

F# Workshop



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Objectives

- > Understand the basic core principles behind FP
- > Understand the F# syntax
- > Understand the F# structures
- > Get motivation to practice and master F#

Materials

- > Exercises Guide
- > Exercises Source Code
- > F# CheatSheet

fsharpworkshop.com

github.com/jorgef/fsharpworkshop

Pre-requisites

> Windows

- > Visual Studio 2015 Community or
- > Xamarin Studio or
- > Atom + F# Compiler + Ionide package or
- > Visual Studio Code + F# Compiler + Ionide package

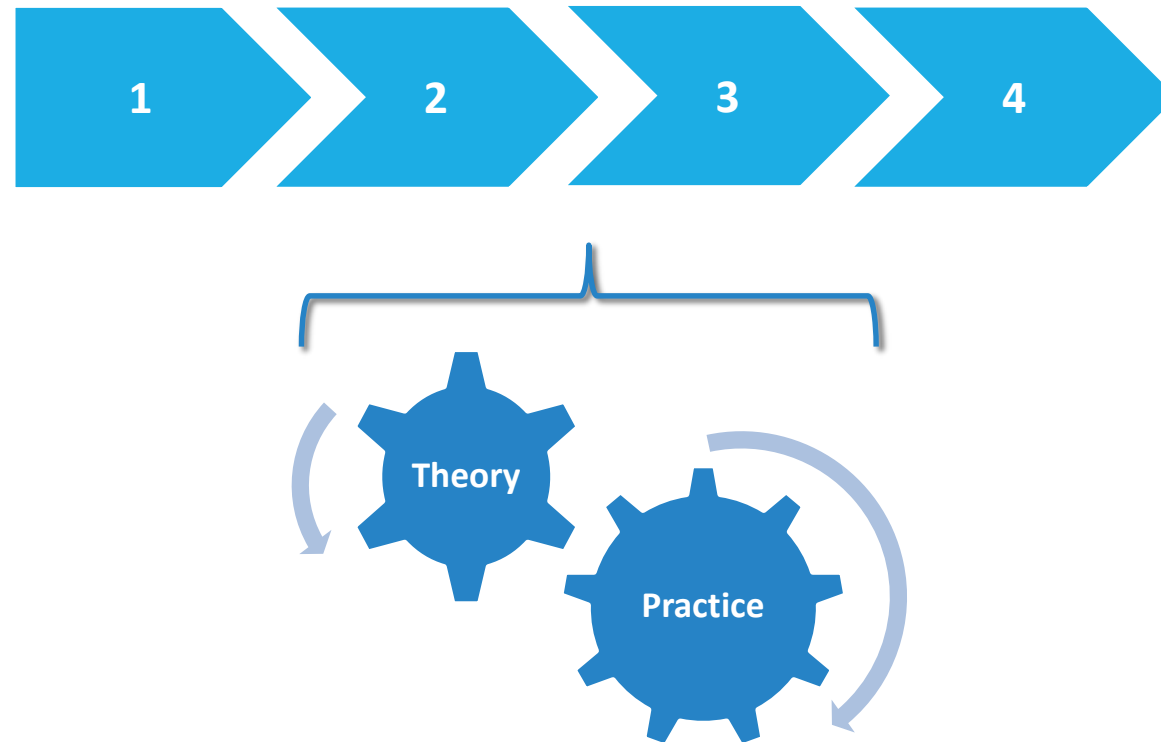
> Linux

- > Atom + Mono + Ionide package or
- > Visual Studio Code + Mono + Ionide package

> Mac

- > Xamarin Studio or
- > Atom + Mono + Ionide package or
- > Visual Studio Code + Mono + Ionide package

Modules



Agenda

Module 1

Bindings | Functions | Tuples | Records

Module 2

High order functions | Pipelining | Partial application | Composition

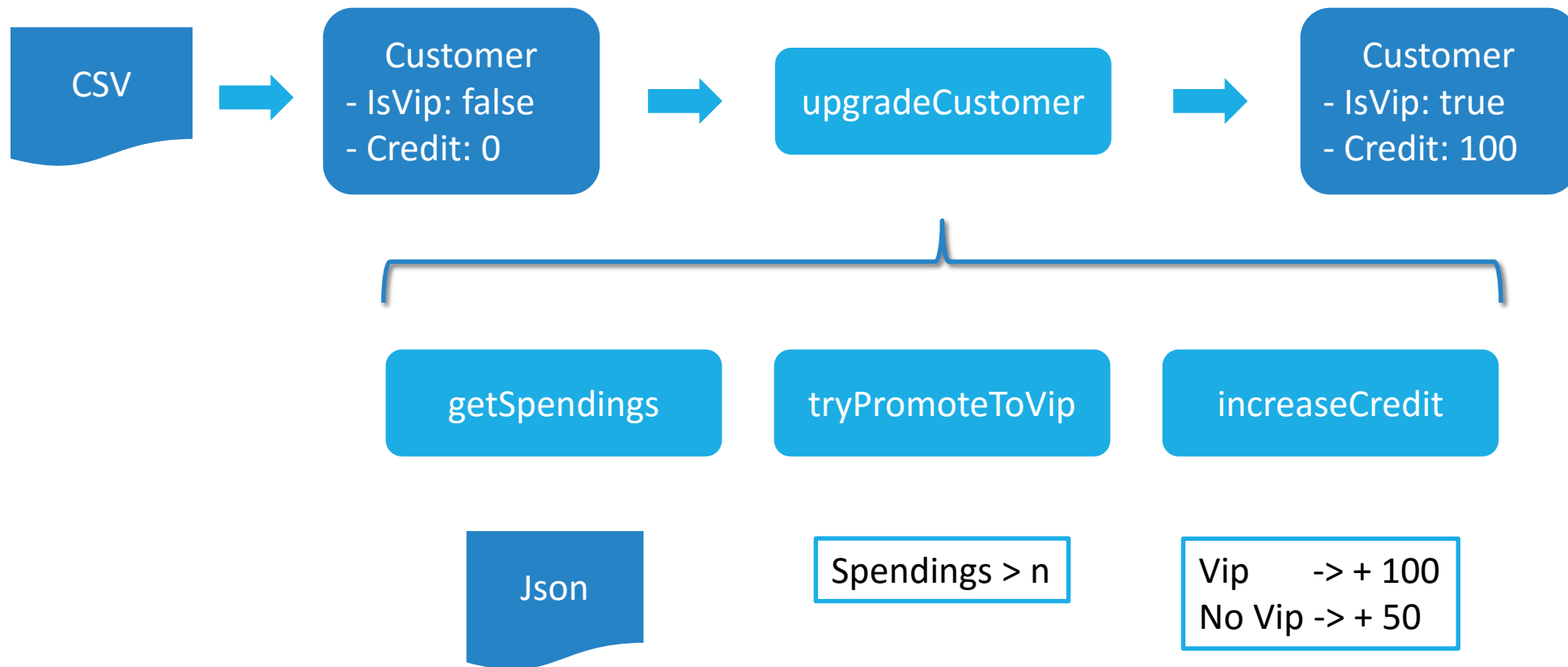
Module 3

Options | Pattern matching | Discriminated unions | Units of measure

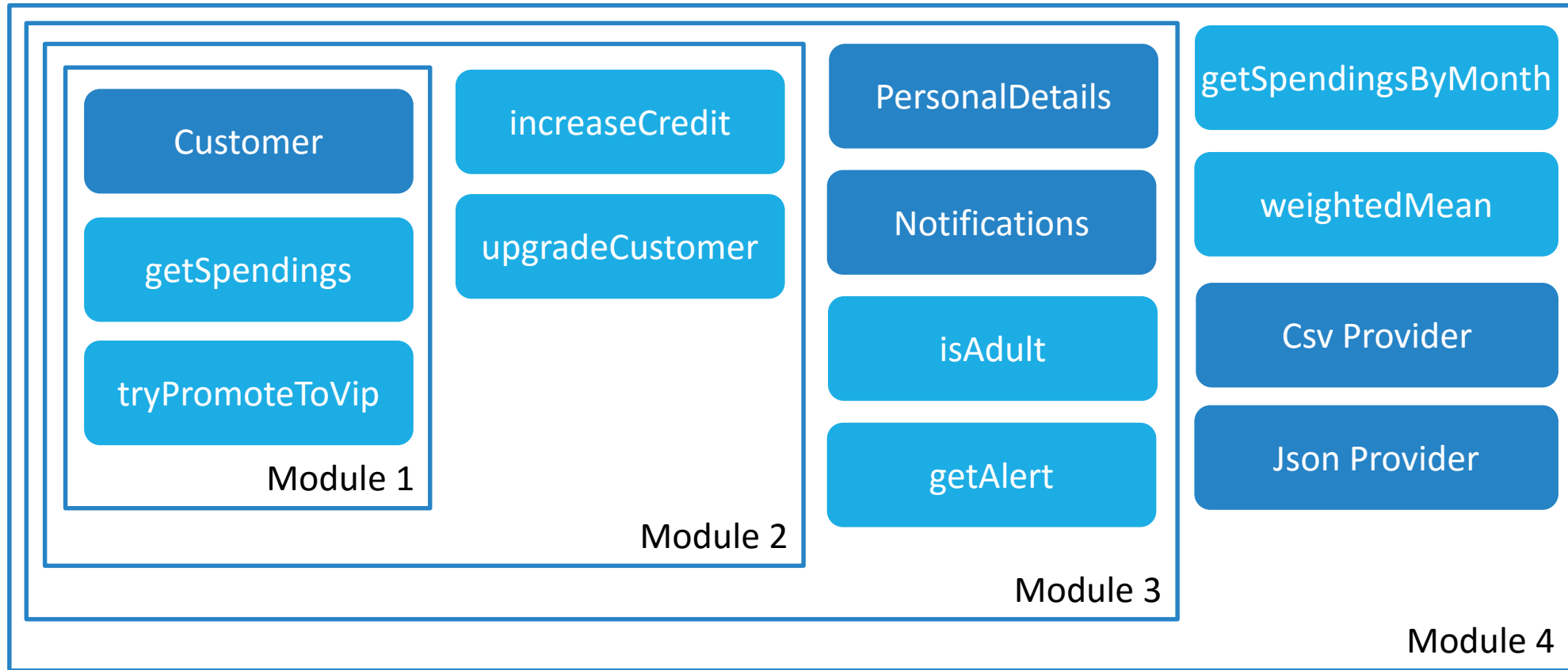
Module 4

Functional lists | Recursion | Object-oriented programming | Type providers

Exercise



Exercise



Module 1

BINDINGS | FUNCTIONS | TUPLES | RECORDS



F# is a mature, open source, cross-platform,
functional-first programming language.

Imperative vs Functional

C#

F#

Imperative

Functional

Conventions

C#

```
var number = 1;
```

F#

```
let number = 1
```

Functional Core Concepts



Declarative Style

The diagram consists of two overlapping ovals. The left oval is light blue and contains the text 'Declarative Style'. The right oval is a darker blue and contains the text 'Immutability'. The ovals overlap in the center, with the darker blue oval partially obscuring the lighter one on the right side.

Immutability

Declarative Style

Imperative →

```
var vipCustomers = new List<Customer>();  
foreach (var customer in customers)  
{  
    if (customer.IsVip)  
        vipCustomers.Add(customer);  
}
```

Declarative →

```
var vipCustomers = customers.Where(c => c.IsVip);
```

Immutability

```
var x = 1;
```

≠

```
let x = 1
```

```
let mutable x = 1  
x <- 2
```

```
x = x + 1
```

```
let y = x + 1
```

Functions

```
int Add(int x, int y)
{
    return x + y;
}
```

Func<int,int,int>

↖ ↗
In Out

```
let add x y = x + y
```

int -> int -> int

↖ ↗
In Out

let instead of
no parens and
no return
concise

Pure Functions

```
public int Sum(int a, int b)
{
    return a + b;
}
```

```
private int accumulator;

public int Sum(int a, int b)
{
    accumulator++;
    return a + b;
}
```

Expressions

Expression

`a == b`



Returns a Boolean

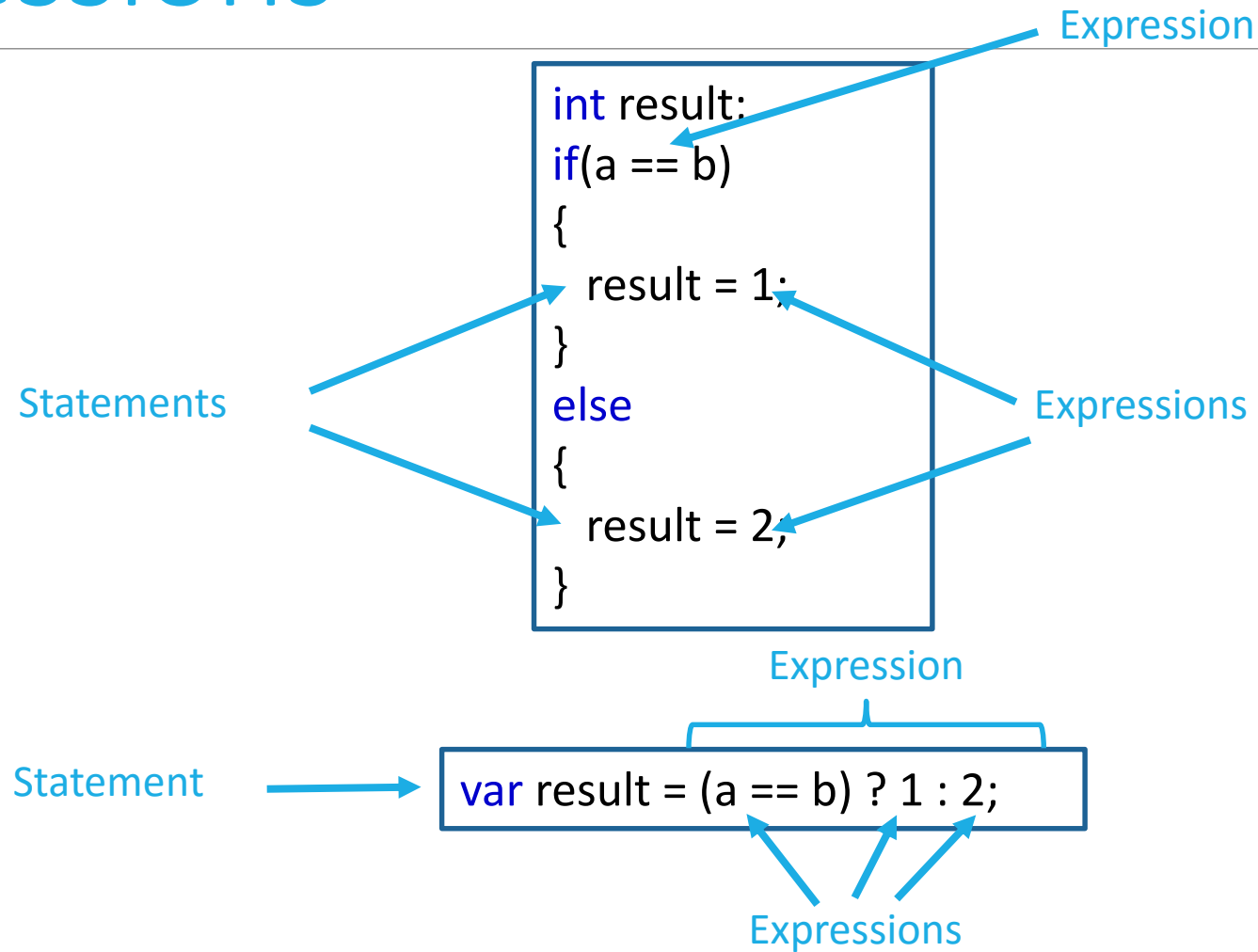
Statement

`var a = 1;`

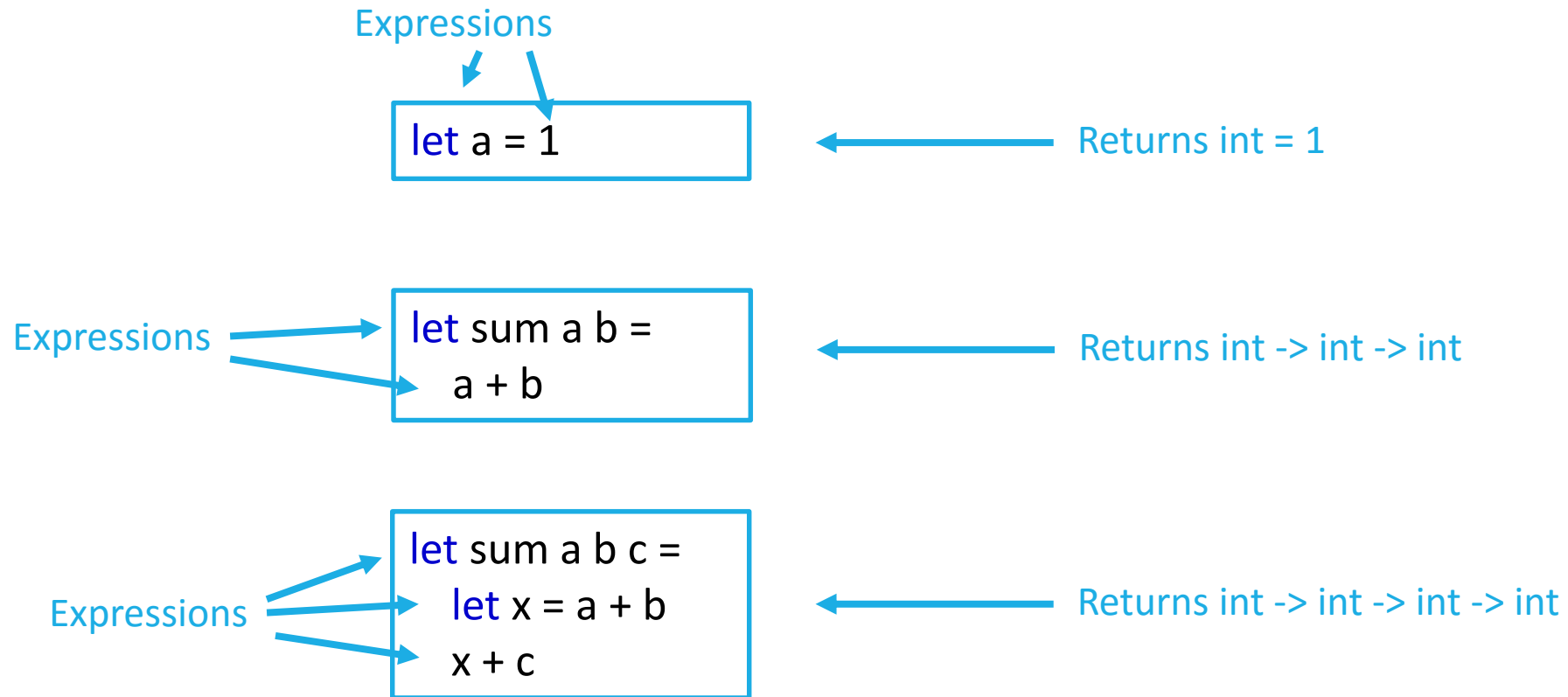


Doesn't return anything

Expressions



Bindings



Tuples

```
Tuple<int, int> Divide(int dividend, int divisor)
{
    var quotient = dividend / divisor;
    var remainder = dividend % divisor;
    return new Tuple<int, int>(quotient, remainder);
}
```

```
var result = Divide(10, 3);
var quotient = result.Item1;
var remainder = result.Item2;
```

```
let divide dividend divisor =
    let quotient = dividend / divisor
    let remainder = dividend % divisor
    (quotient, remainder)
```

```
let quotient, remainder = divide 10 3
```

```
let success, value = Int32.TryParse("42")
```

Records

```
public class DivisionResult
{
    public int Quotient { get; set; }
    public int Remainder { get; set; }
}
```

```
type DivisionResult = {
    Quotient : int
    Remainder : int
}
```

```
public class DivisionResult
{
    private readonly int quotient;
    private readonly int remainder;
    public DivisionResult(int quotient, int remainder)
    {
        this.quotient = quotient;
        this.remainder = remainder;
    }
    public int Quotient
    {
        get { return quotient; }
    }
    public int Remainder
    {
        get { return remainder; }
    }
}
```

Records

```
type DivisionResult = {  
  Quotient : int  
  Remainder : int  
}
```

```
let result = { Quotient = 3; Remainder = 1 }
```

```
let result = { Quotient = 3 }
```

← Error: No assignment given
for field 'Remainder' of type

```
let newResult = { Quotient = result.Quotient; Remainder = 0 }
```

```
let newResult = { result with Remainder = 0 }
```

```
let result1 = { Quotient = 3; Remainder = 1 }  
let result2 = { Quotient = 3; Remainder = 1 }  
result1 = result2 // true
```

← Structural Equality
Reference Types

Immutable and Structural Equality

```
var message1 = "hello John Doe";  
var message2 = "hello John Doe";
```

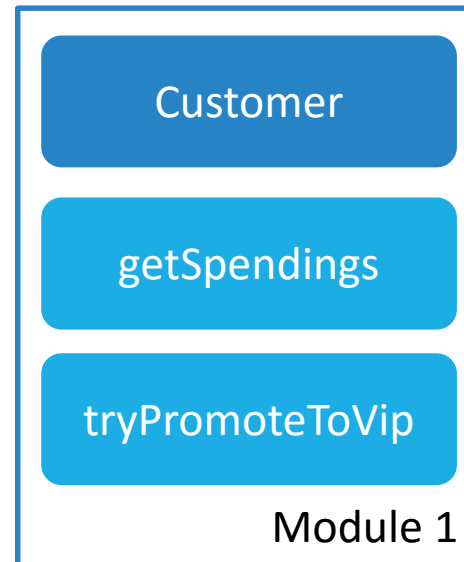
```
var result = message1 == message2; // true
```

```
var message3 = message1.Replace("hello", "hi");
```


Demo 1

BINDINGS | FUNCTIONS | TUPLES | RECORDS

Exercise 1



Exercise 1

BINDINGS | FUNCTIONS | TUPLES | RECORDS

Review

- > How do you return a value in a function?
- > How many parameters has tryPromoteToVip?
- > Can you explain this type? `string -> int -> object`
- > How do you change a Record?
- > Can you explain what is the “it” word in some of the outputs?

Module 2

HIGH ORDER FUNCTIONS | PIPELINING | PARTIAL APPLICATION | COMPOSITION

High Order Functions

```
public int Sum(int a, int b)
{
    return a + b;
}
```

```
public int Execute(int a, int b, Func<int,int,int>operation)
{
    return operation(a, b);
}
```


```
var result = Execute(1, 2, (a,b) => a + b);
```

```
var result = Execute(1, 2, (a,b) => a * b);
```

```
var result = Execute(1, 2, Sum);
```

High Order Functions

High Order
Functions



```
var productNames = products
    .Where(p => p.Category == productCategory)
    .Select(p => p.Name);
```

```
public Func<int,int,int> GetOperation(Type operationType)
{
    if (operationType == Type.Sum)
        return (a, b) => a + b;
    else
        return (a, b) => a * b;
}

var operation = GetOperation(type);
```

High Order Functions

```
let sum a b = a + b
```

```
let execute a b op = op a b
```

```
let getOperation type =  
  if type = OperationType.Sum then fun a b -> a + b  
  else fun a b -> a * b
```

```
let getOperation type =  
  if type = OperationType.Sum then (+)  
  else (*)
```


Extension Methods in C#

```
public List<int> Filter(List<int> list, Func<int,bool>condition)
```

```
public static List<int> Filter(this List<int> list, Func<int,bool>condition)
```

```
var filteredNumbers = Filter(numbers, n => n > 1);
```

```
var filteredNumbers = numbers.Filter( n => n > 1);
```



```
var filteredNumbers = numbers  
    .Filter(n => n > 1)  
    .Filter(n => n < 3);
```

Pipelining Operator


```
public List<int> Filter(List<int> items, Func<int,bool>condition)
```



```
let filter condition items = // ...
```

```
let filteredNumbers = filter (fun n -> n > 1) numbers
```

```
let filteredNumbers = numbers |> filter (fun n -> n > 1)
```



```
let filteredNumbers = numbers  
    |> filter (fun n -> n > 1)  
    |> filter (fun n -> n < 3)
```

Partial Application

```
let sum a b = a + b
```

```
let result = sum 1 2
```

← Returns int = 3

```
let result = sum 1
```

← Returns int -> int

```
let addOne = sum 1
```

← Returns int -> int

```
let result = addOne 2
```

← Returns int = 3

```
let result = addOne 3
```

← Returns int = 4

Composition

```
let addOne a = a + 1
```

```
let addTwo a = a + 2
```

```
let addThree = addOne >> addTwo
```

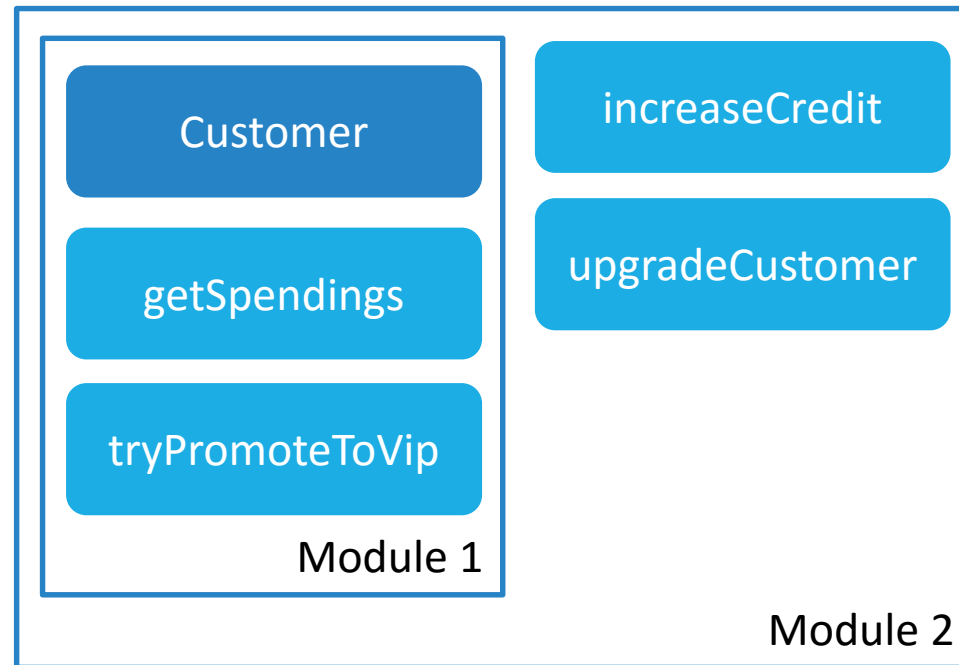
```
let result = addThree 1
```

← Returns int = 4

Demo 2

HIGH ORDER FUNCTIONS | PIPELINING | PARTIAL APPLICATION | COMPOSITION

Exercise 2



Exercise 2

HIGH ORDER FUNCTIONS | PIPELINING | PARTIAL APPLICATION | COMPOSITION

Review

- > What keyword do you use for lambda expressions?
- > What happens if the function I need is defined after the caller?
- > What happens when a function is called without its last parameter?
- > Why `|>` is better than the Extension Methods?

Module 3

OPTIONS | PATTERN MATCHING | DISCRIMINATED UNIONS | UNITS OF MEASURE

NullPointerException

```
var customer = GetCustomerById(42);
```

```
var isAdult = customer.Age >= 18;
```

```
if (customer == null)  
    throw new Exception("Not found");  
var isAdult = customer.Age >= 18;
```

```
if (customer == null)  
    // Try something different  
else  
    var isAdult = customer.Age >= 18;
```

```
public Customer GetCustomerById(int id)
```

← NullPointerException

NullReferenceExceptions

```
var age = GetCustomerAgeById(42);
```

```
var isAdult = age >= 18;
```

```
public int GetCustomerAgeById(int id)
```

```
var isAdult = age.Value >= 18;
```

```
if (!age.HasValue)  
    // Try something different  
else  
    var isAdult = age.Value >= 18;
```

```
public int? GetCustomerAgeById(int id)
```

Hint: Possible Null



Options

int

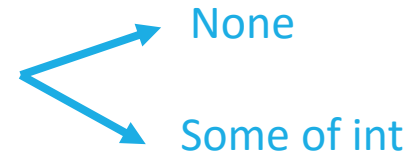
Nullable<int>

Customer

~~Nullable<Customer>~~

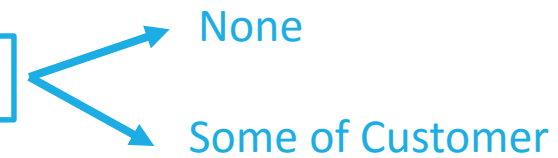
int

Option<int>

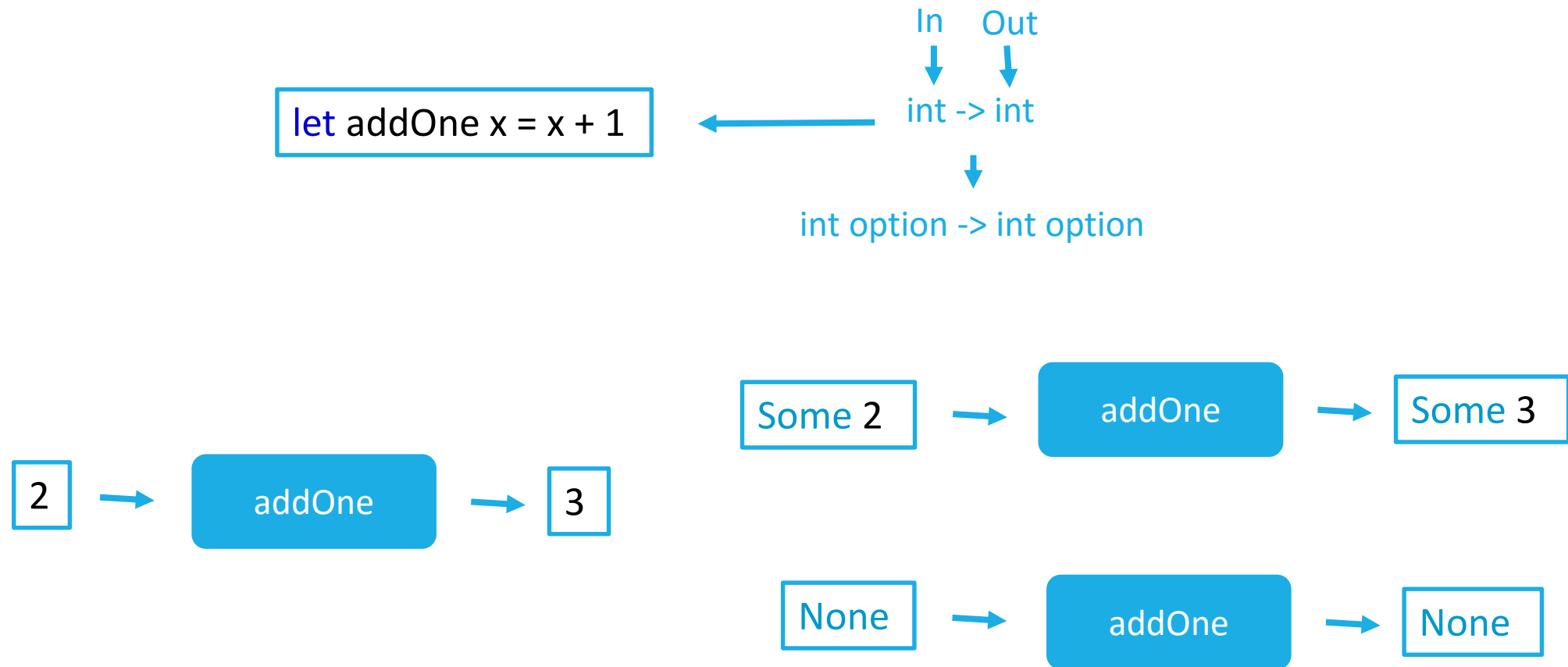


Customer

Option<Customer>



Options



Options

```
let addOne x = x + 1
```

← int -> int

```
let addOne (x: int option) =  
  if x = None then 0  
  else x.Value + 1
```

← int option -> int

```
let addOne x =  
  if x = None then 0  
  else x.Value + 1
```

← int option -> int

```
let addOne x =  
  if x = None then None  
  else Some (x.Value + 1)
```

← int option -> int option

Pattern Matching

```
let addOne x =  
  if x = None then None  
  else Some (x.Value + 1)
```

```
let addOne x =  
  match x with  
  | None -> None  
  | Some n -> Some (n + 1)
```

Discriminated Unions

```
public abstract class DivisionResult
{
}
public class DivisionSuccess : DivisionResult
{
    public int Quotient { get; set; }
    public int Remainder { get; set; }
}
public class DivisionError : DivisionResult
{
    public string ErrorMessage { get; set; }
}
```

```
type DivisionResult =
    | DivisionSuccess of quotient : int * remainder : int
    | DivisionError of message : string
```


Units of Measure

```
let distanceInMts = 11580.0  
let distanceInKms = 87.34  
let totalDistance = distanceInMts + distanceInKms
```

← 11667.34

```
[<Measure>] type m  
[<Measure>] type km  
  
let distanceInMts = 11580.0<m>  
let distanceInKms = 87.34<km>  
let totalDistance = distanceInMts + distanceInKms
```

↑
Error: The unit of measure 'm' does not match the unit of measure 'km'

Units of Measure

[<Measure>] type km

[<Measure>] type h

let time = 2.4<h>

let distance = 87.34<km>

let speed = distance / time

← 36.39<km/h>

[<Measure>] type m

let width = 2<m>

let height = 3<m>

let surface = width * height

← 6<m²>

Units of Measure

```
let distanceInMts = 11580.0<m>  
let distanceInKms = 87.34<km>  
let totalDistance = distanceInMts + distanceInKms
```



Error: The unit of measure 'm' does not match the unit of measure 'km'

```
let mts2Kms (m : float<m>) = m / 1.0<m> / 1000.0 * 1.0<km>
```



float<m> -> float<km>

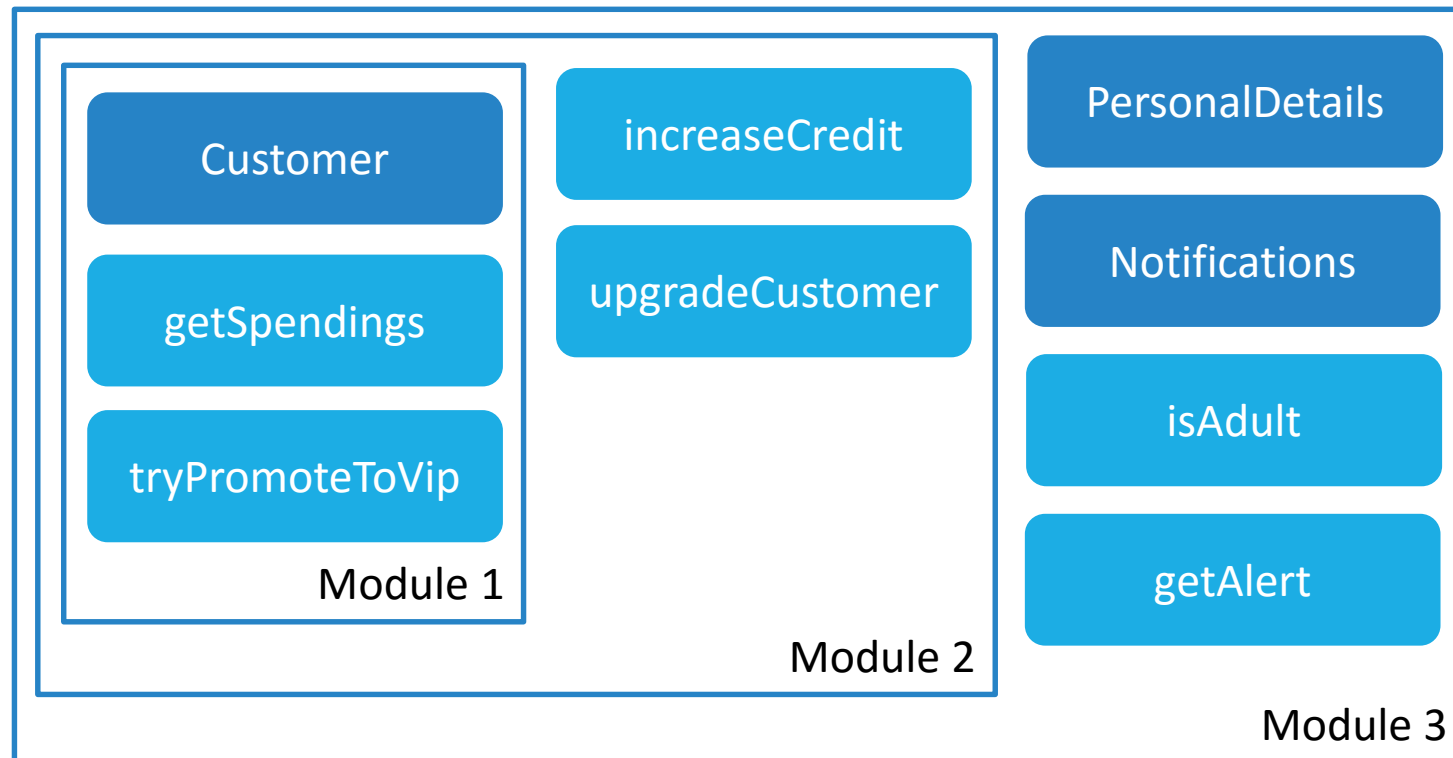
```
let totalDistance = (mts2Kms distanceInMts) + distanceInKms
```

← 98.920<km>

Demo 3

OPTIONS | PATTERN MATCHING | DISCRIMINATED UNIONS | UNITS OF MEASURE

Exercise



Exercise 3

OPTIONS | PATTERN MATCHING | DISCRIMINATED UNIONS | UNITS OF MEASURE

Review

- > How do you convert two units of measure?
- > What happens if you multiply the same unit of measure?
- > Why do we use “%i” in the sprintf function?
- > Why do we use “_”?
- > What are the possible types of Option<string>?

Module 4

FUNCTIONAL LISTS | RECURSION | OBJECT-ORIENTED PROGRAMMING | TYPE PROVIDERS

Functional Lists

```
var numbers = new List<int>{2, 3, 4};  
numbers.Insert(0, 1);
```

```
numbers.AddRange(new List<int>{5, 6});
```

```
var ns = Enumerable.Range(1, 1000).ToList();
```

```
var empty = new List<int>();
```

```
let numbers = [2; 3; 4]  
let newNumbers = 1 :: numbers
```

```
let twoLists = numbers @ [5; 6]
```

```
let ns =[1 .. 1000]
```

```
let empty = []
```

```
let odds =[1 .. 2 .. 1000]
```

```
let oddsWithZero =[ yield 0  
                    yield! odds ]
```

```
let gen = [ for n in numbers do  
            if n%3 = 0 then  
                yield n * n ]
```

Lists vs Arrays vs Sequences

List

```
let myList = [1; 2]
```

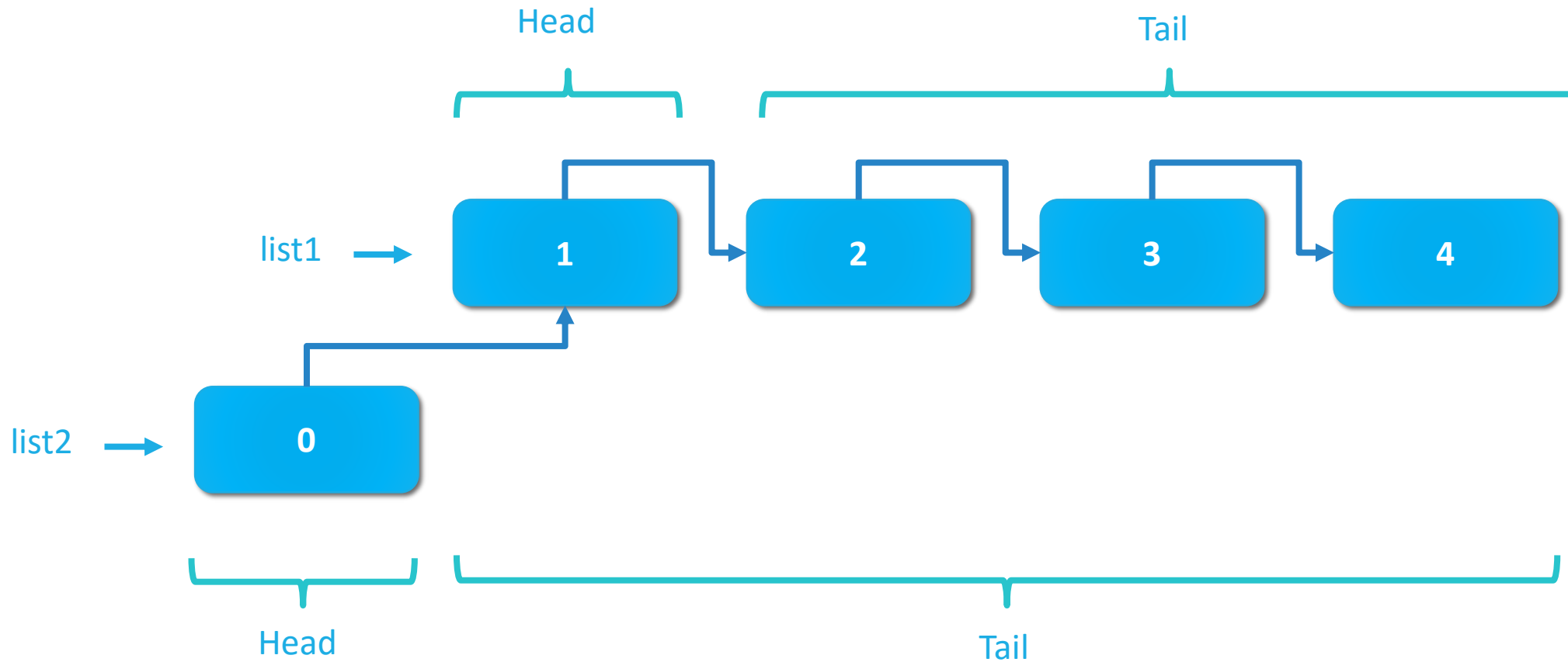
Array

```
let myArray = [|1; 2|]
```

Seq

```
let mySeq = seq { yield 1; yield 2 }
```

Functional Lists



Processing Lists

```
let numbers = [1..4]
let mutable result = [] : int list
for n in numbers do
  if n % 2 = 0 then result <- n :: result
```

Recursive Function

Empty List (end)

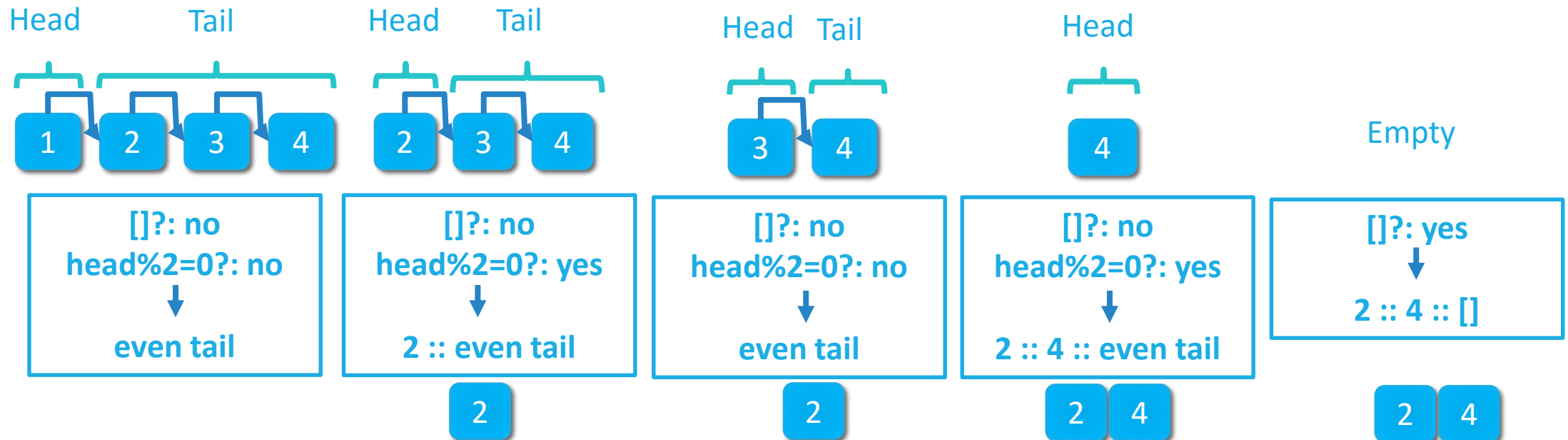
Non Empty List

```
let rec even ls =
  match ls with
  | [] -> []
  | head :: tail when head % 2 = 0 -> head :: even tail
  | _ :: tail -> even tail
```

Decompose List

Recursion

```
let rec even ls =  
  match ls with  
  | [] -> []  
  | head :: tail when head % 2 = 0 -> head :: even tail  
  | _ :: tail -> even tail
```



Tail Recursion

```
let rec even ls =  
  match ls with  
  | [] -> []  
  | head :: tail when head % 2 = 0 -> head :: even tail  
  | _ :: tail -> even tail
```



```
let rec even acc ls =  
  match ls with  
  | [] -> List.rev acc  
  | head :: tail when head % 2 = 0 -> even (head :: acc) tail  
  | _ :: tail -> even acc tail
```

List Module

Complete list:

<http://msdn.microsoft.com/en-us/library/ee353738.aspx>

List.filter
List.map
List.fold
List.find
List.tryFind
List.forall
List.exist
List.partition
List.zip
List.rev
List.collect
List.choose
List.pick
List.toSeq
List.ofSeq

.Where
.Select
.Aggregate
.First
.FirstOrDefault
.All
.Any
-
.Zip
.Reverse
.SelectMany
-
-
.AsEnumerable
.ToList

List Module

```
let vipNames = customers
    |> List.filter (fun c -> c.IsVip)
    |> List.map (fun c -> c.Name)
```

```
var vipNames = customers
    .Where(c => c.IsVip)
    .Select(c => c.Name);
```

Classes – Immutable Properties

```
public class MyClass
{
    private readonly int myFiled;
    public MyClass(int myParam)
    {
        myField = myParam;
    }
    public int MyProperty
    {
        get { return myField; }
    }
}
```

```
type MyClass(myField: int) =
    member this.MyProperty = myField
```

Classes – Mutable Properties

```
public class MyClass
{
    public MyClass(int myParam)
    {
        MyProperty = myParam;
    }
    public int MyProperty { get; set; }
}
```

```
type MyClass(myField: int) =
    let mutable myMutableField = myField
    member this.MyProperty
        with get () = myMutableField
        and set(value) = myMutableField <- value
```

Classes – Public Methods

```
public class MyClass
{
    private readonly int myFiled;
    public MyClass(int myParam)
    {
        myFiled = myParam;
    }
    public int MyMethod(int methodParam)
    {
        return myFiled + methodParam;
    }
}
```

```
type MyClass(myField int) =
    member this.MyMethod methodParam =
        myField + methodParam
```

Classes – Private Methods

```
public class MyClass
{
    public int MyMethod(int methodParam)
    {
        return myPrivateMethod(methodParam);
    }
    private int MyPrivateMethod(int methodParam)
    {
        return methodParam + 1;
    }
}
```

```
type MyClass() =
    let myPrivateFun funParam =
        funParam + 1
    member this.MyMethod methodParam =
        myPrivateFun methodParam
```

Classes – Inheritance

```
public abstract class MyBaseClass
{
    public abstract int MyMethod(int methodParam);
}

public class MyClass : MyBaseClass
{
    public override int MyMethod(int methodParam);
    {
        return methodParam + 1;
    }
}
```

```
[<AbstractClass>]
type MyBaseClass() =
    abstract member this.MyMethod: int -> int

type MyClass() =
    inherits MyBaseClass ()
    override this.MyMethod methodParam =
        methodParam + 1
```

Classes – Interfaces

```
public interface IMyInterface
{
    int MyMethod(int methodParam);
}

public class MyClass : IMyInterface
{
    public int MyMethod(int methodParam);
    {
        return methodParam + 1;
    }
}
```

```
type IMyInterface =
    abstract member MyMethod: int -> int

type MyClass() =
    interface IMyInterface with
        member this.MyMethod methodParam =
            methodParam + 1
```

Classes – Object Expressions

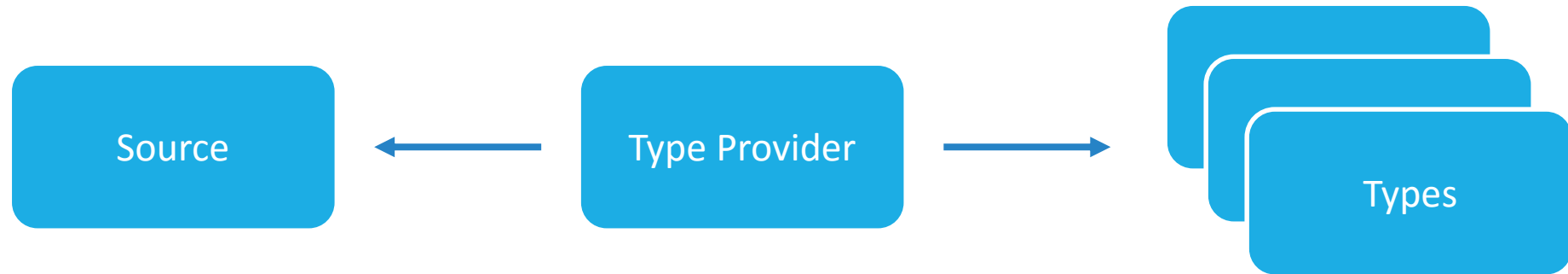
```
public interface IMyInterface
{
    int MyMethod(int methodParam);
}

public class MyClass : IMyInterface
{
    public int MyMethod(int methodParam);
    {
        return methodParam + 1;
    }
}
```

```
type IMyInterface =
    abstract member MyMethod: int -> int

let myInstance =
    { new IMyInterface with
        member this.MyMethod methodParam =
            methodParam + 1 }
```


Type Providers



Type Providers

LINQ2SQL

EF

SQL

SQLClient

World Bank

JSON

CSV

XML

R

Azure Storage

WMI

OData

Hadoop / Hive

Excel

WSDL

And many more

CSV Type Provider

```
type Customer = CsvProvider<"sample.csv">  
let customers = Customer.Load "real.csv"  
  
customers.Rows  
|> Seq.iter (fun -> printfn "%s: $%g" r.Name r.Credit)
```

sample.csv

```
Id,Name,IsVip,Credit  
1,Customer1,false,0.0
```

real.csv

```
Id,Name,IsVip,Credit  
1,Customer1,false,0.0  
2,Customer2,false,10.0  
3,Customer3,false,30.0  
4,Customer4,true,50.0
```

Entity Framework Type Provider

```
[<Literal>]
let cs = "Data Source=.;Initial Catalog=FSharpIntro;Integrated Security=SSPI;"

type EntityConnection = SqlEntityConnection <ConnectionString=cs, Pluralize=true>

let context = EntityConnection.GetDataContext ()

let customers = query { for customer in context.Customers do
                        select customer }
```

Sql Client Type Provider

[<Literal>]

```
let cs = "Data Source=.;Initial Catalog=FSharpIntro;Integrated Security=SSPI;"
```

```
type SelectCustomers = SqlCommandProvider<"SELECT Id, IsVip, Credit FROM dbo.Customers", cs>
```

```
let cmd = new SelectCustomers ()
```

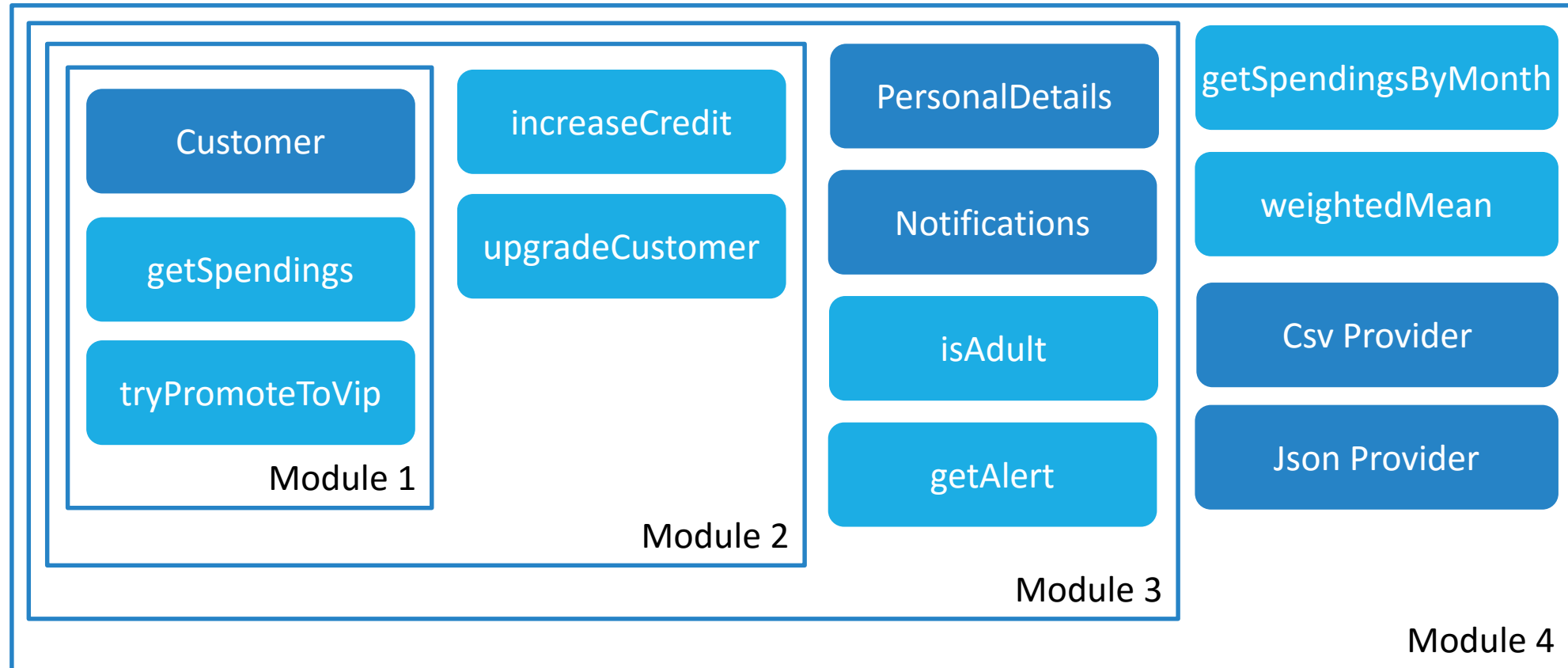
```
let customers = cmd.Execute ()
```

```
type SelectCustomers = SqlCommandProvider<"SELECT Id, IsV, Credit FROM dbo.Customers", cs>
```

Demo 4

FUNCTIONAL LISTS | RECURSION | OBJECT-ORIENTED PROGRAMMING | TYPE PROVIDERS

Exercise 4



Exercise 4

FUNCTIONAL LISTS | RECURSION | OBJECT-ORIENTED PROGRAMMING | TYPE PROVIDERS

Review

- > What does `List.zip` do?
- > Why do we use an accumulator in the `recursiveWeightedMean` function?
- > Why do we wrap `recursiveWeightedMean` inside `recursiveWeighted`?
- > Why do we refer to “Data.json” twice?
- > What happens if I change the name of a column?

Thank you

Resources



fsharp.org / c4fsharp.net



Real-World Functional Programming
By Tomas Petricek



tryfsharp.org



Scott Wlaschin fsharpforfunandprofit.com
fpbridge.co.uk/why-fsharp.html



Skills Matter: skillsmatter.com (tag: f#)