Tree Sitting will continue until Scala highlighting improves

Anton Sviridov, Scala Days 2025

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NOW WITH AI

Anton Sviridov, Scala Days 2025

About me

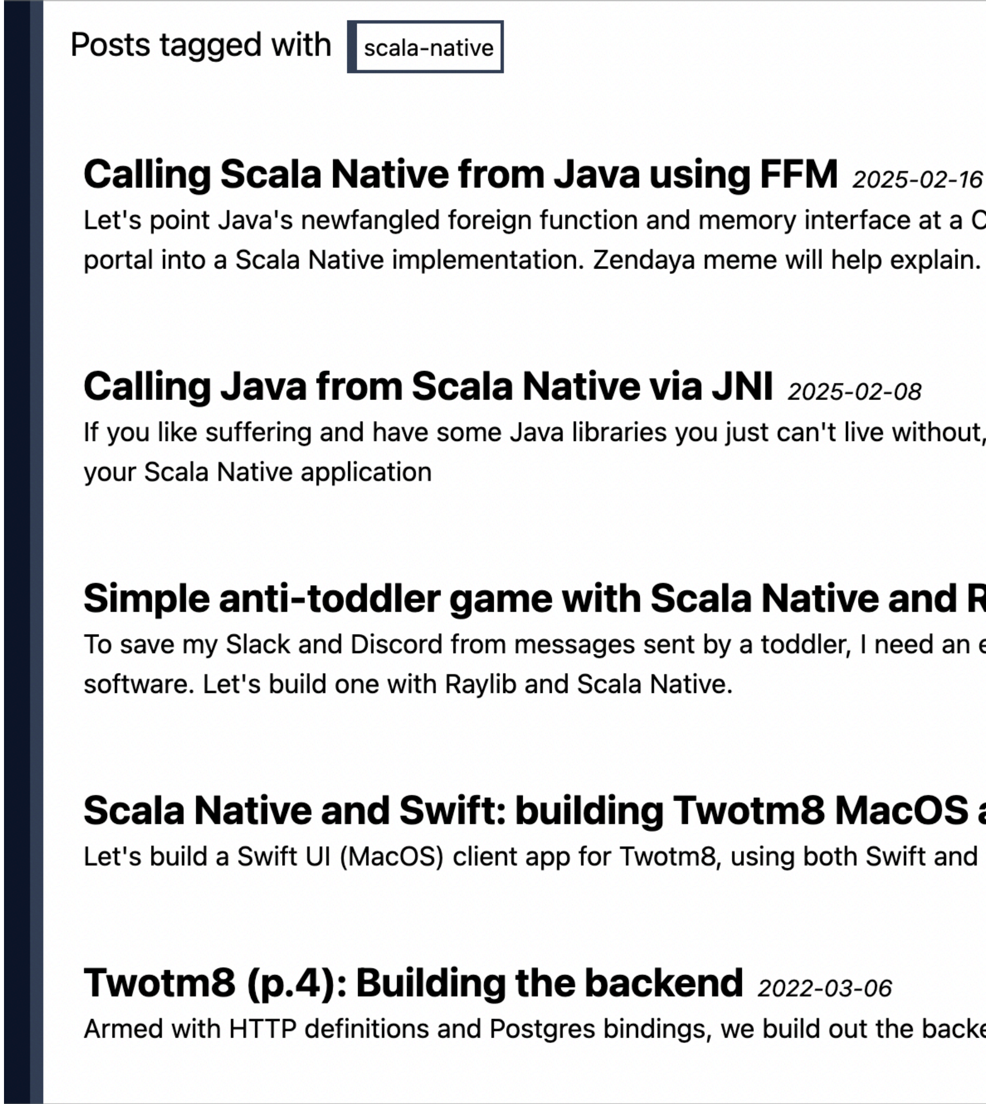
https://blog.indoorvivants.com

- Worked with Scala since 2014
- Advocated for Scala *everywhere* for years
- Maintainer and contributor to Scala Native and Scala.js ecosystem, tools, and libraries
- Run a Scala-centric blog

Github: keynmol

Twitter: velvetbaldmime

Bluesky: @indoorvivants.com



Slides and code

Code

https://github.com/keynmol/scala-treesitter-highlighting

Slides

https://slides.indoorvivants.com/scala-days-2025

Motivation

There are only 4 big issues our industry should be concerned with.

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Scalability

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Security
Scalability
Maintainbility

Motivation

There are only 4 big issues our industry should be concerned with.

Security

Scalability

Maintainbility

Making sure code snippets are pretty and colourful

Motivation

- This didn’t start as a talk
- An in-browser webapp with Scala.js first
- It worked well and gave me inspiration to explore other platforms
- Native first, then JVM
- It was a journey, one I want to take you on

What’s in it for you, the Scala developer?

- Learn a bit about Tree Sitter
- See Scala on all three platforms
- Learn a useful pattern for building interfaces in Scala 3
- Nourish or uncover a deeply destructive obsession with syntax highlighting

Syntax highlighting

- Structure of the program through the usage of colours and text decorators
- Performed without typechecking or involving the compiler
- Speeds up comprehension by involving the subconscious

Syntax highlighting

Even in a particularly egregious case, compare

```
if text.trim.nonEmpty then
  positionedTokens += PositionedToken(
    text,
    x = lineWidth,
    y = height,
    color = color
  )
  lineWidth += ((!extents).width).max((!baseExtents).width * text.length)
else lineWidth += text.count(_.isWhitespace) * (!baseExtents).width
```

with

```
if text.trim.nonEmpty then
  positionedTokens += PositionedToken(
    text,
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  )
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else lineWidth += text.count(_.isWhitespace) * (!baseExtents).width
```

Highlighting with regular expressions

- Most common approach
- Most commonly using Highlight.js
- Regexes are used
- Fast, easy to write, small code in the browser
- Struggles with ambiguity, limited context, "soft" keywords, etc.

It served (and will continue to serve) us well enough – but in some cases we can do better, much better.

Tree Sitter

https://tree-sitter.github.io/tree-sitter/

- A comprehensive parsing system
  - Authoring grammars in JS
  - Queries for syntax tree tagging and processing
  - CLI tools and templates
  - Testing infrastructure
- Lots of languages have high fidelity grammars
- Used on Github for syntax highlighting
- Used by companies doing static analysis

Tree Sitter: in editors

Some popular editors are either built with Tree Sitter at the core, or support it natively

- Neovim
- Zed
- Helix
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- Neovim
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- ~~Emacs~~ Sorry, I meant **popular**

Tree Sitter: grammar

Grammars are defined using a JavaScript DSL.

```
enum_definition: $ =>
  seq(
    repeat($.annotation),
    "enum",
    $._class_constructor,
    field("extend", optional($.extends_clause)),
    field("derive", optional($.derives_clause)),
    field("body", $.enum_body),
  ),
```

Tree Sitter: queries

Queries use a Scheme-like language to deeply match and label particular syntax nodes:

```
(call_expression
  function: (operator_identifier) @function.call)
```

Tree Sitter API allows extracting all the matched nodes along with their labels.

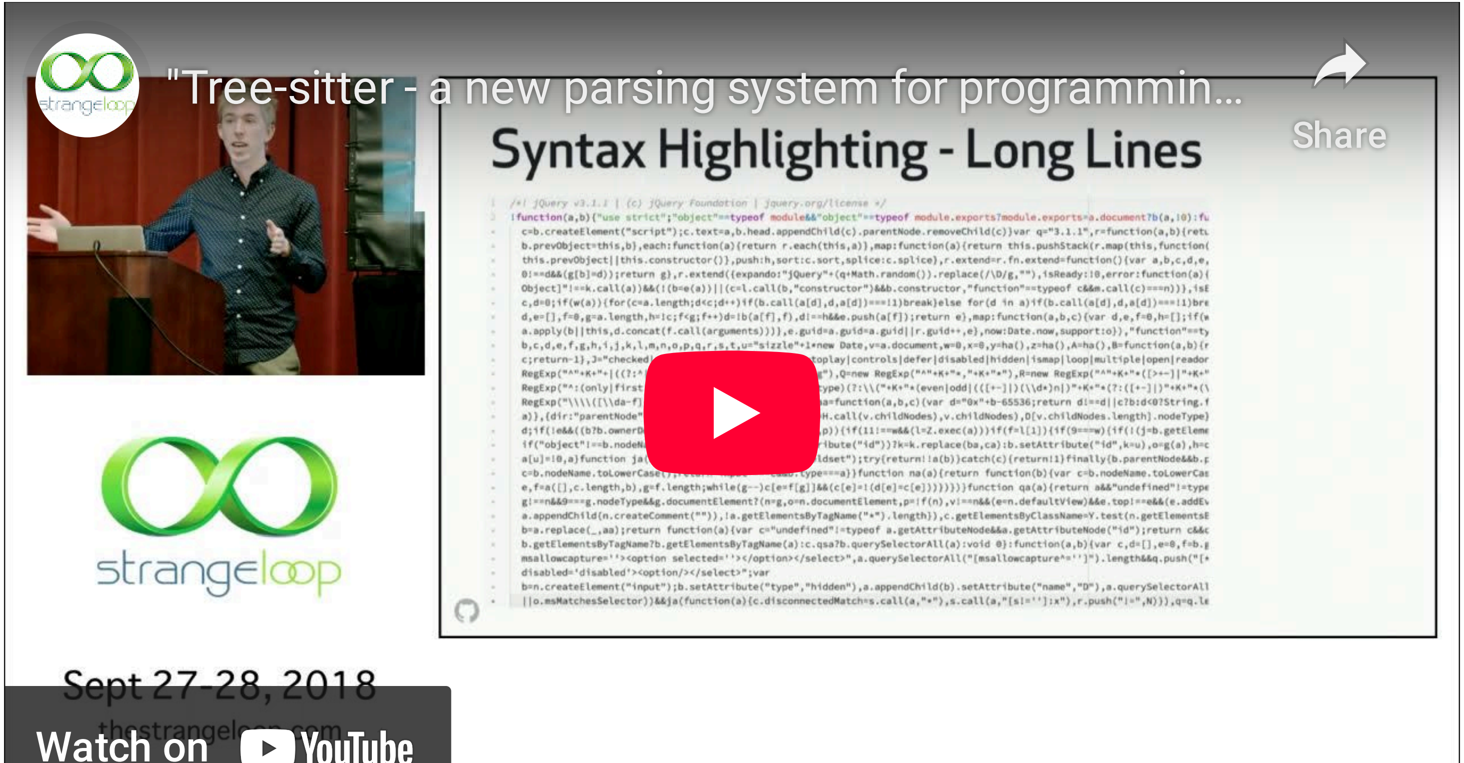
Labels have no meaning in Tree Sitter itself – different applications use different label sets and interpret them as they wish.

Tree Sitter: interface

- Grammar definition is verified and then a **gigantic** C file can be generated from it. It uses C runtime to parse text.
- Generated C parser can be compiled to WASM, usable on the Web
- There are some first-class bindings for popular languages

Tree sitter: learn more

Tree Sitter has a lot more to offer. Watch this video from Max Brunsfield.



The Project

Here's the state of it as of this presentation:

- ✅ Scala.js frontend application
- ✅ Scala Native CLI
- 🚧 Scala JVM backend

Scala code highlighter

This highlighter uses the Tree Sitter parser for Scala, compiled to WASM. It is much more accurate than any regex-based engines such as Highlight.js or Textmate grammars

Github | Author | Tree Sitter Scala grammar

Scala code:

```scala
  basicRequest
    .get(uri"https://wttr.in/London?format=4")
    .send(backend)
    .body
    .right
    .get

@main def hello =
  val mcp = MCPBuilder
    .create()
    .handleRequest(initialize): req =>
      InitializeResult(
        capabilities =
          ServerCapabilities(tools = Some(ServerCapabilities.Tools())),
        protocolVersion = req.params.protocolVersion,
        serverInfo = Implementation("scala-mcp", "0.0.1")
```

Theme: VS Code (light)

Tree Sitter highlighting:

```scala
package sample

import mcp.*
import upickle.default.*

import sttp.client4.*
import sttp.client4.upicklejson.default.*

val backend = DefaultSyncBackend()

def weather(city: String) =
  basicRequest
    .get(uri"https://wttr.in/London?format=4")
    .send(backend)
    .body
    .right
    .get
```

The Project: Scala.js frontend

High level overview:

- Using Vite as a bundler and build tool
- Tree Sitter has special JavaScript bindings specifically designed to work with WASM parsers
- Scala.js and Laminar for the frontend interactivity

The Project: loading WASM parser

```
import TreeSitter from "web-tree-sitter";
import init from "web-tree-sitter/tree-sitter.wasm?init&url";
import initScala from "/tree-sitter-scala.wasm?init&url";

let parser = await (async () => {
  await TreeSitter.init({
    locateFile(scriptName, scriptDirectory) {
      return init;
    },
  });
  const parser = new TreeSitter();
  const Lang = await TreeSitter.Language.load(initScala);
  parser.setLanguage(Lang);
  return parser;
})();

export default parser;
```

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export default parser;
```

The Project: binding to web Tree Sitter

Now that we have the parser on hand, how do we work with it in Scala?

We take a look at the exposed API, and come up with this:

```scala
@js.native
@JSImport("/tree-sitter.js", JSImport.Default)
private object Parser extends js.Any:
  def parse(path: String): Tree = js.native

  def getLanguage(): Language = js.native

  @js.native
  trait Language extends js.Any:
    def query(source: String): Query = js.native

  @js.native
  trait Query extends js.Any:
    def matches(node: Node): Arr[Match] = js.native

  // ...
```

I can already see that Native and JVM bindings won’t look anything like that! **Time to step back.**

Tree Sitter interface

Our goal: **the highlighting logic will be implemented in a syntactically identical way across platforms**

But platforms are different! For example, a Tree Sitter match:

Scala.js

```scala
@js.native
trait Match extends js.Any:
  val name: String = js.native
  val captures: Arr[Capture] = js.native
```

Scala Native

```scala
opaque type TSQueryMatch = CStruct4[uint32_t, uint16_t, uint16_t, Ptr[TSQueryCapture]]
// and a bunch of static methods
```

Scala JVM

```java
public record QueryMatch(@Unsigned int patternIndex, List<QueryCapture> captures) {}
```

No shared traits, no simple shared representation, different memory semantics.

Tree Sitter interface

If we squint, we can uncover the intrinsic Tree Sitter model as such:

```
trait TreeSitterInterface:
  type Tree
  extension (t: Tree) def rootNode: Node
  def parse(source: String): Tree

  def getLanguage: Language

  // ...

  type Capture
  extension (t: Capture)
    @targetName("capture_name")
    def name(q: Query): String
    def node: Node

  type Match
  extension (t: Match)
    def captures: Iterable[Capture]
```

Using abstract extension methods dramatically simplifies the usage.

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    def node: Node

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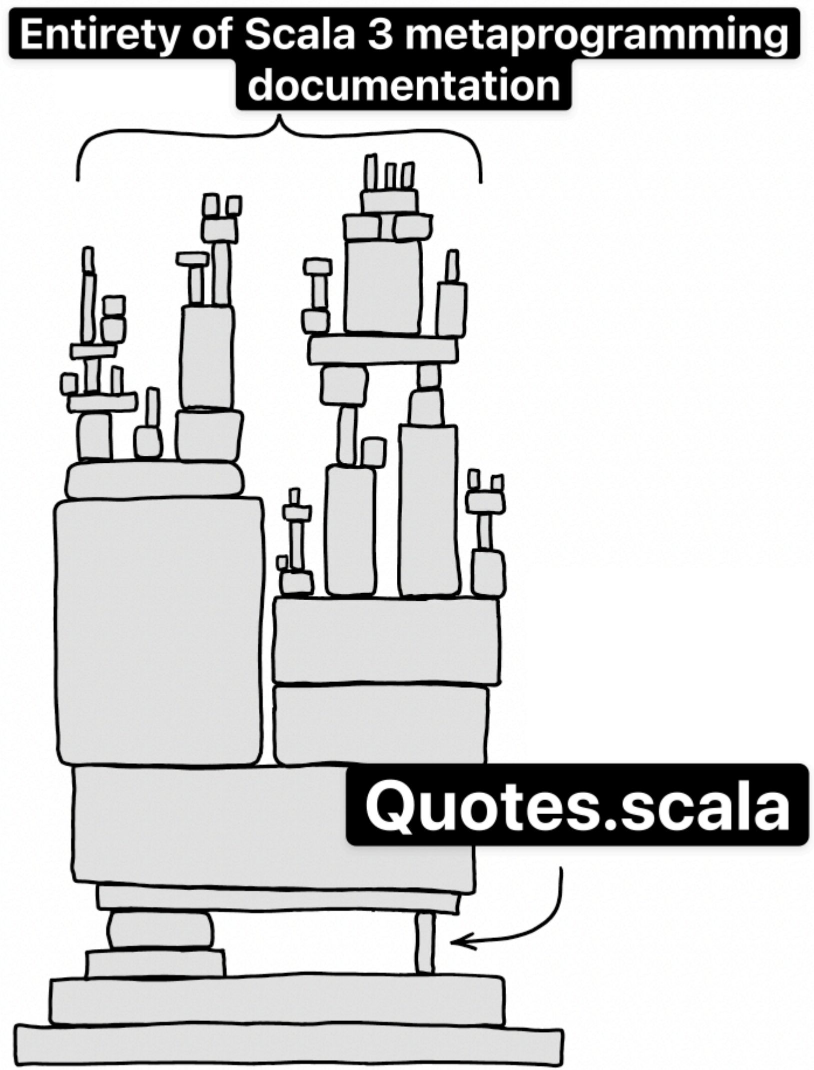
```

Using abstract extension methods dramatically simplifies the usage.

Does this look familiar to anyone?


Entirety of Scala 3 metaprogramming documentation
Quotes.scala

Tree Sitter interface: Scala.js

Here's a sample of concrete implementation:

```scala
class TreeSitter(p: Parser.type) extends TreeSitterInterface:
  // ...
  override opaque type Capture = p.Capture

  extension (t: Capture)
    @annotation.targetName("capture_name")
    override inline def name(q: Query): String = t.name
    override inline def node = t.node
  // ...
```

We use opaque types and inline extension methods to hide the representation semantics of the underlying Tree Sitter API.

Tree Sitter interface: generic usage

With this, we can write generic cross-platform algorithms:

```scala
class HighlightTokenizer[TS <: TreeSitterInterface & Singleton](
    source: String,
    highlightQueries: String,
    treesitter: TS
):
  private lazy val tree = treesitter.parse(source)
  private lazy val lang: treesitter.Language = treesitter.getLanguage
  private lazy val query = lang.query(highlightQueries)
  private lazy val matches: Iterable[treesitter.Match] =
    query.matches(tree.rootNode)
  // ...
```

The values are dependently typed based on the instance of `TreeSitterInterface` – you need to have that in scope for types to align.

Tree Sitter interface: spiralling out of control

- With this generic Tree Sitter interface we can implement highlighting logic in a platform-agnostic way
- Now that we have this outrageous power, what can we do with it?
- How about a Scala Native CLI that generates PNG images?

Tree Sitter interface: Scala Native

On Native, memory management is getting in the way. Thankfully we've adjusted our generic interface to account for that.

Native interface was the trickiest to get right.

```scala
class TreeSitter(parser: Ptr[TSParser], language: Ptr[TSLanguage])(using
    z: Zone
) extends TreeSitterInterface:
  // ...
  override opaque type Capture = Ptr[TSQueryCapture]
  // ...
  extension (t: Capture)
  @annotation.targetName("capture_name")
  override def name(q: Query) =
    val length = stackalloc[UInt]()
    val str = ts_query_capture_name_for_id(q, t.DEREF.index, length)
    val strZero = stackalloc[CChar](length.DEREF.toInt + 1)
    scalanative.libc.string.memcpy(strZero, str, !length)
    strZero(!length) = 0.toByte
    assert(str != null, "ts_query_capture_name_for_id returned null")
    fromCString(strZero)
  // ...
```

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    fromCString(strZero)
  // ...
```

Tree Sitter: using from Scala Native

```
@extern
def tree_sitter_scala(): Ptr[TSLanguage] = extern

val parser = tree_sitter.all.ts_parser_new()
val lang = tree_sitter_scala()

val ts: TreeSitterInterface = TreeSitter(parser, lang)
```

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Tree Sitter interface: sn-bindgen

https://sn-bindgen.indoorvivants.com/

- The low-level interface was generated using sn-bindgen
- Idiomatic, typesafe, low overhead Scala 3 Native bindings from header files
- It's hard to work with directly, but it offers high fidelity foundation

Scala Native CLI: libraries

- Rendering text and producing PNG images is hard
- Using C libraries is a bit less hard

We will use Cairo (https://www.cairographics.org/), with sn-bindgen bindings

> Cairo is a 2D graphics library with support for multiple output devices

Scala Native CLI: outline

The process is a bit involved, so here's a summary:

1. Cairo provides a `cairo_text_extents` function that gives the pixel dimensions of a string given particular font
2. Highlighter produces a set of tokens with colours
3. Size and place each token individually on a cairo surface
4. Cut out the *exact* size of final snippet and move to another cairo surface

All in this file: https://github.com/keynmol/scala-treesitter-highlighting/blob/main/mod/lib/src/main/scala/ImageGenerator.scala

Scala Native CLI: markdown

The CLI also supports pre-processing Markdown files, converting each snippet into an inline HTML block with highlighting already applied.

- Uses cmark – CommonMark reference implementation written in C
- Uses sn-bindgen for the bindings
- Code here: https://github.com/keynmol/scala-treesitter-highlighting/blob/main/mod/lib/src/main/scala/Lib.scala

Now that I've found the main file for your "Simple Scala weather MCP" snippet, let me create a highlighted image of this code for you:

C create_image

```
    .get`
}
```

```scala
//> using scala 3.7.0
//> using dep com.indoorvivants::mcp-quick::0.1.2
//> using dep com.softwaremill.sttp.client4::core::4.0.3

import mcp.*
import sttp.client4.*

@main def getWeatherScalaMCP =
  MCPBuilder
```

Here's the highlighted code for your "Simple Scala weather MCP" server from snippet #56. This code creates a simple Managed Code Protocol (MCP) server that exposes a weather tool.

Key features of this implementation:

Tree Sitter interface: JVM

On the JVM things are much simpler, as Scala natively understands Java.

This requires JDK22+ because tree-sitter on the JVM just delegates to the same native implementation.

```
import io.github.treesitter.jtreesitter as JTS
// ...

class TreeSitter(language: JTS.Language) extends TreeSitterInterface:
  // ...
  extension (t: Capture)
    @targetName("capture_name")
    override def name(q: Query): String = captureName(t)
    override def node: Node = captureNode(t)

  extension (t: Match)
    override def captures: Iterable[Capture] = matchCaptures(t)
// ...
private def captureNode(t: JTS.QueryCapture) = t.node()
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    val strZero = stackalloc[CChar](length.DEREF.toInt + 1)
    scalanative.libc.string.memcpy(strZero, str, !length)
    strZero(!length) = 0.toByte
    assert(str != null, "ts_query_capture_name_for_id returned null")
    fromCString(strZero)
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    val str = ts_query_capture_name_for_id(q, t.DEREF.index, length)
    val strZero = stackalloc[CChar](length.DEREF.toInt + 1)
    scalanative.libc.string.memcpy(strZero, str, !length)
    strZero(!length) = 0.toByte
    assert(str != null, "ts_query_capture_name_for_id returned null")
    fromCString(strZero)
```

```scala
extension (t: Capture)
  @annotation.targetName("capture_name")
  override def name(q: Query) =
    val length = stackalloc[UInt]()
    val str = ts_query_capture_name_for_id(q, t.DEREF.index, length)
    val strZero = stackalloc[CChar](length.DEREF.toInt + 1)
    scalanative.libc.string.memcpy(strZero, str, !length)
    strZero(!length) = 0.toByte
    assert(str != null, "ts_query_capture_name_for_id returned null")
    fromCString(strZero)
```

Self-reflection

- ❌ The Tree Sitter solution requires ~5MB WASM file
- ✅ It is very generalisable to different languages
- ✅ It works really well on Native, very portable
- ❌ On JVM, you have to jump through hoops with native libraries

If we liberate the Scala 3 parser from the rest of Scala 3 compiler and cross-publish it, we can do much better.

Conclusion

- Multiplatform Scala cannot hurt you
- You can do great things with Scala Native and Scala.js
- Scala’s typesystem can help build abstractions that work across platforms

Thank you!