GraalVM

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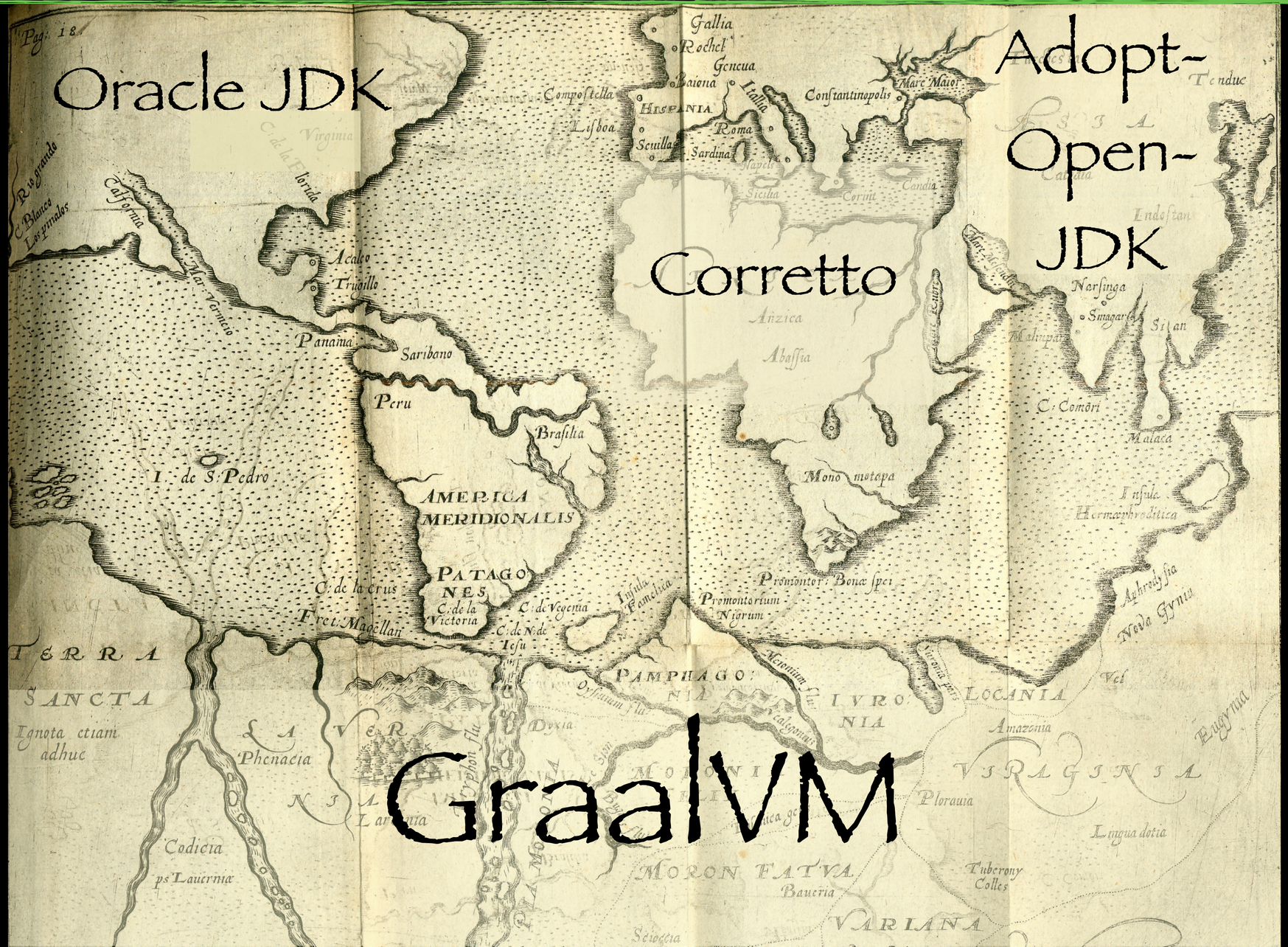
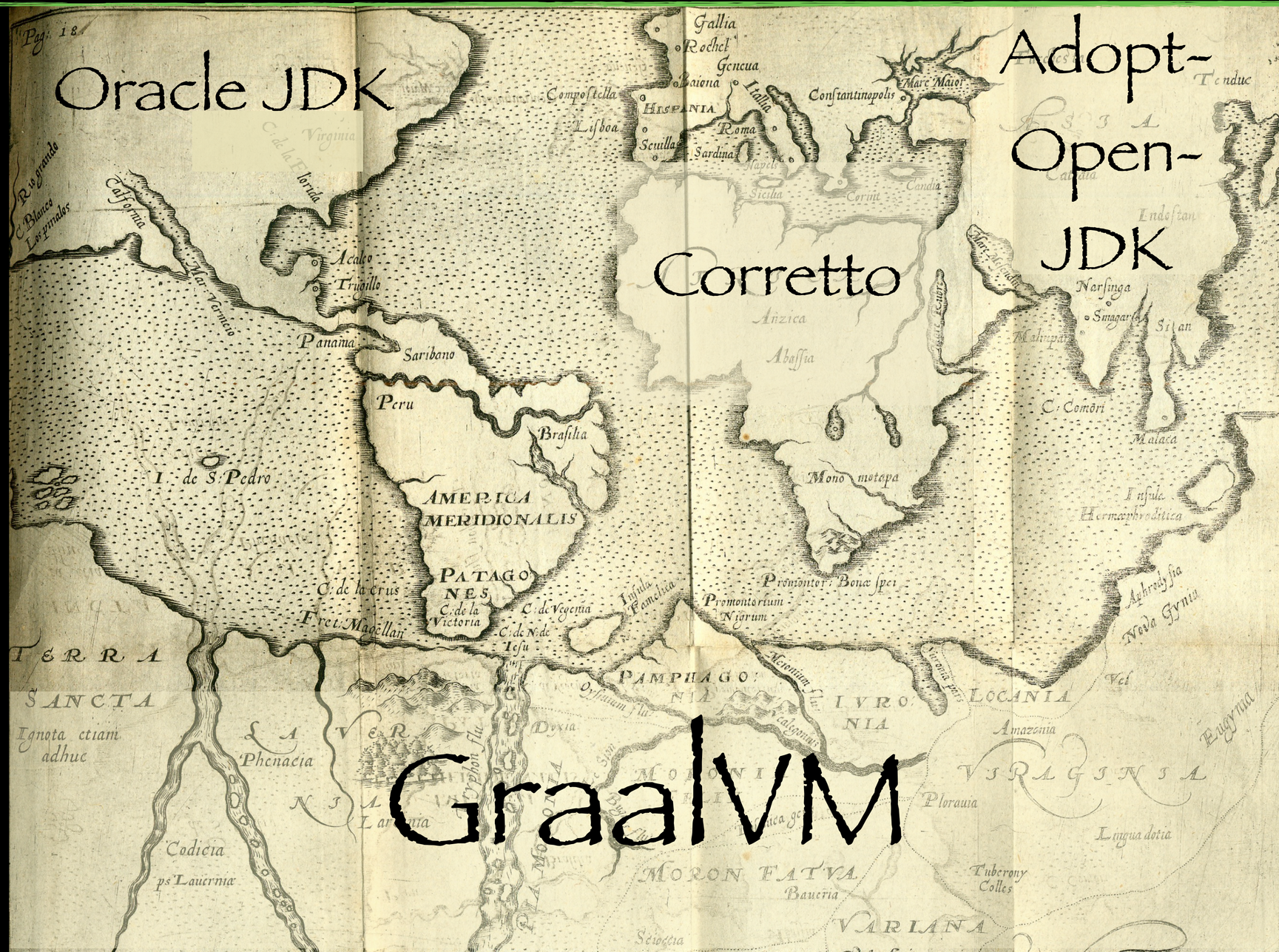
What is GraalVM?

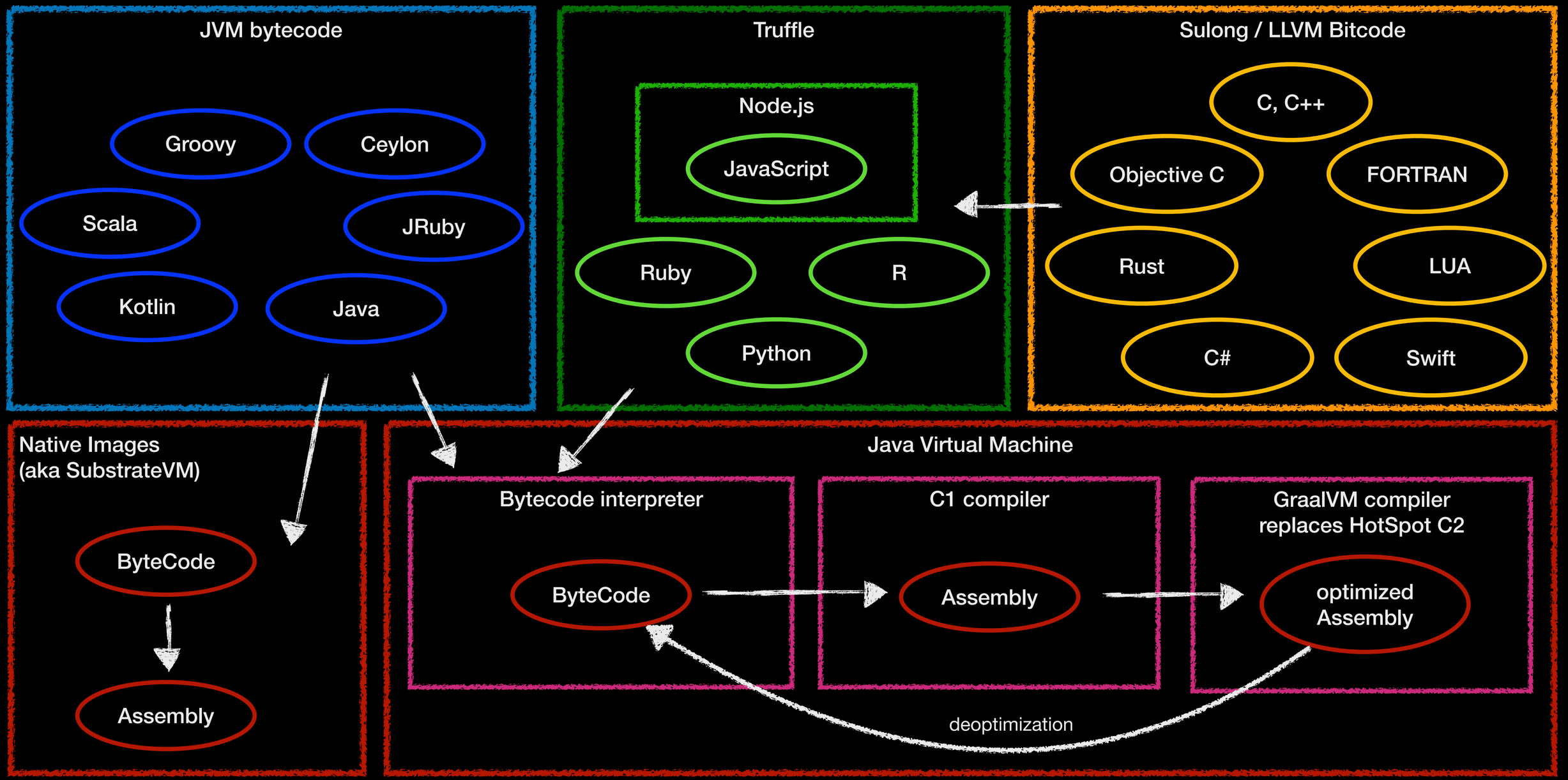


What is GraalVM?

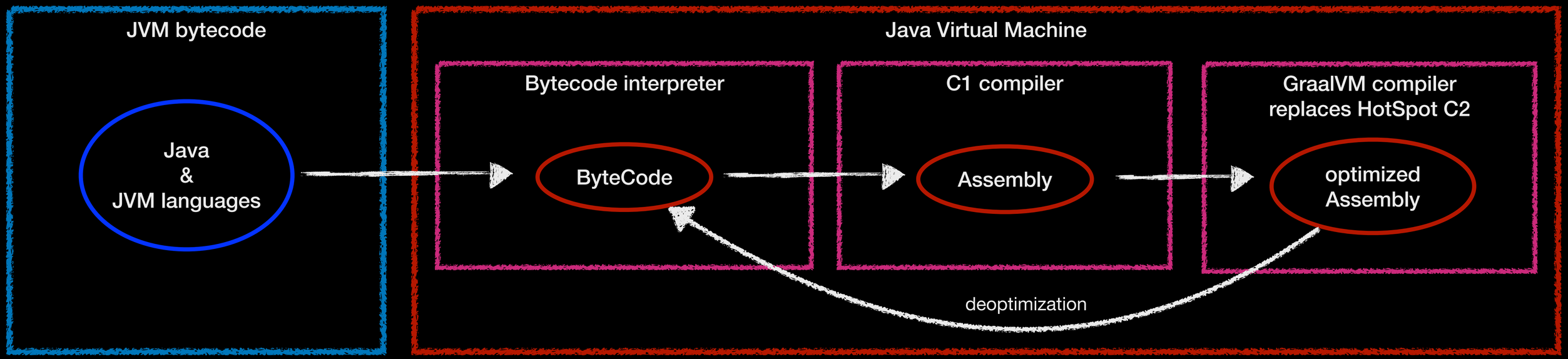
- All-new compiler
- Polyglot programming
- AOT compiler
- LLVM runtime
- Web Assembly



GraalVM at a Glance



All-New Compiler



- New compiler, written in Java
- Plug-in replacement to the OpenJDK compiler
- Getting rid of the weight of 20+ years of development
- Support new programming paradigms from day one

New & Updated Programming Paradigms

Just a few changes of the last couple of decades:

- Functional programming
  - Replacing for loops by chains of Lambdas
- Test automation
  - Megamorphism only during tests
- Dawn of the application servers
- Rise of Kotlin and Scala (among others)

New Optimizations for a New Compiler

- Aggressive inlining
- Partial Escape Analysis
- Data Flow Analysis
- Inter-Procedural Optimization
- Eliminating the price of megamorphism
- Functional programming (almost) for free
- and 60+ more

Partial Escape Analysis

- Todo: code example
- Ideas:
  - Lock elision
  - eliminating global variables
  - eliminating variables altogether

Loop Unrolling

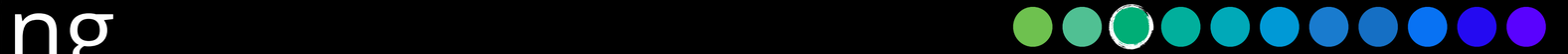
```
var result = 0;
for (int i = 0; i < 5; i++) {
    result += i;
}
```

is equivalent to

```
var result = 0;
result += 0;
result += 1;
result += 2;
result += 3;
result += 4;
```

but the latter is a lot faster!

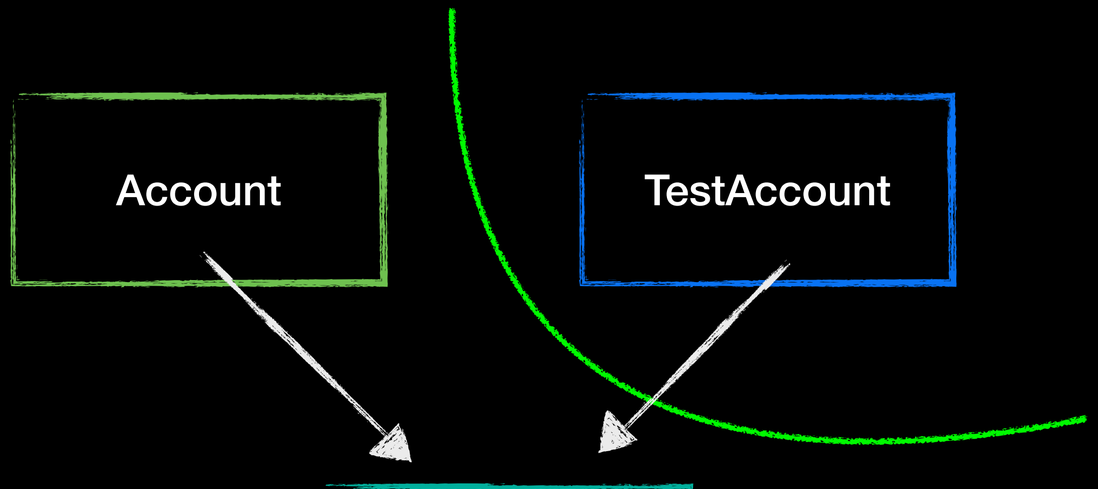
Broken Loop Unrolling



```
var result =
    IntStream.range(1, 5)
             .reduce(0,
              (x, y) -> x + y);
```

can't be unrolled (yet)

Speculative Optimization



- InvokeVirtual is expensive
- But why bother? You ain't gonna use it!

Speculative Optimization

Speculative Optimization

```
class Counter1 implements Counter {
  private int x;
  public int inc() {
    return x++;
  }
}
```

```
class Counter2 implements Counter {
  private int x;
  public int inc() {
    return x++;
  }
}
```

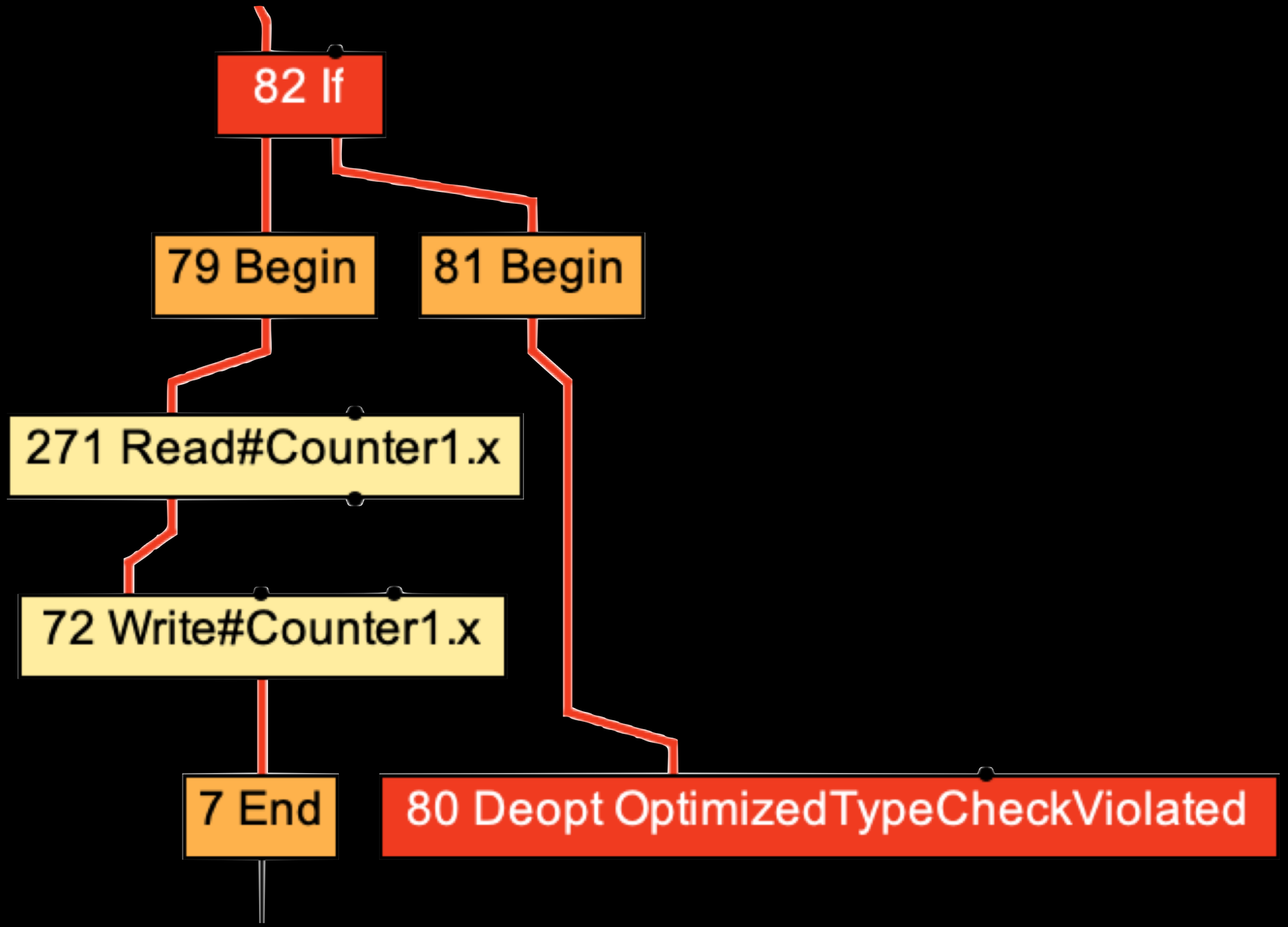
```
class Counter3 implements Counter {
  private int x;
  public int inc() {
    return x++;
  }
}
```

```
interface Counter {
  int inc();
}
```

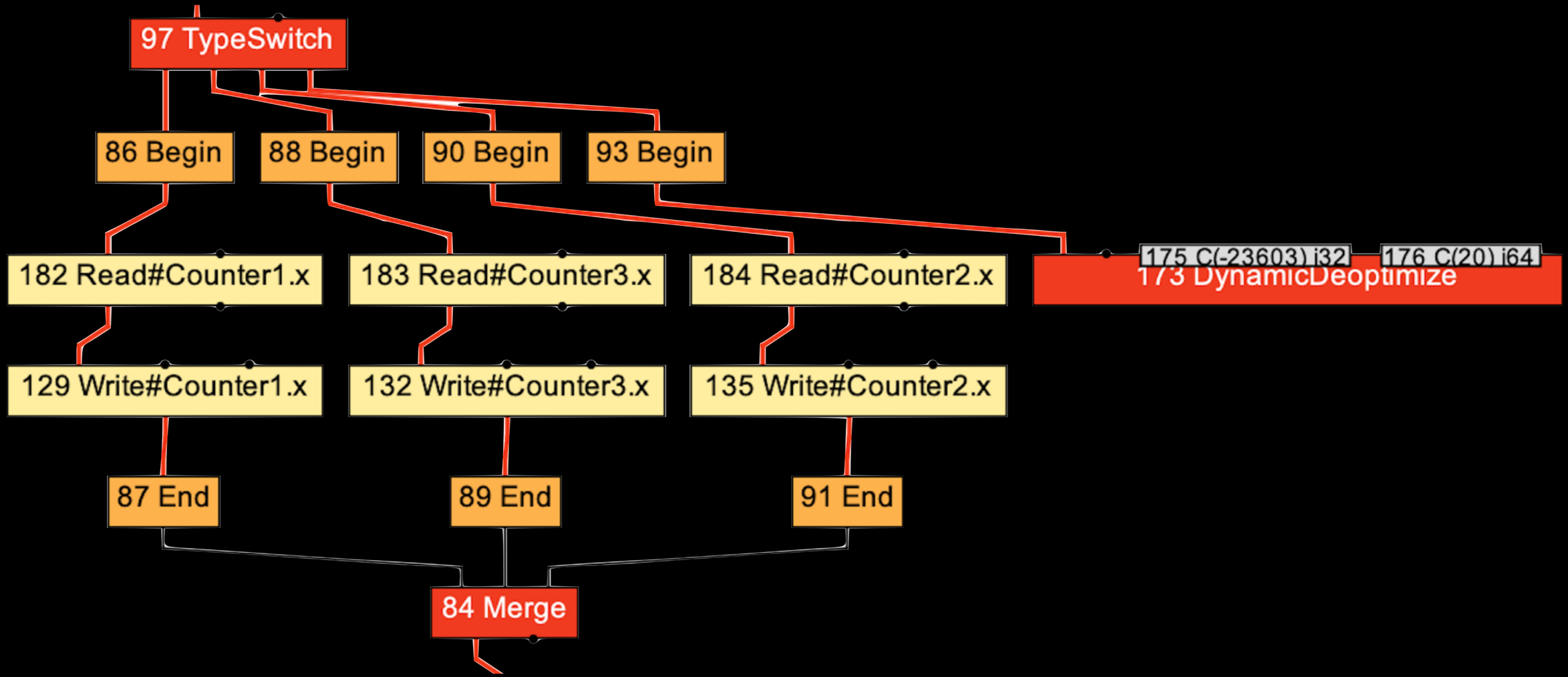
```
measure(new Counter1());
measure(new Counter2());
measure(new Counter3());
```

```
public void measure(Counter c) {
  c.inc();
}
```

Speculative Optimization

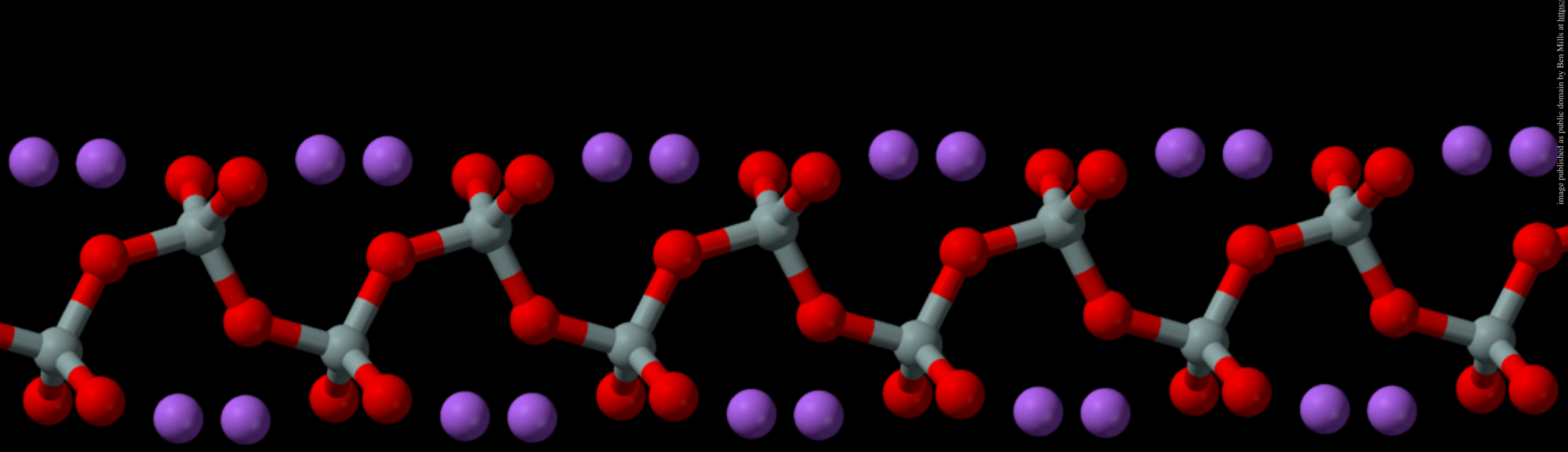


Speculative Optimization

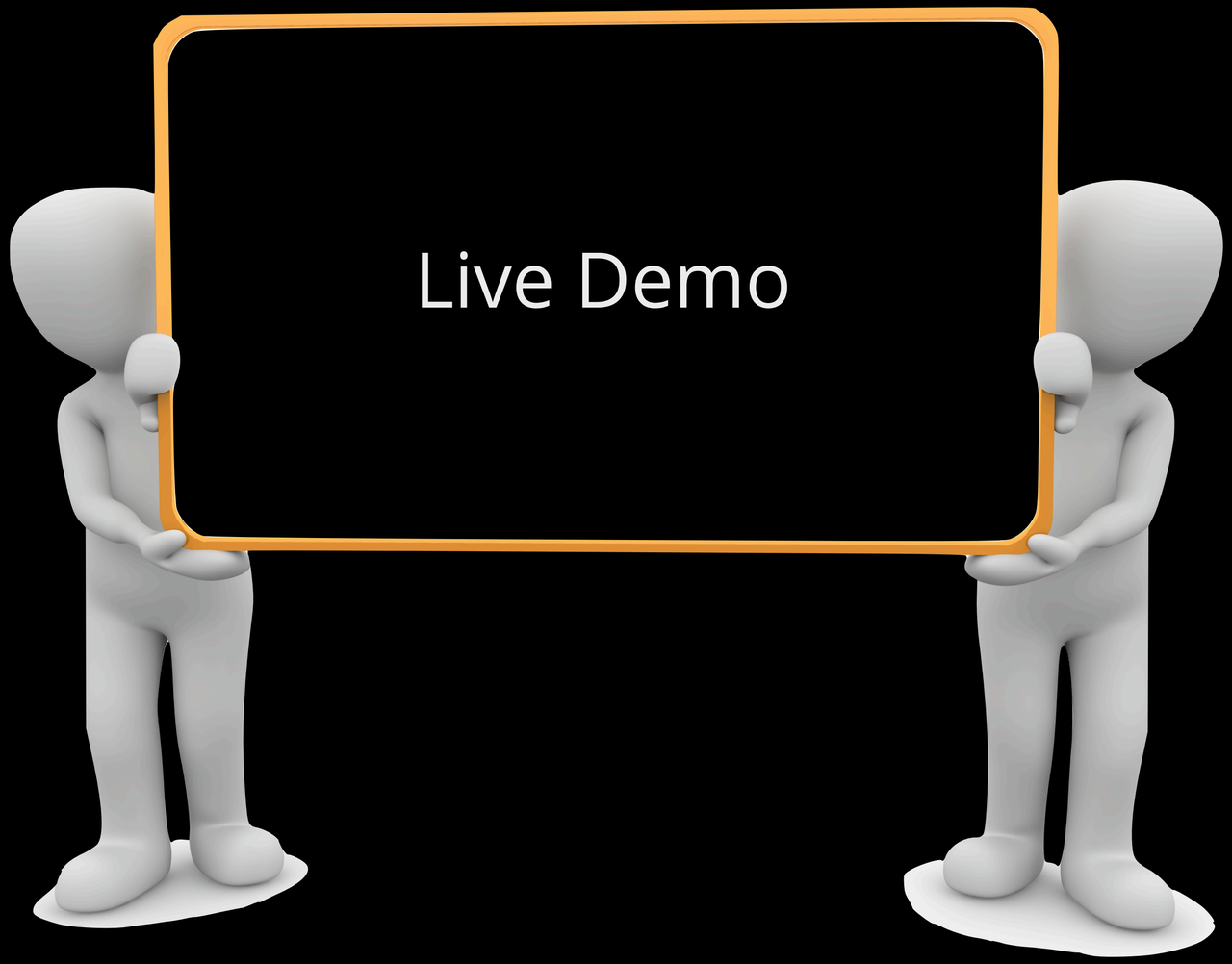


Unchaining Chains of Lambdas

```
File[] files = Arrays.stream(
    Optional.ofNullable(this.file.listFiles())
    .orElse(new File[0]))
    .sorted(Comparator.comparing(File::isDirectory).reversed()
    .thenComparing(File::getName))
    .toArray(File[]::new);
```



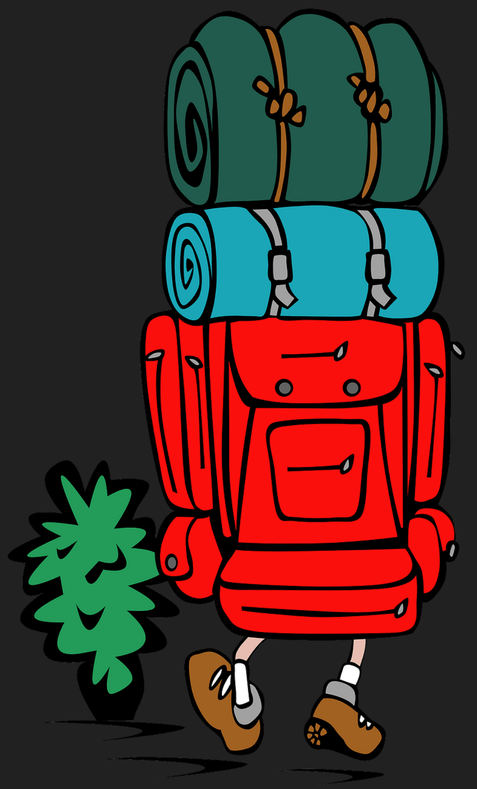
Unchaining Chains of Lambdas



Type-Based Optimization

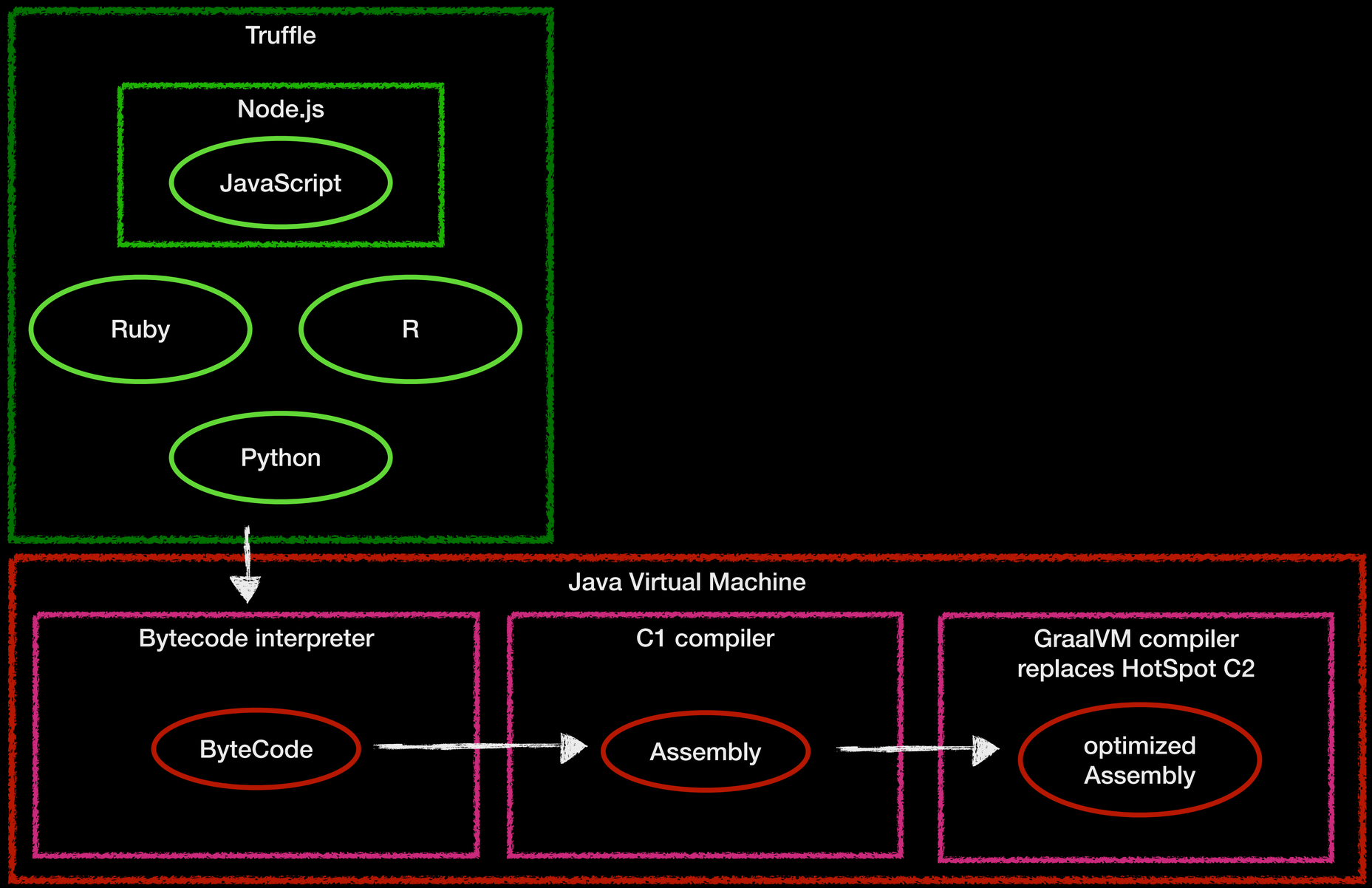
```
// https://medium.com/graalvm/stream-api-performance-with-graalvm-be6cfe7fbb52

public double averageAge(people: Person[]) {
  return Arrays.stream(people)
    .filter(p -> p.age >= 18 && p.age <= 21)
    .mapToInt(p -> p.age)
    .average()
    .getAsDouble();
}

class Person {
  public final int age;
}

/** this is an excerpt of a JVM class */
public class OptionalDouble {
  public double getAsDouble() {
    if (!isPresent) {
      throw new NoSuchElementException("No value present");
    }
    return value;
  }
}
```

Does it Pay to Use the New Compiler?



- GraalVM tends to cope better with modern language patterns than OpenJDK
- GraalVM often runs non-Java JVM languages faster
- It's easier to add improvements to GraalVM than to OpenJDK
  → there's more to come!
  → and you can contribute, too!

Polyglot Programming with Truffle



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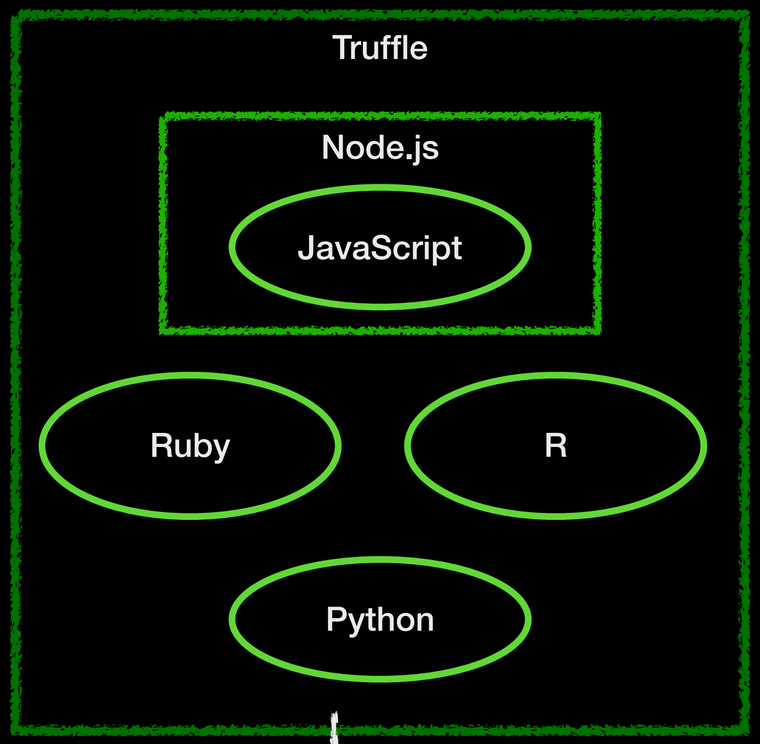
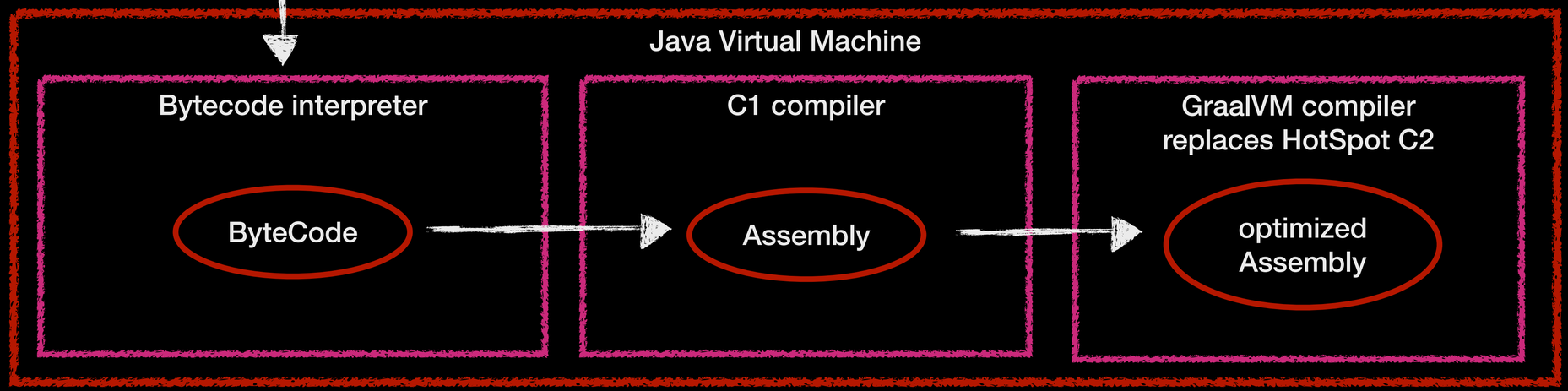
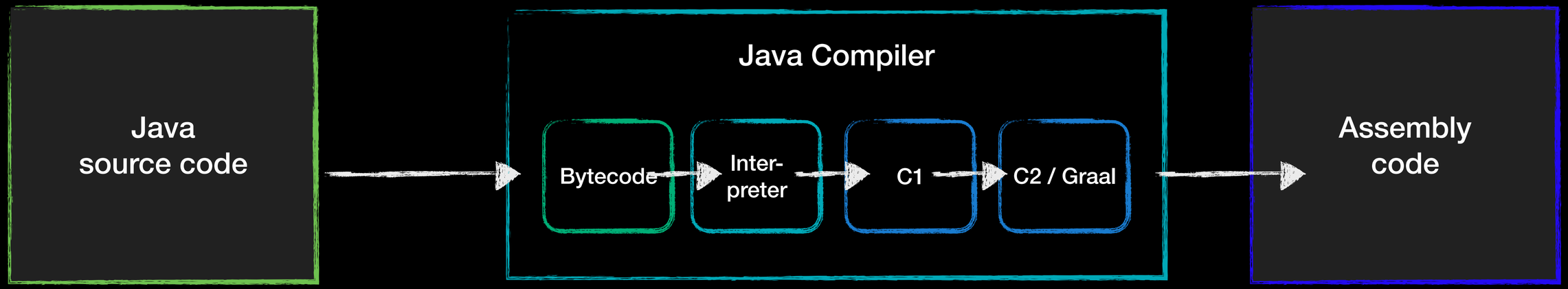


- GraalVM ships with four languages
- You can easily build your own language
  - interesting for academic purposes
  - potential source of future innovation



Futamura Projection (How Truffle Works)



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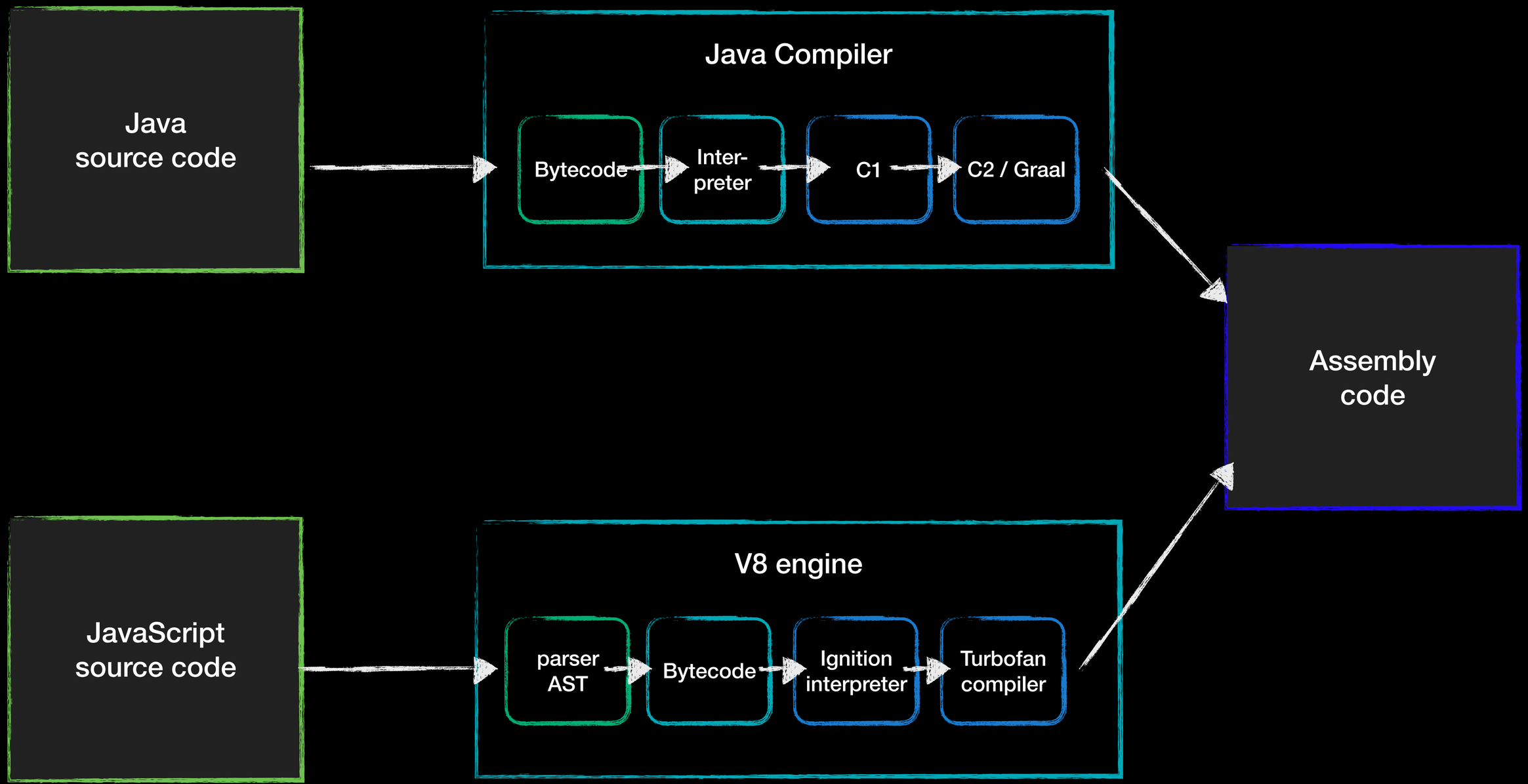

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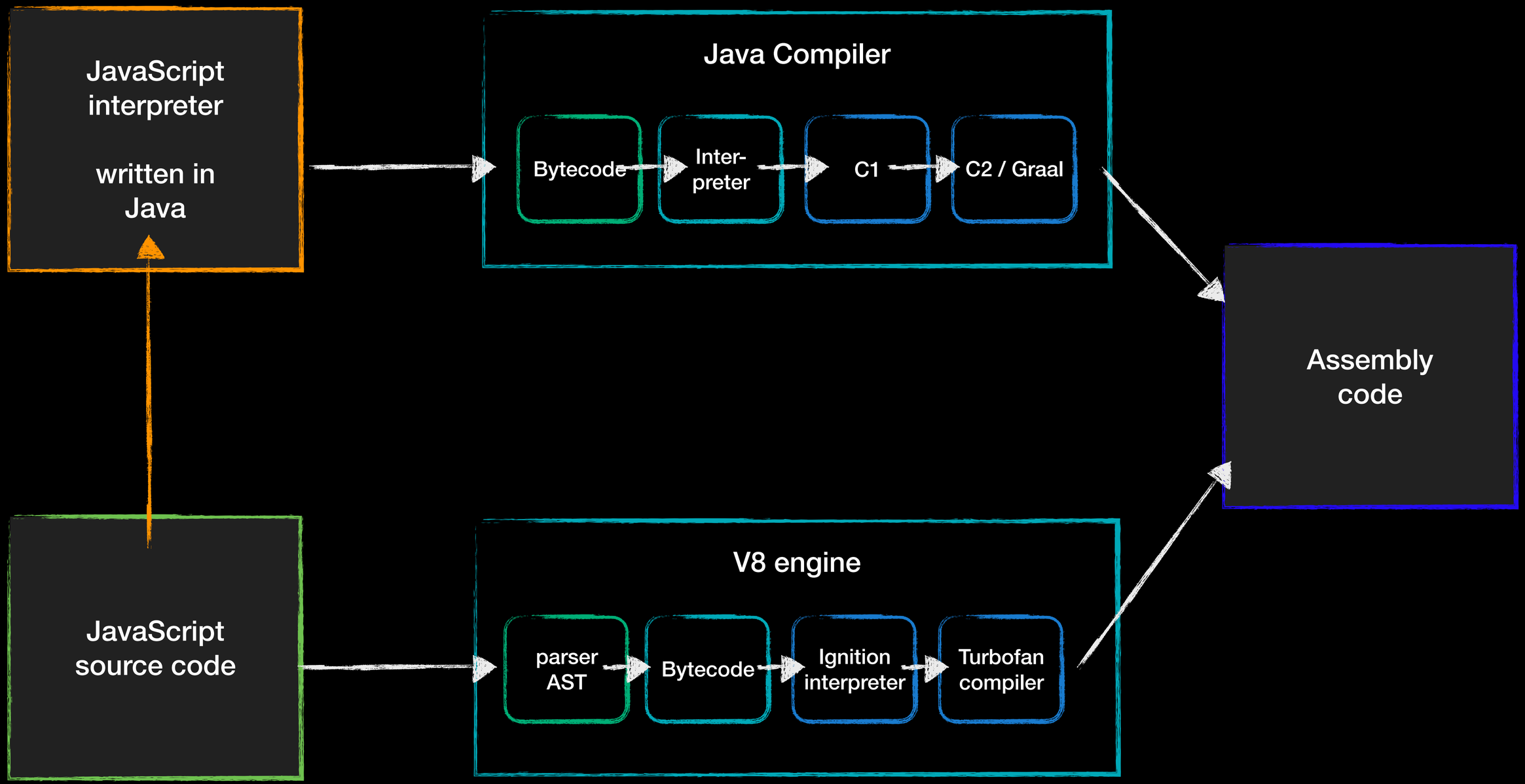

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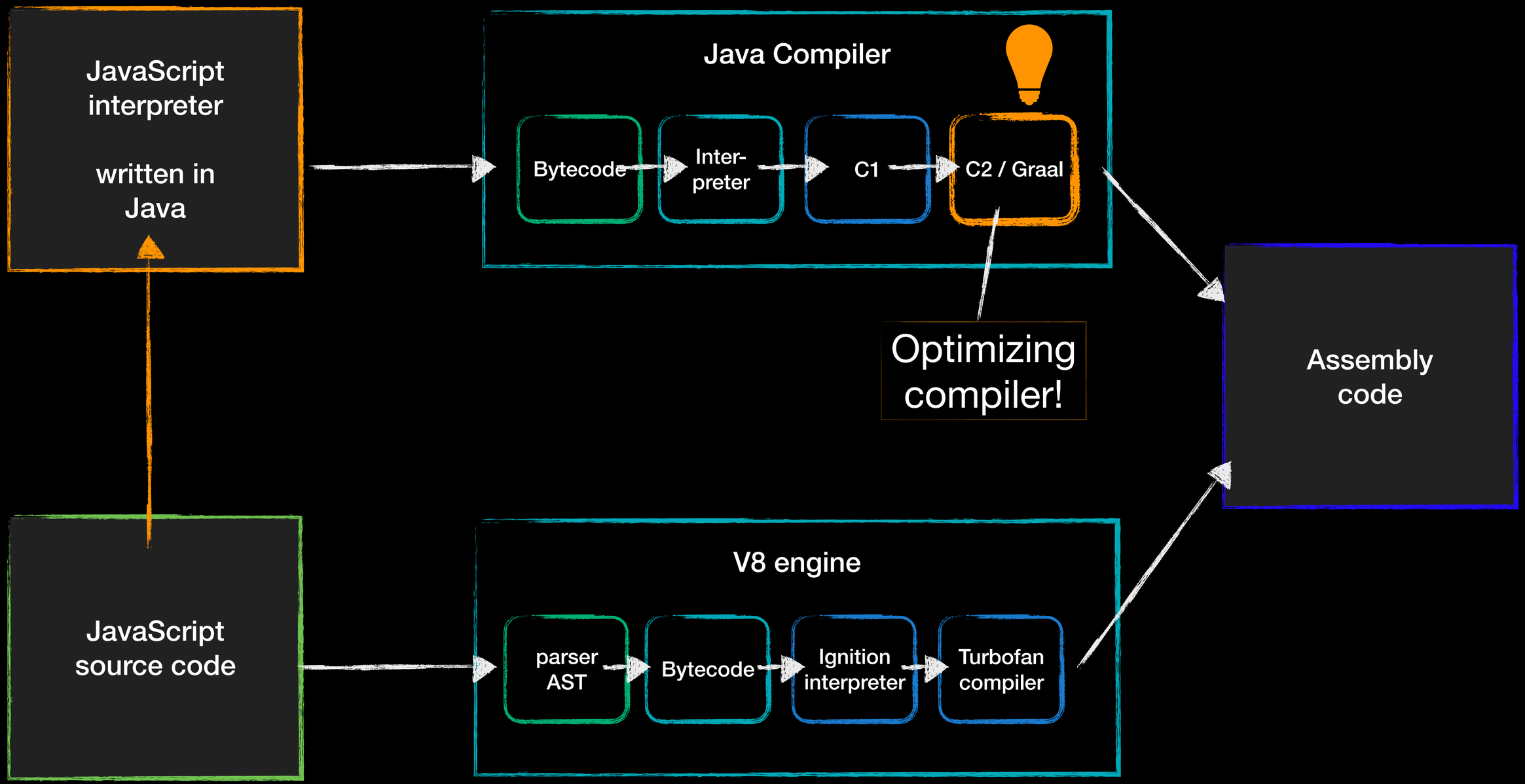

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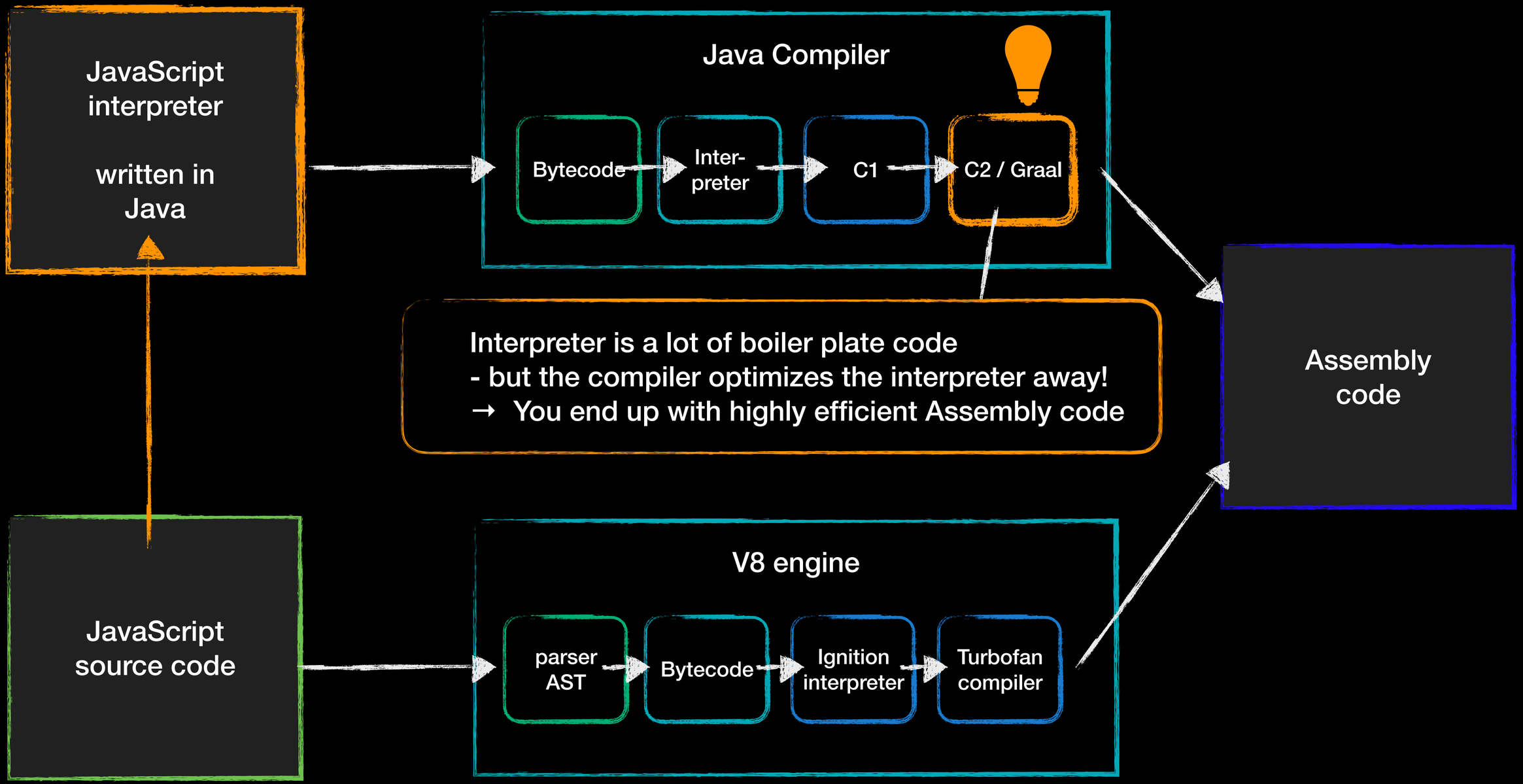


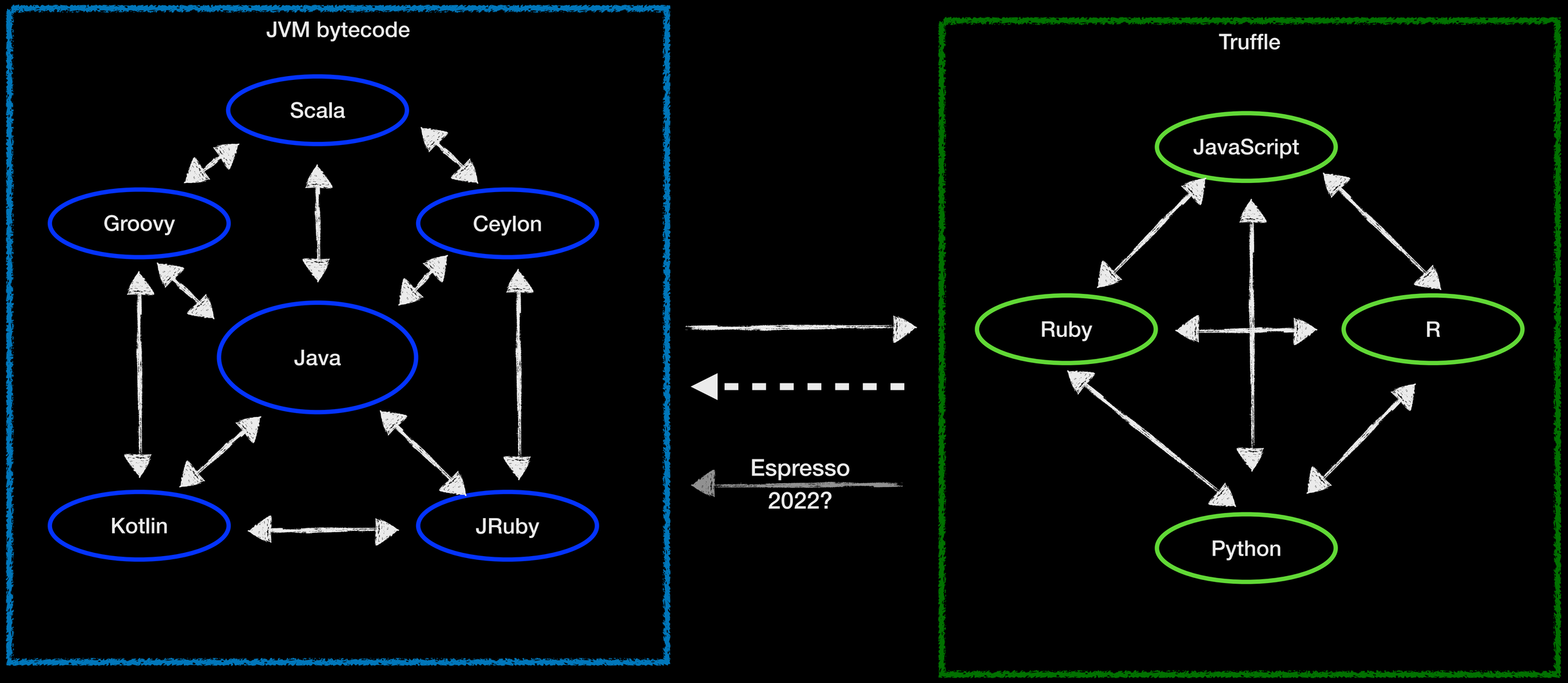
Polyglot Programming with Truffle

- JavaScript:
  - way faster than Nashorn and Rhino
  - severe cold start penalty
- Node.js
  - supported
  - even runs the Angular CLI!
  - but suffers from cold start penalty

Polyglot Programming with Truffle

- Ruby:
  - very good peak performance
  - interesting alternative to the native Ruby interpreters
  - Give it a try!

Is it Truly Polyglot?



Truffle API

register Java code with Truffle (i.e. language-specific API)

LLVM - Project Sulong

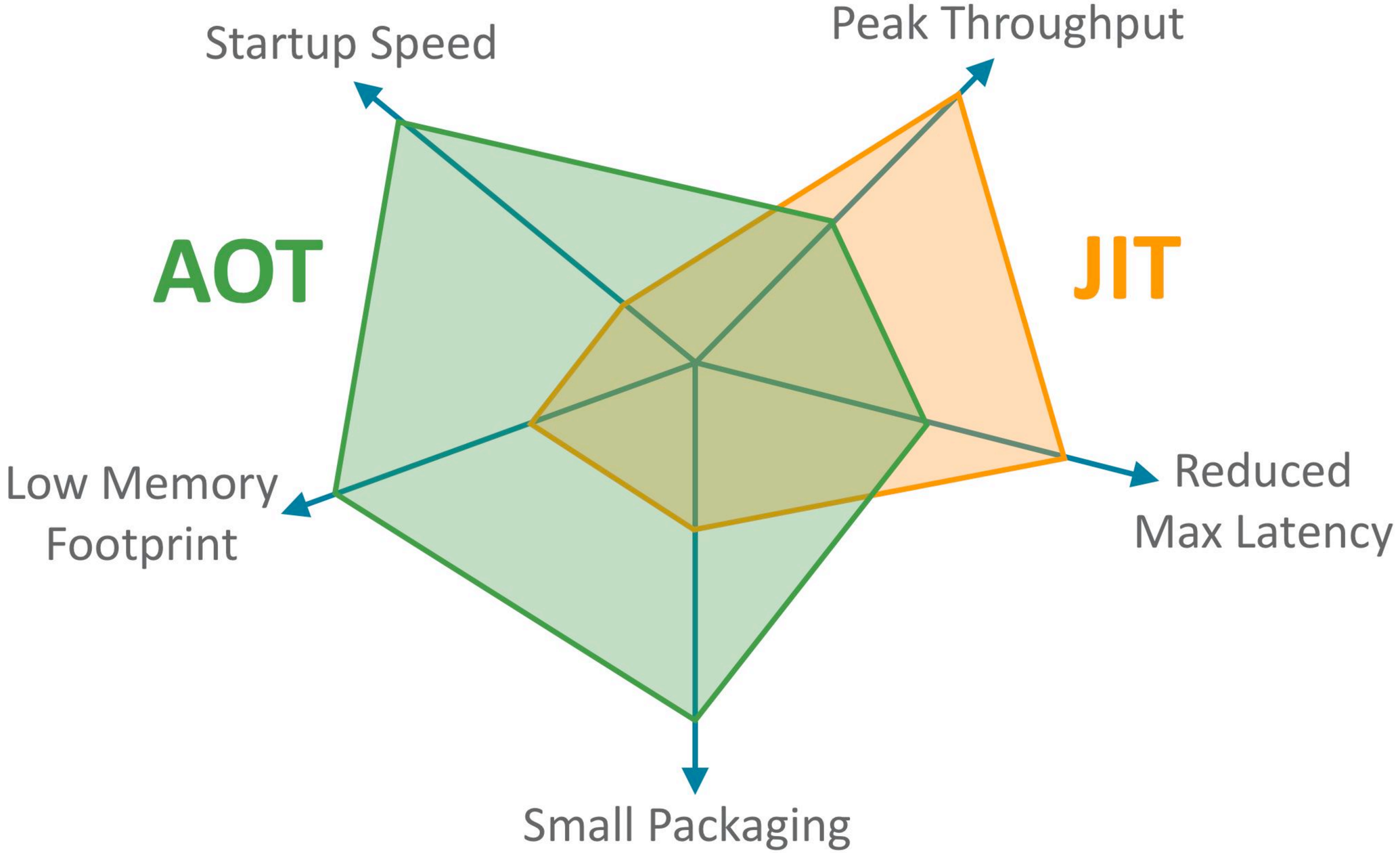
Image source: LLVM Twitter logo https://twitter.com/llvmorg/photo

Native Images (aka AOT, aka SubstrateVM)

- GraalVM ships with an ahead-of-time (AOT) compiler
- Many predecessors, such as Jikes
- AOT compiler were long since dead

What's changed?

Native Images (aka AOT, aka SubstrateVM)



Using Java in AWS Lambda Functions

- Traditionally Java suffers from a slow start
- Great progress recently
- but still, node.js starts way faster
- GraalVM AOT to the rescue!

Reflection and AOT

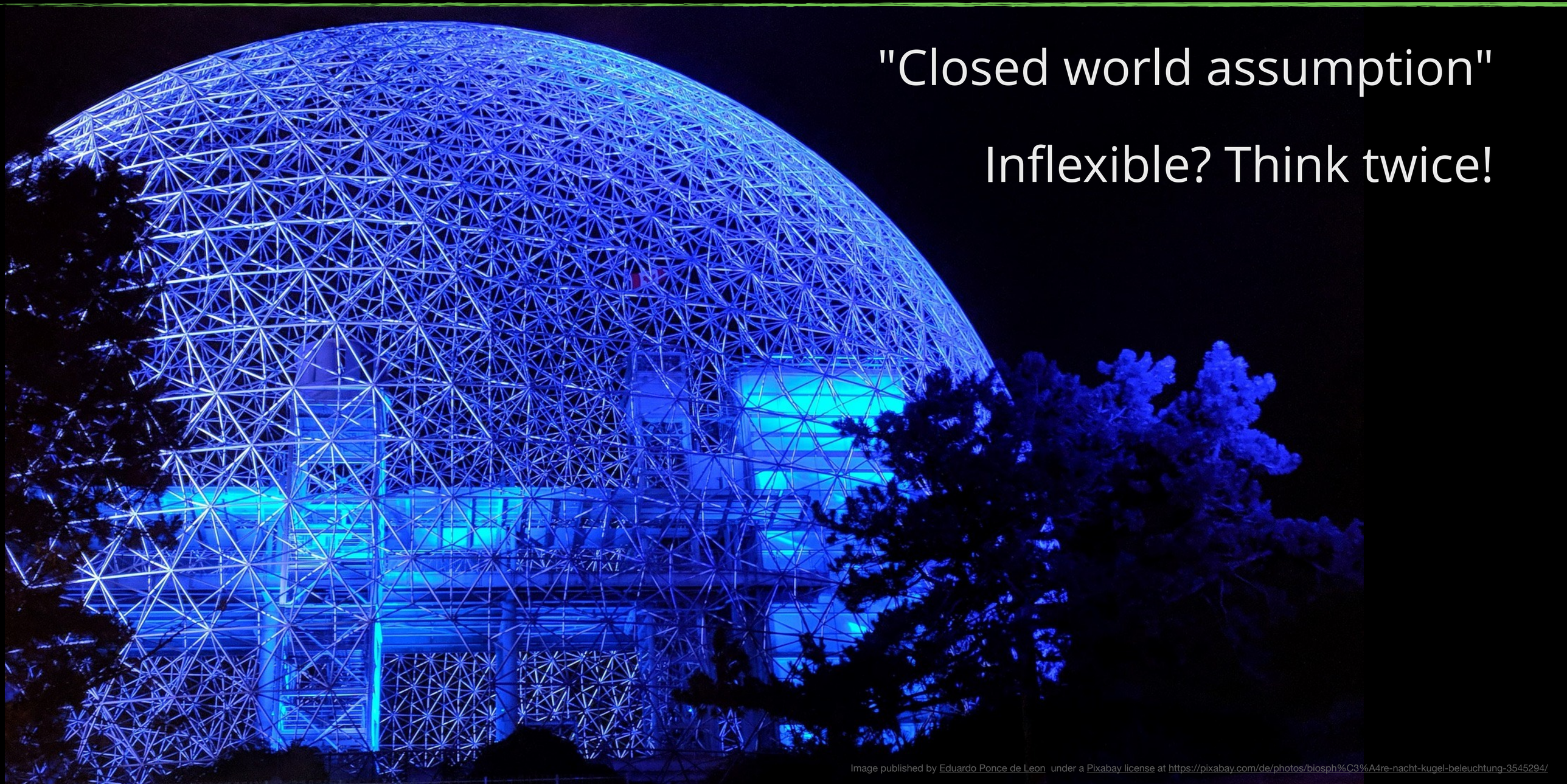
AOT eliminates
info about
classes & methods

→ reflection is broken

→ configure
a configuration file
for reflection

"Closed world
assumption"

Reflection and AOT



"Closed world assumption"

Inflexible? Think twice!

Android, iOS, and Embedded Devices

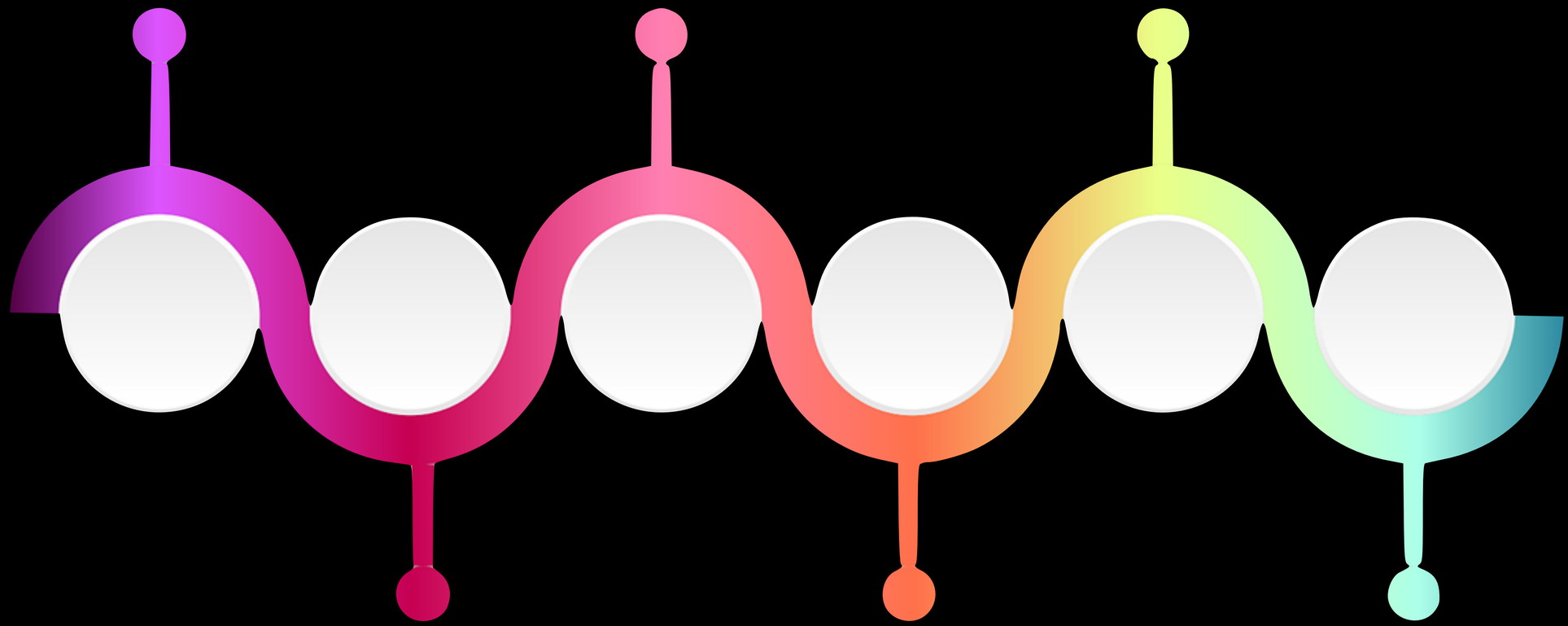
AOT makes many things possible:

- Mobile apps start fast
- no need to bundle the JRE
- JavaFX on Android and iOS w/out the pain
- Java on embedded devices
  - predictable speed, low memory footprint
- Utilitities like babashka

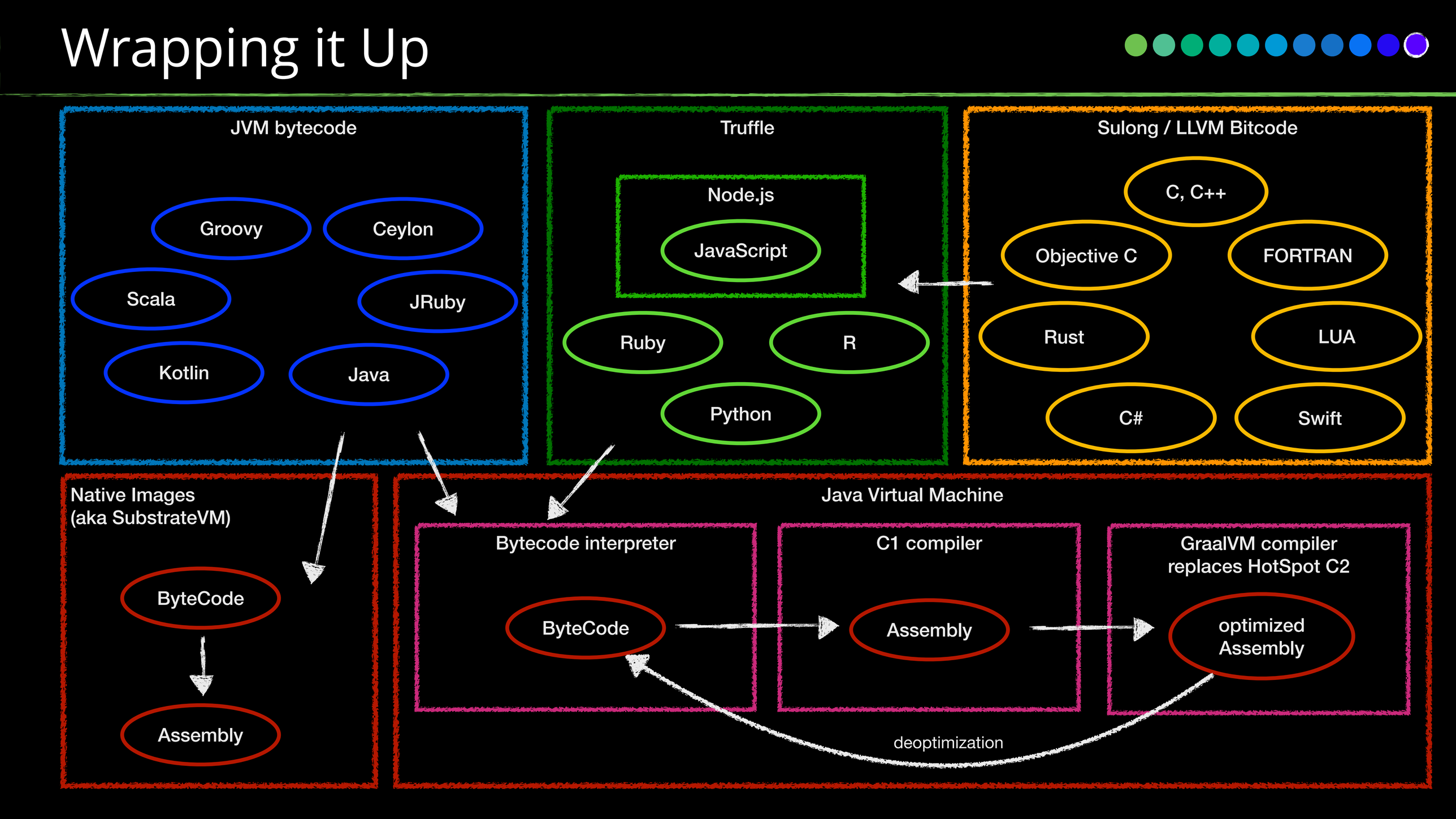
Enterprise Edition vs. Community Edition

Community Edition

Enterprise Edition



Wrapping it Up



Any Questions?

Don't hesitate to reach out to me!

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