SEQUEL: A STRUCTURED ENGLISH QUERY LANGUAGE

by

Donald D. Chamberlin
Raymond F. Boyce

IBM Research Laboratory
San Jose, California

Mehr als eine Abfragesprache: SQL im 21. Jahrhundert

@MarkusWinand • @ModernSQL

http://www.almaden.ibm.com/cs/people/chamberlin/sequel-1974.pdf

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1974

1992

SQL-92 — Tied to the Relational Idea

(Second Informal Review Draft) ISO/IEC 9075:1992, Database
Language SQL- July 30, 1992

SQL-92 — Tied to the Relational Idea

Relational Data Model

- “Atomic” types (domain)

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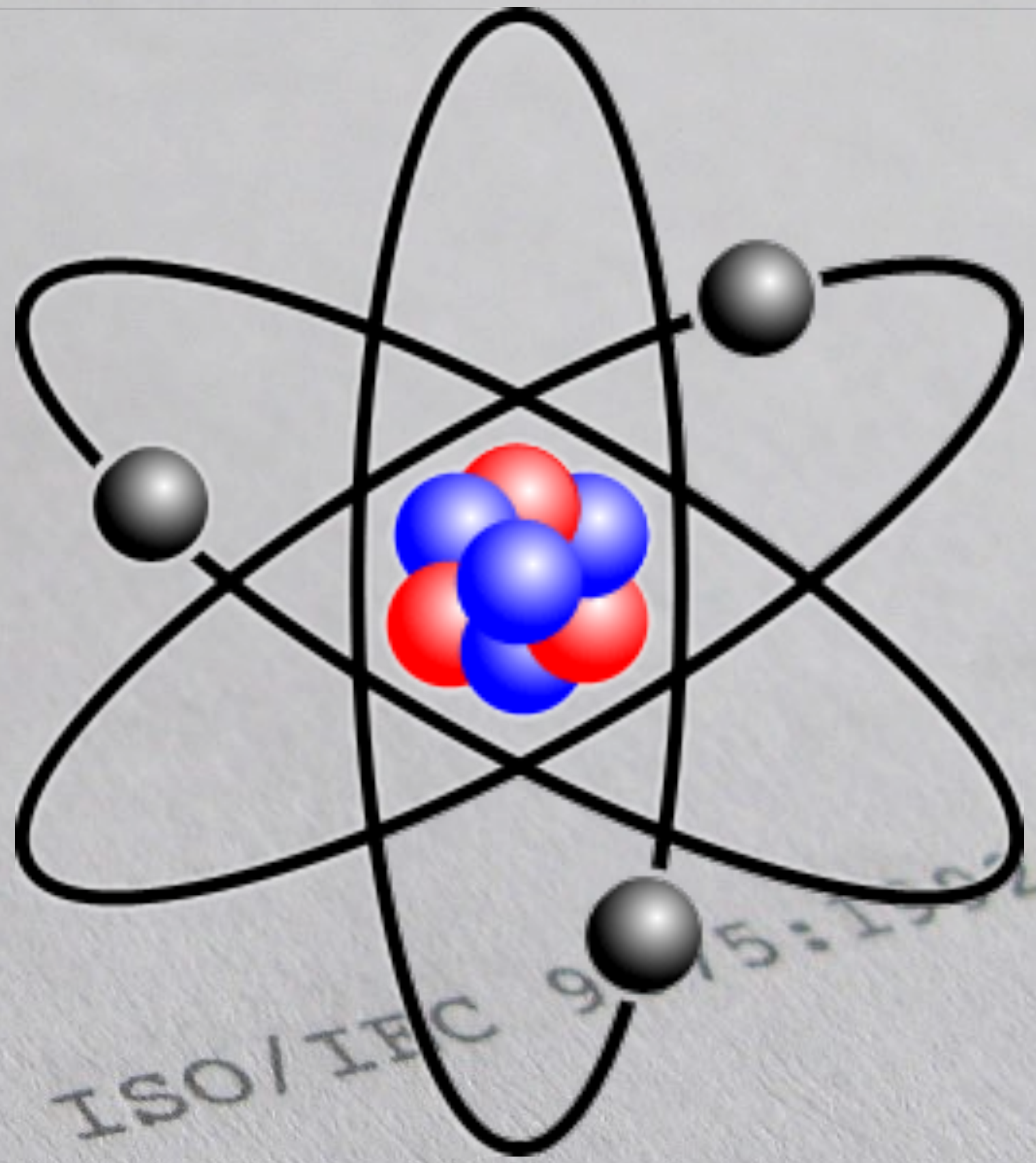

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Atom image: https://commons.wikimedia.org/wiki/File:Stylised_atom_with_three_Bohr_model_orbits_and_stylised_nucleus.png

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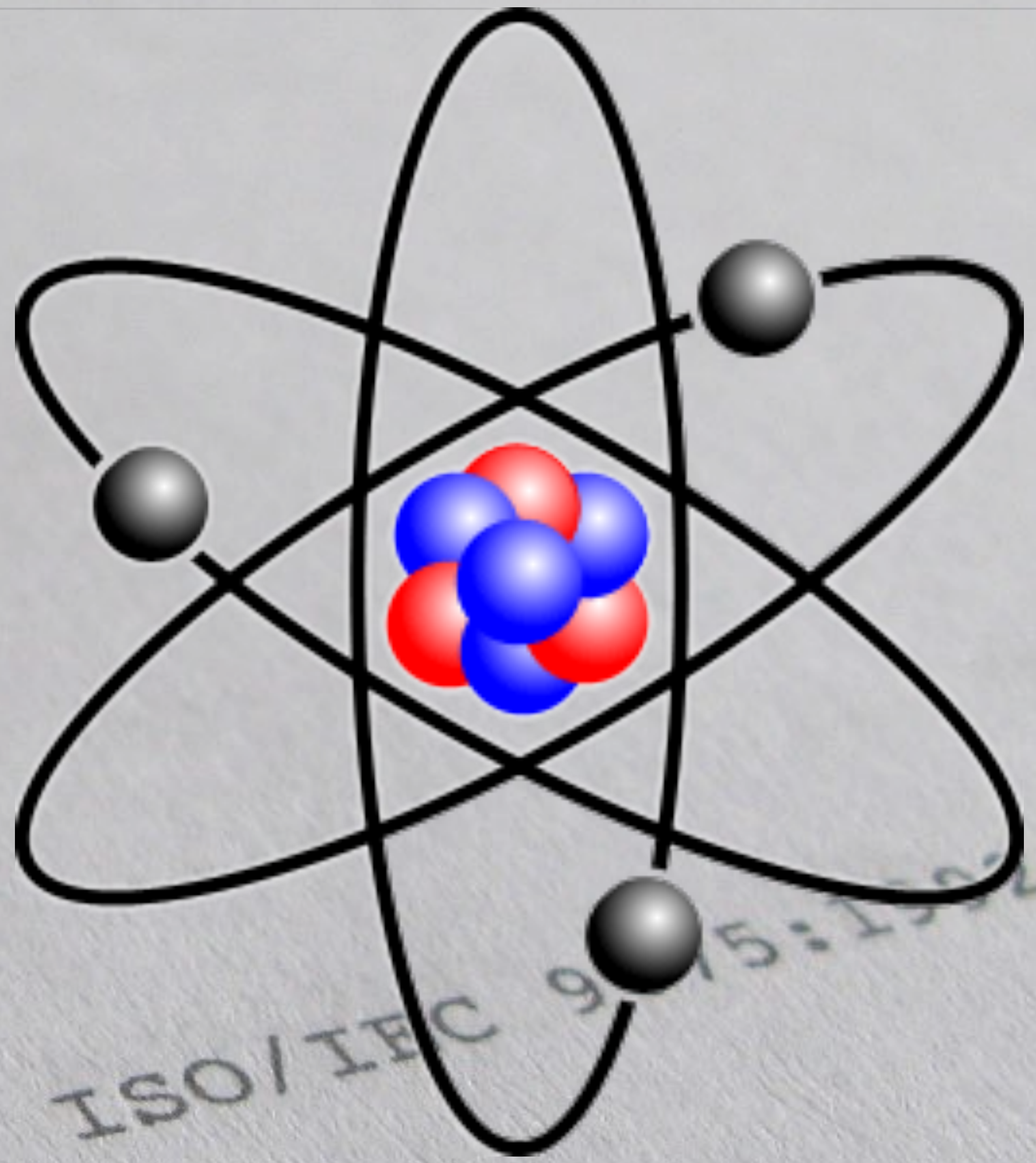
A	B	C



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A	B	C
⚛	⚛	⚛
⚛	⚛	
⚛	⚛	⚛

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Relational Data Model

- “Atomic” types (domain)
- Schema independent of processing purposes
  - “Normalization”

A	B	C
⚛	⚛	⚛
⚛	⚛	
⚛	⚛	⚛

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A	B	C
⚛	⚛	⚛
⚛	⚛	
⚛	⚛	⚛

C	D
⚛	⚛
⚛	⚛

B	E
⚛	⚛
⚛	⚛

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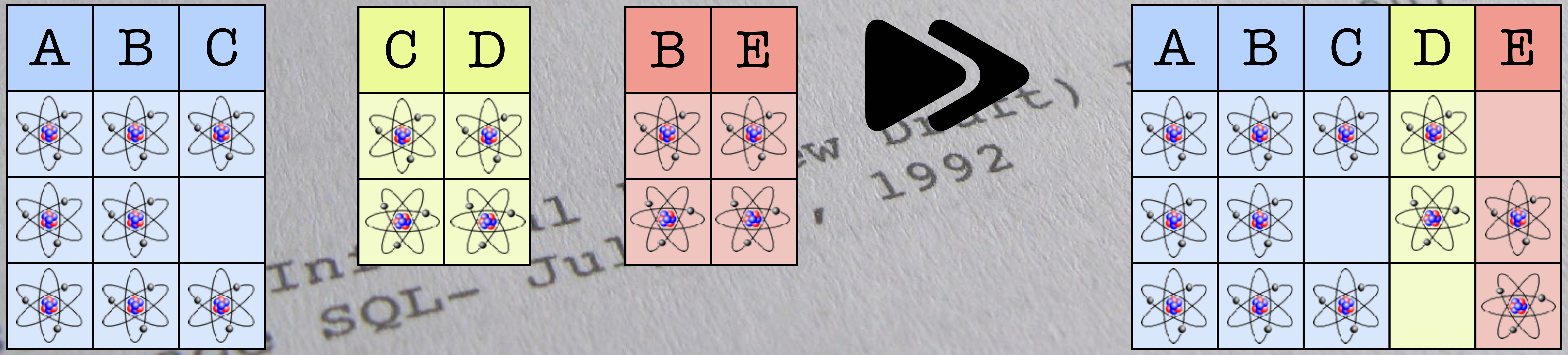
- Transform data for each particular processing purposes
  - JOIN, UNION, nesting, …



A	B	C
⚛	⚛	⚛
⚛	⚛	
⚛	⚛	⚛

C	D
⚛	⚛
⚛	⚛

B	E
⚛	⚛
⚛	⚛

A	B	C	D	E
⚛	⚛	⚛	⚛	
⚛	⚛		⚛	⚛
⚛	⚛	⚛		⚛

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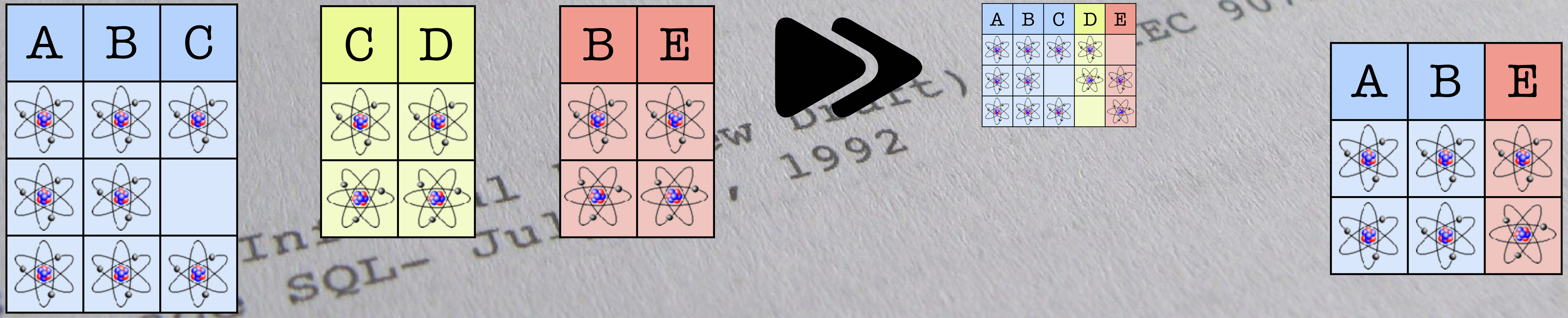

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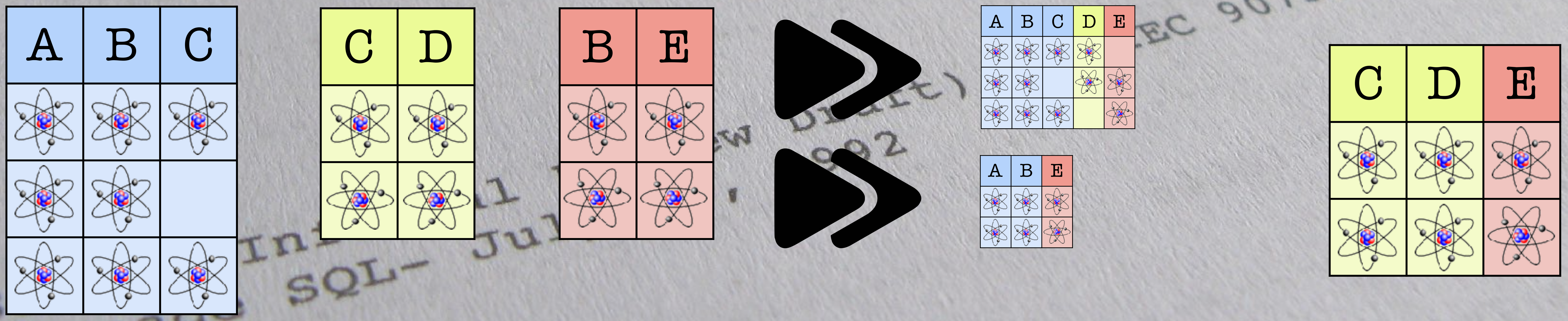

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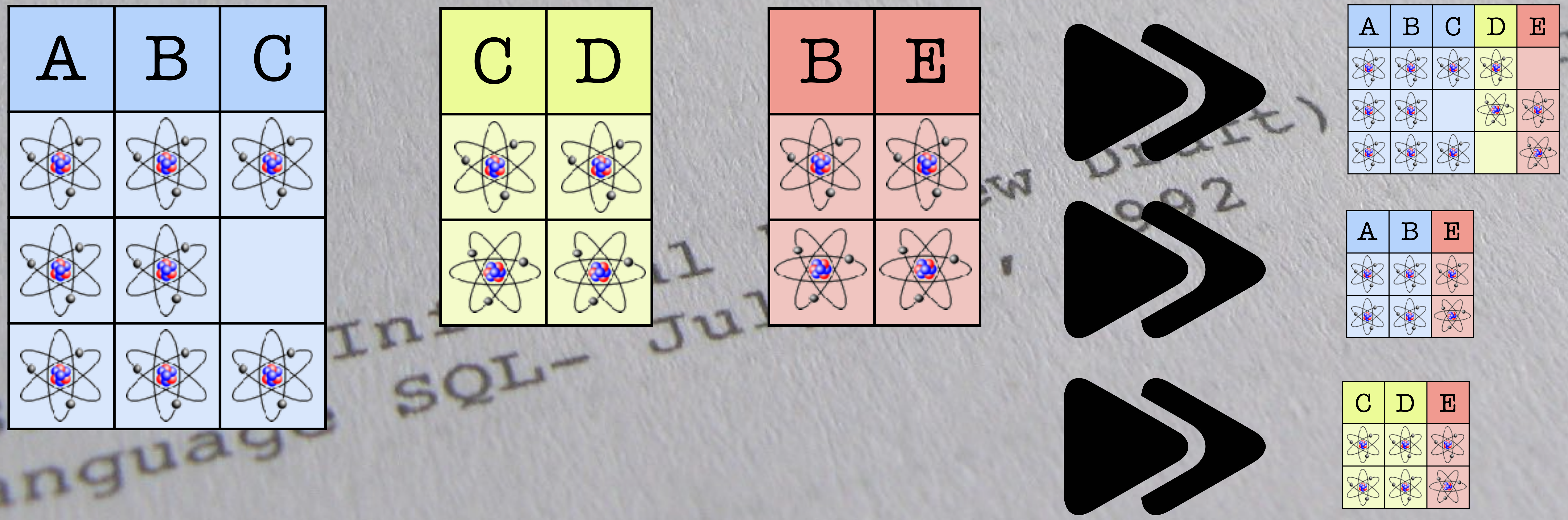

1992 ⏩ 1999

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Whitemarsh
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Great News,
The Relational Data Model is Dead!

https://www.wiscorp.com/DBMS_-_GreatNews-TheRelationalModelIsDead_-_paper_-_sam.pdf

SQL:1999 — Escaping the Relational Cage

> To say that these SQL:1999 extensions are mere "extended interpretations" of the relational data model is like saying that an intercontinental ballistic missile is merely an "extended interpretation" of a spear.

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To say that these SQL:1999 extensions are mere "extended interpretations" of the relational data model is like saying that an intercontinental ballistic missile is merely an "extended interpretation" of a spear.

With SQL/99 you can get the best of both worlds and
of course, you can get the worst of both worlds.
It's up to the database practitioners to do the right thing.

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SQL:1999 — Escaping the Relational Cage

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Information Systems Corporation

Great News,
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Relational Model?

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Relational Model?

I was as confused as anyone else

Date on Database: Writings 2000-2006

Chris Date

SQL:1999 — Escaping the Relational Cage

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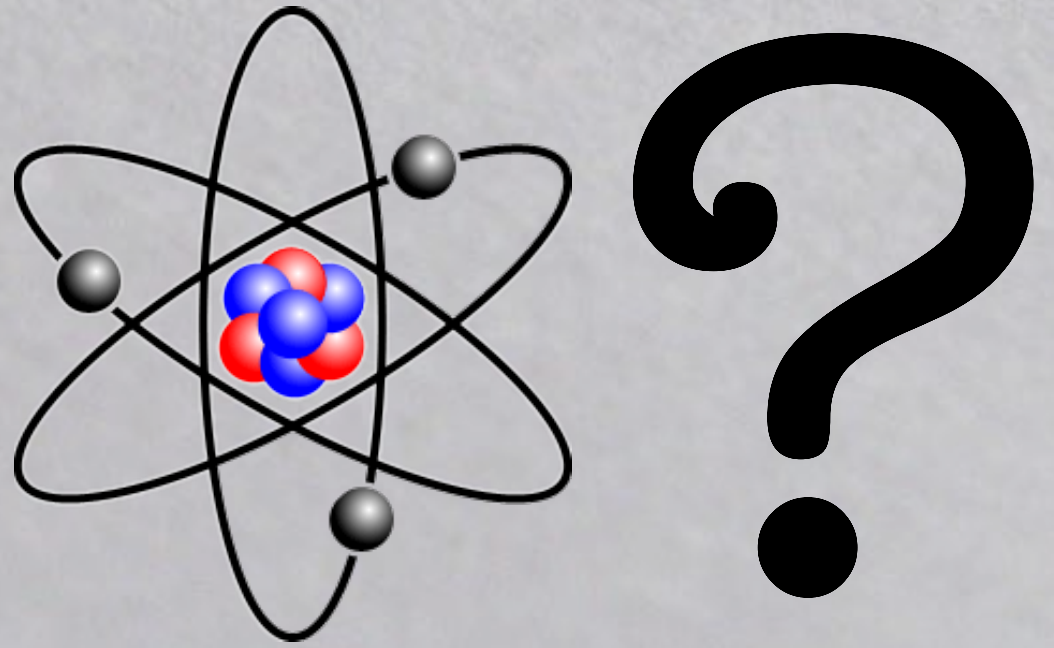

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- Introduced rich types

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A
⚛
⚛
⚛

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SQL:1999 — Escaping the Relational Cage

Relational Model?

- Introduced rich types
  - arrays

A	B
⚛	[⚛,⚛]
⚛	[⚛]
⚛	[]

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Relational Model?

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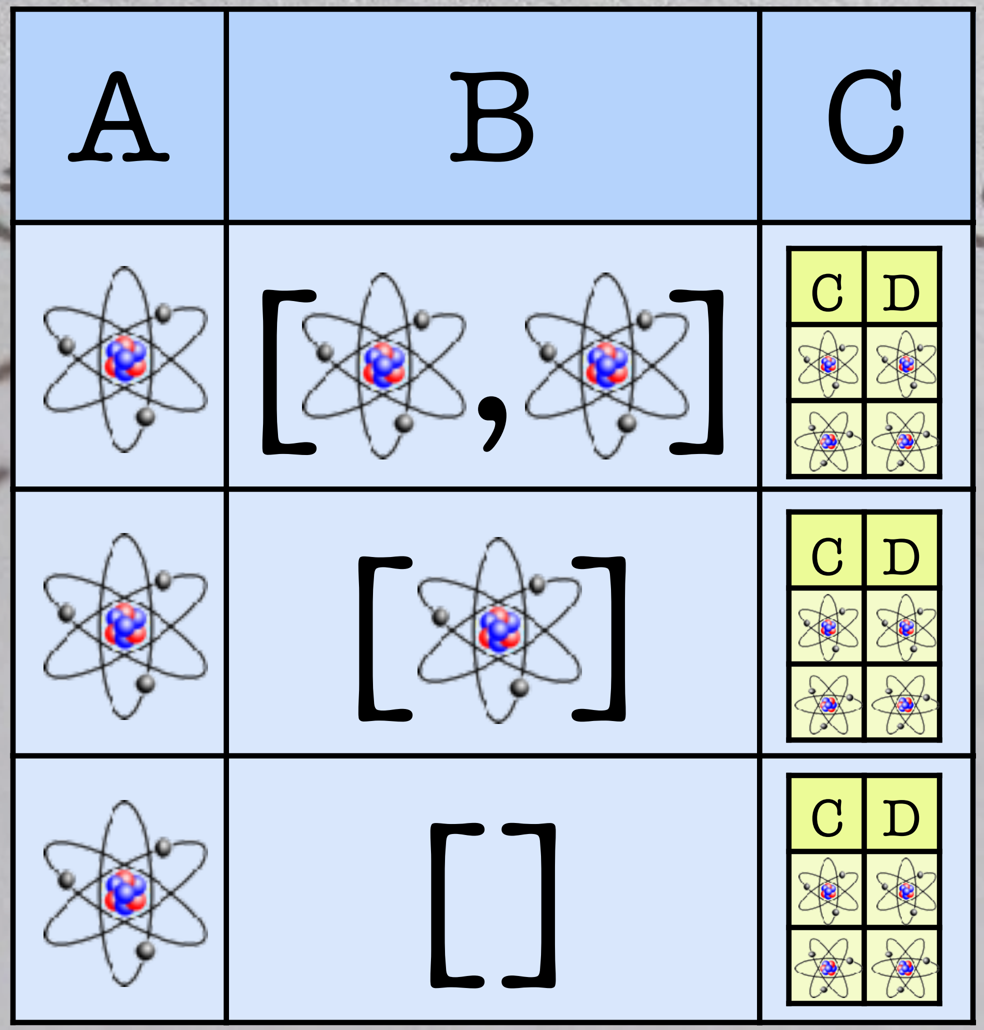
  - Nested tables (multiset)



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SQL:1999 — Escaping the Relational Cage

Relational Model?

- Introduced rich types
  - arrays
  - Nested tables (multiset)
  - composite types (objects)

A	B	C	D
⚛	[⚛, ⚛]	C D ⚛ ⚛ ⚛ ⚛	{x: ⚛, y: ⚛}
⚛	[⚛]	C D ⚛ ⚛ ⚛ ⚛	{x: ⚛, y: ⚛}
⚛	[]	C D ⚛ ⚛ ⚛ ⚛	{x: ⚛, y: ⚛}

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SQL:1999 — Escaping the Relational Cage

Relational Model?

- Introduced rich types
  - arrays
  - Nested tables (multiset)
  - composite types (objects)

Non-Relational Operations

- Introduced recursive queries that process their own output
  - Transitive closure

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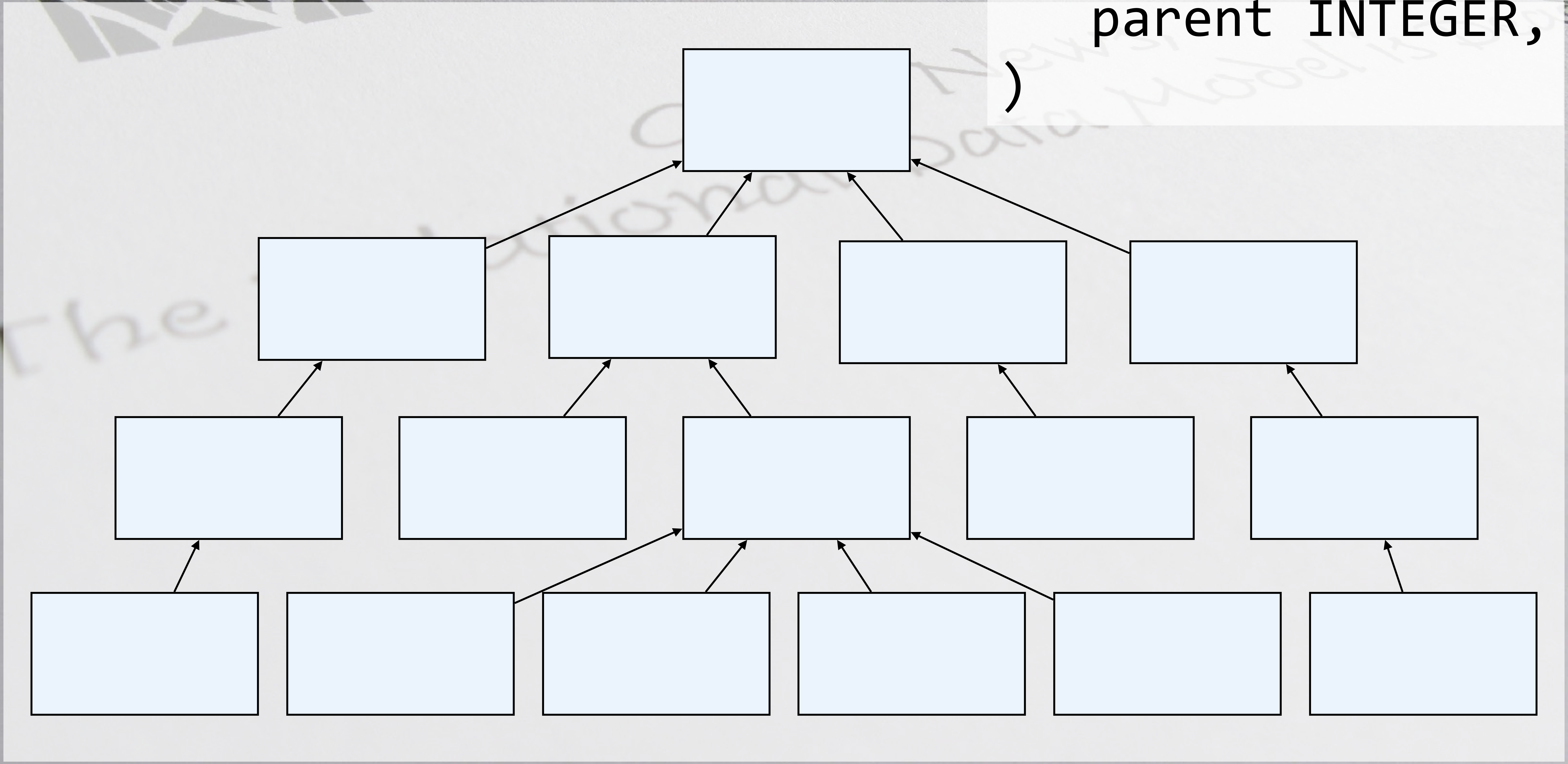
SQL:1999 — Recursion

```
CREATE TABLE t (
   id     INTEGER,
   parent INTEGER,
)
```



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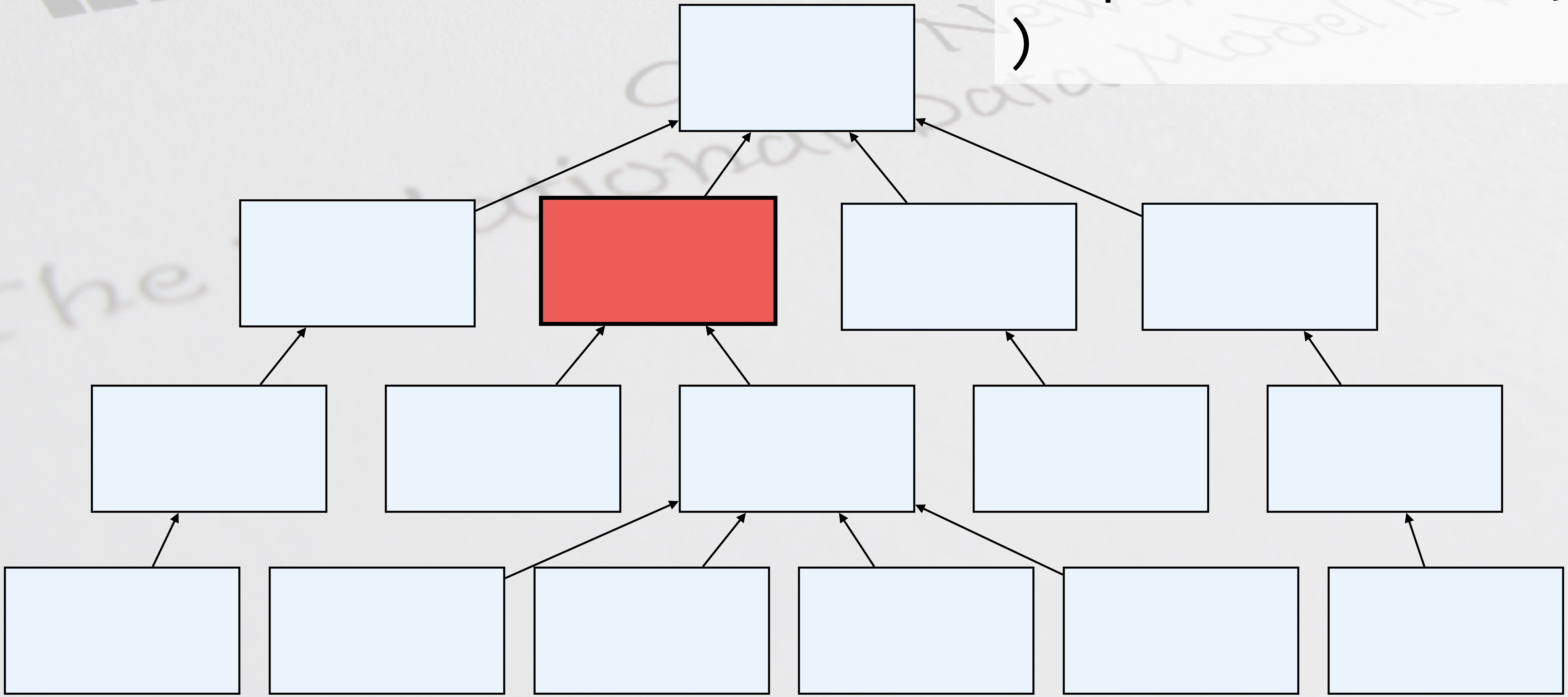

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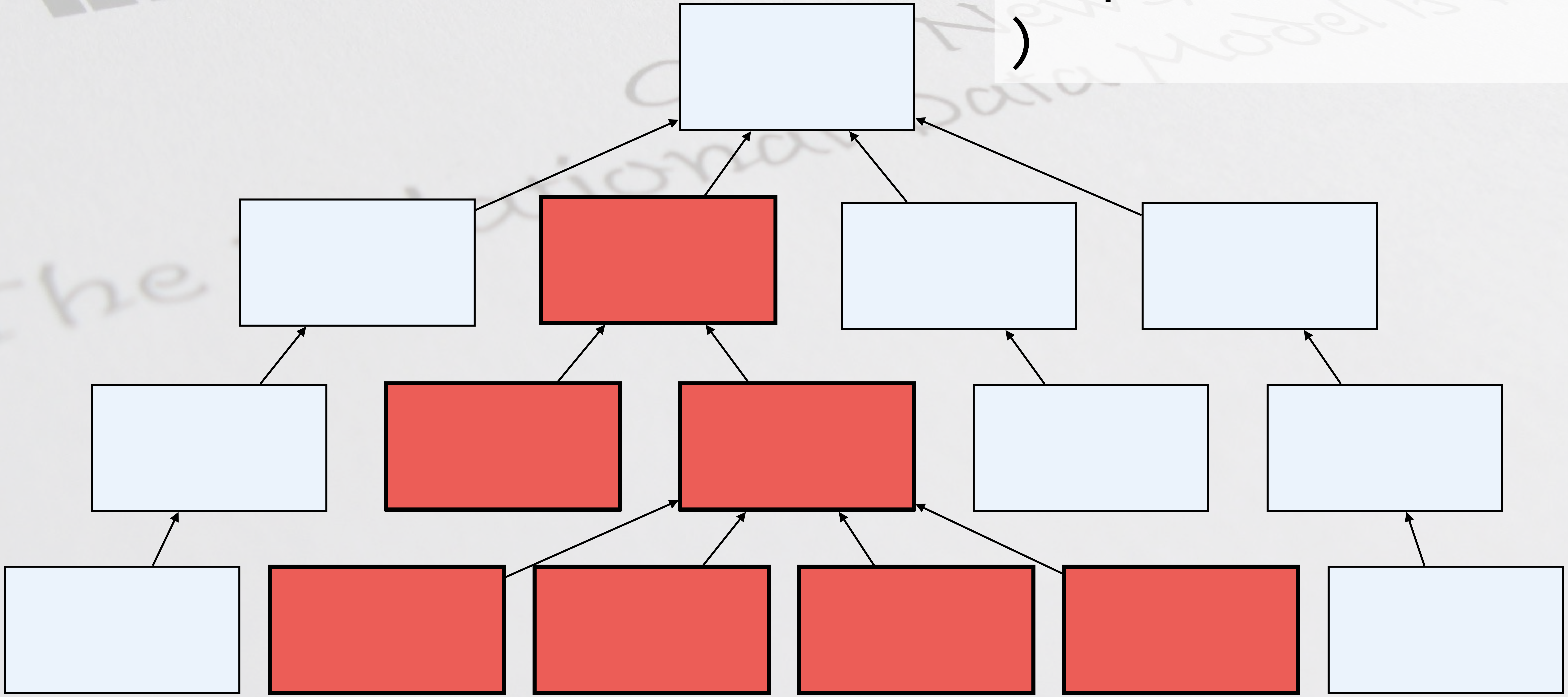

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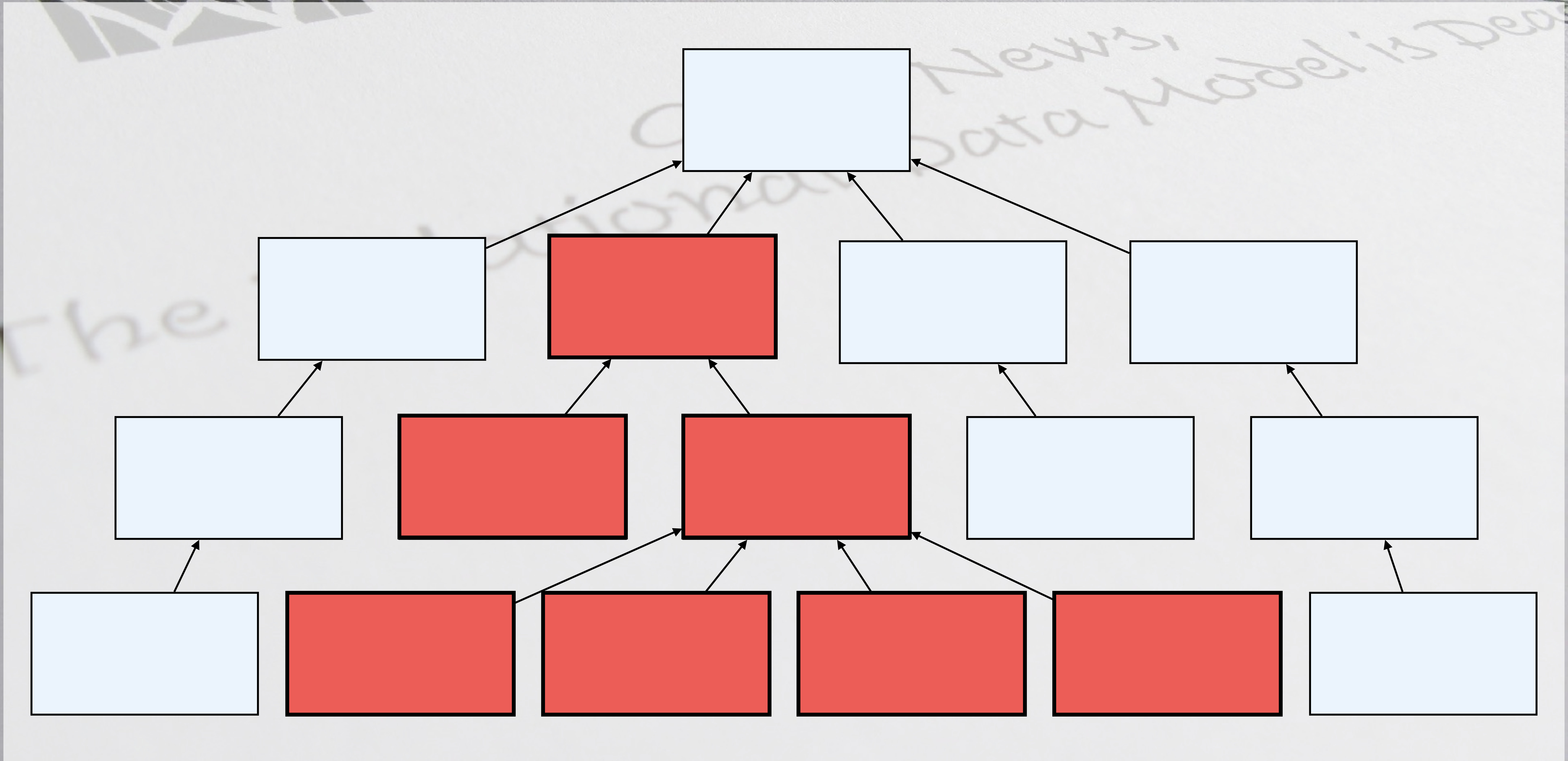

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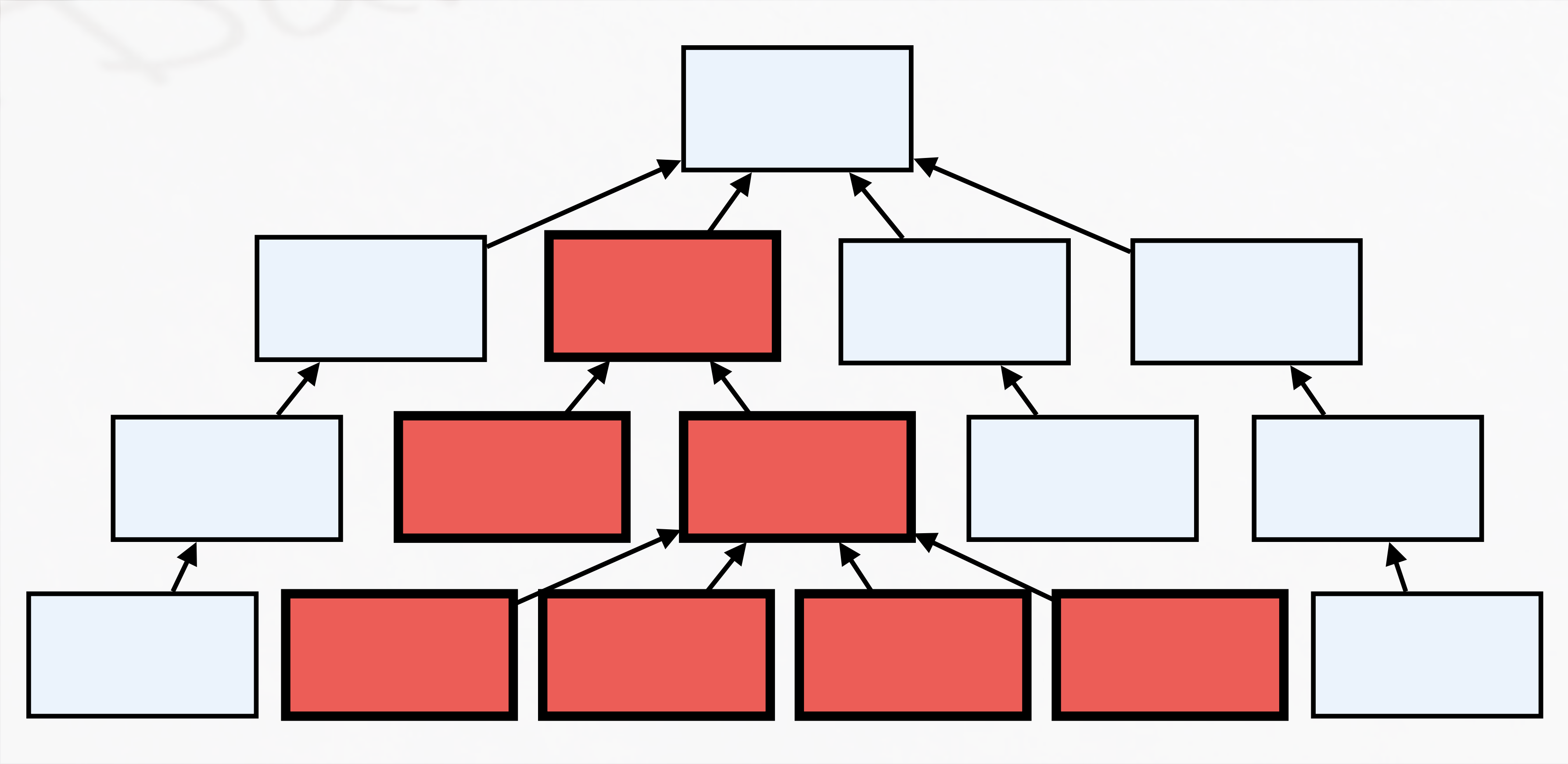
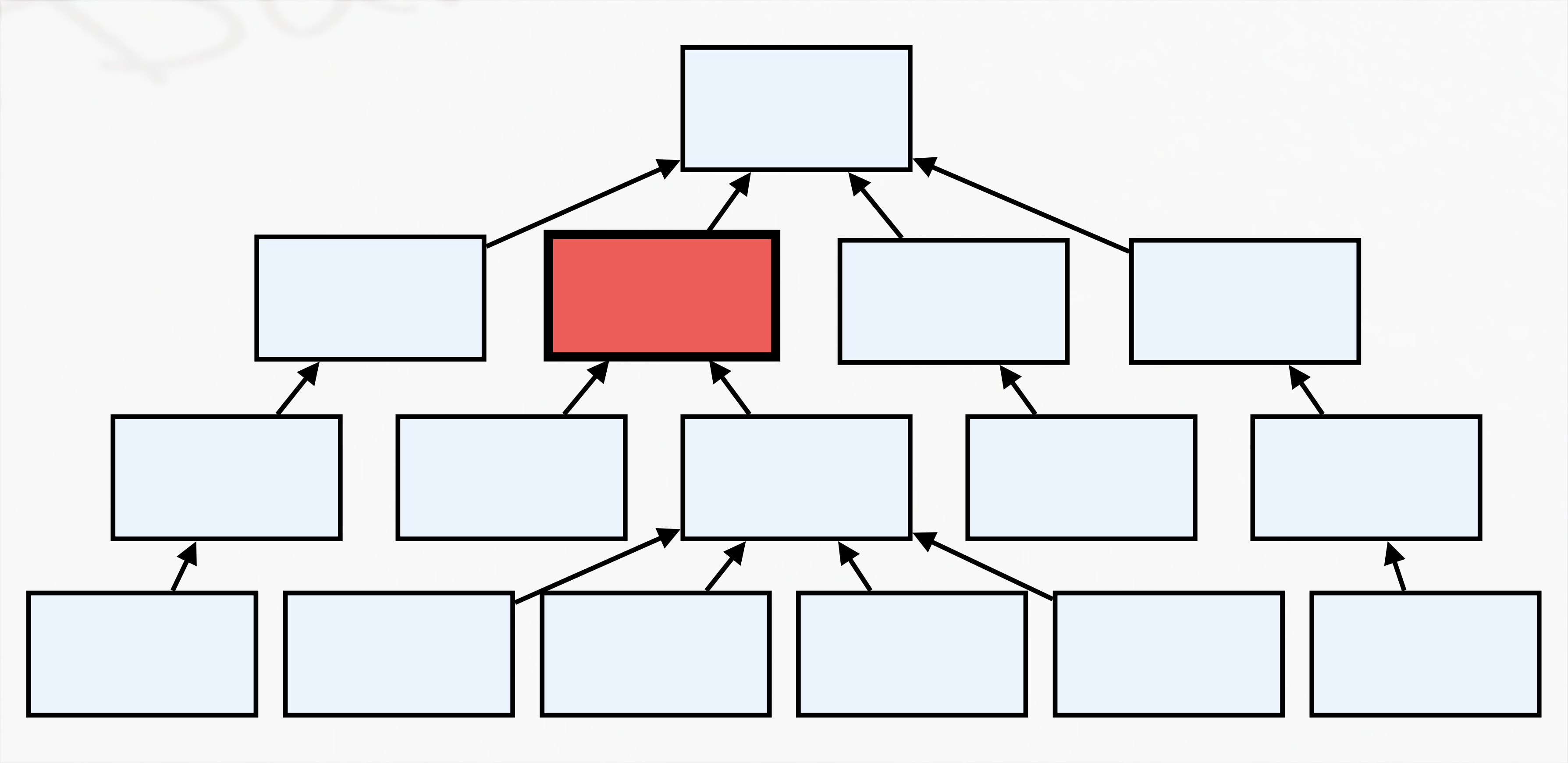


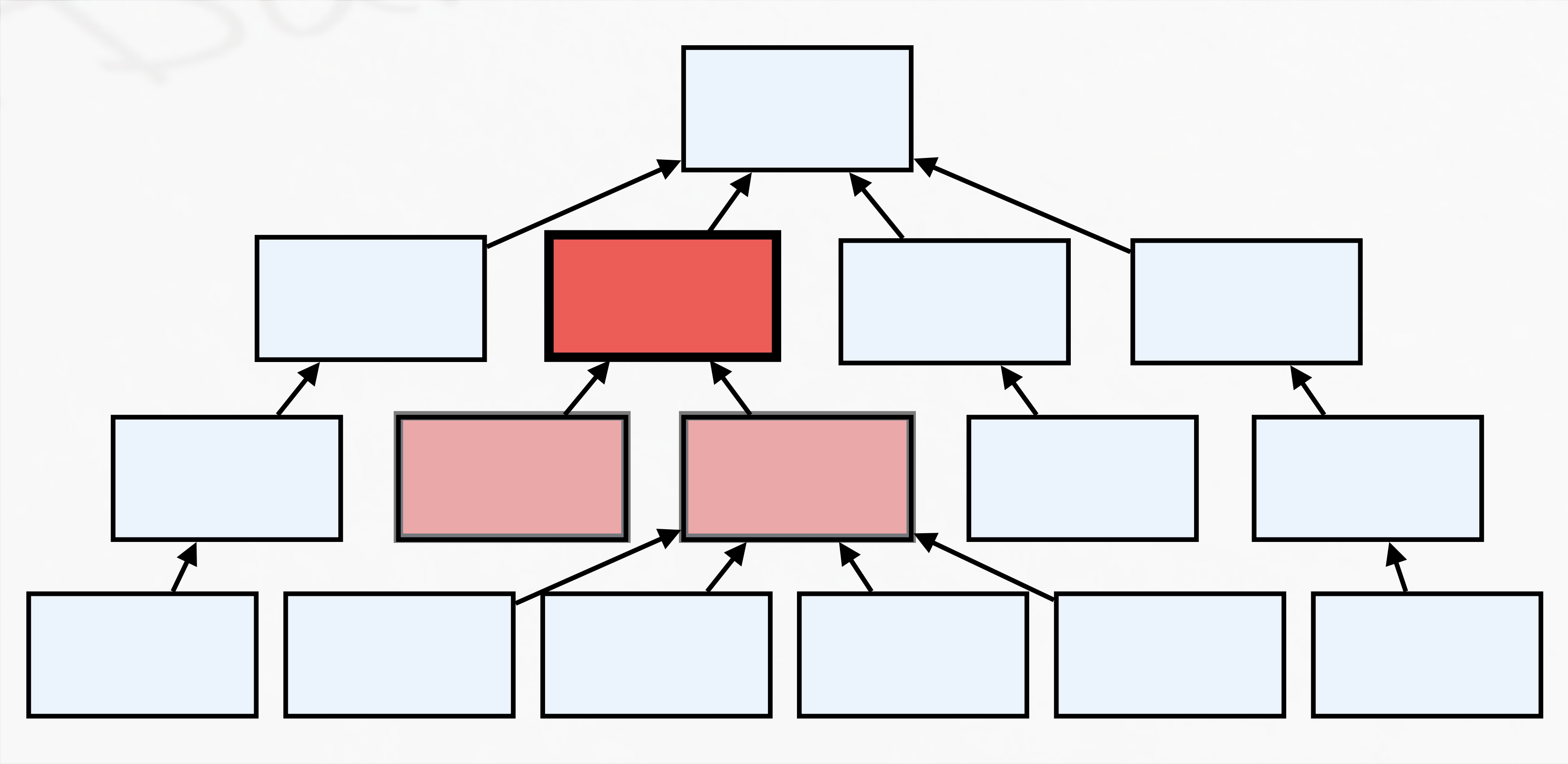
SQL:1999 — Recursion

```
SELECT t.id, t.parent
  FROM t
 WHERE t.id = ?
```



SQL:1999 — Recursion

```
  SELECT t.id, t.parent
    FROM t
   WHERE t.id = ?
UNION ALL
  SELECT t.id, t.parent
    FROM t
   WHERE t.parent = ?
```



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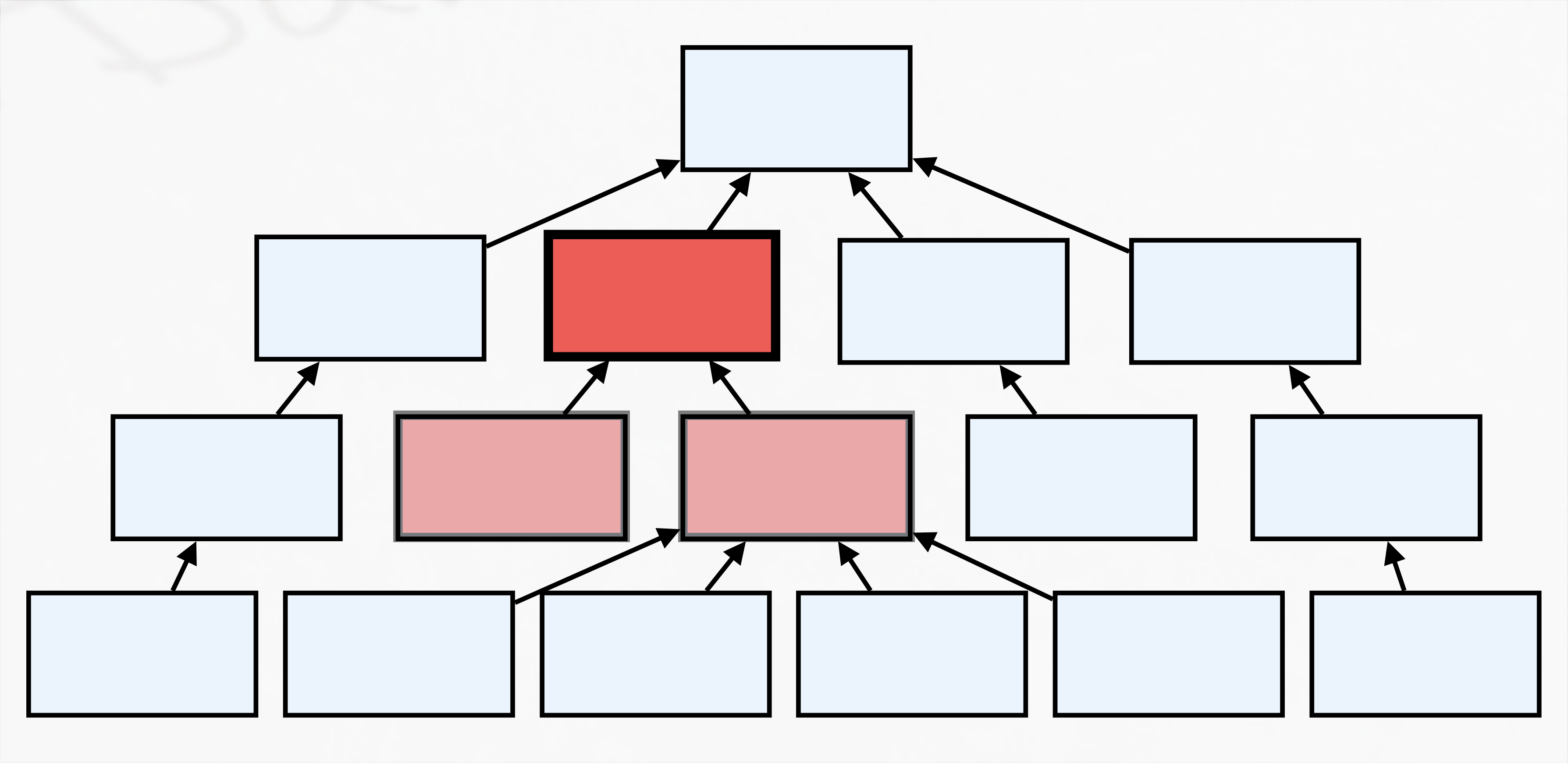

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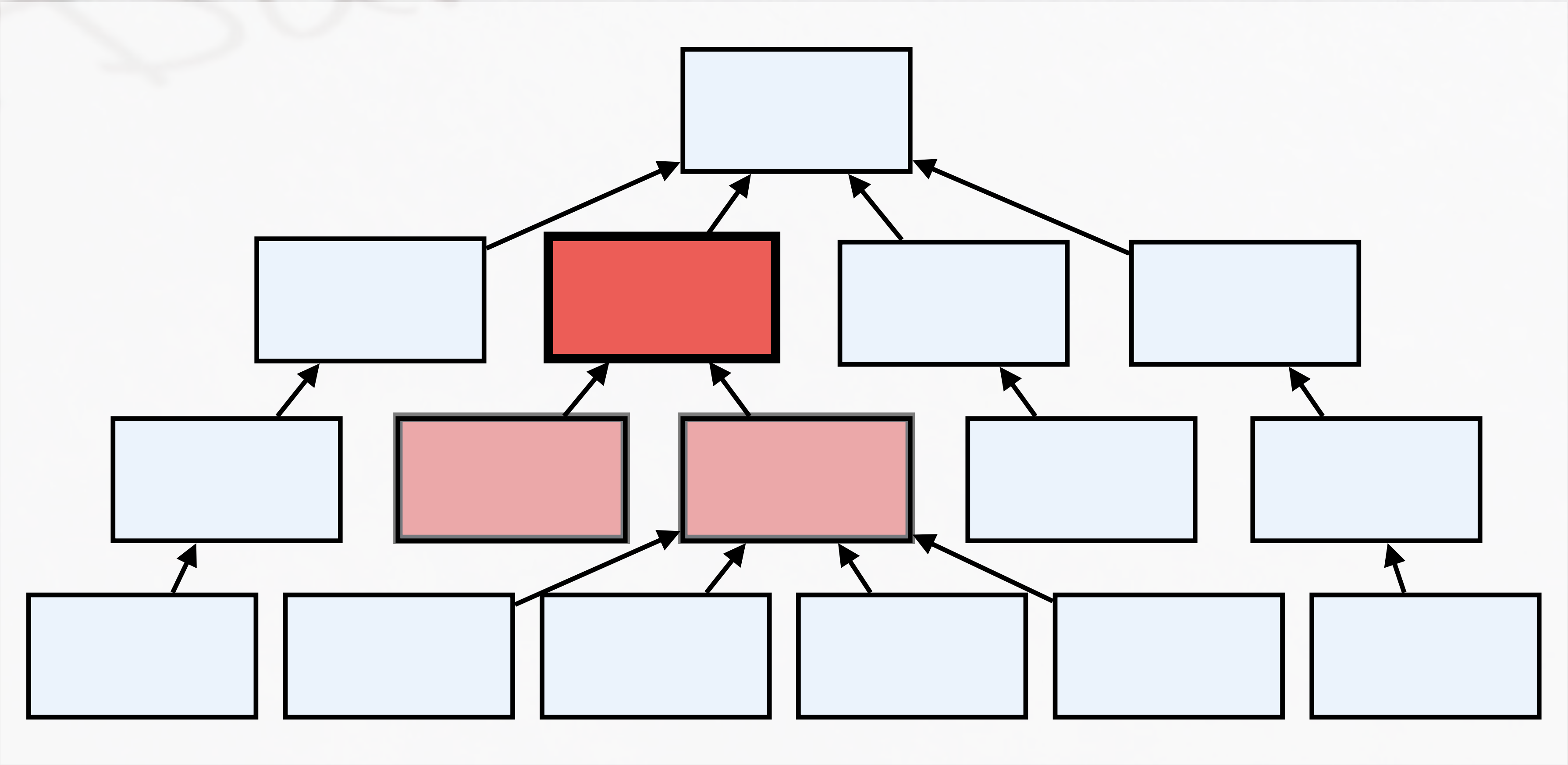
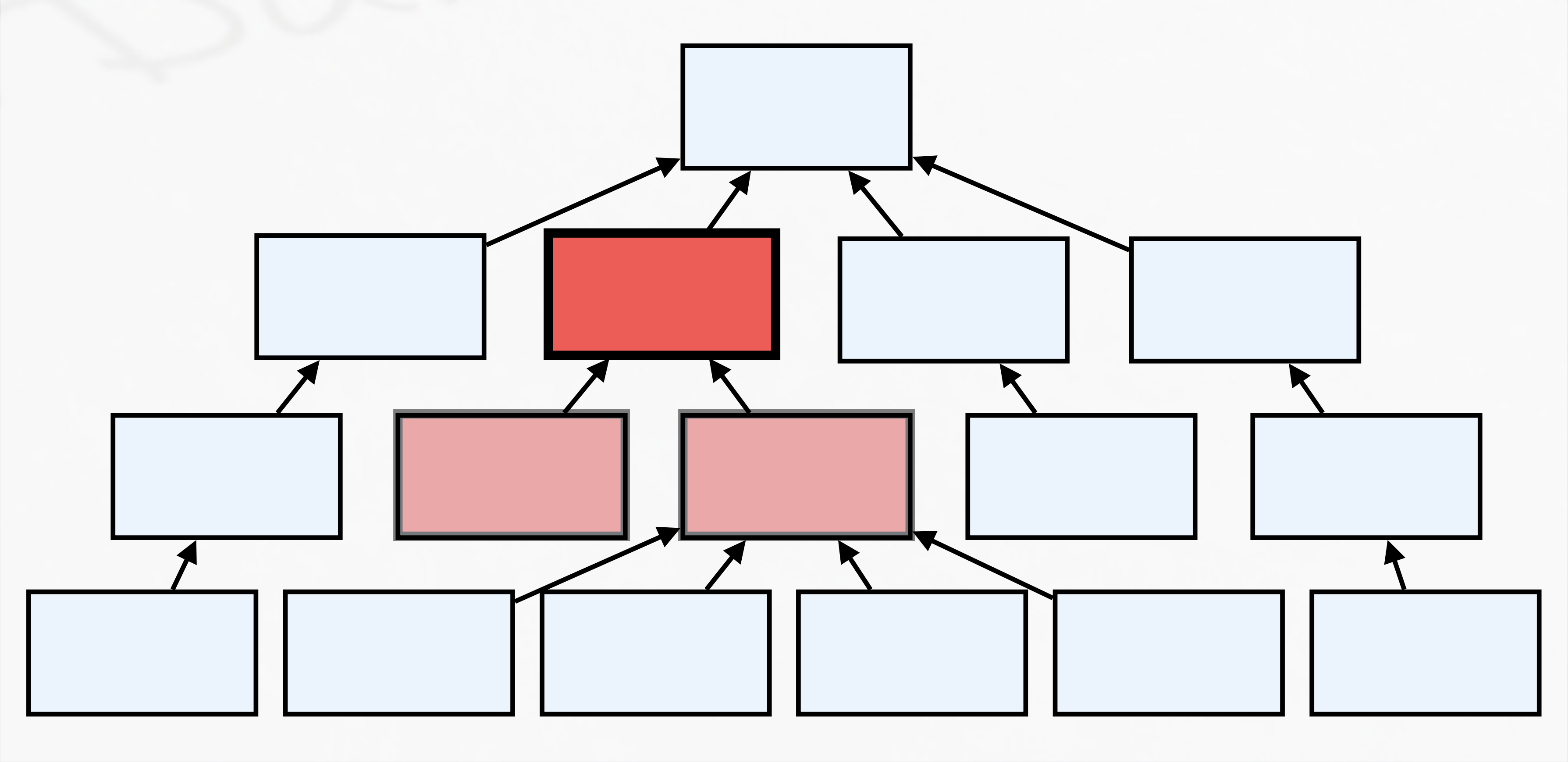


SQL:1999 — Recursion

```
WITH RECURSIVE prev (id, parent) AS (
  SELECT t.id, t.parent
    FROM t
   WHERE t.id = ?
UNION ALL
  SELECT t.id, t.parent
    FROM t
    JOIN prev ON t.parent = prev.id
)
SELECT * FROM prev
```



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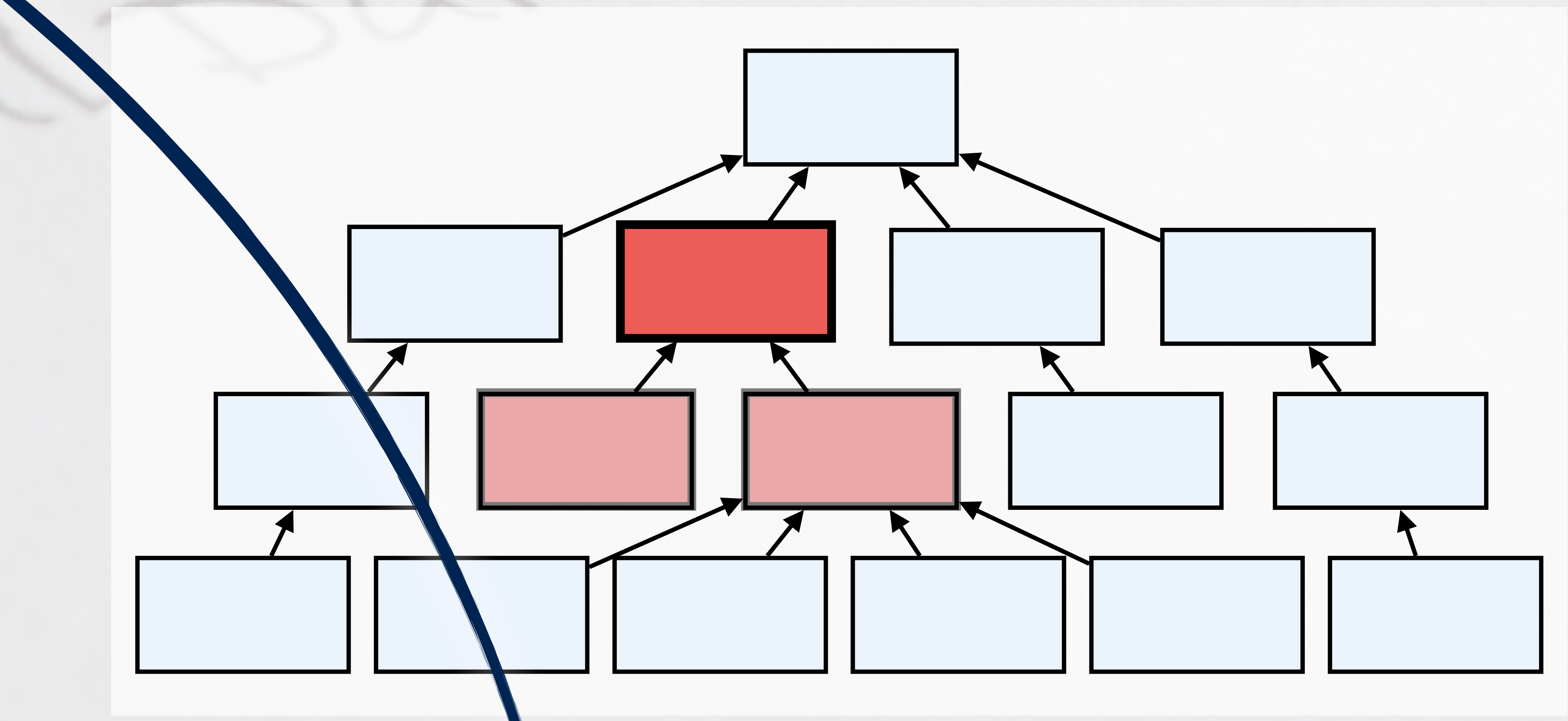

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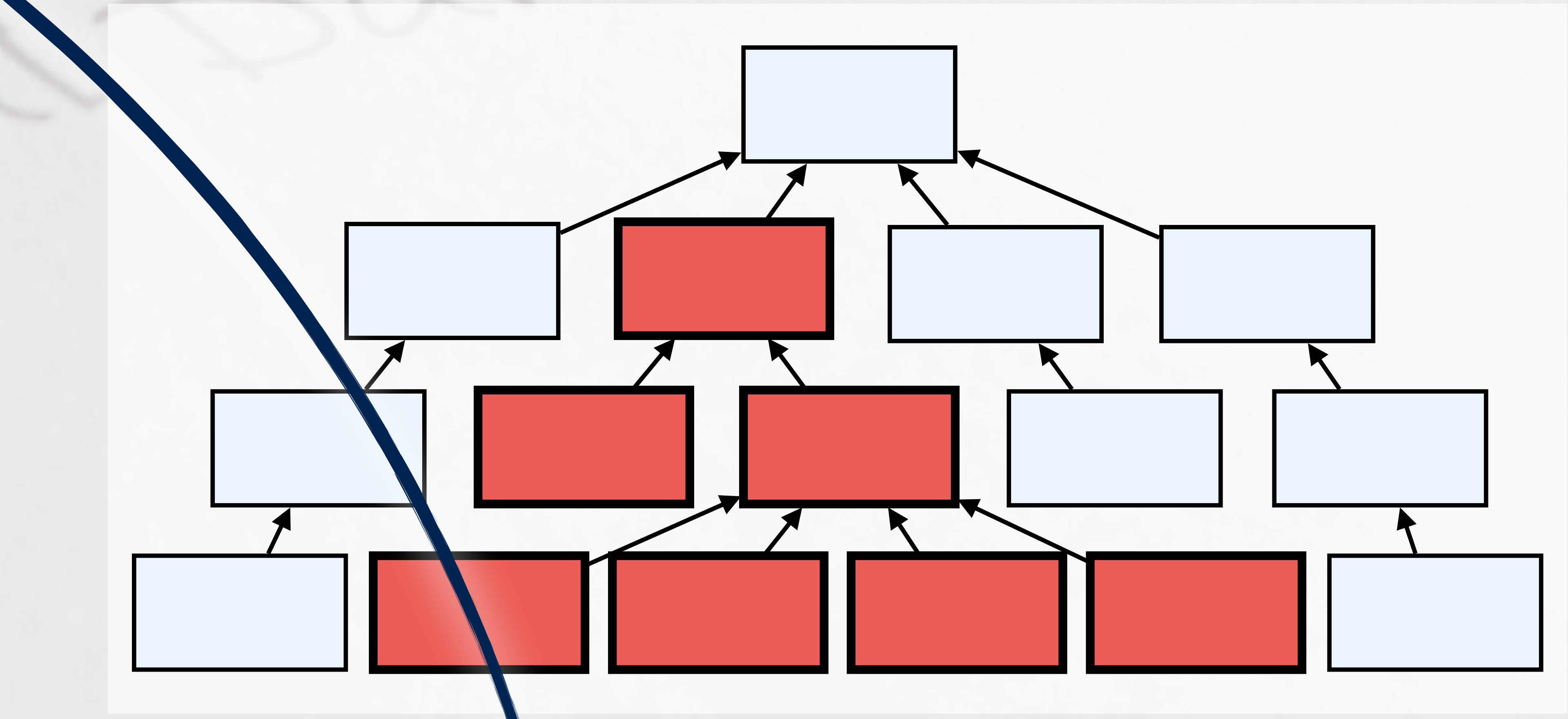

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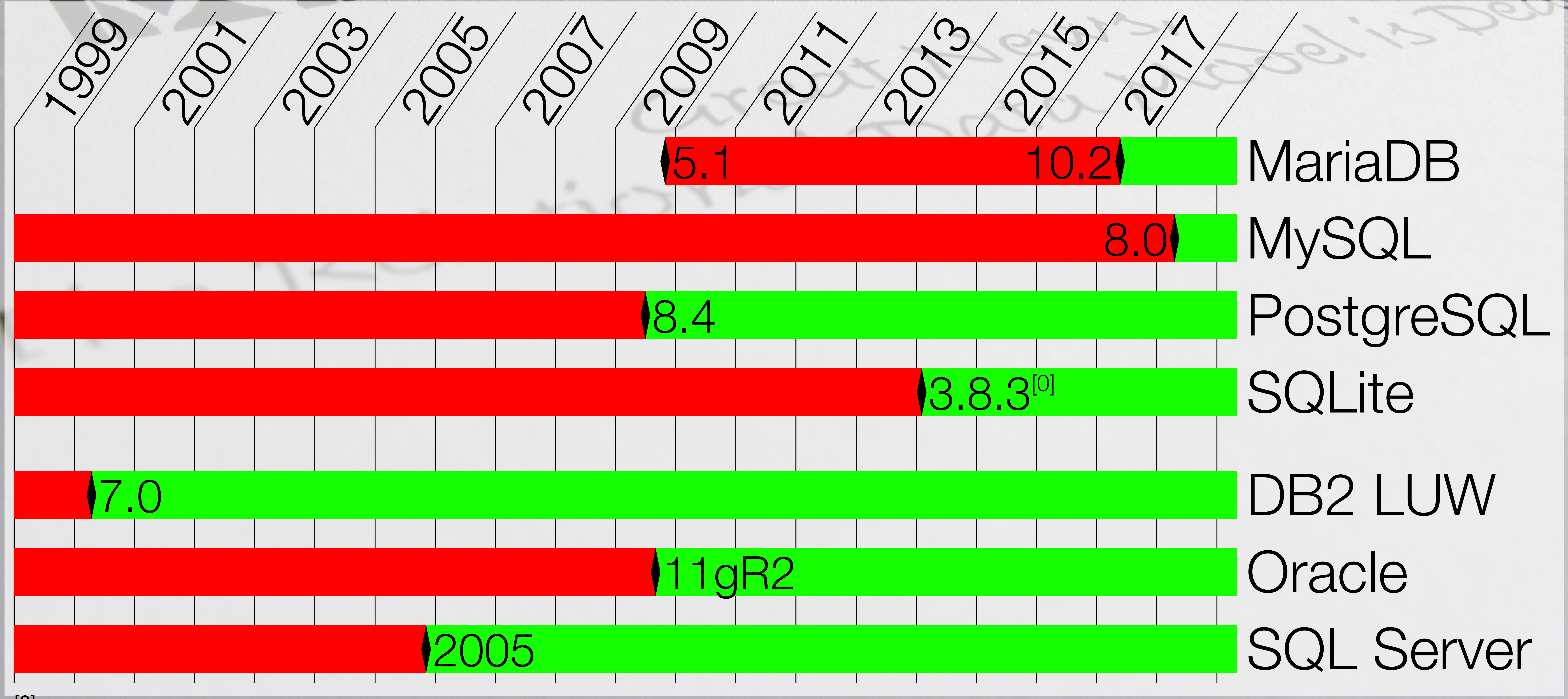

[0]Only for top-level SELECT statements

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Great News,
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1999 ⏩ 2003

SQL/XML is Making Good Progress

Andrew Eisenberg
IBM, Westford, MA 01886
andrew.eisenberg@us.ibm.com

Jim Melton
Oracle Corp., Sandy
jim.melton

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http://www.acm.org:80/sigmod/record/issues/0206/standard.pdf (via Wayback machine)

SQL:2003 — Schemaless & Analytical

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Schemaless

- Introduced XML
  - Non-uniform documents in a single column

SQL:2003 — Schemaless & Analytical

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Later:

- JSON added with SQL:2016
- Proprietary JSON support:
  - 2012: PostgreSQL
  - 2014: Oracle
  - 2015: MySQL
  - 2016: SQL Server

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Analytical

- Introduced window functions
  - Accessing other rows of the current result

SQL:2003 — Schemaless & Analytical

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Analytical

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Later:

- Extended in SQL:2011
- Popular among “New SQLs”
  - 2013: BigQuery, Hive
  - 2014: Impala
  - 2015: Spark SQL
  - 2016: NuoDB, MemSQL, Cockroach DB, VoltDB

SQL:2003 — Analytical

```
SELECT id, value




  FROM t
```

id	value
1	+10
2	+20
3	-10
4	+50
5	-30
6	-20

SQL:2003 — Analytical

```
SELECT id, value




  FROM t
```

id	value	**bal**
1	+10	
2	+20	
3	-10	
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5	-30	
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id	value	bal
1	+10	**+10**
2	+20	**+30**
3	-10	**+20**
4	+50	**+70**
5	-30	**+40**
6	-20	**+20**

SQL:2003 — Analytical

```
SELECT id, value
     , SUM(value)
       OVER (




       ) bal
  FROM t
```

id	value	bal
1	+10	**+10**
2	+20	**+30**
3	-10	**+20**
4	+50	**+70**
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SQL:2003 — Analytical

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SELECT id, value
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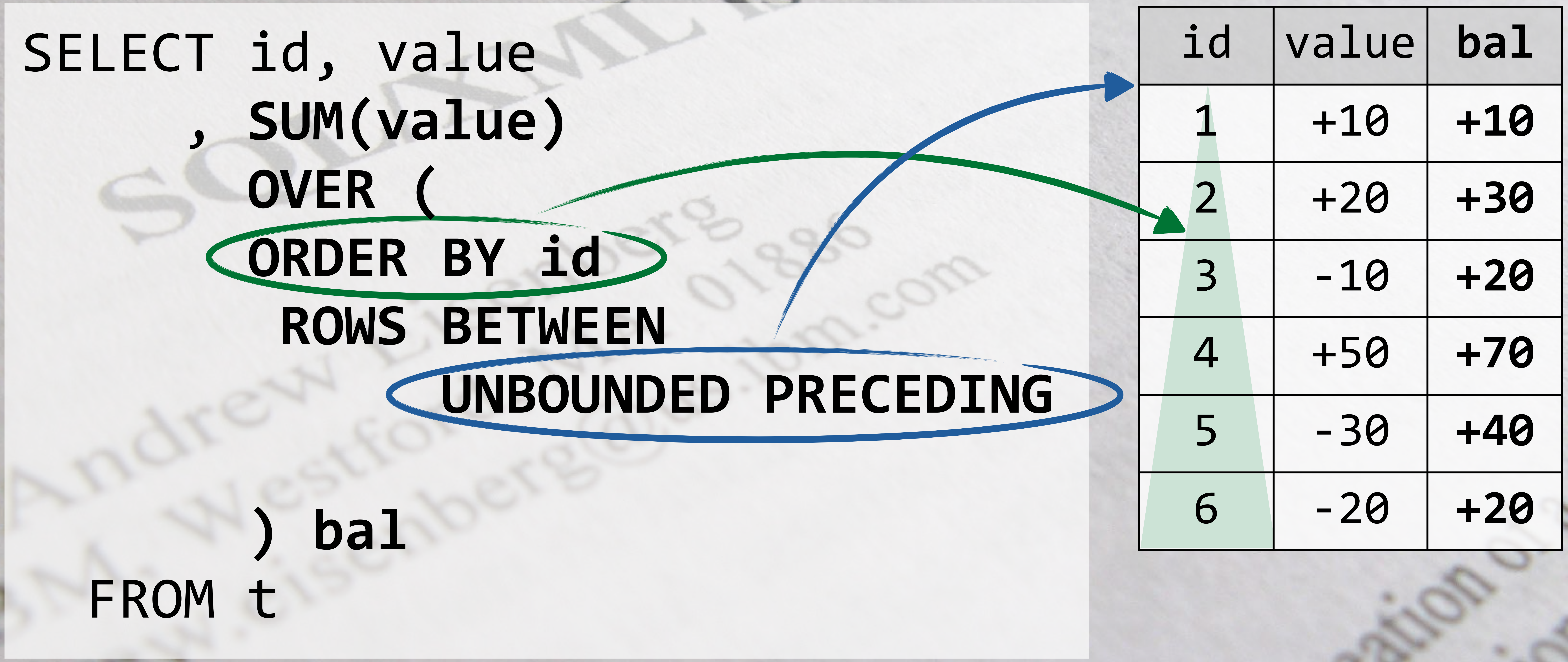

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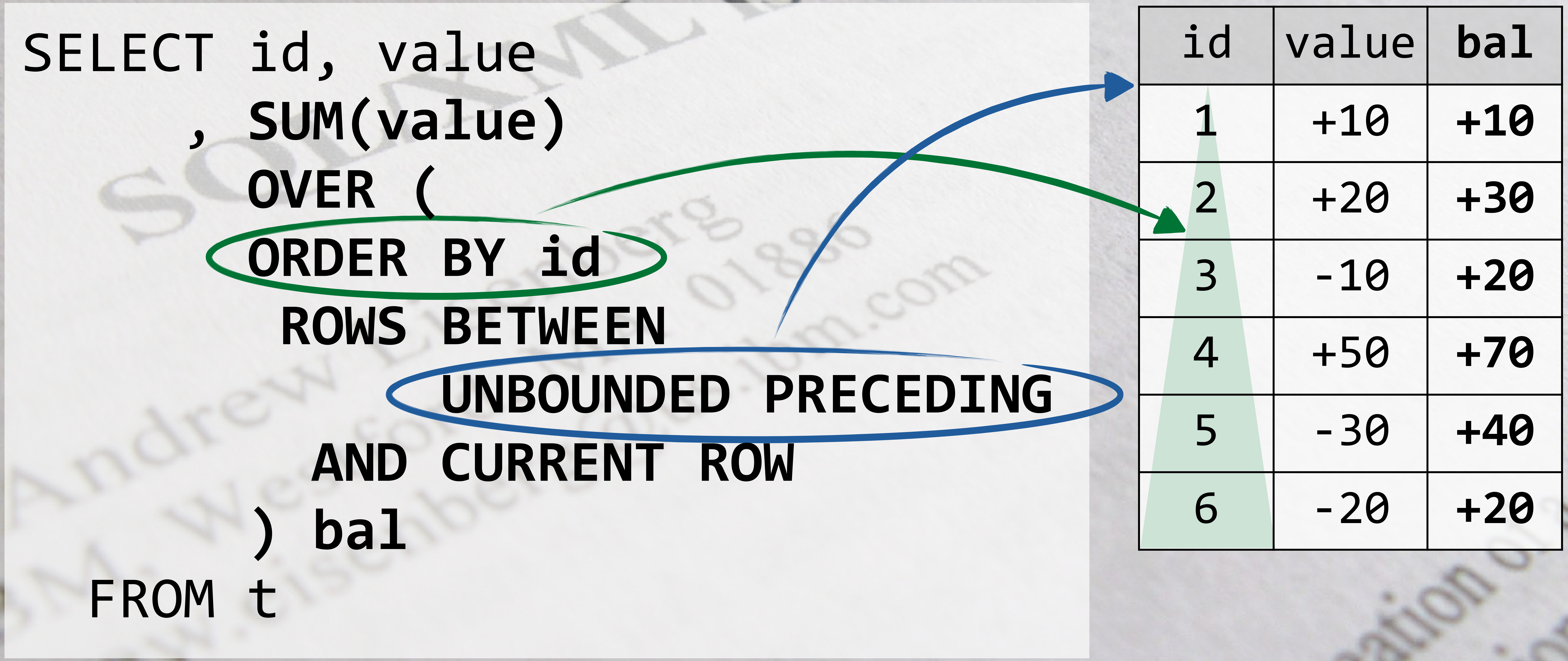

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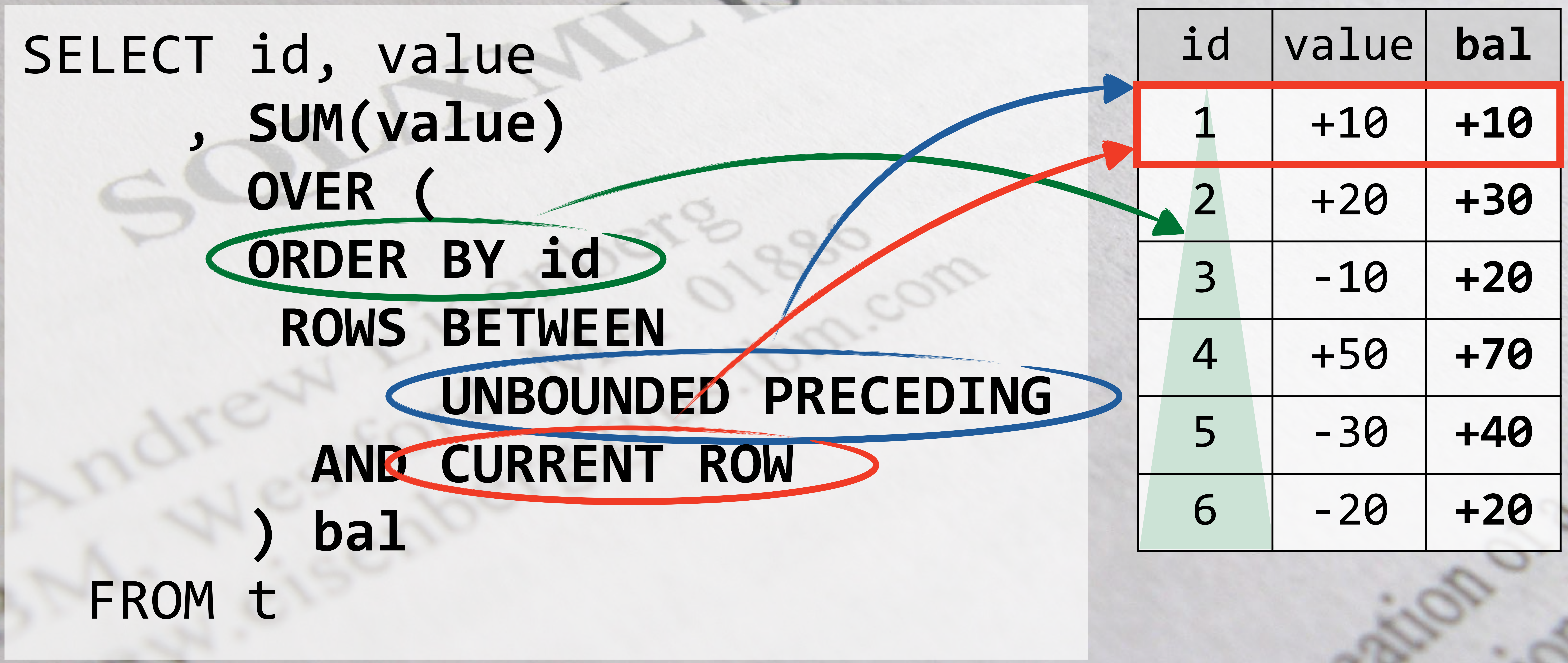

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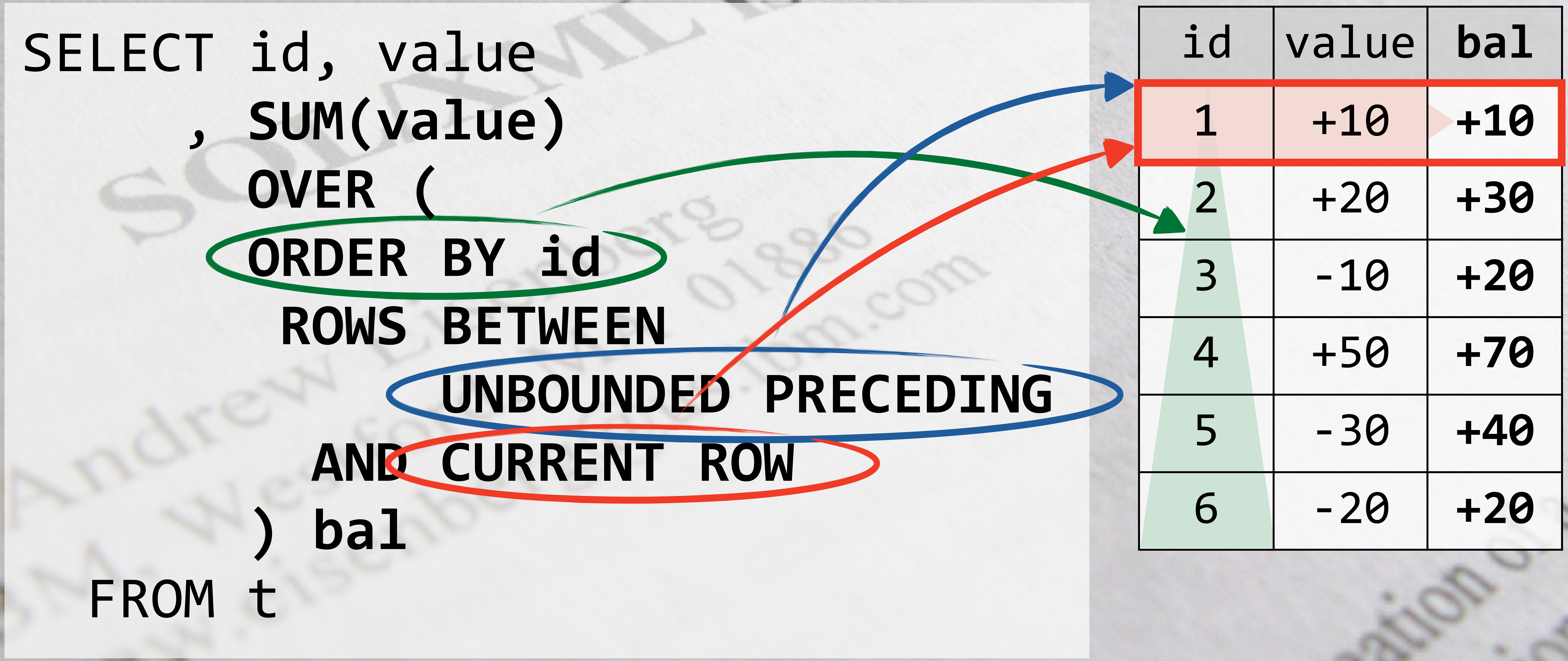

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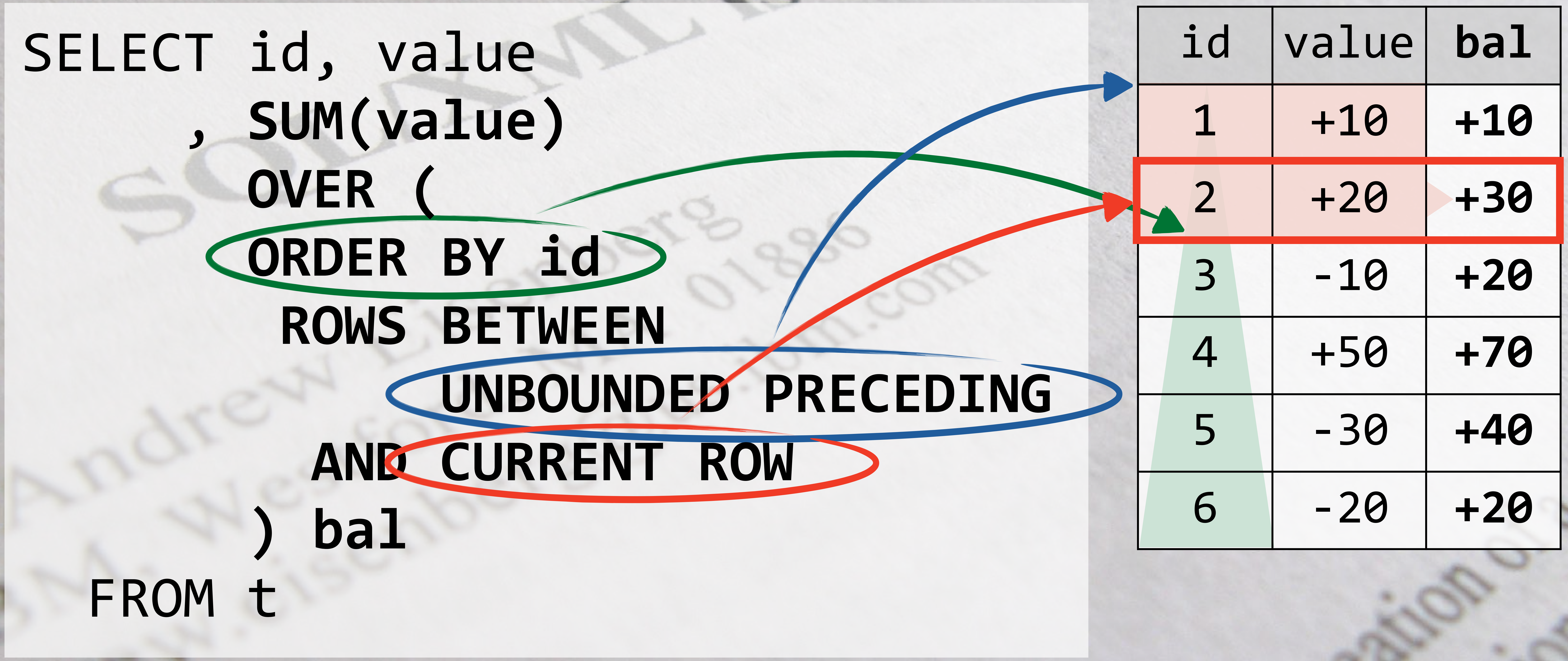
3	-10	+20
4	+50	+70
5	-30	+40
6	-20	+20

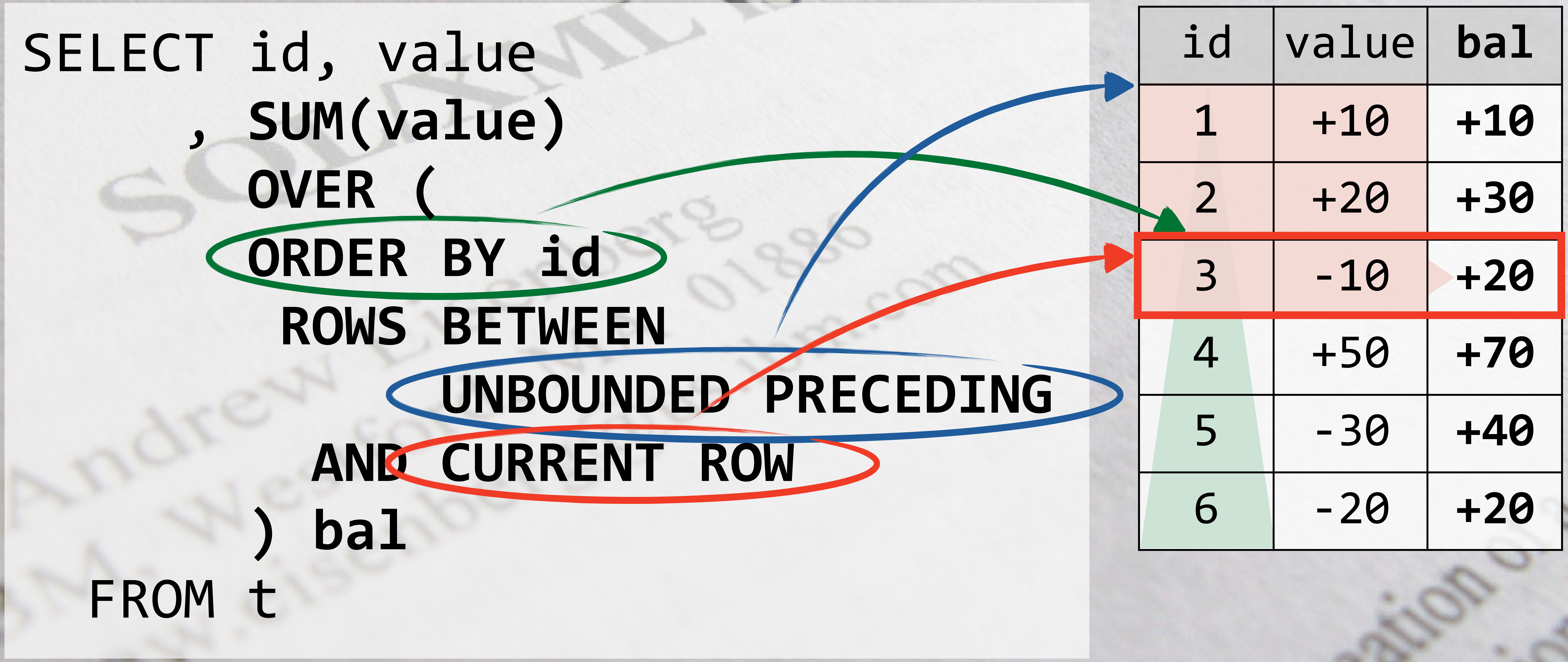
SQL:2003 — Analytical



```
SELECT id, value
     , SUM(value)
       OVER (
       ORDER BY id
        ROWS BETWEEN
             UNBOUNDED PRECEDING
         AND CURRENT ROW
       ) bal
  FROM t
```

id	value	bal
1	+10	+10
2	+20	+30
3	-10	+20
4	+50	+70
5	-30	+40
6	-20	+20

SQL:2003 — Analytical



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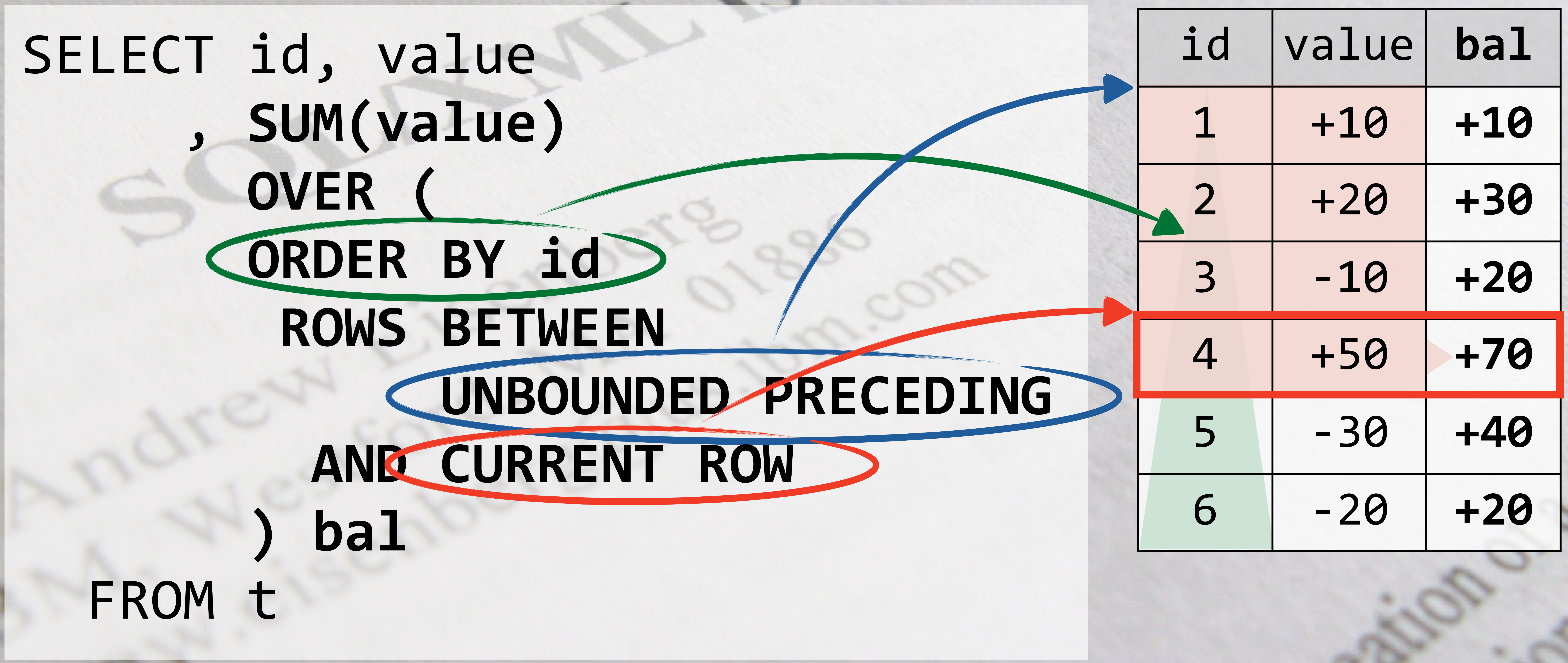

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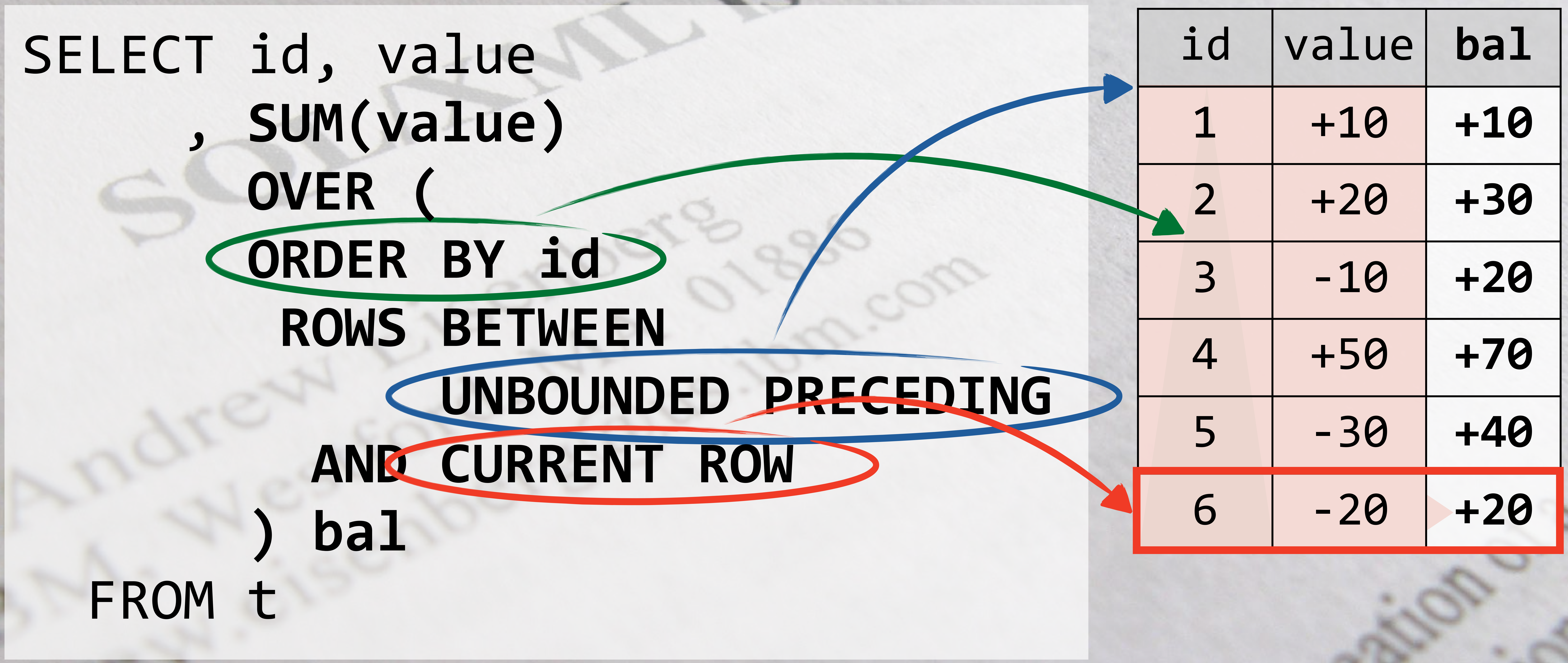

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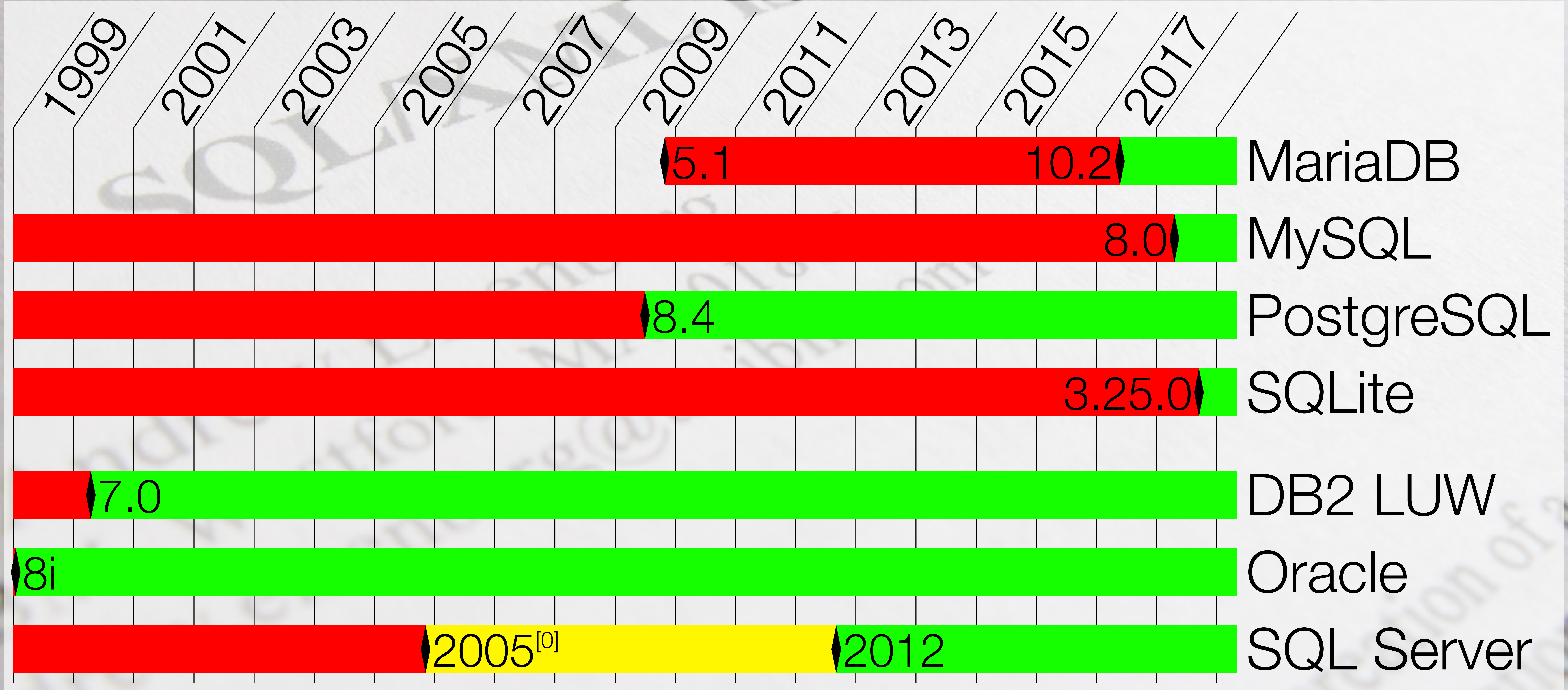

[0]No framing

SQL/XML is Making Good Progress

Jim Melton
Oracle Corp., Sand
jim.melton

Andrew Eis
IBM, Westford
andrew.eisenberg@us.ibm.c

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2003

2016

SQL:2016 — JSON

Information technology — Database languages — SQL Technical Reports —

Part 6:

SQL support for JavaScript Object Notation (JSON)

nologies de l'information — Langages de base de donn

echniques —

rt de SQL pour JavaScript Object No

http://standards.iso.org/ittf/PubliclyAvailableStandards/c067367_ISO_IEC_TR_19075-6_2017.zip

SQL:2016 — JSON

TECHNICAL REPORT

Information technology — Database languages — SQL Technical Reports —

Part 6: SQL support for JavaScript Object Notation (JSON)

Technologies de l'information — Langages de base de donn

techniques —

Partie 6: Support de SQL pour JavaScript Object No

```
[
  {
    "id": 42,
    "a1": "foo"
  },
  {
    "id": 43,
    "a1": "bar"
  }
]
```

http://standards.iso.org/ittf/PubliclyAvailableStandards/c067367_ISO_IEC_TR_19075-6_2017.zip

SQL:2016 — JSON

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    "id": 43,
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  }
]
```

id	a1
42	foo
43	bar

http://standards.iso.org/ittf/PubliclyAvailableStandards/c067367_ISO_IEC_TR_19075-6_2017.zip

SQL:2016 — JSON_TABLE

```
SELECT *
  FROM JSON_TABLE
       ( ?
       , '$[*]'
         COLUMNS
         ( id INT            PATH '$.id'
         , a1 VARCHAR(…) PATH '$.a1'
         )
       ) r
```

```
[
  {
    "id": 42,
    "a1": "foo"
  },
  {
    "id": 43,
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  }
]
```

id	a1
42	foo
43	bar

SQL:2016 — JSON_TABLE

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Bind Parameter

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  },
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    "id": 43,
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  }
]
```

id	a1
42	foo
43	bar

SQL:2016 — JSON_TABLE

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   FROM JSON_TABLE
        ( ?
        , '$[*]'
        COLUMNS
        ( id INT             PATH '$.id'
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        )
      ) r
```

Bind Parameter

SQL/JSON Path

- Query language to select elements from a JSON document
- Defined in the SQL standard

```
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    "id": 42,
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       ) r
```

Bind Parameter

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  {
     "id": 42,
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  {
     "id": 43,
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  }
]
```

id	a1
42	foo
43	bar

SQL:2016 — JSON_TABLE — Use Case

```
SELECT *
  FROM JSON_TABLE
       ( ?
       , '$[*]'
         COLUMNS
         ( id INT            PATH '$.id'
         , a1 VARCHAR(…) PATH '$.a1'
         )
       ) r
```

```
[
  {
    "id": 42,
    "a1": "foo"
  },
  {
    "id": 43,
    "a1": "bar"
  }
]
```

id	a1
42	foo
43	bar

SQL:2016 — JSON_TABLE — Use Case

```
INSERT INTO target_table
SELECT *
  FROM JSON_TABLE
       ( ?
       , '$[*]'
         COLUMNS
         ( id INT            PATH '$.id'
         , a1 VARCHAR(…) PATH '$.a1'
         )
       ) r
```

```
[
  {
    "id": 42,
    "a1": "foo"
  },
  {
    "id": 43,
    "a1": "bar"
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SQL:2016 — JSON_TABLE — Use Case

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         ( id INT            PATH '$.id'
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         )
       ) r
```

```
   },
   {
     "id": 43,
     "a1": "bar"
   }
]
```

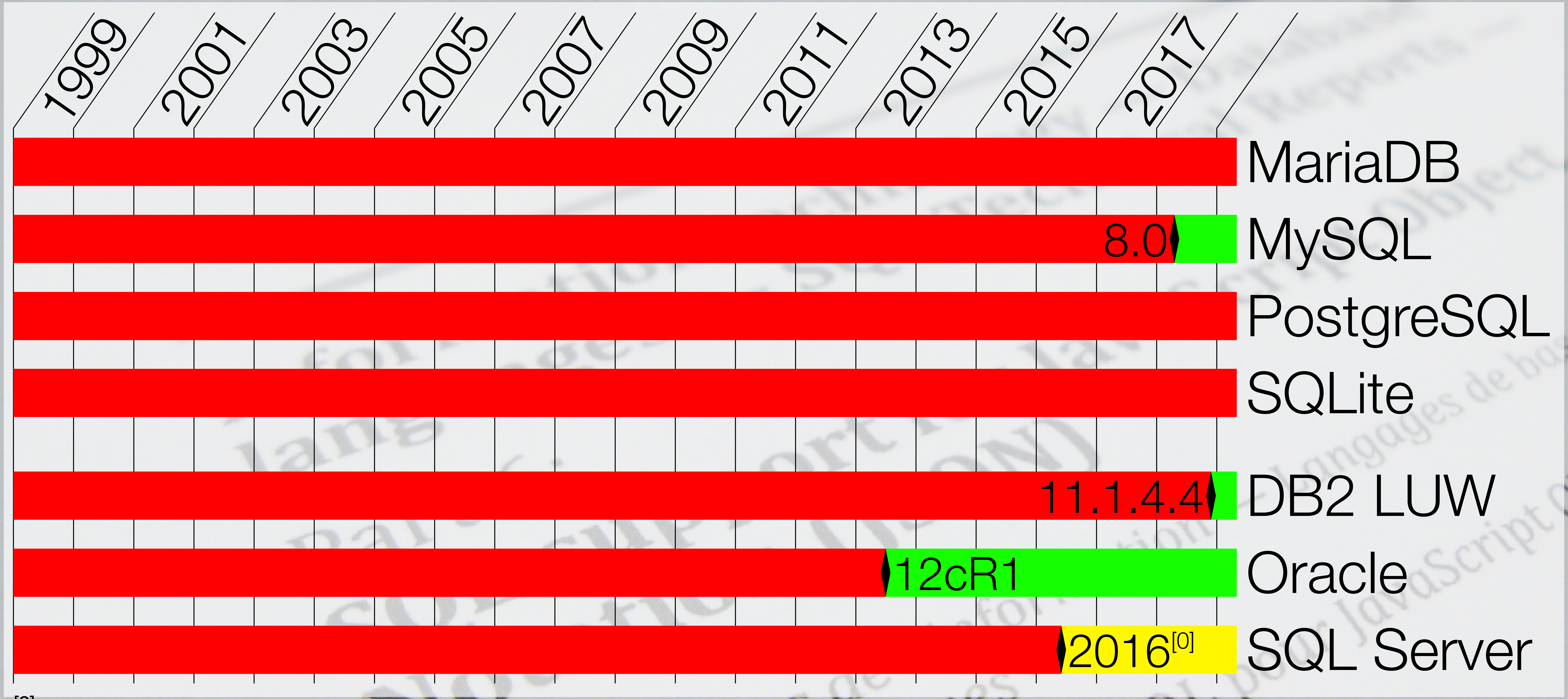
id	a1
42	foo
43	bar

Session tip:

How Well Do Relational Database Engines Support JSON?

Today 15:30!

SQL:2016 — JSON_TABLE



[0]OPENJSON provides similar functionality

TECHNICAL REPORT

Informa — Database

languag nical Reports —

Part 6:

SQL support f avaScr Object

Notation (JSON)

nologies de l'information — Langages de base de donn

techniques —

rt de SQL pour JavaScript Object No

2011

2016

SQL:2011 — Time Travelling

Temporal features in SQL:2011

Krishna Kulkarni, Jan-Eike Michels (IBM Corporation)
{krishnak, janeike}@us.ibm.com

ABSTRACT

SQL:2011 was published in December of 2011, replacing SQL:2008 as the most recent revision of the SQL standard. This paper covers the most important new functionality that is part of SQL:2011: the ability to create and manipulate temporal tables.

implement temporal support as part of the application logic, which often resulted in expensive developm cycles and complex, hard-to-maintain code. In 1995, the ISO SQL committee initi create a new part of SQL standa guage extensions for the te language extension TSQL2 [8] w time

http://cs.ulb.ac.be/public/_media/teaching/infoh415/tempfeaturessql2011.pdf

SQL:2011 — Time Travelling

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Introduction

<u>Application Versioning</u>

- Dedicated syntax added
  - When did something happen in the real world?

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SQL:2011 — Time Travelling

Application Versioning

- Dedicated syntax added
  - When did something happen in the real world?

New syntax (excerpt)

- `FOR PORTION OF` in `UPDATE` and `DELETE`
- `WITHOUT OVERLAPS` in `UNIQUE` constraints & `PRIMARY KEYS`
- `[IMMEDIATELY] PRECEDES`, `OVERLAPS` in `WHERE`, `HAVING`, …

SQL:2011 — Time Travelling

Application Versioning

- Dedicated syntax added
  - When did something happen in the real world?

New syntax (excerpt)

- FOR PORTION OF in UPDATE and DELETE
- WITHOUT OVERLAPS in UNIQUE constraints & PRIMARY KEYS
- [IMMEDIATELY] PRECEDES, OVERLAPS in WHERE, HAVING, …

System Versioning

- Fully automatic and (almost) transparent
  - When did we learn about something

SQL:2011 — Time Travelling

Application Versioning

- Dedicated syntax added
  - When did something happen in the real world?

New syntax (excerpt)

- `FOR PORTION OF` in `UPDATE` and `DELETE`
- `WITHOUT OVERLAPS` in `UNIQUE` constraints & `PRIMARY KEYS`
- `[IMMEDIATELY] PRECEDES`, `OVERLAPS` in `WHERE`, `HAVING`,…

System Versioning

- Fully automatic and (almost) transparent
  - When did we learn about something

Transparent changes, new syntax for queries

- `INSERT`, `UPDATE` & `DELETE` use the system time automatically
- `SELECT` can use `FOR SYSTEM_TIME AS OF`

SQL:2011 — System Versioning

Temporal Features in SQL:2011

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1. Introduction

implement temporal support as part of the application logic, which often resulted in expensive development cycles and complex, hard-to-maintain code.

In 1995, the ISO SQL committee initiated ... create a new part of SQL standard ... guage extensions for the ... language extensions ... TSQL2 [8] ...

SQL:2011 — System Versioning

```
CREATE TABLE t (
   ...
 , from TIMESTAMP(9) GENERATED ALWAYS
                     AS ROW START
 , till TIMESTAMP(9) GENERATED ALWAYS
                     AS ROW END

 , PERIOD FOR SYSTEM_TIME (from, till)
) WITH SYSTEM VERSIONING
```

SQL:2011 — System Versioning

Temporal features in SQL:2011

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{krishnak, janeike}@us.ibm.com

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SQL:2011 was published in December of 2011, replacing SQL:2008 as the most recent revision of the SQL standard. This paper covers the most important new functionality that is part of SQL:2011: the ability to create and manipulate temporal tables.

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guage extensions for the te

language extension

TSQL2 [8] w

SQL:2011 — System Versioning

```
INSERT INTO t (id, data)
       VALUES (1 , 'X' )
```

id	data	from	till
1	X	10:00	

SQL:2011 — System Versioning

```
INSERT INTO t (id, data)
       VALUES (1 , 'X' )
```

id	data	from	till
1	X	10:00	

```
UPDATE t
   SET data = 'Y'
 WHERE id = 1
```

id	data	from	till
1	X	10:00	11:00
1	Y	11:00	

SQL:2011 — System Versioning

```
INSERT INTO t (id, data)
       VALUES (1 , 'X' )
```

id	data	from	till
1	X	10:00	

```
UPDATE t
   SET data = 'Y'
 WHERE id = 1
```

id	data	from	till
1	X	10:00	11:00
1	Y	11:00	

```
DELETE FROM t
 WHERE id = 1
```

id	data	from	till
1	X	10:00	11:00
1	Y	11:00	12:00

SQL:2011 — System Versioning

id	data	from	till
1	X	10:00	11:00
1	Y	11:00	12:00

SQL:2011 — System Versioning

id	data	from	till
1	X	10:00	11:00
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```
SELECT *
  FROM t
```

id	data	from	till

SQL:2011 — System Versioning

id	data	from	till
1	X	10:00	11:00
1	Y	11:00	12:00

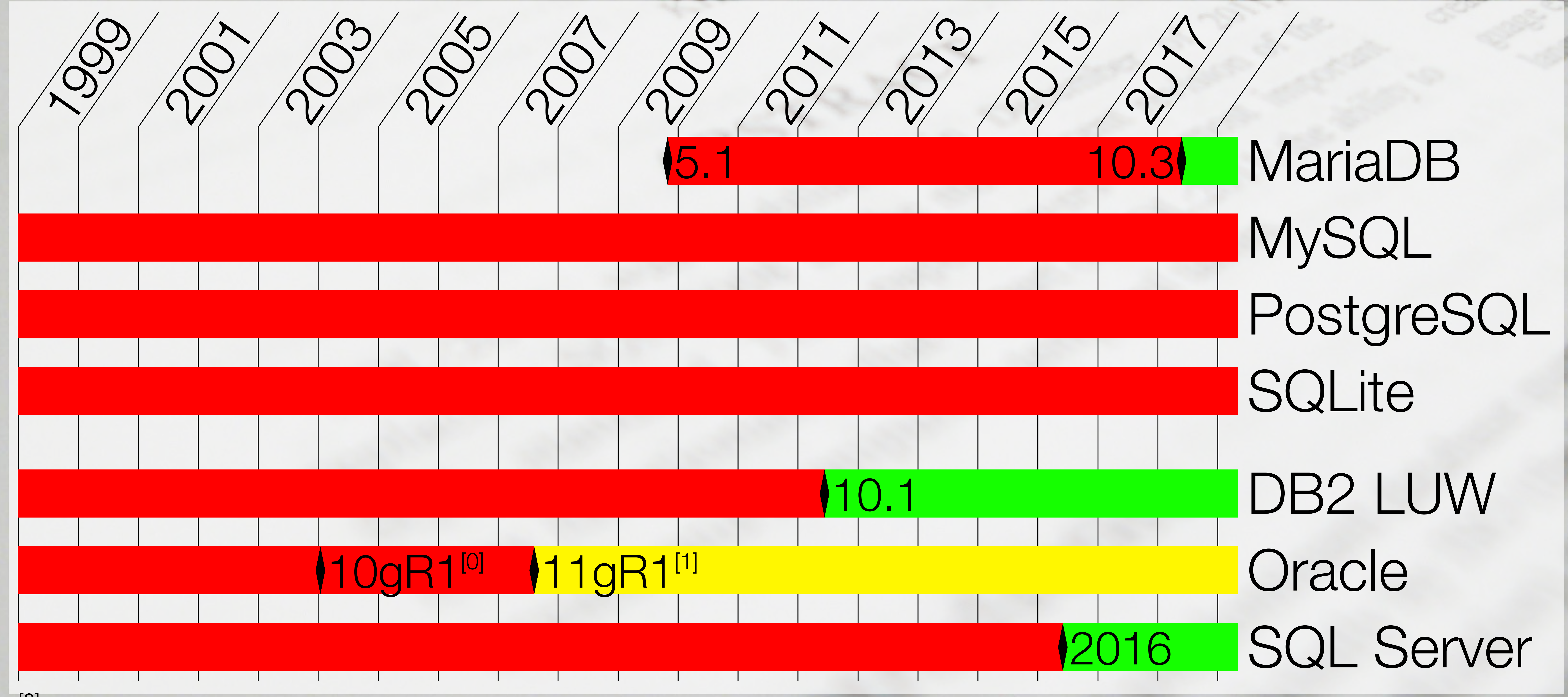
```
SELECT *
  FROM t
```

id	data	from	till

```
SELECT *
  FROM t
   FOR SYSTEM_TIME AS OF
   TIMESTAMP'…10:30:00'
```

id	data	from	till
1	X	10:00	11:00

SQL:2011 — System Versioning



[0] Short term using Flashback.
[1] Flashback Archive. Proprietery syntax.

INTERNATIONAL STANDARD

ISO/IEC 9075-2

Information technology — Database languages — SQL —

Part 2:
Foundation (SQL/Foundation)

Technologies de l'information — Langages de base de données — SQL —

Partie 2: Fondations (SQL/Fondations)

https://webstore.iec.ch/publication/59685

A **lot** has happened since SQL-92

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beyond
the relational idea

If you use SQL for
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INTERNATIONAL
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modern SQL

https://modern-sql.com

@ModernSQL by @MarkusWinand

Training:
https://winand.at/

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