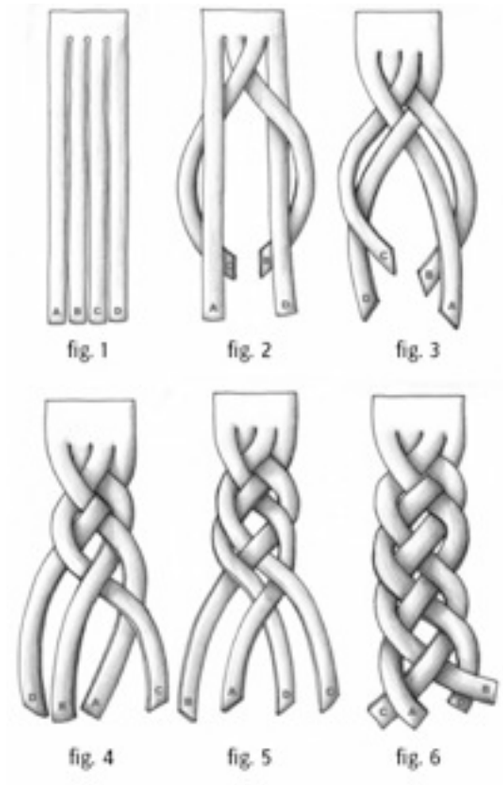
Datomic

Rich Hickey

What is Datomic?

- A new database
- Bringing data power *into* the application
- A sound model of information, with time
- Enabled by architectural and capacity advances

Complexity



- Out of the Tar Pit

  Moseley and Marks (2006)

- Complexity caused by state and control
- Close the loop - process

DB Complexity

- Stateful, inextricably
- Same query, different results
  - no basis
- Over there
- ‘Update’ poorly defined
  - Places

Basis

- Calculation and decision making:

  may involve multiple components

  may visit a component more than once

- Broken by simultaneous change

Update

- What does update mean?
- Does the new replace the old?
- Granularity? new ___ replace the old ___
- Visibility?

Manifestations

- Wrong programs
- Scaling problems
- Round-trip fears
- Fear of overloading server
- Coupling, e.g. questions with reporting

The Choices

- Coordination
  - how much, and where?
    - process requires it
    - perception shouldn’t
- Immutability
  - sine qua non

Coming to Terms

Value

- An *immutable* magnitude, quantity, number... or immutable composite thereof

Identity

- A putative entity we associate with a series of causally related values (states) over time

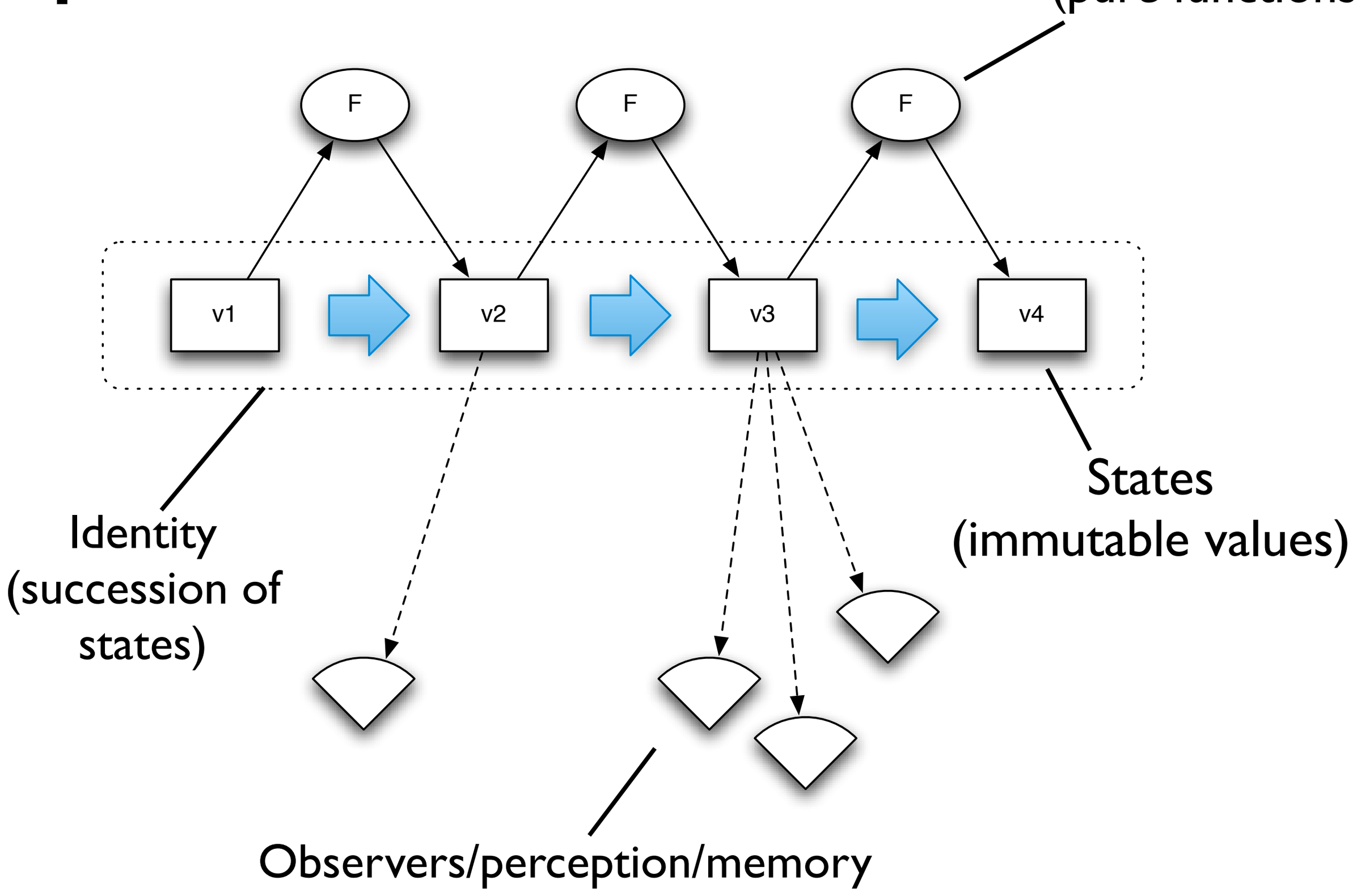
State

- Value of an identity at a moment in time

Time

- Relative before/after ordering of causal values

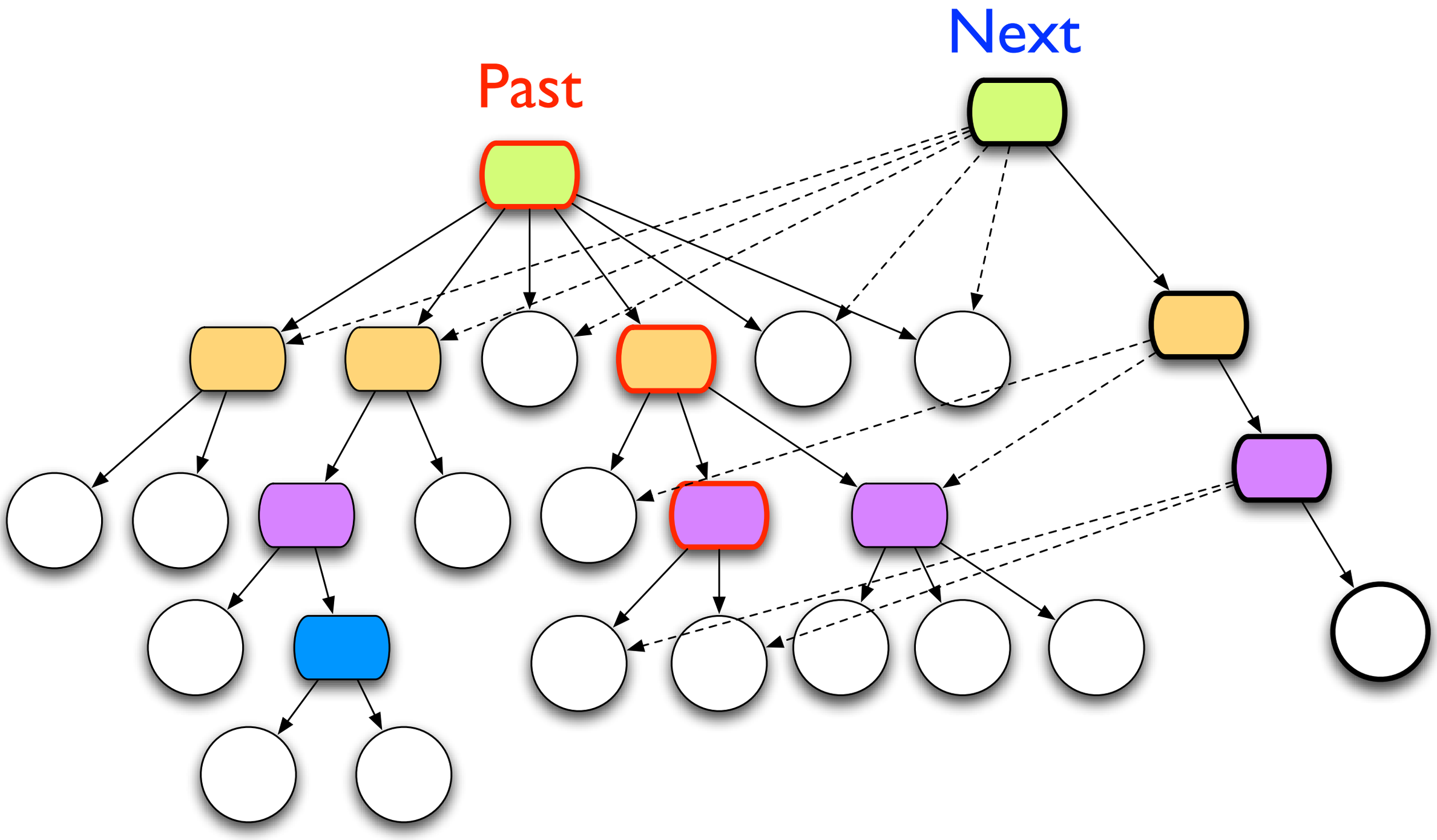
Epochal Time Model



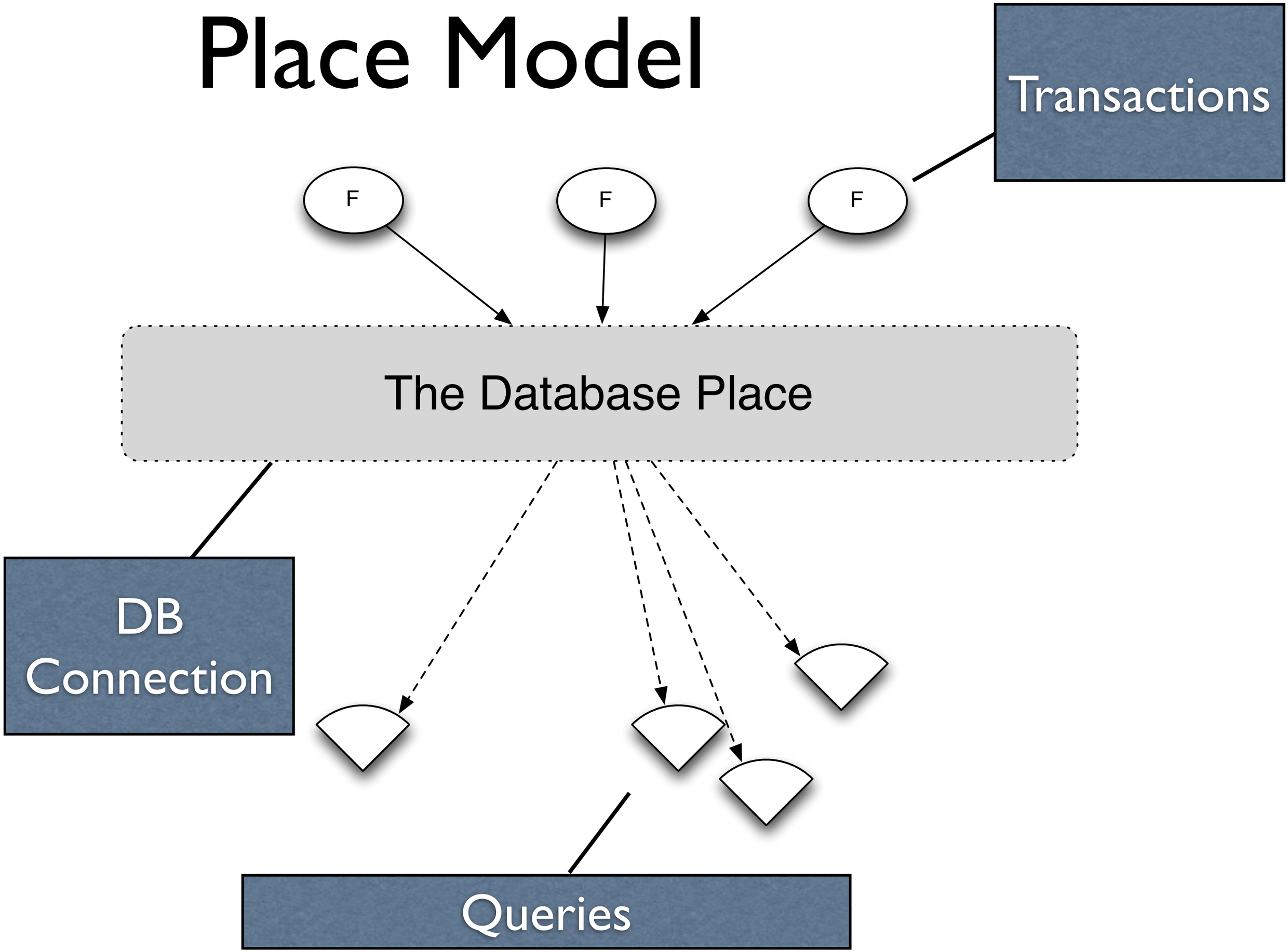
Implementing Values

- Persistent data structures
- Trees
- Structural sharing

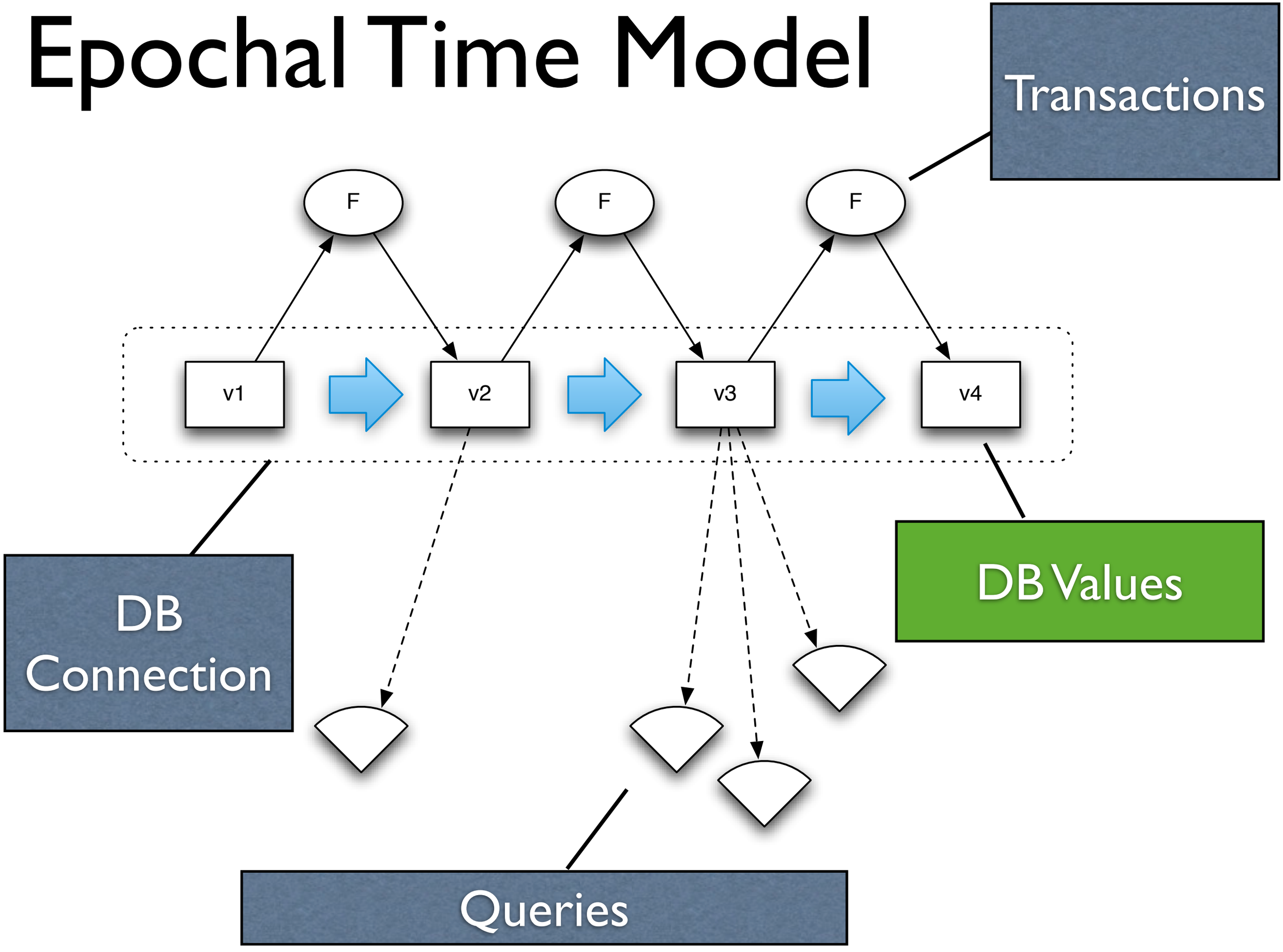
Structural Sharing



Place Model


Transactions
F
F
F
The Database Place
DB
Connection
Queries

Epochal Time Model



Database State

- The database as an expanding value
  - An accretion of facts
    - The past doesn't change - immutable
- Process requires new space
- Fundamental move away from places

Accretion

- Root per transaction doesn't work
  - Crossing processes and time
  - Can't convey/find/maintain roots
    - Can't do global GC
- Instead, latest values include past as well
  - The past is sub-range
- Important for information model

Facts

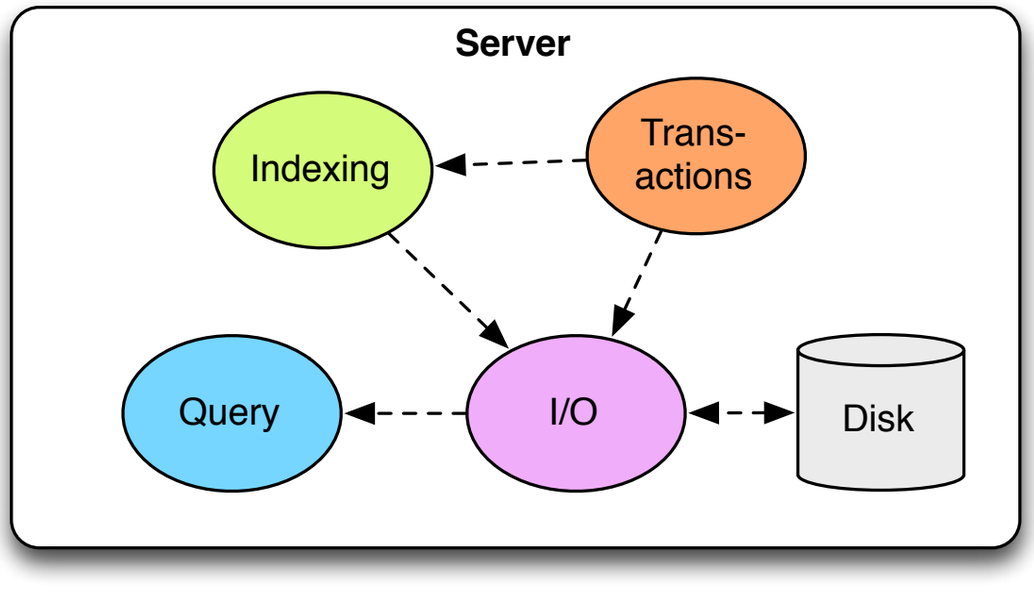
- Remove structure
  - a la RDF
- Atomic
  - Datom
  - Entity/Attribute/Value/Transaction
- Must include time

Process

- Reified
- Primitive representation of novelty
  - Assertions and retractions of facts
  - Minimal
- Other transformations expand into those

Implementation

Deconstruction

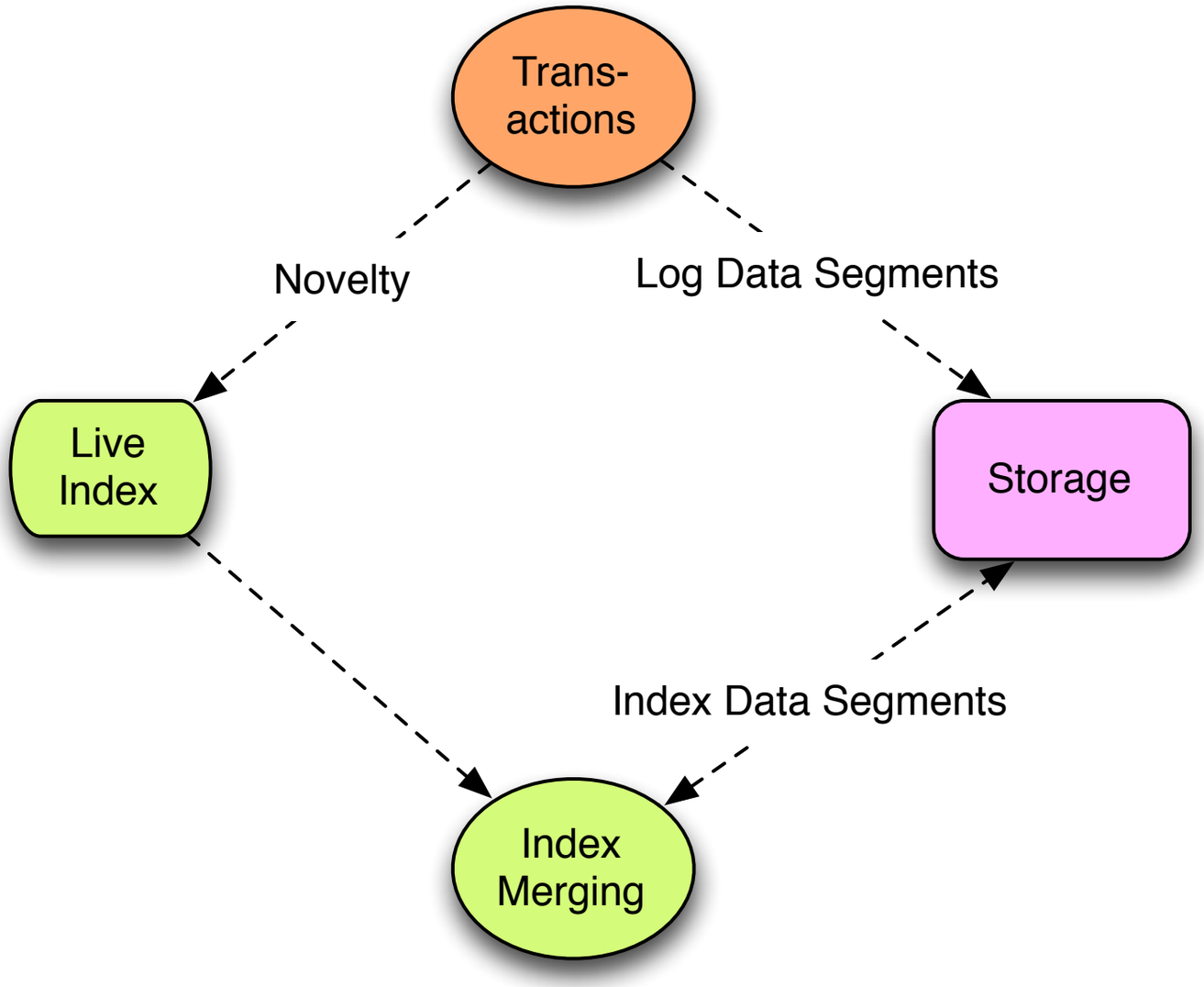


- Process
  - Transactions
  - Indexing?
  - O
- Perception/Reaction
  - Query
  - Indexing?
  - I

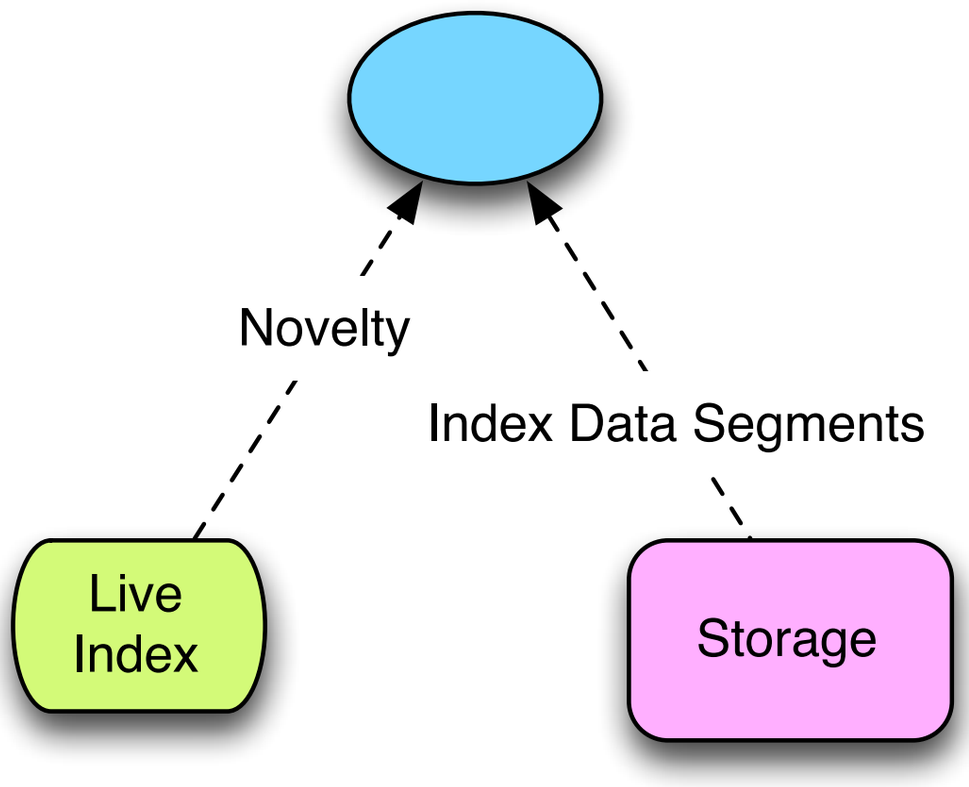
State

- Must be organized to support query
- Sorted set of facts
- Maintaining sort live in storage - bad
  - BigTable - mem + storage merge
  - occasional merge into storage
  - persistent trees

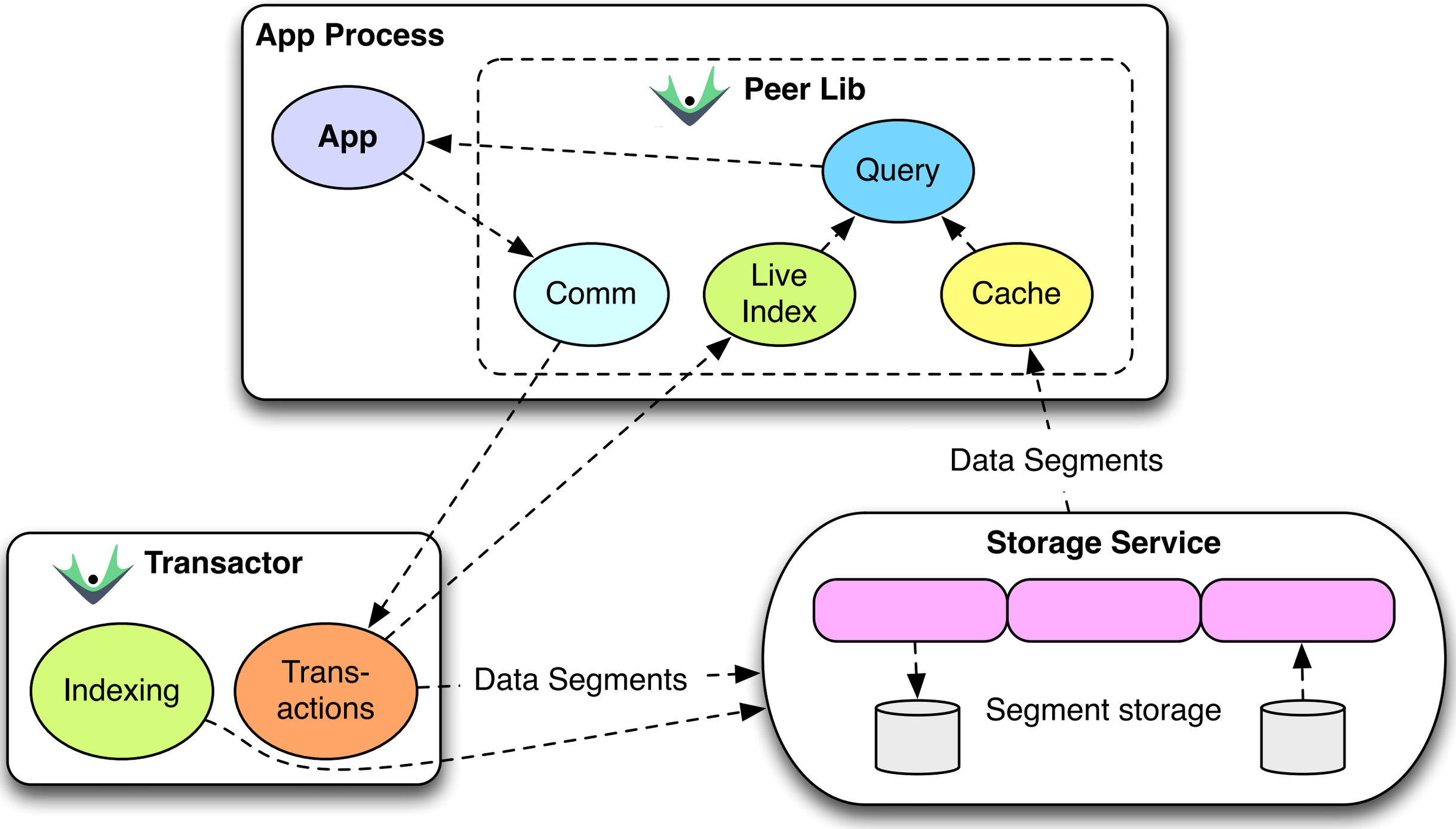
Transactions and Indexing



Perception



Datomic Architecture



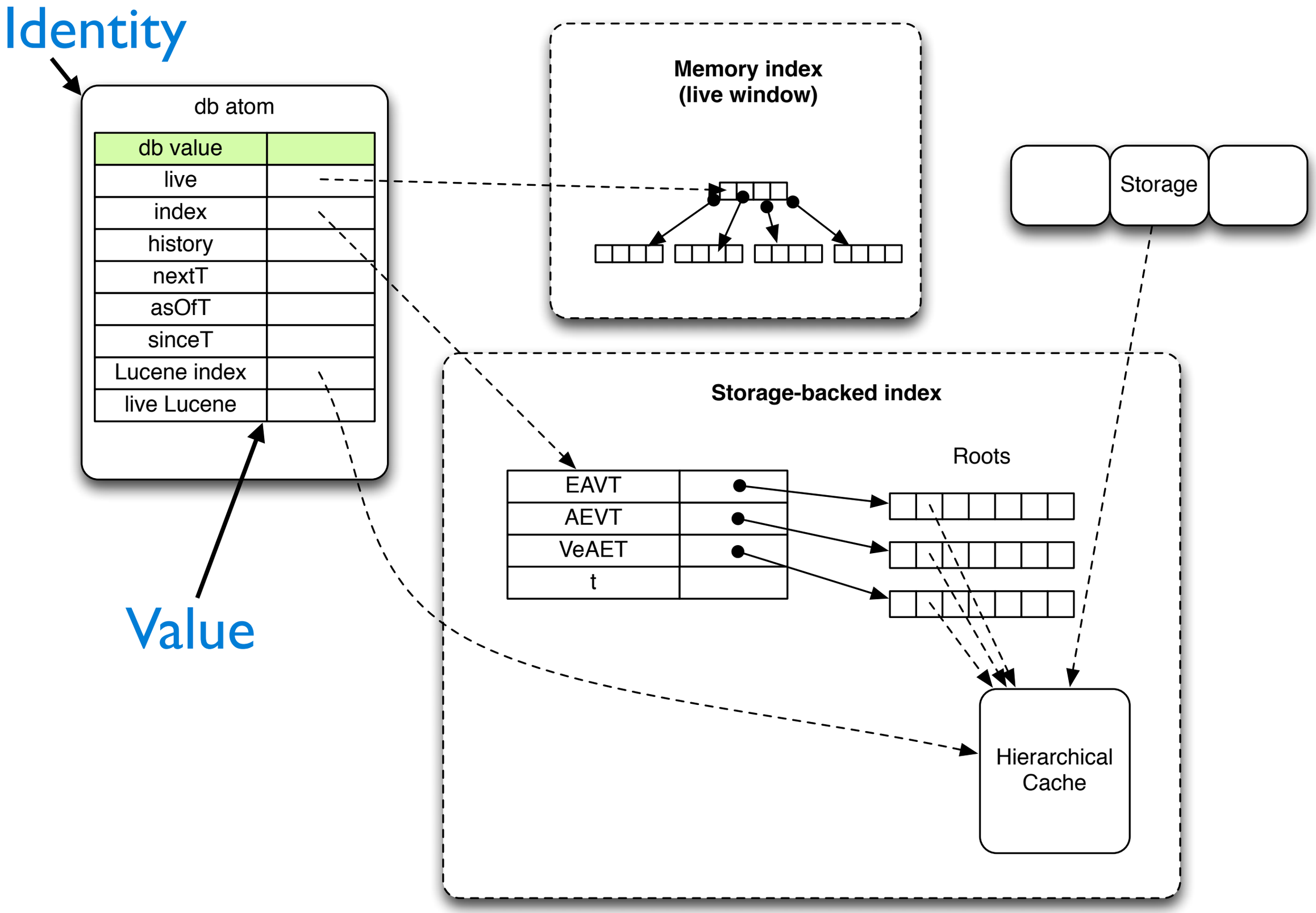
Memory Index

- Persistent sorted set
- Large internal nodes
- Pluggable comparators
- 2 sorts always maintained
  - EAVT, AEVT
- plus AVET, VAET

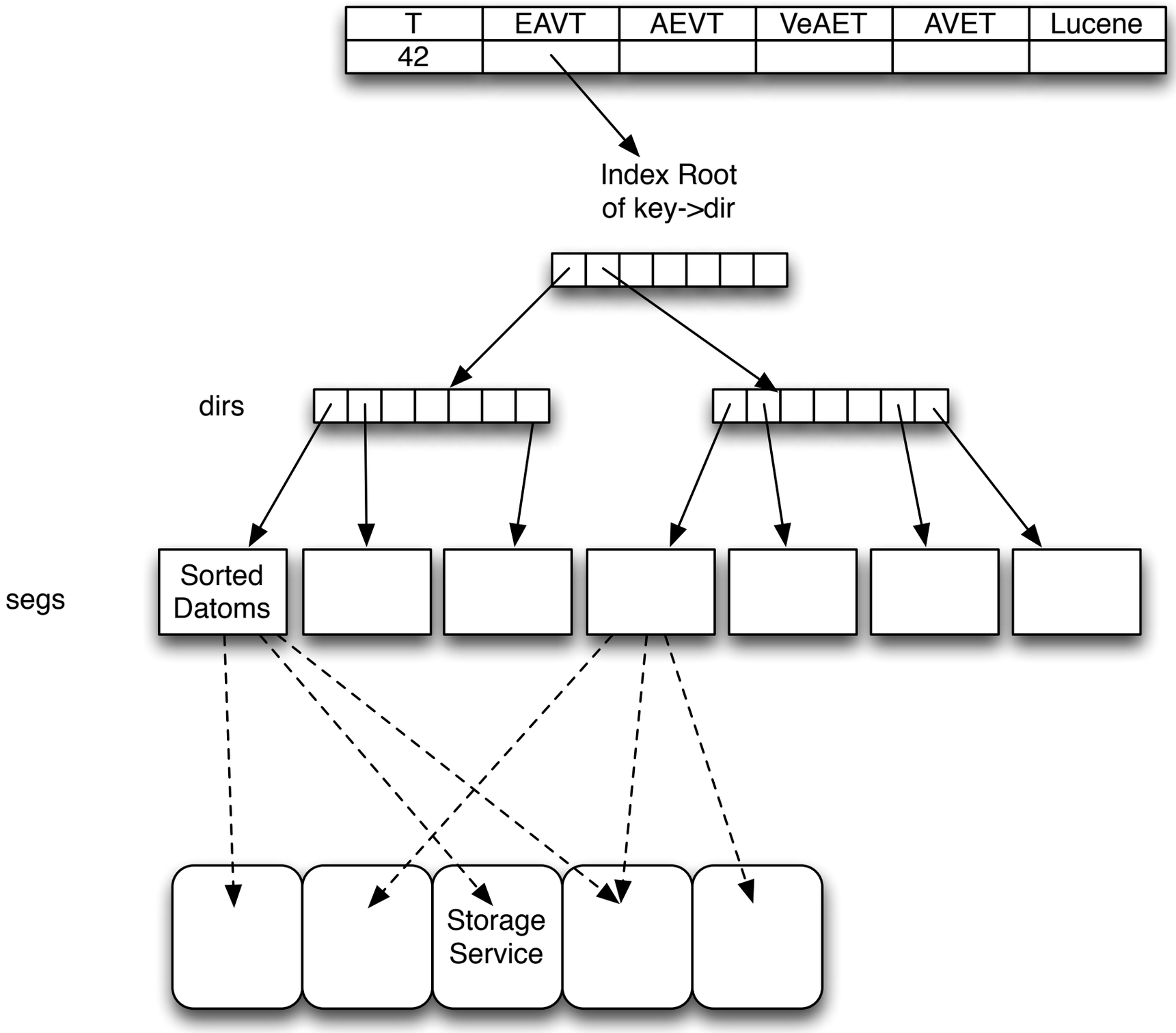
Storage

- Log of tx asserts/retracts (in tree)
- Various covering indexes (trees)
- Storage requirements
  - Data segment values (K->V)
  - atoms (consistent read)
  - pods (conditional put)

What's in a DB Value?



Index Storage

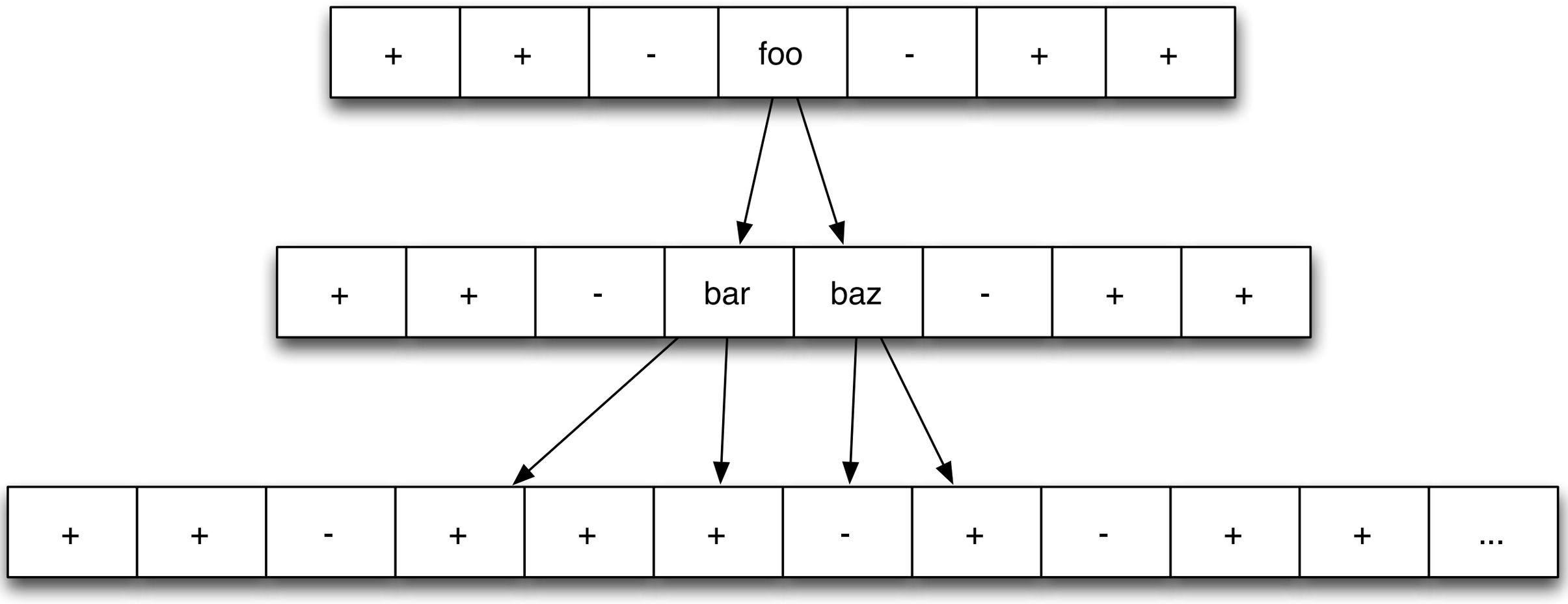


Process

- Assert/retract can't express transformation
- Transaction function:

  f(db, args...) -> tx-data
- tx-data: assert|retract|tx-fn(args...)
- Expand/splice until all assert/retracts

Process Expansion



Transactor

- Accepts transactions
  - Expands, applies, logs, broadcasts
- Periodic indexing, in background
- Indexing creates garbage
  - Storage GC

Peers

- Peers directly access storage service
- Have own query engine
- Have live mem index and merging
- Two-tier cache
  - Segments (off-heap/memcached)
  - Datoms w/object values (on heap)

Declarative Programming

- Embedded Datalog
- Subset of Prolog
- Set oriented, guaranteed termination
- db(s) + rules + queries

Datomic Datalog

- Takes data sources and rule sets as args
- Extended to work with scalars/collections
- Expression clauses call your code
- interface is data structures (maps and lists)

  joins are implicit

Datomic Datalog

```
connection.q(query, db1, db2, otherInputs ...);

{:find [?customer ?product]
 :where [[?customer :shipAddress ?addr]
         [?addr :zip ?zip]
         [?product :product/weight ?weight]
         [?product :product/price ?price]
         [(Shipping/estimate ?zip ?weight) ?shipCost]
         [(<= ?price ?shipCost)]]}
```

JVM Integration

- Transactor, peers are JVM processes
- DB engine, cache, Datalog delivered as Java Library
- Written in Clojure

JVM Issues

- GC pauses kill latency
- Huge inefficiencies for boxed numbers

  tagged numbers desperately needed
- structs of arrays etc

Java Issues

- Insufficiently factored interfaces

  Indexed

  Associative

  Read vs write
- Using basic data structures is pain

  no literals, no accessors
- No symbols

DB Simplicity

- Epochal state
  - Coordination only for process
- Same query, same results
  - stable bases
- Transactions well defined
  - Functional accretion

Other Benefits

- Communicable, recoverable basis
- Freedom to relocate/scale storage, query
- Time travel - db.asOf, db.since, db.aslf
  - Queries comparing times
- Process events

The Database as a Value

- Dramatically less complex
- More powerful
- More scalable
- Better information model

Thanks for Listening!