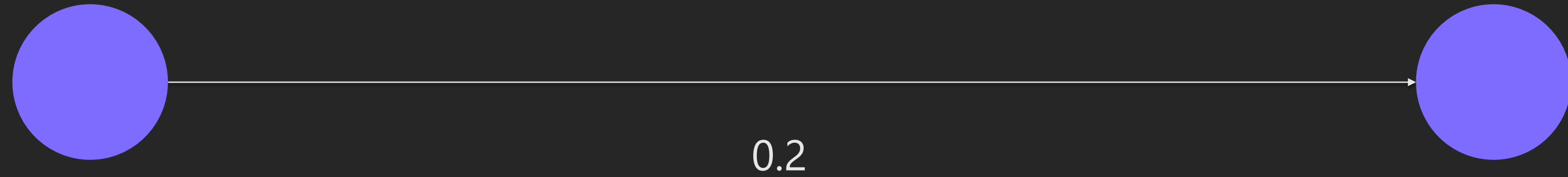


Hyper

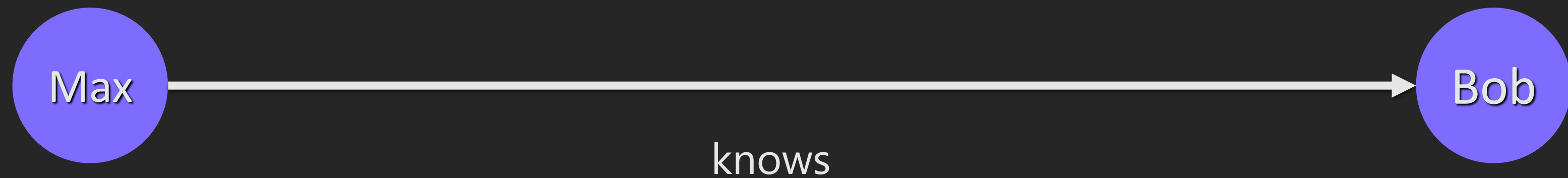


What is a graph?

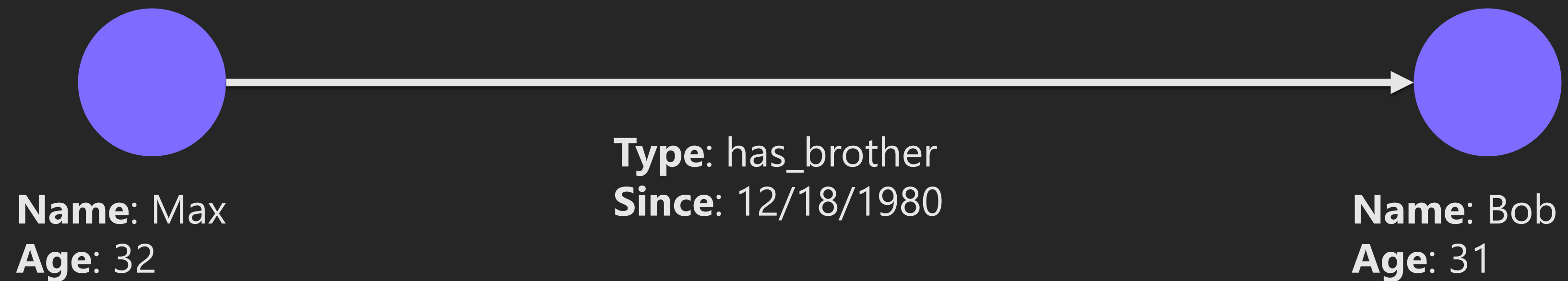
Weighted



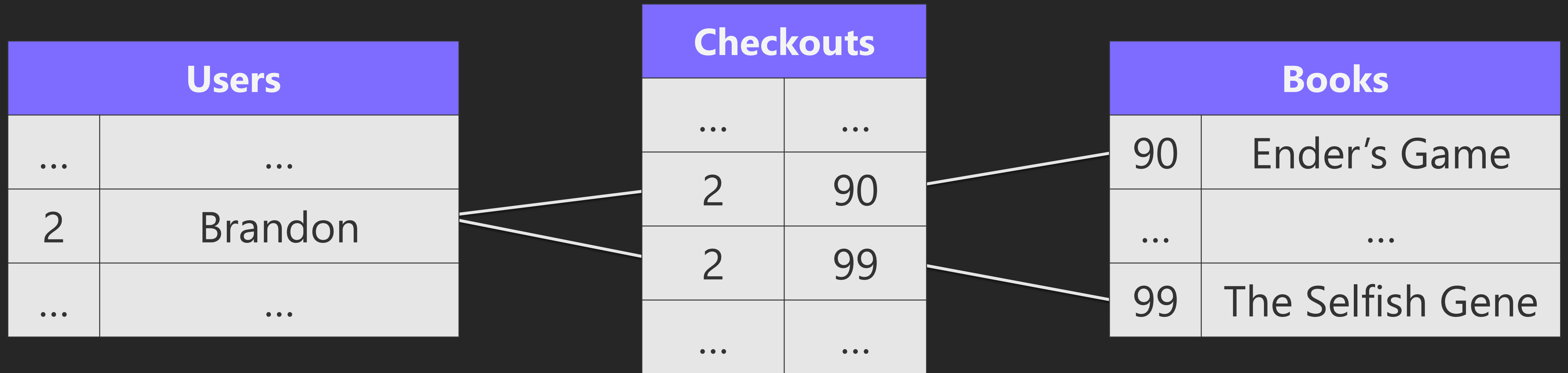
Labeled



Property



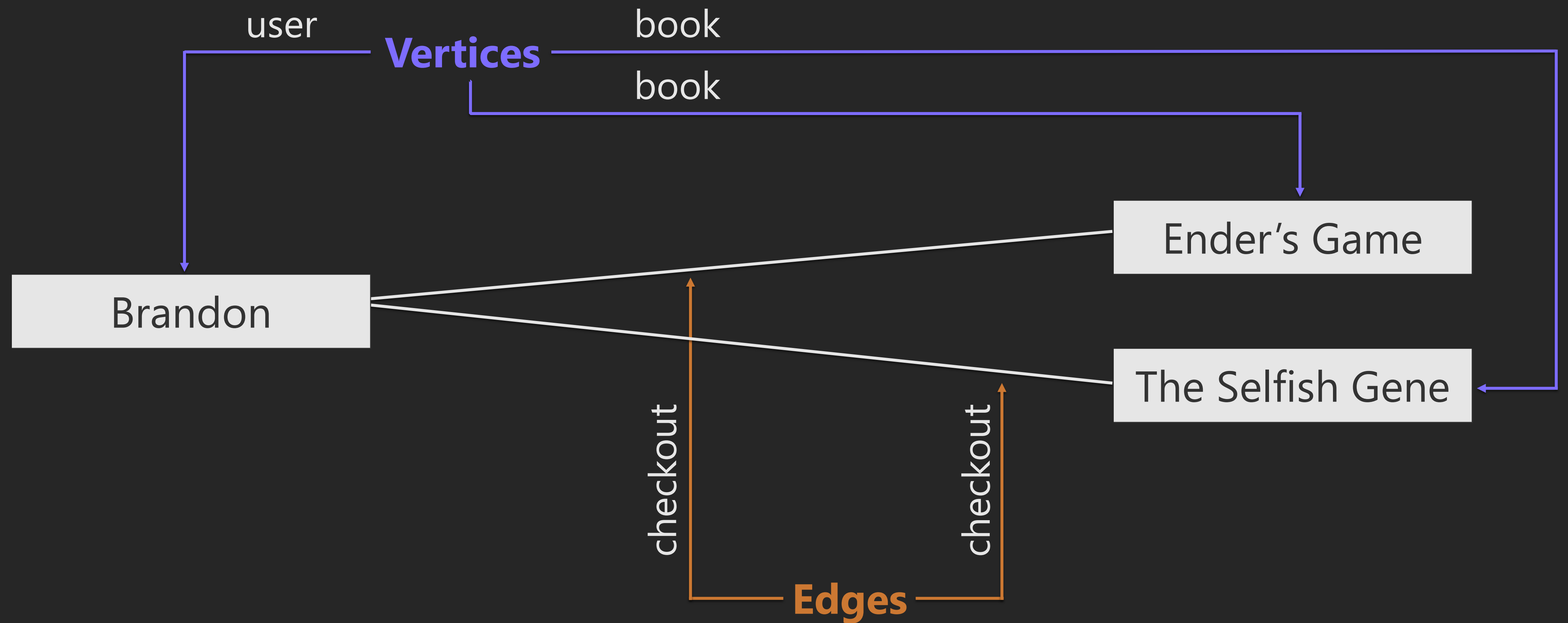
What is a graph?



What is a graph?

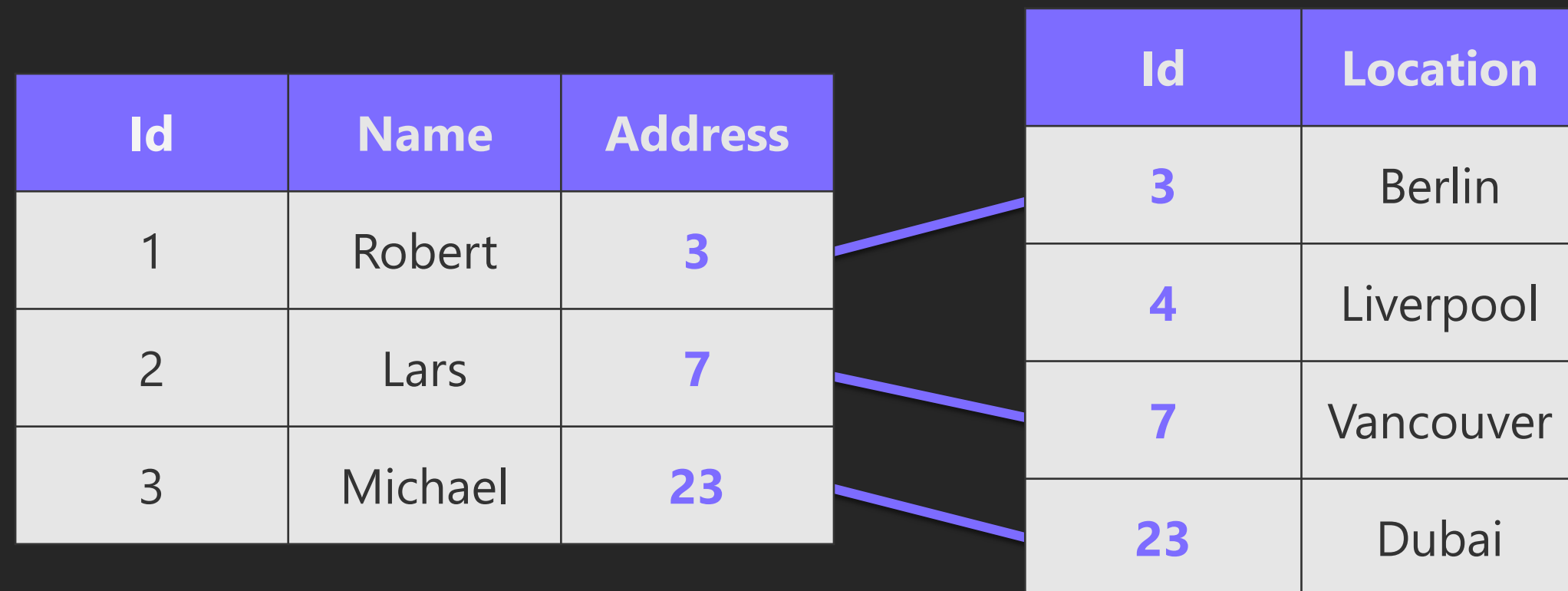


What is a graph?

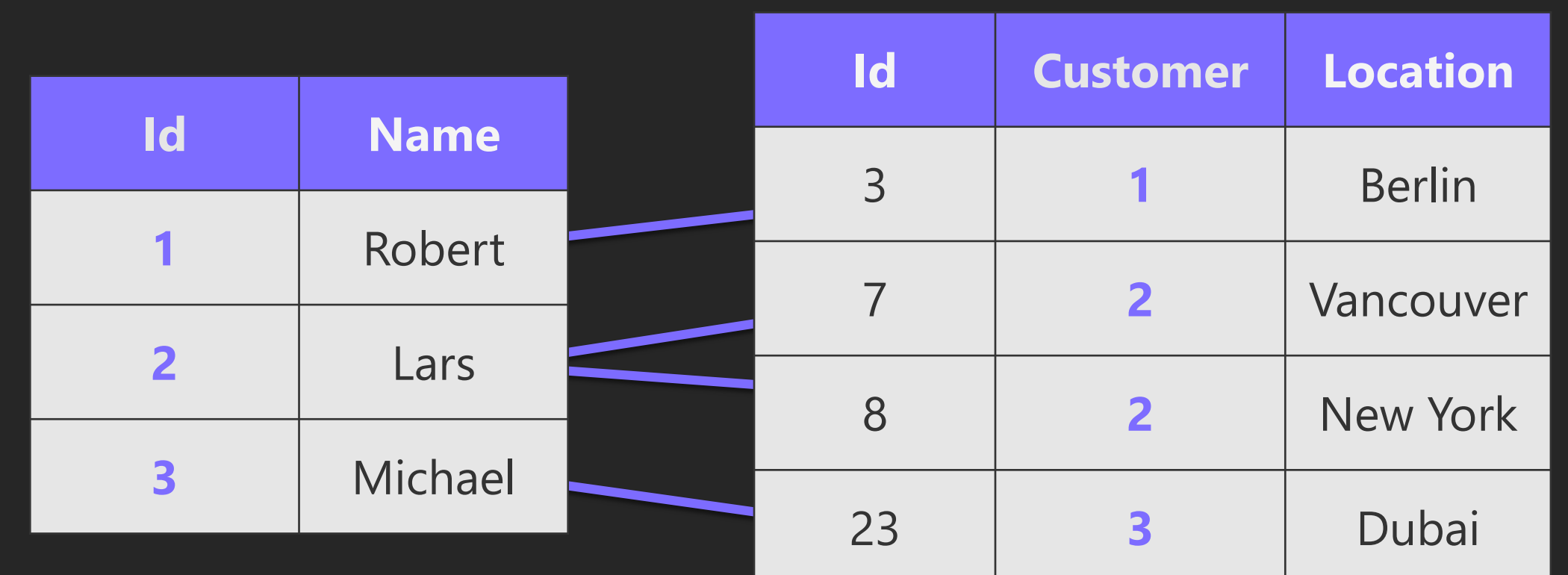


What is a graph?

1:1 Relationship



1:n Relationship



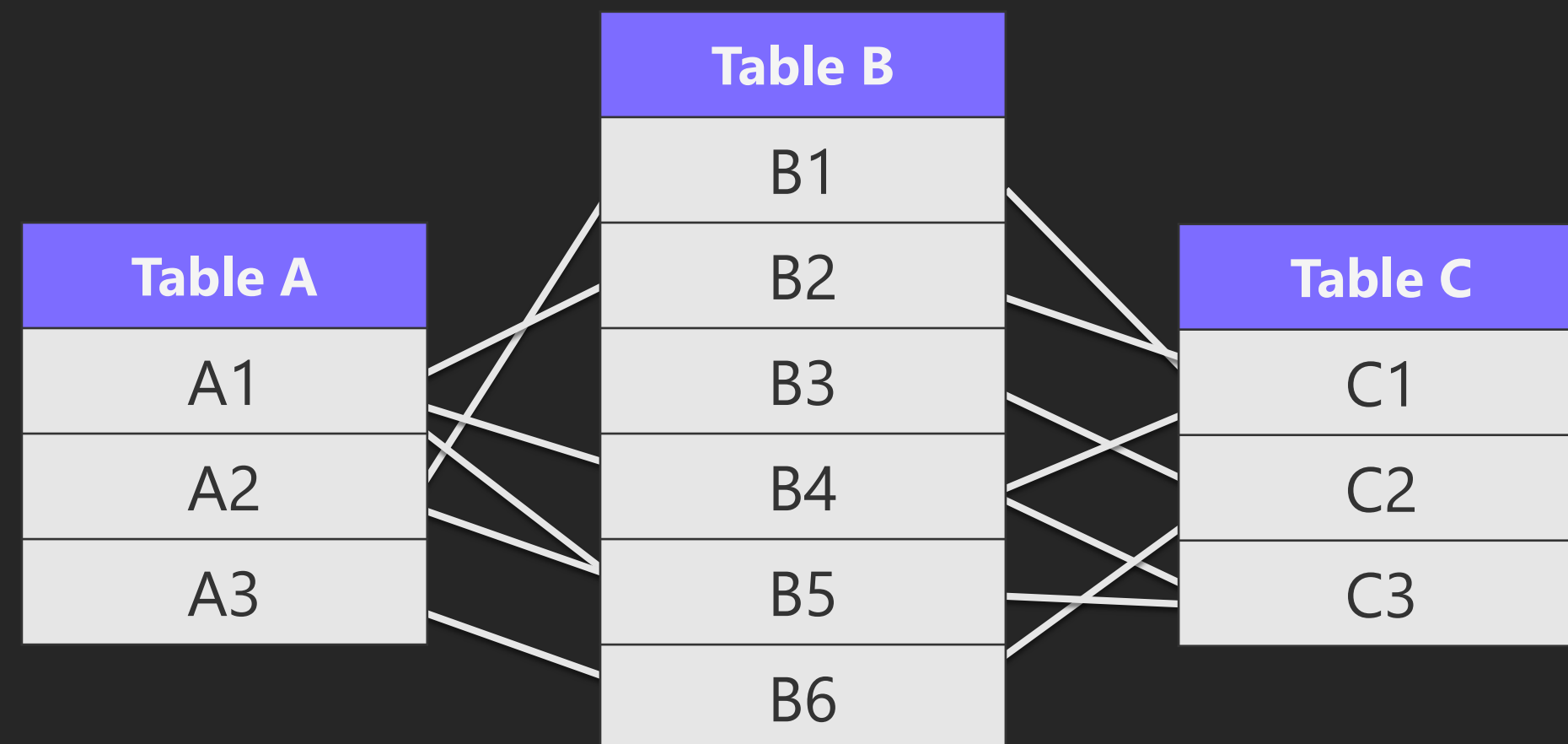
m:n Relationship



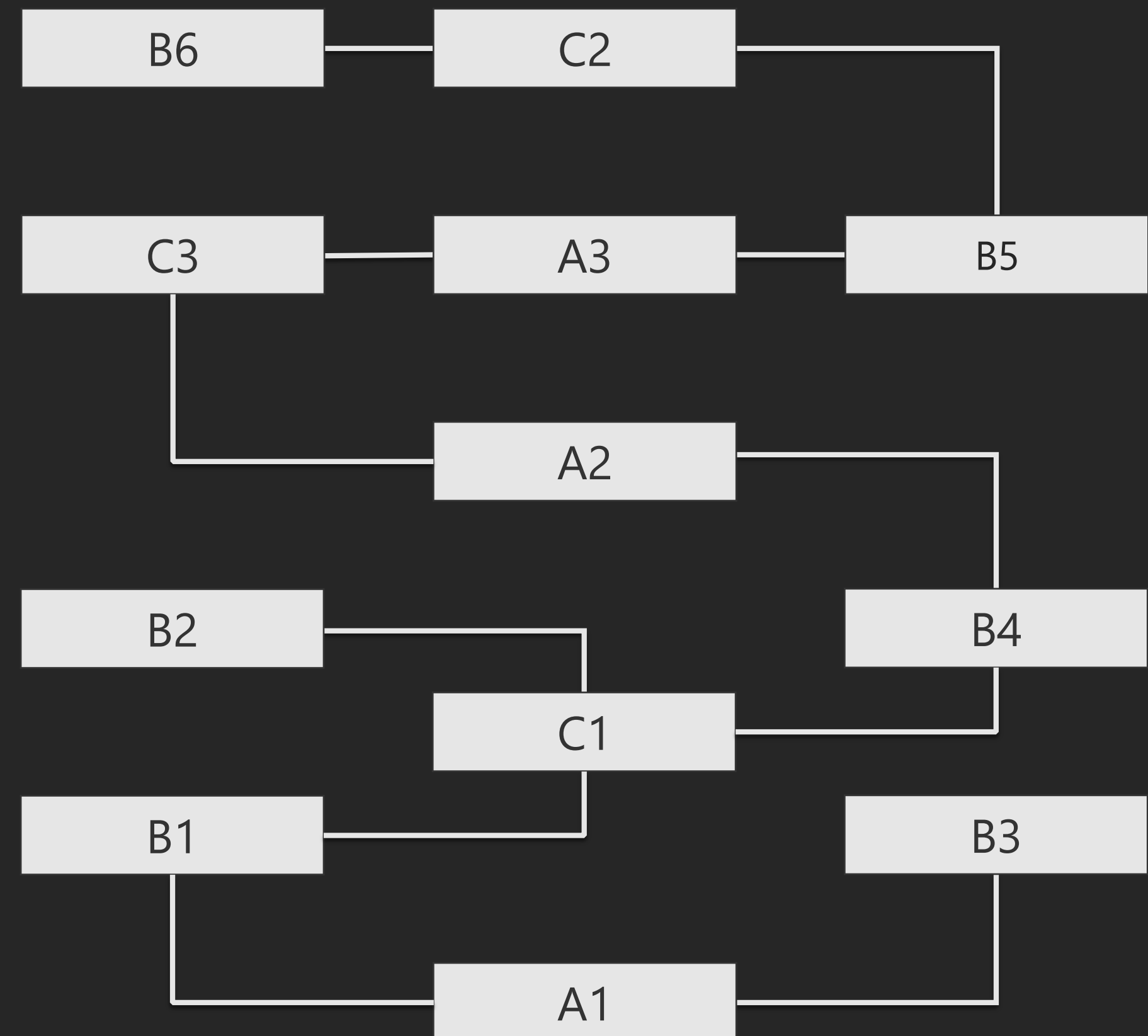
Why use graphs?

Why use graphs?

Optimized for aggregate data



Optimized for connected data



Why use graphs?

Use graphs when:

- Problems with join performance
- Joining more than 7 tables together
- The majority of your tables are junction tables
- Written stored procedures with multiple recursive self and inner joins
- Continuously evolving data set (often involves wide and sparse tables)
- The shape of the domain is naturally a graph
- Constantly changing schema

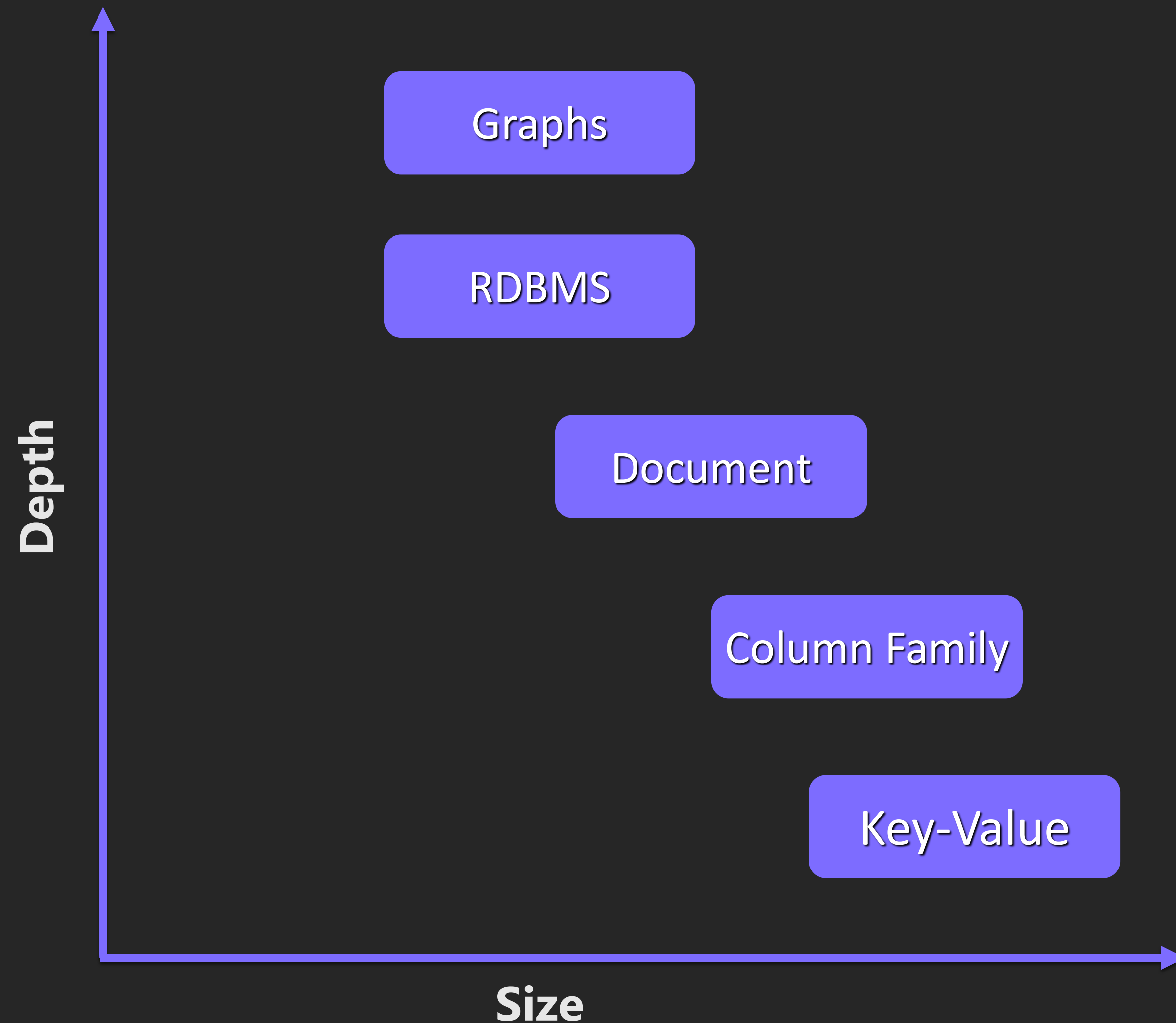
Graphs are good at:

- Path finding (how do people know each other)
- Highly connected data (social networks)
- Recommendations (e-commerce)
- A* (least-cost path analysis)

Graphs are designed to:

- Store interconnected data
- Make it easy to make sense of data connections
- Make it easy to evolve the database
- Enable high-performance on operations for:
 - Discovery of connected data patterns
 - Relatedness queries > depth 1

Why use graphs?



Friends-of-friends
1,000,000 people
~50 friends each

Depth	RDBMS execution time (s)	Neo4j execution time (s)	Records returned
2	0.016	0.01	~2500
3	30.267	0.168	~110k
4	1543.505	1.359	~600k
5	Unfinished	2.132	~800k

Friends-of-friends
~50 friends each
Depths of 4

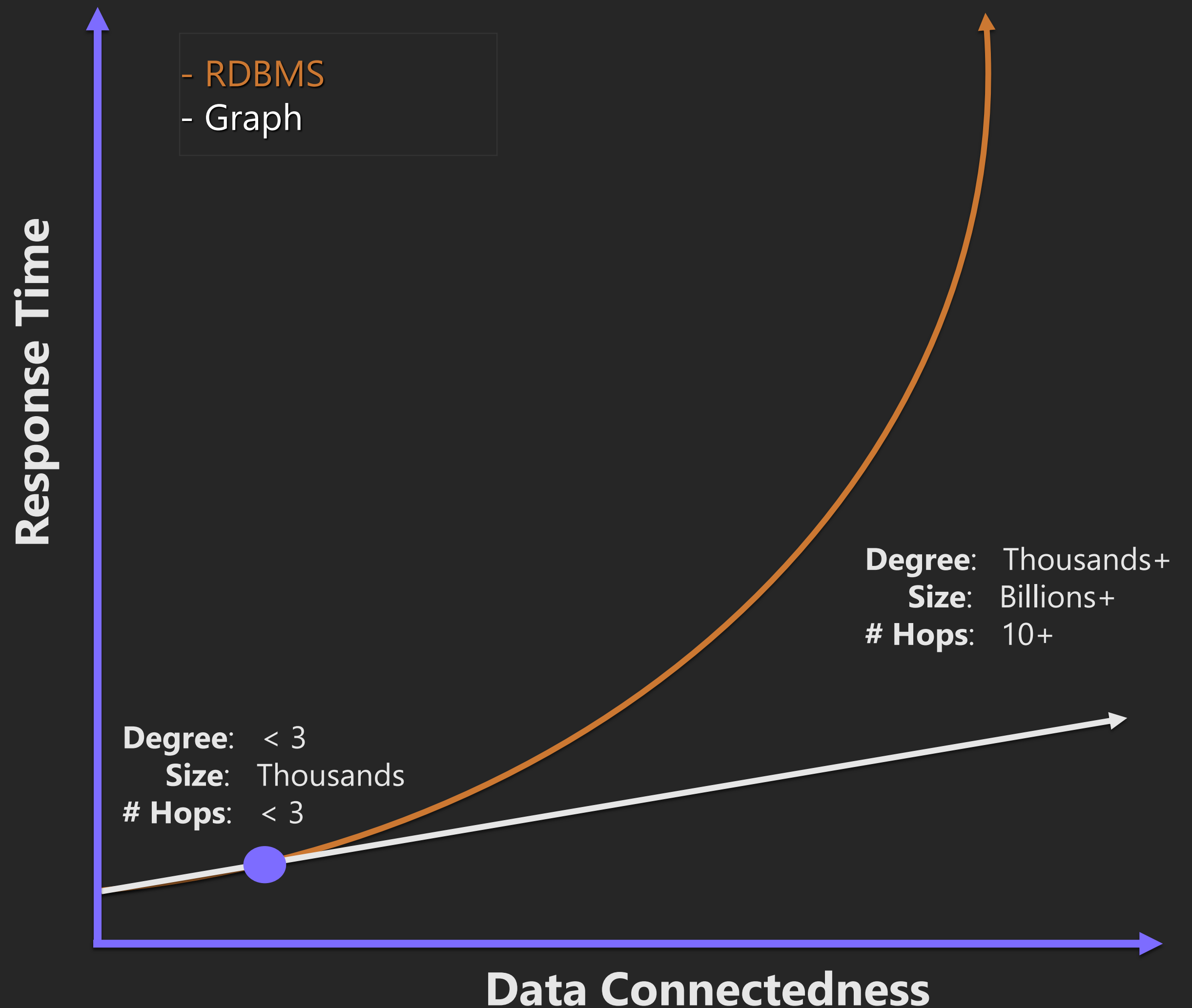
Database	# persons	Query time
MySQL	1,000	2 sec
Neo4j	1,000	2 ms
Neo4j	1,000,000	2 ms

Why use graphs?

Query Response Time

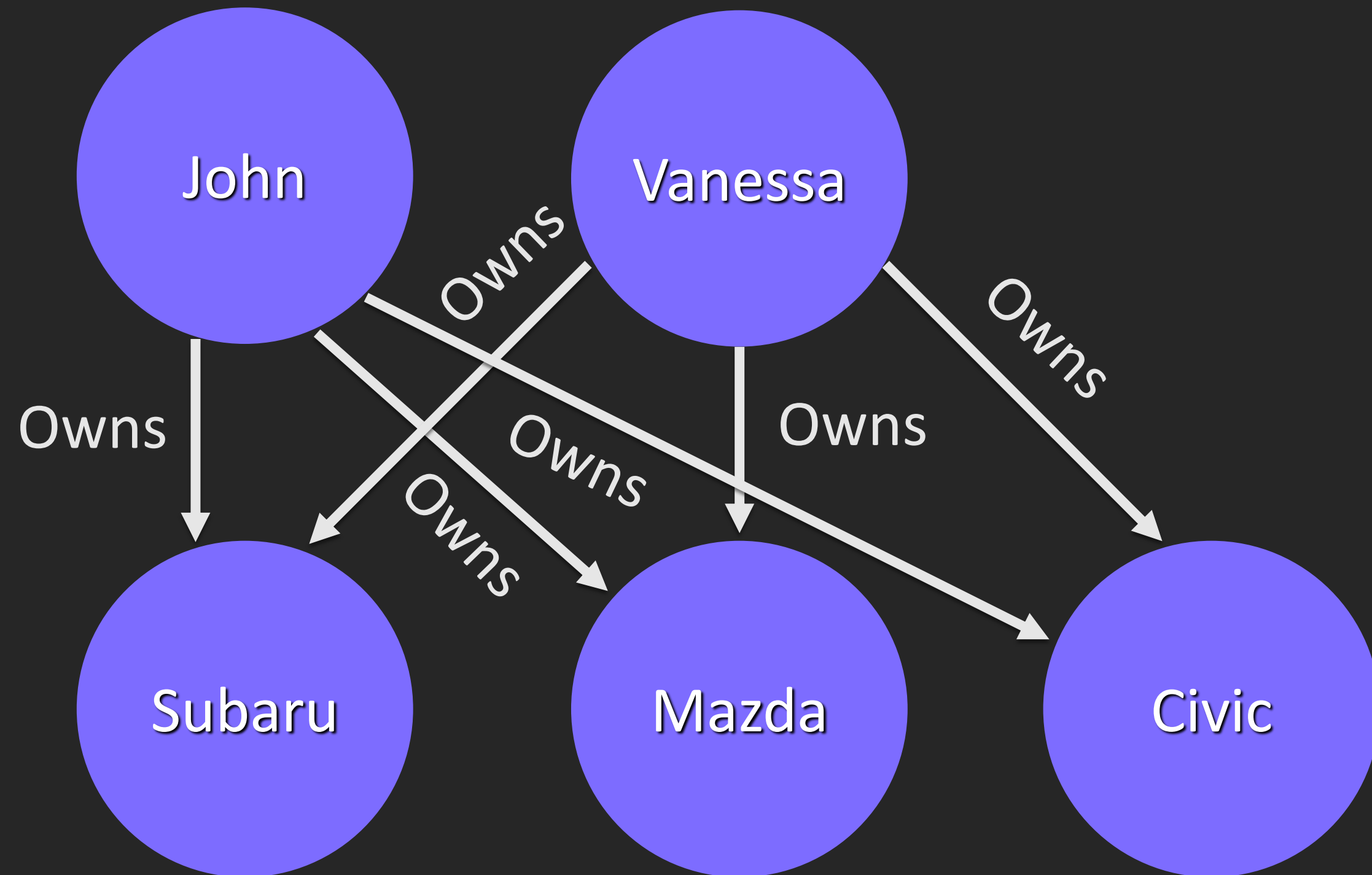
= $f(\text{graph density, graph size, query degree})$

- Graph density (avg # rel's / node)
- Graph size (total # of nodes in the graph)
- Query degree (# of hops in one's query)

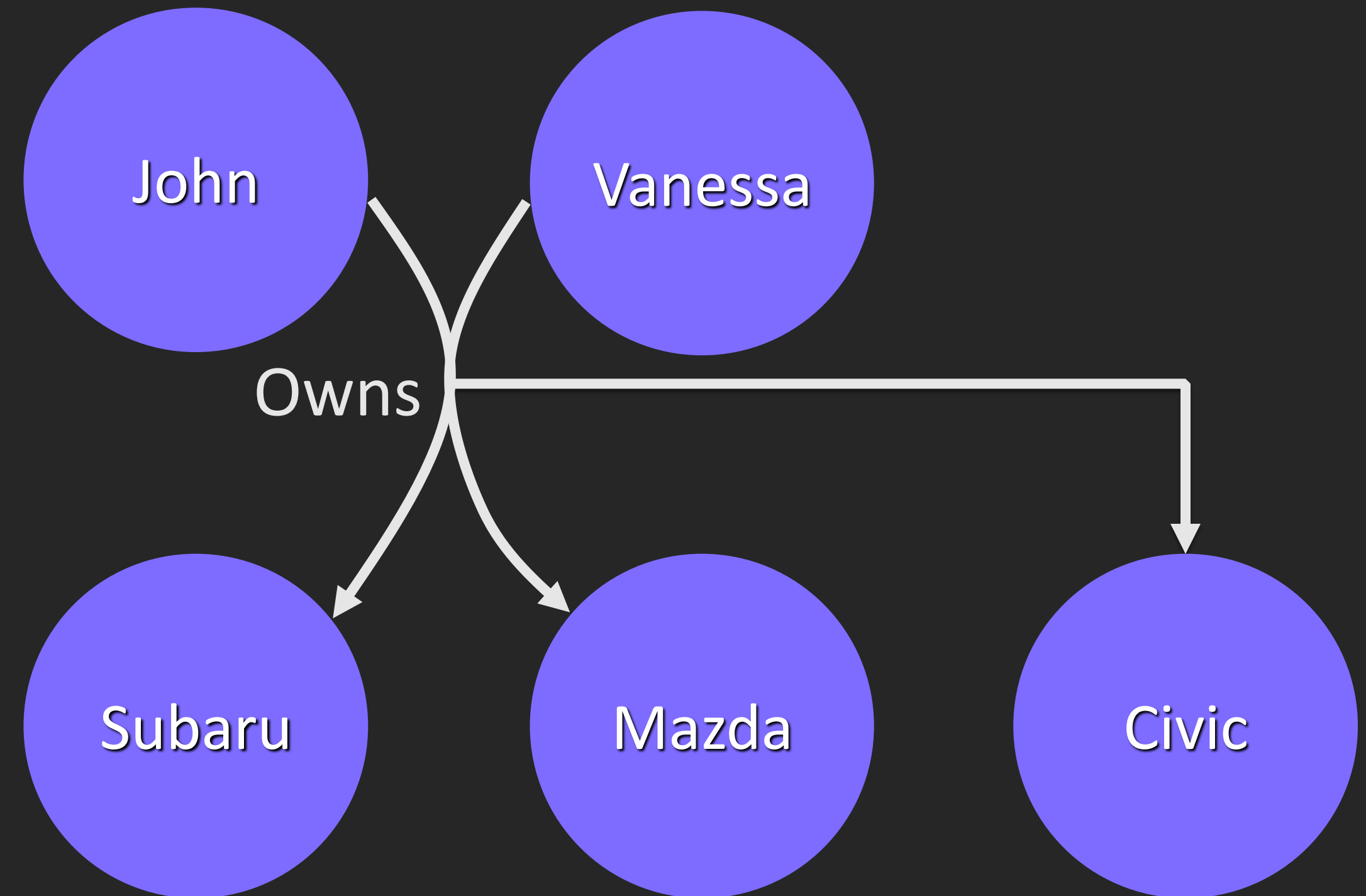


Are hypergraphs useful?

Are hypergraphs useful?



Directed Graph

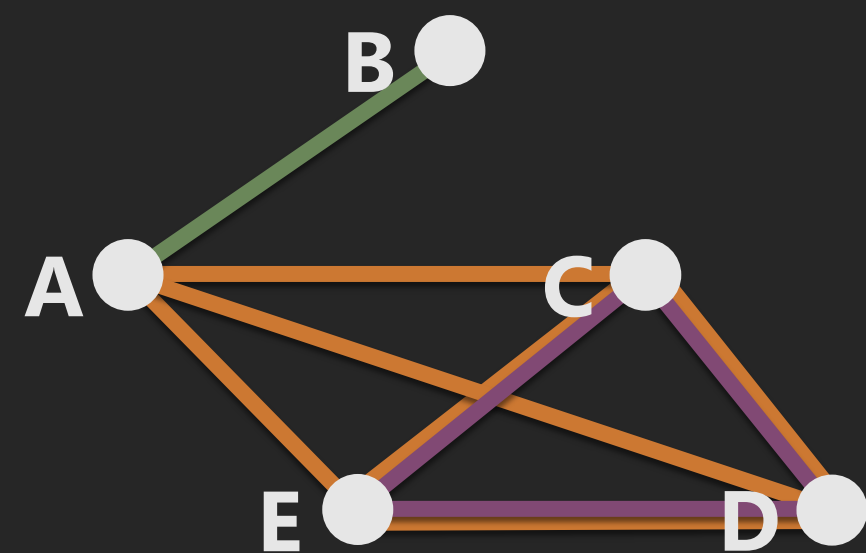


Hypergraph

Are hypergraphs useful?

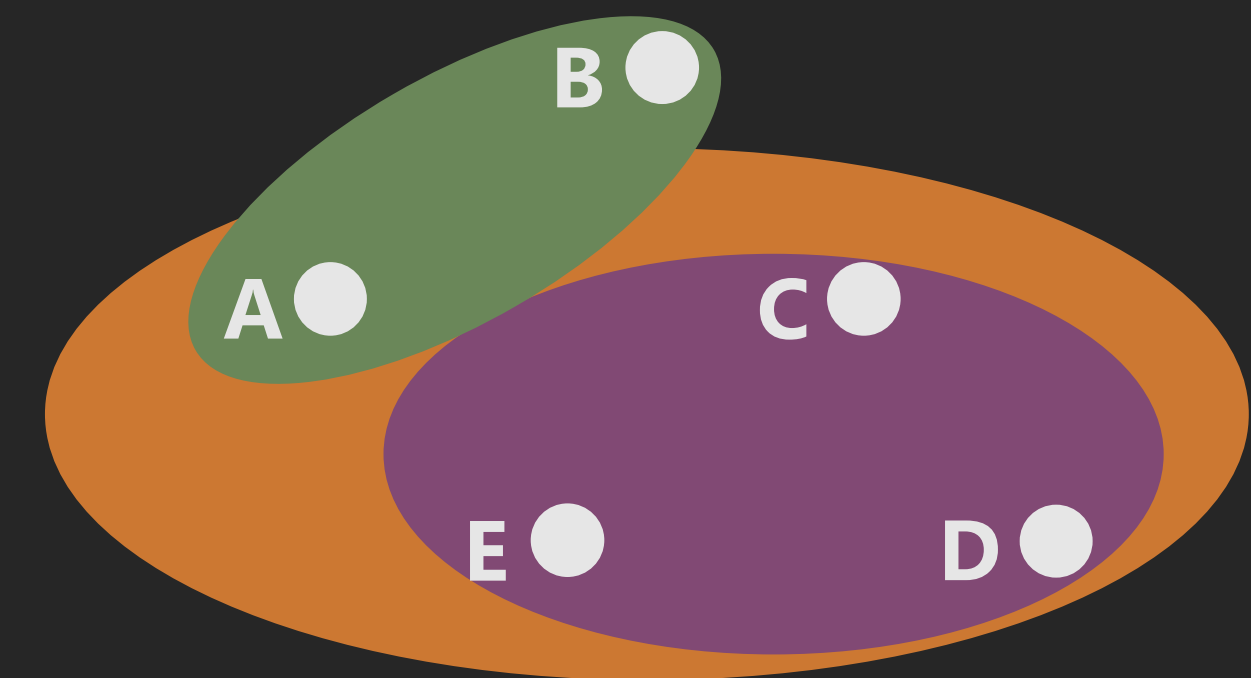
Graph

	1	2	3	4	5	6	7	8	9	10
A	X				X	X	X			
B	X									
C		X	X		X			X	X	
D		X		X		X		X		X
E			X	X			X		X	X



Hypergraph

	1	2	3
A	X		X
B	X		
C		X	X
D		X	X
E		X	X



Hypergraphs generalize the common notion of graphs by relaxing the definition of edges

Graph: Edge = pair of vertices

Hypergraph: Hyperedge = set of vertices

Scenario – Traditional Marriage

Marriages

husband_id	husband_id	wife_id
h1	m1	w1

Husbands

husband_id	name
h1	John

Wives

wife_id	name
w1	Vanessa

Relational



Directed

Scenario – Polygamous Marriage

Marriages

husband_id	husband_id	wife_id
h1	m1	w1

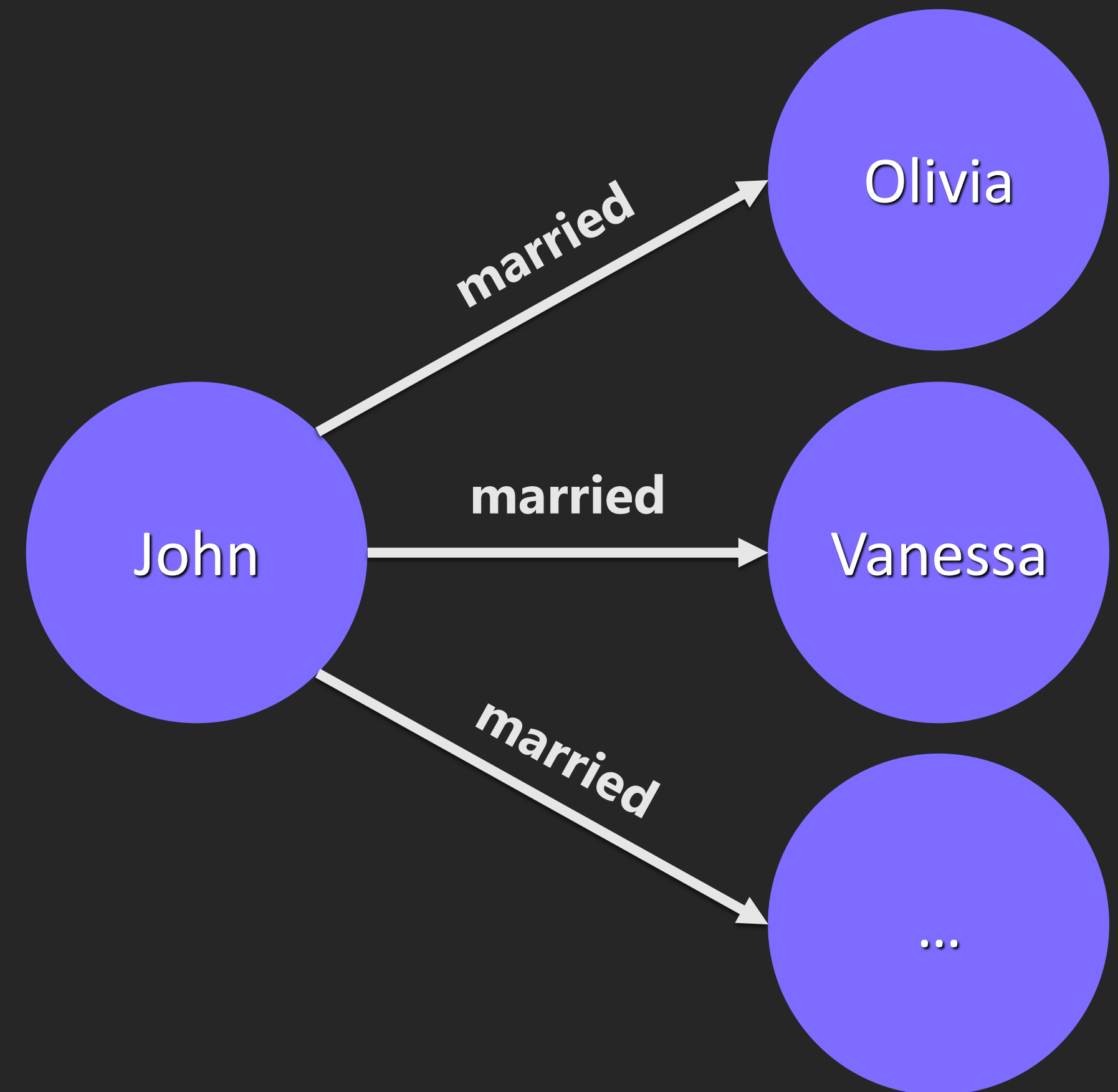
Husbands

husband_id	name
h1	John

Wives

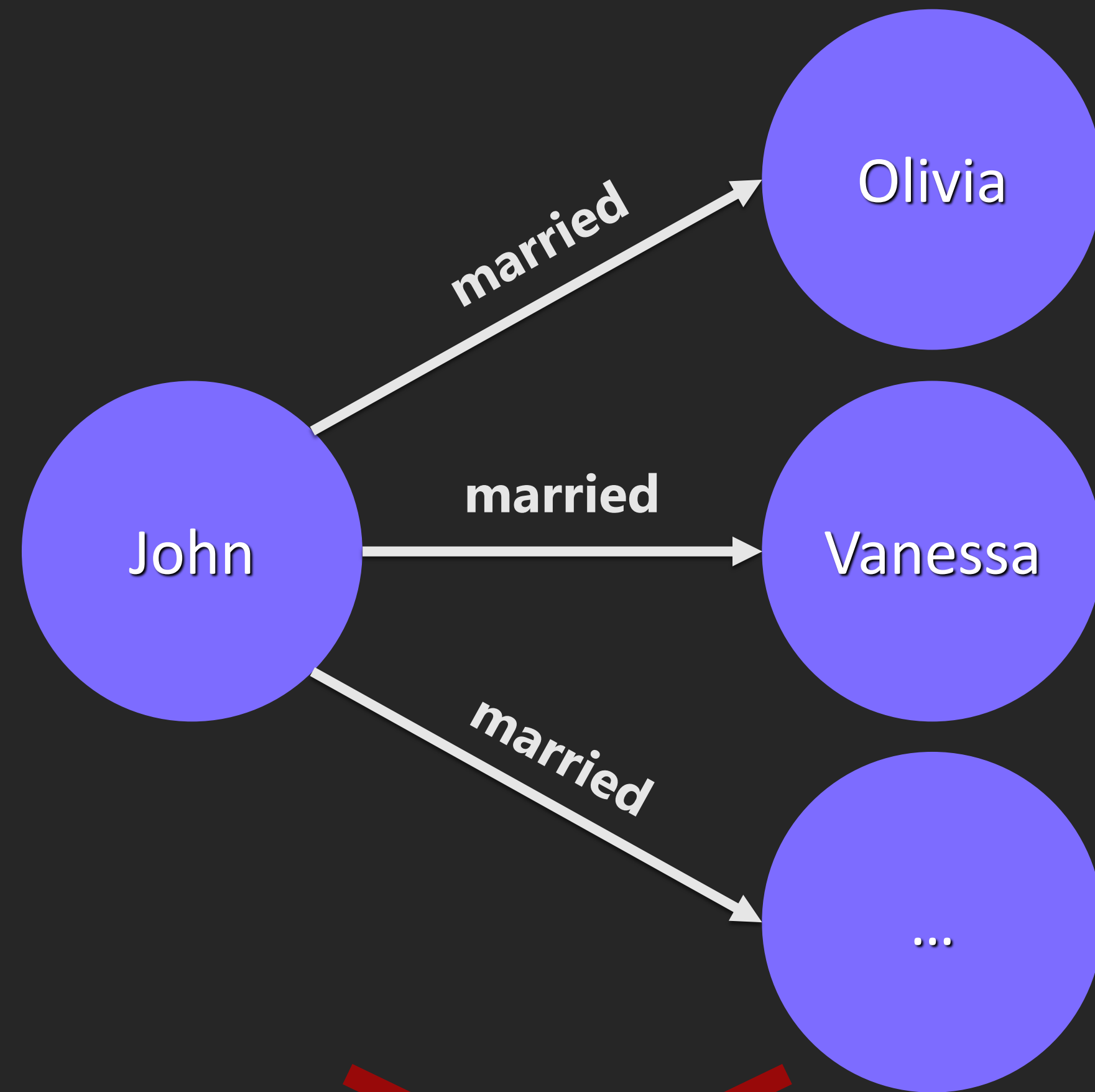
wife_id	name
w1	Vanessa

~~Relational~~

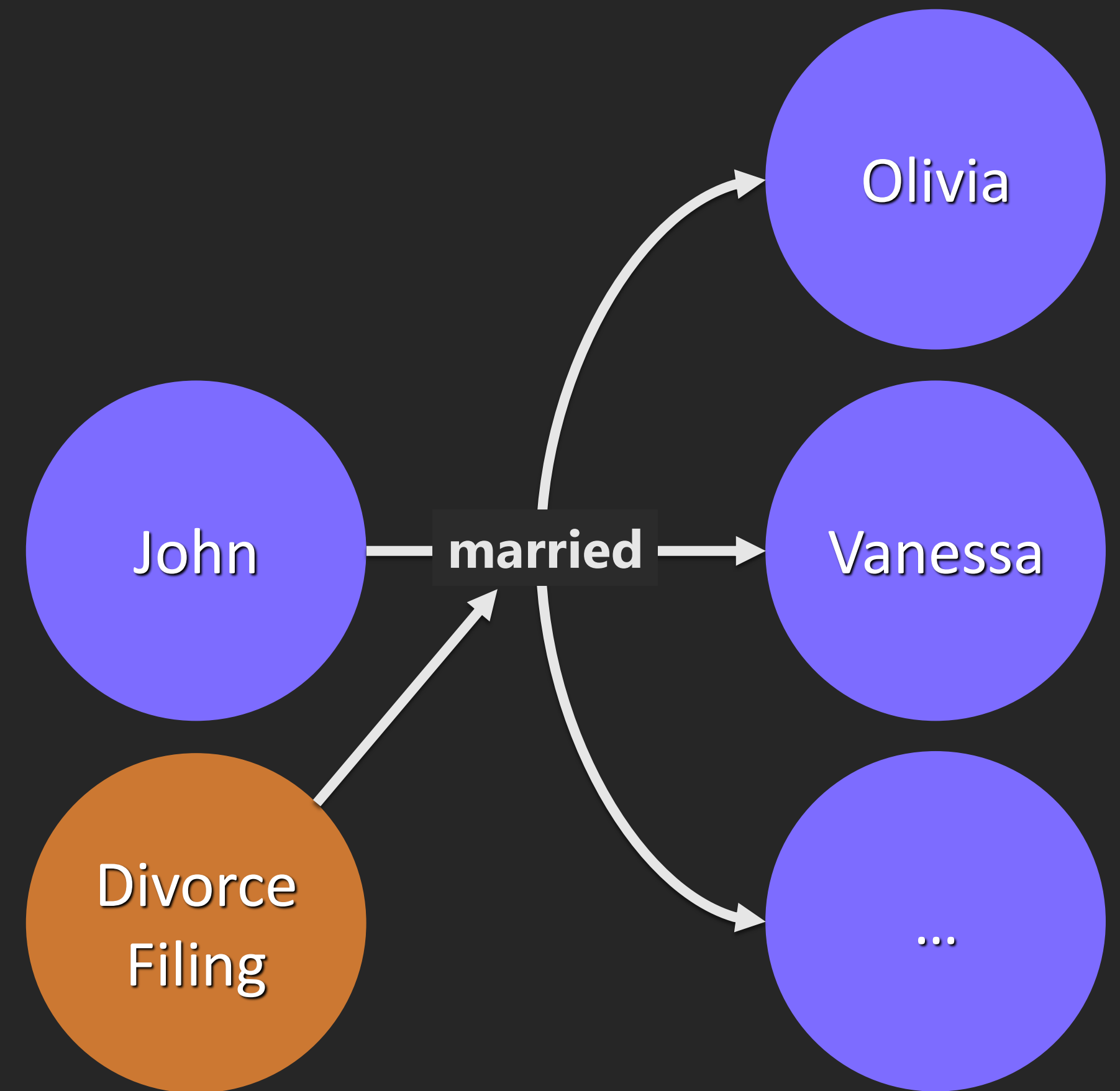


Directed

Scenario – Divorce Filing



~~Directed~~



Hyper

How do I model a graph?

Data Modeling

Technical Expertise



Conceptual Model



Abstraction

Conceptual Model

Entities

- Attribute value comprises a **complex value** type (e.g. address)
- Values with conceptual identities
- Value requires qualification via relation
- Example:
 - Find all recent orders delivered to the **same delivery address** (complex value type)

Relations

- Specify **weight**, **strength**, or some other **quality** about the relationship
- Example:
 - Find all my colleagues who are **level 2 or above** (relationship quality) in a **skill** (attribute value) we have in common

Attributes

- There's no need to qualify the relationship and consists of a **simple value** type (e.g. color)
- Have no conceptual identity (metadata)
- Example:
 - Find those projects written by contributors to my projects that use the same **language** (attribute value) as my projects

Determine Entities

Which library users have books
currently lent which are over-due?

Determine Entities

Which library **users** have **books**
currently lent which are over-due?

Determine Relations

Which library users have books
currently lent which are over-due?

Determine Relations

Which library users have books
currently **lent** which are over-due?

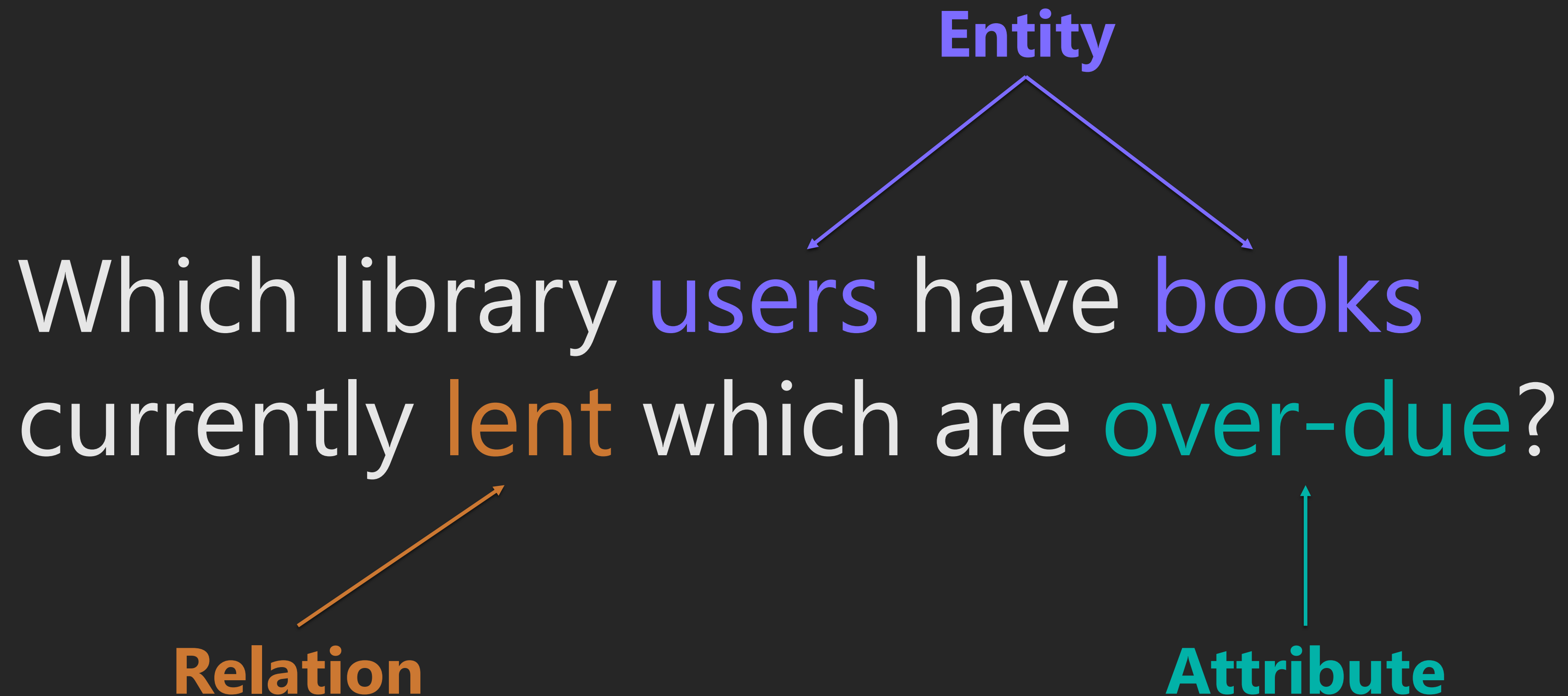
Determine Attributes

Which library users have books
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Determine Attributes

Which library users have books
currently lent which are over-due?

Conceptual Model

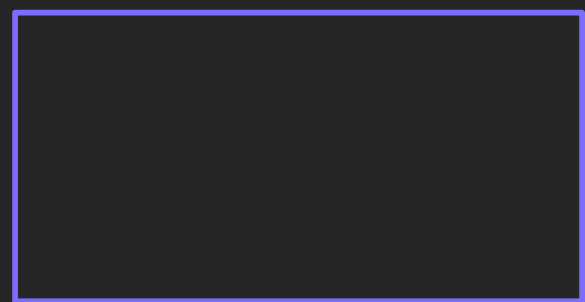


Entity–Relationship Model

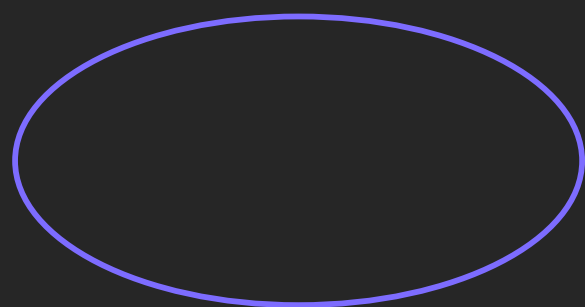
Symbol

Meaning

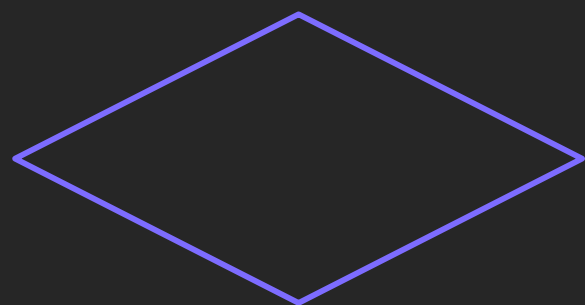
Example



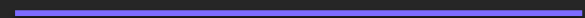
Entity



Attribute



Relationship



Link



Draw Conceptual Model

Objective

Which library users have books currently lent which are over-due?

Data Available

Book

- Author
- Title
- Publish date
- Lend date
- Due date

User

- First/middle/last name
- DOB
- Email
- Gender

Draw Conceptual Model

Objective

Which library users have books currently lent which are over-due?

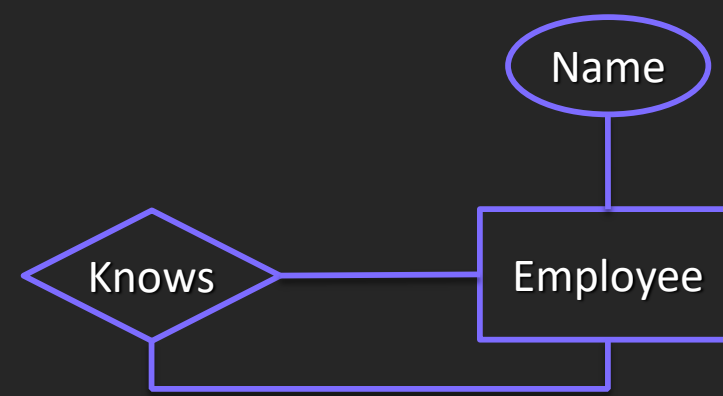
Data Available

Book

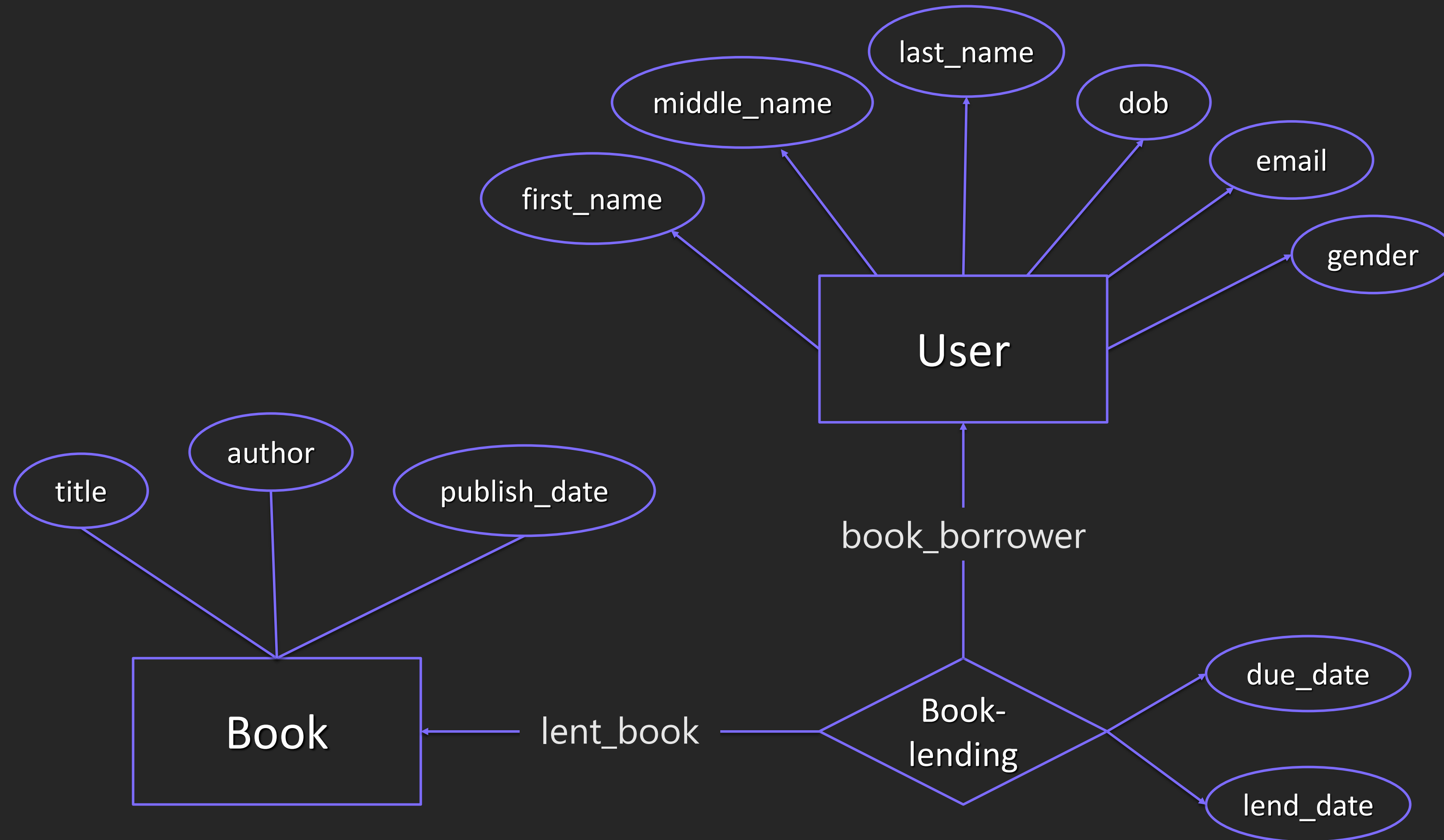
- Author
- Title
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User

- First/middle/last name
- DOB
- Email
- Gender



Conceptual Model



Data Modeling

Technical Expertise



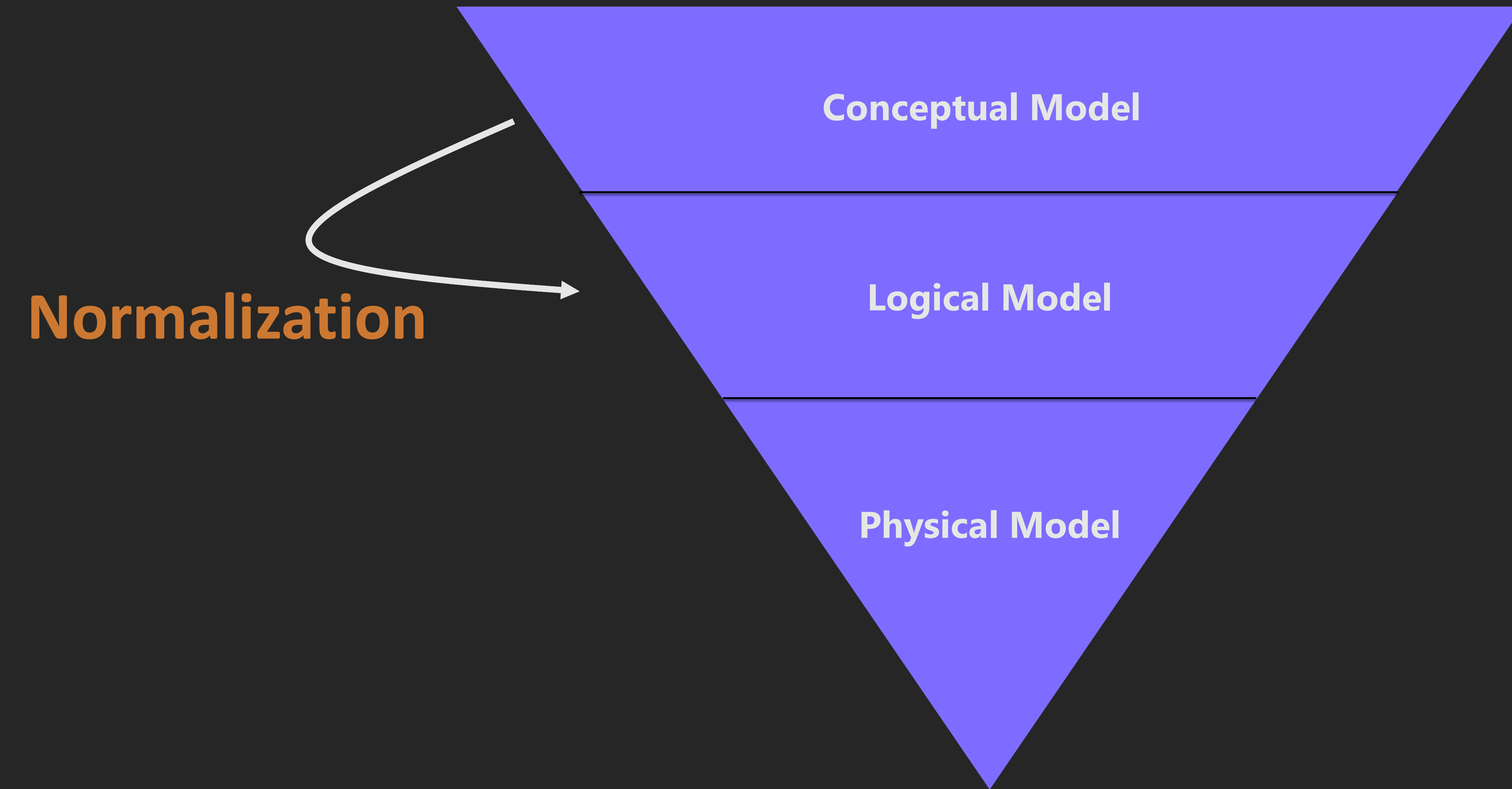
Conceptual Model

Logical Model

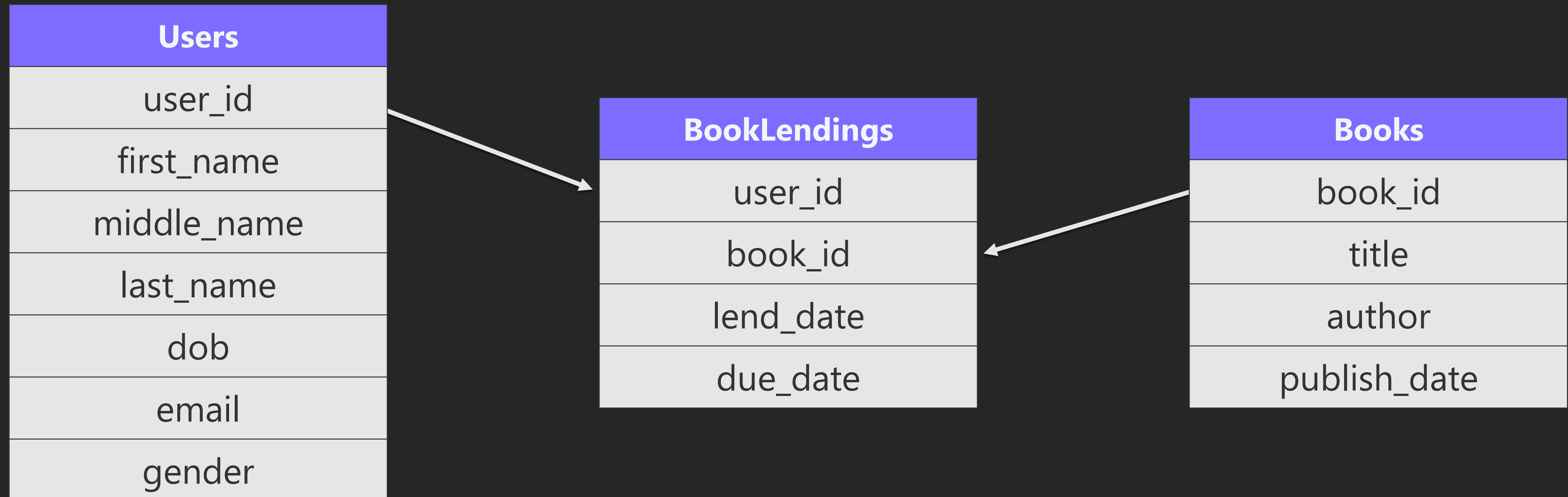
Abstraction



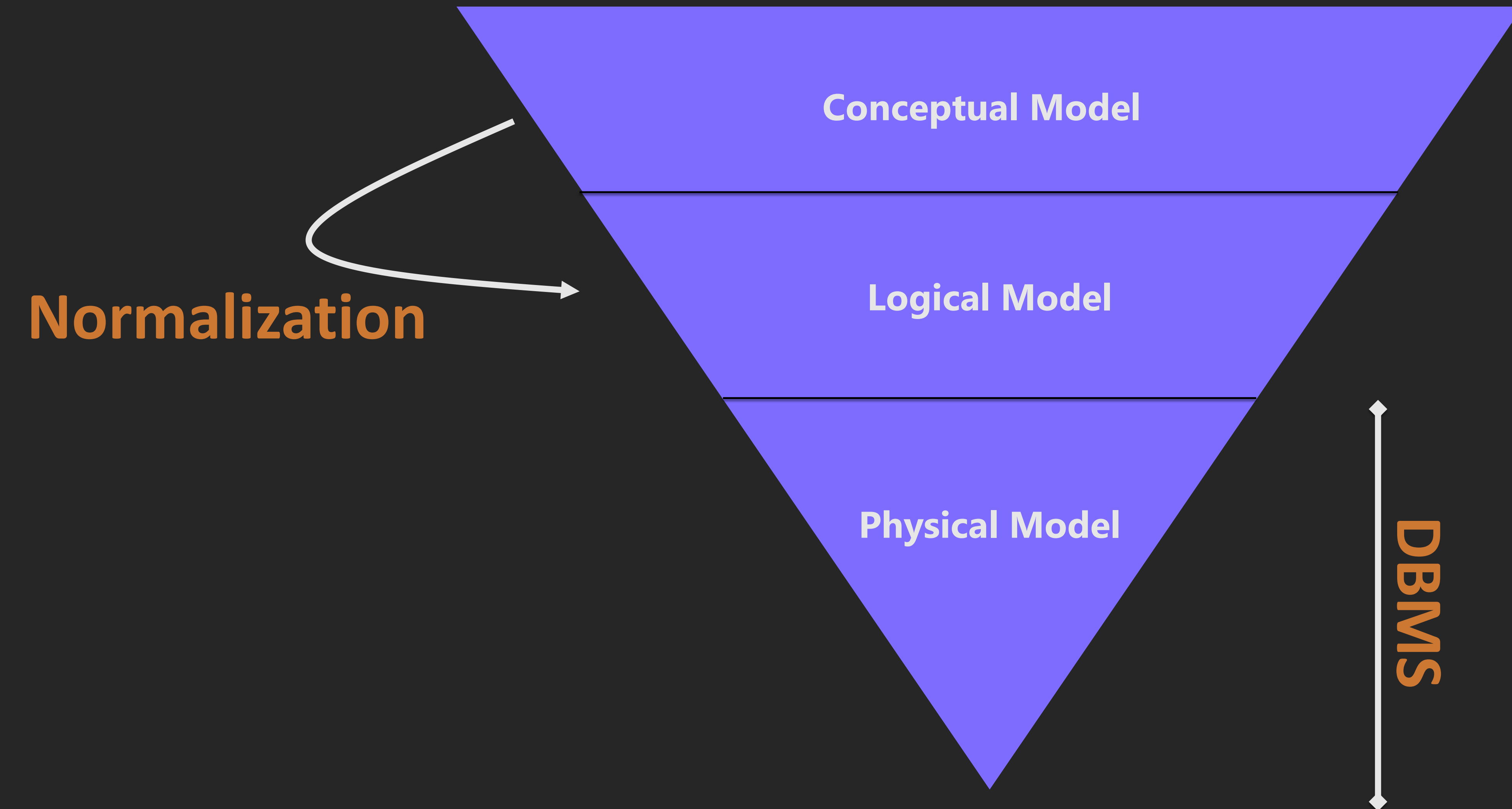
Data Modeling



Data Modeling



Data Modeling



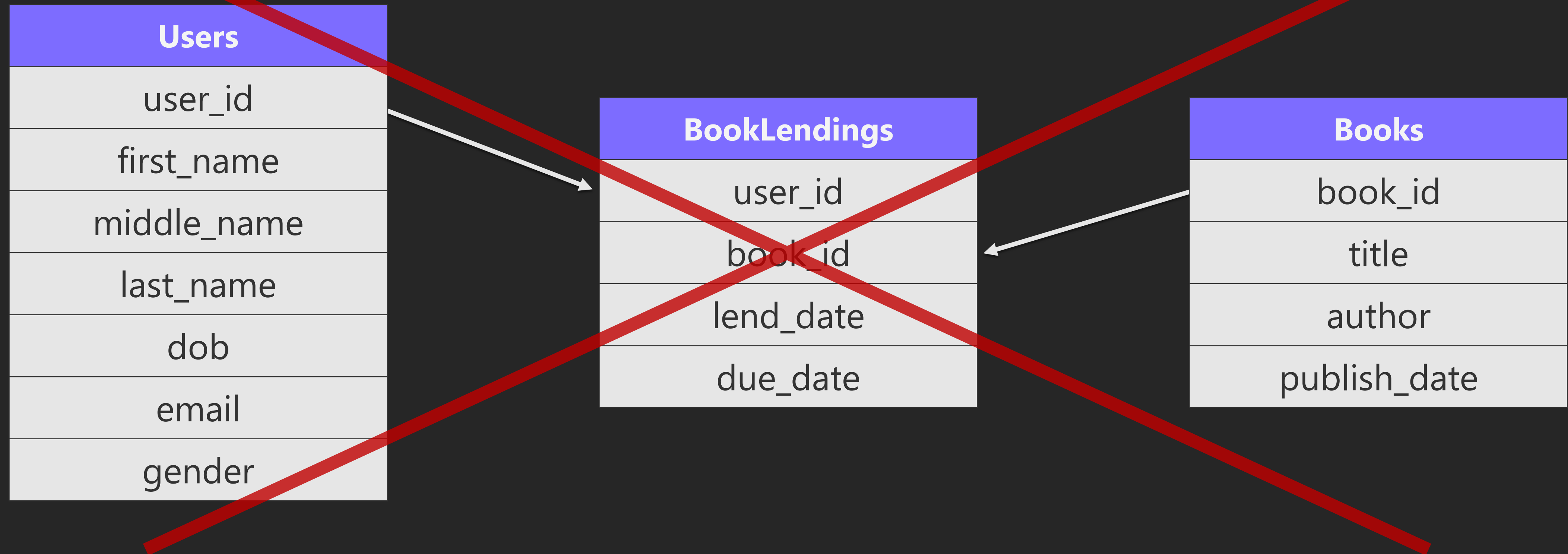
Introducing Grakn



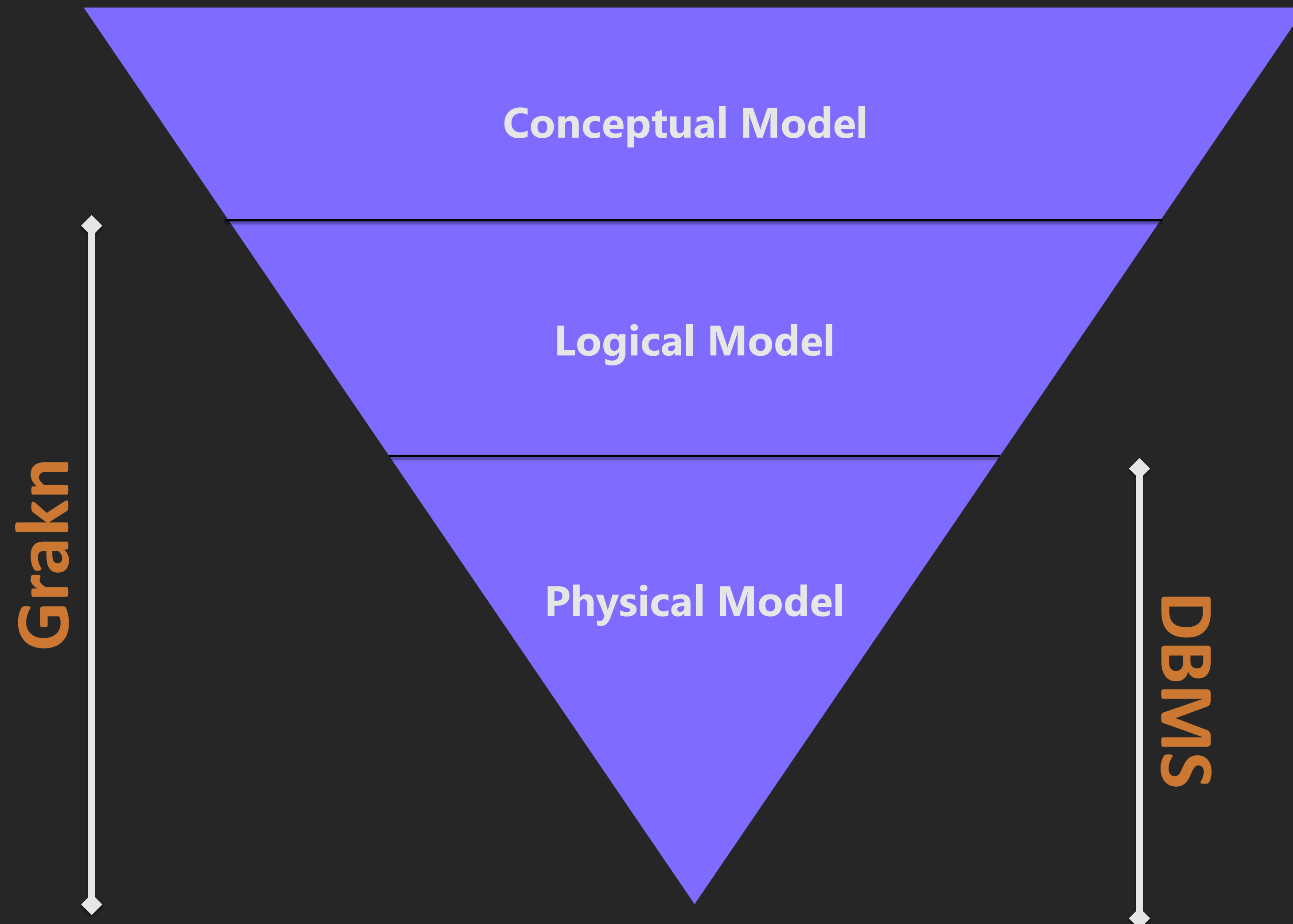
GRAKN.AI

Knowledge Representation System

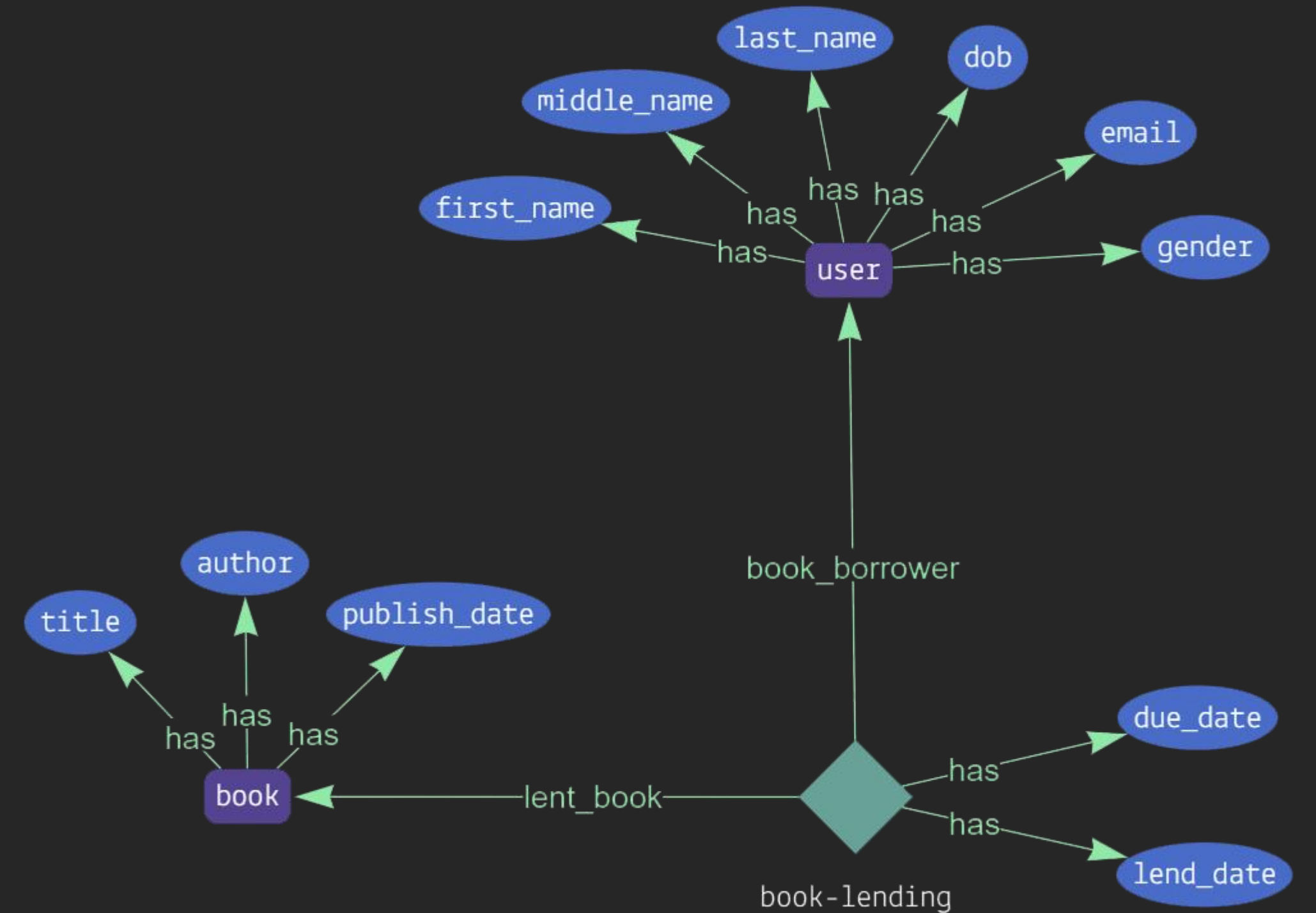
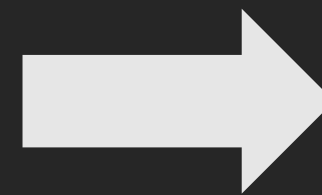
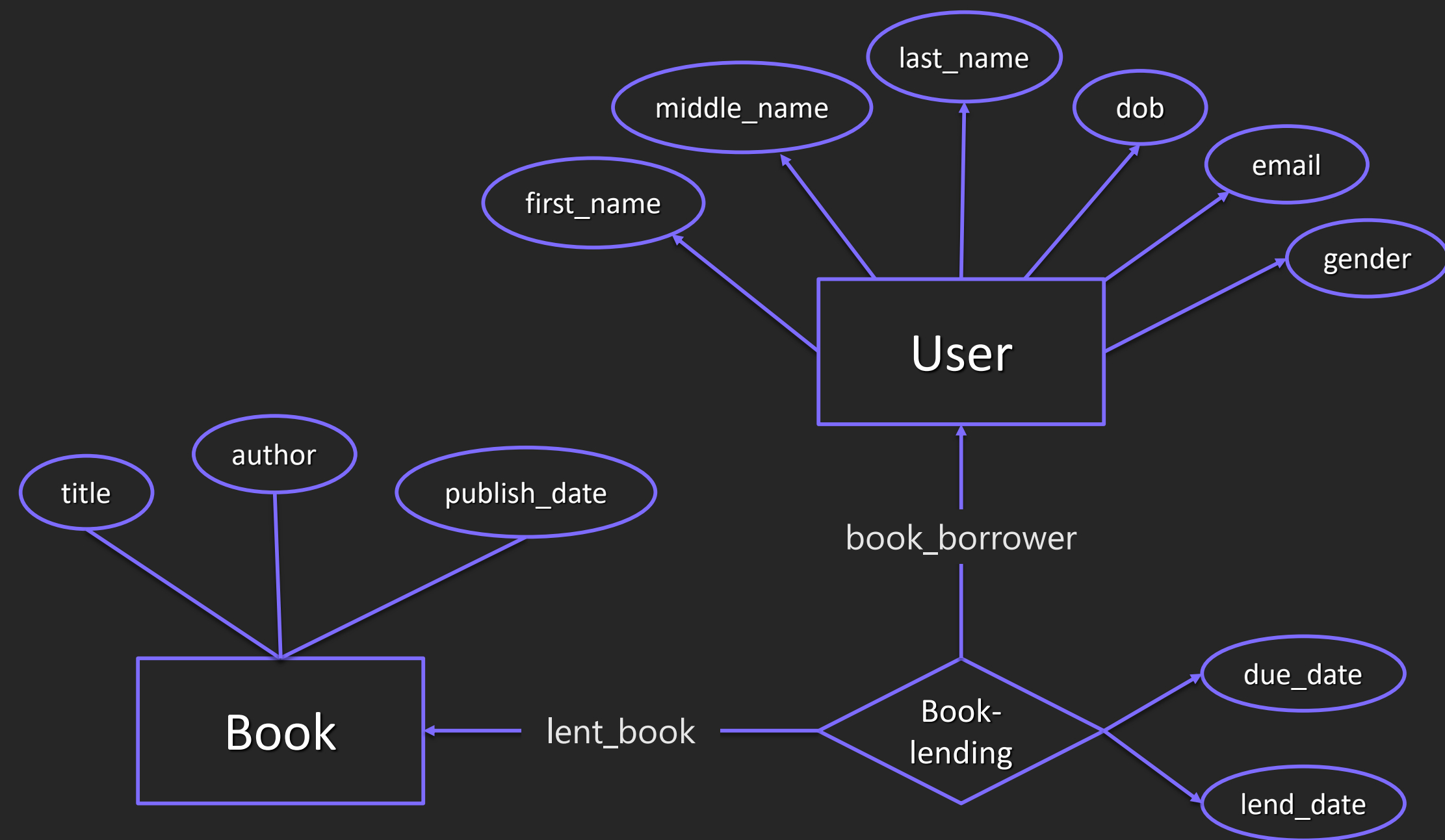
Data Modeling



Data Modeling

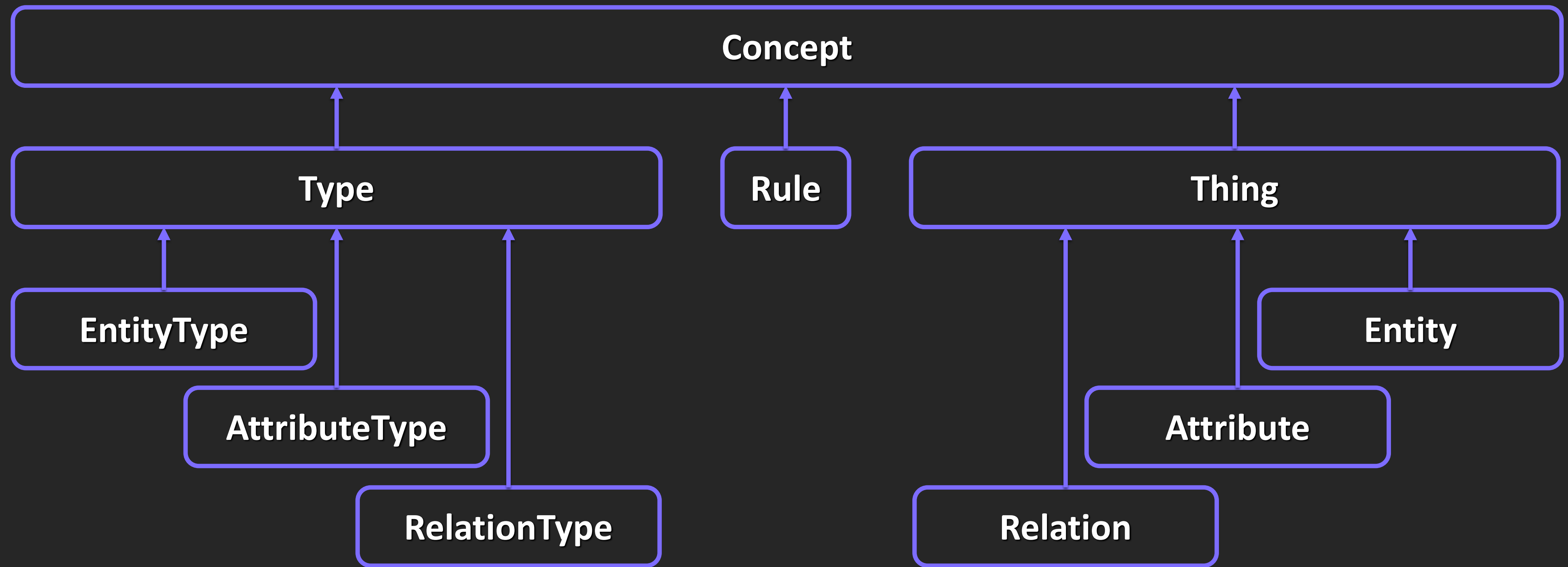


Data Modeling



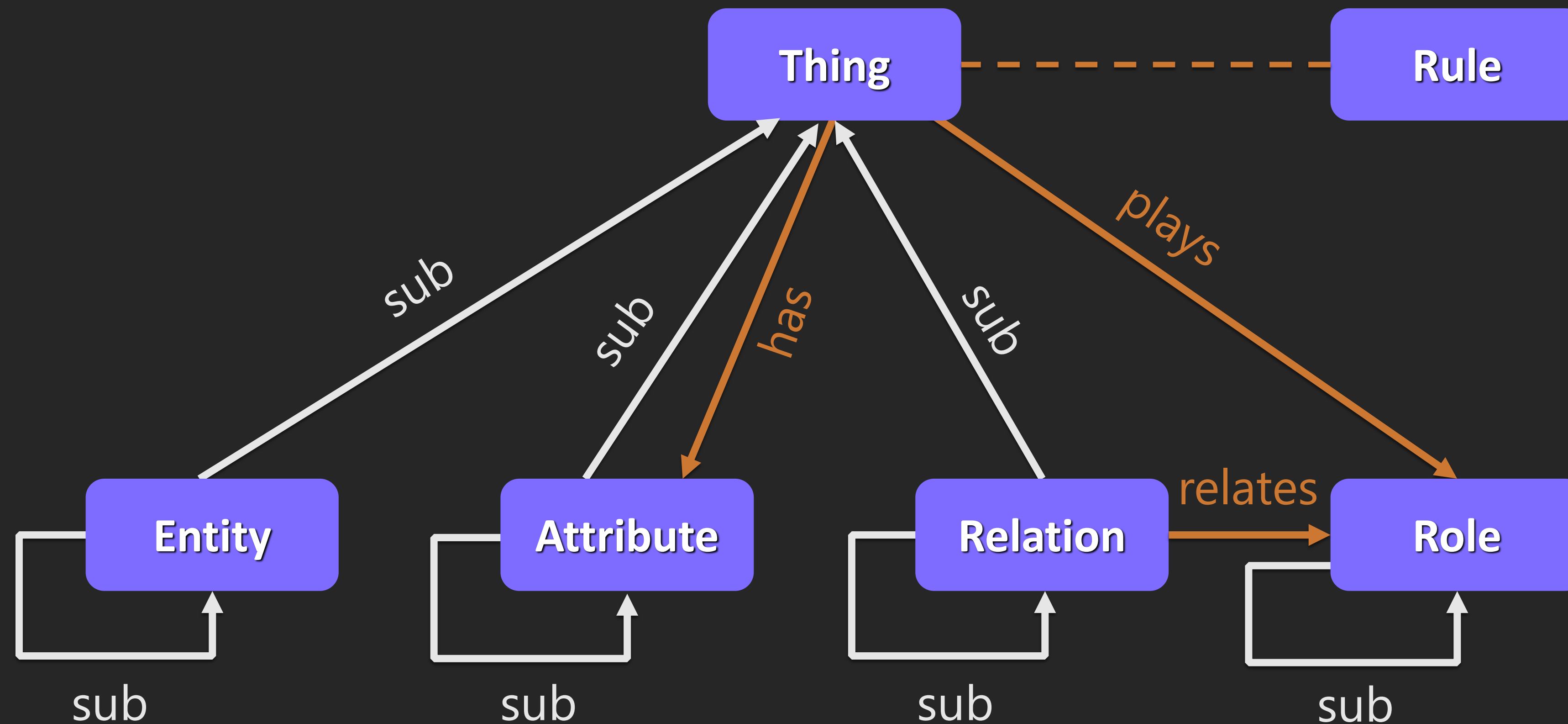
Grakn Ontology

A highly expressive and intelligent
type system for your complex data

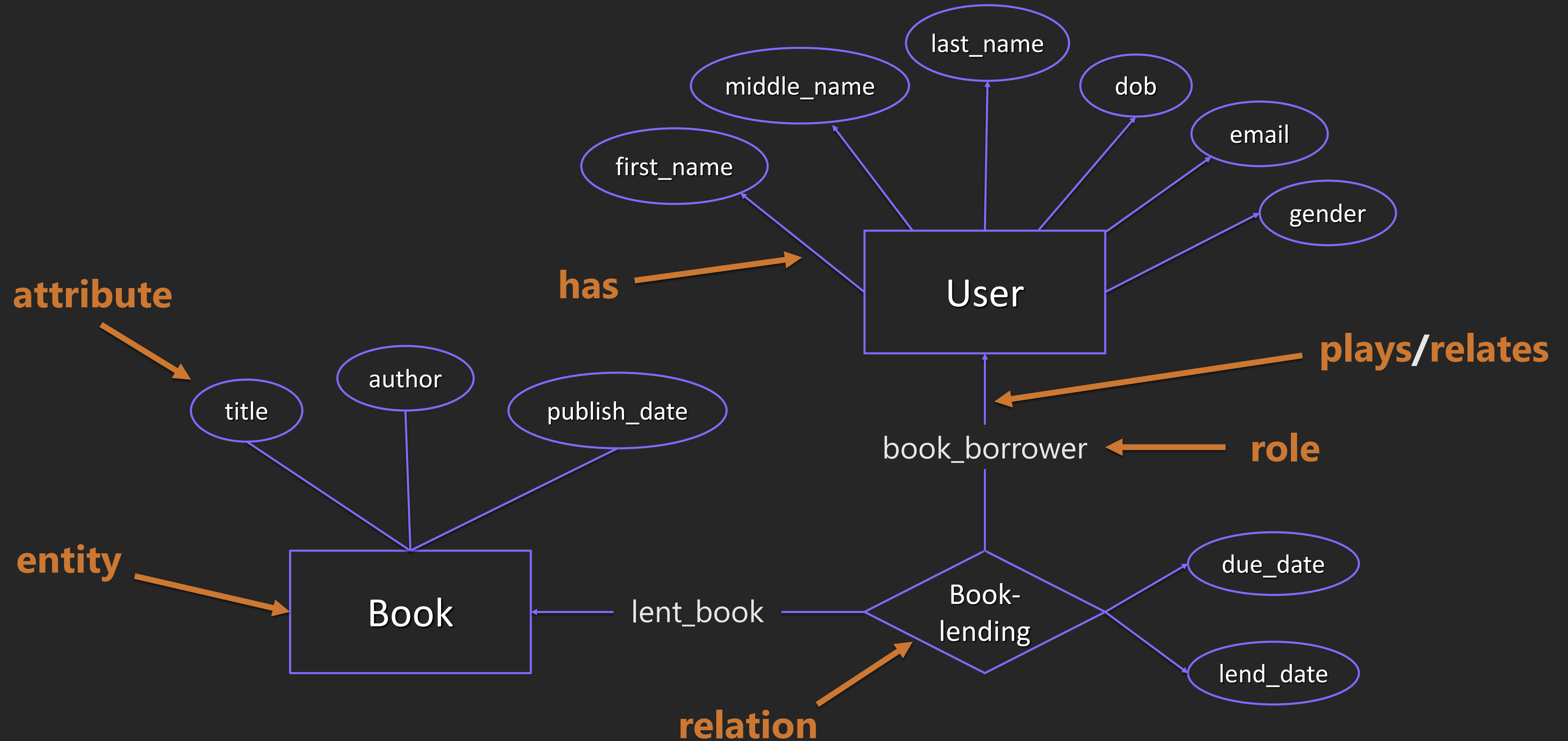


Knowledge Model

A schema which can represent:
type hierarchies, hyper-relations and rules

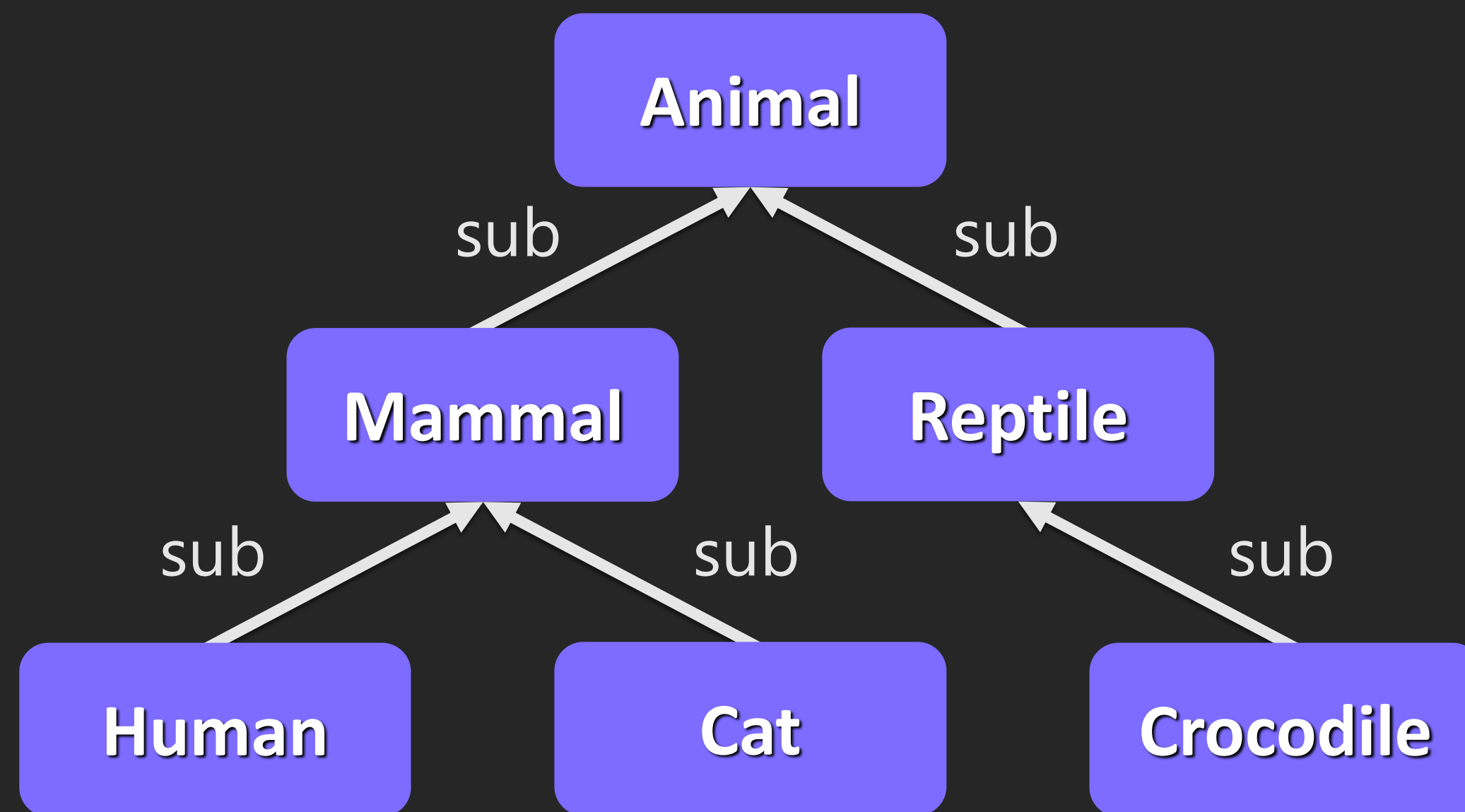


Knowledge Model

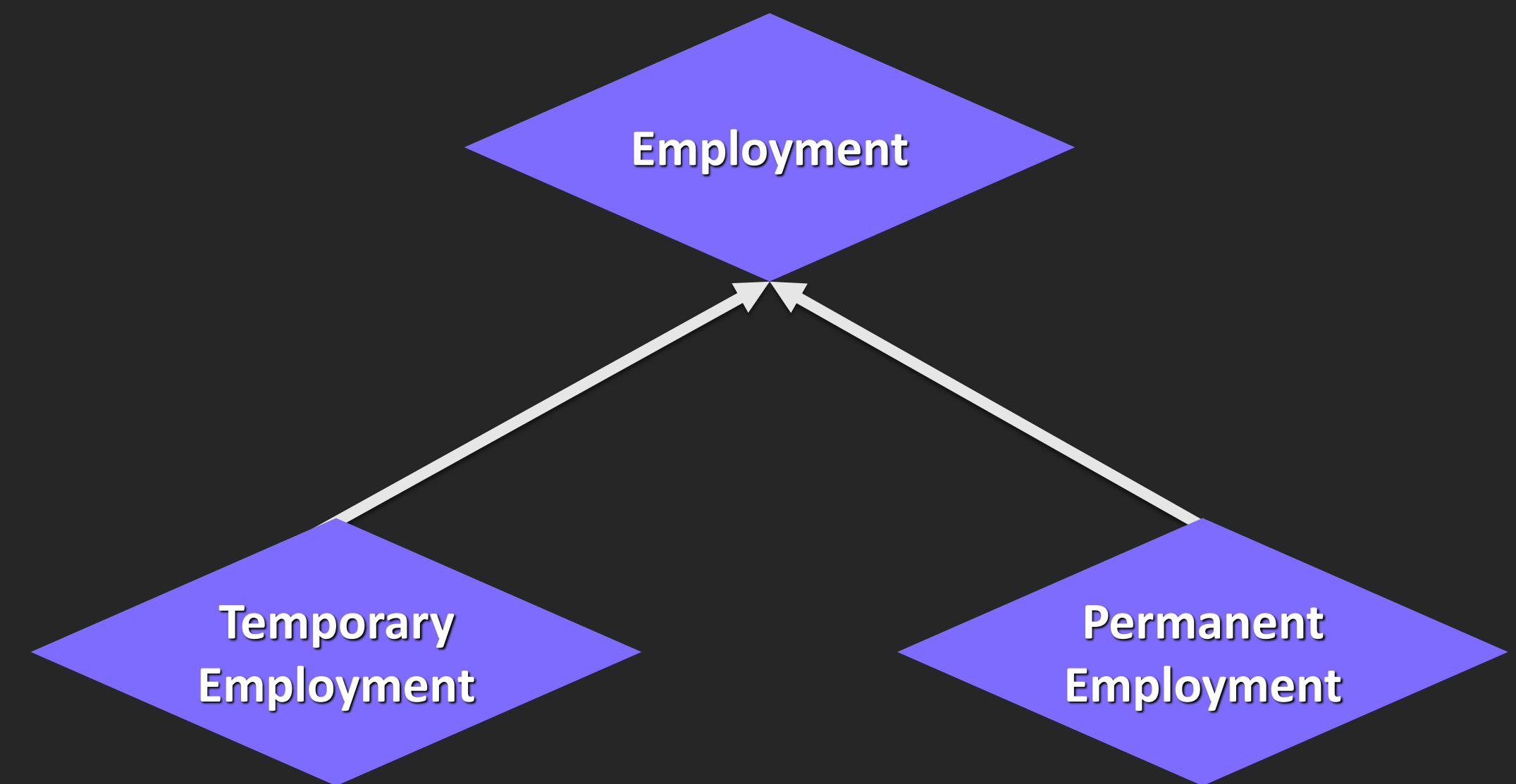


Grakn Modeling – Hierarchies

Entity Type Hierarchies

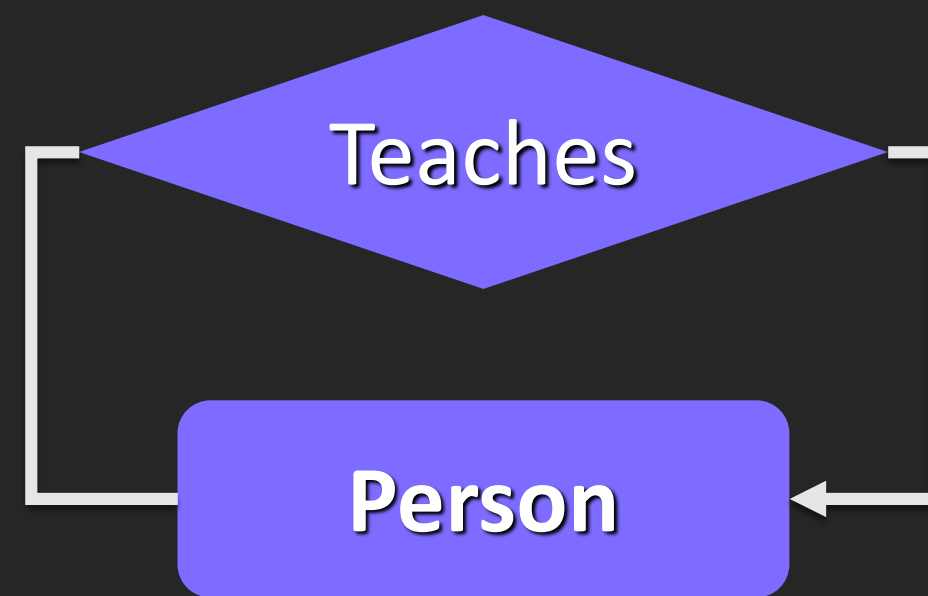


Relation Type Hierarchies

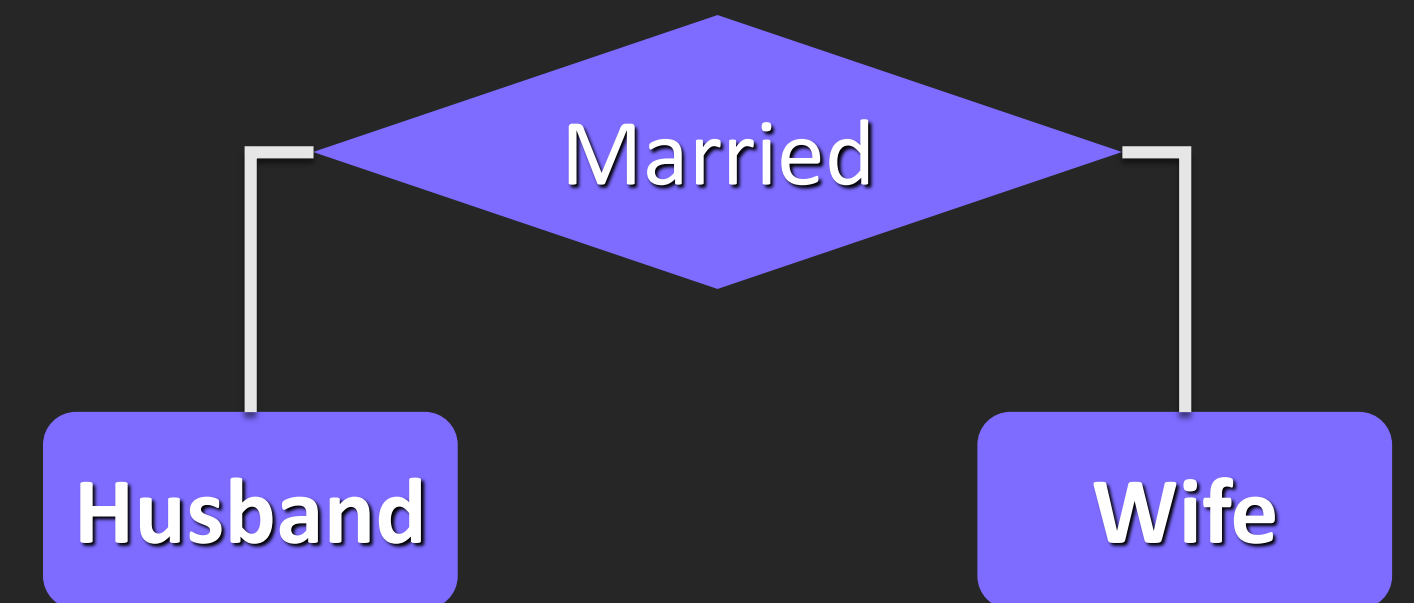


Grakn Modeling – Relations

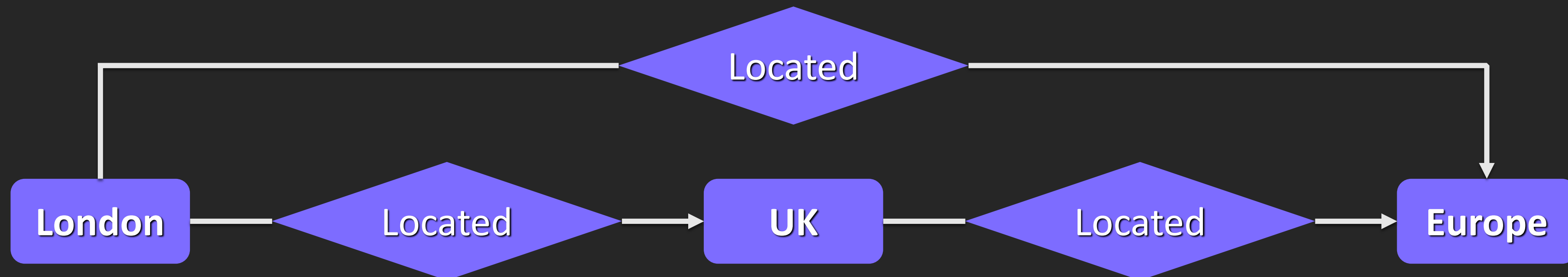
Reflexive Relations



Symmetric Relations

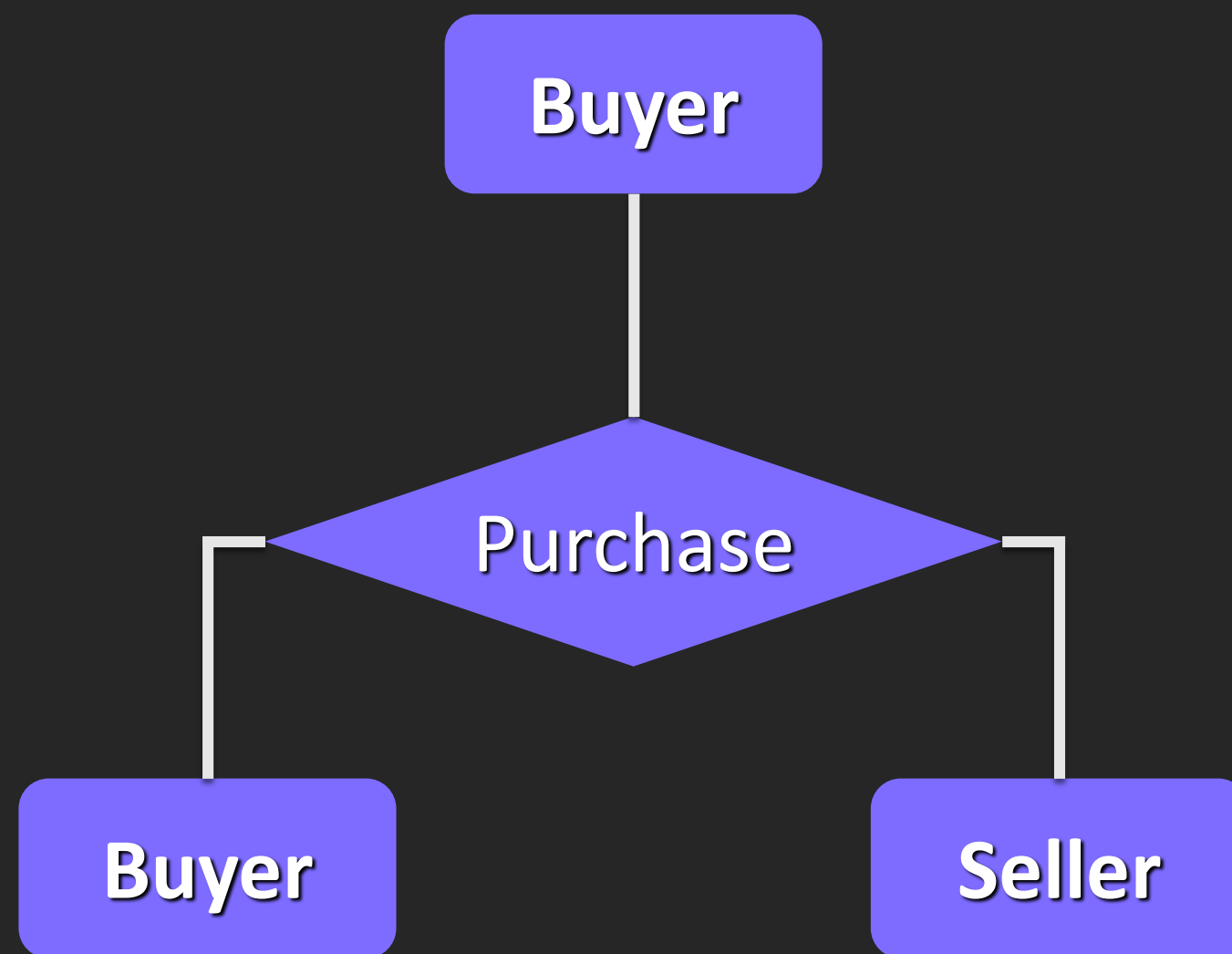


Transitive Relations

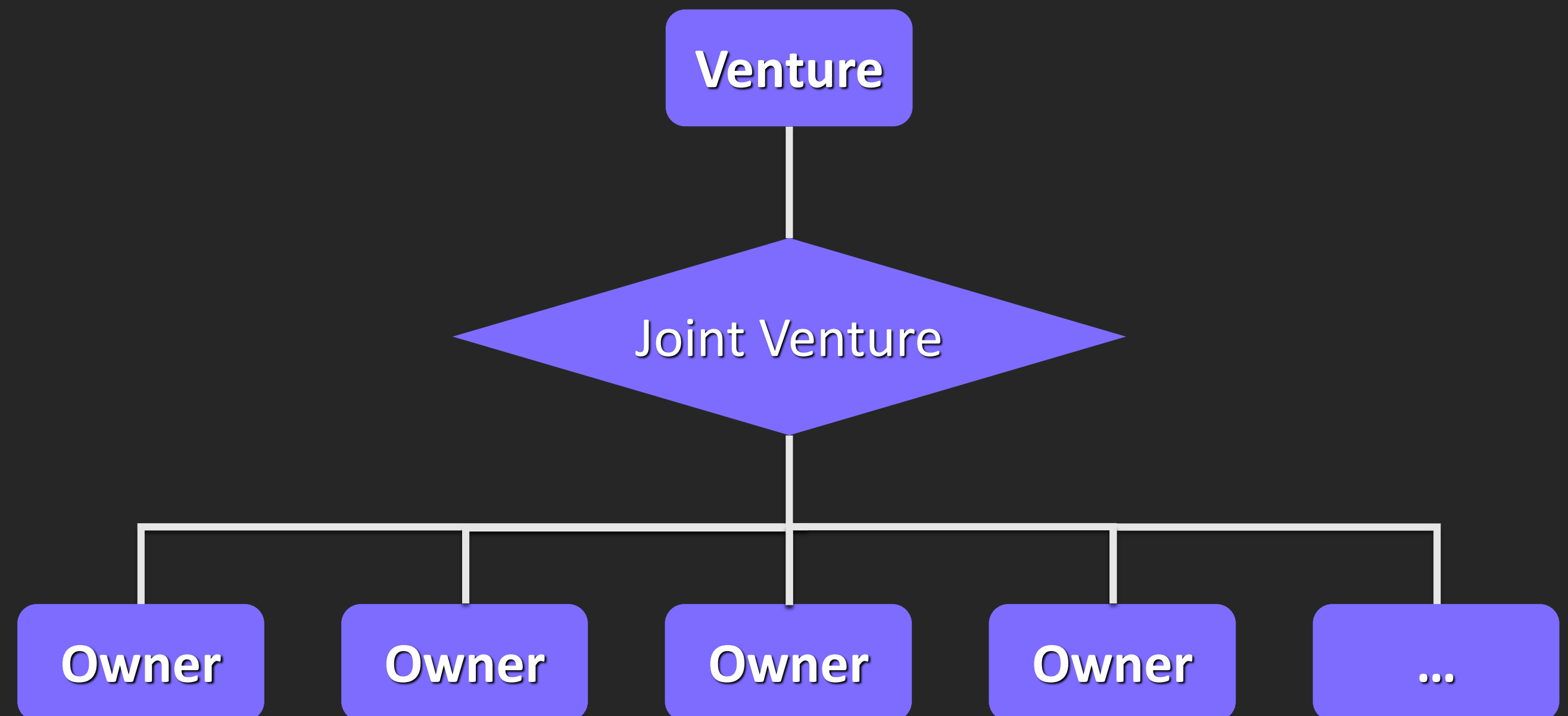


Grakn Modeling – Relations

Ternary Relations

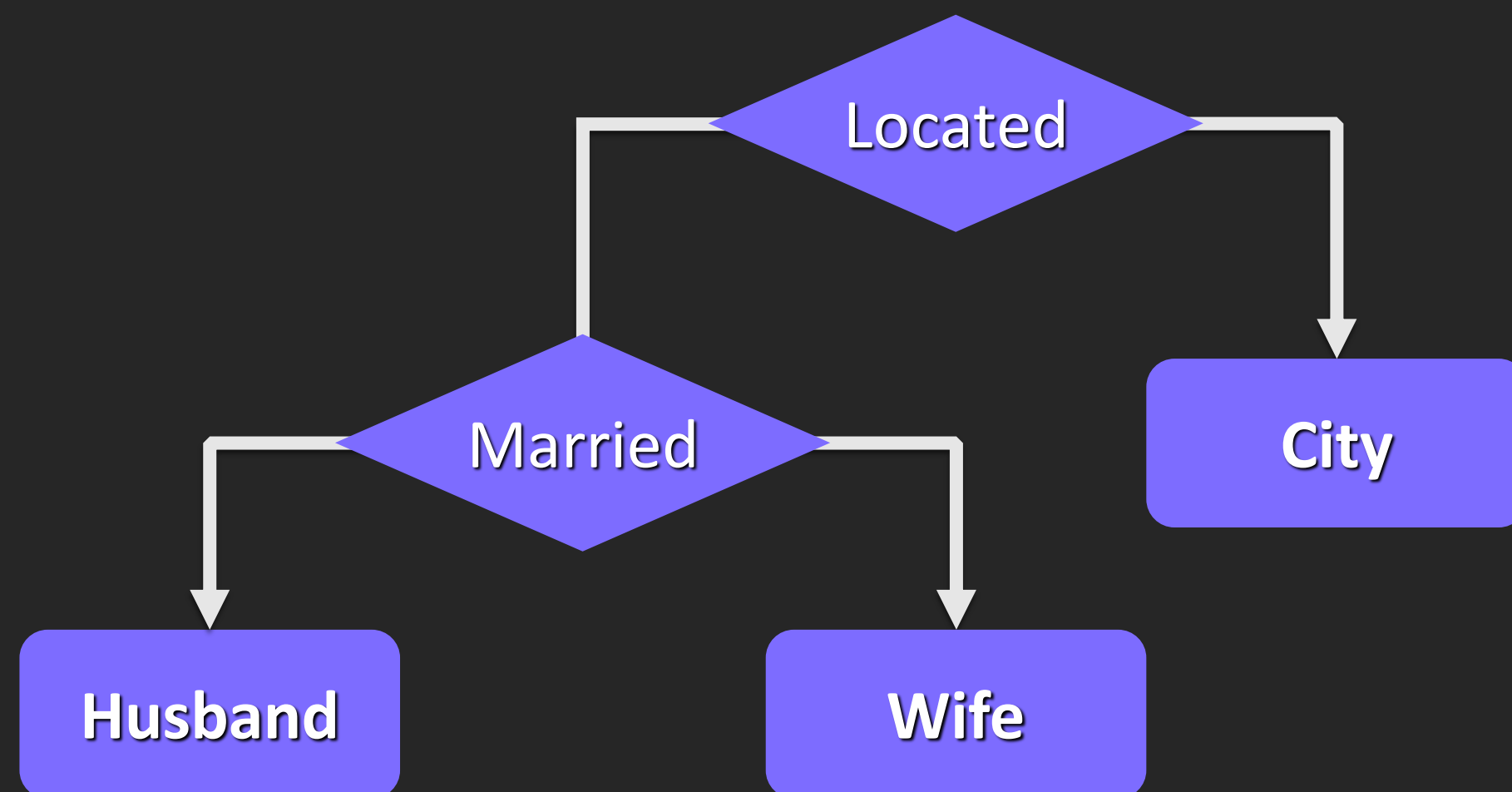


Infinitary Relations

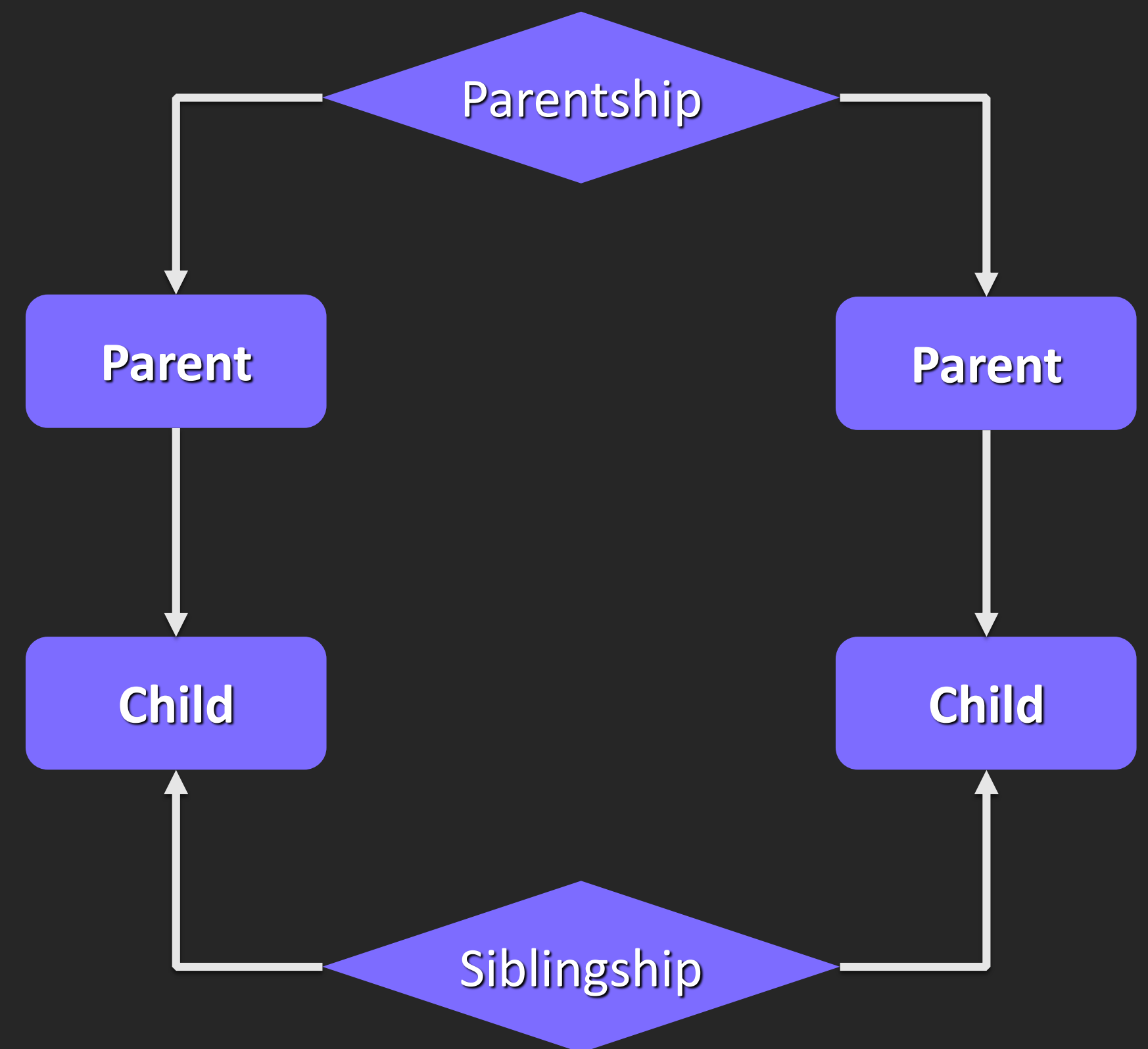


Grakn Modeling – Relations

Nested Relations



Equivalent Relations



Grakn Modeling – Tips



Model incrementally

- Start with questions you want answered now

Be as specific as possible

- father > parent

Relations are first-class citizens

- No foreign keys!

Generally: Tables are entities, rows are instances, columns are attributes

- Associative/junction tables are relations

Unconnected data is hard to reach

- Relations provide easy access to connected data

No such thing as nulls

- The absence of value indicates the lack of value

Prefer ingesting non-changing data (facts) over syncing volatile data

- Represent new data (new facts) with additional values

Introducing Graql

Commands

CREATE/ALTER TABLE

->

define

SELECT+WHERE

->

match+get

INSERT INTO

->

insert

DELETE

->

delete

DROP TABLE

->

undefine

UPDATE

->

match+delete+insert

Data Types

NUMERIC

->

long

DECIMAL

->

double

TEXT

->

string

BOOLEAN

->

boolean

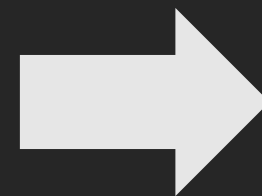
DATE

->

date

Defining Schemas

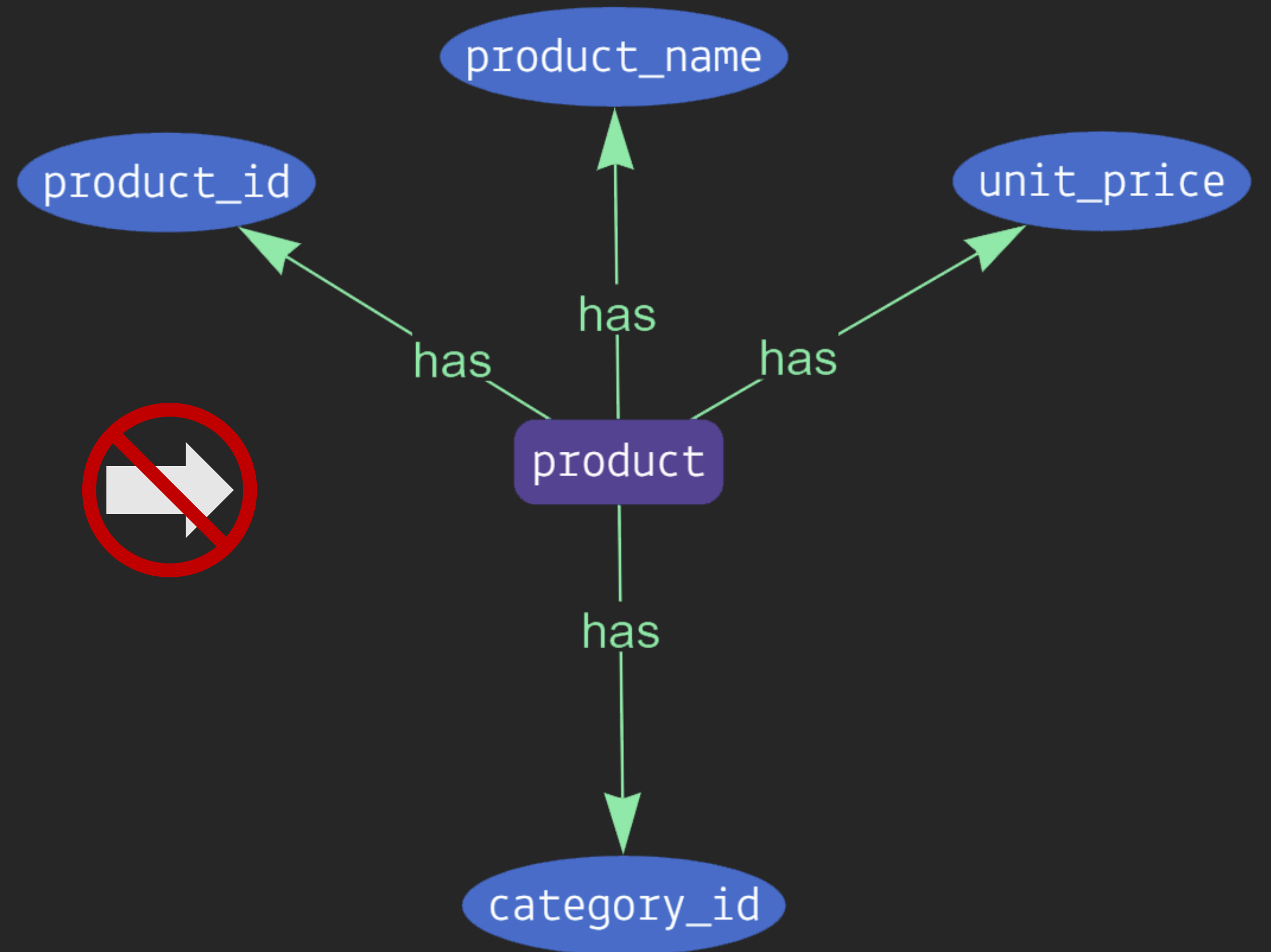
Products
ProductId
ProductName
CategoryId
UnitPrice



```
CREATE TABLE products (  
    product_id smallint NOT NULL PRIMARY KEY,  
    product_name character varying(40) NOT NULL,  
    category_id smallint,  
    unit_price float,  
    FOREIGN KEY (category_id) REFERENCES categories  
);
```

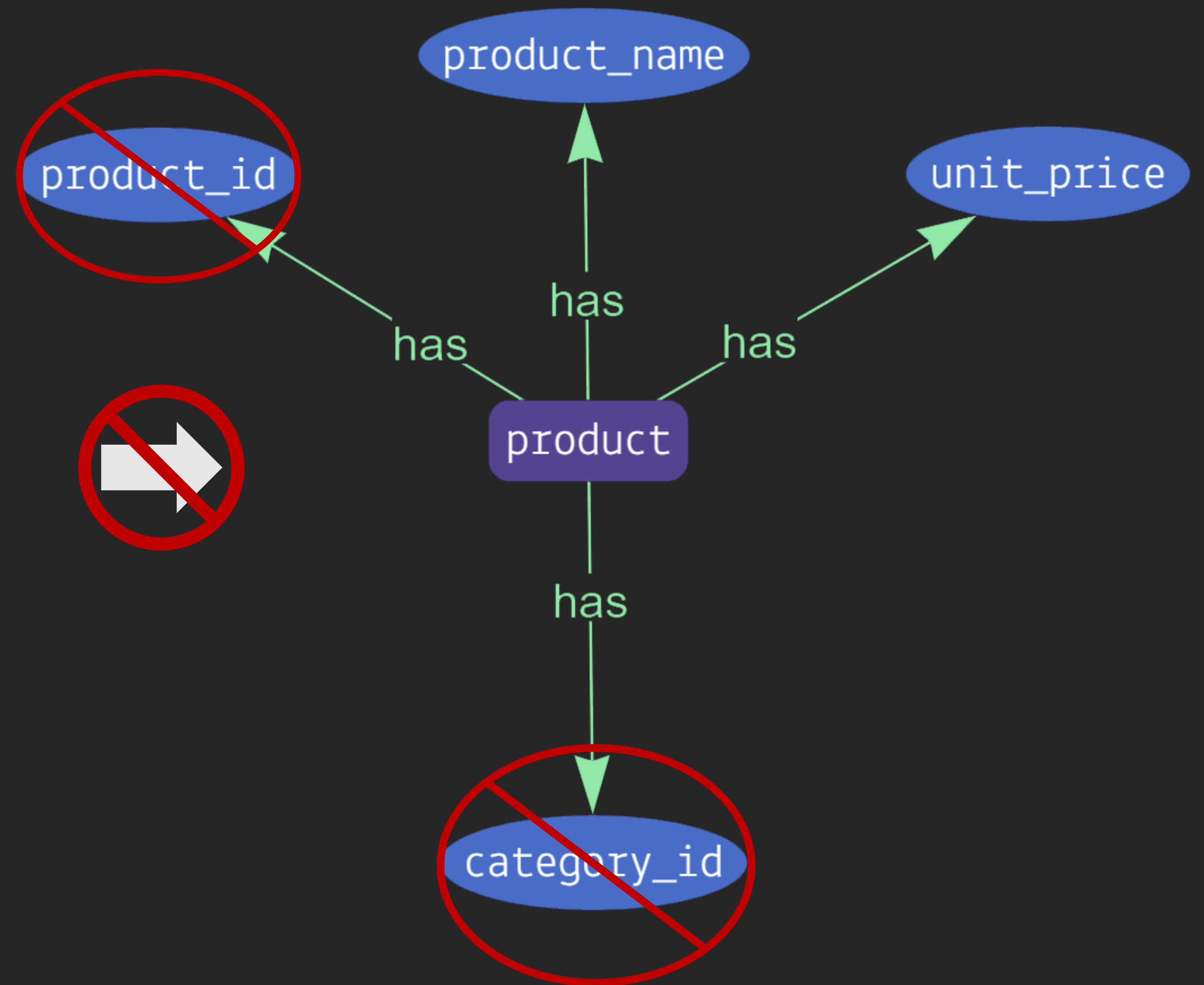
Defining Schemas

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```



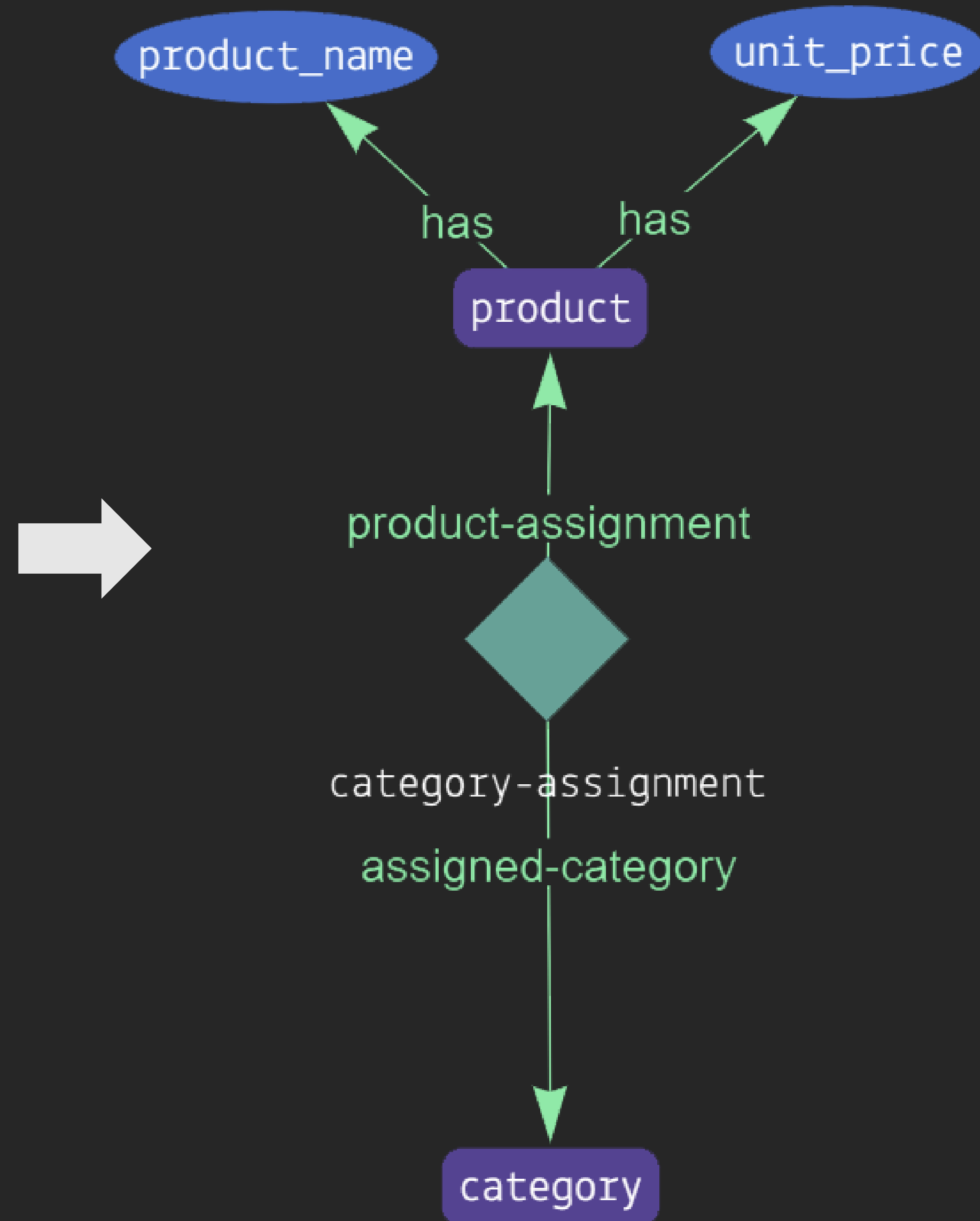
Defining Schemas

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  product_name character varying(40) NOT NULL,  
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  unit_price float,  
  FOREIGN KEY (category_id) REFERENCES categories  
);
```



Defining Schemas

```
CREATE TABLE products (  
  product_id smallint NOT NULL PRIMARY KEY,  
  product_name character varying(40) NOT NULL,  
  category_id smallint,  
  unit_price float,  
  FOREIGN KEY (category_id) REFERENCES categories  
);
```



SQL

```
CREATE TABLE products (  
  product_id smallint NOT NULL PRIMARY KEY,  
  product_name character varying(40) NOT NULL,  
  category_id smallint,  
  unit_price float,  
  FOREIGN KEY (category_id) REFERENCES categories  
);  
  
CREATE TABLE categories (  
  category_id smallint NOT NULL PRIMARY KEY,  
  category_name character varying(40)  
);
```

Graql

```
define  
product sub entity,  
  key product_name,  
  has unit_price,  
  plays product-assignment;  
category sub entity,  
  has category_name,  
  plays assigned-category;  
  
product_name sub attribute, datatype string;  
unit_price sub attribute, datatype double;  
category_name sub attribute, datatype string;  
  
category-assignment sub relation,  
  relates assigned-category,  
  relates product-assignment;
```

SQL

```
CREATE TABLE albums (  
  album_id SMALLINT NOT NULL PRIMARY KEY,  
  album_name CHARACTER VARYING(40) NOT NULL,  
  release_date DATE NOT NULL,  
  artist_id SMALLINT NOT NULL,  
  FOREIGN KEY (artist_id) REFERENCES artists  
);  
  
CREATE TABLE artists (  
  artist_id smallint NOT NULL PRIMARY KEY,  
  artist_name character varying(40)  
);
```

Graql

★ Fill in the Blanks ★

```
_____   
album sub _____,  
  key album_name,  
  has release_date,  
  _____ released_album;  
artist sub entity,  
  ____ artist_name,  
  plays releasing_artist;  
  
album-release sub relation,  
  relates released_album,  
  relates releasing_artist;  
  
album_name sub _____, datatype string;  
release_date sub attribute, datatype date;  
artist_name sub attribute, datatype _____;
```

★ Fill in the Blanks ★

SQL

category_id	category_name
product_id	product_name
100	Candy



```
INSERT INTO categories (category_id, category_name)
VALUES (100, 'Candy');
```

Graql

category_name: Candy

has

category: V4128 \$c

```
insert $c isa category,
  has category_name "Candy";
```


SQL

```
INSERT INTO artists (artist_id, artist_name)
VALUES (1, 'Michael Jackson');
```

Graql

★ Fill in the Blanks ★

```
_____ $a isa _____,
has _____ "Michael Jackson";
```

★ Fill in the Blanks ★

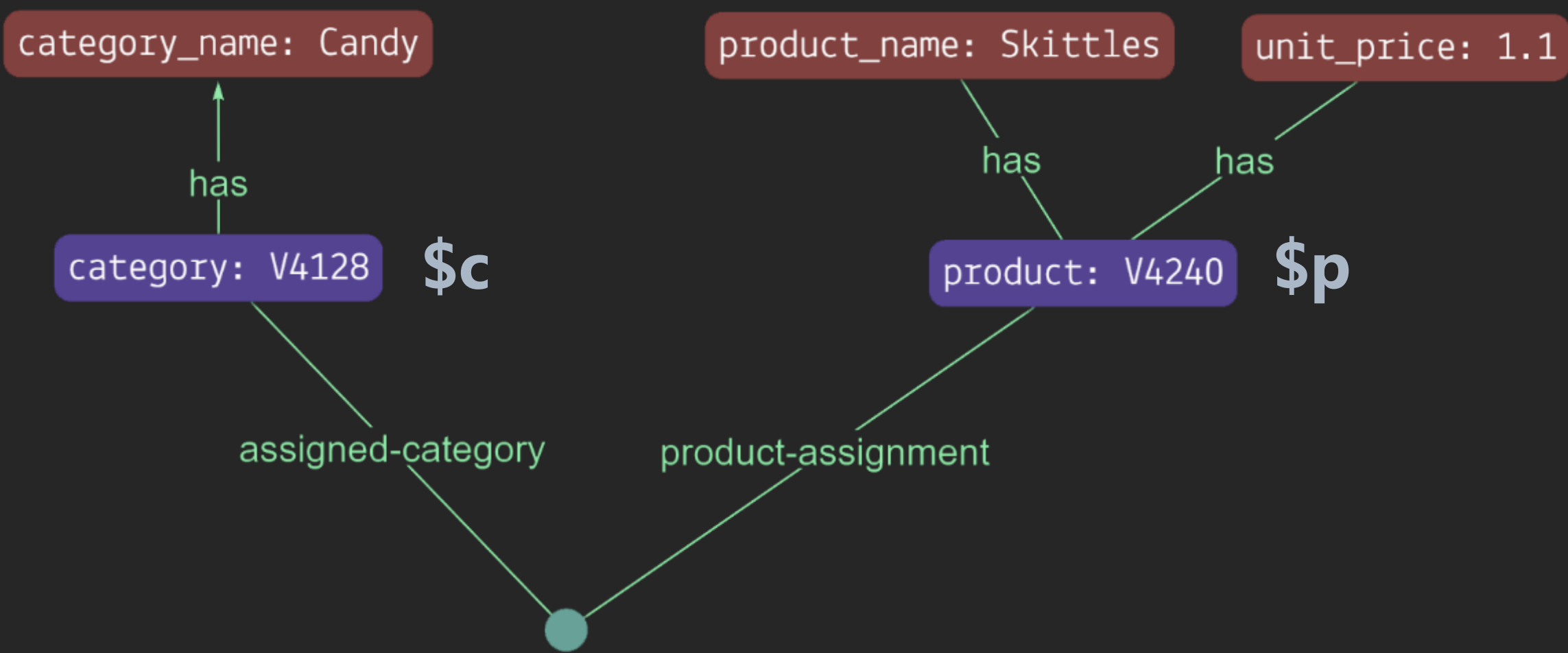
SQL

category_id		category_name	
100		Candy	

product_id	product_name	category_id	unit_price
99	Skittles	100	1.10

```
INSERT INTO products
  (product_id, product_name, category_id, unit_price)
SELECT 99, 'Skittles', category_id, 1.10
FROM categories
WHERE category_name = 'Candy';
```

Graql



```
match
  $c isa category, has category_name "Candy";
insert
  $p isa product, has product_name "Skittles", has unit_price 1.10;
  (product-assignment: $p, assigned-category: $c)
  isa category-assignment;
```

SQL

Graql

★ Fill in the Blanks ★

```
INSERT INTO albums
  (album_id, album_name, release_date, artist_id)
SELECT 1, 'Bad', to_date('1987-08-31','YYYY-MM-DD'), artist_id
FROM artists
WHERE artist_name = 'Michael Jackson';
```

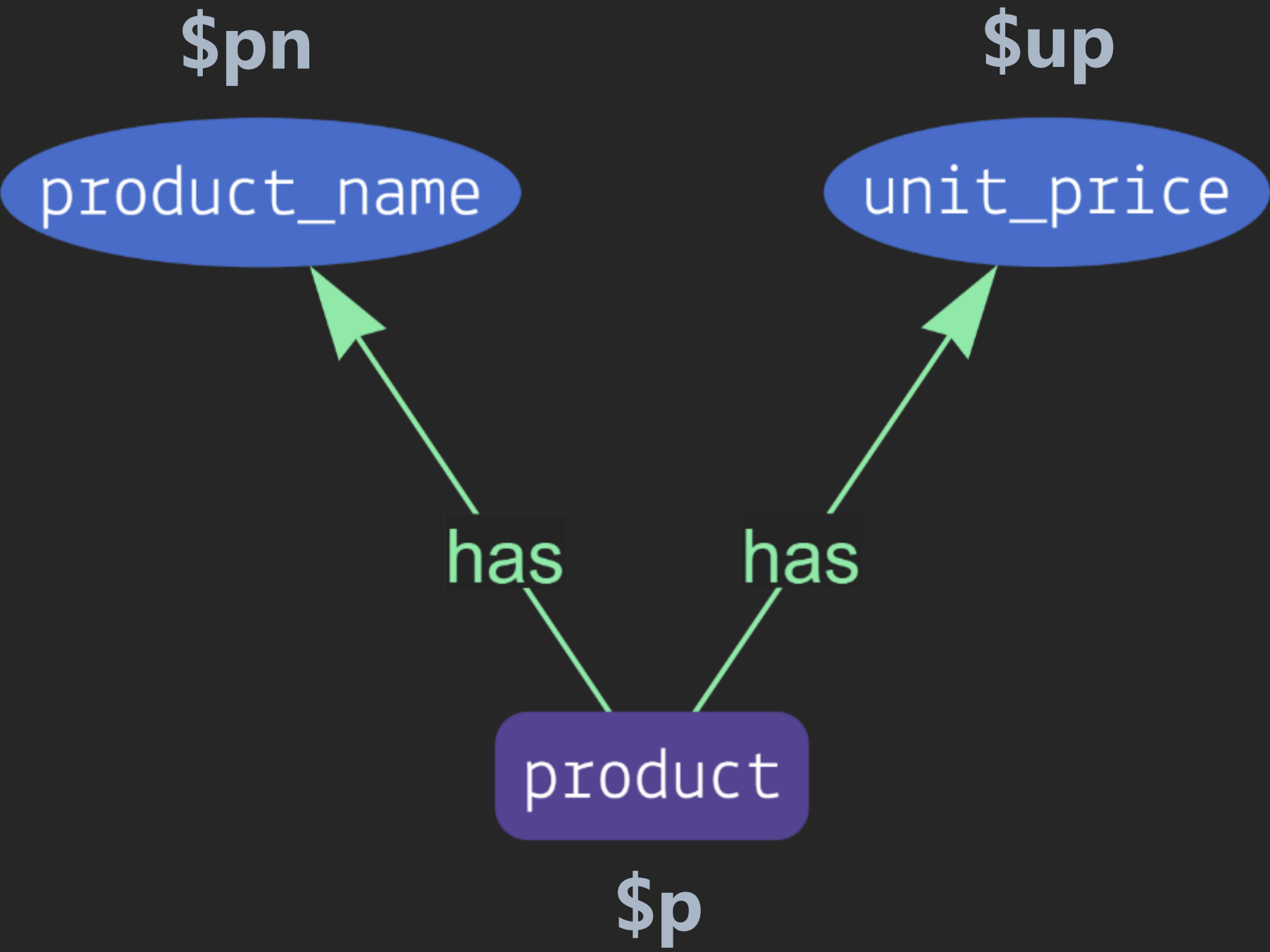
```
____
__ isa artist, ____ artist_name "Michael Jackson";
insert
__ isa album,
  has album_name "Bad",
  has release_date 1987-08-31;
(released_album: $al, releasing_artist: $ar) ____ album-release;
```

★ Fill in the Blanks ★

SQL

Graql

product_id	product_name	category_id	unit_price



SELECT product_name, unit_price
FROM products;

match
\$p isa product,
 has product_name \$pn,
 has unit_price \$up;
get \$pn, \$up;

SQL

```
SELECT album_name, release_date  
FROM albums;
```

Graql

★ Fill in the Blanks ★

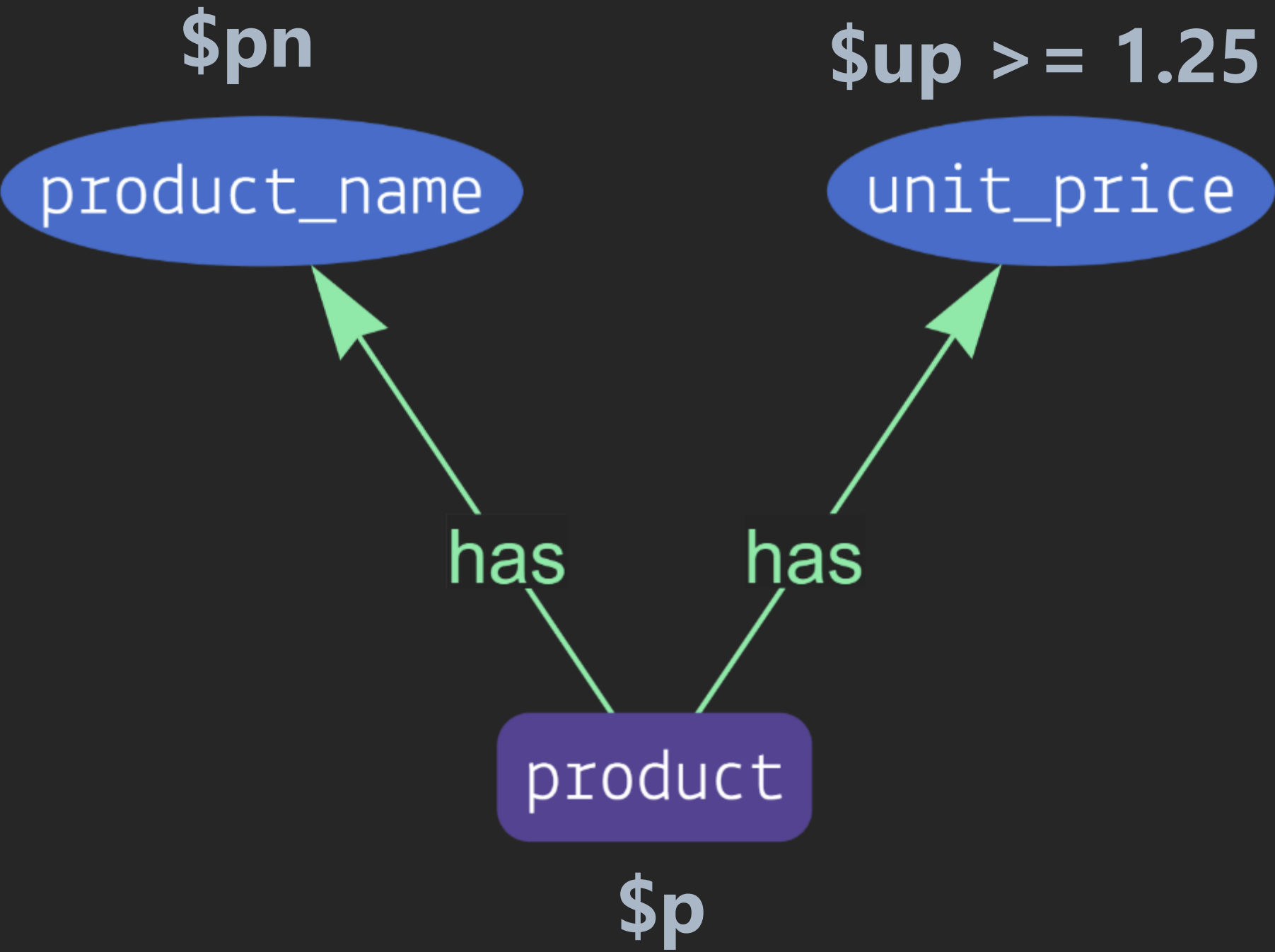
```
match  
$a ____ album,  
  has album_name $n,  
  has release_date $r;  
get __, __;
```

★ Fill in the Blanks ★

SQL

Graql

product_id	product_name	category_id	unit_price
			>= 1.25
			>= 1.25
			>= 1.25



SELECT product_name, unit_price
FROM products
WHERE unit_price >= 1.25;

match
\$p isa product,
 has product_name \$pn,
 has unit_price \$up;
\$up >= 1.25;
get \$pn, \$up;

SQL

Graql

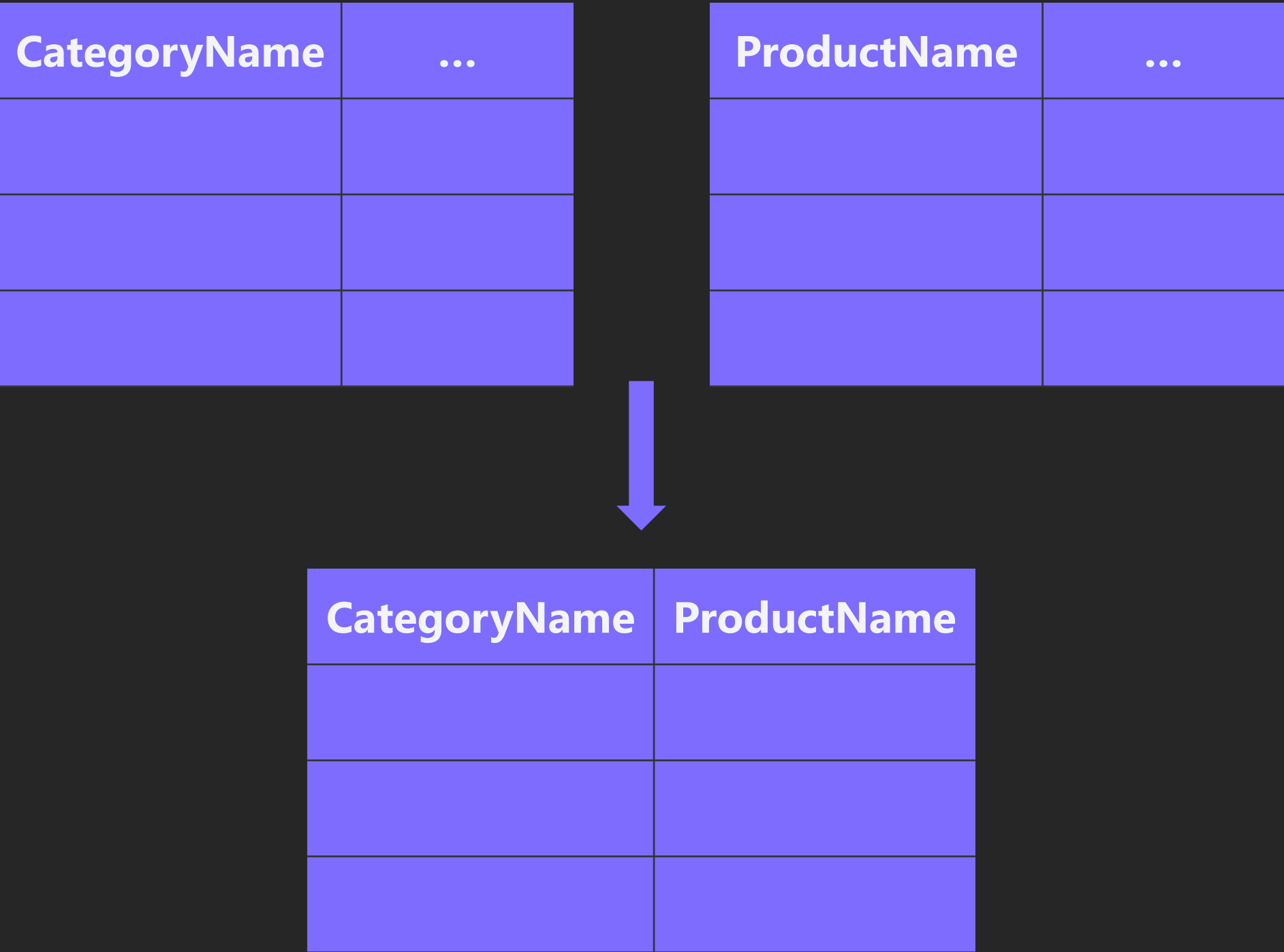
★ Fill in the Blanks ★

```
SELECT album_name, release_date
FROM albums
WHERE release_date < to_date('1990-01-01','YYYY-MM-DD');
```

```
match
$a isa album,
  has album_name $n,
  has release_date $r;
$r < 1990-01-01;
_____, ____;
```

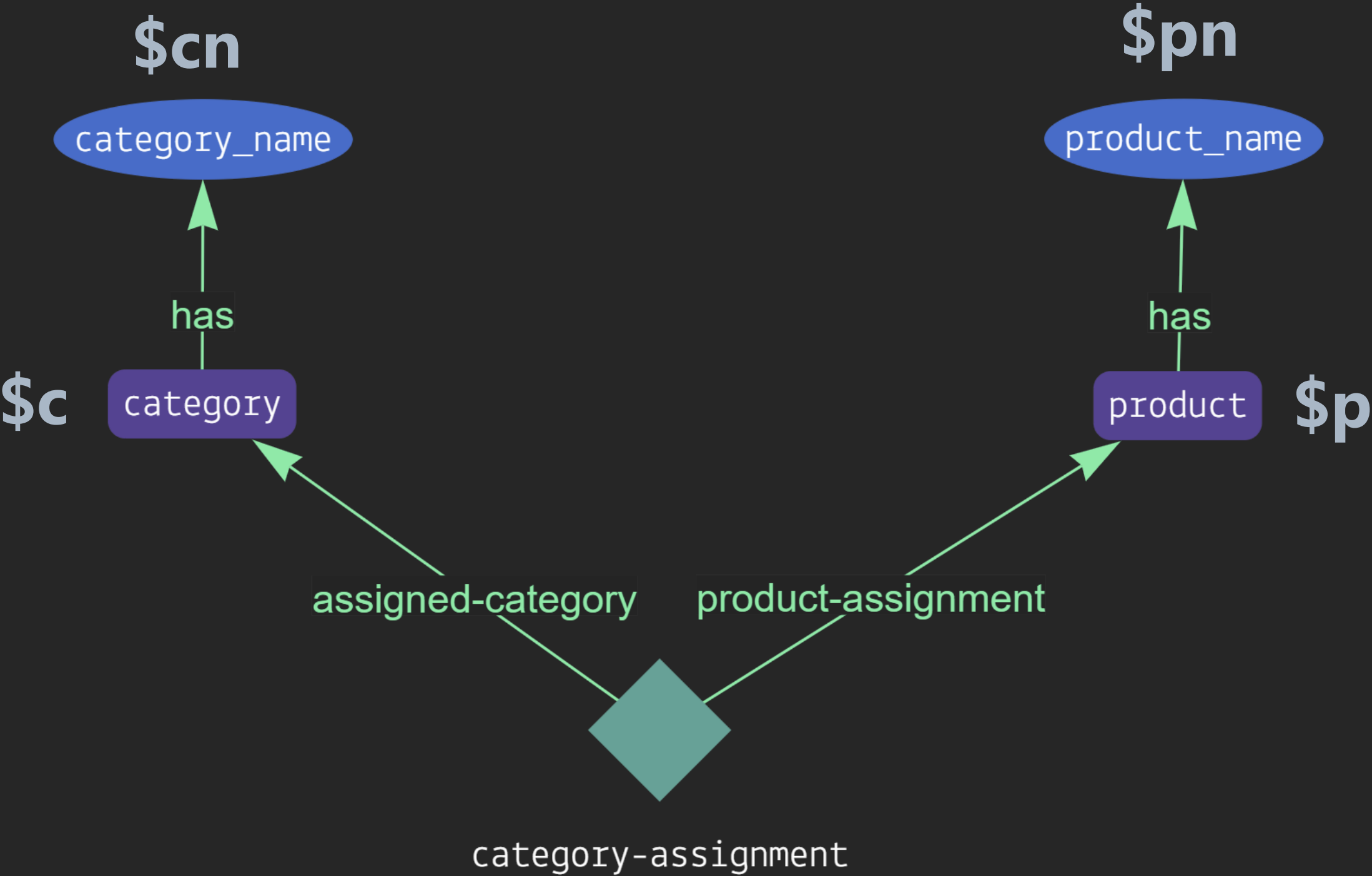
★ Fill in the Blanks ★

SQL



```
SELECT category_name, product_name
FROM categories
INNER JOIN products
ON categories.category_id = products.category_id;
```

Graql



```
match
$c isa category, has category_name $cn;
$p isa product, has product_name $pn;
($c, $p) isa category-assignment;
get $cn, $pn;
```


SQL

```
SELECT artist_name, album_name  
FROM artists  
INNER JOIN albums  
  ON artists.artist_id = albums.artist_id;
```

Graql

★ Fill in the Blanks ★

```
match  
$ar isa artist,  
  has artist_name $ar_name;  
$al isa album,  
  has album_name $al_name;  
(__, __) isa album-release;  
get $ar_name, $al_name;
```

★ Fill in the Blanks ★

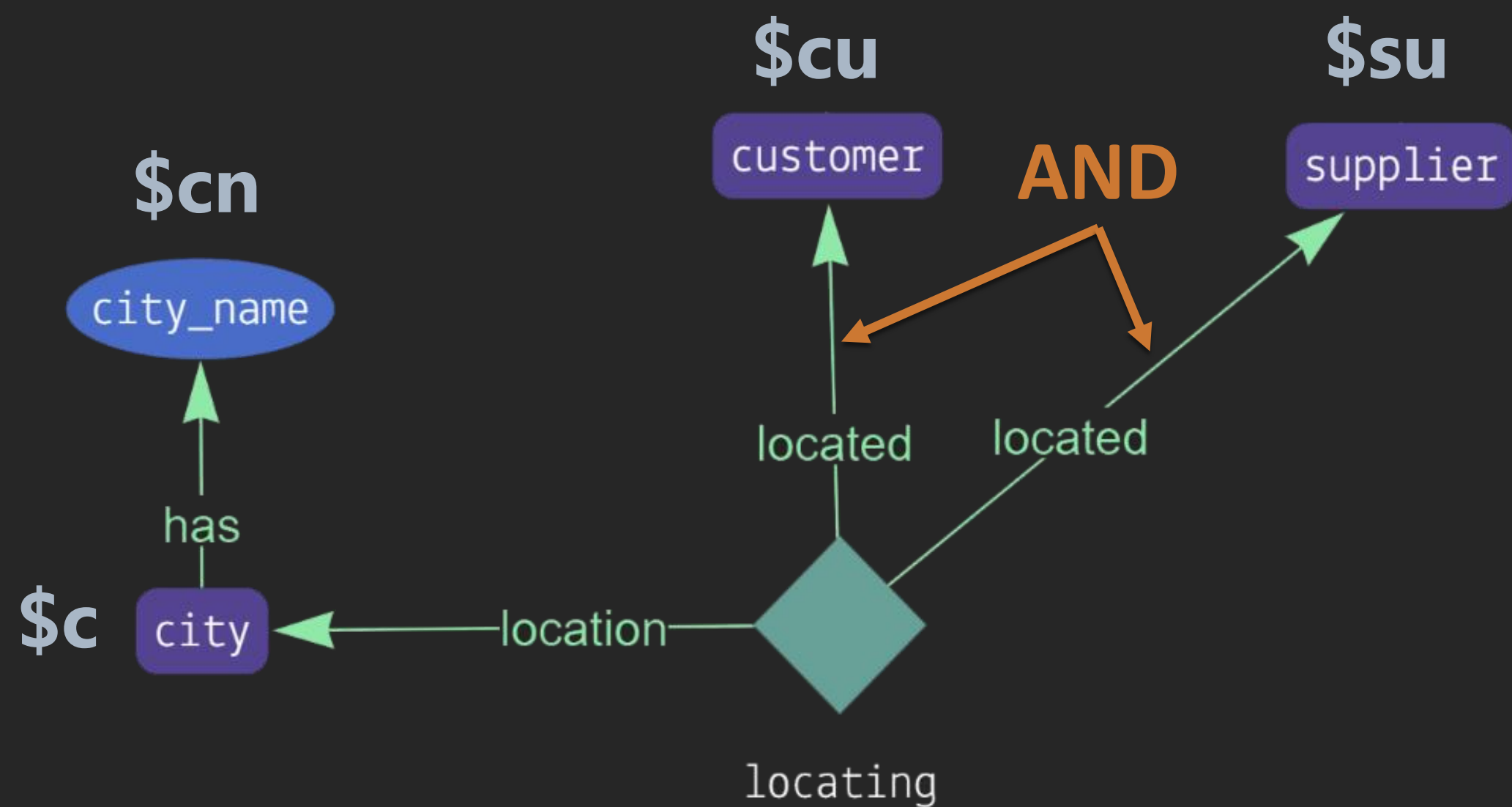
SQL

Suppliers

			city_name		Customers	
			city_name			

```
SELECT city_name
FROM customers
INTERSECT
SELECT city_name
FROM suppliers;
```

Graqi



```
match
$c isa city, has city_name $cn;
$cu isa customer; (location: $c, $cu);
$su isa supplier; (location: $c, $su);
get $cn;
```

SQL

Graql

★ Fill in the Blanks ★

```
SELECT album_name
FROM albums
INNER JOIN artists on albums.artist_id = artists.artist_id
WHERE artist_name = 'Michael Jackson'
INTERSECT
SELECT album_name
FROM albums
WHERE release_date >= to_date('2000-01-01','YYYY-MM-DD');
```

```
_____
$al ____ album, has album_name ____;
$ar isa artist, ____ artist_name "Michael Jackson";
(released_album: ____, releasing_artist: $ar) isa album-release;
$al has release_date >= _____;
get $n;
```

★ Fill in the Blanks ★

SQL

Suppliers

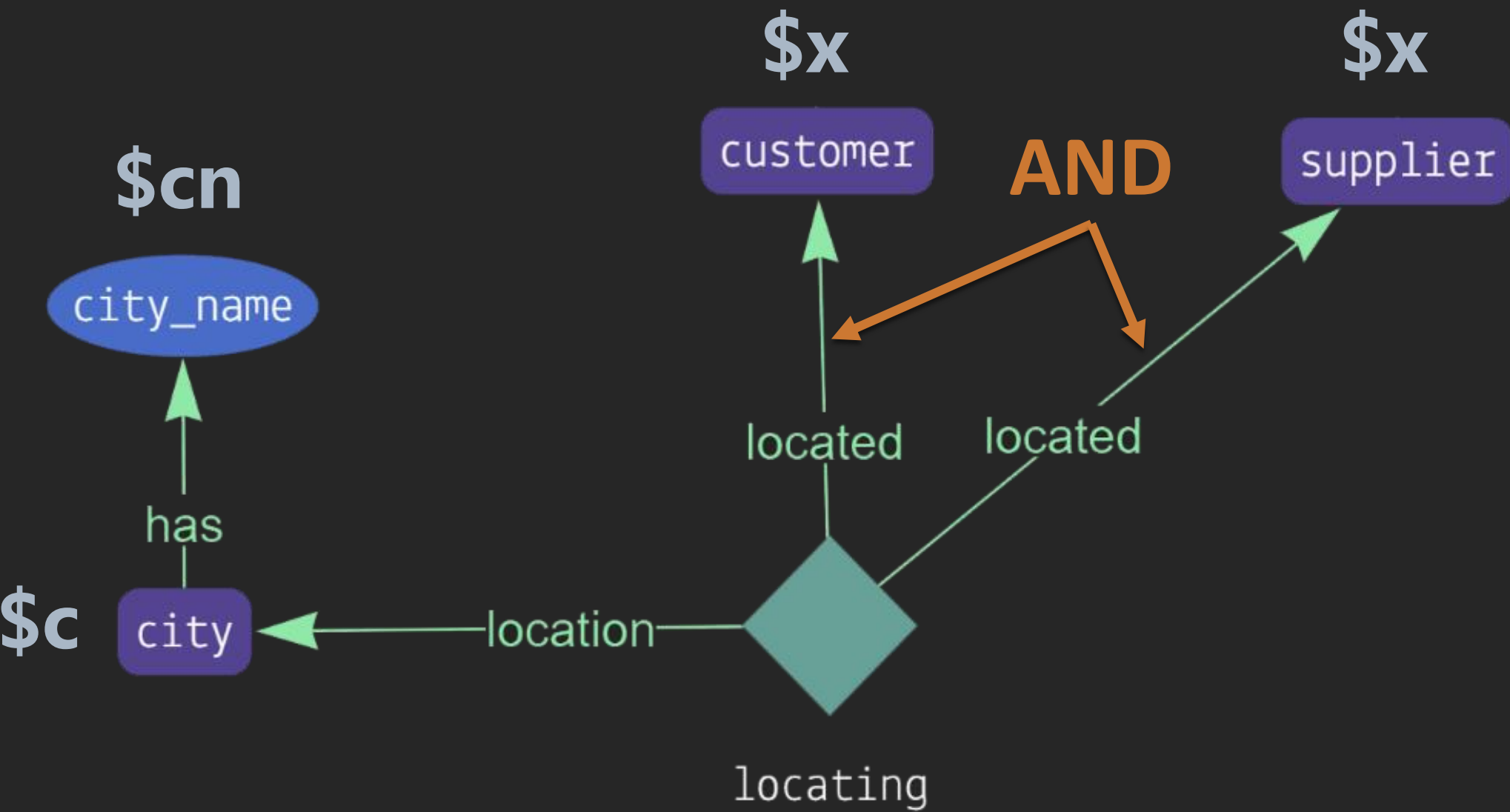
			city_name	

Customers

			city_name			

```
SELECT city_name
FROM customers
UNION
SELECT city_name
FROM suppliers;
```

Graql



```
match
$c isa city, has city_name $cn;
{$x isa supplier;} or {$x isa customer;};
(location: $c, $x);
get $cn;
```

SQL

Graql

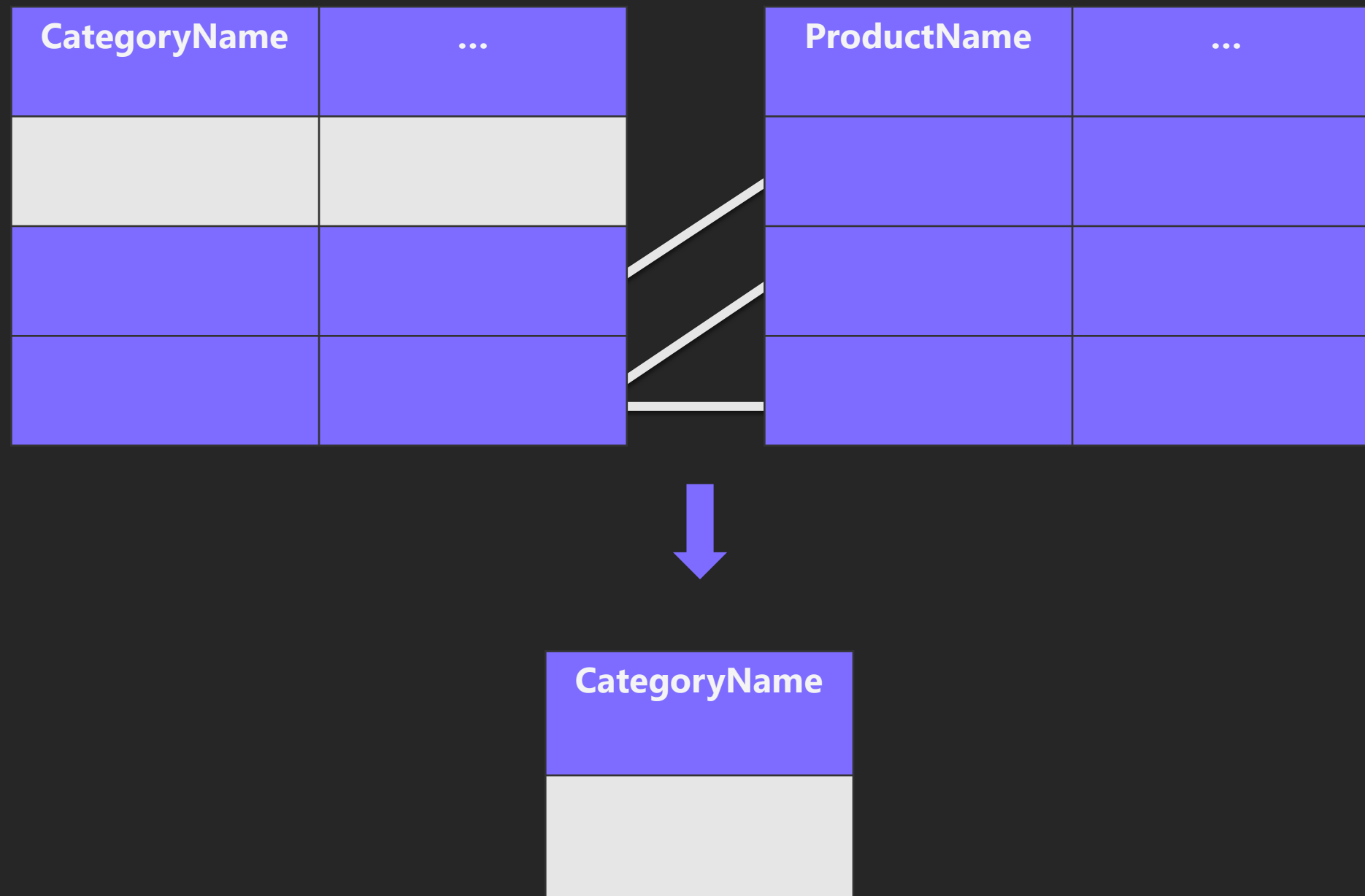
★ Fill in the Blanks ★

```
SELECT album_name
FROM albums
INNER JOIN artists on albums.artist_id = artists.artist_id
WHERE artist_name = 'Michael Jackson'
UNION
SELECT album_name
FROM albums
WHERE release_date >= to_date('2000-01-01','YYYY-MM-DD');
```

```
match
  _____, _____ $n;
{
  $ar isa artist, has artist_name "Michael Jackson";
  (released_album: $al, releasing_artist: $ar) isa album-release;
} ____ {
  $al has release_date >= 2000-01-01;
};
get $n;
```

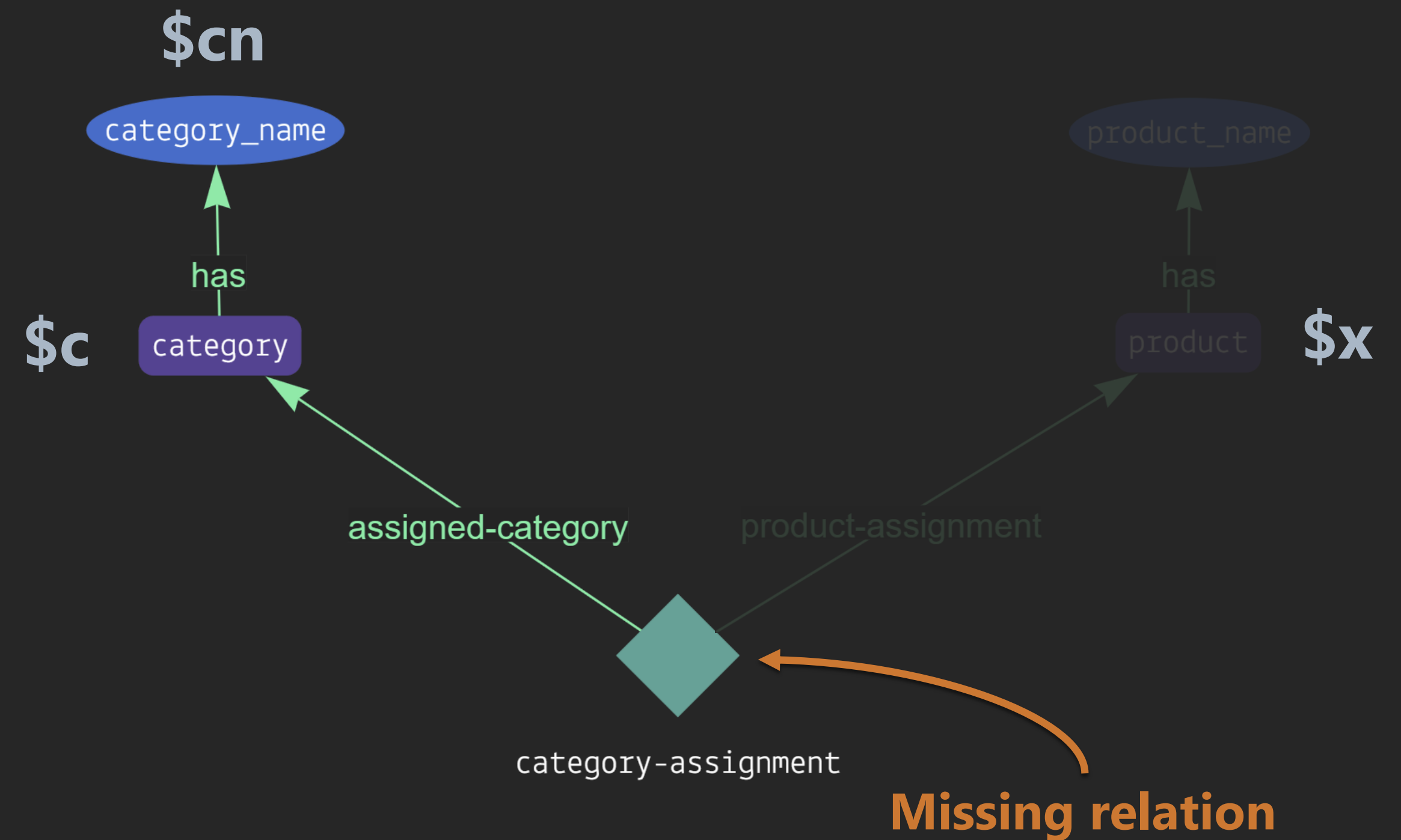
★ Fill in the Blanks ★

SQL



```
SELECT category_name
FROM categories
LEFT JOIN products
  ON categories.category_id = products.category_id
WHERE products.category_id IS NULL;
```

Graql



```
match
$c isa category,
  has category_name $cn;
not { ($c, $x) isa category-assignment; };
get $cn;
```

SQL

```
SELECT artist_name
FROM artists
LEFT JOIN albums
  ON artists.artist_id = albums.artist_id
WHERE albums.artist_id IS NULL;
```

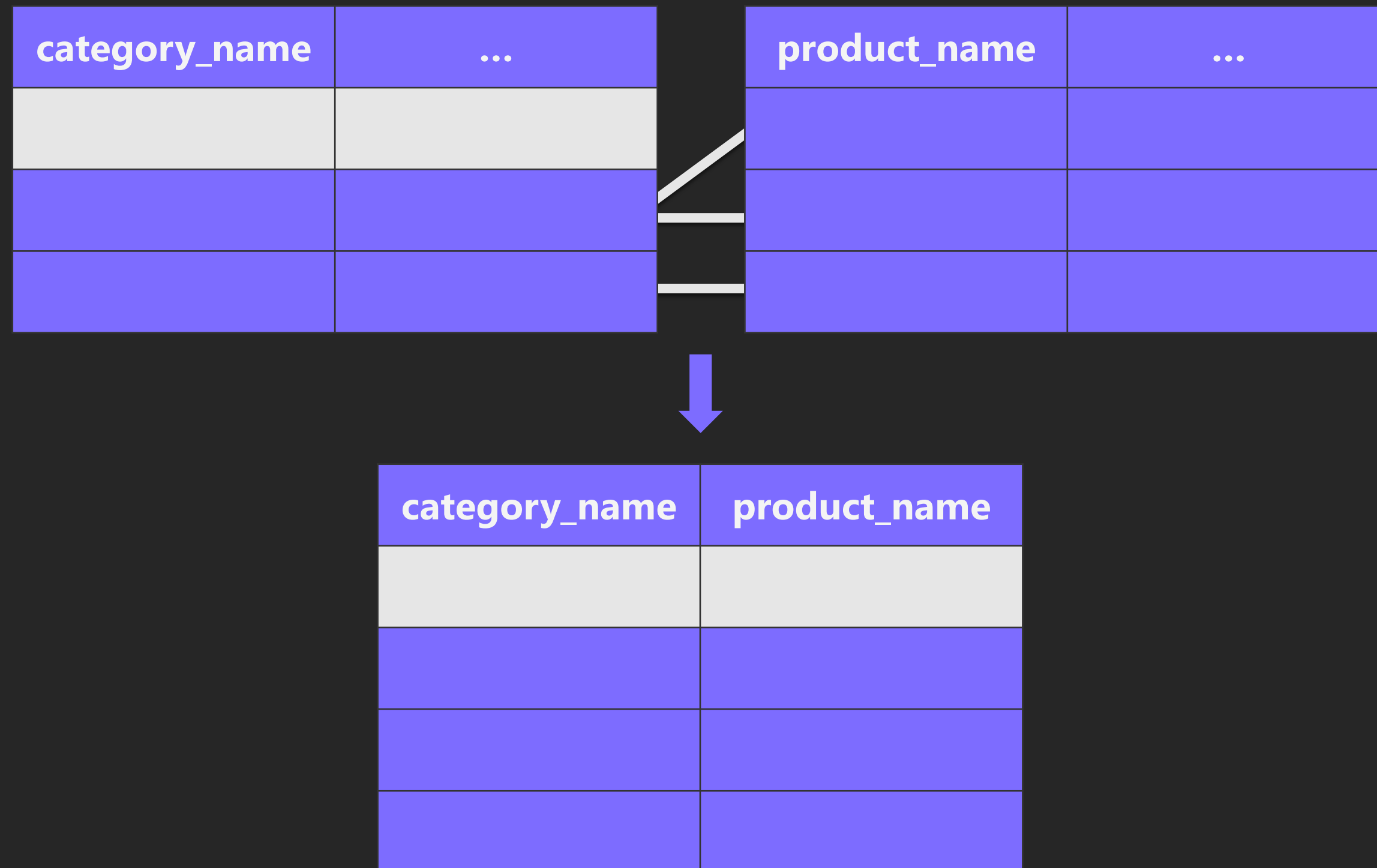
Graql

★ Fill in the Blanks ★

```
____
$ar isa artist,
  has artist_name $ar_name;
____ {
  ($ar, $x) ____ album-release;
};
____ $ar_name;
```

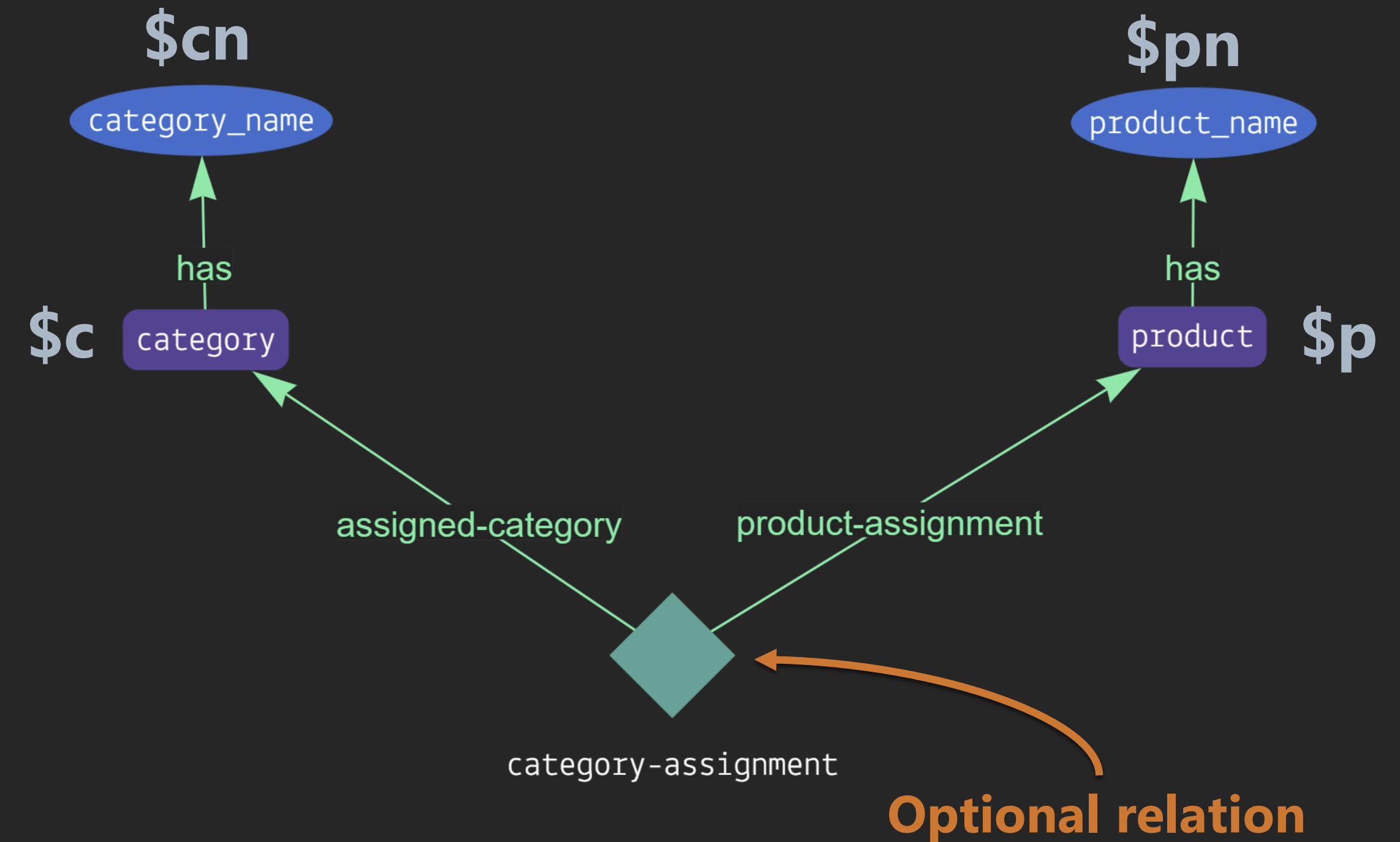
★ Fill in the Blanks ★

SQL



```
SELECT category_name
FROM categories
LEFT JOIN products
  ON categories.category_id = products.category_id
WHERE products.category_id IS NULL;
```

Graql



```
match
  $c isa category, has category_name $cn;
  $p isa product, has product_name $pn;
  { ($c, $p) isa category-assignment; }
  or { not { ($c, $p) isa category-assignment; }; };
  get $cn, $pn;
```


SQL

```
SELECT artist_name, album_name
FROM artists
FULL OUTER JOIN albums
  ON artists.artist_id = albums.artist_id;
```

Graql

★ Fill in the Blanks ★

```
match
$ar isa artist, has artist_name $ar_name;
$al ____ album, has album_name $al_name;
{
  ($ar, $al) isa album-release;
} ____ {
  ____ {
    ($ar, $al) isa ____;
  };
};
get $ar_name, ____;
```

★ Fill in the Blanks ★

Reading Data – Inference

- All men are mortal
- Socrates is a man
- Therefore, Socrates is mortal

```
men-are-mortal sub rule,
```

```
when {
```

```
    $man isa man;
```

```
},
```

```
then {
```

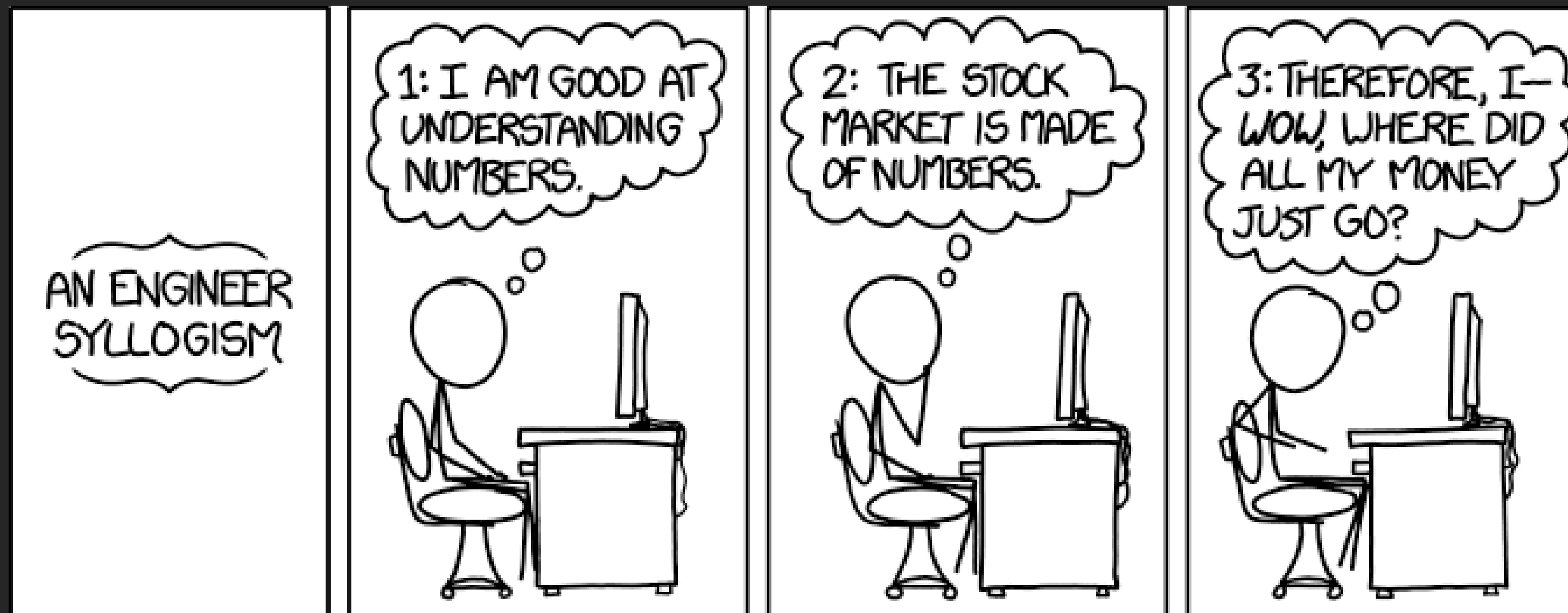
```
    $man isa mortal;
```

```
};
```

```
insert $m isa man, has name "Socrates";
```

```
match $mortal isa mortal; get;
```

Reading Data – Inference



<https://xkcd.com/1570/>

- All women are mortal
- Socrates is a man
- Therefore, Socrates is mortal

Reading Data – Inference

- When
 - Texas ($\$b$) is located in USA ($\a)
 - Dallas ($\$c$) is located in Texas ($\b)
- Then
 - Dallas ($\$c$) is located in USA ($\a)

```
transitive-location sub rule,  
when {  
    (location: $a, located: $b) isa locating;  
    (location: $b, located: $c) isa locating;  
}, then {  
    (location: $a, located: $c) isa locating;  
};
```

SQL

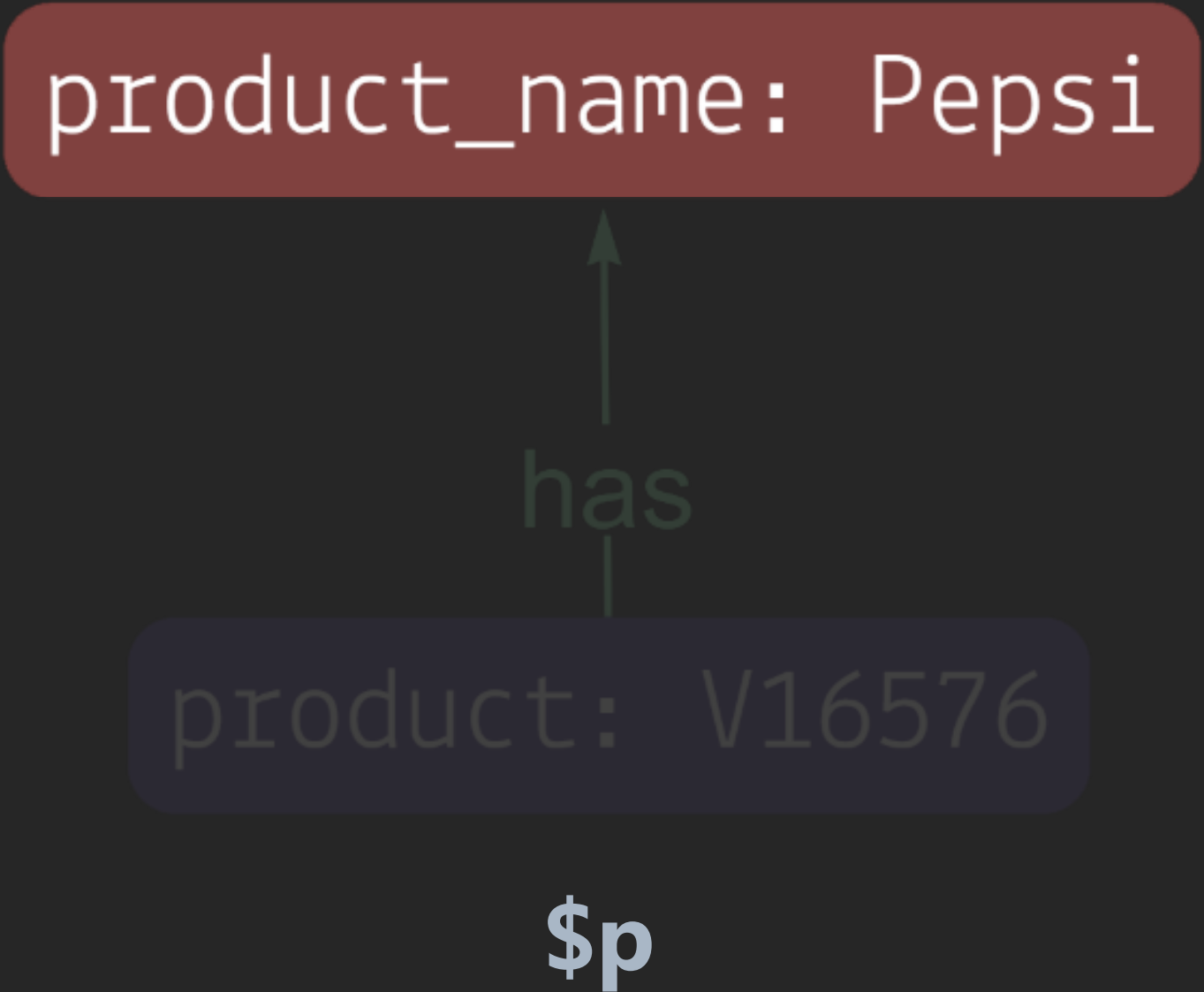
product_id	product_name
14	Pepsi
15	Coca-Cola
16	Fanta

product_id	product_name
15	Coca-Cola
16	Fanta



```
DELETE FROM products
WHERE product_name = 'Pepsi';
```

Graql



```
match
  $p isa product, has product_name "Pepsi";
delete $p;
```

SQL

Graql

★ Fill in the Blanks ★

```
DELETE
FROM albums
USING artists
WHERE albums.artist_id = artists.artist_id
AND artists.artist_name = 'Michael Jackson'
AND albums.album_name = 'Bad';
```

```
_____
$ar isa artist, has artist_name "Michael Jackson";
$al isa album, has album_name "Bad";
($ar, $al) isa album-release;
_____;
```

★ Fill in the Blanks ★

SQL

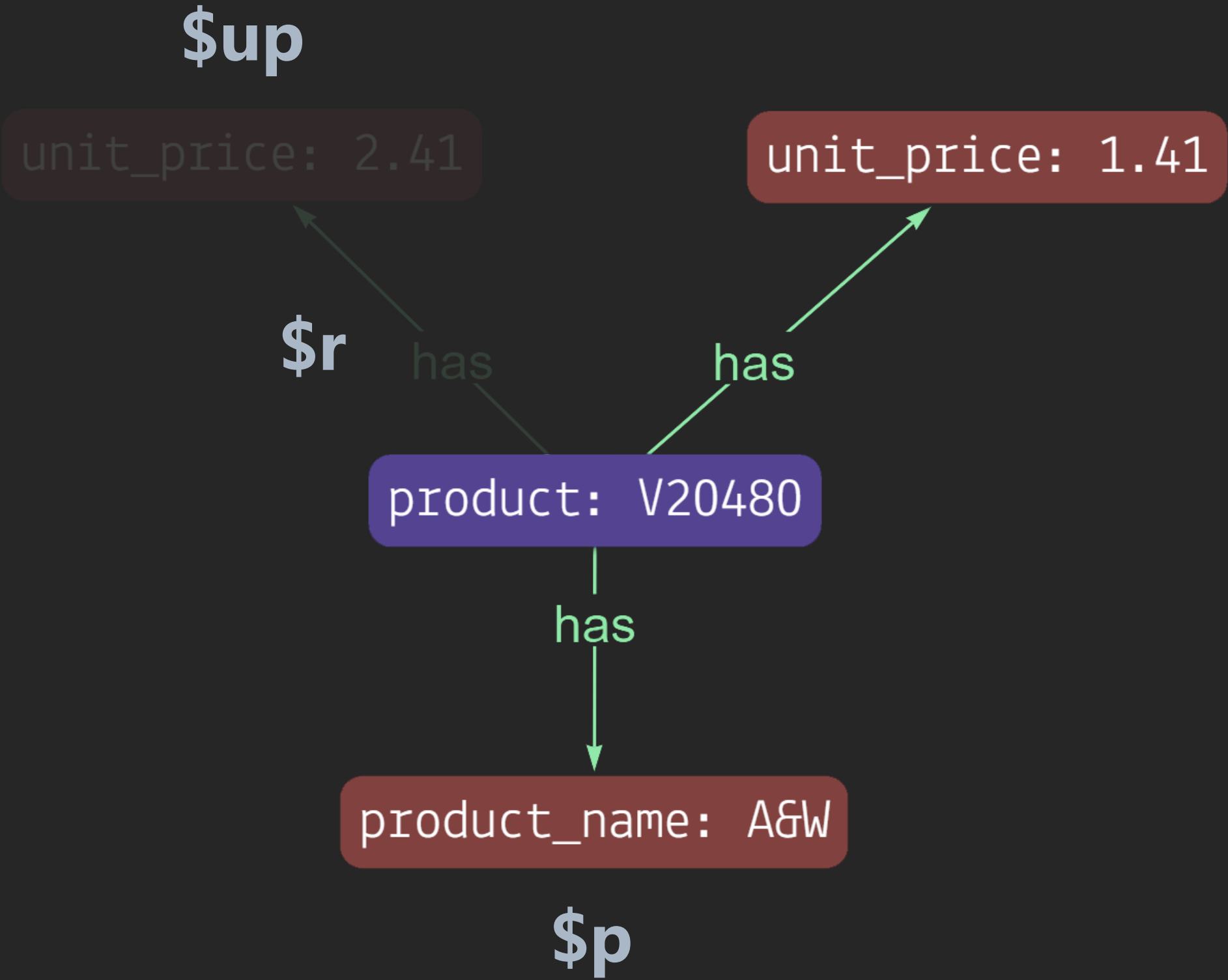
product_id	product_name	unit_price
17	Sprite	\$1.55
18	7 UP	\$1.68
19	A&W	\$2.41

product_id	product_name	unit_price
17	Sprite	\$1.55
18	7 UP	\$1.68
19	A&W	\$1.41



```
UPDATE products
SET unit_price = 1.41
WHERE product_name = 'A&W';
```

Graql



```
match $p isa product,
  has product_name "A&W", has unit_price $sup via $r;
delete $r;

match $p isa product, has product_name "A&W";
insert $p has unit_price 1.41;
```

SQL

Graql

★ Fill in the Blanks ★

```
UPDATE artists
SET artist_name = 'Michael Joseph Jackson'
WHERE artist_name = 'Michael Jackson';
```

```
_____ $ar isa artist, has artist_name "Michael Jackson";
_____ $ar has artist_name "Michael Joseph Jackson";

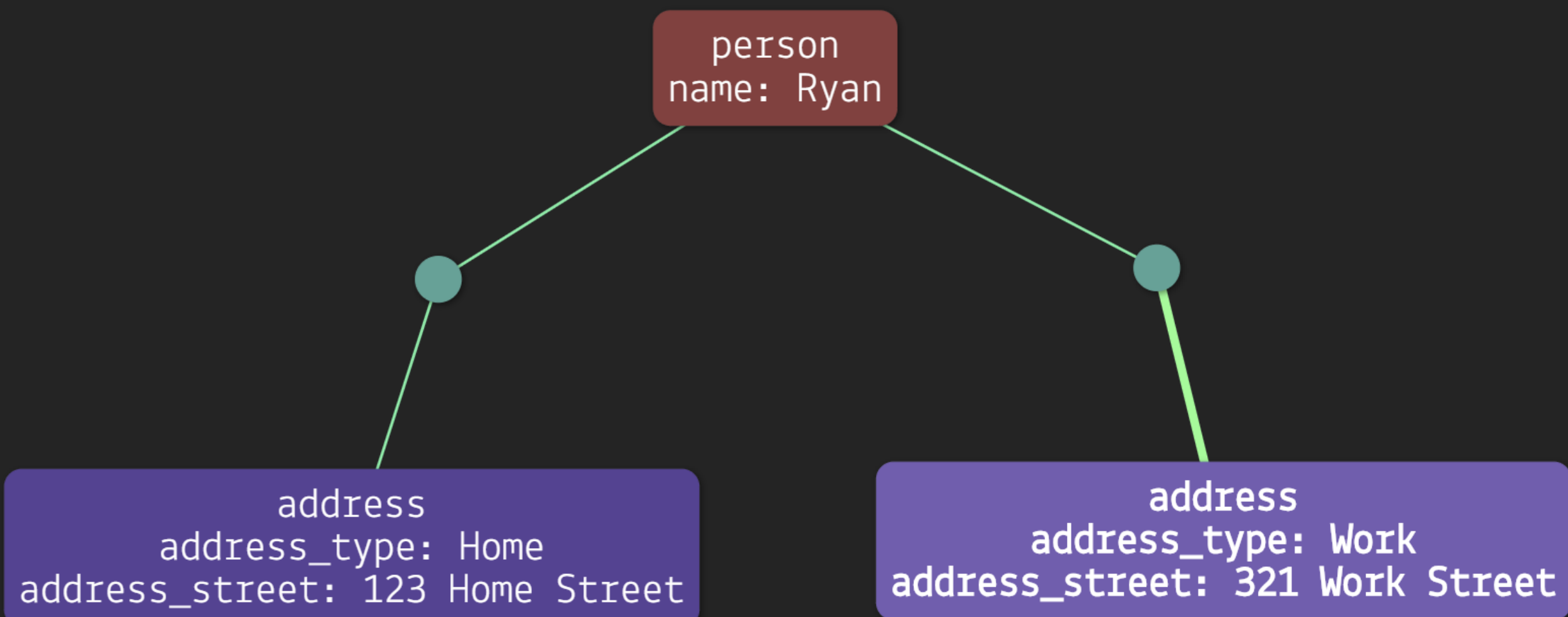
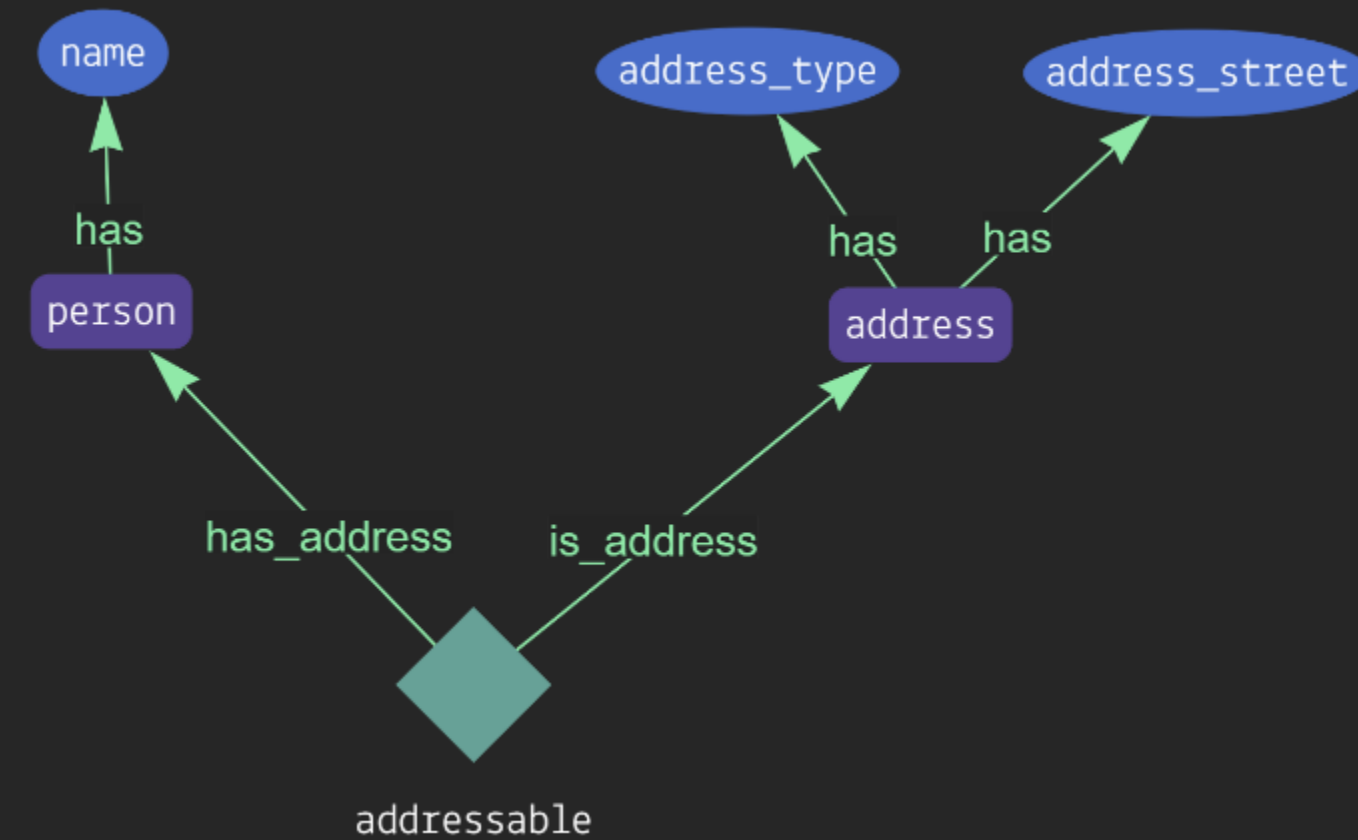
_____ $ar isa artist, has artist_name "Michael Jackson" via $r;
_____ $r;
```

★ Fill in the Blanks ★

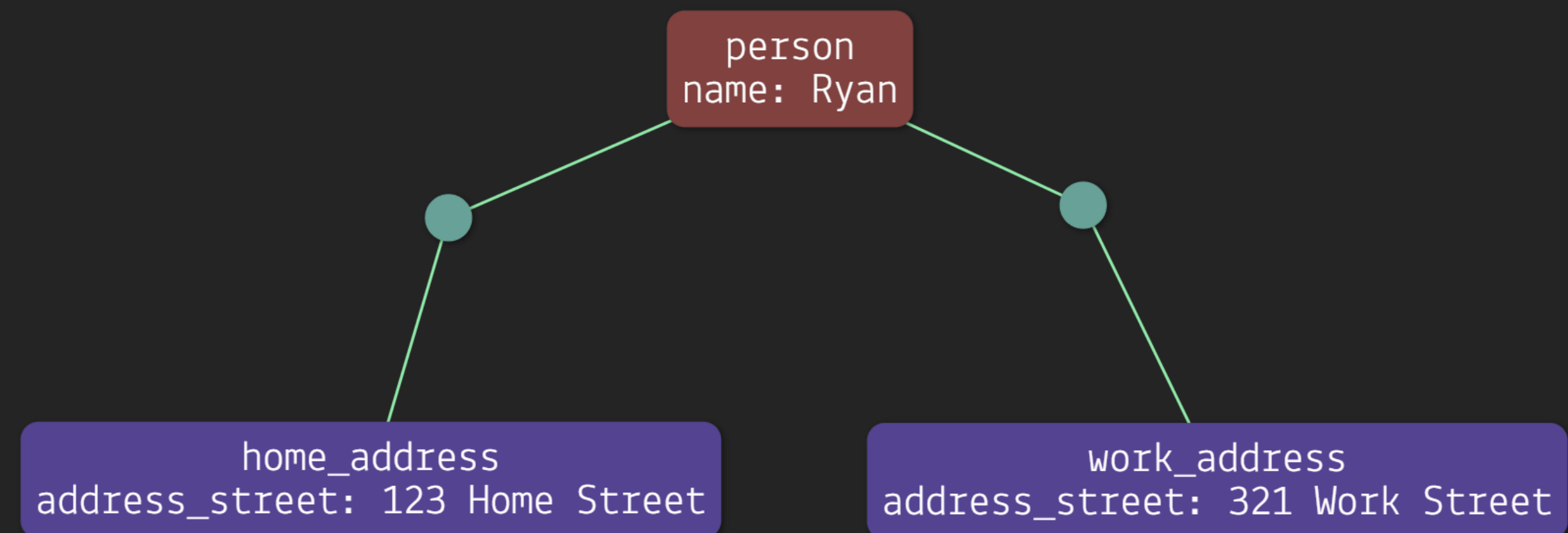
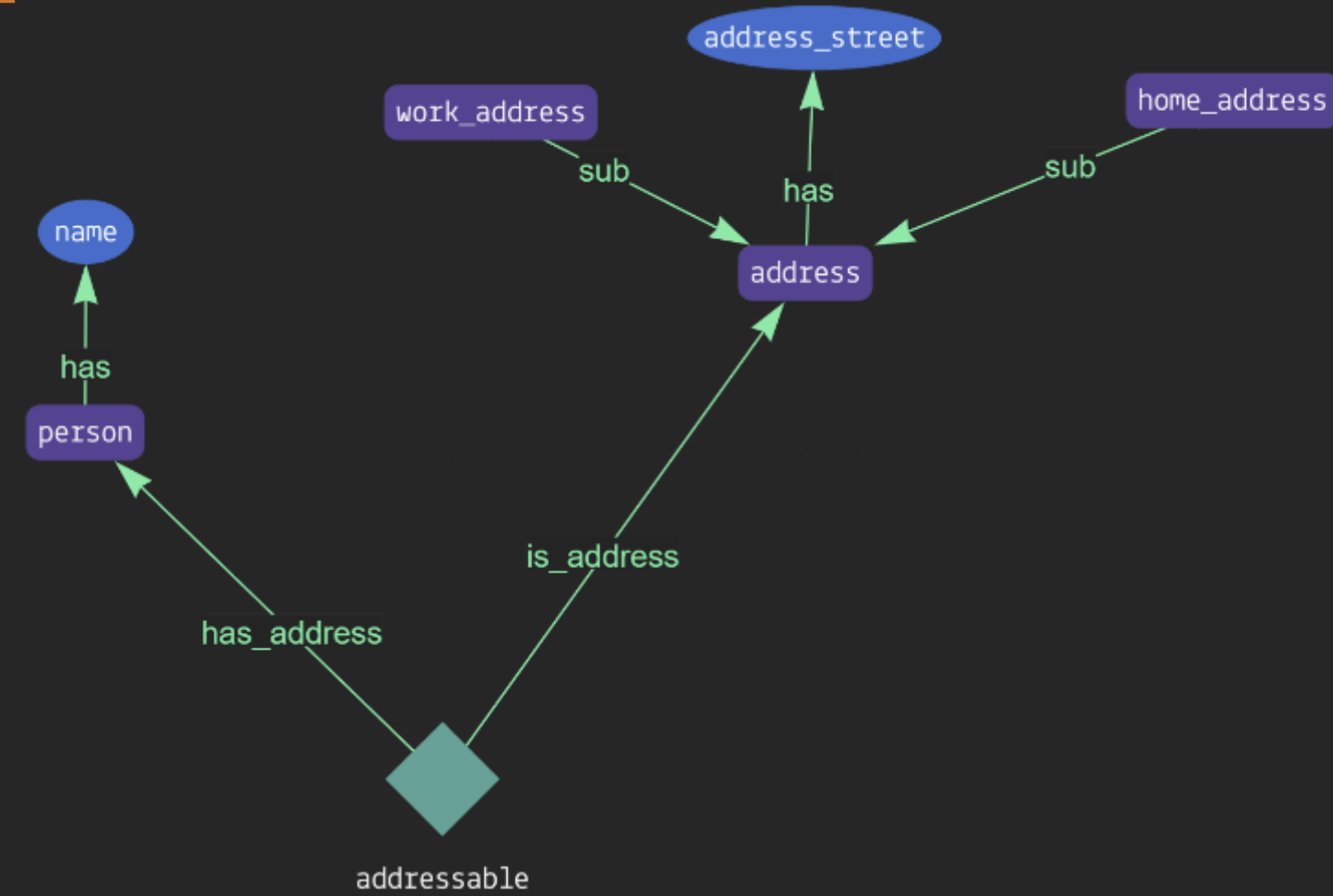
Exercises

Exercise – Which is Better?

Option A



Option B



Exercise – Will This Work?

```
##### SCHEMA #####
```

```
define
product sub entity,
  key product_name;
city sub entity,
  has city_name,
  plays location,
  plays located;
locating sub relation,
  relates location,
  relates located;
product_name sub attribute, datatype string;
city_name sub attribute, datatype string;
```

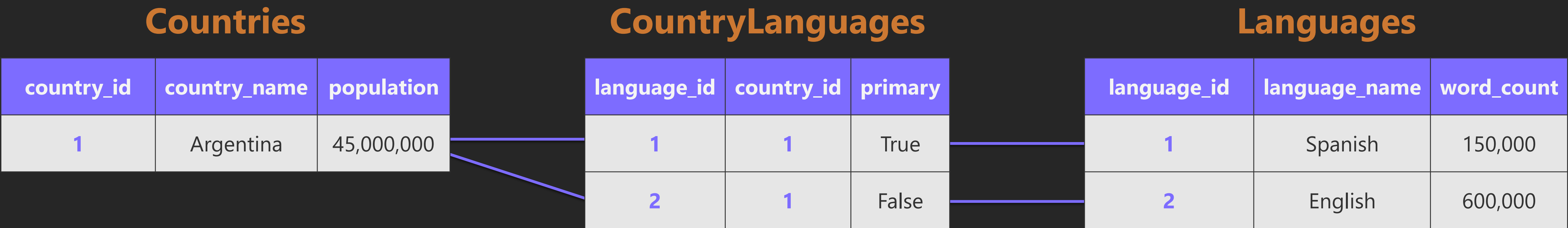
```
##### DATA #####
```

```
insert
$bacon isa product, has product_name "Bacon";
$toronto isa city, has city_name "Toronto";
(location: $bacon, located: $toronto) isa locating;
```

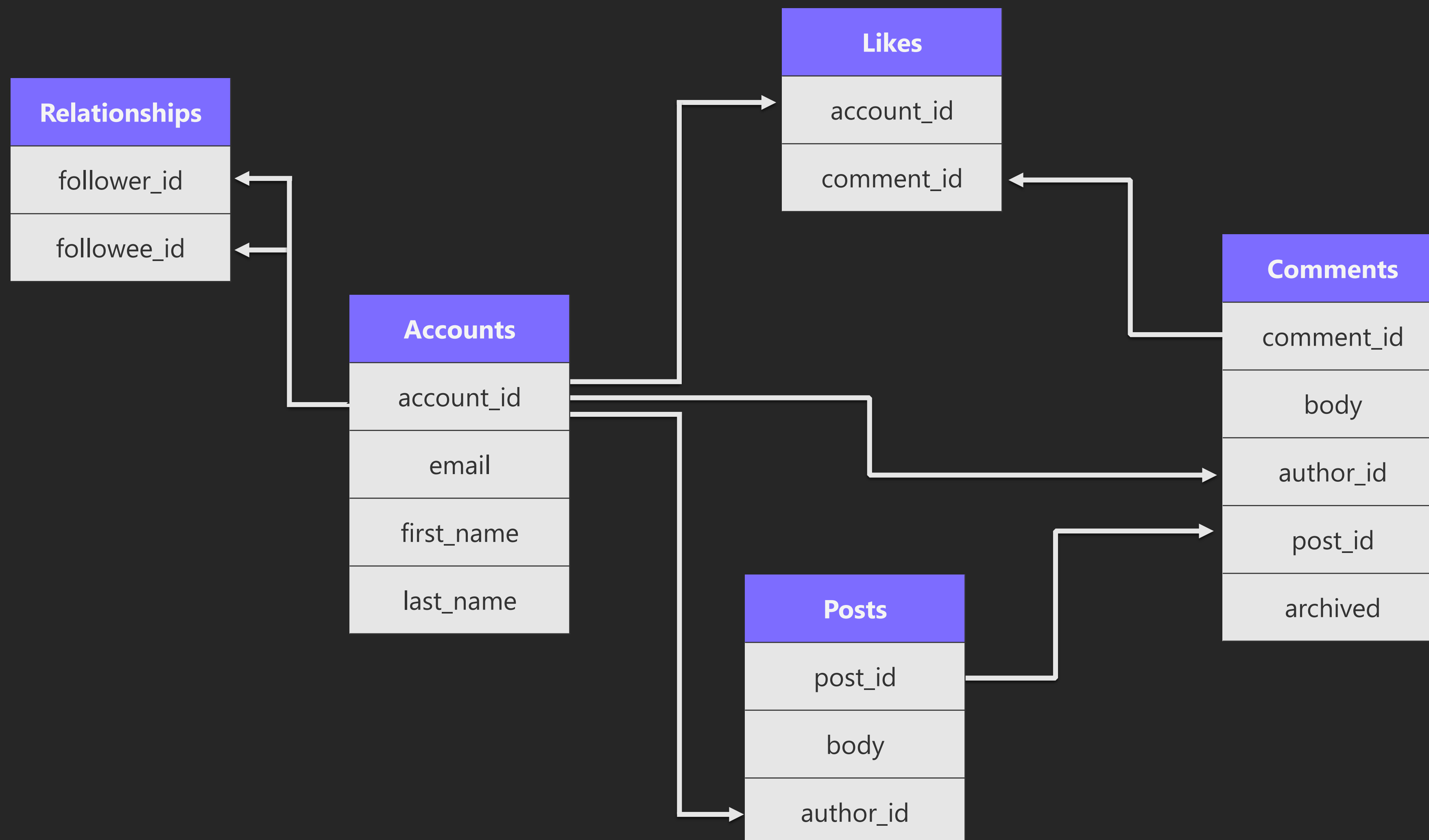
Exercise – Convert Tables

Objectives

- 1. Convert the following tables to an equivalent Grakn schema
- 2. Populate the knowledge base with the equivalent data
- 3. Write a query to get the primary language of Argentina



Exercise – Convert Schema



Exercise – Linked List

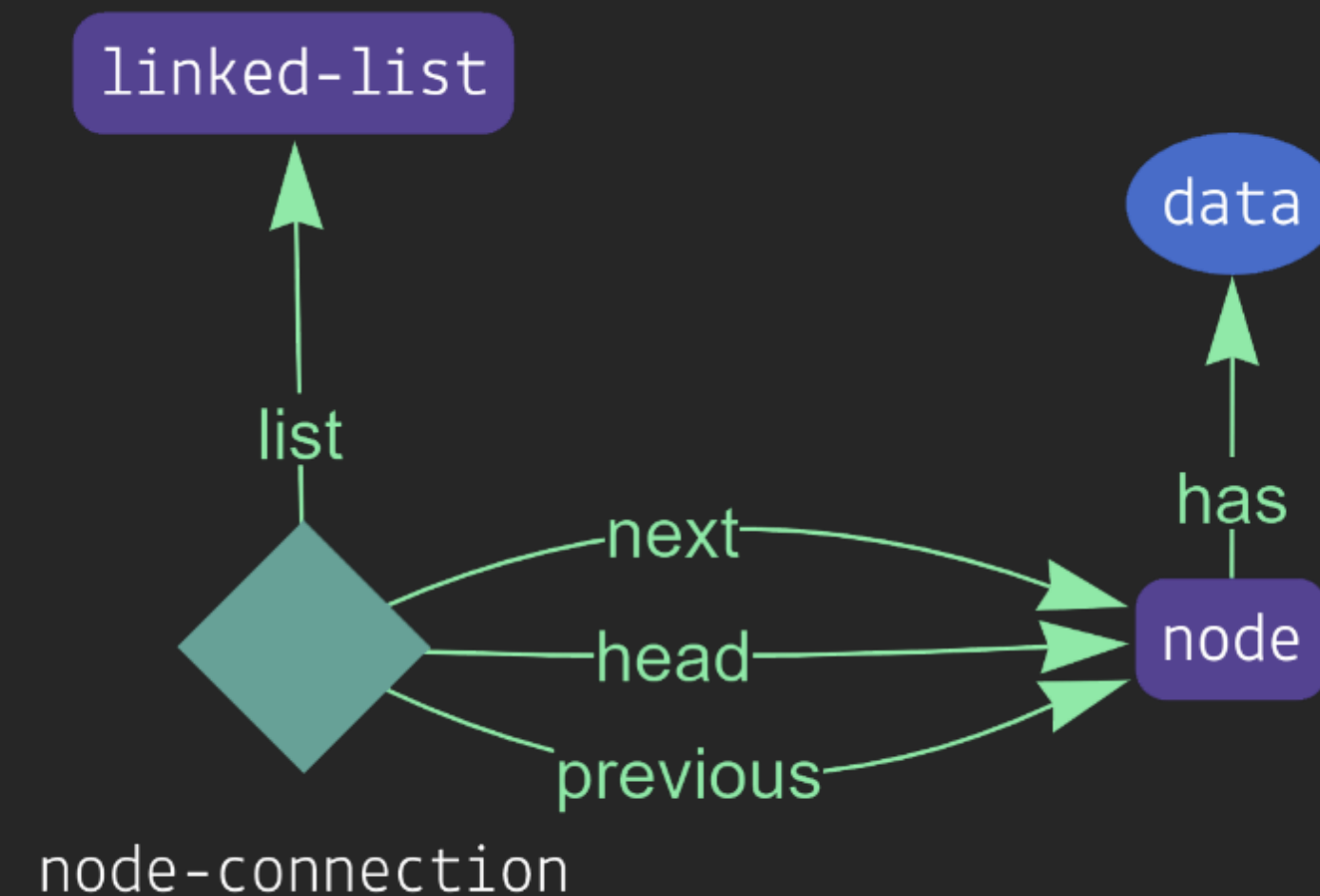
Objectives

1. Implement a linked list using the given schema
2. Populate the linked list with the given data
3. Write queries to answer following questions:
 1. Who is in queue before Alexis?
 2. Who is in queue after the person after Bob?
 3. Who is the last person in the queue?

Data

Bob → Sam → Jessica → Eric → Alexis

Schema



Exercise – Find Friends-of-Friends

Objectives

1. Implement the given schema
2. Populate the knowledge base with the given data
3. Write a query to find the friends of Brandon's friends
4. Create a rule to infer two people may be acquaintances based on mutual friends

Data

Brandon's Friends:

- Travis
- Mark
- Bob
- Melissa

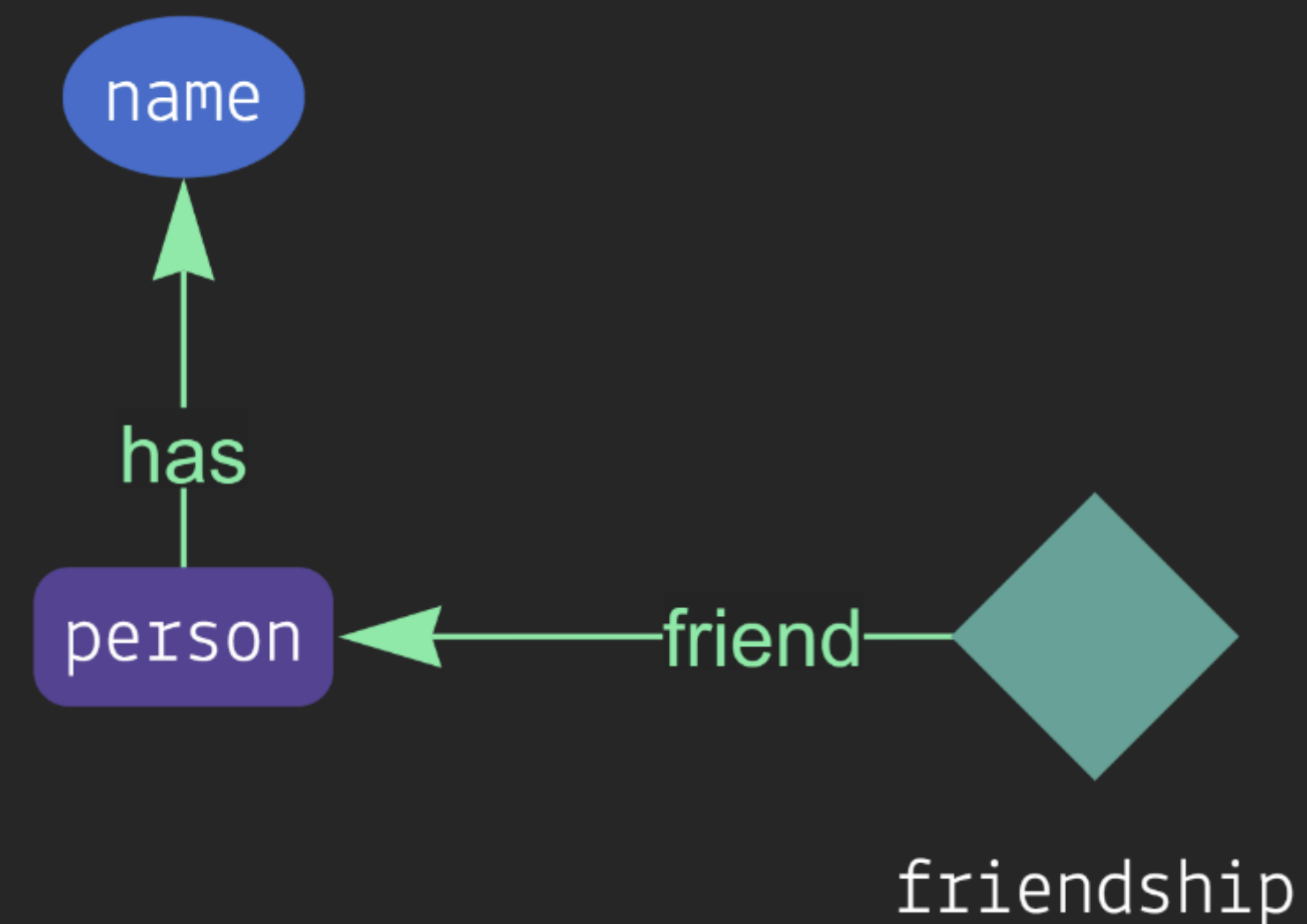
Mark's Friends:

- Bob

Melissa's Friends:

- Louise
- Alice

Schema



Exercise – Find Skilled Colleagues

Objectives

1. Implement the given schema
2. Populate the knowledge base with the given data
3. Write a query to find everyone who is good at Kotlin and Java
4. Write a query to find everyone who has no experience with C#
5. Extend the graph to add the ability to assign skill level (weight)
 1. Update Eric to have a skill level of 3 in current skills
 2. Update Larry to have a skill level of 2 in current skills
 3. Update Sergey to have a skill level of 4 in current skills
4. Write a query to find everyone with a skill level greater than 2 in C#

Data

Company: Google

Employees:

Eric

Skills: Python, C#

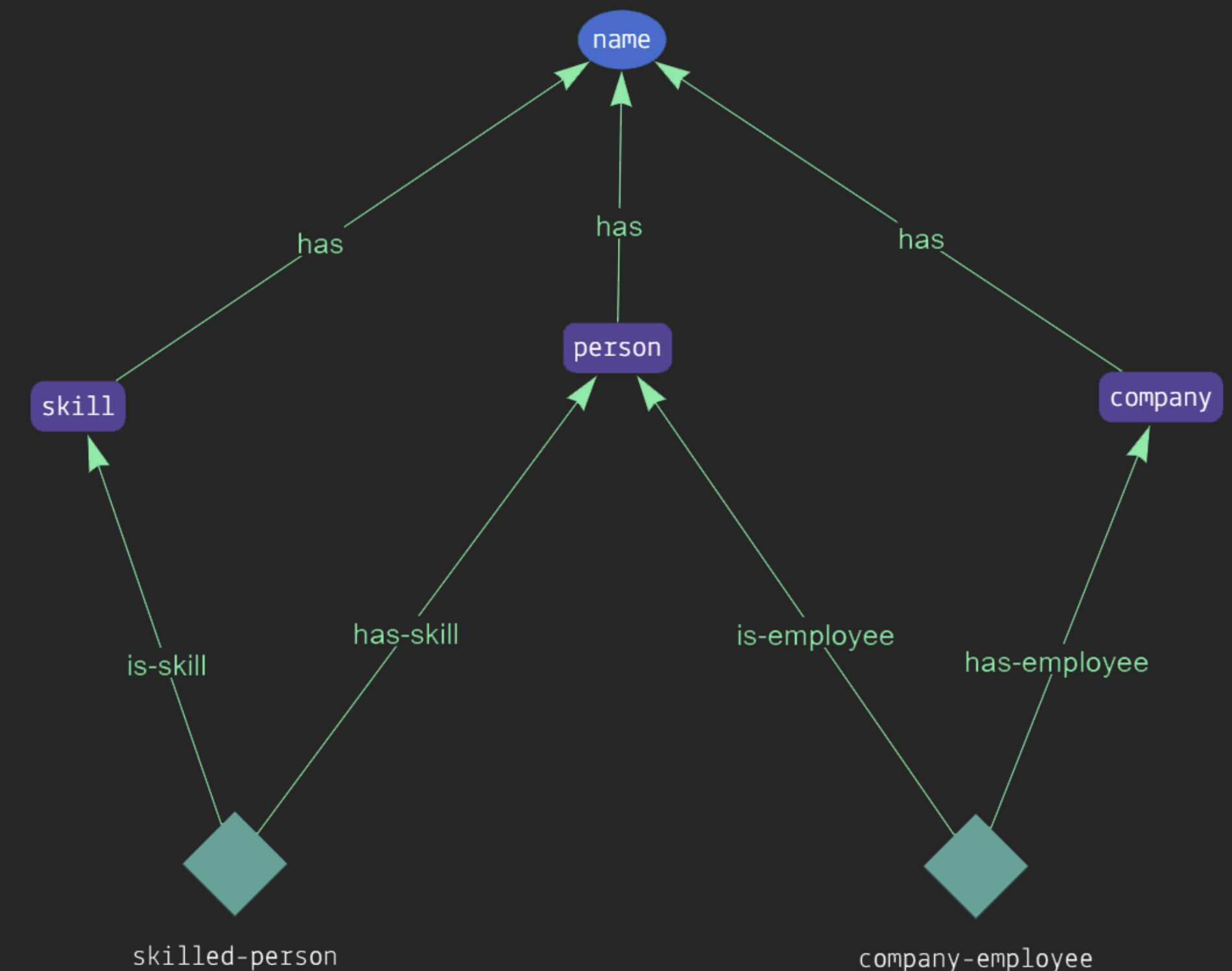
Larry

Skills: C#, Kotlin, Java

Sergey

Skills: Kotlin, Java

Schema



Questions/Comments?

Resources:

- <https://grakn.ai>
- <https://neo4j.com>