Summary of Big Data Modeling and Management

After this video you will be able to..

- Recall why big data modeling and management is essential in preparing to gain insights from your data
- Summarize different kinds of data models
- Describe streaming data and the different challenges it presents
- Explain the differences between a DBMS and a BDMS

Big Data Modeling and Management

- Data modeling tells you
  - How your data is structured
  - What operations can be done on the data
  - What constraints apply to the data
- Database Management Systems
  - Typically handle many low-level details of data storage, manipulation, retrieval, transactional updates, failure and security
  - Relieves a user to focus on higher level operations like querying and analysis

Different Data Models

- Relational Data
  - Where data look like tables
- Semi-structured Data
  - Document data, XML and JSON
- Graph Data
  - Social Networks, email networks
- Text Data
  - Articles, reports

Streaming Data

- An infinite flow of data coming from a data source
  - Sensor data from instruments
  - Stock price data
- Data rates vary – can be too fast and too large to store
- Often processed in memory
- May need to be processed immediately
  - Inform whenever 3 tech stocks go up by 3% within a 30 second span
  - Used for event detection and prediction

DBMS and BDMS

- BDMS
  - Designed for parallel and distributed processing
    - Data-partitioned parallelism
  - May not always guarantee consistency for every update
    - More likely to guarantee eventual consistency
  - Often built-on Hadoop
    - Offer Map-reduce style computation
    - Utilizes replication natively offered by HDFS

Why is Big Data Processing Different?

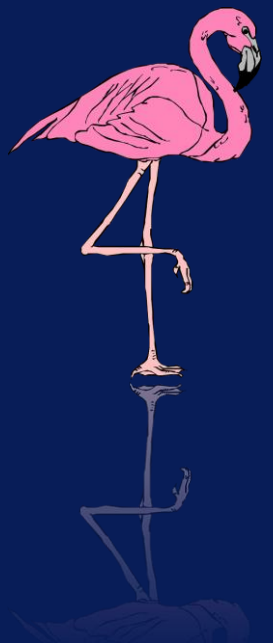
After this video you will be able to..

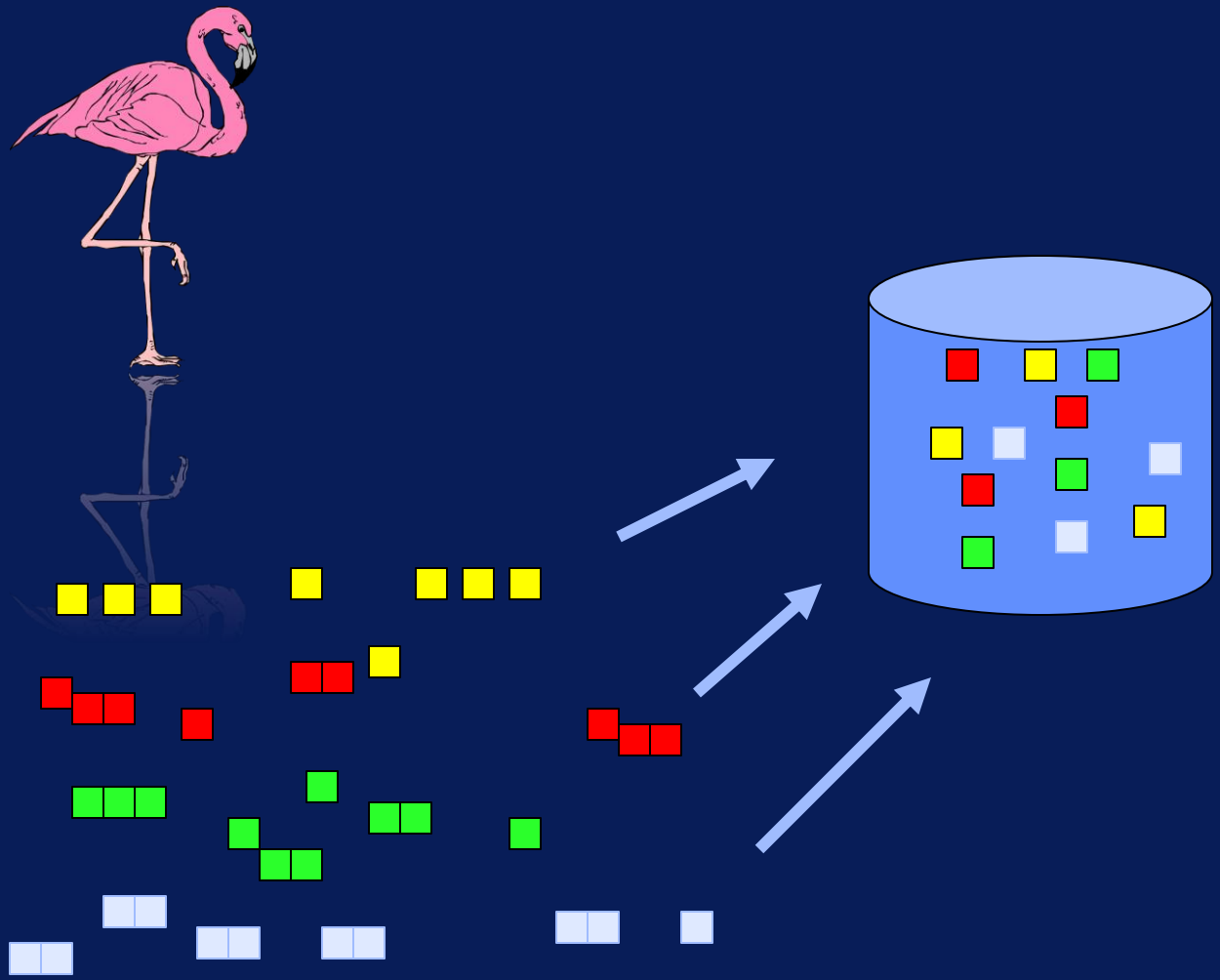
- Summarize the requirements of programming models for big data and why you should care about them

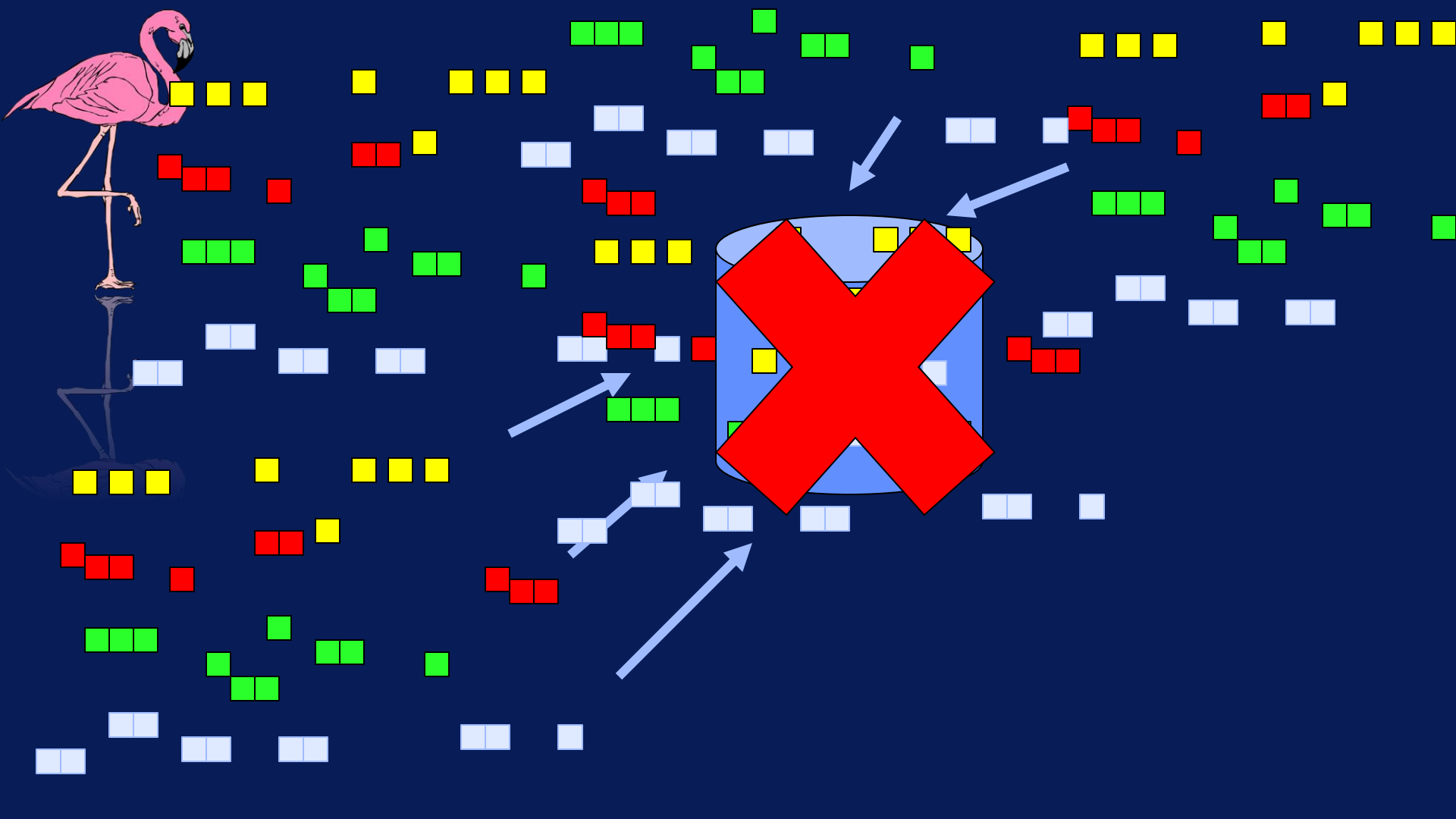
- Explain how the challenges of big data related to its variety, volume and velocity affects its processing

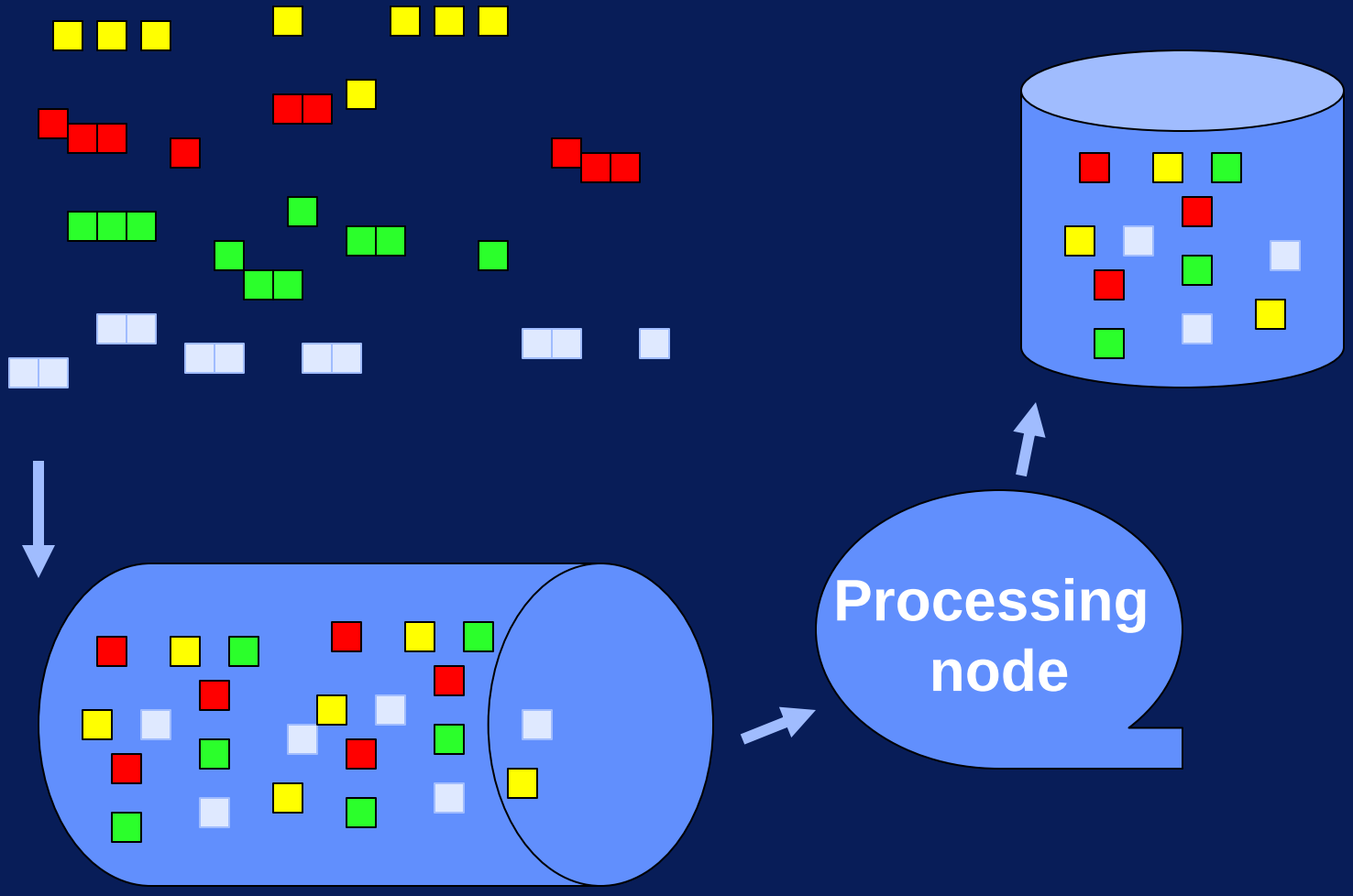
Requirements for Big Data Systems

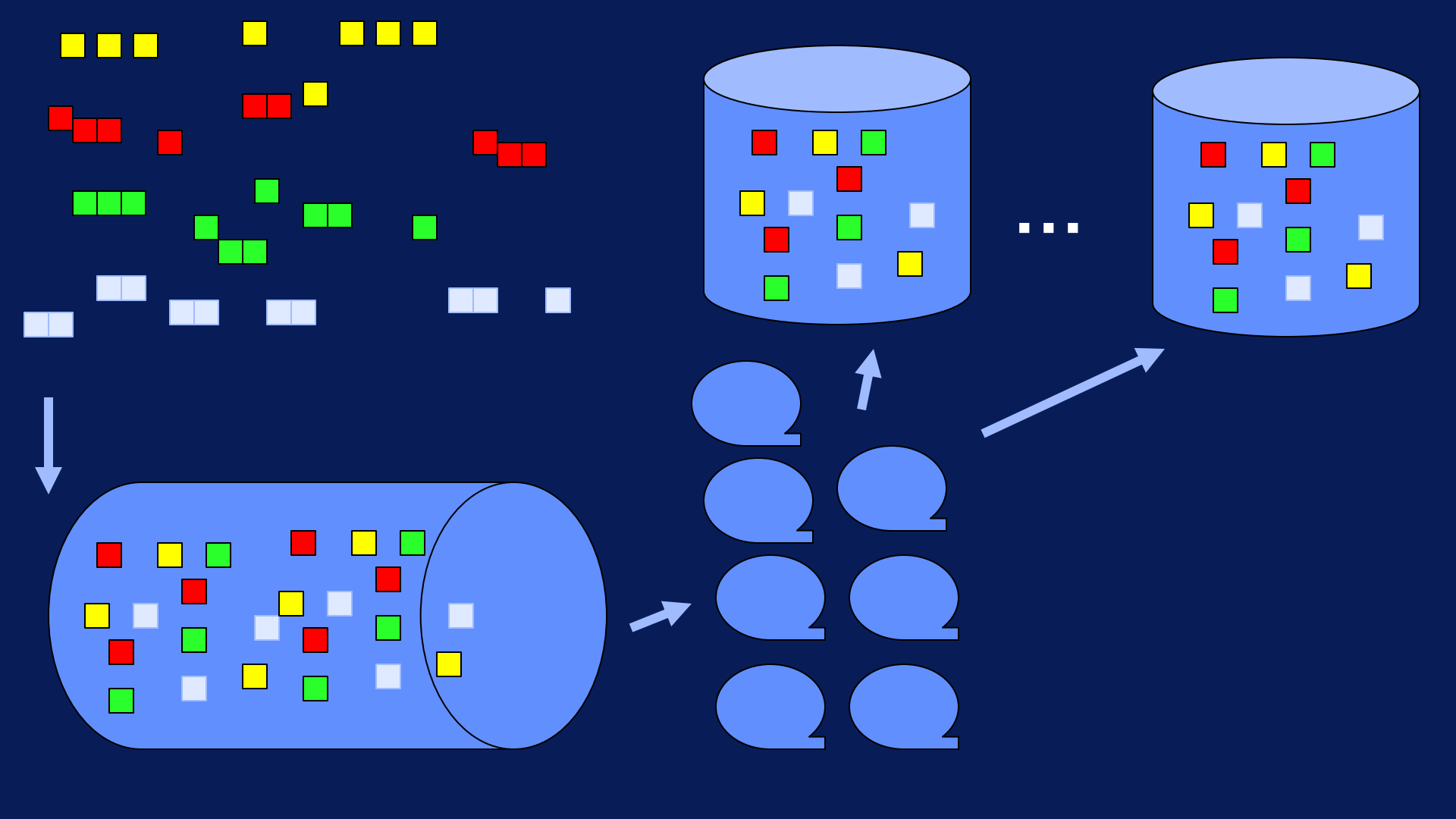
A Big Data System for an Online Game

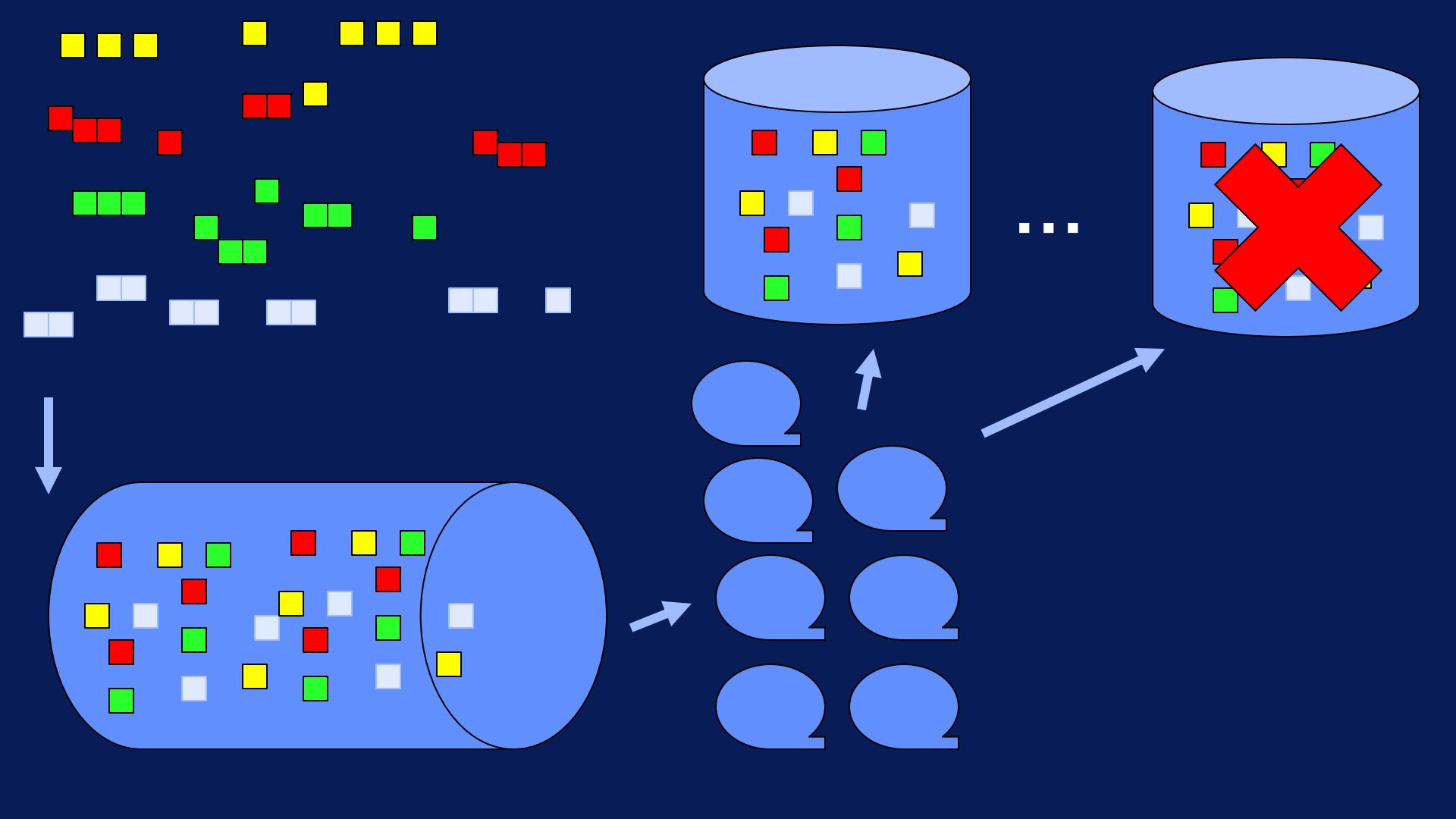


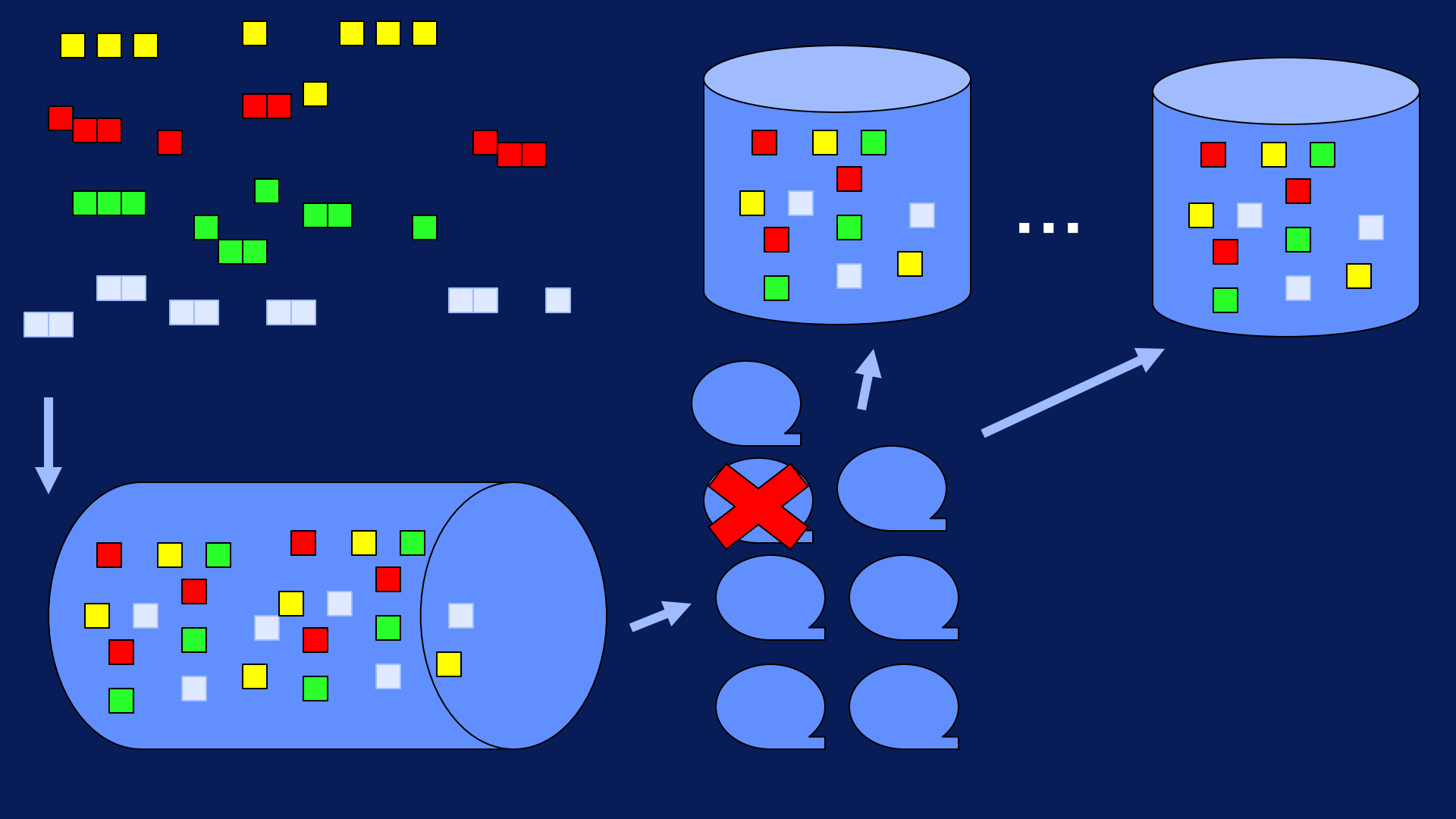


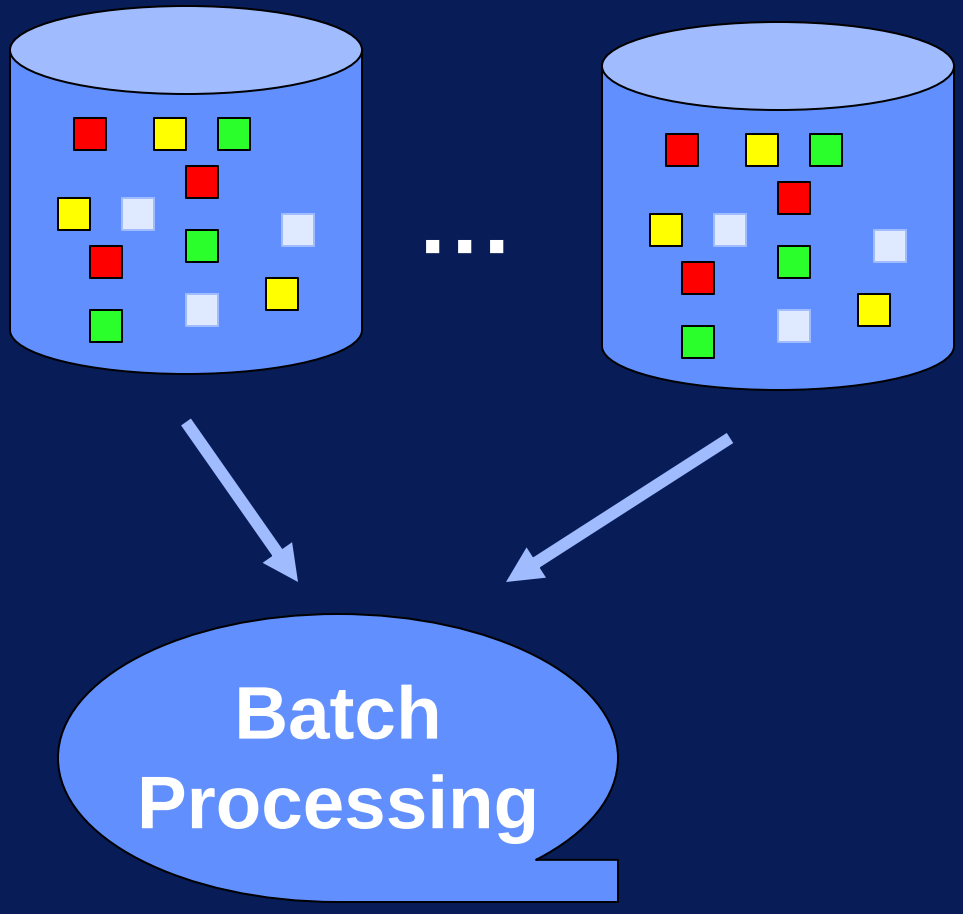


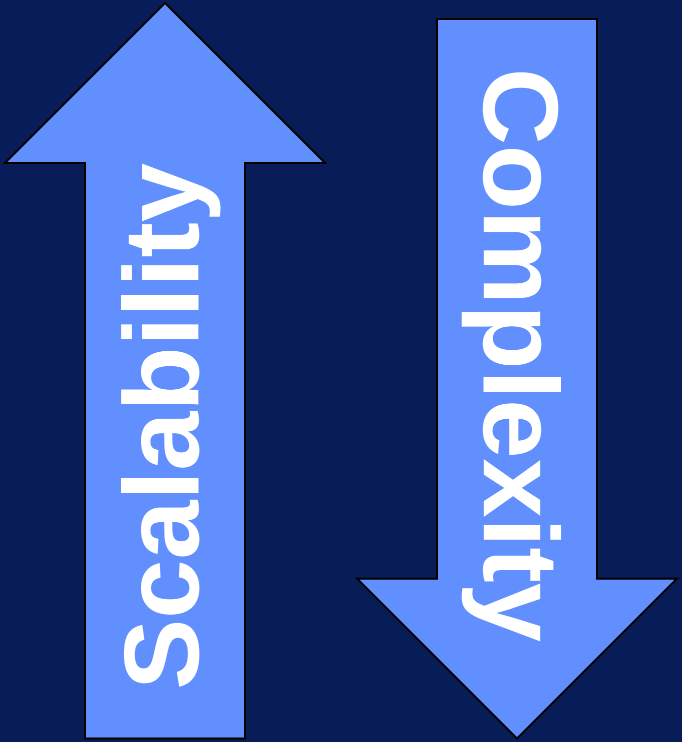

Processing node

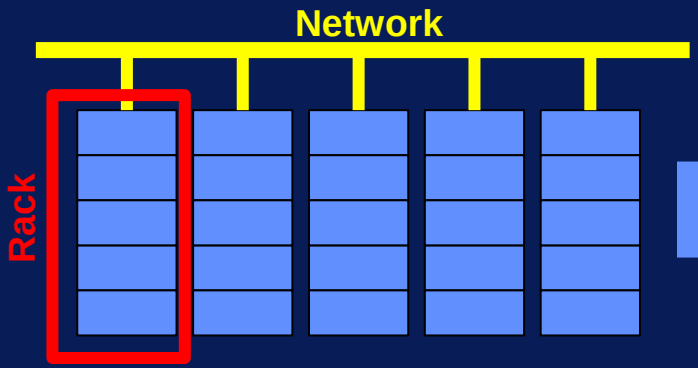




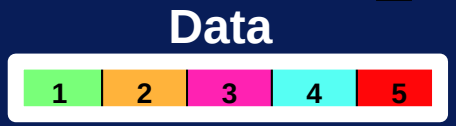


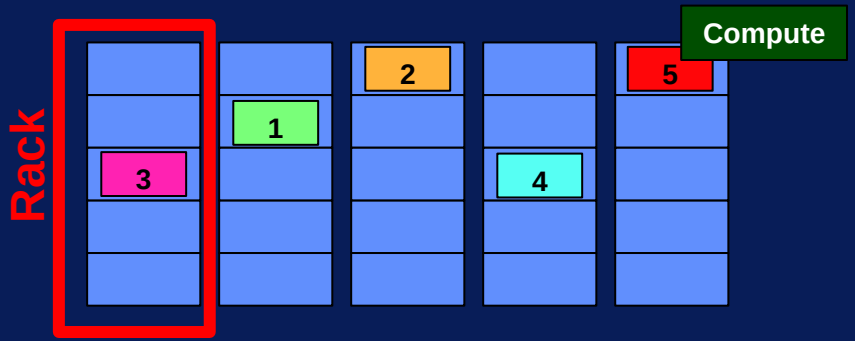

...
Batch
Processing


Scalability
Complexity



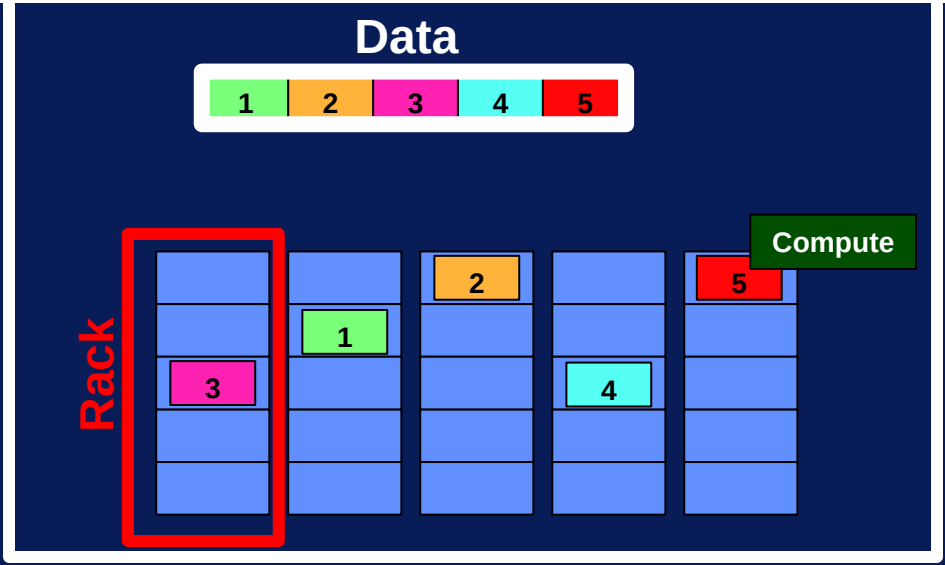
Data-parallel scalability





Programming Model = abstractions

Runtime Libraries + Programming Languages



Requirements for Big Data Systems

1. Support Big Data Operations

Split volumes of data

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Access data fast

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Split volumes of data

Access data fast

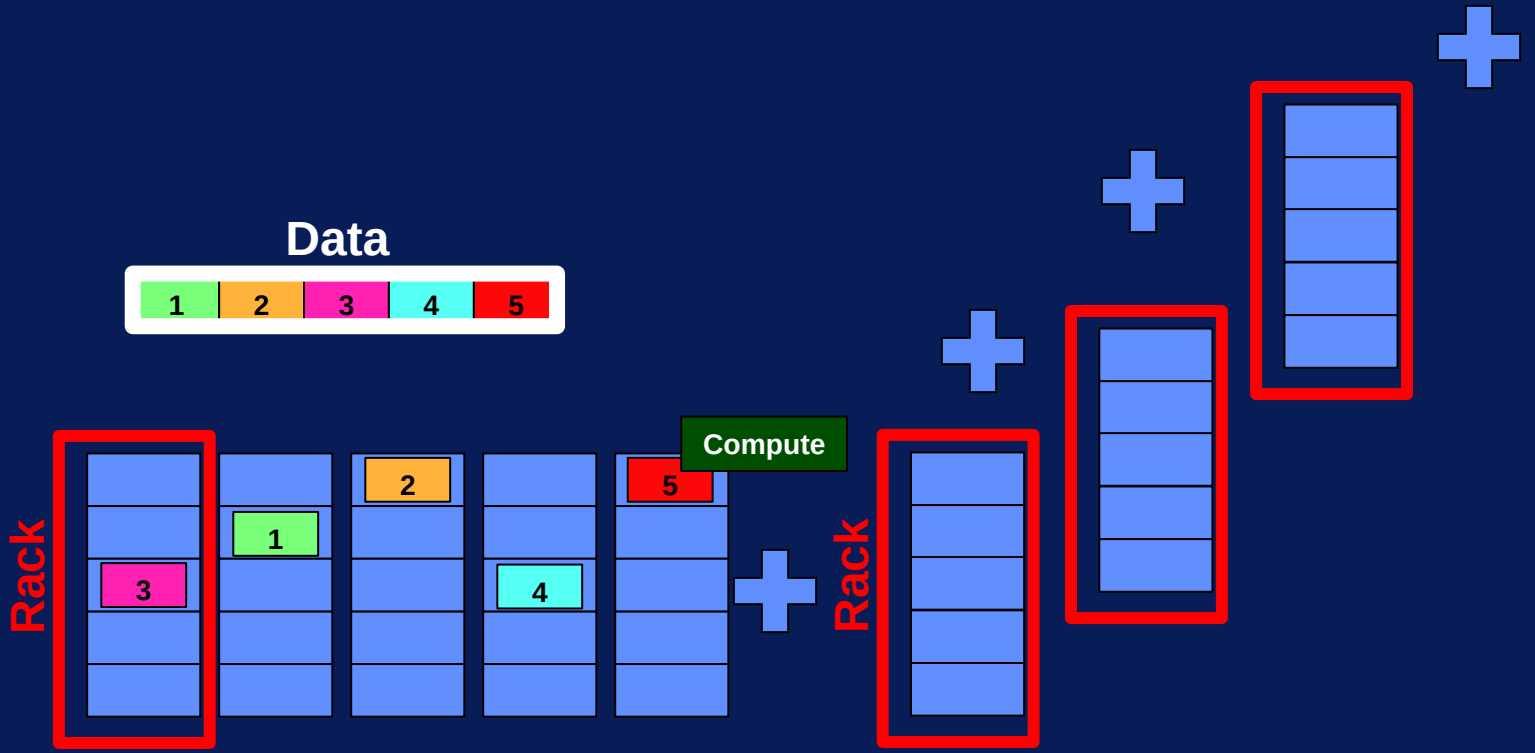
Distribute computations to nodes

2. Handle Fault Tolerance

Replicate data partitions

Recover files when needed

3. Enable Adding More Racks



4. Optimized and extensible for many data types

Document

Table

Graph

Key-value

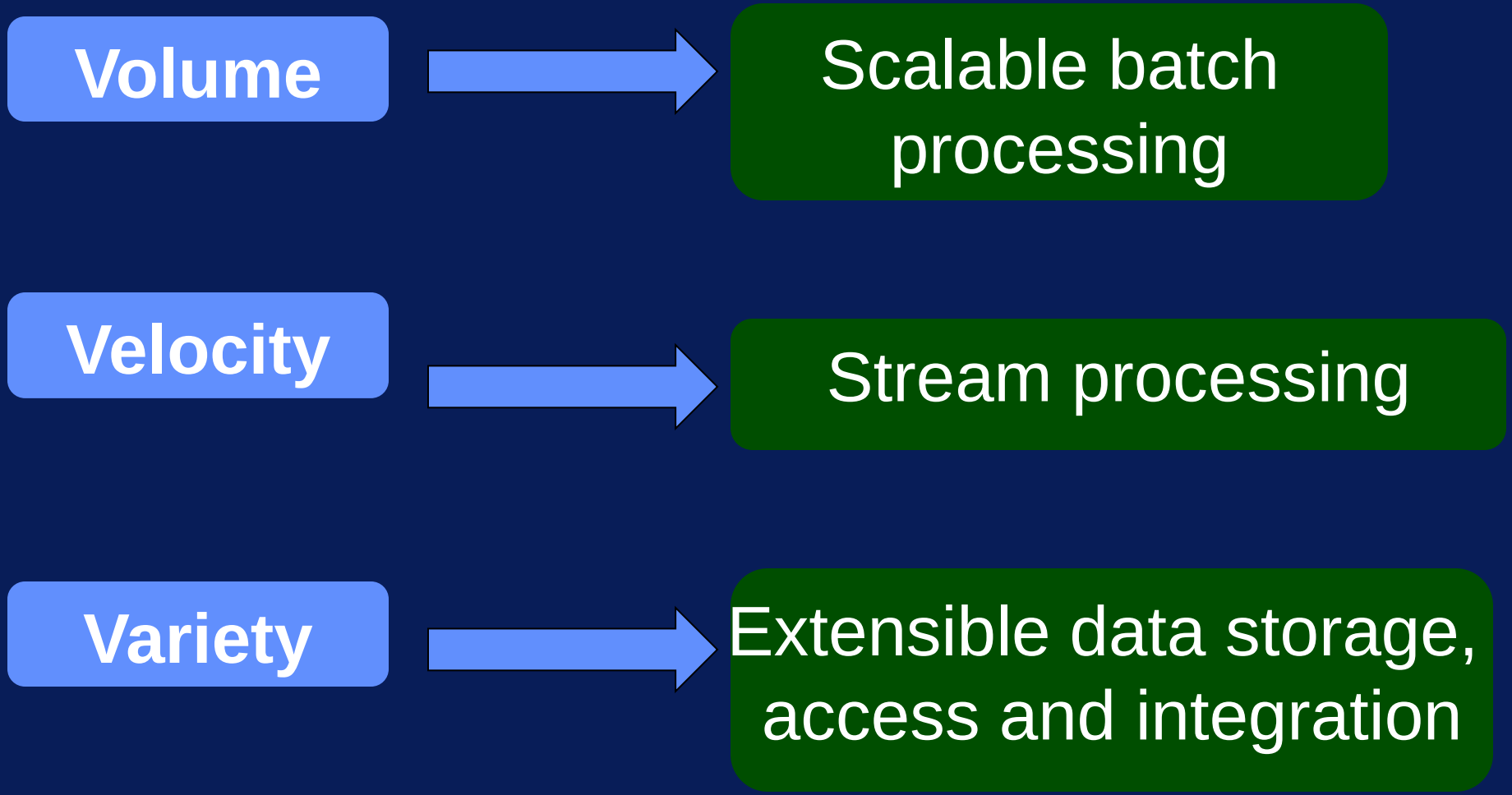
Multimedia

Stream

5. Enable both streaming and batch processing

Low latency processing of streaming data

Accurate processing of all available data


Volume
Scalable batch processing
Velocity
Stream processing
Variety
Extensible data storage, access and integration

What is Data Retrieval?

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What is Data Retrieval?

- **Data retrieval**
  - The way in which the desired data is specified and retrieved from a data store
- **Our focus**
  - How to specify a data request
    - For static and streaming data
  - The internal mechanism of data retrieval
    - For large and streaming data

What is a Query Language?

- **A language to specify the data items you need**
- **A query language is declarative**
  - Specify what you need rather than how to obtain it
  - SQL (Structured Query Language)
- **Database programming language**
  - Procedural programming language
  - Embeds query operations

SQL

- **The standard for structured data**
  - Oracle's SQL to Spark SQL
- **Example Database Schema**

  Bars(name, addr, license)
  Beers(name, manf)
  Sells(bar, beer, price)
  Drinkers(name, addr, phone)
  Frequents(drinker, bar)
  Likes(drinker, beer)

name	addr	license
Great American Bar	363 Main St., SD, CA 92390	41-437844098
Beer Paradise	6450 Mango Drive, SD, CA 92130	41-973428319
Have a Good Time	8236 Adams Avenue, SD, CA 92116	32-032263401

SELECT-FROM-WHERE

- **Which beers are made by Heineken?**

```
SELECT name
FROM Beers
WHERE manf = 'Heineken'
```

Output attribute(s)

Table(s) to use

The condition(s) to satisfy

Strings like 'Heineken' are case-sensitive and are put in quotes

$Select_{manf='Heineken'}(Beers)$

↓

Project(name)

name
Heineken Lager Beer
Amstel Lager
Amstel Light
…

More Example Queries

- **Find expensive beer**
  - SELECT DISTINCT beer, price
  - FROM Sells
  - WHERE price > 15
- **Which businesses have a Temporary License (starts with 32) in San Diego?**
  - SELECT name
  - FROM Bars
  - WHERE addr LIKE '%SD%' **AND** license LIKE '32%' LIMIT 5

name	addr	license
Great American Bar	363 Main St., SD, CA 92390	41-437844098
Beer Paradise	6450 Mango Drive, SD, CA 92130	41-973428319
Have a Good Time	8236 Adams Avenue, SD, CA 92116	32-032263401

Select-Project Queries in the Large

- **Large Tables can be partitioned**
  - Many partitioning schemes
    - Range partitioning on primary key

name	manf
A…	Gambrinus
A…	Heineken
…	
B…	Anheuser-Busch

Machine 1

name	manf
C…	MillerCoors
C…	MillerCoors
…	
D…	Duvel Moortgat

Machine 2

…

name	manf
H…	Heineken
H…	Pabst
…	
H…	Anheuser-Busch

Machine 5

…

Select-Project Queries in the Large

name	manf
A…	Gambrinus
A…	Heineken
…	
B…	Anheuser-Busch

Machine 1

name	manf
C…	MillerCoors
C…	MillerCoors
…	
D…	Duvel Moortgat

Machine 2

name	manf
H…	Heineken
H…	Pabst
…	
H…	Anheuser-Busch

Machine 5

```
SELECT *
FROM Beers
WHERE name like 'Am%'
```

pattern

```
SELECT name
FROM Beers
WHERE manf = 'Heineken'
```

- **Two queries**
  - Find records for beers whose name starts with 'Am'
  - Which beers are made by Heineken?

Evaluating SP Queries for Large Data

name	manf
A…	Gambrinus
A…	Heineken
…	
B…	Anheuser-Busch

Machine 1

name	manf
C…	MillerCoors
C…	MillerCoors
…	
D…	Duvel Moortgat

Machine 2

…

name	manf
H…	Heineken
H…	Pabst
…	
H…	Anheuser-Busch

Machine 5

…

```
SELECT *
FROM Beers
WHERE name like 'Am%'
```

- **A query processing trick**
  - Use the partitioning information
    - Just use partition 1!!

Evaluating SP Queries for Large Data

name	manf
A…	Gambrinus
A…	Heineken
…	
B…	Anheuser-Busch

Machine 1

name	manf
C…	MillerCoors
C…	MillerCoors
…	
D…	Duvel Moortgat

Machine 2

…

name	manf
H…	Heineken
H…	Pabst
…	
H…	Anheuser-Busch

Machine 5

…

```
SELECT name
FROM Beers
WHERE manf = 'Heineken'
```

Broadcast query

In each machine in parallel:

Select $_{manf='Heineken'}$ *(Beers)*

Project(name)

Gather Partial Results

Union

Return

Local and Global Indexing

- **What if a machine does not have any data for the query attributes?**
- **Index structures**
  - Given value, return records
  - Several solutions
    - Use local index on each machine
    - Use a machine index for each value
    - Use a combined index in a global index server

manf	RecordIDs
…	…
MillerCoors	34, 35, 87, 129, …
Duvel Moortgat	5, 298, 943, 994,…
Heineken	631, 683, 882,…
…	…

manf	machineIDs
…	…
MillerCoors	10
Duvel Moortgat	3, 4
Heineken	1, 3, 5
…	…

Pause

Querying Two Relations

- **Often we need to combine two relations for queries**
  - Find the beers liked by drinkers who frequent The Great American Bar
- **In SQL**

```
SELECT DISTINCT beer
FROM Likes L, Frequents F
WHERE bar = The Great American Bar' AND
      F.drinker = L.drinker
```

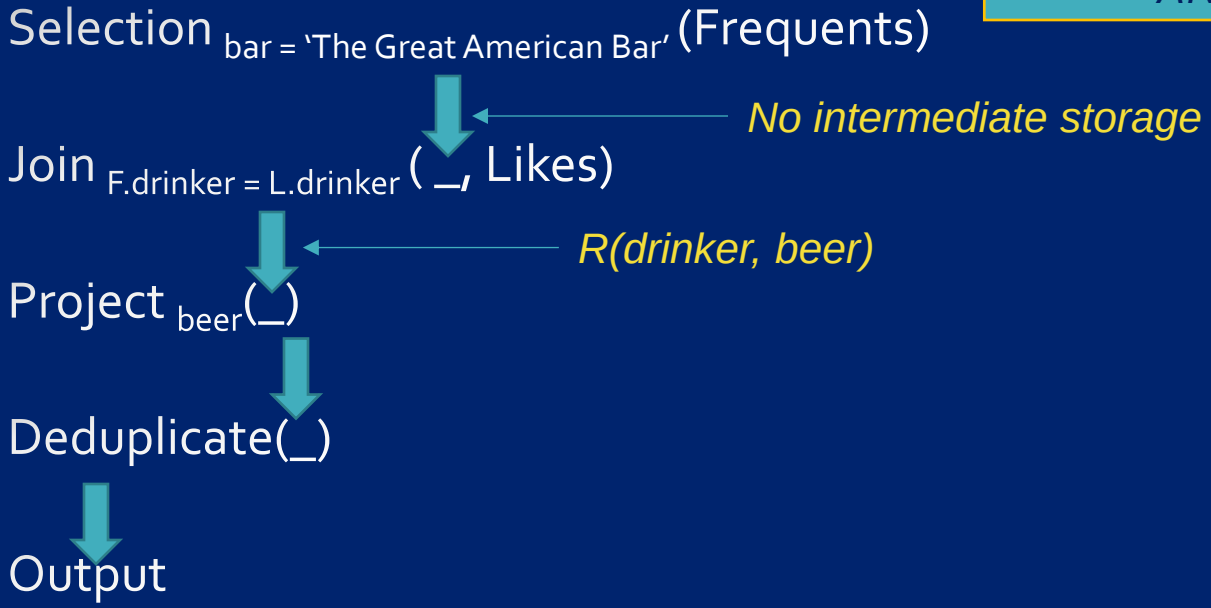
Frequents(drinker, bar)
Likes(drinker, beer)

SPJ Queries

Frequents(drinker, bar)
Likes(drinker, beer)

```
SELECT DISTINCT beer
FROM Likes L, Frequents F
WHERE bar = 'The Great American Bar'
      AND F.drinker = L.drinker
```

- **Steps**

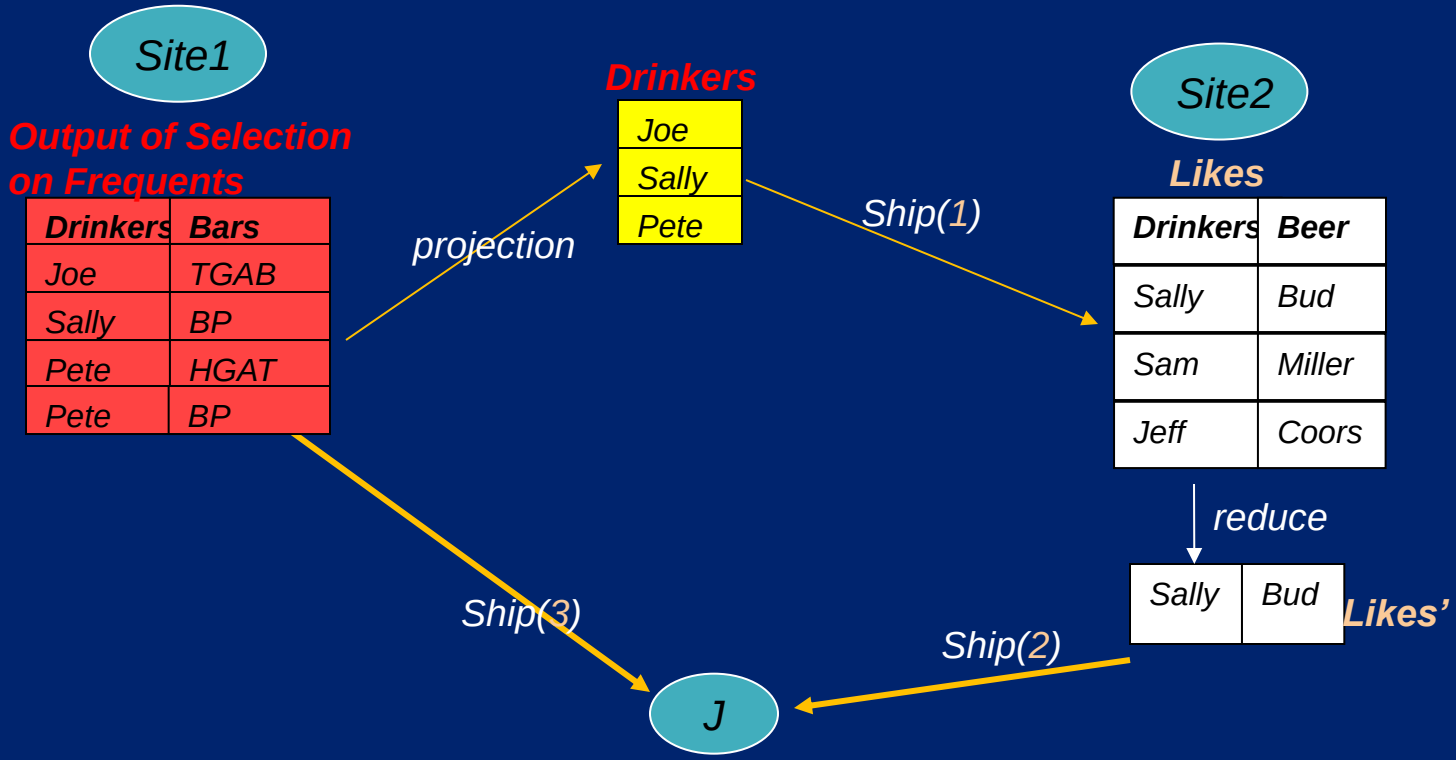


Join in a Distributed Setting

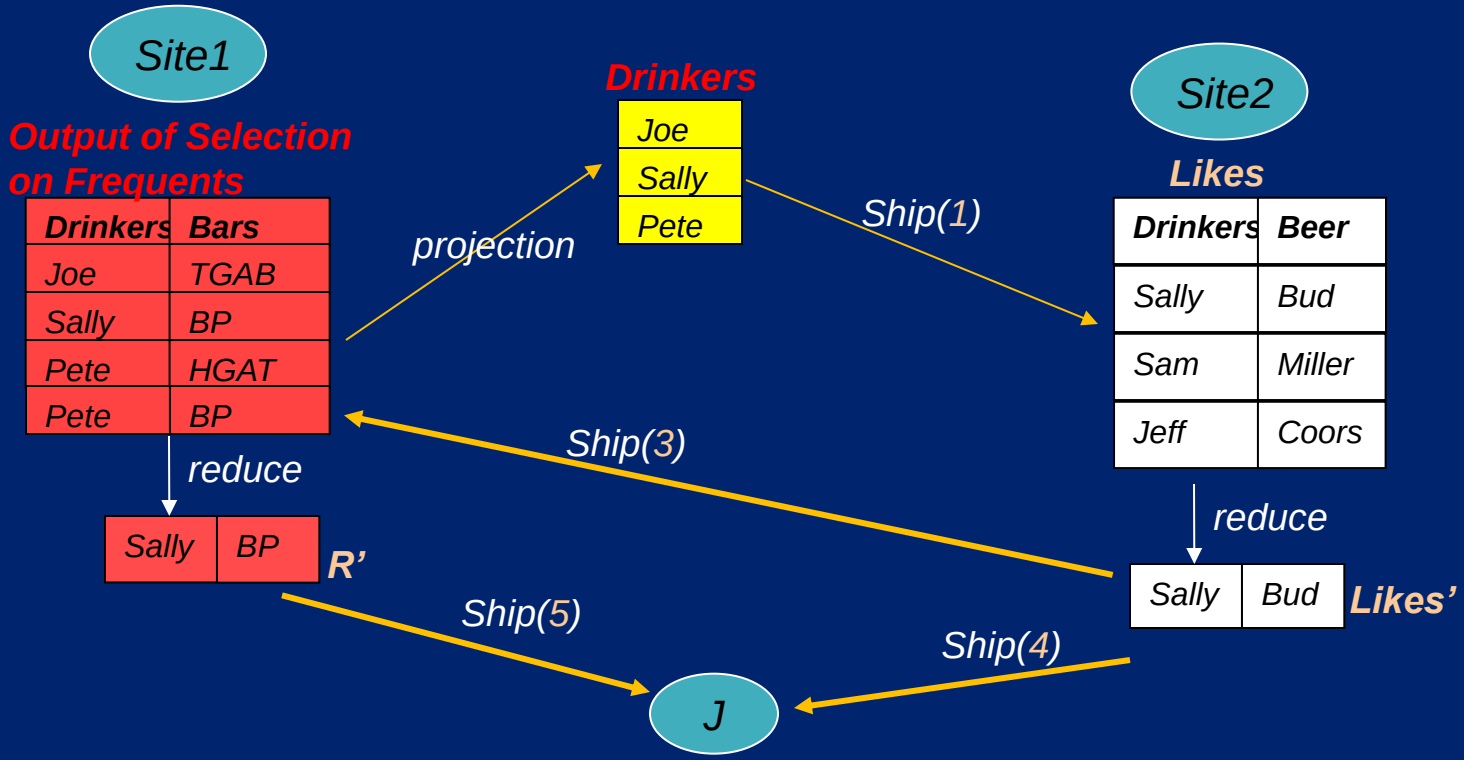
Frequents(drinker, bar)
Likes(drinker, beer)

- **Semijoin**
  - A semijoin from R to S on attribute is used to reduce the data transmission cost
  - Computing steps:
    - **Project** R on attribute A and call it (R[A]) – the Drinkers column
    - **Ship** this projection (a semijoin projection) from the site of R to the site of S
    - **Reduce** S to S' by eliminating tuples where attribute A are not matching any value in R[A]

Semijoin s: Frequents—Drinkers→Likes



Semijoin s: Frequents—Drinkers→Likes



Pause

Subqueries

- A slightly complex query
- Find the bars that serve Miller for the same or less price than what TGAB charges for Bud
- We may break it into two queries:
  1. Find the price TGAB charges for Bud
  2. Find the bars that serve Miller at that price

Subqueries in SQL

```
SELECT bar
FROM Sells
WHERE beer = 'Miller' AND
    price <= (SELECT price
              FROM Sells
              WHERE bar = 'TGAB'
              AND beer = 'Bud');
```

The price at which TGAB sells Bud

Subqueries with IN

- **Find the name and manufacturer of each beer that Fred does not like**
- **Query**

Beers(name, manf)
Likes(drinker, beer)

```
SELECT *
FROM Beers
WHERE name NOT IN
                ( SELECT beer
                        FROM Likes
                        WHERE drinker = 'Fred');
```

Correlated Subqueries

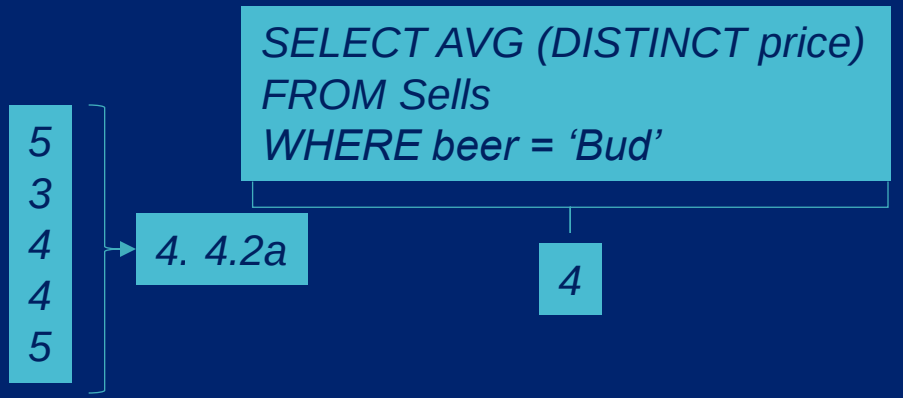
- **Find the name and price of each beer that is more expensive than the average price of beers sold in the bar**

```
SELECT beer, price
FROM  Sells s1
WHERE price >
    (SELECT AVG(price)
     FROM Sells s2
     WHERE s1.bar = s2.bar)
```

Bar	Beer	Price
HGAT	Bud	5
BP	Michelob	4
TGAB	Heineken	6
HGAT	Guinness	10

Aggregate Queries

- **Example**
  - Find the average price of Bud:
  - SELECT AVG(price)
  - FROM Sells
  - WHERE beer = 'Bud';
- **Other aggregate functions**
  - SUM, MIN, MAX, COUNT, ...



GROUP BY Queries

- Find for each drinker the average price of Bud at the bars they frequent

```
SELECT drinker, AVG(price)
FROM Frequents, Sells
WHERE beer = 'Bud' AND
      Frequents.bar = Sells.bar
GROUP BY drinker;
```

Drinker	Bar	Price
Pete	HGAT	5
Pete	BP	4
Joe	TGAB	6
Joe	HGAT	5

Drinker	Price
Pete	4.5
Joe	5.5

Grouping Aggregates over Partitioned Data

Drinker	Bar	Price
Pete	HGAT	5
Pete	BP	4
Joe	TGAB	6
John	HGAT	5

Drinker	Bar	Price
Pete	BO	6
John	BP	4
Sally	TGAB	6
Sally	HGAT	5

Drinker	Bar	Price
Pete	HGAT	5
Pete	BP	4
Pete	BO	6
Joe	TGAB	6

Drinker	Bar	Price
John	HGAT	5
John	BP	4
Sally	TGAB	6
Sally	HGAT	5

Drinker	Price
Pete	5
Joe	6

Drinker	Price
John	4.5
Sally	5.5