Advanced SQL

Summer 2020
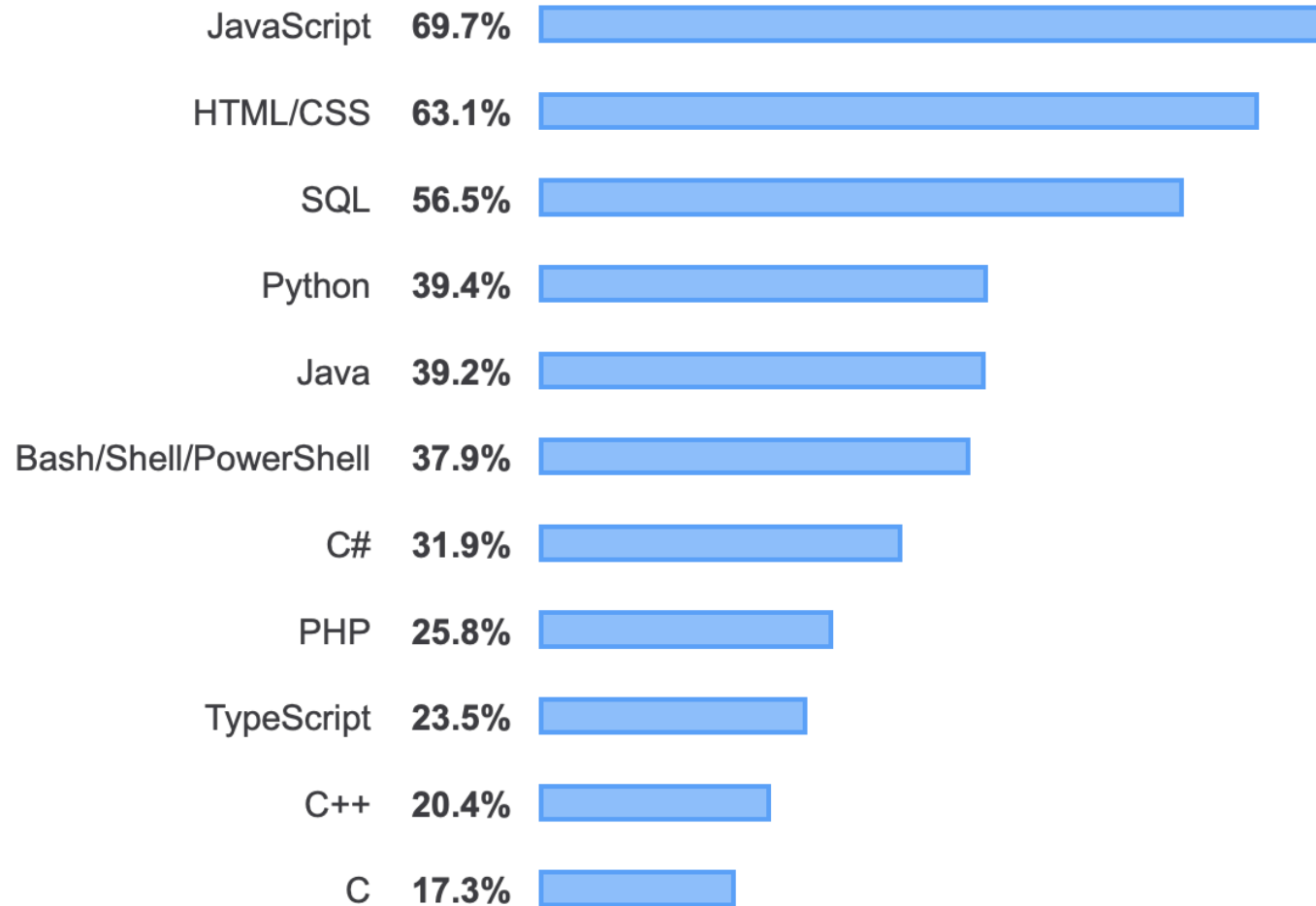
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1 ┊ Welcome...

... to this exploration of **advanced aspects of SQL.** Your current mental image of SQL will change during this course (mine surely did already).

The value—in terms of scientific insight as well as 💶—of knowing the ins and outs of SQL can hardly be overestimated.

SQL is a remarkably rich and versatile **declarative database and programming language.** Let's take a deep dive together!
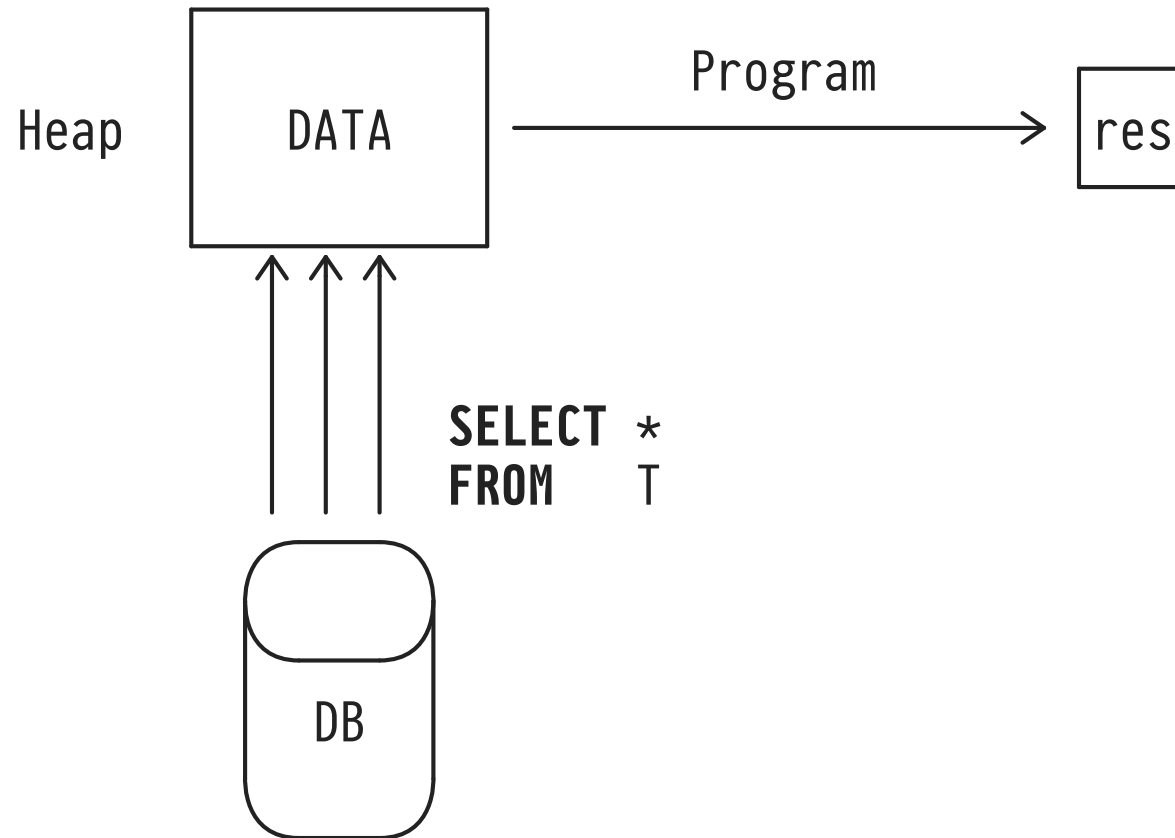
Stack Overflow Developer Survey (March 2019)

Language	Percentage
JavaScript	**69.7%**
HTML/CSS	**63.1%**
SQL	**56.5%**
Python	**39.4%**
Java	**39.2%**
Bash/Shell/PowerShell	**37.9%**
C#	**31.9%**
PHP	**25.8%**
TypeScript	**23.5%**
C++	**20.4%**
C	**17.3%**

Most Popular Technologies — Programming Languages[1]

[1] https://stackoverflow.com/insights/survey/2019

# Operating the Database System as a Dumbed Down Table Storage

👎 Program- and Heap-Centric Operation of Database System

Operating the Database System as a Dumbed Down Table Storage

- **Move tables**—*i.e.*, almost all columns/rows—from database system (DBMS) storage into programming language (PL) heap.

- Count on the PL heap to be able to hold all required row data (otherwise try to chunk or stream data).

- Map rows to PL data structures, then **perform in-heap computation** to obtain result.

Moving Computation Close to the Data

Program

Advanced
SQL

DB

Query

res

fetch
row(s)

res

(prog)
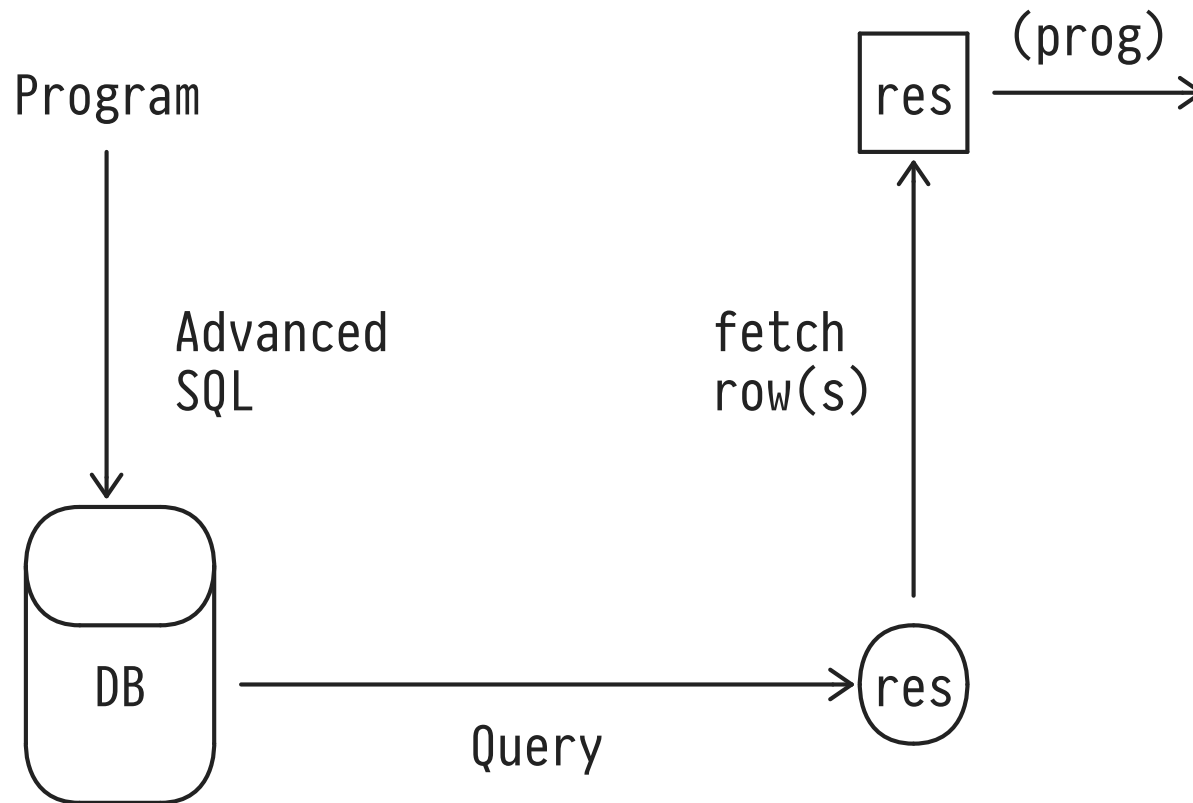
👍 Data- and Query-Centric Operation of Database System

Moving Computation Close to the Data

- **Express complex computation** in terms of the advanced constructs offered by the SQL database language, **ship query to DBMS.**

- **Let the database system operate** over (high-volume) data in native DBMS format, supported by index structures.

- **Fetch the—typically few or even single—result row(s)** into the PL heap, perform lightweight in-heap post-processing (only if needed).

2 ┆ The Origins of SQL

Don Chamberlin

Ray Boyce (✝ 1974)

The Origins and of SQL

- Development of the language started in 1972, first as **SQUARE**, from 1973 on as **SEQUEL** (*Structured English Query Language*). In 1977, SEQUEL became **SQL** because of a trademark dispute. (Thus, both "*S-Q-L*" /ˌɛskjuːˈɛl/ and "*sequel*" /ˈsiːkwəl/ are okay pronounciations.)

- First commercial implementations in the late 1970s/early 1980s. By 1986, the ANSI/ISO standardization process begins.

- Since then, SQL has been in under active development and remains the **"*Intergalactic Dataspeak*".**[2]

[2] Mike Stonebraker, inventor of Ingres (1972, precursor of Postgres, PostgreSQL)

SQL Standards

Year	Name	Alias	Features
1986	SQL-86	SQL-87	first ANSI-standardized version
1989	SQL-89		integrity constraints
1992	SQL-92	SQL2	major revision, ⚠ orthogonality
1999	SQL:1999	SQL3	⚠ recursive queries, PL/SQL, rows/arrays
2003	SQL:2003		XML support, window functions, sequences
2006	SQL:2006		XQuery support
2008	SQL:2008		TRUNCATE, MERGE, improved CASE/WHEN
2011	SQL:2011		temporal data types/operations
2016	SQL:2016		row pattern matching, JSON support

- SQL standards are multi-1000 page documents. *Conformance levels* have been defined to give DBMS implementors a chance to catch up.

- IBM DB2 implements subsets of SQL-92 and SQL:2003. PostgreSQL 12.*x* implements most of core SQL:2011.

3 ┆ This Course

- We will explore the wide variety of **query and procedural constructs** in SQL.

- How much **computation can we push** into the DBMS and thus towards the data?

- Where are the **limits of expressiveness** and pragmatics?

- Have fun along the way! 😎
  We will discuss **offbeat applications of SQL** beyond
  employees–departments and TPC-H examples.[3]

[3] The *drosophila melanogaster* of database research.

Torsten Grust?

Time Frame	Affiliation/Position
1989–1994	Diploma in Computer Science, TU Clausthal
1994–1999	Promotion (PhD), U Konstanz
2000	*Visiting Researcher*, IBM (USA)
2000–2004	Habilitation, U Konstanz
2004–2005	Professor Database Systems, TU Clausthal
2005–2008	Professor Database Systems, TU München
since 2008	Professor Database Systems, U Tübingen

- E-Mail: Torsten.Grust@uni-tuebingen.de
- Twitter: @Teggy (*Professor, likes database systems, programming languages, and SC Freiburg* ツ)
- WSI, Sand 13, Room B318

Administrativa

- To help keep the ongoing COVID-19 🦠 pandemic at bay, there will be **no in-class lectures,** at least until mid-June 2020 (*i.e.,* until the whitsun break).

- *In case* we will finish the semester in the class room, the following are the assigned lecture hall and time slots:

Weekday/Time	Slot	Room
Thursday, 10:15–11:45	Lecture	Sand 14, C215
Tuesday, 14:15–15:45	Tutorial	Sand 14, C215

Lecture Videos, Slides, and Pieces of SQL

- I will post **lecture videos** ($\approx$ 15-min fragments) to a dedicated playlist on YouTube ▶. Those videos will
  - walk through the slides,
  - develop, run, and discuss SQL code snippets,
  - run live PostgreSQL experiments, and
  - expand on slide material.

- These **slides** (PDF), **SQL code fragments**, and **sample data** will be uploaded to a Github repository:

  github.com/DBatUTuebingen/asql-ss20

Weekly Assignments & Tutorial Sessions

- We will distribute, collect, and grade **weekly assignments** (Tuesday→Tuesday) via Github 🐙.
- You work on these in **teams of two**. Hand-in again via 🐙.

Organized and run by **Christian Duta:**

- E-Mail: Christian.Duta@uni-tuebingen.de
- WSI, Sand 13, Room B315

Assignments start once we have collected the first batch of interesting material, probably by the end of April. **Live, interactive tutorials** 😊↔😊😊😊 will be announced in time.

Forum

During this lunatic summer semester, the **Advanced SQL forum** is *the* course hub and more important than ever:

forum-db.informatik.uni-tuebingen.de/c/ss20-asql

⚠ **Registration** (mandatory) and announcements
❓ Questions and answers (do *not* post complete solutions)
☁ Download additional code examples (*e.g.*, SQL)
💬 General discussion
🏁 Quick turnaround (responses often within minutes)

End-Term Exam

⚠️ Exactly when and how we can run the Advanced SQL end-term exam is subject to contact restrictions and regulations of U Tübingen. Our current plans (as of April 20):

- 90-min **written exam** on Thursday, July 23, 10:00.
- Score ⩾ ⅔ of the overall assignment points to be admitted to the exam and earn bonus points in the end-term exam.
- You may bring a DIN A4 double-sided *cheat sheet*.
- Passing earns you 6 ECTS.

Course Homepage

db.inf.uni-tuebingen.de/teaching/AdvancedSQLSS2020.html

- **Organizational matters**
  Curriculum. General announcements regarding the lecture, exams, or dates. Please surf by regularly. Thank you!

- **Contact information**
  Turn to the forum first. But feel free to send e-mail if you seek specific help/need to discuss personal issues with us.

Material

This course is *not* based on a single textbook but based on

- a variety of scientific papers,
- textbook excerpts,
- blog and mailing list postings, Stack Exchange Q&As,[4]
- SQL references/standards,
- Markus Winand's excellent web site modern-sql.com,
- experience, and best practices.

There is plethora of books on SQL Hacks, Quizzes, Puzzles, (Anti-)Patterns, Performance Tweaks, and Idioms. If we will use sources like these, we will name them.

[4] http://dba.stackexchange.com/questions/tagged/sql is worth a look

Get Your Hands Dirty: Install PostgreSQL!

PostgreSQL will be the primary tool in this course:
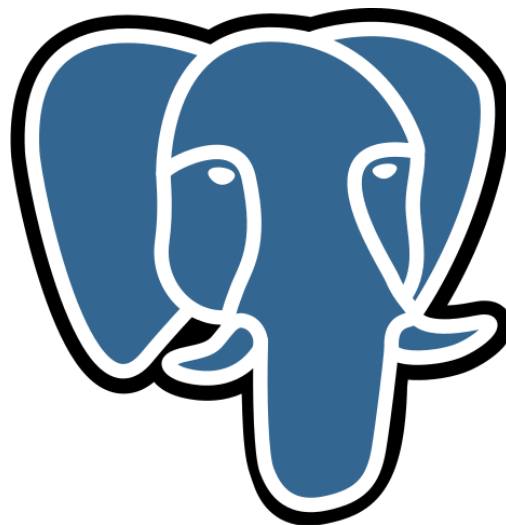
postgresql.org, version 12.*x* assumed (11.*x* probably OK)

- Implements an extensive SQL:2011 dialect, is extensible as well as open to inspection, and generally awesome.
- Straightforward to install/use on macOS, Windows, Linux.

4 ┊ SQL's Tabular Data Model

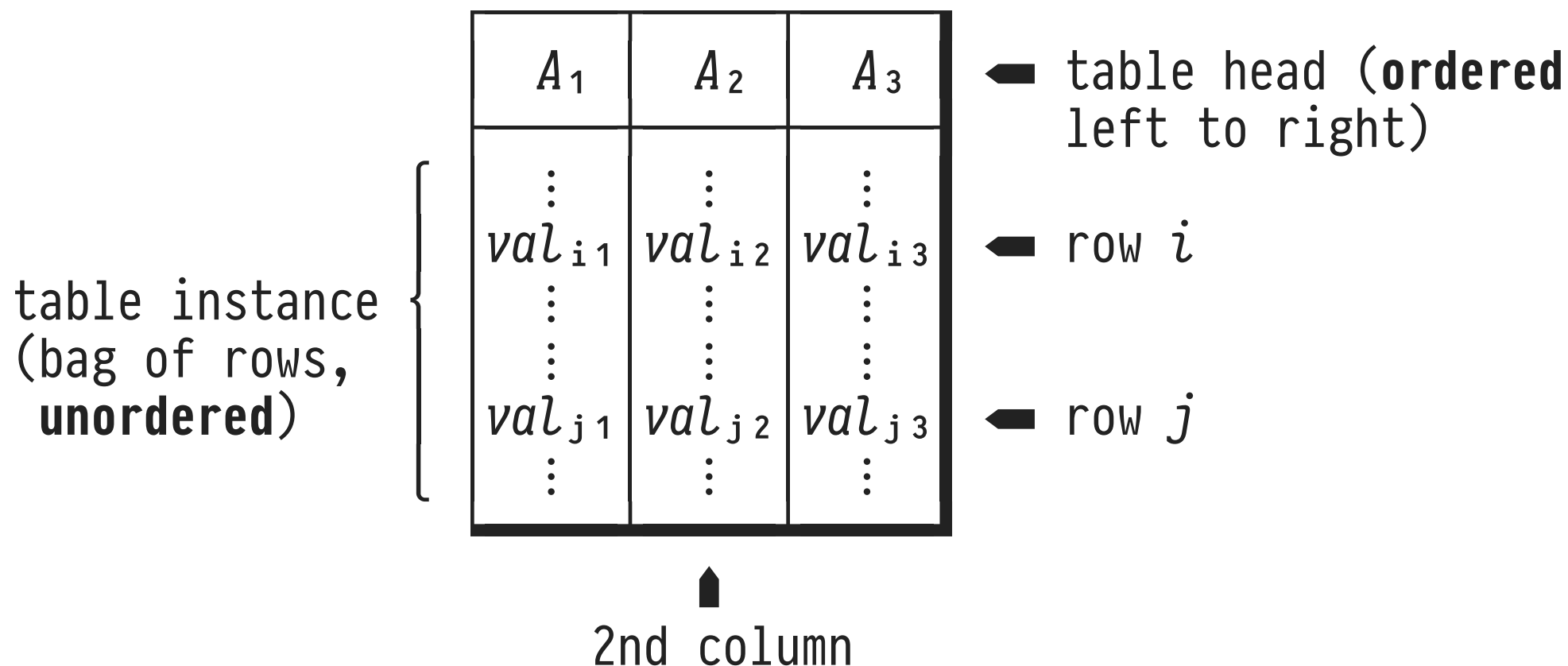This course will *not* provide an introduction to SQL's **tabular data model** or the language itself.[5]

Let us only spend a few moments/slides to recollect the **data model fundamentals** and to synchronize on terminology.

We will do the same with **SQL language fundamentals** right after.

[5] Please see *Database Systems 1* for such an introduction.

Tables

In a SQL-based database instance, *all* data is organized in **tables:**

$$
\begin{array}{|c|c|c|}
\hline
A_1 & A_2 & A_3 \\
\hline
\vdots & \vdots & \vdots \\
val_{i1} & val_{i2} & val_{i3} \\
\vdots & \vdots & \vdots \\
\vdots & \vdots & \vdots \\
val_{j1} & val_{j2} & val_{j3} \\
\vdots & \vdots & \vdots \\
\hline
\end{array}
$$

← table head (**ordered** left to right)

← row i

← row j

table instance (bag of rows, **unordered**)

↑ 2nd column

Columns, Types, Cells, NULL

A_1	A_2	A_3
$\vdots$	$\vdots$	$\vdots$
val_{j1}	val_{j2}	NULL
$\vdots$	$\vdots$	$\vdots$

$\longleftarrow\ A_i :: \tau_i,\ \ i \in \{1,2,3\}$

- On table creation, the ith column is assigned a unique **column name** A_i and **column data type** τ_i.
- **Cell values** val_{ji}, for *any* row j, are of data type τ_i.
- Each data type τ_i features a unique NULL value. Value val_{ji} may be NULL unless column A_i explicitly forbids it.

First Normal Form (1NF)

A_1	A_2	A_3
$\vdots$	$\vdots$	$\vdots$
val_{j1}	val_{j2}	val_{j3}
$\vdots$	$\vdots$	$\vdots$

- SQL tables are in **first normal form (1NF):** all column data types τ_i are **atomic.**

- In particular, val_{ji} may *not* be a table again.[6]

- In modern/real-world SQL, we will see how *row values*, *arrays*, and data types like JSON water down strict 1NF.

[6] Such data nesting is admitted by *non-first normal form* (NFNF, NF²) data models.

Keys: Value-Based Row Identification

key (= subset of columns)

convention in these slides: ➡
---- marks key columns

A_1	A_2	A_3
val_{i1}	val_{i2}	val_{i3}
⋮	⋮	⋮
val_{j1}	val_{j2}	val_{j3}

- If **key** $\{A_1,A_2\}$ has been declared, we are guaranteed that $(val_{i1},val_{i2}) \neq (val_{j1},val_{j2})$ for any $i \neq j$.
- Predicate $A_1 = c_1$ AND $A_2 = c_2$ identifies at most one row.
- Convention: key columns A_1,A_2 are leftmost in the schema, notation: $\underline{A_1\ A_2}\ A_3$.

Foreign Keys: Identifying Rows in Other Tables
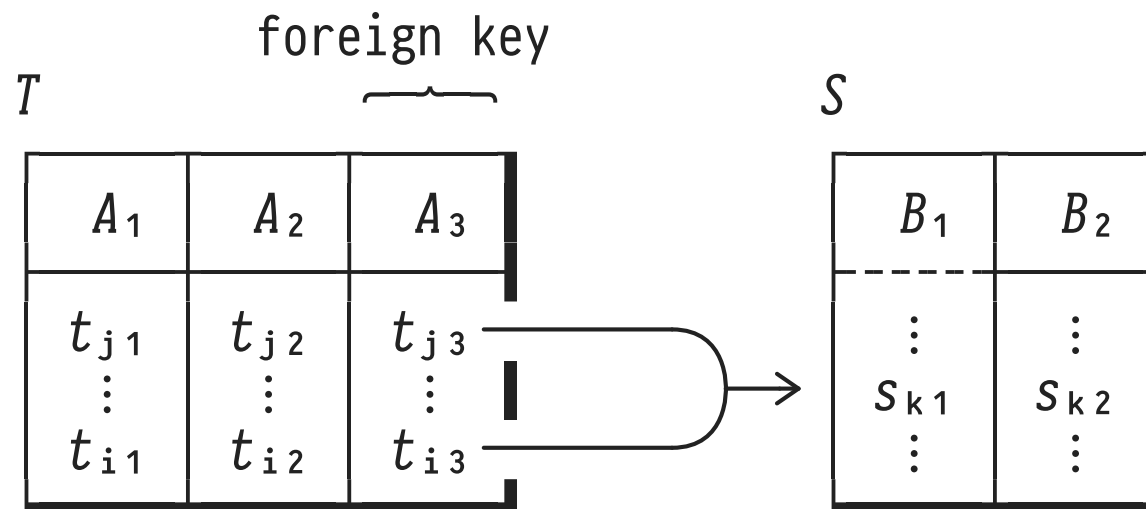
- If **foreign key** $T(A_3) \rightarrow S(B_1)$ has been declared, for any value t_{j3} a matching value s_{k1} is guaranteed to exist (⚠ no "dangling pointers"). If row s_{k1} is deleted, we need to compensate.
- In general, $\{A_3\}$ is *not* a key in T ($t_{j3} = t_{i3}$ is OK).