LANGUAGE-ORIENTED DATA PROCESSING SYSTEMS

Holger Pirk <hlgr@imperial.ac.uk>

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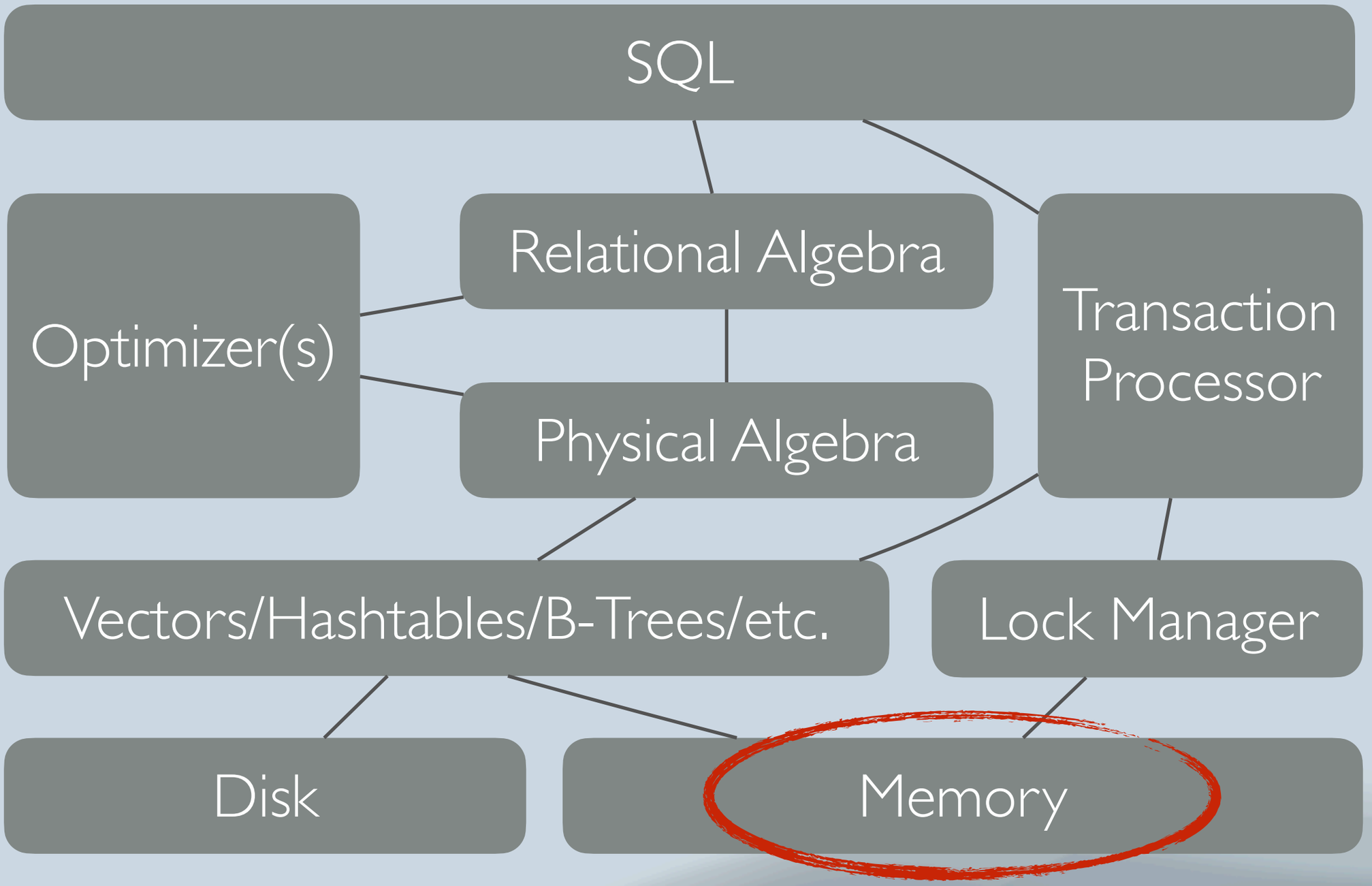
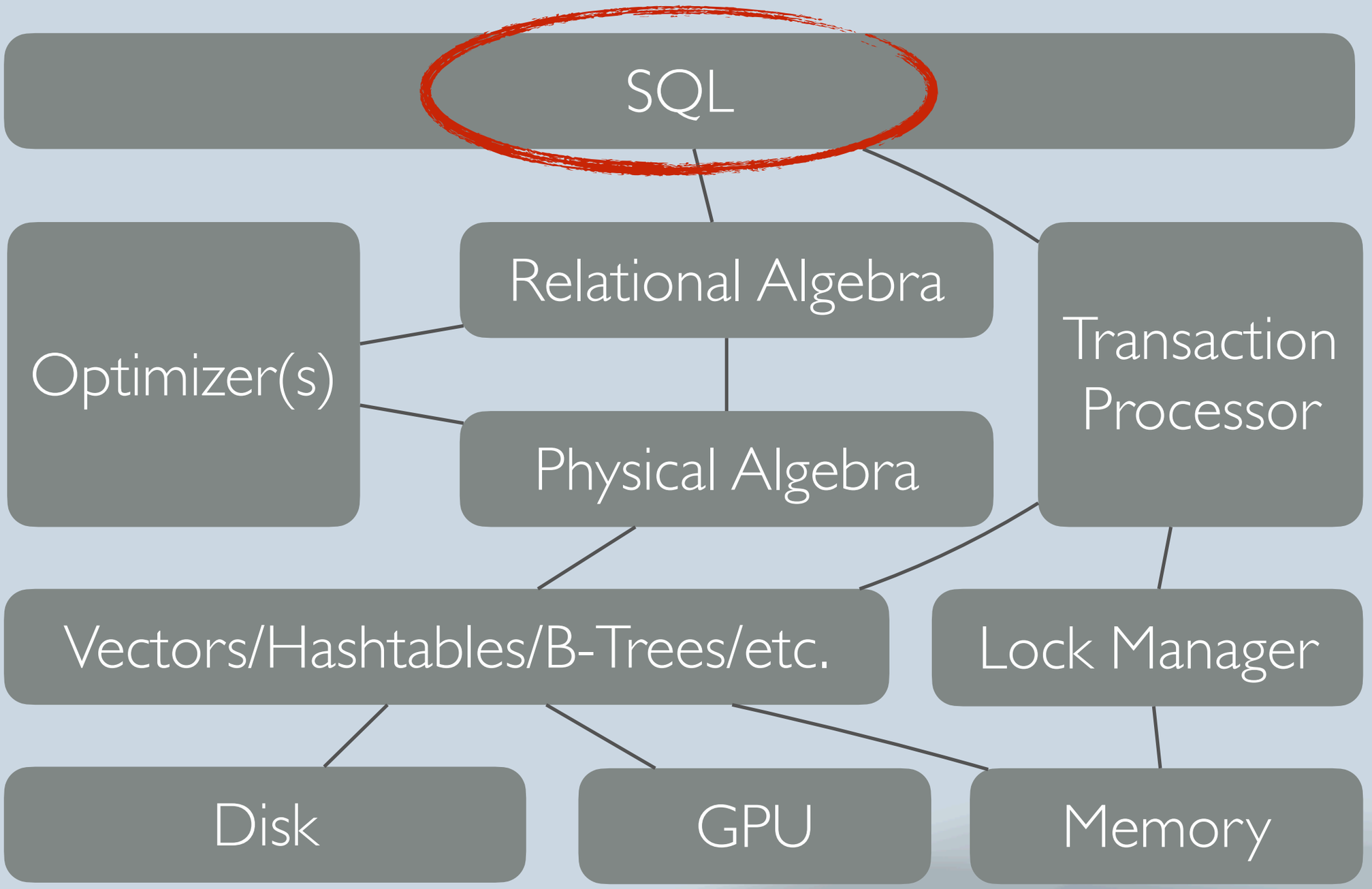
Data Processing Systems



Composable Data Processing Systems



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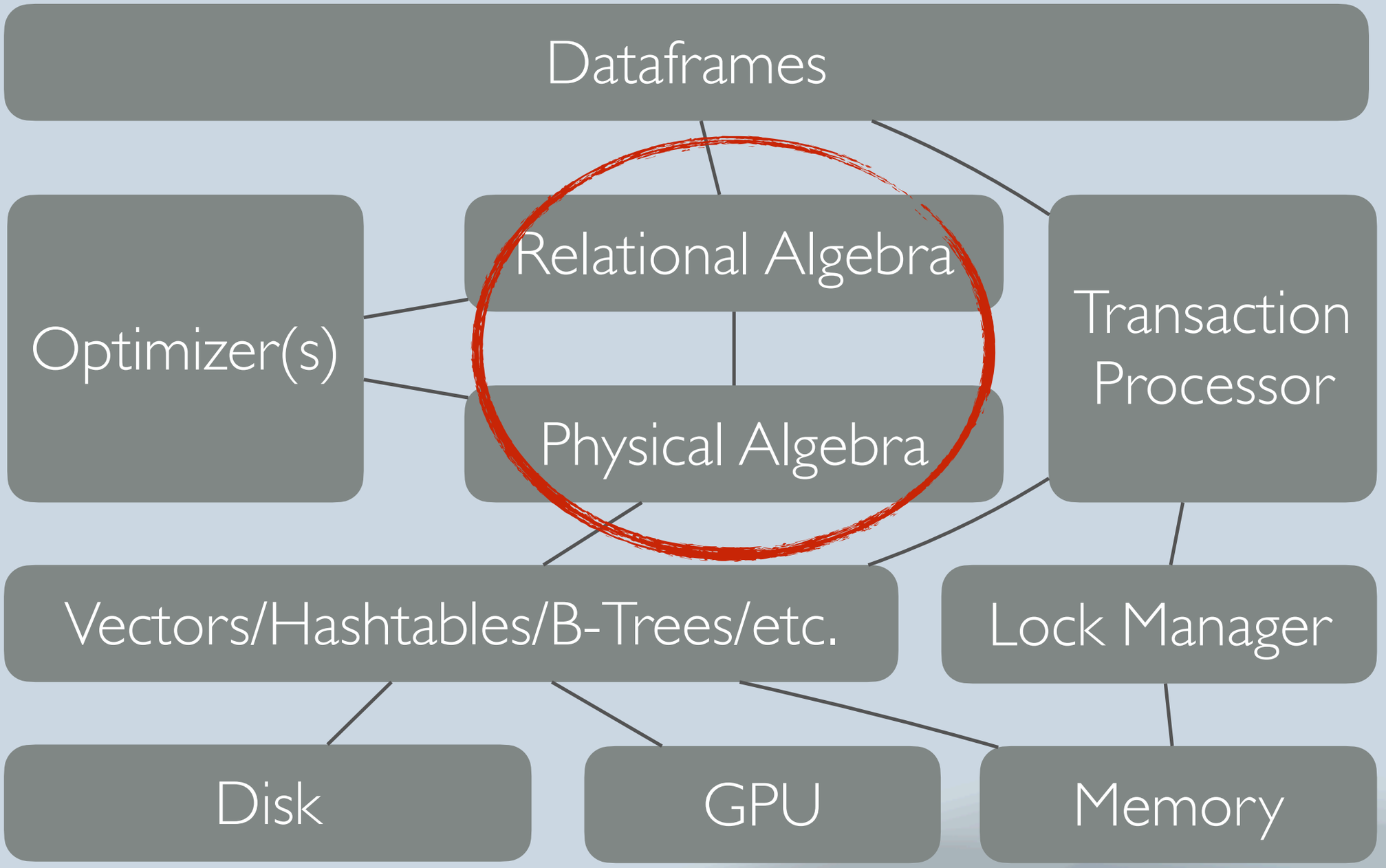

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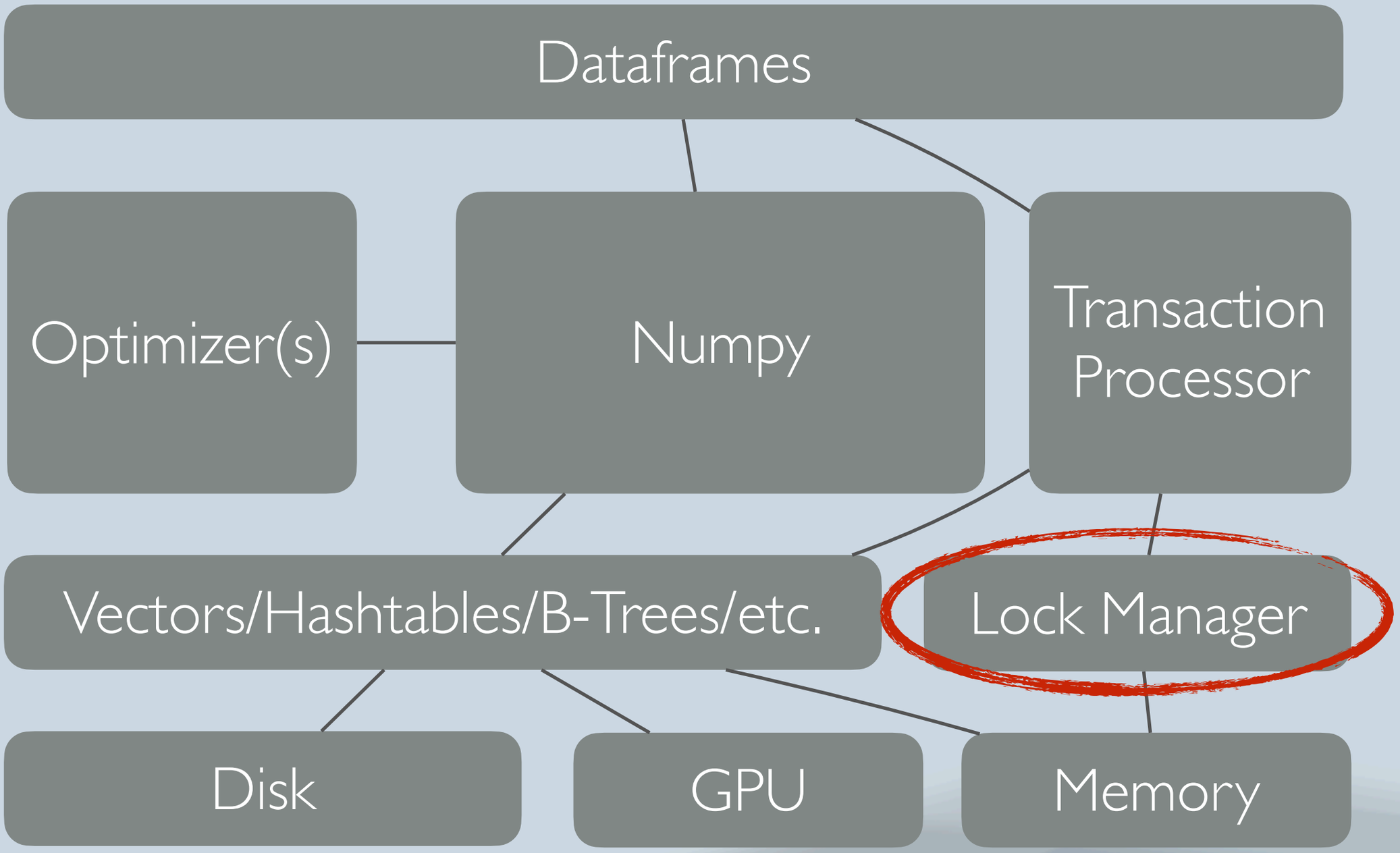

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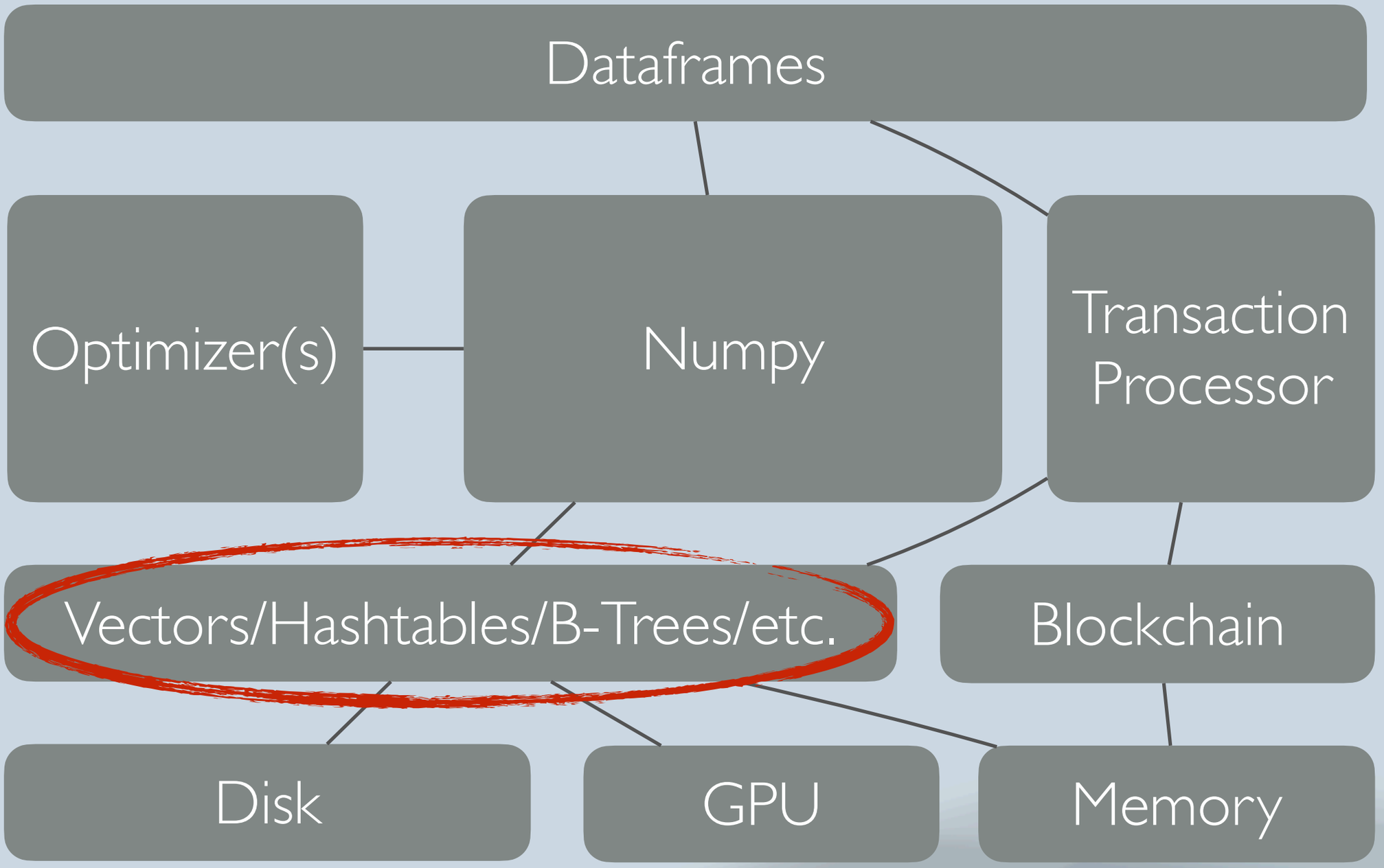

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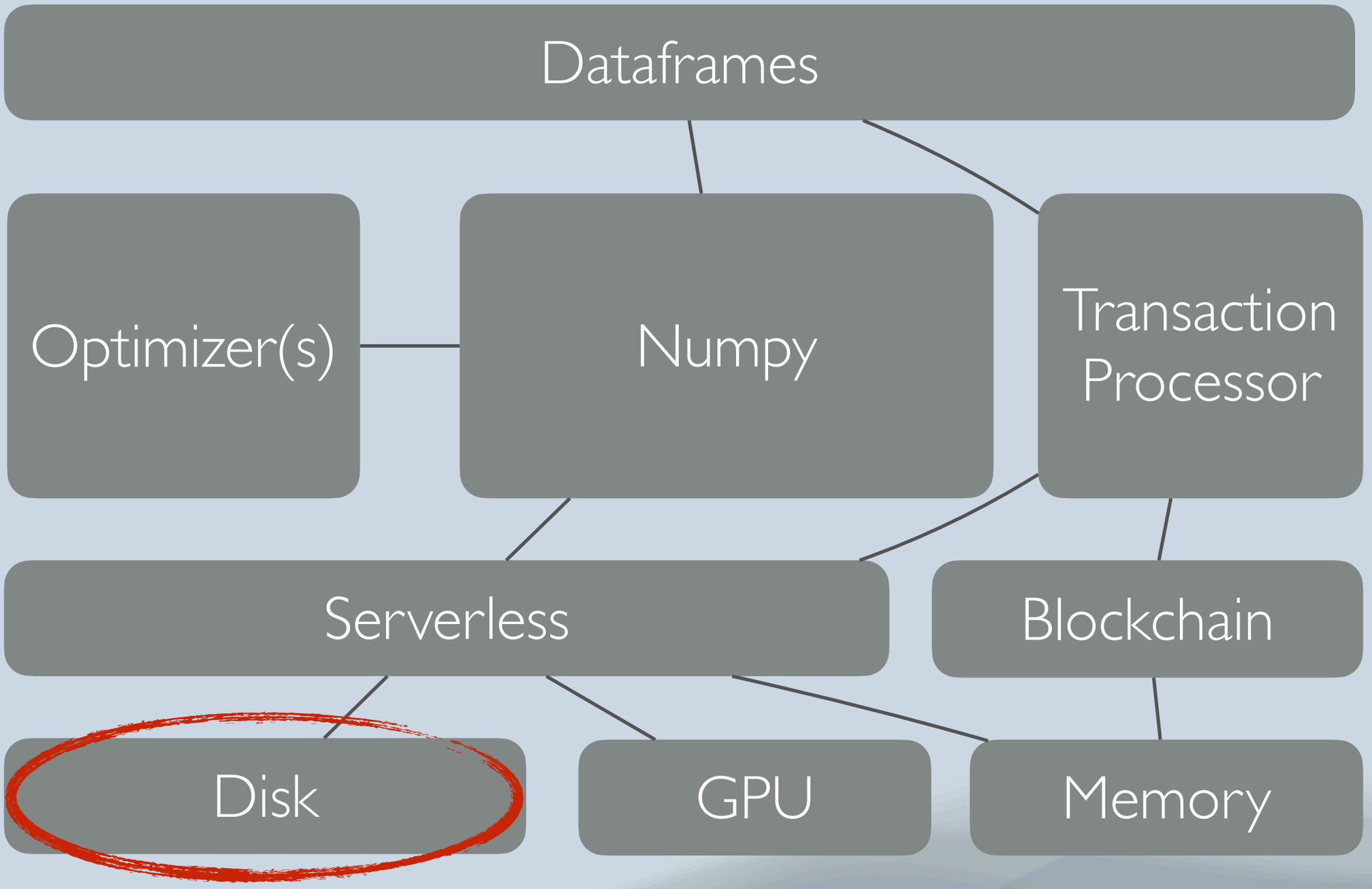

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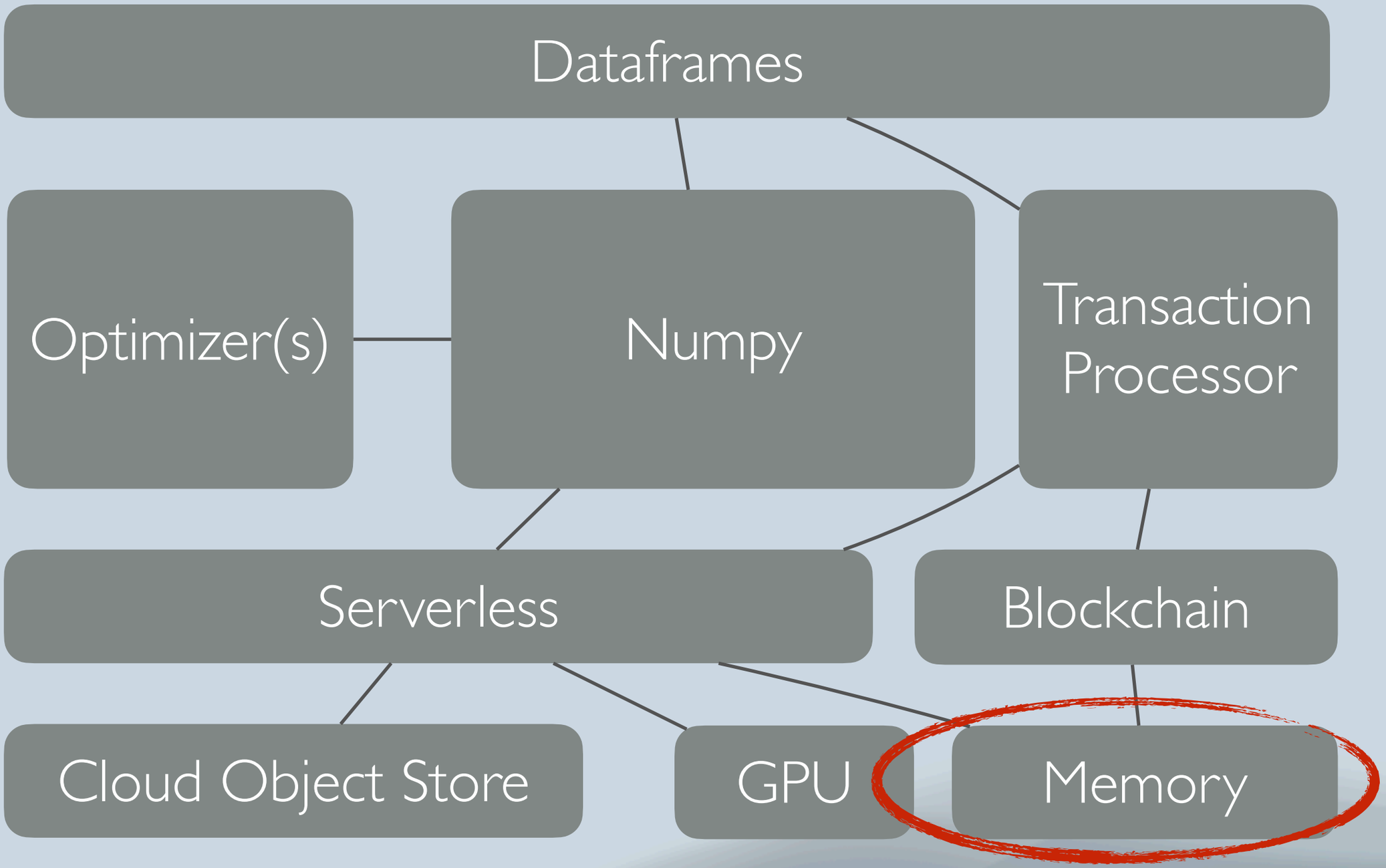
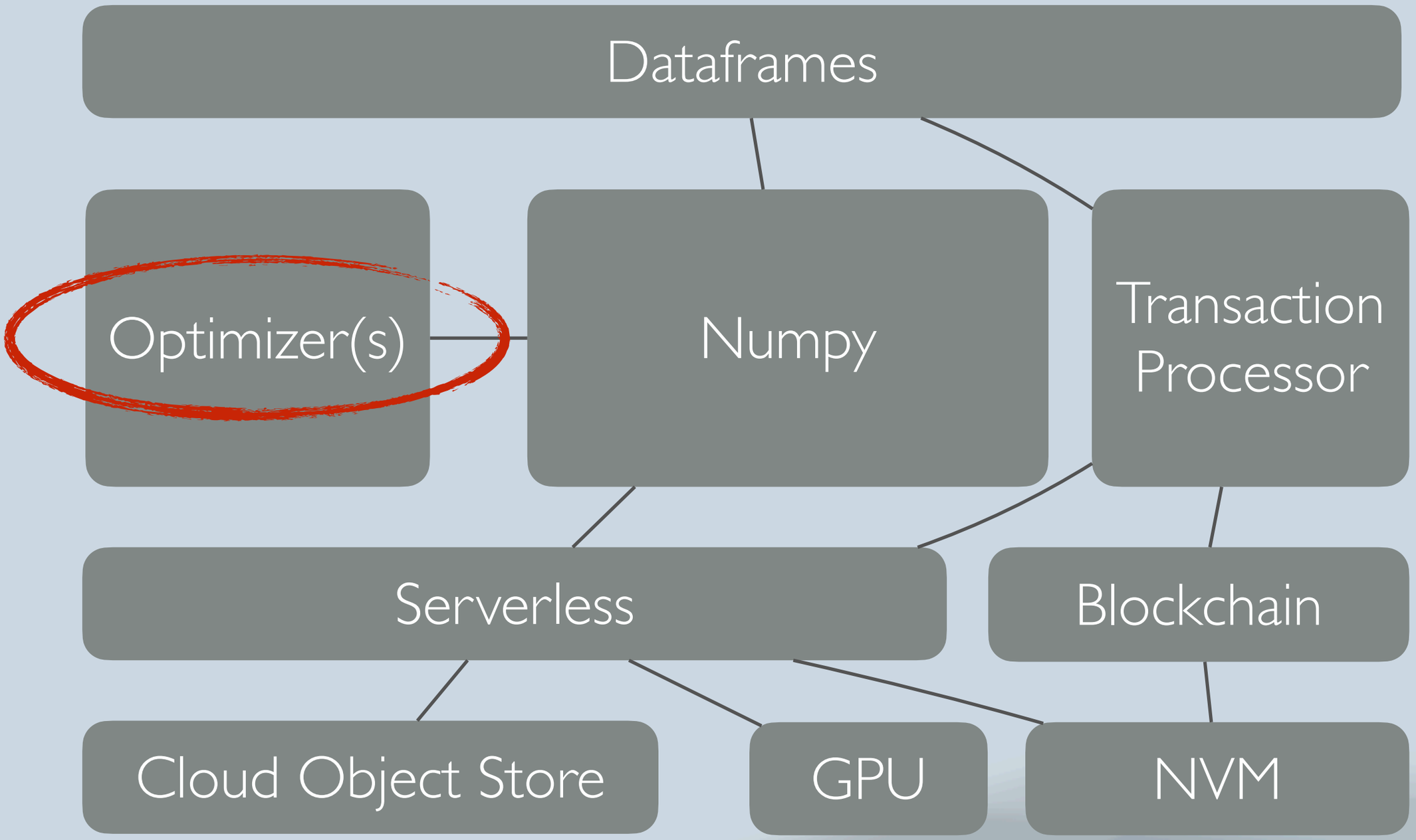


Composable Data Processing Systems



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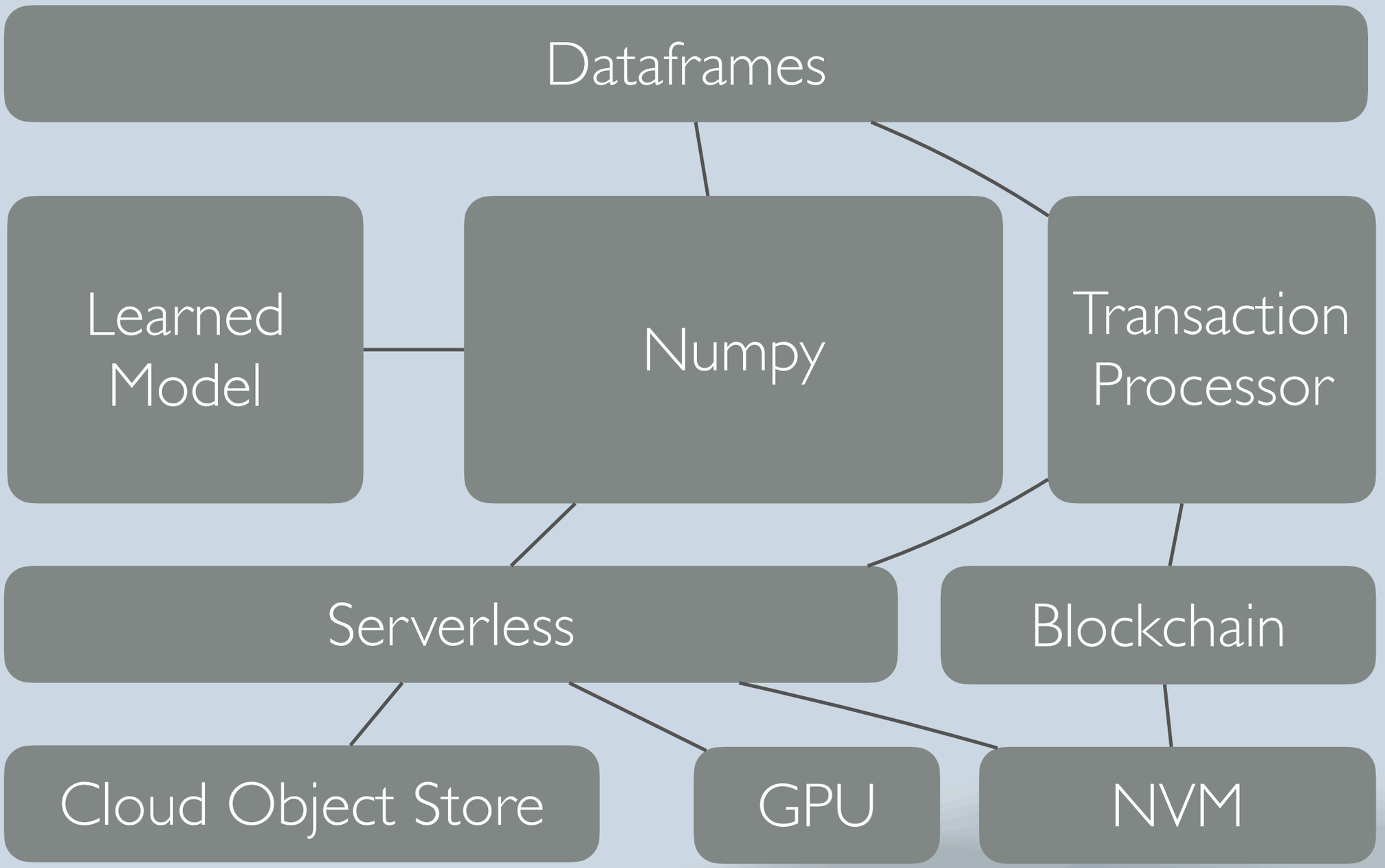

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All Systems Process Two Things

Code/Queries/Plans/UDFs/…

Data

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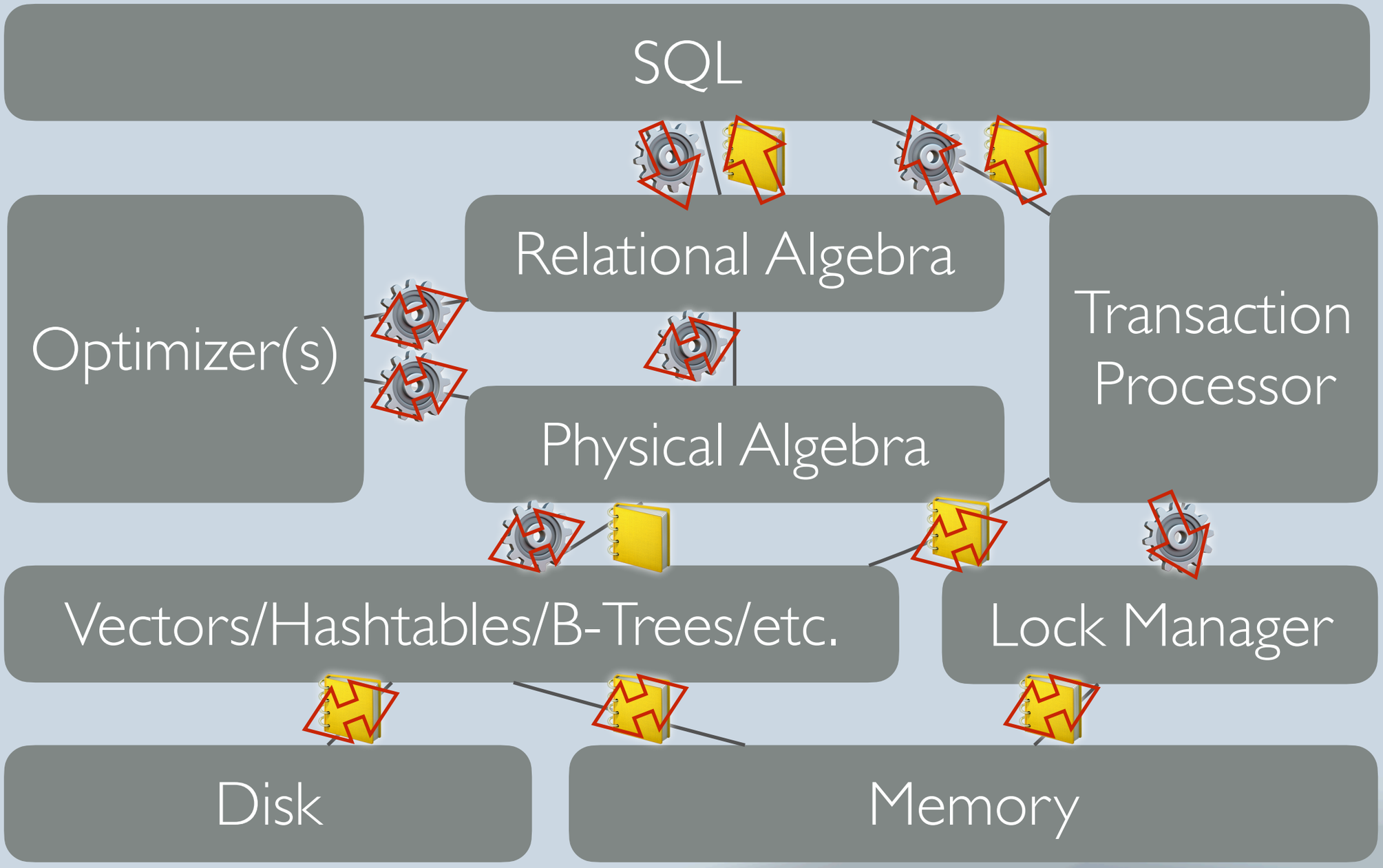

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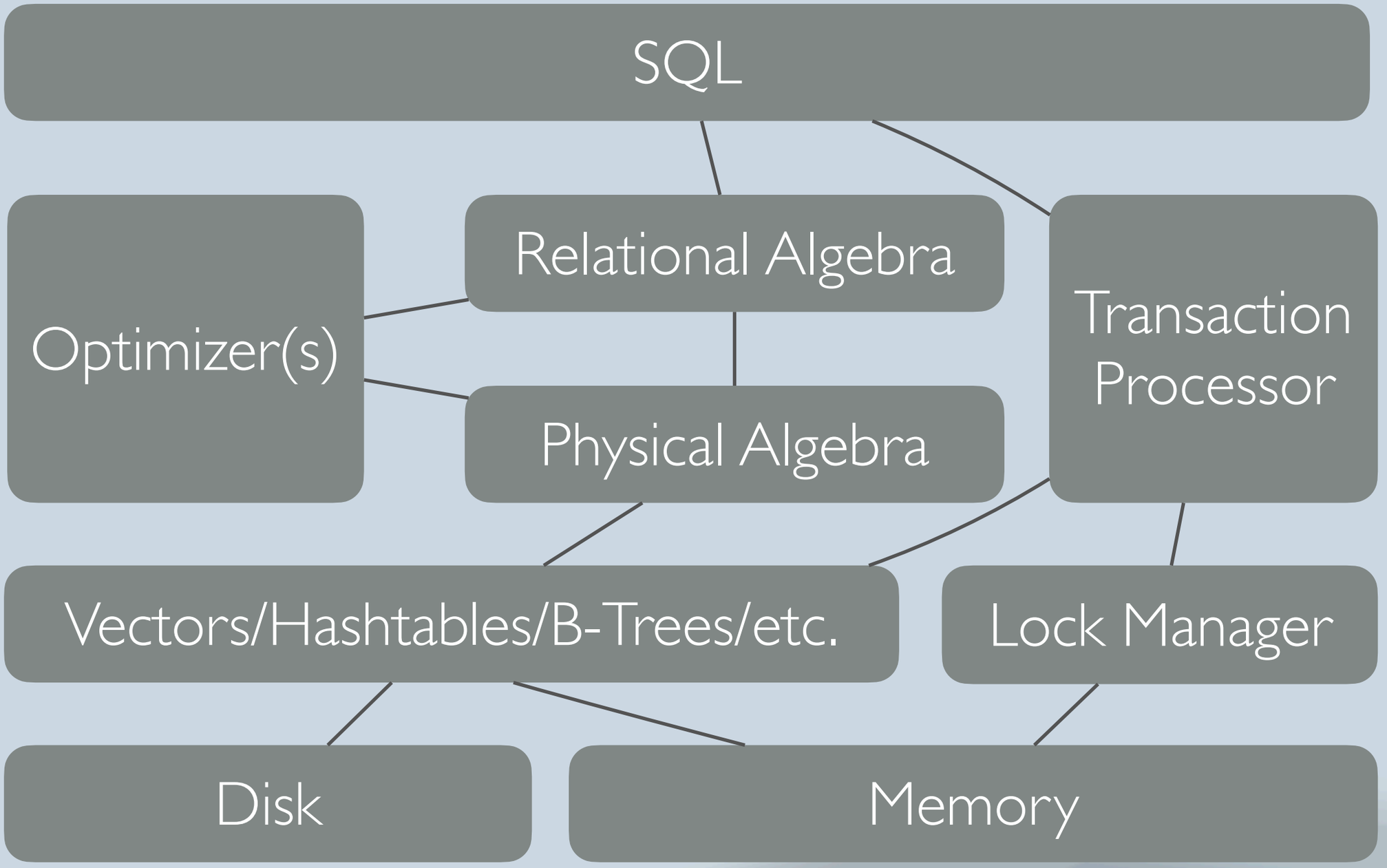

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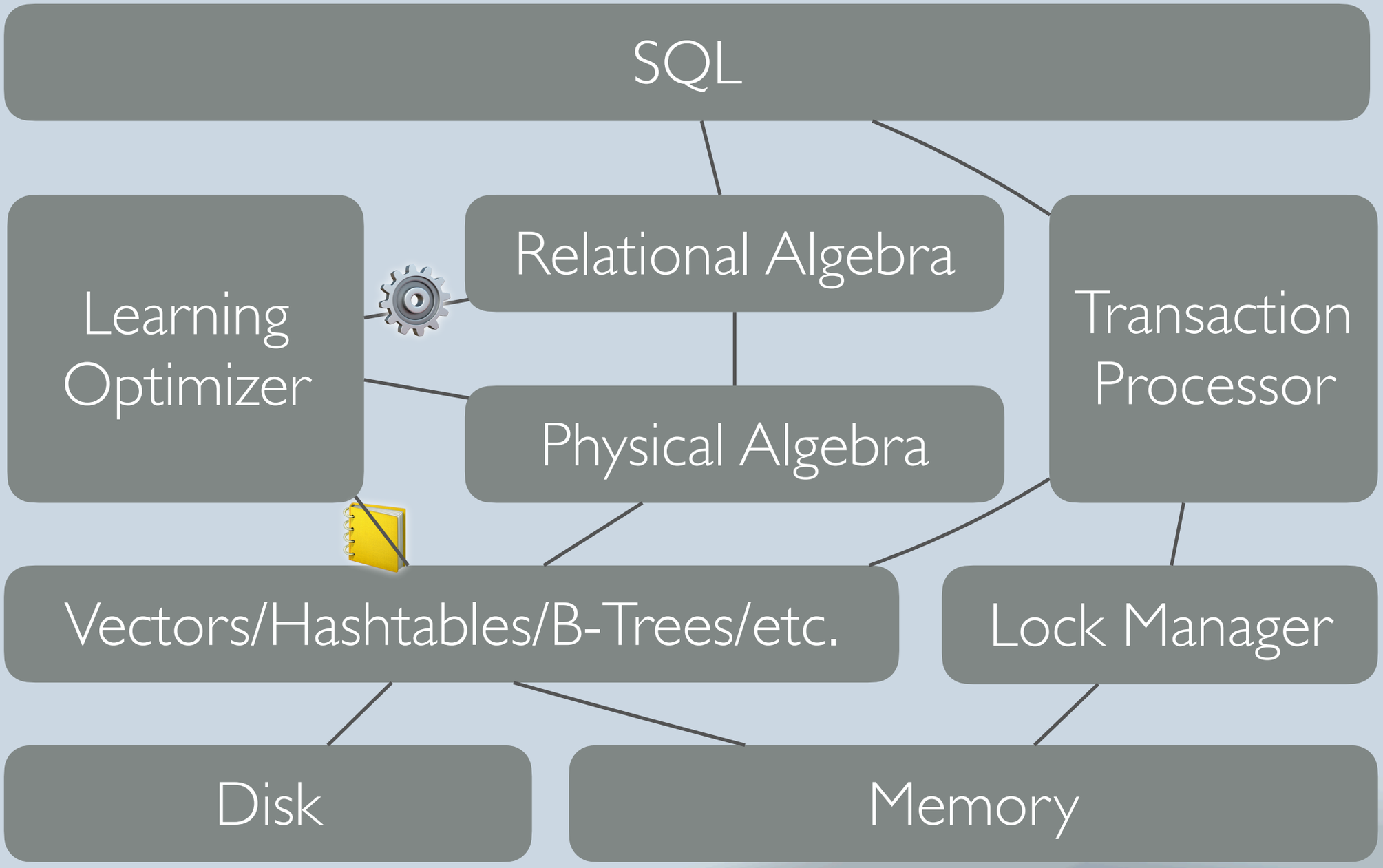

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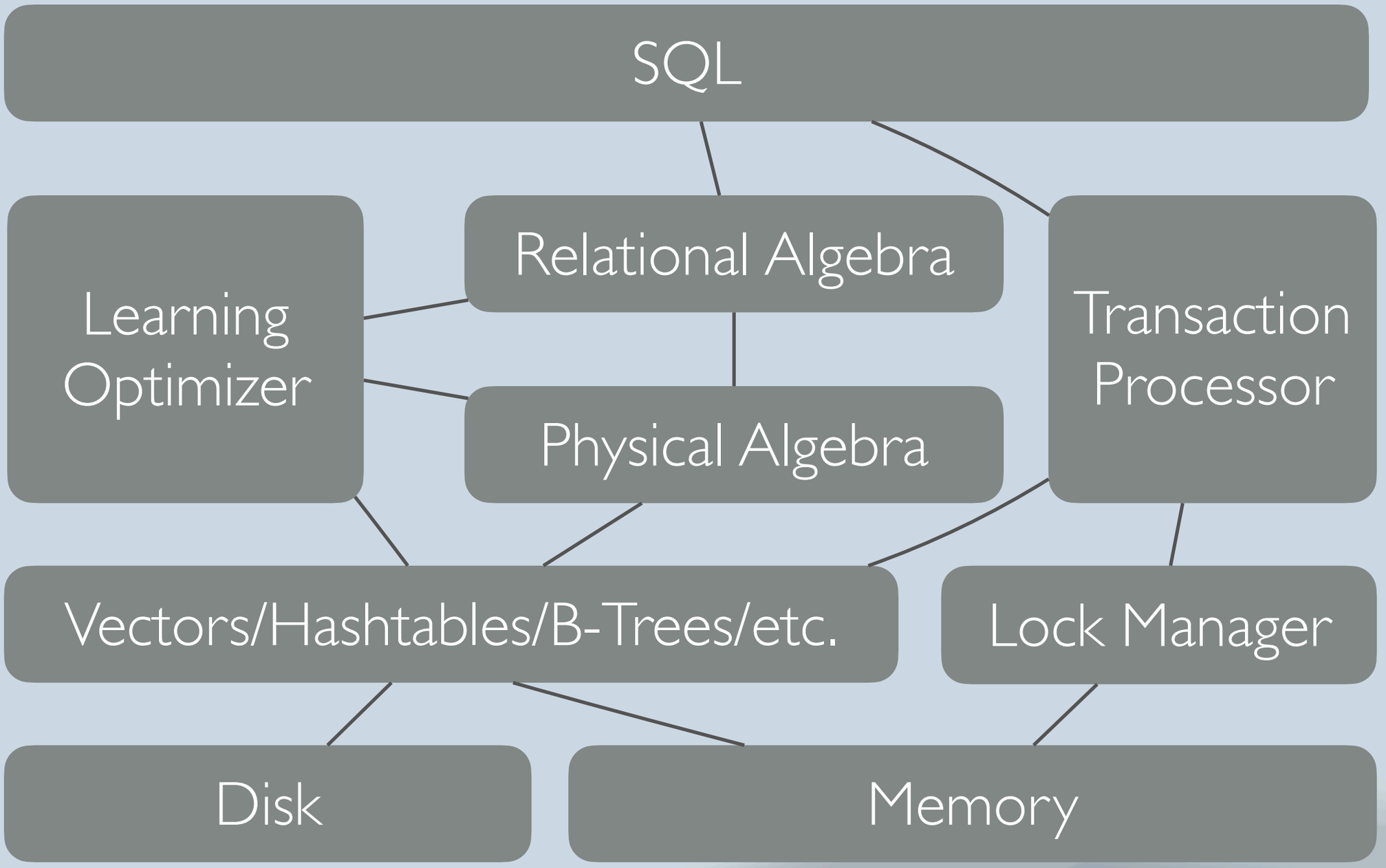

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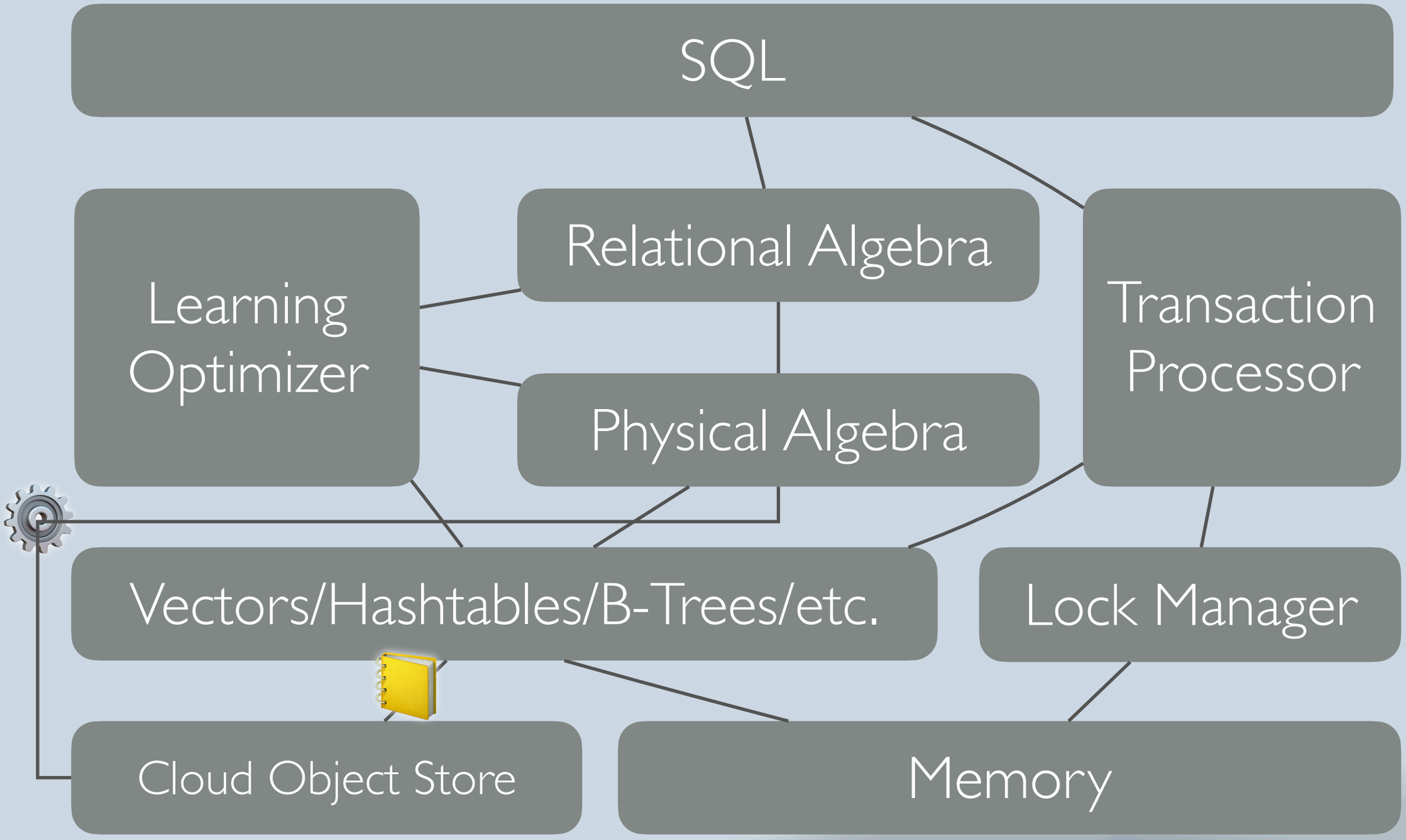

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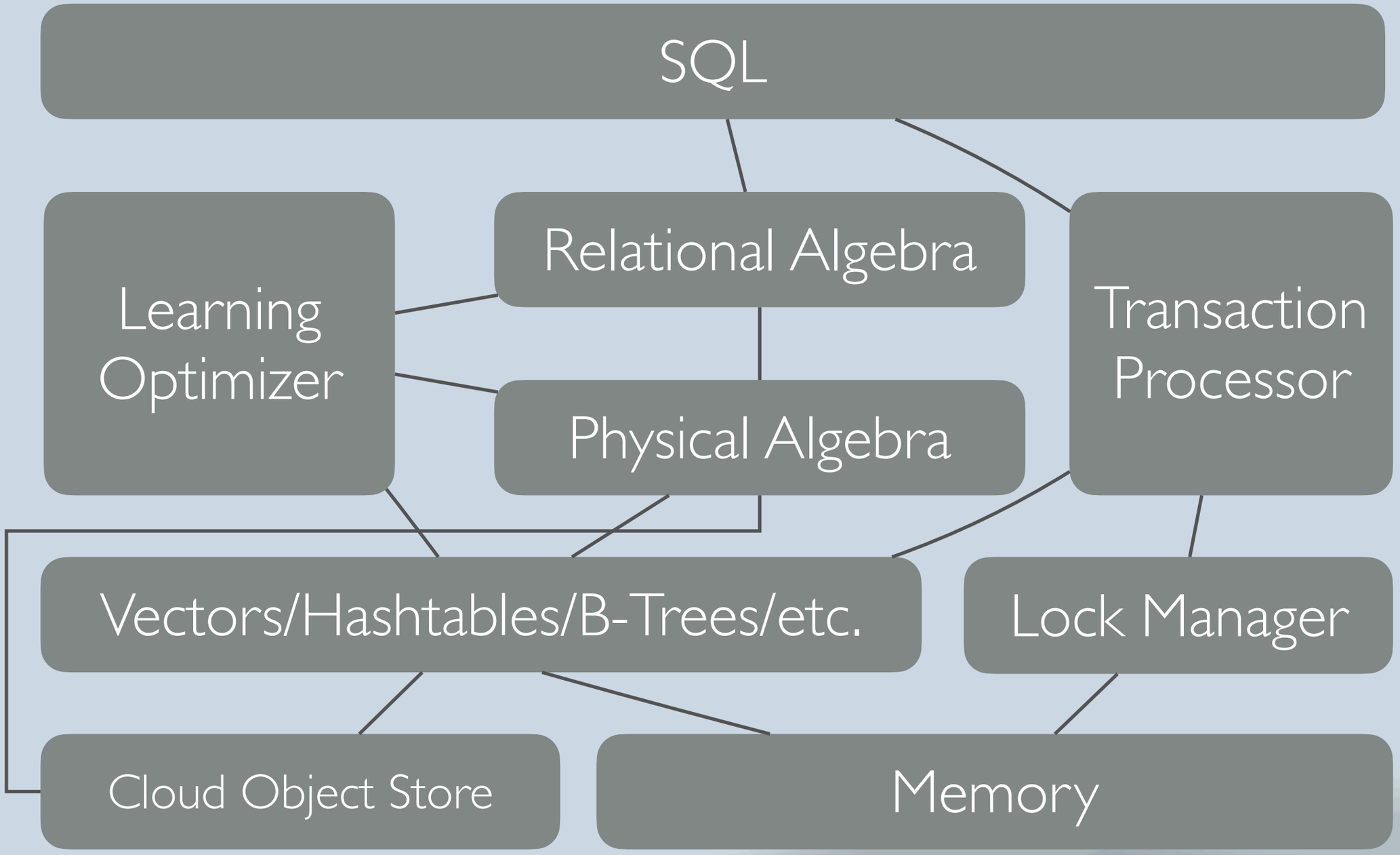

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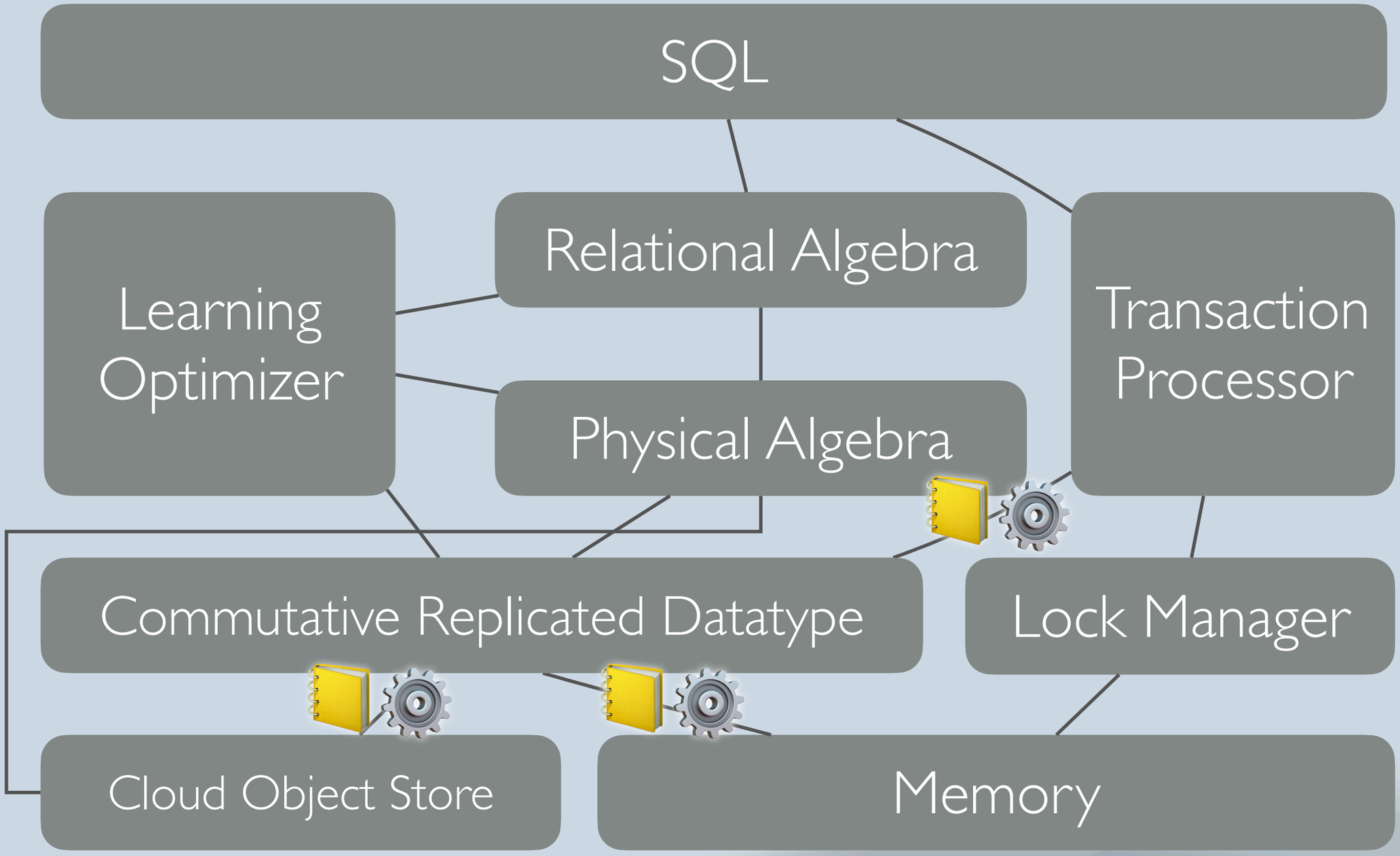
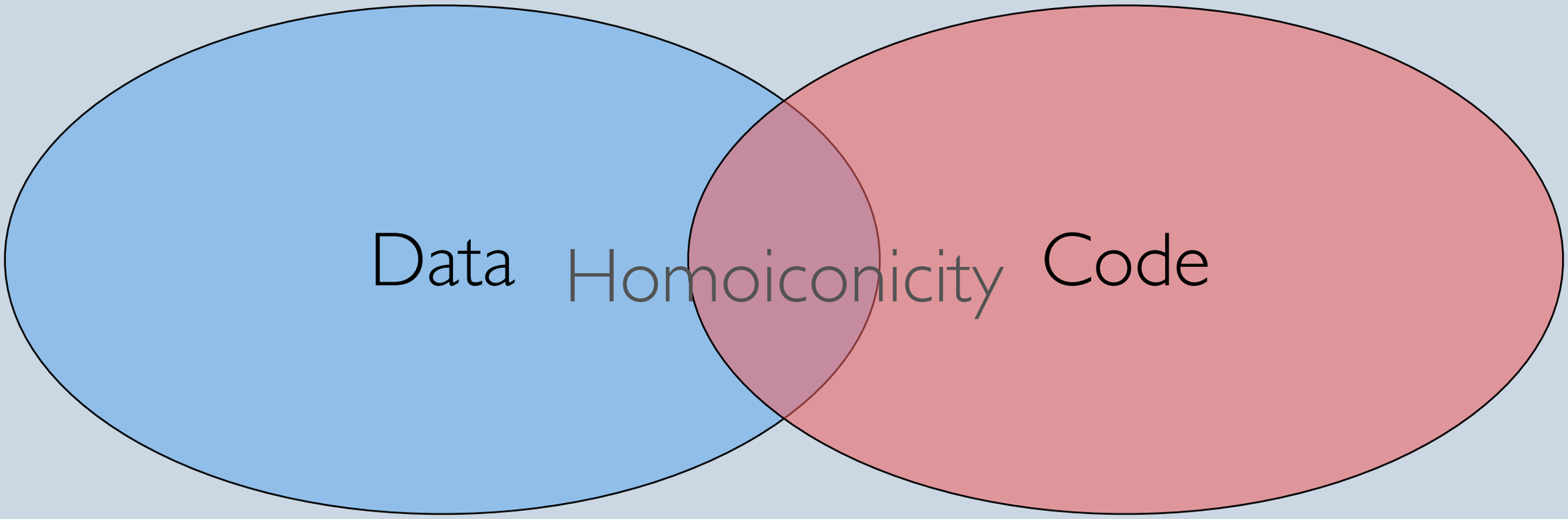
Composable Data Processing Systems



Option B



Classic Homoiconicity

(list 5 1 9 17 5) **Data**

Code (function square (x) (* x x))

(set input (list 5 1 9 17 5)) **???**

Relational Query (select input (where (> v 5)))

Homoiconic Data Processing

- Flavor 1
  - Data as Code
- Flavor 2
  - Code as Data

Flavor 1: Data as Code

Homoiconic Data Processing

(Create Table Caseload date numberOfCases)

(Insert Into Caseload 17 23)

(Insert Into Caseload 18 23)

(Insert Into Caseload 19 23)

(Select From Caseload (Where (> numberOfCases 5)))

Partial Query Evaluation

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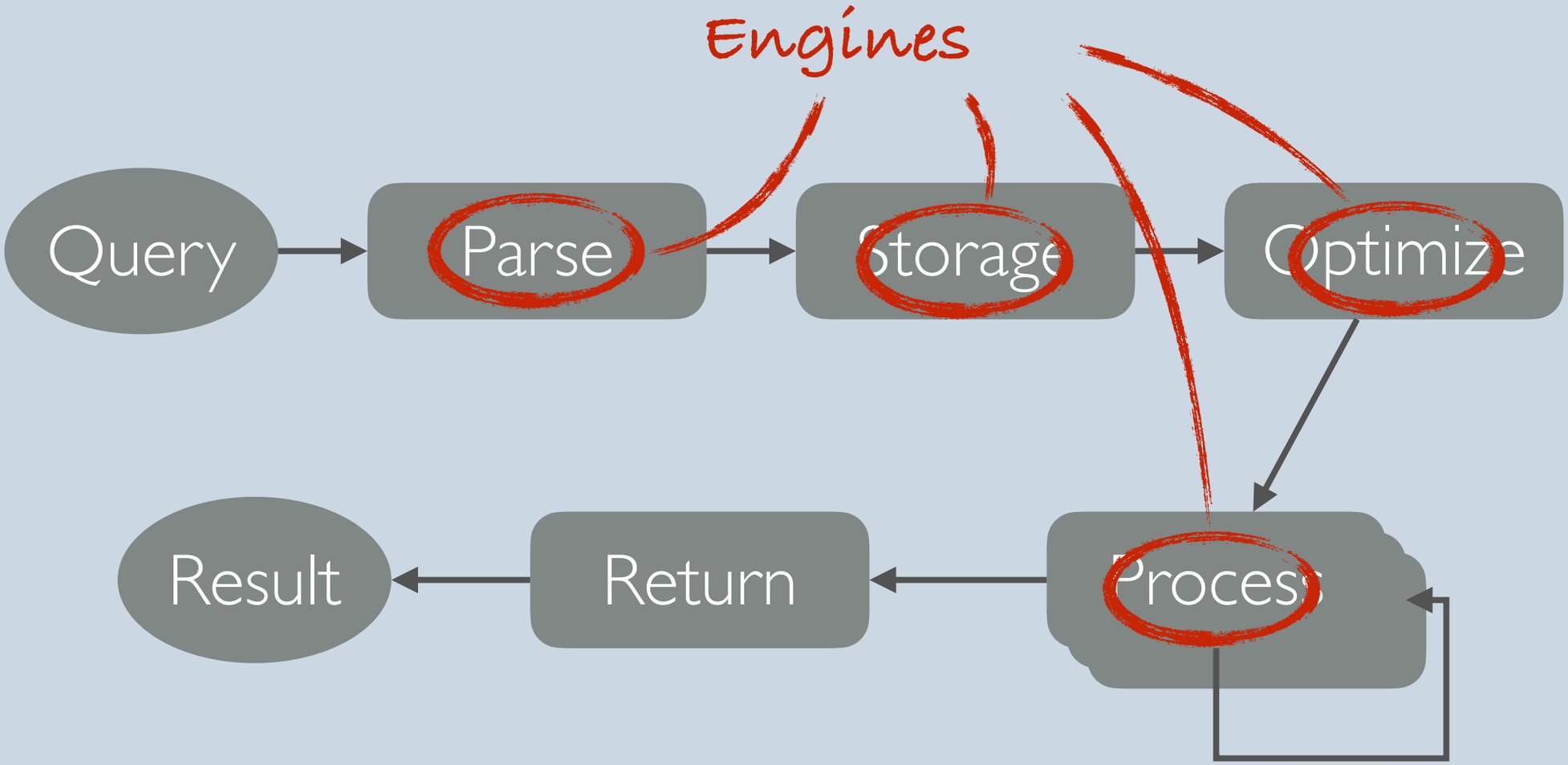
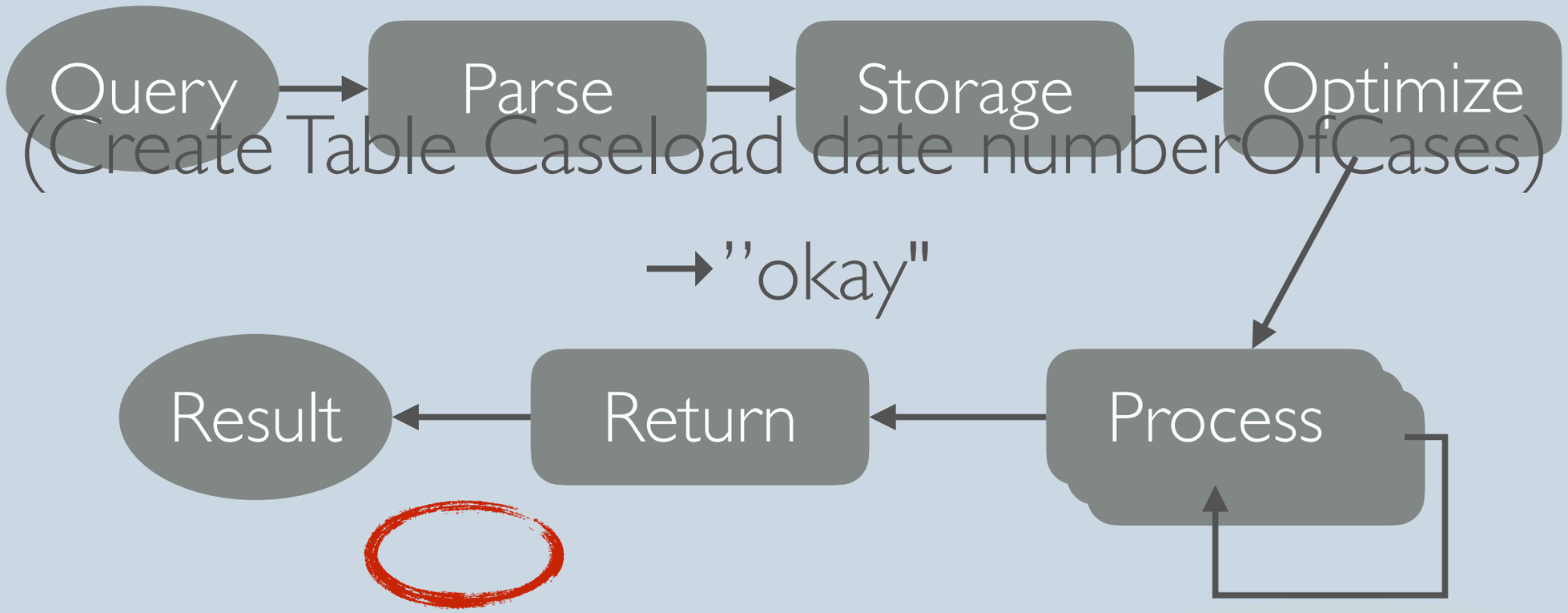
Partial Query Evaluation



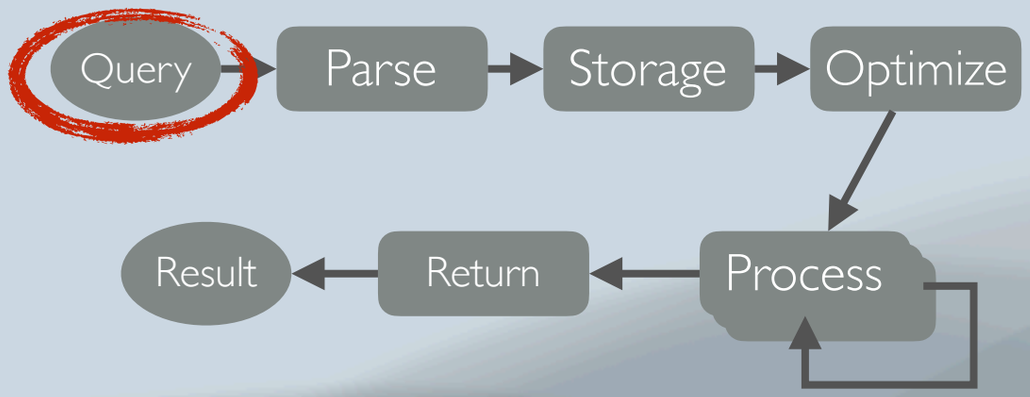
Partial Query Evaluation



Partial Query Evaluation

(Insert Into Caseload 17 23)

→"okay"

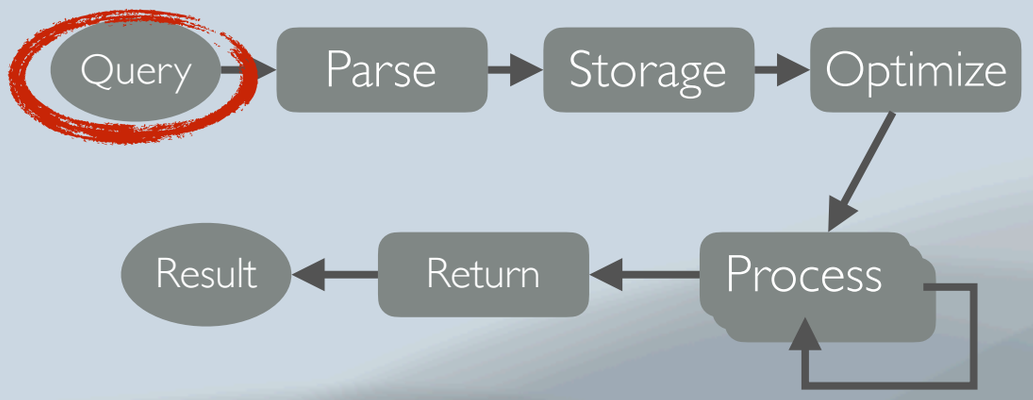


Partial Query Evaluation

(Select From Caseload (Where (> numberOfCases 5)))

→

(Select From
(Table
(data (List 18 19 17))
(numberOfCases (List 5 74 23))))
(Where (> numberOfCases 5)))

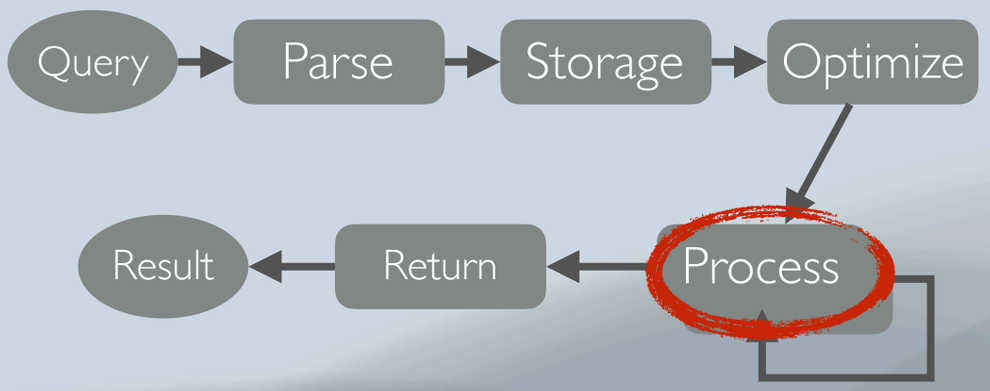


Partial Query Evaluation

```
(Select From
  (Table
      (data (List 18 19 17))
      (numberOfCases (List 5 74 23)))
  (Where (> numberOfCases 5)))
```

→

```
(Table
      (data (List 19 17))
      (numberOfCases (List 74 23)))
```



Flavor 2: Code as Data

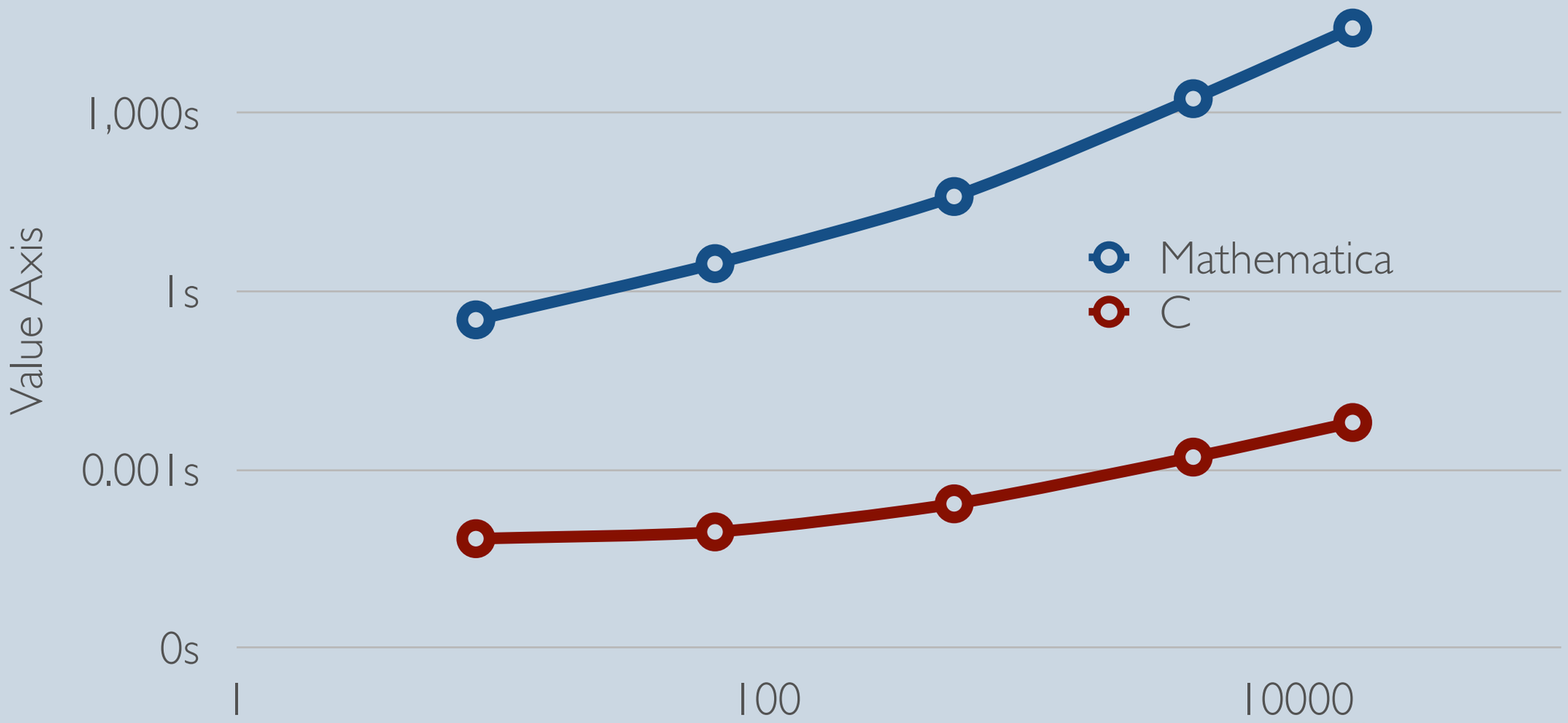
Code in a Database

Id	Name	Description	Price
4	“Cherry"	*'NULL*	0.09
6	“Apple"	“Yummy"	*(Impute)*
(UniqueValue)	“Pear"	"Sweet"	0.69
(UniqueValue)	“Raspberry"	*(fetch “http://…)*	0.04

You're probably thinking

"This all sounds really expensive"

The Problem Homoiconicity: Performance



Select sum(a) from R

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So how do we make it fast?

BOSS - A Bulk-Oriented Symbol Store

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BOSS Engine Interface

```
class Engine {
public:
  Expression evaluate(Expression&&);
};
```

Semi-static Typing

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Physical BOSS Type-System

For Convenient C++-Integration

For Speed & Data Exchange

For flexibility

```
class Symbol : public string {}

template <typename ElementType> struct Span {
  ElementType* element;
  size_t size;
};

template <typename... StaticArguments> class Expression {
  Symbol head;
  tuple<StaticArguments...> staticArguments;
  vector<variant<long, double, string, Expression>> dynamicArguments;
  vector<variant<Span<int>, Span<double>, Span<string>>> spans;
  auto getArgument(int);
};
```

Unified API

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Language Integration Through Semi-Static Typing

Concepts restrict Types

Type Inference during instantiation

Dynamically typed expression

```
operators["Greater"_] =
    [] NumericType FirstArgument>(
        ComplexExpression<FirstArgument>&& input) -> Expression {
  return input.getArgument(0) > (FirstArgument) input.getArgument(1);
};
```

C++ Lambas define operators

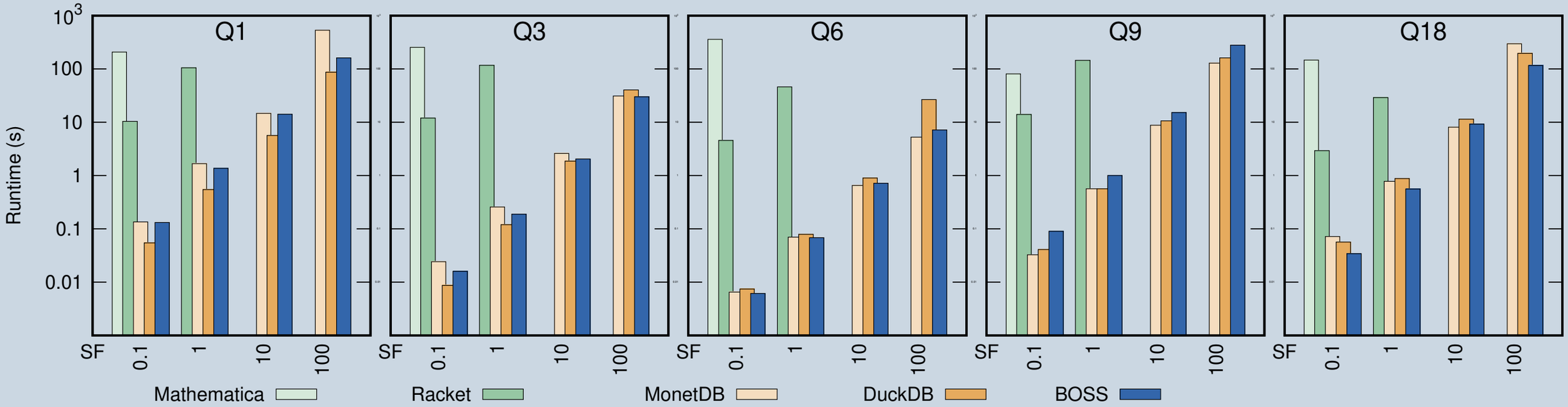
Statically typed

Cast to Statically typed expression

Zero-Copy Data Exchange Through Spans

- Spans are basically C-arrays (with some sugar-coating)
- Virtually all in-memory DBMSs use C-arrays
- Apache Arrow, C++ Vectors, Velox Vectors, ArrayFire Tensors provide zero-copy construction & extraction of C-arrays

TPC-H Performance Is Competitive



Ongoing Work

Storage Engine: Apache Arrow	✔
Processing Engine: Bulk	✔
Processing Engine: Mathematica	✔
Processing Engine: Velox	…
Processing Engine: ArrayFire	…
Adaptive Indexing Engine	
CRDT Engine	…
Data Imputation Engine	✔

These require code in data

Shape-wise Decomposition

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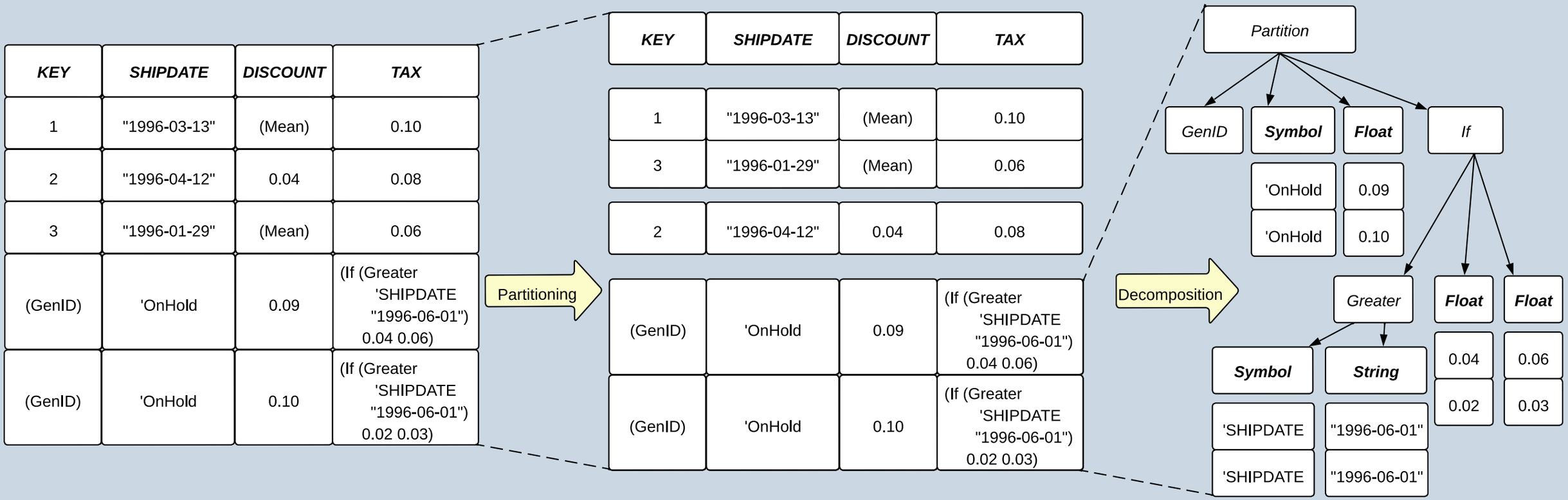
Why Code in Data Is Slow

Sum

KEY	SHIPDATE	DISCOUNT	TAX
1	"1996-03-13"	(Mean)	0.10
2	"1996-04-12"	0.04	0.08
3	"1996-01-29"	(Mean)	0.06
(GenID)	'OnHold	0.09	(If (Greater 'SHIPDATE "1996-06-01") 0.04 0.06)
(GenID)	'OnHold	0.10	(If (Greater 'SHIPDATE "1996-06-01") 0.02 0.03)

Virtual Function Call

Efficiently Representing Homoiconic Databases



Shape-wise Partitioning & Decomposition

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Efficiently Representing Homoiconic Databases

KEY	*SHIPDATE*	*DISCOUNT*	*TAX*
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Partitioning

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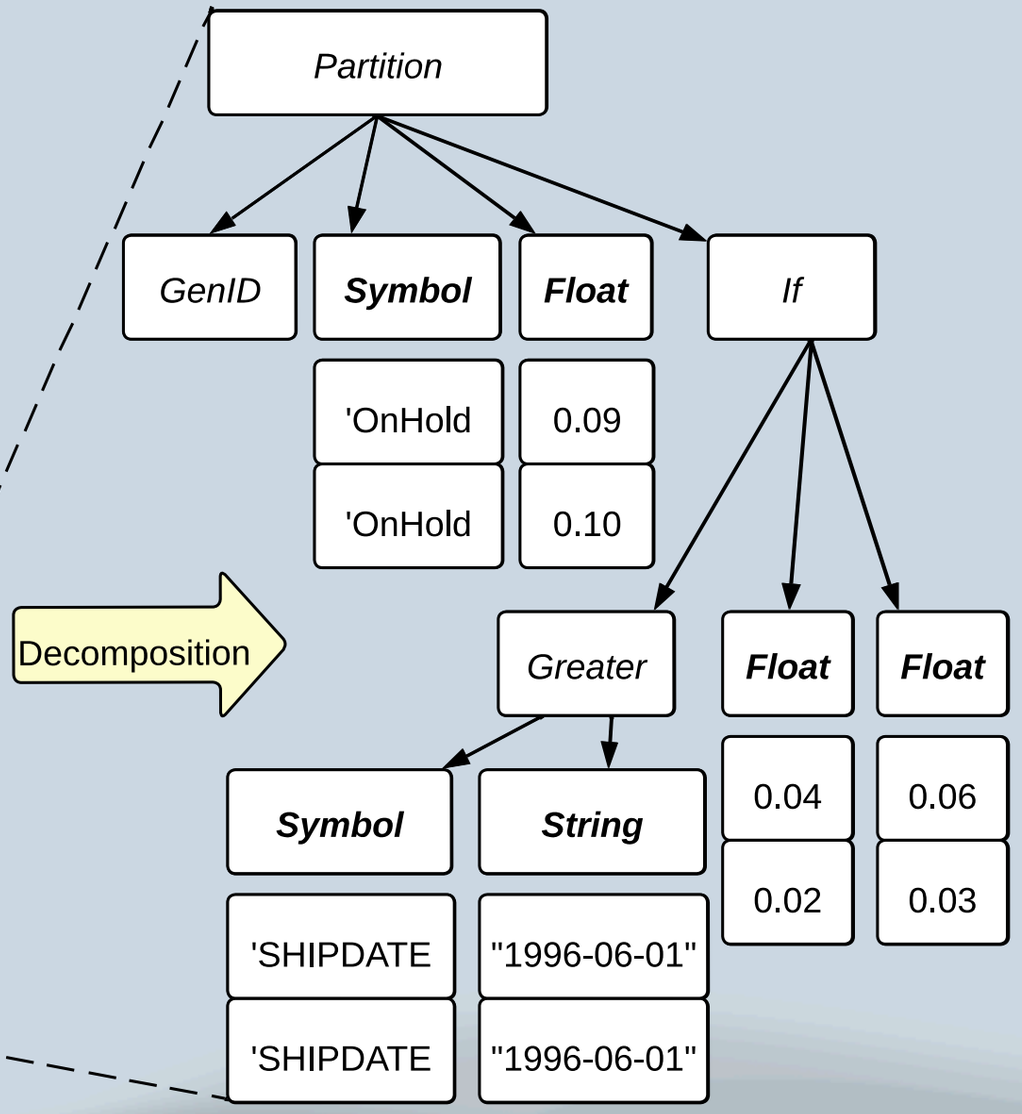
Decomposition



Efficiently Processing Homoiconic Databases

Virtual Function Call

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Efficiently Processing Homoiconic Databases

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Efficiently Processing Homoiconic Databases

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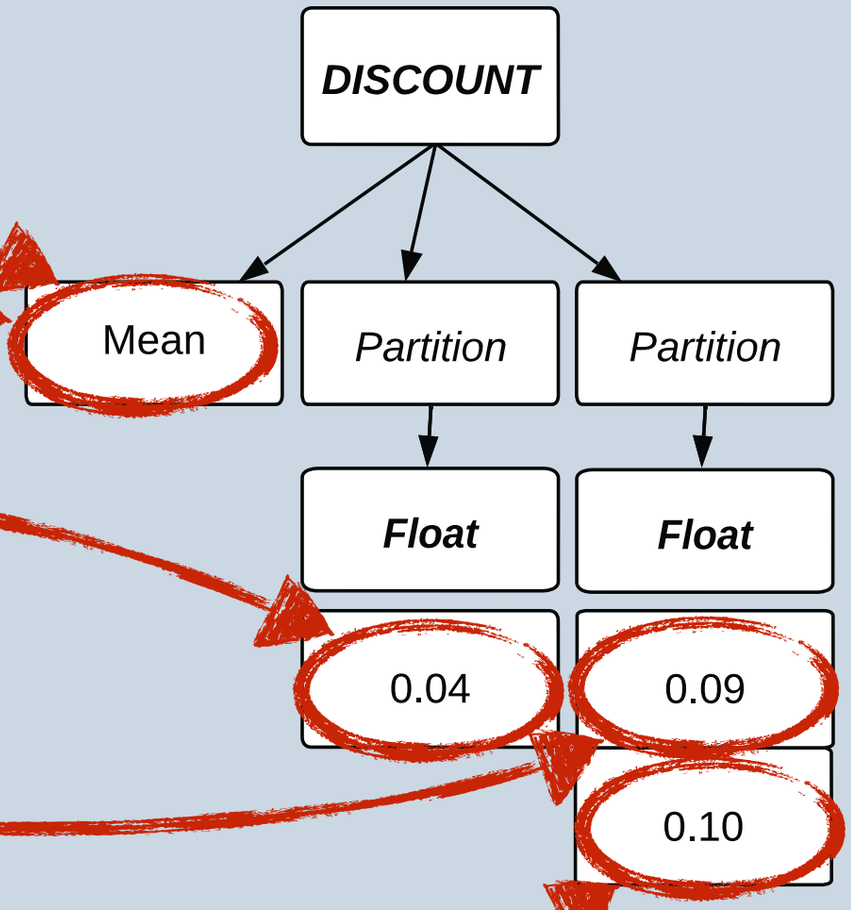
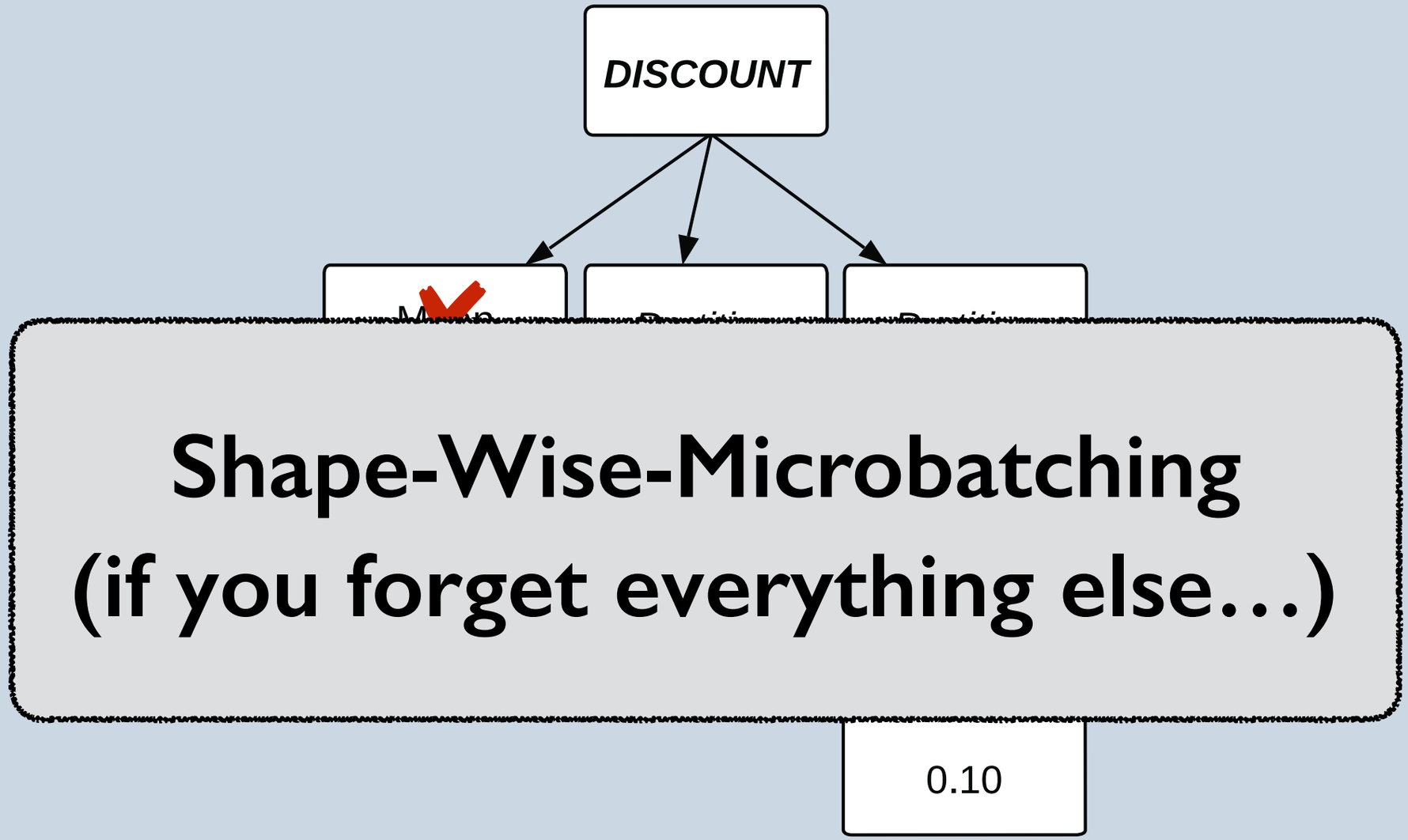
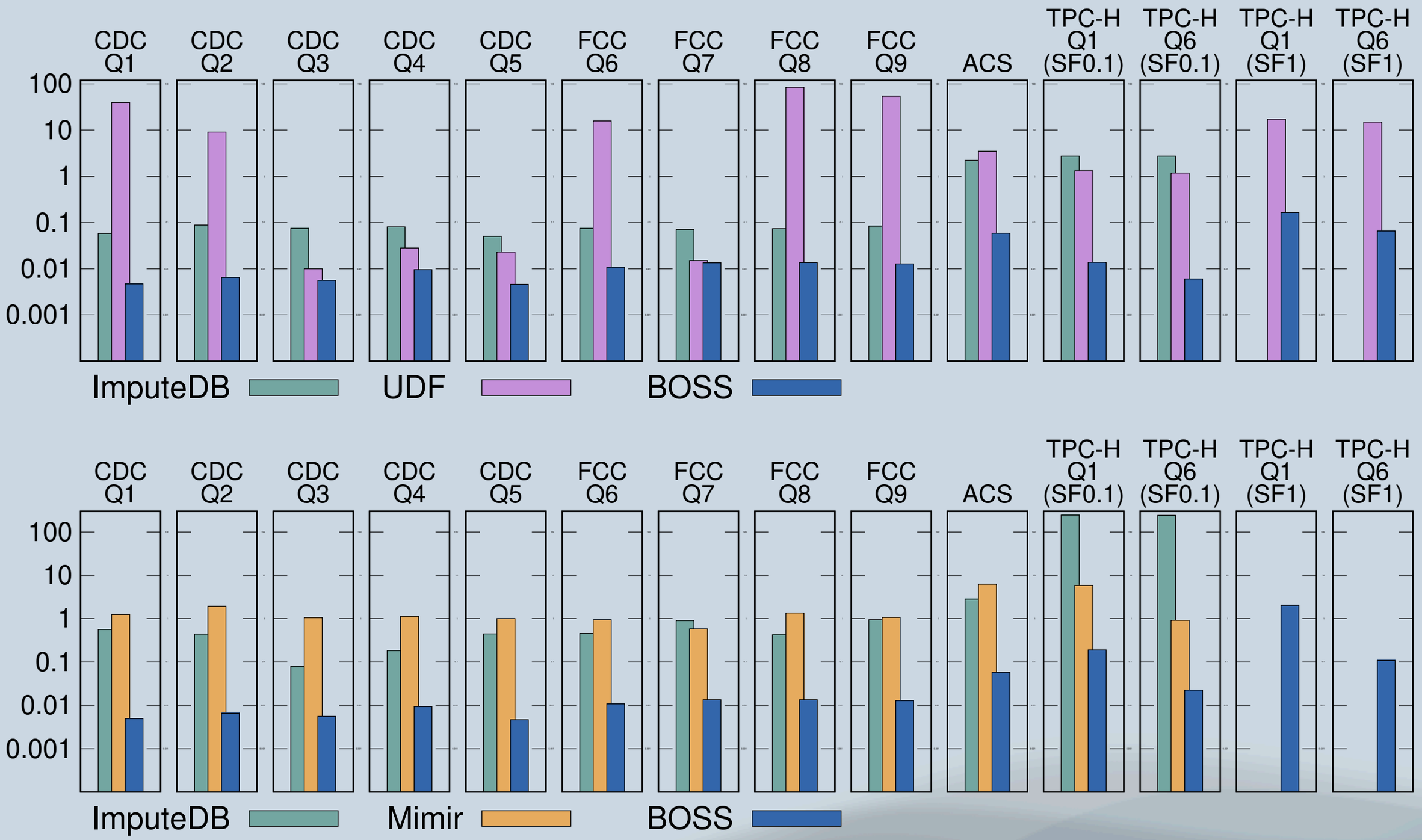


Efficiently Processing Homoiconic Databases



Performance Evaluation



Conclusion

- Separating code and data works well for monolithic systems
- Composable systems need more flexibility
- High-Performance Homoniconicity is
  - Possible
  - Useful

Thank you

Contributors:

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