Kotlin Compiler

In past, 1.4 and beyond

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JetBrains

Topics

- Compiler as a opaque box

- Kotlin Compiler Frontend
  - 1.0
  - New Inference in 1.4
  - New Frontend IR

- Kotlin Compiler Backend
  - 1.0
  - New Backend IR

Why?

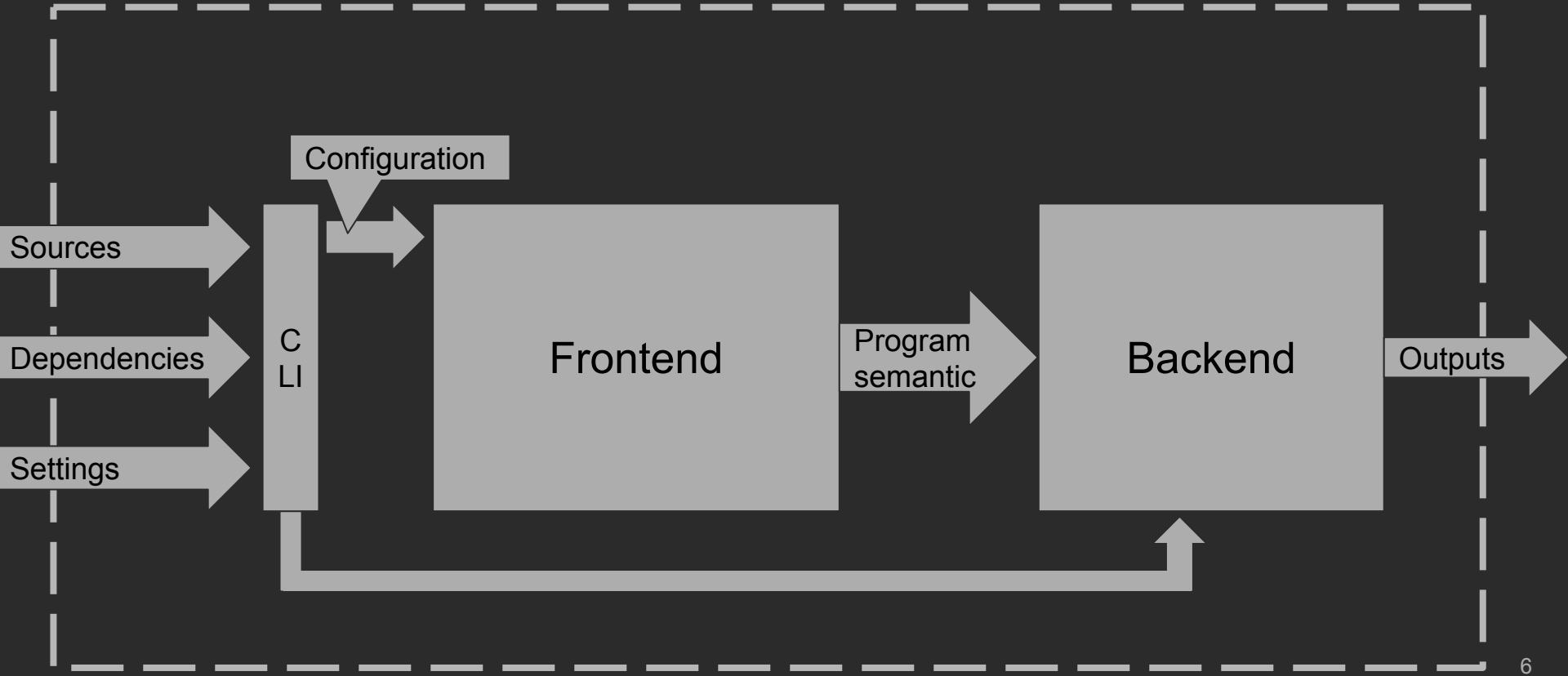
- Major compiler changes
- Complete rewrites of huge compiler parts

- Language evolved since 1.0
- Kotlin Compiler 1.0 wasn’t meant to run fast but to develop fast
- And it is 10 years old

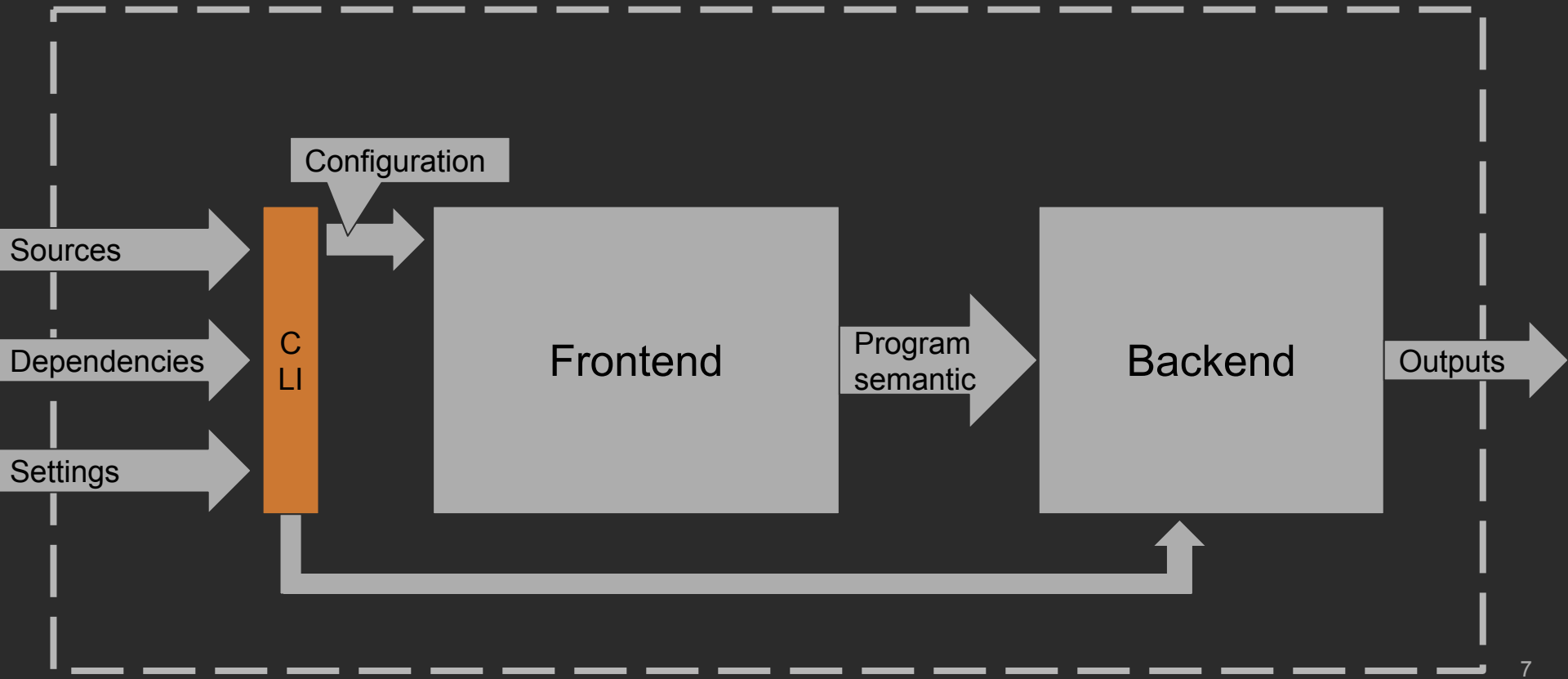
Compiler as a Opaque Box

Compiler as a Opaque Box

Compiler as Transparent Box



Compiler as Transparent Box



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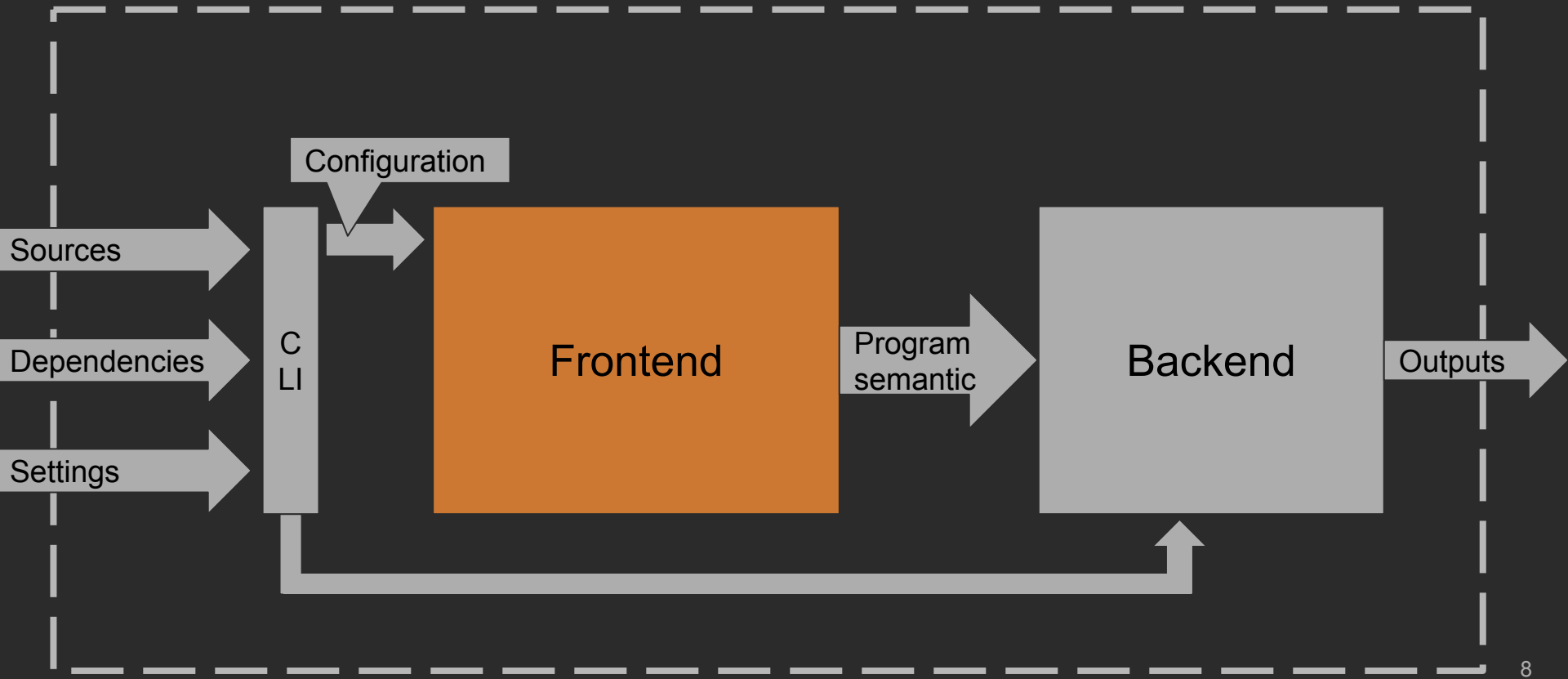

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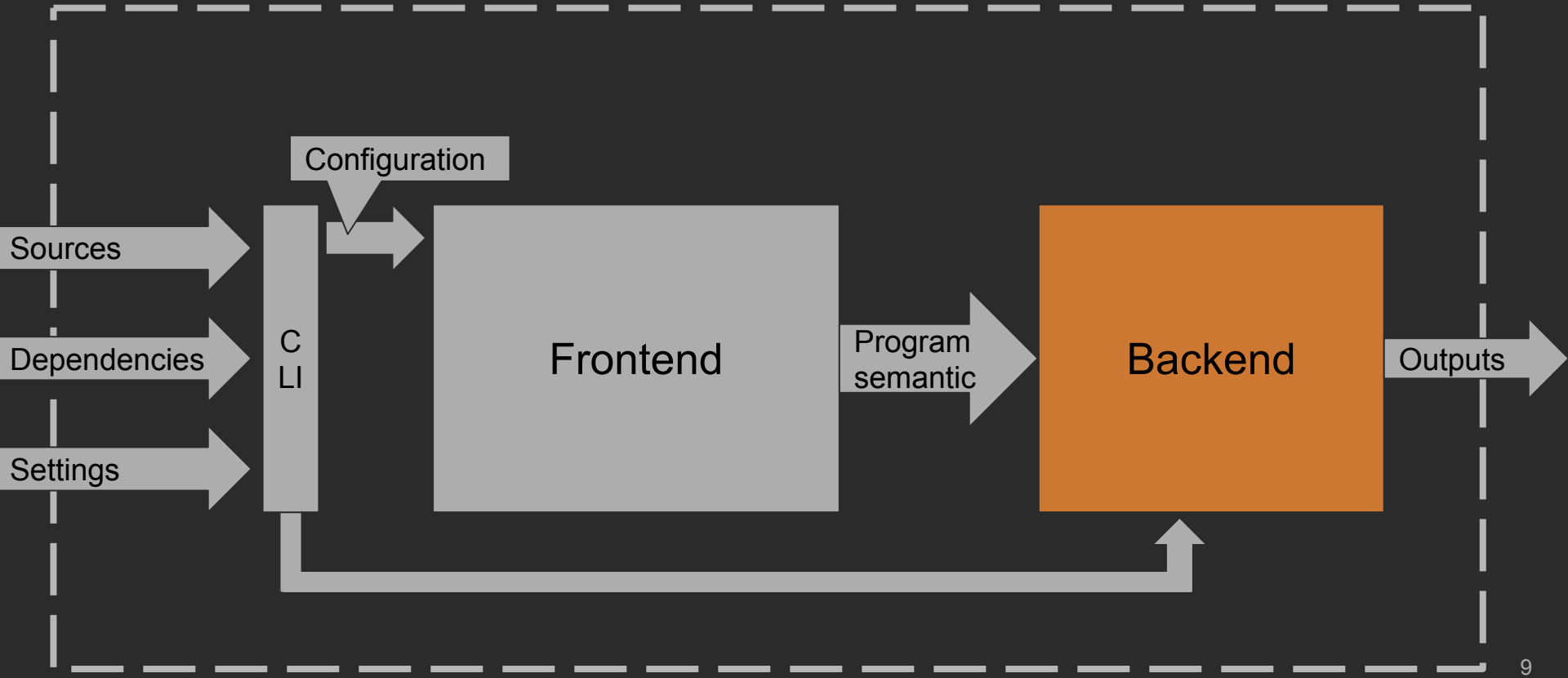

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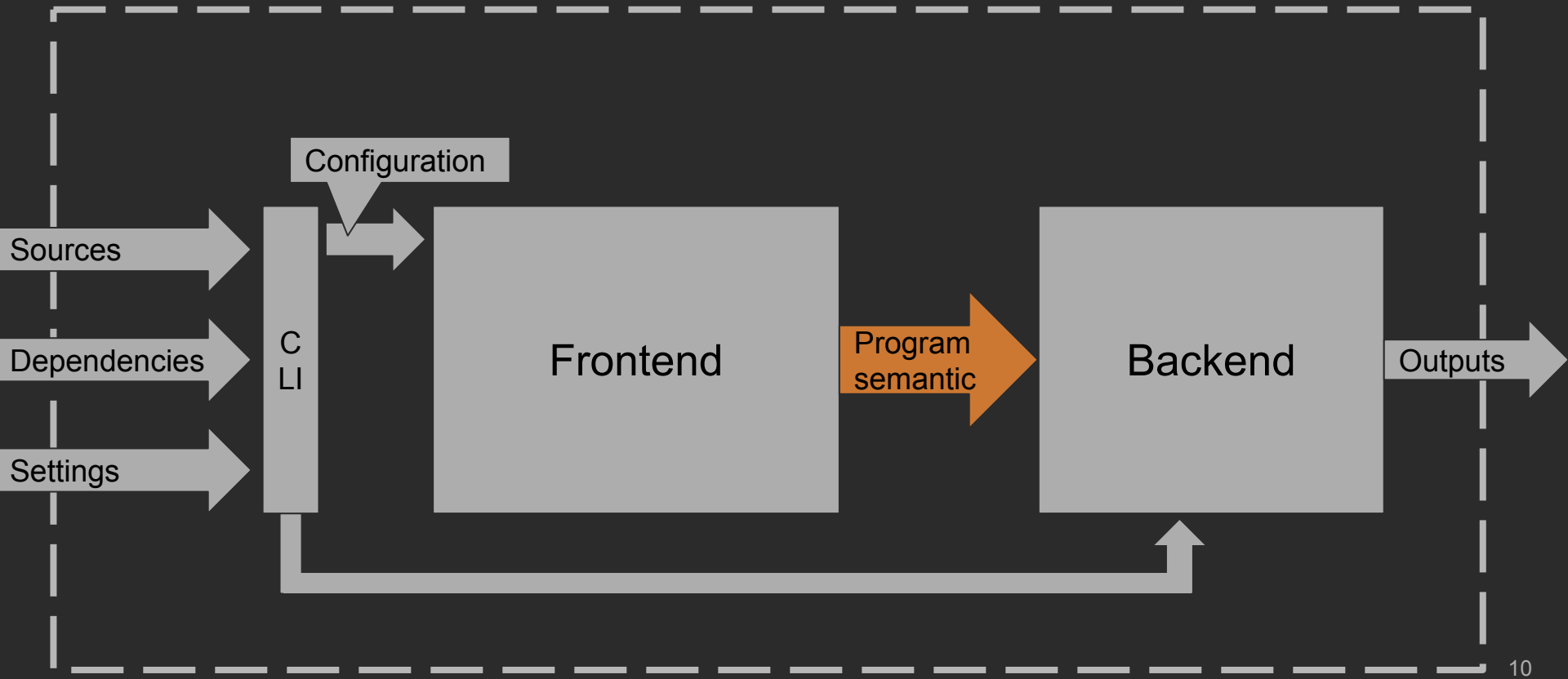

Semantics? Semantics!

```
fun hello(user: String) = println("Hello, $user")
```

Semantics? Semantics!

```
public fun hello(user: kotlin.String): kotlin.String
        defined in example in file Example.kt
```

```
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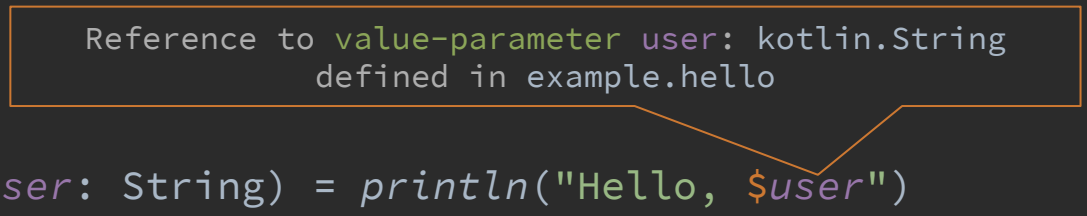

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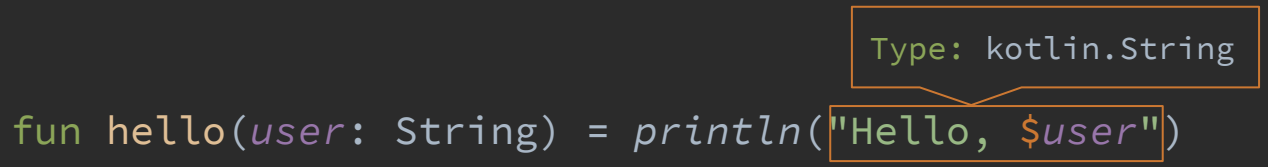

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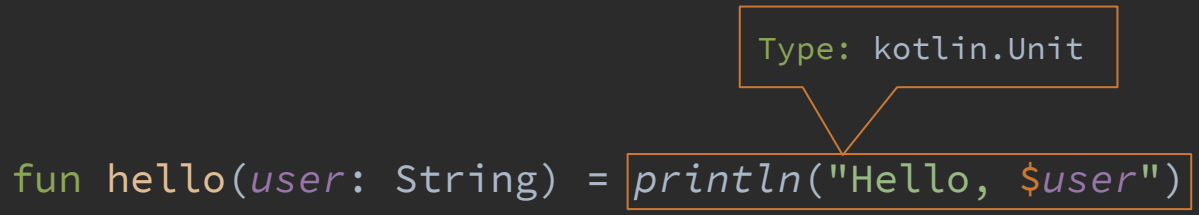

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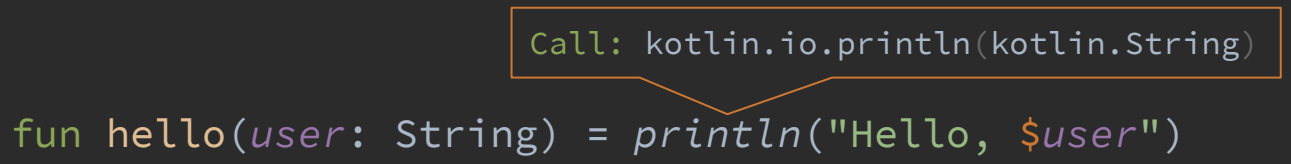

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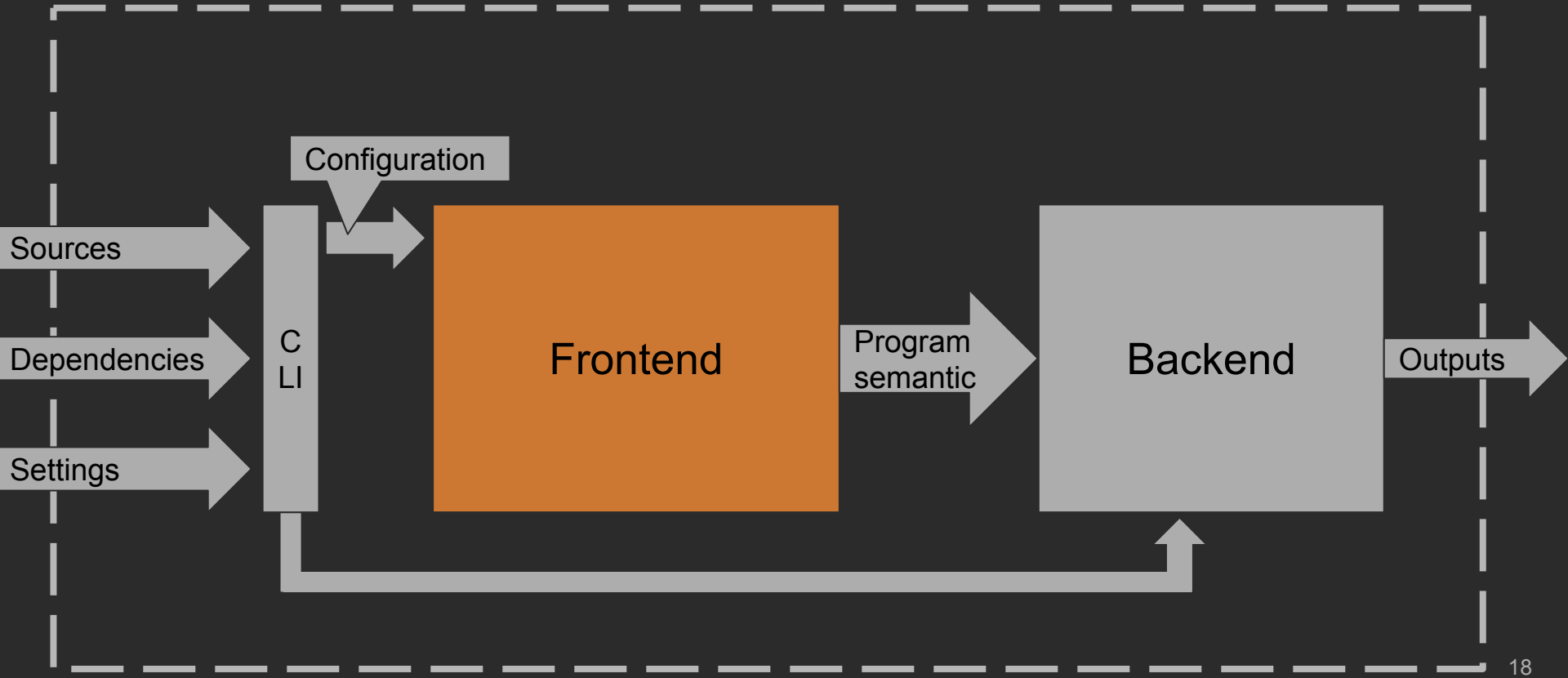
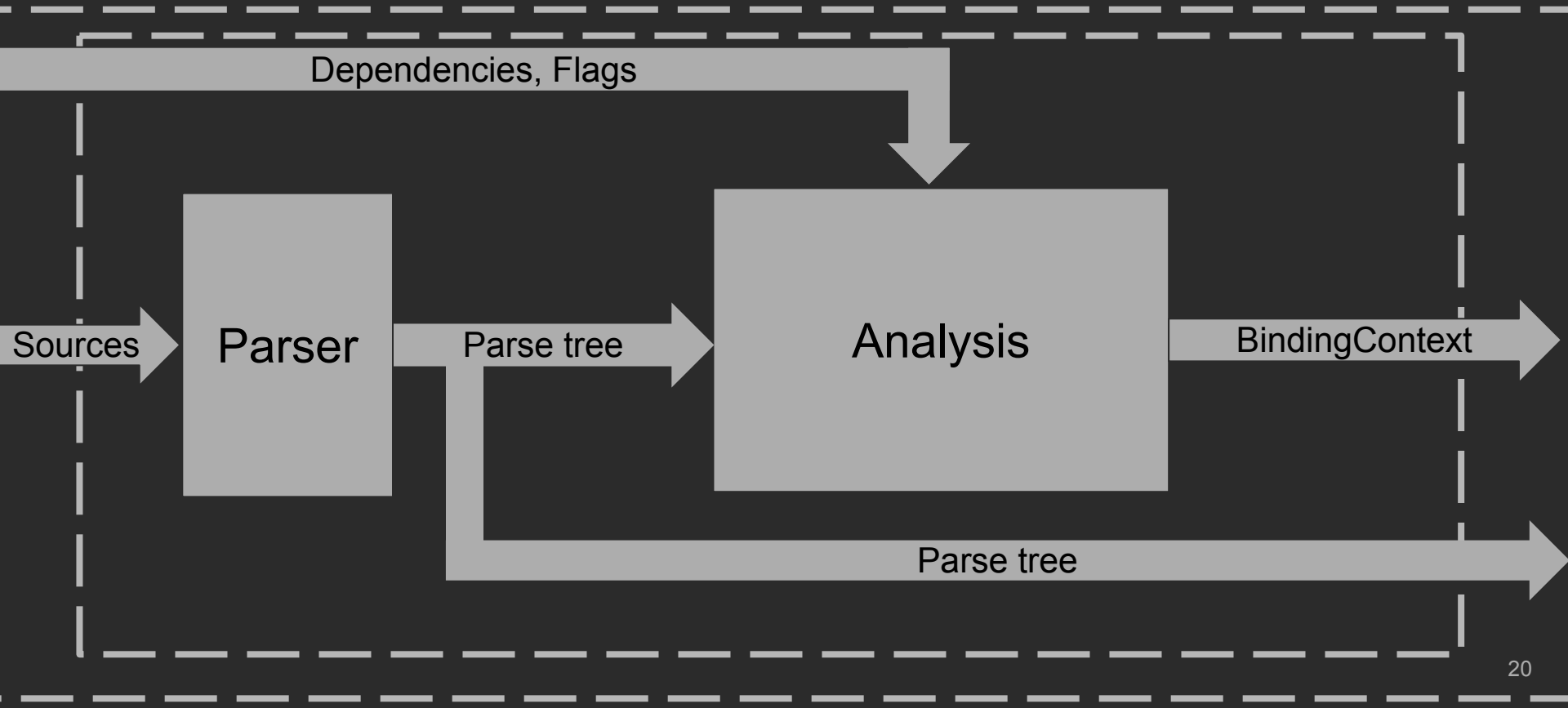


Frontend Timeline

Frontend 1.0 on High-Level



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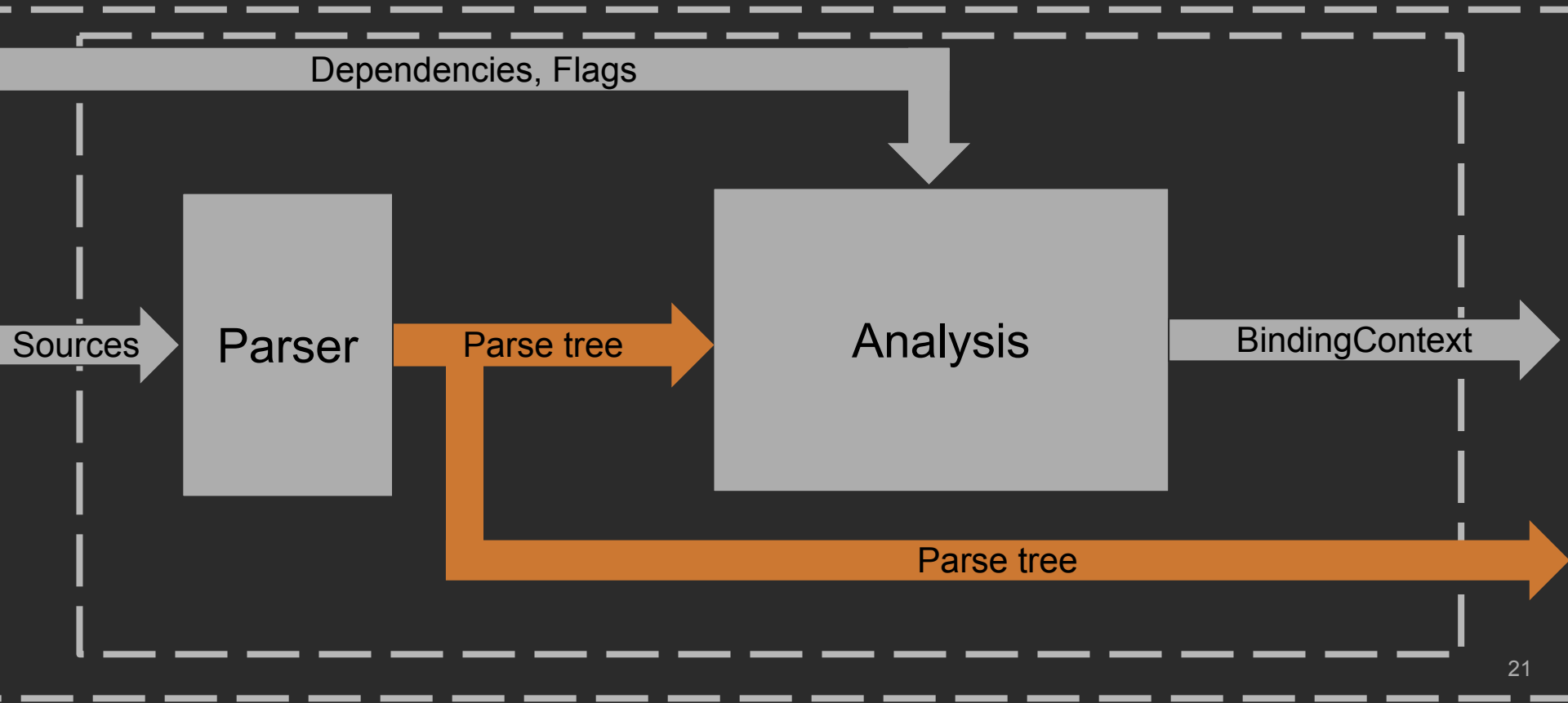
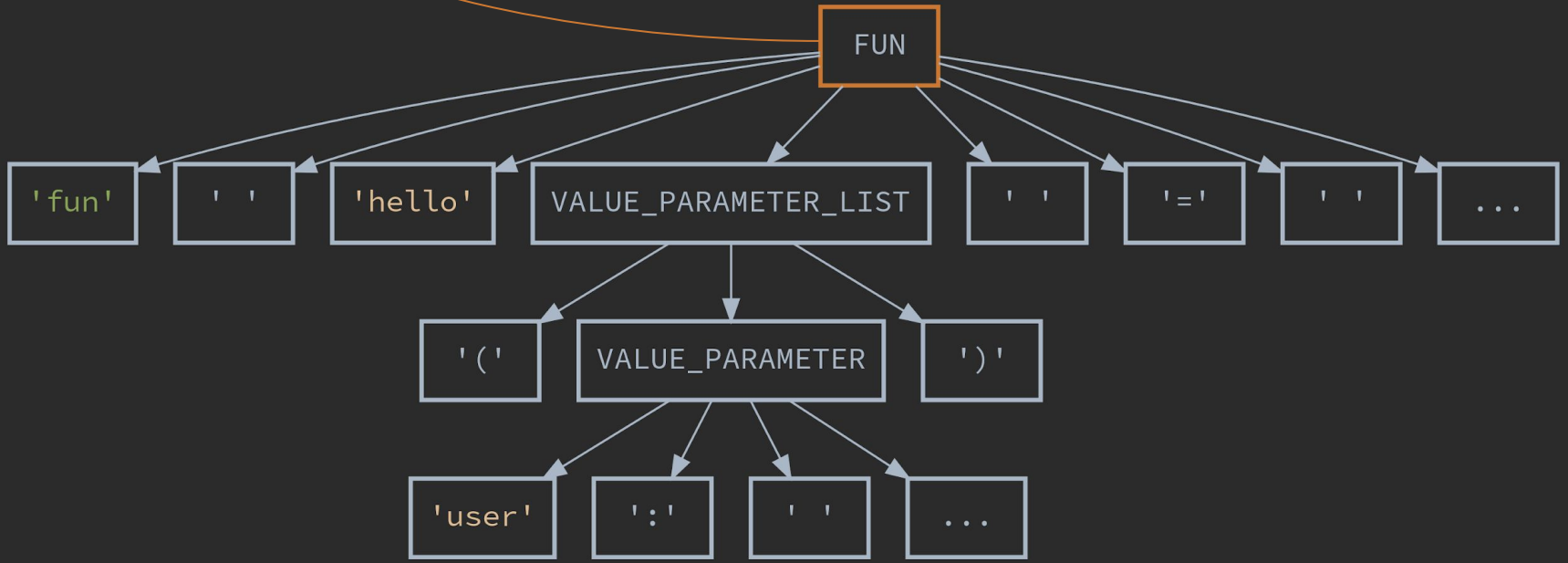


Parse Tree, aka PSI - Program Structure Interface

```
fun hello(user: String) = ...
```

NOTE: CST



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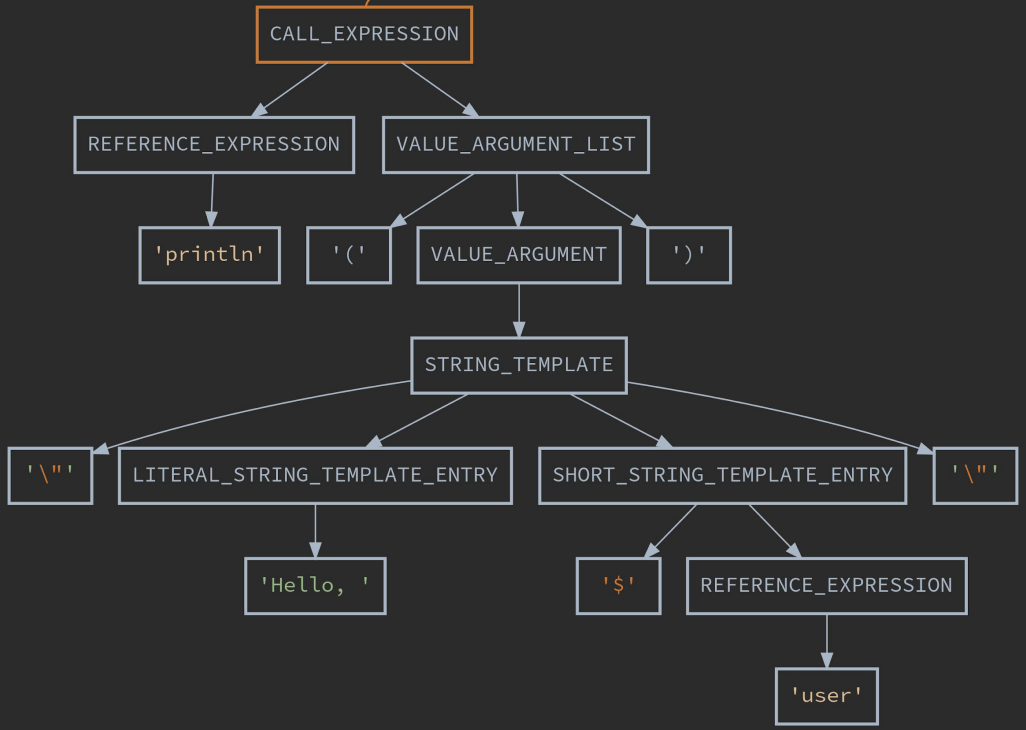

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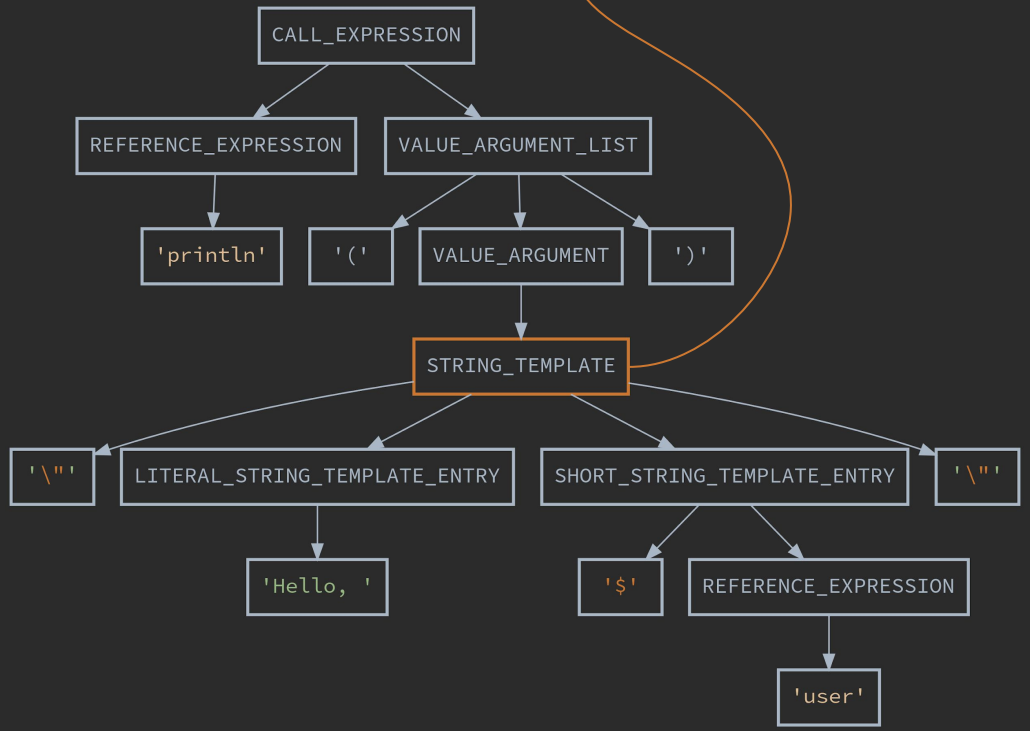

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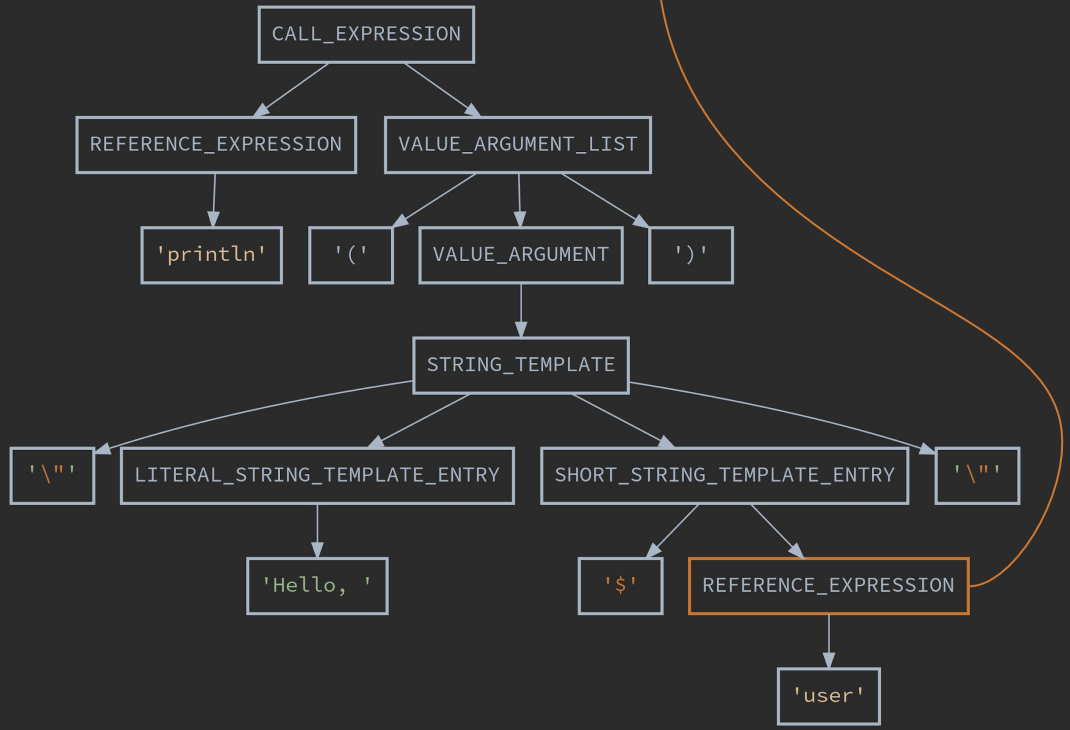

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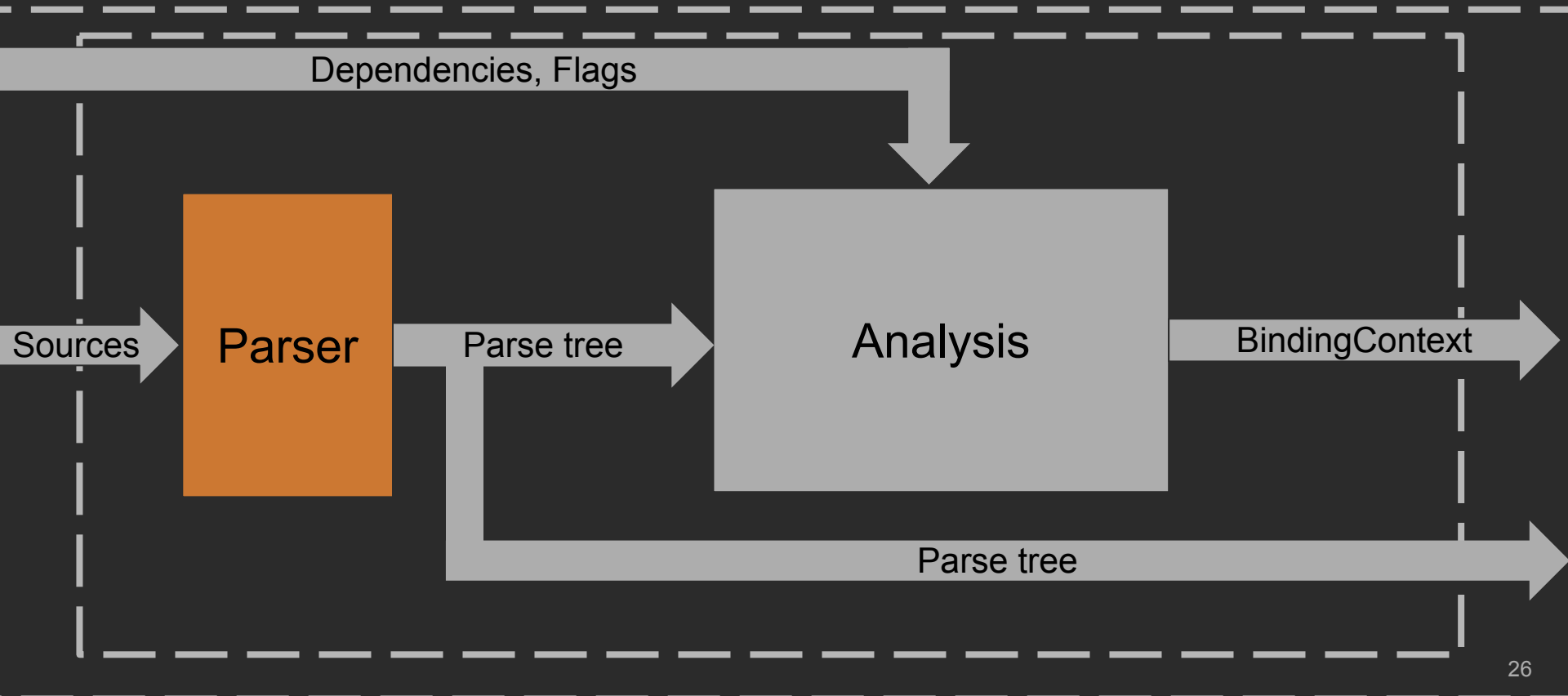

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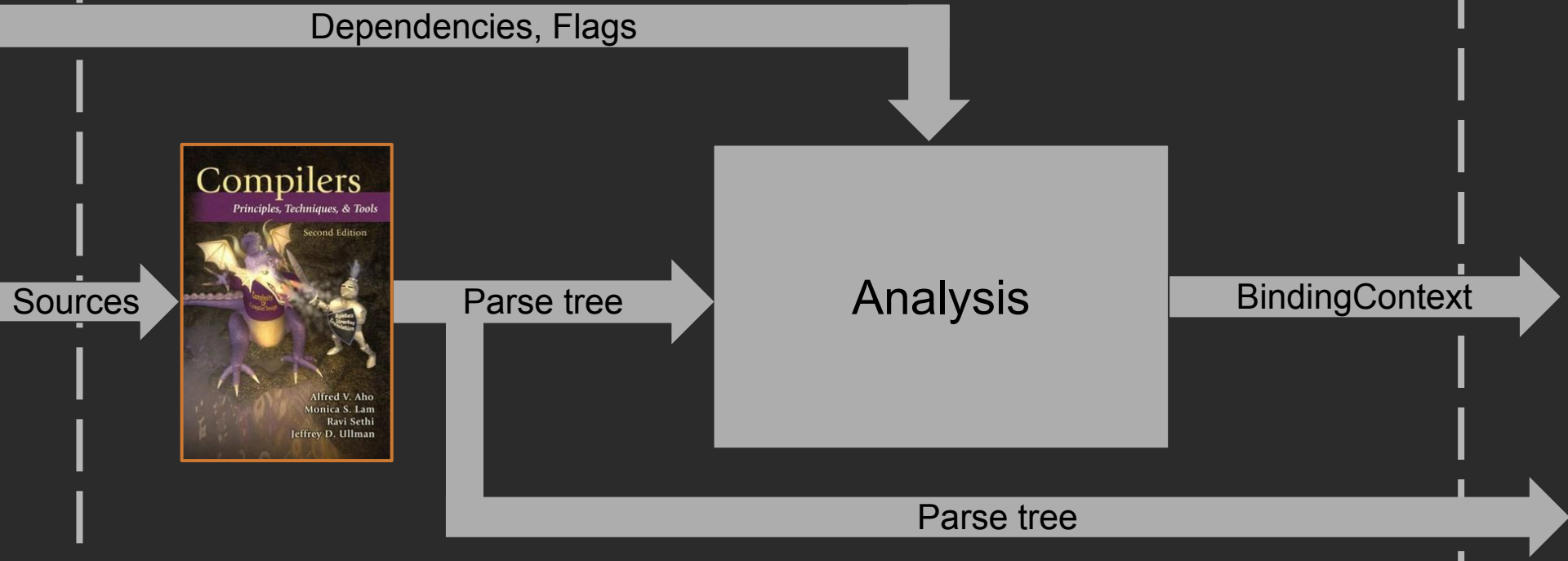

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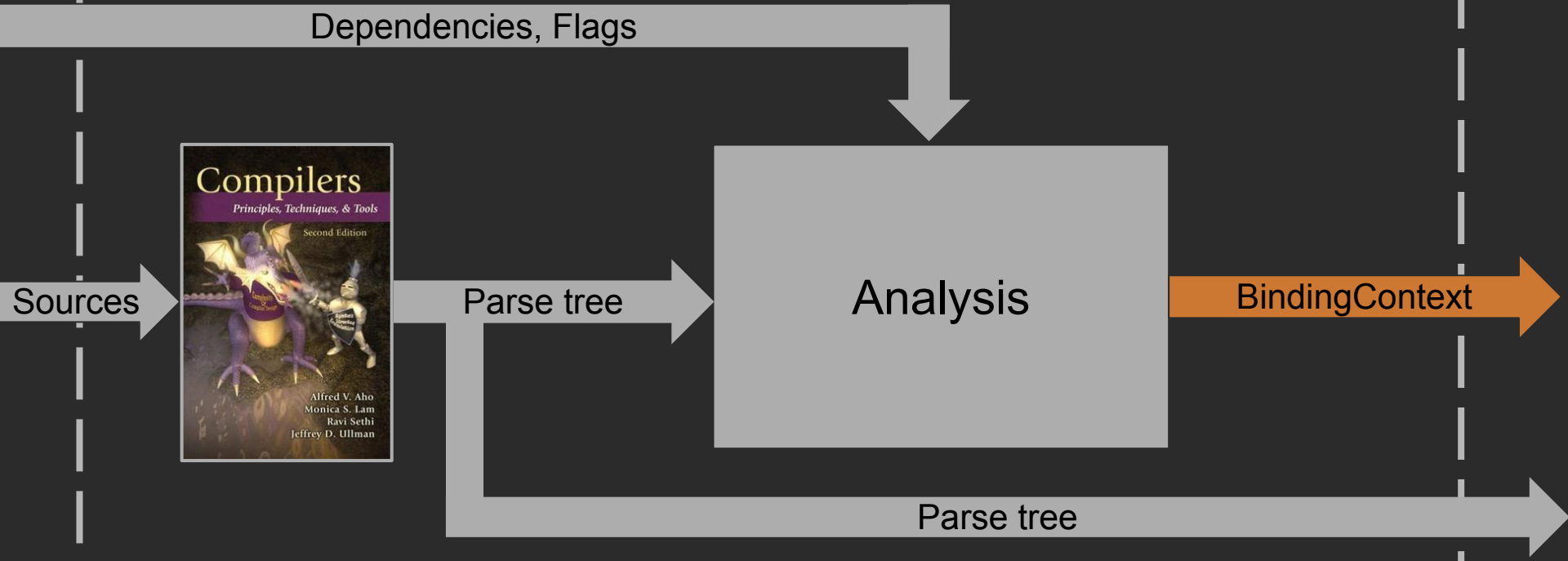
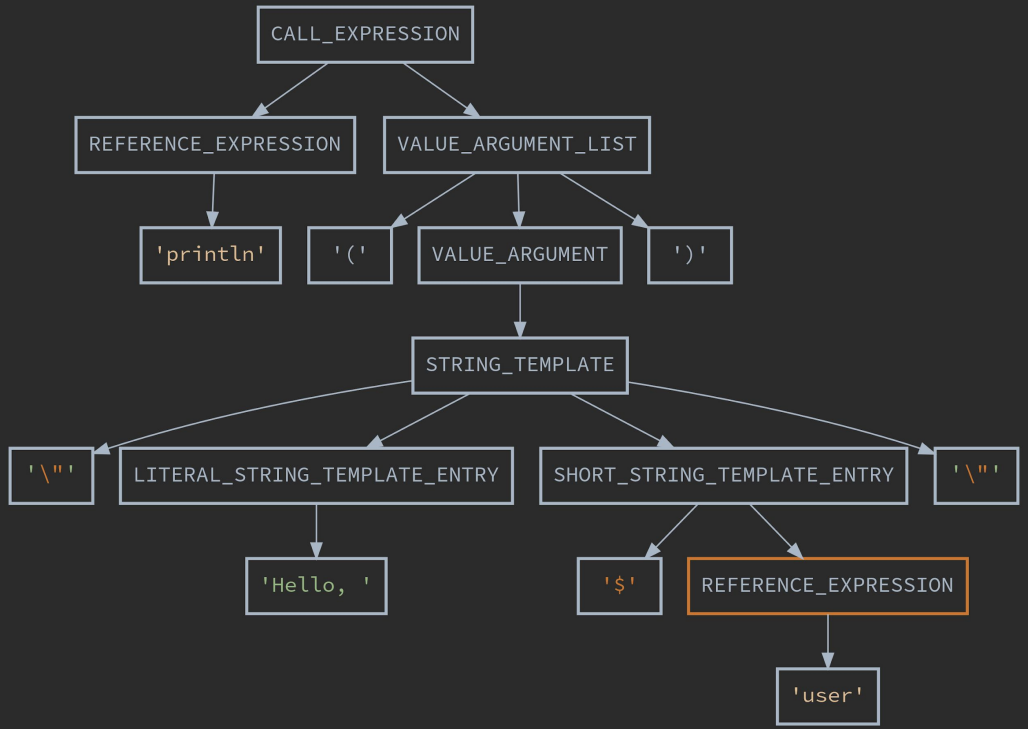


BindingContext?

BindingContext?

Type: kotlin.String

```
println("Hello, $user")
```



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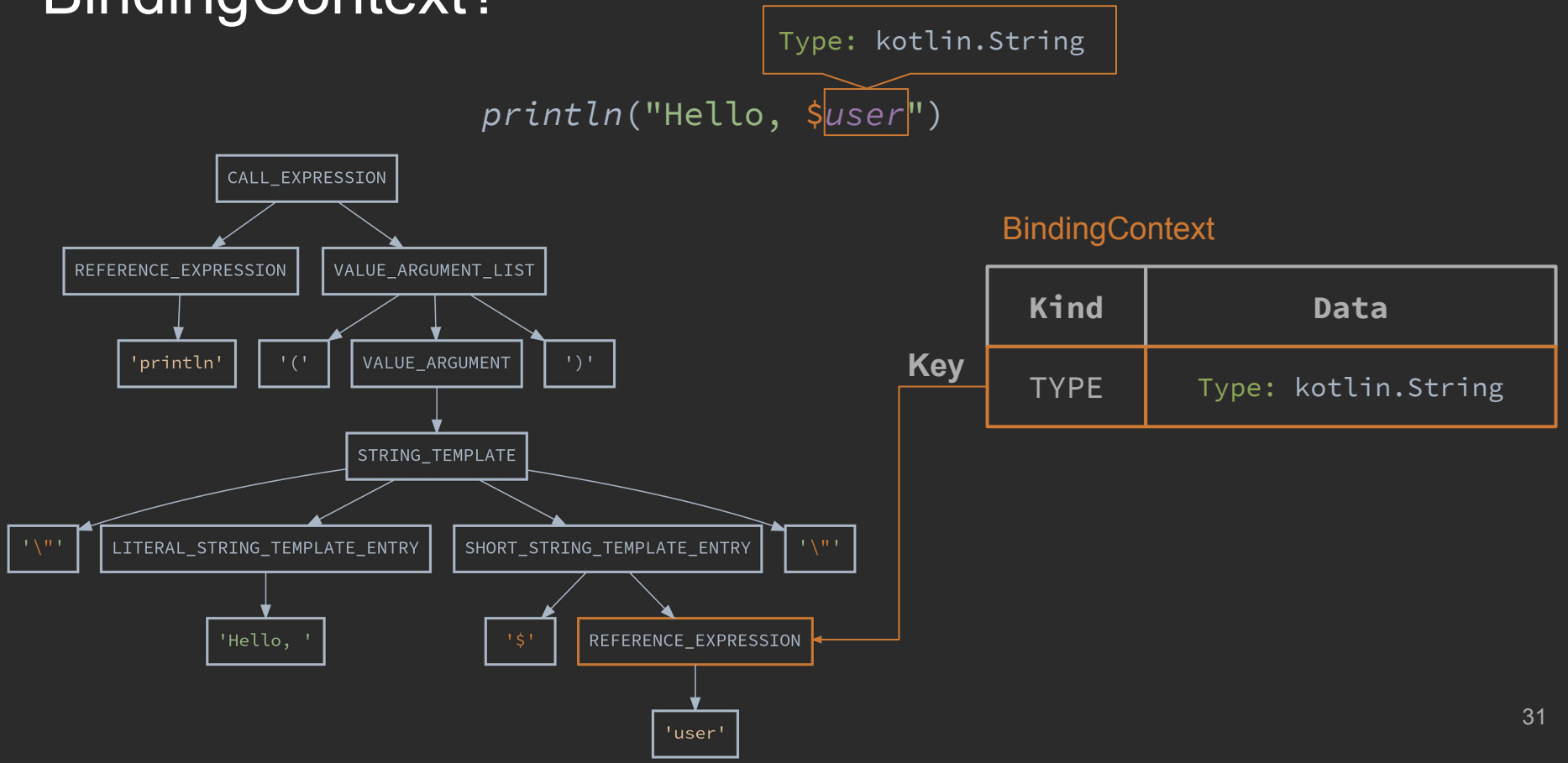

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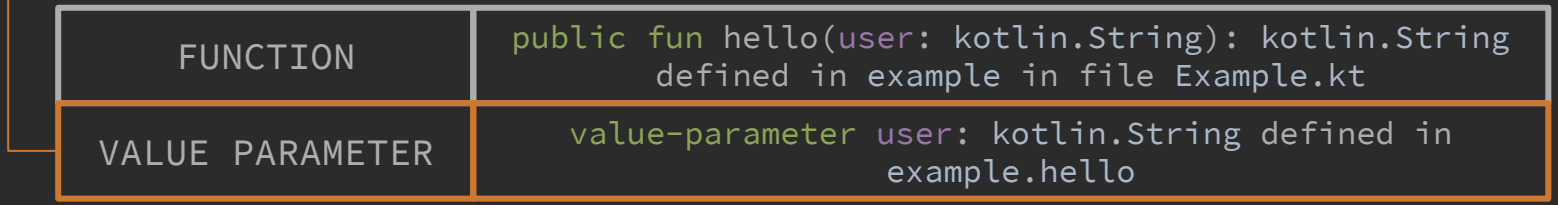

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VALUE PARAMETER	value-parameter user: kotlin.String defined in example.hello
REFERENCE TARGET	deserialized class String

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TYPE	Type: String

BindingContext?

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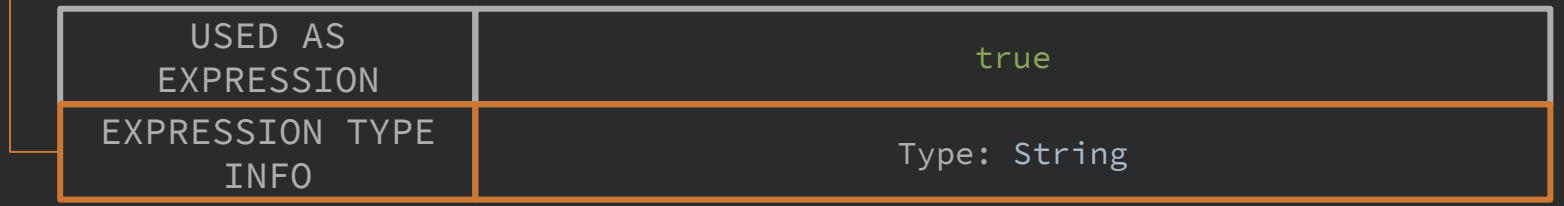

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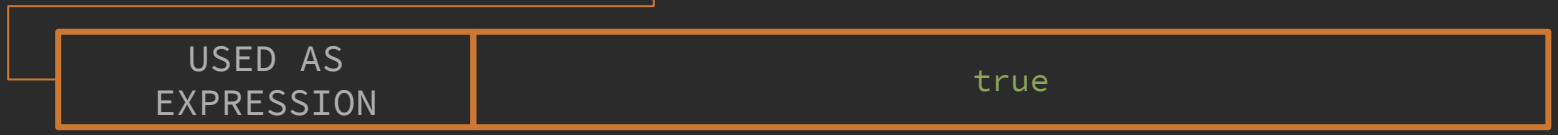

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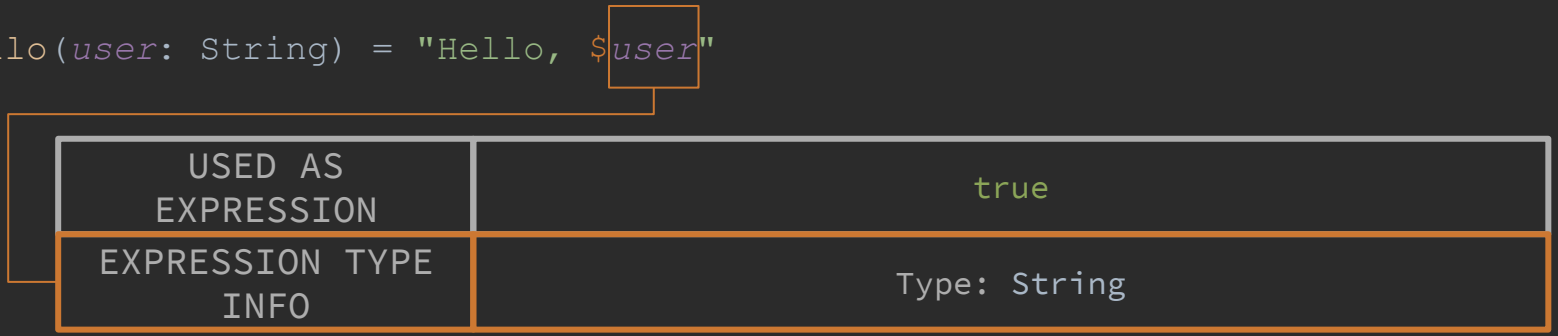

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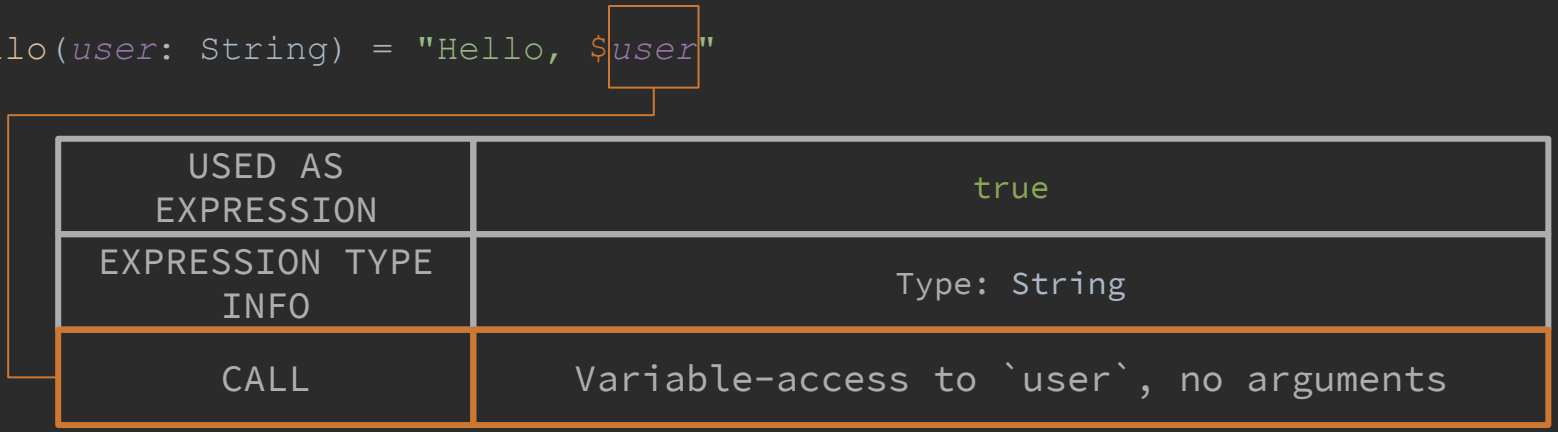

USED AS EXPRESSION	true
EXPRESSION TYPE INFO	Type: String
CALL	Variable-access to `user`, no arguments

BindingContext?

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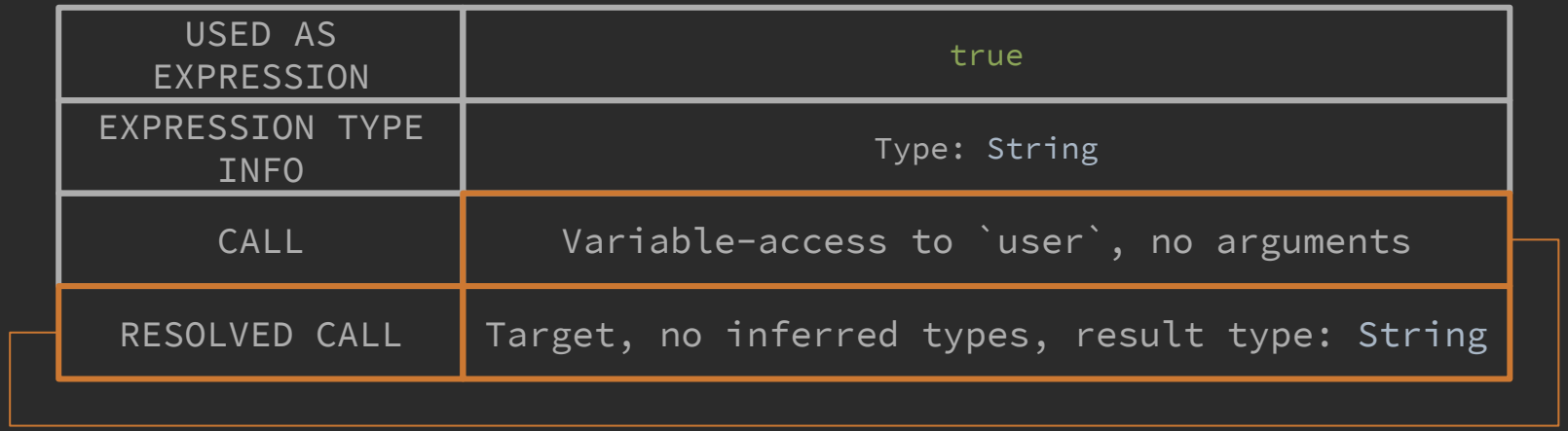

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USED AS EXPRESSION	true
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RESOLVED CALL	Target, no inferred types, result type: String
REFERENCE TARGET	value-parameter user: kotlin.String defined in example.hello

BindingContext?

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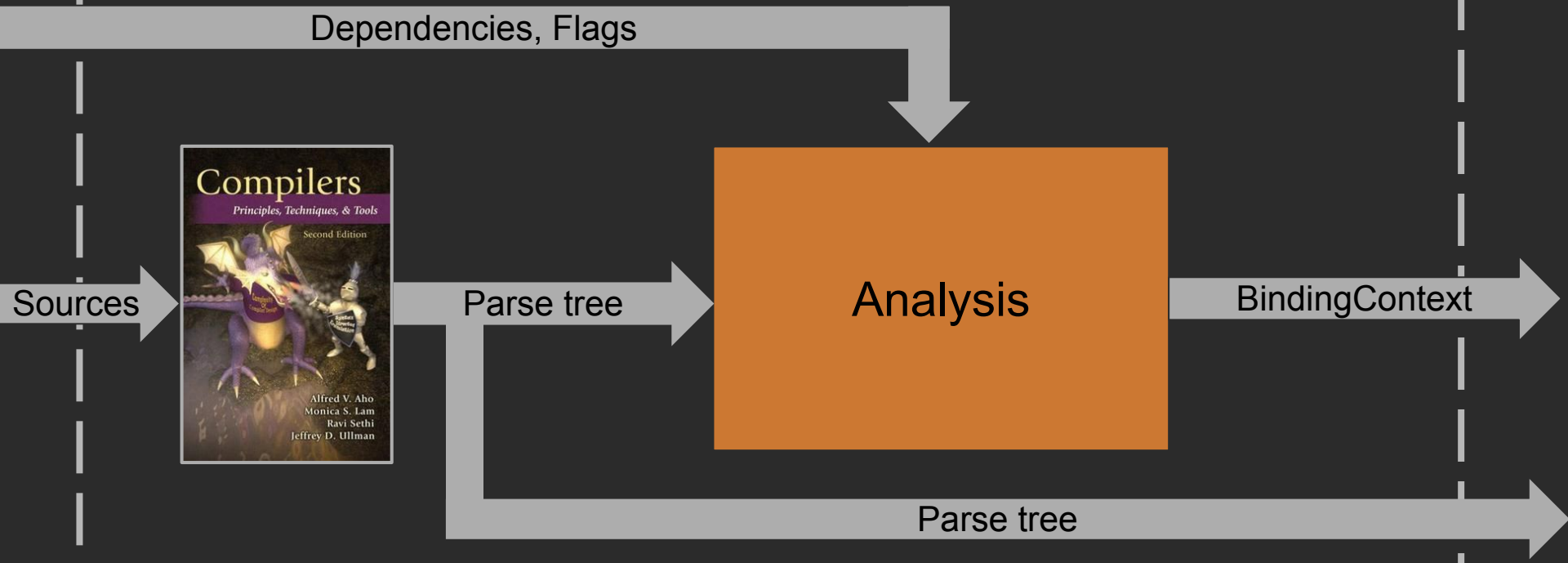
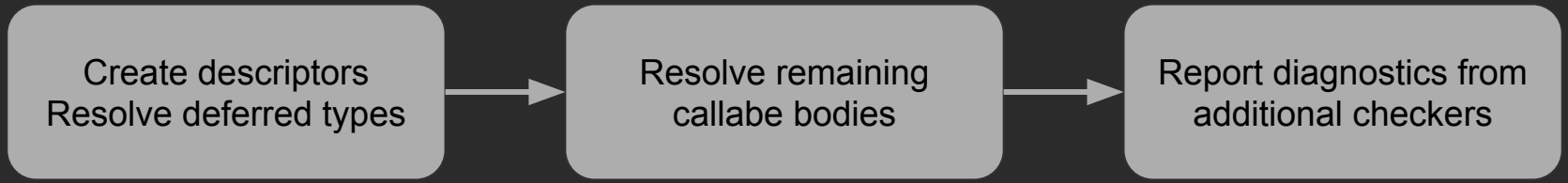
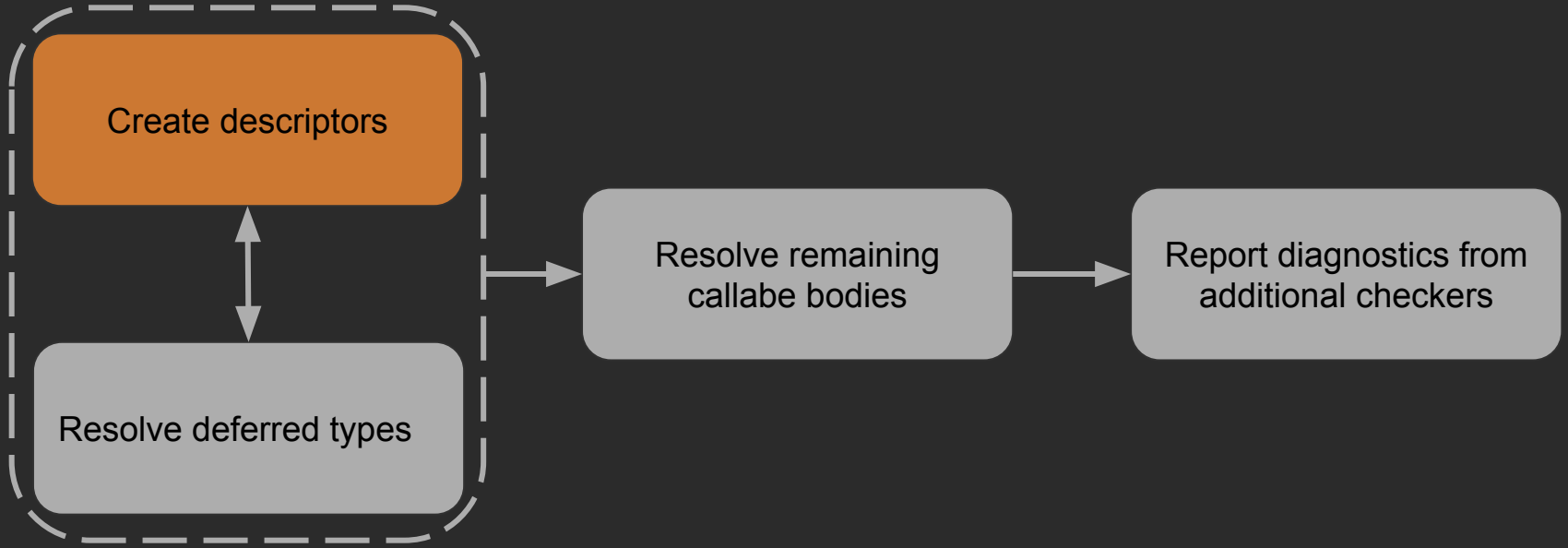


Analysis


Create descriptors
Resolve deferred types
Resolve remaining
callabe bodies
Report diagnostics from
additional checkers

Analysis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Declaring. DeclarationDescriptor

```
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```

FUNCTION	public fun hello(user: kotlin.String): kotlin.String defined in example in file Example.kt
VALUE PARAMETER	value-parameter user: kotlin.String defined in example.hello
REFERENCE TARGET	deserialized class String
TYPE	Type: String

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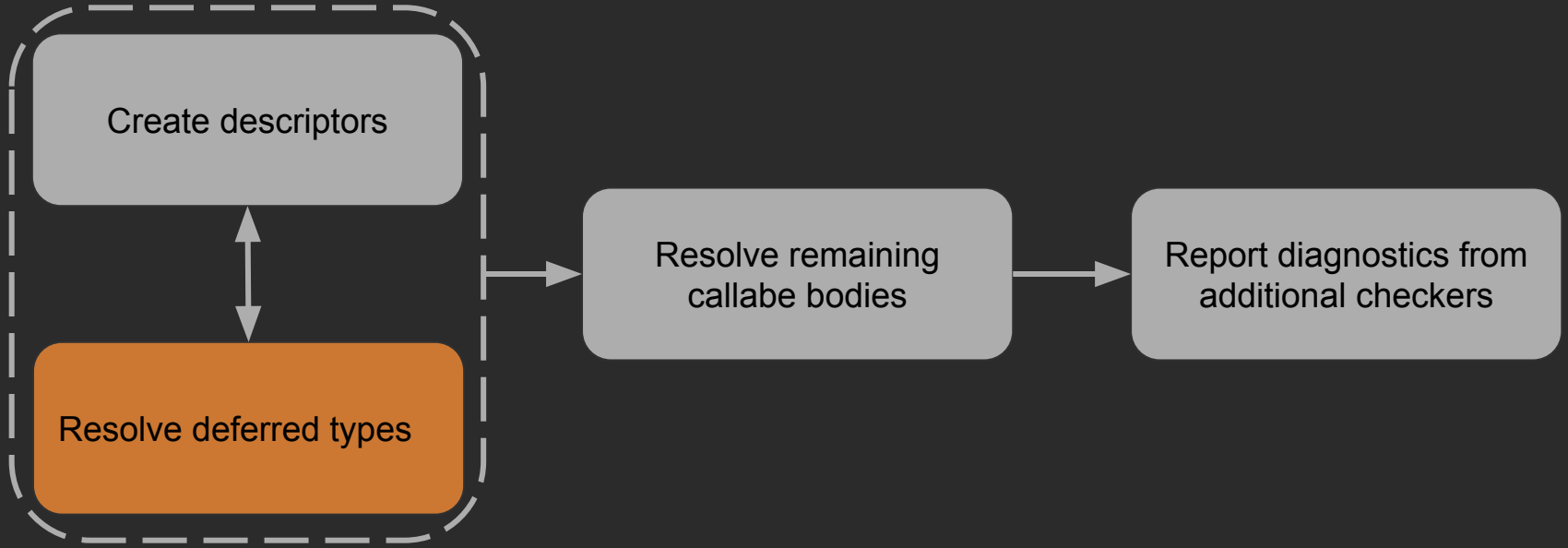
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Lazy Analysis

```
fun hello() = helloWorld

val helloWorld = "Hello, world"
```

Lazy Analysis

```
fun hello(): ??? = helloWorld

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Lazy Analysis

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Lazy Analysis

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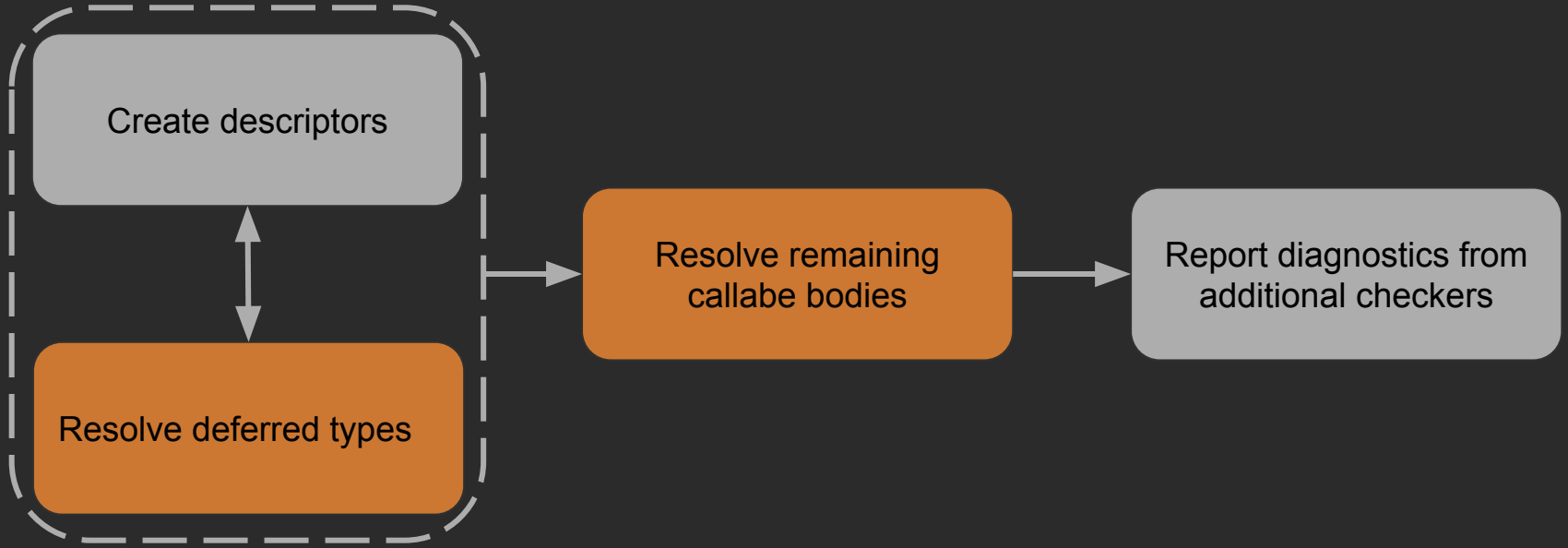
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How to Resolve a Call!

```
fun hello(name: String) = println(name)

class Hello {
    fun hello(user: String) = "Hello, $user"

    fun hey() {
        hello("Me")
    }
}
```

How to Resolve a Call!

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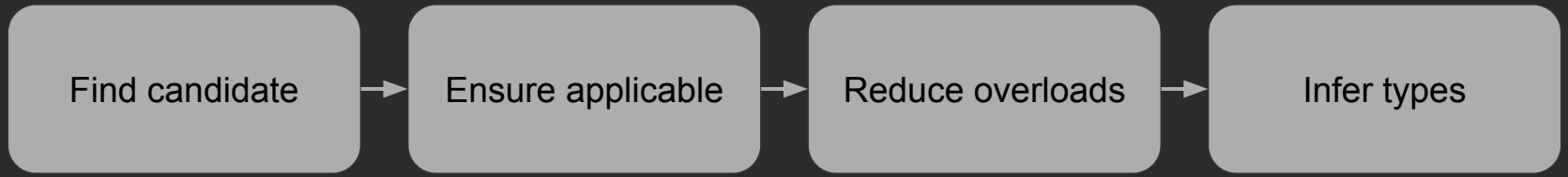

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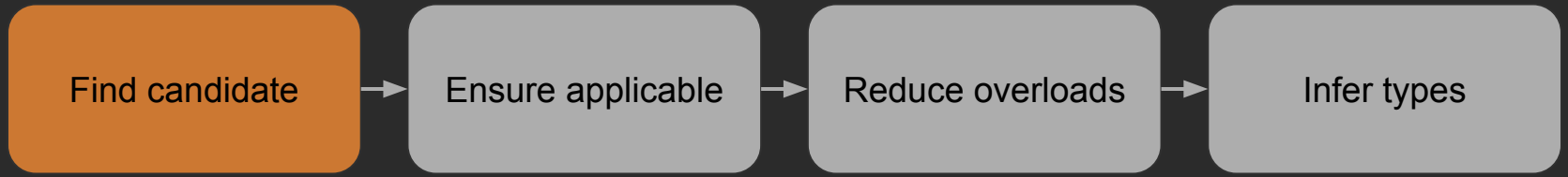

Scopes

Package: helloworld

```kotlin
// FILE: hello.kt

package helloworld

import helloworld.world

fun hello(user: String) = "Hello, $user"
```

```kotlin
// FILE: world.kt

package helloworld

fun world() = "World"
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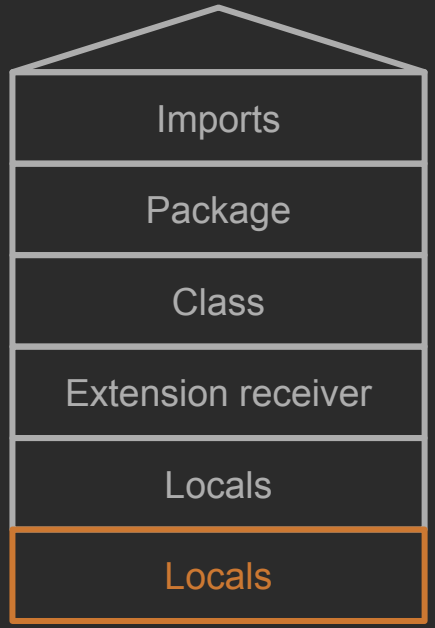
The Tower



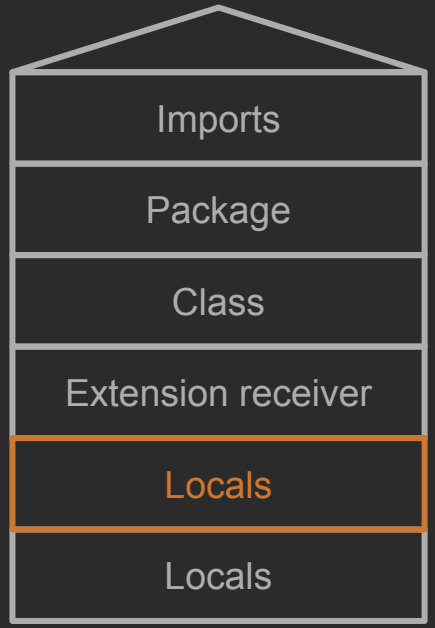

```kotlin
// hello.kt
package example
import other.hello
class Hello {
    fun hello(d: D) = …
    fun World.hey() {
        fun hello(b: B) = …
        run {
            fun hello(a: A) = …
            hello(F())
        }
    }
}
```

```kotlin
// samePackage.kt
package example
class World {
    fun hello(c: C) = …
}
fun hello(e: E) = …

// other.kt
package other

fun hello(f: F) = …
```

The Tower

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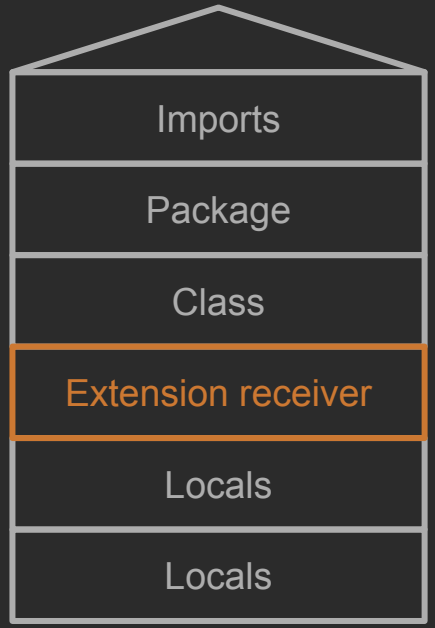


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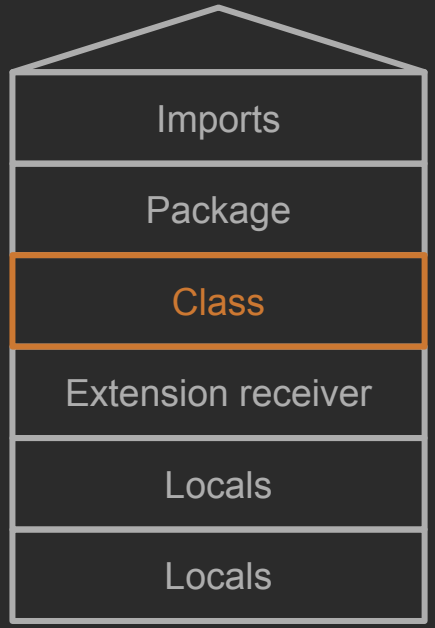


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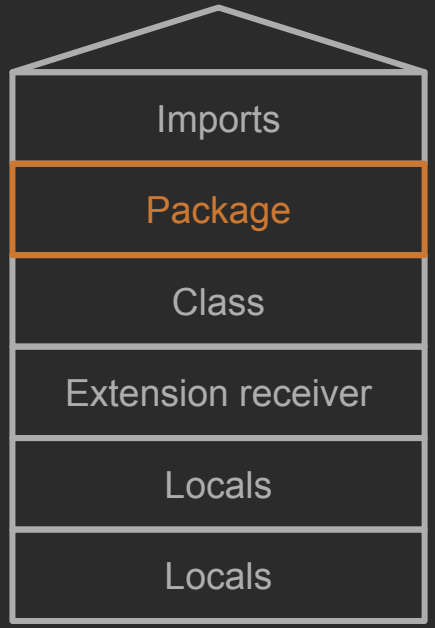
```

The Tower



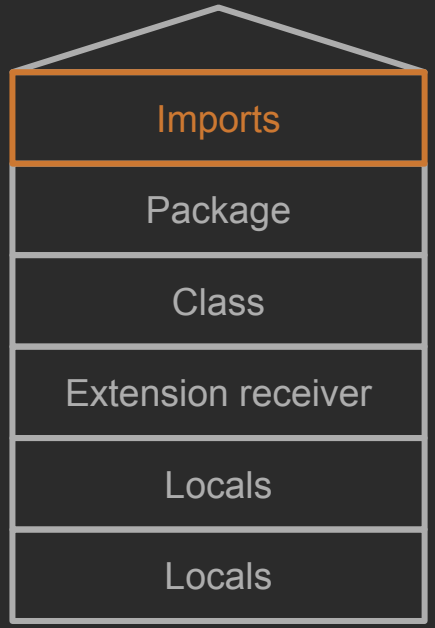

```kotlin
// hello.kt
package example
import other.hello
class Hello {
    fun hello(d: D) = …
    fun World.hey() {
        fun hello(b: B) = …
        run {
            fun hello(a: A) = …
            hello(F())
        }
    }
}
```

```kotlin
// samePackage.kt
package example
class World {
    fun hello(c: C) = …
}
fun hello(e: E) = …

// other.kt
package other

fun hello(f: F) = …
```

The Tower



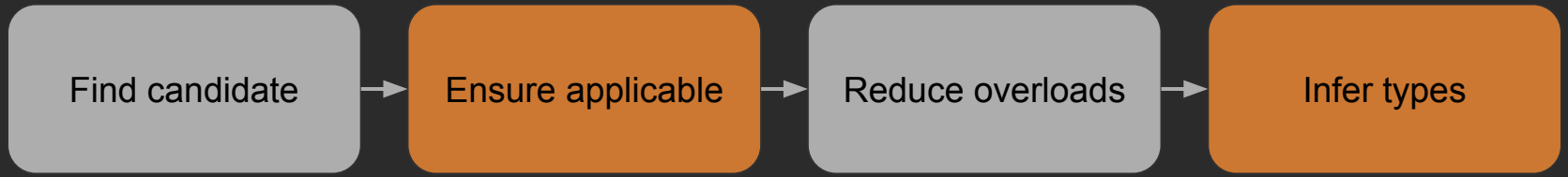

```
// hello.kt
package example
import other.hello
class Hello {
    fun hello(d: D) = …
    fun World.hey() {
        fun hello(b: B) = …
        run {
            fun hello(a: A) = …
            hello(F())
        }
    }
}
```

```
// samePackage.kt
package example
class World {
    fun hello(c: C) = …
}
fun hello(e: E) = …

// other.kt
package other

fun hello(f: F) = …
```

How to Resolve Call!



Type Inference

```
fun <T> id(t: T): T = t

id("")
```

Type Inference

```
fun <T> id(t: T): T = t

id("")
```

```
T <: Any?
```

Type Inference

```
fun <T> id(t: T): T = t

id("")
```

```
T <: Any?
T :> Nothing
```

Type Inference

```
fun <T> id(t: T): T = t

id("")

T <: Any?
T :> Nothing
T :> String
```

Type Inference

```
fun <T> id(t: T): T = t

id("")
```

```
T <: Any?
T :> Nothing
T :> String

=>
T <:> String
```

Type Inference, Expression Level

```
fun <T> materialize(): T = TODO()

val x: Int = materialize()
```

Type Inference, Expression Level

```
fun <T> materialize(): T = TODO()

val x: Int = materialize()
```

```
T <: Any?
T :> Nothing
```

Type Inference, Expression Level

```
fun <T> materialize(): T = TODO()

val x: Int = materialize()
```

~~T <: Any?~~
T :> Nothing
T <: Int

=> T <:> Int

Smart-Casts

```
fun test(x: Any) {
    if (x is String) {
        x.length
    }
    x.length
}
```

Data-flow

Smart-Casts

```
fun test(x: Any) {
    if (x is String) {
        x.length
    }
    x.length
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Data-flow

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Data-flow

Smart-Casts

```
fun test(x: Any) {
    if (x is String) {
        x.length
    }
    x.length
}
```

Data-flow

Smart-Casts: Quiz

```
interface A {
    fun foo()
}

fun bar(x: Any, b: Boolean) {
   while (true) {
       if (b) {
           x as A
           x.foo()
           break
       }
   }
}
```

Smart-Casts: Quiz

```
interface A {
    fun foo()
}

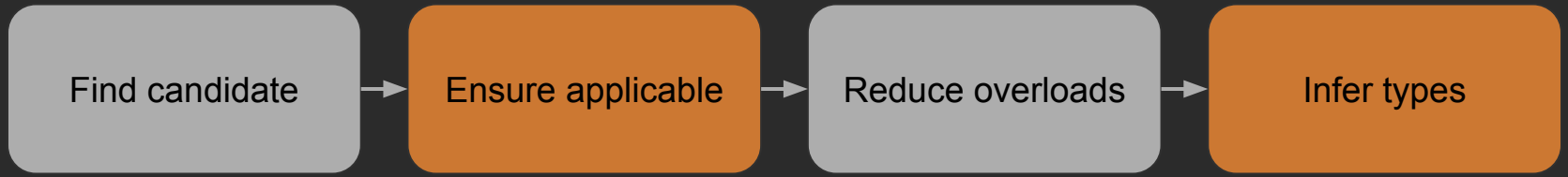
fun bar(x: Any, b: Boolean) {
   while (true) {
       if (b) {
           x as A
           break
       }
   }
   x.foo()
}
```

Frontend Timeline

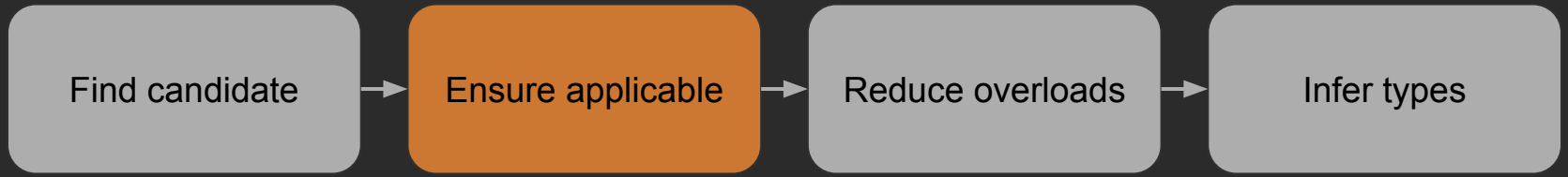
New Inference. Goals

- Call resolve unification
- Conversion improvements
- Better non-denotable types handling

New Inference



New Inference



New Inference. Conversions

KT-7770, KT-11129

```
interface Function1<in P, out R> { ... }
fun interface Action<U> {
   fun perform(data: U)
}

fun <T> enqueue(action: Action<T>) = ...

enqueue { it: String -> println(it) }
```

New Inference. Conversions

KT-7770, KT-11129

```
interface Function1<in P, out R> { ... }
fun interface Action<U> {
    fun perform(data: U)
}

fun <T> enqueue(action: Action<T>) = ...

enqueue { it: String -> println(it) }
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New Inference. Conversions

KT-7770, KT-11129

```
interface Function1<in P, out R> { ... }
fun interface Action<U> {
    fun perform(data: U): Unit // Function1<U, Unit>
}

fun <T> enqueue(action: Action<T>) = ...

enqueue { it: String -> println(it) }
```

New Inference. Conversions

KT-7770, KT-11129

```
interface Function1<in P, out R> { ... }
fun interface Action<U> {
   fun perform(data: U): Unit // Function1<U, Unit>
}

fun <T> enqueue(action: Action<T>) = ...

enqueue { it: String -> println(it) }

Action<T> -> Function1<T, Unit>
 => P <:> T
    R :> Unit
```

New Inference. Conversions

KT-7770, KT-11129

```
interface Function1<in P, out R> { ... }
fun interface Action<U> {
   fun perform(data: U): Unit // Function1<U, Unit>
}

fun <T> enqueue(action: Action<T>) = ...

enqueue { it: String -> println(it) }
```

```
Action<T> -> Function1<T, Unit>
 => P <:> T
    R :> Unit
```

```
Function1<String, R>
 => P <: String
```

New Inference. Conversions

KT-7770, KT-11129

```
interface Function1<in P, out R> { ... }
fun interface Action<U> {
   fun perform(data: U): Unit // Function1<U, Unit>
}

fun <T> enqueue(action: Action<T>) = ...

enqueue { it: String -> println(it) }
```

```
Action<T> -> Function1<T, Unit>
 => P <:> T
    R :> Unit

 => P <:> String, R <:> Unit, T <:> String
```

```
Function1<String, R>
 => P <: String
```

New Inference. Intersection Types

```
fun <T> select(a: T, b: T): T = TODO()

val n = select(5, 5f)
```

New Inference. Intersection Types

```
fun <T> select(a: T, b: T): T = TODO()

val n = select(5, 5f)

T <: Any?
T :> Nothing
```

New Inference. Intersection Types

```
fun <T> select(a: T, b: T): T = TODO()

val n = select(5, 5f)

T <: Any?
T :> Nothing

T :> Int
T :> Float
```

New Inference. Intersection Types

```
fun <T> select(a: T, b: T): T = TODO()

val n = select(5, 5f) // Any

T <: Any?
T :> Nothing

T :> Int
T :> Float

=> T <:> Any // Old inference
```

New Inference. Intersection Types

```
fun <T> select(a: T, b: T): T = TODO()

val n = select(5, 5f) // Comparable<*> & Number

T <: Any?
T :> Nothing

T :> Int
T :> Float

=> T <:> Any // Old inference

T <:> CommonSupertype(Int, Float)
T <:> Comparable<*> & Number
```

New Inference. Intersection Types

```
fun <T> select(a: T, b: T): T = TODO()

val n = if (true) 5 else 5f // Implicit cast to Any in old inference
```

New Inference. Intersection Types

```
fun <T> select(a: T, b: T): T = TODO()

val n: Comparable<*> & Number = if (true) 5 else 5f
```

New Inference. System Joining

```
fun <T> id(t: T) = t
fun <R> materialize(): R = TODO()


fun foo(): String = id(materialize())
```

New Inference. System Joining

```
fun <T> id(t: T) = t
fun <R> materialize(): R = TODO()


fun foo(): String = id(materialize())


R <: Any?, not enough
```

New Inference. System Joining

```
fun <T> id(t: T) = t
fun <R> materialize(): R = TODO()


fun foo(): String = id(materialize())


R <: Any?, not enough

T <:> String, join system
```

New Inference. System Joining

```
fun <T> id(t: T) = t
fun <R> materialize(): R = TODO()


fun foo(): String = id(materialize())
```

R <: Any?, not enough

T <:> String, join system

R <: T => R <:> String

New Inference. System Joining

```
class Some(l: List<String>) {
    val s: Set<String> = l.toCollection(newSetFromMap(IdentityHashMap()))
}

fun <T, C : MutableCollection<in T>> Iterable<T>.toCollection(out: C): C = …
fun <K> newSetFromMap(map: MutableMap<K, Boolean>): MutableSet<K> = …
```

New Inference. System Joining

```
class Some(l: List<String>) {
    val s: Set<String> = l.toCollection(newSetFromMap(IdentityHashMap()))
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fun <T, C : MutableCollection<in T>> Iterable<T>.toCollection(out: C): C = …
fun <K> newSetFromMap(map: MutableMap<K, Boolean>): MutableSet<K> = …

C <: Set<String>
```

New Inference. System Joining

```
class Some(l: List<String>) {
    val s: Set<String> = l.toCollection(newSetFromMap(IdentityHashMap()))
}

fun <T, C : MutableCollection<in T>> Iterable<T>.toCollection(out: C): C = …
fun <K> newSetFromMap(map: MutableMap<K, Boolean>): MutableSet<K> = …

C <: Set<String>
C :> MutableSet<K>
```

New Inference. System Joining

```
class Some(l: List<String>) {
    val s: Set<String> = l.toCollection(newSetFromMap(IdentityHashMap()))
}

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fun <K> newSetFromMap(map: MutableMap<K, Boolean>): MutableSet<K> = …

C <: Set<String>
C :> MutableSet<K>

  => MutableSet<K> <: Set<String>
```

New Inference. System Joining

```
class Some(l: List<String>) {
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}

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C <: Set<String>
C :> MutableSet<K>

  => MutableSet<K> <: Set<String>
  => K <:> String
```
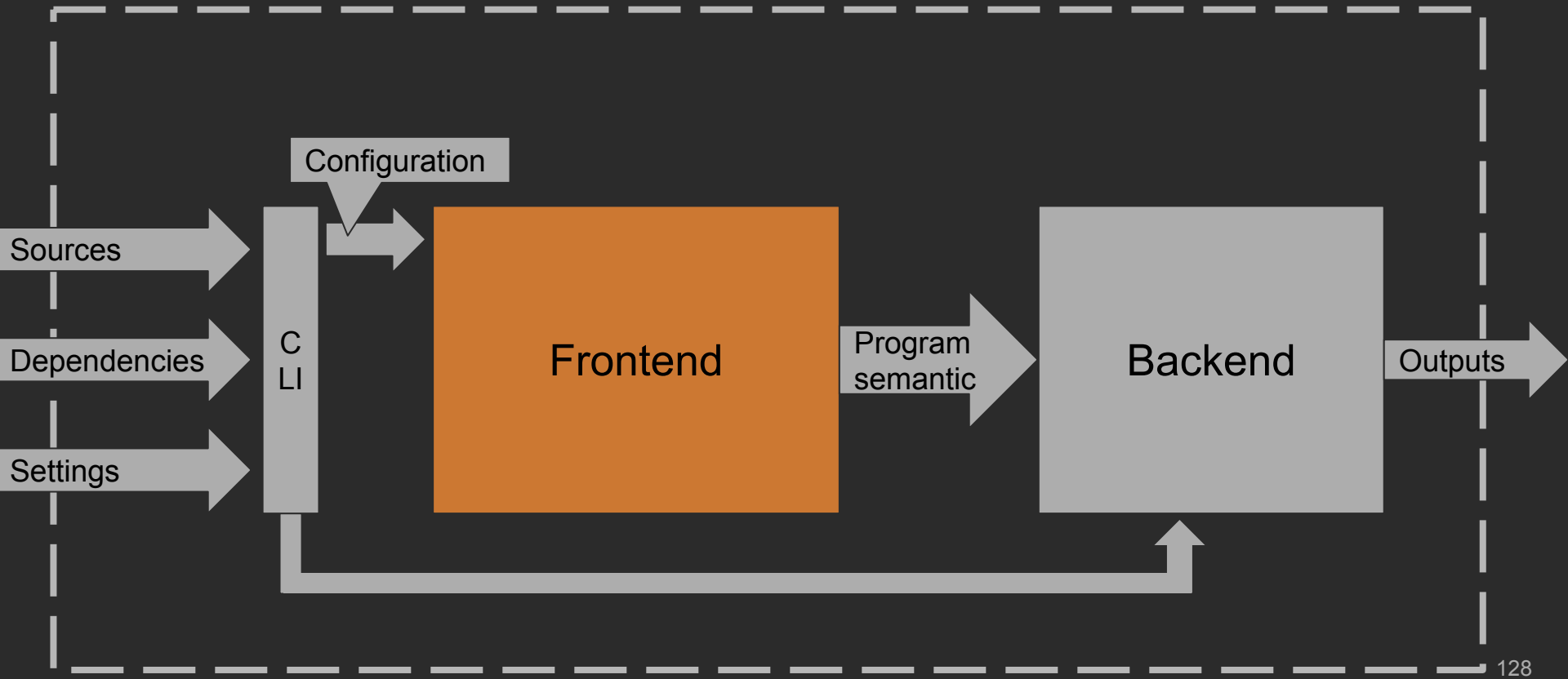

Frontend Timeline

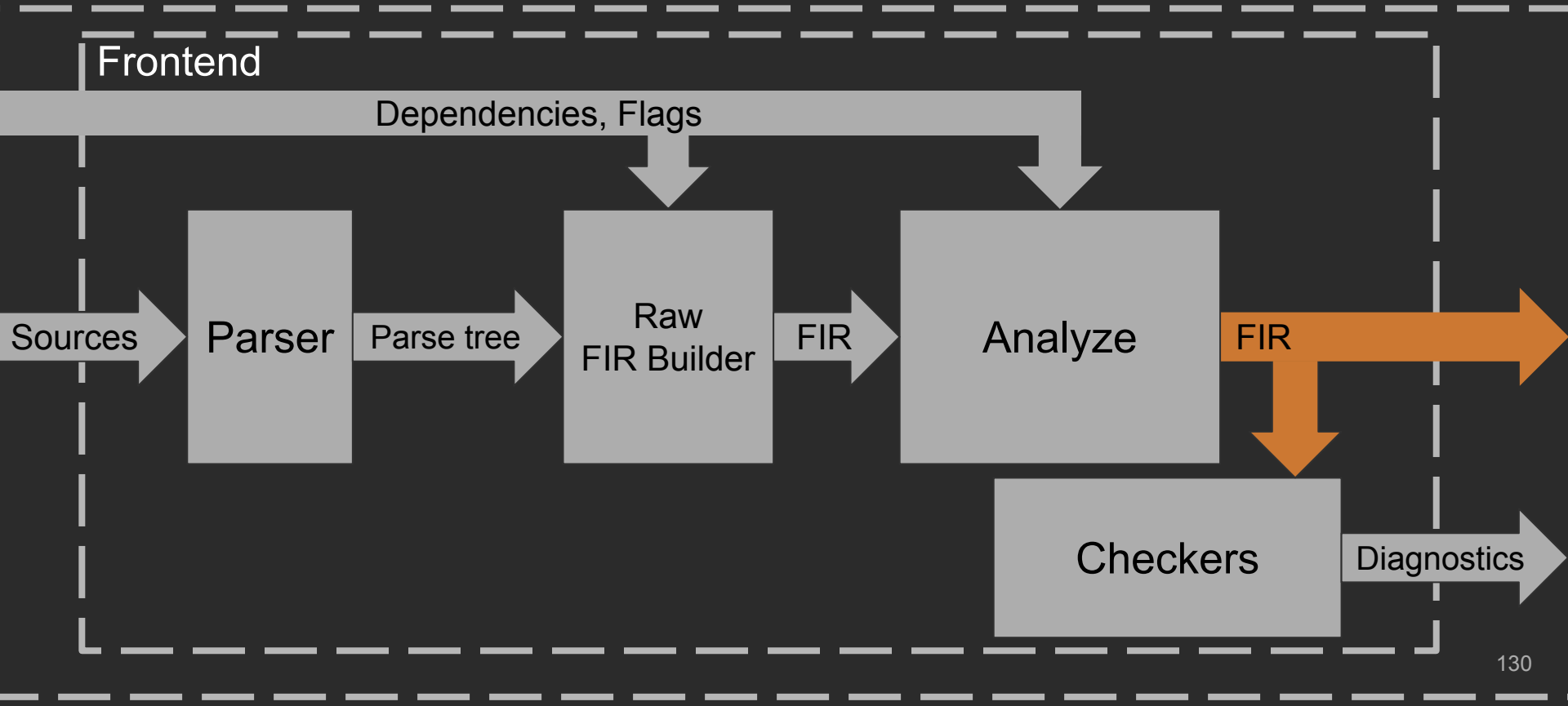
Compiler as a Transparent Box



New Frontend. Goals

- More traditional compiler approach
- Better performance
- Single main data structure to hold semantics

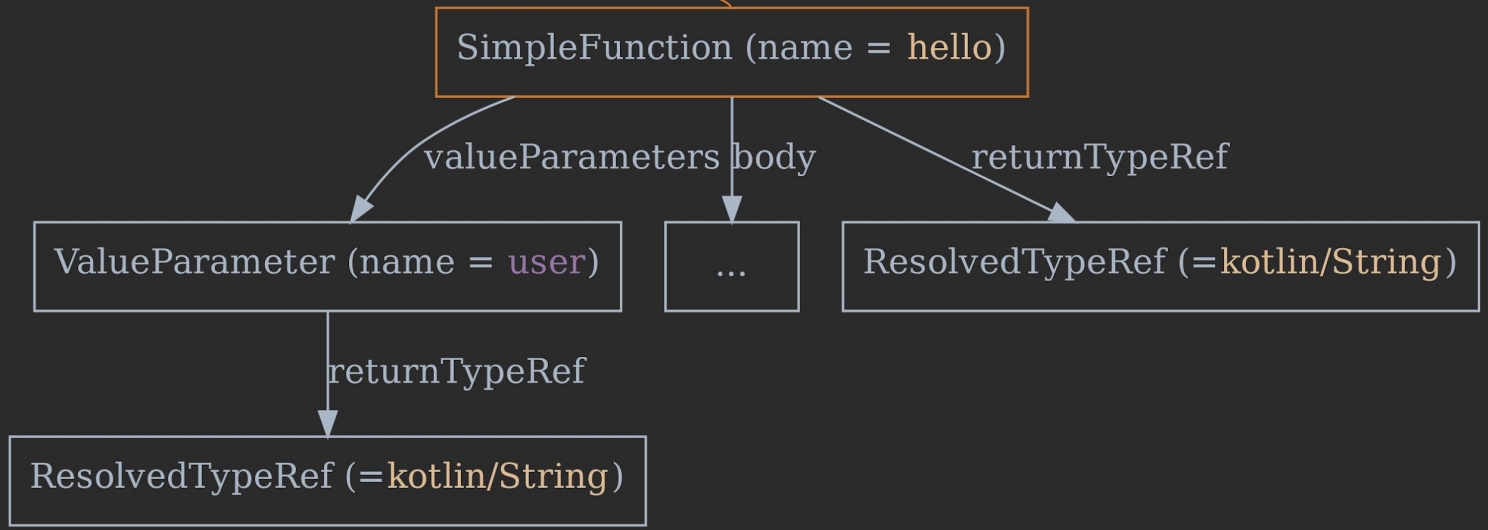
FIR/Frontend as a Transparent Box



FIR? Frontend Intermediate Representation! A Tree!

```
fun hello(user: String) = "Hello, $user"
```

NOTE: AST



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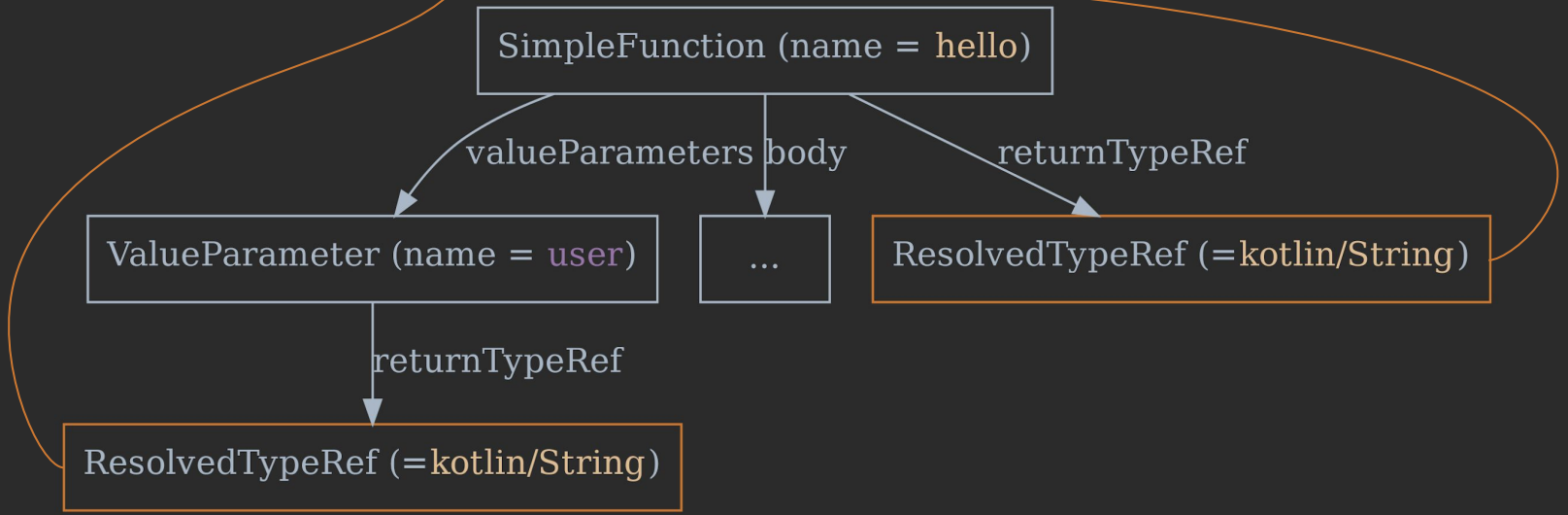

FIR? Frontend Intermediate Representation! A Tree!

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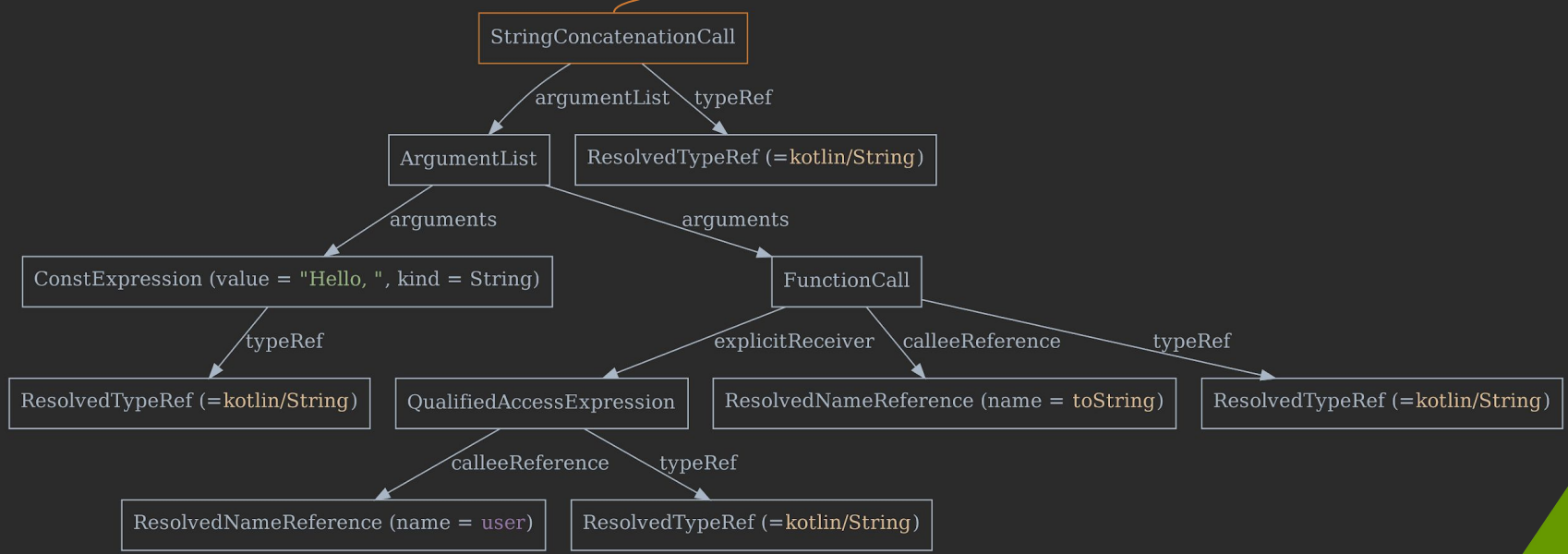

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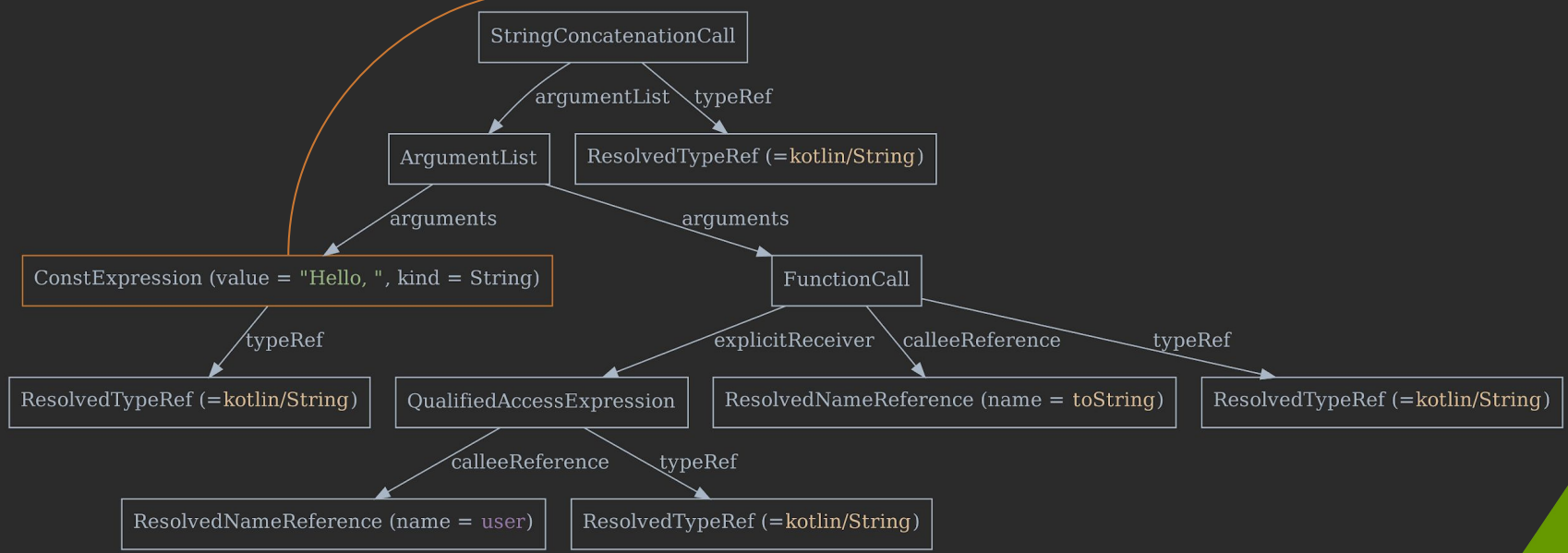

FIR? Frontend Intermediate Representation! A Tree!

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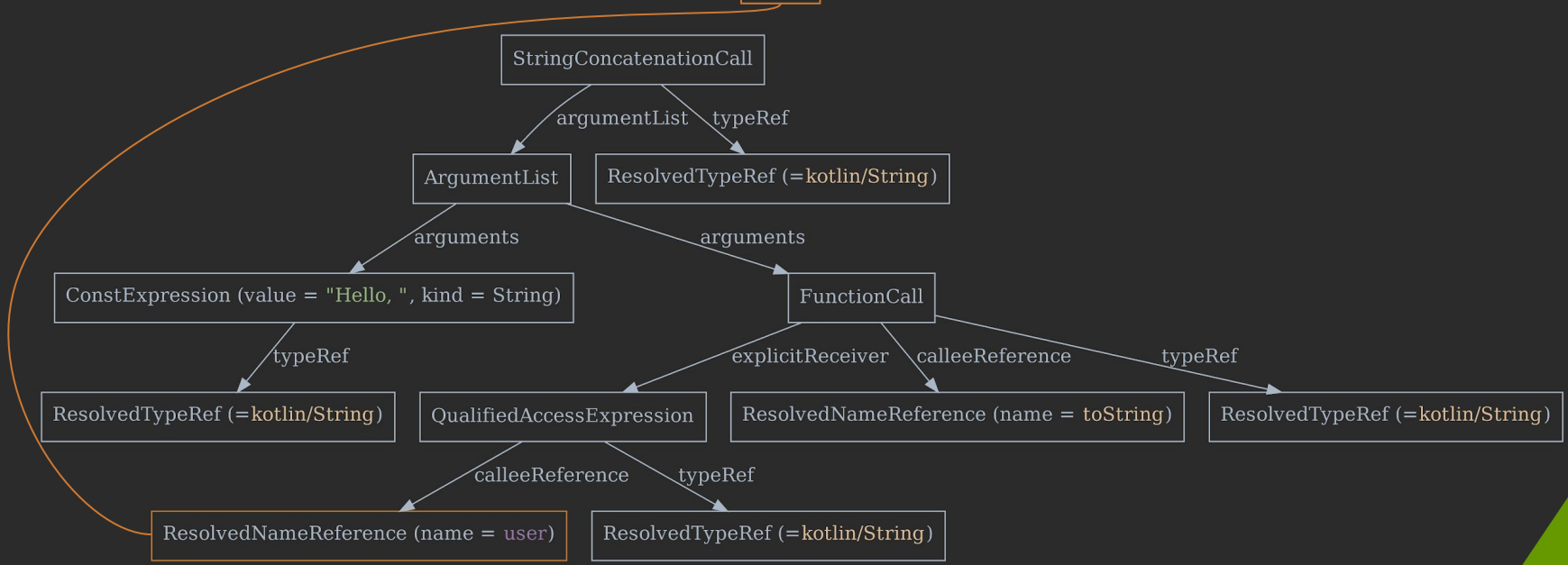
NOTE: AST



FIR? Frontend Intermediate Representation! A Tree!

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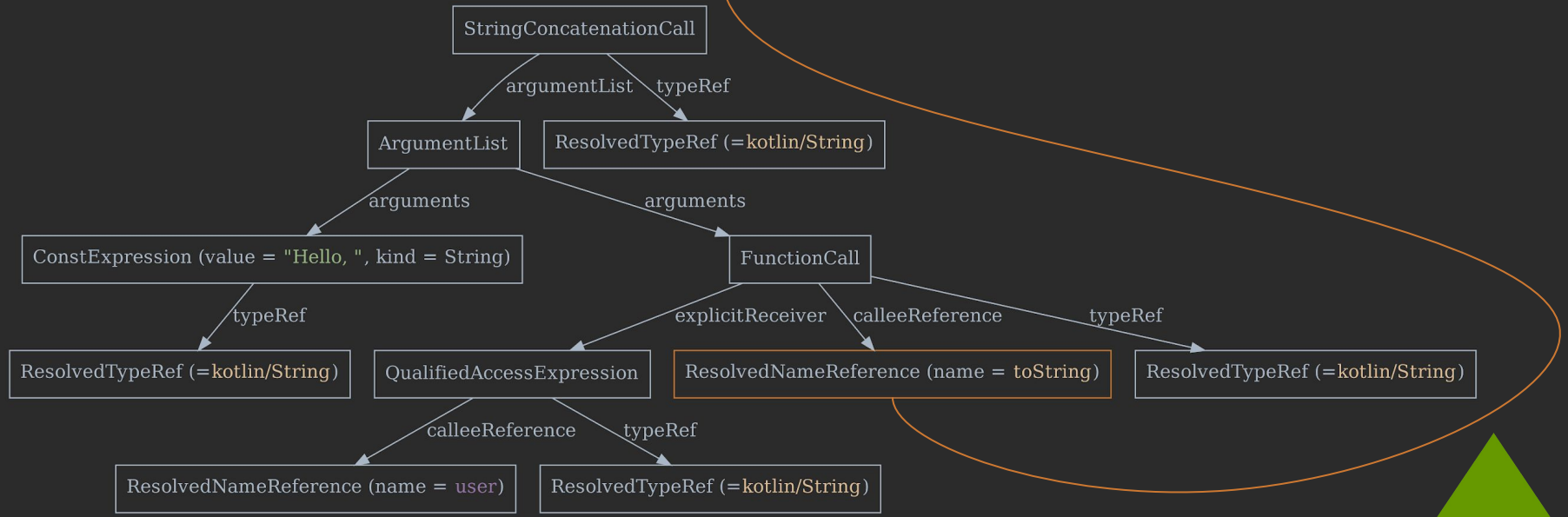
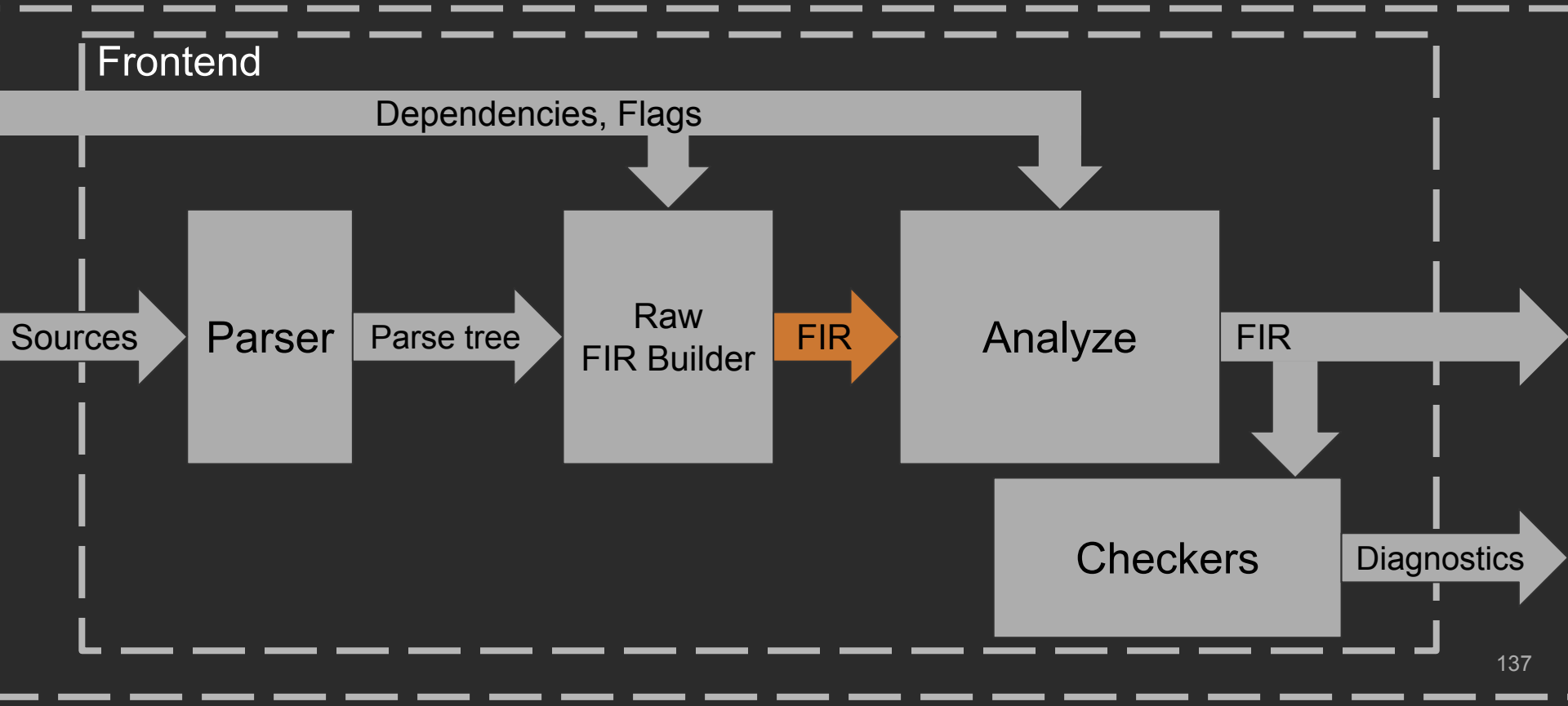
```

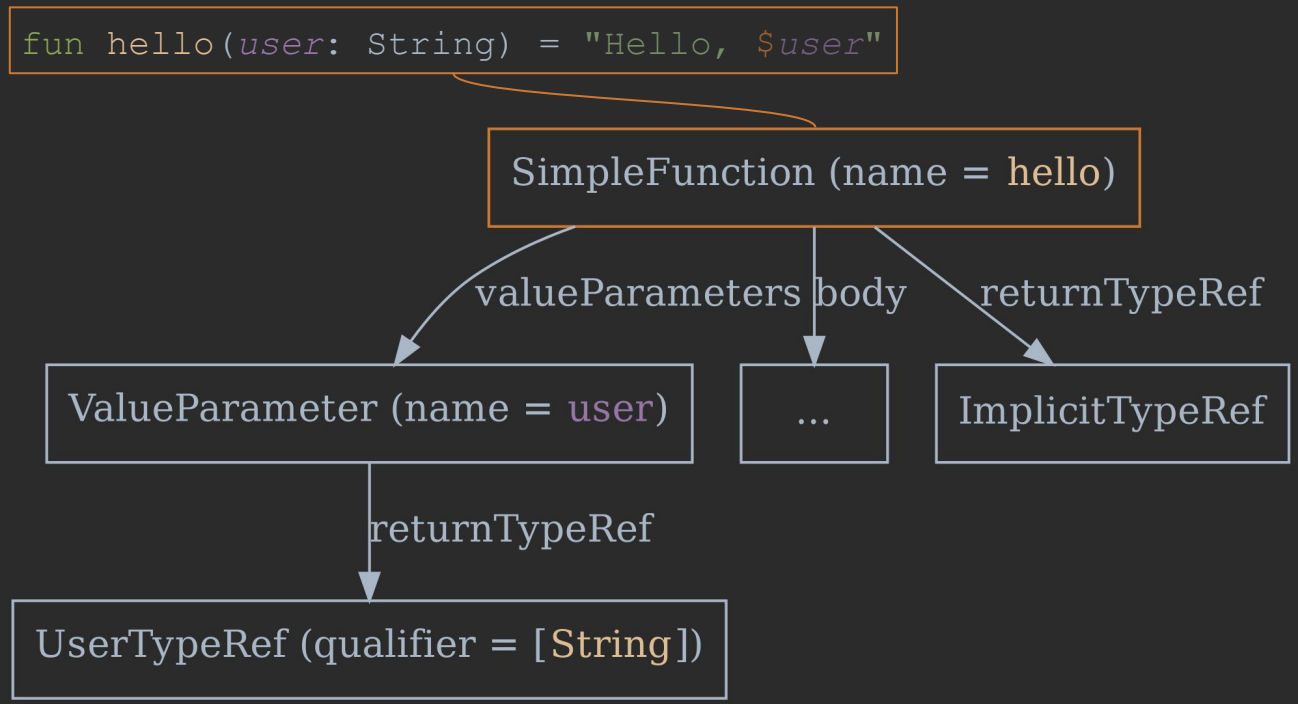
NOTE: AST



FIR/Frontend as a Transparent Box

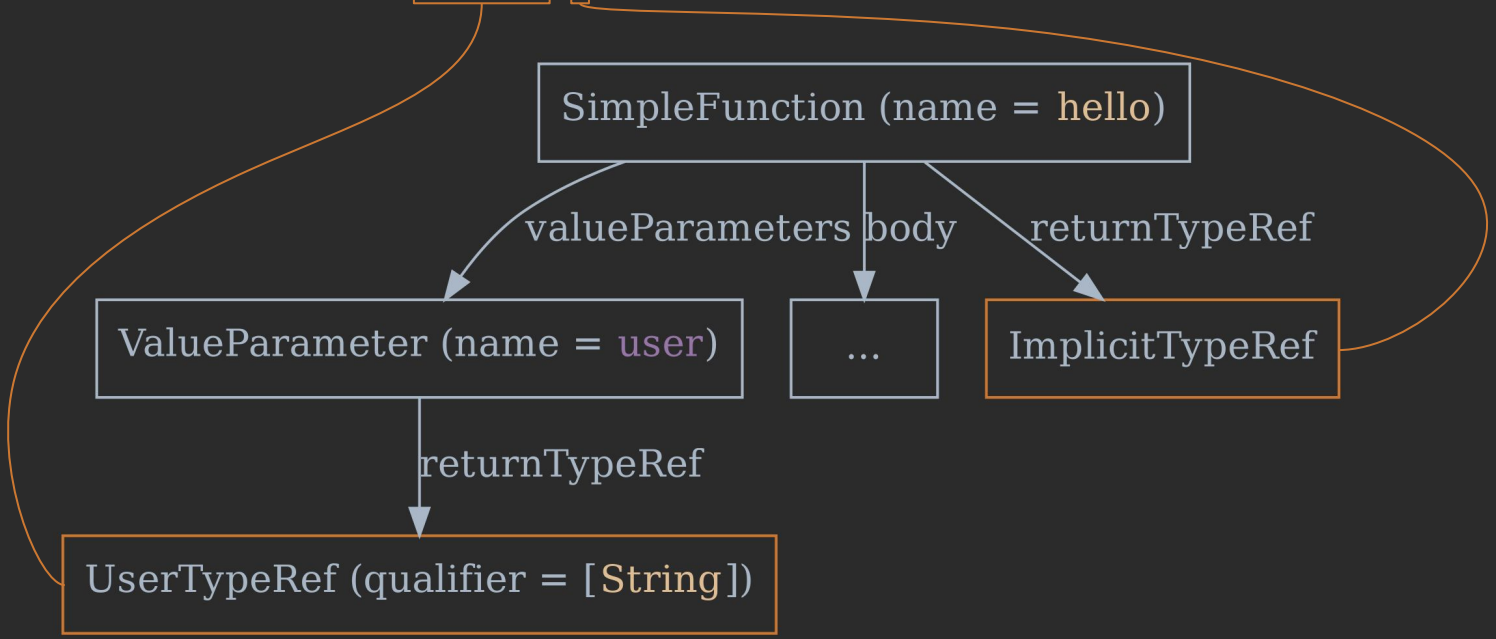


Raw FIR


fun hello(user: String) = "Hello, $user"
SimpleFunction (name = hello)
valueParameters
body
returnTypeRef
ValueParameter (name = user)
...
ImplicitTypeRef
returnTypeRef
UserTypeRef (qualifier = [String])

Raw FIR

```
fun hello(user: String) = "Hello, $user"
```



Raw FIR

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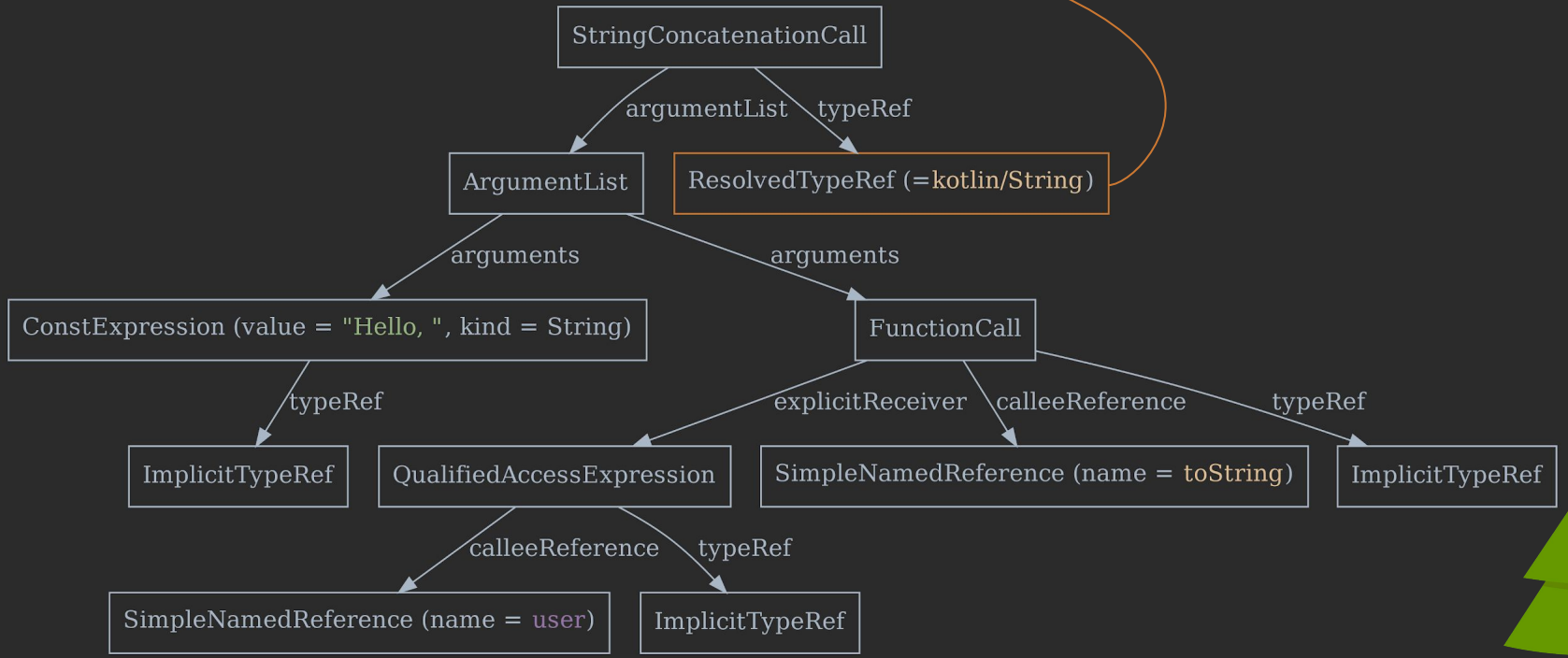

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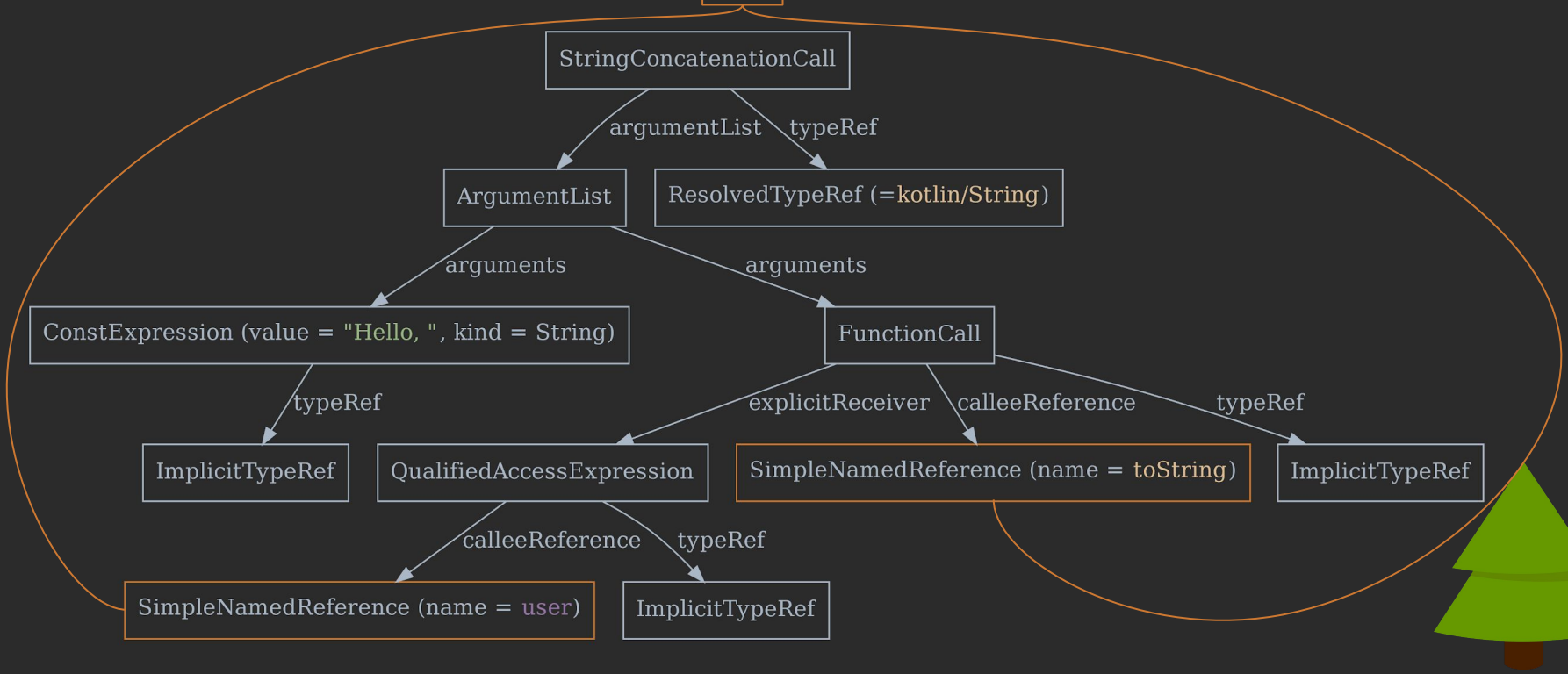


Desugaring

- IF, ?: to when
- For loop to while
- Destructuring declarations

Desugaring

```
if (b) {
    println("Hello")
}
```

```
when {
    b -> println("Hello")
}
```

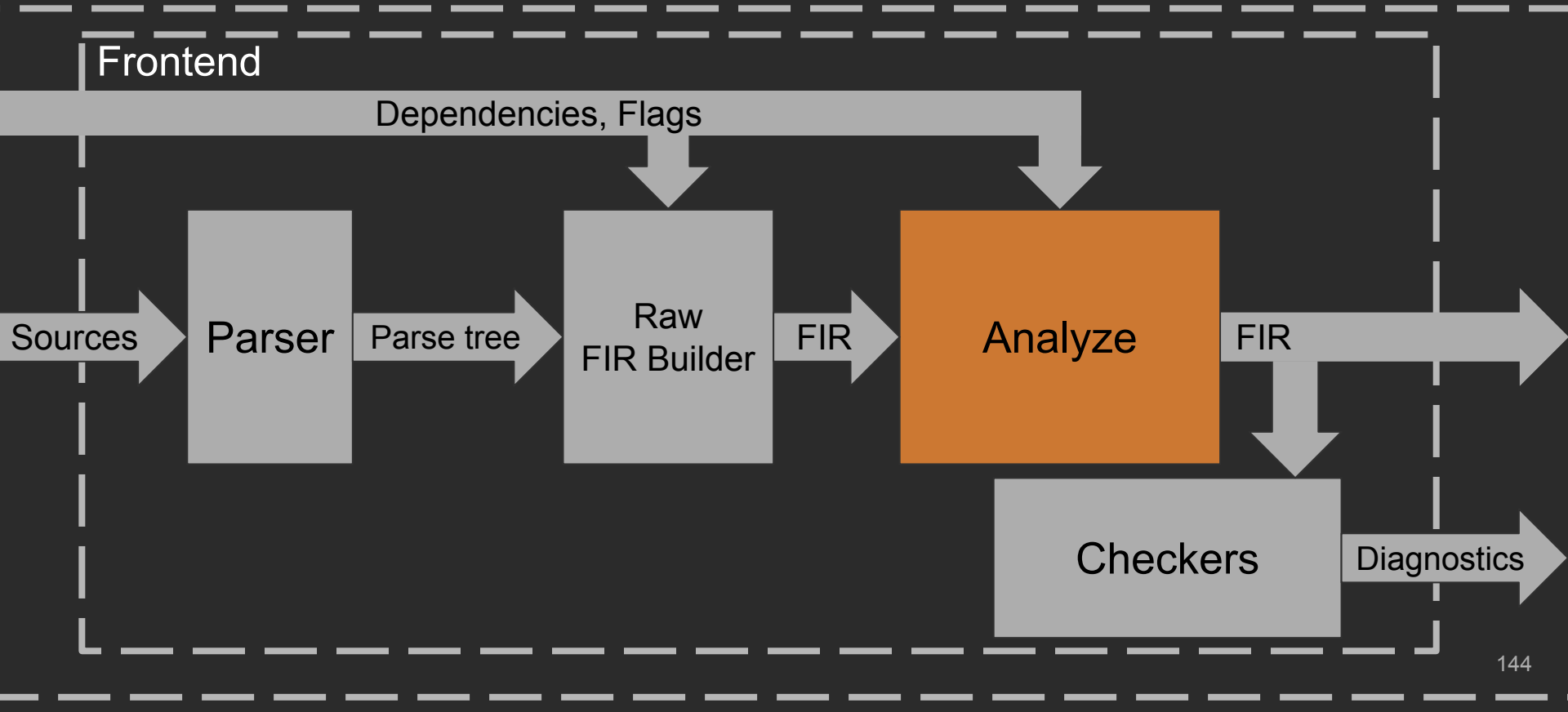
```
for (s in list) {
    println(s)
}
```

```
val <iterator> = list.iterator()
while (<iterator>.hasNext()) {
    val s = <iterator>.next()
    println(s)
}
```

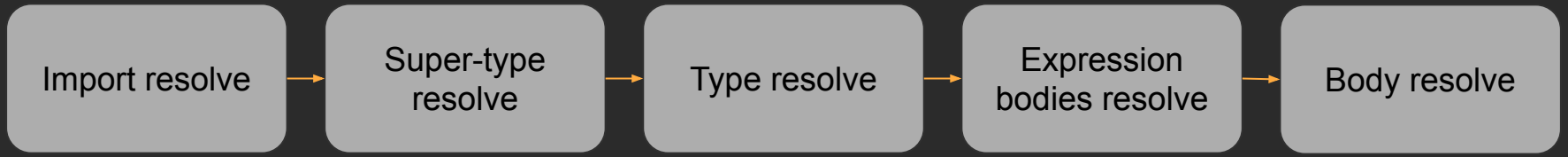
```
val (a, b) = "a" to "b"
```

```
val <destruct> = "a" to "b"
val a = <destruct>.component1()
val b = <destruct>.component2()
```

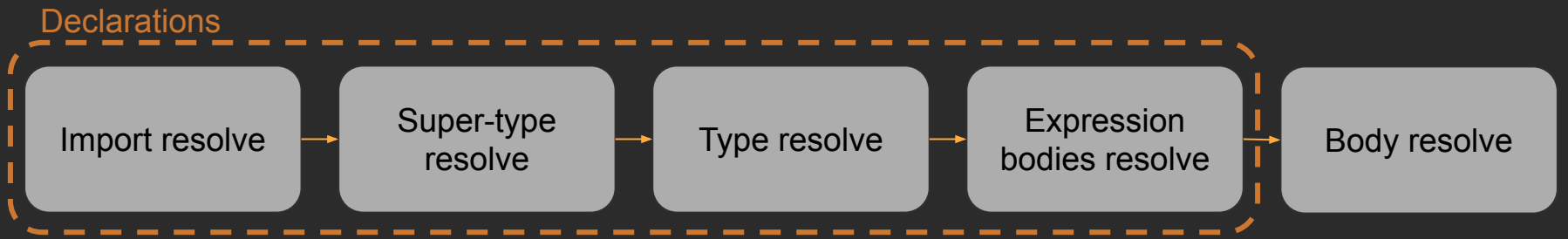
FIR/Frontend as a Transparent Box



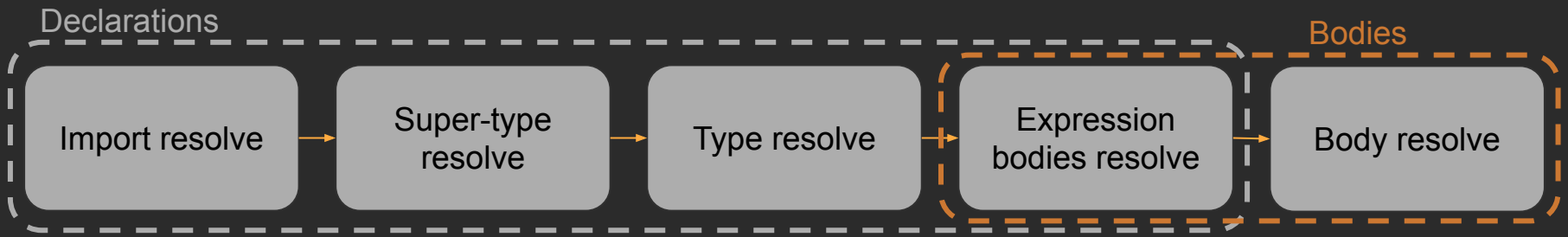
Batch Analysis



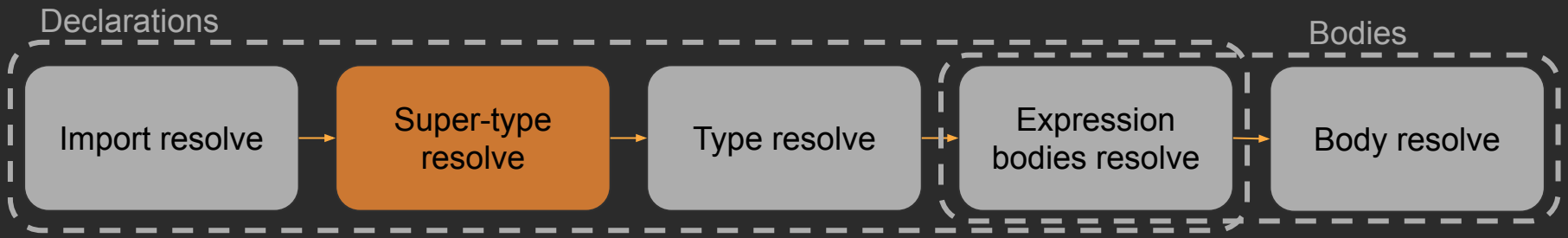
Batch Analysis



Batch Analysis



Batch Analysis



Supertype Resolve

```
// FILE: TopLevel.kt
class TopLevel : Middle() {
    class Nested : BaseNested()
}

// FILE: Middle.kt
open class Middle : Base() {}

// FILE: Base.kt
open class Base {
    open class BaseNested
}
```

Supertype Resolve

```
// FILE: TopLevel.kt
class TopLevel : Middle() {
    class Nested : BaseNested()
}

// FILE: Middle.kt
open class Middle : Base() {}

// FILE: Base.kt
open class Base {
    open class BaseNested
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```

Supertype Resolve

```
// FILE: TopLevel.kt
class TopLevel : Middle() {
    class Nested : BaseNested()
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// FILE: Middle.kt
open class Middle : Base() {}

// FILE: Base.kt
open class Base {
    open class BaseNested
}
```

Supertype Resolve

```
// FILE: TopLevel.kt
class TopLevel : Middle() {
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// FILE: Middle.kt
open class Middle : Base() {}

// FILE: Base.kt
open class Base {
    open class BaseNested
}
```

Supertype Resolve

```
// FILE: TopLevel.kt
class TopLevel : Middle() {
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// FILE: Middle.kt
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// FILE: Base.kt
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Supertype Resolve

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// FILE: TopLevel.kt
class TopLevel : Middle() {
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open class Middle : Base() {}

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open class Base {
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```

Supertype Resolve

```
// FILE: TopLevel.kt
class TopLevel : Middle() {
    class Nested : BaseNested()
}

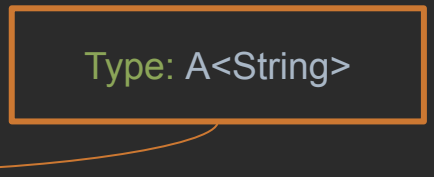
// FILE: Middle.kt
open class Middle : Base() {}

// FILE: Base.kt
open class Base {
    open class BaseNested
}
```

Types in FIR, for MPP

```
// MODULE: A

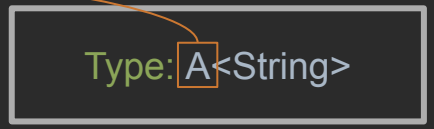
class A<T> {}
fun get(): A<String> = ...
```



Types in FIR, for MPP

```
// MODULE: A

class A<T> {}
fun get(): A<String> = ...
```

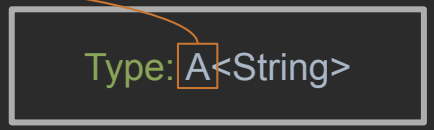


Types in FIR, for MPP

```
// MODULE: A

class A<T> {}
fun get(): A<String> = ...


// MODULE: B
class A<T> {
    fun foo() = ...
}
fun bar() = get().foo() // UNRESOLVED
```

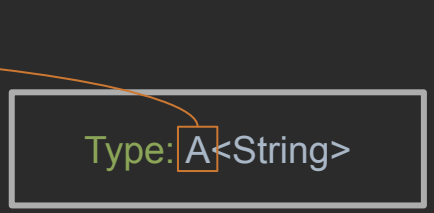


Types in FIR, for MPP

```
// MODULE: A

class A<T> {}
fun get(): A<String> = ...


// MODULE: B
class A<T> {
    fun foo() = ...
}
fun bar() = get().foo() // UNRESOLVED
```

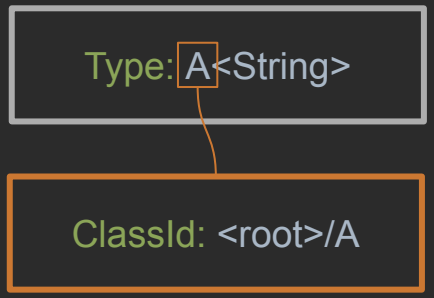


Types in FIR, for MPP

```
// MODULE: A

class A<T> {}
fun get(): A<String> = ...

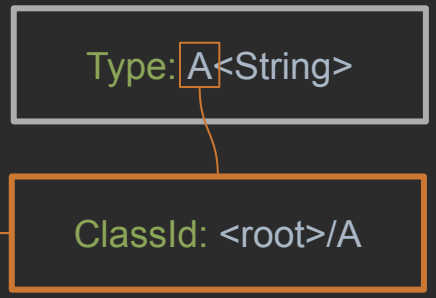

// MODULE: B
class A<T> {
    fun foo() = ...
}
fun bar() = get().foo() // Works now
```



Types in FIR, for MPP

```
// MODULE: A
class A<T> {}
fun get(): A<String> = ...

// MODULE: B
class A<T> {
    fun foo() = ...
}
fun bar() = get().foo() // Works now
```



Types in FIR, for MPP

```
// MODULE: A
expect class A<T> {}
fun get(): A<String> = …

// MODULE: A_platform
actual class A<T> {
    fun foo() = ...
}

// MODULE: B
fun bar() = get().foo() // Works now
```

Smart-Casts: Quiz

```
interface A {
    fun foo()
}

fun bar(x: Any, b: Boolean) {
   while (true) {
       if (b) {
           x as A
           break
       }
   }
   x.foo()
}
```

Smart-Casts: Quiz

```
interface A {
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}
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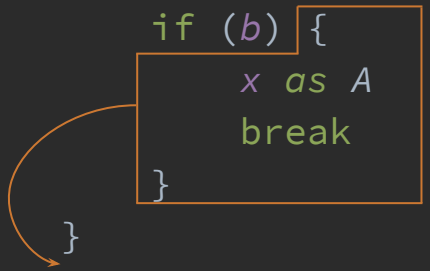

Smarter-Casts and New Data-Flow Analysis

```
fun bar(x: Any, b: Boolean) {
    while (true) {
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            x as A
            break
        }
    }
    x.foo()
}
```

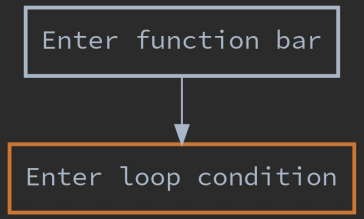

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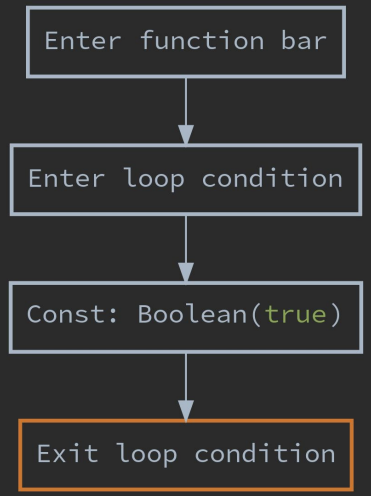

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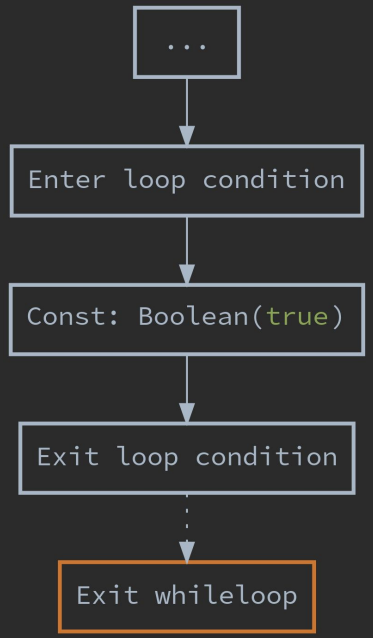

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    x.foo()
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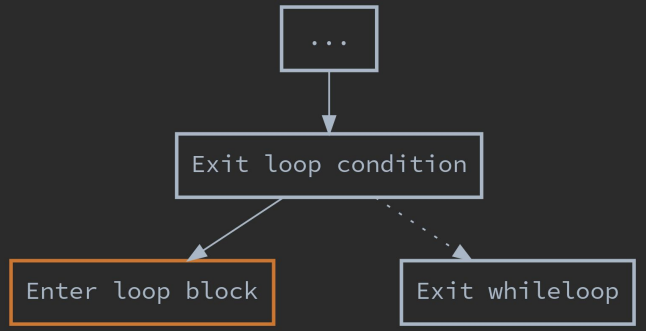

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    }
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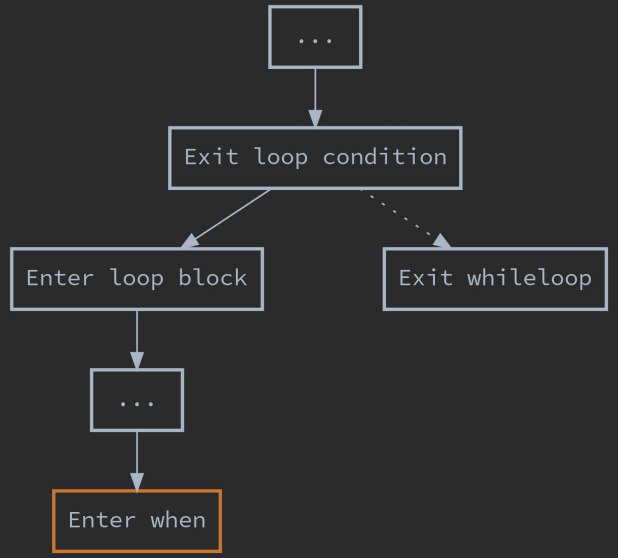
}
```



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```
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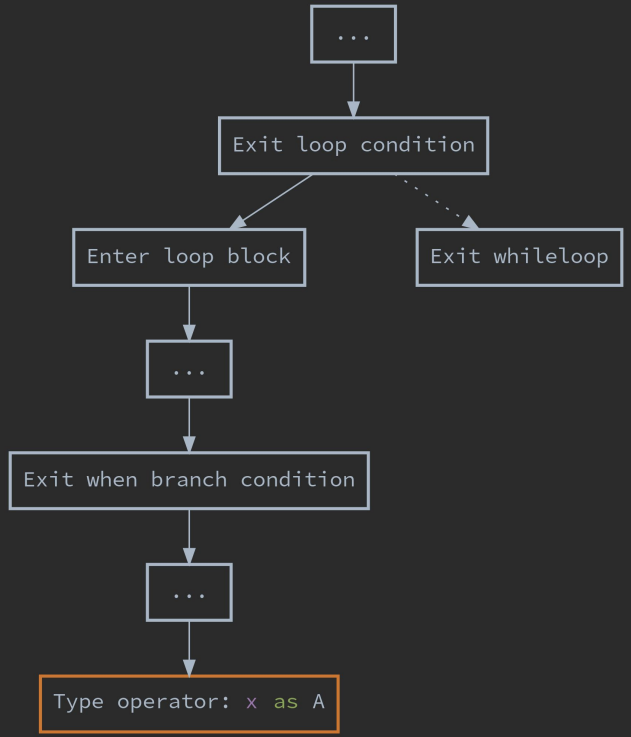

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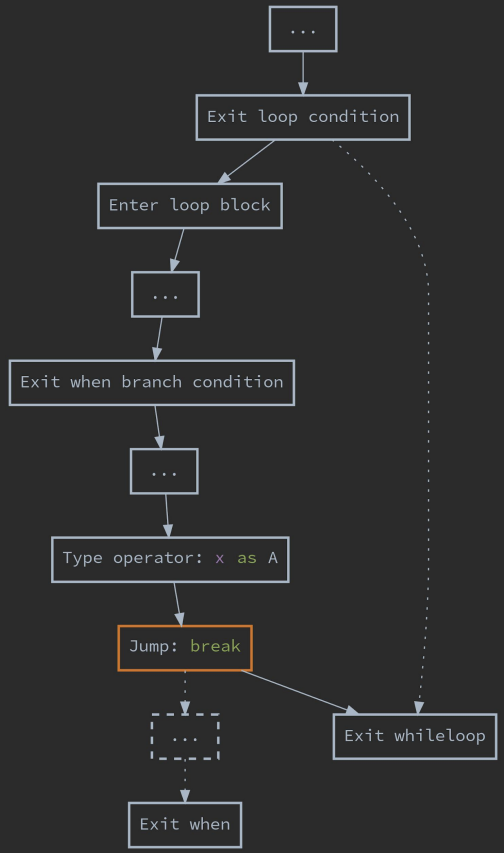

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}
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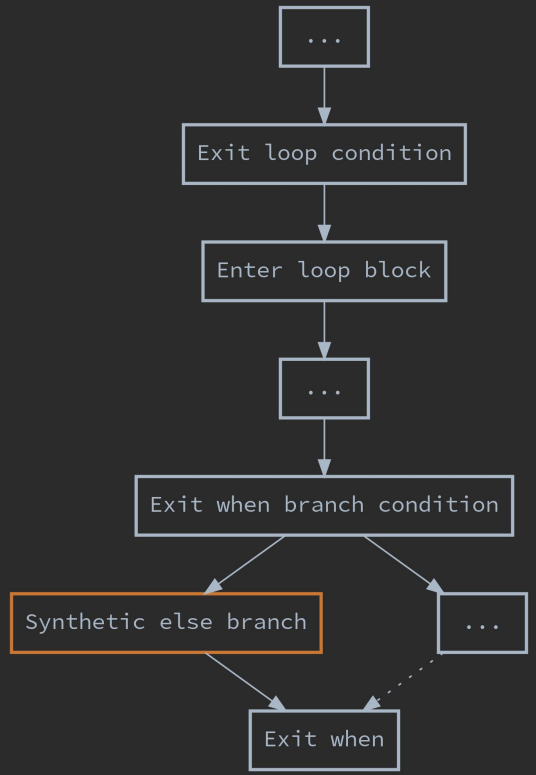

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```
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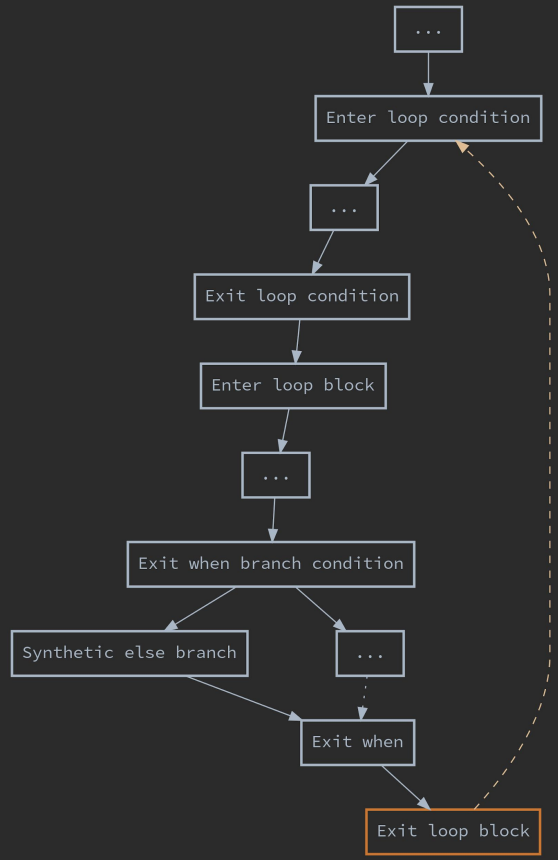

Smarter-Casts and New Data-Flow Analysis

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            break
        }
    }
    x.foo()
}
```
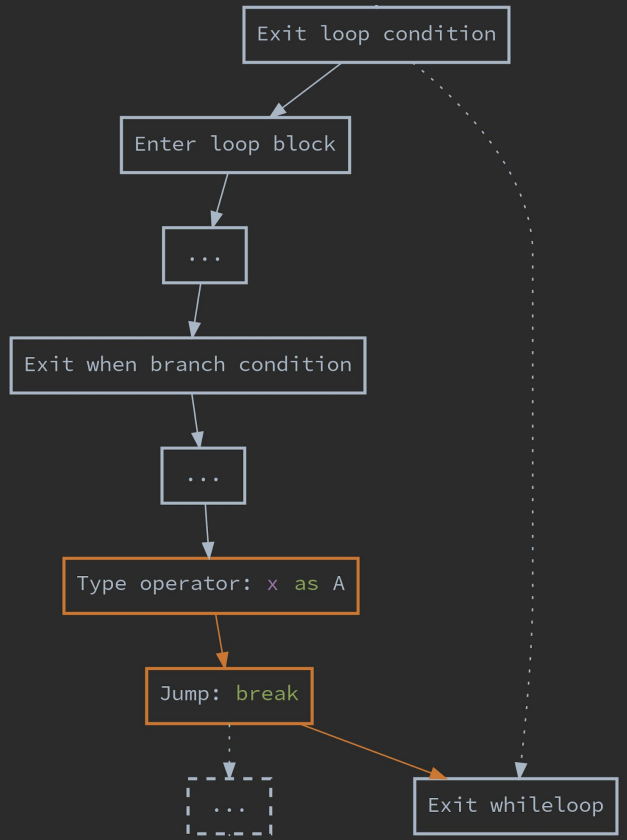

Flow: x is *A*



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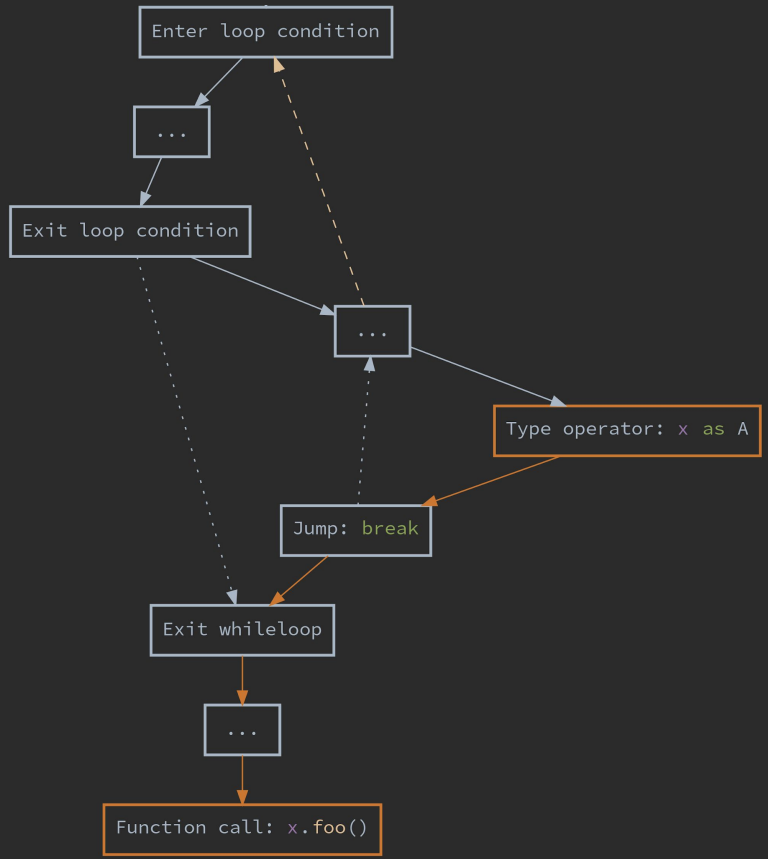
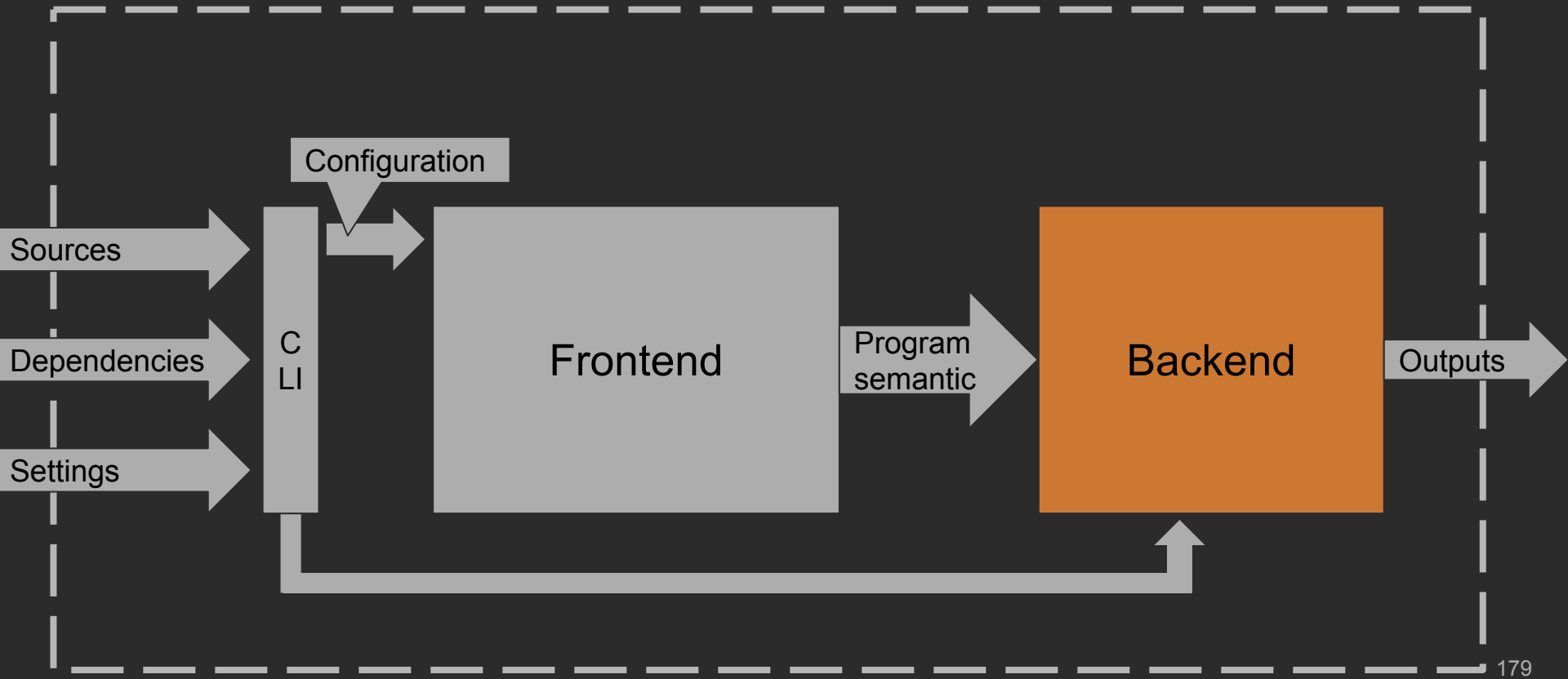


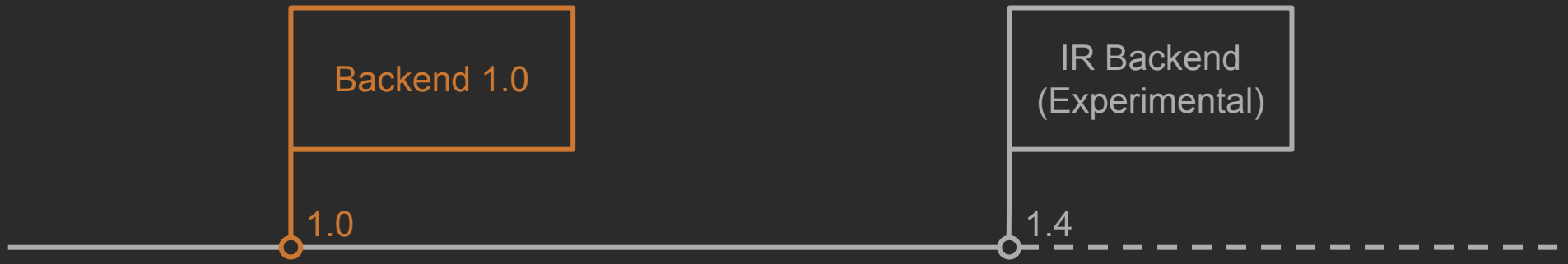
Recap: Frontend

- What’s a compiler frontend
- Kotlin Compiler Frontend 1.0 Architecture
- Type inference and changes to it in 1.4
- New Kotlin Compiler Frontend aka FIR major differences
- New data-flow, control-flow engine

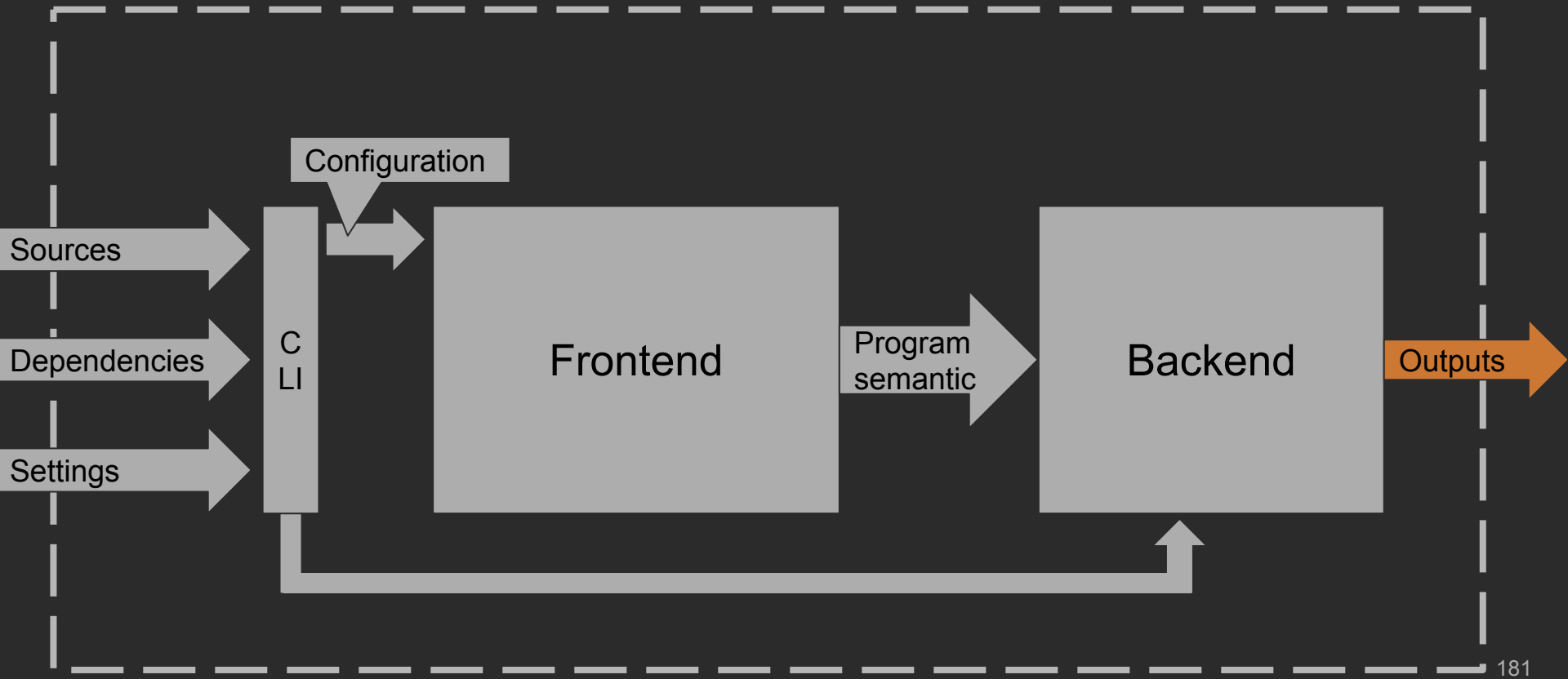
Compiler as a Transparent Box



Backend Timeline



Compiler as a Transparent Box



What Outputs? Let’s take a look on JVM

```
fun hello() = println("Hello, world!")
```

```
public final static hello()V
   L0
    LINENUMBER 1 L0
    LDC "Hello, World"
    ASTORE 0
   L1
    ICONST_0
    ISTORE 1
   L2
    GETSTATIC java/lang/System.out : Ljava/io/PrintStream;
    ALOAD 0
    INVOKEVIRTUAL java/io/PrintStream.println (Ljava/lang/Object;)V
   L3
   L4
    LINENUMBER 1 L4
    RETURN
   L5
    MAXSTACK = 2
    MAXLOCALS = 2
```

What Outputs? Let’s take a look on JVM

```
fun hello() = println("Hello, world!")
```

```
v1 = "Hello, world!"
```

```
L0
    LINENUMBER 1 L0
    LDC "Hello, World"
    ASTORE 0 // v1 - local variable
```

What Outputs? Let’s take a look on JVM

```
fun hello() = println("Hello, world!")

println(v1)

v2 = 0
System.out.println(v1)


L1
    ICONST_0
    ISTORE 1
L2
    GETSTATIC java/lang/System.out : Ljava/io/PrintStream;
    ALOAD 0 // v1 - local variable
    INVOKEVIRTUAL java/io/PrintStream.println (Ljava/lang/Object;)V
```

Wait, what's that? Quiz

```
fun hello() = println("Hello, world!")
```

```
public final static hello()V
   L0
    LINENUMBER 1 L0
    LDC "Hello, World"
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    GETSTATIC java/lang/System.out : Ljava/io/PrintStream;
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    INVOKEVIRTUAL java/io/PrintStream.println (Ljava/lang/Object;)V
   L3
   L4
    LINENUMBER 1 L4
    RETURN
   L5
    ...
    LOCALVARIABLE $i$f$println I L2 L4 1
    ...
```
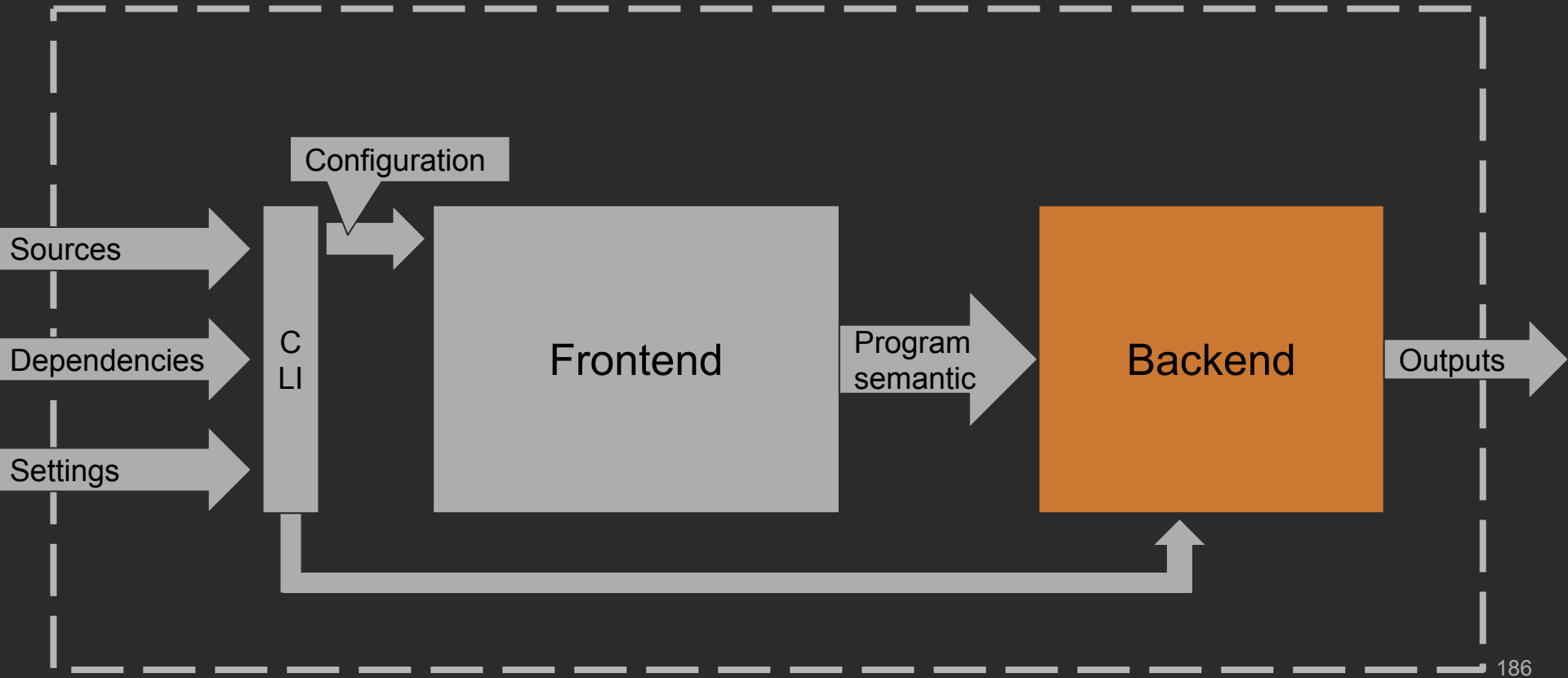
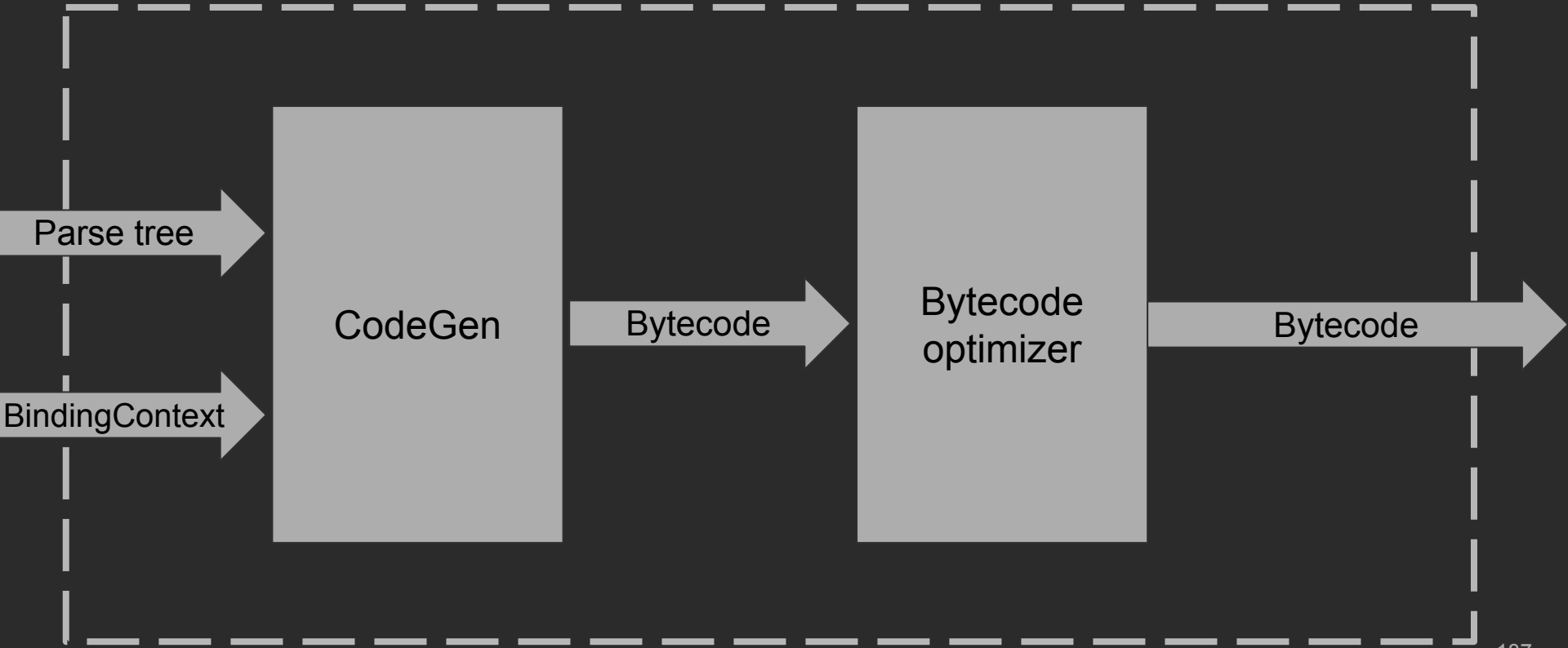
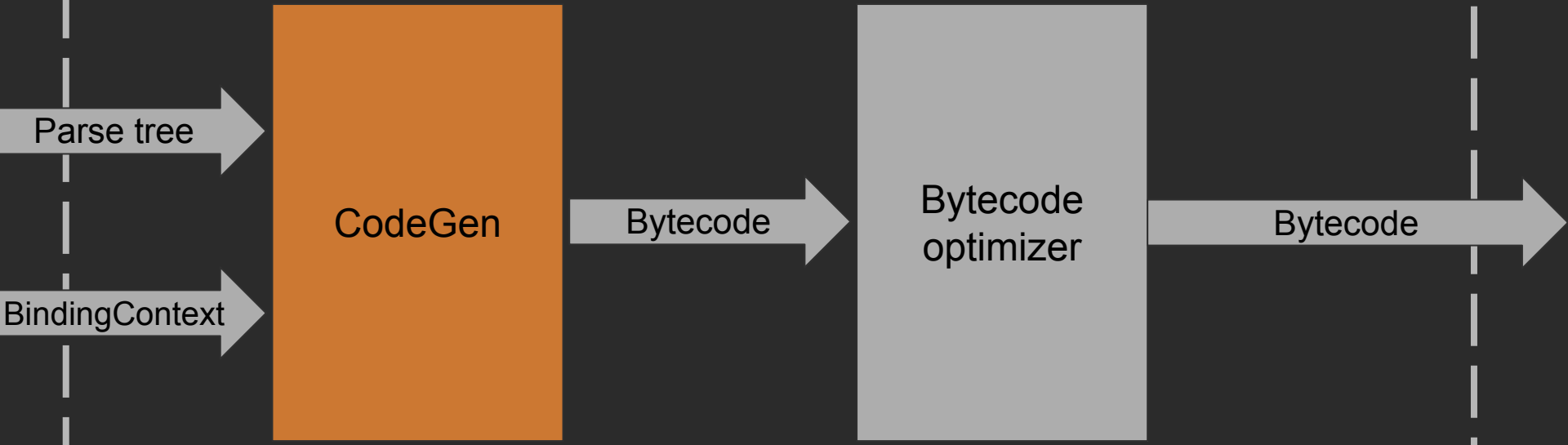

Compiler as a Transparent Box



JVM Backend 1.0



JVM Backend 1.0



JVM CodeGen

- Take PSI
- Take BindingContext
- Generate bytecode directly

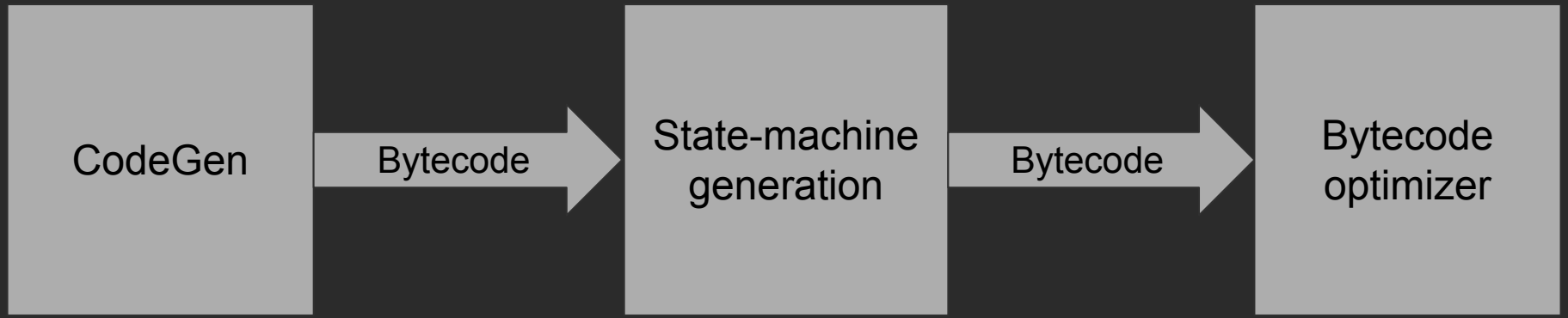
JVM CodeGen

```
fun printLines(lines: List<String>) {
   for (line in lines) {
       println(line)
   }
}
```

```
L1
  ALOAD 0
  INVOKEINTERFACE java/util/List.iterator ()Ljava/util/Iterator;
  ASTORE 2
L2
  ALOAD 2
  INVOKEINTERFACE java/util/Iterator.hasNext ()Z
  IFEQ L3
  ALOAD 2
  INVOKEINTERFACE java/util/Iterator.next ()Ljava/lang/Object;
  CHECKCAST java/lang/String
  ASTORE 1
...
L9
  GOTO L2
```

Suspend Function Transformation

- Suspend functions are state-machines
- It is hard to generate such complex bytecode in one pass



Suspend Function Transformation

- Suspend functions are state-machines
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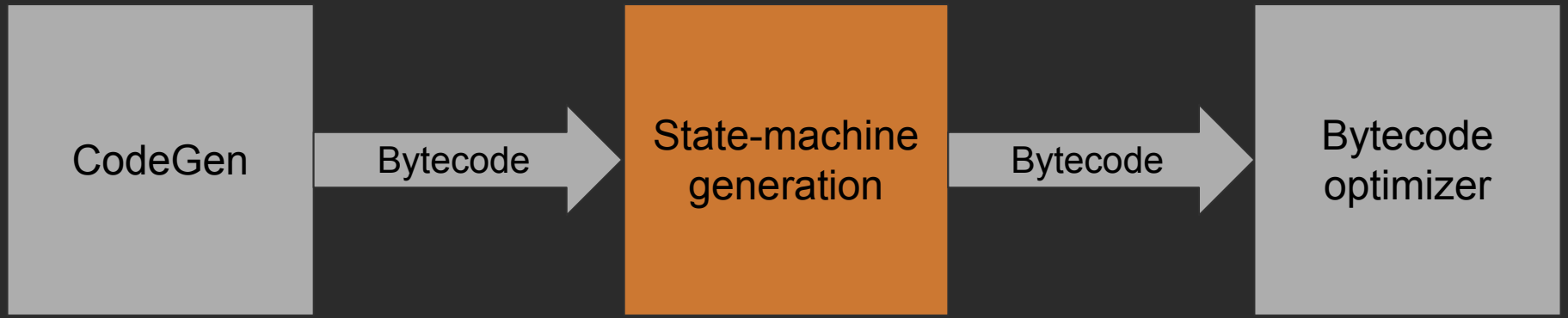

Bytecode Level Inlining

- Take function bytecode
- Merge into target
- Update local variables

Bytecode Level Inlining

```
fun hello(name: String) = println(name)
```

```
public final static hello(Ljava/lang/String;)V
   L0
    ...
   L2
    ICONST_0
    ISTORE 1
   L3
    GETSTATIC java/lang/System.out : Ljava/io/PrintStream;
    ALOAD 0
    INVOKEVIRTUAL java/io/PrintStream.println (Ljava/lang/Object;)V
   L4
    NOP
   L5
    ...
   L6
    LOCALVARIABLE $i$f$println I L3 L5 1
    LOCALVARIABLE name Ljava/lang/String; L0 L6 0
```

Bytecode Level Inlining

```
public inline fun println(message: Any?) {
    System.out.println(message)
}

public final static println(Ljava/lang/Object;)V
    L0
     LDC 0
     ISTORE 1
    L1
     GETSTATIC java/lang/System.out : Ljava/io/PrintStream;
     ALOAD 0
     INVOKEVIRTUAL java/io/PrintStream.println (Ljava/lang/Object;)V
    L2
     RETURN
    L3
     LOCALVARIABLE message Ljava/lang/Object; L0 L3 0
     LOCALVARIABLE $i$f$println I L1 L3 1
```

Bytecode Level Inlining

```
fun hello(name: String) = println(name)
```

```
public final static hello(Ljava/lang/String;)V
   L0
    ...
   L2
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    GETSTATIC java/lang/System.out : Ljava/io/PrintStream;
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   L4
    NOP
   L5
    ...
   L6
    LOCALVARIABLE $i$f$println I L3 L5 1
    LOCALVARIABLE name Ljava/lang/String; L0 L6 0
```
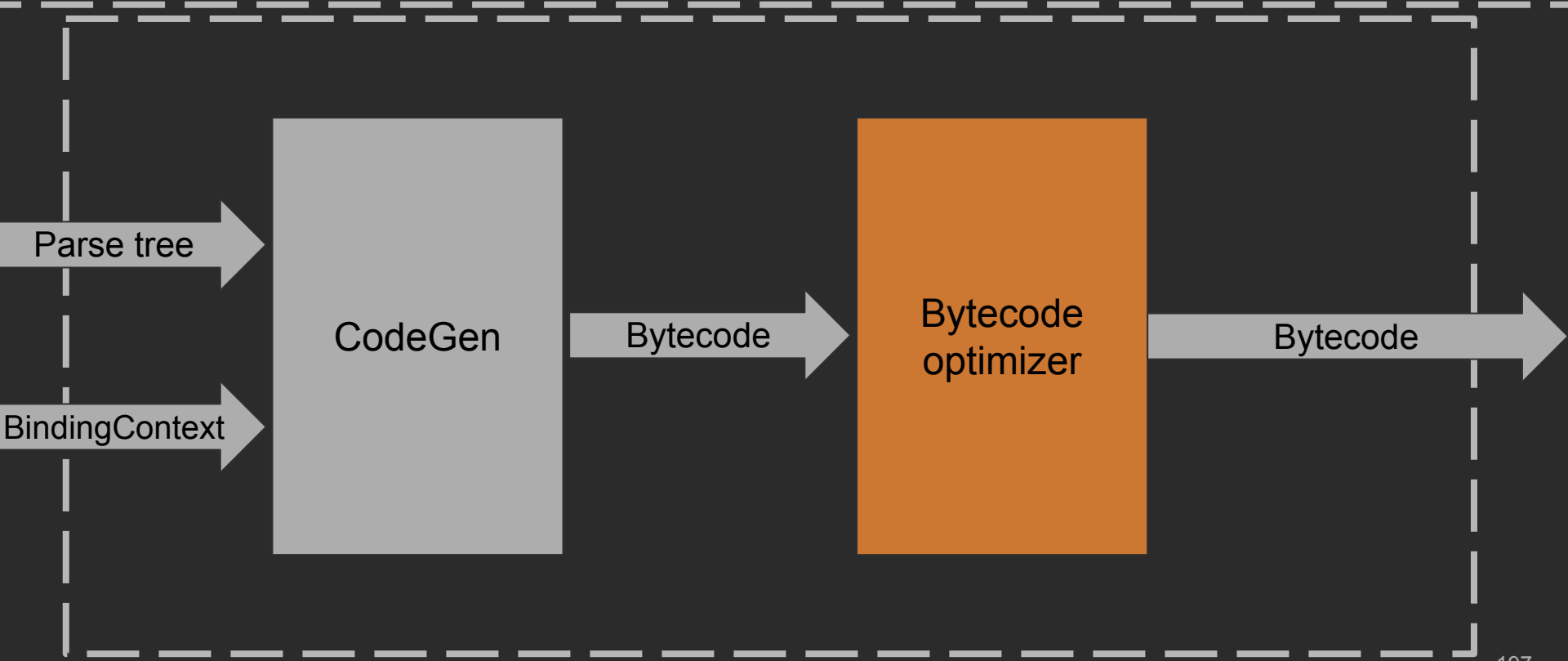

JVM Backend 1.0

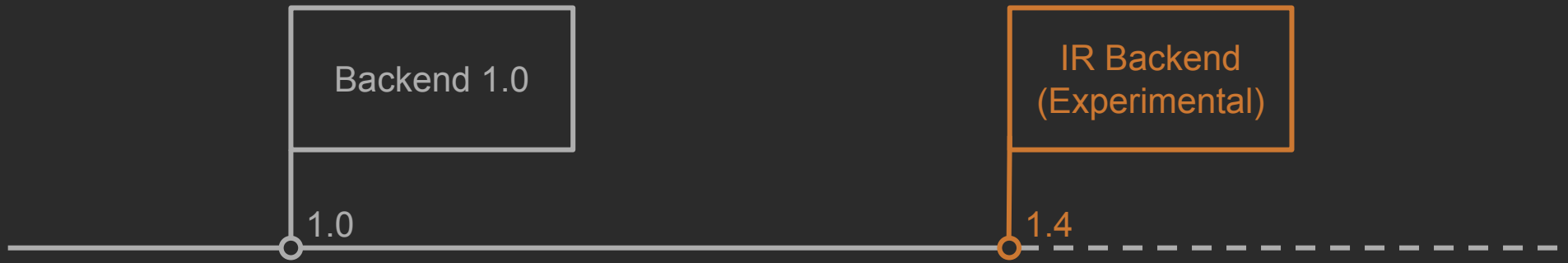


But what about JS and Native?

- JS Backend would like to reuse existing JVM Backend components

- JS text have nothing to do with JVM bytecode
- Kotlin/Native also have nothing to do with JVM bytecode

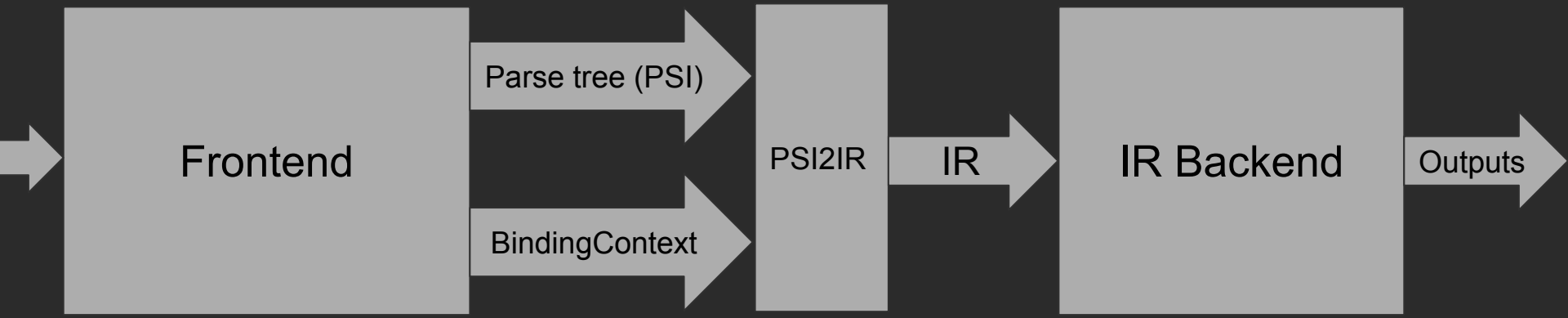
Backend Timeline



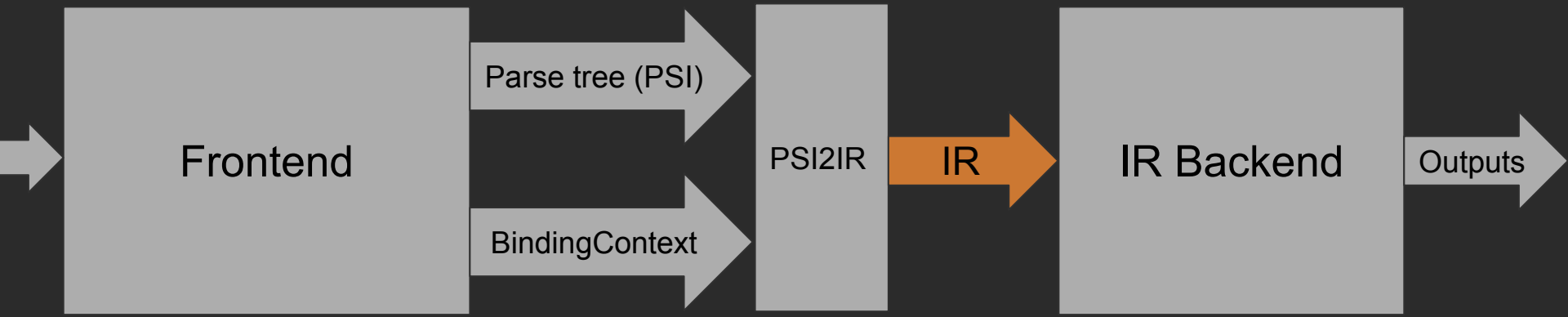
New Backend Goals

- Avoid logic duplication in different backends
- Share high-level optimizations across different backends
- Multi-step transformations suits better for complex constructs
- Pluggability

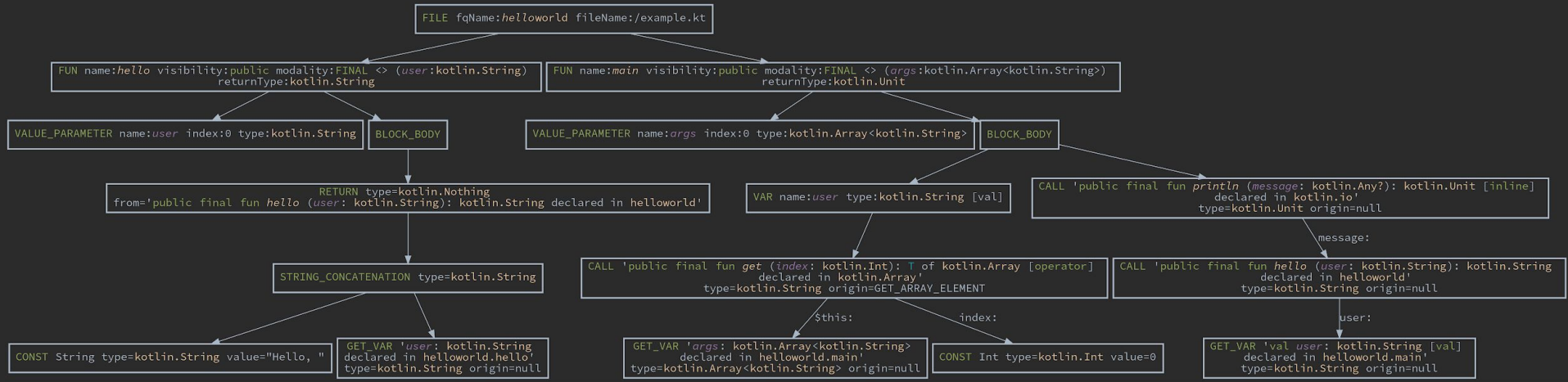
Kotlin Compiler with IR Backend



Kotlin Compiler with IR Backend

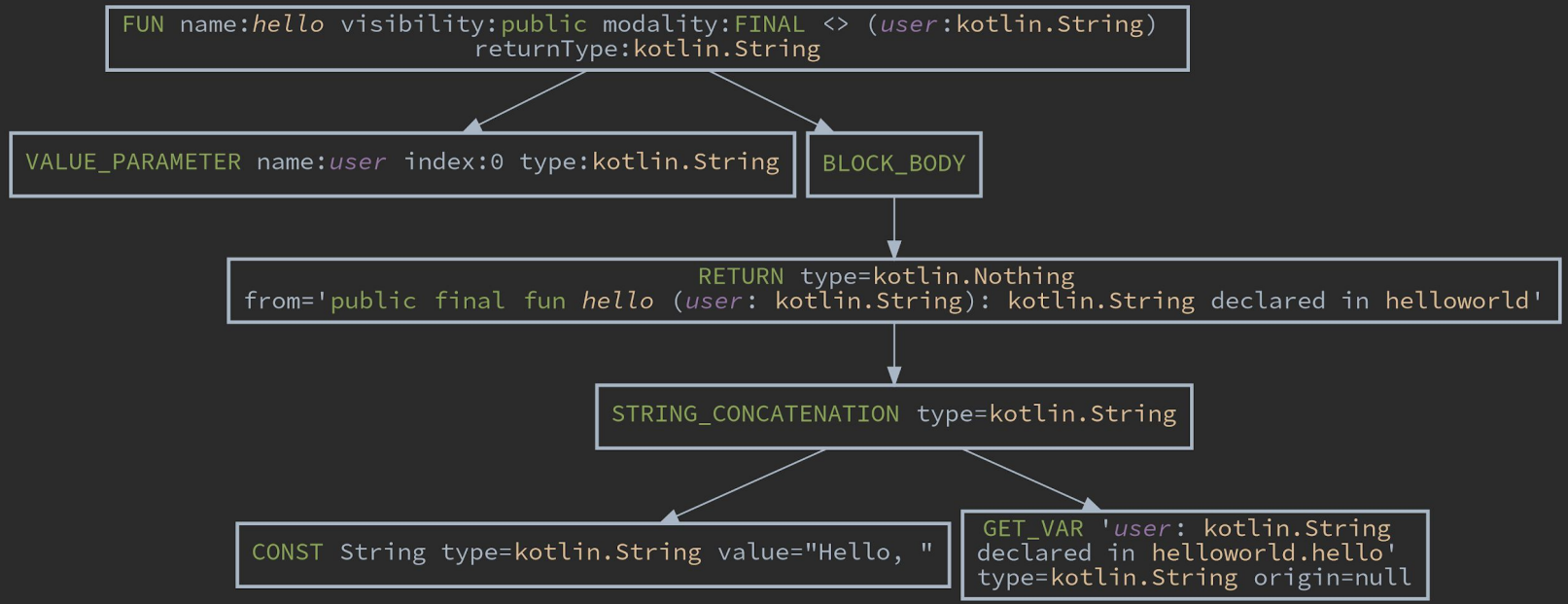


IR? Intermediate Representation! Tree again

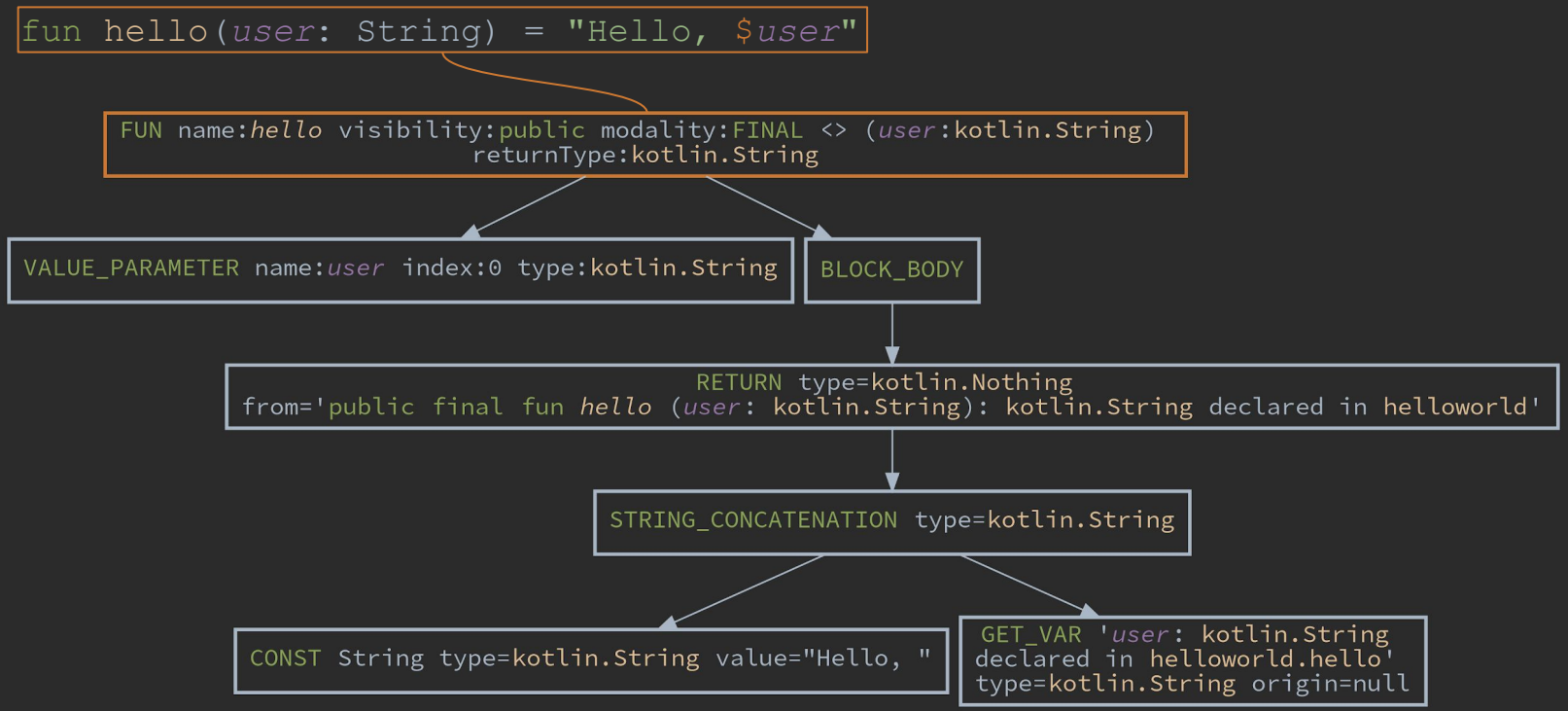


Backend Intermediate Representation: Closer look

```
fun hello(user: String) = "Hello, $user"
```



Backend Intermediate Representation: Closer look



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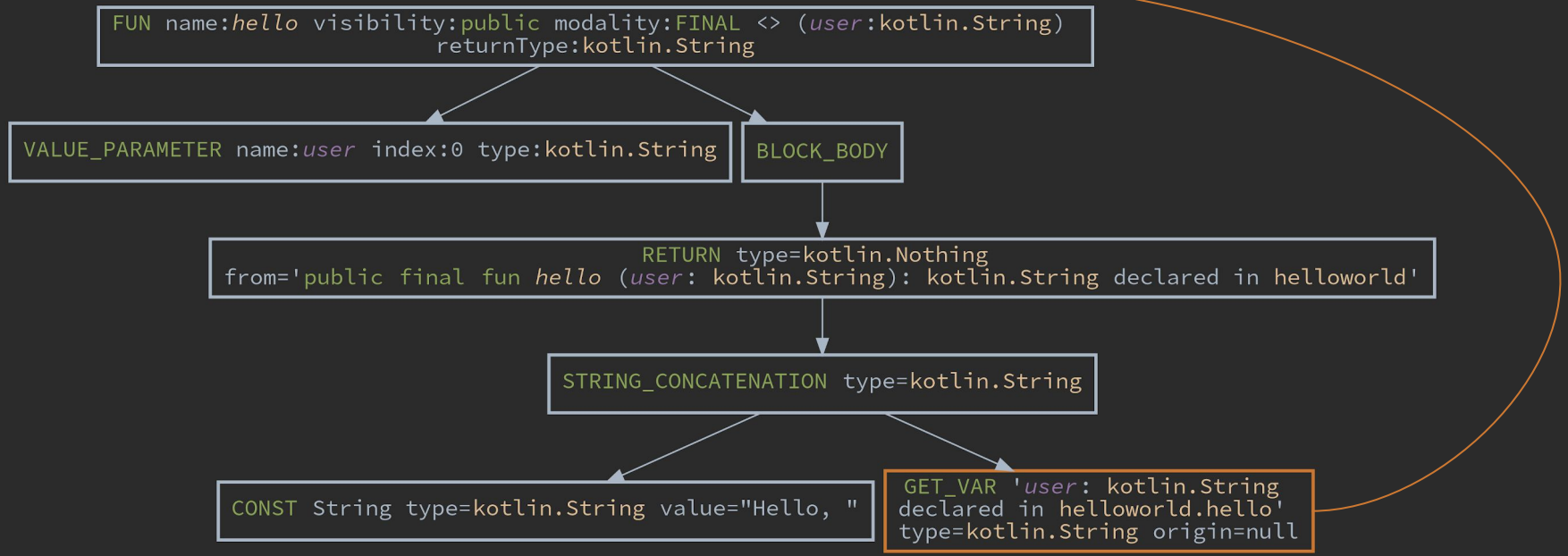
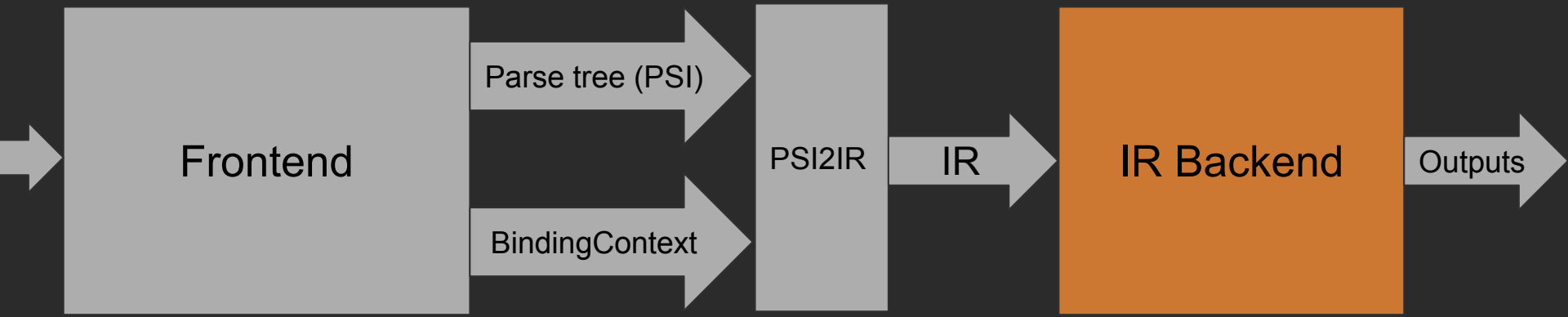
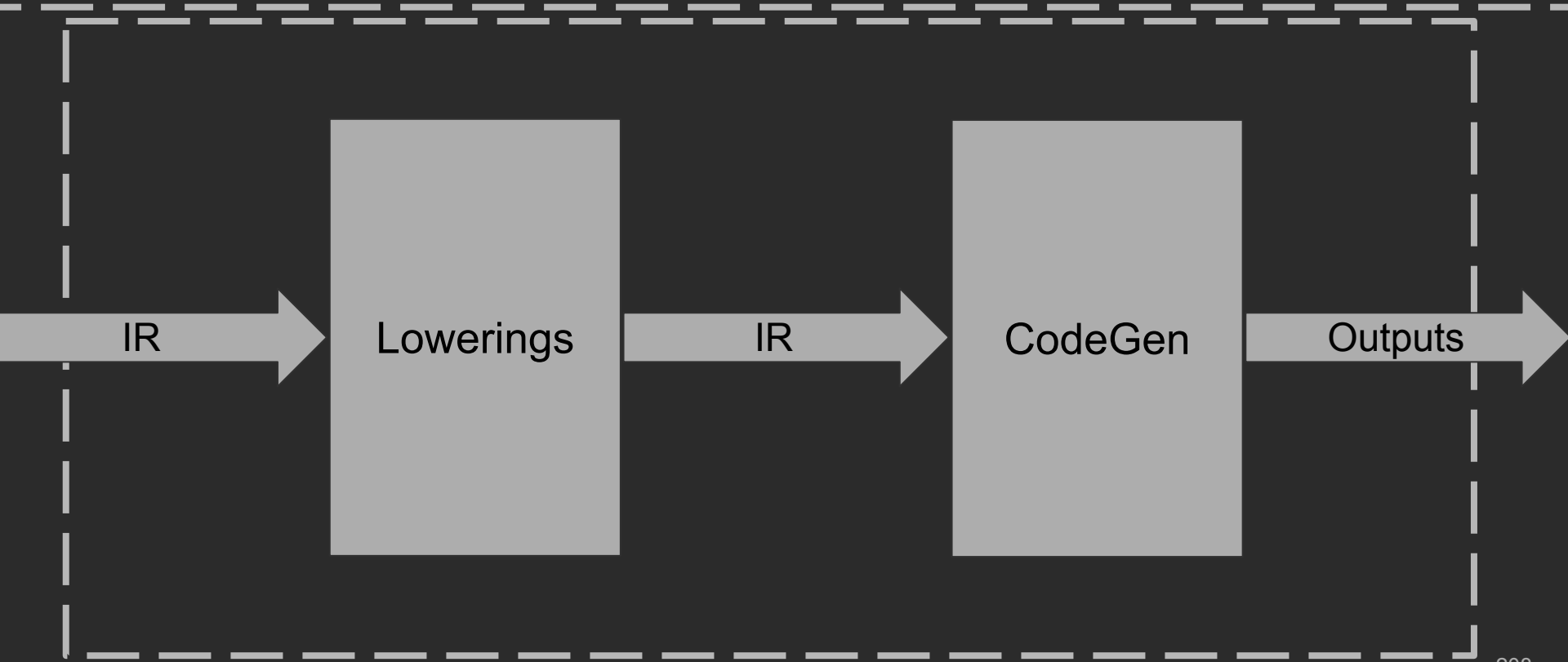


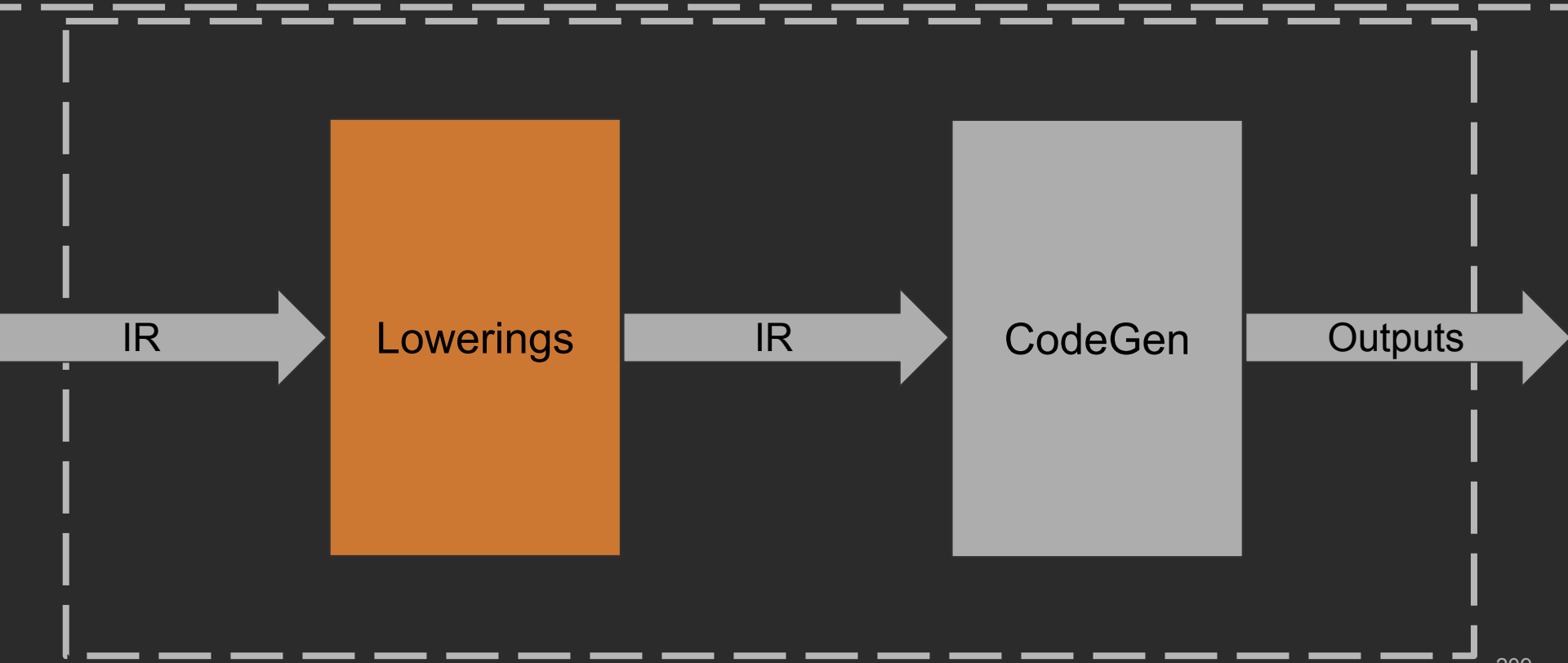
Kotlin Compiler with IR Backend



IR Backend. Pipeline



IR Backend. Pipeline



IR Backend. Lowerings

```
fun interface Action {
   fun perform()
}

fun getHelloAction() = Action { println("Hello!") }
```

IR Backend. Lowerings

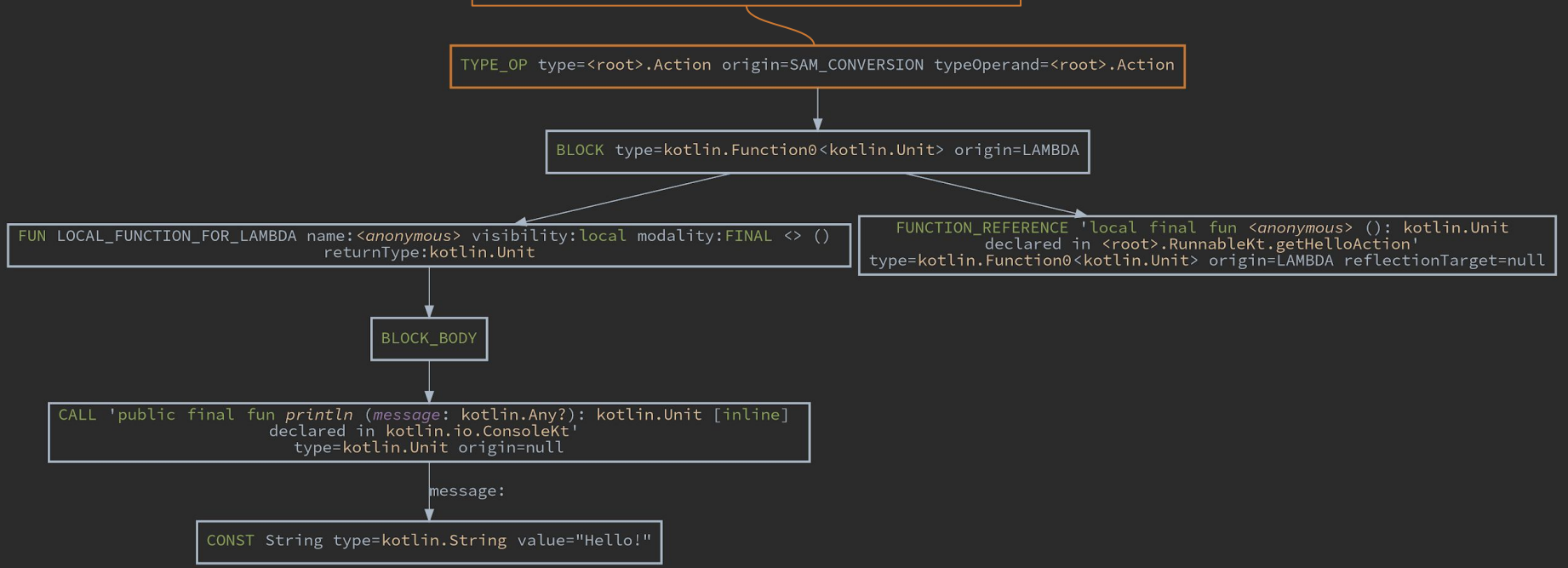
```
fun interface Action {
    fun perform()
}

fun getHelloAction() = Action { println("Hello!") }
```

```
fun getHelloAction() = object : Action {
    override fun perform() {
        println("Hello!")
    }
}
```

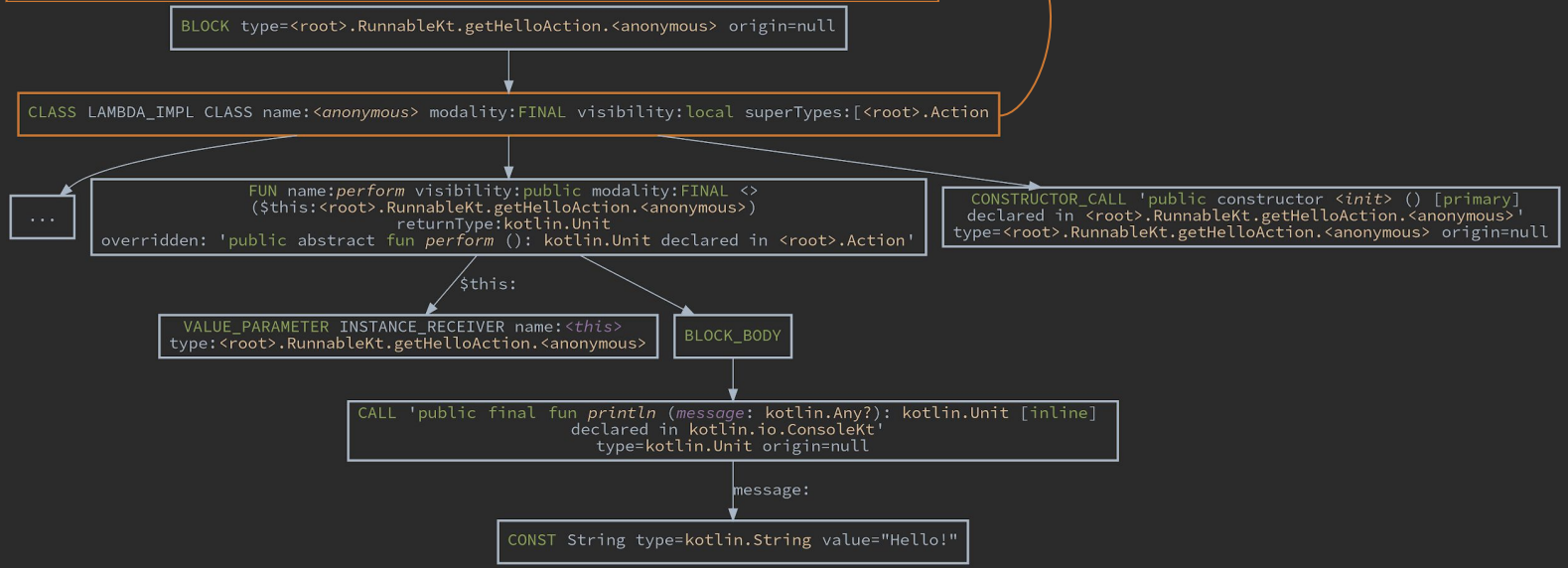
IR Backend. Lowerings

```
fun getHelloAction() = Action { println("Hello!") }
```



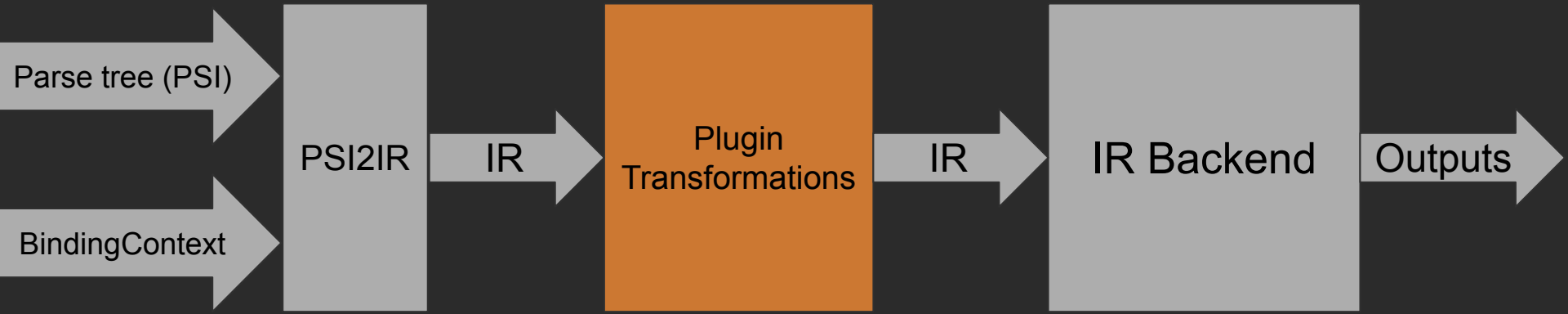
IR Backend. Lowerings

```
fun getHelloAction() = object : Action {
    override fun perform() {
        println("Hello!")
    }
}
```



NOTE: Experimental

IR Backend. Pluggability

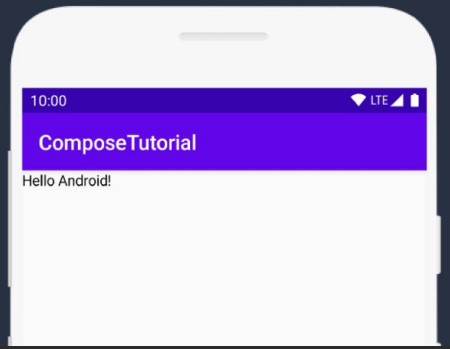


NOTE: Experimental

IR Backend. Pluggability: Jetpack Compose

```
class MainActivity : AppCompatActivity() {
    override fun onCreate(savedInstanceState: Bundle?) {
        super.onCreate(savedInstanceState)
        setContent {
            Greeting("Android")
        }
    }
}

@Composable
fun Greeting(name: String) {
    Text (text = "Hello $name!")
}
```



NOTE: Experimental

IR Backend. Pluggability: Jetpack Compose

```
@Composable fun A(x: Int) {
 f(x)
}
```

NOTE: Experimental

IR Backend. Pluggability: Jetpack Compose

```
@Composable fun A(x: Int) {
 f(x)
}
```

```
@Composable fun A(x: Int, $composer: Composer<*>, $changed: Int) {
   $composer.startRestartGroup()
   f(x)
   $composer.endRestartGroup()?.updateScope { next -> A(x, next, $changed or 0b1) }
}
```

KotlinConf 2019: The Compose Runtime, Demystified: https://youtu.be/6BRII5zfCCk

NOTE: Experimental

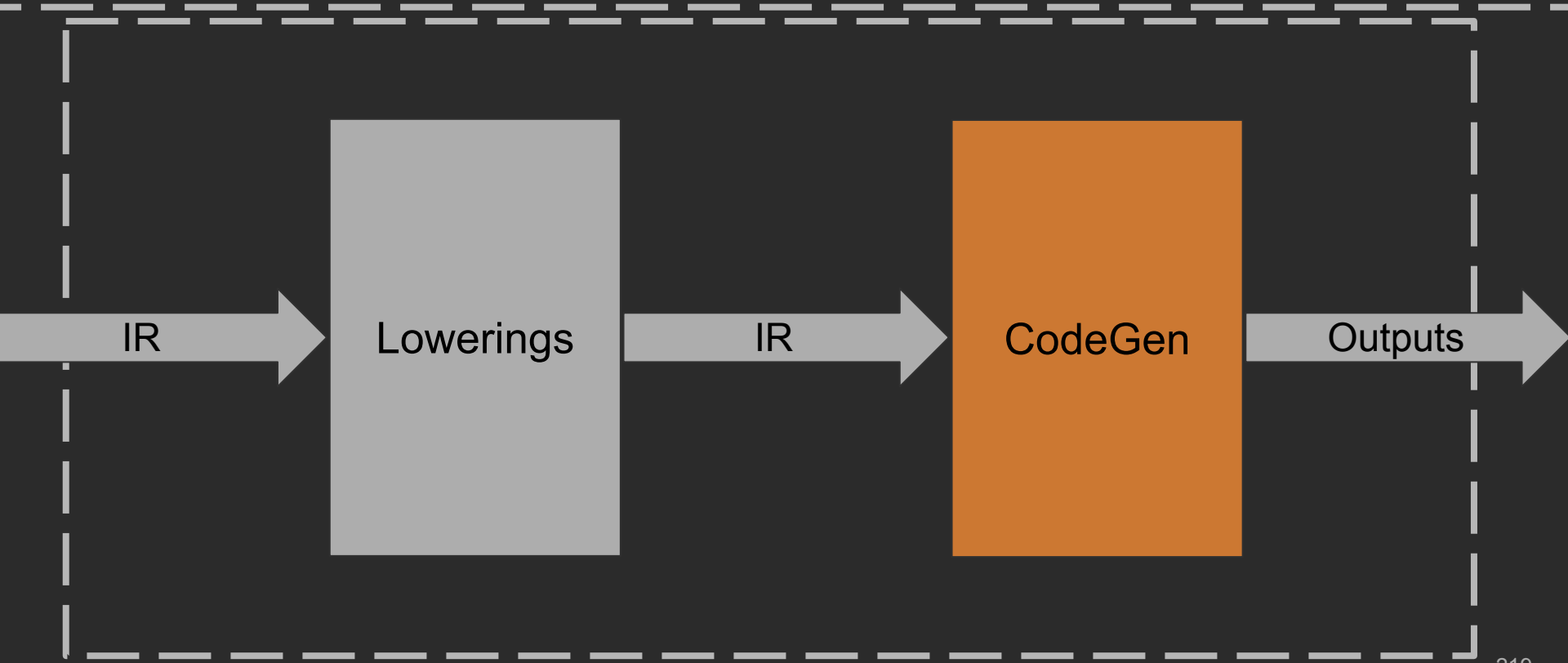
IR Backend. Pluggability: Power-Assert

```
assert(jane != null && jane.firstName == "Jane")

# Example failure
java.lang.AssertionError: Assertion failed
assert(jane != null && jane.firstName == "Jane")
       |    |
       |    false
       null
```

https://medium.com/@bnorm/soft-assertion-with-kotlin-power-assert-4b61fa763b61

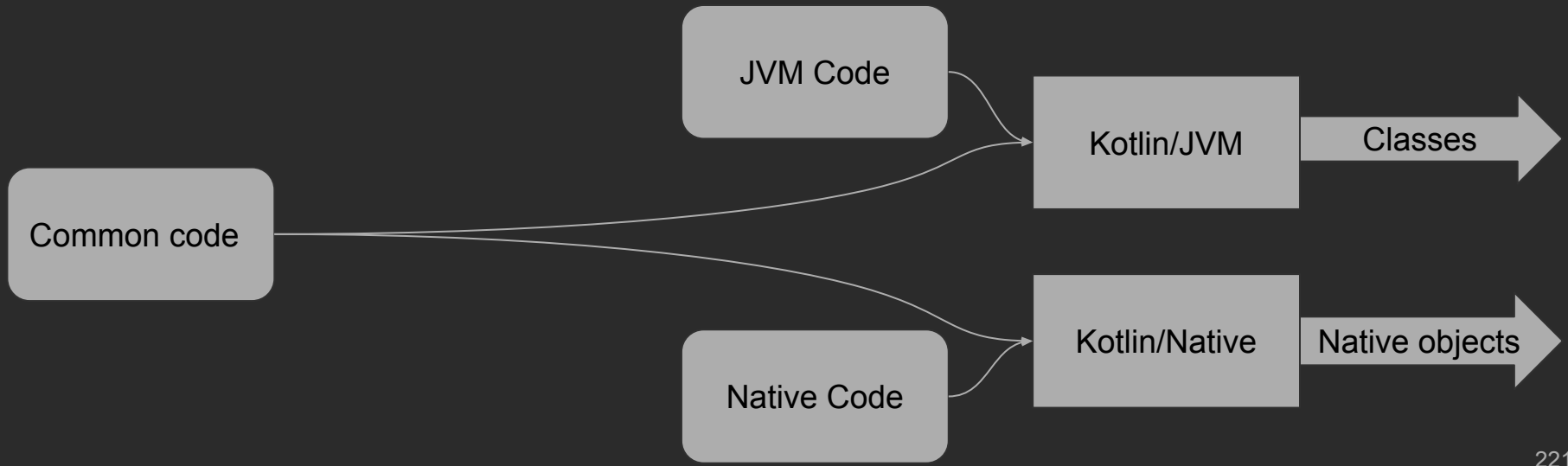
IR Backend. Pipeline



IR Backend. CodeGen

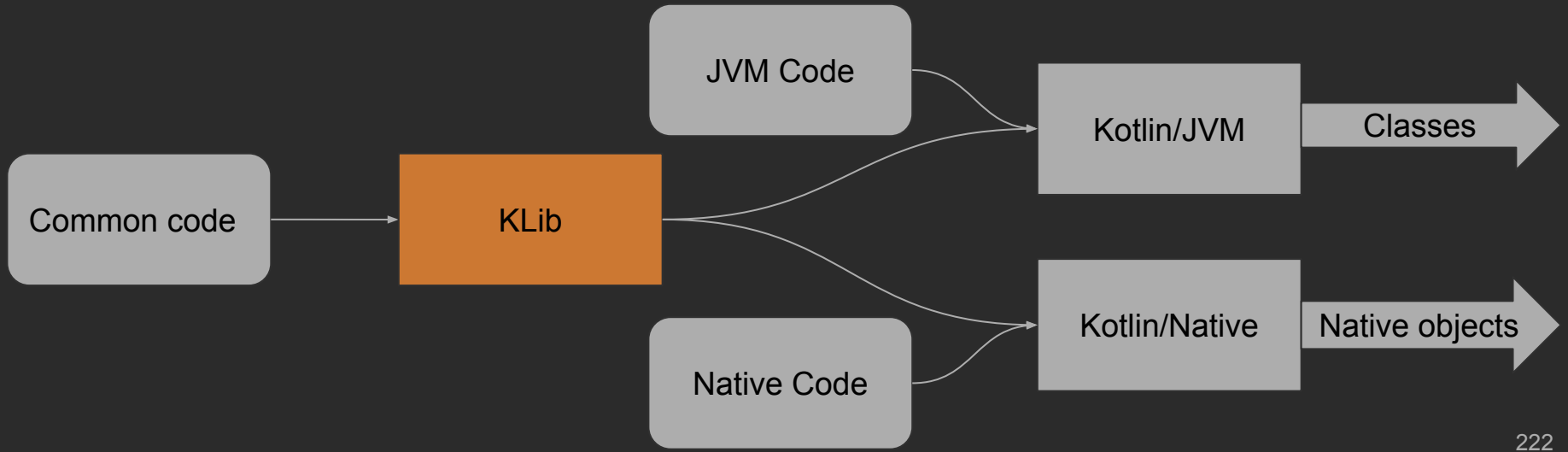
- Take final IR
- Generate bytecode one to one

IR. MPP

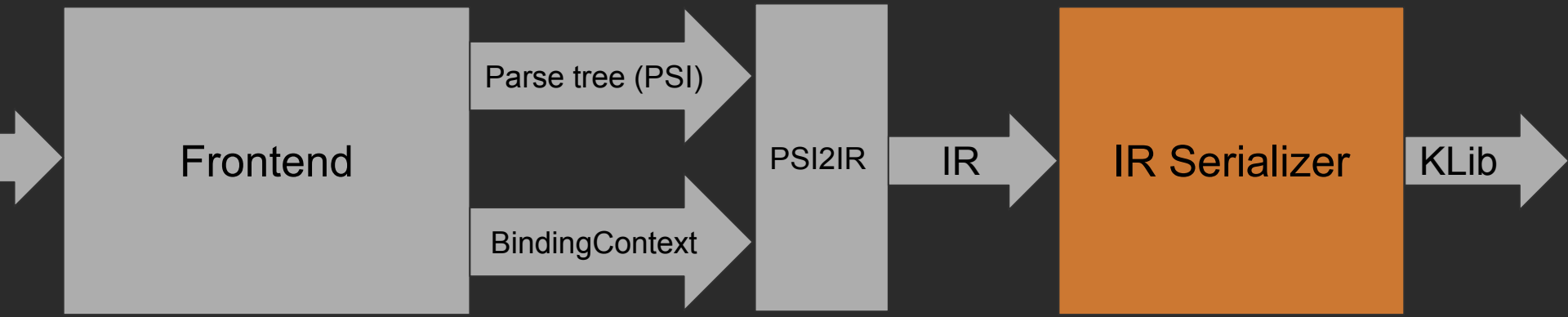

JVM Code
Common code
Native Code
Kotlin/JVM
Kotlin/Native
Classes
Native objects

IR. MPP

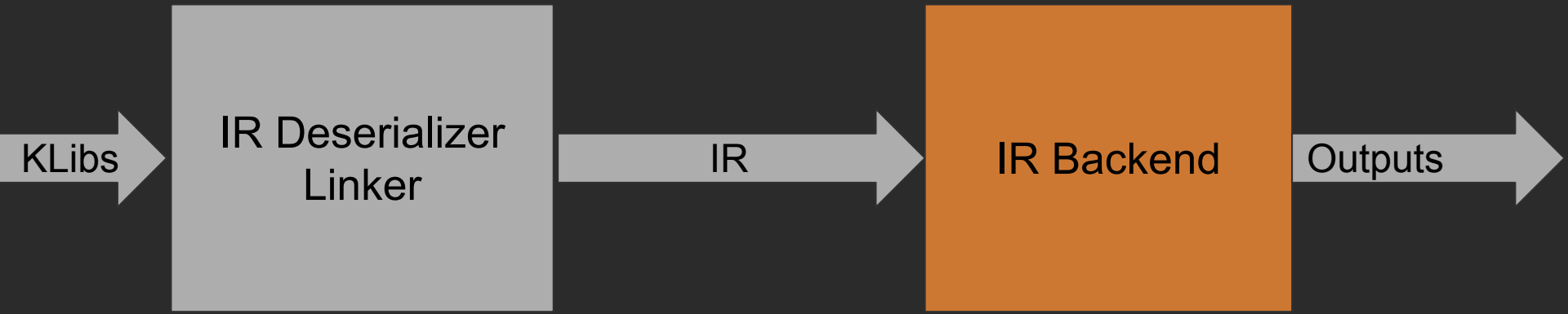
- Compile common modules to KLib
- Link platform modules
- Run target backend to produce final artifacts



IR Backend. KLib



IR Backend. KLib



Summary

- Kotlin Compiler Architecture
- Why and how Kotlin Compiler changes
- Not only language evolving, but also compiler behind it

Questions?

Kotlin Compiler in past, 1.4 and beyond

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