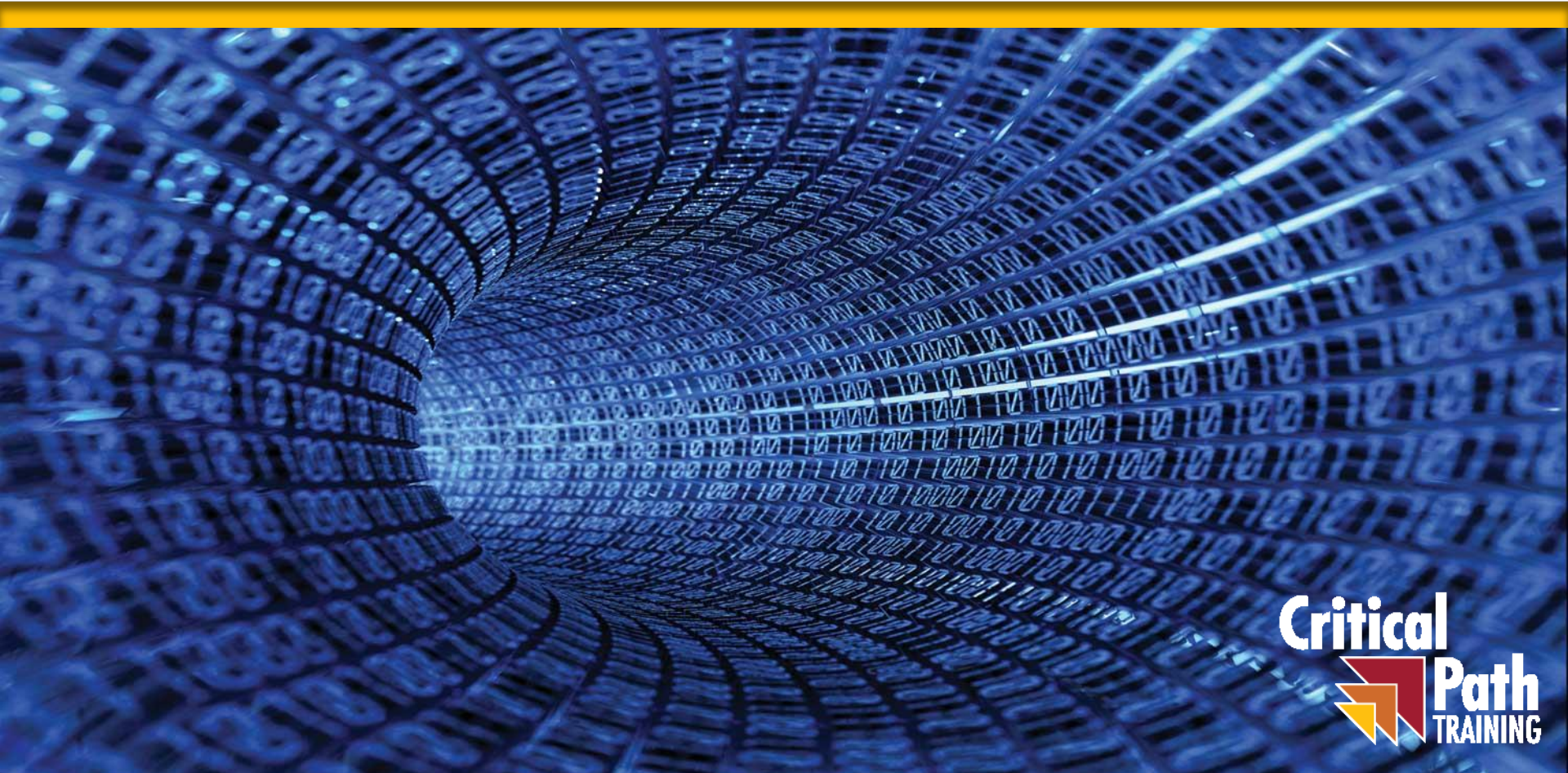# Power BI Master Class

Module 01: Designing Advanced Queries with Power BI Desktop

Agenda

- ➢ Course Introduction
- Importing Data using Power Query
- Writing Query Logic in M
- Understanding Query Folding
- Writing Reusable Function Queries

Student Background

- What is your name?

- What are you doing with Power BI?

- Which products/services have you used
    - Excel
    - Access
    - SQL Server, SSRS, SSAS
    - SharePoint and Office 365
    - Tableau
    - Dynamics 365
    - Salesforce
    - Others

Student Files for This Course

- Copy the **Student** folder from the master zip archive
  - Create a new local folder at **C:\Student**

- Each module has folder inside **Student\Modules** folder
  - Slides and lab writeup available through student manual (not in GitHub repository)
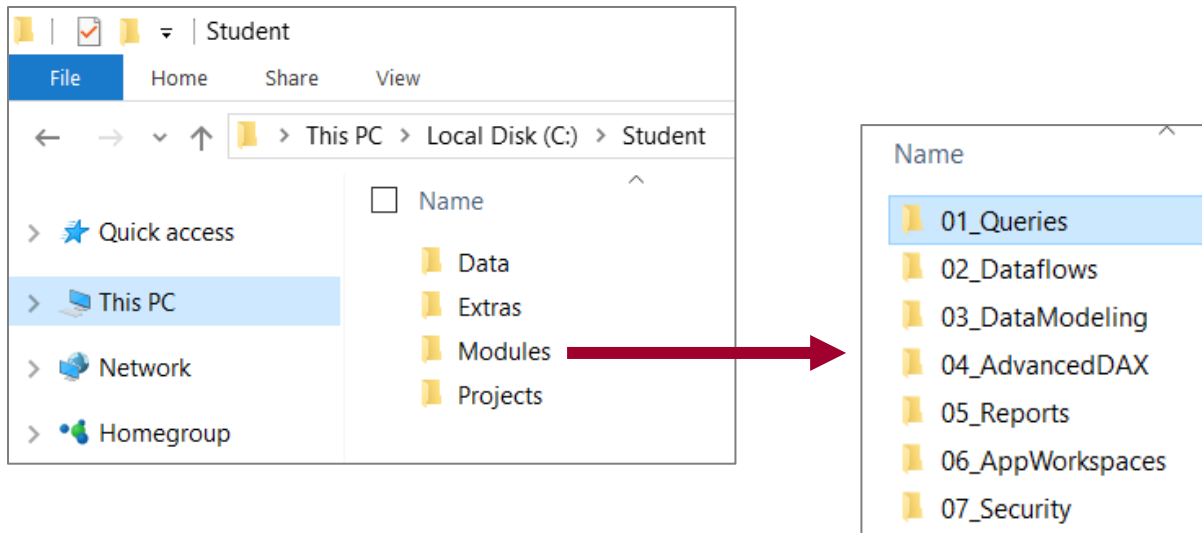
What is Power BI?

- What is Power BI?
  - A cloud-based analytics service for licensed subscribers
  - Environment which supports and promotes self-service BI
  - Powerful builder tools for importing, modeling and visualizing data
  - Enterprise-grade platform for deploying reports and dashboards
  - On-premises server product supporting subset of cloud features

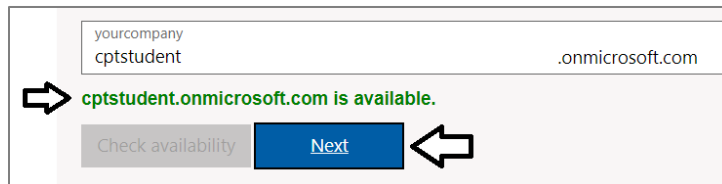| Power BI Service	Power BI Desktop	Power BI Report Server

Creating a Power BI Lab Environment

- Sign up for an Office 365 E5 trial account
  - Sign up process creates new Azure AD tenant
  - Tenant created with user account which is Global tenant admin
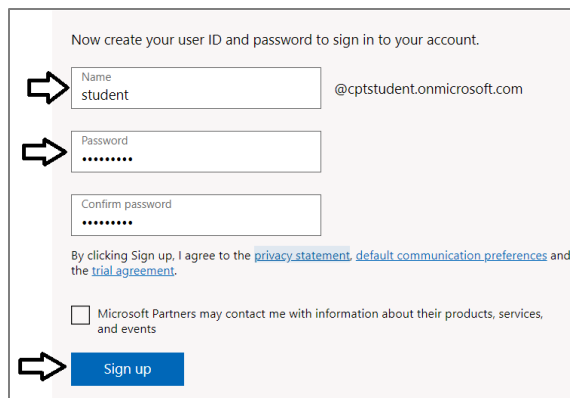 - Tenant gets 30-day trial subscription for 25 Office 365 E5 licenses

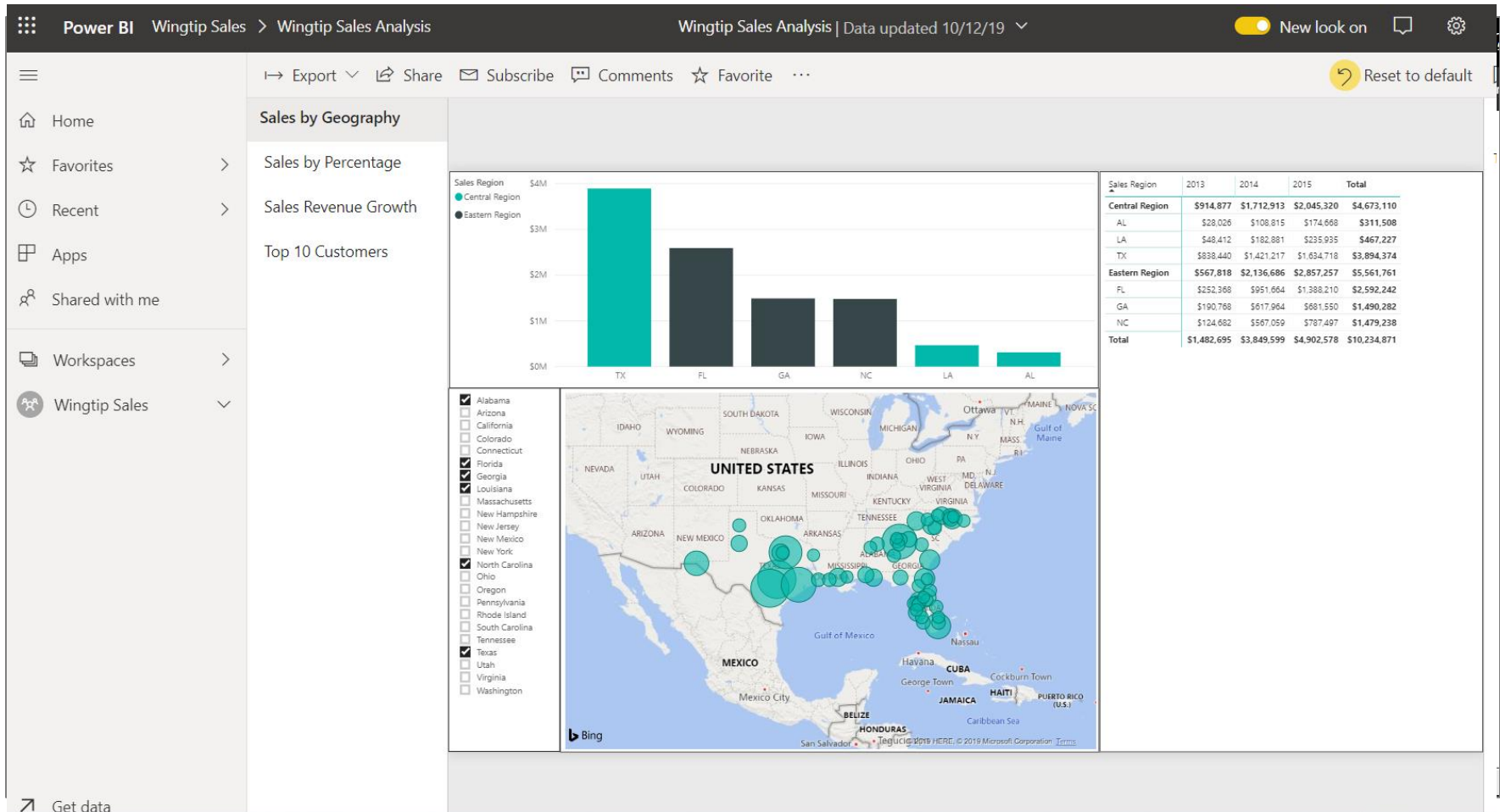# The Power BI Service

- The Power BI Service
  - Provides cloud-based foundation for Power BI platform
  - Provides browser-based portal at https://app.powerbi.com
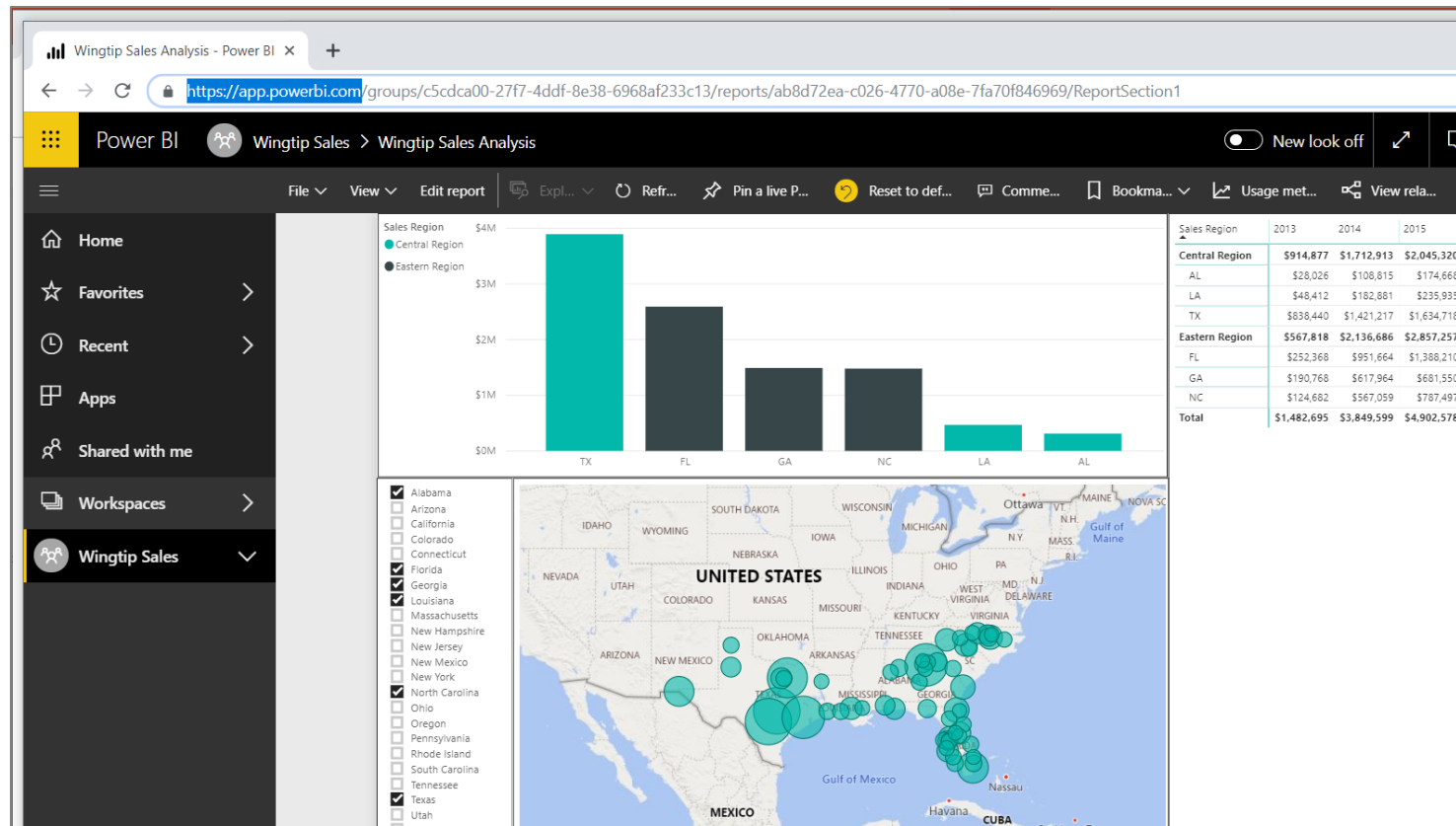
Light Grey is the New Black

Central Power BI Concepts

- Workspace
  - Secured container for Power BI resources
  - Created as personal workspaces and app workspaces
- Dashboard
  - Consolidated high-level view into reports and datasets
  - Provides great experience on mobile device (*e.g. iPhone, Android, tablet, etc.*)
- Report
  - Collection of one or more pages with tables & visualizations
  - Provides consumer with interactive control through filtering and bookmarks
- Dataset
  - In-memory data model containing one or more tables
  - Used to supply the underlying data to reports and dashboards
- Dataflows
  - Persistent data store used for more complex ETL requirements
 - Not required in most Power BI scenarios

Getting Around in Power BI Desktop

- What do you need to learn to use Power BI Desktop?
  - Query features for importing data
  - Designing data model & writing DAX expressions
  - Designing reports with Power BI Desktop report designer

- Navigating between view modes
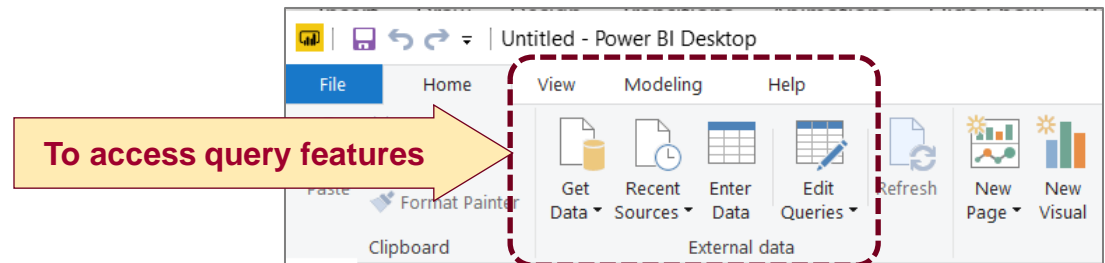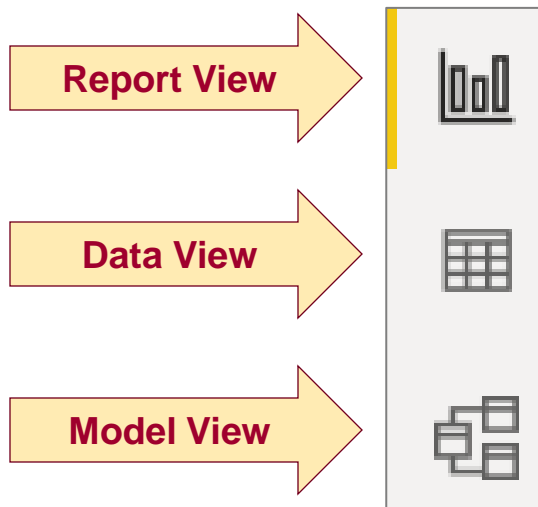
Projects and PBIX Files

- Power BI Desktop projects saved using PBIX files
  - PBIX file contains data source definitions
  - PBIX file contains query definitions
  - PBIX file contains data imported from queries
  - PBIX file contains exactly one data model definition
  - PBIX file contains exactly one report
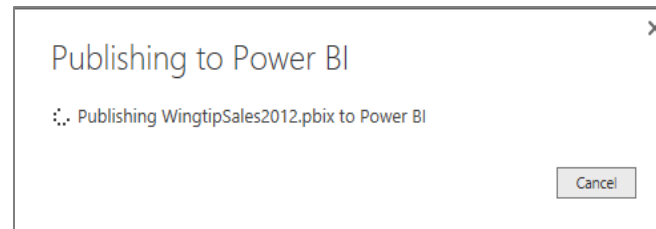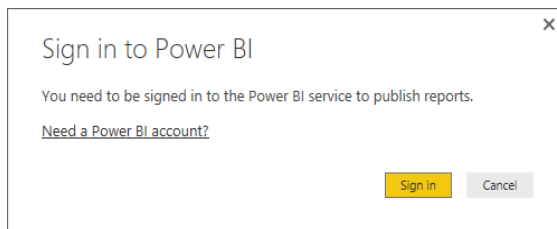 - PBIX file never contains data source credentials
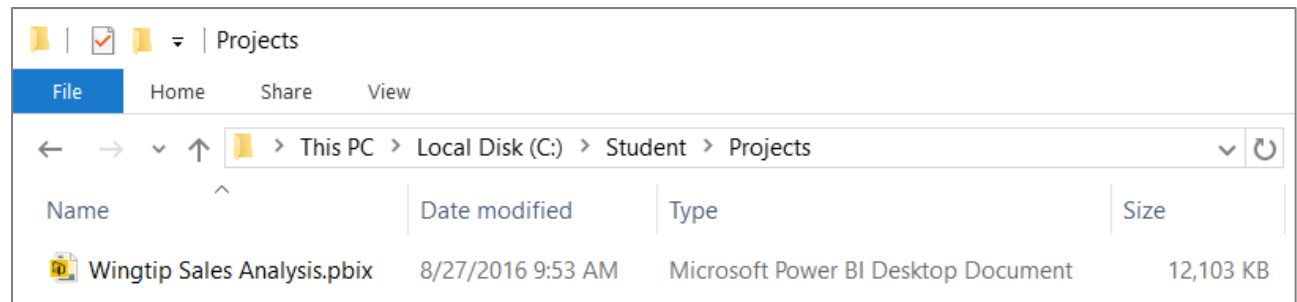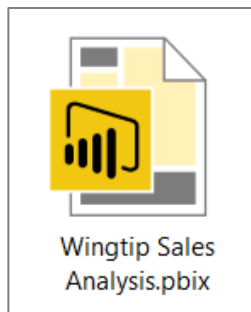
Publishing a Power BI Desktop Project

- Power BI Desktop provides **Publish** command
  - Used to publish project to Power BI service
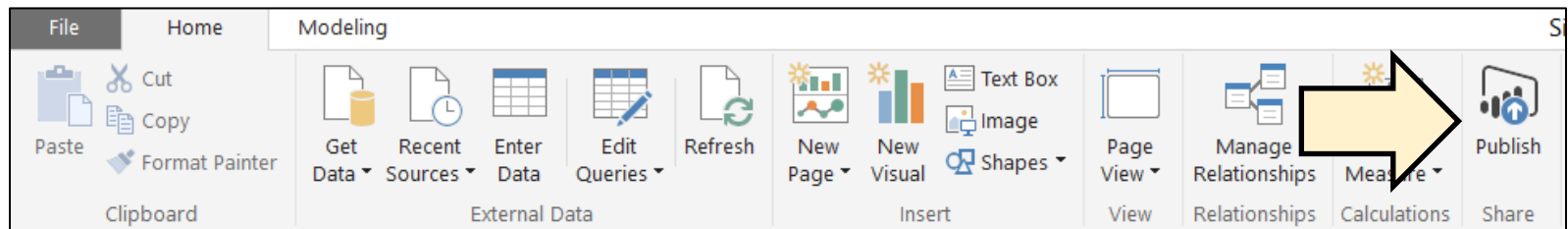
  - Requires logging into your Office 365 account


  - Published articles added to target workspace

Agenda

- ✓ Course Introduction
- ➤ Importing Data using Power Query
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- Understanding Query Folding
- Writing Reusable Function Queries

Power Query is an ETL Tool

- ETL process is essential part of any BI Project
  - **Extract** the data from wherever it lives
  - **Transform** the shape of the data for better analysis
 - **Load** the data into dataset for analysis and reporting
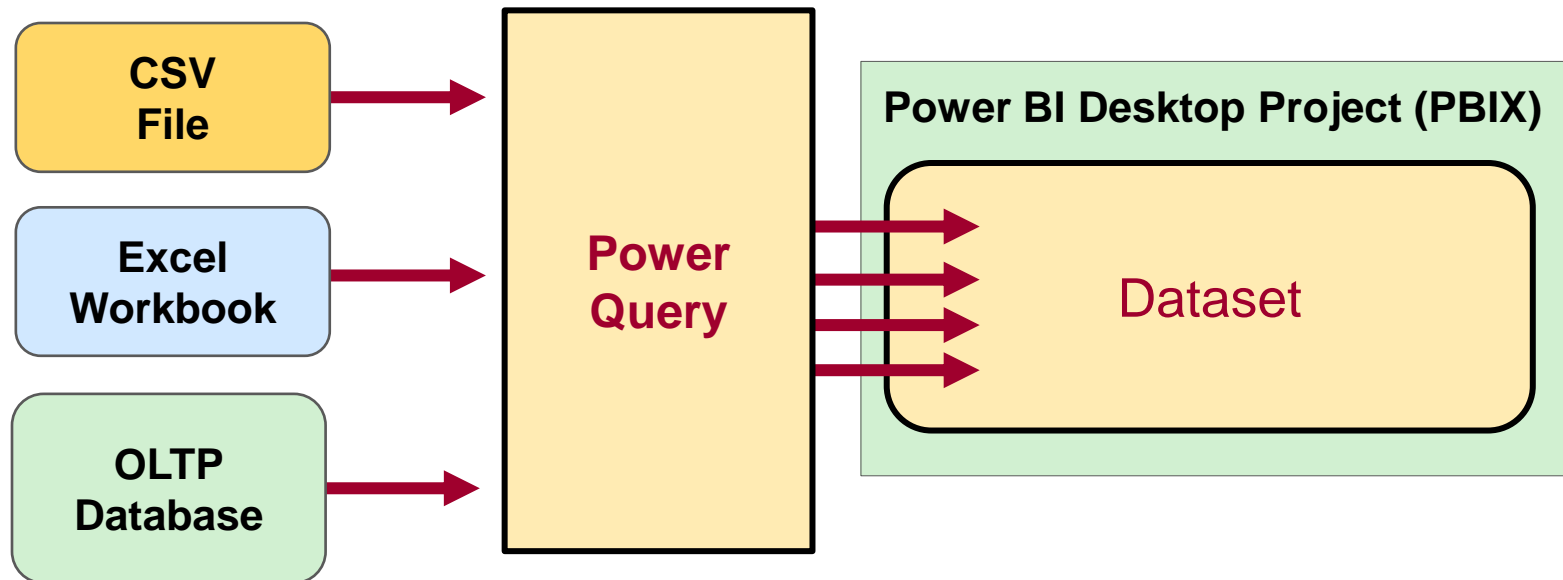
Understanding Query Input and Output

- PBIX project is container for data sources and queries
  - Queries created and saved within scope of Power BI project
  - Queries can pull data from local files
  - Queries can pull data from external content sources
  - Queries main purpose is to load imported data into data model
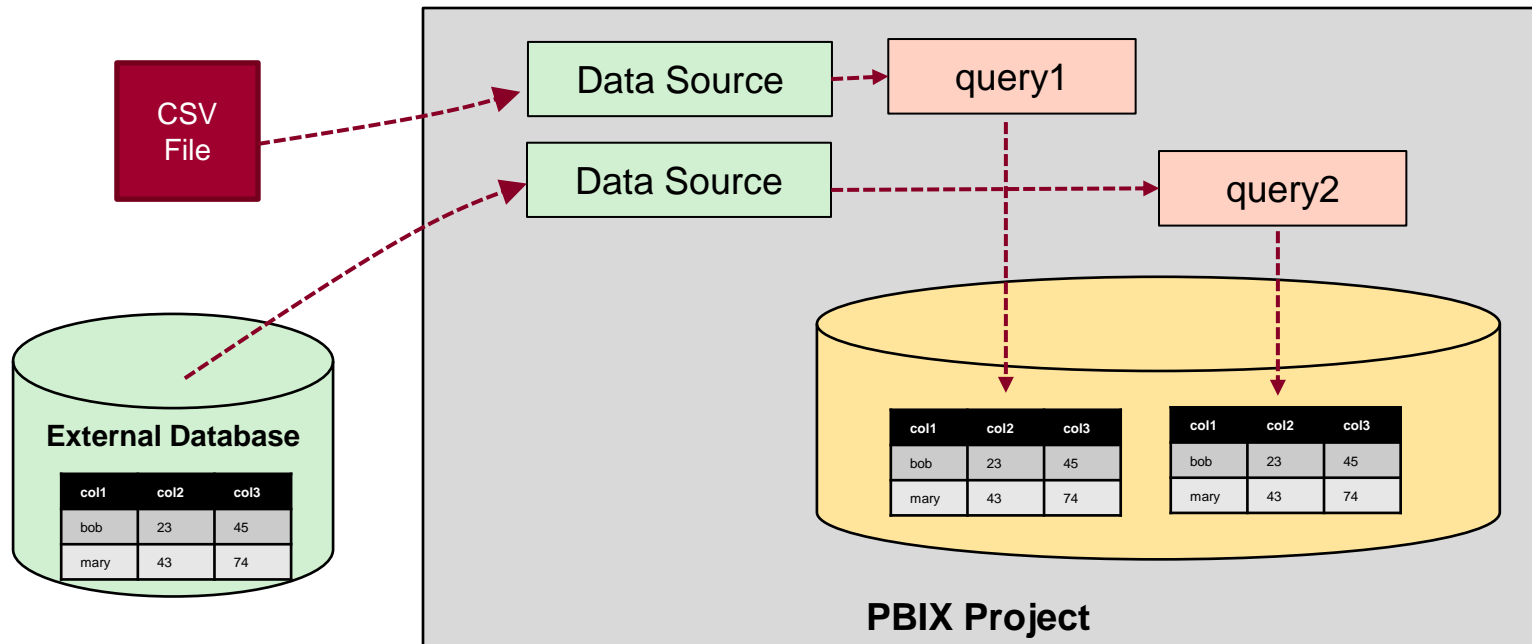
Query Editor Window

- Power BI Desktop provides separate Query Editor window
  - Provides powerful features for designing queries
  - Displays list of all queries in project on the left
  - Displays **Properties** and **Applied Steps** for selected query on right
  - Preview of table generated by query output shown in the middle
  - Query can be executed using **Apply** or **Close & Apply** command
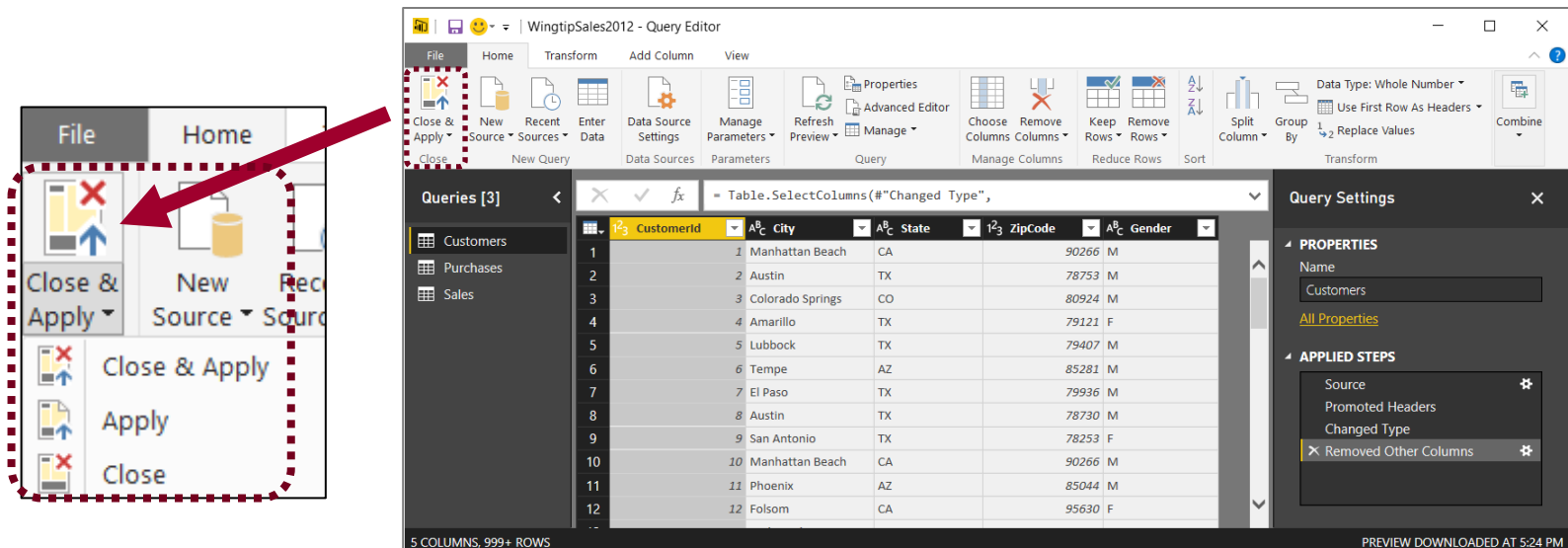
Query Steps

- A query is created as a sequence of steps
  - Each step is a parameterized operation on the data
  - Each step has formula which can be viewed/edited in formula bar
  - Query starts with Source step to extract data from a data source
  - Additional steps added to perform transform operations on data
  - You can replay query operations one by one by clicking on steps

Examples of Basic Power Query Steps

- Rename column

- Convert column type

- Trim and clean column values

- Replace column values

- Format column values

- Expanding related column

- Merging columns

- Splitting columns

Cleaning Data

- Special steps available to clean up string-based data
  - **Transform > Trim** removes whitespace
  - **Transform > Clean** removed non-printable characters
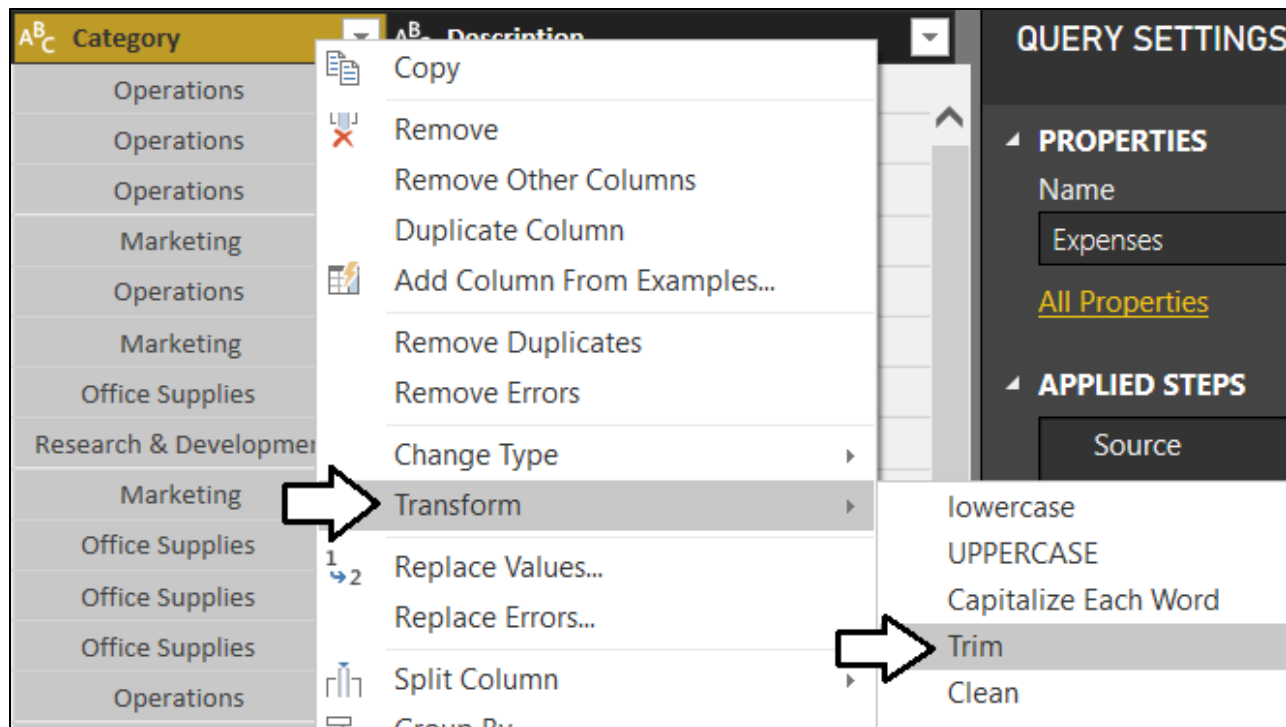
Converting Column Datatypes

- Transform data to make it more reliable
  - Convert date-time column to date column
- Transform data to make it more efficient
  - Convert decimal to fixed decimal number for currency

Combining Queries

- Query can be merged or appended with another query
  - Merge operation allows you combine columns from two tables
  - Append operation allows you to combine rows from two tables
- Two queries are combined into single output for loading
  - Load settings of main query determines where output is loaded
  - Secondary query acts as source for main query
  - Secondary query be can created with connection-only load setting
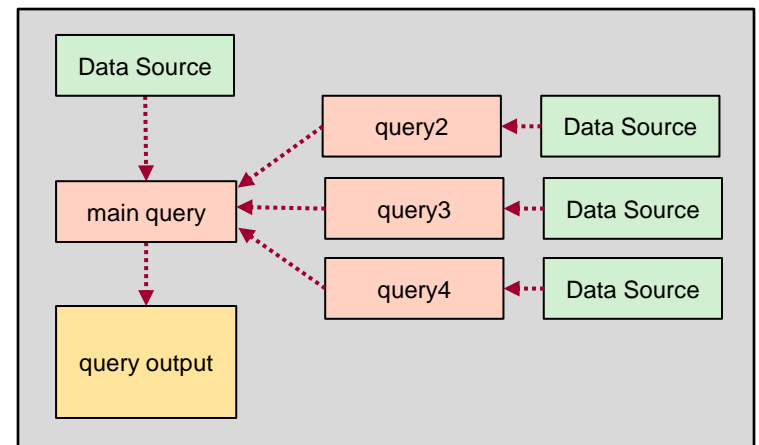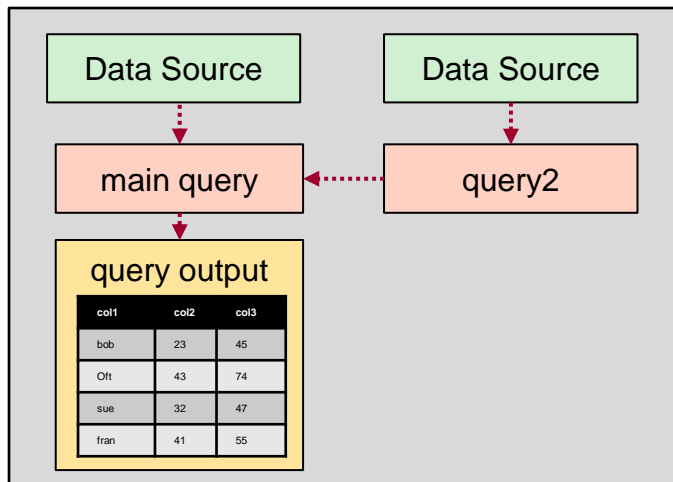
Expanding Related Columns

- Used to pull data from related tables
  - Saves you from performing SQL joins or VLOOKUP

Adding a Custom Column

- Custom column provide custom logic
  - Logic must be written in M programming language

Adding a Conditional Column

- Abstracts away need to write M code
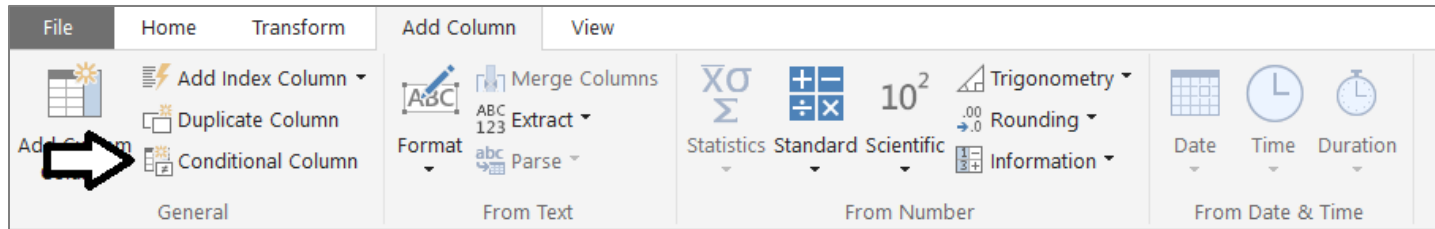
Query Composition

- Query can serve as source for other queries
  - Allows for creation of reusable base queries & query composition
  - Complexity can be hidden in base queries
  - **Reference** command creates new query based on another query
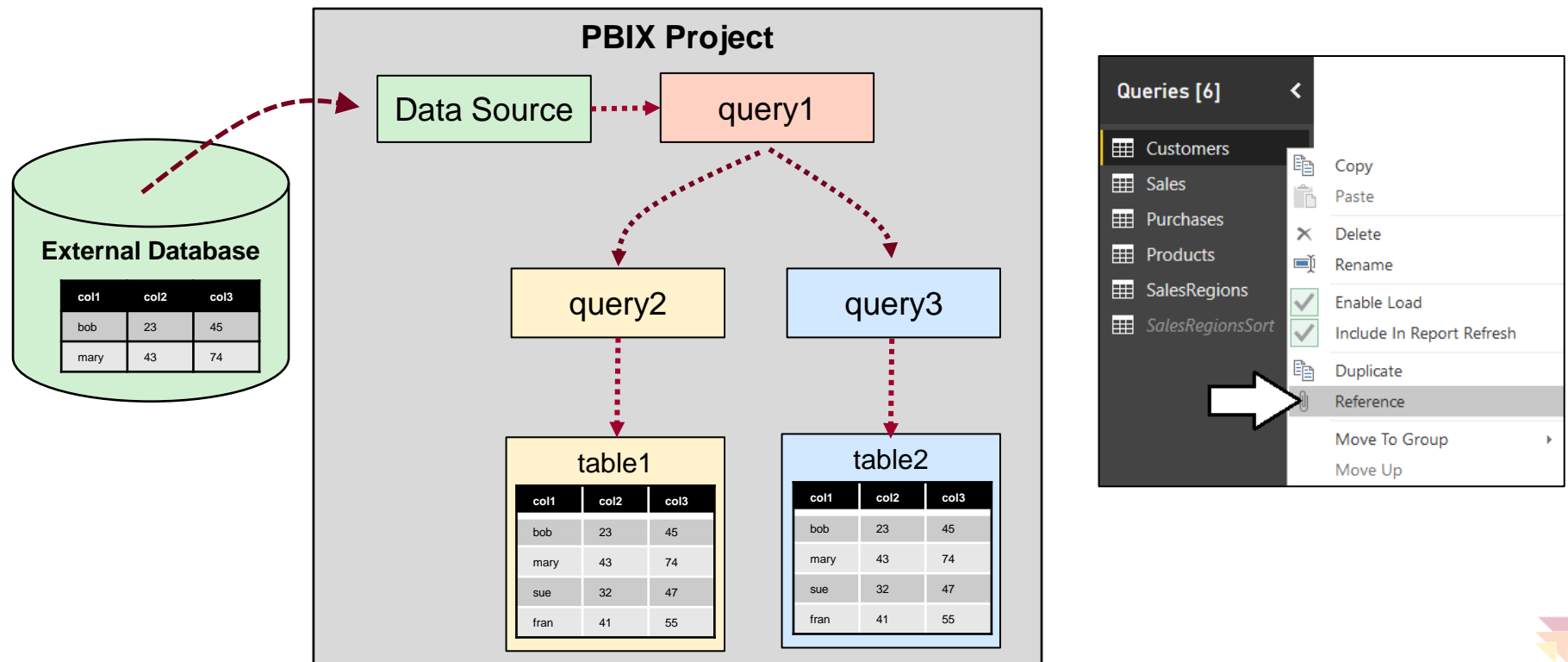
Structuring Queries into Folder Groups

- Queries can be organized into folder groups
  - Folder groups can be created for similar types of queries
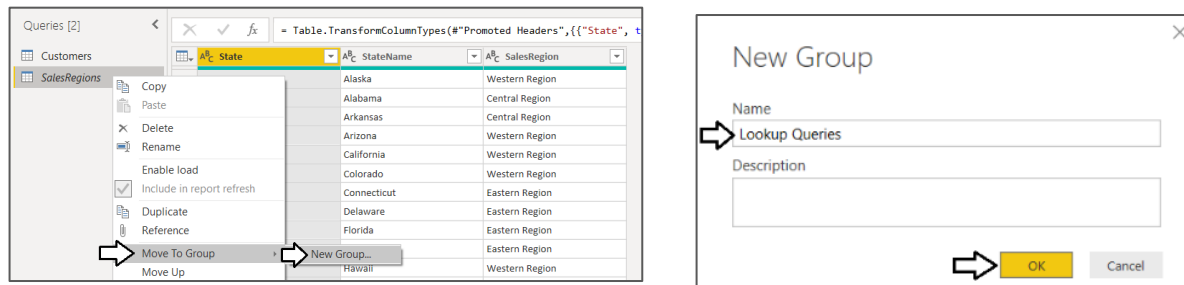
  - Makes it easier to manage project with large number of queries
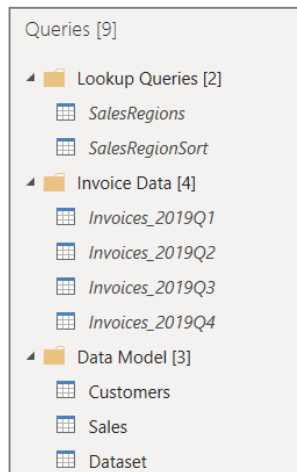
Agenda

- ✓ Course Introduction
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- ➢ Writing Query Logic in M
- • Understanding Query Folding
- • Writing Reusable Function Queries

Advanced Editor

- Power BI Desktop based on "M" functional language
  - Query in Power BI Desktop saved as set of M statements in code
  - Query Editor generates code in M behind the scenes
  - Advanced users can view & modify query code in Advanced Editor
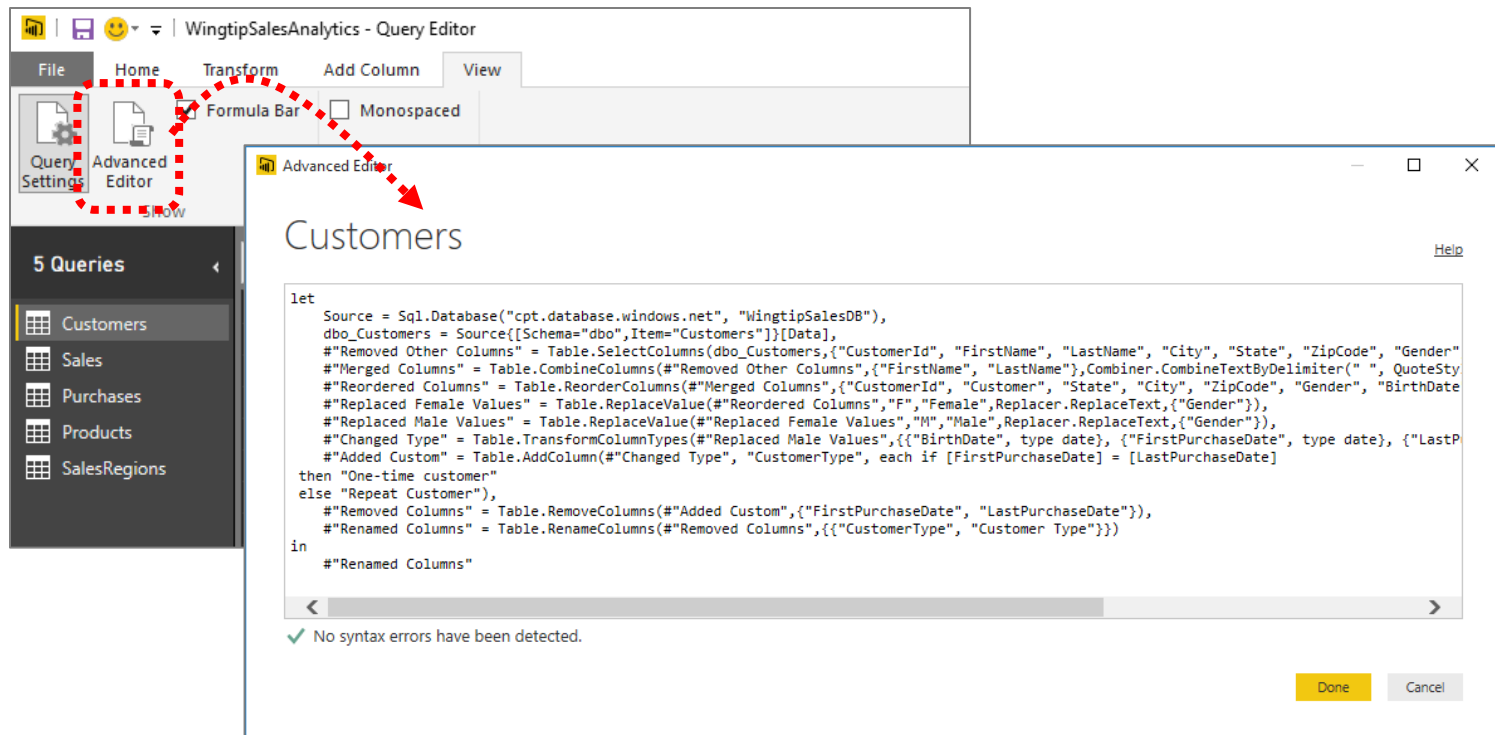
The M Programming Language

- M is a *functional* programming language
  - computation through evaluation of mathematical functions
  - Programming involves writing expressions instead of statements
  - M does not support changing-state or mutable data
  - Every query is a single expression that returns a single value
  - Every query has a return type

- Get Started with M
  - Language is case-sensitive
  - It's all about writing expressions
  - Query expressions can reference other queries by name

Comments and Variable Names

- M supports using C-style comments
  - Multiline comments created using /* */
  - Single line comments created using //

```
/*
  This is my most excellent query
*/
let

  var1 = 42, // the secret of life
```

- Variable names with spaces must be enclosed in #" "
  - Variable names with spaces created automatically by query designer

```
let
  var1 = "Spaces in ",

  #"var 2" = "variable names ",

  #"Bob's your unkle" = "are evil",

  #"Kitchen sink" = var1 & #"var 2" & #"Bob's your unkle"
in
  #"Kitchen sink"
```

```
▲ APPLIED STEPS

   var1
   var 2
   Bob's your unkle
 ✕ Kitchen sink
```

Let Statement

- Queries usually created using `let` statement
  - Allows a single expressions to contain inner expressions
  - Each line in `let` block represents a separate expression
  - Each line in `let` block has variable which is named step
  - Each line in `let` block requires comma at end except for last line
  - Expression inside `in` block is returned as `let` statement value

Flow of Statement Evaluation

- Evaluation starts with expression inside `in` block
  - Expression evaluation triggers other expression evaluation

```
let
    var1 = "Hello",
    var2 = "World",
    var3 = var1 & " " & var2,
    output = Text.Upper(var3)
in
    output
```
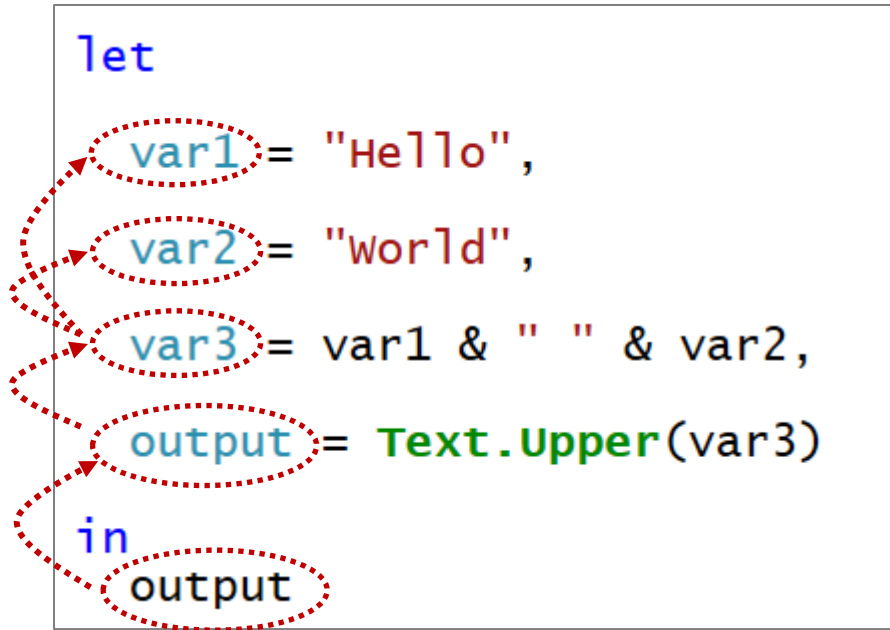
M Type System

- ## Built-in types
  `any, none`
  `null, logical, number, text, binary`
  `time, date, datetime, datetimezone, duration`

- ## Complex types
  `list, record, table, function`

- ## User-defined types
  - You can create custom types for records and tables

Initializing Dates and Times

```
// time
var1 = #time(09,15,00),

// date
var2 = #date(2013,02,26),

// date and time
var3 = #datetime(2013,02,26, 09,15,00),

// date and time in specific timezone
var4 = #datetimezone(2013,02,26, 09,15,00, 09,00),

// time durection
var5 = #duration(0,1,30,0),
```

Lists

- ## List is a single dimension array
  - ### Literal list can be created using { } operators
  - ### List elements accessed using { } operator and zero-based index

```
let

  RatPack = { "Frank", "Dean", "Sammy" } ,

  FirstRat  = RatPack{0} ,
  SecondRat = RatPack{1} ,
  ThirdRat  = RatPack{2} ,

  output = FirstRat & ", " & SecondRat & " and " & ThirdRat

in
  output
```

  - ### Use { }? to avoid error when index range is out-of-bounds

```
Rat4 = RatPack{4},   // error - index range out of bounds
Rat5 = RatPack{5}? , // no error - Rat5 equals null
```

Records

- Record contains fields for single instance of entity

```
// create records by using [] and defining fields
Person1 = [FirstName="Chris", LastName="Webb"],
Person2 = [FirstName="Reza", LastName="Rad"],
Person3 = [FirstName="Matt", LastName="Masson"],


// access field inside a record using [] operator
FirstName1 = Person1[FirstName],
LastName2 =  Person2[LastName],
```

- You must often create records to call M library functions

```
// create a record to define HTTP request headers
RequestHeaders = [ Accept="application/json",
                   #"OData-MaxVersion"="4.0"],

// create a second record which contains the first record
OptionsRecord = [ Headers=RequestHeaders ],

// pass the second record as parameter to Web.Contents
Response = Web.Contents(url, OptionsRecord),
```

Combination Operator (&)

- Used to combine strings, arrays and records

```
// text concatenation: "ABC"
var1  = "A" & "BC",

// list concatenation: {1, 2, 3}
var2 = {1} & {2, 3},

// record merge: [ a = 1, b = 2 ]
var3 = [ a = 1 ] & [ b = 2 ],
```

Table.FromRecords

- Table.FromRecords can be used to create table
  - Table columns are not strongly typed

```
let

  CustomersTable = Table.FromRecords({
    [ FirstName="Matt", LastName="Masson"],
    [ FirstName="Chris", LastName="Webb"],
    [ FirstName="Reza", LastName="Rad"],
    [ FirstName="Chuck", LastName="Sterling"]
  })

in
  CustomersTable
```

	ABC 123 FirstName	ABC 123 LastName
1	Matt	Masson
2	Chris	Webb
3	Reza	Rad
4	Chuck	Sterling

`ABC 123` Bad, Bad, Bad ☹

Creating User-defined Types

- M allows you to create user-defined types
  - Here is a user-defined type for a record and a table

    ```
    CustomerRecordType = type [FirstName = text, LastName = text],

    CustomerTableType = type table CustomerRecordType,
    ```

  - User-defined table used to create table with strongly typed columns

    ```
    let

      CustomerRecordType = type [FirstName = text, LastName = text],

      CustomerTableType = type table CustomerRecordType,

      CustomersTable =
        #table(CustomerTableType, {
          { "Matt", "Masson" },
          { "Chris", "Webb" },
          { "Reza", "Rad" },
          { "Chuck", "Sterilicious"}
        }
      )
    in
      CustomersTable
    ```

	FirstName	LastName
1	Matt	Masson
2	Chris	Webb
3	Reza	Rad
4	Chuck	Sterilicious

Using Each with Unary Functions

- Many library functions take function as parameters
  - Function parameters are often unary *(e.g. they accept 1 parameter)*

```
FilteredRows = Table.SelectRows(CustomersTable, (row) => row[CustomerId]<=10  ),
```

- M provides each syntax to make code easier to read/write

  - Unary parameter passed implicitly using __ variable

```
FilteredRows = Table.SelectRows(CustomersTable, each _[CustomerId]<=10  ),
```

  - You can omit _ variable when accessing fields inside record

```
FilteredRows = Table.SelectRows(CustomersTable, each [CustomerId]<=10  ),
```

```
AddedColumn =Table.AddColumn(FilteredRows, "Display Name", each [FirstName] & " " & [LastName])
```

  - You must use _ variable when using each with a list

```
MyList = { "Item 1", "Item 2", "Item 3" },

MyUpperCaseList = List.Transform(MyList, each Text.Upper(_) )
```

Catching Errors

- Error handling in M done using `try .. otherwise`

```
try Date.FromText([Raw Date]) otherwise null
```

- Error handling can avoid evaluation errors

```
AddedDateColumn1 = Table.AddColumn(Source, "Date1", each Date.FromText([Raw Date])),

AddedDateColumn2 = Table.AddColumn(AddedDateColumn1, "Date2", each ( try Date.FromText([Raw Date]) otherwise null ) )
```
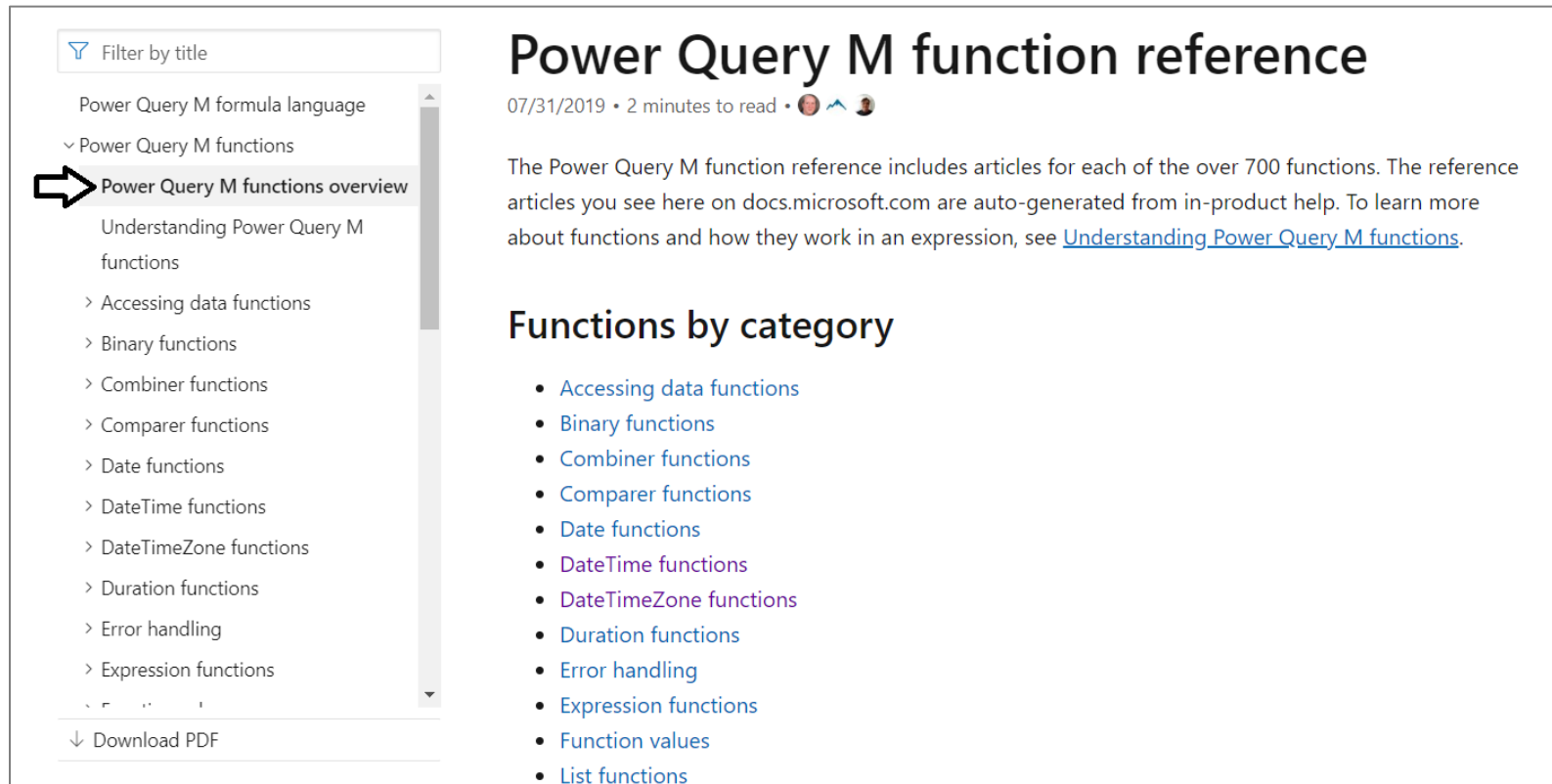
- Expression causing errors replace with value such as `null`

	Raw Date	Date1	Date2
1	Feb 30, 2019	Error	null
2	March 4, 2019	3/4/2019	3/4/2019
3	Cinco de mayo, 2019	Error	null
4	6/4/2019	6/4/2019	6/4/2019
5	07-04-2019	7/4/2019	7/4/2019

M Function Library

- ## Check out the Power Query M function reference

  - ### https://docs.microsoft.com/en-us/powerquery-m/power-query-m-function-reference

Agenda

- ✓ Course Introduction
- ✓ Importing Data using Power Query
- ✓ Writing Query Logic in M
- ➤ Understanding Query Folding
- • Writing Reusable Function Queries

Query Folding

- Mashup engine pushes work back to datasource when possible
    - Column selection and row filtering
    - Joins, Group By, Aggregate Operations
- Datasource that support folding
    - Relational database
    - Tabular and multidimensional databases
    - OData Web services
- What happens when datasource doesn't support query folding?
    - All work is done locally by the mashup engine
- Things that affect whether query folding occurs
    - The way you structure your M code
    - Privacy level of datasources
    - Native query execution

Query Folding Example

- When you execute this query in Power BI Desktop…

```
let
  Source = Sql.Database("ODYSSEUS", "WingtipSalesDB"),
  CustomersTable = Source{[Item="Customers"]}[Data],

  // select rows
  FilteredRows = Table.SelectRows(CustomersTable, each ([State] = "FL")),

  // select columns
  ColumnsToKeep = {"CustomerId", "FirstName", "LastName"} ,
  RemovedOtherColumns = Table.SelectColumns(FilteredRows, ColumnsToKeep),

  // rename columns
  ColumnRenamingMap = { {"FirstName", "First Name"}, {"LastName", "Last Name"} },
  RenamedColumns = Table.RenameColumns(RemovedOtherColumns, ColumnRenamingMap)

in
  RenamedColumns
```

- Mashup Engine executes the following SQL query

```
execute sp_executesql
N'select [_].[CustomerId] as [CustomerId],
         [_].[FirstName] as [First Name],
         [_].[LastName] as [Last Name]
  from [dbo].[Customers] as [_]
  where [_].[State] = ''FL'' and [_].[State] is not null'
```

Native Queries

- No query folding occurs after native query

```
let

    DatabaseServer = "cpt.database.windows.net",

    DatabaseName = "WingtipSalesDB",

    SQL = "SELECT CustomerId, FirstName, LastName" &
          " FROM Customers" &
          " WHERE CustomerId <= 10" &
          " ORDER BY LastName, FirstName" ,

    Source = Sql.Database( DatabaseServer, DatabaseName , [Query=SQL] ),

    output = Source

in
  output
```

Accessing Data using OData.Feed

- OData.Feed can pull data from OData web service
  - OData connector assists with navigation through entities
  - OData connector support query folding

```
let
    Source = OData.Feed("http://subliminalsystems.com/api/"),

    // get Customers table
    CustomersTable = Source{[Name="Customers",Signature="table"]}[Data],

    // select columns
    ColumnsToKeep = {"CustomerId", "FirstName", "LastName", "City", "State", "Zipcode", "Gender", "BirthDate"},
    RemovedOtherColumns = Table.SelectColumns(CustomersTable, ColumnsToKeep),

    // select rows
    FilteredRows = Table.SelectRows(RemovedOtherColumns, each [CustomerId] <= 10),

    // perform other transforms
    ReplacedValue = Table.ReplaceValue(FilteredRows,"F","Female",Replacer.ReplaceText,{"Gender"}),
    ReplacedValue1 = Table.ReplaceValue(ReplacedValue,"M","Male",Replacer.ReplaceText,{"Gender"}),
    ChangedType = Table.TransformColumnTypes(ReplacedValue1,{{"BirthDate", type date}}),
    MergedColumns = Table.CombineColumns(ChangedType,{"FirstName", "LastName"},
                                         Combiner.CombineTextByDelimiter(" ", QuoteStyle.None),
                                         "Customer")
in
    MergedColumns
```

- OData makes extra calls to acquire metadata
  - Let's look at the execution of this query using Fiddler

Web.Contents

- Can be more efficient than OData.Feed
  - You can pass OData query string parameters (e.g. $select)

```
let
    // create REST URI for OData source
    Source = "http://subliminalsystems.com/api/Customers?" &
             "?$select=CustomerId,FirstName,LastName,City,State,Zipcode,Gender,BirthDate" &
             "&filter=(CustomerId+le+10)",

    // create options record for calling Web.Contents
    OptionsRecord =  [Headers=[Accept="application/json;odata=nometadata",
                               #"OData-MaxVersion"="4.0"]],

    // call Web.Content to make call across network
    WebContents = Web.Contents(Source, OptionsRecord),

    // deal with JSON dataset return by Web.Contents
    JsonDocument = Json.Document(WebContents),
    RecordList = Record.ToTable(JsonDocument){1}[Value],
    Table = Table.FromList(RecordList, Splitter.SplitByNothing(), null, null, ExtraValues.Error),
    ColumnsToExpand = {"CustomerId", "FirstName", "LastName", "City", "State", "Zipcode", "Gender", "BirthDate"},
    ExpandedColumns = Table.ExpandRecordColumn(Table, "Column1", ColumnsToExpand, ColumnsToExpand),
```

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Text.Select

- Text.Select can be used to clean up text value
  - You create a list of characters to include

```
// take a text value with unwanted charactors
input = "!!My text has some @bad things !&^",

// get upper and lower case letters
set1 = {"A".."Z"},
set2 = {"a".."z"},

// get digits 0-9 and convert to text
set3 = List.Transform({0..9}, each Number.ToText(_)),

// add any other allowed charactors
set4 = {" ", "-", "_", "."},

// combine all allowed charactors in single list
allowedChars = set1 & set2 & set3 & set4,

// call Text.Select to strip out unwanted charactors
output = Text.Select(input, allowedChars)
```
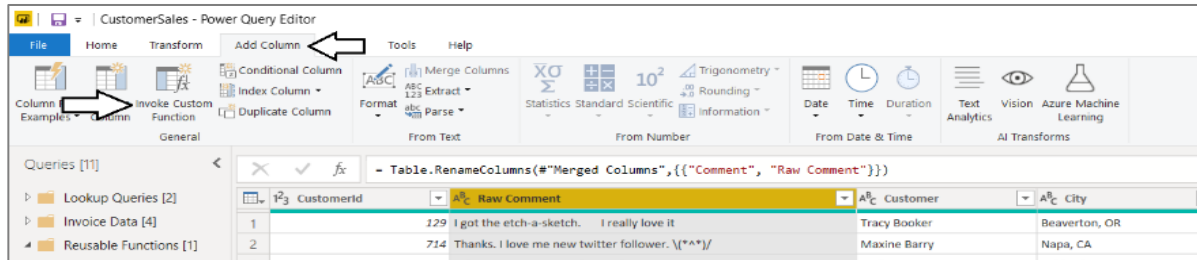
Creating a Function Query

- Requires adding parameter list

Calling a Function Query

Summary

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