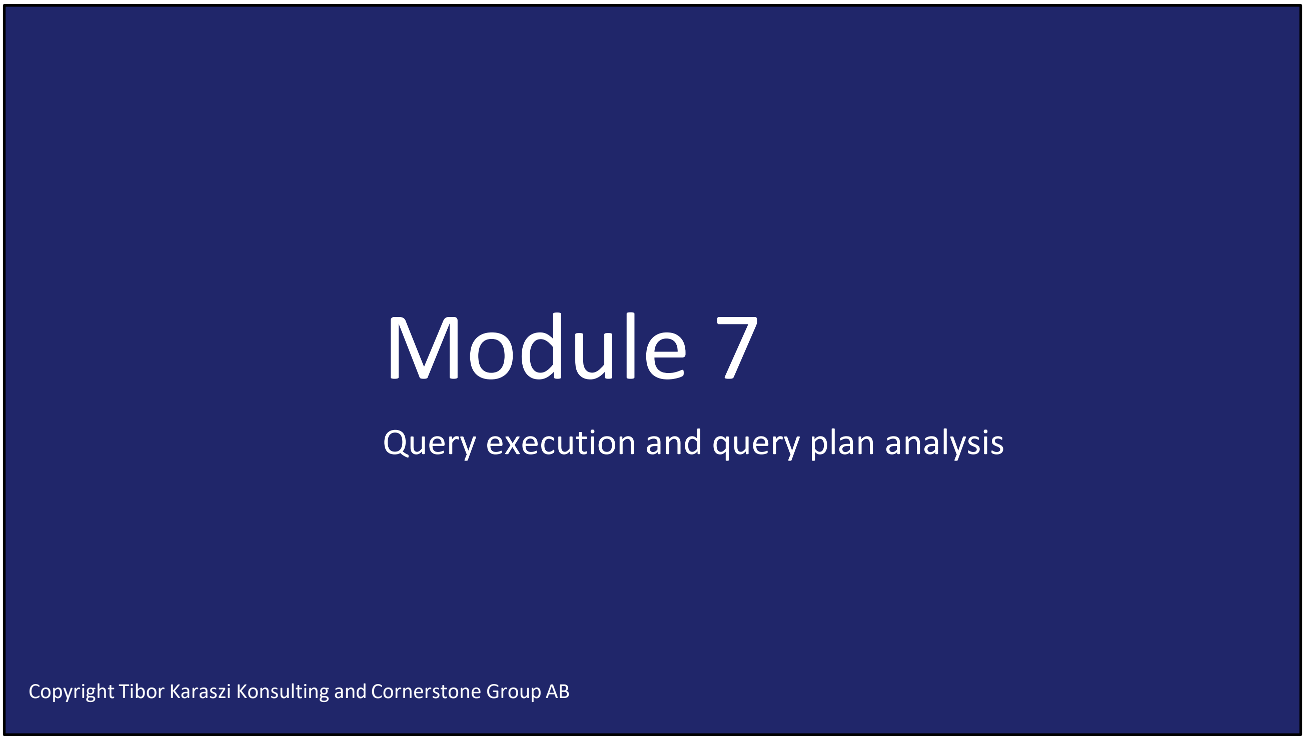
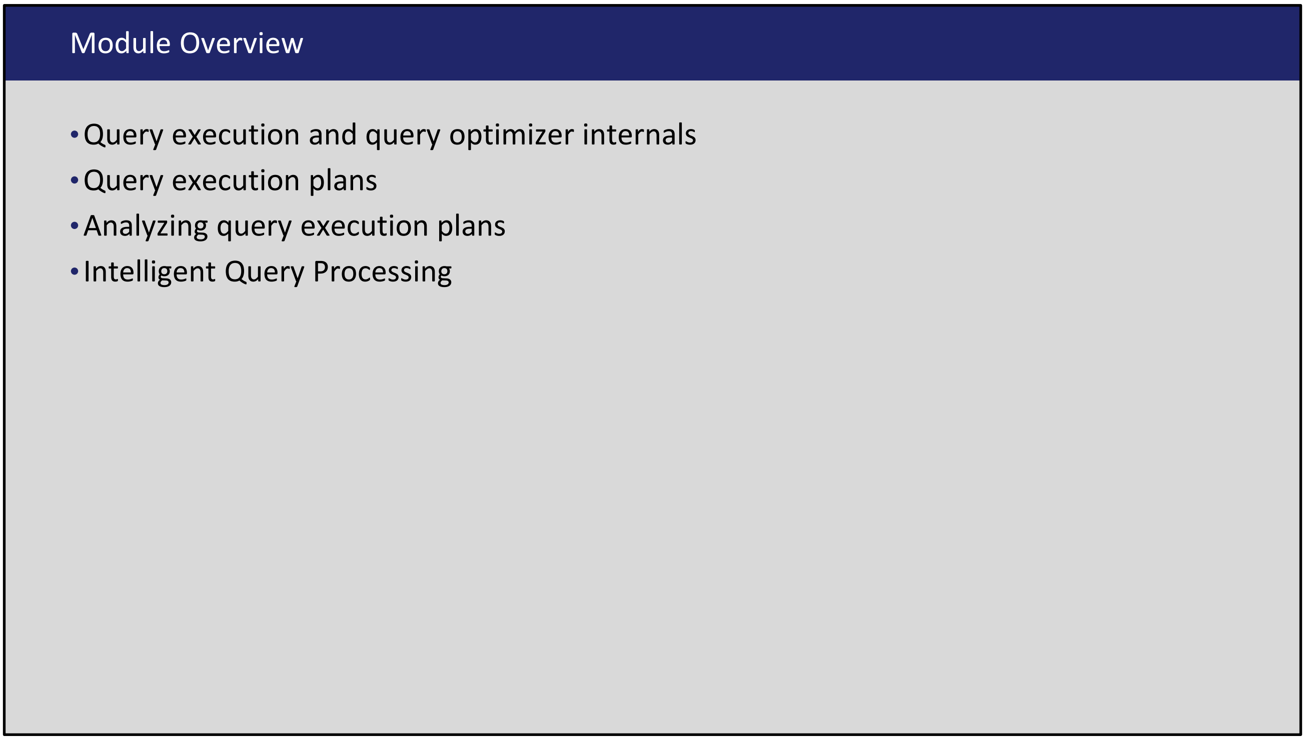


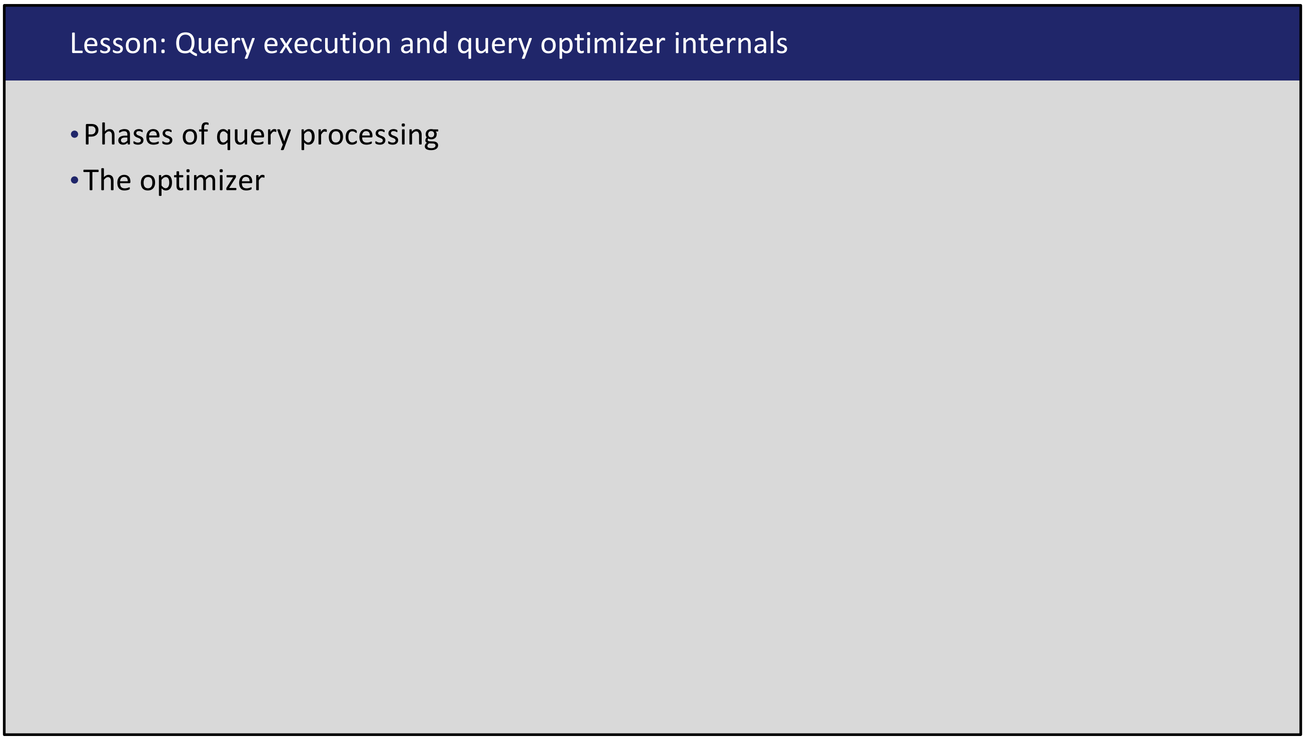
Module 7

Query execution and query plan analysis



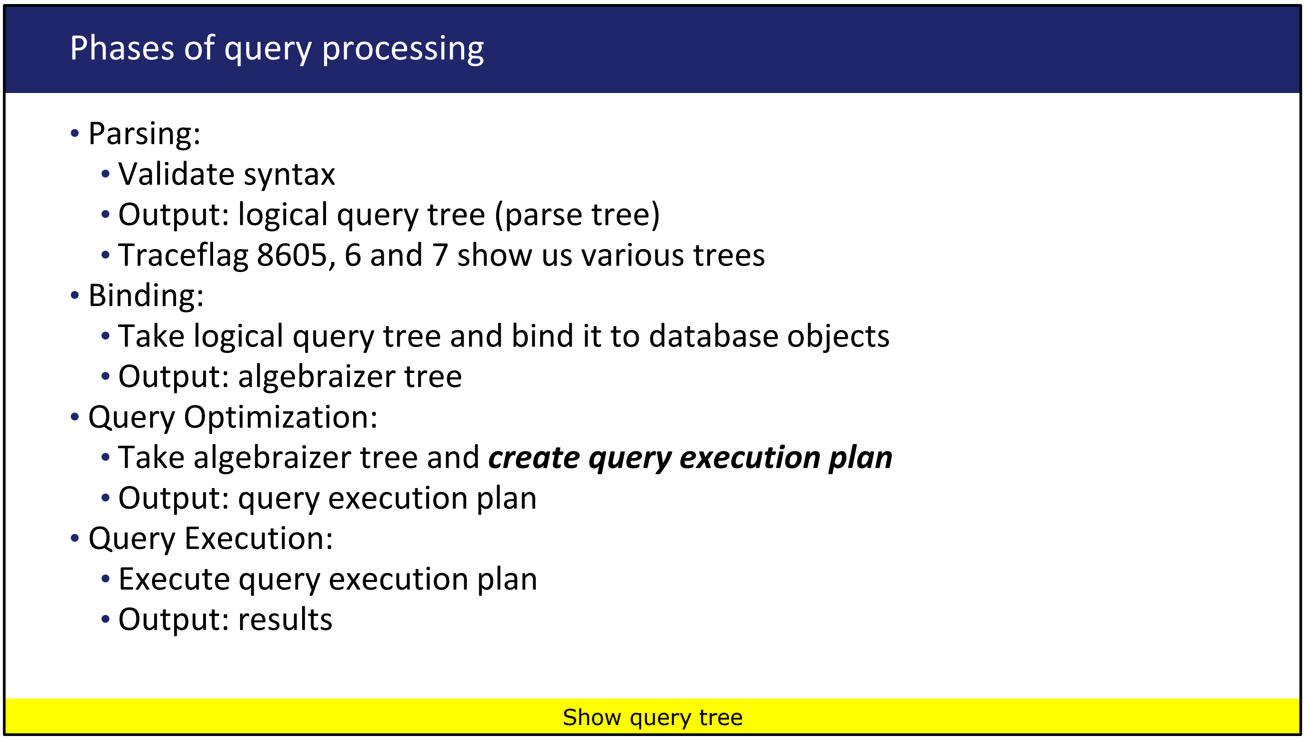
Module Overview

- Query execution and query optimizer internals
- Query execution plans
- Analyzing query execution plans
- Intelligent Query Processing



Lesson: Query execution and query optimizer internals

- Phases of query processing
- The optimizer



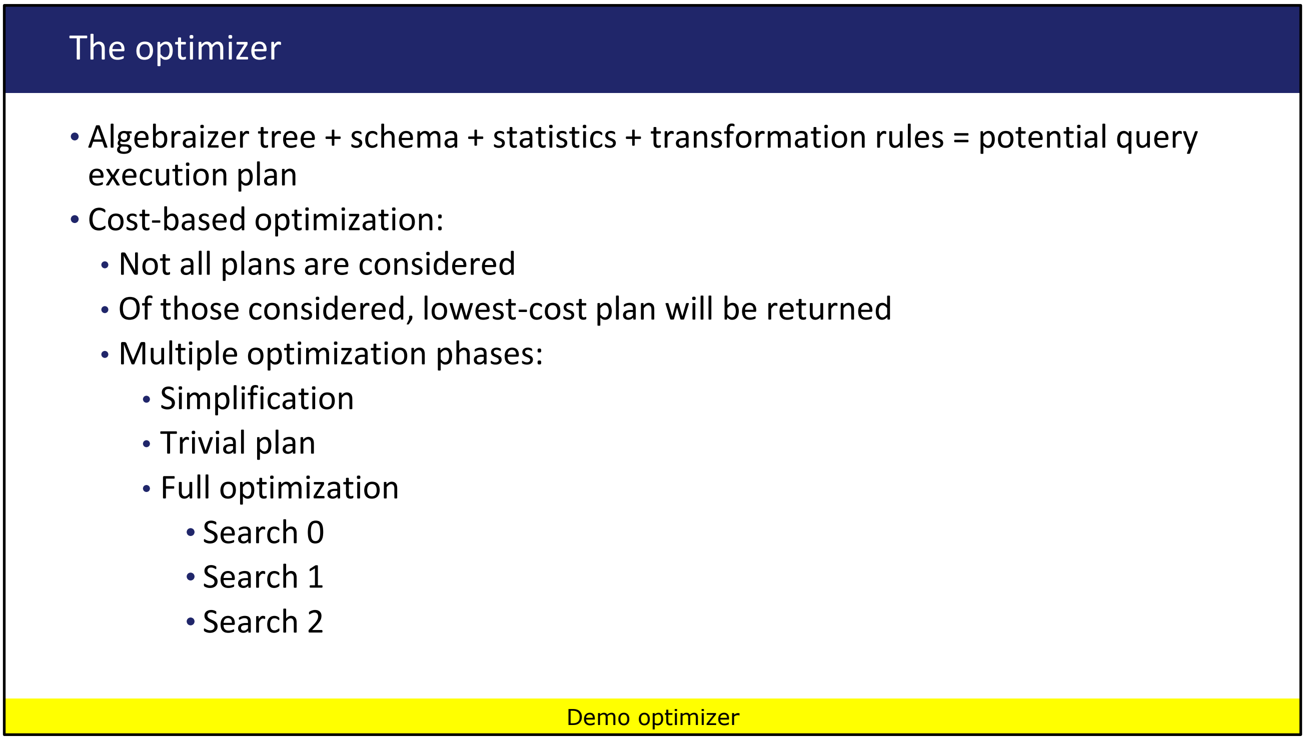
Phases of query processing

- Parsing:
  - Validate syntax
  - Output: logical query tree (parse tree)
  - Traceflag 8605, 6 and 7 show us various trees
- Binding:
  - Take logical query tree and bind it to database objects
  - Output: algebraizer tree
- Query Optimization:
  - Take algebraizer tree and ***create query execution plan***
  - Output: query execution plan
- Query Execution:
  - Execute query execution plan
  - Output: results

Show query tree

Query Processing Architecture Guide
https://docs.microsoft.com/en-us/sql/relational-databases/query-processing-architecture-guide

Query Optimization in SQL Server for beginners
https://www.sqlshack.com/query-optimization-in-sql-server-for-beginners/



The optimizer

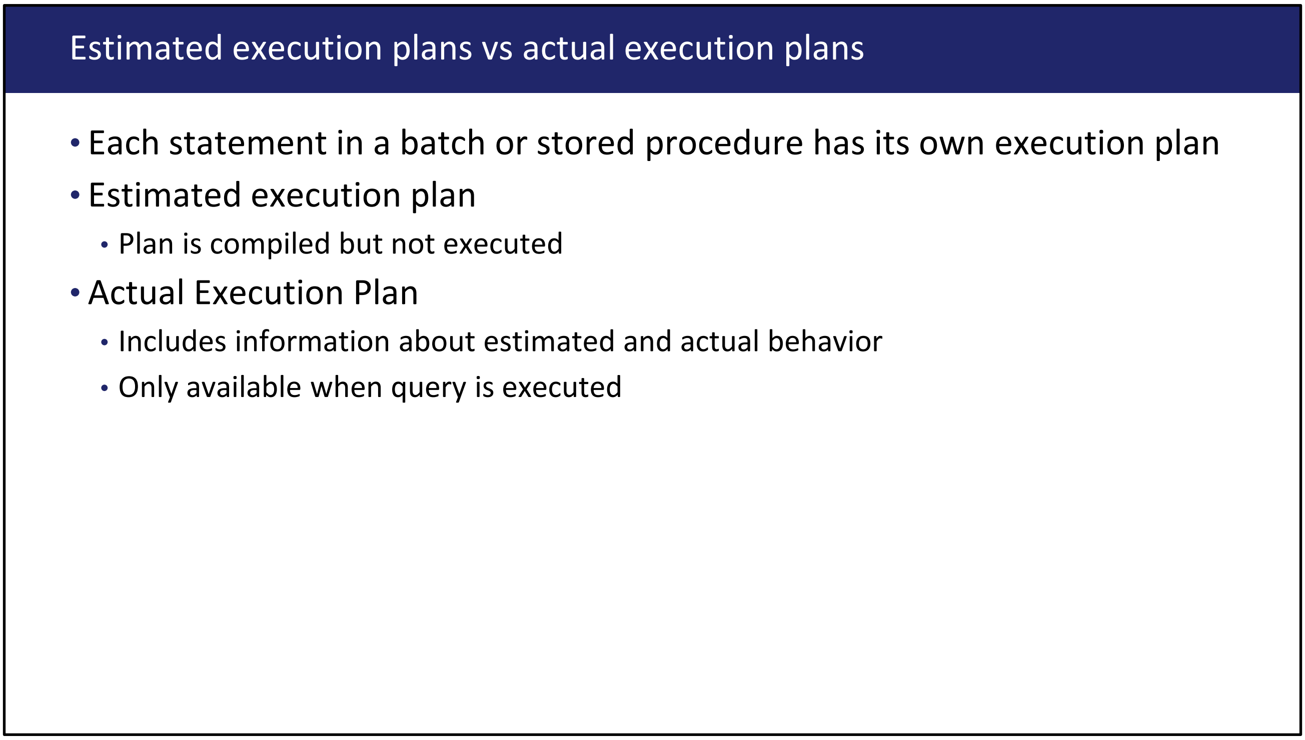
- Algebraizer tree + schema + statistics + transformation rules = potential query execution plan
- Cost-based optimization:
  - Not all plans are considered
  - Of those considered, lowest-cost plan will be returned
  - Multiple optimization phases:
    - Simplification
    - Trivial plan
    - Full optimization
      - Search 0
      - Search 1
      - Search 2

Demo optimizer

Query Processing Architecture Guide
https://docs.microsoft.com/en-us/sql/relational-databases/query-processing-architecture-guide

Lesson: Execution plans

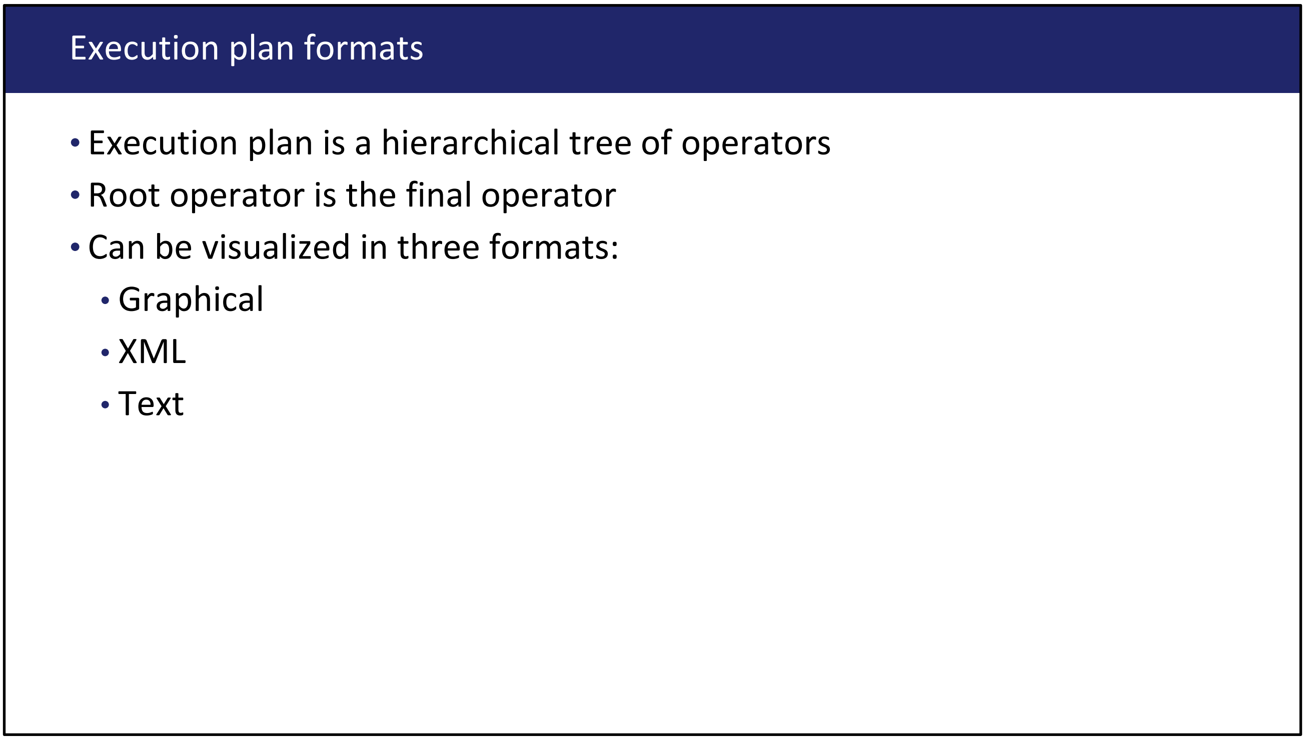
- Estimated execution plans vs actual execution plans
- Execution plan formats
- Capturing execution plans



Estimated execution plans vs actual execution plans

- Each statement in a batch or stored procedure has its own execution plan
- Estimated execution plan
  - Plan is compiled but not executed
- Actual Execution Plan
  - Includes information about estimated and actual behavior
  - Only available when query is executed

Comparing Estimated and Actual Execution Plans in SQL Server
https://www.brentozar.com/archive/2014/07/comparing-estimated-actual-execution-plans-sql-server/



Execution plan formats

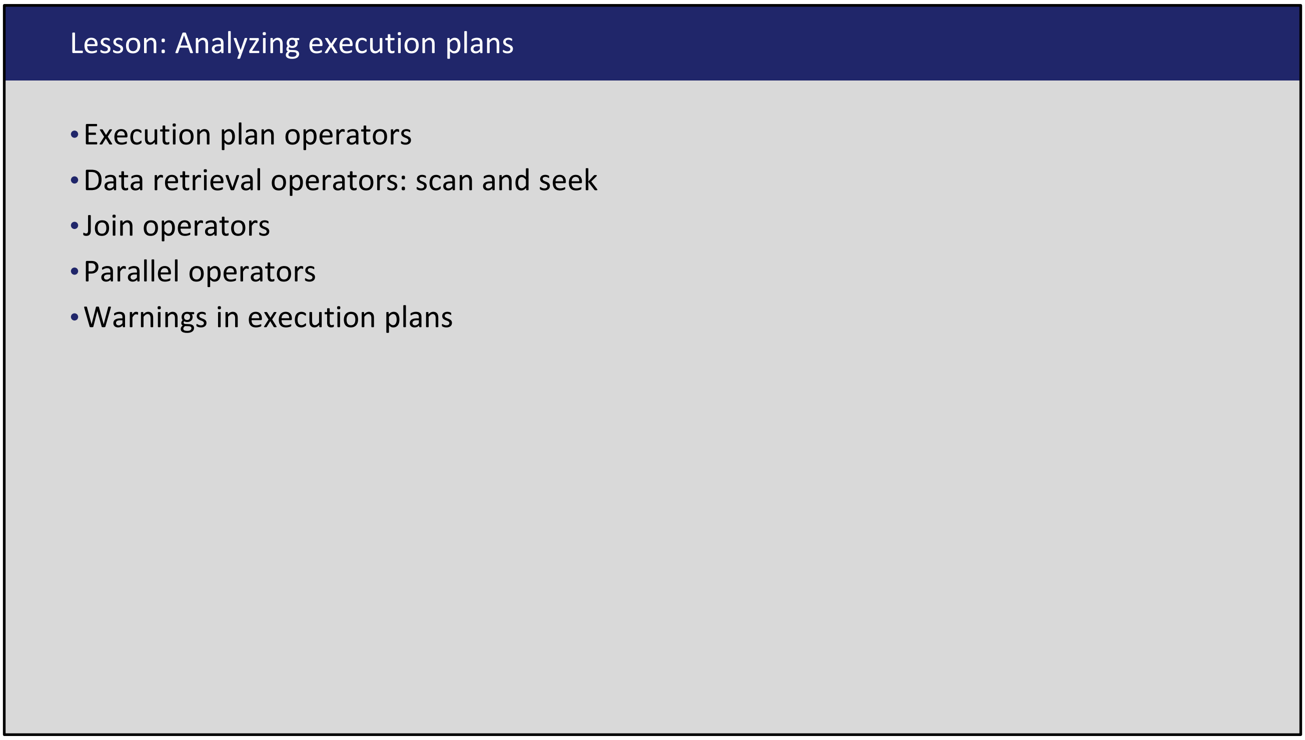
- Execution plan is a hierarchical tree of operators
- Root operator is the final operator
- Can be visualized in three formats:
  - Graphical
  - XML
  - Text

Display and Save Execution Plans
https://docs.microsoft.com/en-us/sql/relational-databases/performance/display-and-save-execution-plans

Capturing execution plans

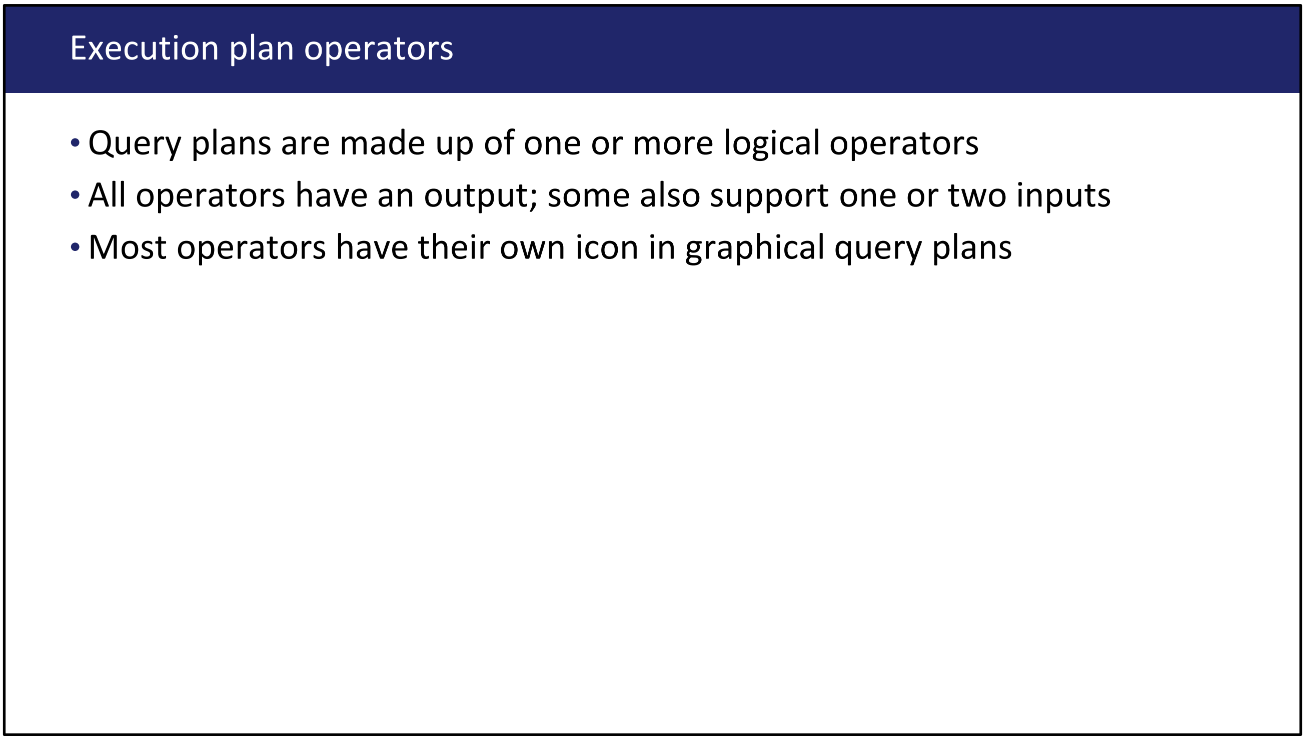
- Graphical plan:
  - From SSMS
  - Can be stored as and retrieved from XML
  - Live Query Statistics shows the plan in operation
- XML:
  - SHOWPLAN_XML: estimated plan
  - STATISTICS XML: actual plan
- Text:
  - SHOWPLAN_TEXT: estimated plan
  - SHOWPLAN_ALL: estimated plan with statistics
  - STATISTICS PROFILE: actual plan

Demo Show execution plan and Live query statistics



Lesson: Analyzing execution plans

- Execution plan operators
- Data retrieval operators: scan and seek
- Join operators
- Parallel operators
- Warnings in execution plans



Execution plan operators

- Query plans are made up of one or more logical operators
- All operators have an output; some also support one or two inputs
- Most operators have their own icon in graphical query plans

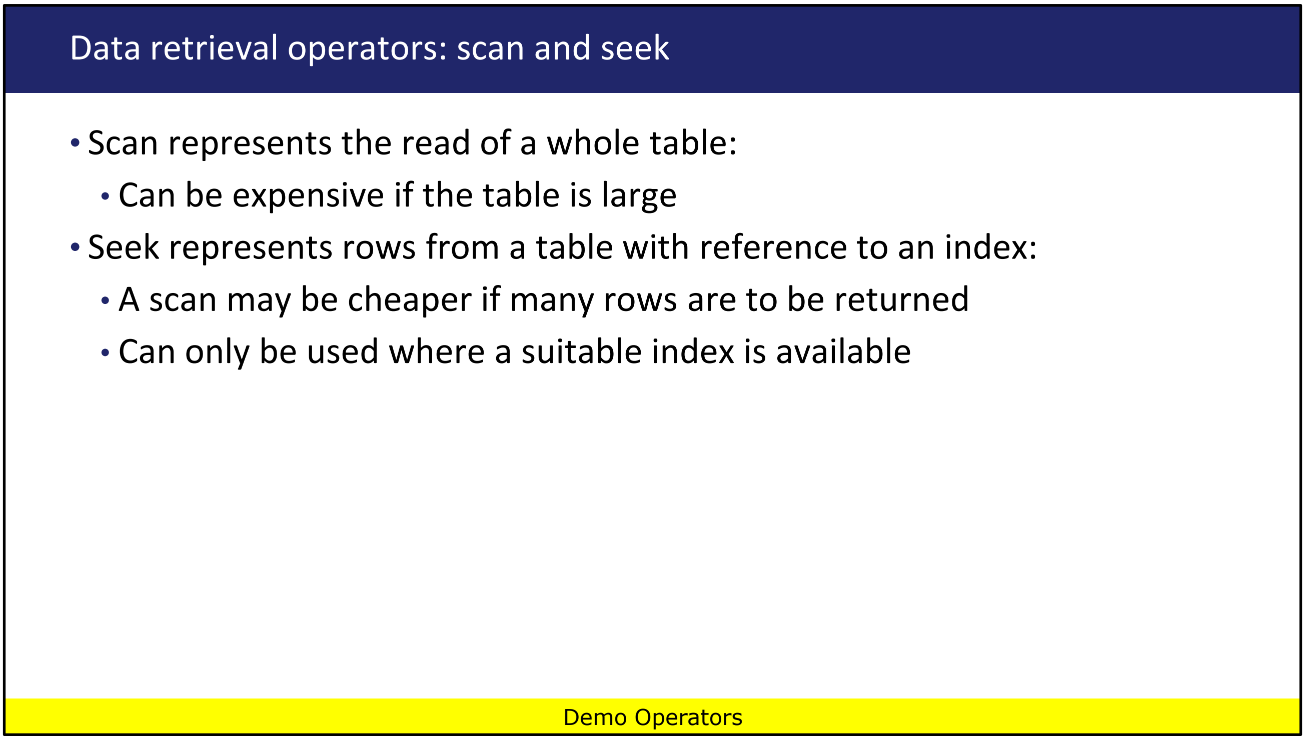
Showplan Logical and Physical Operators Reference
https://docs.microsoft.com/en-us/sql/relational-databases/showplan-logical-and-physical-operators-reference

SQL Server Execution Plan Operators – Part 1
https://www.sqlshack.com/sql-server-execution-plan-operators-part-1/

SQL Server Execution Plan Reference
https://sqlserverfast.com/epr/

Operator List
https://sqlserverfast.com/epr/operator-list/

SQL Server Execution Plans, 3rd Edition, Free eBook
https://www.red-gate.com/products/dba/sql-monitor/entrypage/execution-plans



Data retrieval operators: scan and seek

- Scan represents the read of a whole table:
  - Can be expensive if the table is large
- Seek represents rows from a table with reference to an index:
  - A scan may be cheaper if many rows are to be returned
  - Can only be used where a suitable index is available

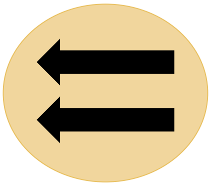
Demo Operators

Join operators

- Nested Loops:
  - The second input is searched once for each value in the first input
  - The second input should be inexpensive to search
- Merge Join:
  - Two sorted inputs are interleaved
  - Both inputs must be sorted
- Hash Match:
  - A hash table built from the first input is compared against hash values from the second input
  - Large unsorted inputs

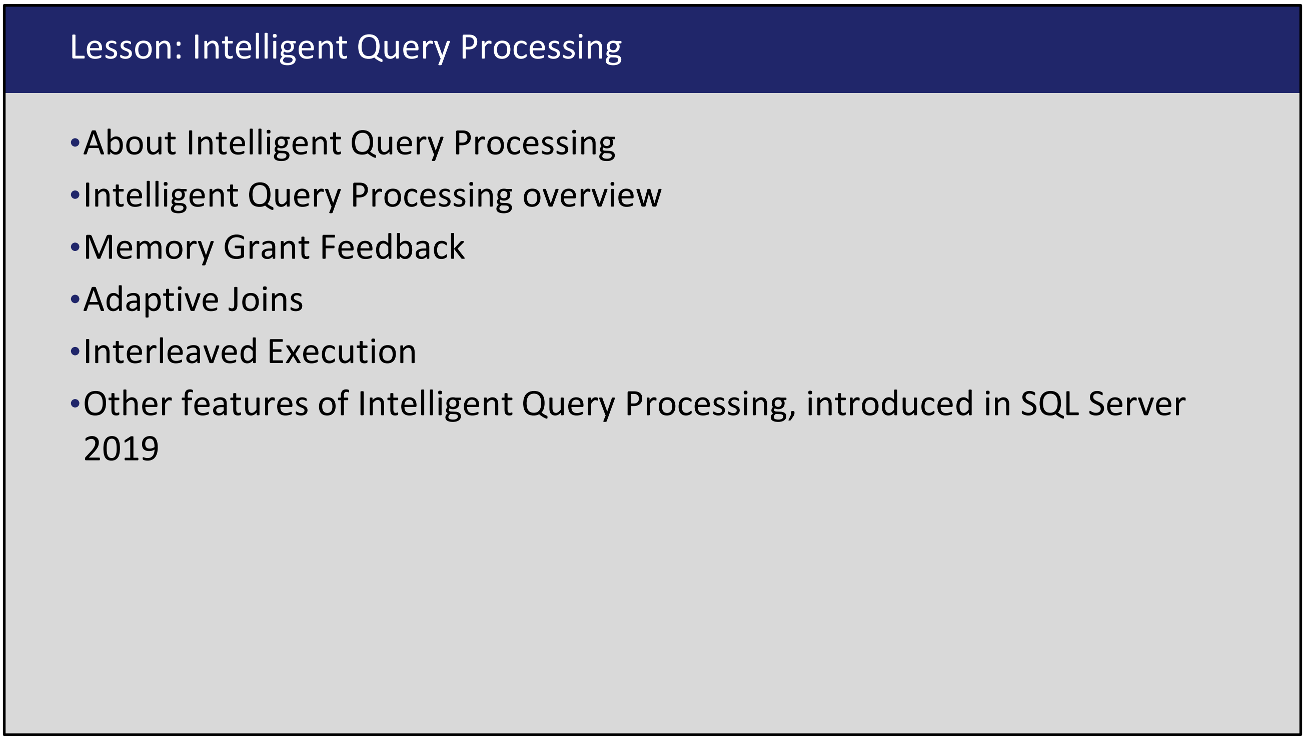
Parallel operators

- Plans for parallelized queries do not show the activity of individual parallel workers
- Query plan operators that use parallelism are indicated in the query plan
- Parallel plans will have at least one instance of the Gather Streams operator, which combines the results of parallel operators



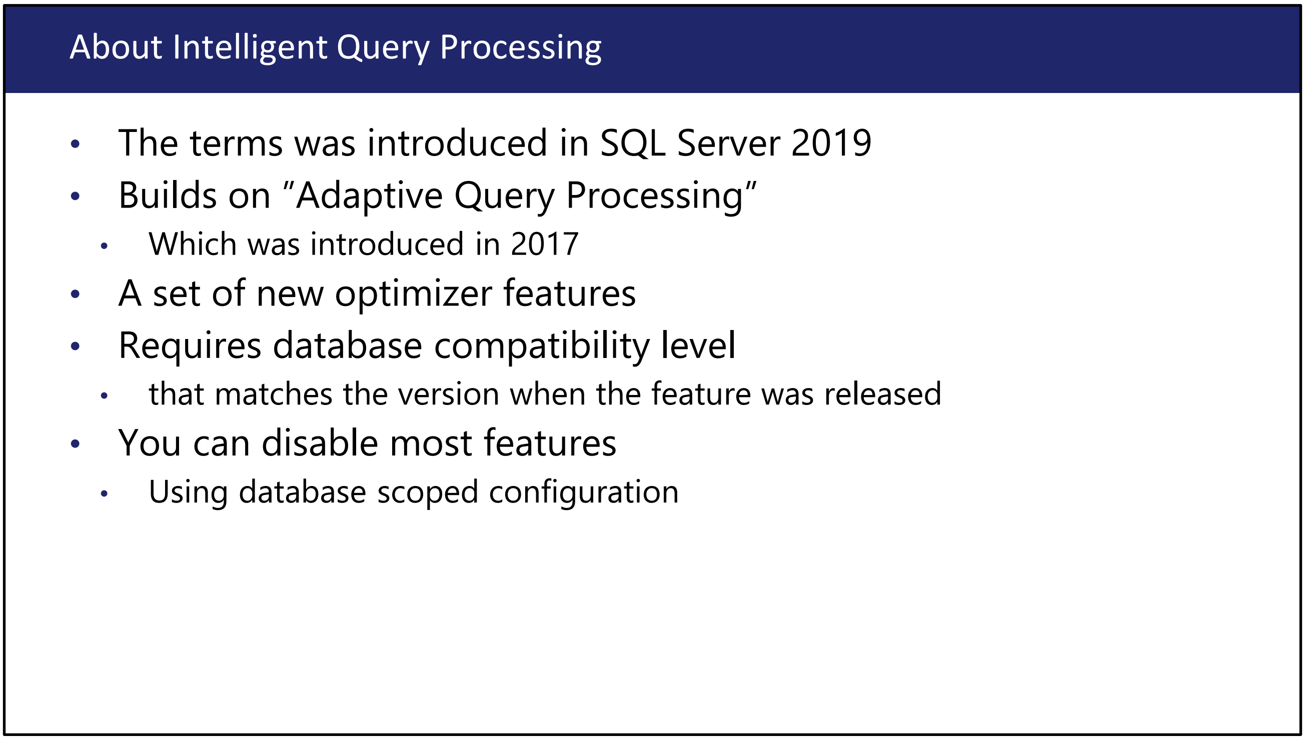
Warnings in execution plans

- Query plan operators may have associated warnings
- Warnings indicate issues that may have significant negative impact on query performance
- Warnings are serious and should be investigated and addressed



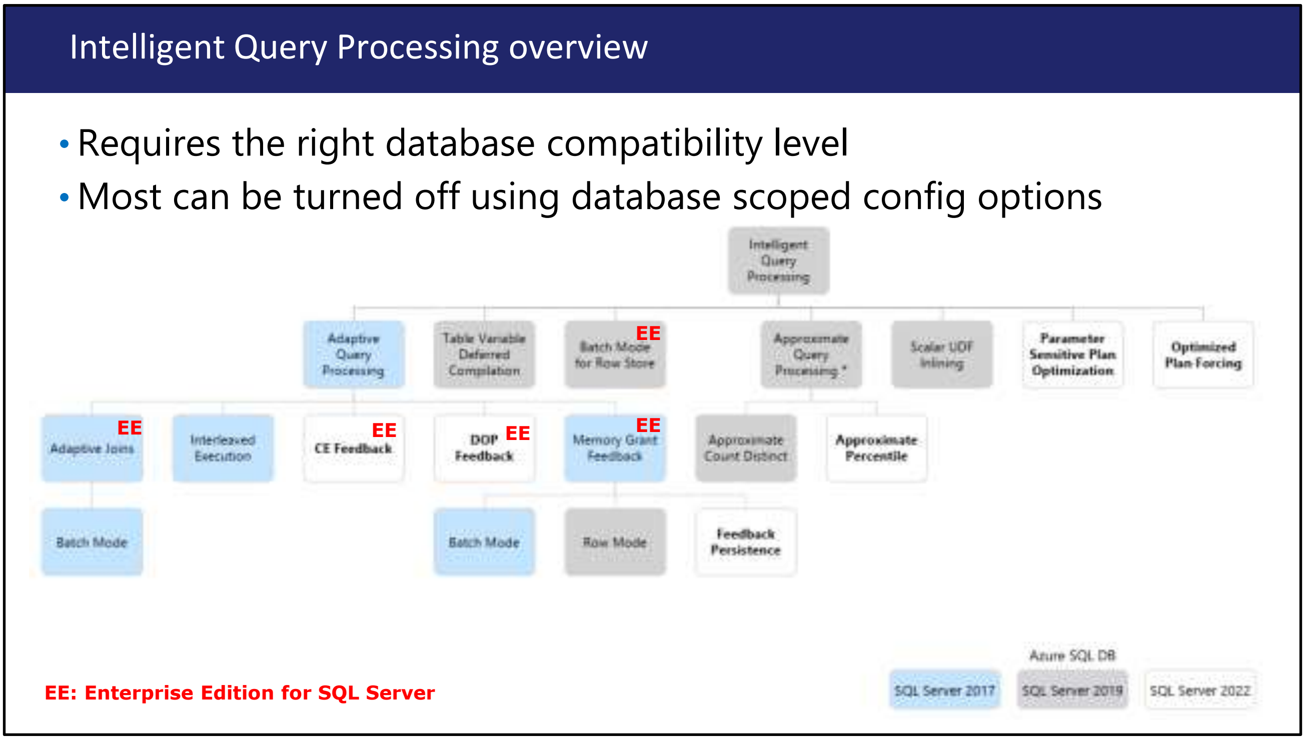
Lesson: Intelligent Query Processing

- About Intelligent Query Processing
- Intelligent Query Processing overview
- Memory Grant Feedback
- Adaptive Joins
- Interleaved Execution
- Other features of Intelligent Query Processing, introduced in SQL Server 2019



About Intelligent Query Processing

- The terms was introduced in SQL Server 2019
- Builds on ”Adaptive Query Processing”
  - Which was introduced in 2017
- A set of new optimizer features
- Requires database compatibility level
  - that matches the version when the feature was released
- You can disable most features
  - Using database scoped configuration



Intelligent Query Processing overview

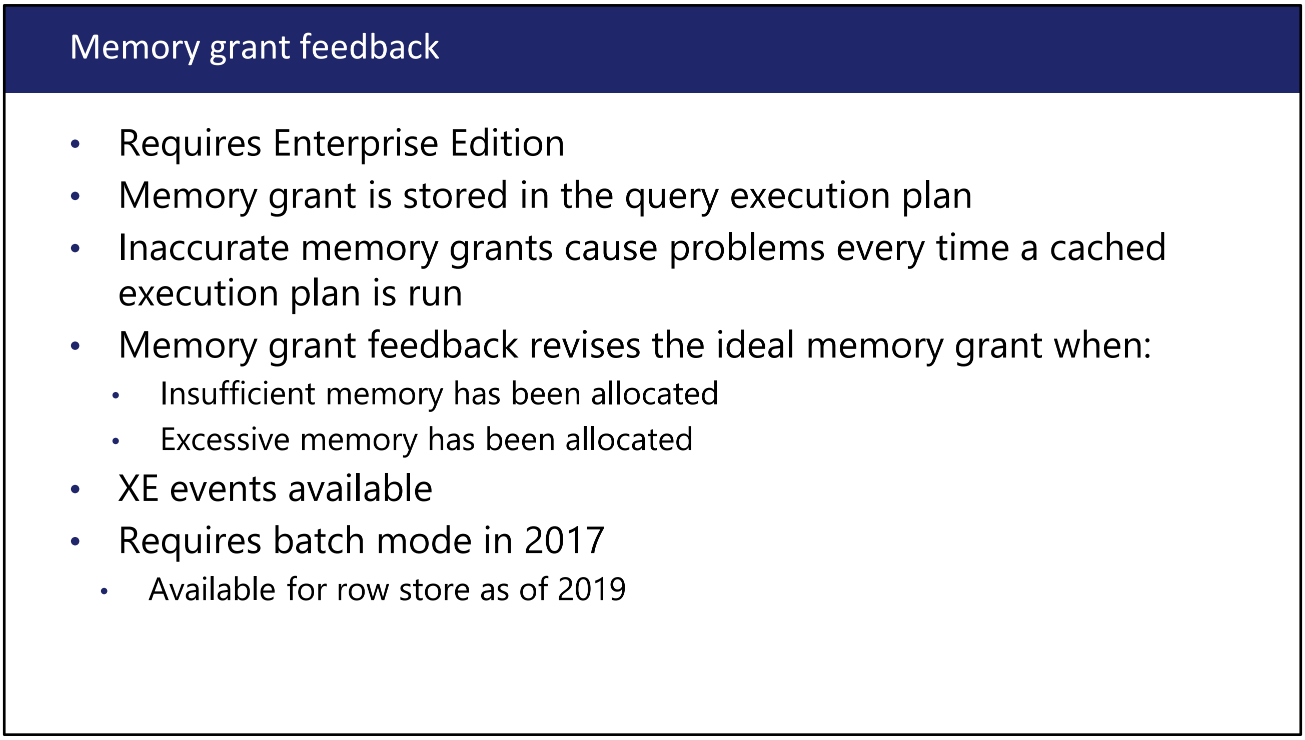
- Requires the right database compatibility level
- Most can be turned off using database scoped config options

EE: Enterprise Edition for SQL Server

Intelligent query processing in SQL databases
https://docs.microsoft.com/en-us/sql/relational-databases/performance/intelligent-query-processing

Intelligent Query Processing Q&A
https://techcommunity.microsoft.com/t5/azure-sql-blog/intelligent-query-processing-q-amp-a/ba-p/446657

Azure SQL & SQL Server 2022: Intelligent Database Futures
https://techcommunity.microsoft.com/t5/video-hub/azure-sql-amp-sql-server-2022-intelligent-database-futures-data/ba-p/3039415

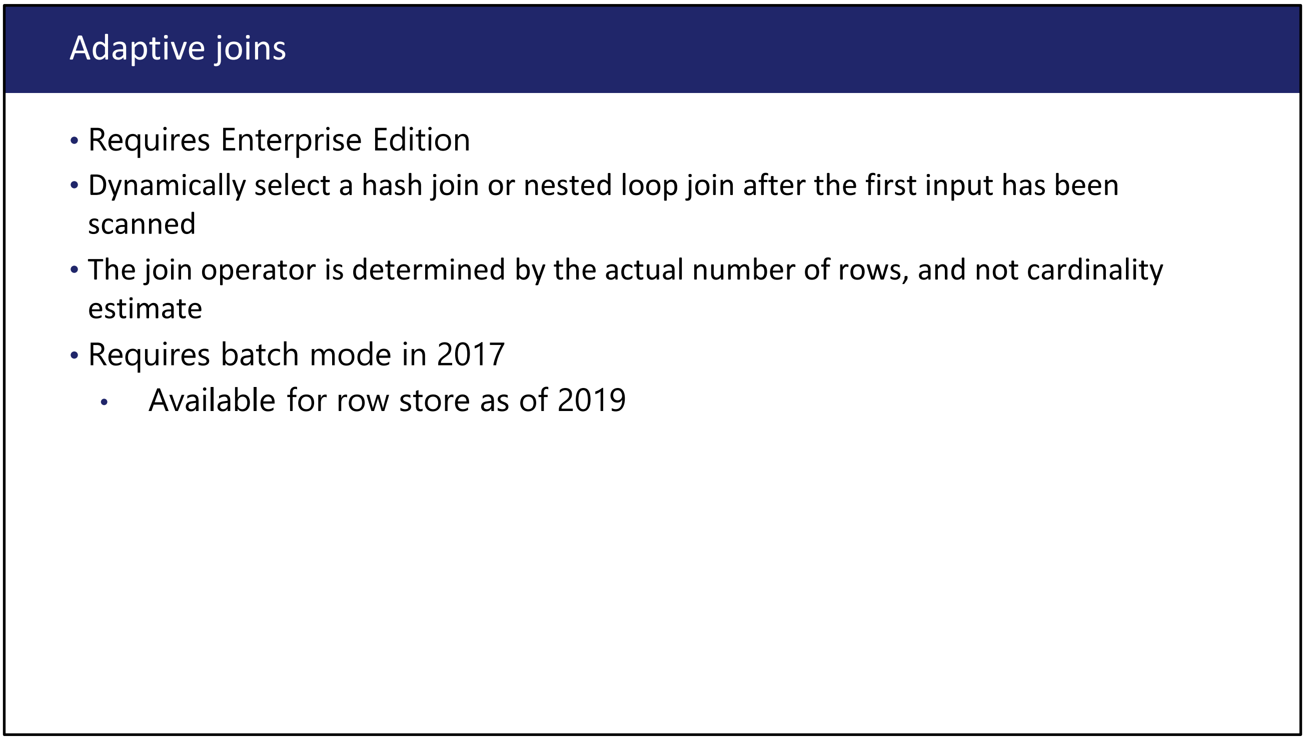


Memory grant feedback

- Requires Enterprise Edition
- Memory grant is stored in the query execution plan
- Inaccurate memory grants cause problems every time a cached execution plan is run
- Memory grant feedback revises the ideal memory grant when:
  - Insufficient memory has been allocated
  - Excessive memory has been allocated
- XE events available
- Requires batch mode in 2017
  - Available for row store as of 2019

Batch mode memory grant feedback
https://docs.microsoft.com/en-us/sql/relational-databases/performance/intelligent-query-processing#batch-mode-memory-grant-feedback

Row mode memory grant feedback
https://docs.microsoft.com/en-us/sql/relational-databases/performance/intelligent-query-processing#row-mode-memory-grant-feedback

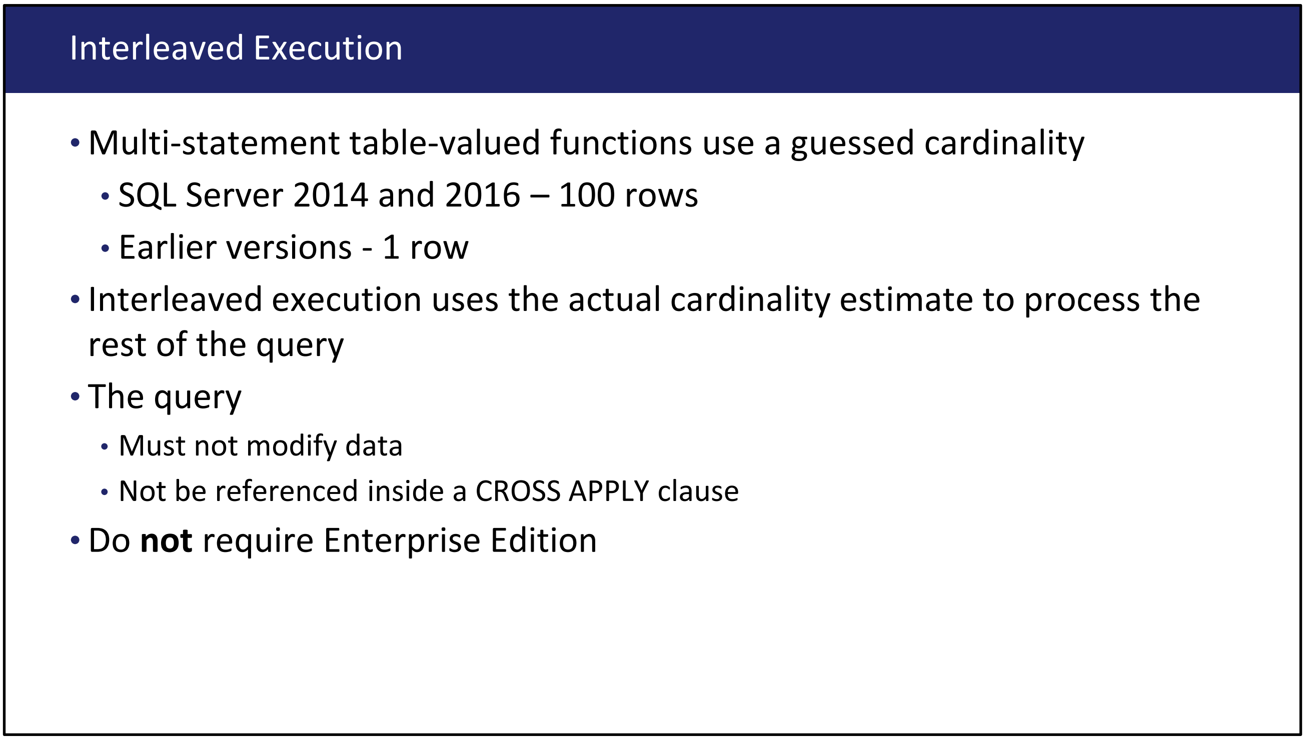


Adaptive joins

- Requires Enterprise Edition
- Dynamically select a hash join or nested loop join after the first input has been scanned
- The join operator is determined by the actual number of rows, and not cardinality estimate
- Requires batch mode in 2017
  - Available for row store as of 2019

Batch mode Adaptive joins
https://docs.microsoft.com/en-us/sql/relational-databases/performance/intelligent-query-processing#batch-mode-adaptive-joins

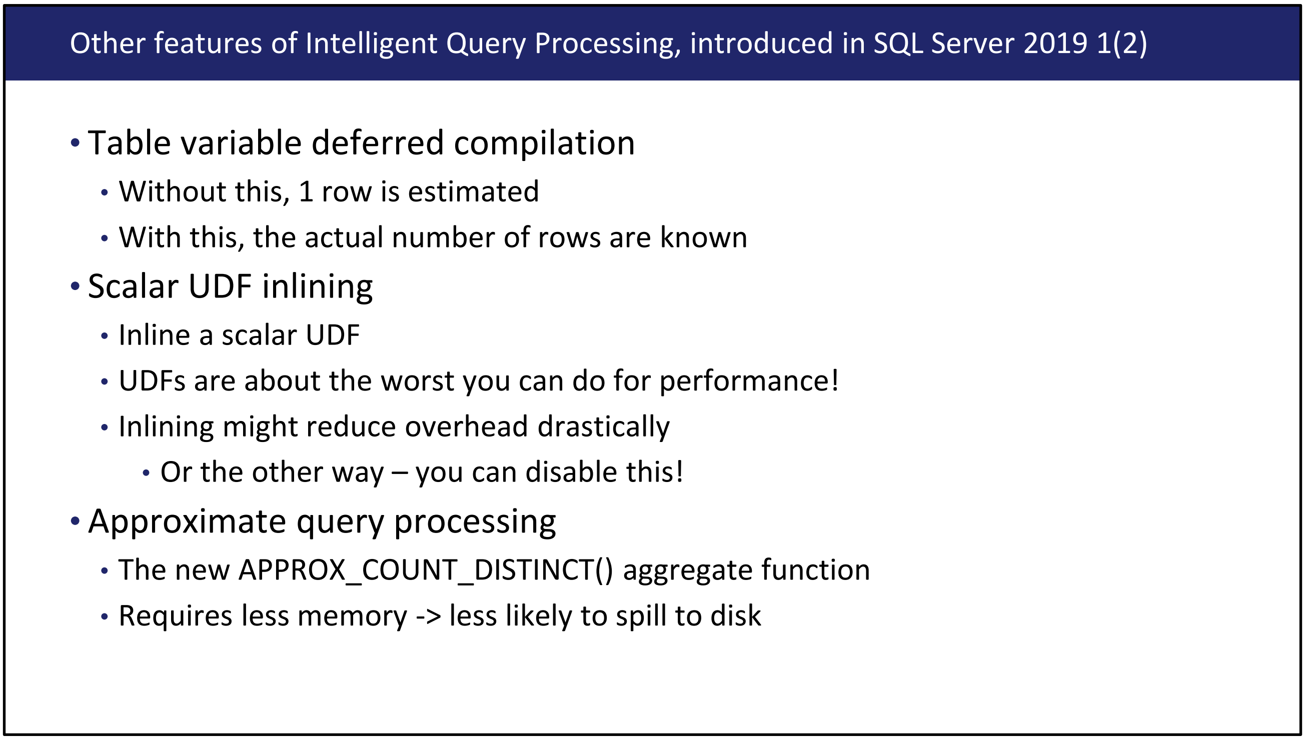
Adaptive Join
https://sqlserverfast.com/epr/adaptive-join/



Interleaved Execution

- Multi-statement table-valued functions use a guessed cardinality
  - SQL Server 2014 and 2016 – 100 rows
  - Earlier versions - 1 row
- Interleaved execution uses the actual cardinality estimate to process the rest of the query
- The query
  - Must not modify data
  - Not be referenced inside a CROSS APPLY clause
- Do **not** require Enterprise Edition

Interleaved execution for MSTVFs
https://docs.microsoft.com/en-us/sql/relational-databases/performance/intelligent-query-processing#interleaved-execution-for-mstvfs



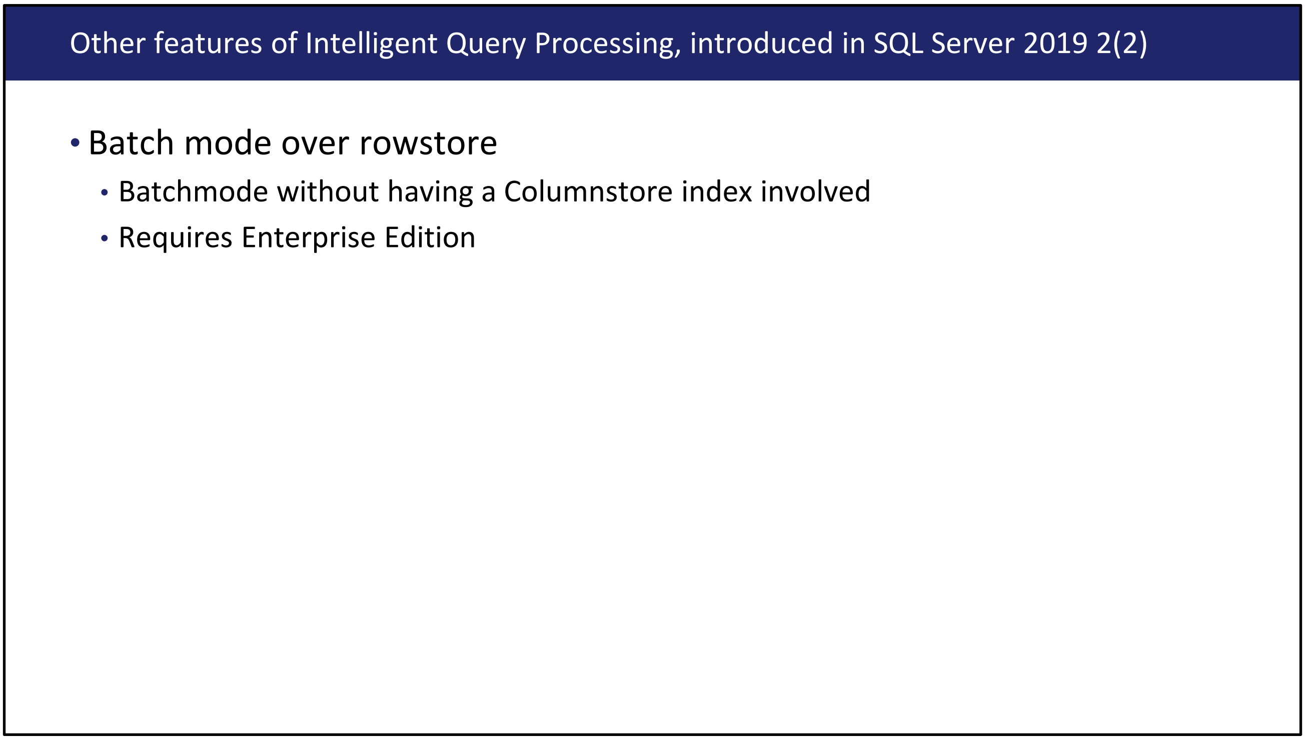
Other features of Intelligent Query Processing, introduced in SQL Server 2019 1(2)

- Table variable deferred compilation
  - Without this, 1 row is estimated
  - With this, the actual number of rows are known
- Scalar UDF inlining
  - Inline a scalar UDF
  - UDFs are about the worst you can do for performance!
  - Inlining might reduce overhead drastically
    - Or the other way – you can disable this!
- Approximate query processing
  - The new APPROX_COUNT_DISTINCT() aggregate function
  - Requires less memory -> less likely to spill to disk

Table variable deferred compilation
https://docs.microsoft.com/en-us/sql/relational-databases/performance/intelligent-query-processing#table-variable-deferred-compilation

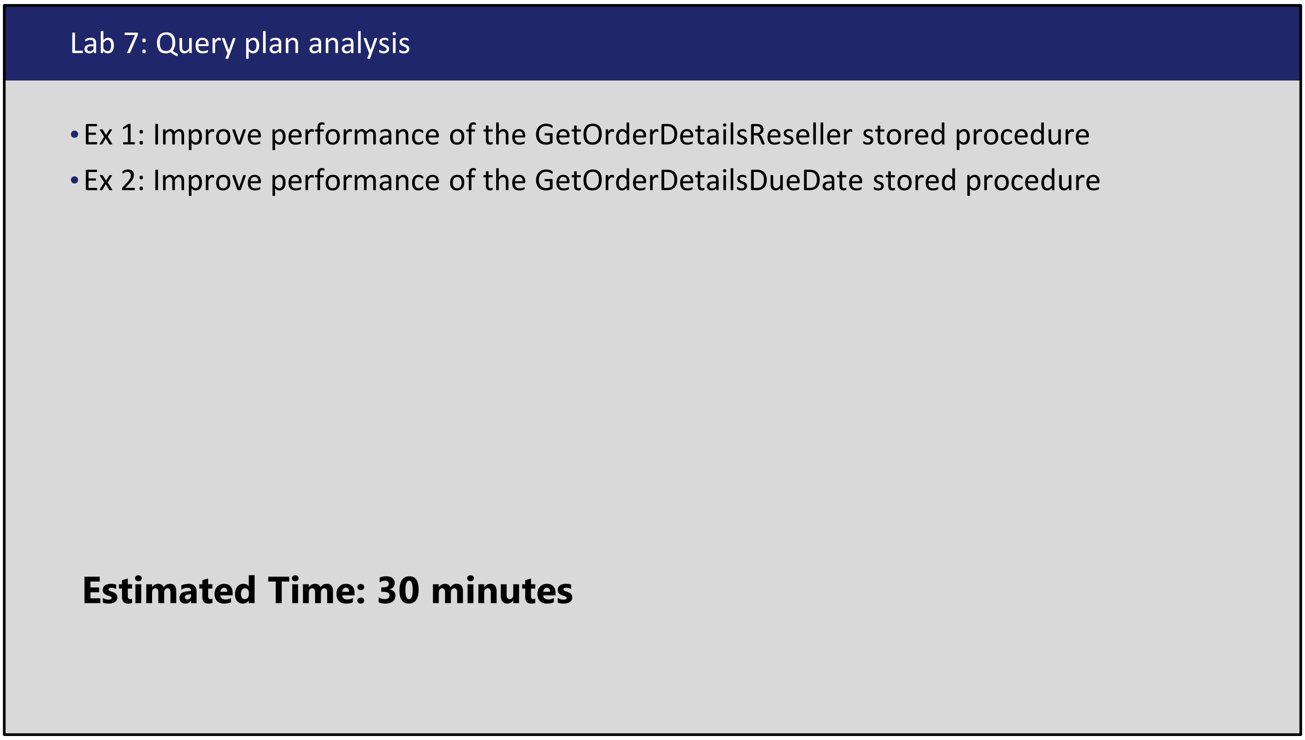
Scalar UDF inlining
https://docs.microsoft.com/en-us/sql/relational-databases/performance/intelligent-query-processing#scalar-udf-inlining

Approximate query processing
https://docs.microsoft.com/en-us/sql/relational-databases/performance/intelligent-query-processing#approximate-query-processing



Other features of Intelligent Query Processing, introduced in SQL Server 2019 2(2)

- Batch mode over rowstore
  - Batchmode without having a Columnstore index involved
  - Requires Enterprise Edition



Lab 7: Query plan analysis

- Ex 1: Improve performance of the GetOrderDetailsReseller stored procedure
- Ex 2: Improve performance of the GetOrderDetailsDueDate stored procedure

Estimated Time: 30 minutes