

Programming in M and Developing Custom Connectors



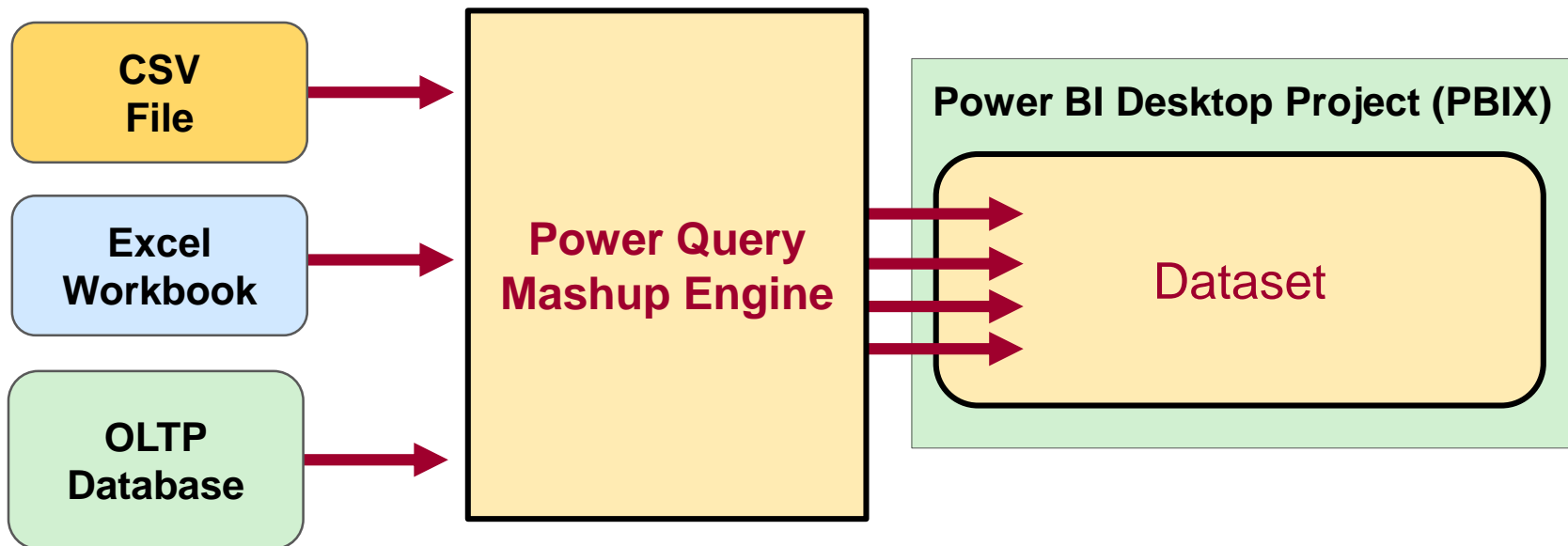
Agenda

- Power Query Mashup Engine
- M Programming Fundamentals
- M Function Library
- Query Functions
- Query Parameters
- Custom Data Connectors



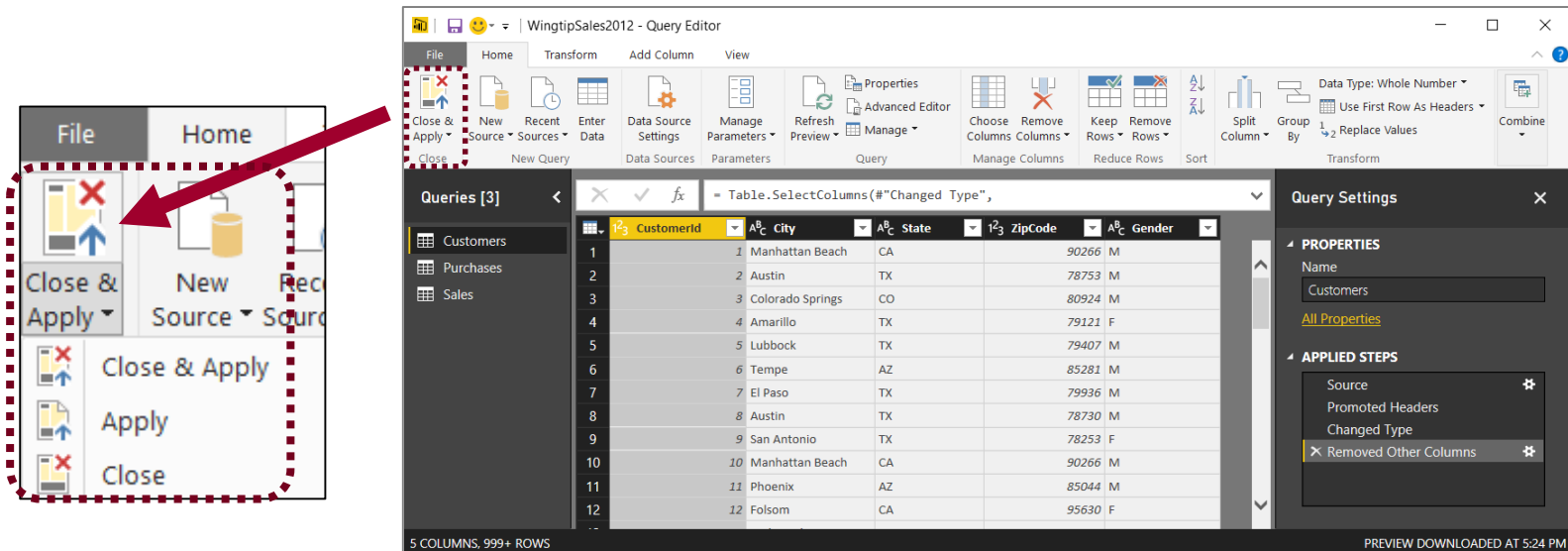
Power BI Desktop is an ETL Tool

- 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



Query Editor Window

- Power BI Desktop provides separate Query Editor window
 - Provides easy-to-use UI experience for designing queries
 - Queries created by creating **Applied Steps**
 - 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 in data processing pipeline
 - Query starts with Source step to extract data from a data source
 - Additional steps added to perform transform operations on data
 - Each step is recorded using M (*aka Power Query Formula Language*)

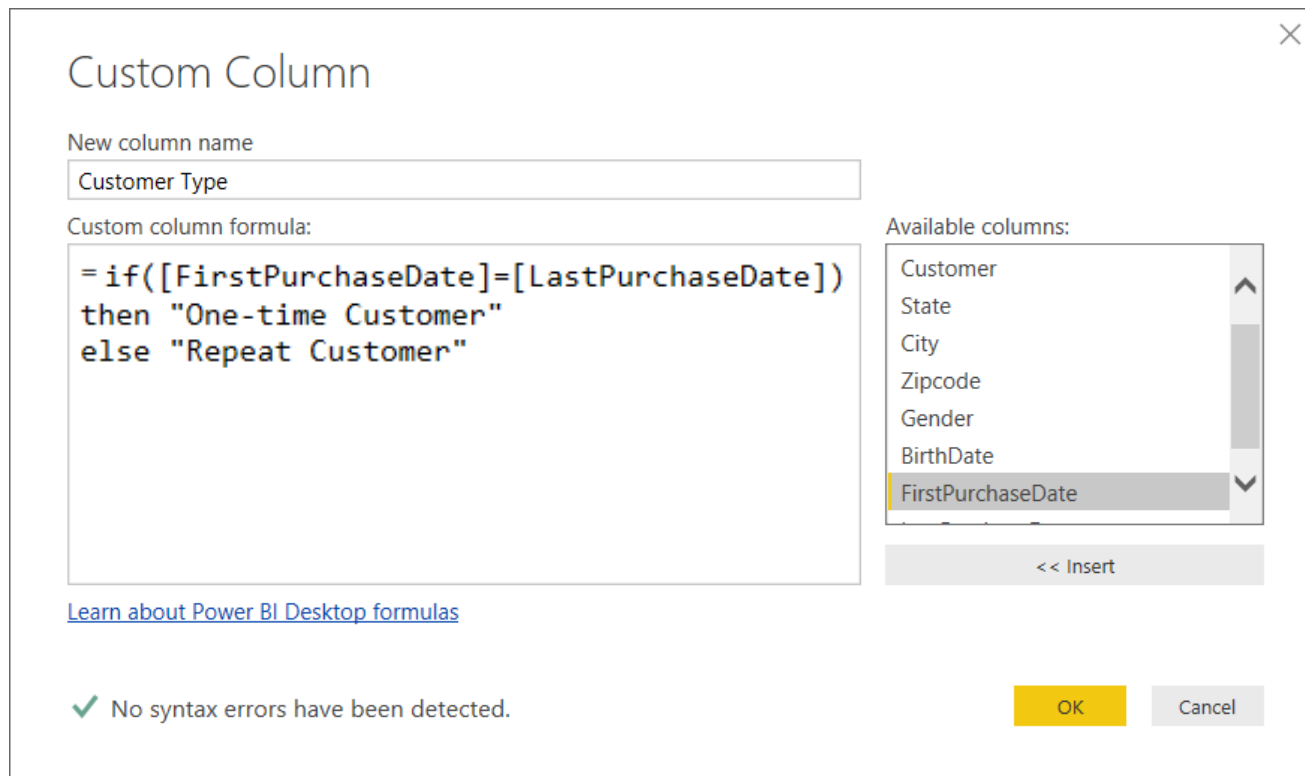
The screenshot displays the Power Query Editor interface. At the top, the ribbon includes tabs for File, Home, Transform, Add Column, and View. The 'Transform' tab is active, showing options like 'Formula Bar', 'Monospaced', 'Always allow', 'Show whitespace', and 'Advanced Editor'. A red dashed box highlights the 'step formula bar' containing the formula: `= Table.ReplaceValue("#Replaced Female Values", "M", "Male", Replacer.ReplaceText, ...)`. Below the ribbon, a table of customer data is shown with columns: Customerid, Customer, State, City, Zipcode, and Gender. The 'Query Settings' pane on the right shows the 'Properties' section with the name 'Customers' and the 'Applied Steps' section, which lists the sequence of steps: Source, Navigation, Removed Other Columns, Merged Columns, Reordered Columns, Replaced Female Values, Replaced Male Values (highlighted with a red dashed box), Changed Type, and Added Conditional Column. A red dashed box also highlights the 'Applied Steps' list, with a callout indicating it is a 'sequential list of steps for query'.

Customerid	Customer	State	City	Zipcode	Gender
1	Nina Diaz	CA	Eureka	95501	Female
2	Melinda Carter	CA	Napa	94558	Female
3	Pam Miller	CA	Napa	94558	Female
4	Merle Blackwell	CA	Sacramento	95823	Female
5	Ariel Hale	CA	Sacramento	95818	Male
6	Randy Carter	CA	Sacramento	95818	Male
7	Lillie Hinton	CA	Eureka	95501	Female
8	Ladonna Moody	CA	Napa	94559	Female
9	Buddy McKay	OR	Bend	97701	Male
10	Warren Sykes	CA	Sacramento	95818	Male
11	Jan Rutledge	OR	Portland	97216	Female
12	Dallas Lester	OR	Eugene	97402	Male
13	Matthew Zimmerman	OR	Portland	97220	Male
14	Sheryl Hernandez	CA	Sacramento	95823	Female

sequential list of steps for query

Custom Column Dialog

- You can write M code directly for custom column
 - The Custom Column dialog provides a simple M code editor



The screenshot shows the 'Custom Column' dialog box in Power BI Desktop. The dialog has a title bar with a close button (X). Inside, there's a section for 'New column name' with a text box containing 'Customer Type'. Below that is a 'Custom column formula:' section with a text area containing the M code: `= if([FirstPurchaseDate]=[LastPurchaseDate])
then "One-time Customer"
else "Repeat Customer"`. To the right of the formula editor is a list of 'Available columns:' including Customer, State, City, Zipcode, Gender, BirthDate, and FirstPurchaseDate (which is highlighted). Below the list is a '<< Insert' button. At the bottom left, there's a green checkmark and the text 'No syntax errors have been detected.' At the bottom right, there are 'OK' and 'Cancel' buttons. A link 'Learn about Power BI Desktop formulas' is also present.

Custom Column

New column name
Customer Type

Custom column formula:
`= if([FirstPurchaseDate]=[LastPurchaseDate])
then "One-time Customer"
else "Repeat Customer"`

Available columns:
Customer
State
City
Zipcode
Gender
BirthDate
FirstPurchaseDate

<< Insert

[Learn about Power BI Desktop formulas](#)

✓ No syntax errors have been detected.

OK Cancel



Advanced Editor

or more correctly - The Simple Editor for Advanced Users

- 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 screenshot displays the Power BI Desktop interface with the 'Advanced Editor' window open. The main window shows a table of customer data with columns 'CustomerId', 'Customer', and 'State'. The 'Advanced Editor' window displays the M code for the 'Customers' query, which includes steps for loading data from a SQL database, reordering columns, replacing values, and adding a new column based on a condition. A red dashed arrow points from the 'Advanced Editor' button in the ribbon to the 'Advanced Editor' window. The status bar at the bottom of the Advanced Editor window indicates 'No syntax errors have been detected'.

Wingtip Sales Analysis - Query Editor

File Home Transform Add Column View Help

Query Settings ☒ Formula Bar ☐ Monospaced ☐ Show whitespace ☒ Always allow

Layout Data Preview Columns Parameters Advanced Editor

Queries [6]

- Customers
- Sales
- Purchases
- Products
- SalesRegions
- SalesRegionsSort

	CustomerId	Customer	State
1	1	Nina Diaz	CA
2	2	Melinda Carter	CA
3	3	Pam Miller	CA
4	4	Merle Blackwell	CA
5	5	Ariel Hale	CA
6	6	Randy Carter	CA
7	7	Lillie Hinton	CA
8	8	Ladonna Moody	CA
9	9	Buddy McKay	OR
10	10	Warren Sykes	CA
11	11	Jan Rutledge	OR
12	12	Dallas Lester	OR
13	13	Matthew Zimmerman	OR

Customers

```
let
Source = Sql.Database("cpt.database.windows.net", "WingtipSalesDB"),
dbo_Customers = Source[Schema="dbo",Item="Customers"][Data],
#"Removed Other Columns" = Table.SelectColumns(dbo_Customers,{"CustomerId", "FirstName", "LastName", "City", "State", "ZipCode", "Gender", "BirthDate", "FirstPurchaseDate", "LastPurchaseDate"}),
#"Merged Columns" = Table.CombineColumns(#"Removed Other Columns",{"FirstName", "LastName"},Combiner.CombineTextByDelimiter(" ", QuoteStyle.None),{"CustomerName"}),
#"Reordered Columns" = Table.ReorderColumns(#"Merged Columns",{"CustomerId", "CustomerName", "State", "City", "ZipCode", "Gender", "BirthDate", "FirstPurchaseDate", "LastPurchaseDate"}),
#"Replaced Female Values" = Table.ReplaceValue(#"Reordered Columns", "F", "Female", Replacer.ReplaceText, {"Gender"}),
#"Replaced Male Values" = Table.ReplaceValue(#"Replaced Female Values", "M", "Male", Replacer.ReplaceText, {"Gender"}),
#"Changed Type" = Table.TransformColumnTypes(#"Replaced Male Values",{{"BirthDate", type date}, {"FirstPurchaseDate", type date}, {"LastPurchaseDate", type date}}),
#"Added Custom" = Table.AddColumn(#"Changed Type", "CustomerType", each if [FirstPurchaseDate] = [LastPurchaseDate] then "One-time customer" else "Repeat Customer"),
#"Removed Columns" = Table.RemoveColumns(#"Added Custom",{"FirstPurchaseDate", "LastPurchaseDate"}),
#"Renamed Columns" = Table.RenameColumns(#"Removed Columns",{{"CustomerType", "Customer Type"}})
in
#"Renamed Columns"
```

✓ No syntax errors have been detected.

Done Cancel



Why Learn M

- Accomplish things that cannot be done in query editor
 - Working with query functions
 - Performing calculations across rows
 - Navigate to SharePoint list by list title instead of GUID with the ID
- Author queries and check them into source control system
 - Add query logic in .m files and store them in GitHub, TFS, etc.
 - Ensure query logic is the same across PBIX projects
- Stay Ahead of the Pack and Win Admiration of Your Peers
 - People will think you are buddies with Chris Webb!



Agenda

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- M Programming Fundamentals
 - M Function Library
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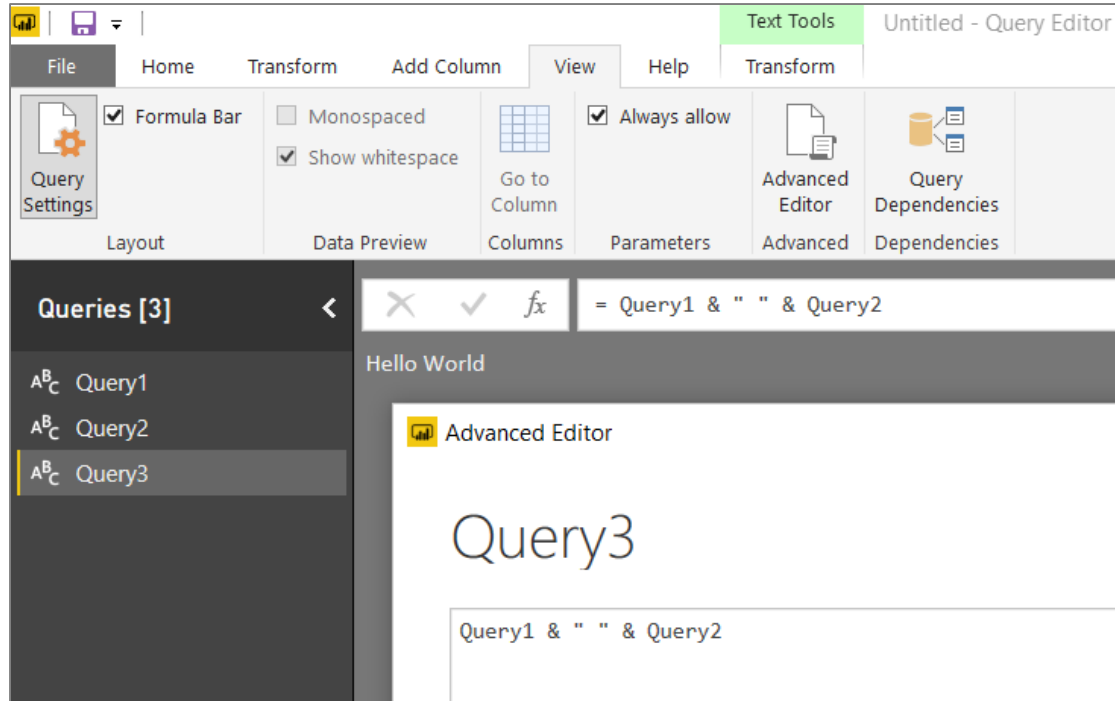
The M Programming Language

- 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



Referencing Other Queries

- Query can reference other queries by name
 - Every query is defined with a return type



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

The screenshot shows an 'Advanced Editor' window. The main text area displays 'Hello World' at the top. Below it, a 'let' block is defined with four lines of code, each enclosed in a red box and connected by a red arrow to the 'APPLIED STEPS' panel on the right. The code lines are: 'var1 = "Hello",', 'var2 = "World",', 'var3 = var1 & " " & var2,', and 'var4 = Text.Upper(var3)'. The 'in' block contains 'var4'. The 'APPLIED STEPS' panel on the right shows a list of variables: 'var1', 'var2', 'var3', and 'var4'. 'var4' is highlighted with a grey background and a small 'X' icon. The 'PROPERTIES' panel on the right shows 'Name' as 'Hello World' and a link to 'All Properties'. At the bottom, a green checkmark indicates 'No syntax errors have been detected.'

```
let
  var1 = "Hello",
  var2 = "World",
  var3 = var1 & " " & var2,
  var4 = Text.Upper(var3)
in
  var4
```

✓ No syntax errors have been detected.



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 uncle" = "are evil",  
  #"kitchen sink" = var1 & #"var 2" & #"Bob's your uncle"  
in  
  #"kitchen sink"
```

APPLIED STEPS

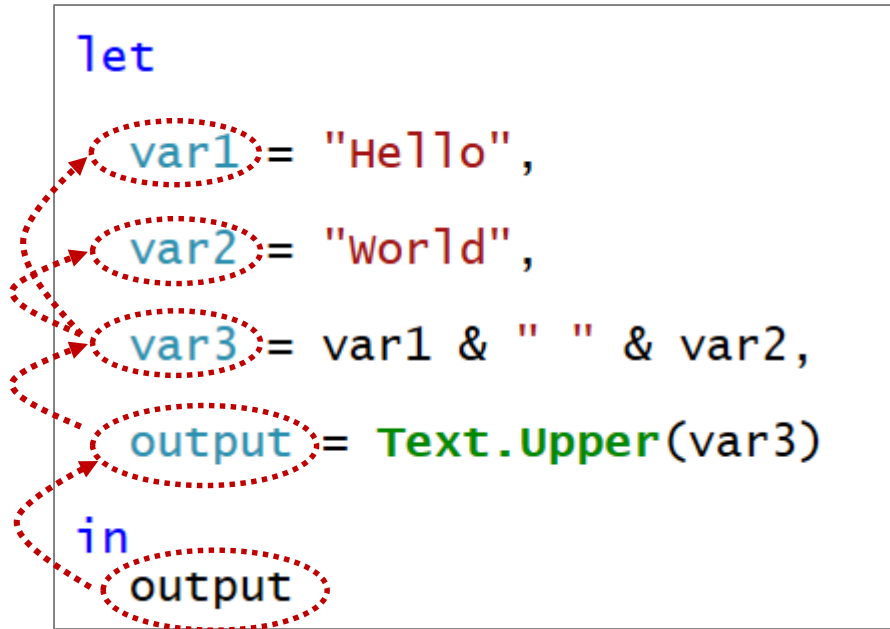
var1
var 2
Bob's your uncle

✕ Kitchen sink



Flow of Statement Evaluation

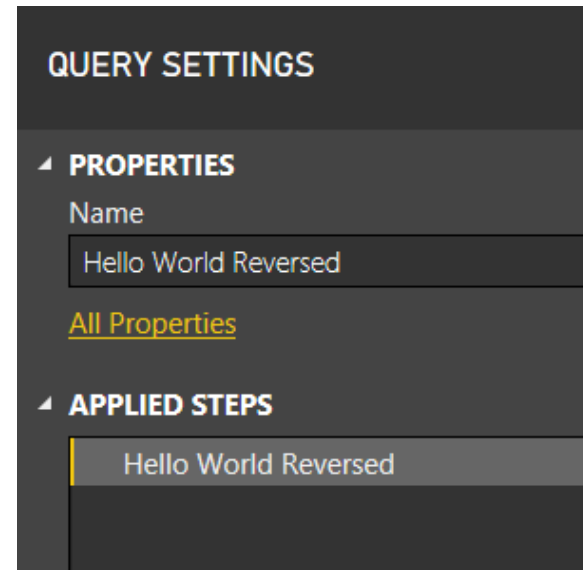
- Evaluation starts with expression inside **in** block
 - Expression evaluation triggers other expression evaluation



Will This M Code Work?

- Yes, the Mashup Engine has no problem with this
 - The order of expressions in **let** block doesn't matter
 - However, the visual designer might get confused

```
let
    var4 = Text.Upper(var3),
    var3 = var1 & " " & var2,
    var2 = "world",
    var1 = "Hello"
in
    var4
```



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(FilterdRows, 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
```



M Type System

- Built-in types

any, none

null, logical, number, text, binary

time, data, datetime, datetimezone, duration

- Complex types

list, record, table, function

- User-defined types

- You can create custom types for records and tables



M Datatypes

```
let

  // primitives
  var1 = 123,      // number
  var2 = true,     // boolean
  var3 = "hello",  // text
  var4 = null,     // null

  // creating lists
  list1 = {1, 2, 3},      // list of three numbers

  // accessing list elements
  var5 = list1{1},

  // create records
  record1 = [ FirstName="Soupy", LastName="Sales", ID=3 ],

  // accessing records
  var6 = record1[FirstName],

  // table
  table1 = #table( {"A", "B"}, { {1, 2}, {3, 4} } ),

  // creating function
  function1 = (x) => x * 2,

  // calling function
  output = function1(var1)

in
  output
```



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
```



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 characters
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 characters
set4 = {" ", "-", "_", "."},

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

// call Text.Select to strip out unwanted characters
output = Text.Select(input, allowedChars)
```



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

	AB C FirstName	AB C 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(_) )
```



Performing Calculations Across Rows

- Requires adding an index column

	Quarter	\$ Sales	1.2 Index	\$ Running Total
1	2016-Q1	124	0	124
2	2016-Q2	154	1	278
3	2016-Q3	167	2	445
4	2016-Q4	188	3	633
5	2017-Q1	150	4	783
6	2017-Q2	193	5	976
7	2017-Q3	208	6	1184
8	2017-Q4	234	7	1418

PROPERTIES

Name

Sales Running Total

[All Properties](#)

APPLIED STEPS

Source

AddedIndex

✕ AddedCustom

Custom Column

New column name

Running Total

Custom column formula:

= List.Sum(List.Range(AddedIndex[Sales], 0, [Index]+1))



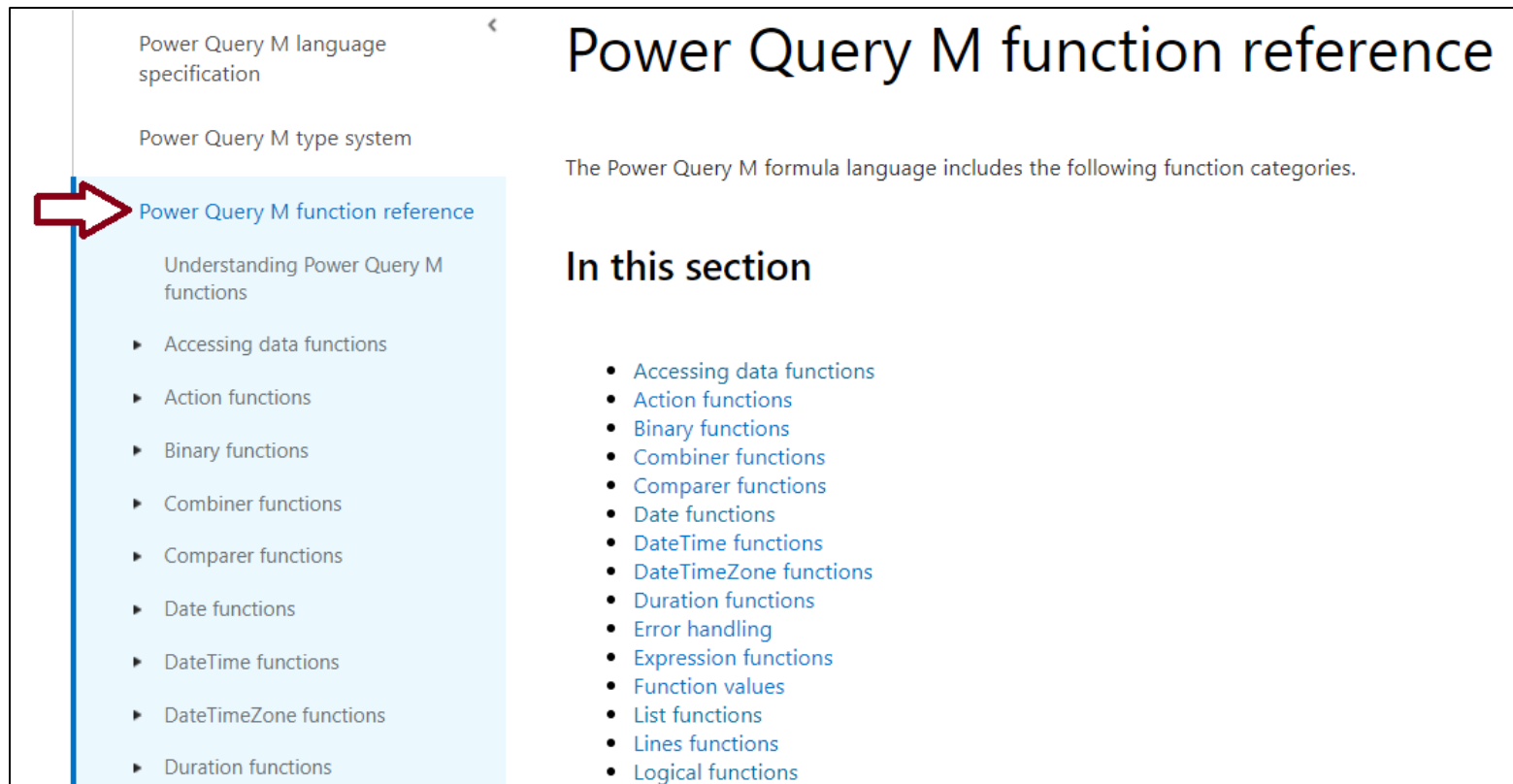
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M Function Library

- Check out the Power Query M function reference
 - <https://msdn.microsoft.com/en-us/library/mt779182.aspx>



Power Query M language specification

Power Query M type system

 **Power Query M function reference**

- Understanding Power Query M functions
 - ▶ Accessing data functions
 - ▶ Action functions
 - ▶ Binary functions
 - ▶ Combiner functions
 - ▶ Comparer functions
 - ▶ Date functions
 - ▶ DateTime functions
 - ▶ DateTimeZone functions
 - ▶ Duration functions

Power Query M function reference

The Power Query M formula language includes the following function categories.

In this section

- Accessing data functions
- Action functions
- Binary functions
- Combiner functions
- Comparer functions
- Date functions
- DateTime functions
- DateTimeZone functions
- Duration functions
- Error handling
- Expression functions
- Function values
- List functions
- Lines functions
- Logical functions



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(FilteredReaders,"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+1e+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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Understanding Function Queries

- Query can be converted into reusable function
 - Requires editing query M code in Advanced Editor
 - Function query defined with one or more parameters

```
GetExpensesFromFile

(FilePath as text) =>

let
    Source = Csv.Document(Web.Contents(FilePath))
    #"Changed Type" = Table.TransformColumnTypes(Source, ...)
```

- Function query can be called from other queries
- Function query can be called using Invoke Custom Function
- Function query can't be edited with visual designer



List.Generate

- **List.Generate** accepts 3 function parameters

```
MyList = List.Generate( ()=>1, (item)=>(item<=10), (item)=>(item+1) )
```

- You can use **each** syntax for 2nd and 3rd parameter

```
MyList = List.Generate( ()=>1, each _<=10, each _+1 )
```

- You can optionally split functions out into separate expressions

```
let  
  
    StartFunction = ()=>1,  
    TestFunction = each _ <= 10,  
    IncrementFunction = each _ + 1,  
  
    MyList = List.Generate( StartFunction, TestFunction, IncrementFunction)  
in  
    MyList
```

List	
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10



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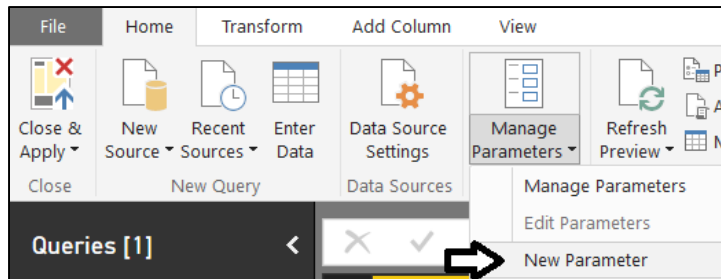
Query Parameters

- What is a Query Parameter?
 - Configurable setting with project scope
 - Strongly-typed value to which you can apply restrictions
 - Can be referenced from a query
 - Selected values can be populated using list
- Where are Parameters commonly used
 - To parameterize data source connection details
 - To filter rows when importing data



Creating Query Parameters

- Parameters can be created using **Manager Parameters** menu



- Parameter properties
 - Name
 - Description
 - Required
 - Allowed Values
 - Default Value
 - Current Value

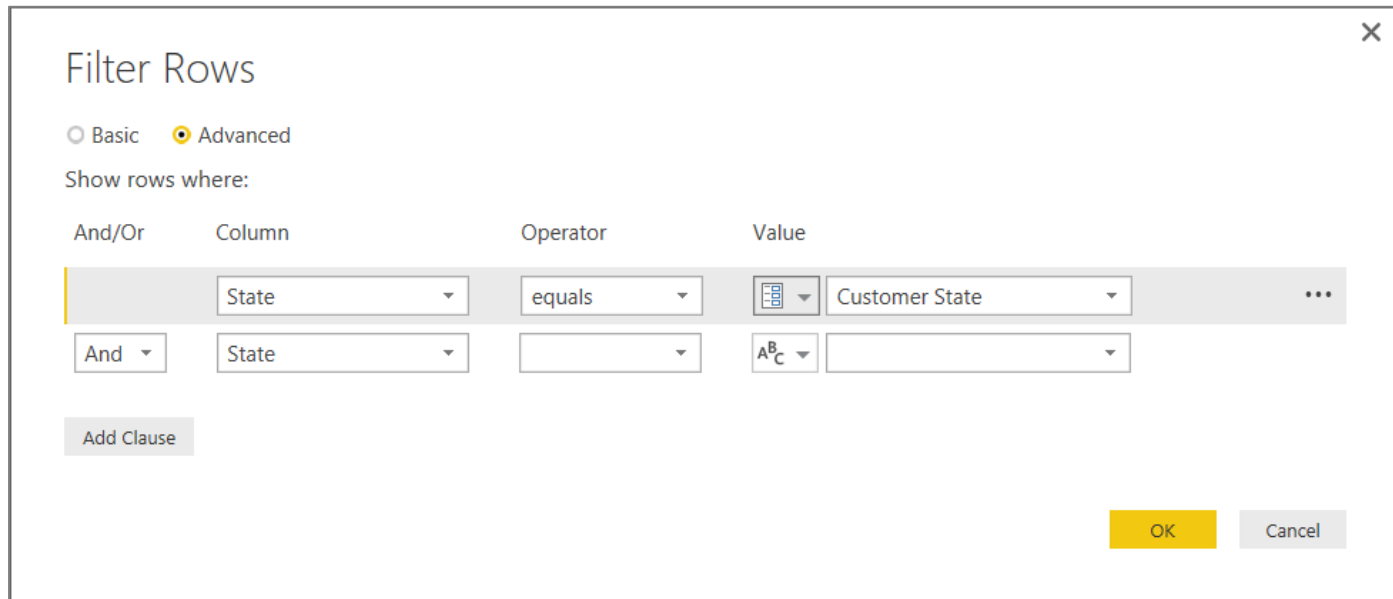
A screenshot of the 'Parameters' dialog box in Power BI. The dialog shows a parameter named 'Customer State' with a description: 'This parameter is used in the Customers query to filter the customer rows which are loaded into the dataset for the Power BI Desktop project.' The parameter is set to be 'Required' with a 'Text' type. The 'Allowed Values' are set to 'List of values', and a table of values is displayed. The 'Default Value' and 'Current Value' are both set to 'CA'.

1	CA
2	OR
3	WA
4	AZ
5	TX
*	



Referencing Parameters in a Query

- Parameters can be referenced inside query
 - Next query execution uses current parameter value



The screenshot shows a 'Filter Rows' dialog box with a close button (X) in the top right corner. It has two tabs: 'Basic' (unselected) and 'Advanced' (selected). Below the tabs, it says 'Show rows where:'. There are two rows of filter criteria. The first row has a column 'State' with the operator 'equals' and the value 'Customer State'. The second row has a column 'State' with the operator 'AB_C' and an empty value field. There is an 'Add Clause' button and 'OK' and 'Cancel' buttons at the bottom right.

And/Or	Column	Operator	Value
	State	equals	Customer State
And	State	AB_C	



Creating a Project Template File

Untitled - Power BI Desktop

File Home View Modeling Help

Paste Cut Copy Format Painter Clipboard

Get Data Recent Sources Enter Data Edit Queries Refresh External data

New Page New Visual Ask A Question Insert Text box Image Shapes

From Marketplace From File Custom visuals

Switch Theme Themes


Manage Relationships Relationships

New Measure New Column New Quick Measure Calculations

Giants Team Roster

City	Conference	Division	Roster
East Rutherford, NJ	NFC	NFC-East	

City and Team



Offensive Players

Number	Player	Position	College
2	Aldrick Rosas	Kicker	Southern Oregon
3	Geno Smith	Quarterback	West Virginia
5	Davis Webb	Quarterback	California
9	Brad Wing	Punter	LSU
10	Eli Manning	Quarterback	Mississippi
12	Tavarres King	Wide Receiver	Georgia
13	Odell Beckham Jr	Wide Receiver	LSU
15	Brandon Marshall	Wide Receiver	Central Florida
17	Dwayne Harris	Wide Receiver	East Carolina
18	Roger Lewis	Wide Receiver	Bowling Green State
19	Travis Rudolph	Wide Receiver	Florida State
22	Wayne Gallman	Running Back	Clemson
26	Orleans Darkwa	Running Back	Tulane
28	Paul Perkins	Running Back	UCLA
34	Shane Vereen	Running Back	California
43	Shane Smith	Tight End	San Jose State
51	Zak DeOssie	Long Snapper	Brown
61	Nick Becton	Offensive Tackle	Virginia Tech
63	Chad Wheeler	Offensive Tackle	USC
65	Jessamen Dunker	Offensive Tackle	Tennessee State
66	Adam Bisnowaty	Offensive Tackle	Pittsburgh
67	Justin Pugh	Guard	Syracuse
69	Brett Jones	Center	Regina (Canada)

Defensive Players

Number	Player	Position
20	Janoris Jenkins	Cornerback
21	Landon Collins	Safety
23	Darryl Morris	Defensive Back
24	Eli Apple	Cornerback
25	Brandon Dixon	Cornerback
27	Darian Thompson	Safety
29	Nat Berhe	Safety
33	Andrew Adams	Safety
36	Ryan Murphy	Safety
37	Ross Cockrell	Cornerback
38	Donte Deayon	Cornerback
39	Derrick Mathews	Linebacker
41	Dominique Rodgers-Cromartie	Cornerback
44	Mark Herzlich	Linebacker
46	Calvin Munson	Linebacker
47	Kelvin Sheppard	Middle Linebacker
48	Akeem Ayers	Linebacker
52	Jonathan Casillas	Linebacker
54	Olivier Vernon	Defensive End
55	Ray-Ray Armstrong	Outside Linebacker
57	Keenan Robinson	Linebacker
58	Curtis Grant	Linebacker
59	Devon Kennard	Linebacker



The Template File Implementation

- Solution required advanced query design

The screenshot shows a data tool interface. On the left is a sidebar with a 'Queries [8]' section. It contains a 'Data [3]' folder with 'Teams' (selected), 'Team List', and 'Position Codes'. Below that is a 'Parameters [2]' section with 'Team (Eagles)' and 'RosterUrl'. Then an 'Extract [1]' section with 'GetPlayers'. Finally, a 'Data Model [2]' section with 'Players' and 'Team Details'. The main area shows a query editor with a formula bar containing '= #table(type table'. Below the formula bar is a table with 6 columns: 'Team', 'Division', 'Conference', 'City', and 'RosterUrl'. The table lists 13 NFL teams, all in the AFC.

	Team	Division	Conference	City	RosterUrl
1	Bills	AFC-East	AFC	Buffalo, NY	http://www.buffal
2	Dolphins	AFC-East	AFC	Miami, FL	http://www.miami
3	Jets	AFC-East	AFC	East Rutherford, NJ	http://www.newyc
4	Patriots	AFC-East	AFC	Foxboro, MA	http://www.patrio
5	Bengals	AFC-North	AFC	Cincinnati, OH	http://www.benga
6	Browns	AFC-North	AFC	Cleveland, OH	http://www.clevel
7	Ravens	AFC-North	AFC	Baltimore, MD	http://www.baltim
8	Steelers	AFC-North	AFC	Pittsburg, PA	http://www.steele
9	Colts	AFC-South	AFC	Indianapolis, IN	http://www.colts.c
10	Jaguars	AFC-South	AFC	Jacksonville, FK	http://www.jaguar
11	Texans	AFC-South	AFC	Houston, TX	http://www.houst
12	Titans	AFC-South	AFC	Nashville, TN	http://www.titans
13	Broncos	AFC-West	AFC	Denver, CO	http://www.denve



Agenda

- ✓ Power Query Mashup Engine
- ✓ M Programming Fundamentals
- ✓ M Function Library
- ✓ Query Functions
- ✓ Query Parameters
- Custom Data Connectors

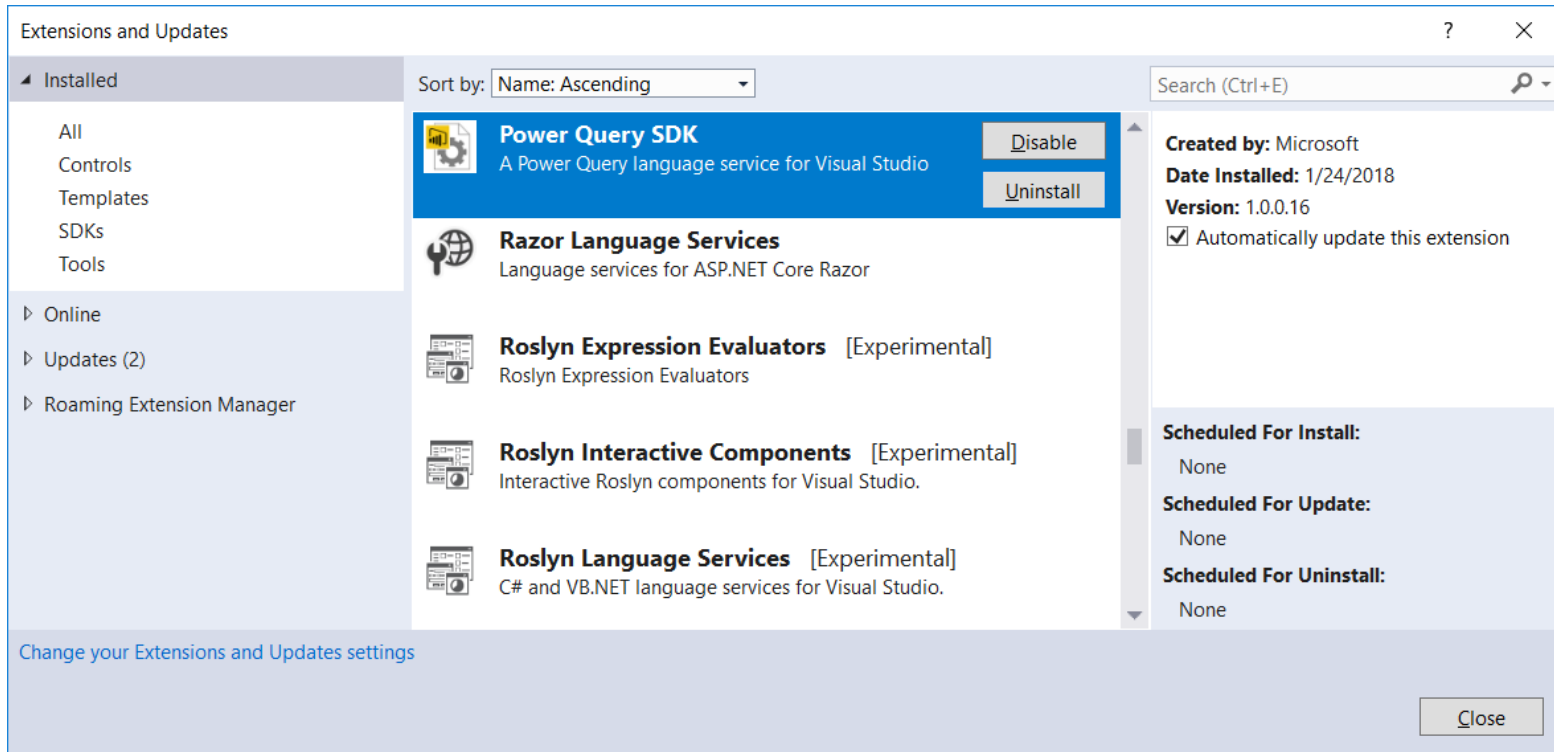


Developing Custom Data Connectors

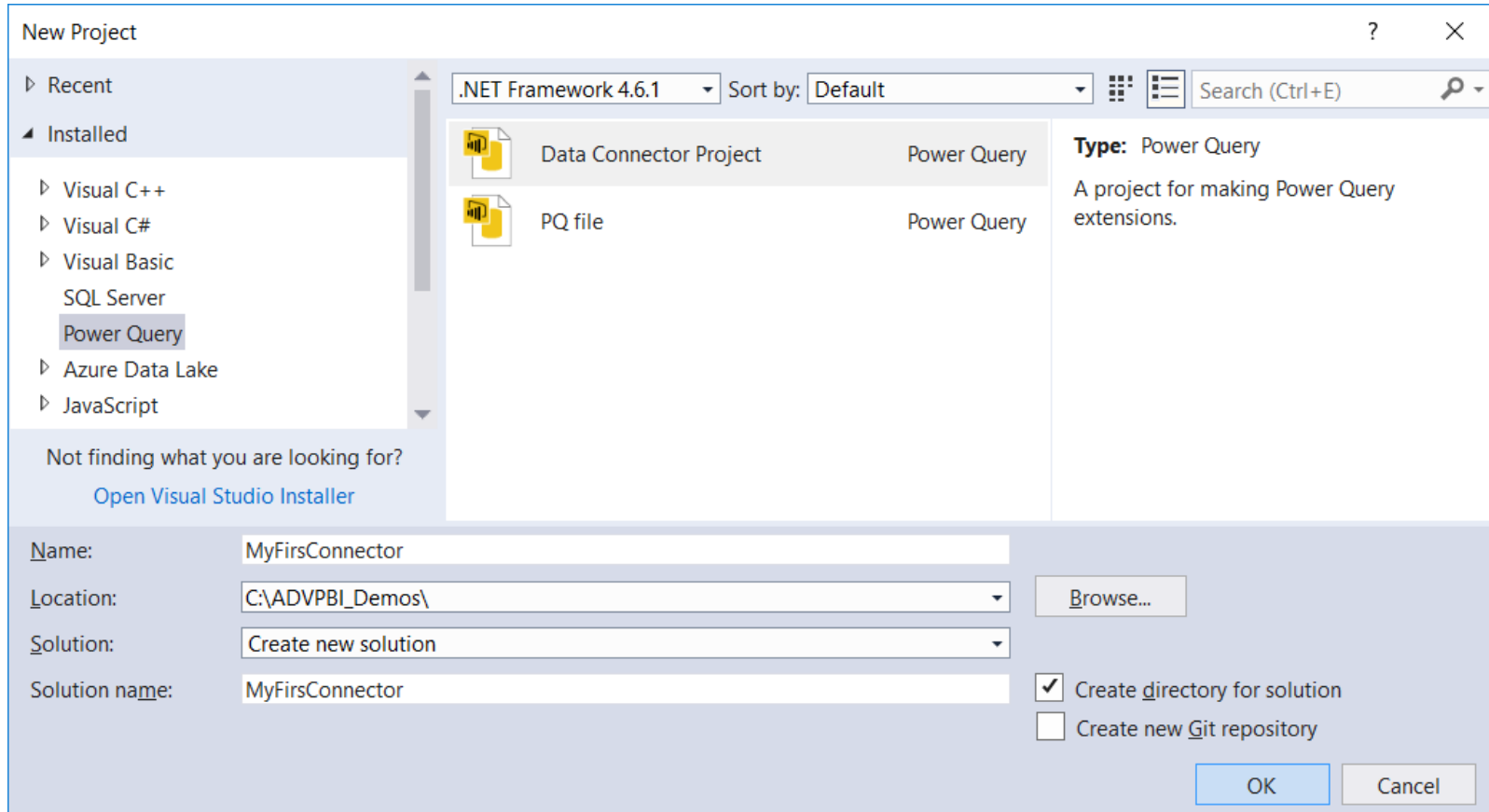
- Custom Connectors let you write reusable query logic
 - Custom connector is written using M programming language
 - Custom connector can be used across PBIX project files
- Common motivation for developing a custom connector
 - Creating a friendly view of a REST API for business analyst
 - Providing branding on top of existing connector
 - Exposing a limited/filtered view over your data source
 - Control how mashup engine authenticates against datasource
 - Implementing OAuth v2 authentication flow for a SaaS offering
 - Enabling Direct Query for a data source via an ODBC driver`



Power Query SDK



Creating a New Data Connector Project



The screenshot shows the 'New Project' dialog box in Visual Studio. The 'Installed' section on the left lists various project types, with 'Power Query' selected. The main pane displays two options: 'Data Connector Project' and 'PQ file', both categorized as 'Power Query'. The 'Type' section on the right provides a description for the 'Power Query' type. At the bottom, the project name is set to 'MyFirsConnector', the location is 'C:\ADVPBI_Demos\', and the solution is 'Create new solution'. The 'Solution name' is also 'MyFirsConnector'. The 'Create directory for solution' checkbox is checked, and the 'Create new Git repository' checkbox is unchecked. The 'OK' and 'Cancel' buttons are at the bottom right.

New Project



Recent

Installed

- Visual C++
- Visual C#
- Visual Basic
- SQL Server
- Power Query**
- Azure Data Lake
- JavaScript

Not finding what you are looking for?
[Open Visual Studio Installer](#)

.NET Framework 4.6.1 Sort by: Default Search (Ctrl+E)

Icon	Project Name	Type
	Data Connector Project	Power Query
	PQ file	Power Query

Type: Power Query
A project for making Power Query extensions.

Name: MyFirsConnector

Location: C:\ADVPBI_Demos\ Browse...

Solution: Create new solution

Solution name: MyFirsConnector

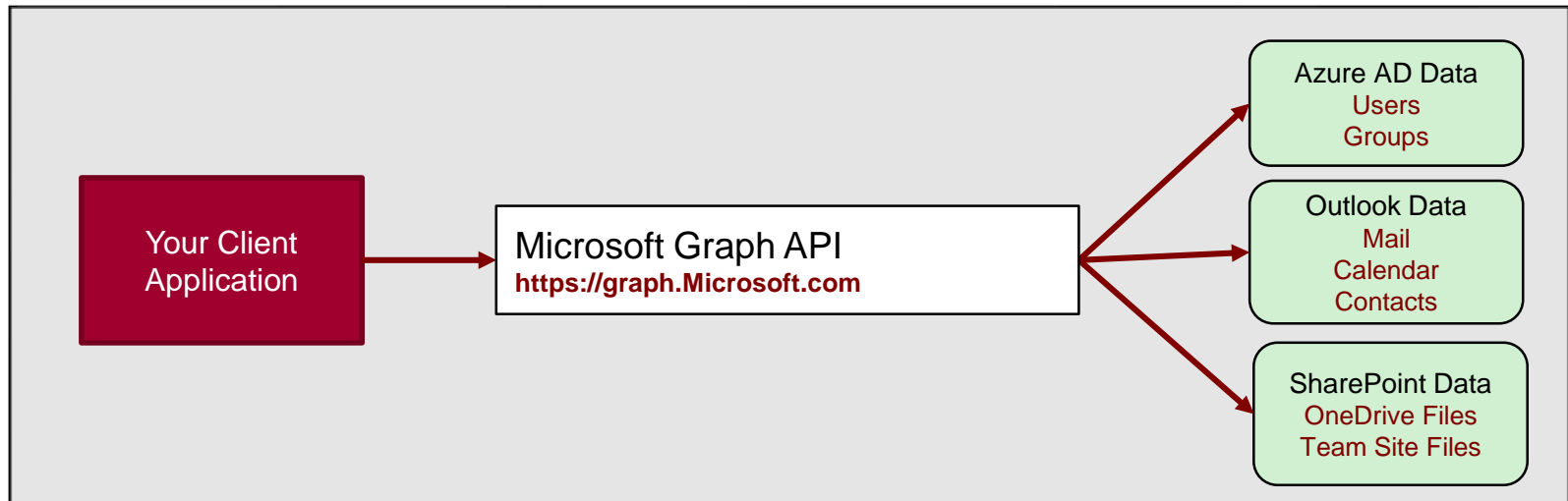
☒ Create directory for solution
☐ Create new Git repository

OK Cancel



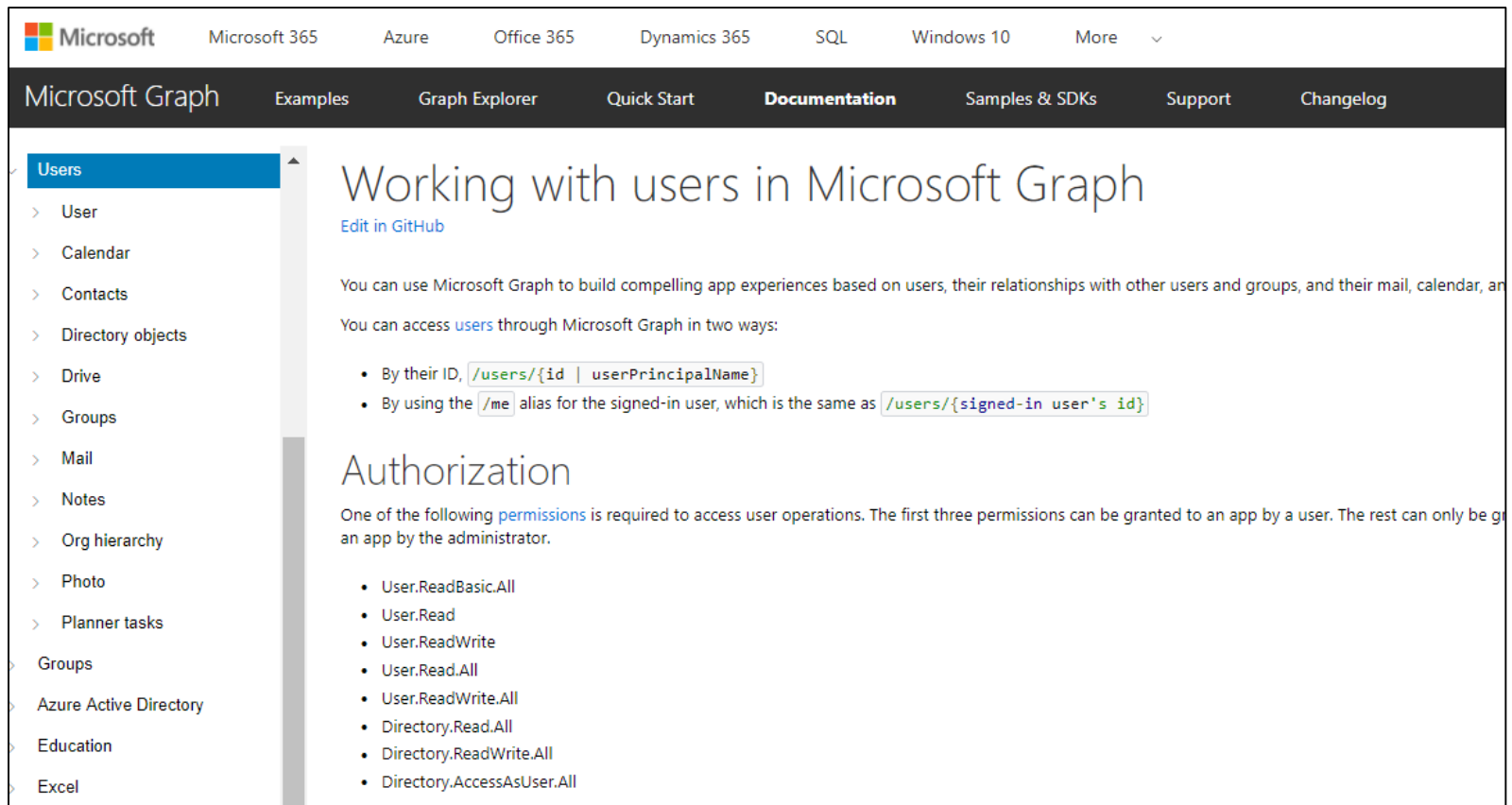
The Microsoft Graph API

- Designed as a one-stop-shopping kind of service
 - Abstracts away divisions between AD, Exchange and SharePoint
 - No need to discover endpoints using the Discovery Service
 - You can acquire and cache a single access token per user



More Info on the Microsoft Graph API

- <https://developer.microsoft.com/en-us/graph/docs/api-reference/v1.0>



The screenshot shows the Microsoft Graph documentation website. The top navigation bar includes links for Microsoft 365, Azure, Office 365, Dynamics 365, SQL, Windows 10, and a 'More' dropdown. The main navigation bar features 'Microsoft Graph', 'Examples', 'Graph Explorer', 'Quick Start', 'Documentation' (which is highlighted), 'Samples & SDKs', 'Support', and 'Changelog'. On the left, a sidebar lists various resource categories: Users (highlighted), Calendar, Contacts, Directory objects, Drive, Groups, Mail, Notes, Org hierarchy, Photo, Planner tasks, Groups, Azure Active Directory, Education, and Excel. The main content area is titled 'Working with users in Microsoft Graph' and includes a link to 'Edit in GitHub'. It explains that Microsoft Graph can be used to build app experiences based on users and their relationships. It then lists two ways to access users: by their ID using the path `/users/{id | userPrincipalName}`, or by using the `/me` alias for the signed-in user, which is equivalent to `/users/{signed-in user's id}`. Below this, the 'Authorization' section states that one of the following permissions is required to access user operations. The first three permissions can be granted to an app by a user, while the remaining three can only be granted by an administrator.

Users

- > User
- > Calendar
- > Contacts
- > Directory objects
- > Drive
- > Groups
- > Mail
- > Notes
- > Org hierarchy
- > Photo
- > Planner tasks
- > Groups
- > Azure Active Directory
- > Education
- > Excel

Working with users in Microsoft Graph

[Edit in GitHub](#)

You can use Microsoft Graph to build compelling app experiences based on users, their relationships with other users and groups, and their mail, calendar, and more.

You can access [users](#) through Microsoft Graph in two ways:

- By their ID, `/users/{id | userPrincipalName}`
- By using the `/me` alias for the signed-in user, which is the same as `/users/{signed-in user's id}`

Authorization

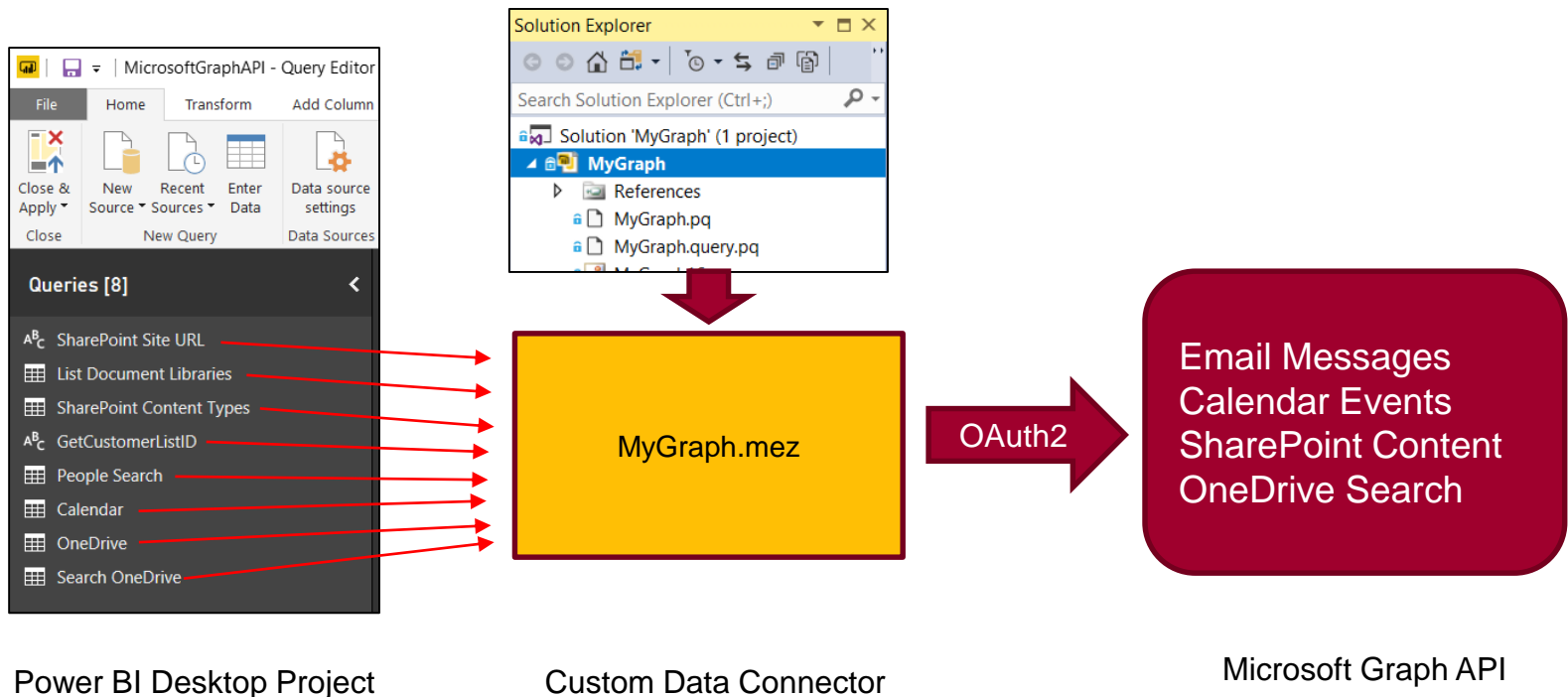
One of the following [permissions](#) is required to access user operations. The first three permissions can be granted to an app by a user. The rest can only be granted to an app by the administrator.

- User.ReadBasic.All
- User.Read
- User.ReadWrite
- User.Read.All
- User.ReadWrite.All
- Directory.Read.All
- Directory.ReadWrite.All
- Directory.AccessAsUser.All



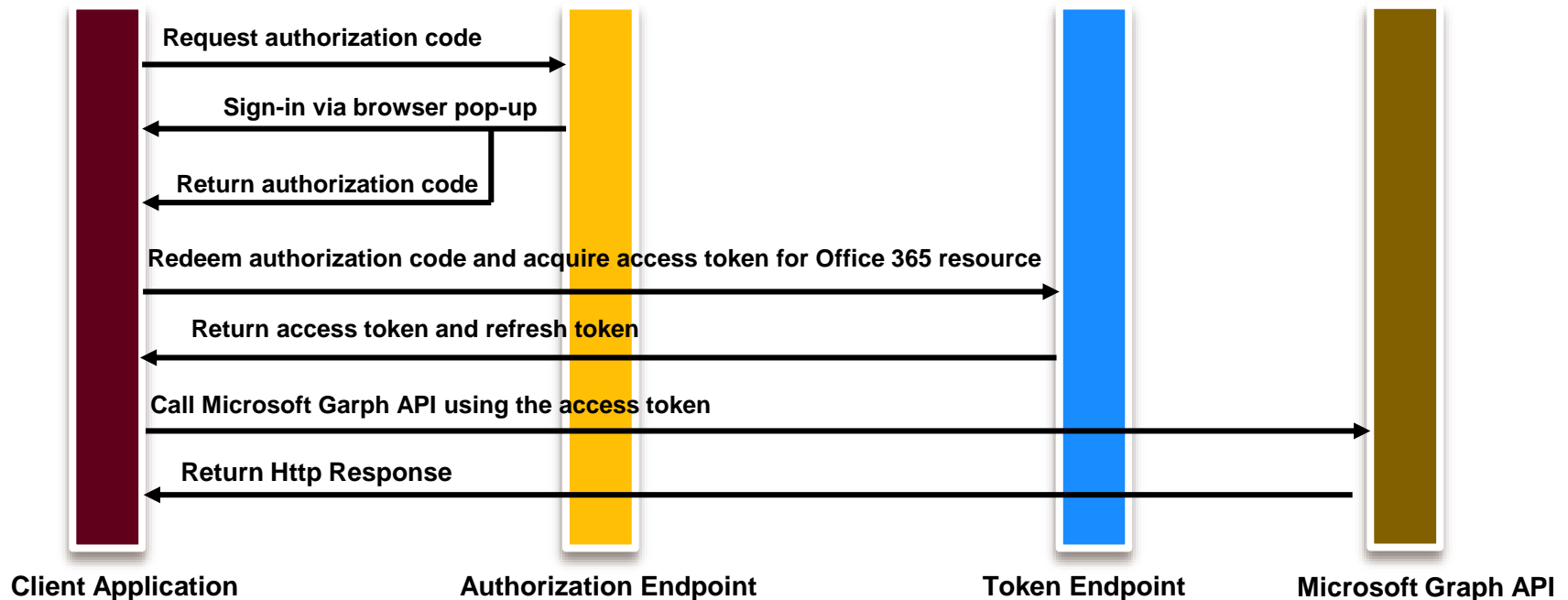
MyGraph Demo

- Project originally created by Matt Masson
 - Connector designed to query Microsoft Graph API
 - Connector provides code to authenticate with OAuth2



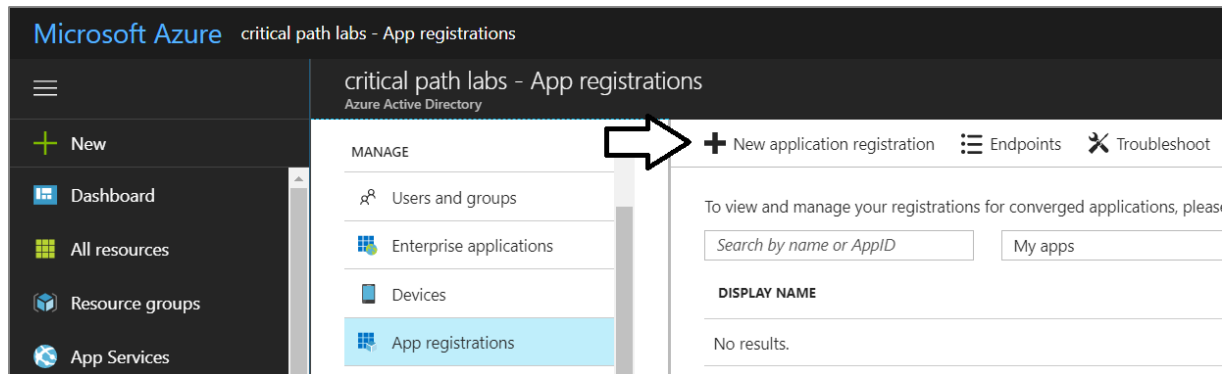
Authorization Code Grant Flow

- Sequence of Requests in Authorization Code Grant Flow
 - Application redirects to AAD authorization endpoint
 - User prompted to log on at Windows logon page
 - User prompted to consent to permissions (first access)
 - AAD redirects to application with authorization code
 - Application redirects to AAD access token endpoint



Registering an Azure Application

- Can be done using Azure portal



- Details you need for the custom data connector
 - Client ID
 - Client Secret
 - Redirect URL



Summary

- ✓ Power Query Mashup Engine
- ✓ M Programming Fundamentals
- ✓ M Function Library
- ✓ Query Functions
- ✓ Query Parameters
- ✓ Custom Data Connectors

