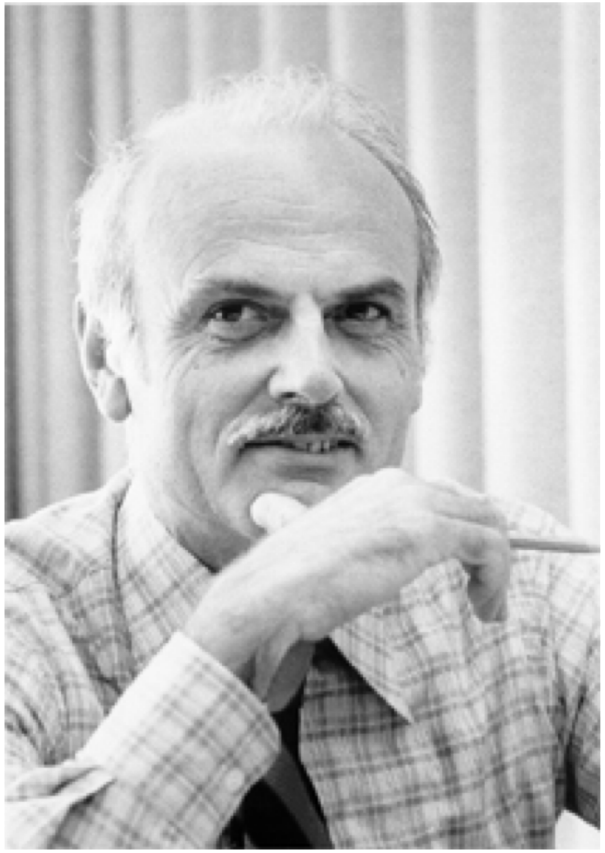
ETH zürich

Ghislain Fourny

Big Data for Engineers Spring 2020

2. Lessons learnt from the past

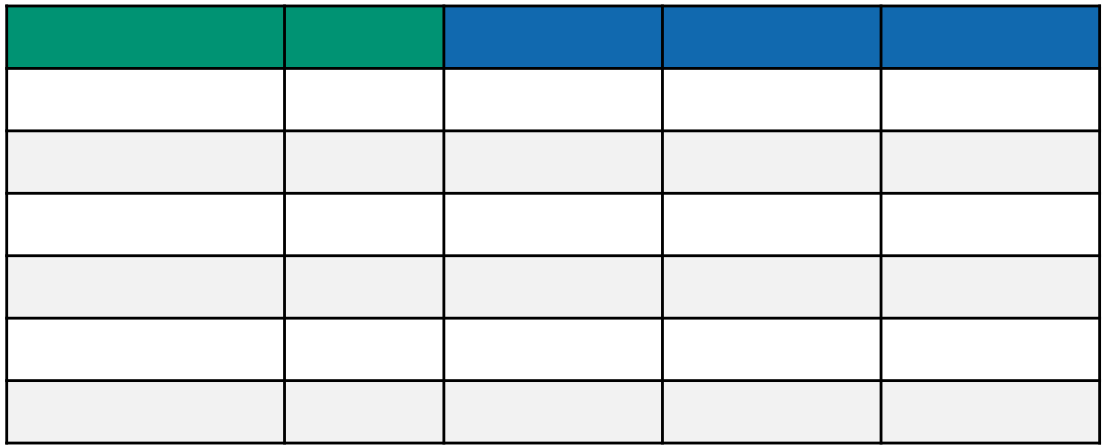
Mr. Databases: Edgar Codd



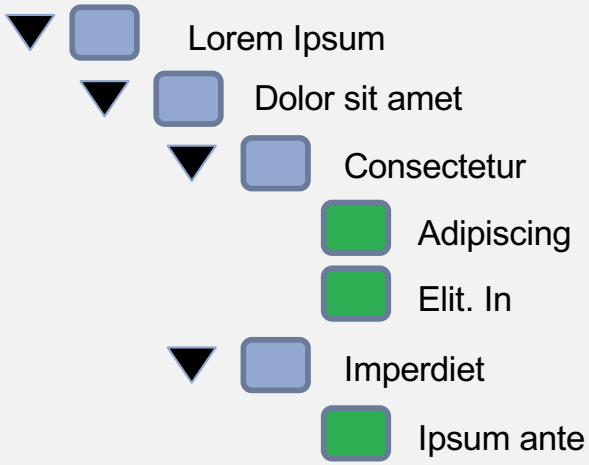
Wikipedia

Data Independence (Edgar Codd)

Logical data model



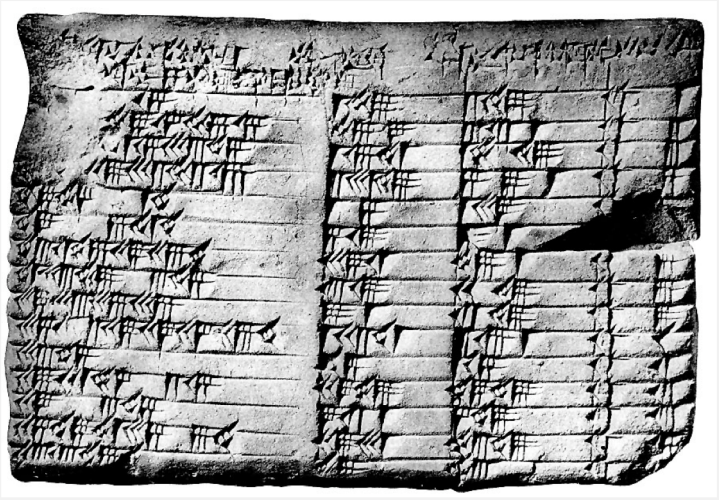
Physical storage



Data Independence (Edgar Codd)

Logical data model

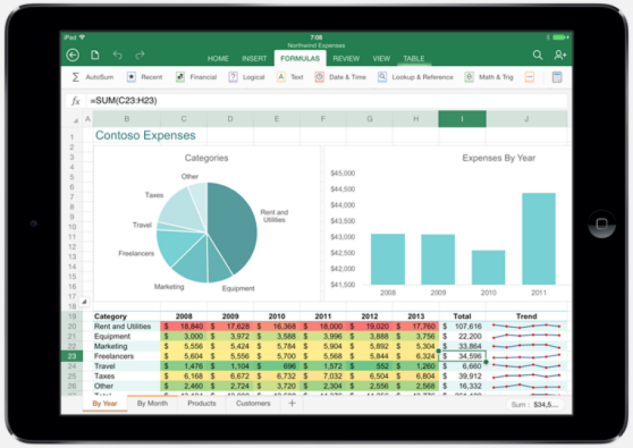
Physical storage



Data Independence (Edgar Codd)

Logical data model

Physical storage



Data Independence (Edgar Codd)

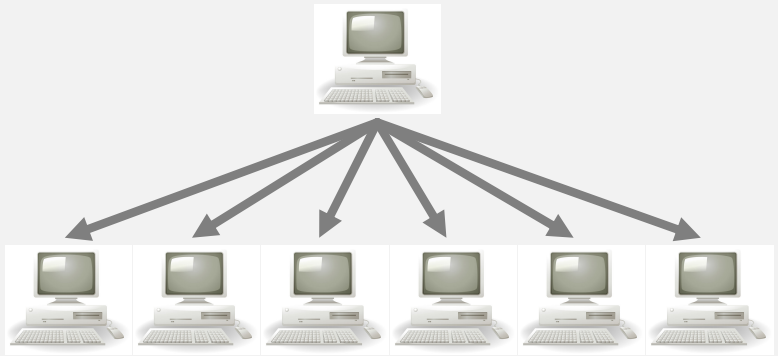
Logical data model

Physical storage

Data Independence (Edgar Codd)

Logical data model

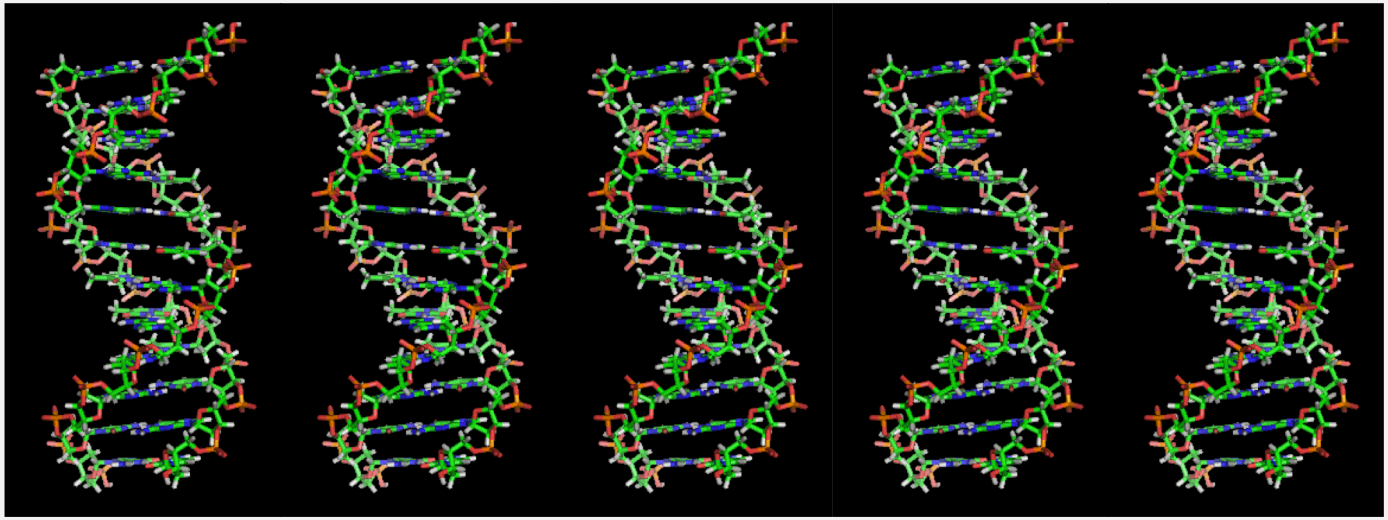
Physical storage



Data Independence (Edgar Codd)

Logical data model

Physical storage



Data Shapes

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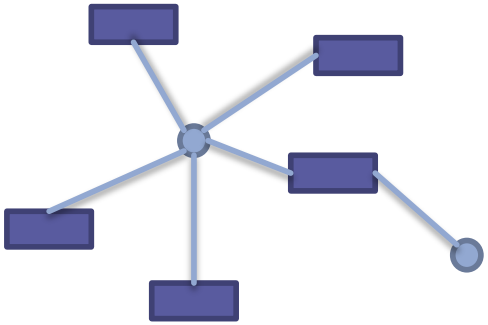

Data Shapes

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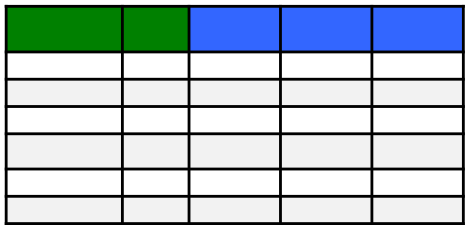
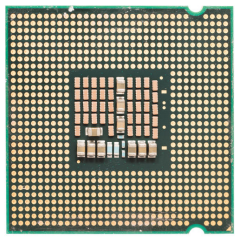
Praesent nec libero metus. Praesent at turpis placerat, congue ipsum eget, scelerisque justo. Ut volutpat, massa ac lacinia cursus, nisl dui volutpat arcu, quis interdum sapien turpis in tellus. Suspendisse potenti. Vestibulum pharetra justo massa, ac venenatis mi condimentum nec. Proin viverra tortor non orci suscipit rutrum. Phasellus sit amet euismod diam. Nullam convallis nunc sit amet diam suscipit dapibus. Integer porta hendrerit nunc. Quisque pharetra congue porta. Suspendisse vestibulum sed mi in euismod. Etiam a purus suscipit, accumsan nibh vel, posuere ipsum. Nulla nec tempor nibh, id venenatis lectus. Duis lobortis id urna eget tincidunt.

Overall architecture

SQL





Language

Model

Compute

Storage

Data model

What data **looks like**

+

What you can **do** with it

Analogy: a very simple "model of cooking"

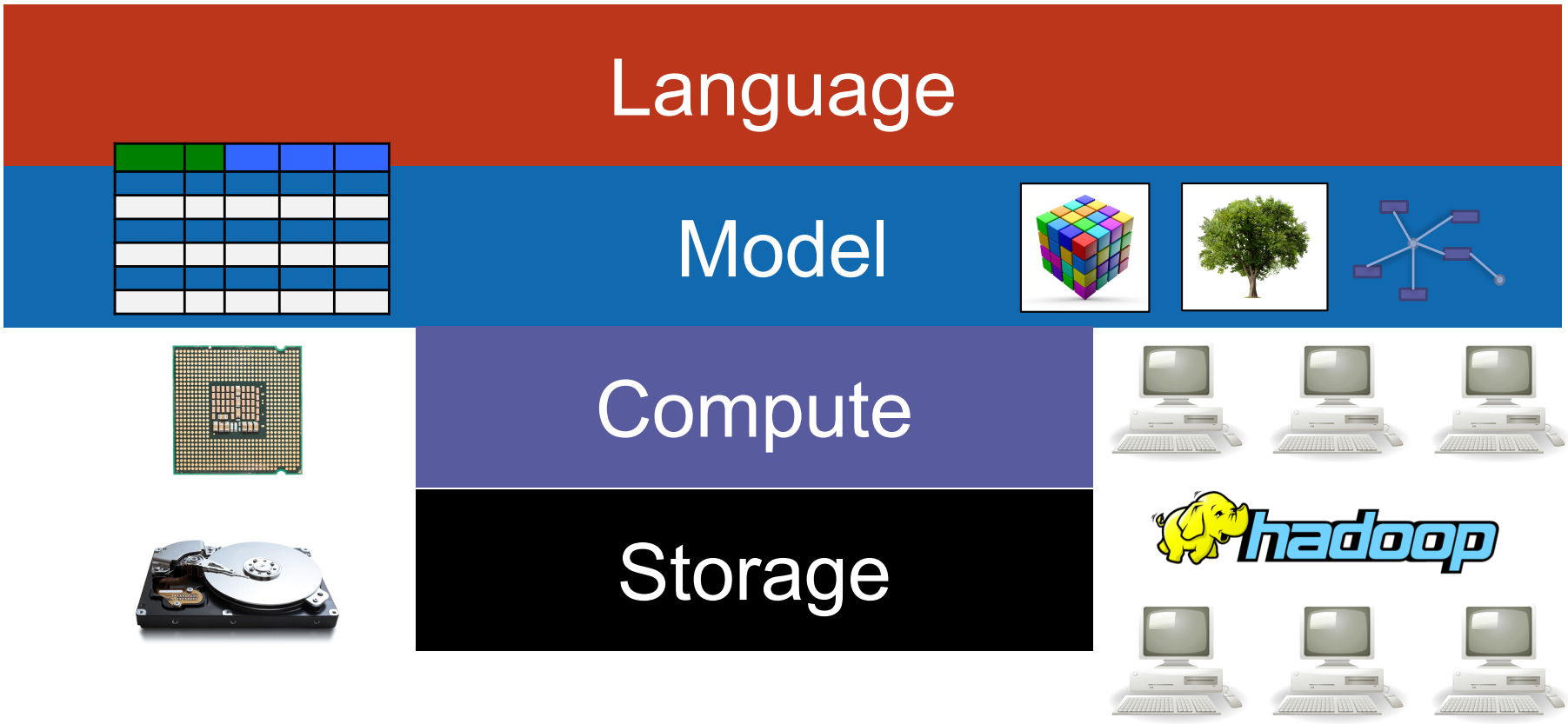
What food **looks like**

→ Something that can be eaten

What you can **do** with it

→ You can **mix, pour, break, dry, bake, grill, melt, mince, mix...**

Overall architecture

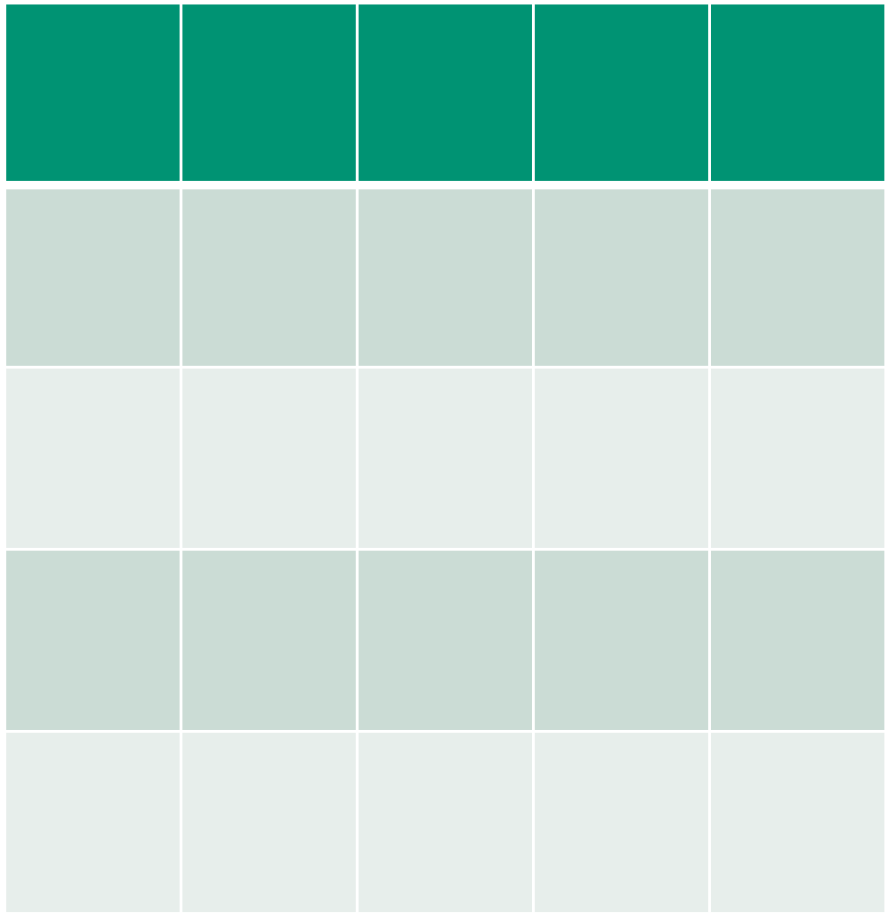


Take-away Concepts

Take-away Concepts

Table

Collection



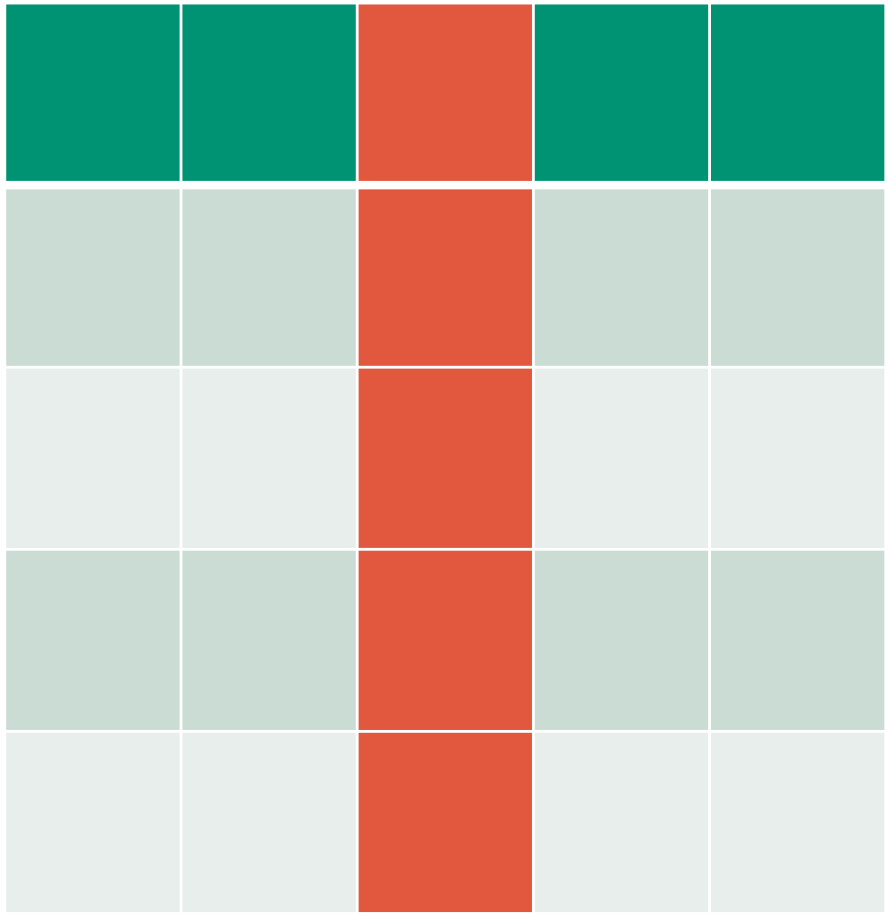
Take-away Concepts

Attribute

Column

Field

Property

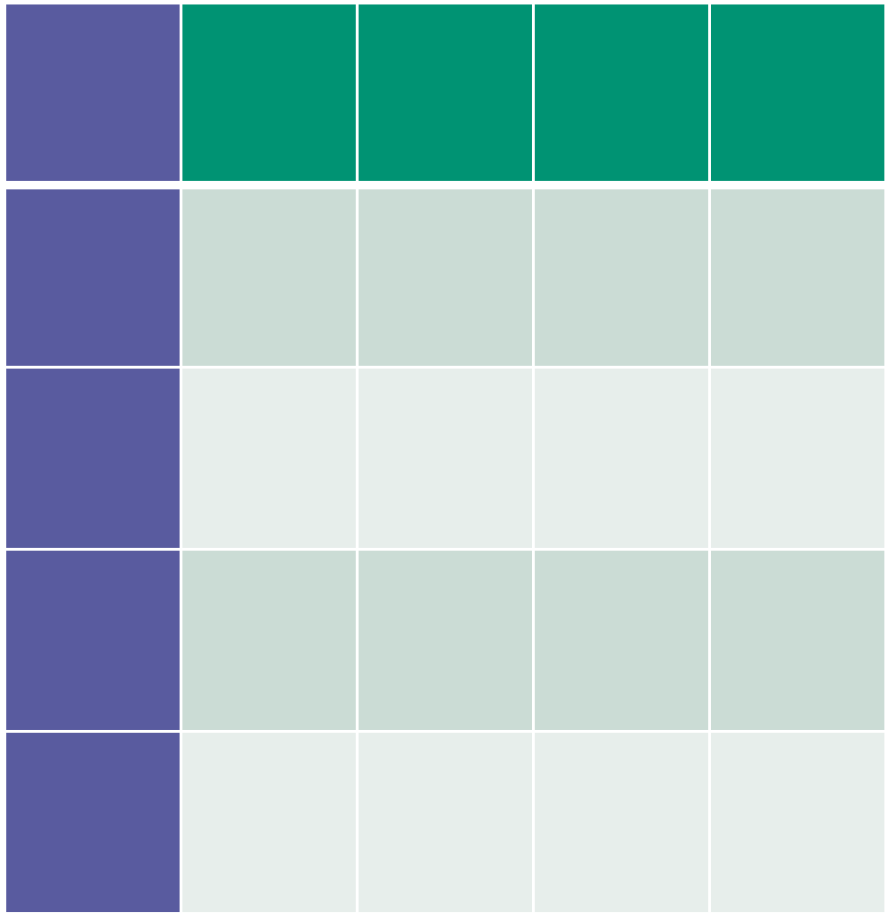


Take-away Concepts

Primary Key

Row ID

Name



Take-away Concepts

Row

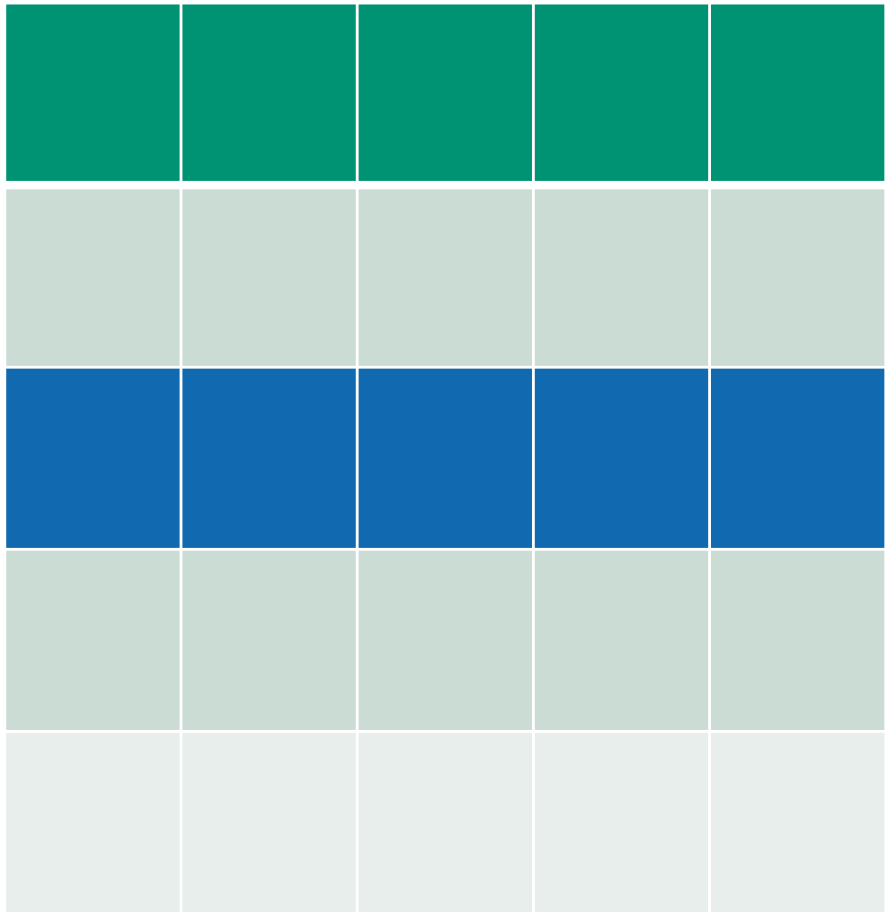
Business Object

Item

Entity

Document

Record

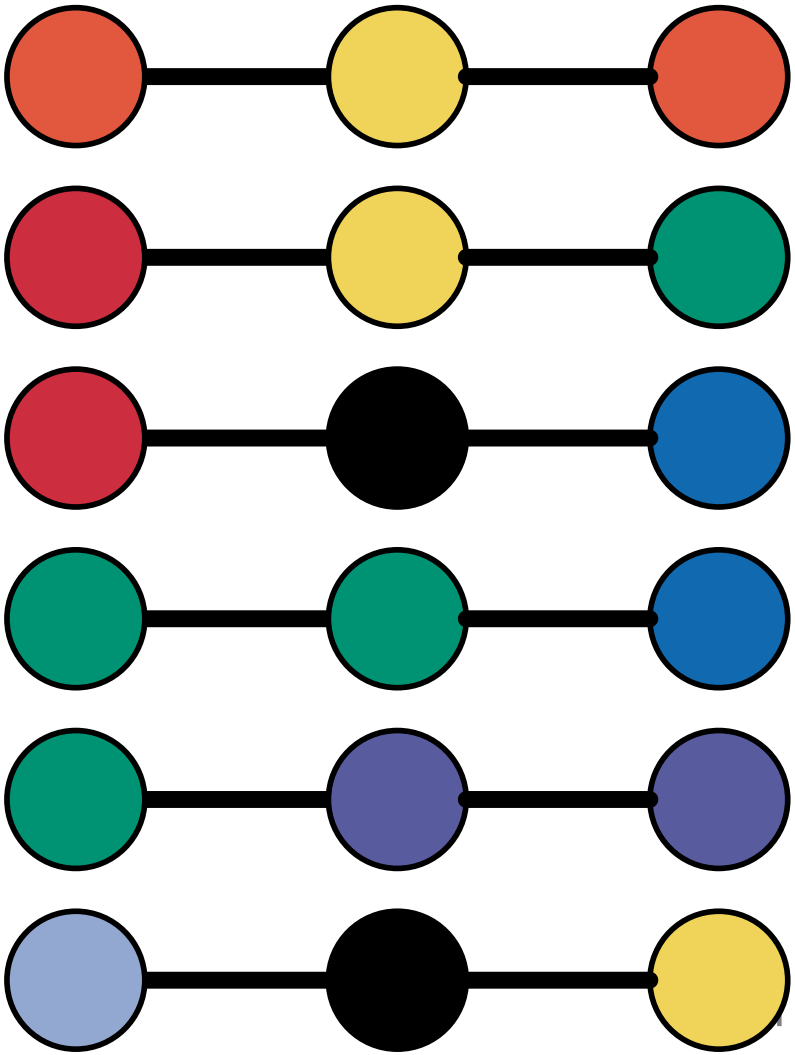


Relational Algebra

Table as a relation

1	2	3

$$R \subseteq \mathcal{D}_1 \times \mathcal{D}_2 \times \mathcal{D}_3$$



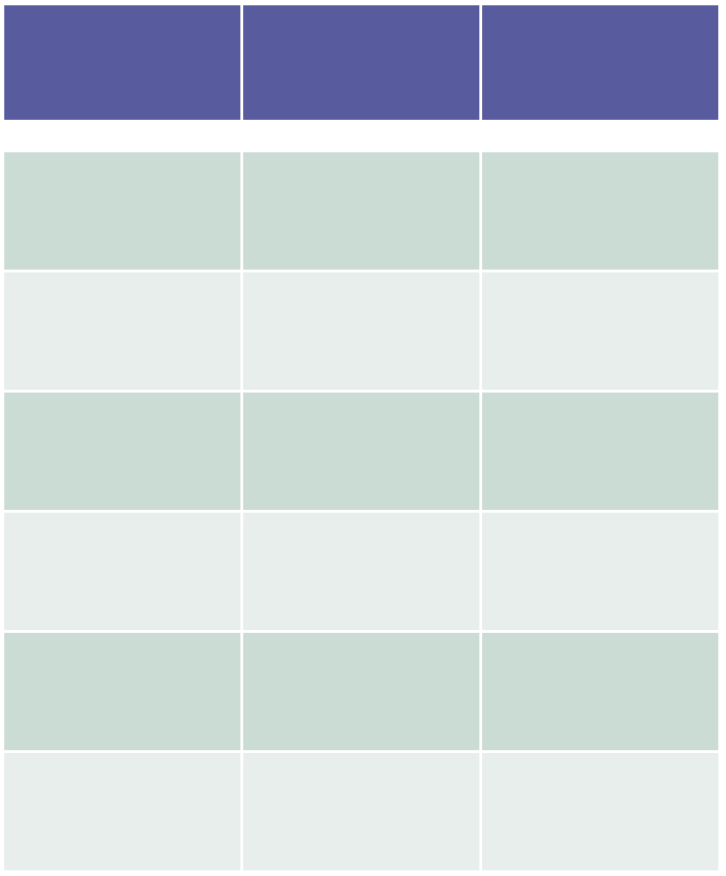
Relations (the math)

A relation R is made of

1. A **set of attributes**
2. An **extension** (set of tuples)

$Attributes_R \subseteq \mathbb{S}$

$Extension_R \subseteq \mathbb{S} \nrightarrow \mathbb{V}$



Tuple: example

Name	$\mapsto$	Einstein
First name	$\mapsto$	Albert
Physicist	$\mapsto$	true
Year	$\mapsto$	1905

$\mathbb{S}$ $\mathbb{V}$

Tuple: more intuitive display

$\mathbb{S}$

Name	First name	Physicist	Year
Einstein	Albert	true	1905

$\mathbb{V}$

(The order is irrelevant)

Rule #1: Tabular integrity

Name	First name	Physicist	Year

Name	First name	Physicist	Year
Einstein	Albert	true	1905

Name	First name	Physicist	Year
Turing	Alan	false	1936

Name	First name	Physicist	Year
Gödel	Kurt	false	1931

Rule #1: Tabular integrity

Name	First name	Physicist	Year
Einstein	Albert	true	1905
Turing	Alan	false	1936
Gödel	Kurt	false	1931

Rule #1: Broken tabular integrity

	Name	First name	Physicist	Year
	Einstein	Albert	true	1905
Country		Alan	false	1936
A	Gödel	Kurt		1931

Rule #2: Atomic integrity (1st normal form)

Legi	Name	Lecture ID	Lecture Name	City	State	PLZ
32-000-000	Alan Turing	xxx-xxxx-xxX	Cryptography	Bletchley Park	UK	MK3 6EB
32-000-000	Alan Turing	263-3010-00L	Big Data	Bletchley Park	UK	MK3 6EB
62-000-000	Georg Cantor	263-3010-00L	Big Data	Pfäffikon	SZ	8808
62-000-000	Georg Cantor	123-4567-89L	Set theory	Pfäffikon	SZ	8808
25-000-000	Felix Bloch	123-4567-89L	Set theory	Pfäffikon	ZH	8330

Rule #2: Broken atomic integrity

Legi	Name	Lecture	City	State	PLZ
32-000-000	Alan Turing	Lecture ID: xxx-xxxx-xxX, Lecture Name: Cryptography Lecture ID: 263-3010-00L, Lecture Name: Big Data	Bletchley Park	UK	MK3 6EB
62-000-000	Georg Cantor	Lecture ID: 263-3010-00L, Lecture Name: Big Data Lecture ID: 123-4567-89L, Lecture Name: Set theory	Pfäffikon	SZ	8808
25-000-000	Felix Bloch	Lecture ID: 123-4567-89L, Lecture Name: Set theory	Pfäffikon	ZH	8330

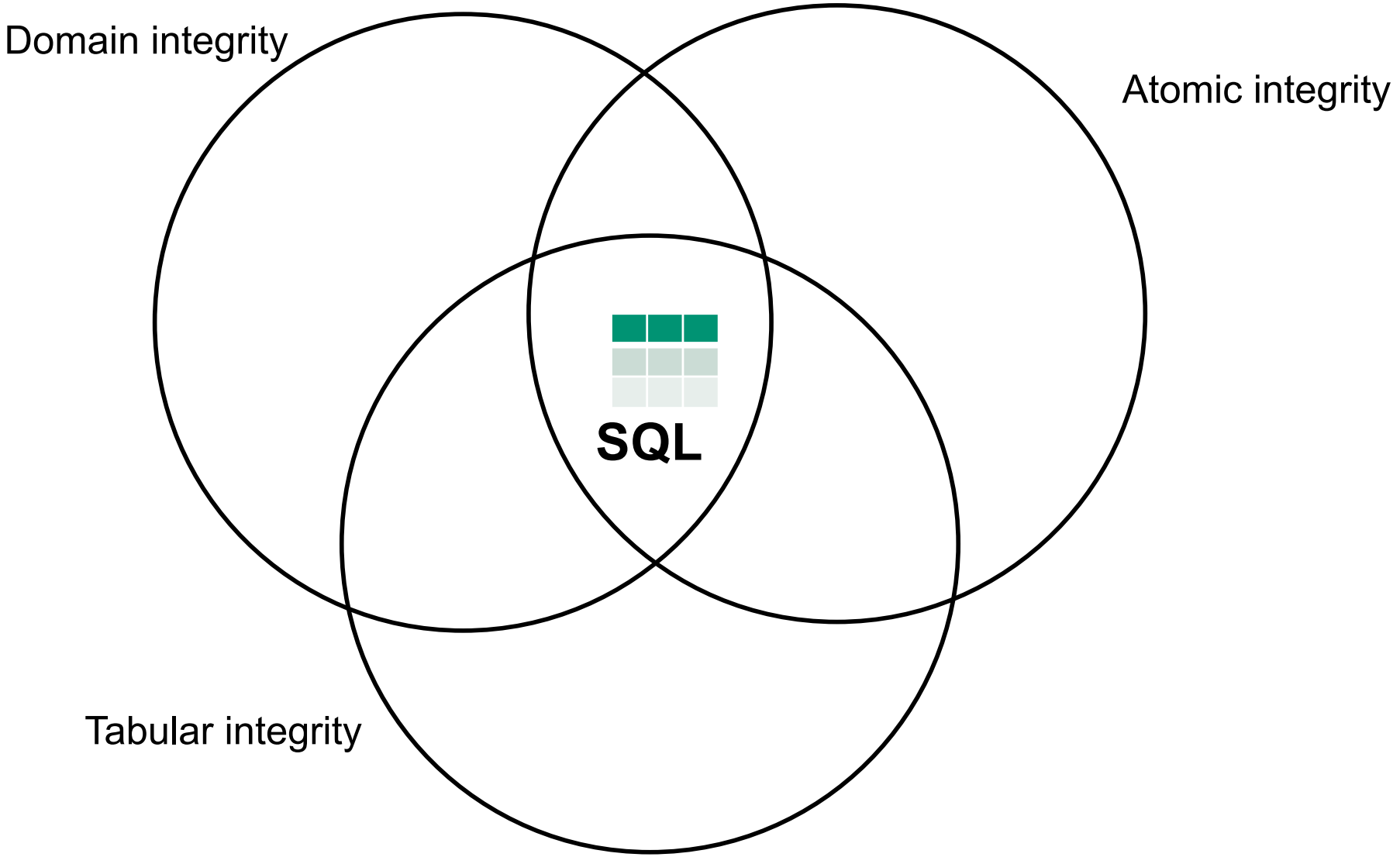
Rule #3: Domain integrity

Name	First name	Physicist	Year
String	String	Boolean	Integer
Einstein	Albert	true	1905
Turing	Alan	false	1936
Gödel	Kurt	false	1931

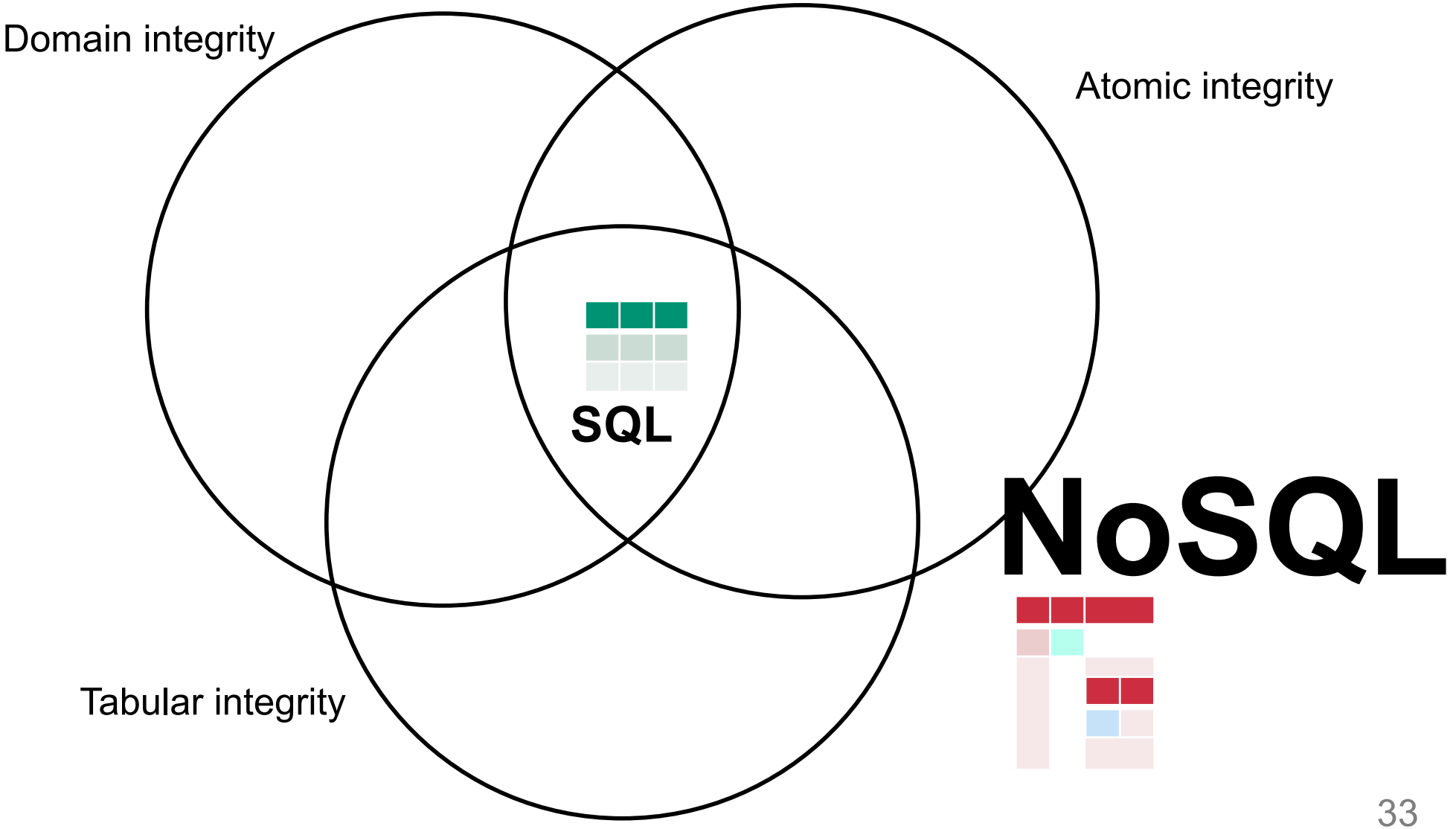
Rule #3: Broken domain integrity

Name	First name	Physicist	Year
String	String	Boolean	Integer
Einstein	Albert	true	1905
Turing	Alan	0	1936
Gödel	Kurt	false	thirty-one

From SQL to NoSQL



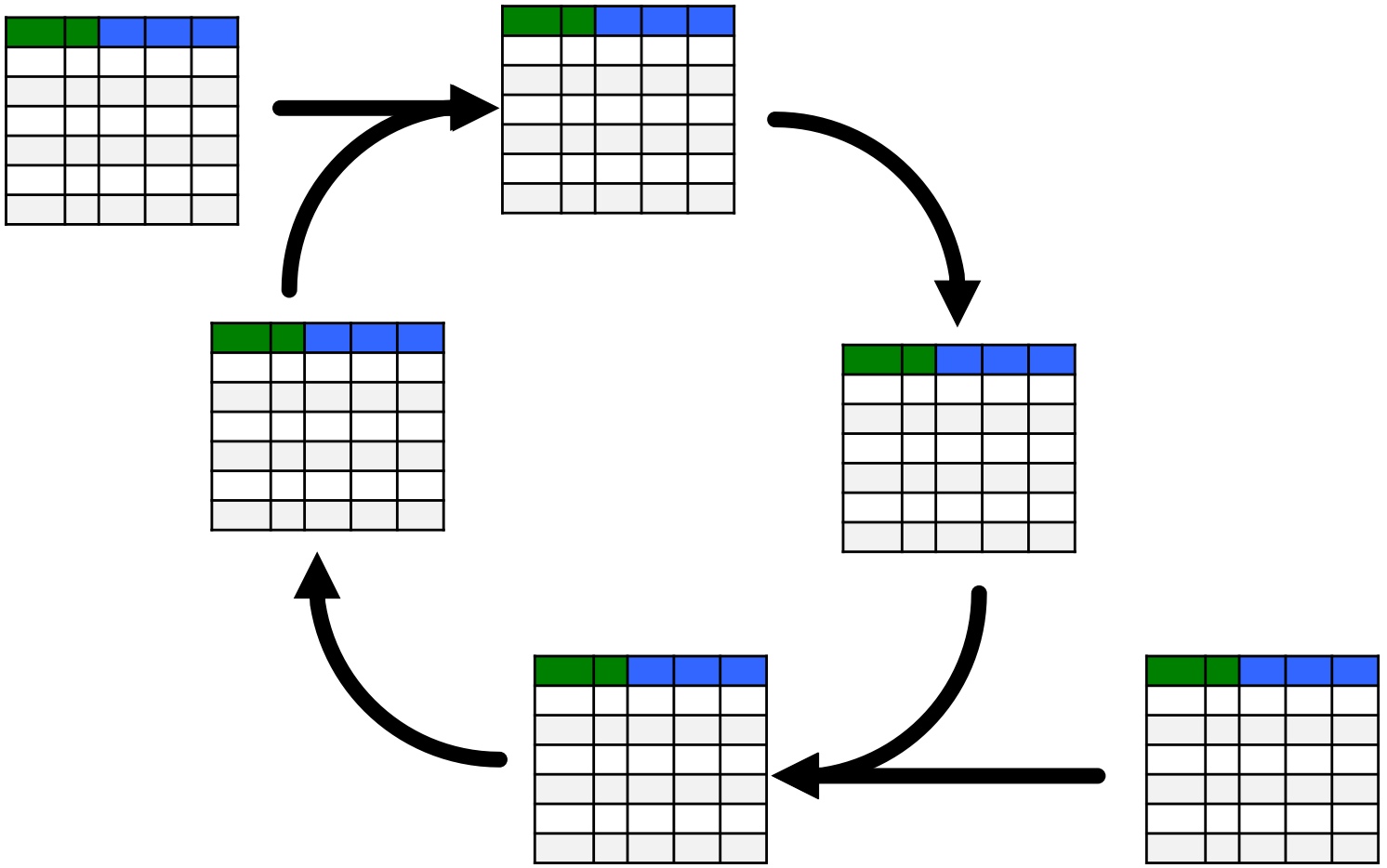
From SQL to NoSQL



From SQL to NoSQL

SQL

Relational Algebra



Summary of relational queries

Union
Intersection
Subtraction

Set queries

Selection
Projection

Filter queries

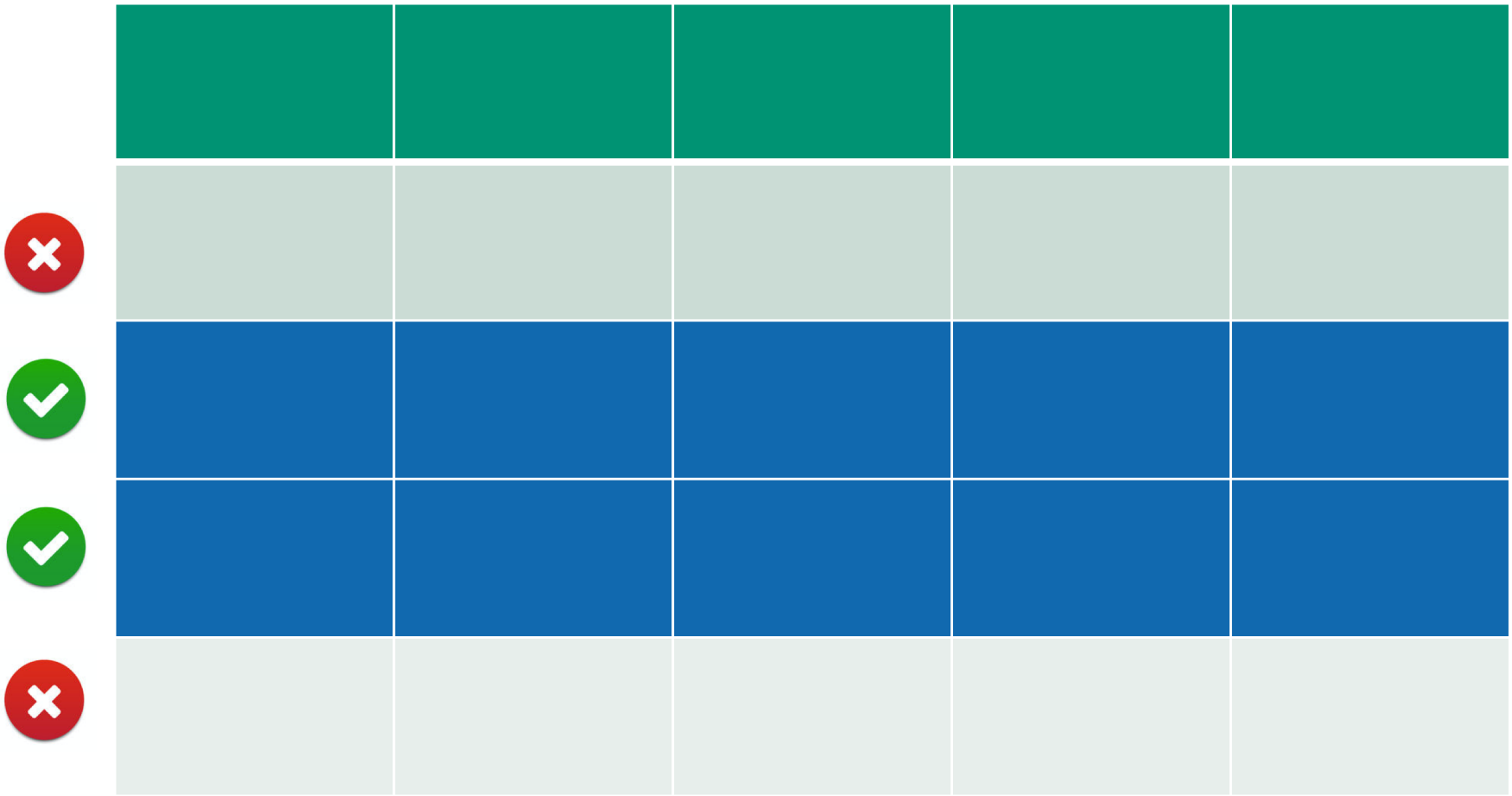
Relation renaming
Attribute renaming

Renaming queries

Cartesian product
Natural join
Theta join

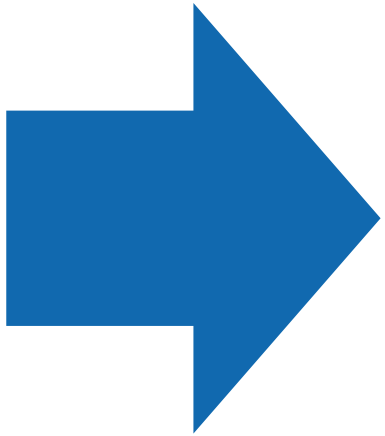
Binary queries

Selection



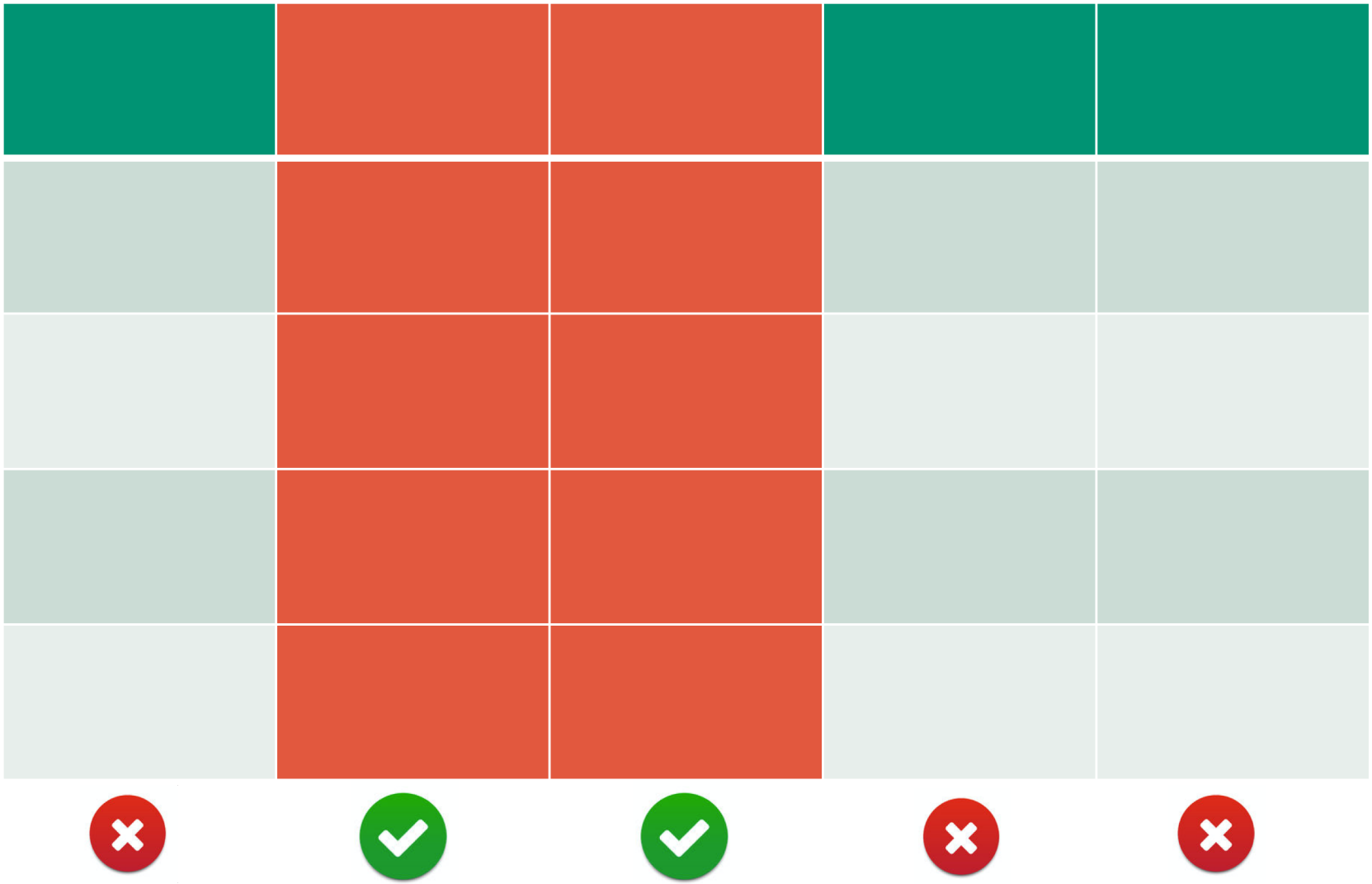
Selection

R		
A	B	C
string	integer	boolean
foo	1	true
bar	2	false
foo	3	false
foobar	4	true



S		
A	B	C
string	integer	boolean
foo	1	true
bar	2	false

Projection



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bar	2	false
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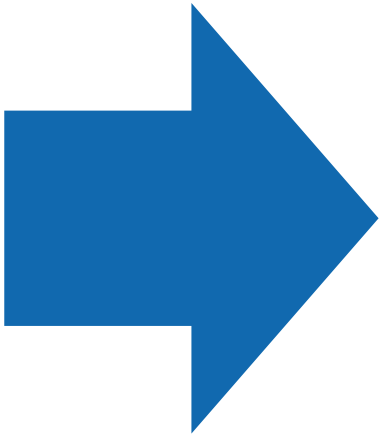
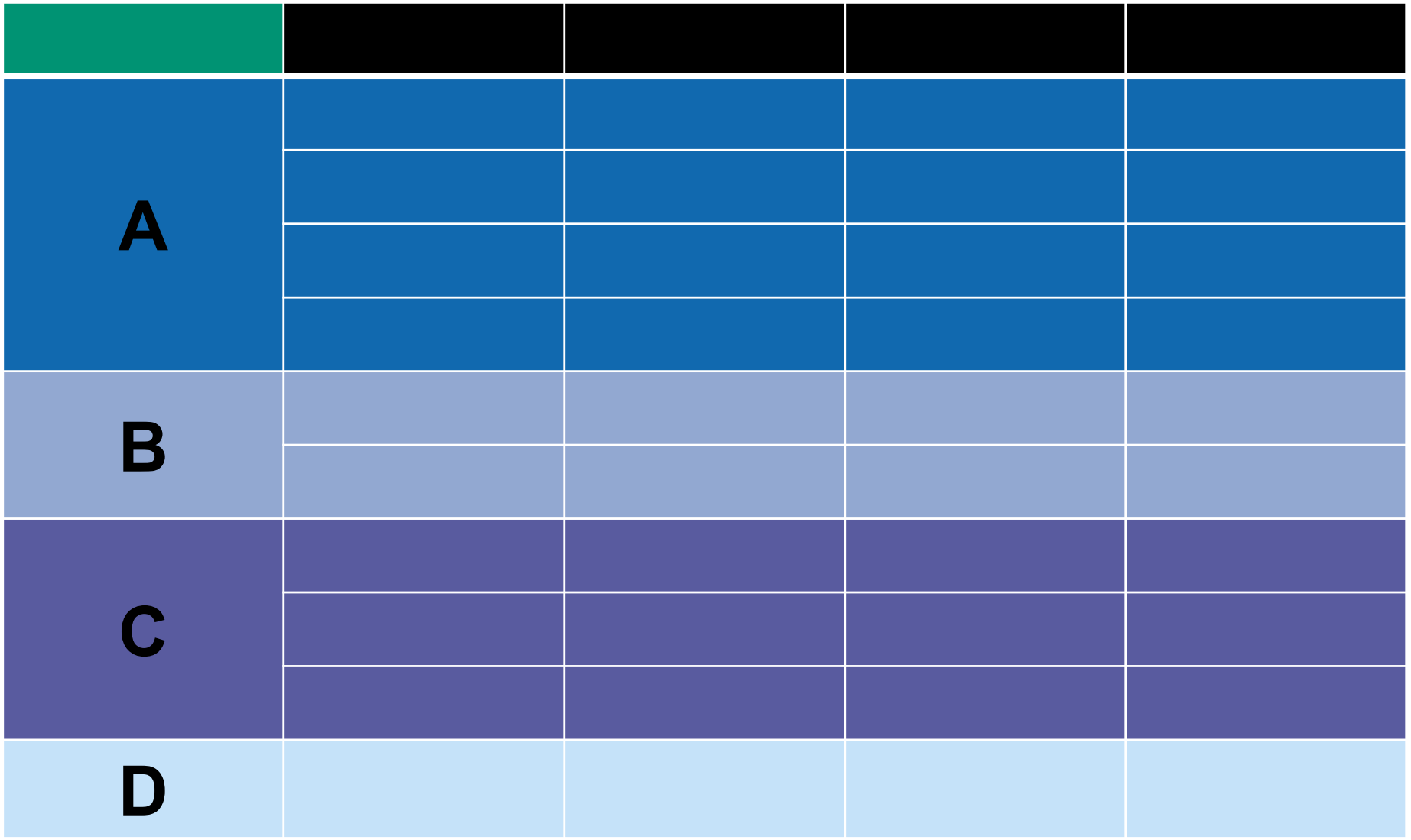


S	
A	C
string	boolean
foo	true
bar	false
foo	false
foobar	true

Grouping



Grouping

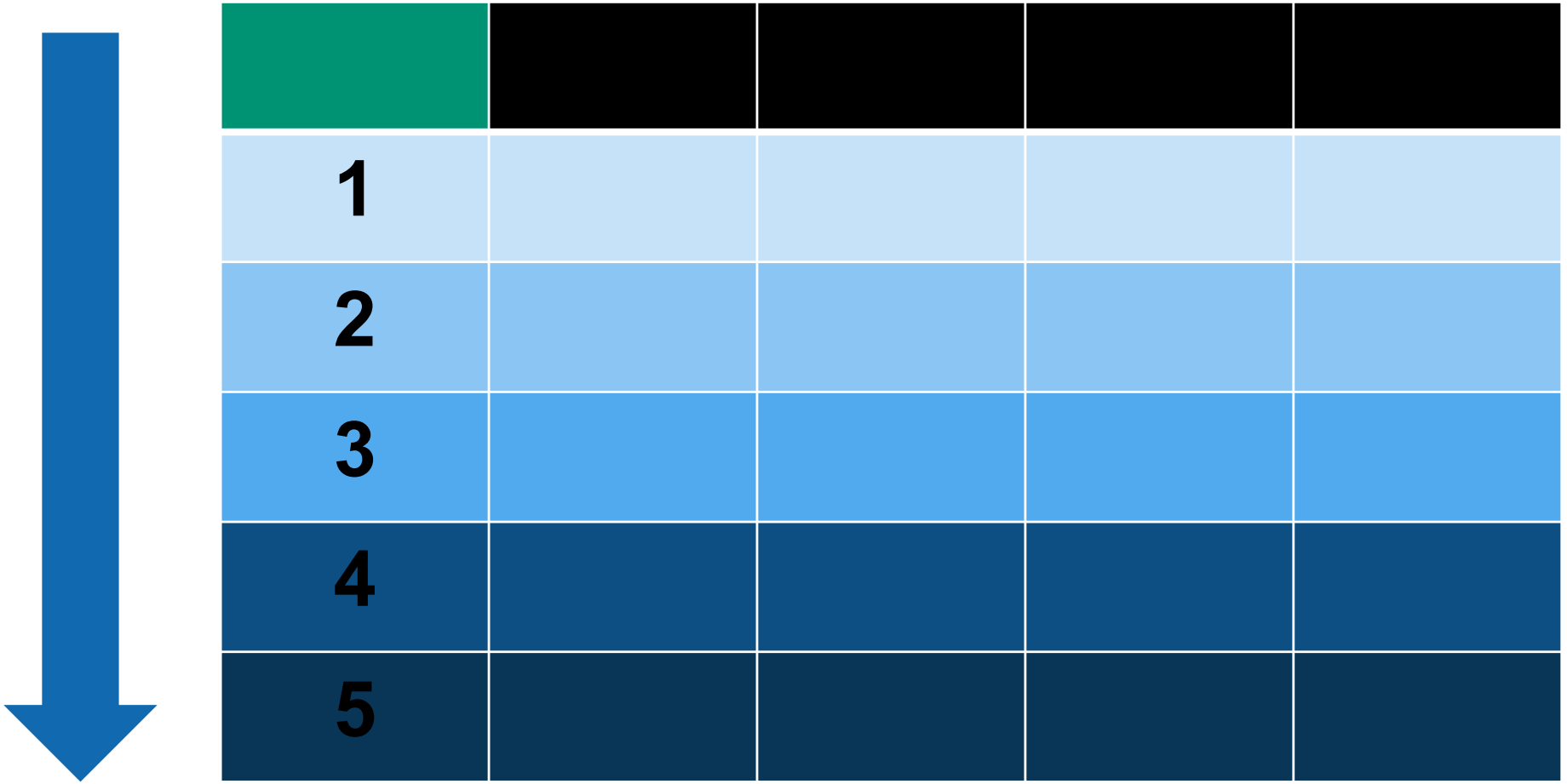
R	
G	A
string	integer
foo	19
bar	28
bar	265
foo	4
foobar	54
foo	46
bar	245
foobar	3456
bar	139

R	
G	A
string	integer
foo	19
foo	4
foo	46
bar	28
bar	265
bar	245
bar	139
foobar	54
foobar	3456

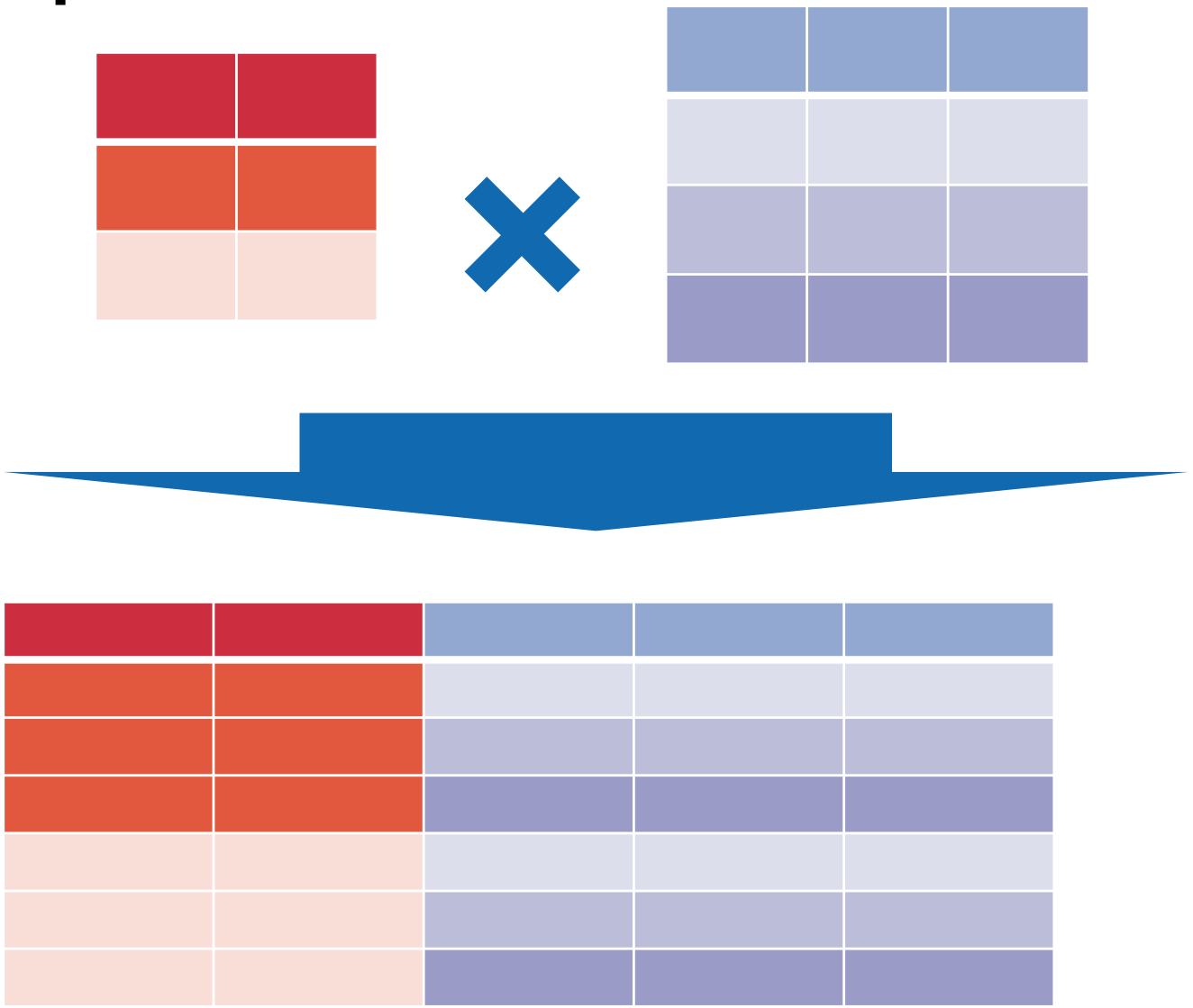
R	
G	A
string	integer
foo	19
	4
	46
bar	28
	265
	245
	139
foobar	54
	3456

R	
G	A
string	integer
foo	69
bar	677
foobar	3510

Sorting



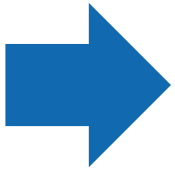
Cartesian product



Cartesian product

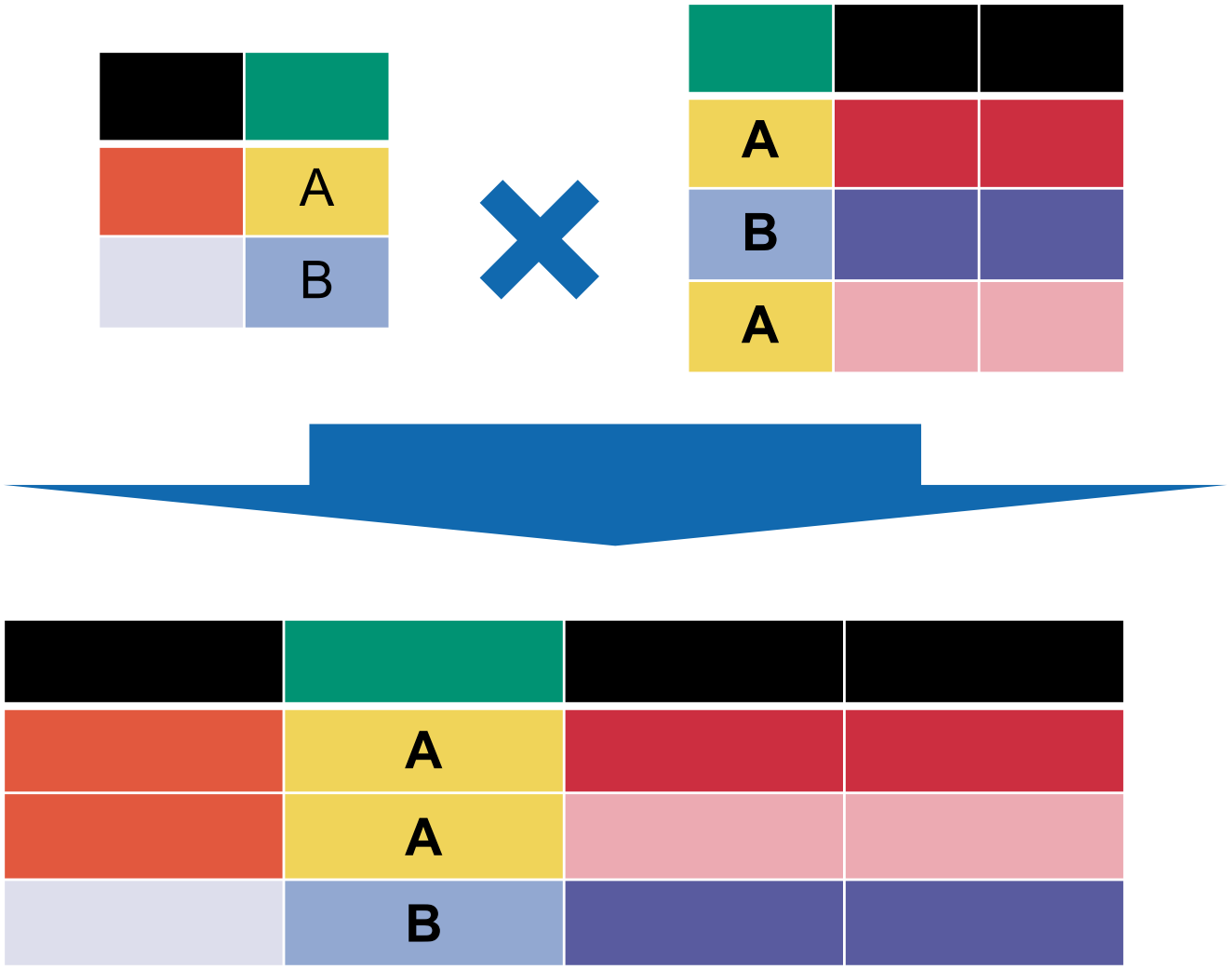
R		
A	B	C
string	integer	boolean
foo	1	true
bar	2	false

S	
D	E
string	integer
foo	1
bar	2
foo	3



T				
A	B	C	D	E
string	integer	boolean	string	integer
foo	1	true	foo	1
foo	1	true	bar	2
foo	1	true	foo	3
bar	2	false	foo	1
bar	2	false	bar	2
bar	2	false	foo	3

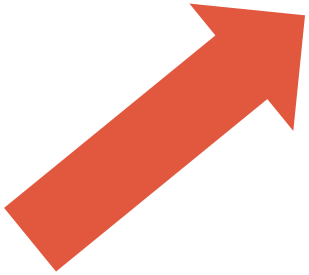
Join



Join

R		
A	B	C
string	integer	boolean
foo	1	true
bar	2	false

S	
D	B
string	integer
bar	1
bar	2
foo	3



T			
A	B	C	D
string	integer	boolean	string
foo	1	true	bar
bar	2	false	bar

SQL Brush-Up

SQL History

Don Chamberlin

Raymond Boyce

The early days (early 1970s)

IBM

Almaden (San Jose)

First commercial relational database

System R

+

SEQUEL

First commercial relational query language

Pratt & Whitney

A United Technologies Company

First customer (1977)

Public availability

1977

Software Development Laboratories

1979

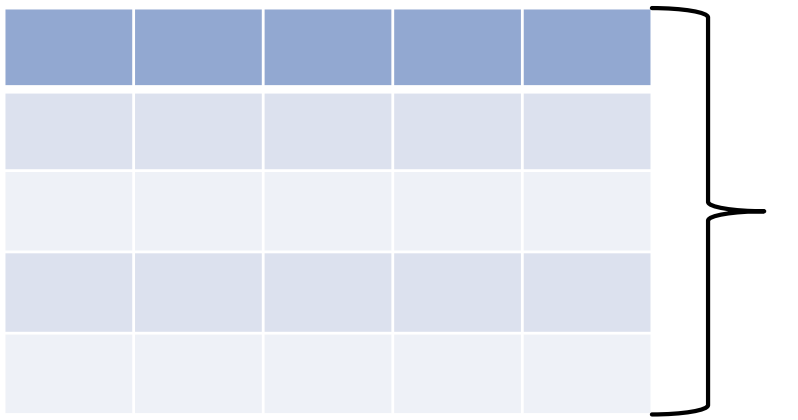
Relational Software

1982

ORACLE

SEQUEL
Structured English QUEry Language

Declarative language



Set-based
(Manipulates entire relations
with a single command)

Renaming

SEQUEL

(Trademark issue)

SQL

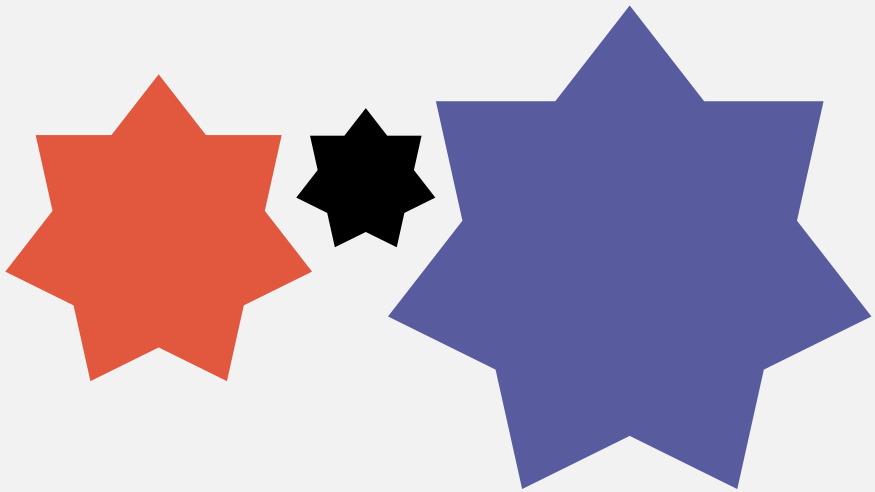
ESS**-kew-**EL or ***SEE**-kwəl*

SQL is a declarative language

Logical model

"What, not how"

Physical execution

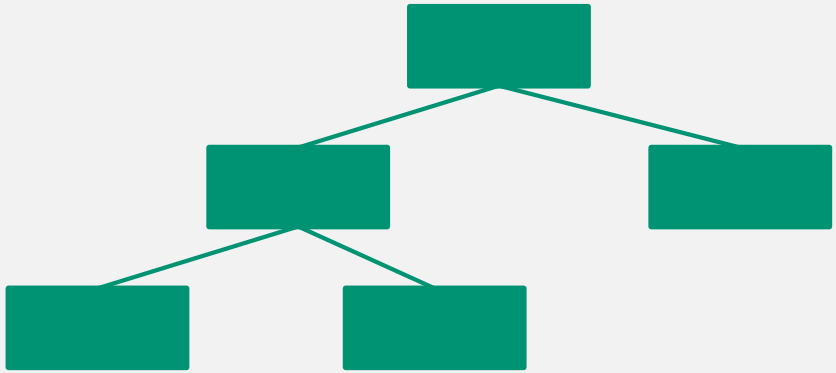


SQL is a declarative language

Logical model

"What, not how"

Query Plan

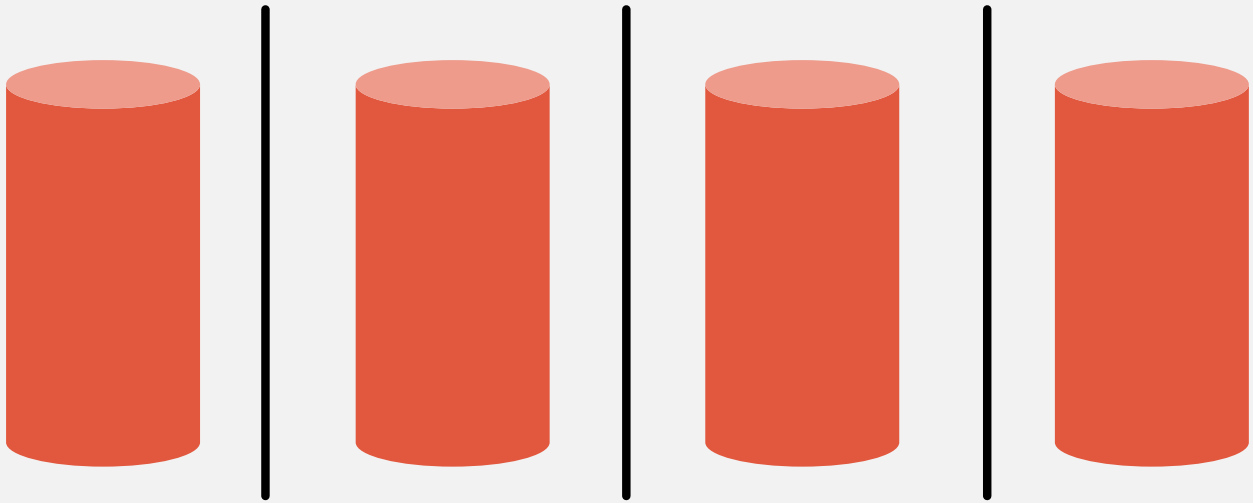


SQL is a declarative language

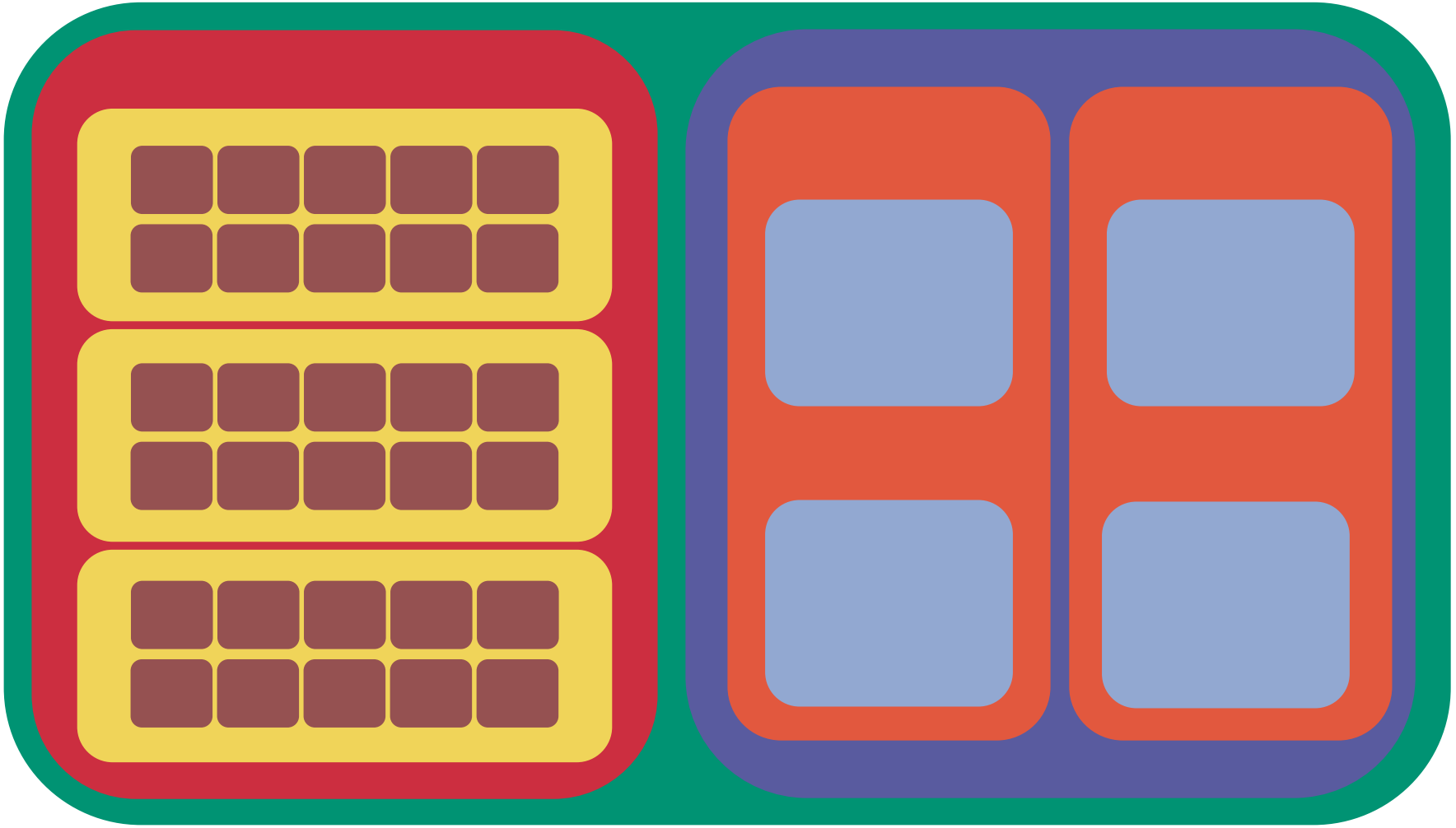
Logical model

"What, not how"

Parallelism



SQL is a functional language



"Expressions that nest"

A selecting query

persons					
name	middle_initial	last_name	birth_date	gender	passport_scan
varchar(30)	char(1)	text	date	boolean	bytea
James	T	Kirk	2233-03-22	TRUE	AD10E7
Beverly	**C**	**Crusher**	**2324-10-13**	**FALSE**	**AD234F7**
Spock	NULL	NULL	2230-01-06	TRUE	AD234F7

```
SELECT *
FROM persons
WHERE last_name = 'Crusher'
```

persons					
name	middle_initial	last_name	birth_date	gender	passport_scan
varchar(30)	char(1)	text	date	boolean	bytea
Beverly	C	Crusher	2324-10-13	FALSE	AD234F7

A projecting query

persons					
name	middle_initial	last_name	birth_date	gender	passport_scan
varchar(30)	char(1)	text	date	boolean	bytea
James	T	Kirk	**2233-03-22**	TRUE	AD10E7
Beverly	C	Crusher	**2324-10-13**	FALSE	AD234F7
Spock	NULL	NULL	**2230-01-06**	TRUE	AD234F7

```
SELECT name, birth_date
FROM persons
```

name	birth_date
varchar(30)	date
James	2233-03-22
Beverly	2324-10-13
Spock	2230-01-06

A renaming query

persons					
name	middle_initial	last_name	birth_date	gender	passport_scan
varchar(30)	char(1)	text	date	boolean	bytea
James	T	Kirk	**2233-03-22**	TRUE	AD10E7
Beverly	C	Crusher	**2324-10-13**	FALSE	AD234F7
Spock	NULL	NULL	**2230-01-06**	TRUE	AD234F7

```
SELECT name AS who,
       birth_date AS when
FROM persons
```

who	when
varchar(30)	date
James	2233-03-22
Beverly	2324-10-13
Spock	2230-01-06

A sorting query

persons					
name	middle_initial	last_name	birth_date	gender	passport_scan
varchar(30)	char(1)	text	date	boolean	bytea
James	T	Kirk	2233-03-22	TRUE	AD10E7
Beverly	**C**	**Crusher**	**2324-10-13**	**FALSE**	**AD234F7**
Spock	NULL	NULL	2230-01-06	TRUE	AD234F7

```
SELECT *
FROM persons
ORDER BY birth_date
```

persons					
name	middle_initial	last_name	birth_date	gender	passport_scan
varchar(30)	char(1)	text	date	boolean	bytea
Spock	NULL	NULL	2230-01-06	TRUE	AD234F7
James	T	Kirk	2233-03-22	TRUE	AD10E7
Beverly	C	Crusher	2324-10-13	FALSE	AD234F7

A grouping query

Grouping column

persons

name	middle_initial	last_name	century	gender
varchar(30)	char(1)	text	integer	boolean
James	T	Kirk	**23**	TRUE
Beverly	C	Crusher	**24**	FALSE
Spock	NULL	NULL	**23**	TRUE
Kathryn	NULL	Janeway	**24**	FALSE

```
SELECT century, COUNT(*) AS count
FROM persons
GROUP BY century
```

century	count
integer	bigint
23	2
24	2

Post-aggregation selection

persons				
name	middle_initial	last_name	century	captain
varchar(30)	char(1)	text	integer	boolean
James	T	Kirk	**23**	TRUE
Beverly	C	Crusher	**24**	FALSE
Jean-Luc	NULL	Picard	**24**	TRUE
Kathryn	NULL	Janeway	**24**	TRUE

```
SELECT century AS c
FROM persons
GROUP BY century
HAVING COUNT(*) > 2
```

c
integer
24

Natural join

persons				
name	middle_initial	last_name	century	captain
varchar(30)	char(1)	text	integer	boolean
James	T	Kirk	23	TRUE
Beverly	C	Crusher	24	FALSE
Kathryn	NULL	Janeway	24	TRUE

spaceships			
warp	spaceship_name	last_name	code
numeric	varchar(30)	text	integer
5	USS Enterprise A	Kirk	NCC-1701-A
4	USS Enterprise	Kirk	NCC-1701
9.2	USS Enterprise D	Picard	NCC-1701-D
9.975	USS Voyager	Janeway	NCC-74656

```
SELECT *
FROM persons NATURAL FULL OUTER JOIN spaceships
```

name	middle_initial	last_name	captain	century	warp	spaceship_name	code
varchar(30)	char(1)	text	boolean	integer	numeric	varchar(30)	integer
James	T	Kirk	TRUE	23	5	USS Enterprise A	NCC-1701-A
James	T	Kirk	TRUE	23	4	USS Enterprise	NCC-1701
NULL	NULL	Picard	NULL	NULL	9.2	USS Enterprise D	NCC-1701-D
Beverly	C	Crusher	24	FALSE	NULL	NULL	NULL
Kathryn	NULL	Janeway	TRUE	24	9.975	USS Voyager	NCC-74656

A union query

spaceships1

warp	name	last_name	code	successor
numeric	varchar(30)	text	varchar	varchar
5	USS Enterprise A	Kirk	NCC-1701-A	NCC-1701-B
6	USS Enterprise B	Kirk	NCC-1701-B	NCC-1701-C
7	USS Enterprise C	Kirk	NCC-1701-C	NCC-1701-D

spaceships2

warp	name	last_name	code	successor
numeric	varchar(30)	text	varchar	varchar
7	USS Enterprise C	Kirk	NCC-1701-C	NCC-1701-D
4	USS Enterprise	Kirk	NCC-1701	NCC-1701-A
9.2	USS Enterprise D	Picard	NCC-1701-D	NCC-1701-E

```
SELECT * FROM spaceships1 UNION spaceships2
```

duplicate elimination

warp	name	last_name	code	successor
numeric	varchar(30)	text	varchar	varchar
5	USS Enterprise A	Kirk	NCC-1701-A	NCC-1701-B
6	USS Enterprise B	Kirk	NCC-1701-B	NCC-1701-C
7	USS Enterprise C	Kirk	NCC-1701-C	NCC-1701-D
4	USS Enterprise	Kirk	NCC-1701	NCC-1701-A
9.2	USS Enterprise D	Picard	NCC-1701-D	NCC-1701-E

An intersection query

spaceships1				
warp	name	last_name	code	successor
numeric	varchar(30)	text	varchar	varchar
5	USS Enterprise A	Kirk	NCC-1701-A	NCC-1701-B
6	USS Enterprise B	Kirk	NCC-1701-B	NCC-1701-C
7	USS Enterprise C	Kirk	NCC-1701-C	NCC-1701-D

spaceships2				
warp	name	last_name	code	successor
numeric	varchar(30)	text	varchar	varchar
7	USS Enterprise C	Kirk	NCC-1701-C	NCC-1701-D
4	USS Enterprise	Kirk	NCC-1701	NCC-1701-A

```
SELECT * FROM spaceships1 INTERSECT spaceships2
```

duplicate elimination

warp	name	last_name	code	successor
numeric	varchar(30)	text	varchar	varchar
7	USS Enterprise C	Kirk	NCC-1701-C	NCC-1701-D

An set substraction query

spaceships1

warp	name	last_name	code	successor
numeric	varchar(30)	text	varchar	varchar
5	USS Enterprise A	Kirk	NCC-1701-A	NCC-1701-B
6	USS Enterprise B	Kirk	NCC-1701-B	NCC-1701-C
7	USS Enterprise C	Kirk	NCC-1701-C	NCC-1701-D

spaceships2

warp	name	last_name	code	successor
numeric	varchar(30)	text	varchar	varchar
7	USS Enterprise C	Kirk	NCC-1701-C	NCC-1701-D
4	USS Enterprise	Kirk	NCC-1701	NCC-1701-A

```
SELECT * FROM spaceships1 EXCEPT spaceships2
```

warp	name	last_name	code	successor
numeric	varchar(30)	text	varchar	varchar
5	USS Enterprise A	Kirk	NCC-1701-A	NCC-1701-B
6	USS Enterprise B	Kirk	NCC-1701-B	NCC-1701-C

duplicate elimination

Nesting

```
SELECT pname, warp
FROM (
      SELECT persons.name AS pname,
             last_name,
             century,
             spaceships.name AS sname,
             warp
      FROM persons FULL OUTER JOIN spaceships USING last_name
)
```

Some terminology

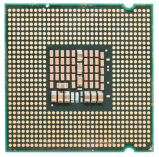
DML: Data Manipulation Language
(Query, insert, remove rows)

Data

Schema

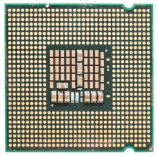
DDL: Data Definition Language
(Create or table/schema, drop it)

Language landscape

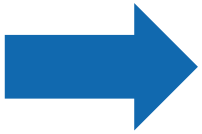


Proto-imperative language

Language landscape

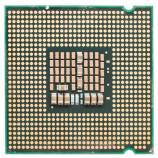


Proto-imperative language



Imperative language

Language landscape



Proto-imperative language

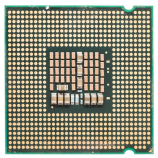
Java

Imperative language

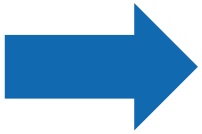
SPARQL

Functional/declarative language

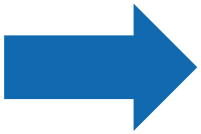
Language landscape



Proto-imperative language



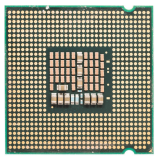
Imperative language



Proto-declarative language

Functional/declarative language

Language landscape



Proto-imperative language

Java

Imperative language

APACHE Spark™

Proto-declarative language

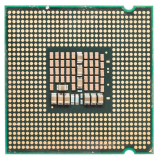
SPARQL

Functional/declarative language

TensorFlow™

Proto-here-is-an-example language

Language landscape



Proto-imperative language

Imperative language

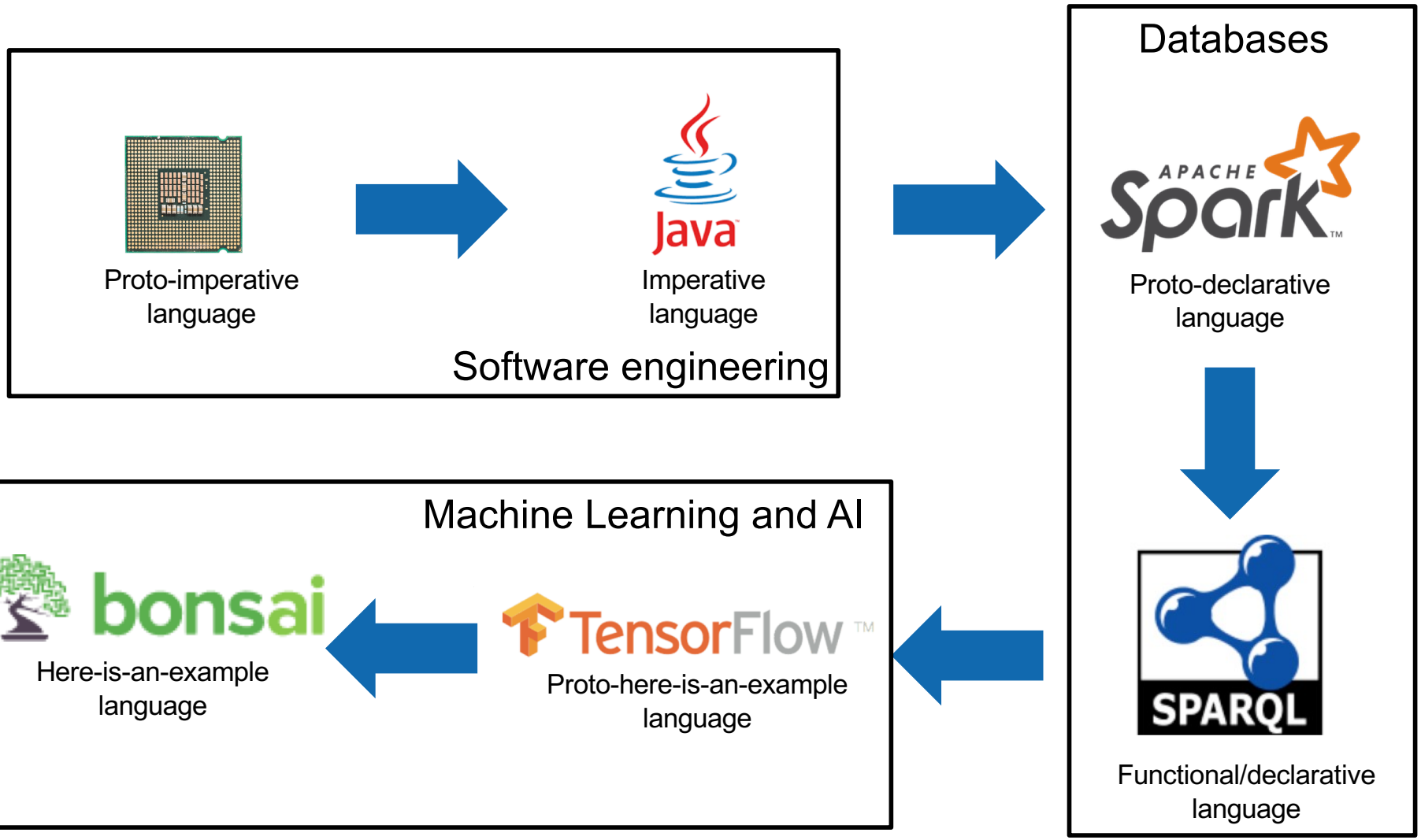
Proto-declarative language

Functional/declarative language

Proto-here-is-an-example language

Here-is-an-example language

Language landscape



Transactions

The good old times of databases: ACID

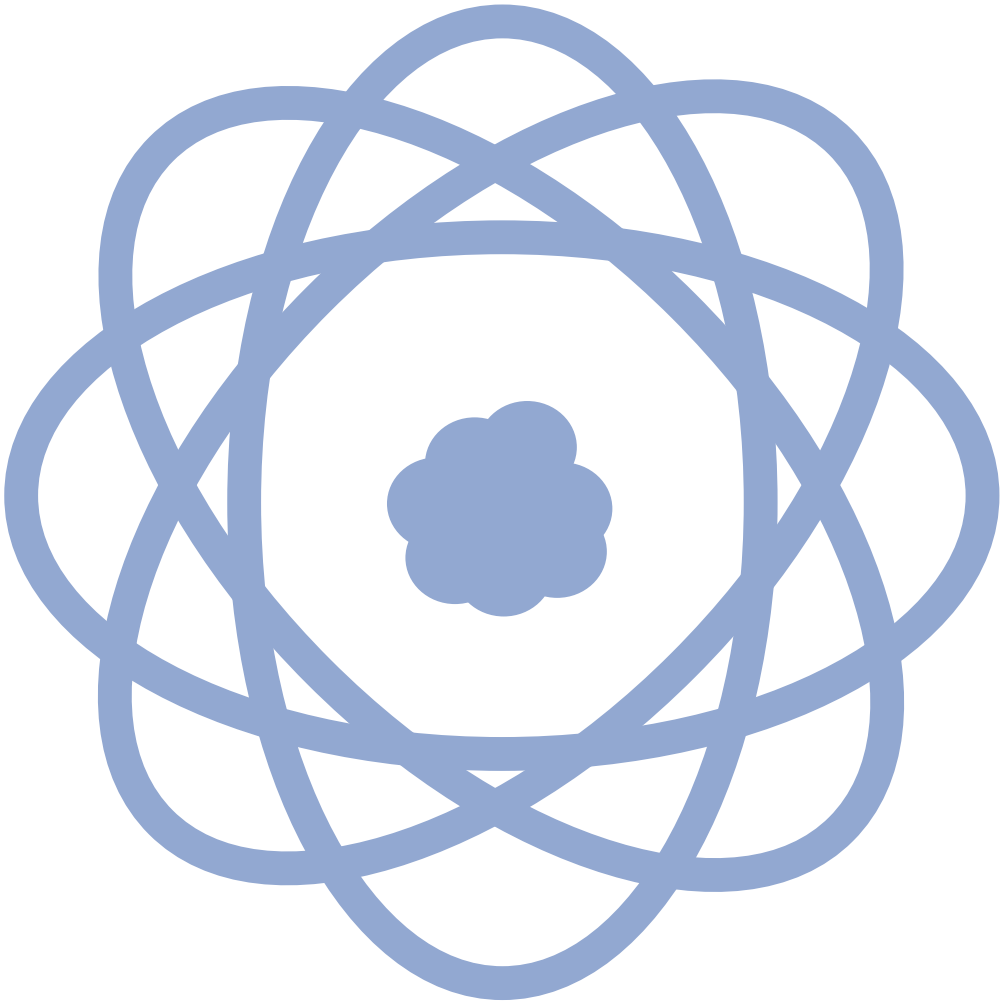
Atomicity

Consistency

Isolation

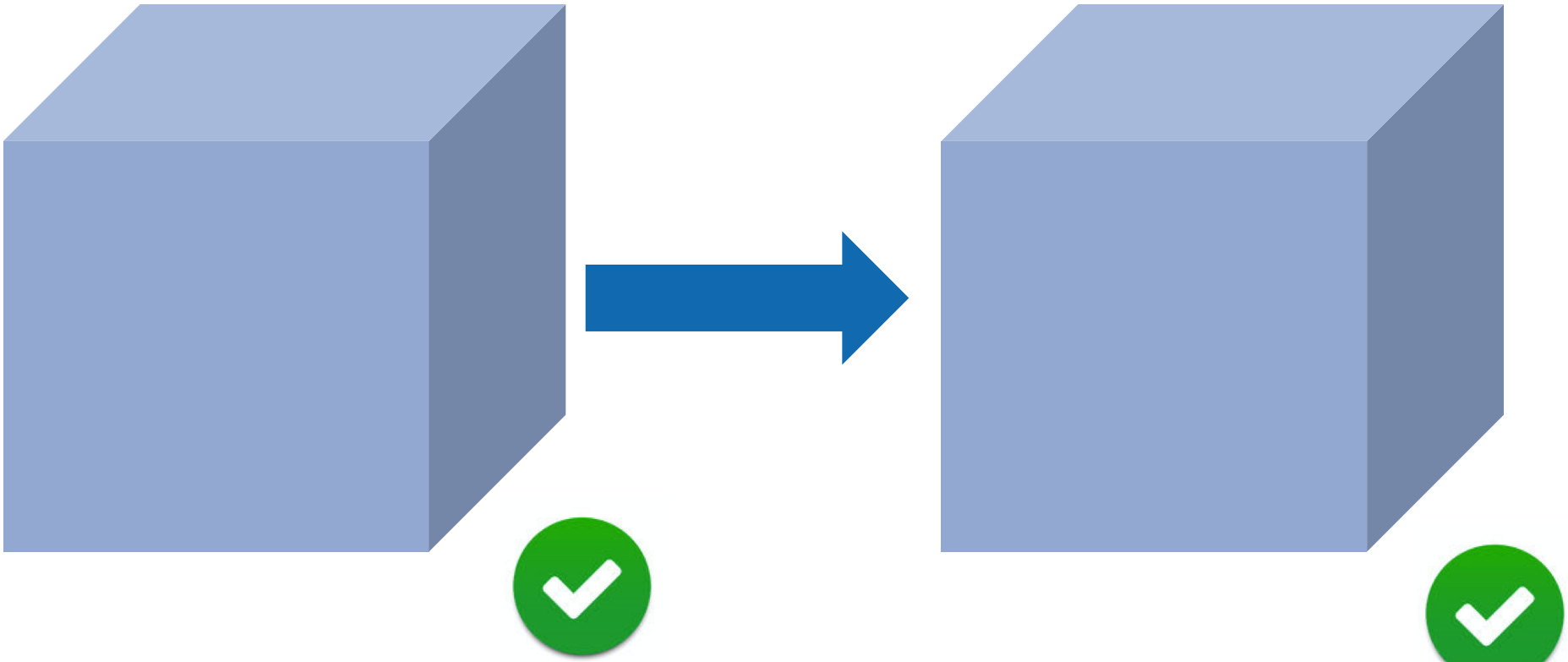
Durability

Atomicity



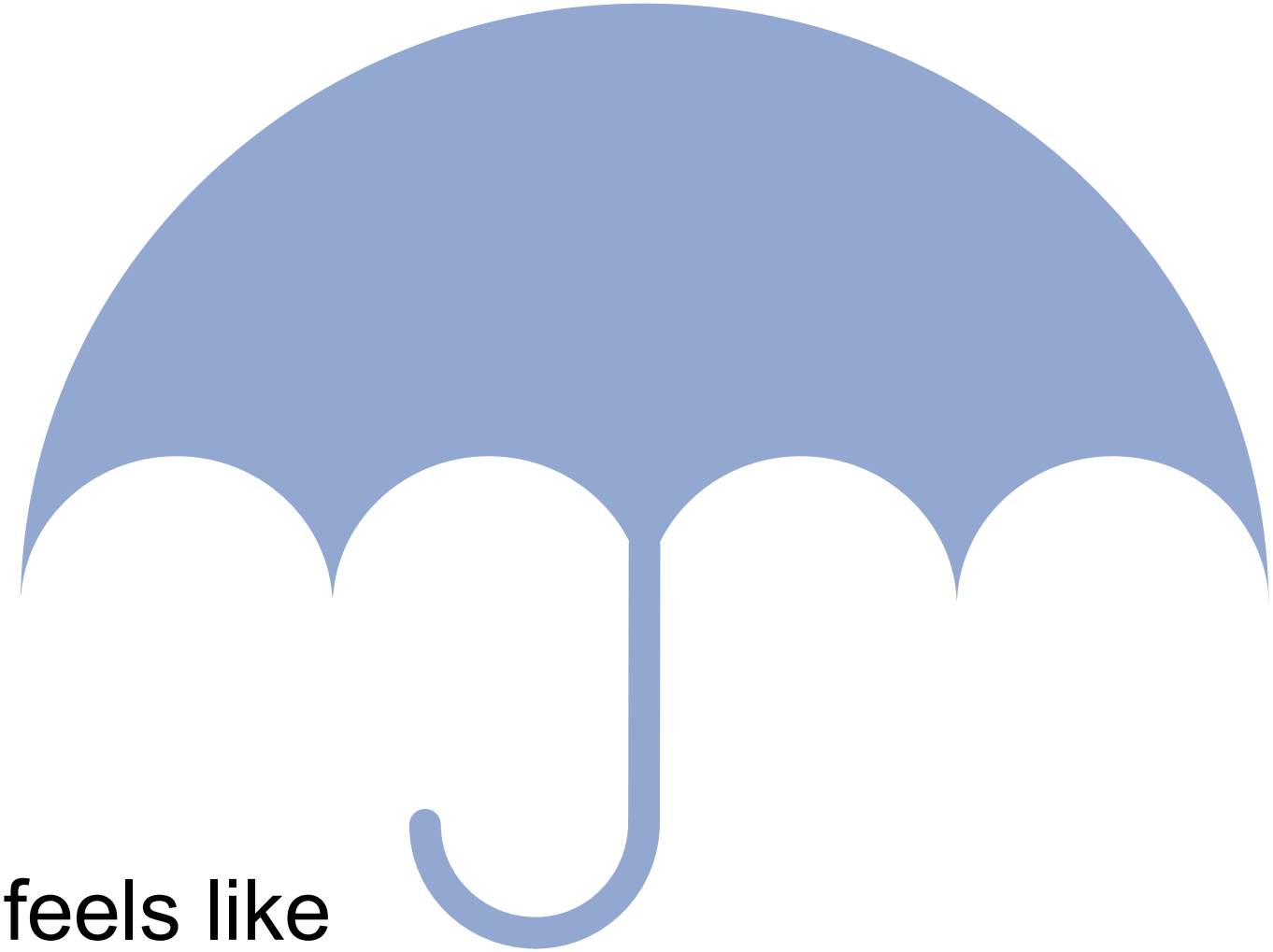
Either the entire transaction is applied,
or none of it (rollback).

Consistency



After a transaction, the database is in a consistent state again.

Isolation



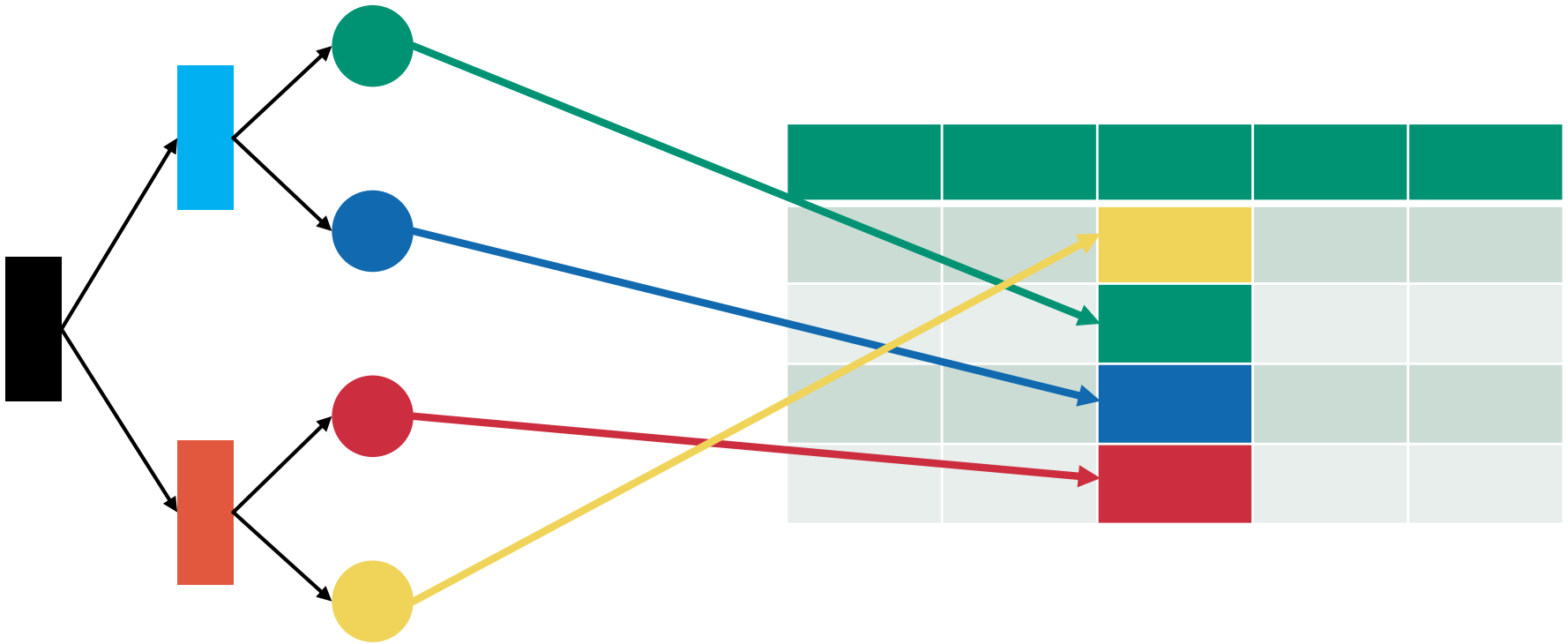
A transaction feels like
nobody else is writing to the database.

Durability

Updates made do not disappear again.

Performance

Indices



Optimize for read vs. write intensive

OnLine Transaction Processing

OnLine Analytical Processing

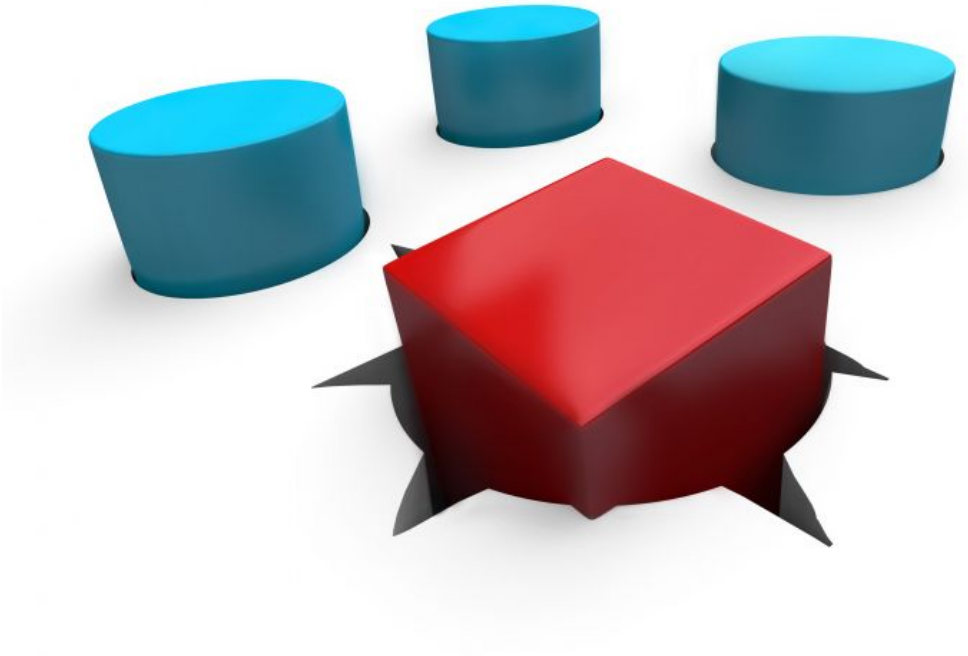
Write-intensive

Read-intensive

No such thing as "one size fits all"

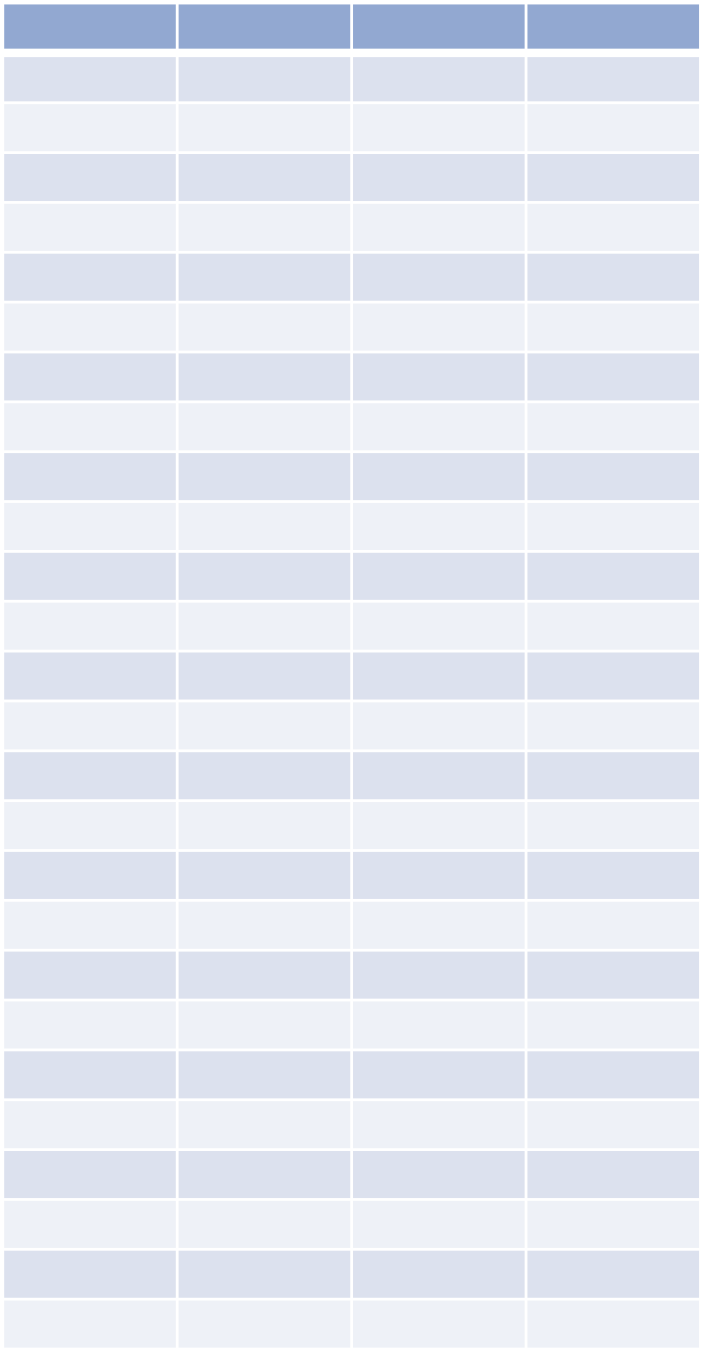
Data shapes

matter



Data Scale-Up

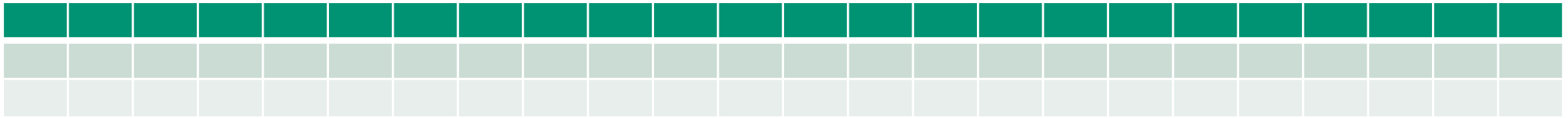
Data can have...



Lots of rows

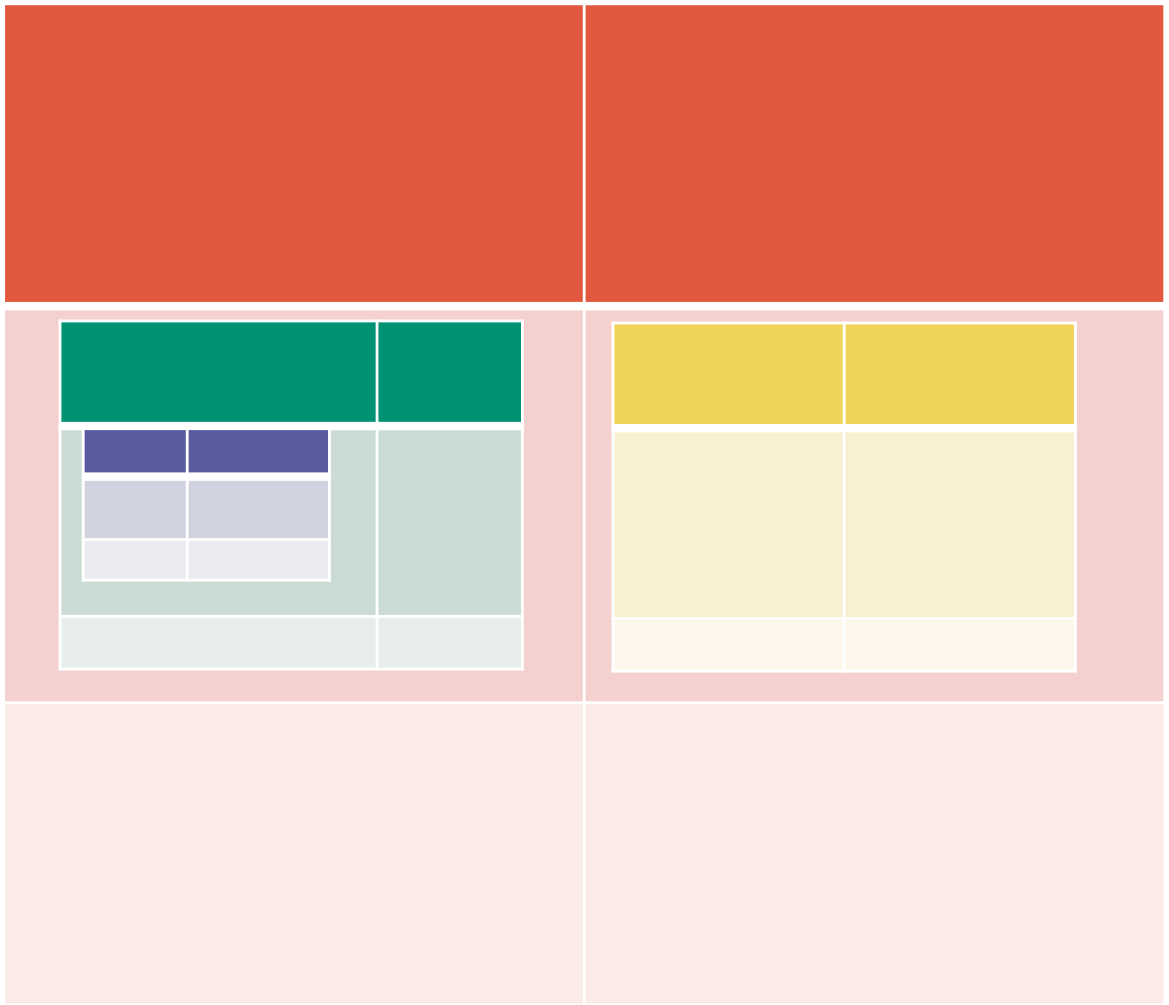
Data can have...

Lots of columns



Data can have...

Lots of nesting



The rest of the lecture: Scaling up

Lots of rows	Object Storage
Lots of rows	Distributed File Systems
Lots of nesting	Syntax
Lots of rows/columns	Column storage
Lots of nesting	Data Models
Lots of rows	Massive Parallel Processing
Lots of nesting	Document Stores
Lots of nesting	Querying