Streaming Queries

CSE 4/562: Database Systems | Lecture 16

Sequential Data

Sequential Data


```
CREATE TABLE Transactions(transaction_date date,
                          product_id int,
                          price decimal);
```

Find the % change in monthly sales, each month

```
CREATE TABLE Transactions(transaction_date date,
                          product_id int,
                          price decimal);
```

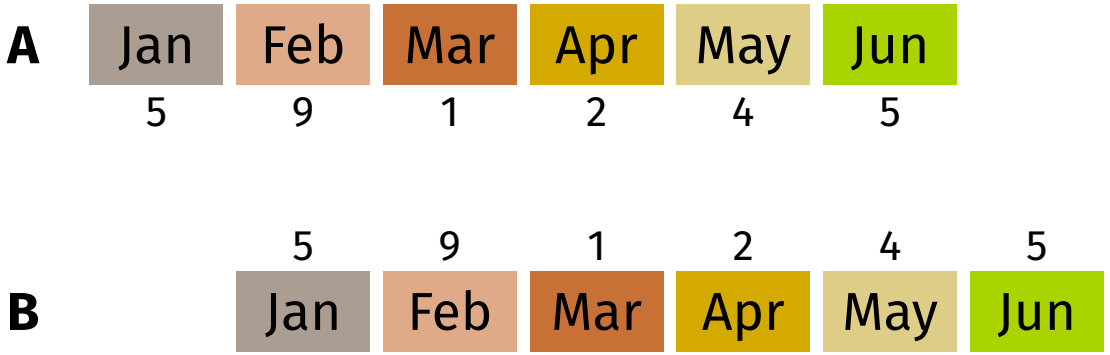
Find the % change in monthly sales, each month

```
SELECT A.Month, (A.Sales-B.Sales) / B.Sales
 FROM (SELECT … AS Month, SUM(…) AS Sales FROM …) A,
      (SELECT … AS Month, SUM(…) AS Sales FROM …) B
WHERE A.Month = B.Month + 1
```

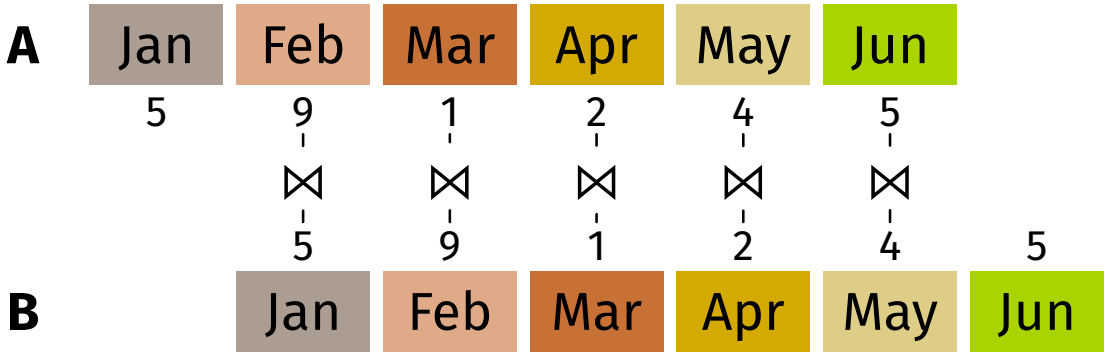
Find the % change in monthly sales, each month

	Jan	Feb	Mar	Apr	May	Jun
A	5	9	1	2	4	5

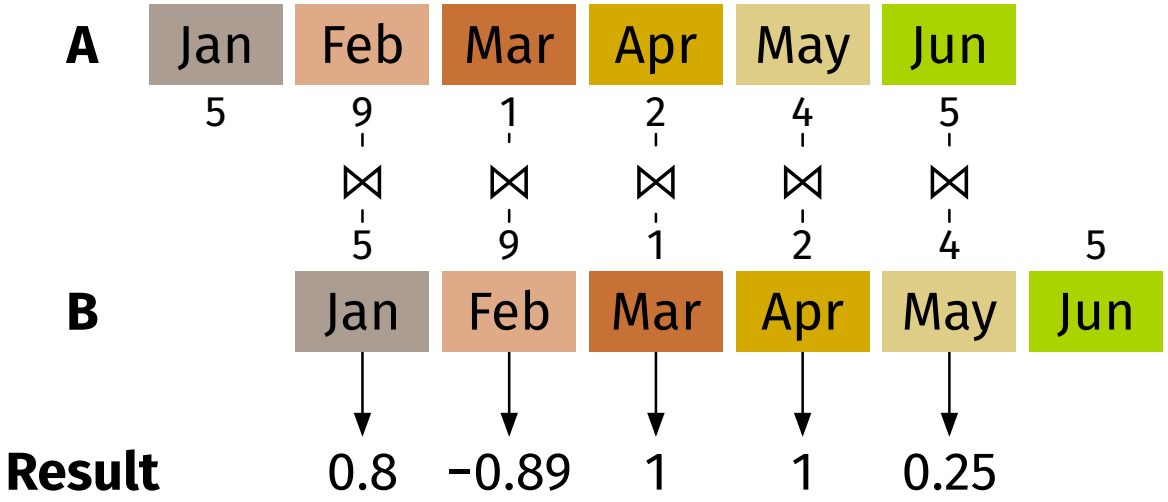
Find the % change in monthly sales, each month



Find the % change in monthly sales, each month



Find the % change in monthly sales, each month



```
CREATE TABLE Transactions(transaction_date date,
                          product_id int,
                          price decimal);
```

Find the daily top-5 products by sales in the last week

```
CREATE TABLE Transactions(transaction_date date,
                          product_id int,
                          price decimal);
```

Find the daily top-5 products by sales in the last week

```
SELECT product_id, SUM(…) AS Sales FROM … WHERE … = today - 1
ORDER BY Sales Desc LIMIT 5 UNION ALL
SELECT product_id, SUM(…) AS Sales FROM … WHERE … = today - 2
ORDER BY Sales Desc LIMIT 5 UNION ALL …
```

```
CREATE TABLE Transactions(transaction_date date,
                          product_id int,
                          price decimal);
```

Find the trailing n-day moving average of sales

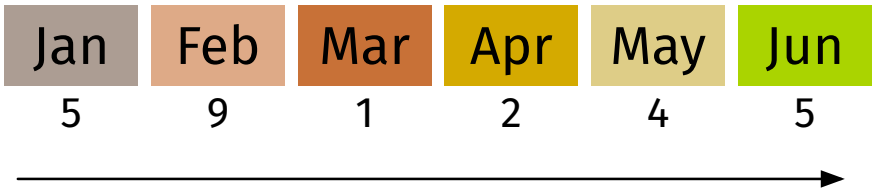
```
CREATE TABLE Transactions(transaction_date date,
                          product_id int,
                          price decimal);
```

Find the trailing n-day moving average of sales

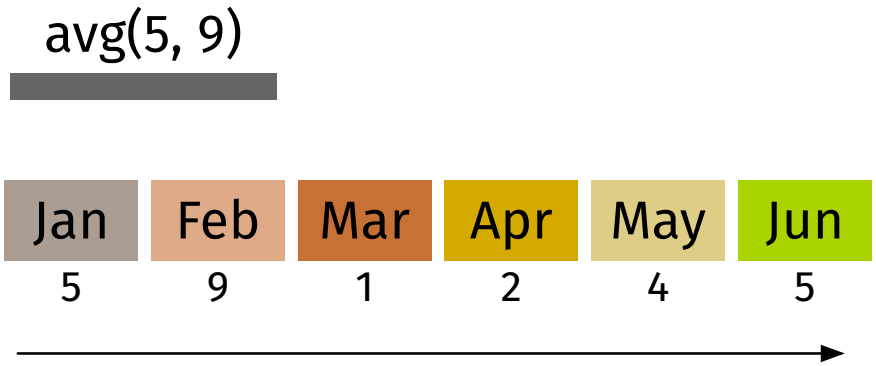
> ... almost impossible to express if n is a parameter (i.e., query size depends on N)

The WINDOW Operator

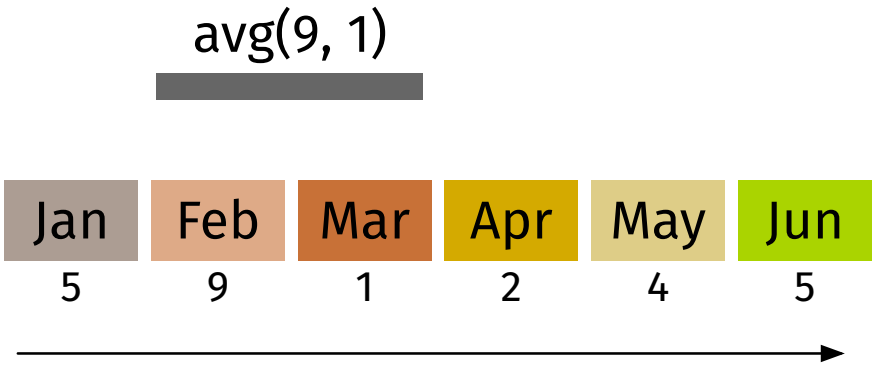
The WINDOW Operator



The WINDOW Operator



The WINDOW Operator



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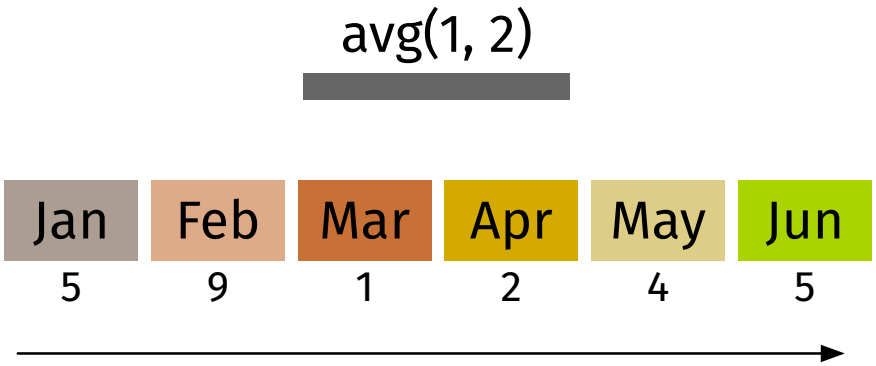

Windows

1. Partition the records into bins
2. Sort the records in each bin
3. Construct a window for each record consisting of records...
   - ... in the same bin
   - ... preceding the record within a given range
   - ... or following the record within a given range
4. Compute an aggregate for each window

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   - ... or following the record within a given range
4. Compute an aggregate for each window

Ranges

- **Physical Size**: N records exactly.
- **Logical Size**: Records within a given range on the sort order.

WINDOW Queries

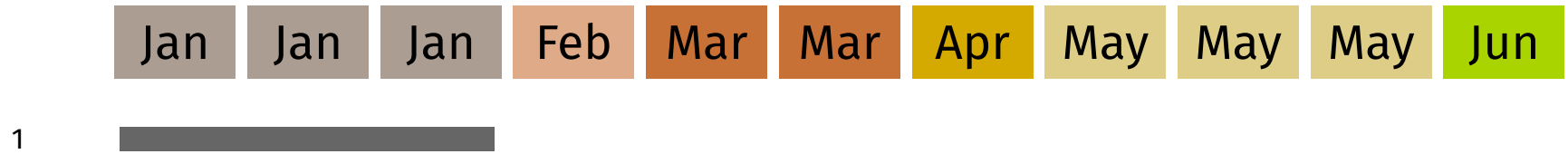

```
SELECT ...,  AGG(...) OVER W
...
WINDOW W AS (
  PARTITION BY attr
  ORDER BY attr
  RANGE BETWEEN range PRECEDING
        AND range FOLLOWING
)
```

WINDOW Queries


```
SELECT L.state, T.month,
   AVG(S.sales) OVER W as movavg
FROM   Sales S, Times T, Locations L
WHERE  S.timeid = T.timeid
  AND  S.locid = L.locid
WINDOW W AS (
   PARTITION BY L.state
   ORDER BY T.month
   RANGE BETWEEN INTERVAL ‘2’ MONTH PRECEDING
         AND INTERVAL ‘0’ MONTH FOLLOWING
)
```

WINDOW Queries

WINDOW Queries



WINDOW Queries

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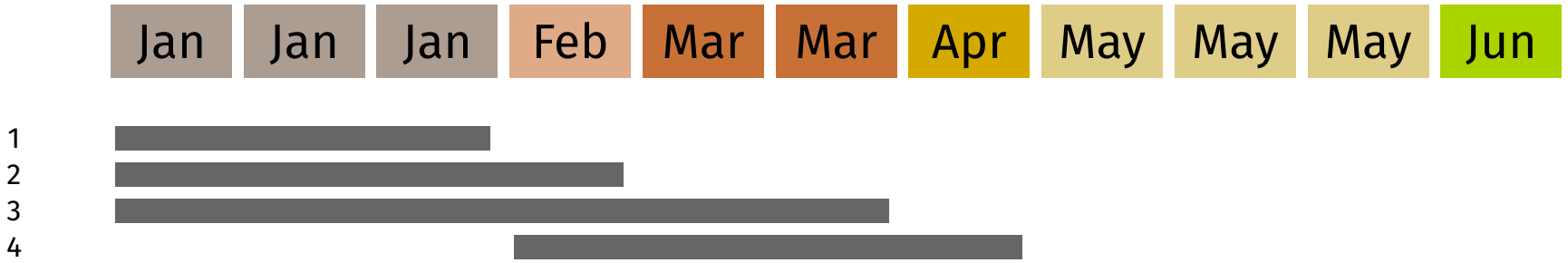
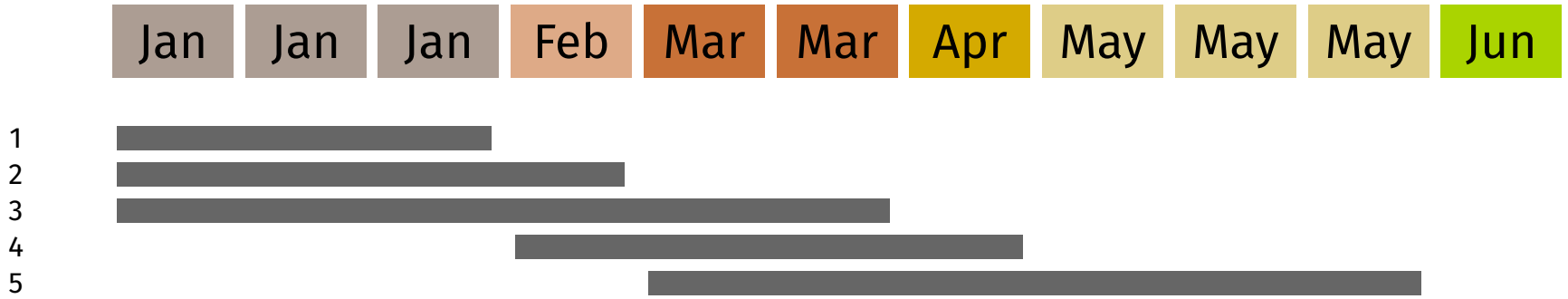


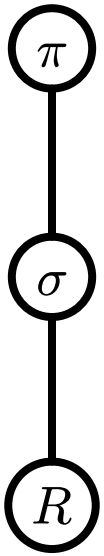
WINDOW Queries



Streaming Queries

Challenge: Standing queries react to new data *as it arrives*

Push vs Pull - Pull



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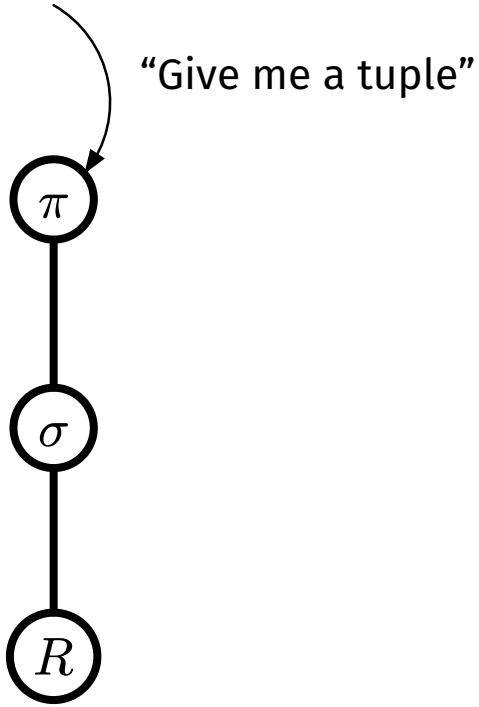
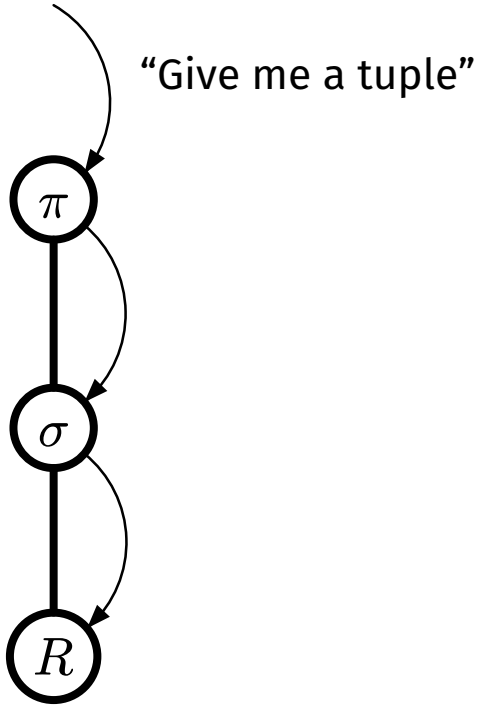


Push vs Pull - Pull



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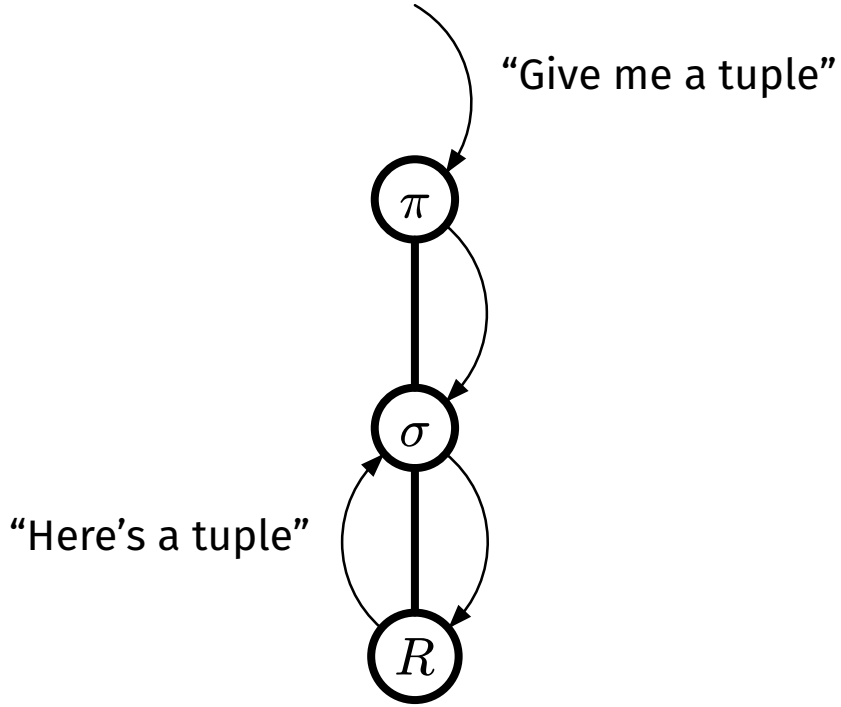

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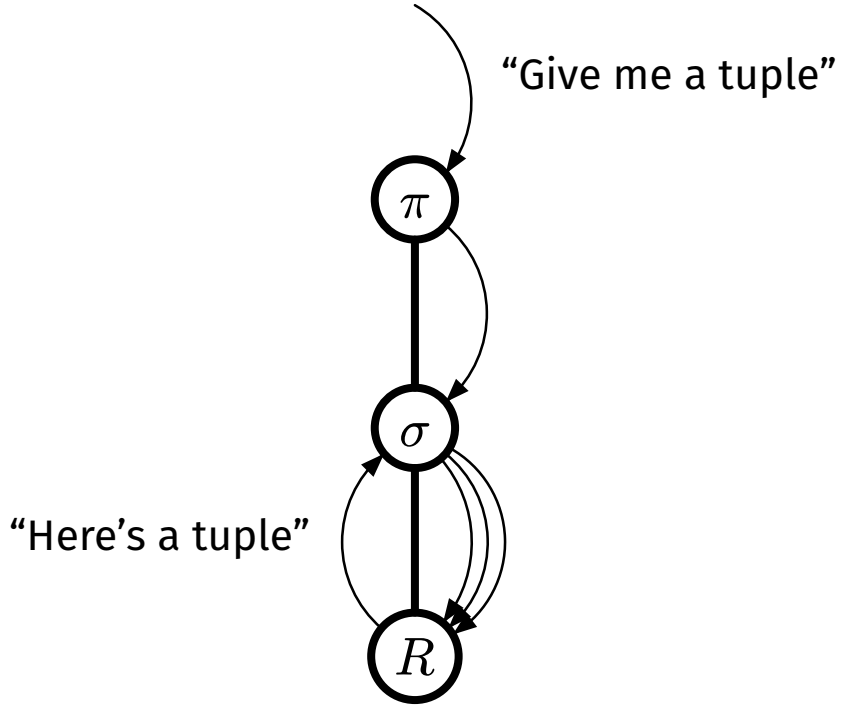

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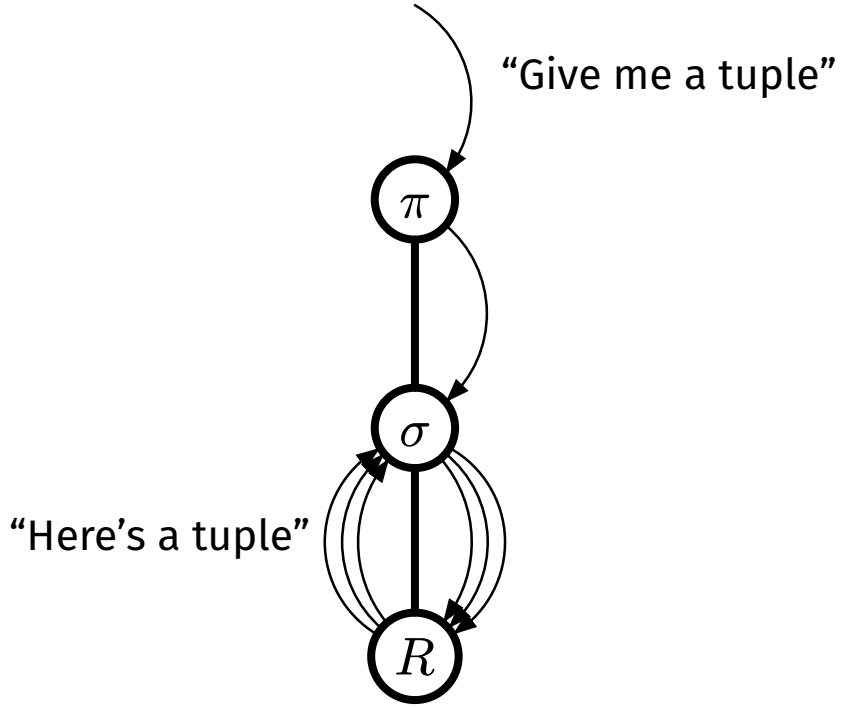

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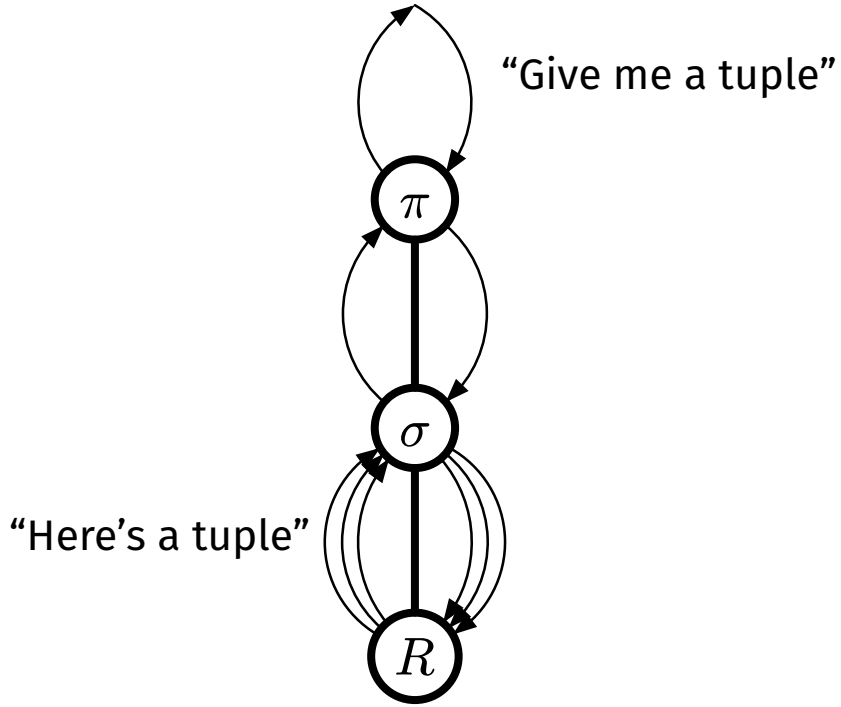
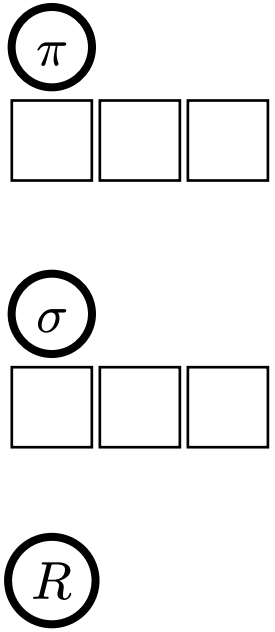
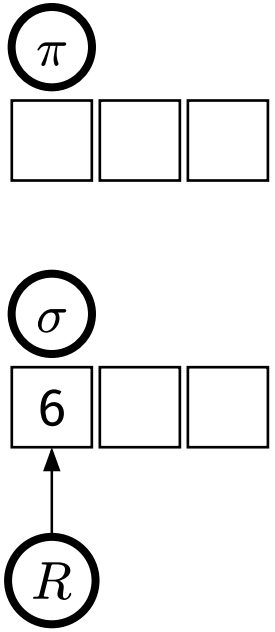


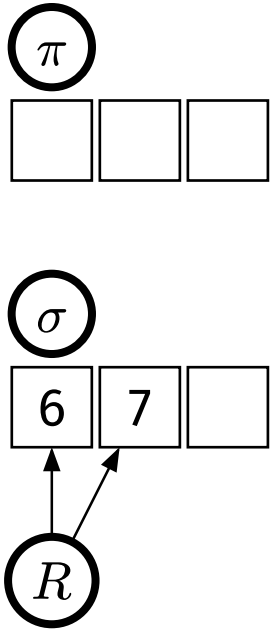
Push vs Pull - Push



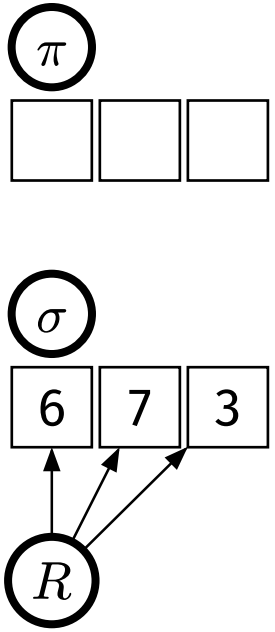
Push vs Pull - Push



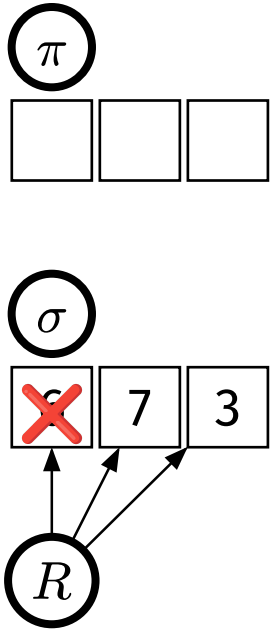
Push vs Pull - Push



Push vs Pull - Push



Push vs Pull - Push



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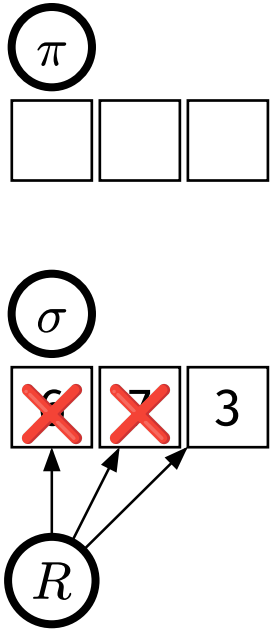

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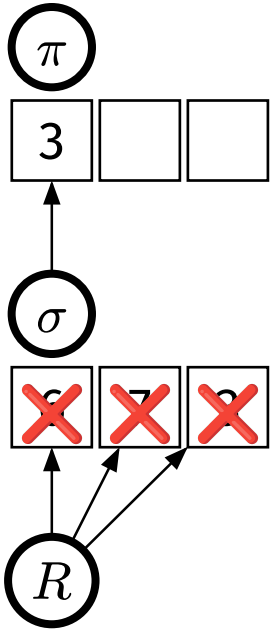
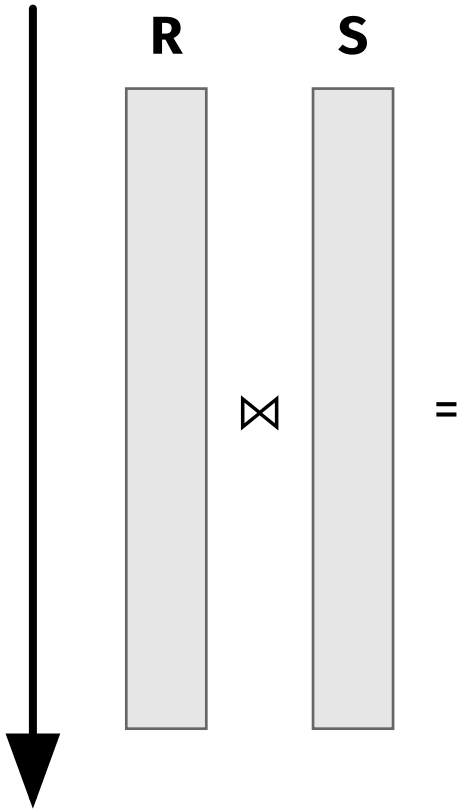


Push Operators

- Each operator acts independently
- Each operator buffers input
- Operators are scheduled

Streaming Joins

Streaming Join



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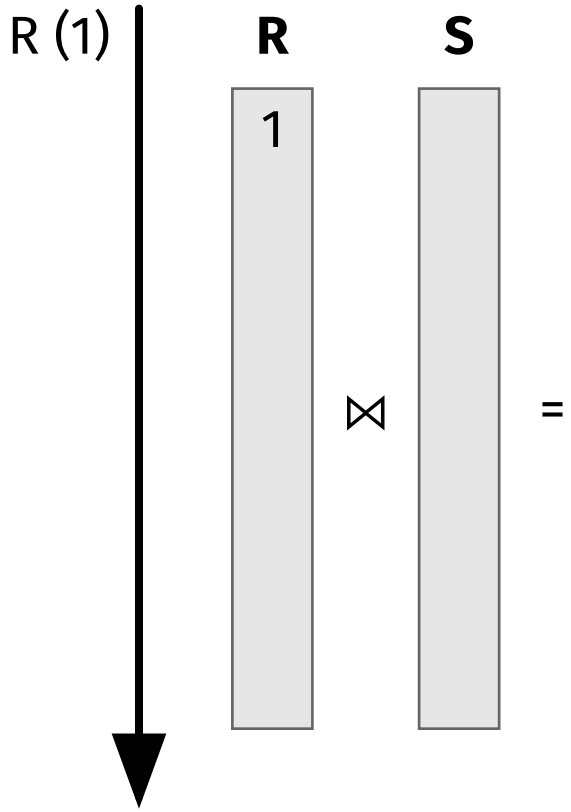

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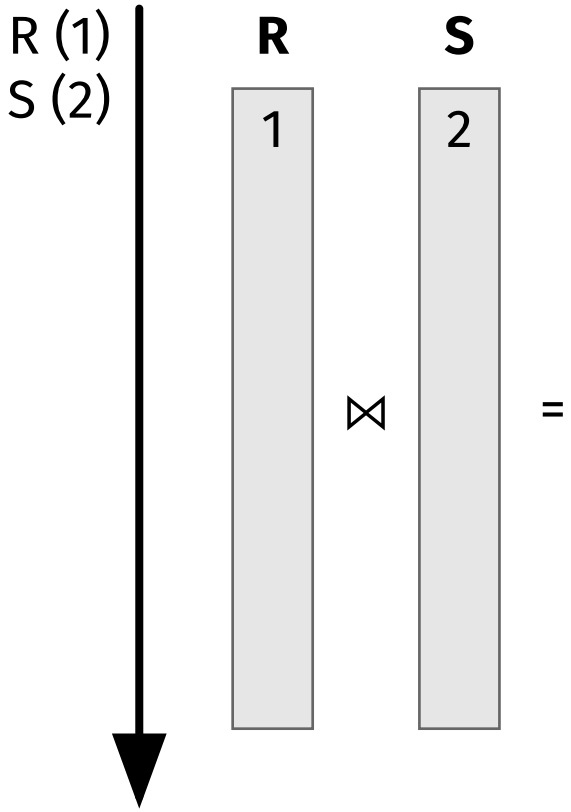

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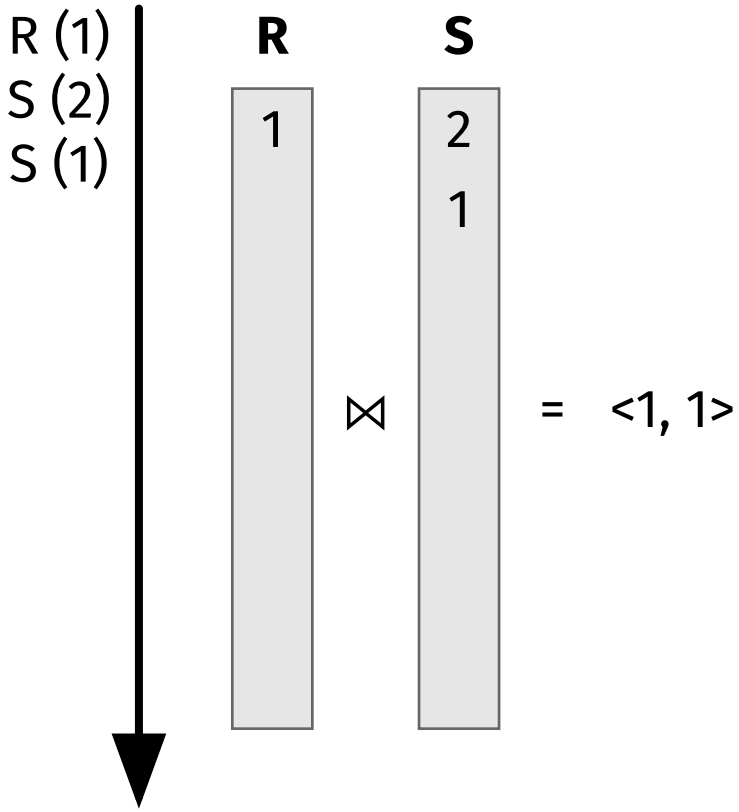

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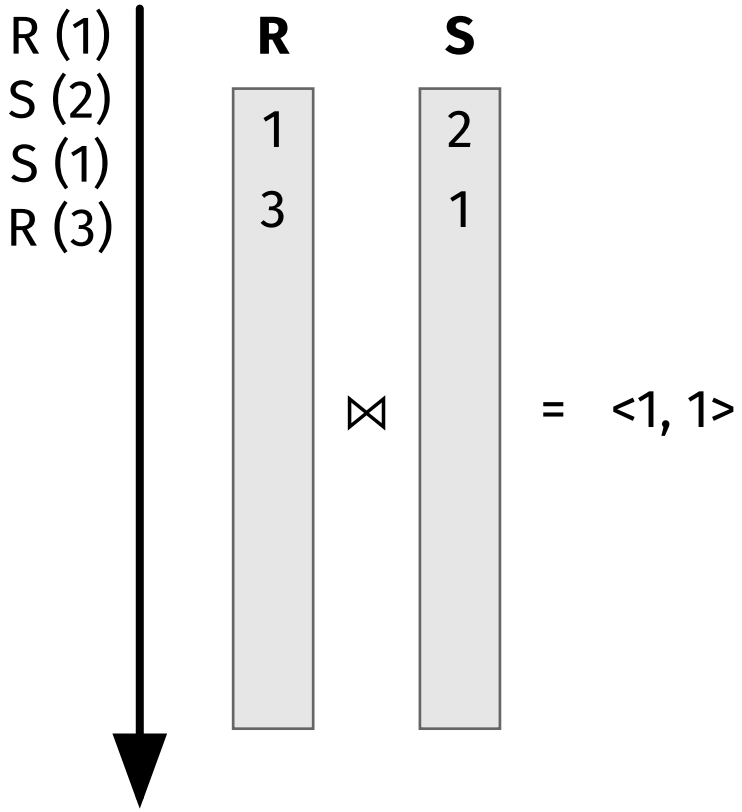

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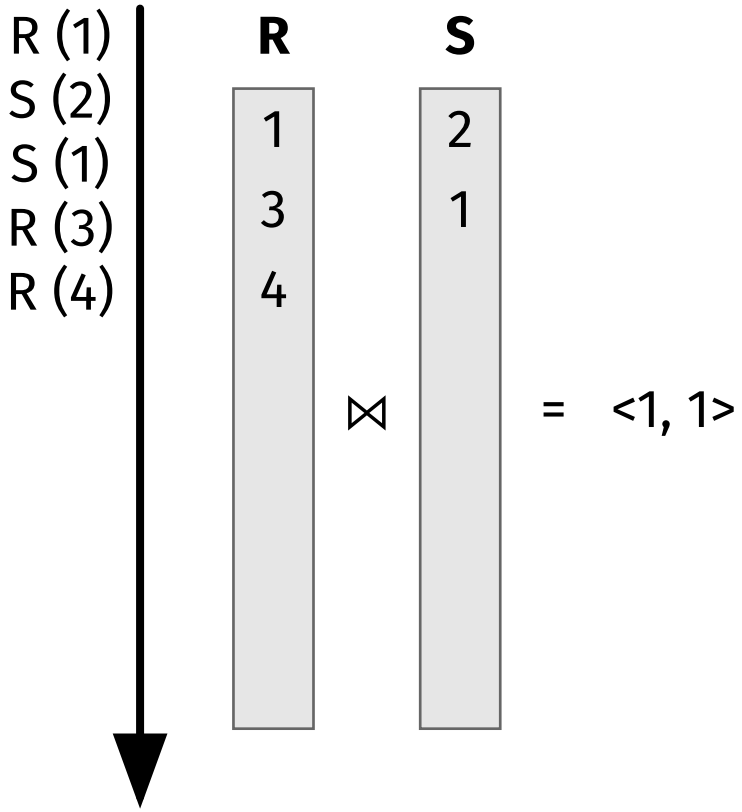

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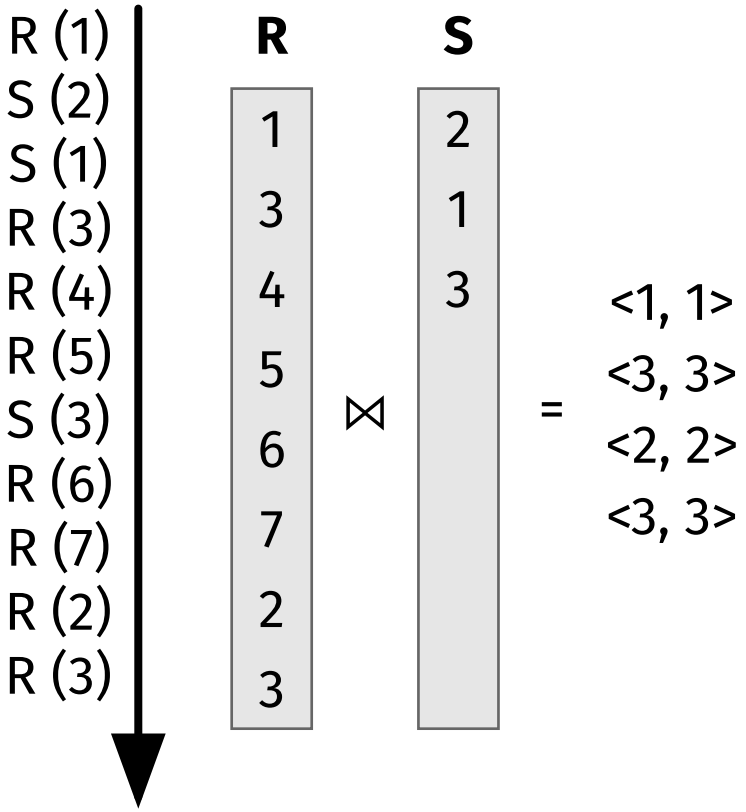

- **Problem 1**: You eventually run out of memory.
- **Problem 2**: The cost of iterating over the buffer keeps growing.

Streaming Joins

- **Idea 1**: Mandate only `WINDOW` queries

Streaming Joins

- **Idea 1**: Mandate only `WINDOW` queries
- **Idea 2**: Index the buffer

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- **Idea 2**: Index the buffer

Challenge: How do we maintain the index as tuples fall out of the buffer?

Streaming Indexes

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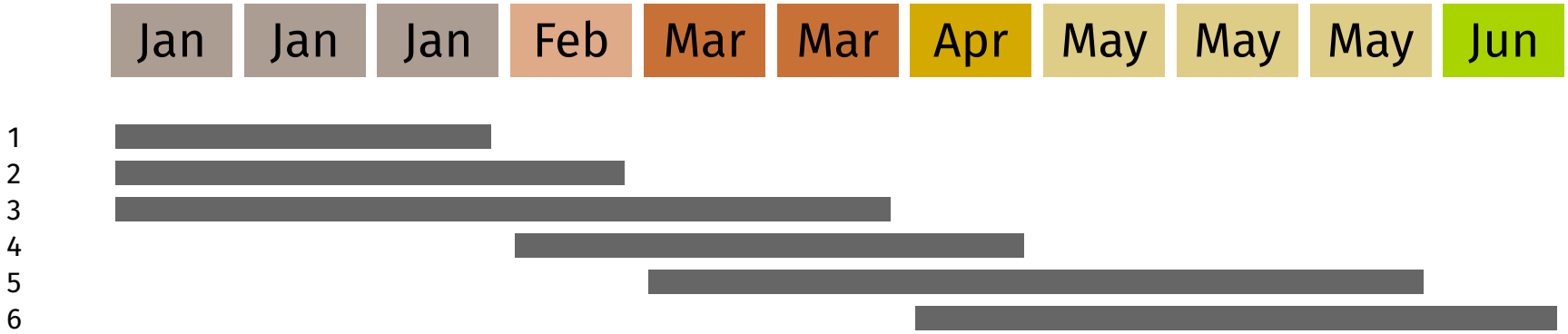
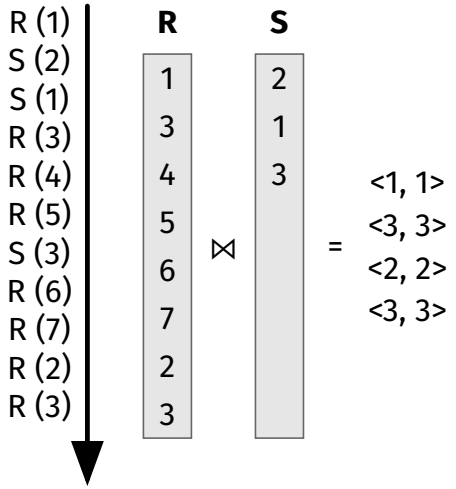


Tuples always enter from one side and exit out the other



Lots of lookups for active tuples

How do we organize the data?

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Queue/Linked List

- Insert/remove in (nearly) temporal order

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Queue/Linked List

- Insert/remove in (nearly) temporal order

Hash/Tree

- Efficient lookup for (randomly ordered) join keys

Streaming Indexes

<1, **1**>

<2, **3**>

<3, **4**>

<4, **3**>

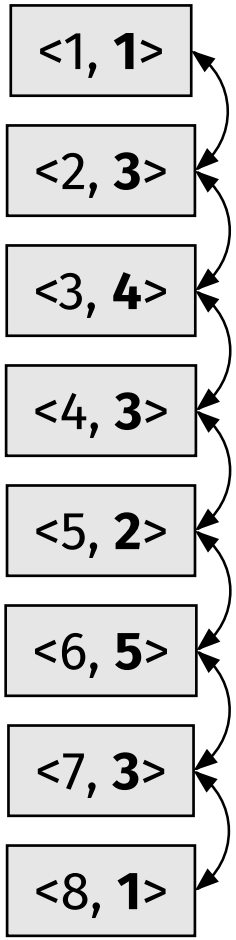
<5, **2**>

<6, **5**>

<7, **3**>

<8, **1**>

Streaming Indexes



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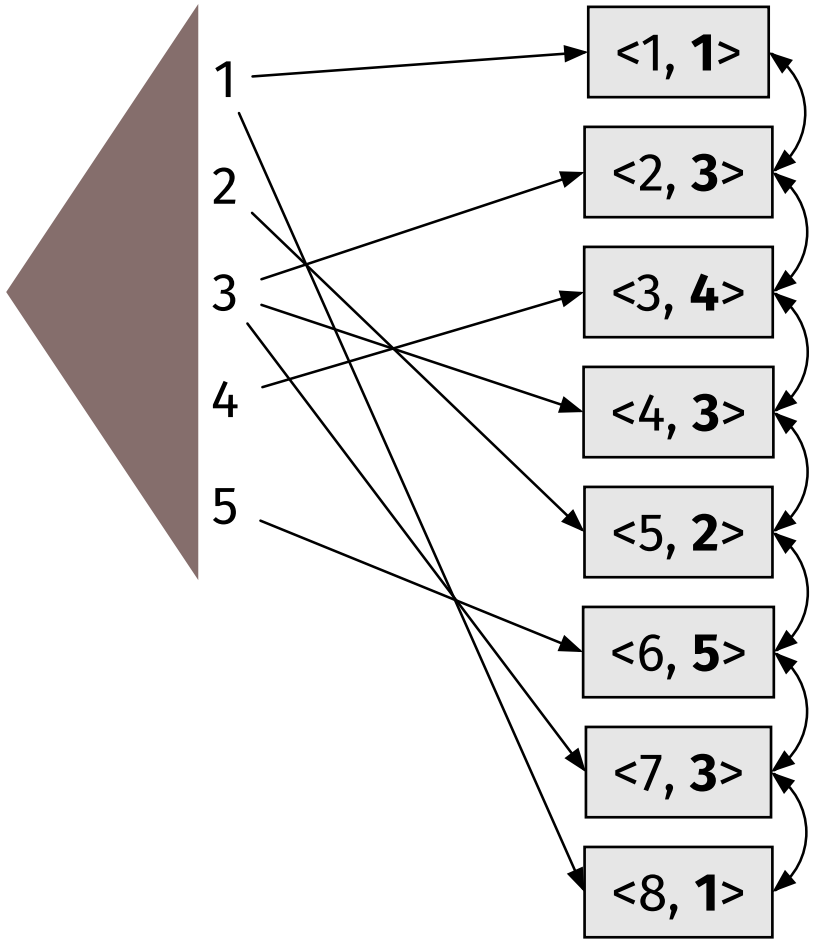

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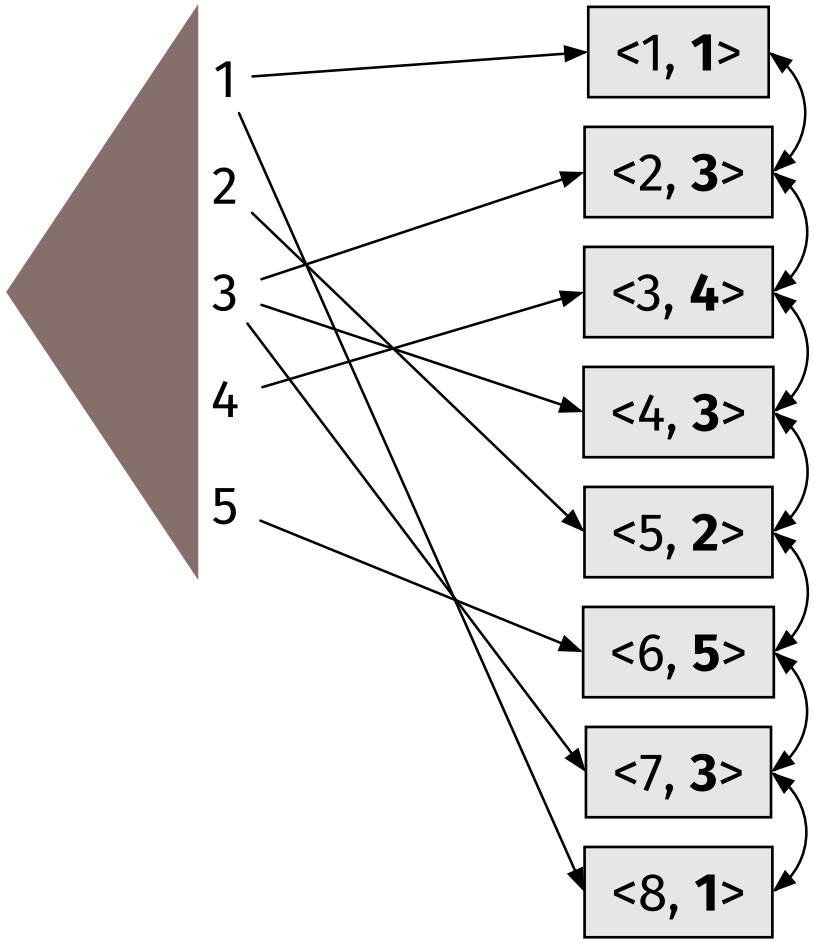

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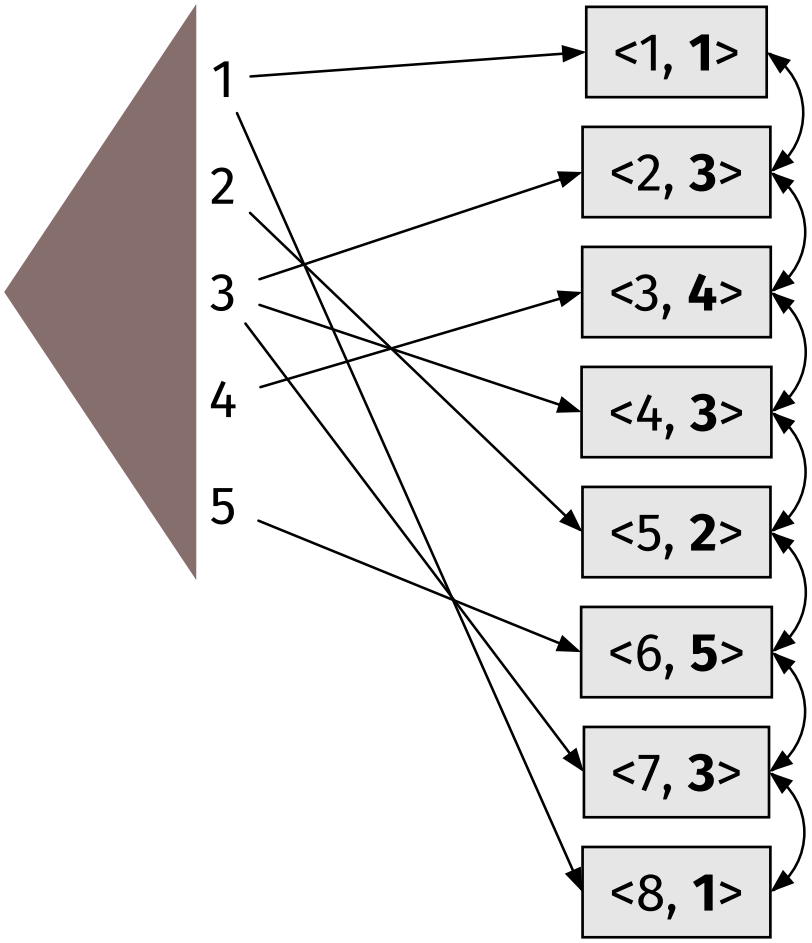

Streaming Indexes

$O(1 + \log(|W|))$ per insertion.

$O(1 + \log(|W|))$ per expiration.

WINDOW Indexes - SUM

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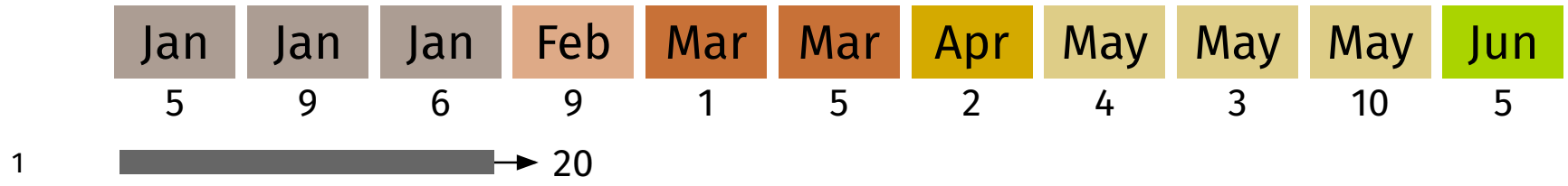
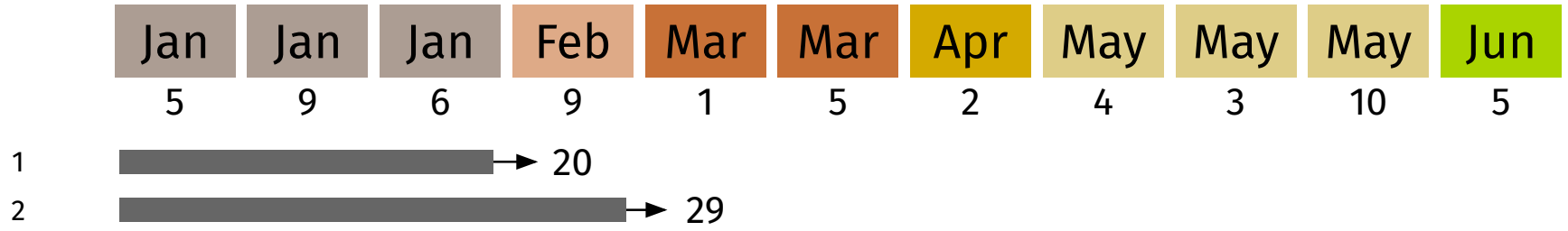
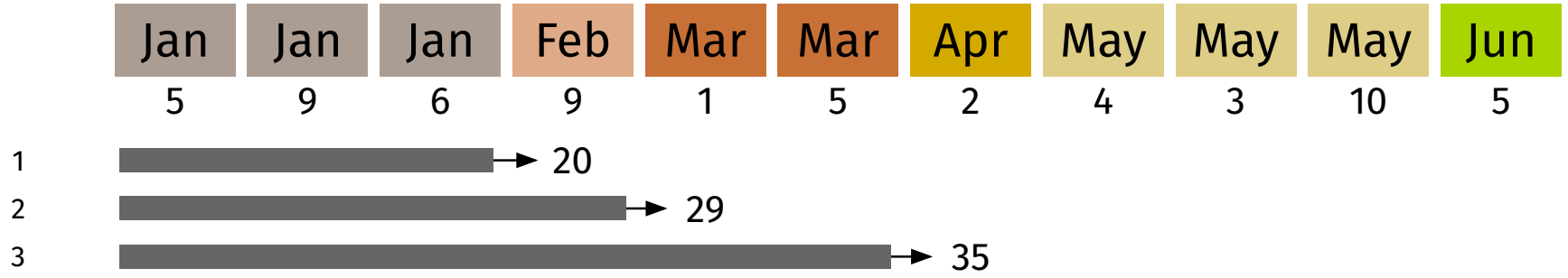


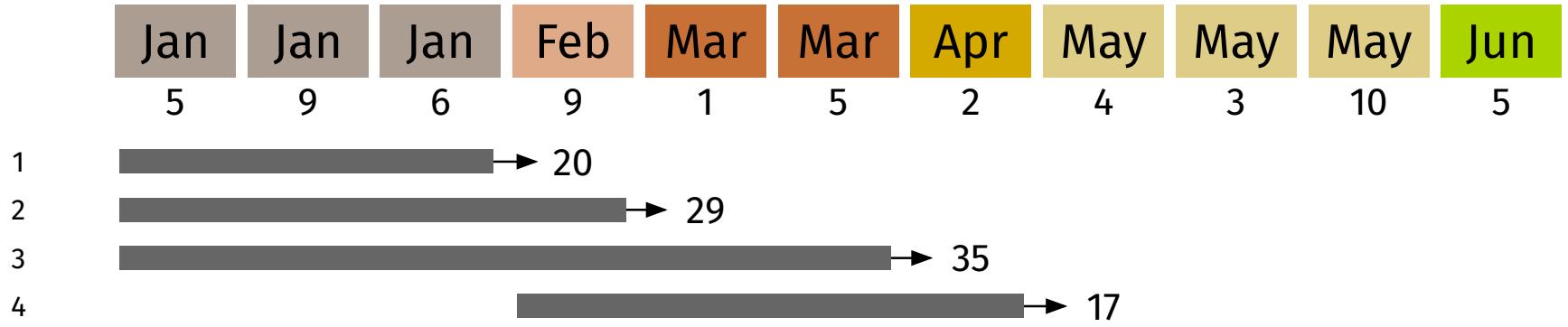
WINDOW Indexes - SUM



WINDOW Indexes - SUM



WINDOW Indexes - SUM



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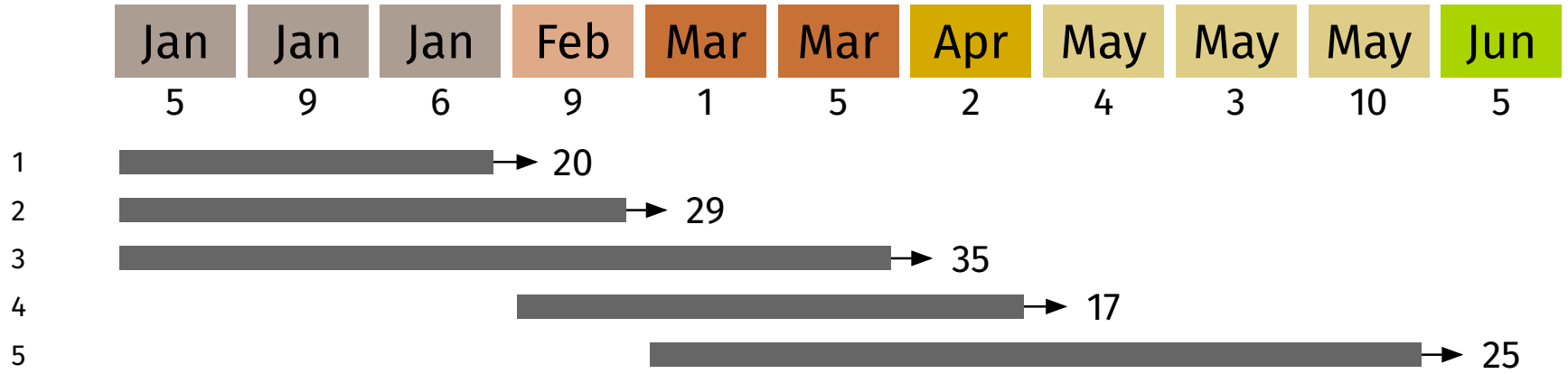

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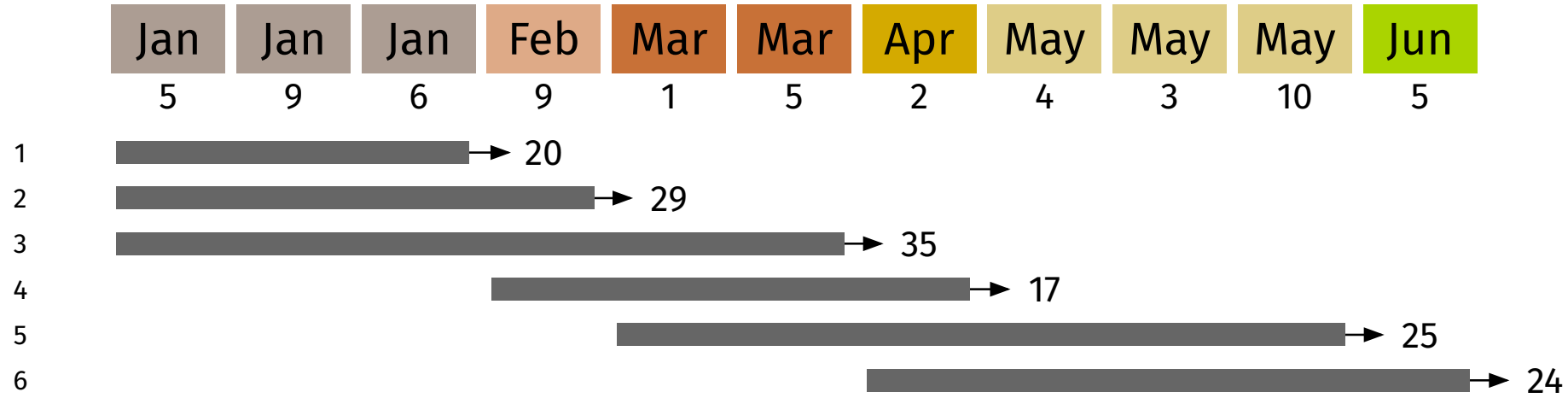

WINDOW Indexes - MAX

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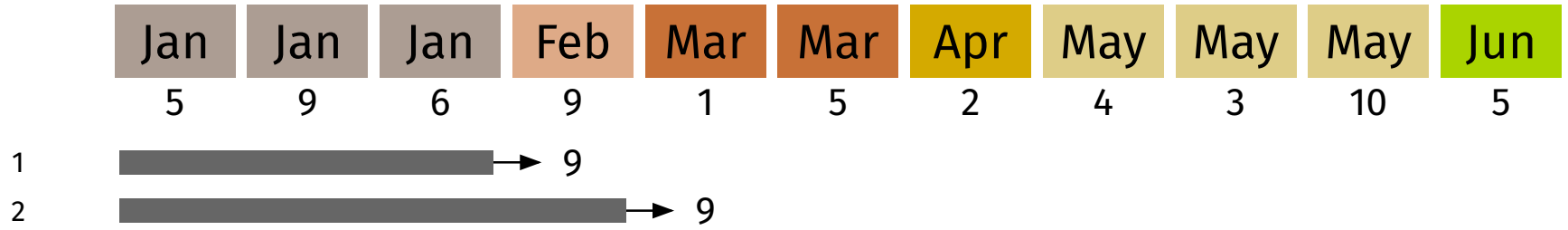
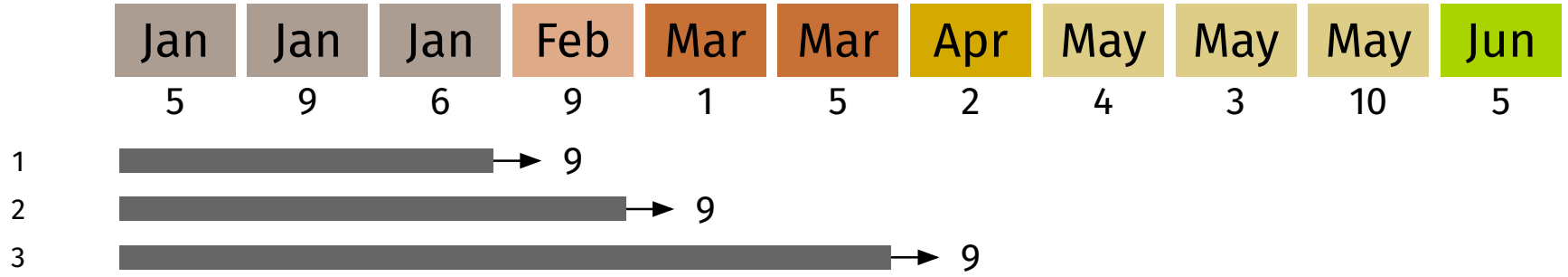


WINDOW Indexes - MAX



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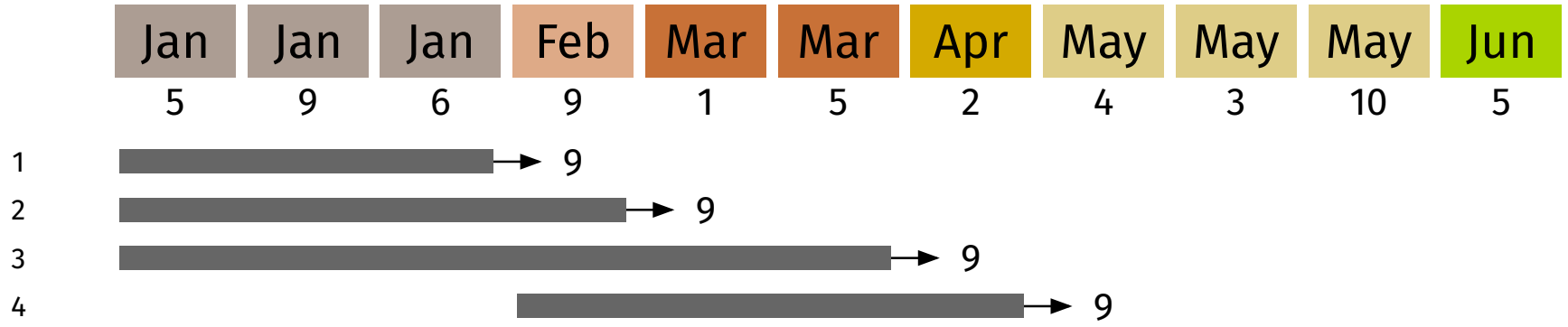
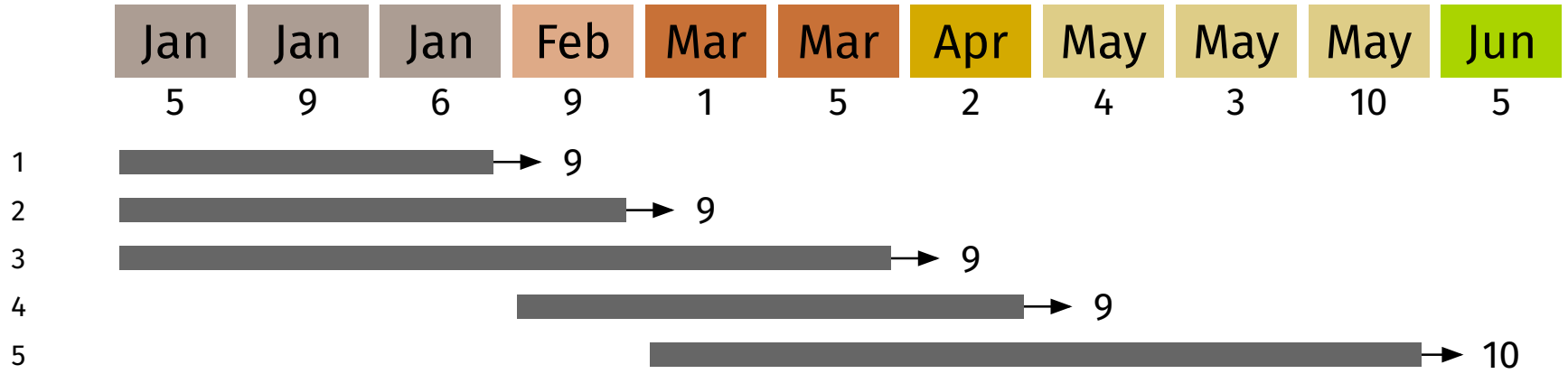


WINDOW Indexes - MAX



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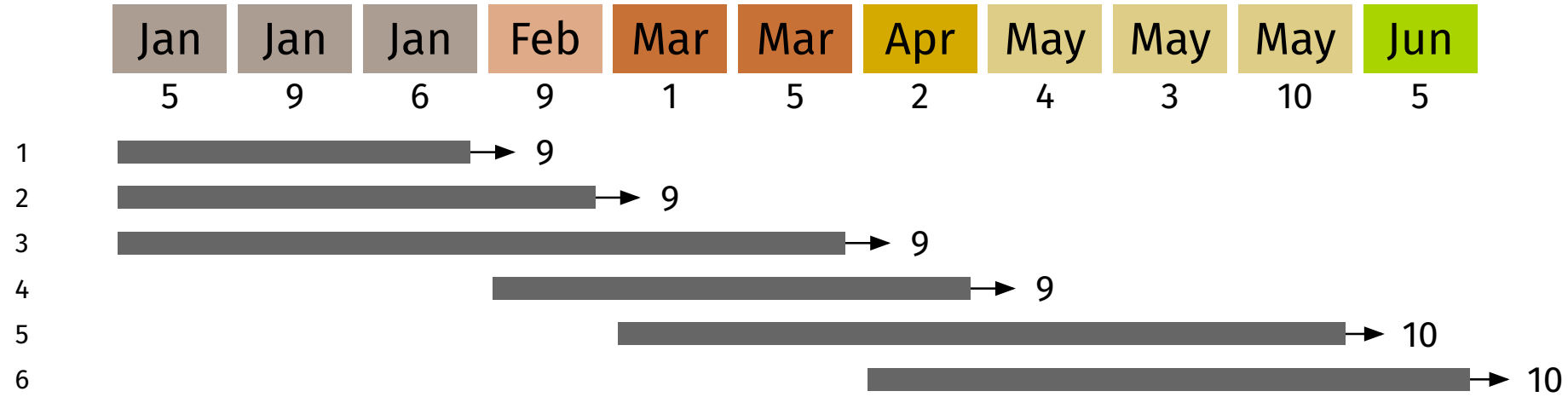


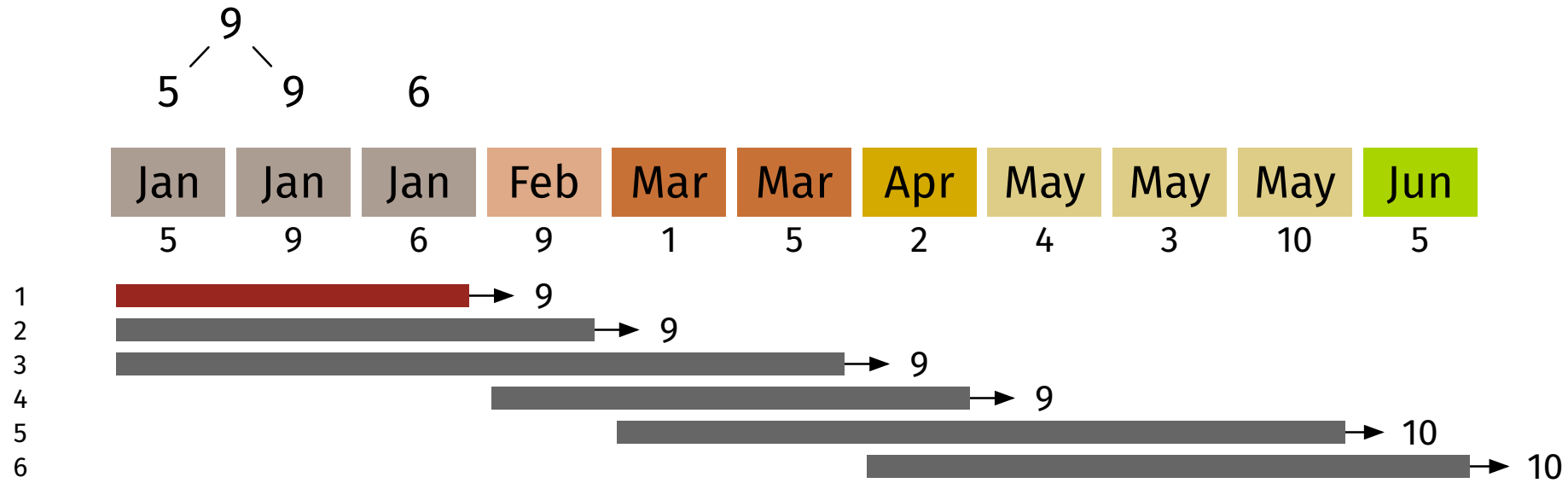
Ring Aggregates (Sum, Count, Average)

- Add new values: $O(1)$ per value
- Remove old values: $O(1)$ per value

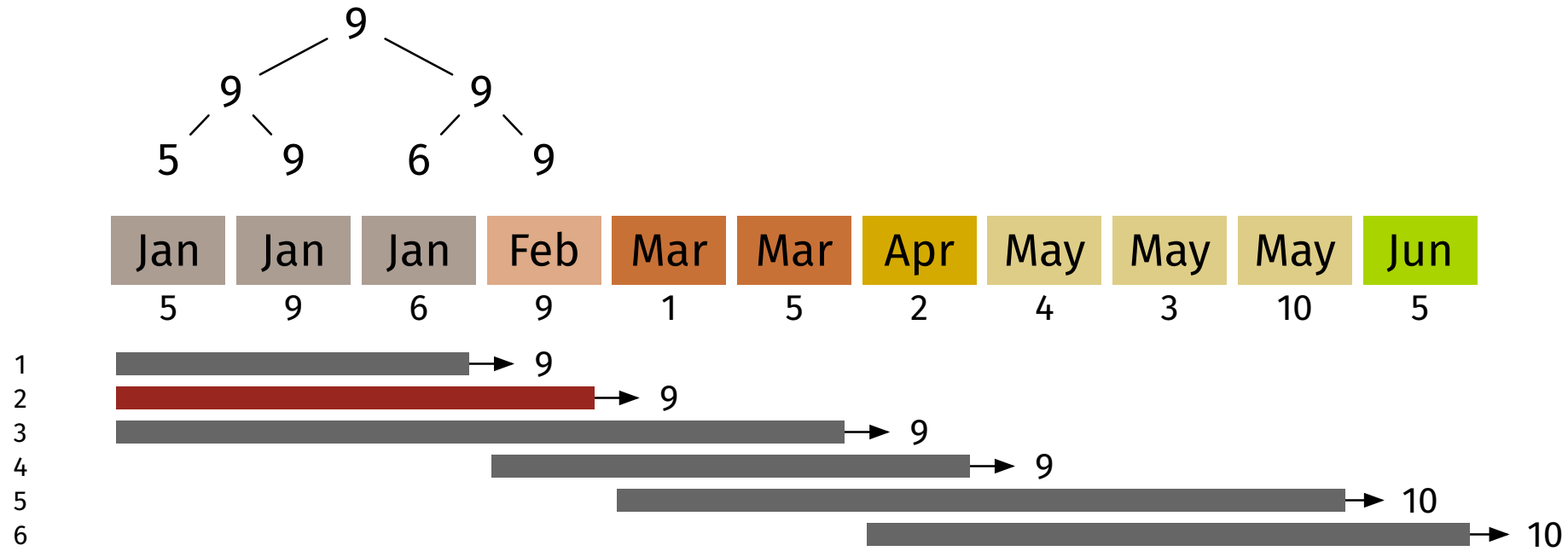
Semiring Aggregates (Min, Max)

- Rescan for new max: $O(|W|)$ per value

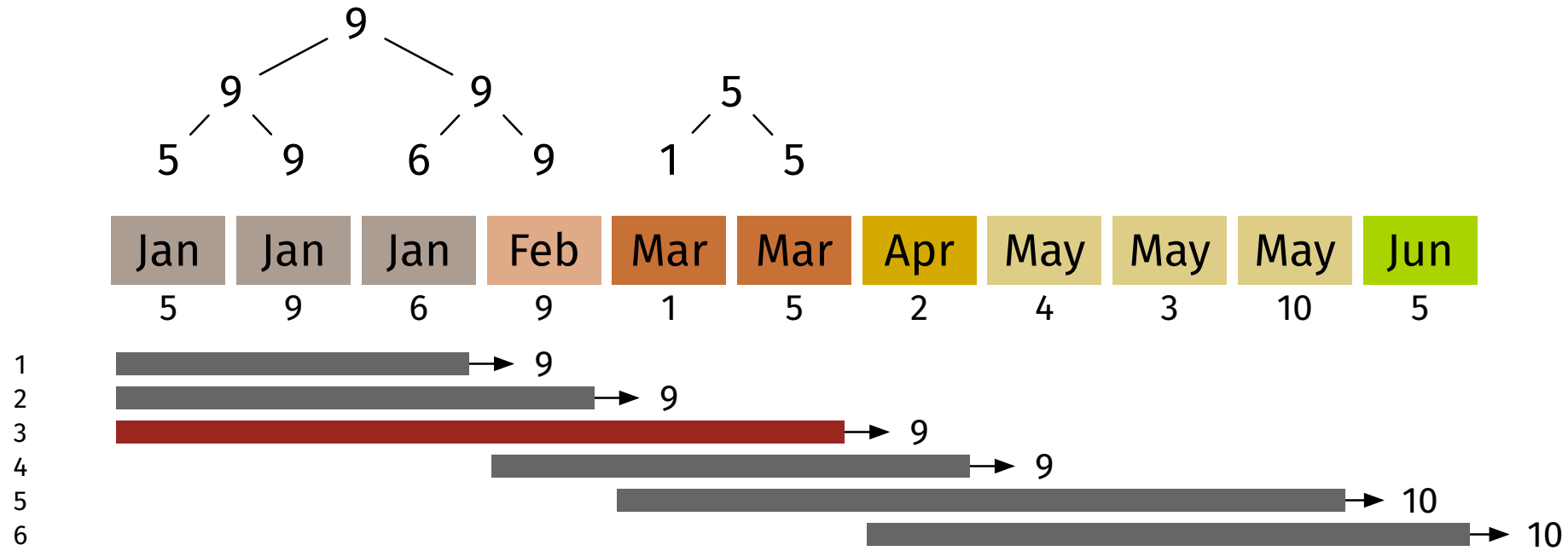
WINDOW Indexes



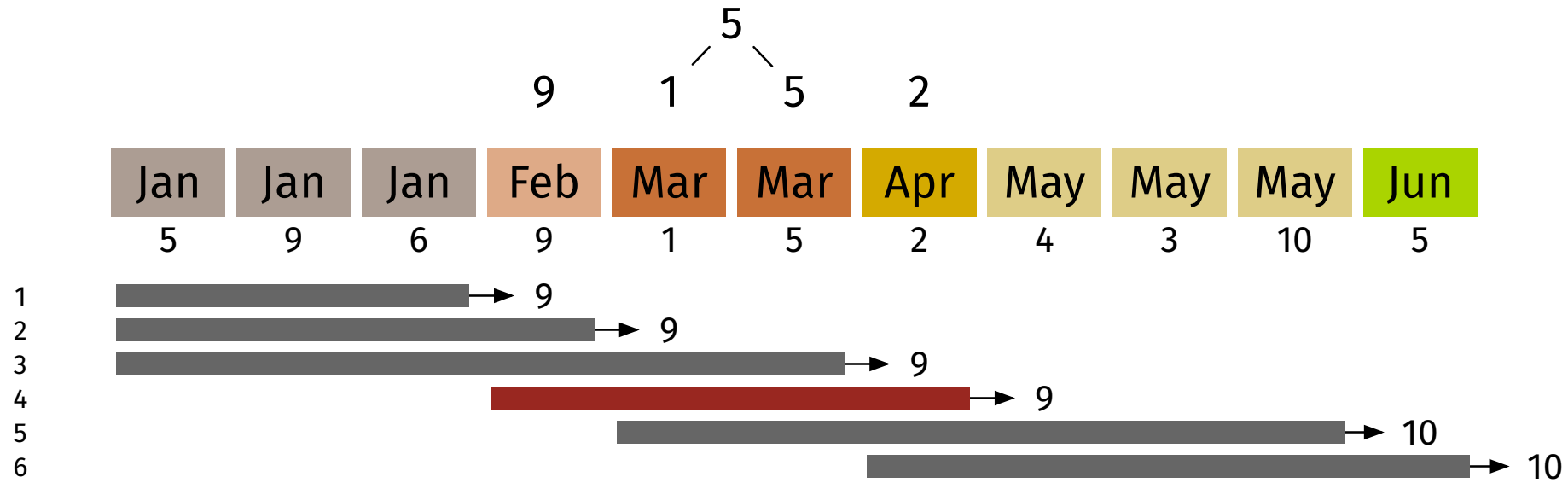
WINDOW Indexes



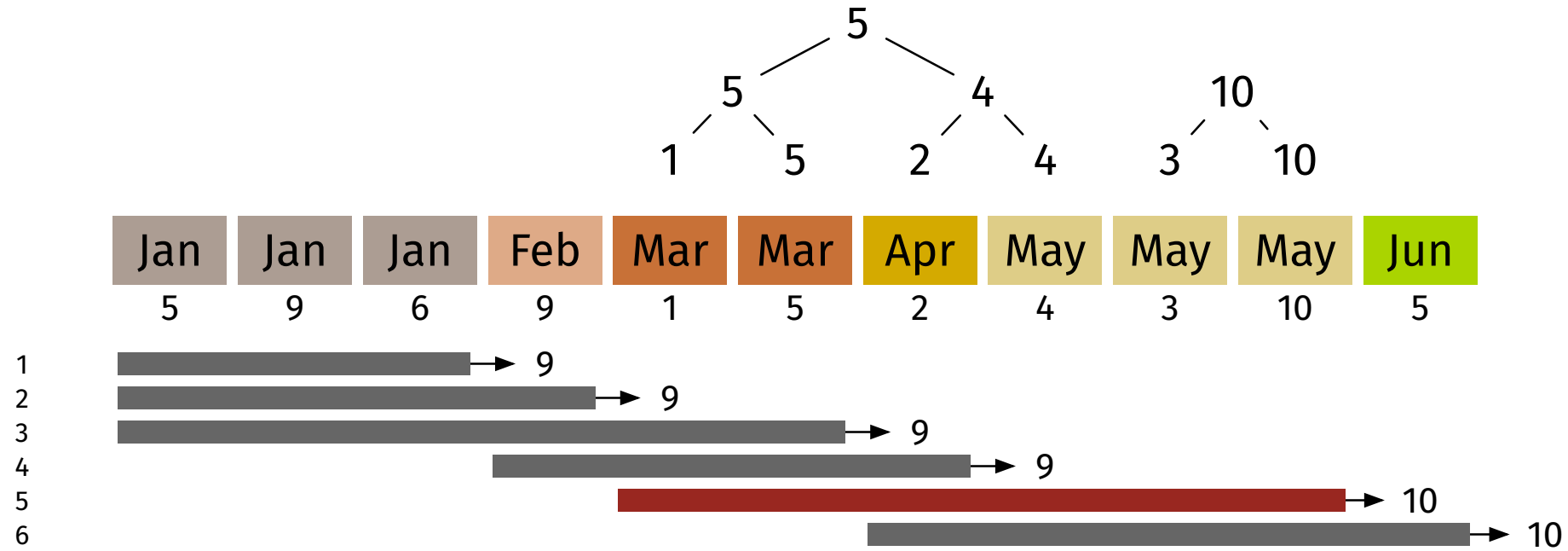
WINDOW Indexes



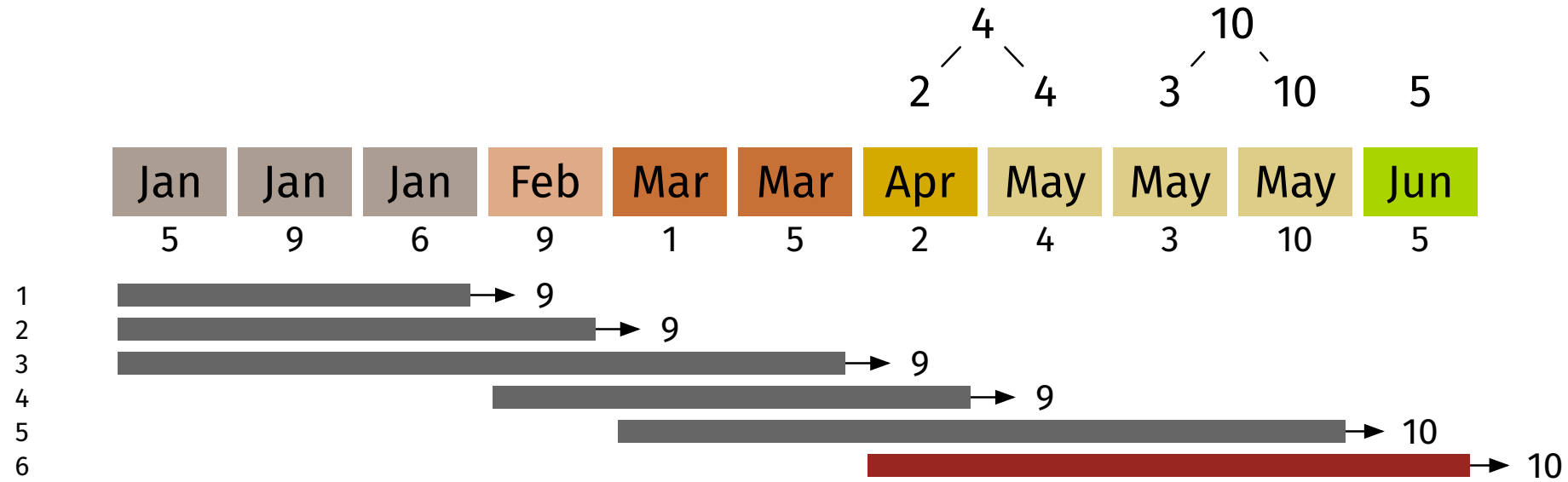
WINDOW Indexes



WINDOW Indexes



WINDOW Indexes



WINDOW queries

- Aggregate values over sequential ranges

Push vs Pull Data

- Push works better when sources produce data at different rates

Streaming Joins

- Streaming focuses on ripple-style joins

Streaming Indexing

- Linked Hash/Tree index for efficient windowed joins

Aggregation

- Sliding window aggregation