HOW JAVASCRIPT WORKS BEHIND THE SCENES

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THE COMPLETE JAVASCRIPT COURSE

FROM ZERO TO EXPERT!

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SECTION

HOW JAVASCRIPT WORKS BEHIND THE SCENES

LECTURE

AN HIGH-LEVEL OVERVIEW OF JAVASCRIPT

JS

WHAT IS JAVASCRIPT: REVISITED

JAVASCRIPT

JAVASCRIPT IS A HIGH-LEVEL, OBJECT-ORIENTED, MULTI-PARADIGM PROGRAMMING LANGUAGE.

WHAT IS JAVASCRIPT: REVISITED

JAVASCRIPT

JAVASCRIPT IS A HIGH-LEVEL, PROTOTYPE-BASED OBJECT-ORIENTED, MULTI-PARADIGM, INTERPRETED OR JUST-IN-TIME COMPILED, DYNAMIC, SINGLE-THREADED, GARBAGE-COLLECTED PROGRAMMING LANGUAGE WITH FIRST-CLASS FUNCTIONS AND A NON-BLOCKING EVENT LOOP CONCURRENCY MODEL. 🤔 🤯 🤣

DECONSTRUCTING THE MONSTER DEFINITION

- High-level
- Garbage-collected
- Interpreted or just-in-time compiled
- Multi-paradigm
- Prototype-based object-oriented
- First-class functions
- Dynamic
- Single-threaded
- Non-blocking event loop

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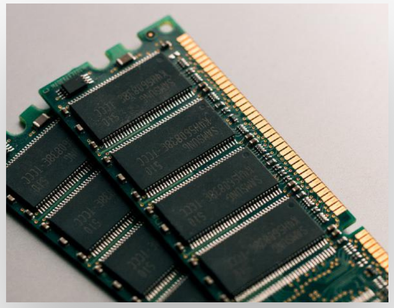
👉 **Any computer program needs resources:**



+

LOW-LEVEL

Developer has to manage resources **manually**

HIGH-LEVEL

Developer does **NOT** have to worry, everything happens automatically

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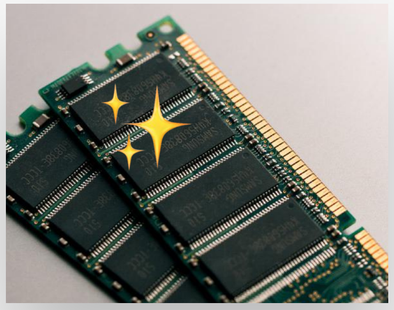

Cleaning the memory
so we don’t have to

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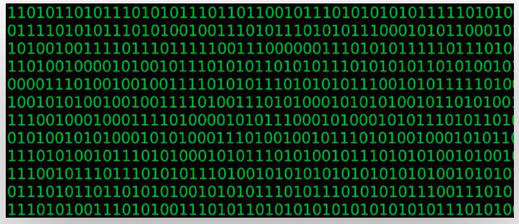
```
document.querySelector(".again").addEventListener("click", () => {
  document.querySelector(".message").textContent = "Start guessing...";
  document.querySelector(".number").textContent = "?";
  document.querySelector(".guess").value = "";
  score = 20;
  document.querySelector(".score").textContent = score;
  number = Math.floor(Math.random() * 20) + 1;
});
```

Abstraction over 0s and 1s

CONVERT TO MACHINE CODE = COMPILING



Happens inside the JavaScript engine

More about this **Later in this Section** 👇

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👉 **Paradigm**: An approach and mindset of structuring code, which will direct your coding style and technique.

The one we've been using so far

1. Procedural programming
2. Object-oriented programming (OOP)
3. Functional programming (FP)

☝️ **Imperative vs.**
👋 **Declarative**

More about this later in **Multiple Sections** 👉

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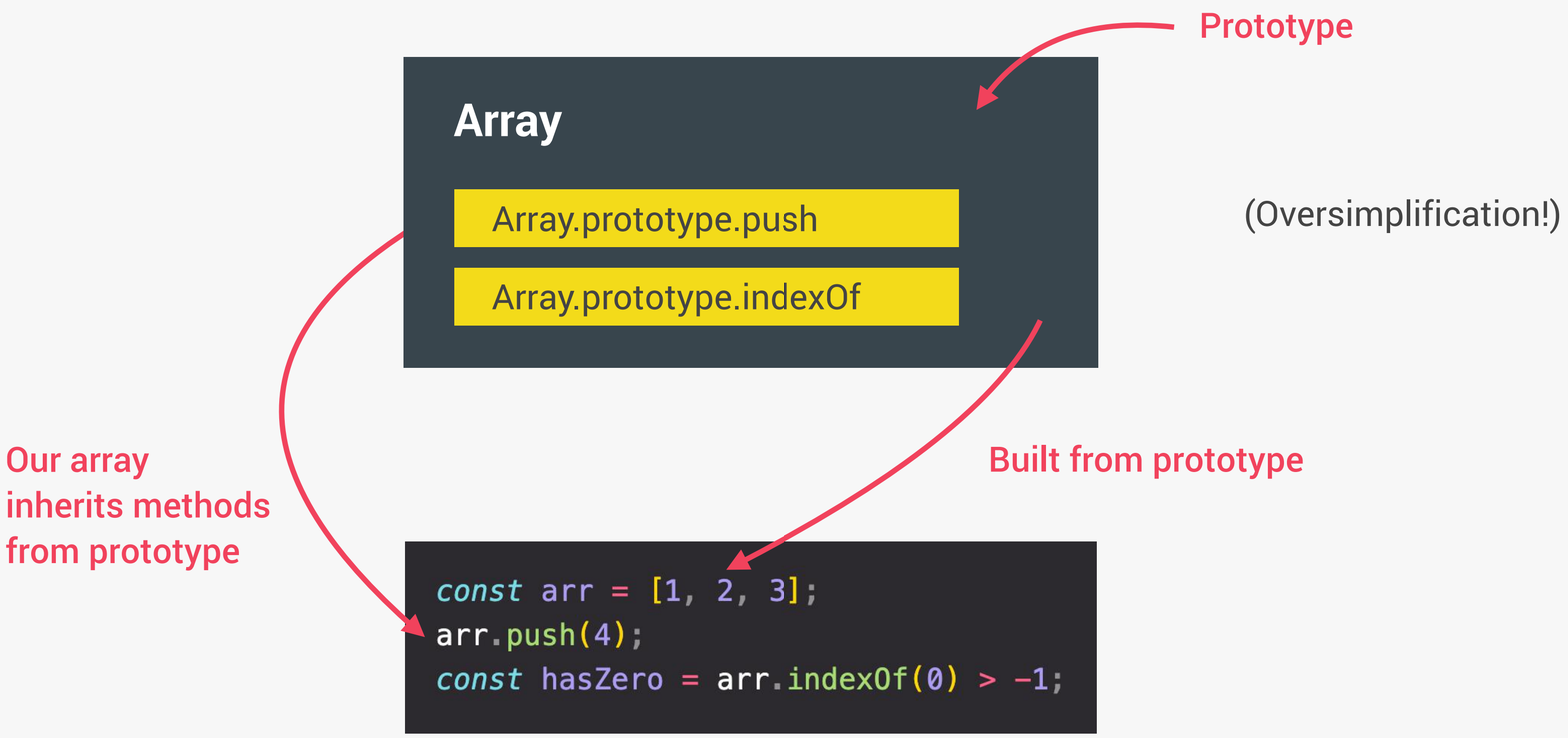

More about this in Section **Object Oriented Programming** 👉

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👉 In a language with **first-class functions**, functions are simply **treated as variables**. We can pass them into other functions, and return them from functions.

```
const closeModal = () => {
  modal.classList.add("hidden");
  overlay.classList.add("hidden");
};

overlay.addEventListener("click", closeModal);
```

Passing a function into another function as an argument: First-class functions!

More about this in Section **A Closer Look at Functions** 👉

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👉 **Dynamically-typed language:**

No data type definitions. Types becomes known at runtime

Data type of variable is automatically changed

```
let x = 23;
let y = 19;
x = "Jonas";
```

TS

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👉 **Concurrency model**: how the JavaScript engine handles multiple tasks happening at the same time.

↓ Why do we need that?

👉 JavaScript runs in one **single thread**, so it can only do one thing at a time.

↓ So what about a long-running task?

👉 Sounds like it would block the single thread. However, we want non-blocking behavior!

↓ How do we achieve that?

(Oversimplification!)

👉 By using an **event loop**: takes long running tasks, executes them in the "background", and puts them back in the main thread once they are finished.

More about this **Later in this Section** 👇

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SECTION

HOW JAVASCRIPT WORKS BEHIND THE SCENES

LECTURE

THE JAVASCRIPT ENGINE AND RUNTIME

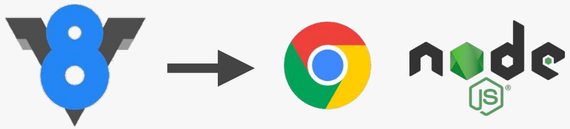
JS

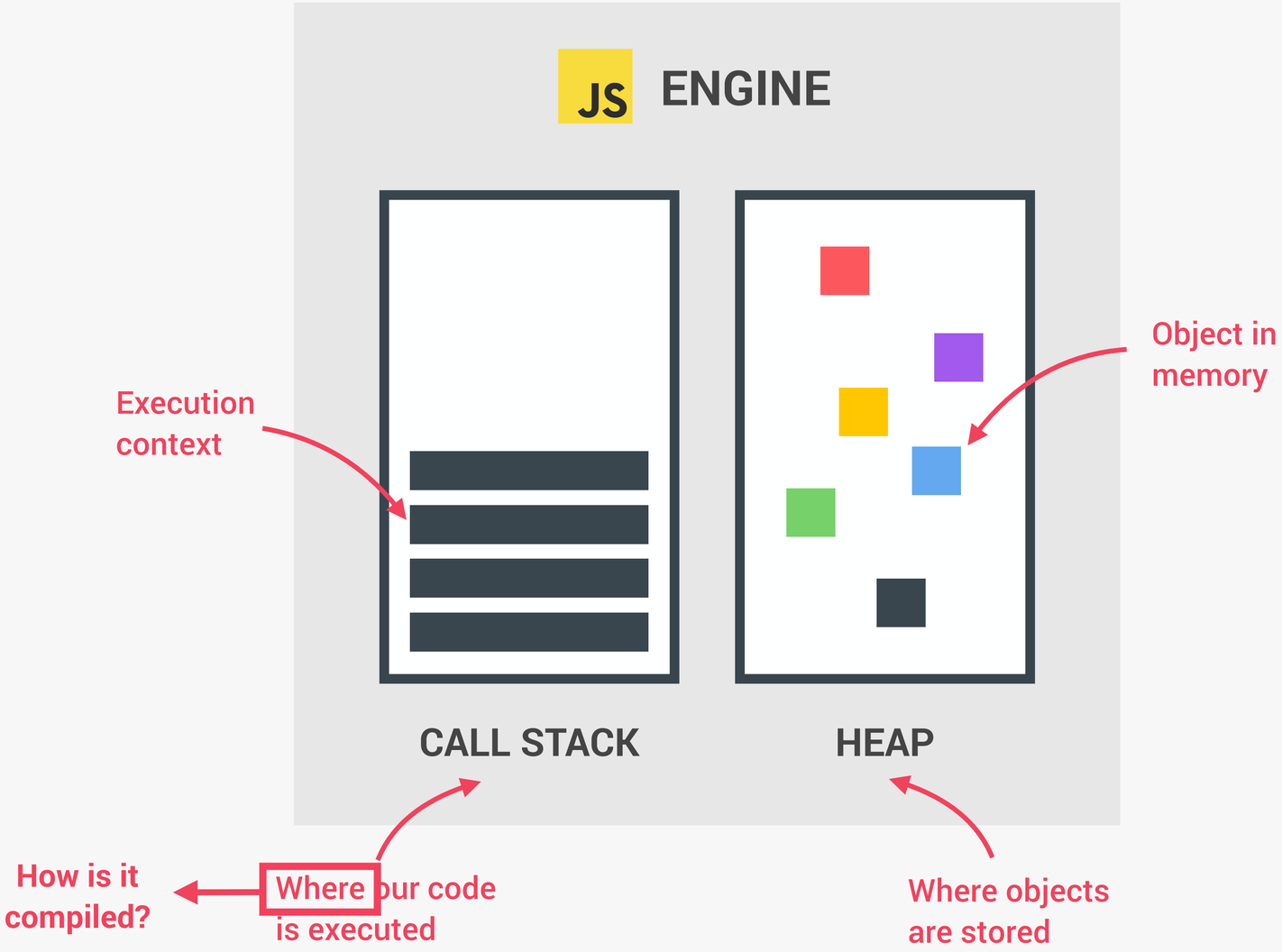
WHAT IS A JAVASCRIPT ENGINE?

JS ENGINE

PROGRAM THAT **EXECUTES** JAVASCRIPT CODE.

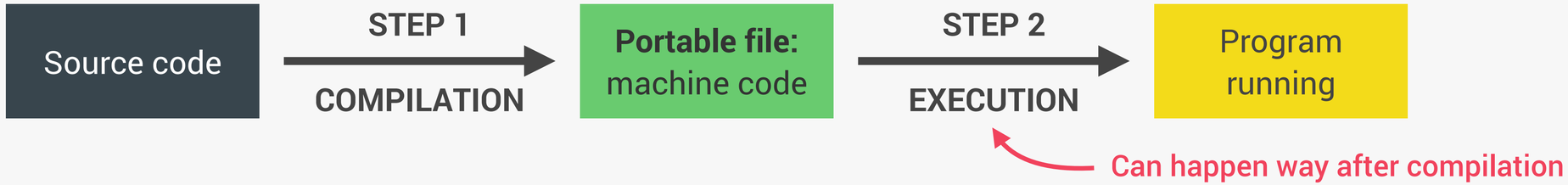
👉 **Example: V8 Engine**



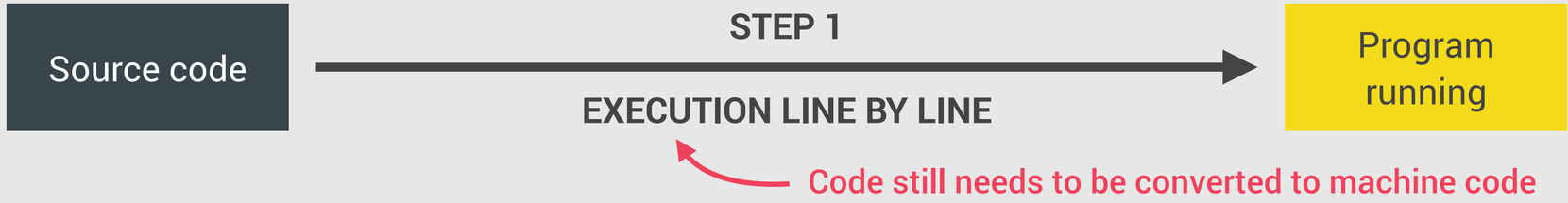


COMPUTER SCIENCE SIDENOTE: COMPILATION VS. INTERPRETATION 🤓

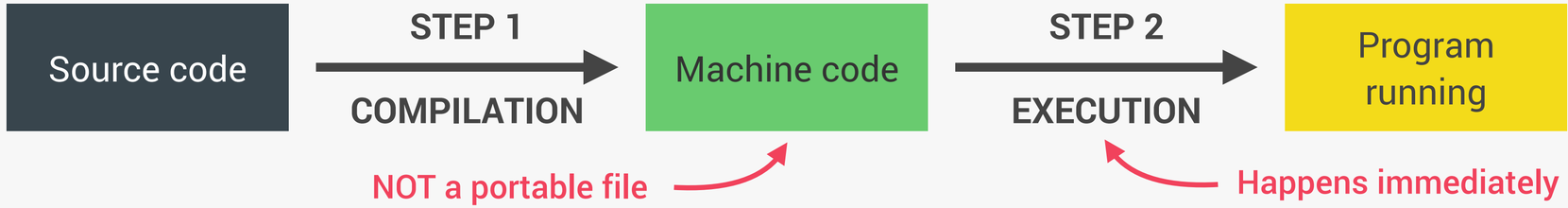
👉 **Compilation:** Entire code is converted into machine code at once, and written to a binary file that can be executed by a computer.



👉 **Interpretation:** Interpreter runs through the source code and executes it line by line.



👉 **Just-in-time (JIT) compilation:** Entire code is converted into machine code at once, then executed immediately.



MODERN JUST-IN-TIME COMPILATION OF JAVASCRIPT

```
document.querySelector(".again").addEventListener("click", () => {
  document.querySelector(".message").textContent = "Start guessing...";
  document.querySelector(".number").textContent = "?";
  document.querySelector(".guess").value = "";
});
```

~~"JavaScript is an interpreted language"~~

JS ENGINE

Happens in special threads that we can't access from code

Parsing

AST

Example

Compilation

Just-in-time compilation

Optimization

Execution

Happens in Call Stack

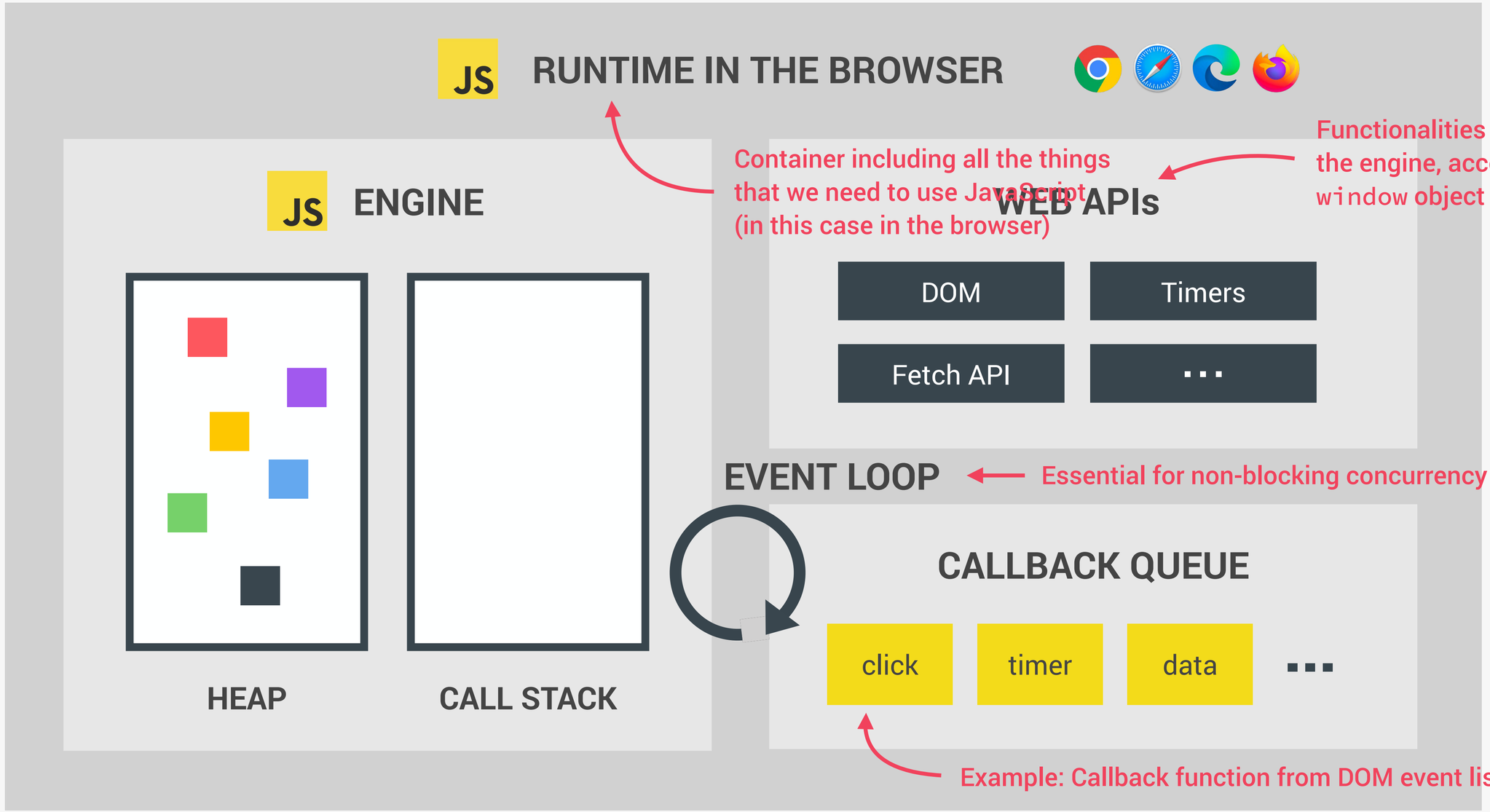
During execution!

👉 AST Example

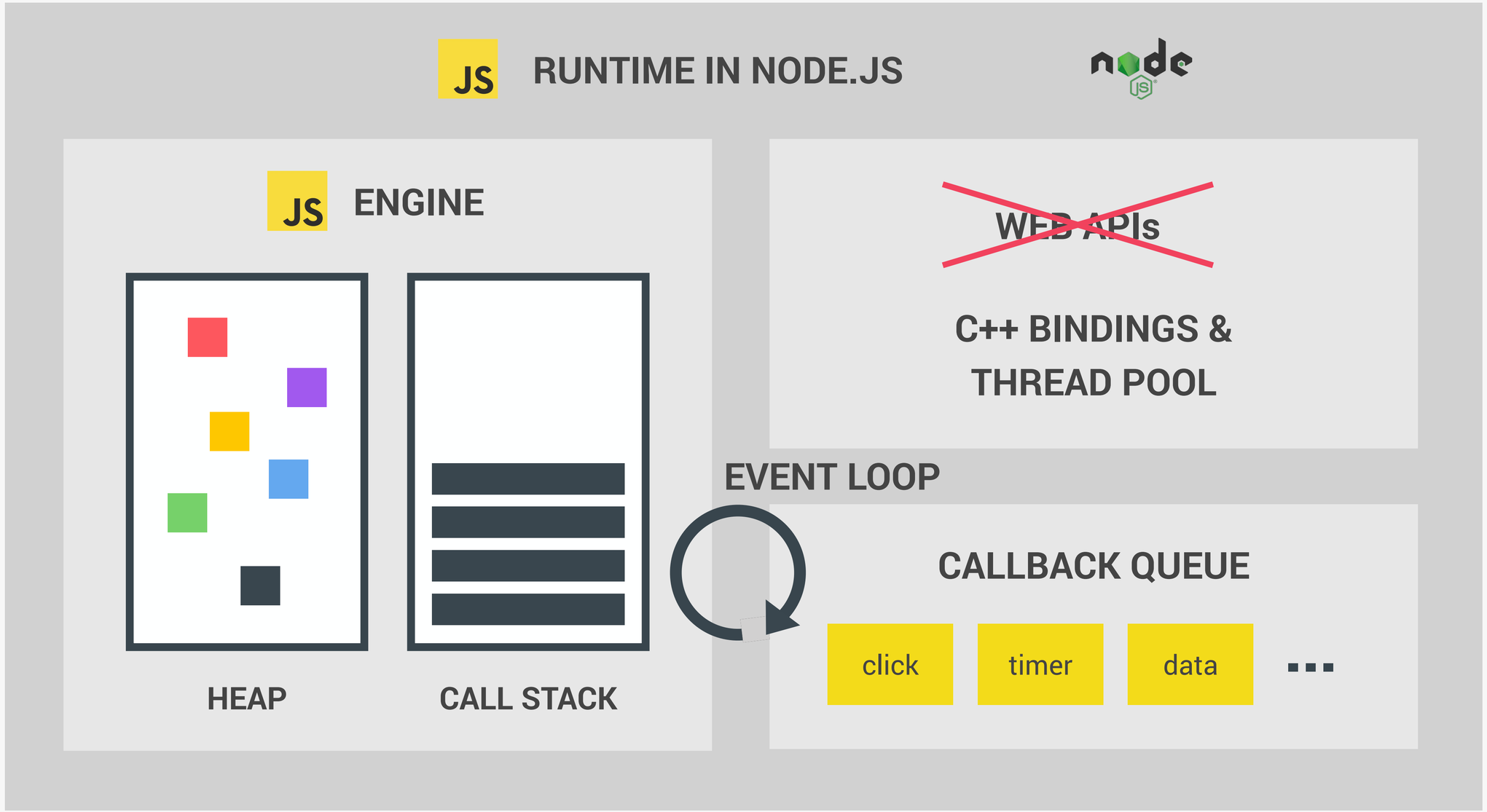
```
const x = 23;
```

```
- VariableDeclaration {
    start: 0
    end: 13
  - declarations: [
    - VariableDeclarator {
        start: 6
        end: 12
      - id: Identifier {
          start: 6
          end: 7
          name: "x"
        }
      - init: Literal = $node {
          start: 10
          end: 12
          value: 23
          raw: "23"
        }
    }
  ]
  kind: "const"
```

THE BIGGER PICTURE: JAVASCRIPT RUNTIME



THE BIGGER PICTURE: JAVASCRIPT RUNTIME



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SECTION

HOW JAVASCRIPT WORKS BEHIND THE SCENES

LECTURE

EXECUTION CONTEXTS AND THE CALL STACK

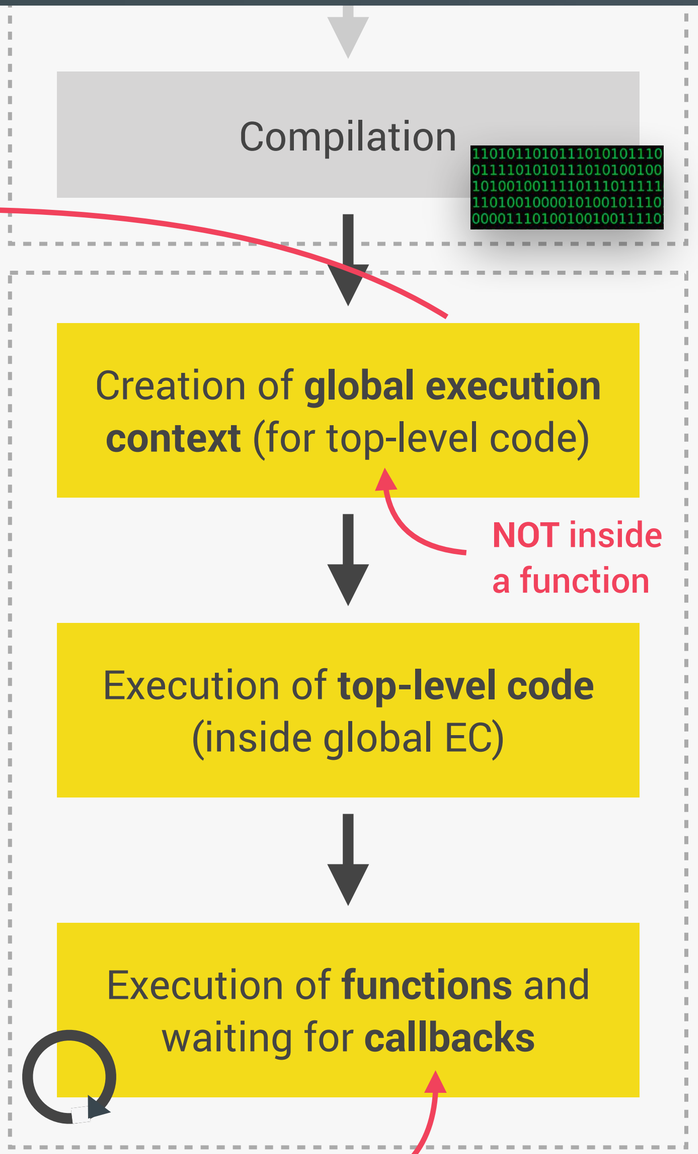
JS

WHAT IS AN EXECUTION CONTEXT?

👉 Human-readable code:

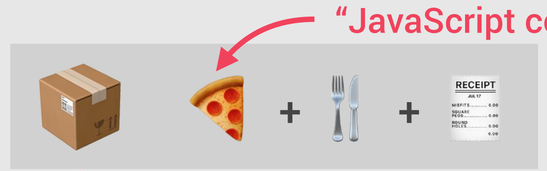
```
const name = 'Jonas';

const first = () => {
  let a = 1;
  const b = second();
  a = a + b;
  return a;
};

function second() {
  var c = 2;
  return c;
}
```

Function body only executed when called!



EXECUTION CONTEXT

Environment in which a piece of JavaScript is executed. Stores all the necessary information for some code to be executed.



👉 **Exactly <u>one</u> global execution context (EC):** Default context, created for code that is not inside any function (top-level).

👉 **One execution context <u>per function</u>:** For each function call, a new execution context is created.

All together make the call stack

EXECUTION CONTEXT IN DETAIL

WHAT'S INSIDE EXECUTION CONTEXT?

1. Variable Environment
   - 👉 `let`, `const` and `var` declarations
   - 👉 Functions
   - 👉 ~~`arguments`~~ object
2. Scope chain
3. ~~this~~ keyword

NOT in arrow functions!

Generated during “creation phase”, right before execution

```
const name = 'Jonas';

const first = () => {
  let a = 1;
  const b = second(7, 9);
  a = a + b;
  return a;
};

function second(x, y) {
  var c = 2;
  return c;
}

const x = first();
```

Global

```
name = ‘Jonas’
first = <function>
second = <function>
x = <unknown>
```

Literally the function code

Need to run `first()` first

first()

```
a = 1
b = <unknown>
```

Need to run `second()` first

second()

```
c = 2
arguments = [7, 9]
```

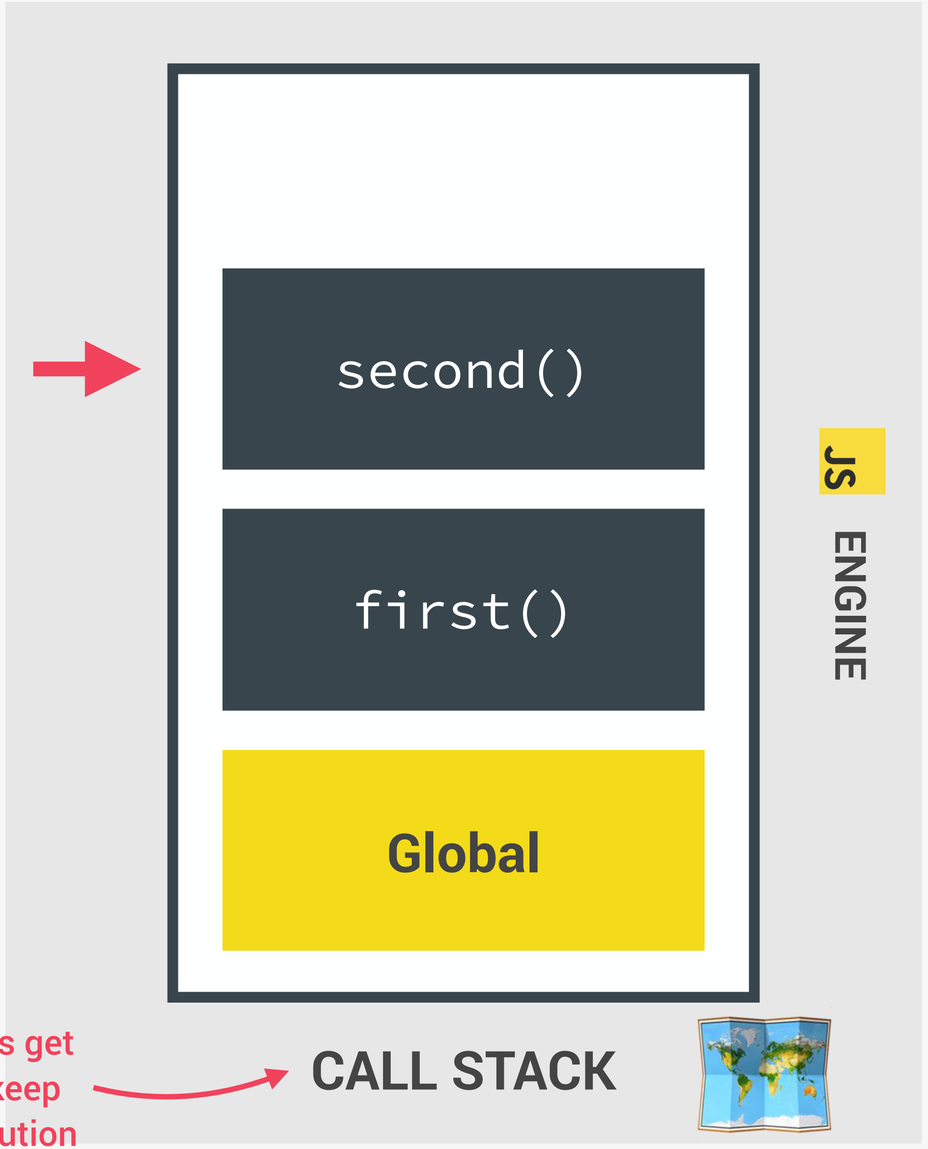
Array of passed arguments. Available in all “regular” functions (not arrow)

(Technically, values only become known during execution)

THE CALL STACK

👉 Compiled code starts execution

```
const name = 'Jonas';

const first = () => {
  let a = 1;
  const b = second(7, 9);
  a = a + b;
  return a;
};

function second(x, y) {
  var c = 2;
  return c;
}

const x = first();
```



"Place" where execution contexts get stacked on top of each other, to keep track of where we are in the execution

CALL STACK

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LECTURE

SCOPE AND THE SCOPE CHAIN

JS

SCOPING AND SCOPE IN JAVASCRIPT: CONCEPTS

EXECUTION CONTEXT

- 👉 Variable environment
- 👉 Scope chain
- 👉 `this` keyword

SCOPE CONCEPTS

- 👉 **Scoping:** How our program's variables are **organized** and **accessed**. *"Where do variables live?"* or *"Where can we access a certain variable, and where not?"*;
- 👉 **Lexical scoping:** Scoping is controlled by **placement** of functions and blocks in the code;
- 👉 **Scope:** Space or environment in which a certain variable is **declared** (*variable environment in case of functions*). There is **global** scope, **function** scope, and **block** scope;
- 👉 **Scope of a variable:** Region of our code where a certain variable can be **accessed**.

THE 3 TYPES OF SCOPE

GLOBAL SCOPE

```
const me = 'Jonas';
const job = 'teacher';
const year = 1989;
```

- 👉 Outside of **any** function or block
- 👉 Variables declared in global scope are accessible **everywhere**

FUNCTION SCOPE

```
function calcAge(birthYear) {
  const now = 2037;
  const age = now - birthYear;
  return age;
}

console.log(now); // ReferenceError
```

- 👉 Variables are accessible only **inside function**, **NOT** outside
- 👉 Also called local scope

BLOCK SCOPE (ES6)

```
if (year >= 1981 && year <= 1996) {
  const millenial = true;
  const food = 'Avocado toast';
}
```

Example: `if` block, `for` loop block, etc.

```
console.log(millenial); // ReferenceError
```

- 👉 Variables are accessible only **inside block** (block scoped)
- ⚠️ **HOWEVER**, this only applies to **`let`** and **`const`** variables!
- 👉 Functions are **also block scoped** (only in strict mode)

THE SCOPE CHAIN

```
const myName = 'Jonas';

function first() {
  const age = 30;

  if (age >= 30) {  // true
    const decade = 3;
    var millenial = true;
  }

  function second() {
    const job = 'teacher';

    console.log(`${myName} is a ${age}-old ${job}`);
    // Jonas is a 30-old teacher
  }

  second();
}

first();
```

let and const are **block-scoped**

var is **function-scoped**

Variables not in current scope

(Considering only variable declarations)

VARIABLE LOOKUP IN SCOPE CHAIN

Global variable

Global scope

`myName = "Jonas"`

SCOPE CHAIN

first() scope

`age = 30`
`millennial = true`

`myName = "Jonas"`

Scope has access to variables from all outer scopes

if block scope

`decade = 3`

`age = 30`
`millennial = true`

`myName = "Jonas"`

second() scope

`job = "teacher"`

`age = 30`
`millennial = true`

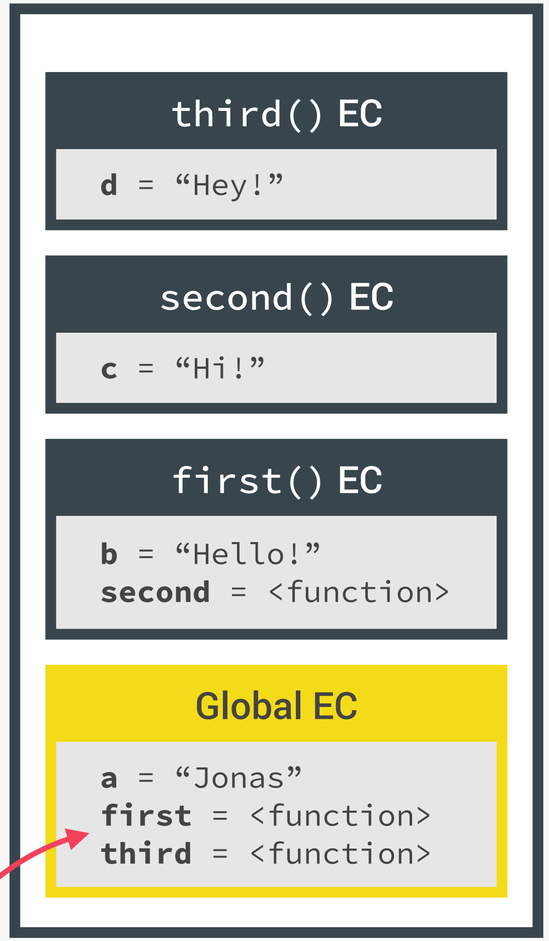
`myName = "Jonas"`

SCOPE CHAIN VS. CALL STACK

```
const a = 'Jonas';
first();

function first() {
  const b = 'Hello!';
  second();

  function second() {
    const c = 'Hi!';
    third();
  }
}

function third() {
  const d = 'Hey!';
  console.log(d + c + b + a);
  // ReferenceError
}
```

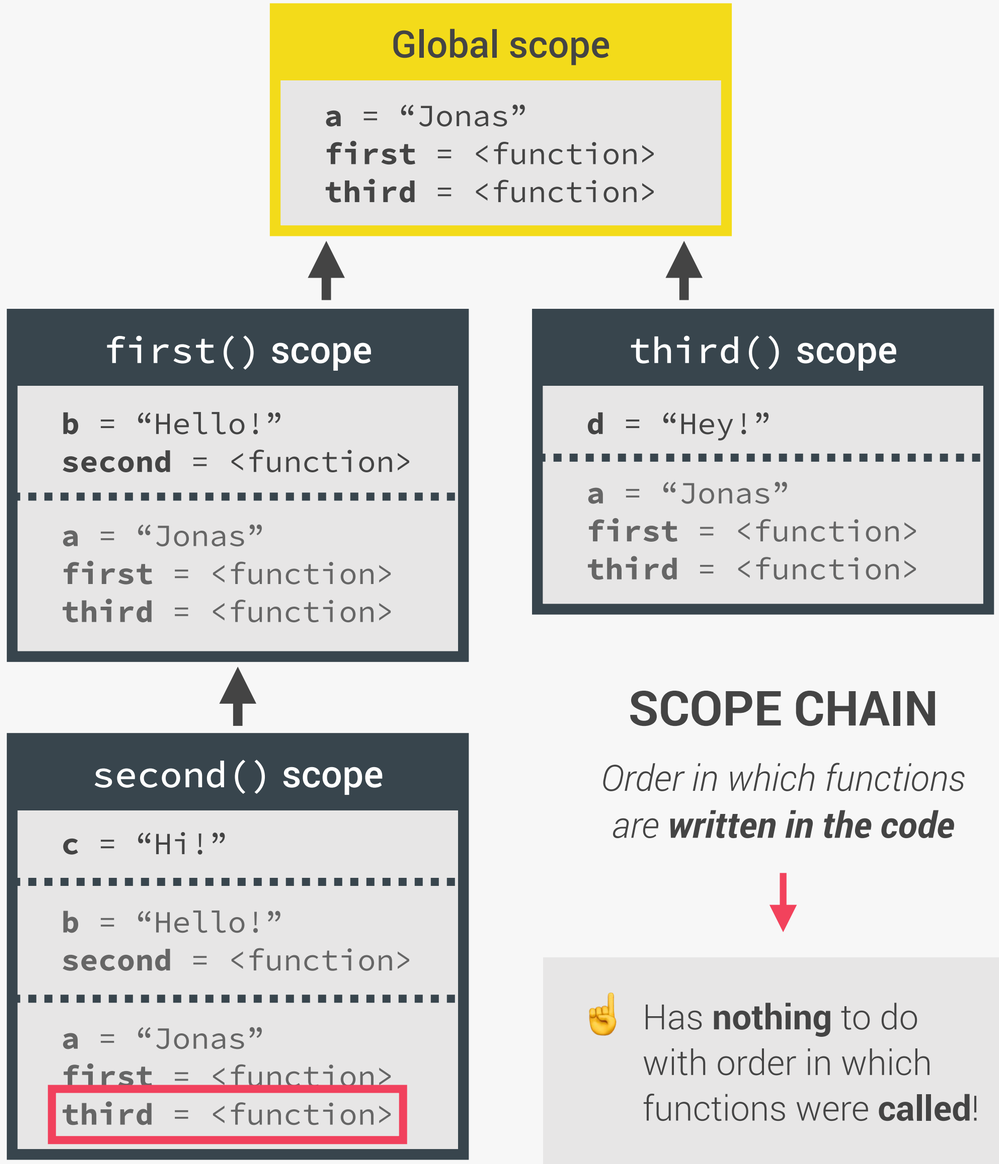
c and b can NOT be found in third() scope!

Variable environment (VE)



CALL STACK

*Order in which functions were **called***



SCOPE CHAIN

*Order in which functions are **written in the code***

☝ Has **nothing** to do with order in which functions were **called**!

SUMMARY 🥳

- 👉 Scoping asks the question *“Where do variables live?”* or *“Where can we access a certain variable, and where not?”*;
- 👉 There are 3 types of scope in JavaScript: the global scope, scopes defined by functions, and scopes defined by blocks;
- 👉 Only `let` and `const` variables are block-scoped. Variables declared with `var` end up in the closest function scope;
- 👉 In JavaScript, we have lexical scoping, so the rules of where we can access variables are based on exactly where in the code functions and blocks are written;
- 👉 Every scope always has access to all the variables from all its outer scopes. This is the scope chain!
- 👉 When a variable is not in the current scope, the engine looks up in the scope chain until it finds the variable it’s looking for. This is called variable lookup;
- 👉 The scope chain is a one-way street: a scope will never, ever have access to the variables of an inner scope;
- 👉 The scope chain in a certain scope is equal to adding together all the variable environments of the all parent scopes;
- 👉 The scope chain has nothing to do with the order in which functions were called. It does not affect the scope chain at all!

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VARIABLE ENVIRONMENT: HOISTING AND THE TDZ

JS

HOISTING IN JAVASCRIPT

👉 **Hoisting:** Makes some types of variables accessible/usable in the code before they are actually declared. “Variables lifted to the top of their scope”.

BEHIND THE SCENES

Before execution, code is scanned for variable declarations, and for each variable, a new property is created in the **variable environment object**.

EXECUTION CONTEXT

- 👉 Variable environment
- ✅ Scope chain
- 👉 `this` keyword

	HOISTED? 👇	INITIAL VALUE 👇	SCOPE 👇
`function` declarations	✅ YES	Actual function	Block
`var` variables	✅ YES	`undefined`	Function
`let` and `const` variables	🚫 NO	`<uninitialized>`, TDZ	Block
`function` expressions and arrows	🤷‍♂️ Depends if using `var` or `let/const`		

In strict mode. Otherwise: function!

Technically, yes. But not in practice

Temporal Dead Zone

TEMPORAL DEAD ZONE, LET AND CONST

```
const myName = 'Jonas';

if (myName === 'Jonas') {
  console.log(`Jonas is a ${job}`);
  const age = 2037 - 1989;
  console.log(age);
  const job = 'teacher';
  console.log(x);
}
```

TEMPORAL DEAD ZONE FOR `job` VARIABLE

👉 **Different kinds of error messages:**

```
ReferenceError: Cannot access 'job' before initialization
ReferenceError: x is not defined
```

WHY HOISTING?

👉 **Using functions before actual declaration;**

👉 `var` hoisting is just a byproduct.

WHY TDZ?

👉 **Makes it easier to avoid and catch errors:** accessing variables before declaration is bad practice and should be avoided;

👉 **Makes `const` variables actually work**

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THE THIS KEYWORD

JS

HOW THE THIS KEYWORD WORKS

👉 **`this` keyword/variable:** Special variable that is created for every execution context (every function). Takes the value of (points to) the "owner" of the function in which the `this` keyword is used.

☝️ `this` is **NOT** static. It depends on **how** the function is called, and its value is only assigned when the function **is actually called**.

EXECUTION CONTEXT

- ✅ Variable environment
- ✅ Scope chain
- 👉 `this` keyword

Method 👉 `this` = <Object that is calling the method>

Simple function call 👉 `this = undefined`

In strict mode! Otherwise: `window` (in the browser)

Don't get own `this`

Arrow functions 👉 `this` = <`this` of surrounding function (lexical `this`)>

Event listener 👉 `this` = <DOM element that the handler is attached to>

`new`, `call`, `apply`, `bind` 👉 *<Later in the course... ⏳>*

☝️ `this` does **NOT** point to the function itself, and also **NOT** the its variable environment!

👉 Method example:

```
const jonas = {
  name: 'Jonas',
  year: 1989,
  calcAge: function() {
    return 2037 - this.year;
  }
};
jonas.calcAge(); // 48
```

`calcAge` is method

`jonas`

`1989`

Way better than using `jonas.year`!

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GOT QUESTIONS? FEEDBACK?

JUST POST IT IN THE Q&A OF THIS VIDEO, AND YOU WILL GET HELP THERE!

JS

JONAS.IO
SCHMEDTMANN

THE COMPLETE JAVASCRIPT COURSE

FROM ZERO TO EXPERT!

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SECTION

HOW JAVASCRIPT WORKS BEHIND THE SCENES

LECTURE

PRIMITIVES VS. OBJECTS (PRIMITIVE VS. REFERENCE TYPES)

JS

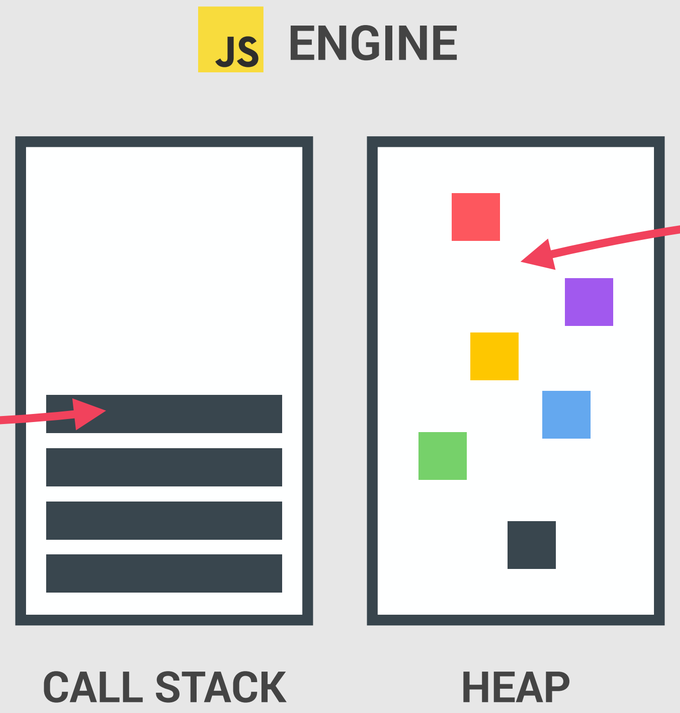
REVIEW: PRIMITIVES, OBJECTS AND THE JAVASCRIPT ENGINE

PRIMITIVES

- 👉 Number
- 👉 String
- 👉 Boolean
- 👉 Undefined
- 👉 Null
- 👉 Symbol
- 👉 BigInt

PRIMITIVE TYPES

STORED IN



STORED IN

OBJECTS

- 👉 Object literal
- 👉 Arrays
- 👉 Functions
- 👉 Many more...

REFERENCE TYPES

PRIMITIVE VS. REFERENCE VALUES

👉 **Primitive** values example:

```
let age = 30;
let oldAge = age;
age = 31;
console.log(age); // 31
console.log(oldAge); // 30
```

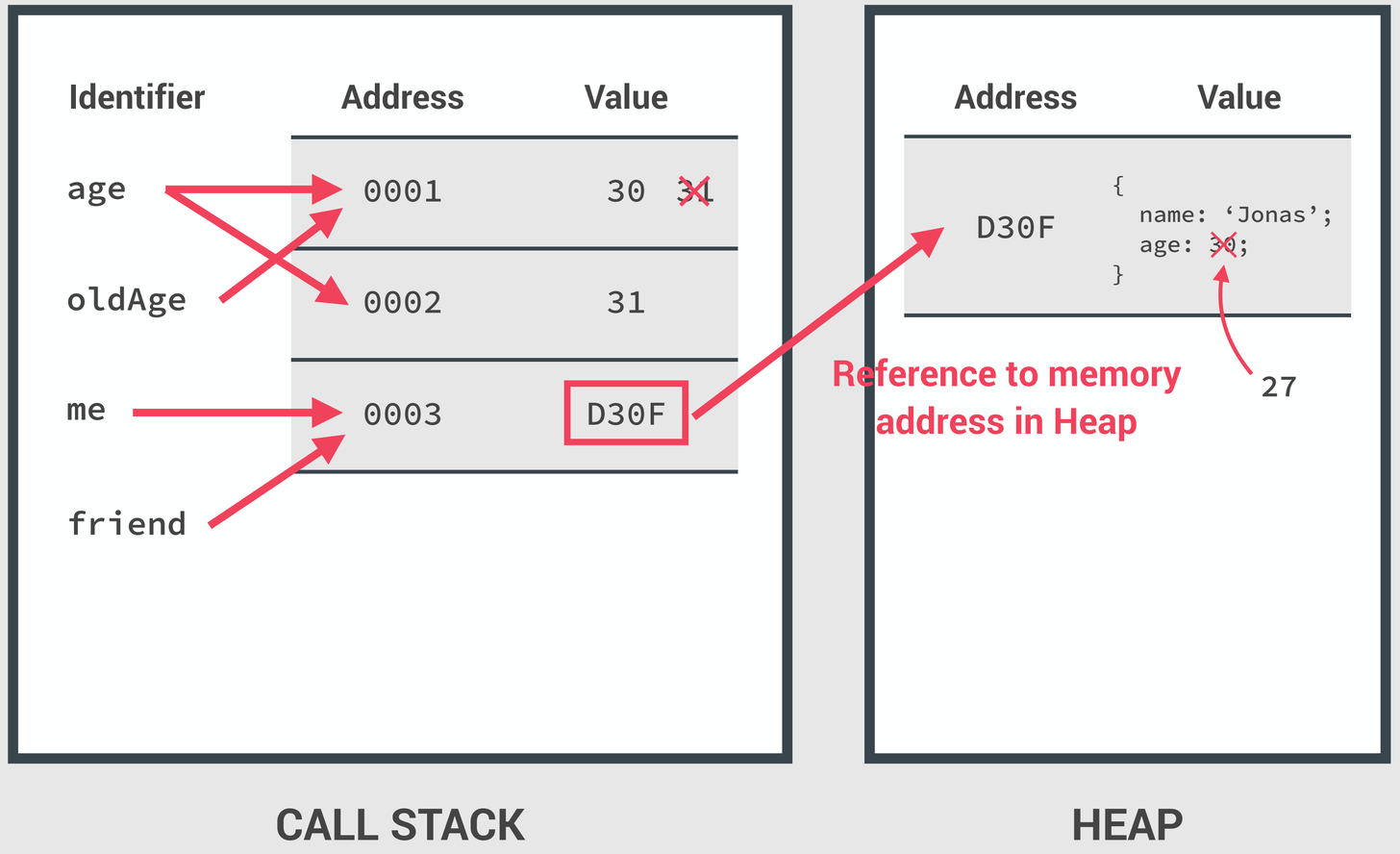
👉 **Reference** values example:

```
const me = {
  name: 'Jonas'
  age: 30
};
const friend = me;
friend.age = 27;

console.log('Friend:', friend);
// { name: 'Jonas', age: 27 }

console.log('Me:', me);
// { name: 'Jonas', age: 27 }
```

No problem, because we're NOT changing the ***value*** at address `0003`!



"HOW JAVASCRIPT WORKS BEHIND THE SCENES" TOPICS FOR LATER... ⏳

1. **Prototypal Inheritance** 👉 Object Oriented Programming (OOP) With JavaScript
2. **Event Loop** 👉 Asynchronous JavaScript: Promises, Async/Await and AJAX
3. **How the DOM Really Works** 👉 Advanced DOM and Events