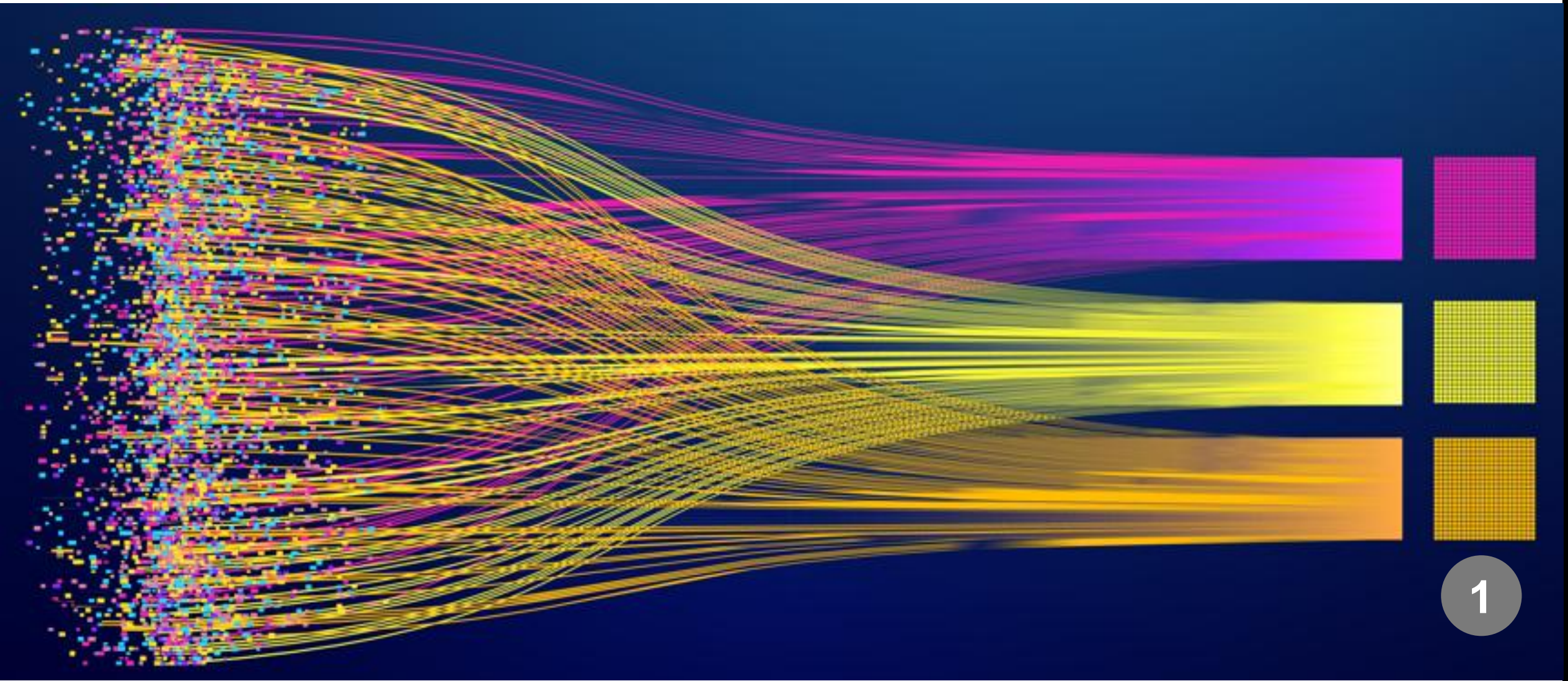


Real-Time Data Processing using Apache Flink



logistics



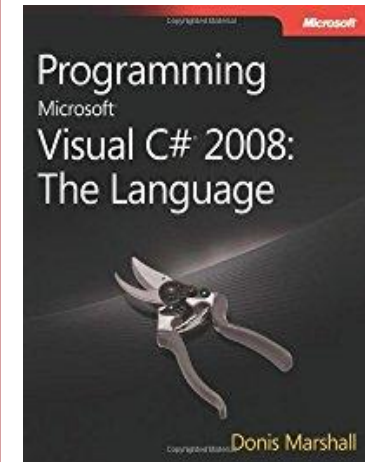
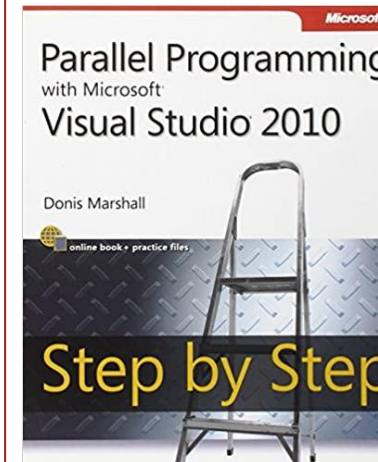
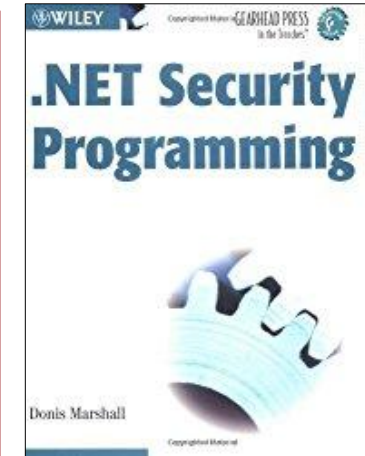
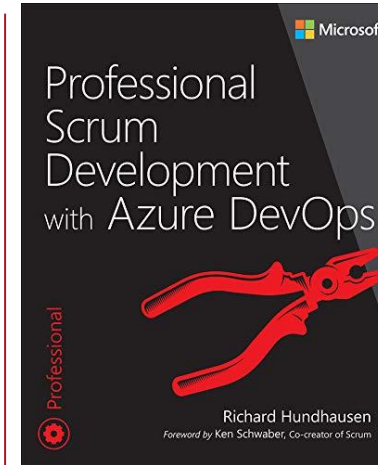
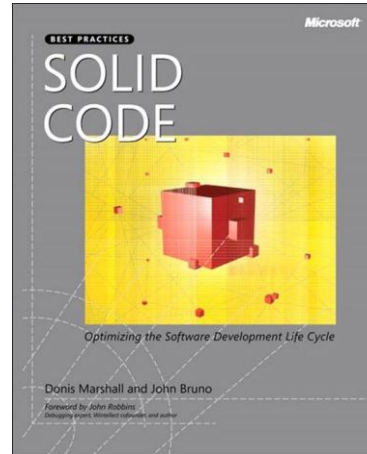
- **Class Hours:**
- Instructor will set class start and end times.
- There will be regular breaks in class.
- Planned lunch breaks for 1:15



- **Telecommunication:**
 - Turn off or set electronic devices to silent (not vibrate)
 - Reading or attending to devices can be distracting to other students
 - Try to delay until breaks or after class
-
- **Miscellaneous:**
 - Courseware
 - Bathroom
 - Fire drills

George Niece

- Data Engineering
- Security
- Multicloud
- Resilience
- Certified in many technologies



Introduce yourself

- Time to introduce yourself:
- Name
- What is your role in the organization
- Indicate OWASP experience



labs



- In this class, some labs are completed as teams.
- The labs are intended as a collaborative exercise and team members work together in breakout rooms.
- Teams are expected to present their lab solutions to the class.

Introduction to Stream Processing



Introduction to Stream Processing

Understanding Data Processing

Batch Processing Overview

Stream Processing Overview

When to Use Stream

Processing

Common Use Cases

Stream Processing Concepts

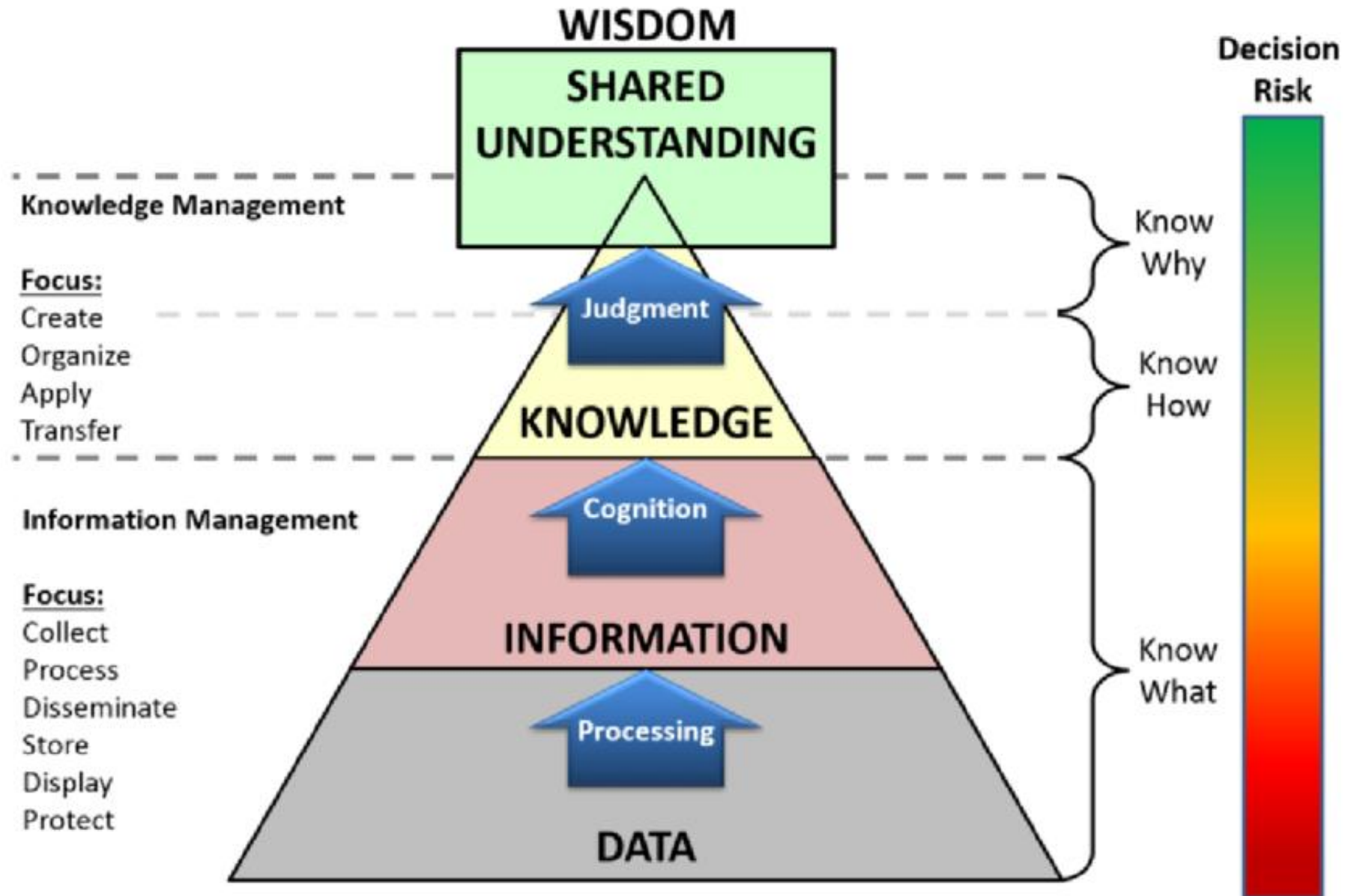
Events and Streams

Real-time vs Near Real-time

Processing Guarantees

Basic Architecture Patterns

SINGLE LARGE IMAGE



BULLETED LIST

- Data that has been processed, structured, or organized to provide context or meaning.
- Characteristics:
 - Answers questions like who, what, when, and where.
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IMAGE RIGHT

Chen's four levels correspond to the three level architecture proposed for data base development

- Has a wide range of applications, as we shall see

The correspondences are:

- **External views:** a specific group of users' view of the data. Data at this level is *discovered* through investigation
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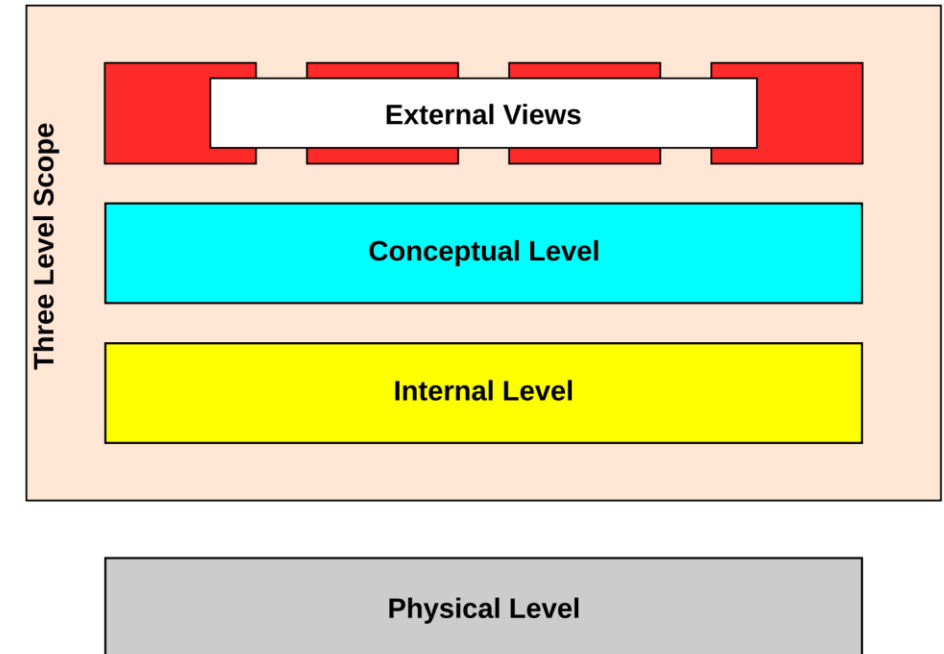
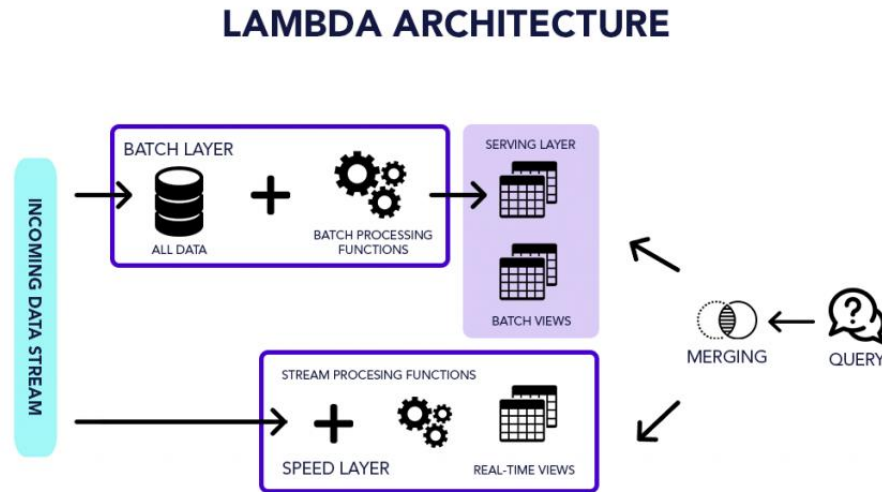


IMAGE BOTTOM

- Used when we have streaming data and historical data
 - We set up a two part architecture
 - A real time speed layer, that could be part of a OLTP transactional system
 - The real time layer keeps track of data being used in transactions
 - The batch storage layer keeps historical data for training and BI



UNDERSTANDING DATA PROCESSING

- There are two forms of data processing, real-time (stream) and batch. The majority of large organizations have both, in some cases both pattern for a specific business case, like fraud detection.
- Data engineering enables efficient and scalable data pipelines for various applications, including real-time analytics and event-driven systems.
- We have multiple data processing characteristics:
 - Data processing characteristics encompass the stages and qualities involved in transforming raw data into usable information, including collection, preparation, transformation, and output, all while ensuring data quality, security, and performance.
 - Processing, data enrichment, sinks & sources, transformations, information, analytics, and actionable insight.
- We can structure information in different ways
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DATA PROCESSING CHARACTERISTICS

1. Data Collection:

Where is the data coming from? Surveys, sensors, databases, and web scraping.

2. Data Input:

What is the format needed?

3. Data Preparation (Data Cleaning/Wrangling):

What is needed to augment or enrich the data,, de-dup, ...

4. Data Transformation:

Are sorting, summarization, or aggregates required?

5. Data Validation:

Are there standards we need to meet or inconsistencies to resolve?

6. Data Output:

How is the data going to be used for visualization, analysis or decision support?

7. Data Storage:

Where is this data at rest?

8. Data Quality Characteristics:

What is needed for accuracy, completeness, reliability, relevance, and timeliness?

9. Security Aspects:

Are protections in place for the data from unauthorized access, use, disclosure, disruption, modification, or destruction?

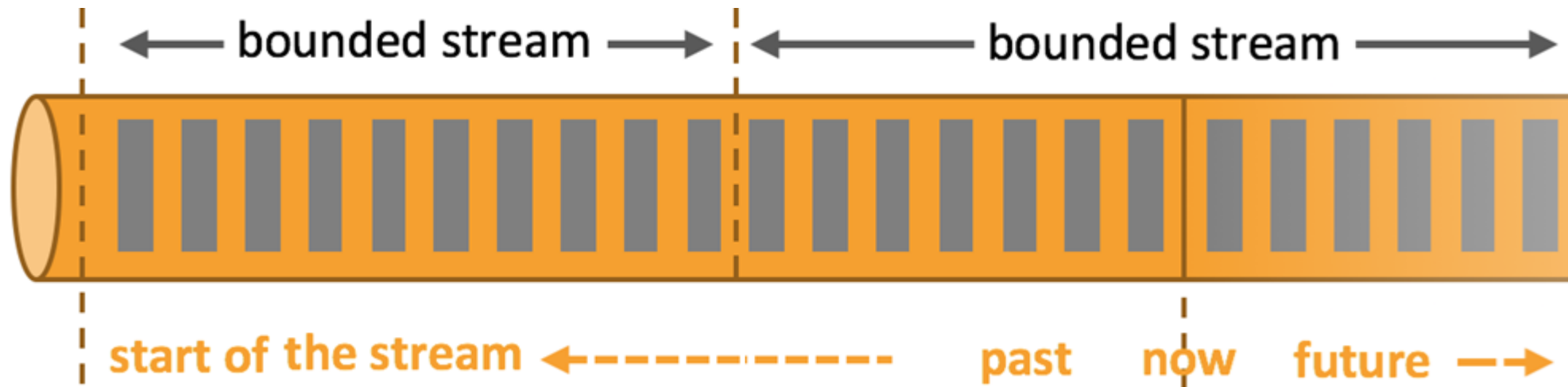
Have we implemented encryption, access control, cyber recovery, and regular audits

10. Performance:

Do we have observability around system for speed, scalability, and resource utilization.

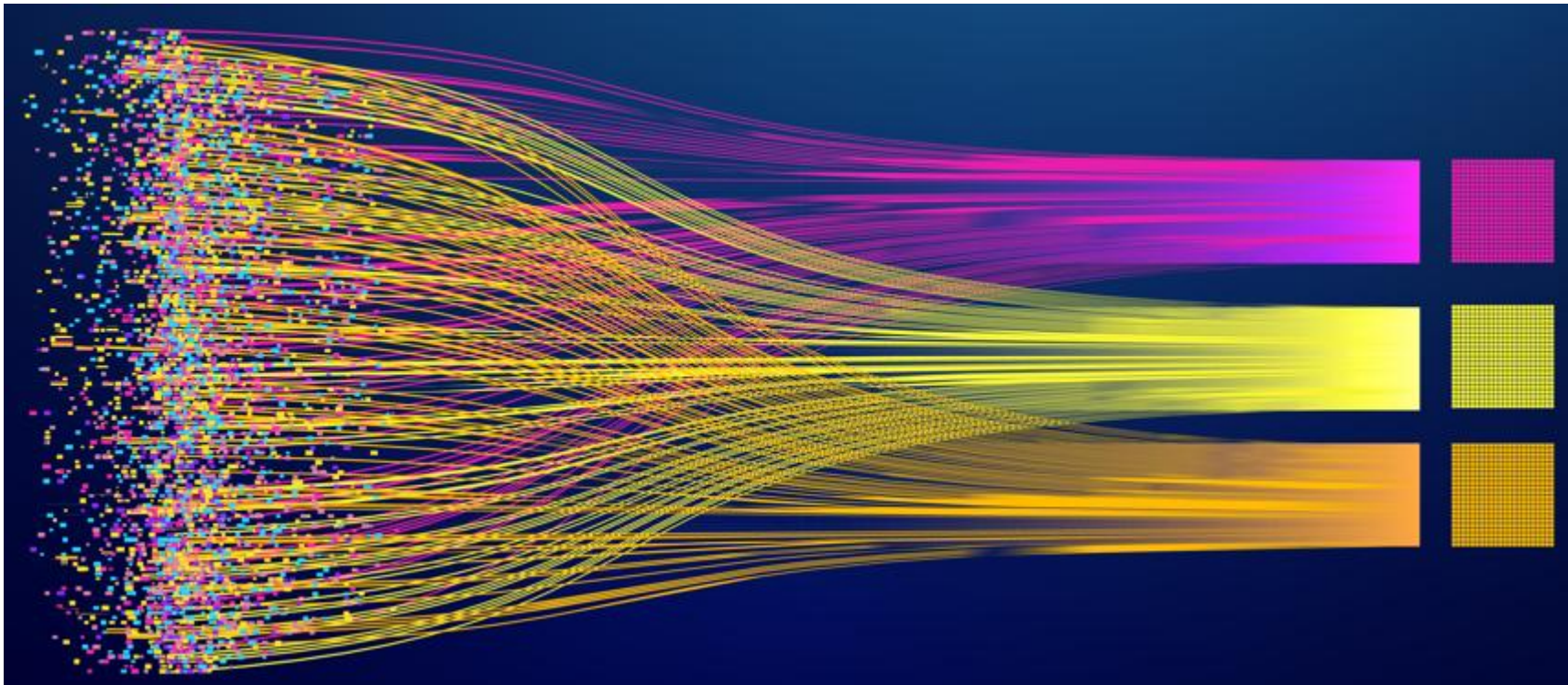
BATCH PROCESSING OVERVIEW

- Batch processing involves processing finite, bounded datasets, often at scheduled intervals, prior to Flink 2.0 the DataSet API, used this as a special case of stream processing where the order and time of records don't matter.
- Flink batch processing is now considered a special case with the stream being finite, this is a path with the DataStream API for a unified approach.
- Using known data sets allows for scheduling and optimization.



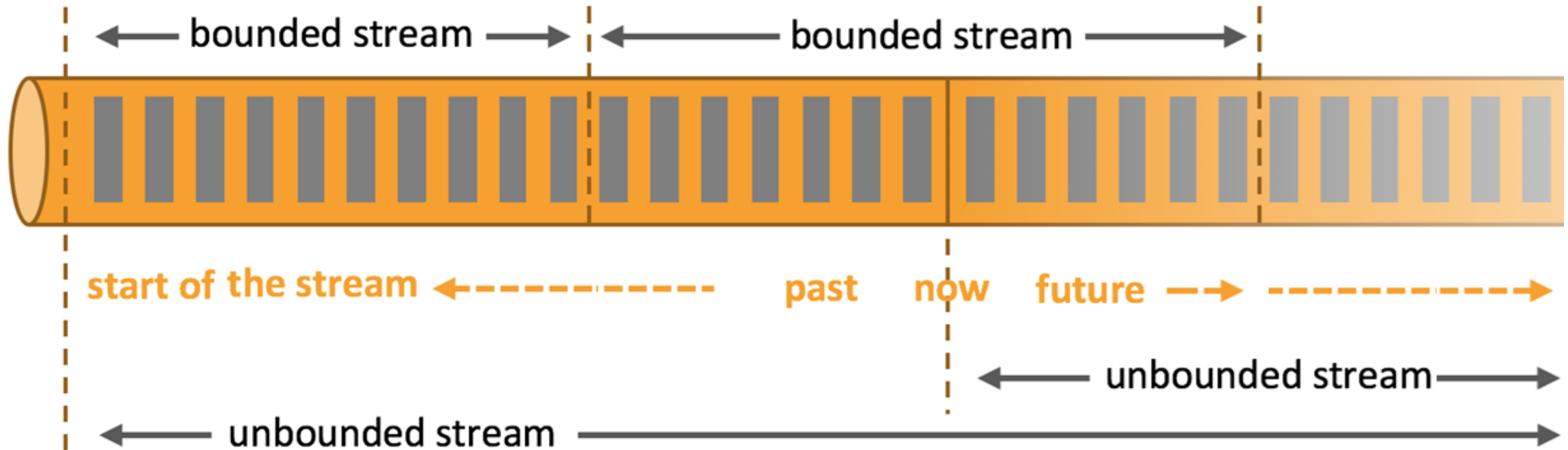
BATCH PROCESSING

- **Batch processing** is the paradigm at work when you process a **bounded data stream**. In this mode of operation, you can choose to ingest the entire dataset before producing any results, which means that it's possible, for example, to sort the data, compute global statistics, or produce a final report that summarizes all of the input.



STREAM PROCESSING OVERVIEW

- Stream processing involves unbounded data streams. Conceptually, at least, the input may never end, and so you are forced to continuously process the data as it arrives. This leads to thinking about this time series data over a period, rather than the consumption of the entire data set as you would with batch processes.

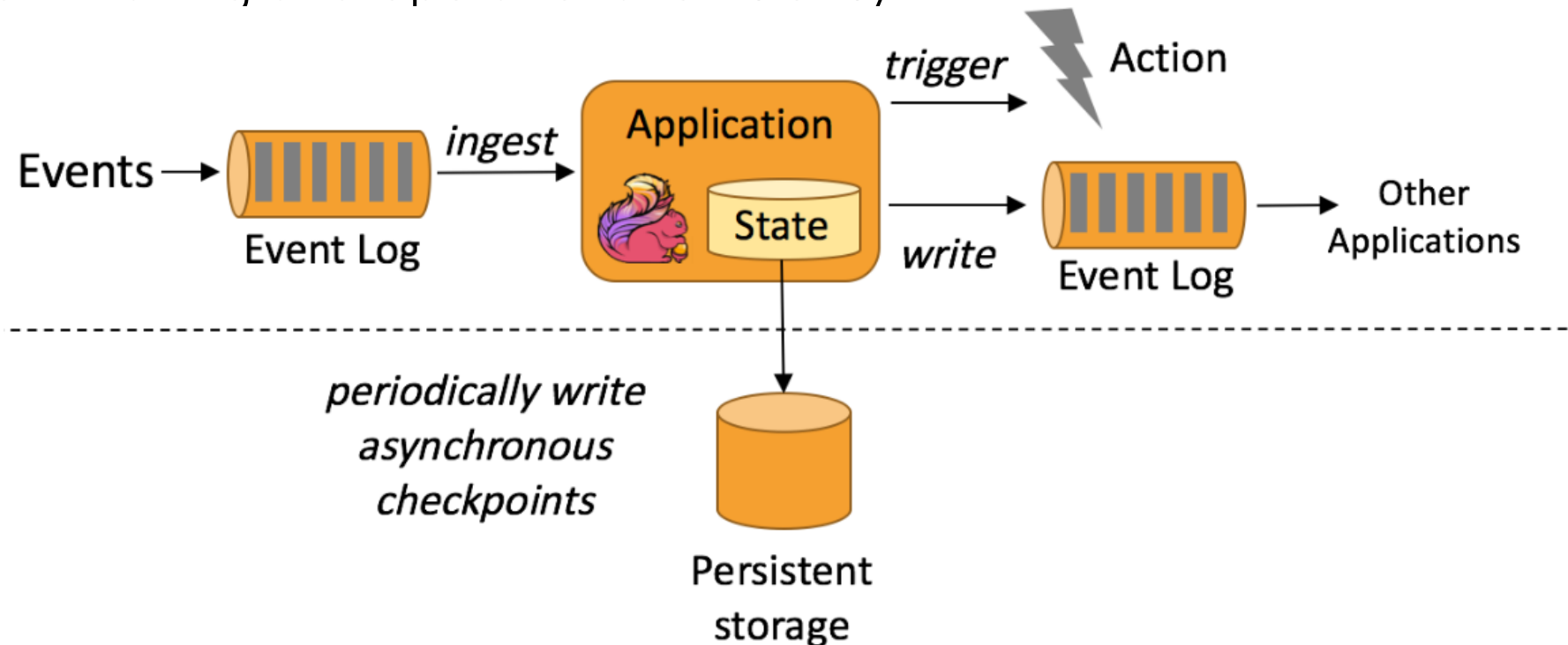


WHEN TO USE STREAM PROCESSING?

Always

WHEN TO USE STREAM PROCESSING

Opt for streaming processing if your business **requires real-time insights and immediate action**. This is ideal for applications such as **fraud detection, live traffic management, or real-time customer engagement**, where timely data analysis is critical for decision-making and operational efficiency.



TIMELY STREAM PROCESSING

- For most streaming applications it is very valuable to be able re-process historic data with the same code that is used to process live data – and to produce deterministic, consistent results, regardless.
- The order in which events occurred, rather than the order in which they are delivered for processing, and to be able to reason about when a set of events is (or should be) complete.
- Use event time timestamps that are recorded in the data stream to be able to capture the view of a time period within the stream.

COMMON USE CASES

Flink streams, a powerful stream processing framework, are commonly used for real-time analytics, event-driven applications, and building data pipelines, including tasks like:

- fraud detection
- real-time dashboards
- data processing.

COMMON USE CASES

Real-time analytics and dashboards: Flink can be used to process real-time data streams and generate real-time dashboards and reports.

Fraud detection: Flink can be used to detect fraudulent transactions and activities in real-time.

Event-driven applications: Flink can be used to build event-driven applications that react to real-time events.

Data pipelines and ETL: Flink can be used to build data pipelines and ETL (extract, transform, load) processes.

Financial market analysis: Flink can be used to analyze financial market data in real-time.

Social media analysis: Flink can be used to analyze social media data in real-time.

Internet of Things (IoT): Flink can be used to process data from IoT devices.

STREAM PROCESSING CONCEPTS

Streams are the de-facto way data is created. Whether the data comprises events from web servers, trades from a stock exchange, or sensor readings from a machine on a factory floor, data is created as part of a stream. We may chunk this data up into a finite (bounded) set of transactions for something like Friends Day or Cyber Monday, in Digital Commerce.

EVENTS AND STREAMS

Stream processing systems process data promptly upon arrival, often in small, incremental units known as events. This capability allows organizations to swiftly extract value from their data, for time-sensitive decisions and situations demanding real-time insights. We could consider health for a person as a lifetime stream, but typically we're looking at events, a day/week/year of life, or for specific health events like catching a cold or have your teeth cleaned.

STATE MANAGEMENT

Stream processing frequently integrates state management to effectively handle continuous data streams. This state captures pertinent information necessary for subsequent event processing or assistance. State can take various forms, such as:

- Incremental Aggregates
- Static Data
- Previously Seen Events

REAL-TIME VS NEAR REAL-TIME

Usually when we talk about streaming, we think about two categories:

- Real-time: usually in the realms of sub-milliseconds to seconds
- Near real-time: sub-seconds to hours

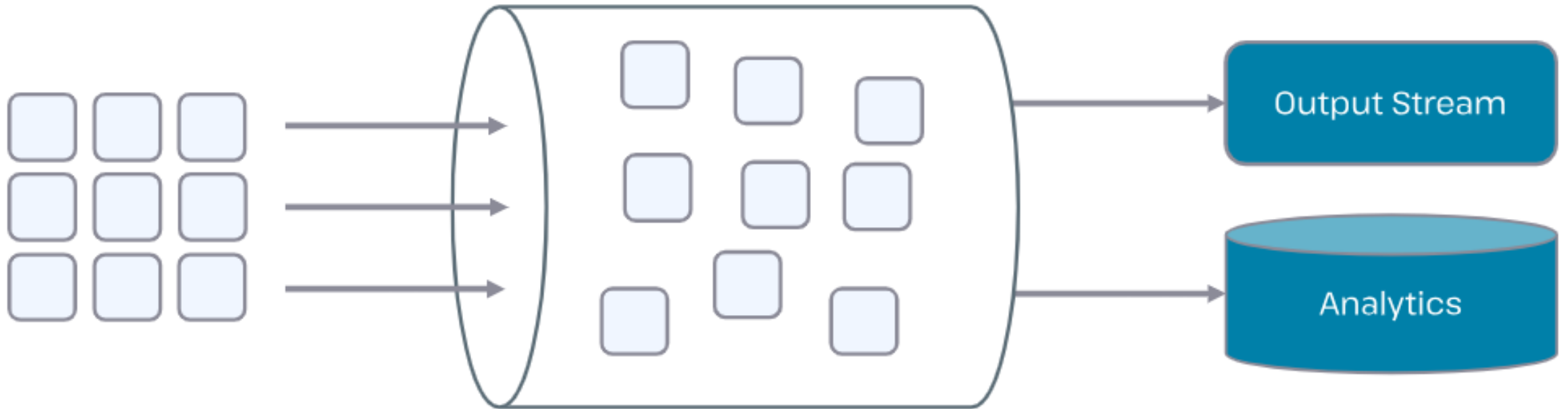
The distinction isn't in the actual timing of the stream, but rather the decision, deadline or response that the event or signal generates. The response should occur similarly under any system load, rather than becoming bi-modal.

PROCESSING GUARANTEES

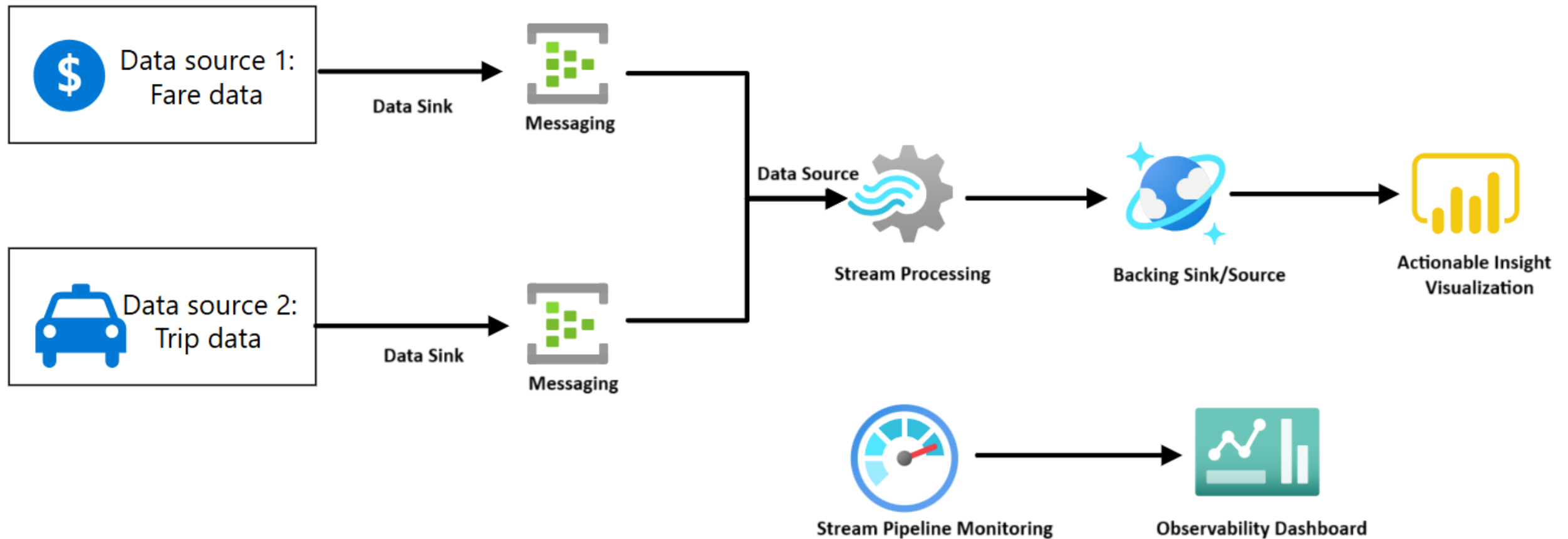
Fault tolerance mechanisms recover processes in the presence of failures and continues to execute them. Such failures include hardware failures, network failures, transient program failures, etc.

Fault tolerance guarantees of data sources and sinks, are tied to the concepts of at least once, at most once, and exactly once. Stream processing pipelines can guarantee exactly-once state updates to user-defined state only when the source or sink participates in the snapshotting or checkpointing mechanism.

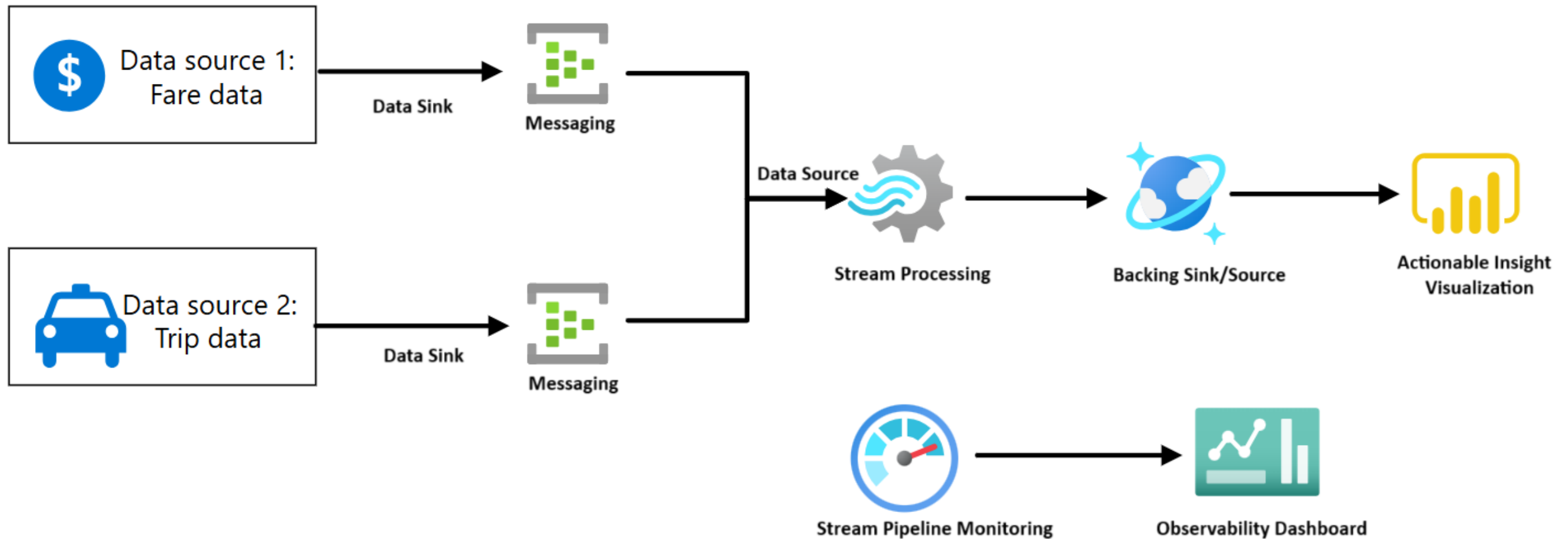
BASIC ARCHITECTURE PATTERNS



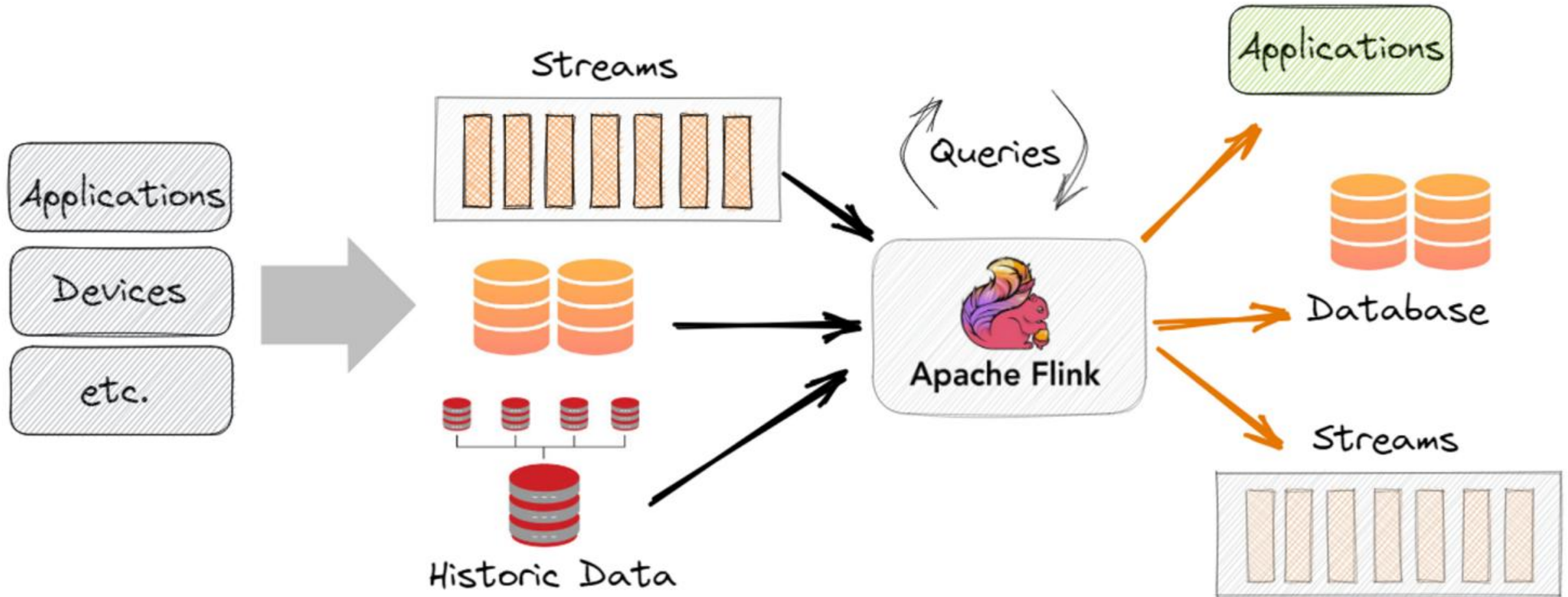
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BASIC ARCHITECTURE PATTERNS



BASIC ARCHITECTURE PATTERNS



Q&A AND OPEN DISCUSSION



Getting Started with Apache Flink



Getting Started with Apache Flink

Apache Flink Basics

- What is Apache Flink?

- Key Features and Components

- Basic Architecture

- Development Environment Setup

Your First Flink Application

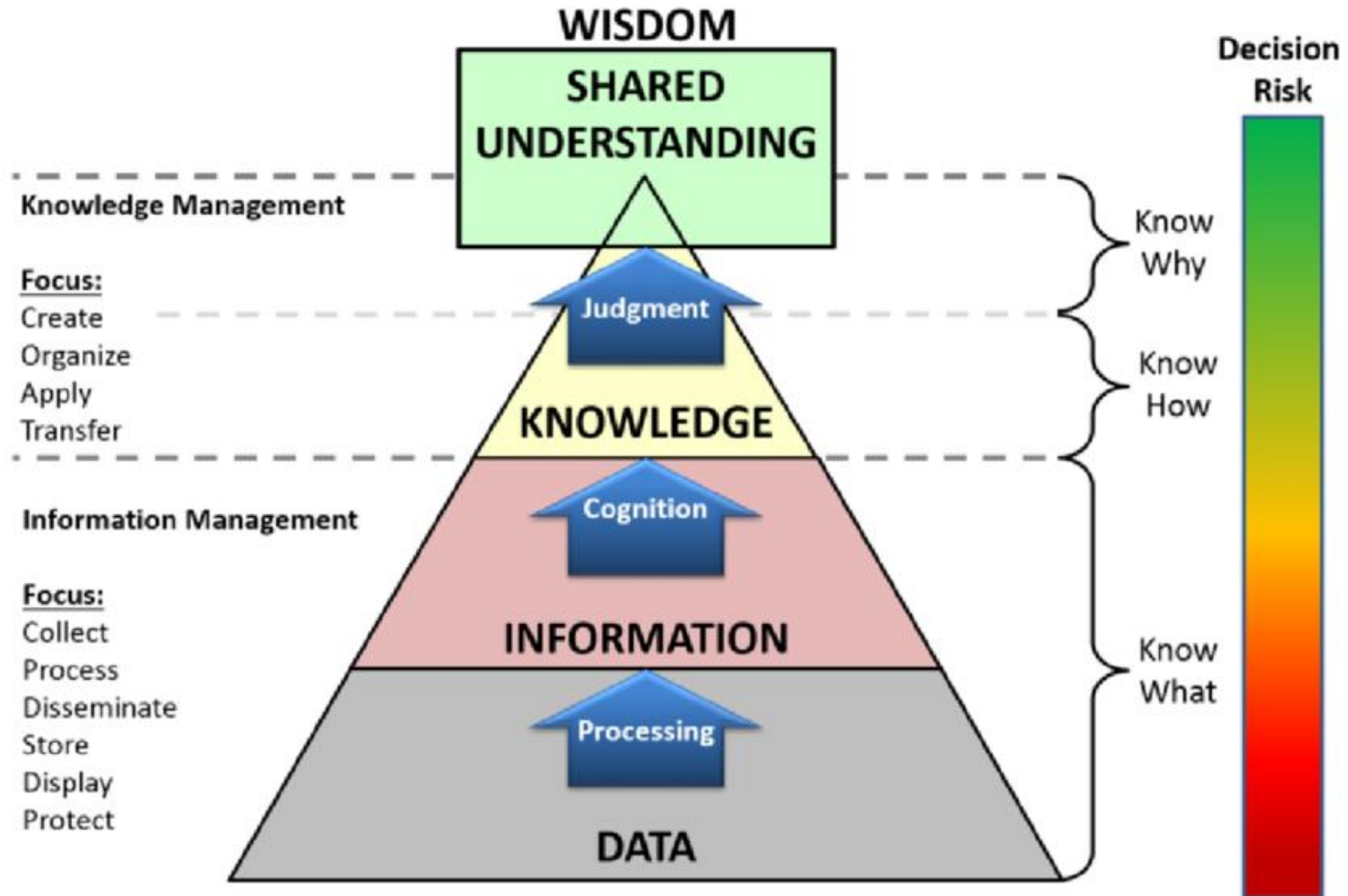
- Project Structure

- Basic Configuration

- Hello World Example

- Running Locally

SINGLE LARGE IMAGE



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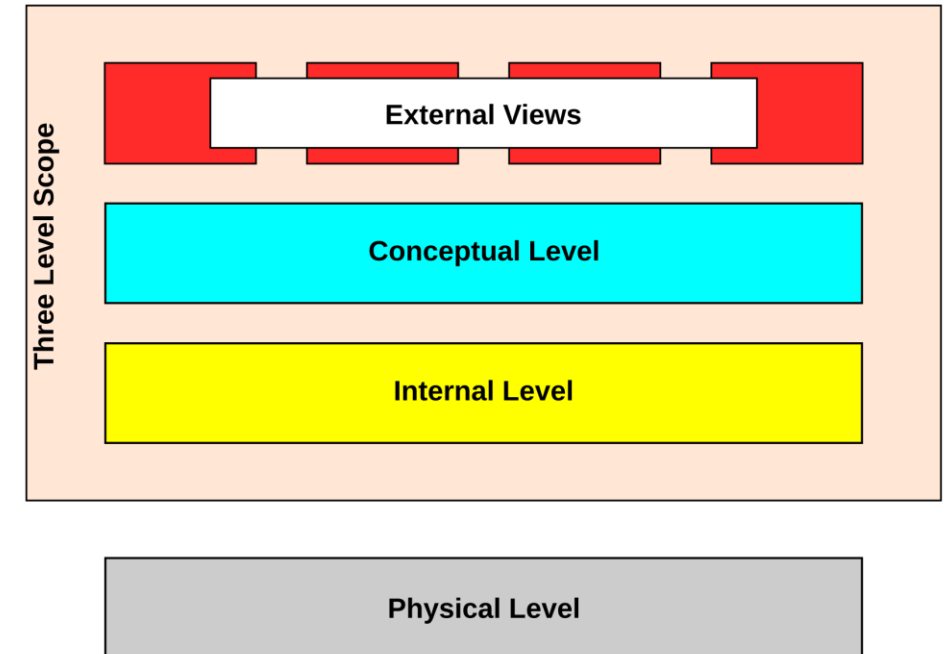
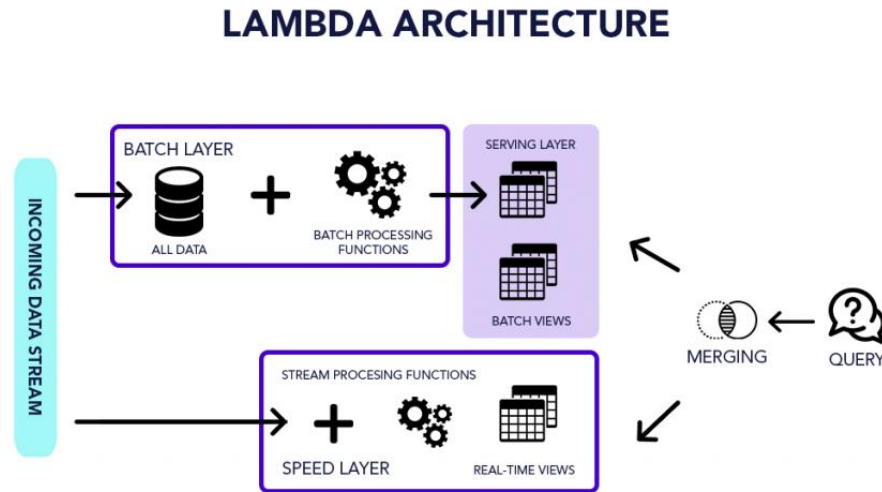


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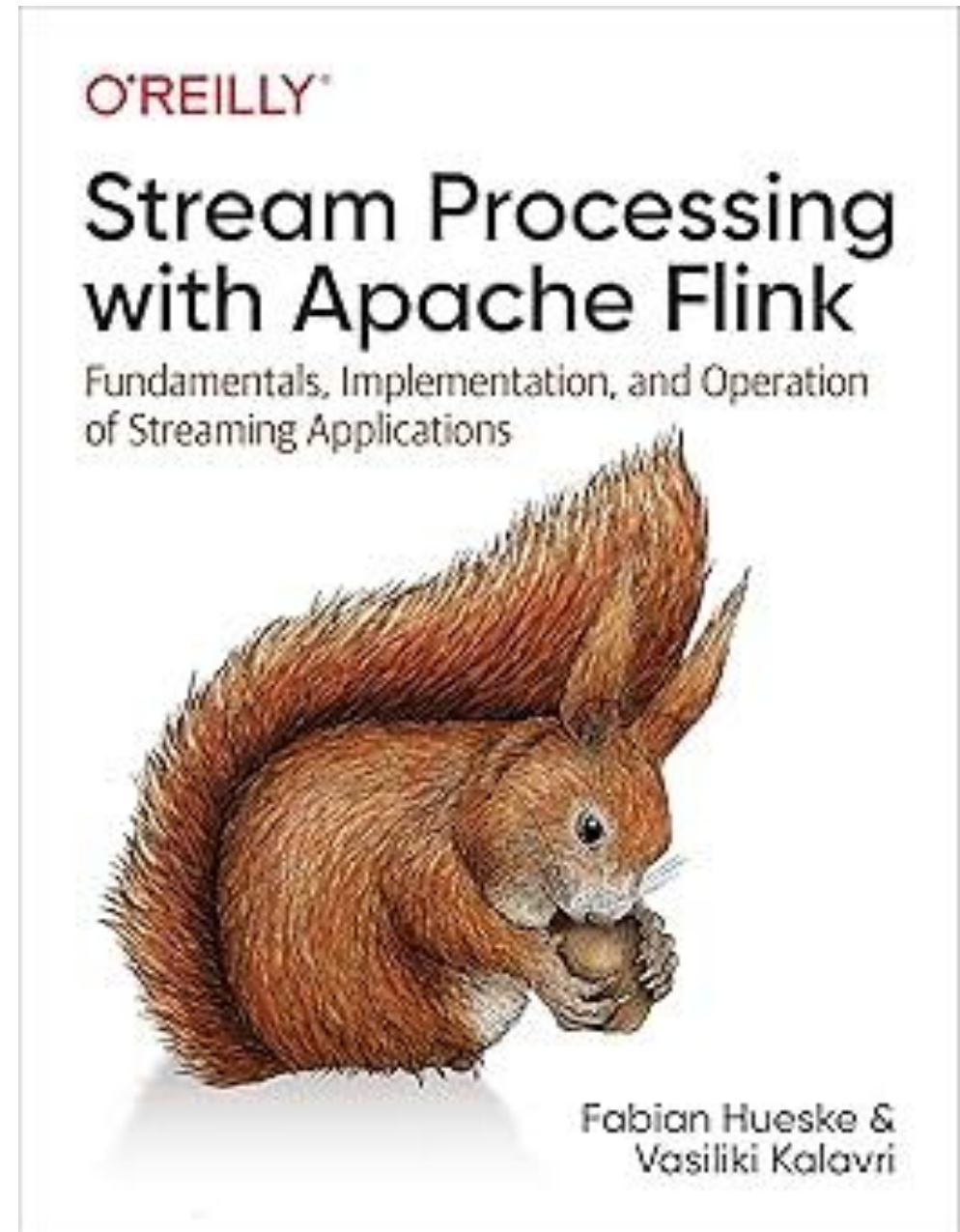
APACHE FLINK BASICS

What is Apache Flink?

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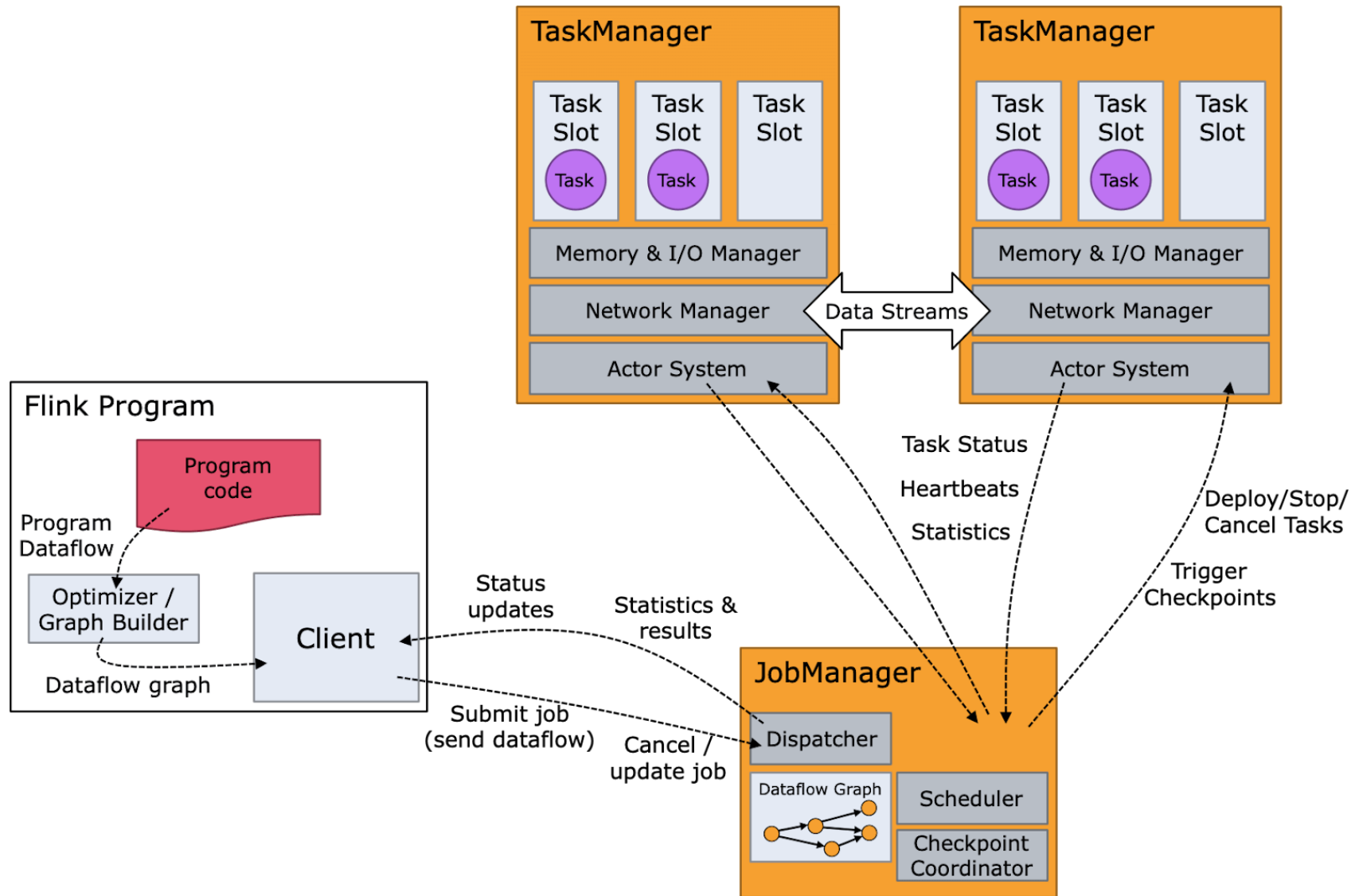
Development Environment Setup



WHAT IS APACHE FLINK

Apache Flink is a framework and distributed processing engine for stateful computations over unbounded and bounded data streams. Flink has been designed to run in all common cluster environments, and perform computations at in-memory speed, at any scale. Developers build applications for Flink using APIs such as Java or SQL, which are executed on a Flink cluster by the framework.

KEY FEATURES AND COMPONENTS



BASIC ARCHITECTURE – STREAMS & ENVIRONMENT

Apache Flink excels at processing unbounded and bounded data sets. Precise control of time and state enable Flink's runtime to run any kind of application on unbounded streams. Bounded streams are internally processed by algorithms and data structures that are specifically designed for fixed sized data sets, yielding excellent performance.

Apache Flink is a distributed system and requires compute resources in order to execute applications. Flink integrates with all common cluster resource managers such as Hadoop YARN and Kubernetes but can also be setup to run as a stand-alone cluster.

KEY FEATURES

Unified Stream and Batch Processing:

Flink provides a unified programming interface for both stream and batch processing, allowing developers to handle real-time and historical data in a single system.

Stateful Computations:

Flink excels at performing stateful computations on data streams, meaning it can maintain and manage data state across different events and time intervals.

Low Latency and High Throughput:

Flink is designed for low-latency, real-time data processing, enabling applications to react quickly to incoming data streams.

Fault Tolerance and Scalability:

Flink is built to be fault-tolerant, meaning it can continue running even if individual nodes fail, and it can scale horizontally to handle large volumes of data.

KEY FEATURES

Exactly-Once Semantics:

Flink provides exactly-once consistency guarantees for state, ensuring that each event is processed exactly once, even in the presence of failures.

Event-Time Processing:

Flink supports event-time processing, which allows applications to process data based on the time of the event itself, rather than the time it was received.

Rich APIs:

Flink offers a variety of APIs, including the DataStream API for stream processing, the Table API for relational data processing, and the SQL API for declarative data processing.

Integration with Common Systems:

Flink integrates well with various data sources and sinks, including Kafka, Hadoop, and cloud storage services.

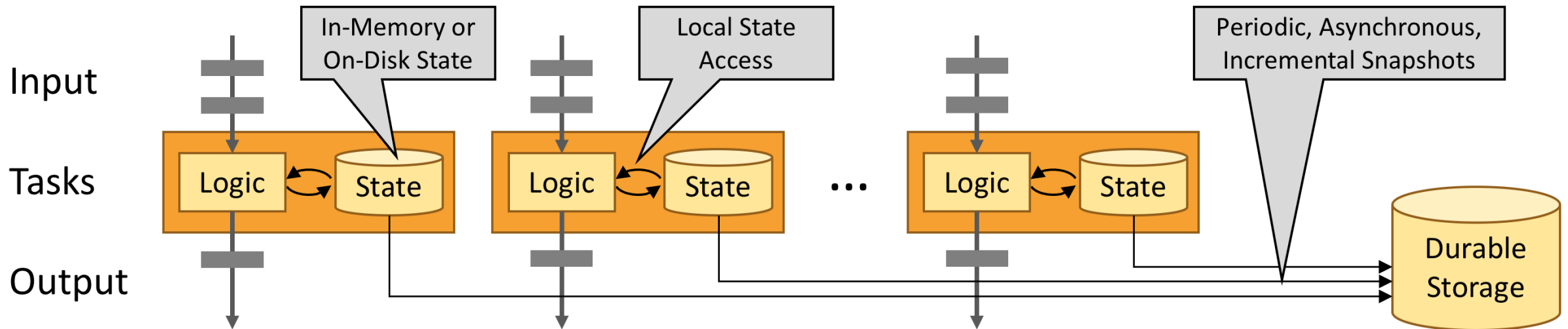
BASIC ARCHITECTURE - SCALE

Flink is designed to run stateful streaming applications at any scale. Applications are parallelized into possibly thousands of tasks that are distributed and concurrently executed in a cluster. Therefore, an application can leverage virtually unlimited amounts of CPUs, main memory, disk and network IO. Moreover, Flink easily maintains very large application state. Its asynchronous and incremental checkpointing algorithm ensures minimal impact on processing latencies while guaranteeing exactly-once state consistency.

- applications processing multiple trillions of events per day
- applications maintaining multiple terabytes of state
- applications running on thousands of cores.

BASIC ARCHITECTURE – IN-MEMORY

Stateful Flink applications are optimized for local state access. Task state is always maintained in memory or, if the state size exceeds the available memory, in access-efficient on-disk data structures. Hence, tasks perform all computations by accessing local, often in-memory, state yielding very low processing latencies. Flink guarantees exactly-once state consistency in case of failures by periodically and asynchronously checkpointing the local state to durable storage.



DEVELOPMENT ENVIRONMENT SETUP

- ***Install Java:*** Flink requires Java 8 or 11, so you need to have one of these versions
- ***Download and Install Apache Flink:*** You can download the latest [binary of Apache Flink](#) from the official Flink website.
- ***Start a Local Flink Cluster:*** Start a local Flink cluster using the command. `/start-cluster.sh`
- ***Set up an Integrated Development Environment (IDE):*** For writing and testing your Flink programs
- ***Create a Flink Project:*** You can create a new Flink using a build tool like Maven or Gradle.

YOUR FIRST FLINK APPLICATION

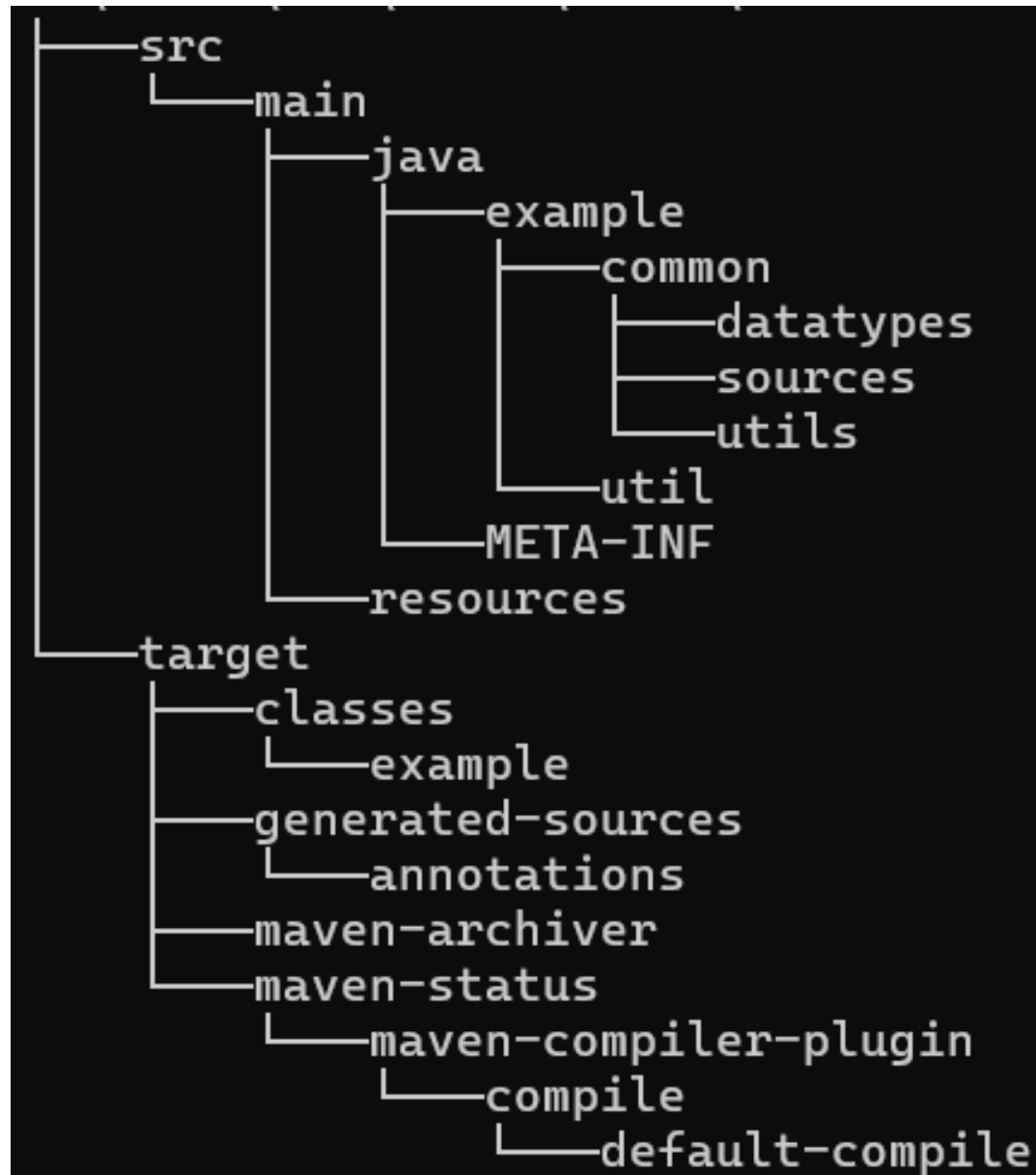
- *Project Structure – Java, Scala or Python. Java for our work*
- *Basic Configuration – easy enough executable Jar*
- *Streaming Example – but that's everything now*
- *Running Local – run a basic cluster with our experiments*

FIRST FLINK APPLICATION ANATOMY

Flink programs look like regular programs that transform DataStreams. Each program consists of the same basic parts:

- Obtain an execution environment,
- Load/create the initial data,
- Specify transformations on this data,
- Specify where to put the results of your computations,
- Trigger the program execution

PROJECT STRUCTURE



BASIC CONFIGURATION

- *Java 8 or 11*
- *Maven up to 3.8.6*
- *New code in the Apache Flink GitHub requires Java 17, but that won't run in the current LTS Apache Flink Clusters*
- *Code editor – favorites are Eclipse, IntelliJ and VSCode.*
- *Windows, Linux, or MacOS, but we'll have Ubuntu 22 environments for our development cluster. Recommend at least 16GB of RAM.*

```
c:\projects\flink\flink-data-processing-2day>mvn -version
Apache Maven 3.8.6 (84538c9988a25aec085021c365c560670ad80f63)
Maven home: C:\apache-maven-3.8.6
Java version: 11.0.26, vendor: Eclipse Adoptium, runtime: C:\java\jdk-11.0.26+4
Default locale: en_US, platform encoding: Cp1252
OS name: "windows 11", version: "10.0", arch: "amd64", family: "windows"
```

STREAMING EXAMPLE

```
import ....  
public class HelloWorld {  
    public static void main(String[] args) throws Exception {  
        final StreamExecutionEnvironment env =  
            StreamExecutionEnvironment.getExecutionEnvironment();  
        env.fromElements(1, 2, 3, 4, 5)  
            .map(i -> 2 * i)  
            .print();  
        env.execute();  
    }  
}
```

FLINK EXECUTION ENVIRONMENT

We always start out with a `StreamExecutionEnvironment`

```
final StreamExecutionEnvironment env =  
StreamExecutionEnvironment.getExecutionEnvironment  
( );
```

The `StreamExecutionEnvironment` is the basis for all Flink programs. You can obtain one using these static methods:

- `StreamExecutionEnvironment : getExecutionEnvironment();`
- `createLocalEnvironment();`
- `createRemoteEnvironment(String host, int port, String... jarFiles);`

FLINK EXECUTION ENVIRONMENT

Typically, you only need to use `getExecutionEnvironment()`, since this will do the right thing depending on the context: if you are executing your program inside an IDE or as a regular Java program it will create a local environment that will execute your program on your local machine. If you created a JAR file from your program, and invoke it through the command line, the Flink cluster manager will execute your main method and `getExecutionEnvironment()` will return an execution environment for executing your program on a cluster.

For specifying data sources the execution environment has several methods to read from files using various methods: you can just read them line by line, as CSV files, or using any of the other provided sources.

BUILT-IN DATASOURCES

Flink provides special data sources which are backed by Java collections to ease testing.

// Create a DataStream from a list of elements

```
DataStream<Integer> myInts = env.fromElements(1, 2, 3, 4, 5);
```

// Create a DataStream from any Java collection

```
List<Tuple2<String, Integer>> data = ...
```

```
DataStream<Tuple2<String, Integer>> myTuples =  
env.fromCollection(data);
```

// Create a DataStream from an Iterator

```
Iterator<Long> longIt = ...;
```

```
DataStream<Long> myLongs = env.fromCollection(longIt,  
Long.class);
```


MAP TRANSFORMATION

In Apache Flink, a "map" refers to a transformation operation on a `DataStream` or `DataSet` where a user-defined function is applied to each element, producing a one-to-one mapping. The map function transforms each input element into exactly one output element.

Key aspects of Flink's map transformation:

- One-to-one mapping:

Each input element is processed, and a single output element is produced for it.

- User-defined function:

The map operation requires a user-defined function (like a `MapFunction`) to specify the transformation logic.

```
.map(i -> 2 * i) // multiply each input element by 2
```

PRINT OPERATION

The print operation can be used to write to stdout which we do in our HelloWorld example, or to the invoker which we will see in a number of our experiments.

```
.print() ;
```

For the debugging with standard out we can see that in the log folder under the flink installation. The files are named in the format

```
flink-environment-taskexecutor-n-ip-xx.yy.zz.ww.out
```

EXECUTION

Once you specified the complete program you need to trigger the program execution by calling `execute()` on the `StreamExecutionEnvironment`. Depending on the type of the `ExecutionEnvironment` the execution will be triggered on your local machine or submit your program for execution on a cluster.

The `execute()` method will wait for the job to finish and then return a `JobExecutionResult`, this contains execution times and accumulator results.

```
env.execute ();
```

Q&A AND OPEN DISCUSSION



Working with DataStreams



Working with DataStreams

- DataStream Basics

 - Creating DataStreams

 - Basic Operations

 - Data Types

 - Simple Transformations

- Common Operations

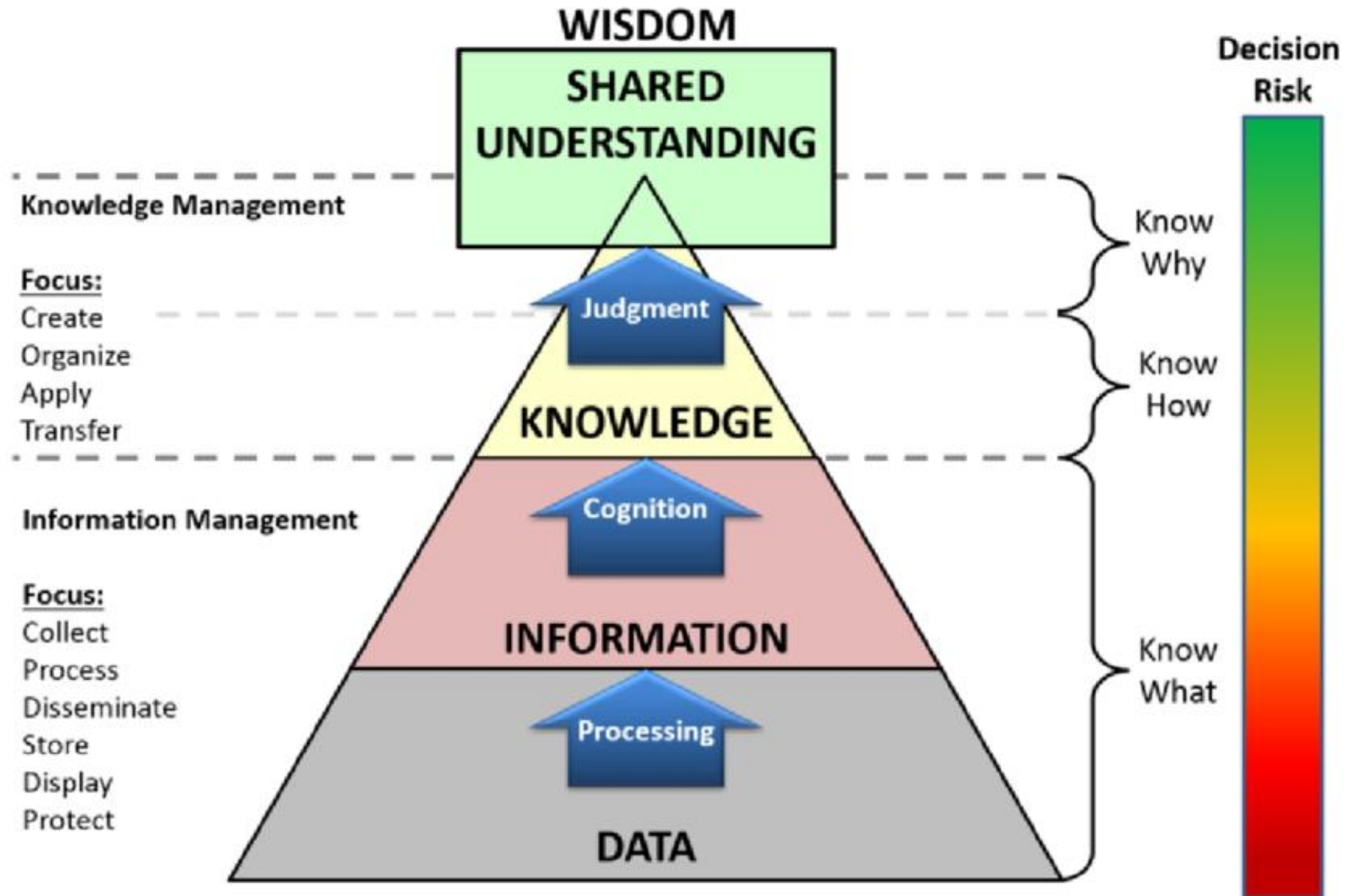
 - Map and FlatMap

 - Filter Operations

 - Basic Aggregations

 - Field Selection

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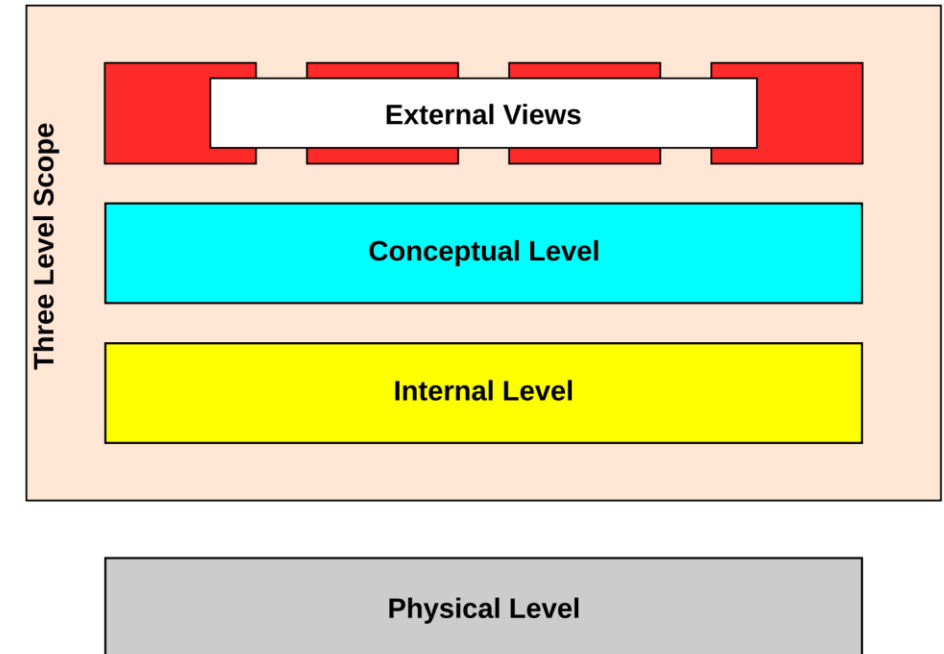
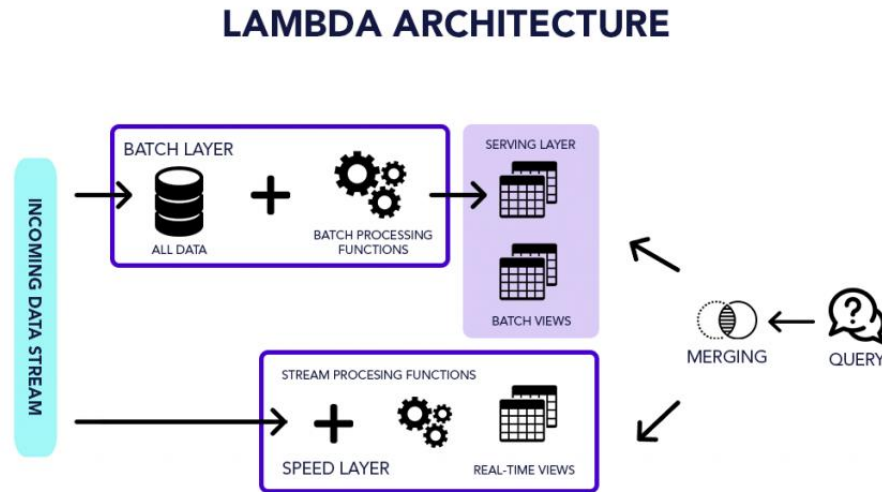


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Q&A AND OPEN DISCUSSION



Data Sources and Sinks



Data Sources and Sinks

Built-in Sources

- File-based Sources

- Socket Sources

- Collection Sources

- Generating Test Data

Built-in Sinks

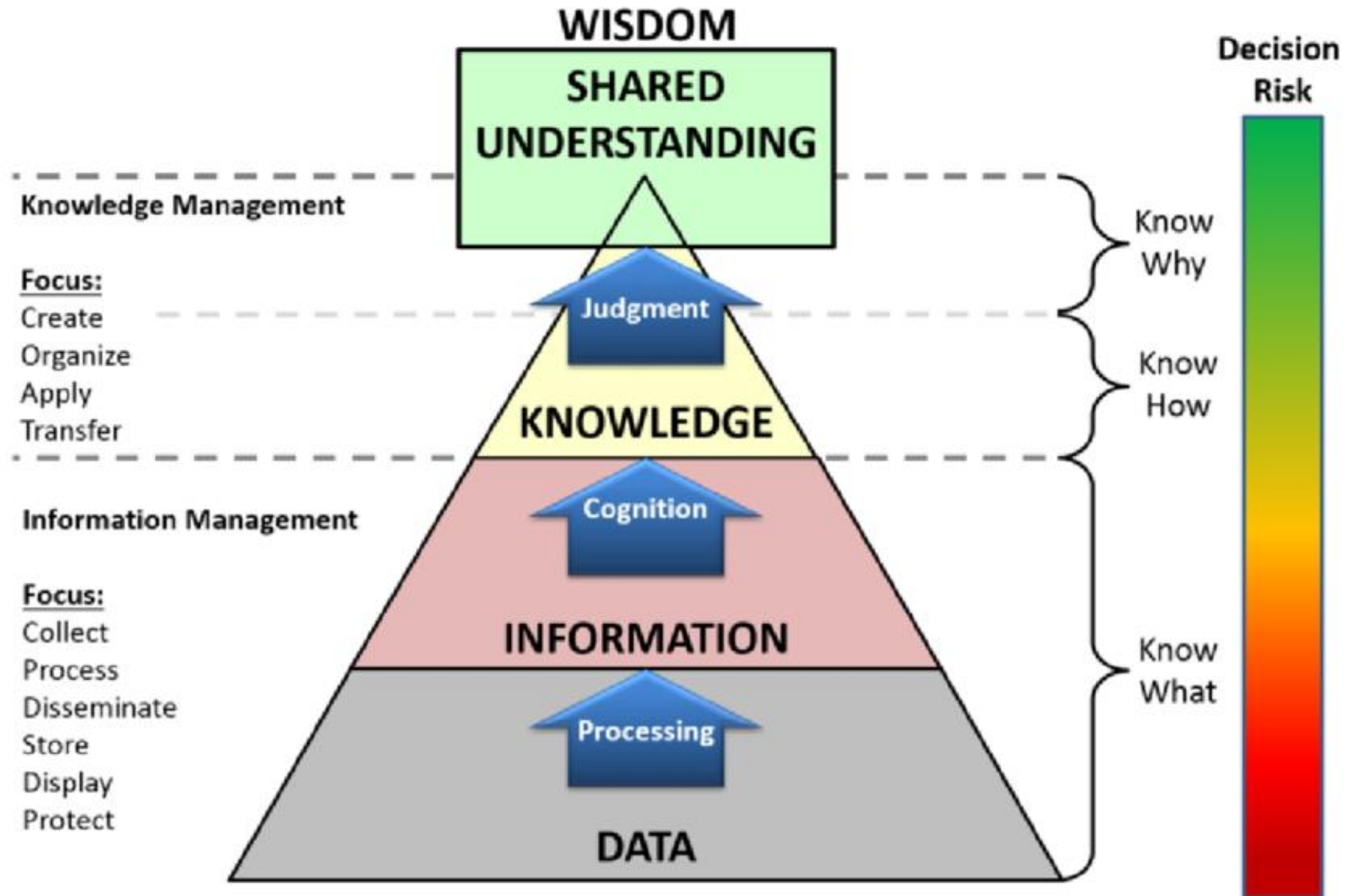
- File Sinks

- Print Sink

- Socket Sink

- Common Formats

SINGLE LARGE IMAGE



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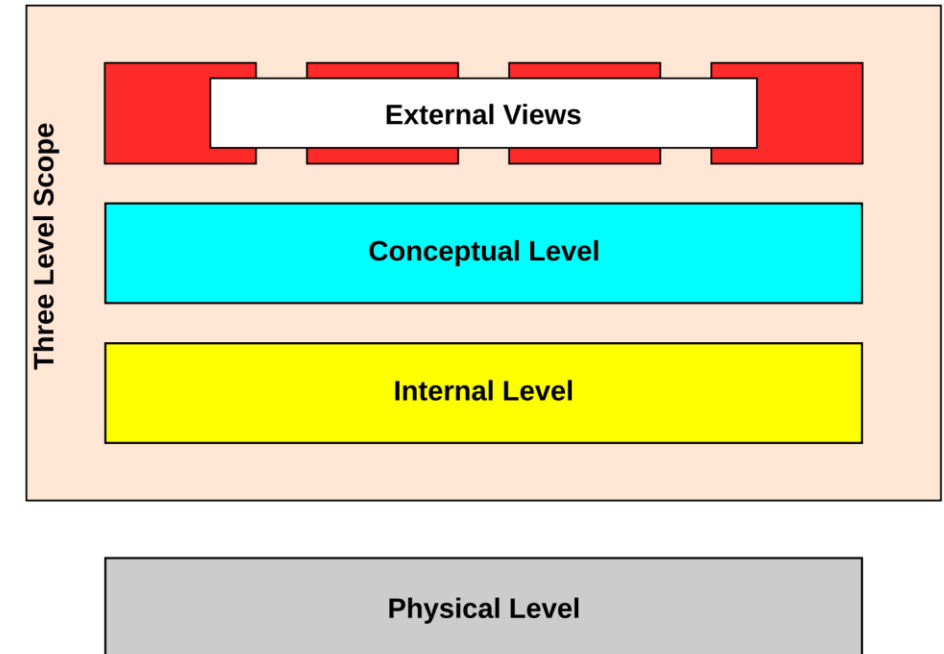
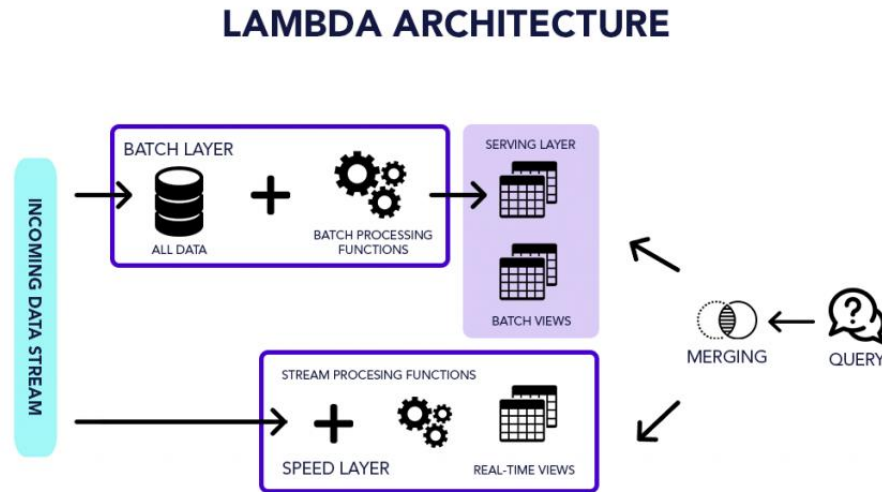


IMAGE BOTTOM

- Used when we have streaming data and historical data
 - We set up a two part architecture
 - A real time speed layer, that could be part of a OLTP transactional system
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Q&A AND OPEN DISCUSSION



Time and Windows



Time and Windows

- Understanding Time

 - Event Time vs Processing Time

 - Timestamps

 - Watermarks Basics

 - Dealing with Late Events

- Window Operations

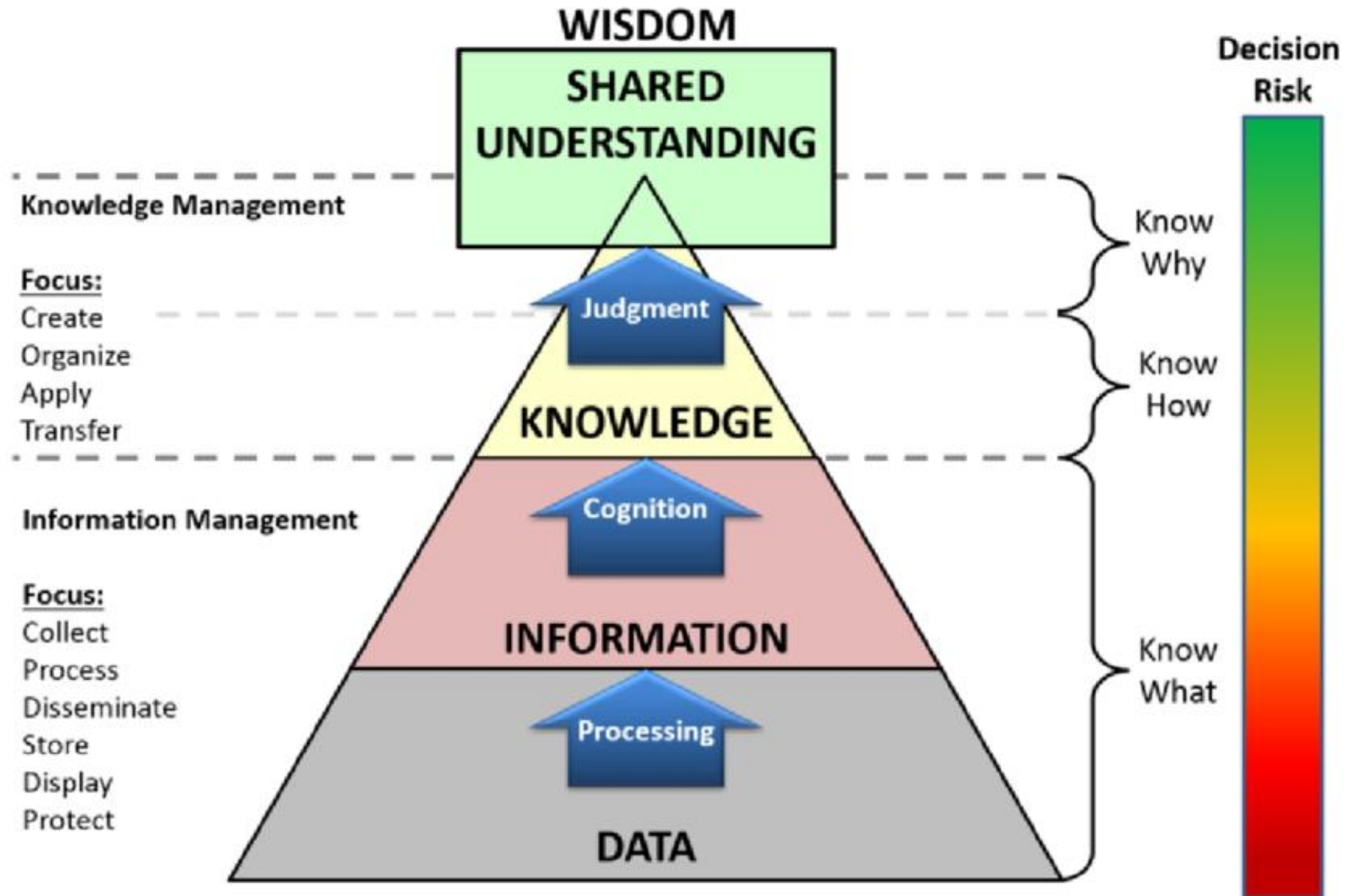
 - Types of Windows

 - Tumbling Windows

 - Sliding Windows

 - Session Windows

SINGLE LARGE IMAGE



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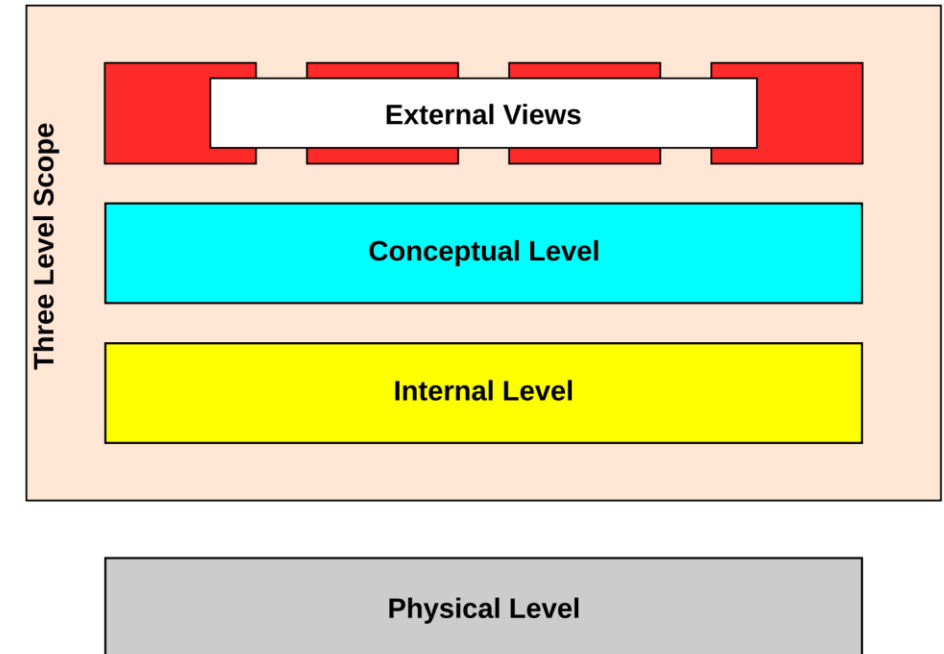
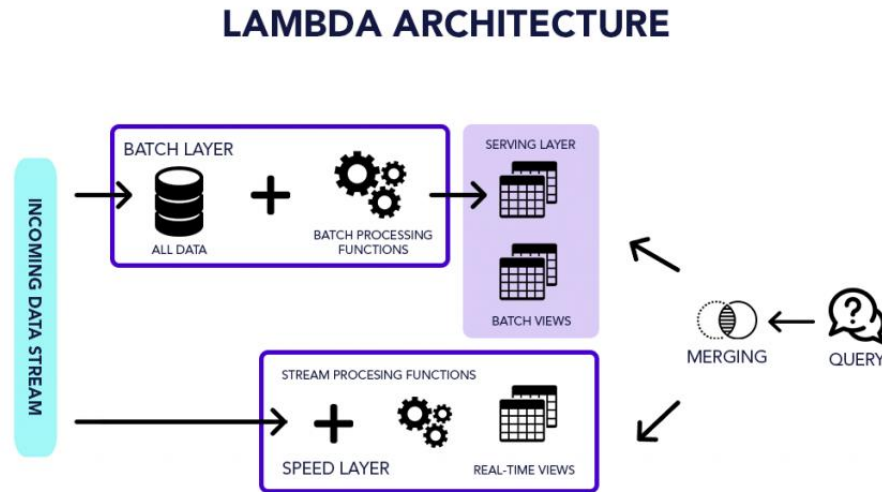


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Q&A AND OPEN DISCUSSION



Basic State Management



Basic State Management

State Concepts

- What is State?

- When to Use State

- Simple State Examples

- State Backends

Working with State

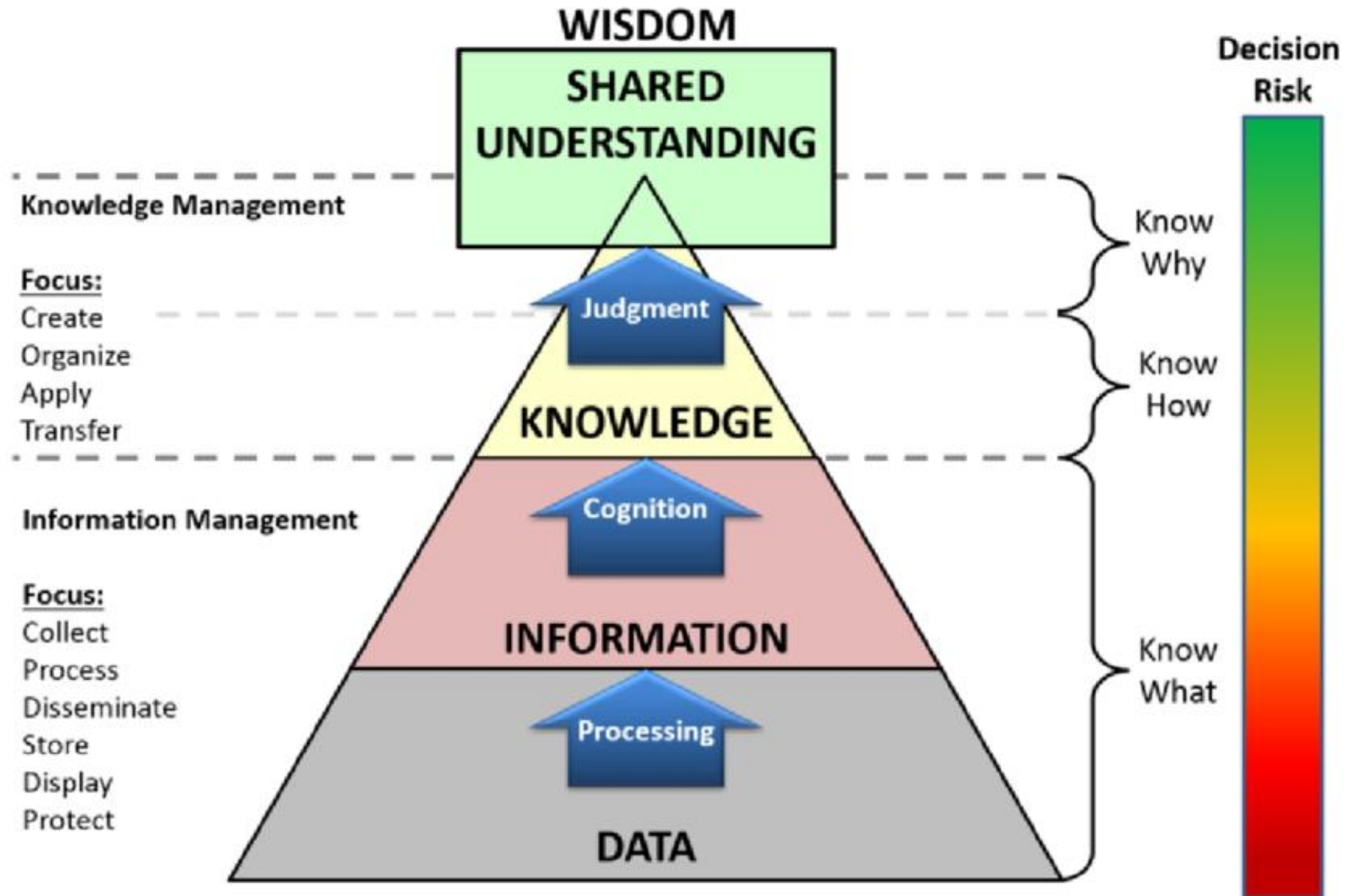
- Keyed State

- Value State

- List State

- Basic State Patterns

SINGLE LARGE IMAGE



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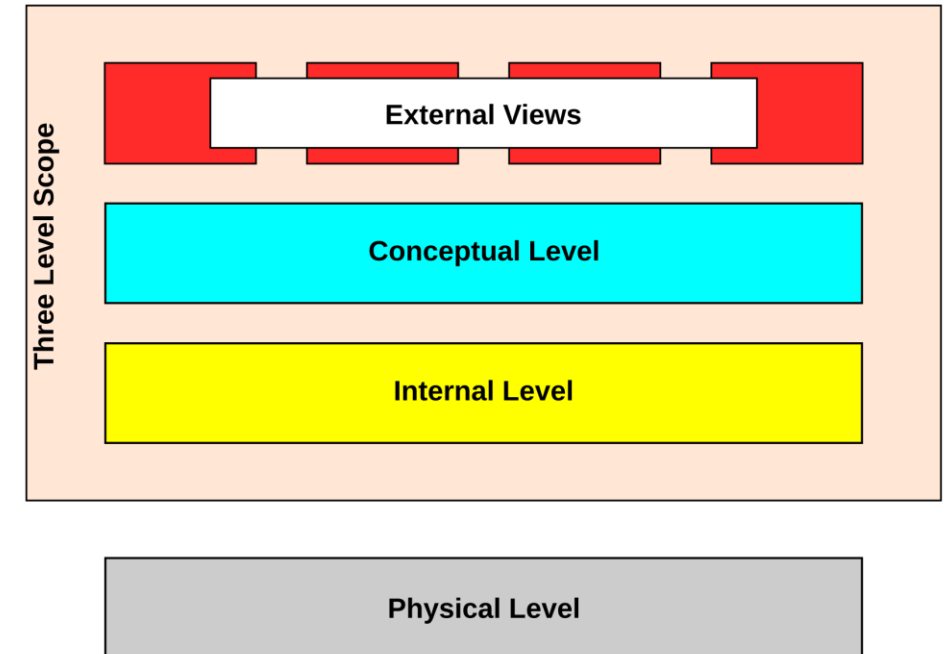
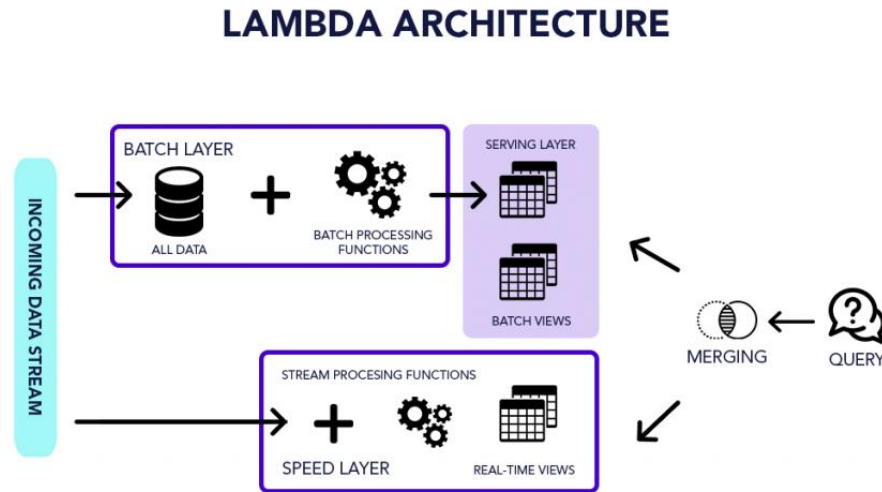


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Q&A AND OPEN DISCUSSION



Deployment and Next Steps



Deployment and Next Steps

Basic Deployment

- Deployment Options

- Local Cluster

- Configuration Basics

- Resource Planning

Moving Forward

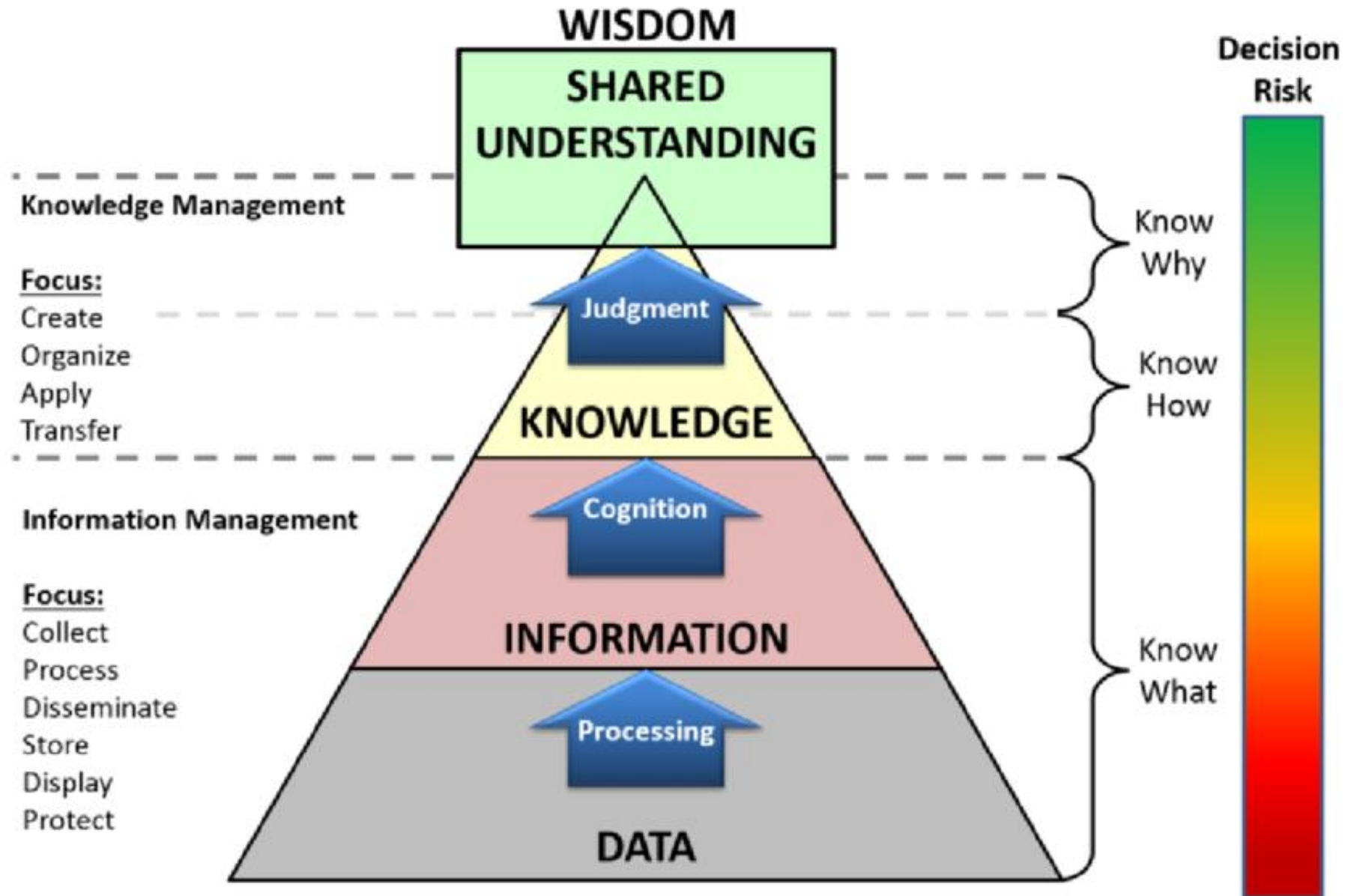
- Best Practices Review

- Advanced Topics Preview

- Learning Resources

- Common Use Cases

SINGLE LARGE IMAGE



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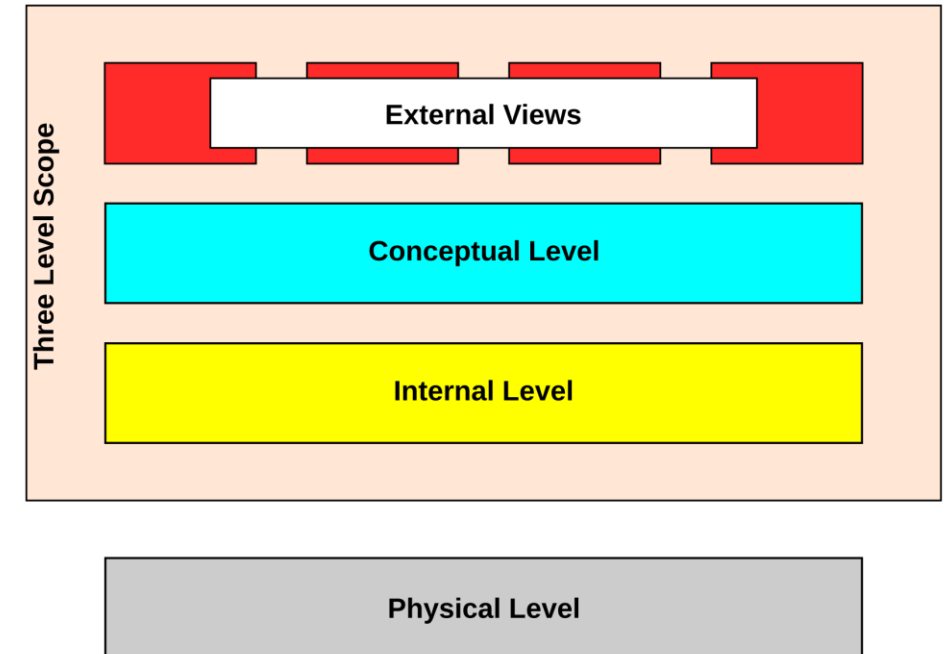
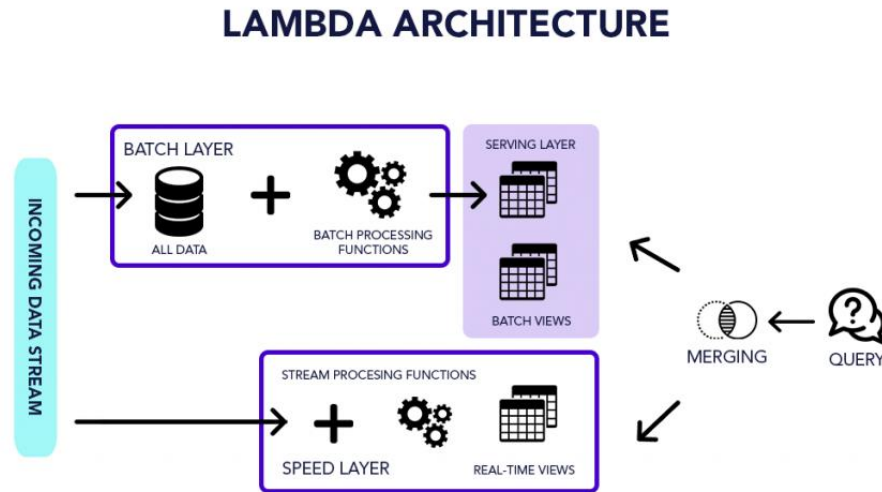


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