



# ADcenter

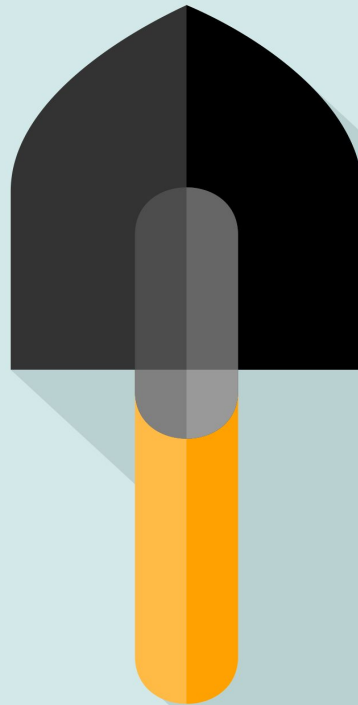
Agile Delivery Center



# Digging(in) JavaScript and TypeScript

<https://github.com/soyrochus/diggingisandts>

JS



TS



I have been working for nearly thirty years in the industry, working on the crosscut between Business, Technology, and Users; Designing, building & running teams, systems & services.

Currently CTO at Capgemini's European Industrial Center in Spain and Program Manager for devonfw, the standard Open Source software development platform for Capgemini Europe & India.

<https://www.capgemini.com/experts/enterprise-architecture/iwan-van-der-kleijn/>

<https://twitter.com/soyrochus>







I am Computer Science Engineer with more than 20 years of experience currently focused on software architecture, industrialization processes and management of projects and teams, designing methodologies to ensure the delivery of projects of any kind: from monolith applications to microservices in cluster related technologies and cloud providers.

Currently Senior Software and Lead Architect at ADCenter Valencia (Spain) and Product Owner for devonfw, the standard Open Source software development platform for Capgemini Europe & India.

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**1** Digging In (History, background)

**2** Prerequisites

**3** Basics

**4** Functions and more ...

**5** Digging Deeper





# Digging In...

(History, background)

A large, stylized blue graphic of a robot arm or mechanical structure on the left side of the slide, composed of various geometric shapes like circles, rectangles, and lines.

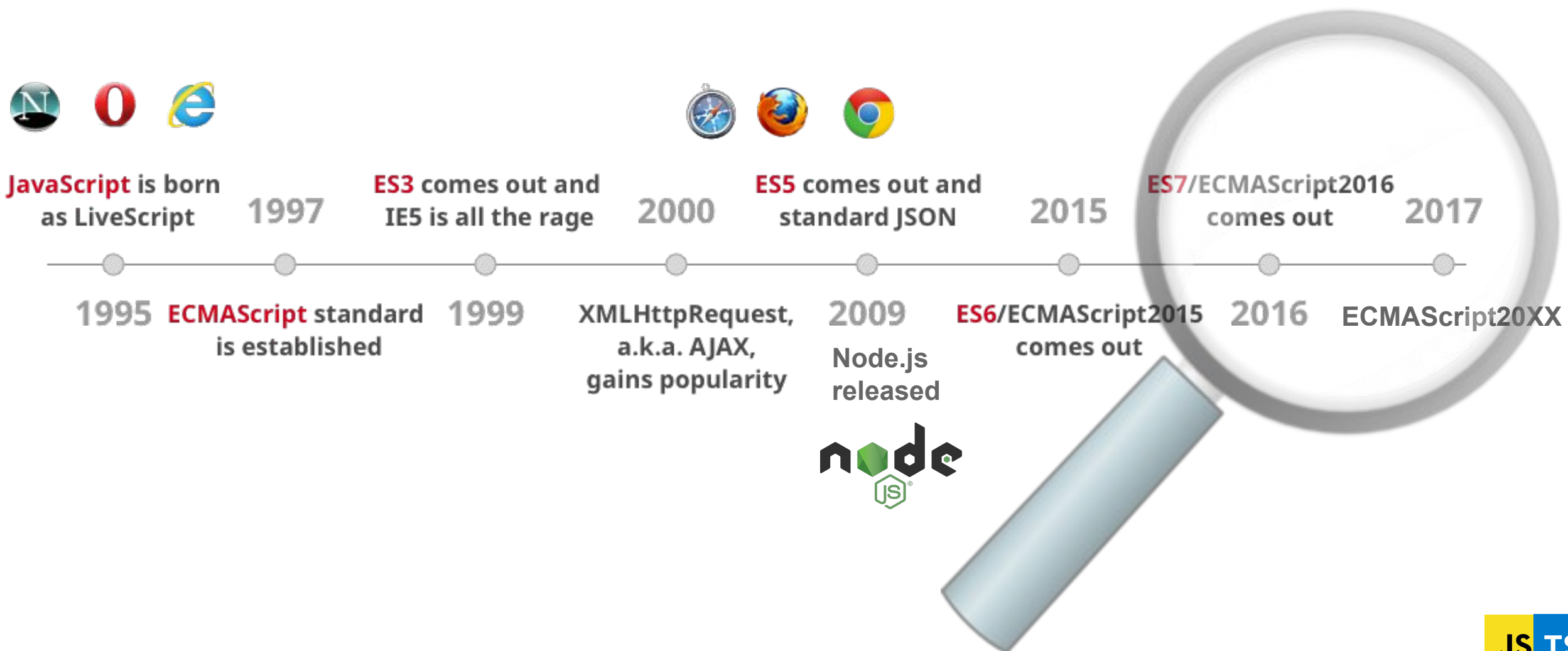
**JS**

**TS**

# "JavaScript" - it's not Java



# JavaScript History





# Big changes in ES6: in effect a new language



# What name to use?



**ES6** or The **ECMAScript 2015** Language version was the last big release. Future updates to the specification will be smaller. New language features will be implemented in JavaScript engines before they are officially included in the specification.

You should talk about

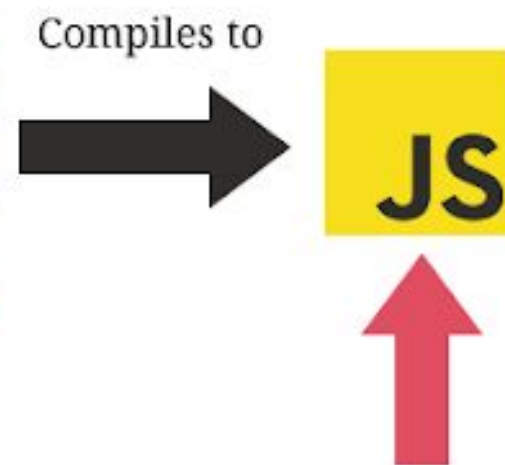
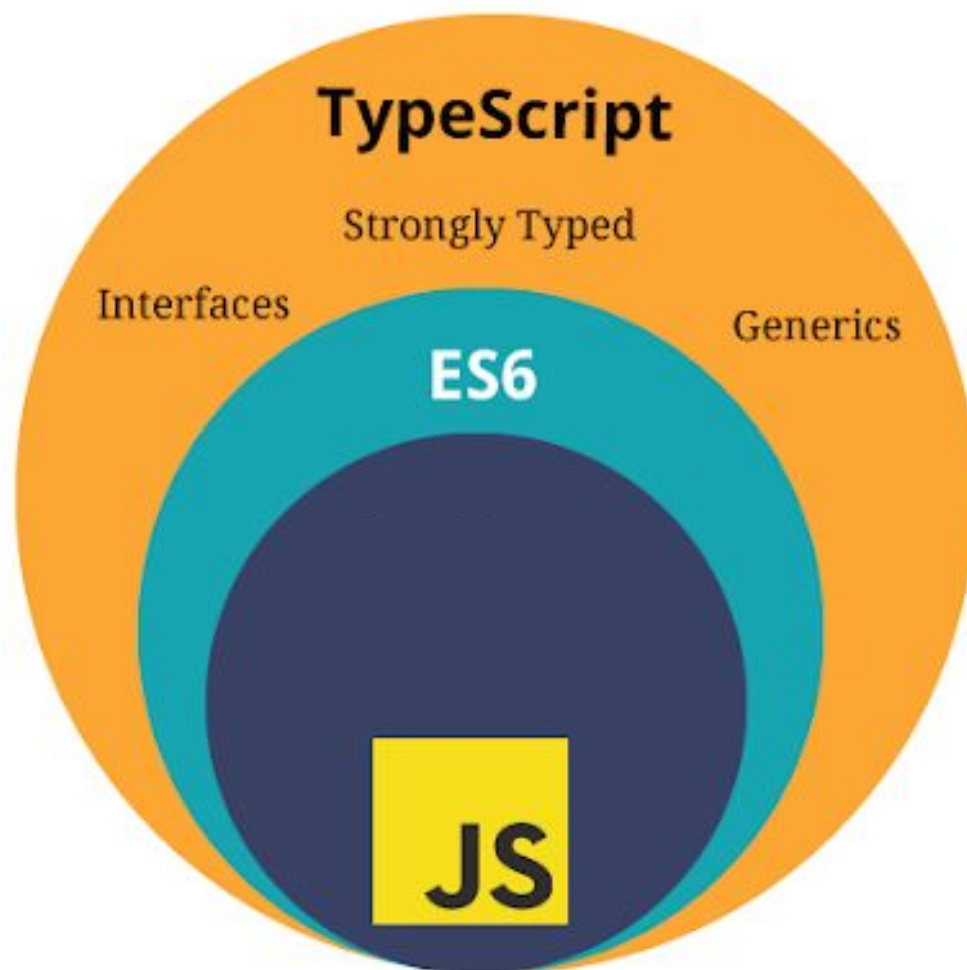
- **use ES6** to refer to "*ECMAScript 2015 Language*" (arrow functions, template strings, Promises), it's shorter than ES2015, and both are unofficial, ES6 was the last big release, and the name is in line with the previous big release ES5, things change after that
- **after ES6, use names of language features**, such as ["globalThis"](#) and ["Array.prototype.flatMap"](#), the specification is only updated after working implementations exist in JS engines, check [TC39 Finished Proposals](#) for a list of features to be included in the next specification
- for historically referring one year's updates to the ECMAScript specification use ES[year]

# TypeScript



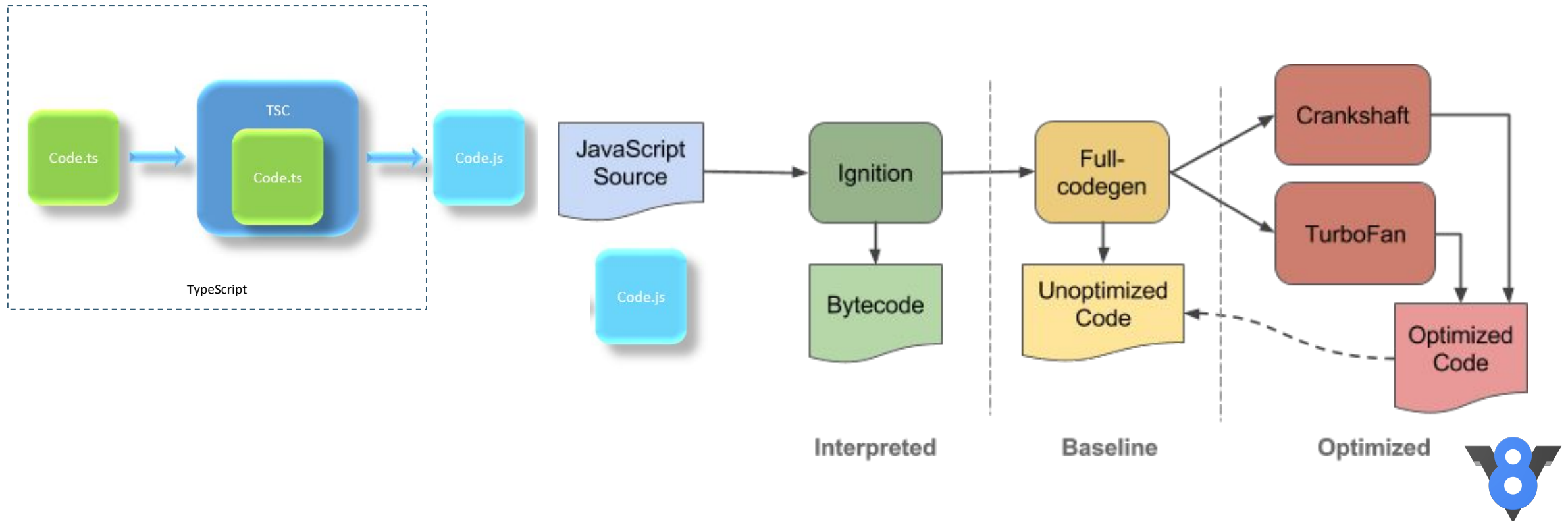
**“...TypeScript is a typed superset of JavaScript that compiles to plain JavaScript...”**

TypeScript was launched for public use in October 2012. It was a result of two years of development at Microsoft. One of the lead designers and developers is Anders Hejlsberg, who is very well known as being the lead architect of C#, as well as the creator of Delphi and Turbo Pascal.



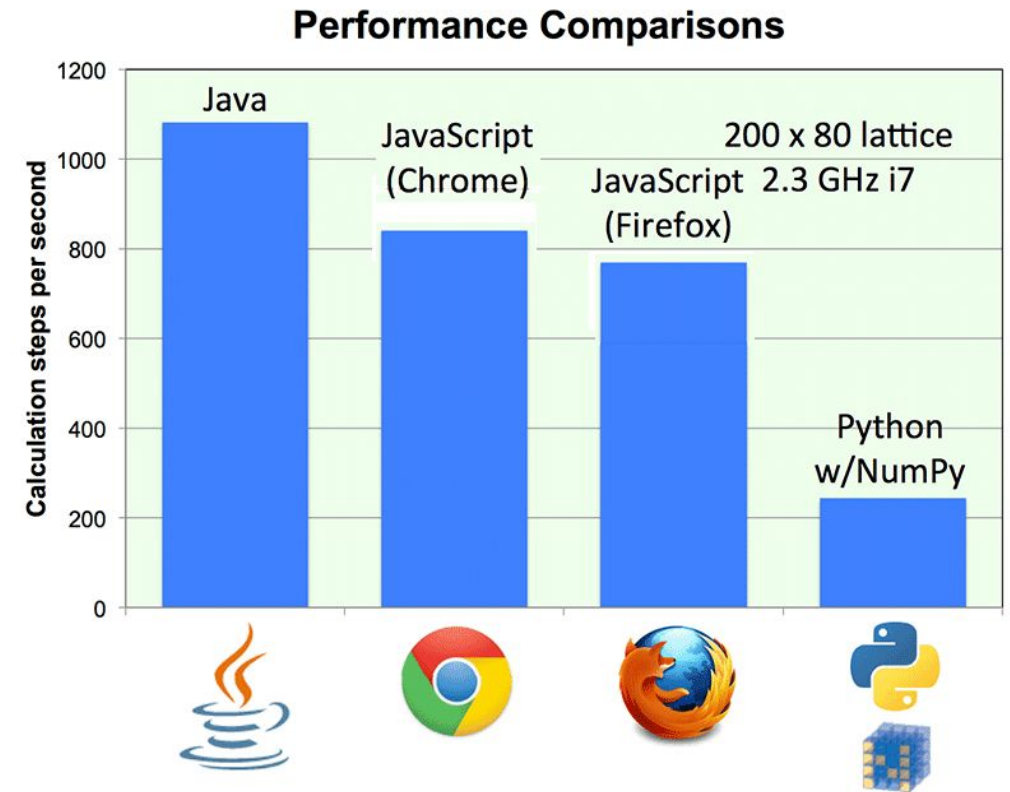
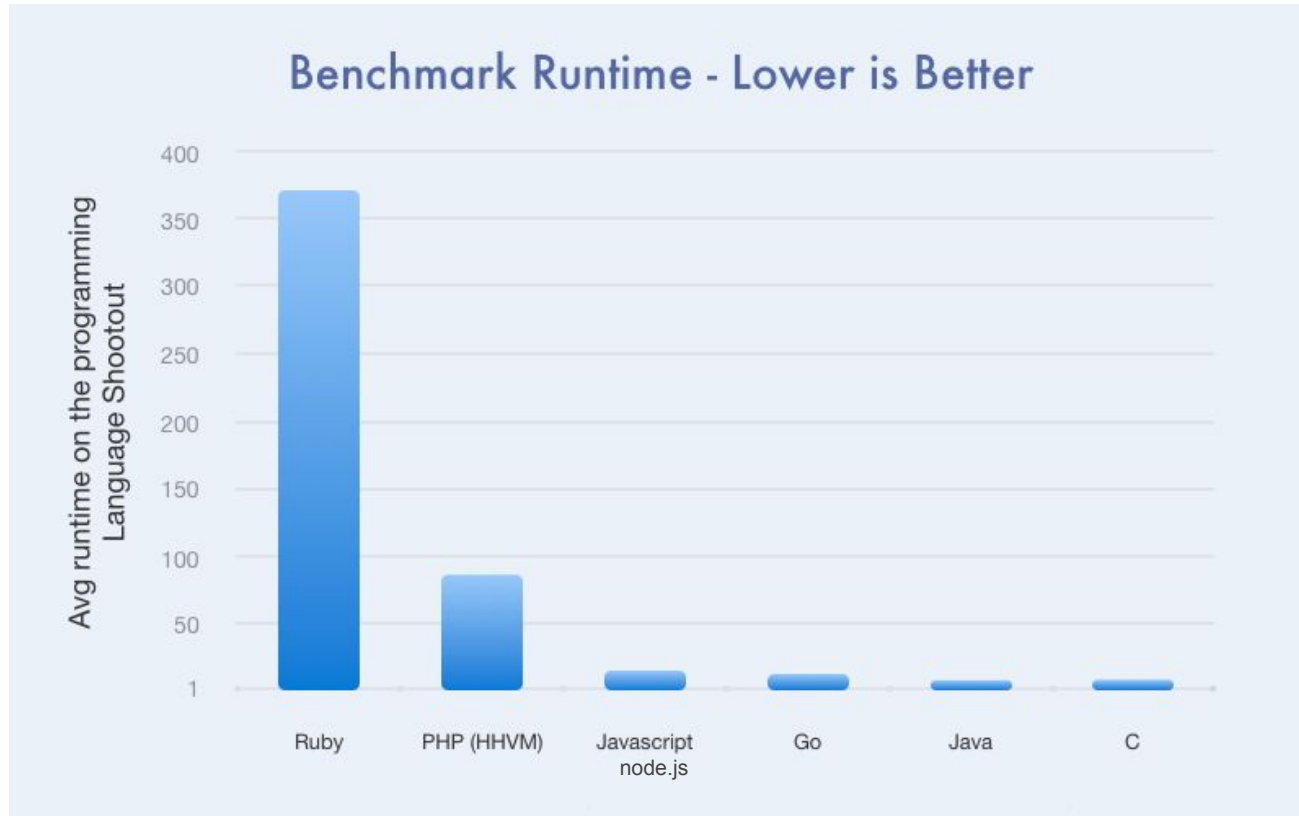
Neither the Browser nor Node.js can run TypeScript so it must be compiled (“transpiled”) to JavaScript

# From source code to execution



V8 is a **JavaScript engine** built developed by Google. It is **open source** and written in **C++**. It is used for both client side (Google Chrome) and server side (node.js) JavaScript applications. V8 and other modern JavaScript engines get their speed via [just-in-time \(JIT\) compilation](#) of script to native machine code immediately prior to execution. Code is initially compiled by a baseline compiler, which can generate non-optimized machine code quickly. The compiled code is analyzed during runtime and optionally re-compiled dynamically with a more advanced optimizing compiler for peak performance. In V8, this script execution pipeline has a variety of special cases and conditions which require complex machinery to switch between the baseline compiler and two optimizing compilers, Crankshaft and TurboFan. Apart from this a JavaScript interpreter, called Ignition, can replace V8's baseline compiler, executing code with less memory overhead on some platforms.

# Performance





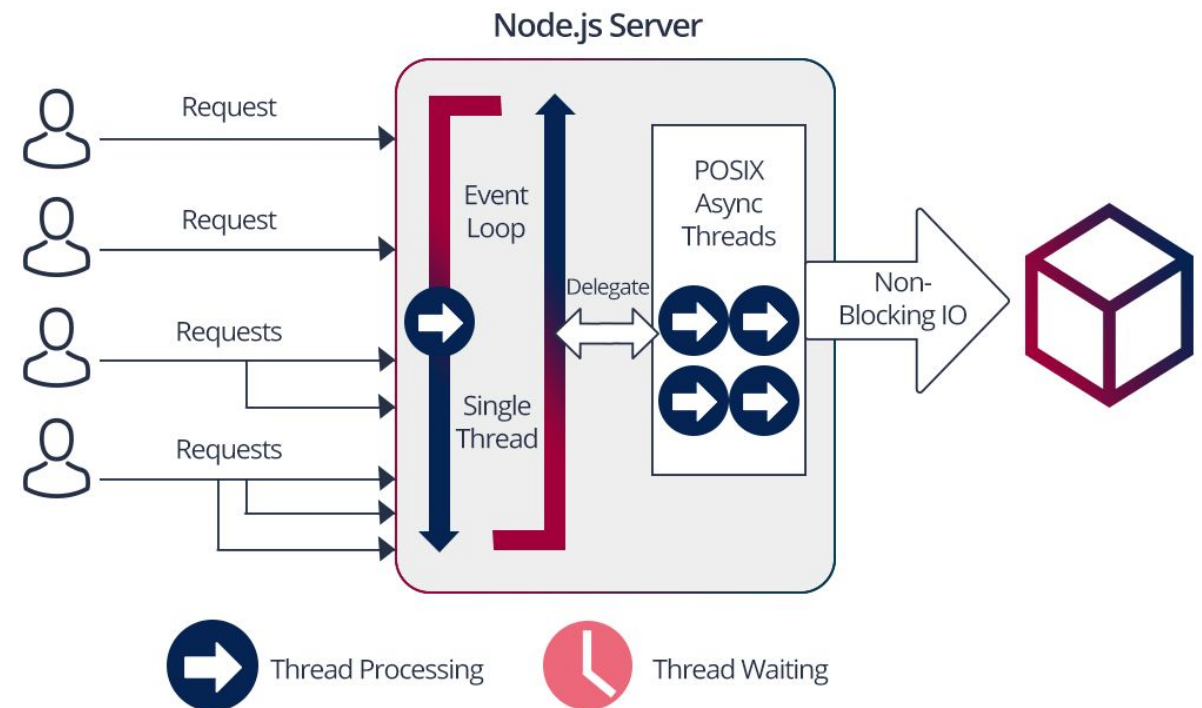
# Single threaded



All Node JS applications uses the “Single Threaded Event Loop Model” architecture to handle multiple concurrent clients.

The main event loop is single-threaded but most of the I/O works run on separate threads, because the I/O APIs in Node.js are asynchronous/non-blocking by design, in order to accommodate the event loop.

So JavaScript code runs on **one single thread** but library code executes multi-threaded. This leads to **subtle but significant differences** with languages like Java or C# as related with the run-time model. For example: **you should never block a thread as no other requests can be served (!)**





# Prerequisites

**JS**

**TS**

# Quick Installation



- Install **node.js** (see: <https://nodejs.org/> )
- Install **TypeScript and other tools** globally with the command:

```
npm install -g typescript ts-node prettier eslint
```

- Note that the executables will be installed to a path - typically something like `C:\Users\<<user>>\AppData\Roaming\npm\` - which needs to be included in your `PATH` environment variable (see: <https://www.architectryan.com/2018/03/17/add-to-the-path-on-windows-10/>)
- Installed will be **ts-node**, which allows running a node shell with TypeScript without having a separate compile phase
- Installed will be **ESLint**, the primary linter for both JavaScript and TypeScript. A linter is a tool that analyzes source code to flag programming errors, bugs, stylistic errors, and suspicious constructs.
- Installed will be **Prettier**, which handles code formatting, important to guarantee a consistent coding style in a team
- For configuration option of both ESLint and Prettier see:  
<https://www.robertcooper.me/using-eslint-and-prettier-in-a-typescript-project>
- Clone the source code accompanying this presentation with

```
git clone https://github.com/soyrochus/diggingjsandts
```

- Install the remaining dependencies by running in the `diggingjsandts/src` directory

```
npm install
```

# Integrated Development Environment



Use an **IDE** with full EcmaScript and TypeScript support:

- **Visual Studio Code**
- **SublimeText** with the TypeScript plugin  
<https://github.com/Microsoft/TypeScript-Sublime-Plugin>
- **Atom** with the atom-typescript plugin  
<https://atom.io/packages/atom-typescript>
- **WebStorm** <https://www.jetbrains.com/webstorm/>

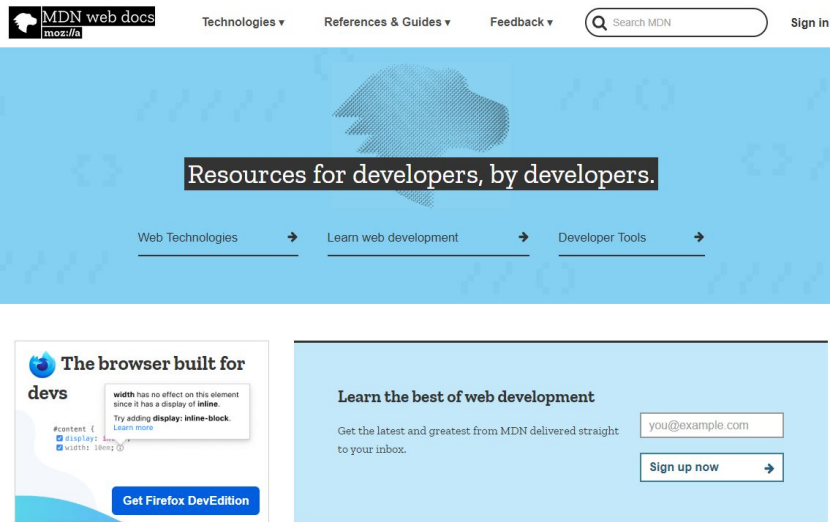


Or [just install devonfw](#) which will provide you with a fully configured Visual Studio Code instance

# Resources



# JS



★ Hacks Blog

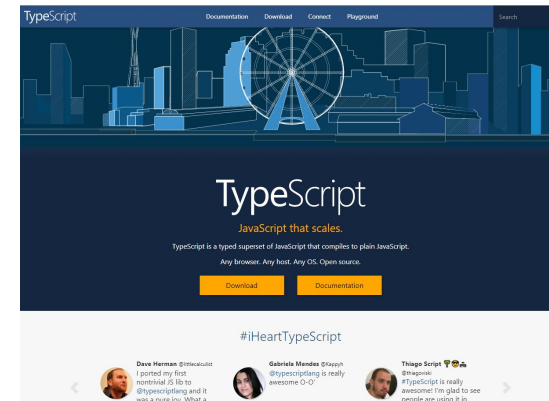
☺ Help improve

## Mozilla Developer Network (MDN)

The foremost resource for web developers

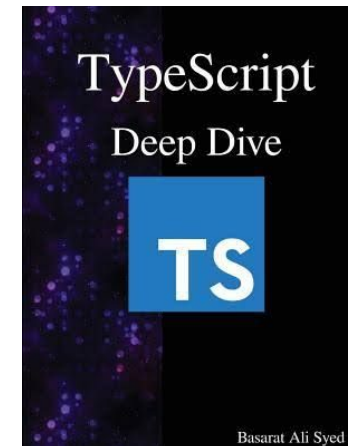
<https://developer.mozilla.org/>

# TS



## TypeScript website

<https://www.typescriptlang.org/>



## TypeScript Deep Dive

(free e-book about  
Advanced TypeScript)

<https://basarat.gitbook.io/typescript/>

# JS TS





# Basics

**JS** **TS**



# Basic syntax



```
// single line comment
/* multi-line
   comment */

let age = 15 // variable declaration
let status // not initialized (set to 'undefined')

const planets = 8 // like let but cannot change

// if statement
if ((age >= 14) && (age < 19)) {
    console.log("Eligible")
} else {
    console.log("Not eligible.")
}
```



Before ES6, before the introduction of **let** and **const**, the only way to declare variables in JavaScript was with the keyword **var**. This is now obsolete. Don't use it.

```
// switch statement
switch (new Date().getDay()) { // input is current
day
    case 0: // if (day == 0)
        console.log("Sunday")
        break
    case 5: // if (day == 5)
        console.log("Friday")
        break
    case 6: // if (day == 6)
        console.log("Saturday")
        break
    default: // else...
        console.log("No Sabbath or equivalent for major
three religions")
}
```

Basic syntax intentionally (nearly) identical  
to Java, C, C++

# Of “;” and Holy Wars



```
let a = 1;  
//semi-colon “;” as line separator  
//(NOT terminator) is optional
```

Like many things in ES6 and TypeScript, this is one of those topics which is subject to Holy Wars. We will not pick a position during this course. For the subject of clarity, most “;” are omitted from the examples.



# Basic syntax - loops



```
//for loop
for (let i = 0; i < 10; i++) {
  console.log(i)
}
```

```
// while loop
let j = 0;
while (j < 10) {
  console.log(j)
  j = j + 1
  //j++
}
```

```
// do while loop
let k = 0
do {
  k = k + 1
  console.log(k)
} while (k < 10)
```

```
// loop with break
for (let l = 0; l < 10; l++) {
  if (l == 5) { break; }           // stops and exits
  the cycle
  console.log(l)
}
// loop with continue
for (let m = 0; m < 10; m++) {
  if (m == 5) { continue }       // skips the rest of
  the cycle
  console.log(m)
}
// for-in loop ; iterate over a sequence or iterable
for (let n in [0, 1,2,3,4]) {
  console.log(n)
}
```



The basic loop constructs are error-prone. Preferred are for-of and sequence and stream operations (which will be shown later on)

# Basic types (not identical !)



JS

```
//Number
let decimal = 6
let hex = 0xf00d
let binary = 0b1010
let octal = 0o744

//bigInt
let big = 9007199254740992n //note 'n' at end
let bigger = 2n ** 153n
//11417981541647679048466287755595961091061972992n

//Boolean
let isDone = false

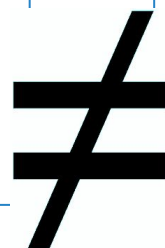
//String
let part= "Rubeus Hagrid"
let actor = "Robbie Coltrane"
let fact = `${part} is played by ${actor}`
```

TS

```
//Number
let decimal = 6
let hex = 0xf00d
let binary = 0b1010
let octal = 0o744
// bigInt - NOTE do not work on TS
// when compiled to ES5 !!
let big = 9007199254740992n //note 'n' at end
let bigger = 2n ** 153n
//11417981541647679048466287755595961091061972992n

//Boolean
let isDone = false

//String
let part= "Rubeus Hagrid"
let actor = "Robbie Coltrane"
let fact = `${art} is played by ${actor}`
```





JS TS



# Type inference

In modern statically typed programming languages like TypeScript, it is not necessary to always declare the type of a variable. The compiler can *infer* the type of the expression.



```
//Number
let decimal    : number = 6
let hex        : number = 0xf00d
let binary     : number = 0b1010
let octal      : number = 0o744

//bigInt
let big        : bigint = 9007199254740992n //note 'n' at end
let bigger     : bigint = 2n ** 153n
//11417981541647679048466287755595961091061972992n

//Boolean
let isDone     : boolean = false

//String
let part       : string = "Rubeus Hagrid"
let actor      : string = "Robbie Coltrane"
let fact       : string = `${part} is played by ${actor}`
```

# Type inference

In modern statically typed programming languages like TypeScript, it is not necessary to always declare the type of a variable. The compiler can *infer* the type of the expression.



```
//Number
let decimal      = 6
let hex          = 0xf00d
let binary       = 0b1010
let octal        = 0o744

//bigInt
let big          = 9007199254740992n //note 'n' at end
let bigger       = 2n ** 153n
//11417981541647679048466287755595961091061972992n

//Boolean
let isDone       = false

//String
let part         = "Rubeus Hagrid"
let actor        = "Robbie Coltrane"
let fact         = `${part} is played by ${actor}`
```

# Static vs Dynamic typing

## Strong vs Weak typing



With JavaScript variable declaration & initialisation has the form of:

```
let <<name>> = <<value>>
```

```
let decimal = 6  
let isDone = false
```

JavaScript is characterized by:

**dynamic typing:**

- a variable can be assigned to a value of a different type

```
decimal = "Robbie Coltrane"
```

**weak typing:**

- operations of different types are valid (and can give unexpected results)

```
console.log(decimal + isDone)  
//'Robbie Coltranefalse'
```

JS

With TypeScript variable declaration & initialisation has the form of:

```
let <<name>> : <<type>> = <<value>>
```

```
let decimal : number = 6  
let isDone : boolean = false
```

JavaScript is characterized by:

**static typing:**

- a variable **cannot** be assigned to a value of a different type

```
decimal = "Robbie Coltrane"
```

```
// error TS2322: Type '"Robbie Coltrane"' is not  
assignable to type 'number'.
```

**weak typing:**

- operations of different types are **invalid**

```
console.log(decimal + isDone)
```

```
//error TS2365: Operator '+' cannot be applied to types 'number' and  
'boolean'.
```

TS





# The “any” type in TypeScript

As a superset of JavaScript, TypeScript offers the “any” type. This allows the programmer to opt-out of type checking and **let a variable have the same compile and run-time behaviour as in JavaScript**. So any call to a non-existing method on an object is compiled although it will generate a run-time error.

```
let notSure: any = 4
// same as
let notSure
notSure = 4
notSure.ifItExists() // okay, ifItExists might exist at runtime
notSure.toFixed()    // okay, toFixed exists (but the compiler doesn't check)
```

The **Object** type plays a similar role, as it does in other languages. However, variables of type **Object** only allow assignment of properties. You can't call arbitrary methods on them, even ones that actually exist.

```
let prettySure: Object = 4
prettySure.toFixed() // Error: Property 'toFixed' doesn't exist on type 'Object'.
```

# String type extra



```
let part= "Rubeus Hagrid"  
let actor = "Robbie Coltrane"  
let fact = "The role as ${part} is played by ${actor}"
```

TEMPLATE STRING

TEMPLATE STRING

This is equivalent to:

```
let fact = "The role as " + part + " is played by " + actor
```

//which in TypeScript can be written as

```
let fact : string = "The role as " + part + " is played by " + actor
```





# Basic types: Array

An **array** is the basic **sequence type** in both JavaScript and TypeScript

```
let list = [1, 2, 3]
let names = ["Harry", "Hermione", "Ron"]
```

Arrays are accessed by using square brackets and putting the position of the element (0 based)

```
console.log(names[0]) // -> "Harry"
```

Neither the length of a JavaScript array nor the types of its elements are fixed.

```
let shoppingItem = ["orange", 10, false]
shoppingItem.push("fruit") // add an element to the back of the array
console.log(shoppingItem) // -> [ 'orange', 10, false, 'fruit' ]
```

In TypeScript an array which behaves like a JavaScript array is an array which all elements of type **any**.

```
TS let shoppingItem : any[] = ["orange", 10, false]
```

Arrays typically are typed in TypeScript. There are two notations: the “`<typename>[]`” variant and the “`Array<typename>`”. The former is a specific notation for arrays while the latter is an array expressed as a *Generic Type*.

```
let list1: number[] = [1, 2, 3]
let list2: Array<number> = [1, 2, 3];
```



# Basic types: Tuple & type aliases

TS

In TypeScript a **tuple** represent an array where the type of a determined number of items is known and does not have to be the same.

```
// Declare a tuple type
let x: [string, number];
// Initialize it
x = ["hi", 10]; // OK
console.log(x[0]) // -> 'hi'

// Initialize it incorrectly
// error TS2322: Type 'number' is not assignable to
type 'string'.
// error TS2322: Type 'string' is not assignable to
type 'number'.
x = [10, "hi"];
```

TS

A **type alias** can be created with the **type** keyword to simplify type notation.

```
type seat = [string, number]
```

```
let john : seat = ["John", 15]
```

Note that a type alias is not a “real” new type. And type aliases cannot be inferred. So the following are not equivalent:

```
let karen : seat = ["Karen", 15]
let karen      = ["Karen", 15]
```

# Basic types: enum



## TS Enum

An **Enum** allows us to assign names to sets of numeric variables.

```
enum Color {Red, Green, Blue};  
let c: Color = Color.Green;
```

By default **enums** start to initialize the indexes by 0. But we can initialize manually:

```
enum Color {Red = 1, Green, Blue};  
let c: Color = Color.Green;
```

Or define them completely:

```
enum Color {Red = 1, Green = 2, Blue = 4};  
let c: Color = Color.Green;
```

If we are not sure of the assigned mapping, **enums** allows us the following:

```
enum Color {Red = 1, Green, Blue};  
let colorName: string = Color[2];  
console.log(colorName);
```



# Basic types: null, undefined (and void)

## Null and Undefined

Both are types shared by JavaScript and TypeScript. They seem similar but have specific meanings.

**Undefined** is a value set to a variable if no value has been assigned.

```
let u; // undefined
```

**Null** can be used to explicitly state that “no value” is returned.

```
let n = null;
```

By default, both are subtypes of all the other, therefore we can assign **null** or **undefined** to any variable of any other type like **number** or **string**.

Both values evaluate to “false”. See “Falsy Values”.

## Void

Basically the opposite of any. It is used in functions that do not return any type.

```
function warnUser() {  
    alert("This is my warning message");  
}
```

or in TypeScript

```
function warnUser(): void {  
    alert("This is my warning message");  
}
```

```
let nothing = warnUser()  
//nothing is undefined
```

# Falsy Values



In JavaScript and TypeScript there is a specific **boolean** type which can have the value of **true** and **false**.

Values of this type can be used for boolean expressions, expressions which evaluate to **true** and **false**. But not just values of the boolean type can be used. It is possible to use a series of values from other types. These evaluate to false when coerced by JavaScript's typing engine into a boolean value, but they are not necessarily equal to each other. It is said that these values are “falsy”. Not equal to **false** but evaluating to it.

The falsy values in JavaScript are **0**, **0n**, **null**, **undefined**, **false**, **NaN**, and the empty string **""**.

```
let realfalse    : boolean = false
let falsyNumber  : number  = 0
let falseNaN     : number  = NaN
let falsyBigInt  : bigint  = 0n
let nullValue: any = null
let undefinedVar // undefined
let falseString: string = ""
```

TS

# Type assertions



TS

When we end up in a situation where you'll know more about a value than TypeScript does, we can tell the compiler "trust me, I know what I'm doing".

Usually this will happen when you know the type of some entity could be more specific than its current type. There are two ways to do it:

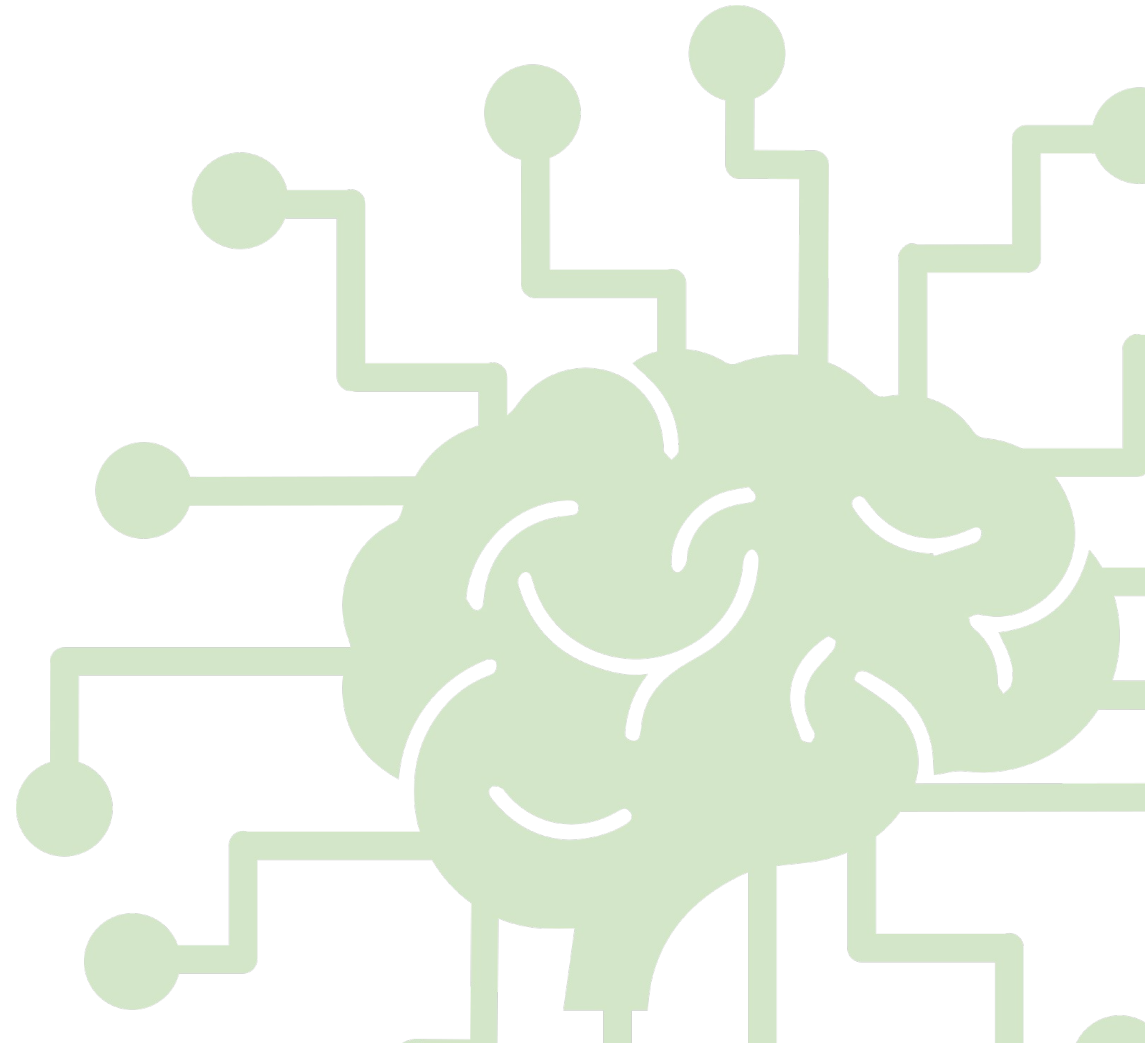
```
let someValue: any = "this is a string";  
// angle-bracket syntax  
let strLength: number = (<string>someValue).length;  
// as syntax  
let strLength: number = (someValue as string).length;
```



Functions  
and more...

**JS**

**TS**





# Functions



Functions are one of the fundamental building blocks in JavaScript. A function is a JavaScript procedure—a set of statements that performs a task or calculates a value. The basic definition shared with all version of JavaScript and TypeScript is:

```
function multiply(x, y) {  
    return x * y  
}
```

Note that the function is a value (the executable code) assigned to a variable (the function name). So the above definition can be written as :

```
let multiply = function(x, y) {  
    return x * y  
}
```

In ES6 and TypeScript a new syntax has been introduced, the so-called Arrow functions (“fat arrow functions”). It's a shorter, more concise way to write functions and the arrow function behave differently (very subtle, this will be treated later), solving an issue with “function”.

```
let multiply = (x, y) => x * y //single line, without { .. } and with implicit return
```

```
let multiply = (x, y) => {  
    return x * y  
}
```



# Function parameters

Functions can have zero or more parameters. A parameter is used to pass information to the code inside the function. JavaScript does not support Optional parameters through syntax. But if a parameter is not passed a value, it will evaluate to “undefined”.

ES6 also supports **default parameters**. These can be assigned default values which are set once a parameter is not passed to the function.

```
let buildName = (firstName, lastName, title= 'Mr./Ms.') =>{
  if (lastName)
    return `${title} ${firstName} ${lastName}`
  else
    return `${firstName}`
}
```

```
// Note that this will not work in TypeScript with strict options set. It will fail to compile with
// error TS2554: Expected 2-3 arguments, but got 1.
console.log(buildName("John")) // -> 'John'
console.log(buildName("Rupert", "Grint")) // -> 'Mr./Ms. Rupert Grint'
console.log(buildName("Emma", "Watson", "Miss")) // -> 'Miss Emma Watson'
```

The rest parameter syntax allows us to represent an indefinite number of arguments as an array.

```
let cast = (...castmembers) =>{
  console.log( Harry Potter cast members are: ${castmembers} `)
}

cast("Daniel Radcliffe", "Emma Watson", "Rupter Grint", "Alan Rickman", "Michael Gambon")
// -> Harry Potter cast members are: Daniel Radcliffe,Emma Watson,Rupter Grint,Alan Rickman,Michael Gambon
```

# Optional parameters in TypeScript



TS

Note that in TypeScript with strict compile options set, if a parameter is not passed a value, it will NOT evaluate to “undefined” but rather generate an error.

Instead of the implicit behaviour, in TypeScript a parameter can be explicitly defined to be **optional** by putting a question mark behind its name: “*typename?*”

```
let buildName = (firstName, lastName?, title= 'Mr./Ms.') =>{  
  if (lastName)  
    return `${title} ${firstName} ${lastName}`  
  else  
    return `${firstName}`  
}
```

```
console.log(buildName("John")) // -> 'John'  
console.log(buildName("Rupert", "Grint")) // -> 'Mr./Ms. Rupert Grint'  
console.log(buildName("Emma", "Watson", "Miss")) // -> 'Miss Emma Watson'
```

# Values, references and parameters



In JavaScript there exist so-called value-types and reference types. **Value types** are simple atomic values like numbers but also strings. They are **immutable**: they cannot be changed. A variable points to a value type. It is not the value itself.

```
let name2 = "Harry" // variable "name" can be
re-assigned but the value "Harry" cannot be changed
```

A **reference type** on the other hand is a value which can refer to, point at, other types: both value and reference types. Both arrays and objects are examples of reference types. The elements **IN** a reference type can be changed or rather: the elements in a reference type can "point at" other type, i.e. behave like variables.

```
let shoppingItem = ["orange", 10, false]
shoppingItem[1] = 500
console.log(shoppingItem) // -> ["orange", 500, false]
```

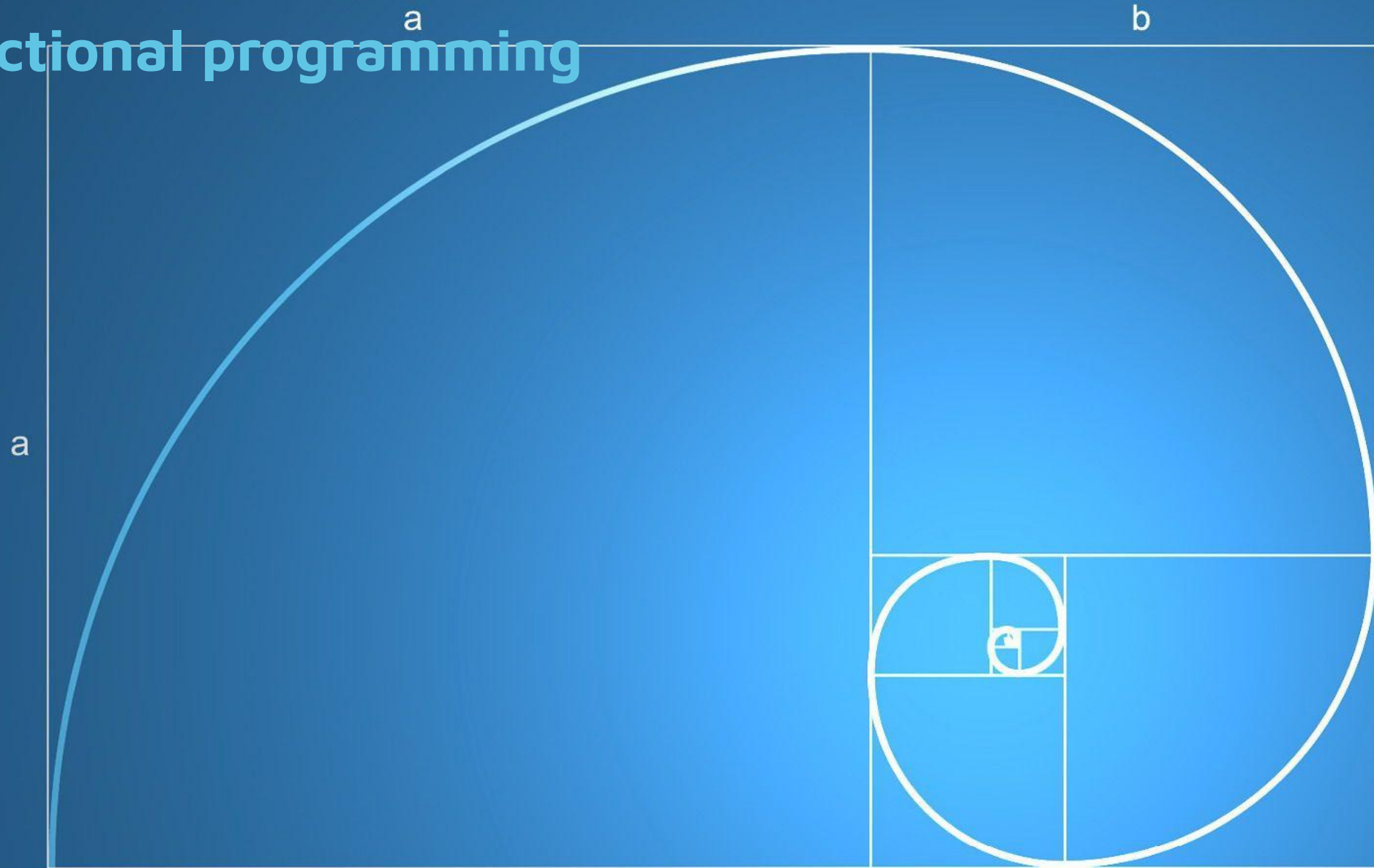
Now function parameters which are of a value type are "passed by value". That means that an assignment on the parameter inside the function does not change the value of the variable which passed the value to the function.

```
let reset = (x) => {
  x = null
}
let a = 100
reset(a)
console.log(a) // -> 100
```

When a reference type is passed, the original variable cannot be changed. But the members of the reference type it points to can be changed!

```
let resetArr = (x) => {
  x[0] = null
}
let a = [100, 200, 300]
resetArr(a)
console.log(a) // -> [null, 200, 300]
```

# Functional programming



$$\frac{a+b}{a} = \frac{a}{b} = \varphi \approx 1,61803$$

# Recursion



JavaScript and TypeScript functions support recursion. Which is a critical feature where a function can call itself, multiple times if necessary. Many algorithms are recursively defined so a language which support recursion is a great help in implementing such algorithms, even if for a first, naive, version (as recursion is “expensive” a more optimal, but more complex function are typically possible). For example:

Given a number  $N$  return the index value of the **Fibonacci sequence**, where the sequence is:

1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, ...

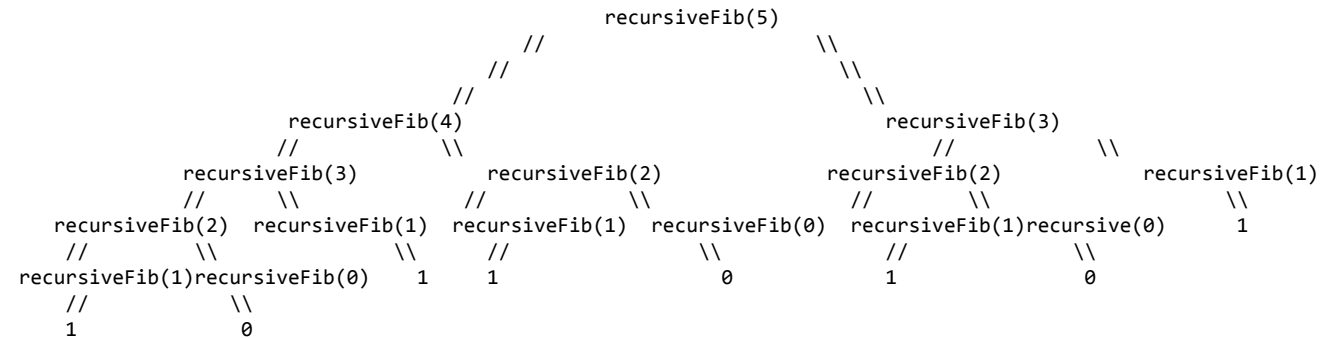
After a quick look, you can easily notice that the pattern of the sequence is that each value is the sum of the **2 previous values**, that means that for  $N=5 \rightarrow 2+3$  or in maths:

$$F(n) = F(n-1) + F(n-2)$$

The implementation in JavaScript is:

```
let fibonacci = (n) => {  
  console.log(`fibonacci(${n})`)  
  if (n === 0 || n === 1)  
    return n;  
  else  
    return fibonacci(n - 1) + fibonacci(n - 2);  
}
```

```
console.log(fibonacci(20)) // -> 6765
```



This diagram shows the inefficiency of a naive recursive implementation. Calculation the 5th fibonacci number leads to 15 calls to the function. Calculation of the 50th Fibonacci number leads to calling the function over **40 billion times**.

# Memoization



Recursion can be inefficient. For example, when calculating the 50th Fibonacci number, the function is called over **40 billion times**.

Through the usage of reference types (array, objects) it is possible to implement **memoization or caching** of values in recursive functions. In case of calculation of the 50th Fibonacci number, this brings the **number of calls to the fibonacci function back to a mere 99(!)**.

```
let fibonacci2 = (n, seq = []) => {
  console.log(`fibonacci2(${n})`)
  if (seq[n]) {
    return seq[n]
  } else {
    if (n === 0 || n === 1)
    {
      seq[n] = n
    } else {
      seq[n] = fibonacci2(n - 1, seq) + fibonacci2(n - 2, seq)
    }
    return seq[n]
  }
}

let seq = []
console.log(fibonacci2(20, seq)) //-> 6765
console.log(seq) // -> [0,1,1,2,3,5,8,13,21,34,55,89,144,233,377,610,987,1597,2584,4181,6765]
```



# Function as values



In JavaScript functions are not only syntax but also values, which means they can be assigned to variables, stored in the properties of objects or the elements of arrays, passed as arguments to functions, and so on. This is a critical part of JavaScript and a principal reason why it has been so successful.

The canonical example is to pass functions to the JavaScript sequence (array) methods like map, filter, reduce etc. The functions are operations which are executed by these generic functions (methods) on the array.

```
let shoppingList = [
  ["orange", 10, "REGULAR"],
  ["apple", 2, "SALE"],
  ["orange", 15, "REGULAR"]
]
```

```
let toSale = (e) => {
  if (e[2] == "SALE")
    e[2] = true
  else
    e[2] = false
  return e
}
```

```
let big = (e) => e[1] > 5
```

```
let products = shoppingList.map(toSale).filter(big)
```

```
console.log(products) // -> [ [ 'orange', 10, false ], [ 'orange', 15, false ] ]
```

The **map()** method **creates a new array** populated with the results of calling a provided function on every element in the calling array. It allows **transformation of a sequence**

The **filter()** method **creates a new array** with all elements that pass the test implemented by the provided function. It allows **searching for particular conditions** ("filtering") in a sequence

# Closure

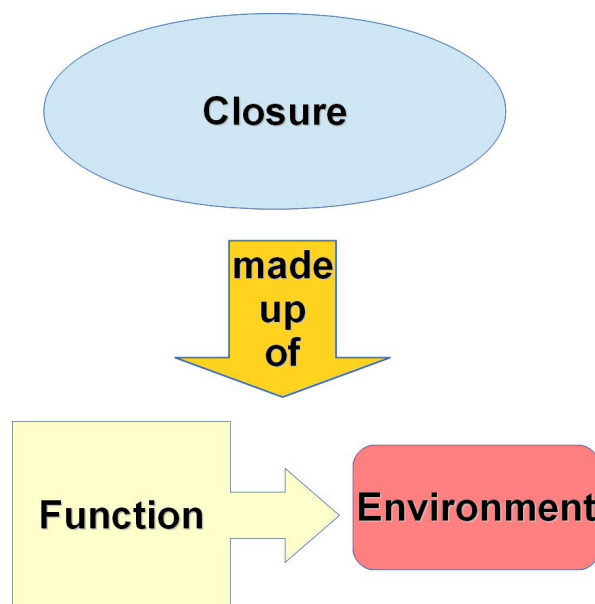


A **closure** is the combination of a function bundled together (enclosed) with references to its surrounding state (the **lexical environment**). In other words, a closure gives you access to an outer function's scope from an inner function. In JavaScript, closures are created every time a function is created, at function creation time. With closures a function can be **parameterized**:

```
let toPower = (exponent) => {  
  return (base) => base ** exponent  
}
```

```
let square = toPower(2)  
let cube = toPower(3)
```

```
console.log(square(3)) // -> 9  
console.log(cube(3))   // -> 27
```



With closures **state can be passed between function calls** (without using global variables):

```
let counter = (step, init=0) => {  
  let state = init  
  return () => {  
    state += step  
    return state  
  }  
}
```

```
}  
let one = counter(1)  
let pair = counter(2)  
let triple = counter(3)  
let cuad = counter(4)
```

```
console.log(one()) // -> 1  
console.log(one()) // -> 2  
console.log(one()) // -> 3  
console.log(cuad()) // -> 4  
console.log(cuad()) // -> 8  
console.log(cuad()) // -> 12
```

# Parameter and Function types



TS

In TypeScript parameters and function return are typed as variables declared with `let` and `const` (and so are they inferred when no type declaration is given)

```
let multiply = function(x: number, y: number): number {
    return x * y
}
```

It should be noted that functions have their own types. Either the generic, primitive Function type (which should be avoided) or a syntax which defines the type as a function without function body (with the `{ .. }`). **The type alias keyword** is very useful for this purpose to make the code more readable.

In the example of the left that allows writing the definition of **mapmatrix** as

```
let mapMatrix = (matrix: matrix2d, operation: cellop)
rather than the more convoluted
let mapMatrix2 = (matrix: Array<Array<number>>,
operation: (_: number) => number)
```

TS

```
type matrix2d = Array<Array<number>>
type cellop = (_: number) => number
let mapMatrix = (matrix: matrix2d, operation: cellop)=> {

    let submatrix = (matrix : Array<number>)=>{
        return matrix.map(operation)
    }
    return matrix.map(submatrix)
}

let data = [[5, 9, -1], [100, 2], [-10, -8, 56]]
let floorzero : cellop = (e) => {
    if (e < 0)
        return 0
    else
        return e
}

console.log(mapMatrix(data, floorzero)) // -> [ [ 5, 9, 0 ],
[ 100, 2 ], [ 0, 0, 56 ] ]
```



# Object literals - old style

Apart from functions, a powerful feature of JavaScript is the capability to **create objects without defining classes**. This unifies the concept of *hashmaps*, *structs* and *object singletons* of other program languages in one simple construct. **Object literals** make it easy to quickly create objects with properties inside the curly braces. To create an object, we simply notate a list of key: value pairs delimited by comma.

Note that methods in JavaScript are simple functions assigned to properties. The properties of the object can be read from within the function with the **this keyword**. “**this**” refers to the parent object.

Due to the history of JavaScript this is one of the areas where the **function keyword** is preferred over the **arrow notation for functions**. The two differ in the value which “**this**” evaluates to:

**function keyword:** this refers to **parent object** or **global scope** (if function not assigned to property of object)

**arrow notation:** this refers to the **lexical environment** at the time of the function definition (as in closures)

```
let shoppingItem = {
  name: "orange",
  number: 10,
  sale: true,
  report: function() {
    let forSale
    if(this.sale){
      forSale = "for Sale! See the offer..."
    } else {
      forSale = "not for Sale. Normal price-quote in effect."
    }
    console.log(`The product ${this.name} is ${forSale}`)
  }
}
```

```
shoppingItem.report() // -> The product orange is for Sale! See the offer...
```

# Object literals - ES6



ES6 makes the declaring of object literals concise and thus easier. Three major ways it does this are :

1. It provides a shorthand syntax for initializing properties from variables.
2. It provides a shorthand syntax for defining function methods.
3. It enables the ability to have computed property names in an object literal definition.

See the (somewhat contrived) example on the right.

Note that properties in objects can be accessed with:

**dot notation:** `shoppingItem.name = "orange"`  
**square bracket notation:** `shoppingItem["name"] = "orange"`

The latter allows for computed property name indexing. It is equivalent to how hashmaps work in other languages. However, in JavaScript there is some overlap between Arrays and Objects so care have to be taken the two are not mixed up.

```
let getlang = (name)=>{
    return "EN" // mock for demonstration purposes
}
let name = "orange"
let number = 10

let shoppingItem = {
    number,
    sale: true,
    [getlang(name)]: name.toLowerCase(),

    report() {
        let forSale
        if(this.sale){
            forSale = "for Sale! See the offer..."
        } else {
            forSale = "not for Sale. Normal price-quote in effect."
        }
        console.log(`The product ${this.EN} ${forSale}`)
    }
}

shoppingItem.report() // -> The product orange is for Sale! See the offer...
```

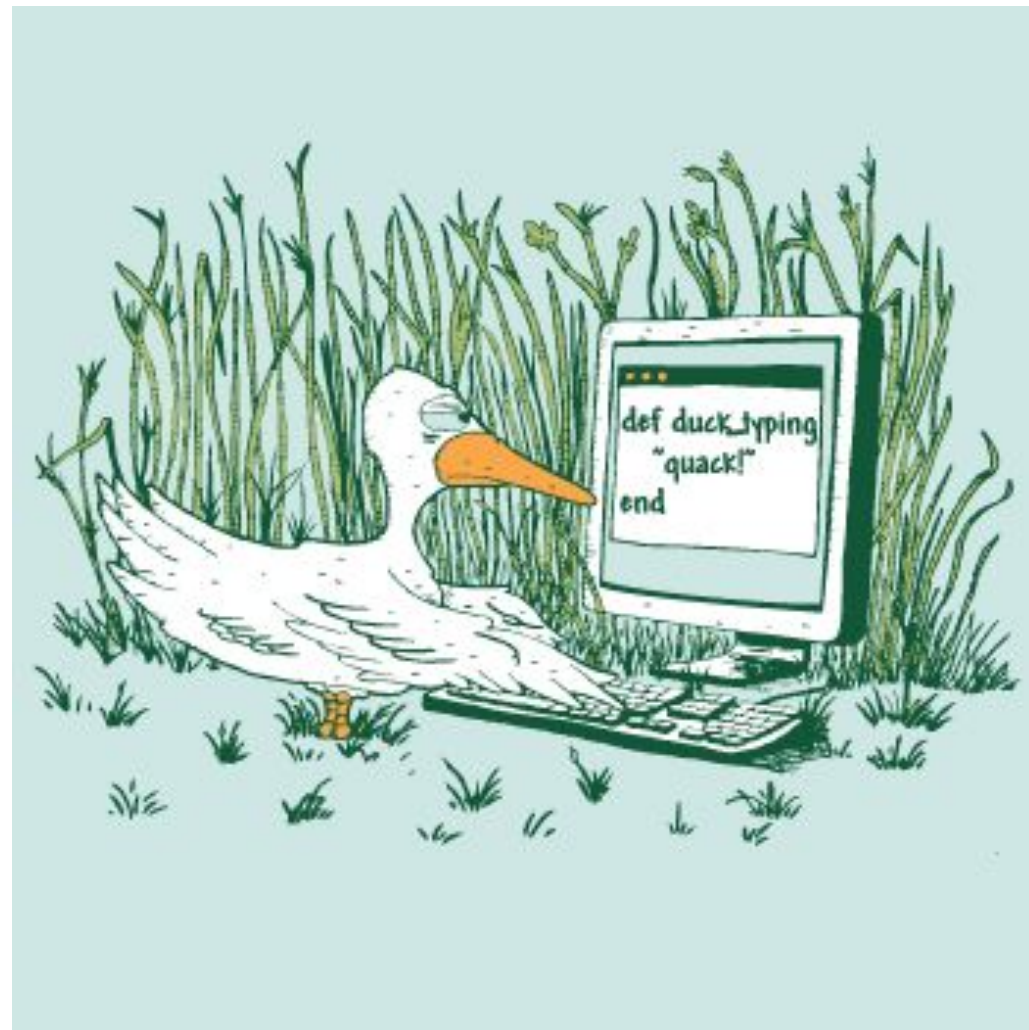
# Structural subtyping



One of TypeScript's core principles is that type-checking focuses on the shape that values have. This is sometimes called “***duck typing***” or “structural subtyping”.

The concept name refers to the **duck test**, a joke of inductive reasoning attributed to the writer James Whitcomb Riley, that could be as it follows:

"When I see a bird that walks like a duck, swims like a duck and quacks like a duck, I call that bird a duck."



# Interfaces



TS

**Structural subtyping** can be demonstrated by giving an object type definition to a function parameter. An object passed to the parameter can have more properties than the ones mentioned in the type declaration, but it must implement

```
// Any object passed to printLabel1 needs to have the "label"
// property
let printLabel = (labeledObj: { label: string }) =>{
    console.log(labeledObj.label)
}

let goodObj = {size: 10, label: "Size 10 Object"}
printLabel(goodObj) // -> Size 10 Object

let badObj = {size: 10, text: "Size 10 Object"}
// Does not compile with error TS2345: Argument of type '{ size:
// number; text: string; }' is not assignable to parameter of type '{
// label: string; }'.
// Property 'label' is missing in type '{ size: number; text: string;
// }' but required in type '{ label: string; }'.

printLabel(badObj)
```

TS

In TypeScript, **interfaces** fill the role of naming these structural types and are a powerful way of defining contracts within your code as well as contracts with code outside of your project.

```
interface LabeledValue {
    label: string
}
```

With the LabeledValue interface we define the requirement of the function. It still represents having a single property called **label** that is of type string.

```
function printLabel(labeledObj: LabeledValue) {
    console.log(labeledObj.label)
}

let goodObj = {size: 10, label: "Size 10 Object"}
printLabel(goodObj)

let badObj = {size: 10, text: "Size 10 Object"};
// Does not compile with error TS2345: Argument of type '{ size:
// number; text: string; }' is not assignable to parameter of type
// 'LabeledValue'.
// Property 'label' is missing in type '{ size: number; text:
// string; }' but required in type 'LabeledValue'.
printLabel(badObj)
```



# Interfaces extra



## TS Optional properties

Not always we will need all the properties of an interface. With the symbol ? we represent what is optional.

```
interface SquareConfig {  
  color?: string  
  width?: number  
}
```

## Read-only properties

We can define a read-only interface with readonly:

```
interface Point {  
  readonly x: number  
  readonly y: number  
}  
  
let p1: Point = { x: 10, y: 20 }  
p1.x = 5 // error TS2540: Cannot assign to 'x' because it is a  
read-only property.
```

## TS

Interfaces can also define a function. This ensures the function signature.

```
// Using Point Interface from the left column  
interface SetPoint {  
  (x: number, y: number) : Point  
}  
  
let setPoint: SetPoint = (x, y)=> ({x, y})  
let p1 = setPoint(10, 20)  
console.log(p1) // => { x: 10, y: 20 }
```

Note: in current versions of TypeScript the difference between a type alias with the **type keyword** and an Interface declaration is small and subtle.

The problem is that at the moment of writing this, the official documentation not correctly reflect the latest development in the language. See: [Typescript: Interfaces vs Types](#) for more information

# Classes



From ES6 onwards JavaScript developers are able to use a more classic approach to Object Oriented Programming which resembles other programming languages.

In the sample there is a **Greeter** class with a **greeting** property, a **constructor** and a **greet** method.

With **this**. access to the class members is provided

In order to construct an instance of the class the reserved word **new** is used.

```
class Greeter {  
    greeting: string;  
    constructor(message: string) {  
        this.greeting = message;  
    }  
    greet() {  
        return "Hello, " + this.greeting;  
    }  
}  
  
let greeter = new Greeter("world");
```

# Inheritance



The **extends** keyword is used in *class declarations* or *class expressions* to create a class as a child of another class.

The **super** keyword allows calling the parent object that is being inherited. It is good advice to avoid this as this can cause an even tighter coupling between objects, but there are occasions where it is appropriate to use.

In the example on the right case, it is be used in the constructor to assign to the super constructor.

If a constructor is not defined on a child class the super class constructor will be invoked by default.

```
class Animal {
  name: string;
  constructor(theName: string) { this.name = theName; }
  move(distanceInMeters: number = 0) {
    console.log(`${this.name} moved ${distanceInMeters}m.`);
  }
}

class Snake extends Animal {
  constructor(name: string) { super(name); }
  move(distanceInMeters = 5) {
    console.log("Slithering...");
    super.move(distanceInMeters);
  }
}

class Horse extends Animal {
  constructor(name: string) { super(name); }
  move(distanceInMeters = 45) {
    console.log("Galloping...");
    super.move(distanceInMeters);
  }
}
```

# Properties and getters and setters



With the JavaScript field declaration syntax, **class definitions** become more self-documenting, and the fields are always present.

As seen above, the fields can be declared with or without a default value. In TypeScript with strict options enabled, declaring field variables is mandatory.

A **getter** is a method that gets the value of a specific property. A **setter** is a method that sets the value of a specific property. Getters and setters can be defined on any predefined core object or user-defined object that supports the addition of new properties.

The syntax for defining getters and setters uses the object literal syntax.

```
class Person {
  _name = ""
  constructor(name) {
    this._name = name;
  }
  get name() {
    return this._name.toUpperCase();
  }
  set name(newName) {
    this._name = newName; // validation could be
checked here such as only allowing non numerical values
  }
  walk() {
    console.log(this._name + ' is walking.');
```

```
}

let bob = new Person('Bob');
console.log(bob.name); // Outputs 'BOB'
```

# Public, private and protected modifiers



TS

By default, in TypeScript every member is marked as **public**. Every member without any modifier behaves as if marked by public.

When a member is marked as **private** it is not possible access to it outside the class.

When a member is marked as **protected** it is only possible to access it from members from the class or its subclasses.

TS

```
class Person2 {
  private _name : string
  constructor(name: string) {
    this._name = name;
  }
  public get name() {
    return this._name.toUpperCase();
  }
  public set name(newName) {
    this._name = newName; // validation could be checked
    here such as only allowing non numerical values
  }
  public walk() {
    console.log(this._name + ' is walking.');
```

```
  }
}

let bob = new Person2('Bob');
console.log(bob.name); // Outputs 'BOB'
```

# Destructuring assignment



The **destructuring assignment** syntax is a JavaScript expression that makes it possible to unpack values from arrays, or properties from objects, into distinct variables.

It works with a simple form of pattern matching, which is the inverse of the array and object literal syntax. Instead of a structure with values in a array or object notation on the right-hand side of an assignment, **destructuring works with putting a structure with variables in an array or object notation on the *left-hand side* of an assignment.**

For example: array destructuring

```
[a, b] = [10, 20];  
console.log(a); // -> 10  
console.log(b); // -> 20
```

The **rest or spread operator** can be used to capture the tail of an array.

```
[a, b, ...rest] = [10, 20, 30, 40, 50];  
console.log(a); // -> 10  
console.log(b); // -> 20  
console.log(rest); // -> [30, 40, 50]
```

For example: object destructuring

```
({ a, b } = { a: 10, b: 20 });  
console.log(a); // 10  
console.log(b); // 20
```

The parentheses ( ... ) around the assignment statement are required when using object literal destructuring assignment without a declaration.

{a, b} = {a: 1, b: 2} is not valid stand-alone syntax, as the {a, b} on the left-hand side is considered a block and not an object literal.

However, ({a, b} = {a: 1, b: 2}) is valid, as is const {a, b} = {a: 1, b: 2}


**Note:** The ( ... ) expression needs to be preceded by a semicolon or it may be used to execute a function on the previous line(!)

The **rest or spread operator** can be used to capture the remaining properties in a object destructuring.

```
({a, b, ...rest} = {a: 10, b: 20, c: 30, d: 40})  
console.log(rest) // -> {c: 30, d: 40}
```



# Digging Deeper

A large, stylized blue graphic of a robot arm or mechanical structure on the left side of the slide, composed of various geometric shapes like circles, rectangles, and lines.

**JS**

**TS**



# Import statement



The static **import** statement is used to import bindings which are exported by a module. This allows the developer to import and use modules which are provided by many thousands of packages in the Javascript & TypeScript ecosystem, primarily with the npm package manager.

The definition of the import statement unfortunately is unwieldy and not that easy to fully grasp. It takes some trial and error to get it right. [The MDN page is required reading](#) The following basic forms are important to know:

Import an entire module contents

```
import * as myModule from './modules/my-module.js';  
myModule.doAllTheAmazingThings();
```

Import a single export from a module

```
import {myExport} from './modules/my-module.js';
```

Import multiple exports from module

```
import {foo, bar} from './modules/my-module.js';
```

Import an **export** with a more convenient alias

```
import {reallyReallyLongModuleExportName as shortName}  
from './modules/my-module.js';
```

Rename **multiple exports** during import

```
import {  
  reallyReallyLongModuleExportName as shortName,  
  anotherLongModuleName as short  
} from './modules/my-module.js';
```

Import a module for its **side effects only**. This runs the module's global code, but doesn't actually import any values.

```
import './modules/my-module.js';
```

It is possible to have a **default export** (whether it is an object, a function, a class, etc.). The import statement may then be used to import such defaults.

```
import myDefault from './modules/my-module.js';  
import myDefault, * as myModule from './modules/my-module.js';  
import myDefault, {foo, bar} from './modules/my-module.js';  
// specific, named imports
```



In node.js the support for ES6 import is only available through optional command line options and the standard is not fully implemented. Node.js uses its own “**require**” function (Common js). Using TypeScript allows skipping that problem as ES6 imports are compiled to “require” statements

# Modules



TypeScript and ECMAScript 201x have a concept of **modules**. Any file containing a top-level import or export is considered a module.

Modules are executed within their own scope, not in the global scope; this means that variables, functions, classes, etc. declared in a module are not visible outside the module unless they are explicitly **exported** using one of the **export forms**.

Conversely, to consume an export (variables, etc.) from a different module, it has to be imported using one of the **import forms** (see: Import Statement=

Examples can be found on the right:

```
export function hello() {  
    return 'Hello World!'  
}  
  
export function hola(){  
    return 'Hola mundo!'  
}
```

```
export default class {  
    public hello() {  
        return 'Hello World!';  
    }  
  
    public hola() {  
        return 'Hola mundo!';  
    }  
}
```

```
import { hello } from './app/services';  
import { hola as spanishhello } from './app/services';  
import * as greetings from './app/services';  
  
import Msg from './app/defaultservices'  
  
console.log(hello())  
console.log(spanishhello())  
console.log(greetings.hello())  
let msg = new Msg()  
console.log(msg.hola())
```

# Asynchronous functions and callbacks



In traditional programming practice, most I/O operations happen synchronously. In the example on the right, the function `readFileSync` is a synchronous and will perform its task until it returns the content of the file.

This is fine for simple scripts but **it is an anti-pattern in node.js**. As node.js is single-threaded, the JavaScript interpreter cannot execute any code while `readFileSync` is executed. Not so much an issue for a throw away script, but fatal for larger applications, for example web api's, who need to respond to many simultaneous requests.

So nearly all I/O functions in the run-time library in both node.js as well as the web browser are **asynchronous**. Asynchronous I/O is a form of input/output processing that permits other processing to continue before the transmission has finished.

An asynchronous functions take a function - a so-called call-back function - which will be executed once the operations is finished. As the asynchronous library functions are not written in Javascript but in C, C++ or Rust (etc), they are executed by multiple threads from the thread-pool of node.js or the browser. It's only the JavaScript which is executed on a single thread!

```
import {readFile} from 'fs'
//const {readFile} = require('fs')

const data = readFileSync("app/ironman.txt", 'utf8')
for(let s of data.split('\n')){
  console.log(s)
}

console.log("you see me first")
readFile("app/ironman.txt", 'utf8', (error, data)=> {
  if (error) throw error
  console.log("you see me last")
  for(let s of data.split('\n')){
    console.log(s)
  }
}))
console.log("you see me second")
```

# Promises



A Promise is an object representing the eventual completion or failure of an asynchronous operation.

Essentially, a promise is a returned object to which you attach callbacks, instead of passing callbacks into a function.

```
import {promisify} from 'util'
import {readFile} from 'fs'
//const {promisify} = require('util');
//const {readFile} = require('fs');

let prnerror = (error)=> {
  console.log(error)
}

console.log("you see me first")
let readFp = promisify(readFile)

readFp("app/ironman.txt", 'utf8').then((data)=> {

  console.log("you see me last")
  for(let s of data.split('\n')){
    console.log(s)
  }
}).catch(prnerror)
```

# Async / Await



Using **async await** makes it possible to use Promises in a reliable and safe way. This method prevents chances of any programming errors.

Writing asynchronous functions is really easy. Just write a function and add the `async` keyword to it like in the example on the right.

Asynchronous functions can use the `await` operator in their bodies. The `await` operator can be attached to any variable. If that variable is not a Promise, the value returned for the `await` operator is the same as the variable.

But if the variable is a Promise, then the execution of the function is paused until it is clear whether the Promise is going to be resolved or rejected.

If the Promise resolves, the value of the `await` operator is the resolved value of Promise, and if the variable is a promise that gets rejected, the `await` operator throws an error in the body of the `async` function which we can catch with `try/catch` constructs.

```
import {promisify} from 'util'
import {readFile} from 'fs'
//const {promisify} = require('util');
//const {readFile} = require('fs');
let readFp = promisify(readFile)

console.log("you see me first")
async function printIronMan() {
  let data = await readFp("app/ironman.txt", 'utf8')
  console.log("you see me last")
  for(let s of data.split('\n')){
    console.log(s)
  }
}
printIronMan()
console.log("you see me last")
```

# let and const are the new var



In earlier versions of JavaScript , a variable can be declared with the **var** keyword after it has been used. In other words; a variable can be used before it has been declared. This behaviour is called “*hoisting*” and is as if all variables are as if defined at the beginning of the function. It is said that these variables have **function scope**.

This causes all kinds of subtle errors and counterintuitive behaviours. With **let** and **const** a more conventional block scope is used for variables (no more “*hoisting*”) which allows for more predictable and more advanced behaviour.

TS

```
//compiles fine
function functionscope(){

    for(i=0;i < 10; i++){
        console.log(i)
    }
    if (true){
        var i = 10000
    }
    console.log(i)
}
//gives error TS2304: Cannot find name 'i'.
function blockscope(){
    //let i;

    for(i=0;i < 10; i++){
        console.log(i)
    }
    if (true){
        let i = 100000
    }
    console.log(i)
}
functionscope()
blockscope()
```

# let is the new var; fixes problem with closures



Using **let** fixes a longstanding problem with **closures**

block scoped references captured in a closure will maintain the value at the moment of capture

That is **NOT** the case with **var** (the reference will point to the last value it was set to)

```
for(var j= 0; j < 10; j++){
  setTimeout(()=> console.log(`setTimeout with var: ${j}`),100)
}
// writes 10 times -> setTimeout with var: 10

for(let k= 0; k < 10; k++){
  setTimeout(()=> console.log(`setTimeout with let: ${k}`),100)
}
// writes  setTimeout with let: 2, setTimeout with let: 1, setTimeout
with let: 2 etc
```

# How constant is const



Use const when you want to denote immutability of a reference (the “variable”)

Notice that objects and arrays are not const. Only their references.

Use *Object.freeze* or Immutable.js (a library) for this.

No compile time, type level, support

TS

```
const co = 100
//ES6 gives error: Assignment to constant variable
//TS gives error TS2540: Cannot assign to 'co'
because it is a constant or a read-only property.
//co = 1000

const co2 = {a: 100}
co2.a = 100000

console.log(co2)
Object.freeze(co2)
//RUN-TIME ERROR: TypeError: Cannot assign to read
only property 'a' of object '#<Object>'
co2.a = 0
```



# TypeScript's Type System



The type system in TypeScript is designed to be **optional** so that your JavaScript is TypeScript.

TypeScript does not stop generating JavaScript code in the presence of type errors, allowing you to progressively update your JS to TS.

But that does mean that TypeScript is not “safe”

But `--noEmitOnError` flag prevents generating JavaScript code when there are Type errors

Therefore: **Types are annotations**; they don't “exist” run-time (**type erasure**)

```
TS let foo = {};  
  
foo.bar = 123; // Error: property 'bar' does not  
exist on `{}`  
console.log(foo.bar)  
  
foo.baz = "ABC" // Error: property 'baz' does not  
exist on `{}`  
console.log(foo.baz)
```

# --strict (TypeScript 2.3)



flag	Meaning
--alwaysStrict	Parse in strict mode and emit "use strict" for each source file
--noImplicitThis	Raise error on this expressions with an implied any type.
--strictNullChecks	Strict null checking mode, the null and undefined values are not in the domain of every type and are only assignable to themselves and any (the one exception being that undefined is also assignable to void).
--noImplicitAny	Raise error on expressions and declarations with an implied any type.
--noImplicitReturns	Report error when not all code paths in function return a value.
	... more ...

TypeScript supports a whole series of “compiler flags” which can be set in tsconfig.json. From version 2.3 on, all flags related with “strict” compilation can be set in with the `--strict` flag. In 2.2 and below the flags need to be set individually.

# Contextual inference



Type inference also works in "the other direction" in some cases in TypeScript. Meaning: not from right-to left, impacting the variable declarations on the left-hand side.

It also work in callbacks. This is known as "contextual typing".

Contextual typing occurs when the type of an expression is implied by its location.

```
import { readFile } from "fs"

readFile("d:/tmp/data.txt", function(err, buf){
    console.log(buf.toString())
})
```

```
readFile(filename: string,
encoding: string,
callback: (err:
NodeJS.ErrnoException, data:
string) => void
): void

1/4 Asynchronous readFile -
readFile("d:/tmp/data.txt",
```

# Best practice



**DRY and don't be verbose: use type inference**

```
let s1 = "lala"
/*NOT*/
let s2: string = "lala"
```

**Avoid the *implicit* usage of *any***

```
--noImplicitAny
```

**Type the parameters of your own non call-back functions.  
Optionally type the return value of the function**

```
function translate(text:string) :string {
    return `¿Eh? ¿Que signifie '${text}'?`
}
function translate2(text:string) {
    return `¿Eh? ¿Que signifie '${text}'?`
}
let s = translate("Blah")
let s2 = translate2("Blah")
```

# Type inference with assignment & declarations



There is a difference in the behaviour of type inference between **declarations** (“let”) with their corresponding *initializers* and **assignment**.

In the example assignment works but the variable initializer must exactly match the structure of Named, i.e. the Object literal may only specify known properties, and 'surname' does not exist in type 'Named'

```
TS interface Named {  
    name: string;  
}  
let p: Named;  
    // also with anonymous objects  
let o = { name: "Olaf" , surname: "Leifson"}  
p = o;  
console.log(p)  
  
    // compile error  
    //let n : Named = { name: "Olaf" , surname:  
    "Leifson"}
```

# Decorators



A **Decorator** is a special kind of declaration that can be attached to a *class declaration, method, accessor, property, or parameter*. Decorators use the form **@expression**, where expression must evaluate to a function that will be called at runtime with information about the decorated declaration.

It is a form of **meta-programming** which follows the model as set by *Decorators* in Python, i.e. they are actively executing functions, rather than the model followed by *Annotations* in Java (objects as passive meta-data)

The application of Decorators is an “experimental” feature of EcmaScript / TypeScript. It may change but it is unlikely to disappear (as many important libraries like Angular are already depending on it).

Decorators are an advanced topic and extremely powerful but also very “magical”, complex and therefore fraught with danger. Use with care.

TS

```
function log(target: any, key: string, value: any) {
    return {
        value(...args: any[]) {
            const result = value.value.apply(this, args)
            console.log(`method: '${key}' called with arguments
'${args}' and with result: '${result}'`)
            return result
        }
    }
}

class Demo {
    @log
    public say(...args: string[]) {
        console.log("Inside say with arguments: ", args)
        return 100
    }
}

let d = new Demo()
d.say("Booh", "Lala")
d.say("Bah")
```

# Links



<https://www.javascripttutorial.net/es6/>

<https://codetower.github.io/es6-features/>

<http://es6-features.org/>

<https://medium.com/@harisbaig100/things-to-keep-in-mind-while-moving-from-es3-es5-to-es6-javascript-12e6ea2acafa>

<https://mariusschulz.com/blog>

<https://github.com/techfort/LokiJS>

<https://dev.to/robertcoopercode/using-eslint-and-prettier-in-a-typescript-project-53jb>

<https://htmlcheatsheet.com/js/>

<https://www.typescriptlang.org/docs/handbook/declaration-files/do-s-and-don-ts.html#general-types>

<https://khalilstemmler.com/articles/typescript-domain-driven-design/make-illegal-states-unrepresentable/>



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