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

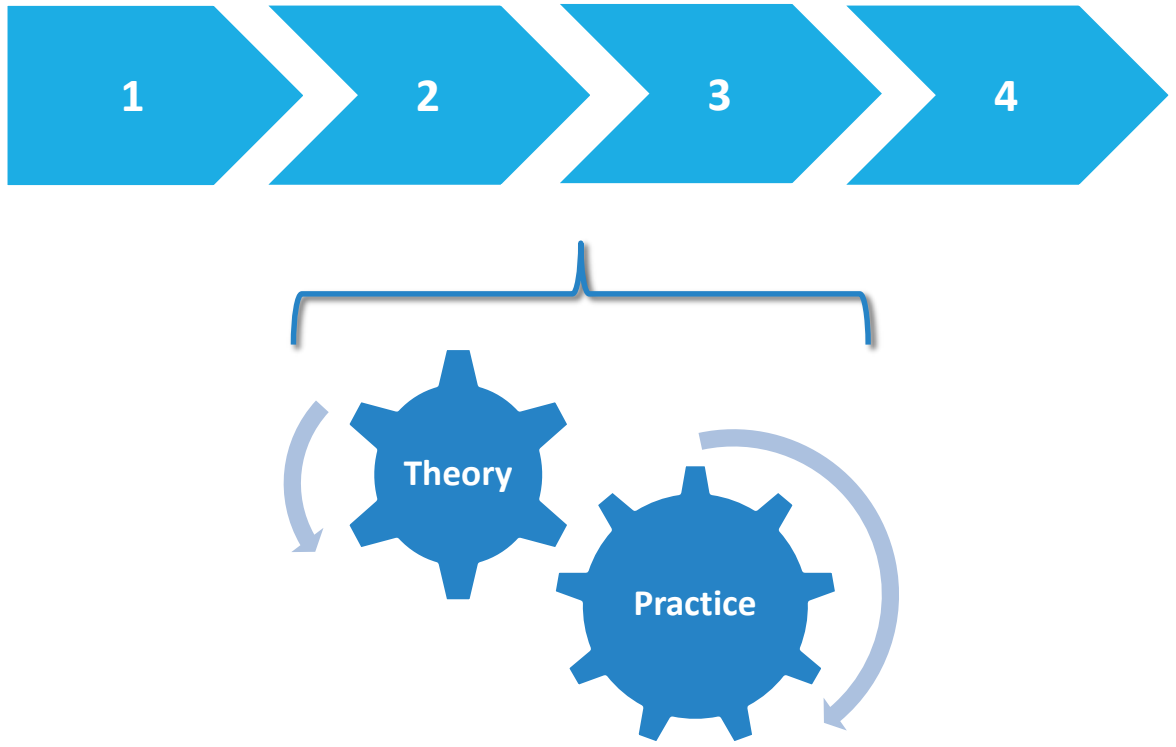
> Linux

- > 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

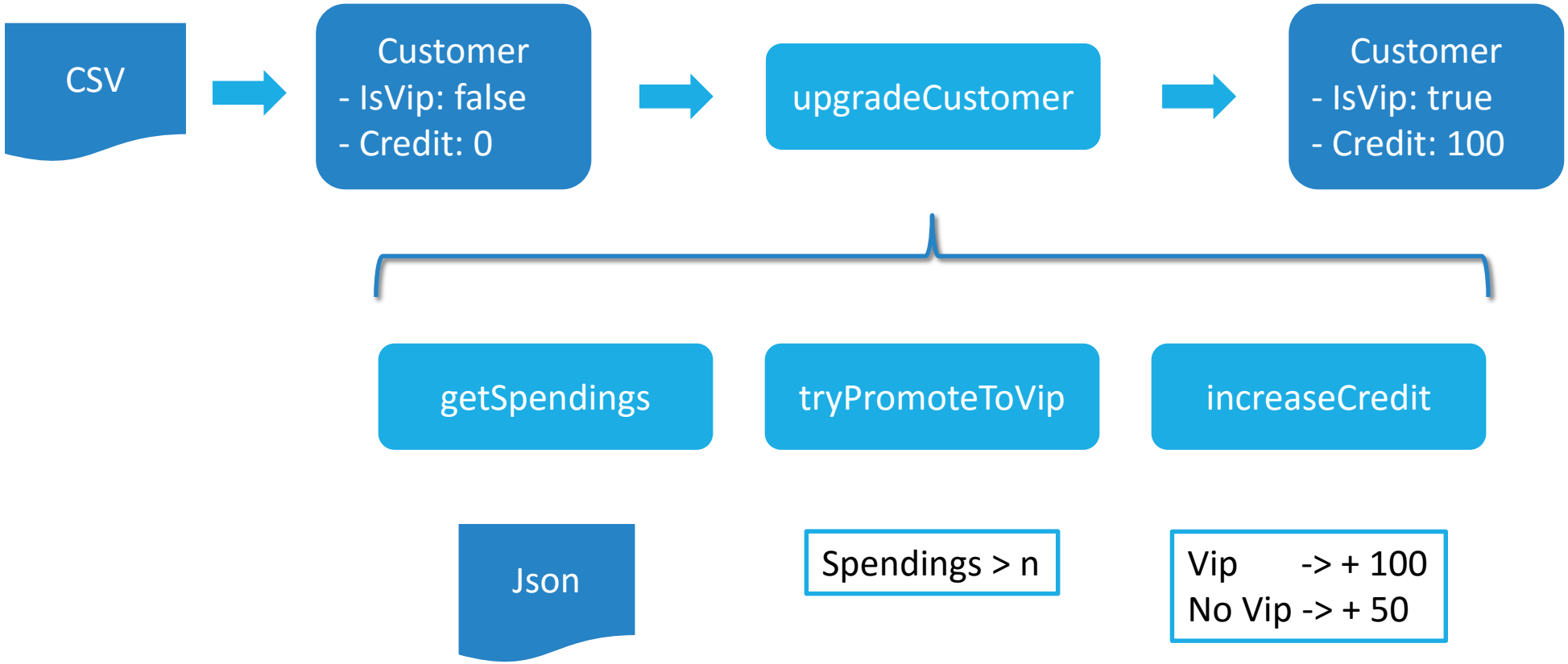
Module 3

Options | Pattern matching | Discriminated unions | Units of measure

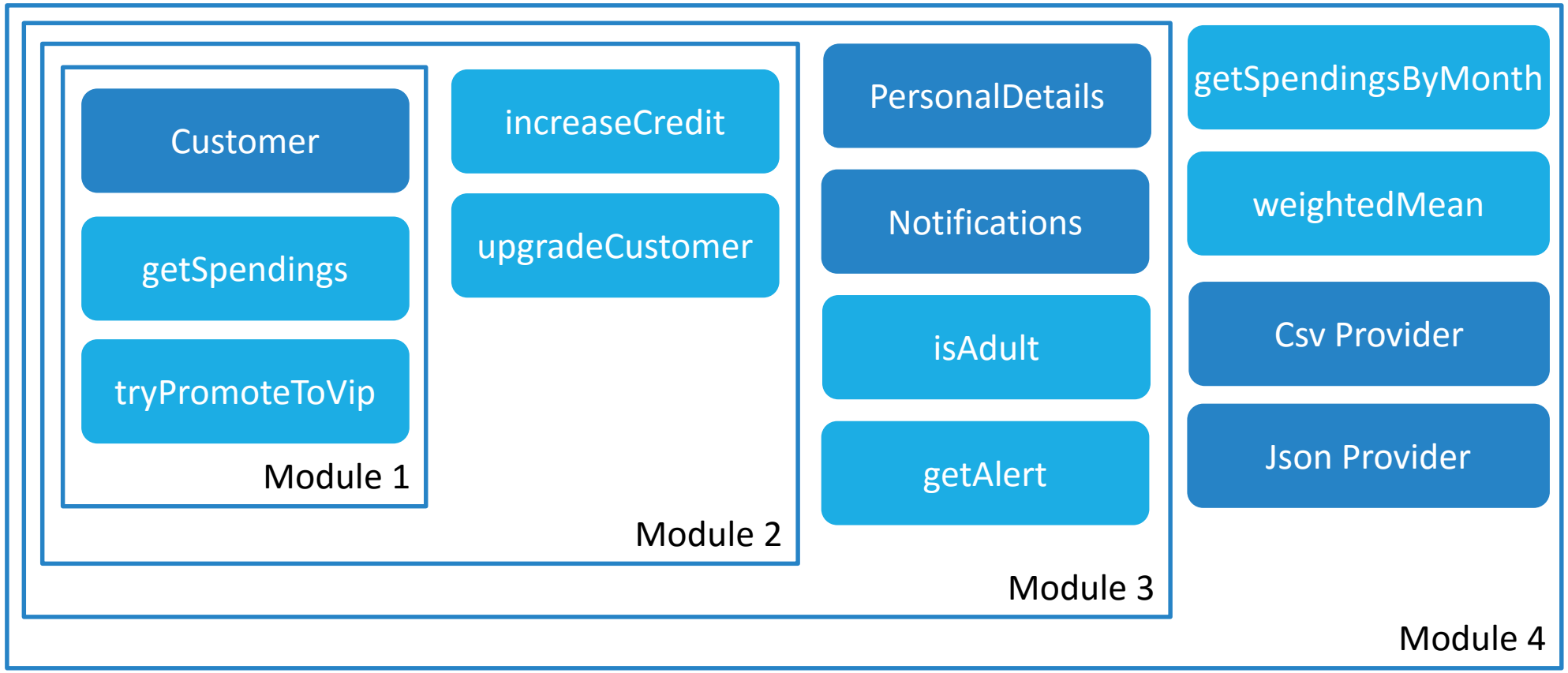
Module 4

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

Exercise


CSV
Customer
- IsVip: false
- Credit: 0
upgradeCustomer
Customer
- IsVip: true
- Credit: 100
getSpendings
tryPromoteToVip
increaseCredit
Json
Spendings > n
Vip -> + 100
No Vip -> + 50

Exercise


Customer
getSpendings
tryPromoteToVip
Module 1
increaseCredit
upgradeCustomer
Module 2
PersonalDetails
Notifications
isAdult
getAlert
Module 3
getSpendingsByMonth
weightedMean
Csv Provider
Json Provider
Module 4

Module 1

BINDINGS | FUNCTIONS | TUPLES | RECORDS

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

Imperative vs Functional

Conventions

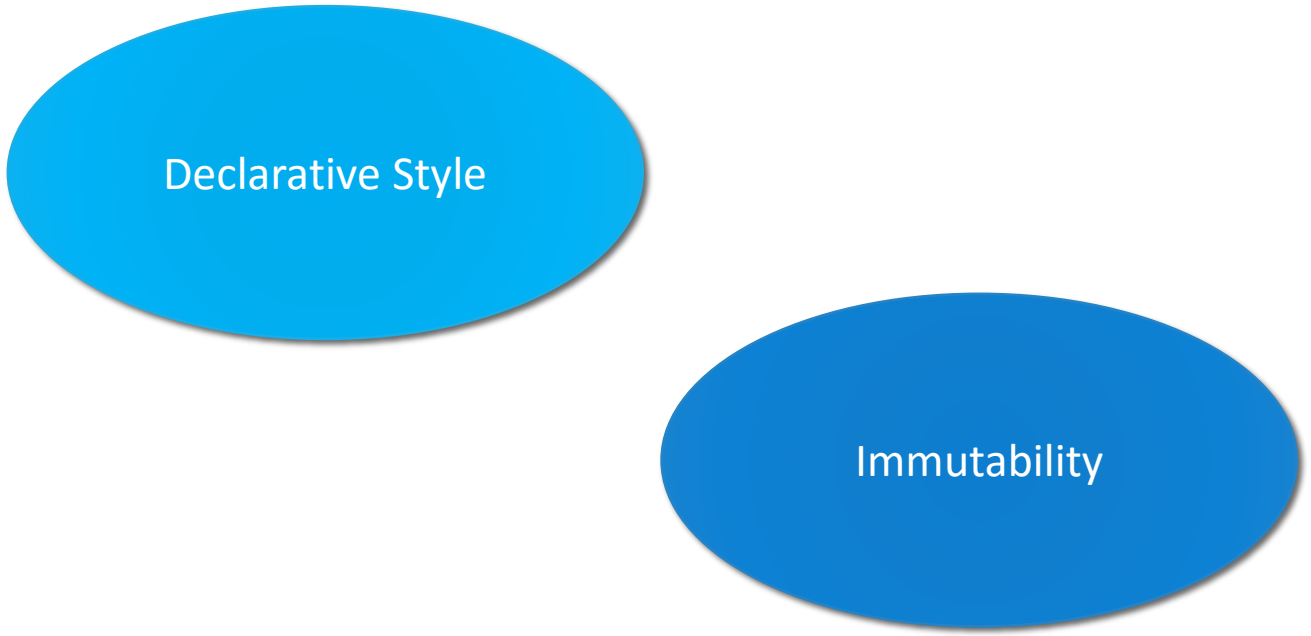
C#

```
var number = 1;
```

F#

```
let number = 1
```

Functional Core Concepts



Declarative Style

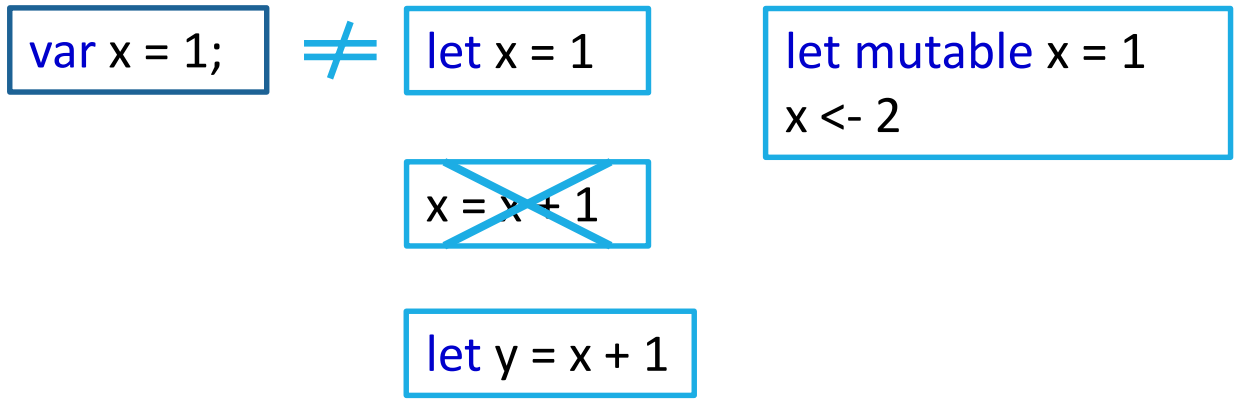
Imperative →

```
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



Functions

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

Func<int,int,int>


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

let instead of

int -> int -> int

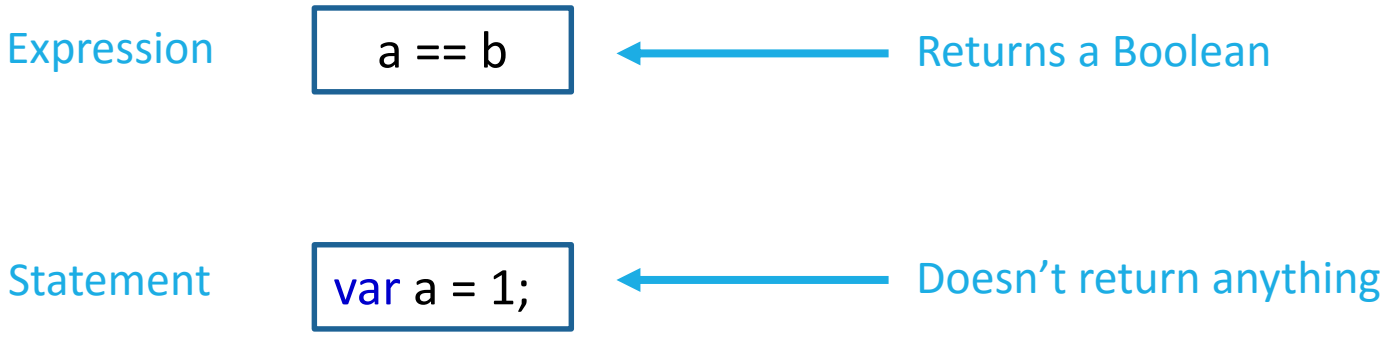
Pure Functions

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

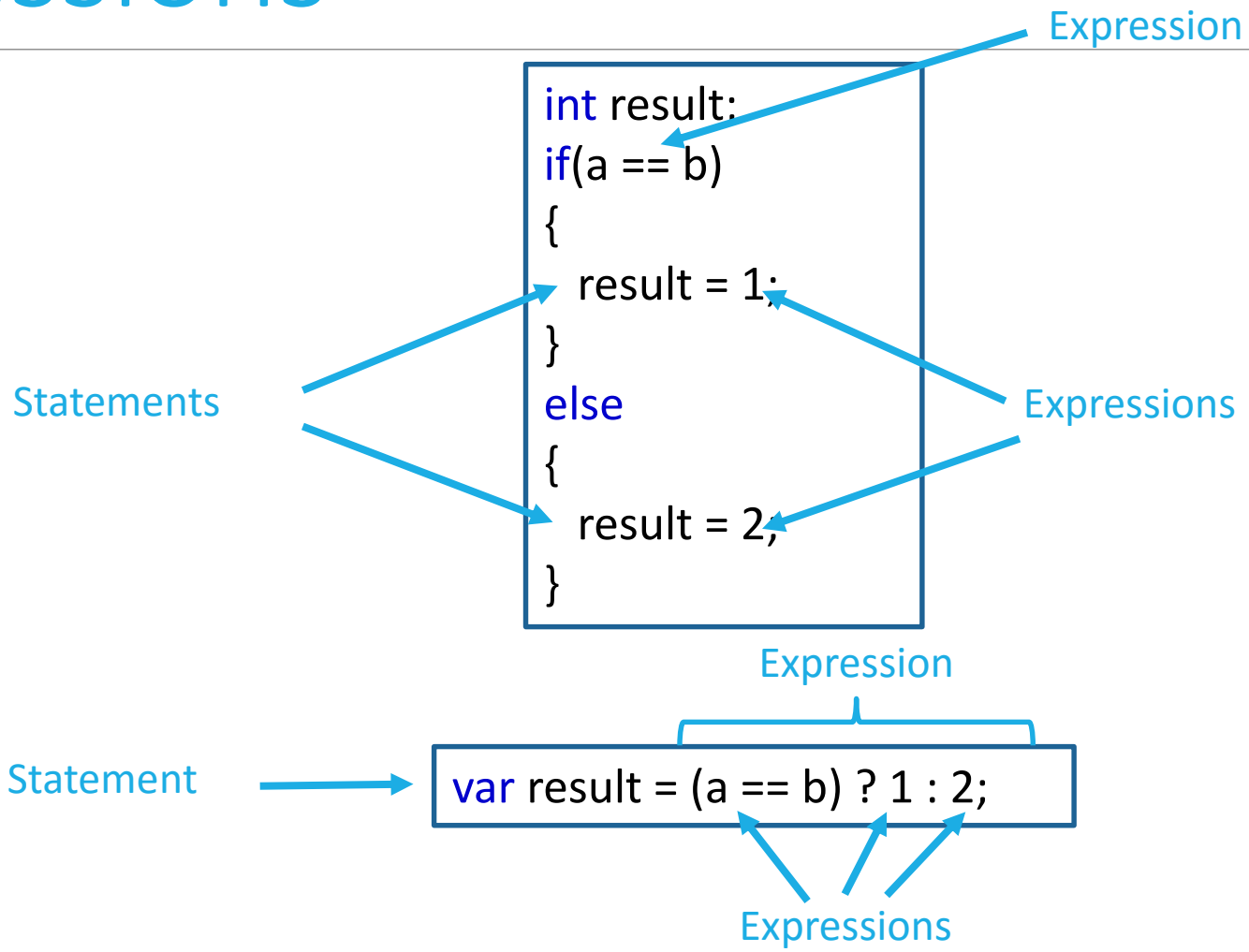
```
private int accumulator;

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

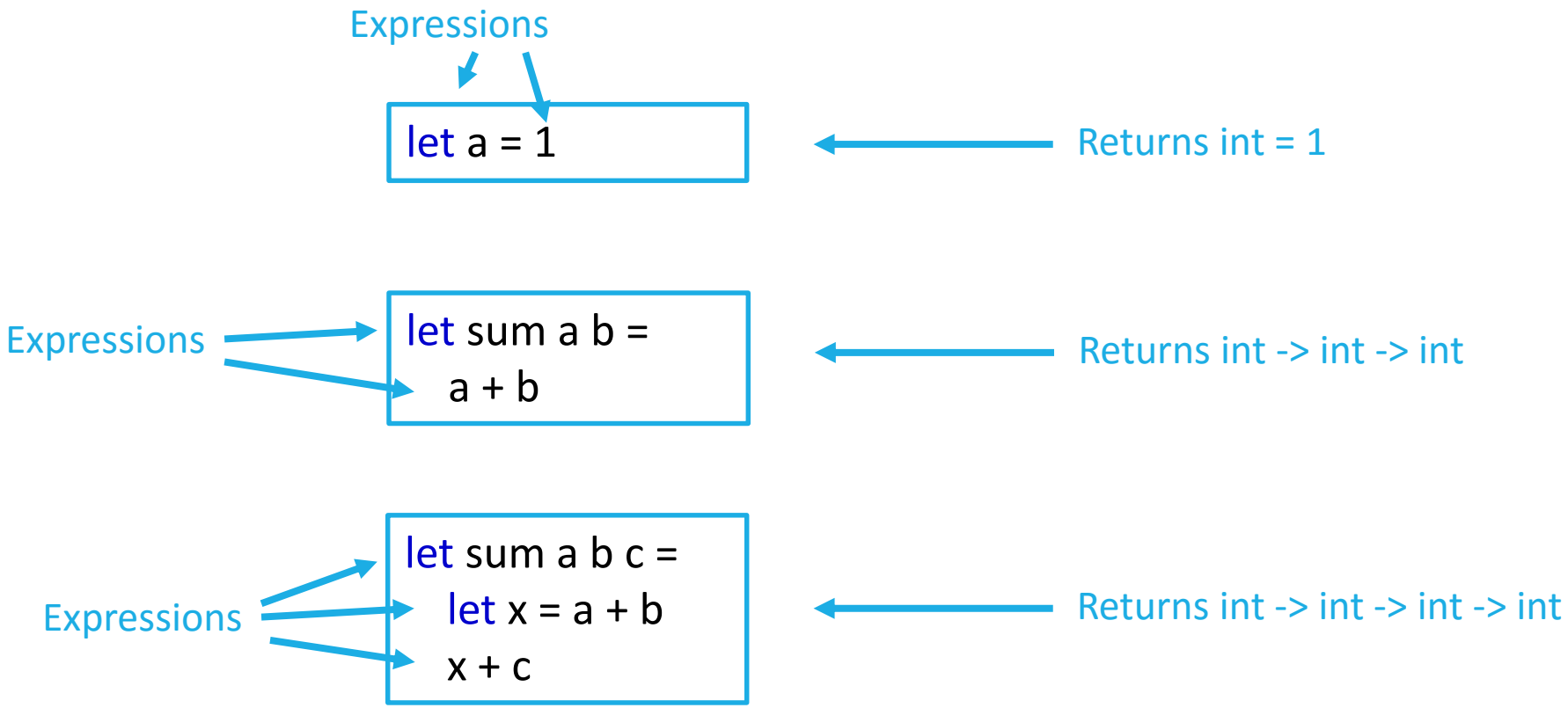
Expressions



Expressions



Bindings


Expressions
let a = 1
Returns int = 1
Expressions
let sum a b =
a + b
Returns int -> int -> int
Expressions
let sum a b c =
let x = a + b
x + c
Returns int -> int -> int -> int

Tuples

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

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

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

```
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”;
```

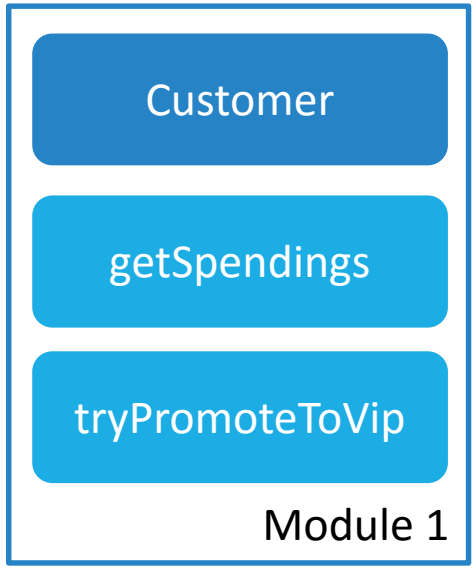
```
var result = message1 == message2; // true
```

```
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
```

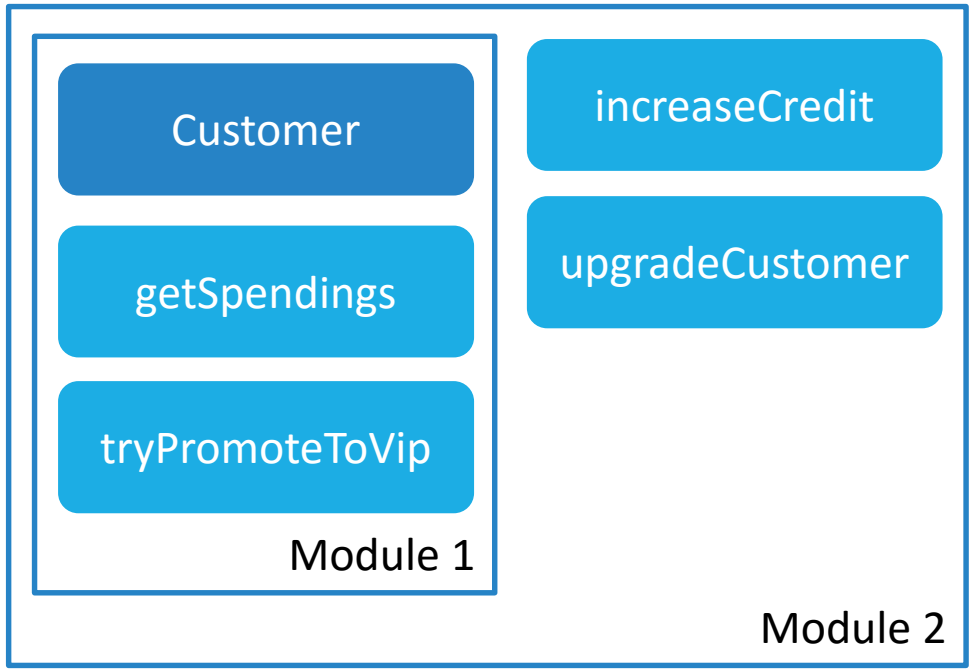
```
let result = addThree 1
```

Returns int = 4

Demo 2

HIGH ORDER FUNCTIONS | PIPELINING | PARTIAL APPLICATION | COMPOSITION

Exercise 2


Customer
getSpendings
tryPromoteToVip
Module 1
increaseCredit
upgradeCustomer
Module 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

NullReferenceExceptions

```
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)
```

NullReferenceException

NullReferenceExceptions

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

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

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

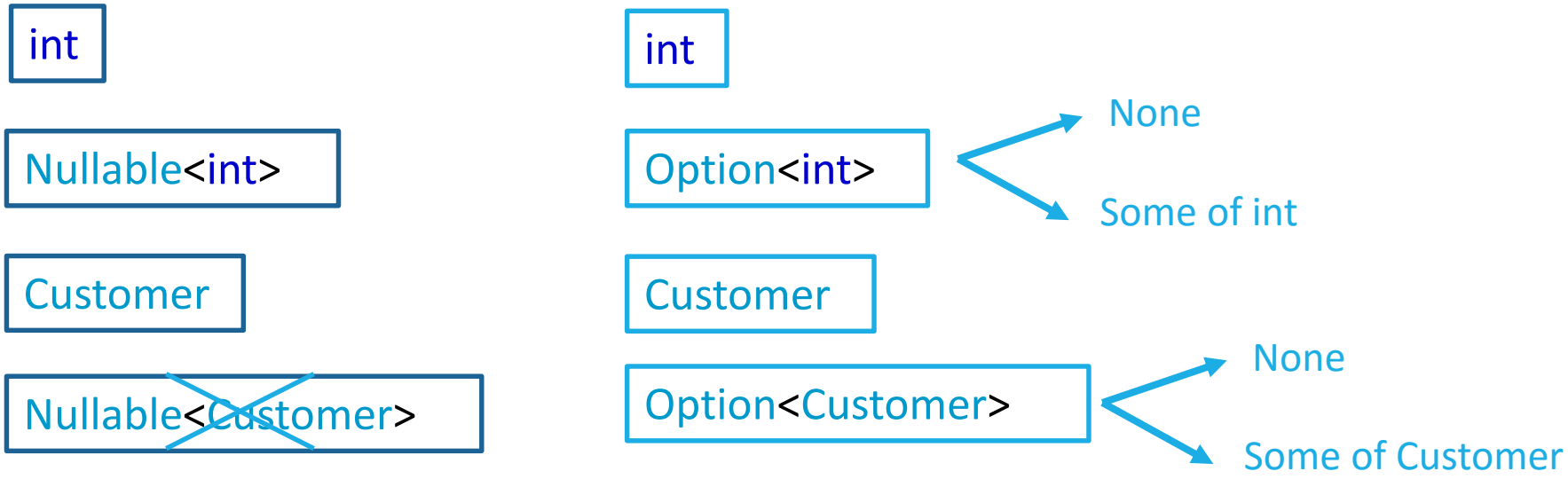
Hint: Possible Null

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

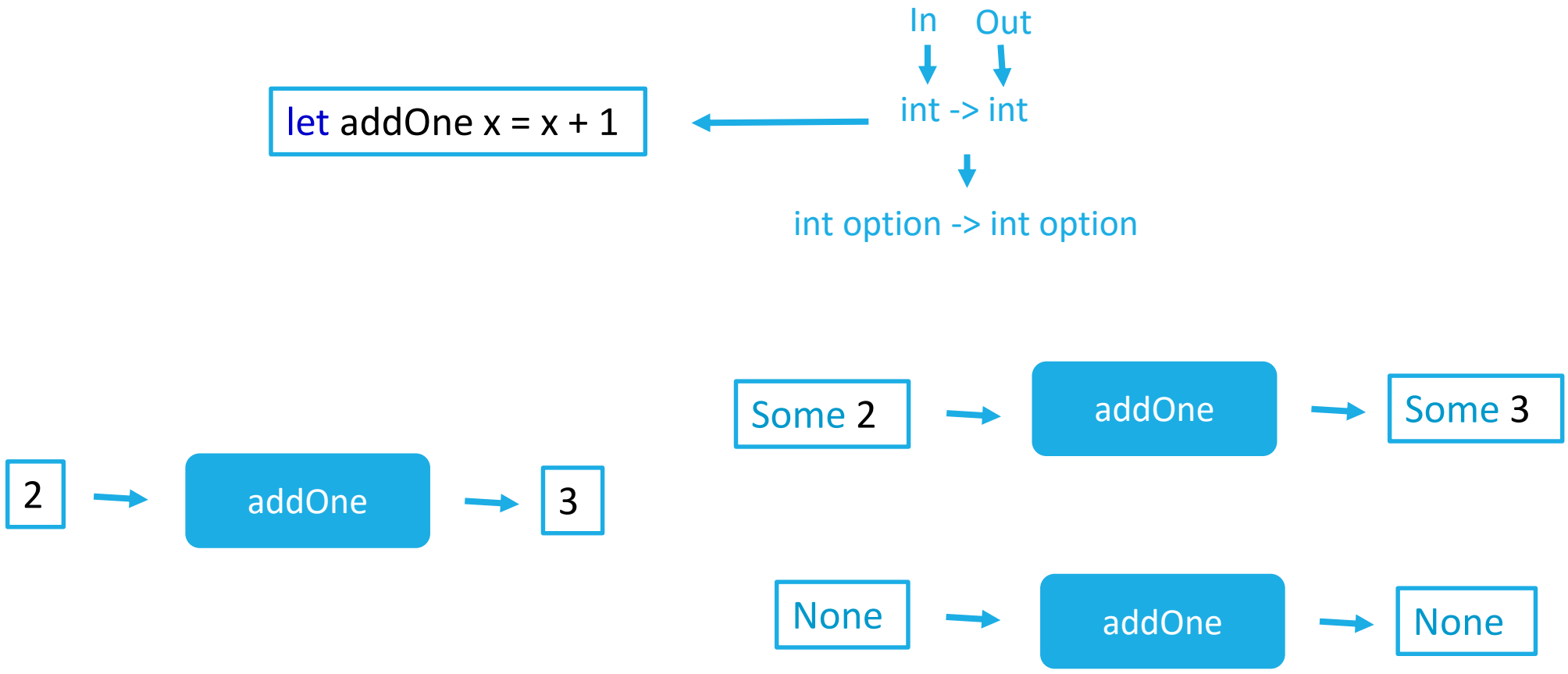
```
public int? GetCustomerAgeById(int id)
```

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

Options


int
Nullable<int>
Customer
Nullable<Customer>
int
Option<int>
None
Some of int
Customer
Option<Customer>
None
Some of Customer

Options


let addOne x = x + 1
In
Out
int -> int
int option -> int option
2
addOne
3
Some 2
addOne
Some 3
None
addOne
None

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
```

Discriminated Unions

```
let result = divide 2 0
match result with
| DivisionSuccess (quotient, remainder) ->
    printfn "Quotient:%i Remainder:%i" quotient remainder
| DivisionError message ->
    printfn "Error: %s" message
```

```
let divide dividend divisor =
   match divisor with
   |0 -> DivisionError (message = "Divide by zero")
   |_ -> DivisionSuccess (quotient = dividend / divisor,
                          remainder = dividend % divisor)
```

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<m^2>

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>

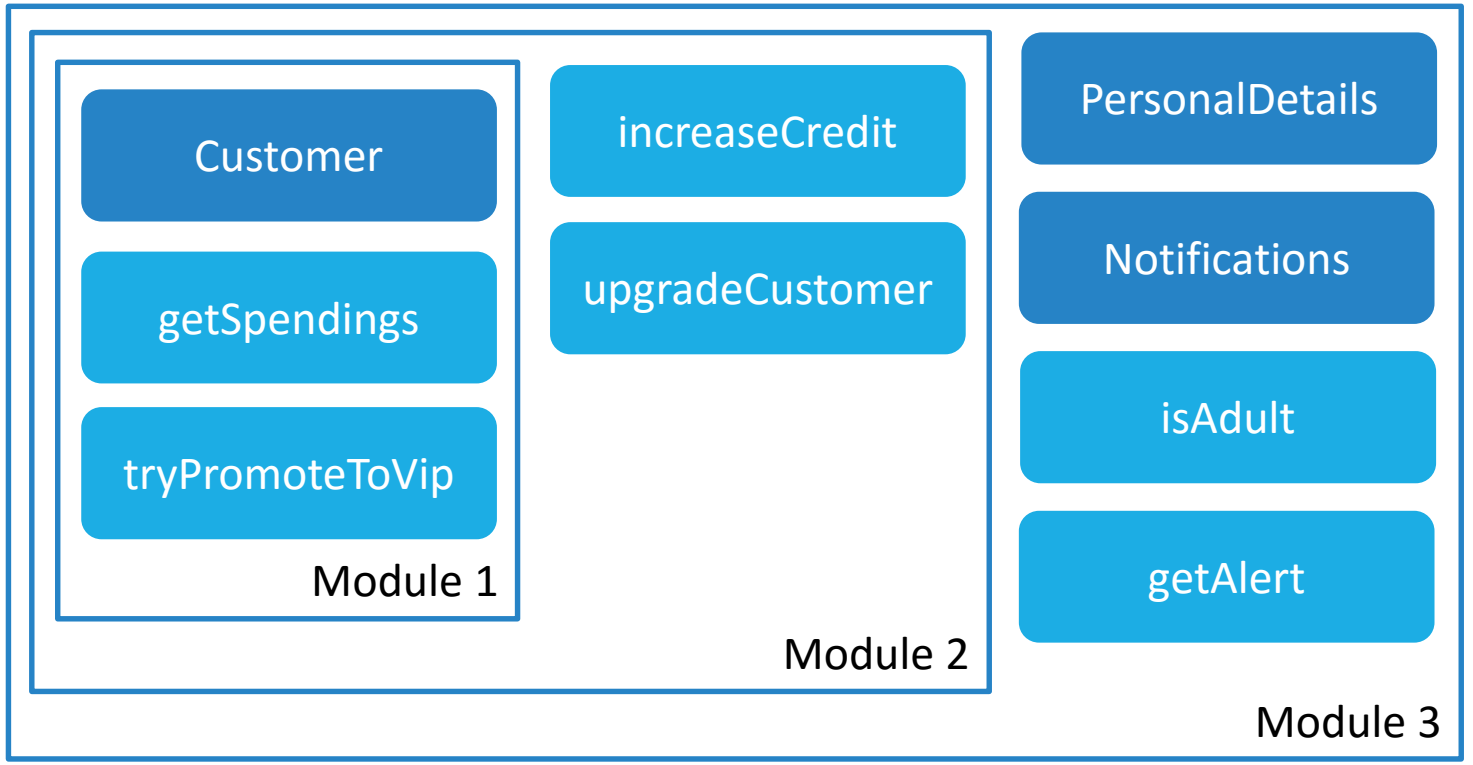
```
let totalDistance = (mts2Kms distanceInMts) + distanceInKms
```

98.920<km>

Demo 3

OPTIONS | PATTERN MATCHING | DISCRIMINATED UNIONS | UNITS OF MEASURE

Exercise


Customer
getSpendings
tryPromoteToVip
Module 1
increaseCredit
upgradeCustomer
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PersonalDetails
Notifications
isAdult
getAlert
Module 3

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]
```

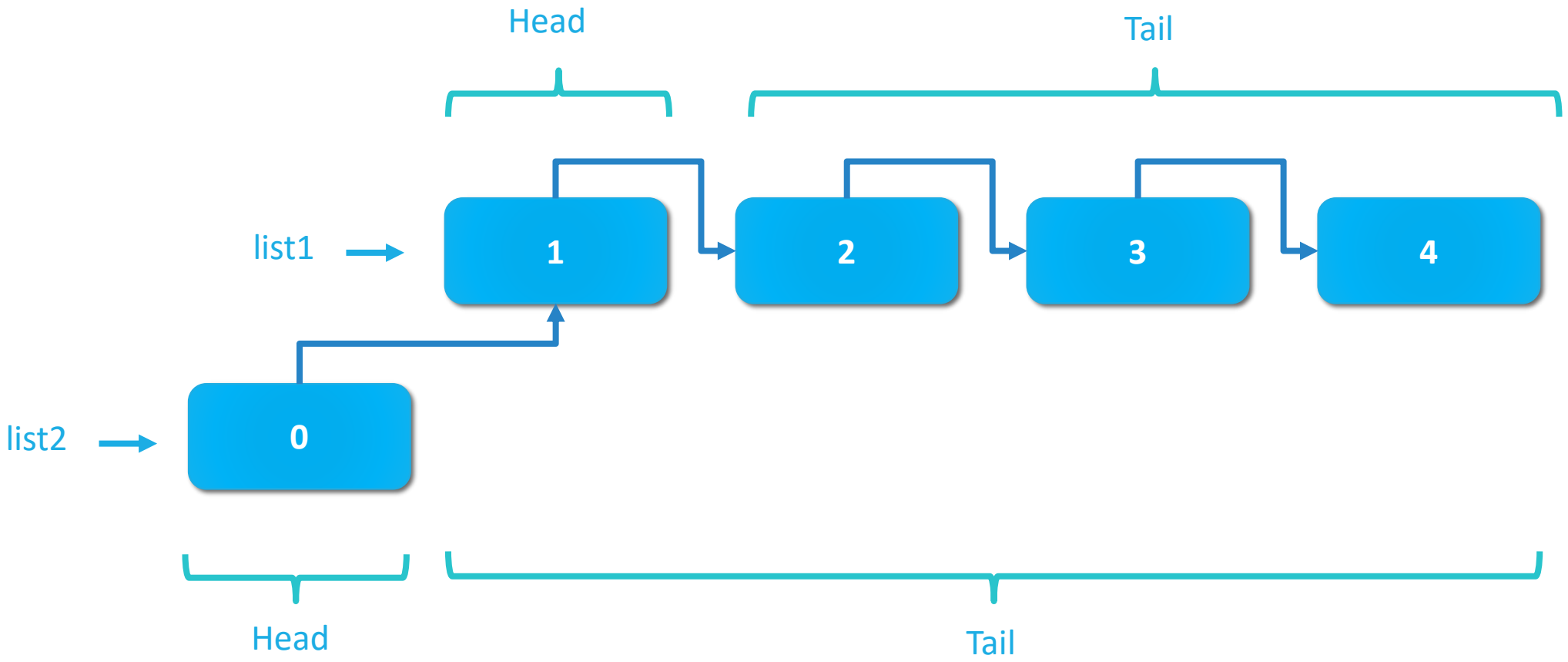
Array

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

Seq

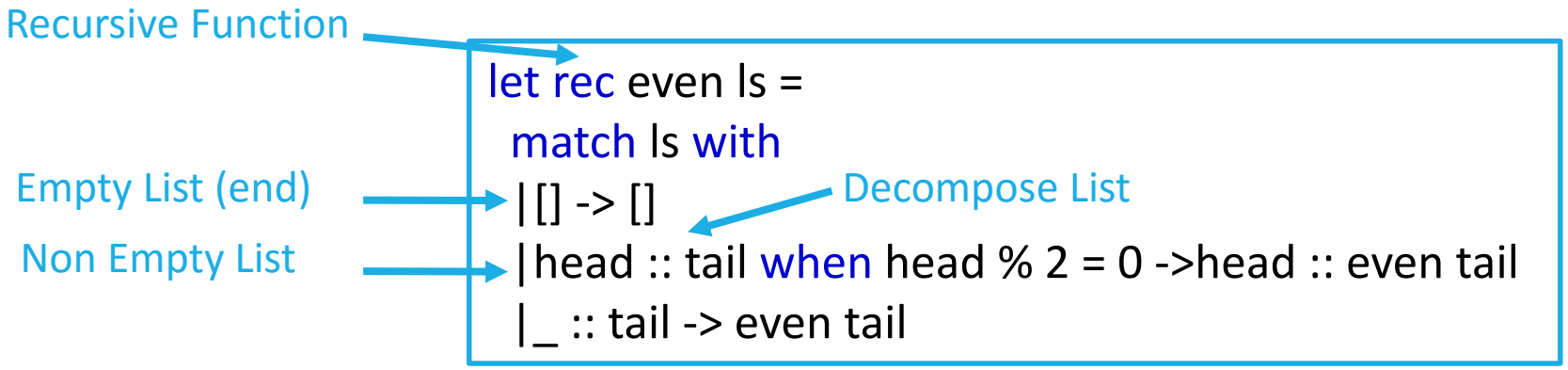
```
let mySeq = seq { yield 1; yield 2 }
```

Functional Lists



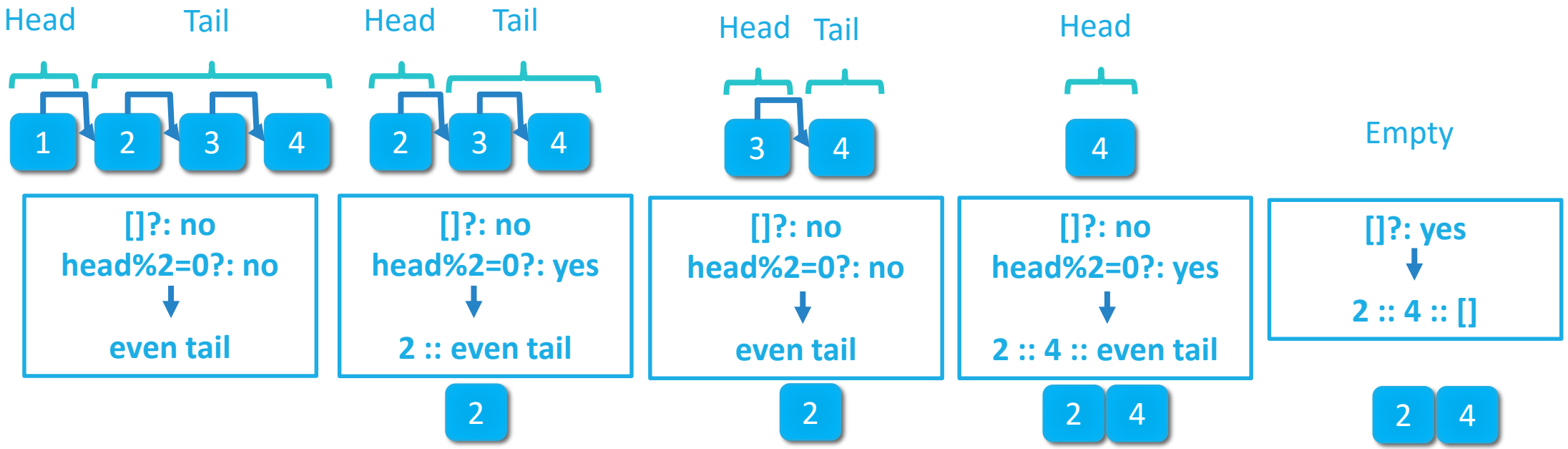
Processing Lists

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



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

List.filter	.Where
List.map	.Select
List.fold	.Aggregate
List.find	.First
List.tryFind	.FirstOrDefault
List.forall	.All
List.exist	.Any
List.partition	-
List.zip	.Zip
List.rev	.Reverse
List.collect	.SelectMany
List.choose	-
List.pick	-
List.toSeq	.AsEnumerable
List.ofSeq	.ToList

Complete list:
http://msdn.microsoft.com/en-us/library/ee353738.aspx

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

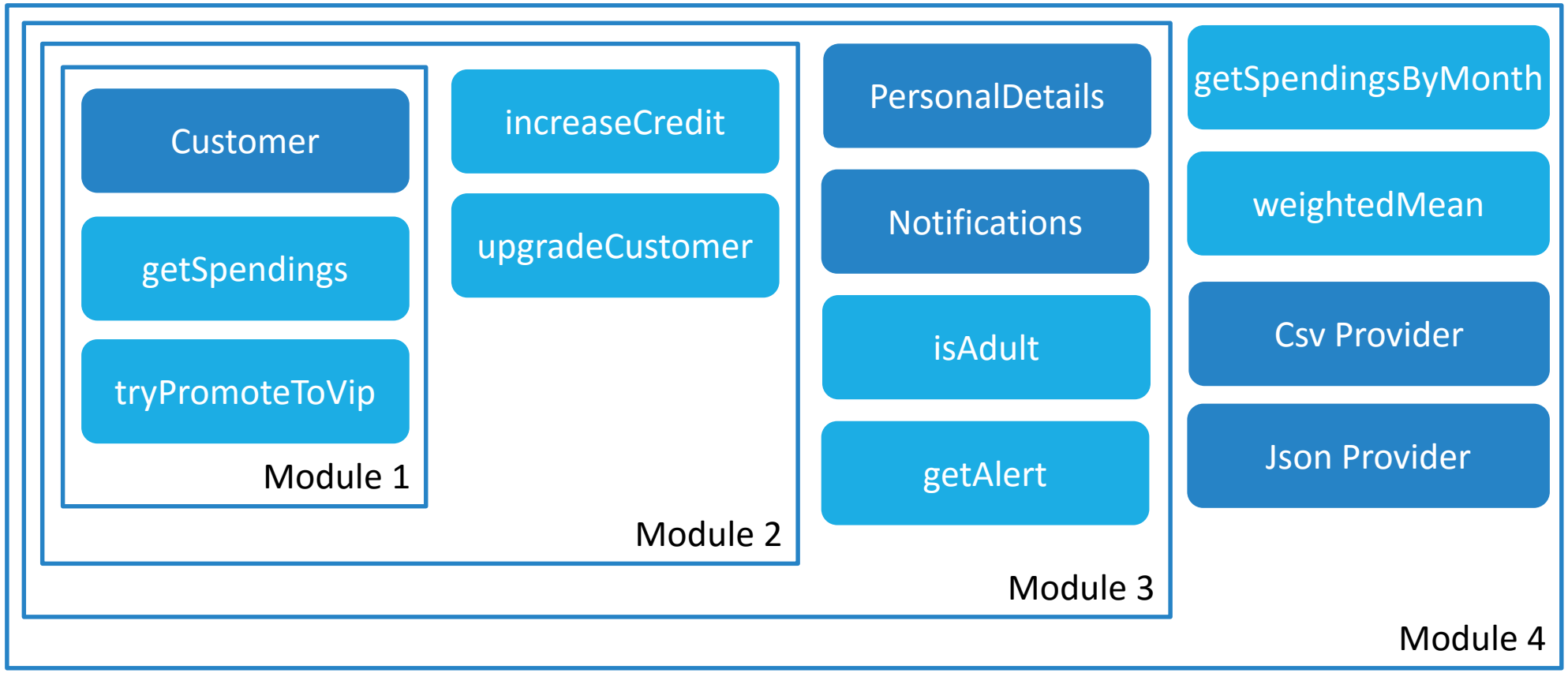
```
[<Literal>]
let cs = "Data Source=.;Initial Catalog=FSharpIntro;Integrated Security=SSPI;“

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


Customer
getSpendings
tryPromoteToVip
Module 1
increaseCredit
upgradeCustomer
Module 2
PersonalDetails
Notifications
isAdult
getAlert
Module 3
getSpendingsByMonth
weightedMean
Csv Provider
Json Provider
Module 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 to 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#)