# DB 2

## 04 – Row Internals

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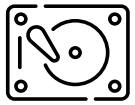
## 1 $Q_3$ — Projecting on Columns

**SQL probe** $Q_3$ projects on selected columns only (column b) of table ternary is "projected away"):

```
SELECT t.a, t.c          -- access some columns of row t
FROM   ternay AS t
```

Retrieve all rows. Unpack/navigate the row and **extract selected columns.** Recall table ternary:

```
CREATE TABLE ternary (a int  NOT NULL,
                      b text NOT NULL, -- variable width
                      c float);        -- may be NULL
```

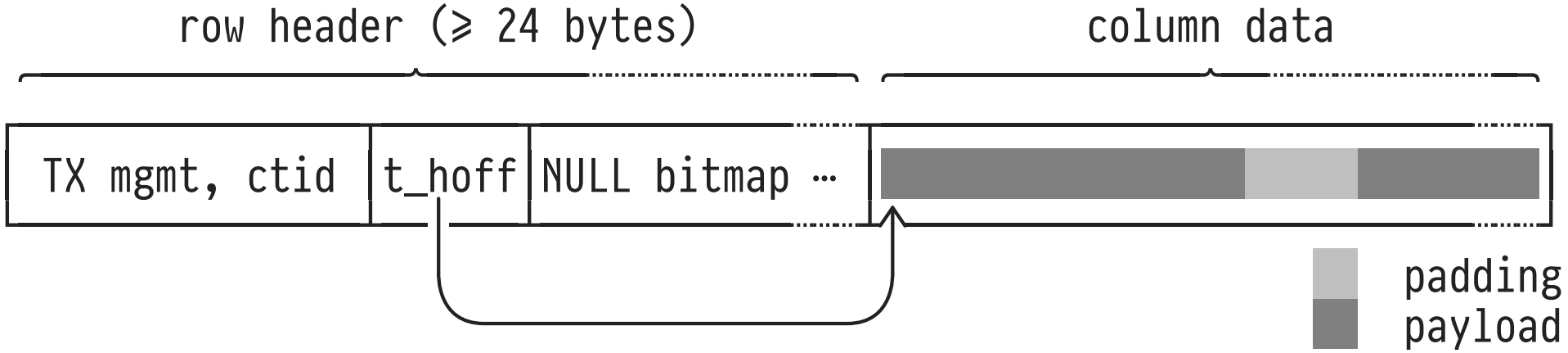
## Using EXPLAIN on $Q_3$ 

```
EXPLAIN VERBOSE
  SELECT t.a, t.c
  FROM   ternary AS t;
```

```
                                QUERY PLAN
-------------------------------------------------------------------------
 Seq Scan on public.ternary t  (cost=0.00..20.00 rows=1000 width=12)
   Output: a, c
```

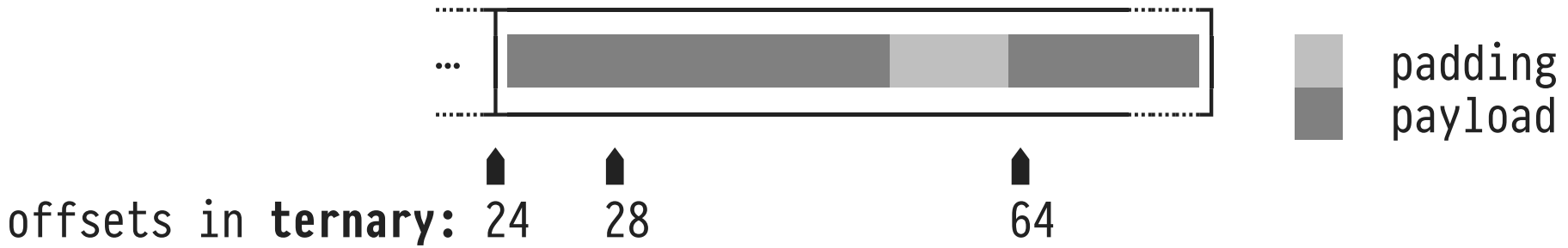
- For each row t, only columns a and c are extracted.
- **Seq Scan** emits narrower rows now, *average* width: 12 bytes = 4 (int) + 8 (float) bytes.
- Estimated cost of 20.00 unchanged from $Q_2$: $Q_3$ does *not* scan fewer data pages (→ row storage).

# 2 Internal Layout of a PostgreSQL Row



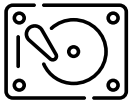

- NULL bitmap is of variable length (1 bit per column), offset t_hoff points to first byte of row payload data.
- NB: EXPLAIN's *width=w* reports payload bytes only.

# Padding and Alignment




- CPU and memory subsystem require **alignment:** value of width $n$ bytes is stored at address $a$ with $a \bmod n = 0$.[1]
- $\Rightarrow$ Pad payload such that each column starts at properly aligned offset (PostgreSQL: see table pg_attribute).

[1] Non-aligned data access incur performance penalties (multiple accesses) or even exceptions.

## “Column Tetris” 

Padding may lead to substantial space overhead. If viable, reorder columns to tightly pack rows and avoid padding:

```
CREATE TABLE padded (
  d int2,
  a int8,
  e int2,
  b int8,
  f int2,
  c int8)
```

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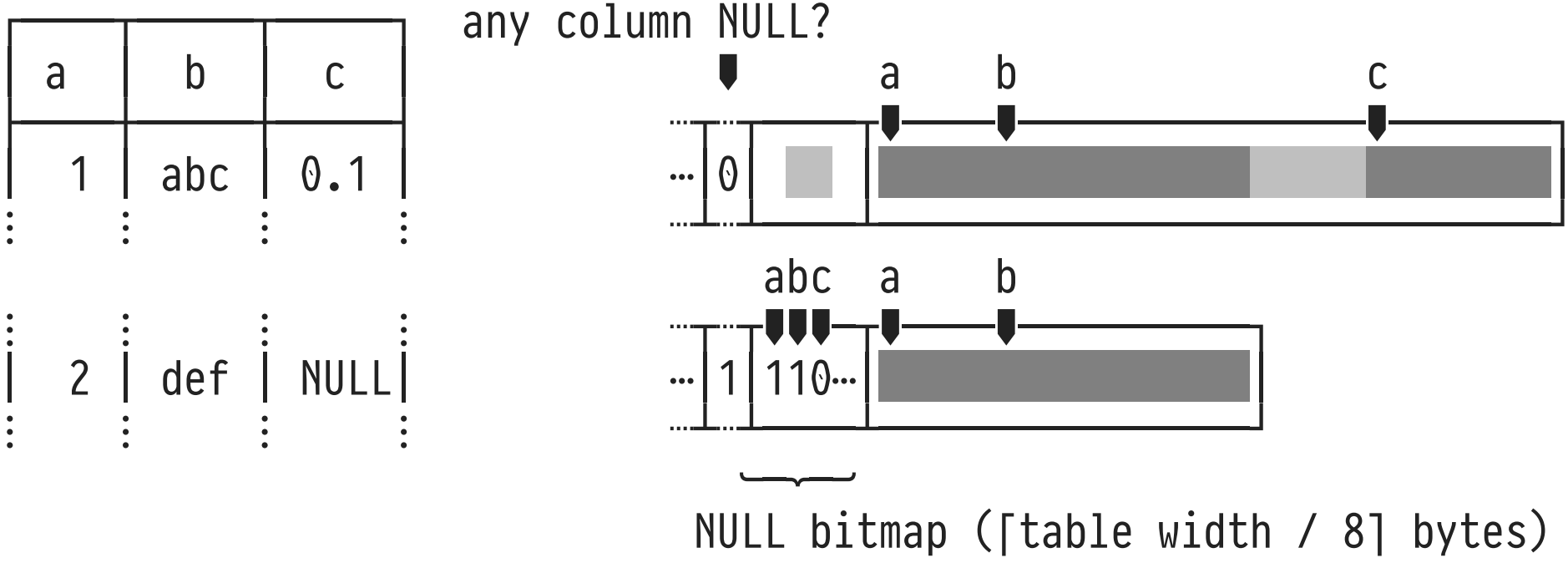
```
CREATE TABLE packed (
  a int8  -- int8: 8-byte aligned
  b int8
  c int8
  d int2  -- int2: 2-byte aligned
  e int2
  f int2)
```

30 (+2) column data width

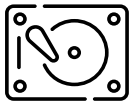
- +2: Rows start at MAXALIGN offsets (≡ 8 on 64-bit CPUs).

# NULL (Non-)Storage



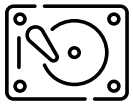

- NULL values are represented by 0 bits in a **NULL bitmap** (bitmap is present only if the row indeed contains a NULL).

## Column Access (Projection)



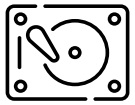
- If `t` denotes a row, **column access** — denoted using dot notation `t.a` — is the most common operation in SQL query expressions.
  - A typical SQL query will perform multiple column accesses per row (in `SELECT`, `WHERE`, `GROUP BY`, … clauses), potentially millions of times during evaluation of a single query.
- Even tiny savings in processing effort (here: CPU time) will add up and can lead to substantial benefits.[2]

[2] This is a recurring theme in DBMS implementation. The larger the table cardinalities, the more worthwhile “micro optimizations” become.

## Column Access (Projection) 

- PostgreSQL: access $i$th column of a row using C routine `slot_getattr(i)`:
  1. Has value for column $i$ been cached? If so, immediately return value.
  2. Check bit for $i$th column in NULL bitmap (if present): if `0`, immediately return `NULL`.
  3. Scan row payload data **from left to right** for all columns $k \leqslant i$:
     - Use type of column $k$ to decode payload bytes.
     - Skip over contents if column $k$ has variable width.
     - **Cache decoded value** for column $k$ for subsequent `slot_getattr(k)` calls.

## Column Access: PostgreSQL's slot_getattr()



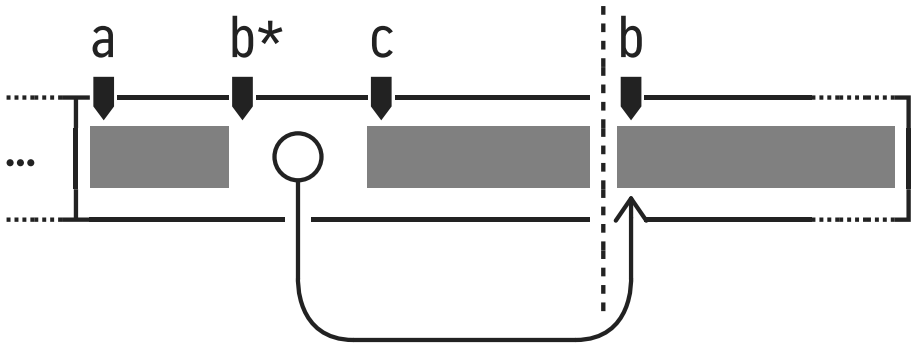
See PostgreSQL source code (a prime example of readable, consistent, well-documented C code — go read it!):

- File src/backend/access/common/heaptuple.c:

```
Datum
slot_getattr(TupleTableSlot *slot, int attnum, bool *isnull)
{
  /* step 1. check cache for column attnum (≡ i) */
  /* step 2. check NULL bitmap */
  ⋮
  /*
   * Extract the attribute, along with any preceding attributes.
   */
  slot_deform_tuple(slot, attnum);
  ⋮
}
```

- slot_deform_tuple() does the hard decoding work (step 3.)

# Alternative Layout of Row Payload: Fixed-Width First



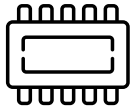

- **Separate fixed- from variable-width** payload data at ┆:
  - ■■┆ : fixed-width columns a, c (types int, double) + fixed-width pointers b* to variable-width columns
  - ┆■■ : variable-width value for column b (type text)
- ⇒ Can calculate offsets of fixed-width columns **at query compile time**, no left-to-right scanning at run time.

## 3 $Q_3$ — Projecting on Columns

Column b of table ternary(a,b,c) is irrelevant for the projection query $Q_3$:

```
SELECT t.a, t.c          -- access some columns of row t
FROM   ternay AS t
```

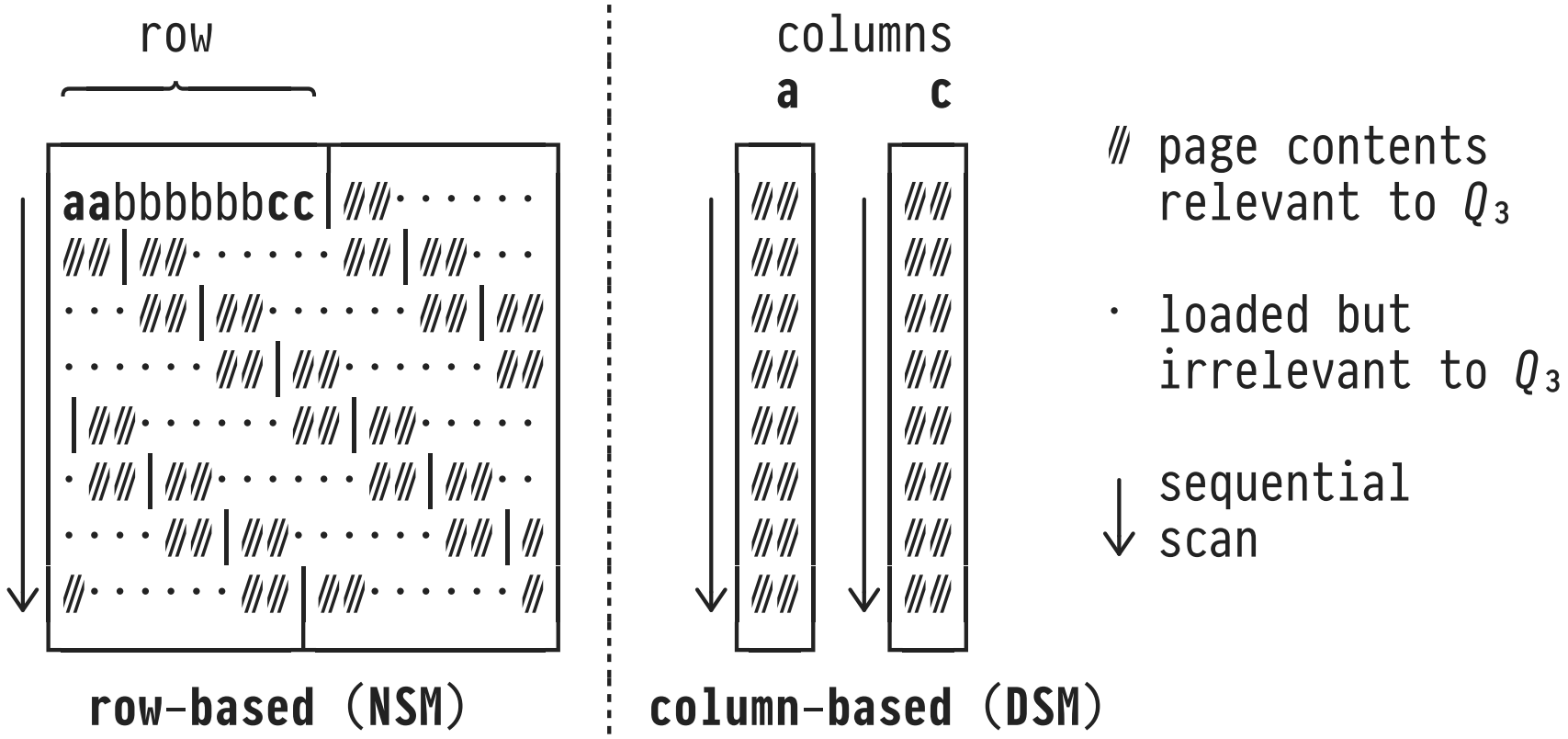
We expect the column-oriented DBMS to **exclusively touch the relevant columns.** The wider the input table (and the less columns are accessed), the higher the expected benefit over the row-based DBMS.

## Using EXPLAIN on $Q_3$ 

MAL program for $Q_3$, shortened and formatted (compare with the MAL program for $Q_2$):

```
 ⋮
X_4              := sql.mvc();
C_5 :bat[:oid] := sql.tid(X_4, "sys", "ternary");
X_18:bat[:dbl] := sql.bind(X_4, "sys", "ternary", "c", …);
X_24:bat[dbl]  := algebra.projection(C_5, X_18);
X_8 :bat[:int] := sql.bind(X_4, "sys", "ternary", "a", …);
X_17:bat[:int] := algebra.projection(C_5, X_8);
 ⋮
 ‹create schema of result table›
 ⋮
sql.resultSet(…, X_17, X_24);
```

# Don't Need it? Don't Load it!




- **100%** of the data loaded by the column-based DBMS is useful for query evaluation.