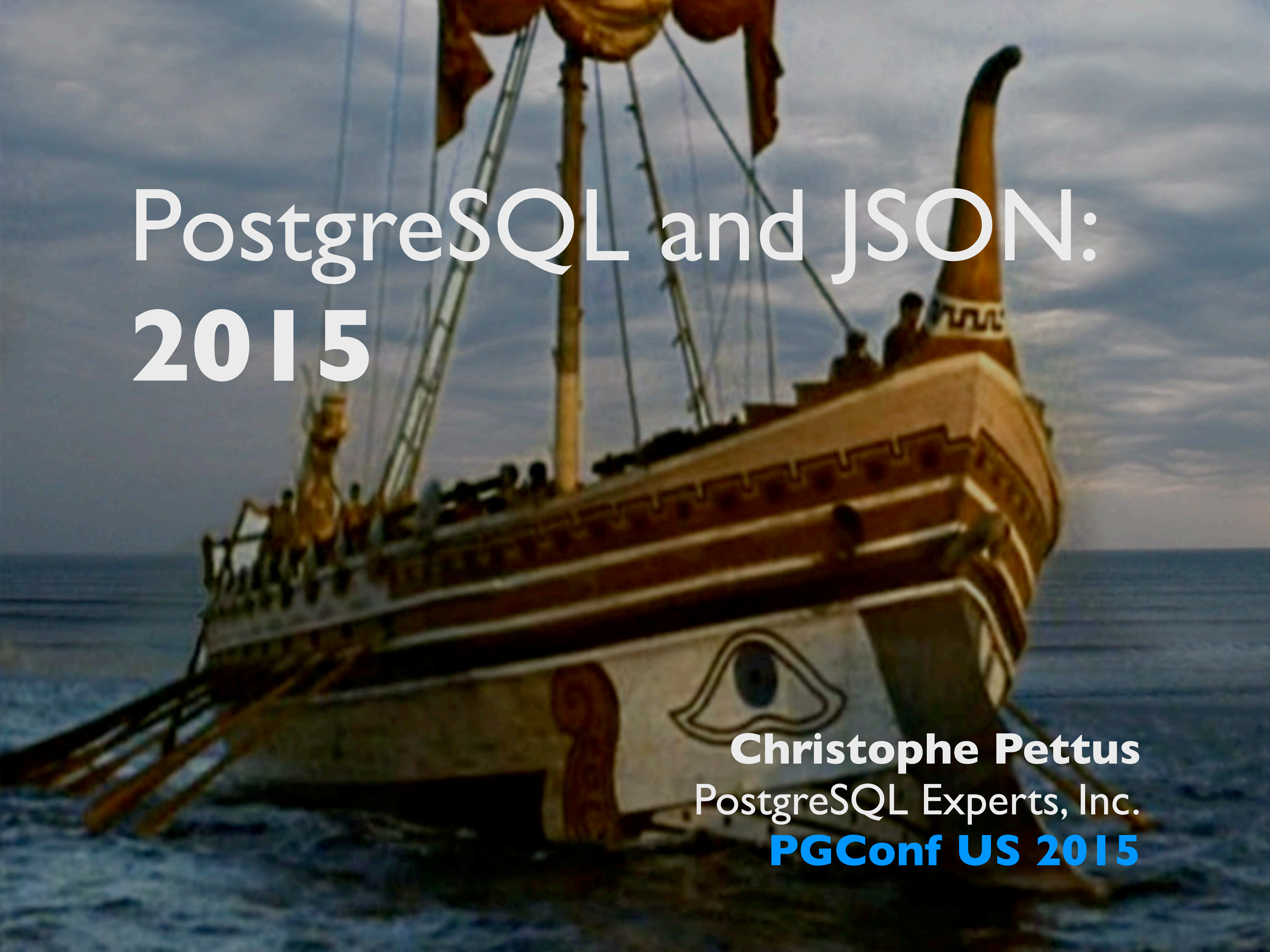

PostgreSQL and JSON: **2015**

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PGConf US 2015

Greetings!

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JSON, what is?

- JavaScript Object Notation.
- A text format for serializing nested data structures.
- Based on JavaScript's declaration syntax.
- Intended to be passed directly into JavaScript's eval() function (don't do this!)

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JSON Primitive Types.

- Strings, always Unicode.
  - De facto, always UTF-8 in flight.
- Numbers, integer and float.
- Boolean: `true` and `false`.
- `null`

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JSON Structured Types.

- Arrays, using [ ].
- Hash / dictionaries / whatever you want to call them (the JSON spec calls them Objects), using { }
  - { "string" : value }
  - Keys have to be strings; values can be anything.

More complex types.

- Everything else is built out of those.
- There’s no type declaration mechanism.
  - “Object” is unfortunate terminology.
- There’s no “schema” or similar validation method.
- Everything is delegated to the application.

The good…

- It's super-simple to generate and parse.
  - The operational part of the spec is five pages, with diagrams.
- It's the de facto standard for data interchange in web APIs.
  - POST format is still used, but apps that do that are wrong.

The bad…

- No higher-level standards.
  - How is a datetime represented? I dunno, you figure it out.
- Remember SQL injection attacks? Now we have JSON injection attacks.
  - Don't use eval(). Just. Don't.

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And PostgreSQL has JSON!

- It's a core type.
  - Not a contrib/ or extension module.
- Introduced in 9.2.
- Enhanced in 9.3.
- And really enhanced in 9.4.

We liked JSON so much…

- … we created two types.
  - json
  - jsonb
- json is a pure text representation.
- jsonb is a parsed binary representation.
- Each can be cast to the other, of course.

json type.

- Stores the actual json text.
- Whitespace included.
- What you get out is what you put in.
- Checked for correctness, but not otherwise processed.

Why use json?

- You are storing the json and never processing it.
- You need to support two JSON "features":
  - Order-preserved fields in objects.
  - Duplicate keys in objects.
- For some reason, you need the *exact* JSON text back out.

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Oh, and…

- jsonb wasn't introduced until 9.4.
- So, if you are on 9.2-9.3, json is what you've got.
- Otherwise, you want to use jsonb.

jsonb

- Parsed and encoded on the way in.
- Stored in a compact, parsed format.
- Considerably more operator and function support.
- Has indexing support.

They're just types.

- Fully transactional, can have multiple `json`/`jsonb` fields in a single table, etc.
- Uses the TOAST mechanism.
    - Can be up to 1GB.
- Can be a NULLable field if you like.

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Basic Operators (both json and jsonb)

- -> gets a JSON array element or object field, as JSON.
- ->> gets the array element or object field cast to TEXT.
- #> gets the array element or object field at a path.
- #>> … cast to TEXT.

jsonb only!

- @> — Does the left-hand value contain the right-hand value?
- <@ — Does the right-hand value contain the left hand value?

Containment

- Containment work at the top level of the json object only, and on full JSON structures.
- It does not apply to individual keys.
- It does not apply to nested elements.

@>

```
postgres=# select '{"a": 1, "b": 2}'::jsonb @> '{"a": 1}'::jsonb;
 ?column?
----------
 t
(1 row)


postgres=# select '[1, 2, 3]'::jsonb @> '[1, 3]'::jsonb;
 ?column?
----------
 t
(1 row)

postgres=# select '{"a": {"b": 7, "c": 8}}'::jsonb @>
                  '{"a": {"c": 8}}'::jsonb;
 ?column?
----------
 t
(1 row)
```

but.

```
postgres=# select '{"a": {"b": 7}}'::jsonb @> '{"b": 7}'::jsonb;
 ?column?
----------
 f
(1 row)

postgres=# select '{"a": 1, "b": 2}'::jsonb @> '"a"'::jsonb;
 ?column?
----------
 f
(1 row)
```

?, ?|, ?&

- True if:
  - ? — The key on the right-hand side appears in the left-hand side.
  - ?| ?& — Any of the array of keys on the right-hand side appear on the left-hand side.
  - PostgreSQL array type, not JSON array.

?, ?|, ?&

```
postgres=# select '{"a": 7, "b": 4}'::jsonb ? 'a';
 ?column?
----------
 t
(1 row)

postgres=# select '{"a": 7, "b": 4}'::jsonb ?& ARRAY['a', 'b'];
 ?column?
----------
 t
(1 row)

postgres=# select '{"a": 7, "b": 4}'::jsonb ?| ARRAY['a', 'q'];
 ?column?
----------
 t
(1 row)
```

but.

```
postgres=# select '{"a": {"b": 7, "c": 8}}'::jsonb ? 'b';
 ?column?
----------
 f
(1 row)

postgres=# select '[1, 2, 3, 4]'::jsonb ?| ARRAY[1, 100];
ERROR:  operator does not exist: jsonb ?| integer[]
LINE 1: select '[1, 2, 3, 4]'::jsonb ?| ARRAY[1, 100];
                                     ^
HINT:  No operator matches the given name and argument type(s). You might
need to add explicit type casts.

postgres=# select '[1, 2, 3, 4]'::jsonb ?| '[1, 2]'::jsonb;
ERROR:  operator does not exist: jsonb ?| jsonb
LINE 1: select '[1, 2, 3, 4]'::jsonb ?| '[1, 2]'::jsonb;
                                     ^
HINT:  No operator matches the given name and argument type(s). You might
need to add explicit type casts.
```

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JSON functions

- Lots and lots and lots.
- Create JSON from records, arrays, etc.
- Expand JSON into records, arrays, rowsets, etc.
- Many have both json and jsonb versions.

Example: row_to_json

- Accepts an arbitrary row.
- Returns a json (not jsonb) object.
- For non-string/int/NULL types, uses the output function to create a string.
- Properly handles composite/array types.

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Behold!

```
xof=# select row_to_json(rel.*) from rel where array_length(tags, 1) > 2  order by id limit 3;
                                                         row_to_json
-----------------------------------------------------------------------------------------------------------
 {"id":636572,"first_name":"OLENE","last_name":"OGRAM","tags":["female","square","violet"]}
 {"id":636744,"first_name":"SHAYNE","last_name":"GALPIN","tags":["female","square","silver","aquamarine","green","octogon"]}
 {"id":636769,"first_name":"YASMIN","last_name":"AKEN","tags":["female","red","green"]}
(3 rows)
```

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But seriously…

- … can be used in a trigger to append to an audit table regardless of the schema.
- Extremely useful for shared triggers.

Example: jsonb_each_text

- Takes a jsonb object, and returns a rowset of key/value pairs.
- Returns each as text object.
- Can be used to write the world's most expensive EAV query!

Behold!

```
xof=# WITH s AS (
xof(# SELECT row_to_json(rel.*)::jsonb AS j FROM rel ORDER BY id LIMIT 3
xof(# ) SELECT (s.j->>'id')::bigint AS entity, key as attribute, value FROM s,
LATERAL jsonb_each_text(s.j) WHERE key <> 'id';
 entity | attribute  |   value
--------+------------+------------
 636526 | tags       | ["female"]
 636526 | last_name  | EILTS
 636526 | first_name | REGENA
 636527 | tags       | ["male"]
 636527 | last_name  | POTO
 636527 | first_name | ANTONIO
 636528 | tags       | ["female"]
 636528 | last_name  | LUFSEY
 636528 | first_name | ROXY
(9 rows)
```

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But seriously…

- … it can be used to expand jsonb into relational data for JOINs and the like.
- Often more efficient than using the extraction operators.

Indexing.

Indexing json

- The textual json type has no inherent indexing (that you'd ever use).
- Can do an expression index on extracted values…
- … but that requires knowing exactly which fields / elements you are going to query on.
- If you know that, make that data relational.

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jsonb indexing.

- jsonb has GIN indexing.
- Default type supports queries with the @>, ?, ?& and ?| operators.
- The query must be against the top-level object for the index to be useful.
- Can query nested objects, but only in paths rooted at the top level.

jsonb_path_ops

- Optional GIN index type for jsonb.
- Only supports @>.
- Hashes paths for each item, rather than just storing the key itself.
- Faster for @> operations with nesting.

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jdoc @> '{"tags": ["qui"]}'

- Both index types support this.
- jsonb_ops (the default) will seach for everything that has "tags", has "qui", AND them, and then do a recheck for the path structure.
- jsonb_path_ops will go directly to entries for that path.

Which to use?

- If you just need @>, jsonb_path_ops will probably be faster.
- If you need the other supported operators, you need jsonb_ops.
- But let's find out!


ADAC
ÖAMTC
FO4304OZ01
0.15

Test results.

The Usual Caveats

- The universe of possible workloads and schemas is infinite.
- Always build and test using data that simulates your real application.
- Don’t take these results as being applicable to every situation.
- Relative, not absolute results.

That said…

- Four column schema:
  - id — Primary key, bigint.
  - first_name, last_name — Text.
  - tags — Array of short text tags. Two extremely common ones (one per record), a diminishing number of rare ones.

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The test setup.

- Amazon i2.2xlarge instance.
- Ubuntu.
- PostgreSQL 9.4.0.
- Basic tuning for instance size.

Test data.

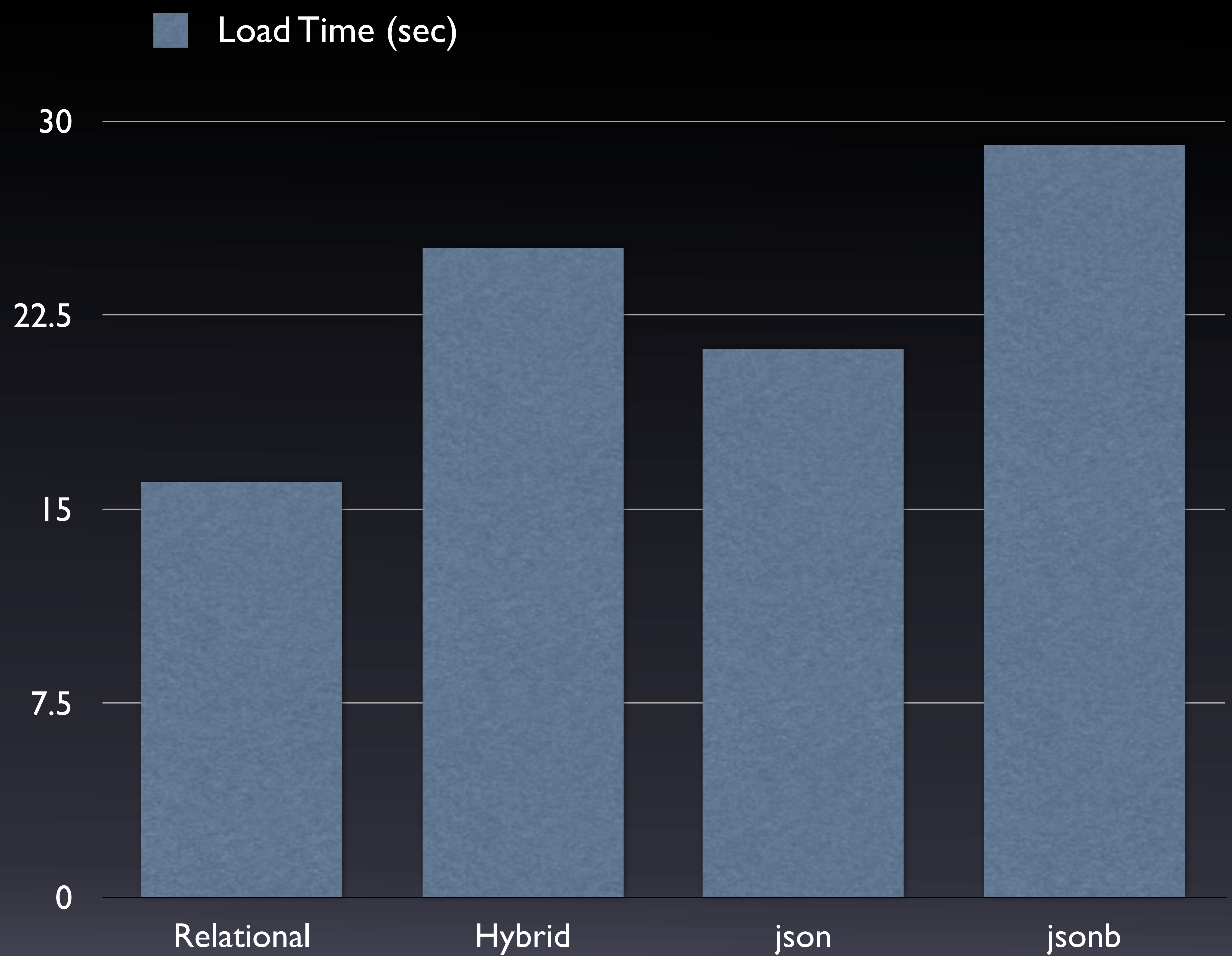
- 10,000,000 records generated at random.
- Schemas:
  - Pure relational data.
  - hybrid (names in relational, tags jsonb).
  - json and jsonb for non-ID.

Methodology

- 100 iterations per test, top and bottom 10 rejected.
- Query execution time only; does not include time to return results.
  - Python test harness can distort considerably if objects need to be created.

Test #1: Load

- Load 10,000,000 records using COPY.
- No index rebuilds.
- Relational, "hybrid," all json, all jsonb.



Load Time (sec)
30
22.5
15
7.5
0
Relational
Hybrid
json
jsonb

Test #1: Results

- Relational beats everything (no surprise).
- jsonb is slower to load than json.
  - Parsing and conversion time.
- The same order of magnitude.

Test #2: Sequential scan for a single last name.

- Scan table sequentially (no index) for a single last name.
- Uses a relational field for relational and hybrid.
- Uses ->> operator for json and jsonb.
- Also tried with @> operator for jsonb.

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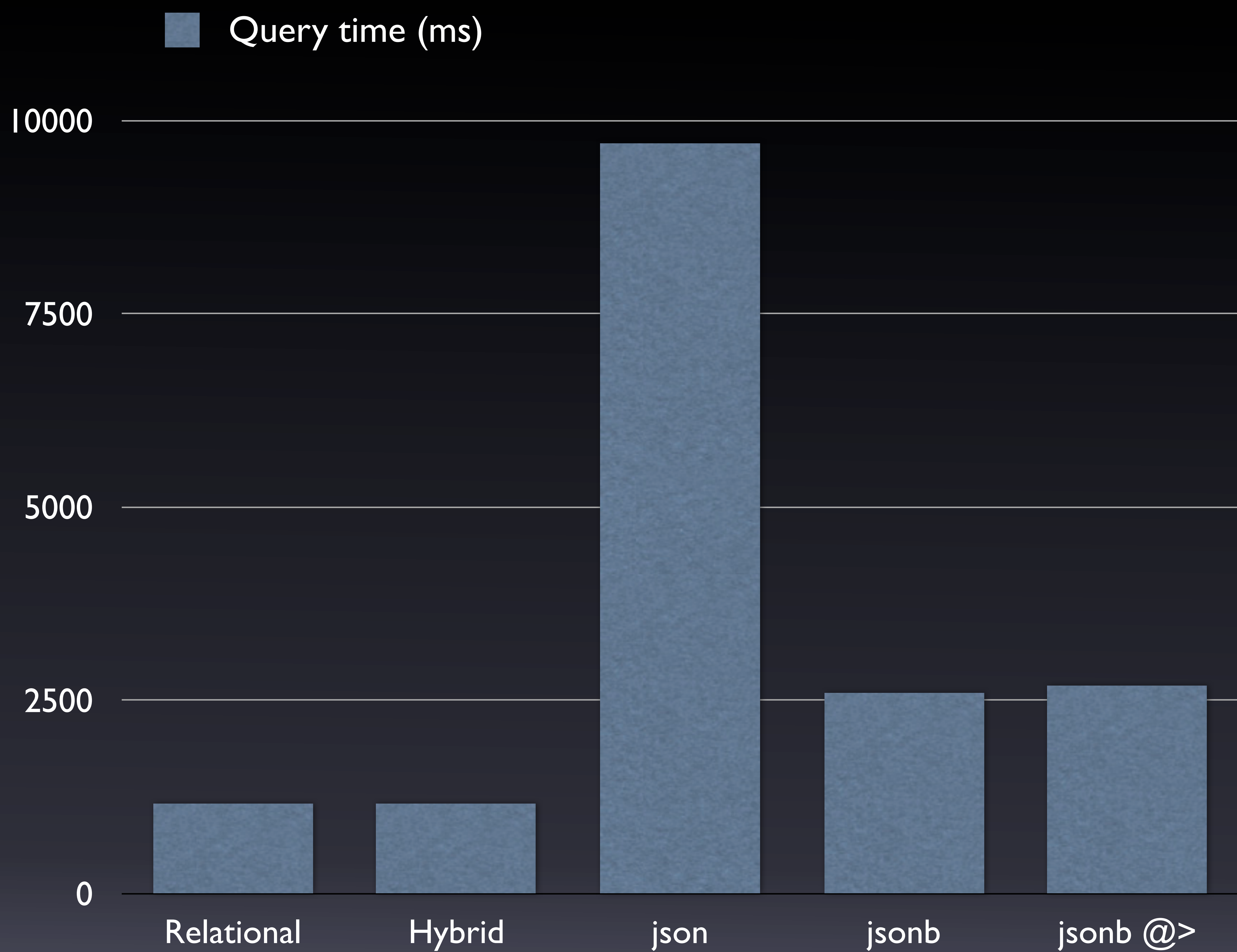
Query time (ms)
10000
7500
5000
2500
0
Relational
Hybrid
json
jsonb
jsonb @>

Test #2: Results.

- json dramatically slower than jsonb.
- Relational faster than jsonb by about 2x.
- ->> and @> operators roughly same speed in this application.

Test #3: b-tree index lookup by name.

- Create a traditional b-tree index.
- Directly on last_name for relational and hybrid.
- Expression index on (jdoc->>'last_name') for json and jsonb.
- Also tried GIN index on jsonb field, using @>.

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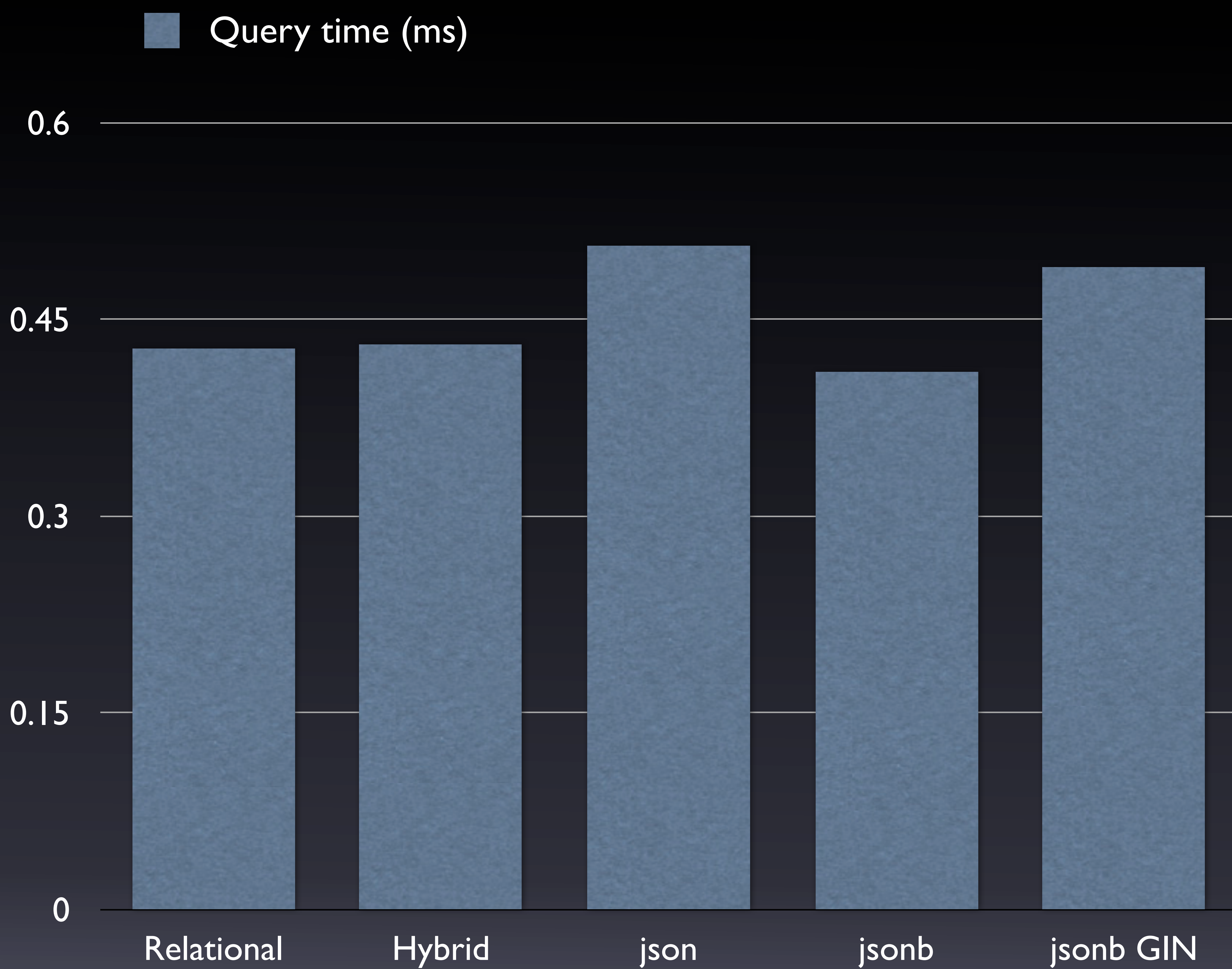

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Test #3: Results.

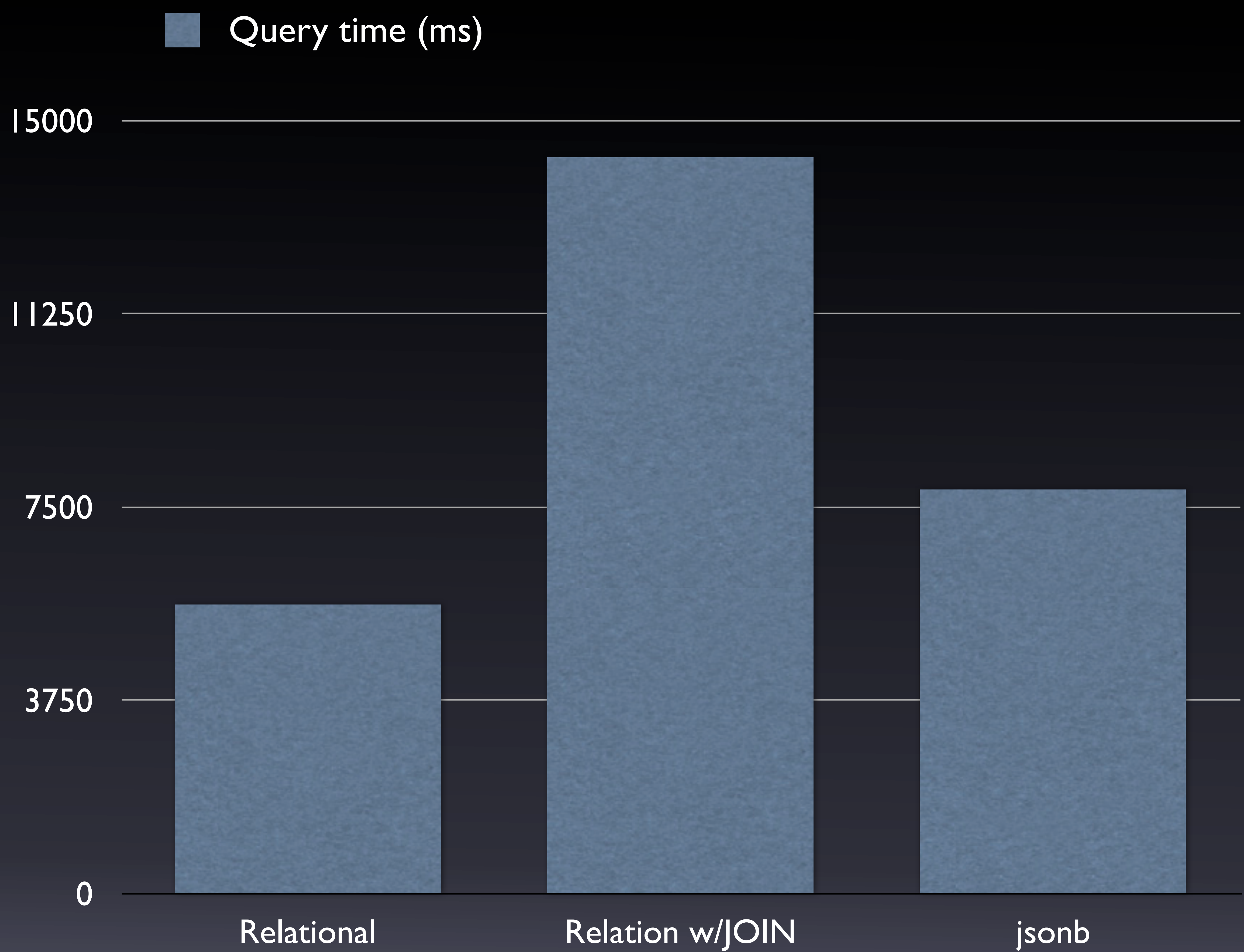
- All of comparable speed.
- jsonb actually faster than anything else!
- json somewhat slower due to extraction overhead.
- Always the fastest way to look up a highly selective field.

Test #3: Results, 2

- jsonb w/GIN very comparable to b-tree index.
- Didn’t have to specify a particular field in advance.
- Huge improvement over 9.3 days.

Test #4: Common tag lookup by seq scan.

- Every record has a ‘male’ or ‘female’ tag, 50%/50%.
- Scan looking for all of one.
- Uses @> operator for tag array.
- Uses @> operator for jsonb.
- Also tried with a secondary table of tags to which we join.



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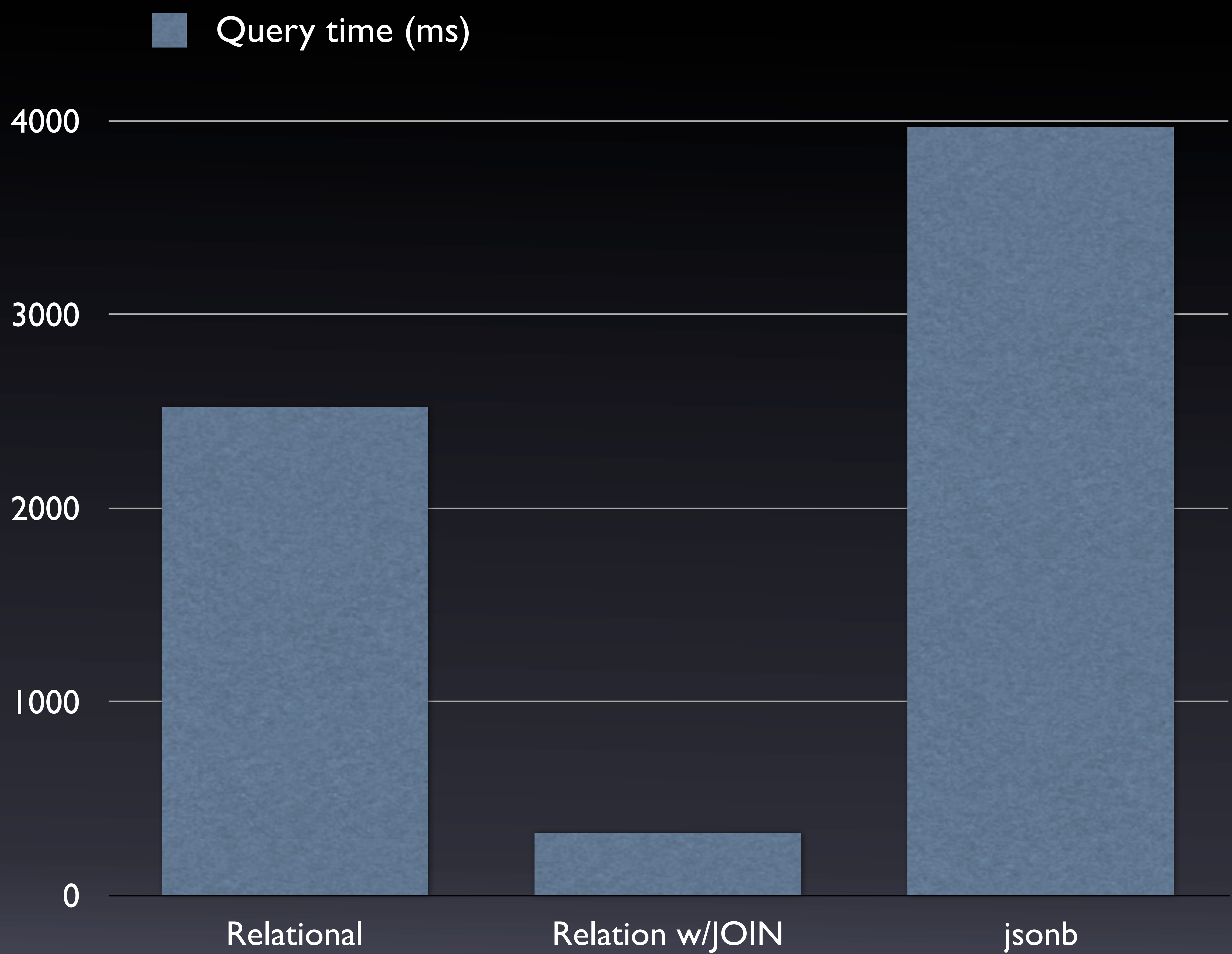
Test #4: Results.

- Secondary join table a huge loss in this scenario.
- jsonb slower than relational, but within the same general range.

Test #5: Rare tag lookup by seq scan.

- Scan for a rare tag (0.075% of records).
- Uses @> operator for relational.
- Uses @> operator for jsonb.
- Also tried with JOIN table.
  - In both cases, JOIN table indexed on tag, but didn't use in seq scan case.



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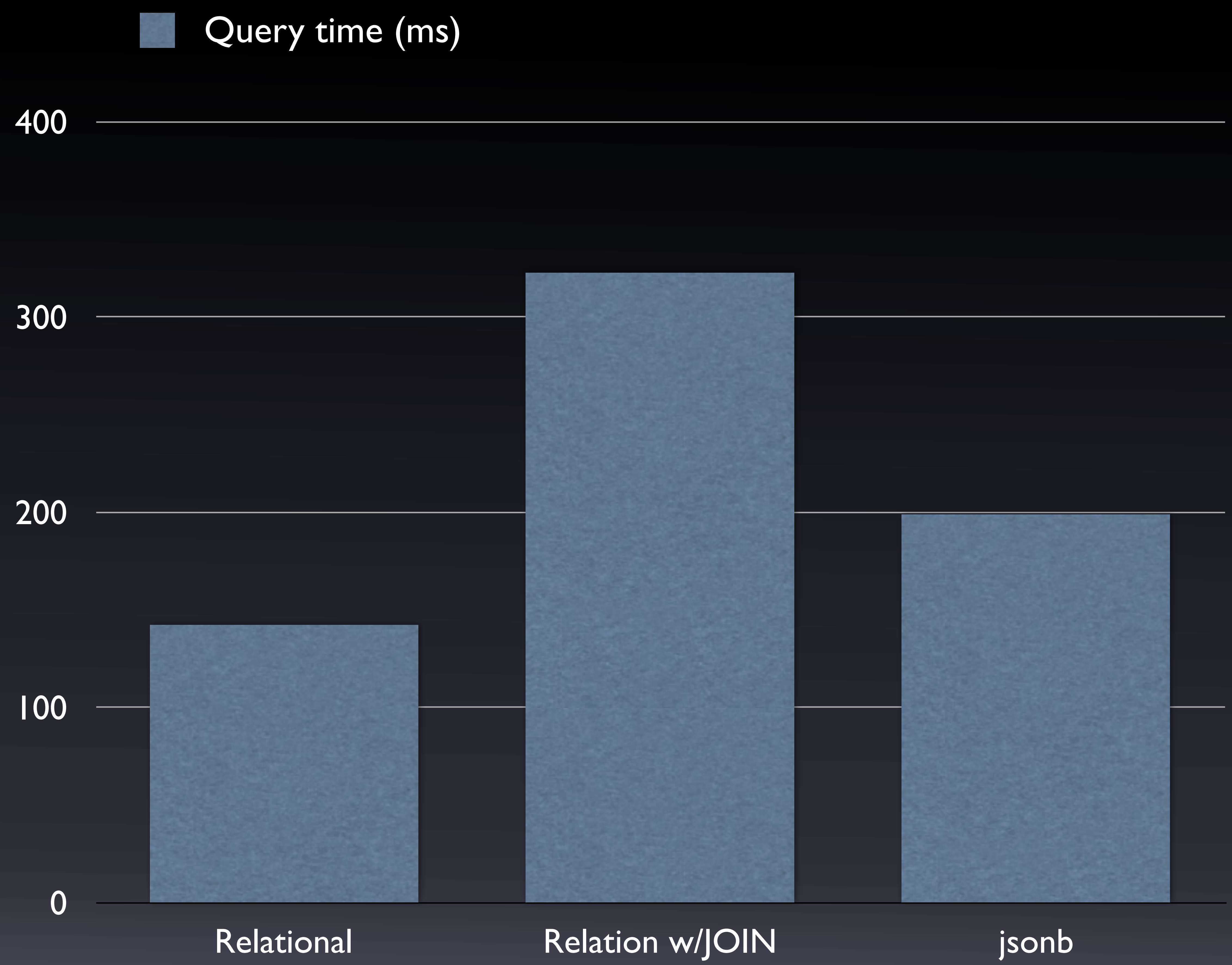
Test #5: Results.

- Secondary join table a huge win in this scenario.
  - Unsurprising, since it can isolate the rare tag faster.
- jsonb remains slower but comparable.

Test #6: Rare tag lookup by index.

- Create a GIN index on relational array field and jsonb document
- Use @> operator for tag array.
- Use @> operator for jsonb.
- Also tried with JOIN table.



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Test #6: Results.

- Relational fastest in this situation…
- … but jsonb performs comparably.
- If you are storing rare tags and don't need full JSON, consider an array field.

Note: GIN indexes and selectivity.

- GIN indexes on jsonb fields have hard-wired selectivity calculations (as of 9.4).
- Will almost always use the index even if selectivity is very low.
- This can result in bad performance in cases of low selectivity.
- An area that definitely needs attention.

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Test #7: Index Creation.

- Timed index creation for the various index types.
- last_name b-tree on relational.
- GIN on relational array.
- GIN json_ops and json_path_ops on jsonb.

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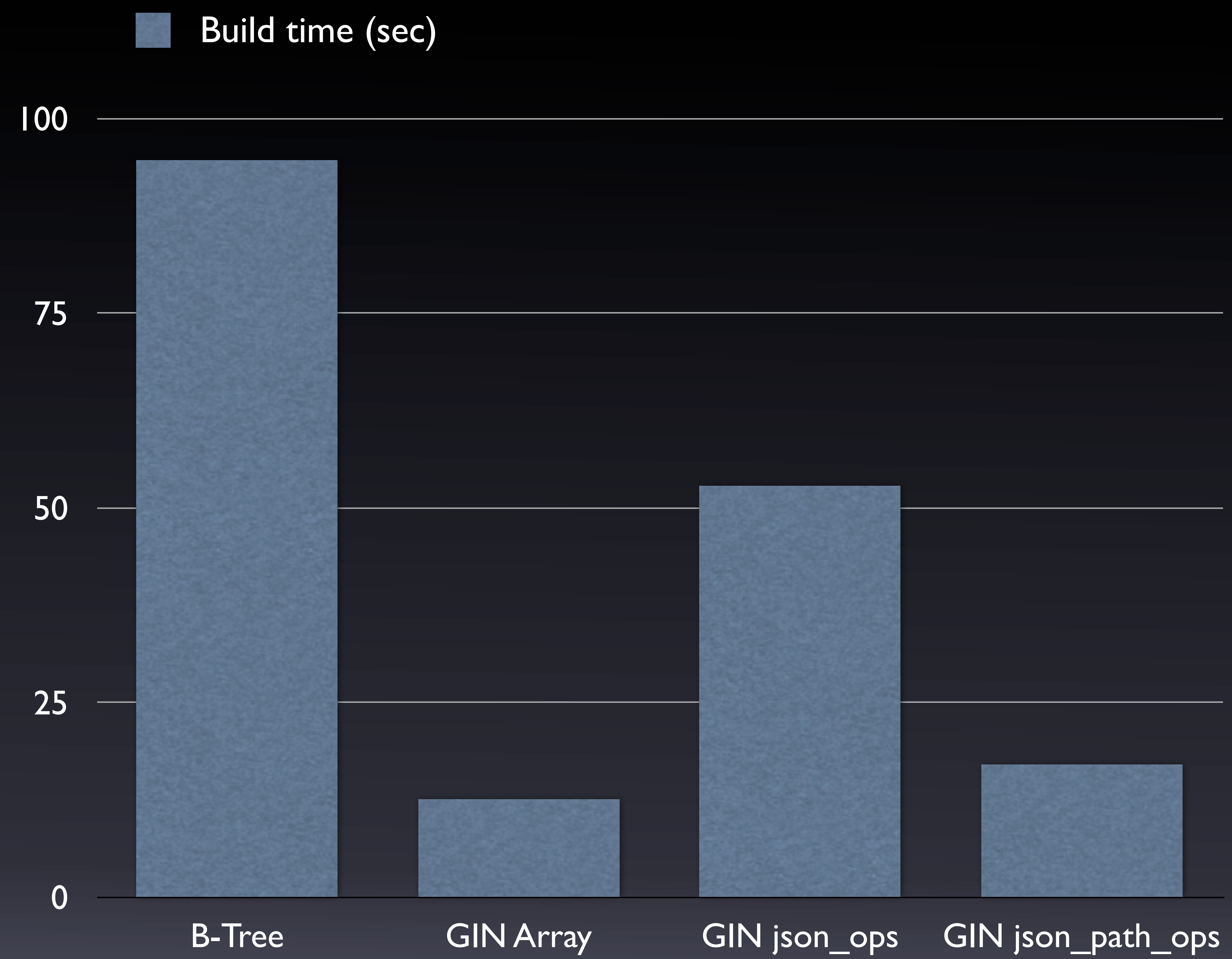

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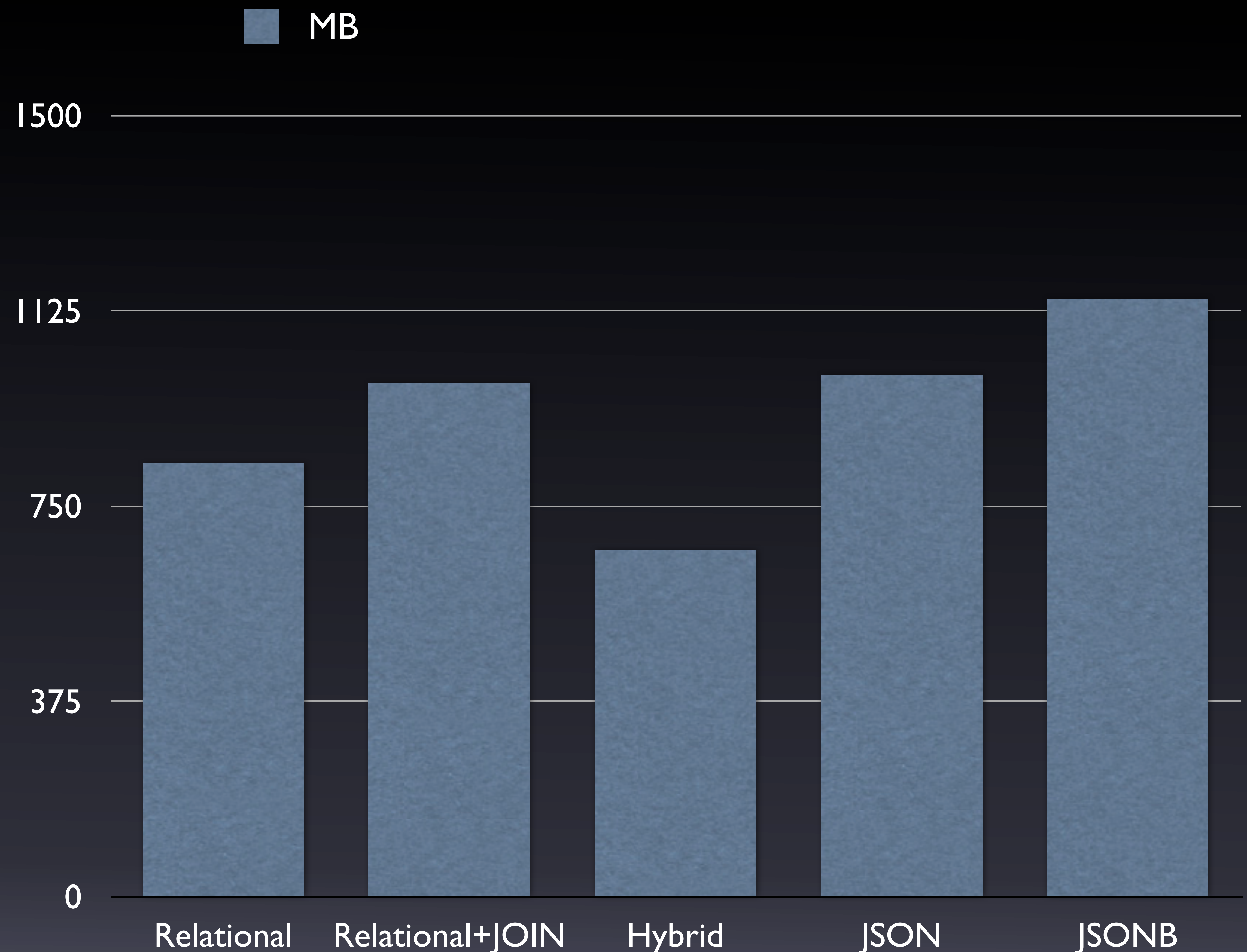
Test #7: Results.

- GIN build time is very fast.
- json_path_ops build time is very fast.
- GIN indexing on arrays, too.

Test #8: Relation size.

- Total size, excluding indexes.
- For relation + JOIN table, includes JOIN table as well.



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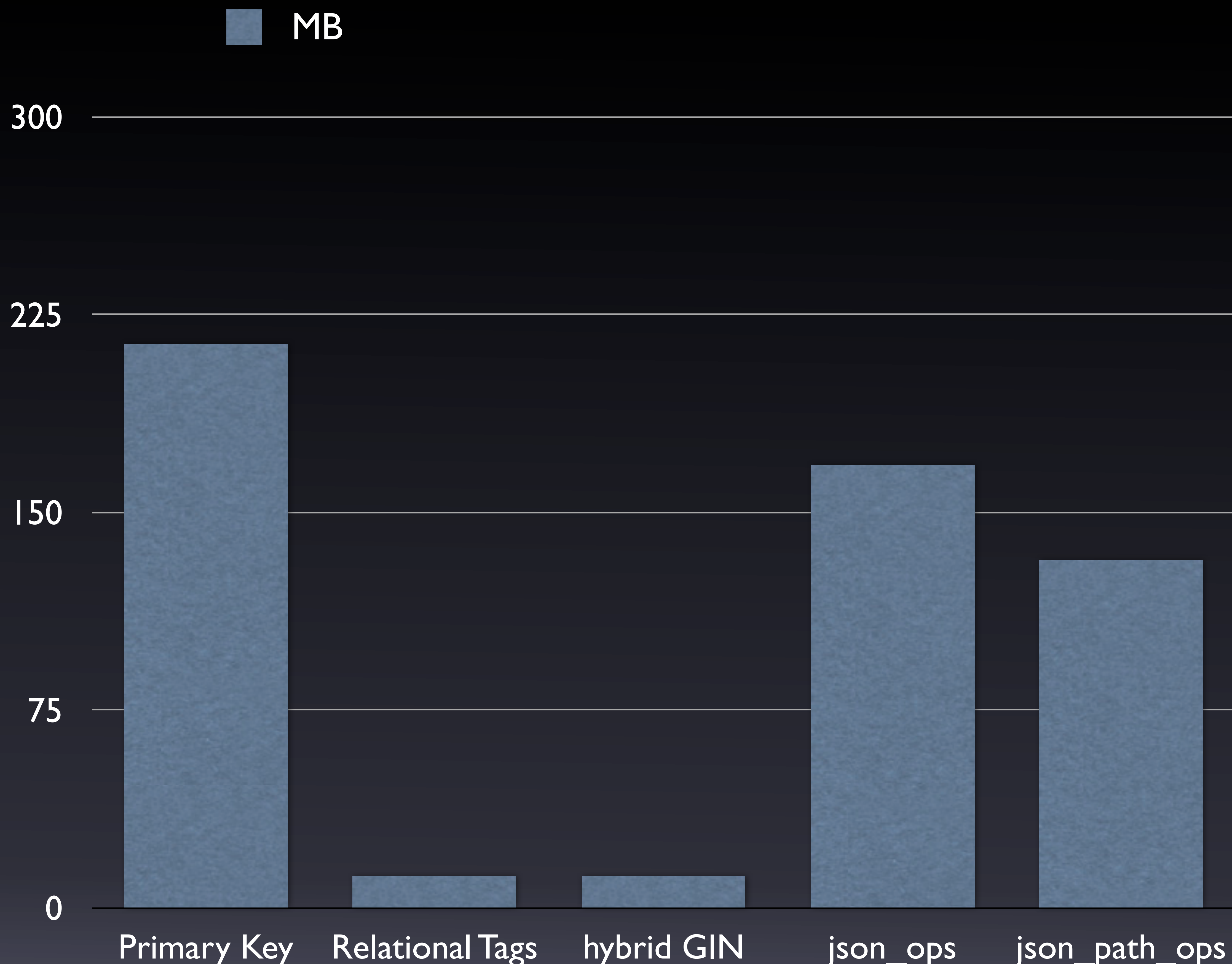
Test #8: Results.

- Generally comparable size.
- hybrid is the most compact by a significant margin.
- jsonb slightly larger than json due to internal structure overhead.

Test #9: Index size.

- Size of various indexes.
- Primary key index (same for all tables).
- GIN index on relational tags.
- json_ops
- json_path_ops


MB
300
225
150
75
0
Primary Key
Relational Tags
hybrid GIN
json_ops
json_path_ops

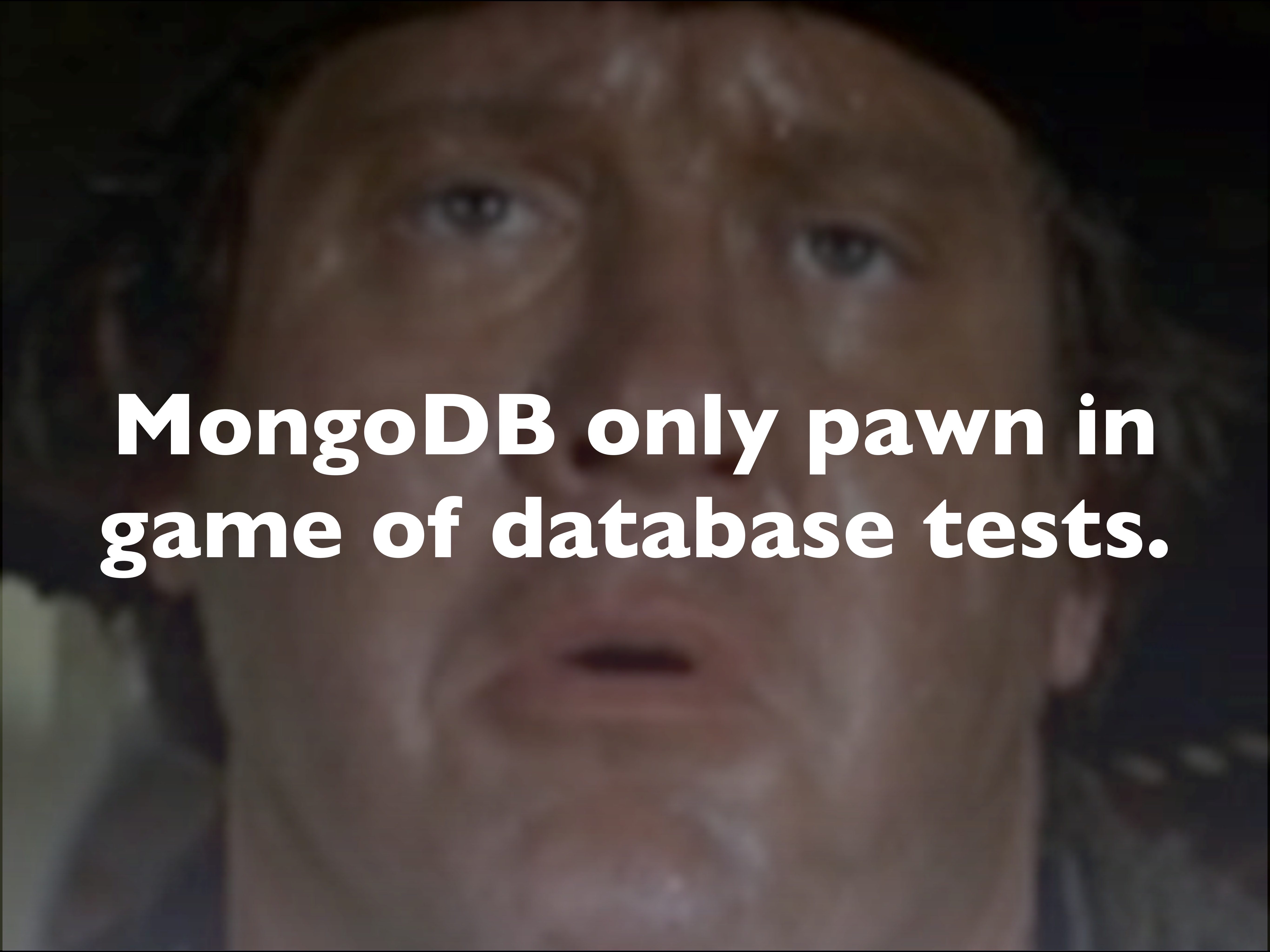
Test #9: Results.

- Indexes on just the tags are very compact.
- json_path_ops indexes are (as expected) somewhat smaller than json_ops indexes.

Now that we know this, what do we know?

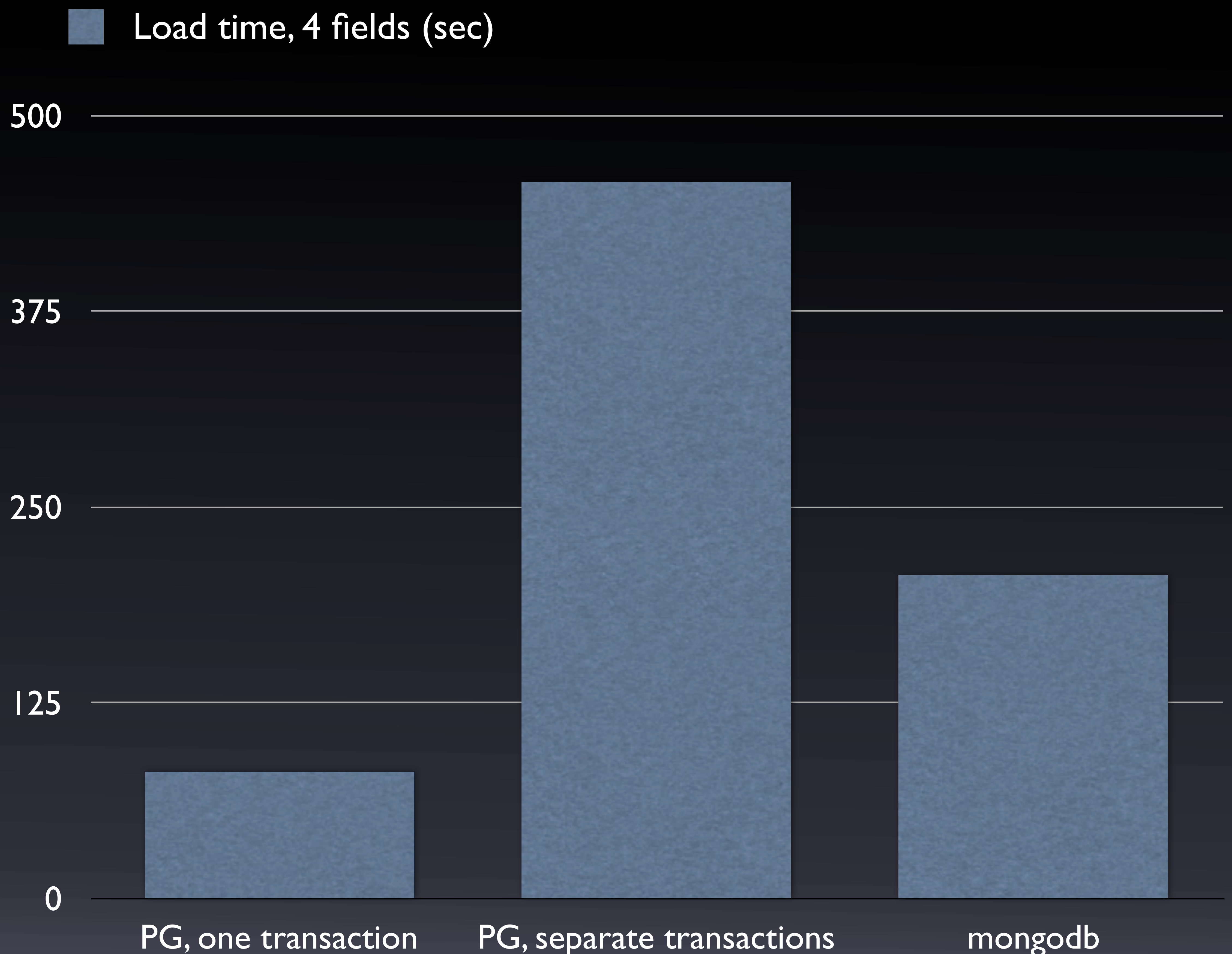
The One-Slide Oversimplification.

- Use relational data for the basic set of attributes.
- Use either array fields or jsonb for extended attributes.
- Use file-system storage for really big stuff.
- Always use jsonb. No reason to use json.


MongoDB only pawn in
game of database tests.

How do we compare to mongodb?

- mongodb 3.0.1
  - New, faster storage engine.
- Two data sets:
  - Each with 1 million records.
  - One with 4, one with 200, json fields.



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Load time, 200 fields (sec)
800
600
400
200
0
PG, one transaction
PG, separate transactions
mongodb

Query for a single field, single value

- PostgreSQL:
  - No index, functional index, GIN index, GIN index, with jsonb_path_ops,
- Mongo
  - No index, field index.

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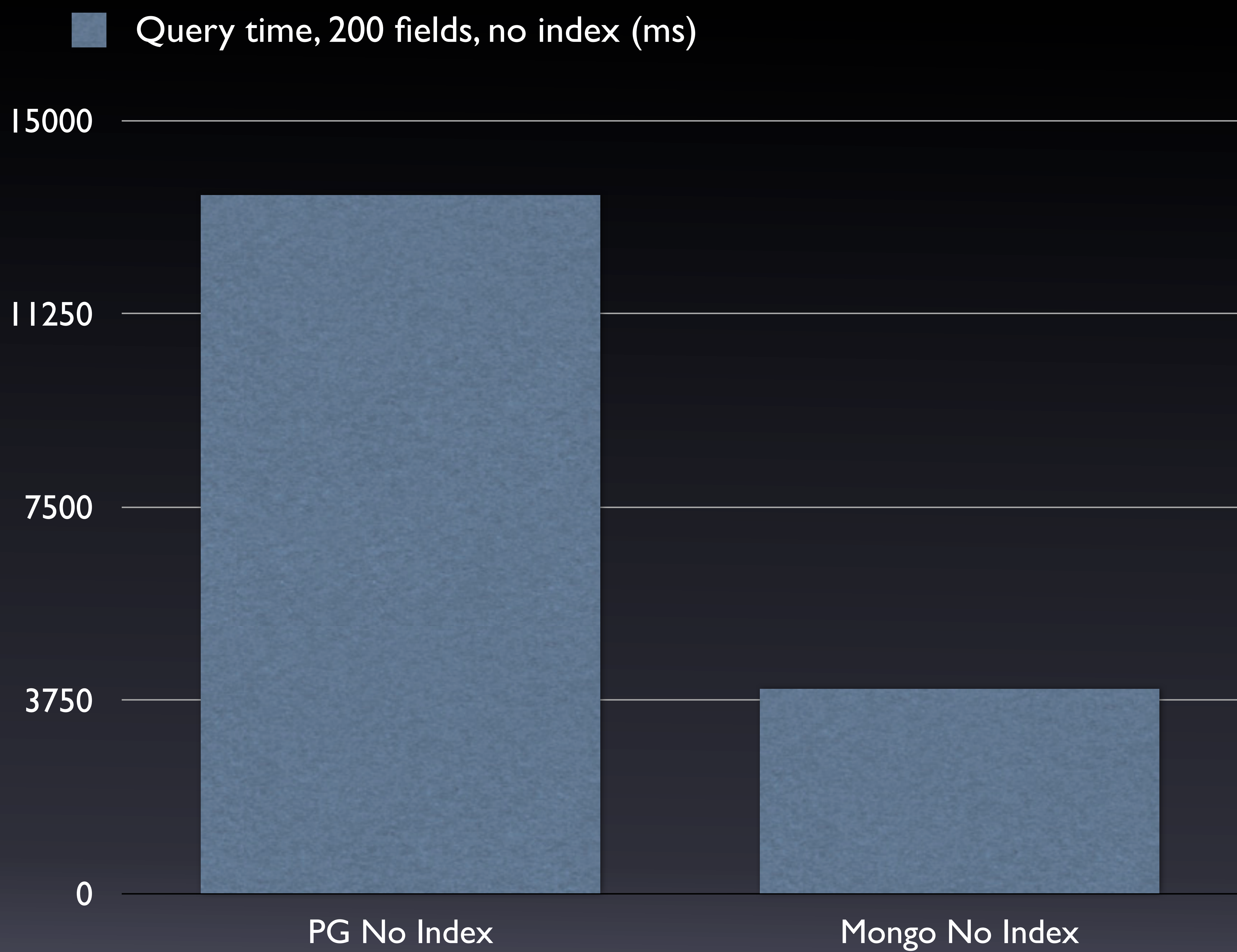

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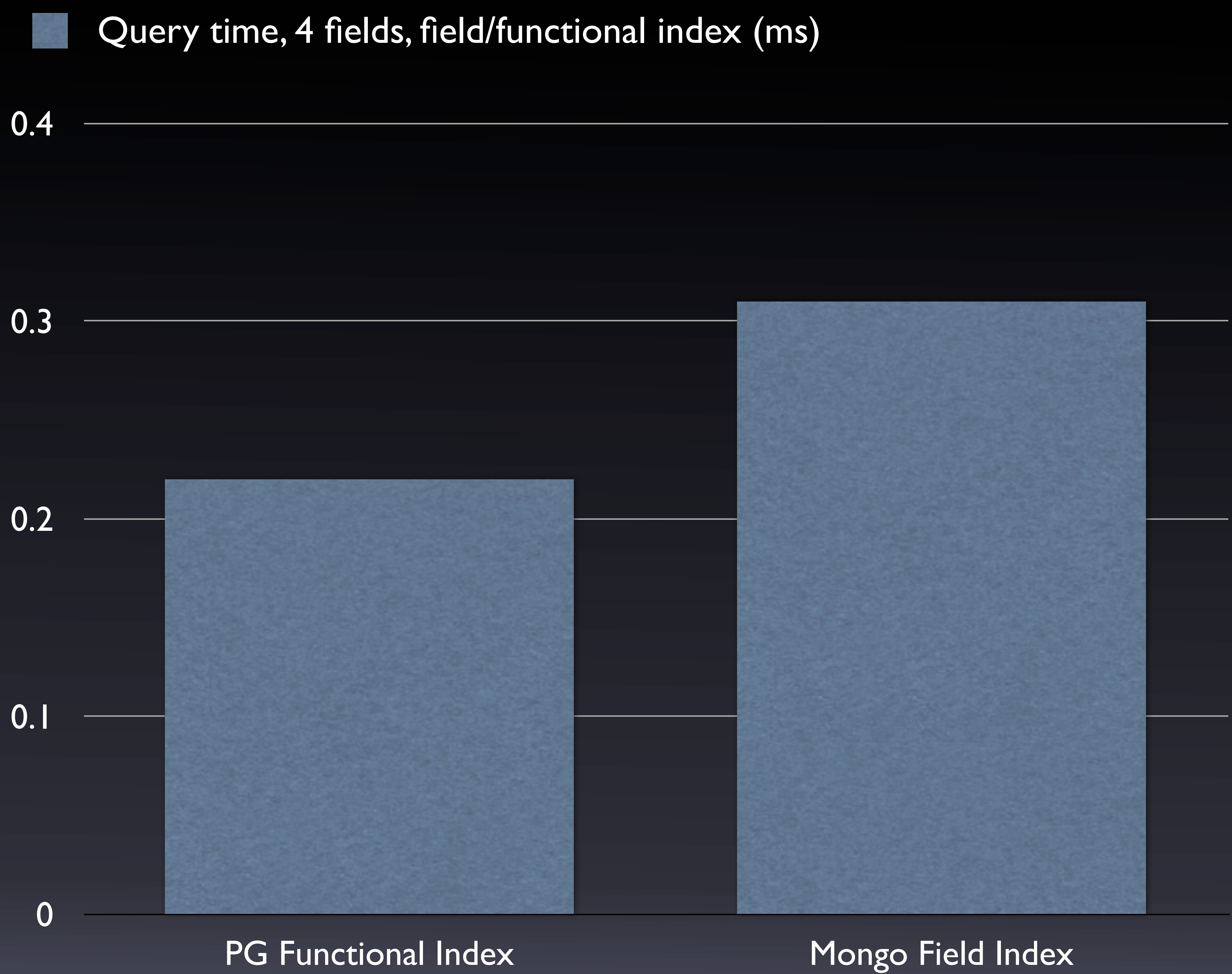

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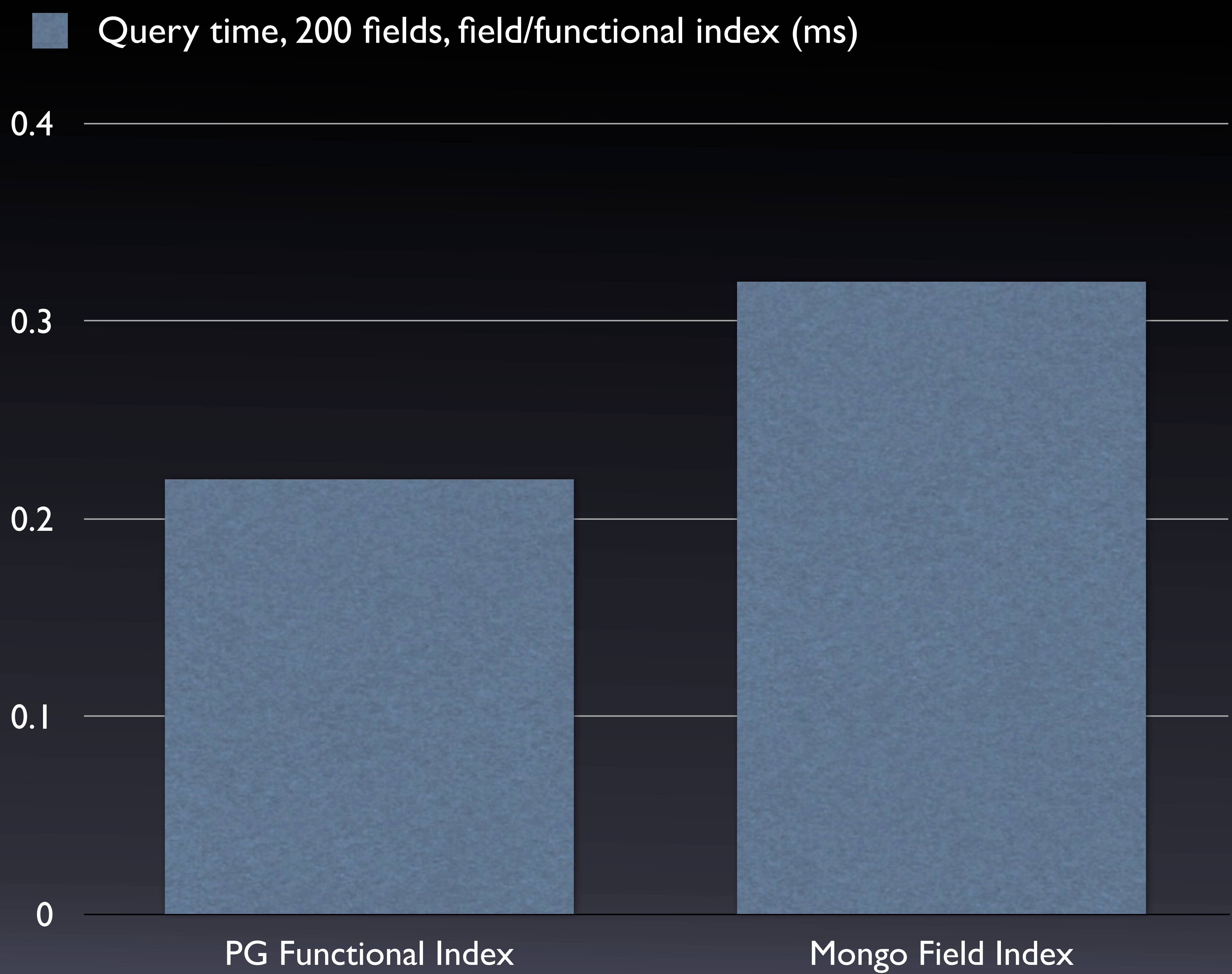

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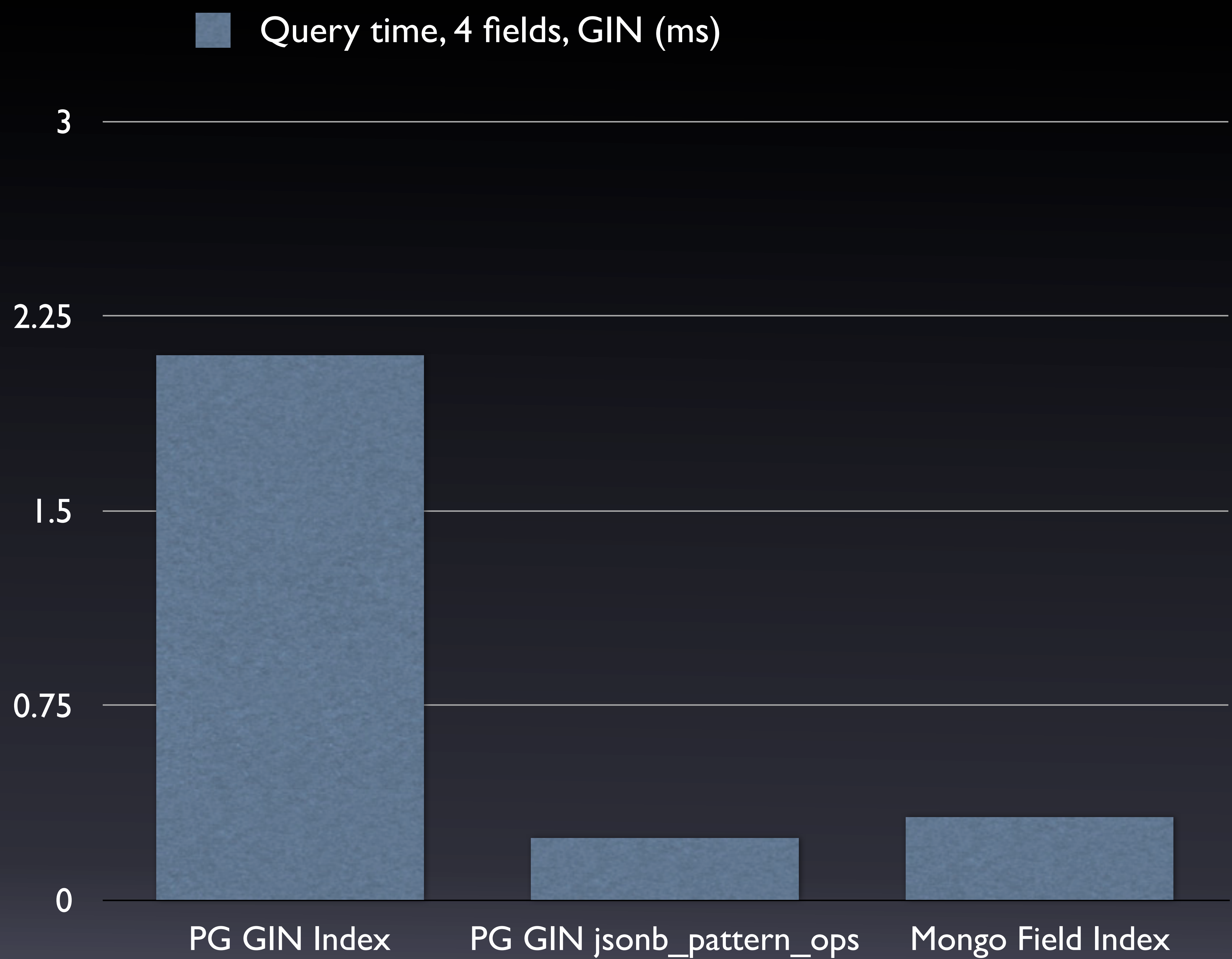

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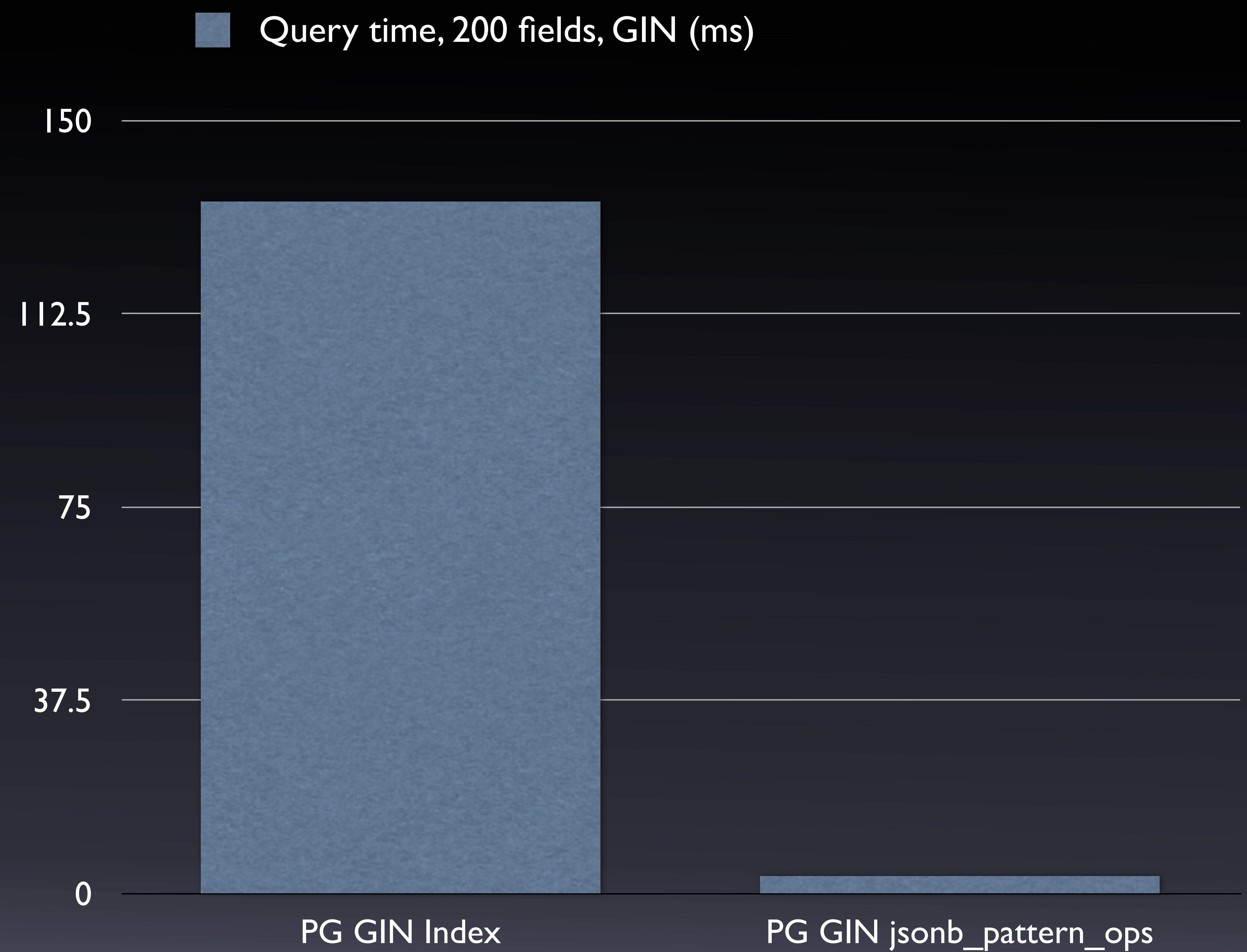

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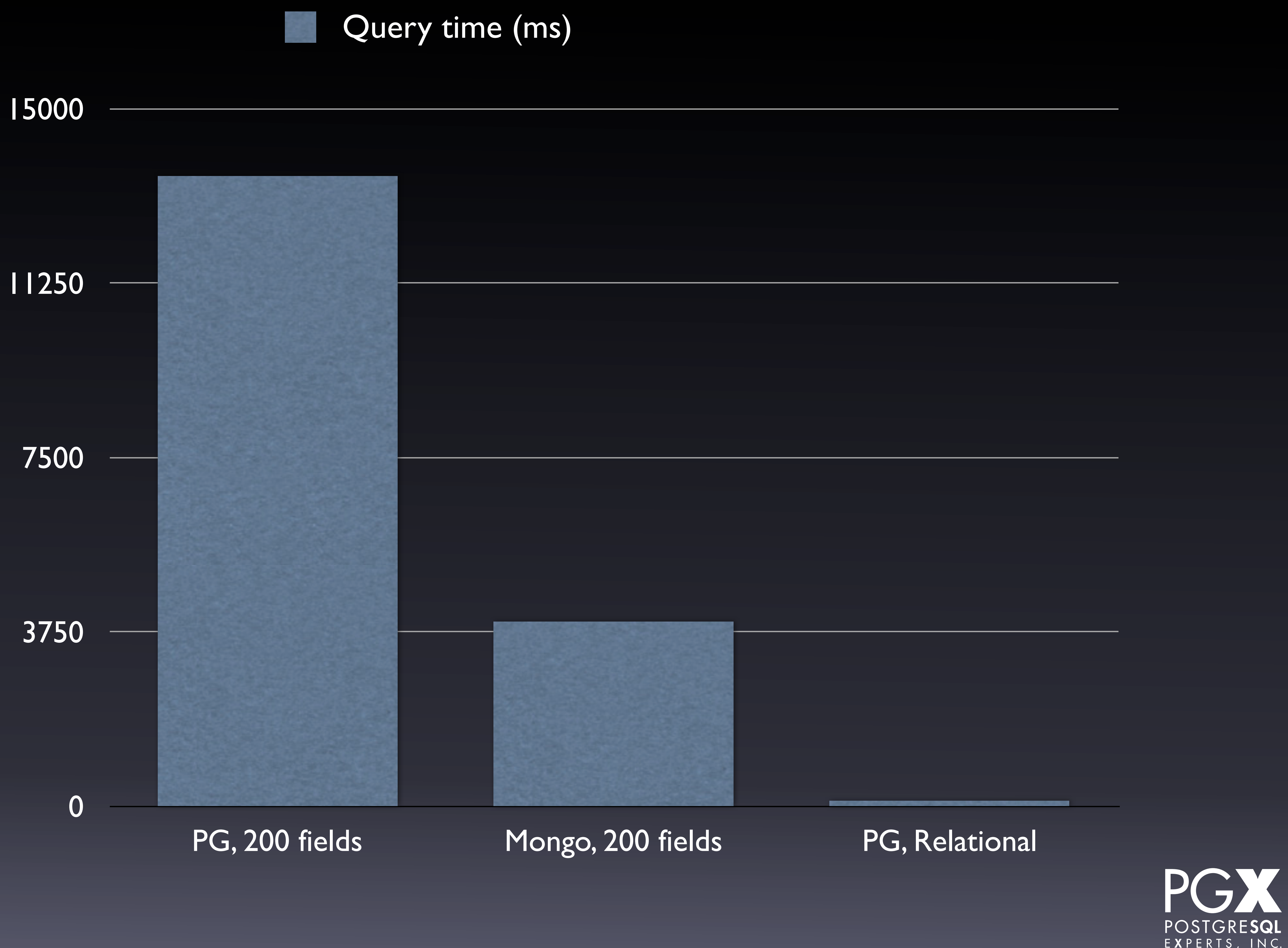
Query time (ms)
15000
11250
7500
3750
0
PG, 200 fields
Mongo, 200 fields
PG, Relational
PGX
POSTGRESQL
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Mongo Notes.

- Mongo 3.0 is much improved.
- Performs very well in extracting a single field from a very large JSON body.
- Indexing a single field performs comparably to a PostgreSQL index.
- No real equivalent of PostgreSQL GIN.
- Game on!

Conclusions.

- Mongo does well for documents with a large number of JSON fields, sequentially scanned.
- PostgreSQL `jsonb` performs better in most other cases.
- PostgreSQL relational performance destroys JSON performance, of course.

And here we are!

- PostgreSQL 9.4 has world-class JSON support.
- Mix and match! Use JSON for what is good for, relational data for speed.
    - (Check out ToroDB.)

Thank you!

Questions?

- thebuild.com — personal blog.
- pgexperts.com — company website.
- Twitter @Xof
- christophe.pettus@pgexperts.com

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