RakuAST: a foundation for Raku macros

Jonathan Worthington
Edument

Two questions that you may already have

What on earth is an

AST?

AST

What compiler folk call a Document Object Model for a programming language

Who on earth are

you?

I do Raku things...

Rakudo compiler architect

MoarVM founder and architect

Raku concurrency designer

Founder of Cro

I do Raku things...

Rakudo compiler architect

MoarVM founder and architect

Raku concurrency designer

Founder of Cro

And lead a team at Edument building developer tooling...

Including the Comma IDE for Raku

IntelliJ platform consultancy

Compiler/language design consultancy

The motivation

for making an AST form of Raku part of the language

The design

of RakuAST, and a compiler based around it

The progress

on implementing RakuAST so far

The impact

of RakuAST on Raku users

The motivation

for making an AST form of Raku part of the language

"It'd be cool to have macros!"

~~"It'd be cool to have macros!"~~

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I mean, it would be, but it's only one motivation for all of this work...

There's more than one way to macro...

Textual macros

(a la C)

Textual macros

(a la C)

Really, they work at the token level

I'm not saying textual macros aren't fun...

```
#define do      {
#define end     }

int main() do
    printf("Phew, no curlies!\n");
end
```

I mean, they are fun, until some day they aren't.

```
#define THING_HEADER_SIZE    16
#define THING_BODY_SIZE      40
#define THING_SIZE \
    THING_HEADER_SIZE + THING_BODY_SIZE
```

```
// Allocate memory for things.
Thing *things = malloc(
    num_things * THING_SIZE);
```

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#define THING_HEADER_SIZE    16
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// Allocate memory for things.
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```
// Allocate memory for things.
Thing *things = malloc(
    num_things * 16 + 40);
```

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#define THING_HEADER_SIZE    16
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```

```
// Allocate memory for things.
Thing *things = malloc(
    num_things * 16 + 40);
```

Oops!

AST macros

(a la Lisp)

Macros operate on the *parsed* program, and so are aware of its structure

```
(define-macro (THING_SIZE) `(+ 40 6))

(* 5 (THING_SIZE))
```

```
(define-macro (THING_SIZE) `(+ 40 6))

(* 5 (THING_SIZE))
     └──────────┘
```

A function call, but made at compile time

```
(define-macro (THING_SIZE) `(+ 40 6))

(* 5 (+ 40 6))
```

Correct!

Lisp is conceptually *beautiful*

It's a language for processing lists

Programs themselves are lists

So what about Raku?

A much greater diversity of syntax

Requires a more complex model

But still...

A Raku macro is a function called at compile time

The arguments that are passed represent the code, not its result

They return value is also a representation of a piece of program

```
macro while-defined($cond, $body) {
    quasi {
        while (my $temp = {{{ $cond }}}).defined {
            {{{ $body }}}($temp);
        }
    }
}

my @a = False, True, False;
while-defined @a.shift, -> $val {
    say $val;
}
```

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macro while-defined($cond, $body) {
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while-defined @a.shift, -> $val {
    say $val;
}
```

Macro is called by the compiler after parsing its arguments

```
macro while-defined($cond, $body) {
    quasi {
        while (my $temp = {{{ $cond }}}).defined {
            {{{ $body }}}($temp);
        }
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my @a = False, True, False;
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```

Arguments are ASTs - objects modeling the program

```
macro while-defined($cond, $body) {
    quasi {
        while (my $temp = {{{ $cond }}}).defined {
            {{{ $body }}}($temp);
        }
    }
}

my @a = False, True
while-defined @a.shi
    say $val;
}
```

Quasi-quote construct lets us make ASTs by writing code and interpolating other ASTs

```
macro while-defined($cond, $body) {
    quasi {
        while (my $temp = {{{ $cond }}}).defined {
            {{{ $body }}}($temp);
        }
    }
}

my @a = False, True, False;
while-defined @a.shift, -> $val {
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my @a = False
while-defined @a.shift, -> $val {
    say $val;
}
```

```
quasi {
    while (my $temp = @a.shift).defined {
        (-> $val { say $val })($temp);
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    quasi {
        while (my $temp = {{{ $cond }}}).defined {
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        }
    }
}

my @a = False, True, False;
while (my $temp = @a.shift).defined {
    (-> $val { say $val })($temp);
}
```

Except this $temp is really a generated name, and would not clobber a $temp in the macro caller

"It'll be cool to have AST macros!"

But wait, there's more...

```
class Signup does Cro::WebApp::Form {
    has Str $.username
        is validated(/^<[A..Za..z0..9]>+$/,
            'Only alphanumerics are allowed');
    has Str $.password is required is password;
    has Str $.verify-password is required;

    ...
}
```

```
class Signup does Cro::WebApp::Form {
    has Str $.username
        is validated(/^<[A..Za..z0..9]>+$/,
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    has Str $.password is required is password;
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    ...
}
```

Trait handlers run at compile time...

```
class Signup does Cro::WebApp::Form {
    has Str $.username
        is validated(/^<[A..Za..z0..9]>+$/,
            'Only alphanumerics are allowed');
    has Str $.password is required is password;
    has Str $.verify-password is required;

    ...
}
```

...so if they can get the AST, then it's possible to compile the Raku regex into something for the HTML5 pattern attribute!

ECMA262Regex

Compiles JavaScript regex syntax into Raku regexes (used by `JSON::Schema`)

File::Ignore

Compiles .gitignore style patterns into Raku regexes

JSON::Mask, JSON::Path

Have interpreters written in Raku - but could be more efficient if we compiled them into Raku

Today, modules that want to compile into Raku look something like this...

```
method control-letter($/) {
    my $name = %control-char-to-unicode-name{~$/};
    unless $name.defined {
        die 'Unknown control character escape is present: '
                ~ $/.Str;
    }
    make '"\c[' ~ $name ~ ']"';
}

method character-class($/) {
    my $start = '<';
    $start ~= '-' if $/.Str.starts-with('[^');
    $start ~= '[' ~ $<class-ranges>.made;
    make $start ~ ']>';
}
```

```
method control-letter($/) {
    my $name = %control-char-to-u
    unless $name.defined {
        die 'Unknown control character escape is present: '
                ~ $/.Str;
    }
    make '"\c[' ~ $name ~ ']"';
}

method character-class($/) {
    my $start = '<';
    $start ~= '-' if $/.Str.starts-with('[^');
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```

```
method control-letter($/) {
    my $name = %control-char-to-u
    unless $name.defined {
        die 'Unknown control character escape is present: '
                ~ $/.Str;
    }
    make '\c[' ~ $name ~ ']';
}
```

Ewwwwwwwwww!
Strings?!

How do we know it's well-formed?

Could there be an injection attack?

Ewwwwwwwwww! Strings?!

How do we know it's well-formed?

```
        -to-u
        u {
            die 'Unknown control character escape is present: '
                    ~ $/.Str;
        }
        make '\e ~ ']"';
    }
    $start ~= '-' if $/.Str.starts-with('[^');
    $start ~= '[' ~ $<class-ranges>.made;
    make $start ~ ']>';
}
```

```
                -to-un
            ed {
        die 'Unknown control character escape is present: '
                ~ $/.Str;
    }
    make '"\c[' ... e ~ ']"';

            ($/) {
    my $s...'<';
    $start ~= '-' if $/.Str.starts-wi
    $start ~= '[' ~ $<class-ranges>.made;
    make $start ~ ']>';
}
```

Could there be an injection attack?

Ewwwwwwwwww! Strings?!

How do we know it's well-formed?

Raku compiler has to spend time parsing too! ☹

Instead, they could produce a Raku AST

Either by building up an object graph, or by using quasi quoting

"It'll be cool to have various ways of accessing a Raku AST at compile time, as well as using it as a compilation target!"

But wait, there's still more...

What if we want to build...

A Raku linter?

A fancier Raku type checker?

Domain-specific compile-time checks?

Often, these tools must be built with their own parser and program model

Those can get out of sync with new language features, or end up having their own bugs

Instead, they could consume a standard Raku AST

By serving as an extra compiler phase

"It'll be cool to be able to produce and consume Raku code in all kinds of scenarios using a standardized Raku AST!"

Surely there isn't more?

What if Rakudo's 10 year old frontend compiler architecture could be improved?

Because surely we've all learned a thing or ten in that time...

A standard Raku AST isn't just something we're going to add to the Rakudo compiler.

RakuAST will be found at the very heart of Rakudo.

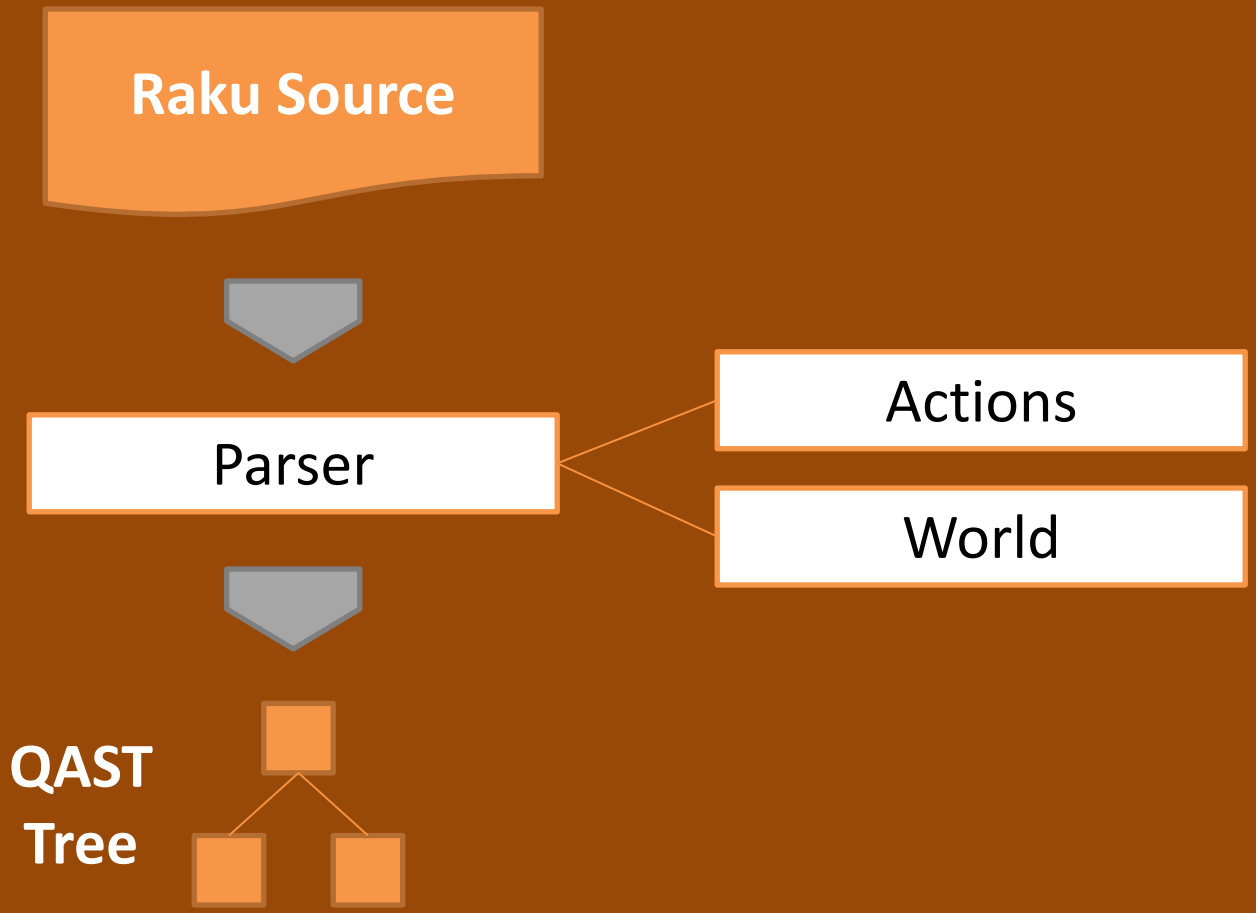
"It'll be cool!"

But how will we get there?

The design

of RakuAST, and a compiler based around it

The Rakudo compiler frontend today



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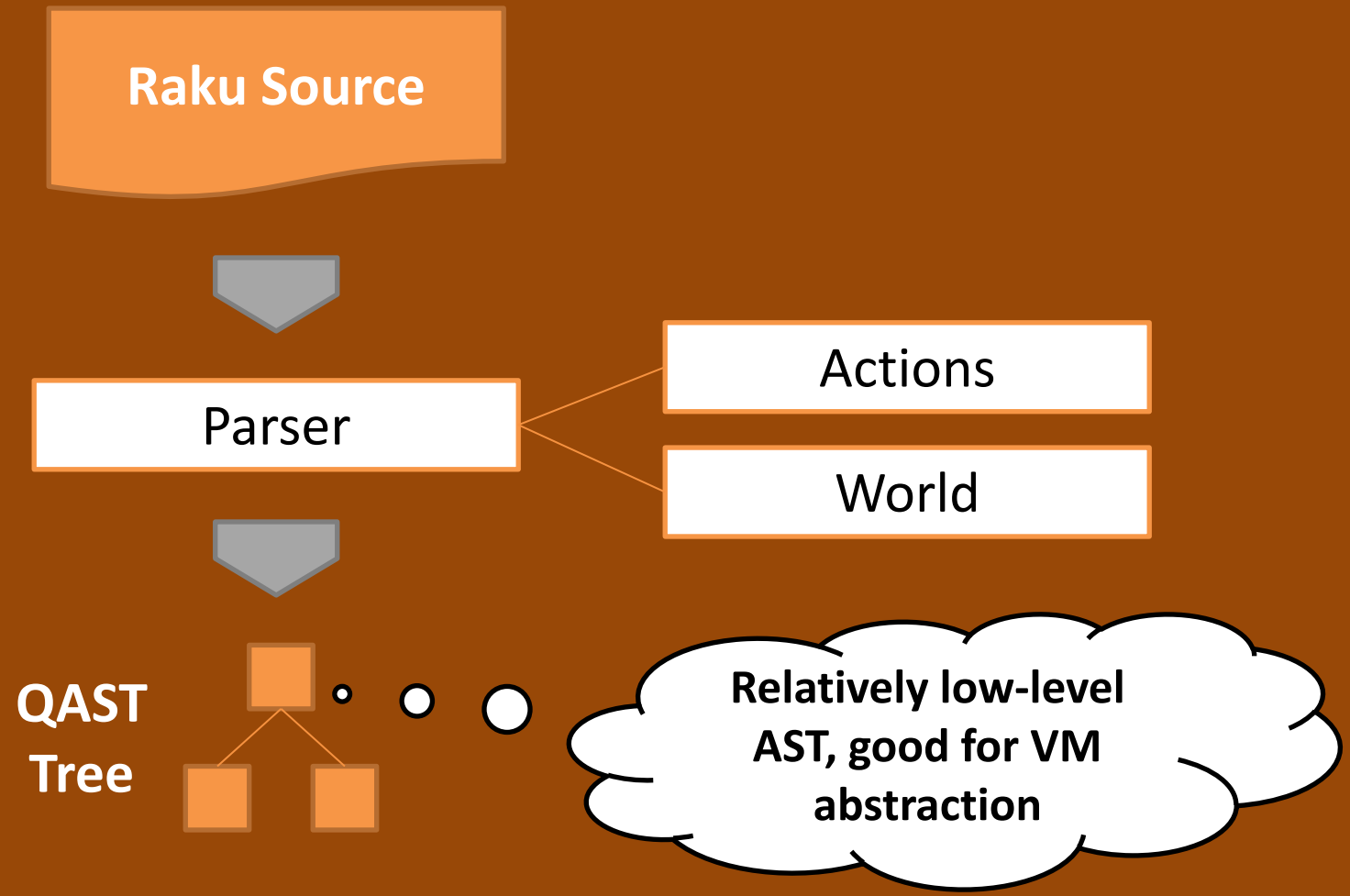

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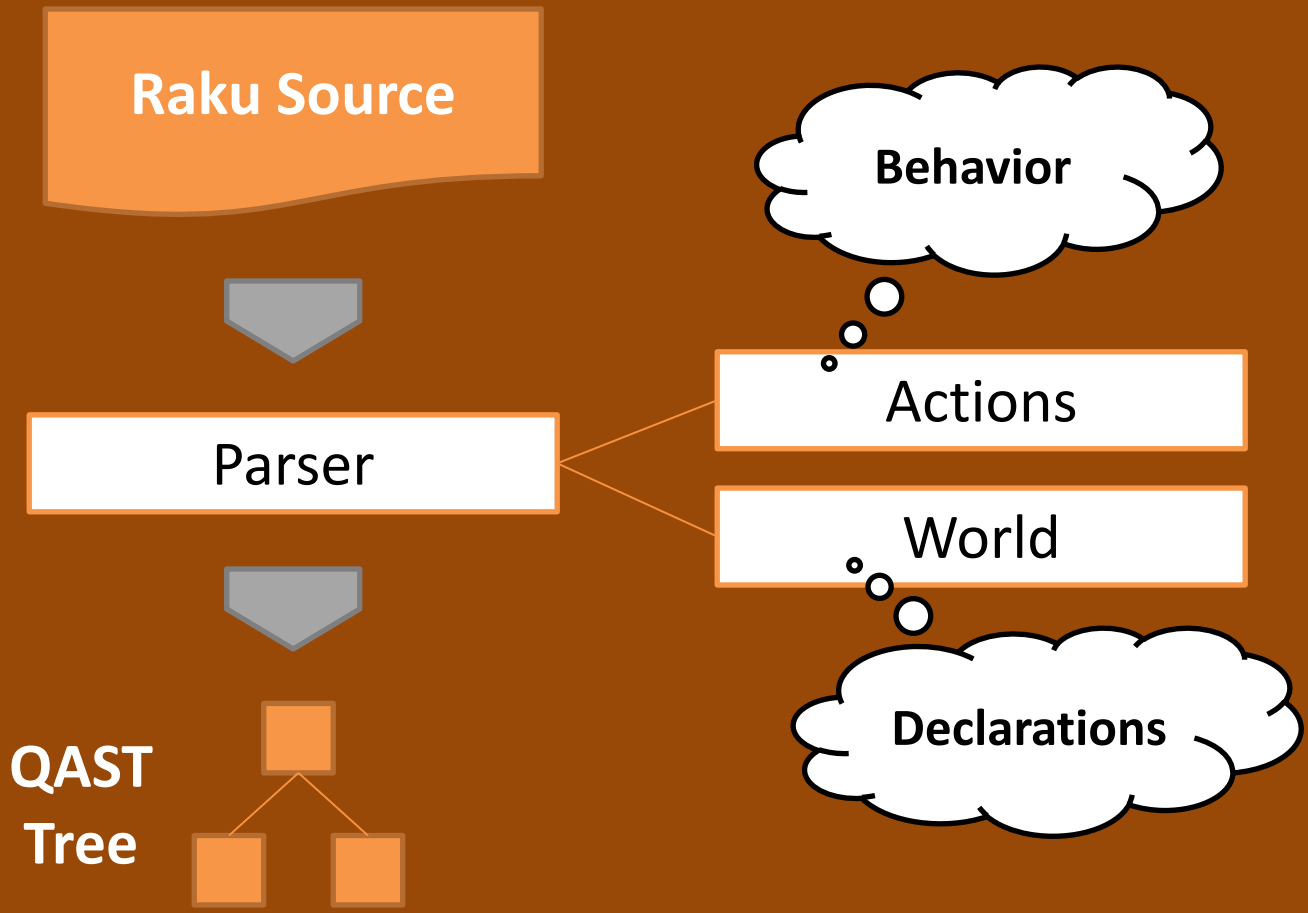
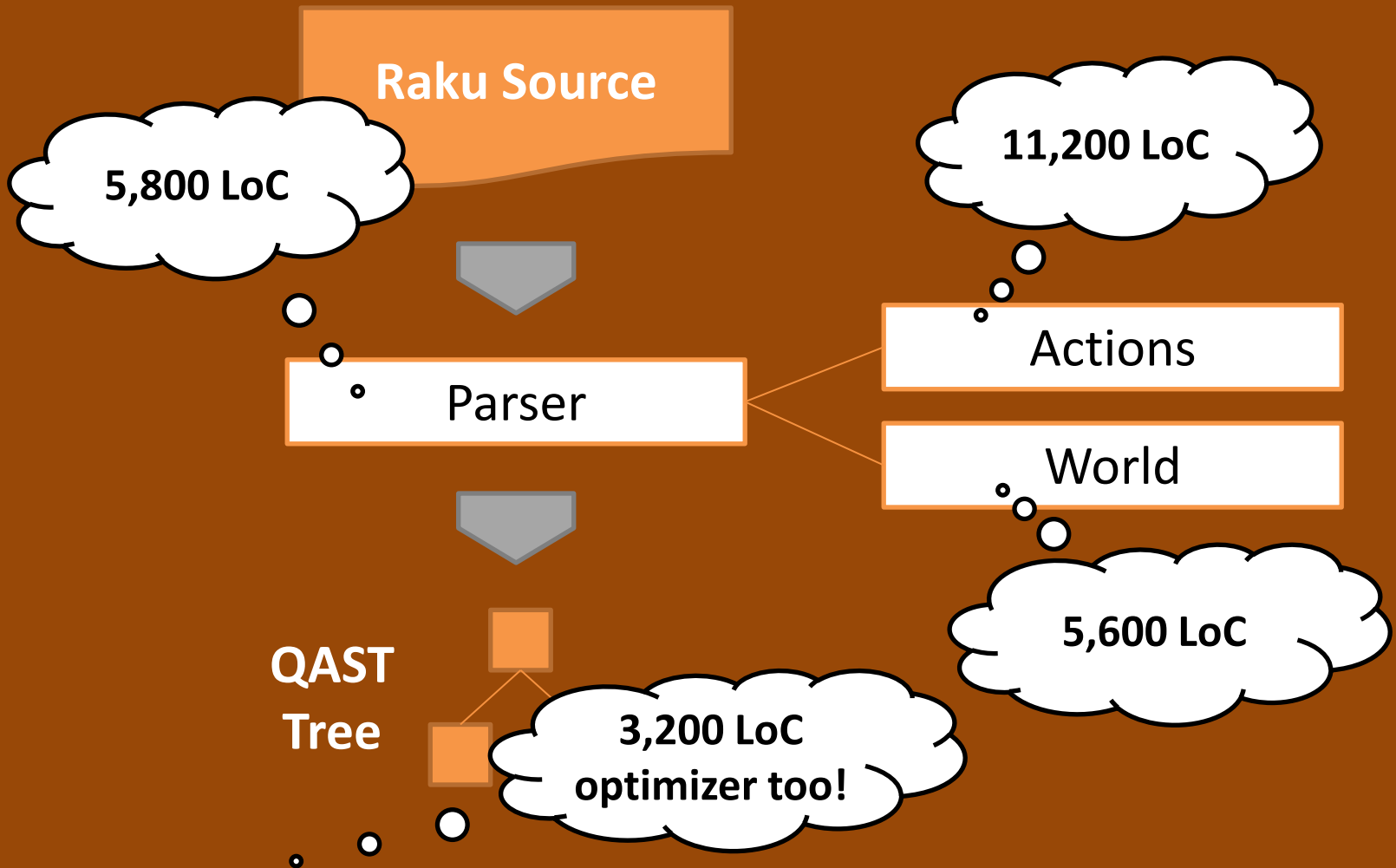
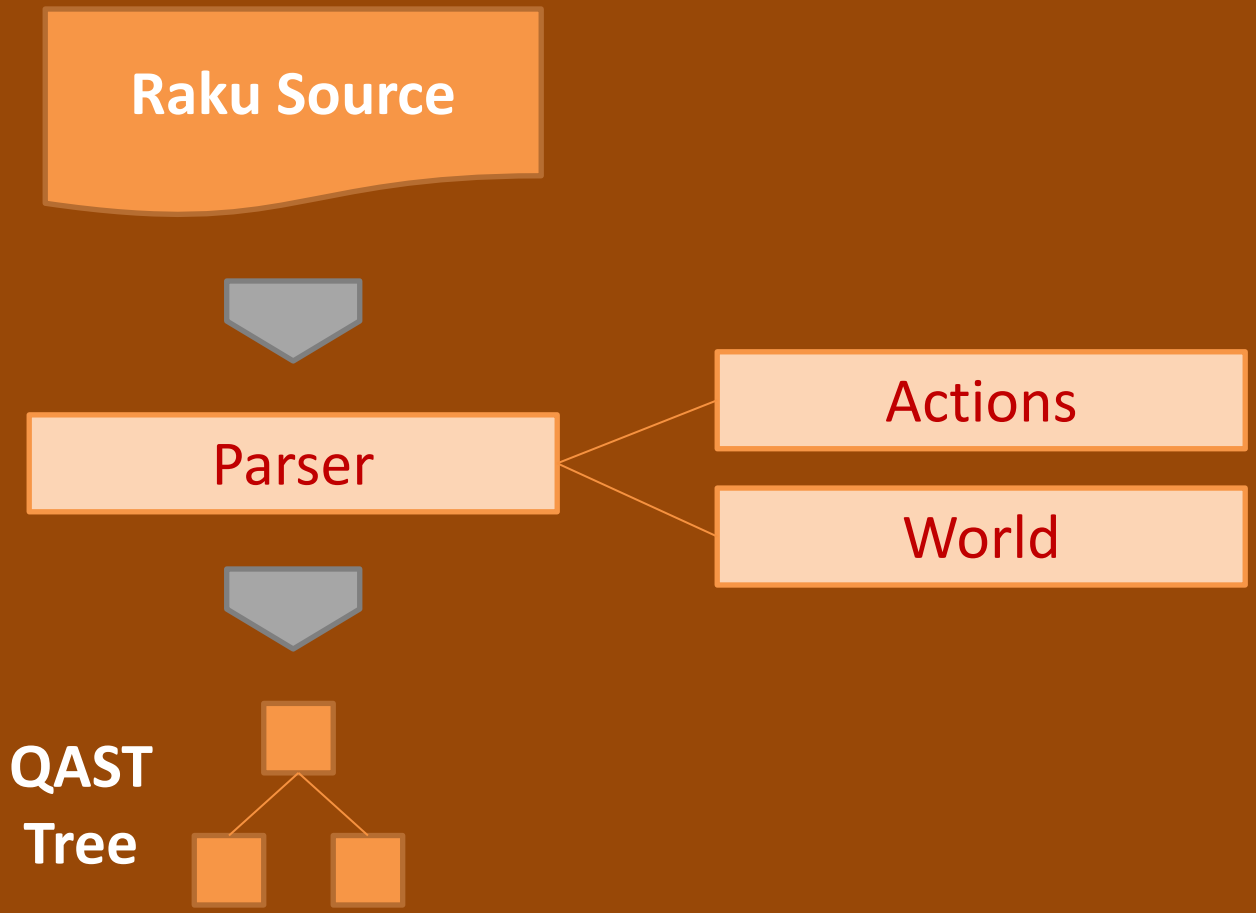


Large components that know the whole language



Error reporting spread throughout them



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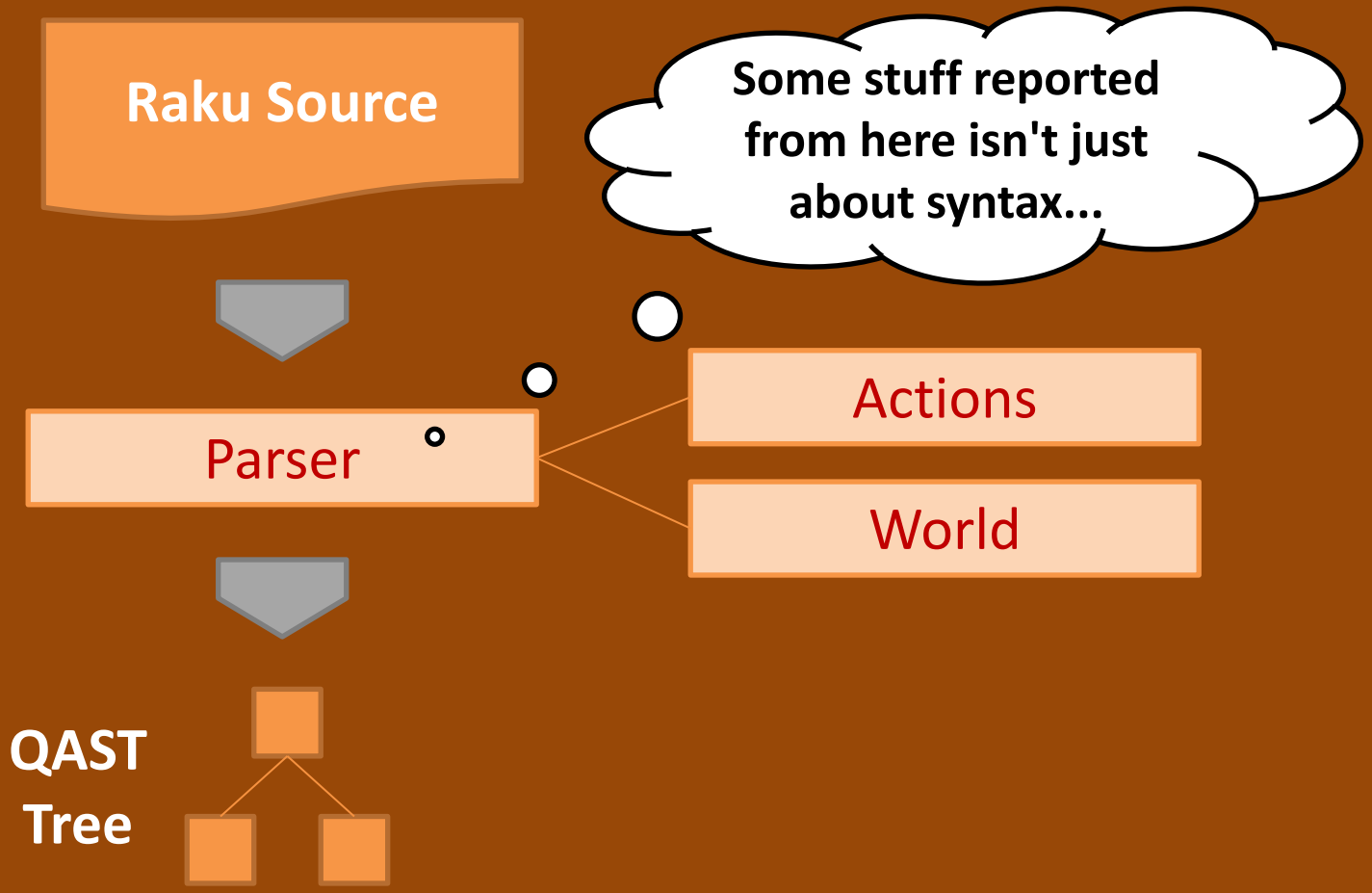


RakuAST node

=

The expert on a language construct

(Excluding its syntax)

A RakuAST node knows about a language construct's...

Semantics (code-gen)

Declarations and meta-objects

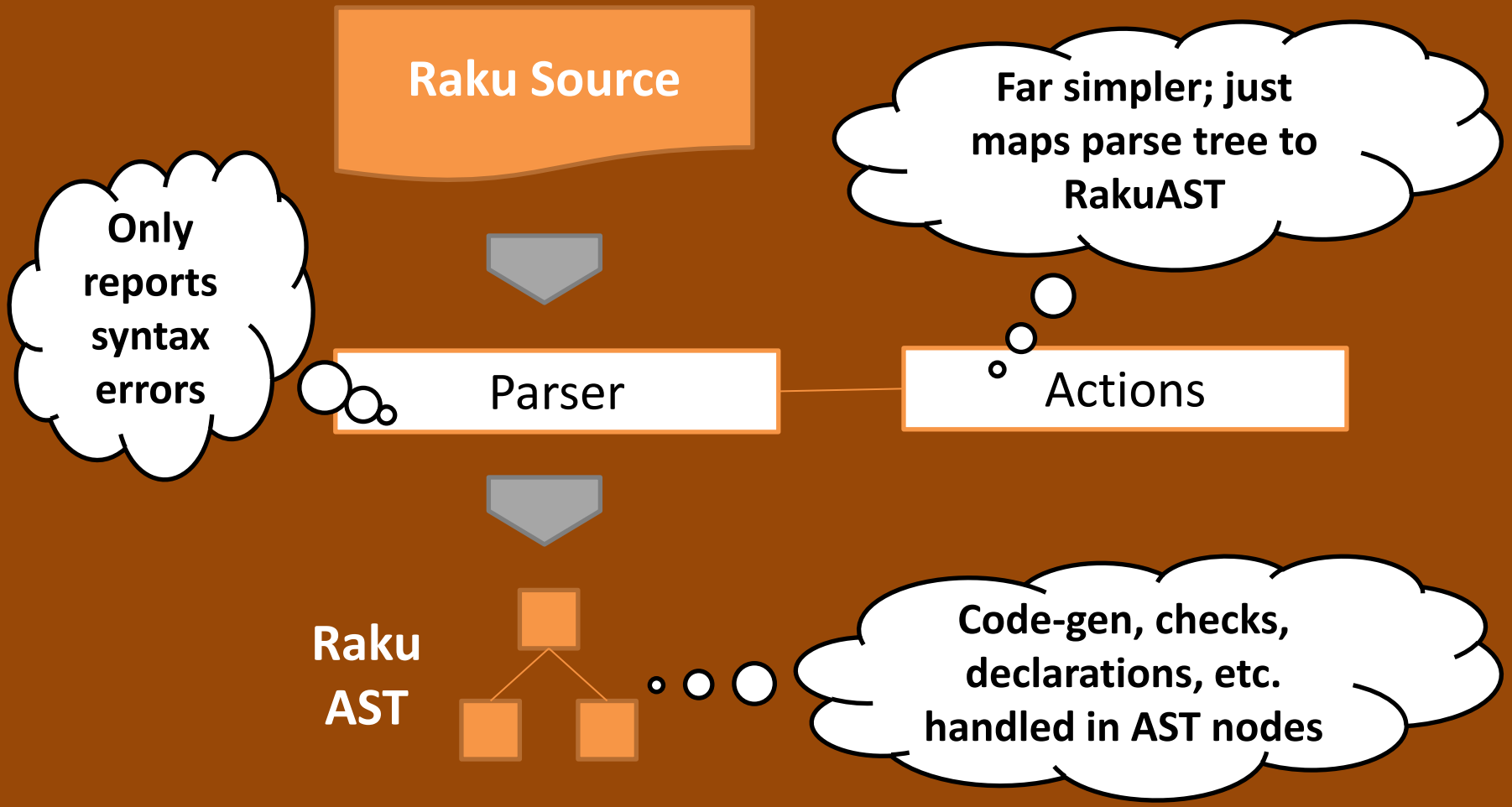
Symbol usage (explicit, implicit)

CHECK time (semantic errors)

Sink context handling

Optimization

The Rakudo compiler frontend with RakuAST



What about the ECMA262Regex module?

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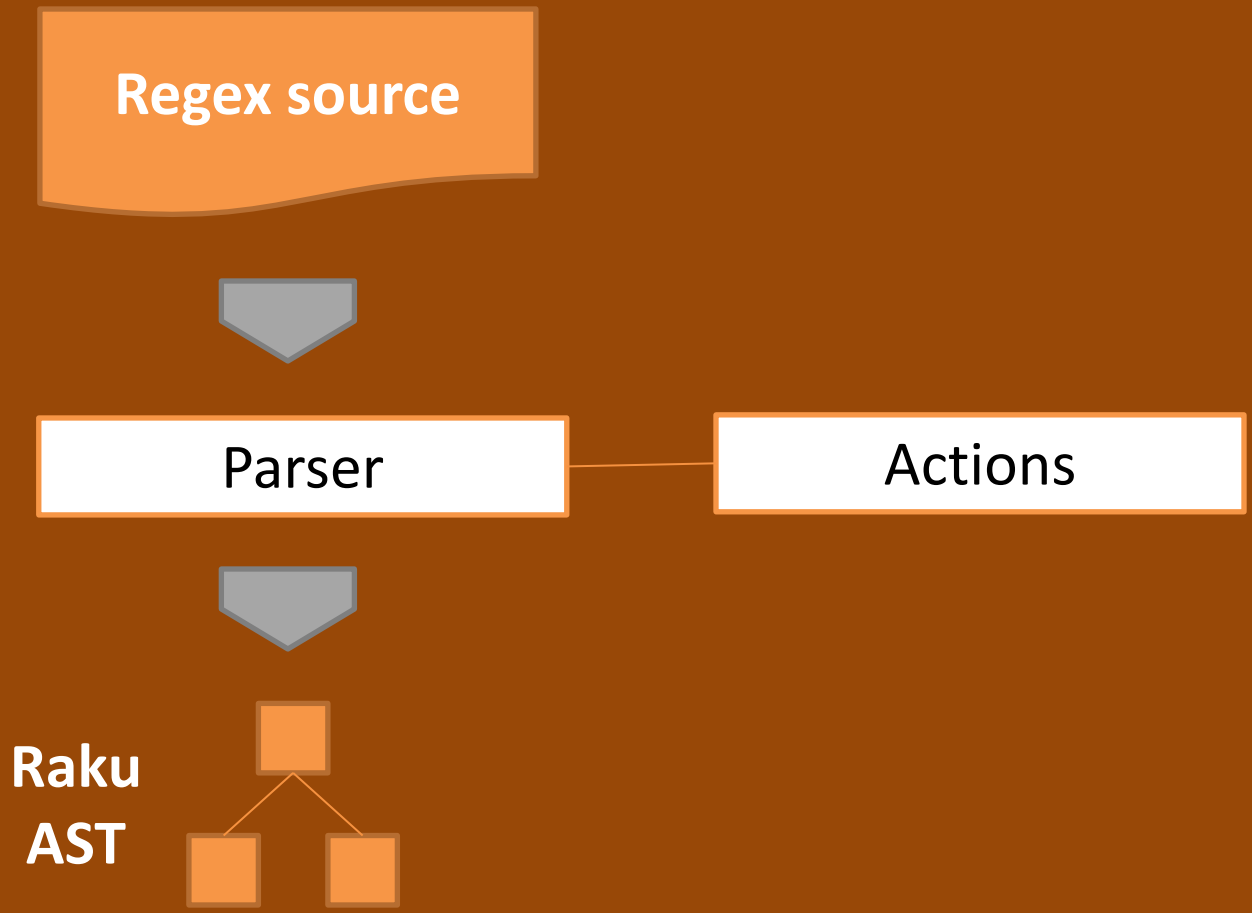
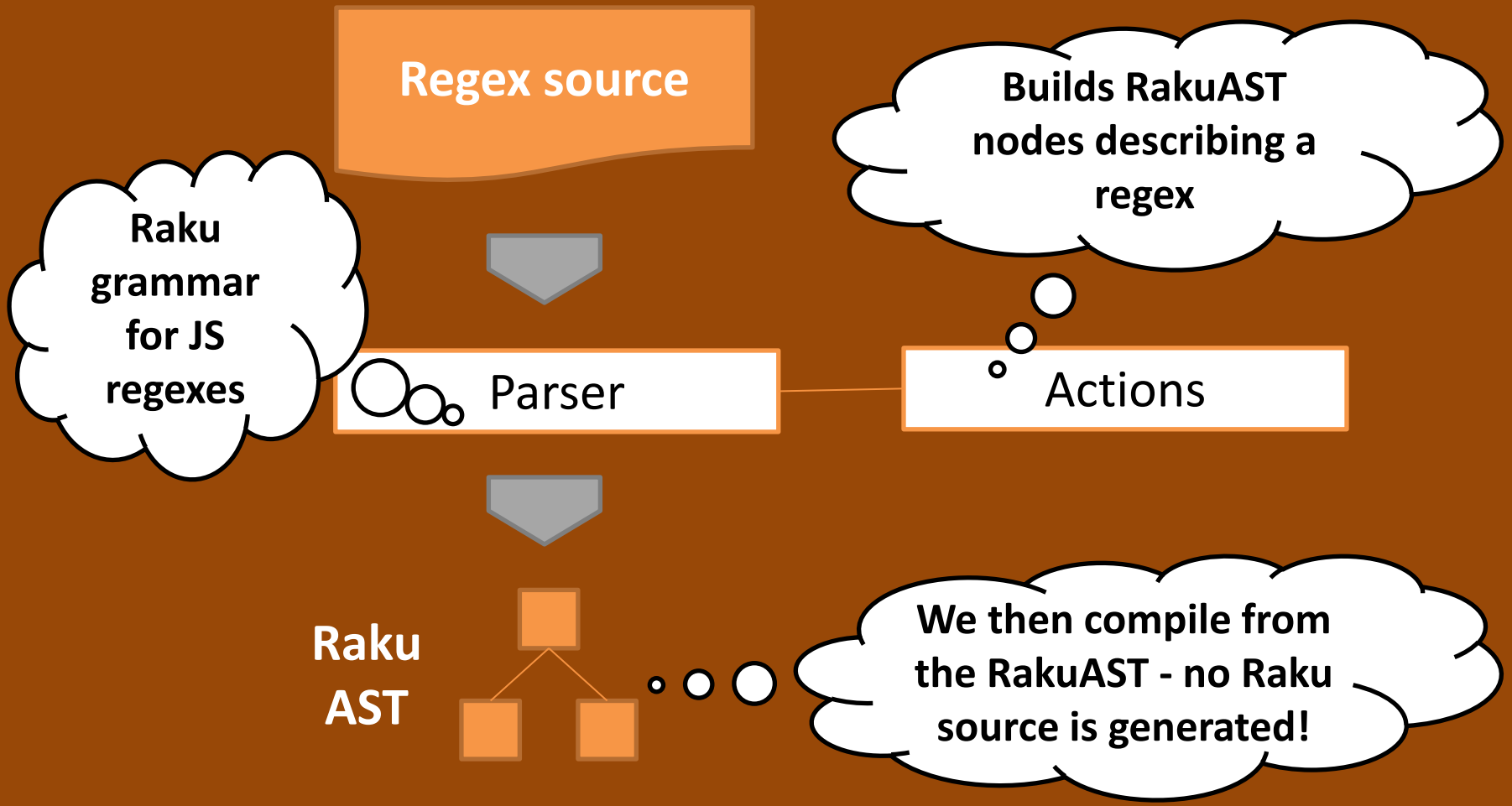


What about the ECMA262Regex module?



RakuAST nodes model language constructs

For example, there's a node for a parenthesized expression, even if these are usually free of semantics

RakuAST nodes should work just like any other Raku object

Must fit within the type system

So we can multi-dispatch over them, destructure them using signatures, and so forth

Must be introspectable

So we can explore them in the REPL, have auto-complete on them in the IDE, etc.

Must be easy to construct

Just create them with `.new`. No context objects or compiler state required.

Use types to encode valid syntactic structure

(Also, macros will be able to use RakuAST types on parameters - which can map back into syntax errors.)

Use roles to extract common features and/or interfaces of AST nodes

RakuAST::Statement
RakuAST::Term
RakuAST::LexicalScope
RakuAST::Lookup
RakuAST::Sinkable

The progress

on implementing RakuAST so far

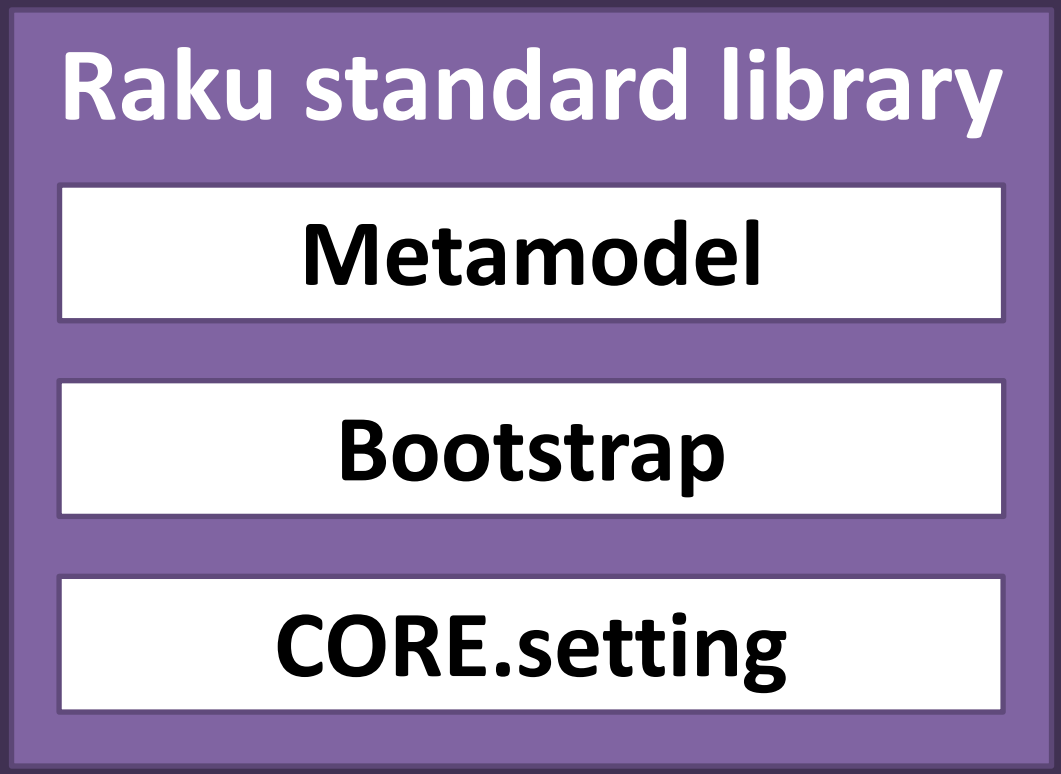
I'm currently working on making RakuAST a reality

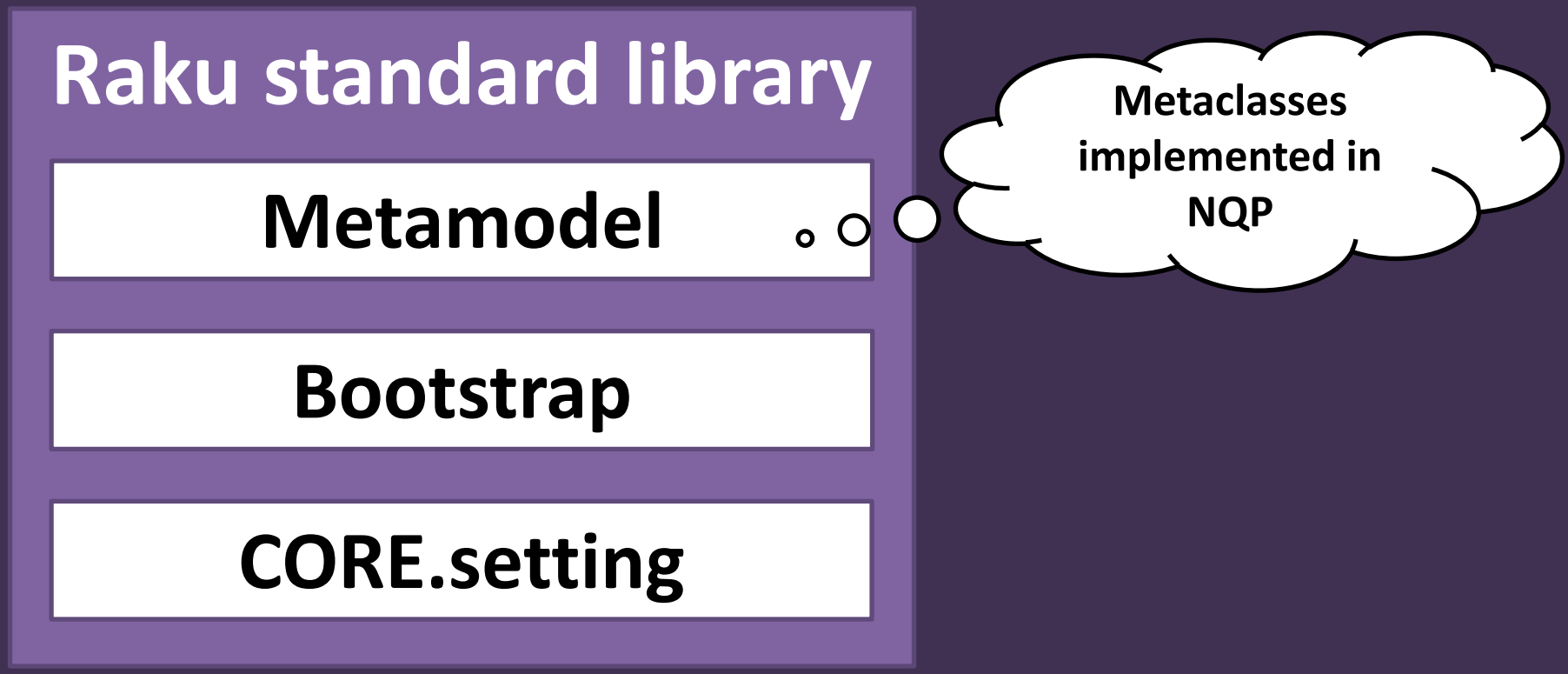
Supported by a grant from The Perl Foundation

A slight problem:

We want RakuAST nodes to work as if they are implemented in Raku

But we need RakuAST in order to compile Raku code!


Raku standard library
Metamodel
Bootstrap
CORE.setting


Raku standard library
Metamodel
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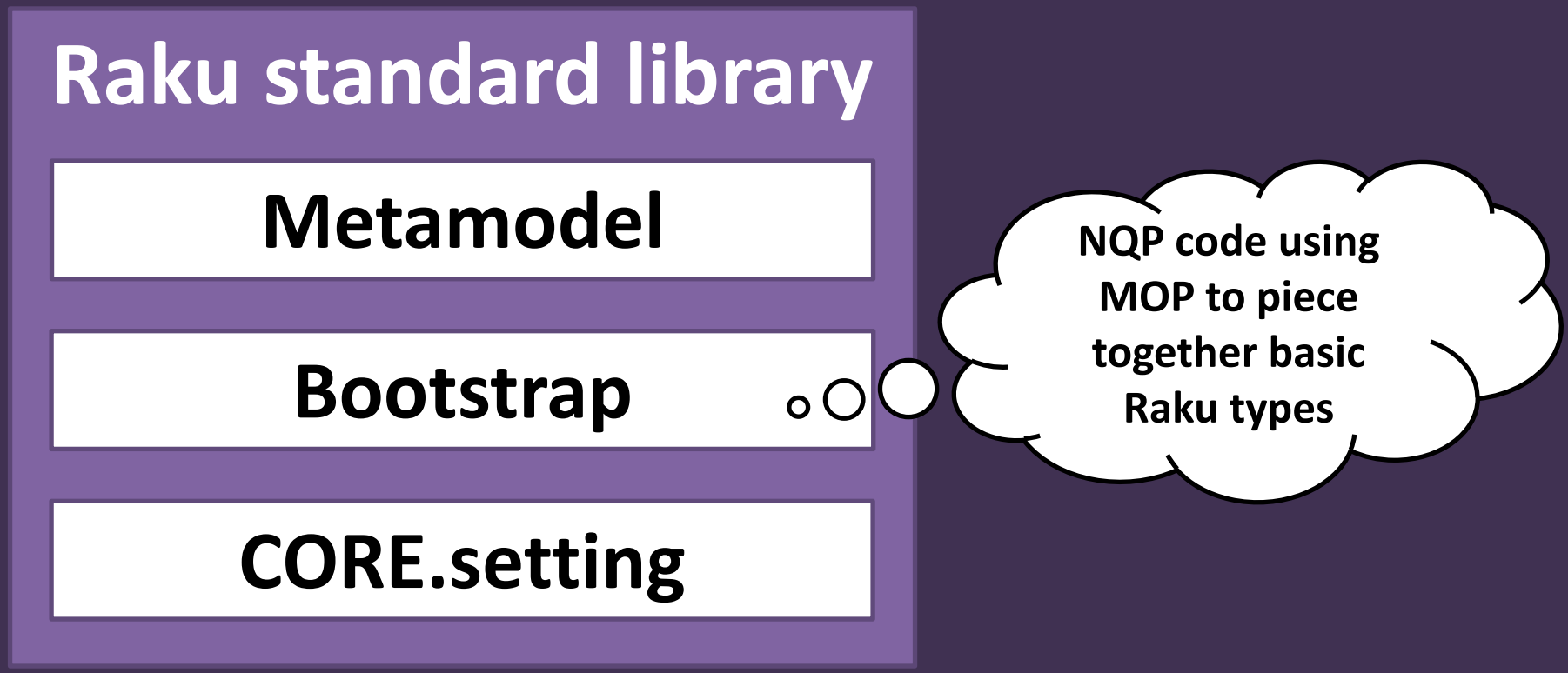
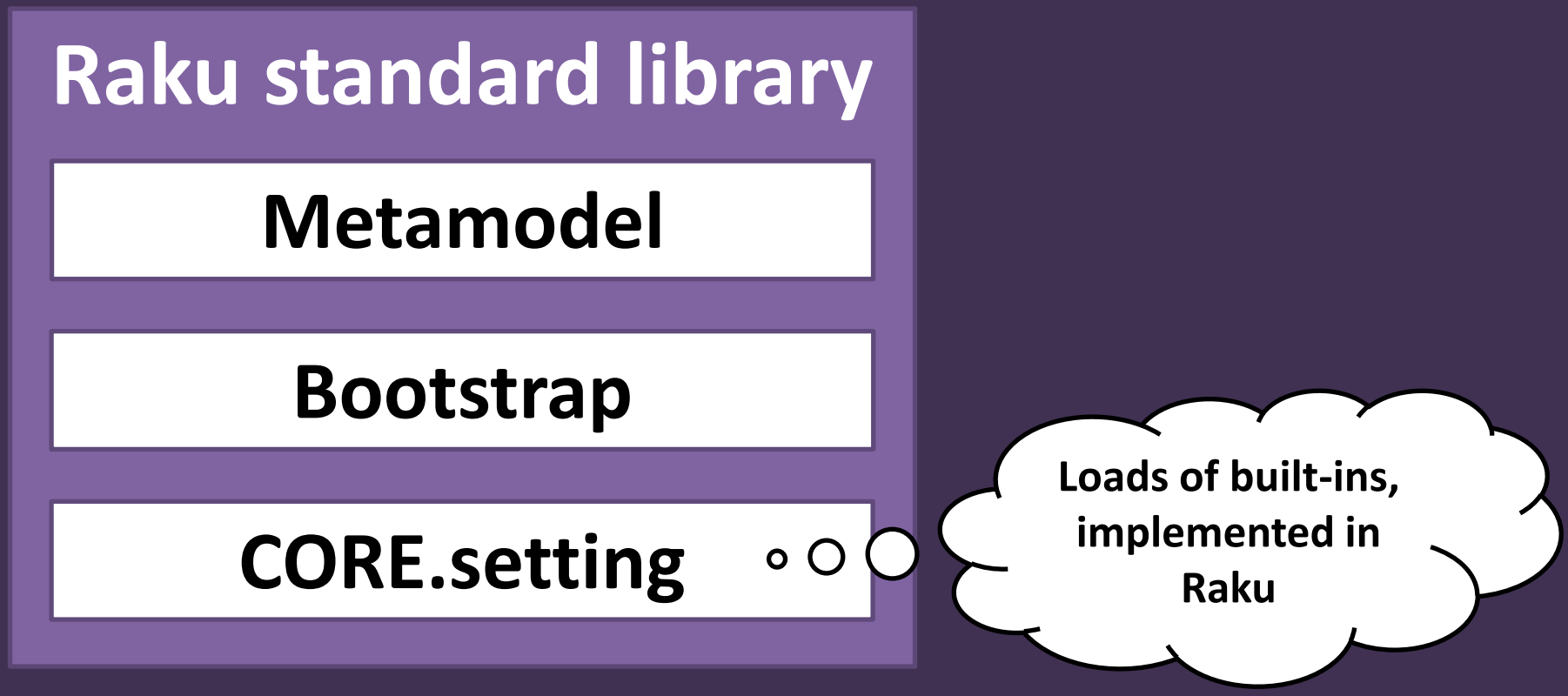
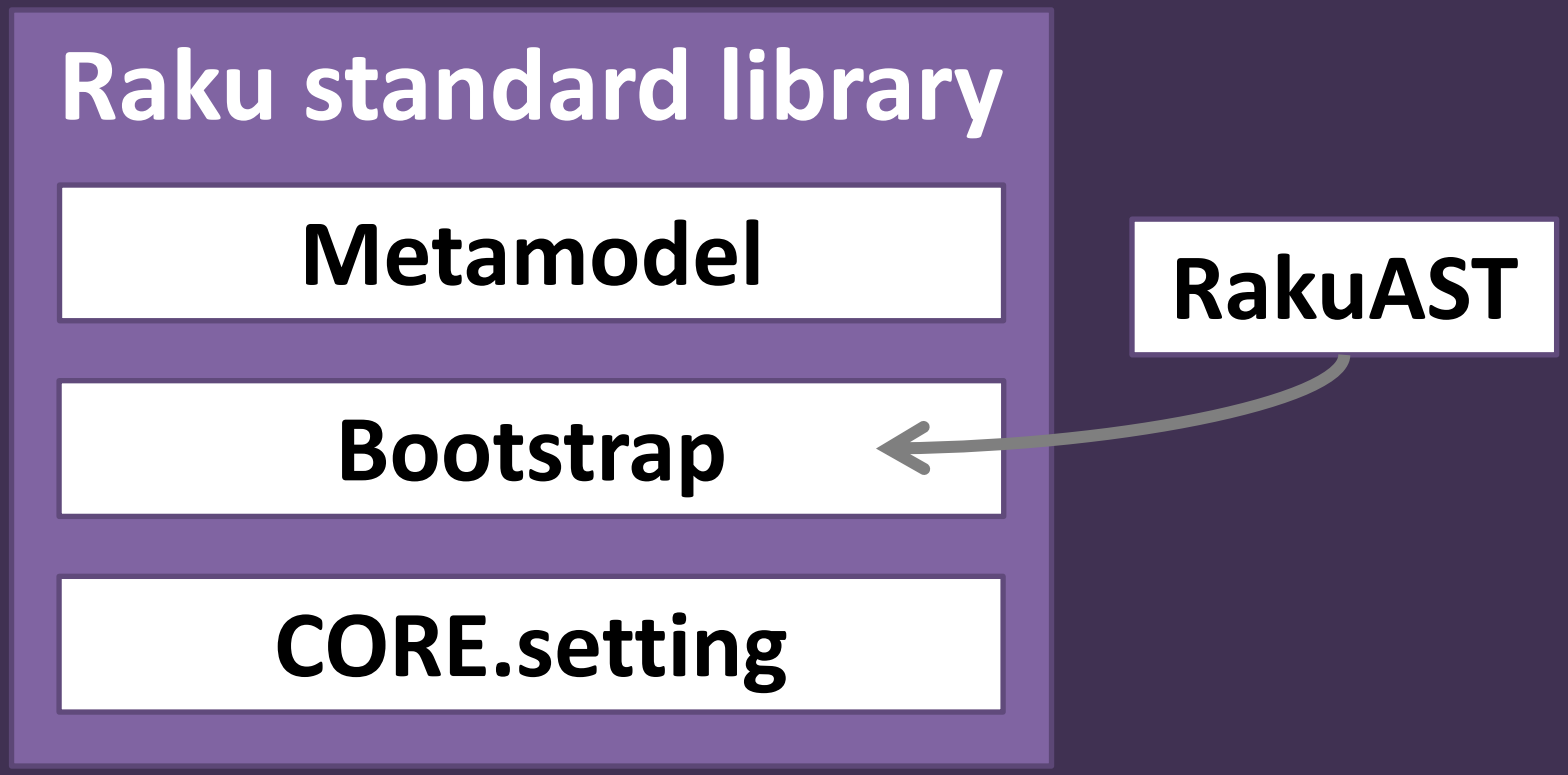
CORE.setting
Metaclasses implemented in NQP


Raku standard library
Metamodel
Bootstrap
CORE.setting
NQP code using MOP to piece together basic Raku types


Raku standard library
Metamodel
Bootstrap
CORE.setting
Loads of built-ins, implemented in Raku

The bootstrap already exists to put together just enough that we can write the rest in Raku...



...so it makes sense to have the RakuAST nodes pieced together there too.

But it's *really, really* tedious to manually instantiate all of the meta-objects and piece them all together!

But it's *really, really* tedious to manually instantiate all of the meta-objects and piece them all together!

Thankfully, I'm a compiler writer, so I just wrote a little compiler to do that for me! ☺

Current status

- ✓ Over 100 node types (some abstract) implemented
- ✓ Around 200 tests covering construction and EVAL from RakuAST nodes
- ✓ New RakuAST-based compiler frontend, enabled by an environment variable, passes half the sanity tests

Following progress or trying it out

Find the source

In the rakuast branch of the Rakudo repository

Try it out

Using RAKUDO_RAKUAST=1 in the environment

Follow grant reports

On The Perl Foundation blog

The impact

of RakuAST on Raku users

Compatibility goal

The *vast majority* of Raku users won't notice any changes in their program's behavior when they upgrade Rakudo to a version based around RakuAST

How?

Passing the specification tests

Should not show any regressions

Checking its impact with Blin

Runs the tests of all ecosystem modules; only those dabbling in compiler internals should be affected

Ensuring updates are available

For the few widely used modules that depend on compiler internals

Naively, an "extra layer" could be expected to lead to a slowdown

However, I'm cautiously optimistic we can come out ahead

Why might it be faster?

More straightforward compilation

Thanks to a better program representation

Potential for better optimization

The static optimizer today has become challenging to extend; RakuAST should offer a cleaner approach

Potential for parallelism

Some AST processing may be able to happen while we parse the rest of the compilation unit

What next?

RakuAST nodes for all the language

Early autumn 2020

RakuAST-based compiler as default

Late autumn 2020

Macros

Christmas (2020 ☺)

Language release including RakuAST

Spring 2021

Thank you!

Questions?

@ jonathan@edument.cz

W jnthn.net

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