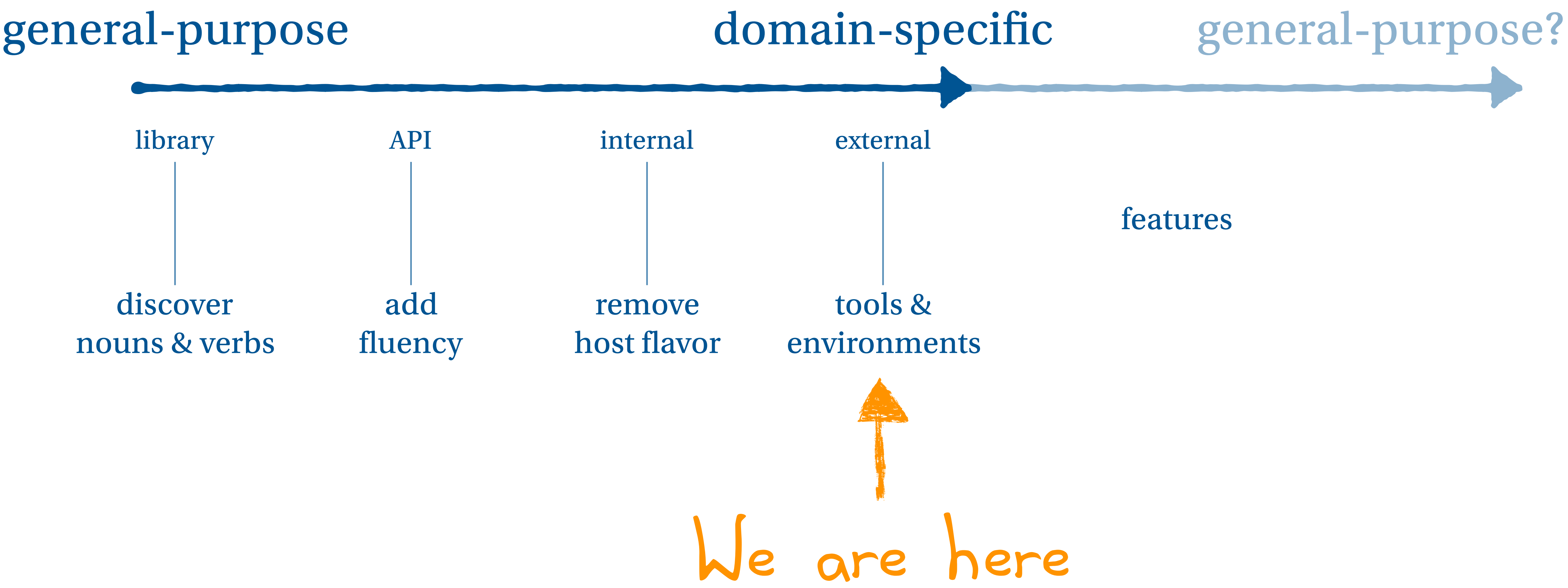
Parsing &
Language Architecture

The evolution of a DSL?



general-purpose

domain-specific

general-purpose?

library

discover nouns & verbs

API

add fluency

internal

remove host flavor

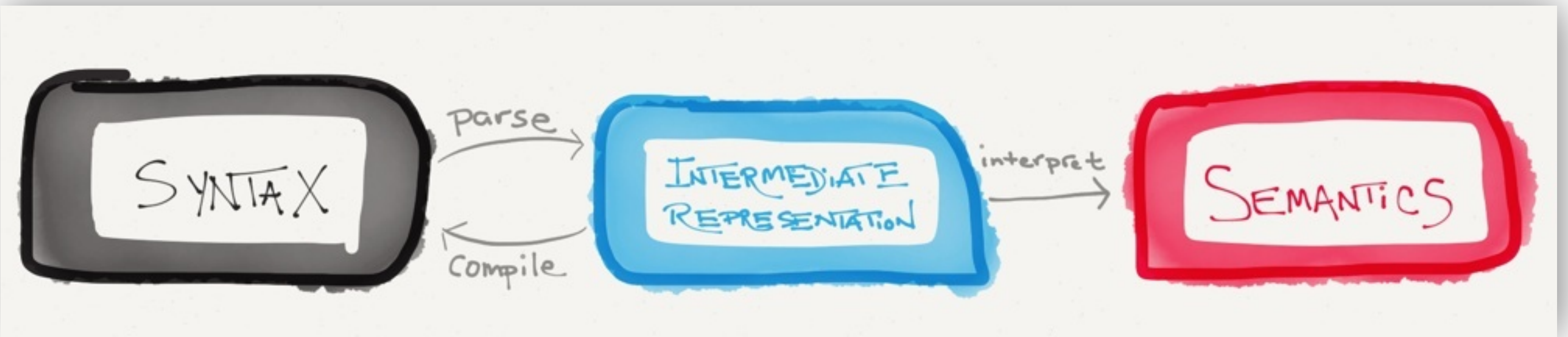
external

tools & environments

features

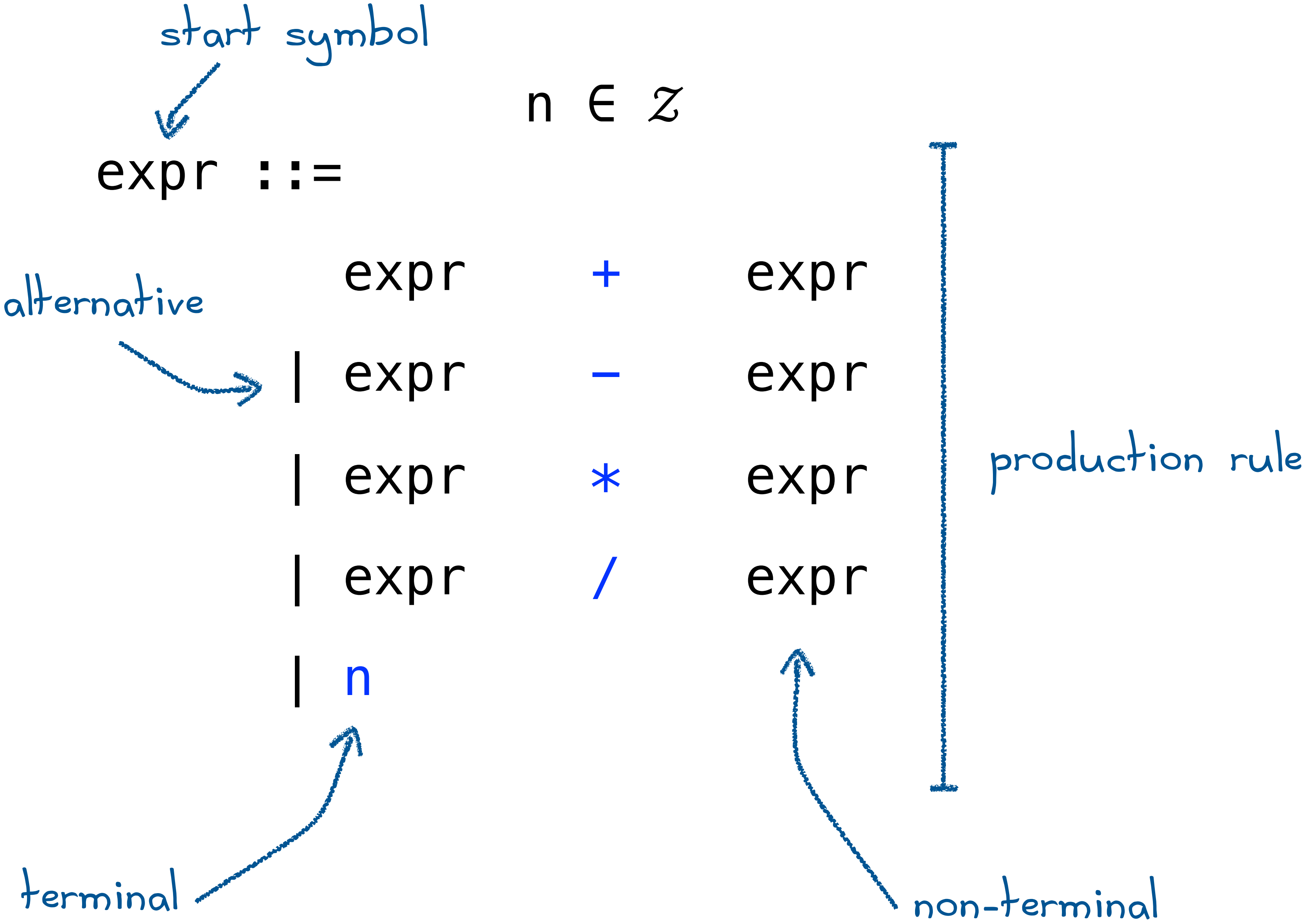
We are here

Towards a language architecture



Grammars

A notation for defining all the syntactically valid programs of a language. (Whitespace usually ignored.)



```
                      n ∈ ℤ
expr ::=
          expr    +    expr
        | expr    -    expr
        | expr    *    expr
        | expr    /    expr
        | n
```

Grammars (Is this a DSL?)

A notation for defining all the syntactically valid programs of a language. (Whitespace usually ignored.)

```
expr ::=
           expr    +    expr
         | expr    -    expr
         | expr    *    expr
         | expr    /    expr
         | n
```

Parser combinators

An internal DSL for **recursive-descent** parsers

```
import scala.util.parsing.combinator._

object Parser extends JavaTokenParsers {

  def expr: Parser[String] =

           (   expr ~ "+" ~ expr

             | expr ~ "-" ~ expr

             | expr ~ "*" ~ expr

             | expr ~ "/" ~ expr

             | wholeNumber )

}
```

Warning: left-recursion

build.sbt

```
libraryDependencies += "org.scala-lang.modules" %% "scala-parser-combinators" % "1.0.4"
```

Packrat parsing

Allows left-recursion. Recursive-descent parsing with backtracking.

```
import scala.util.parsing.combinator._

object Parser extends JavaTokenParsers with PackratParsers {

  lazy val expr: PackratParser[AST] =

          (   expr ~ "+" ~ expr

            | expr ~ "-" ~ expr

            | expr ~ "*" ~ expr

            | expr ~ "/" ~ expr

            | wholeNumber )

}
```

Warning: associativity / precedence

build.sbt

```
libraryDependencies += "org.scala-lang.modules" %% "scala-parser-combinators" % "1.0.4"
```

Abstract syntax

Describes the intermediate representation, i.e., the abstract syntax tree. An inductive data structure.

```
               n ∈ 𝒵
expr ::=
           expr   +   expr
         | expr   -   expr
         | expr   *   expr
         | expr   /   expr
         | n
```

```scala
sealed abstract class Expr
case class Plus(left: Expr, right: Expr) extends Expr
case class Sub(left: Expr, right: Expr)  extends Expr
case class Mult(left: Expr, right: Expr) extends Expr
case class Div(left: Expr, right: Expr)  extends Expr
case class Num(n: Int)                   extends Expr
```

Actions: transform strings to IR

```
import scala.util.parsing.combinator._

object Parser extends JavaTokenParsers with PackratParsers {

  lazy val expr: PackratParser[String] =

          (   expr ~ "+" ~ expr

            | expr ~ "-" ~ expr

            | expr ~ "*" ~ expr

            | expr ~ "/" ~ expr

            | wholeNumber )

}
```

Warning: associativity / precedence

build.sbt

```
libraryDependencies += "org.scala-lang.modules" %% "scala-parser-combinators" % "1.0.4"
```

Actions: transform strings to IR

```
import scala.util.parsing.combinator._

object Parser extends JavaTokenParsers with PackratParsers {

  lazy val expr: PackratParser[AST] =

          (   expr ~ "+" ~ expr ^^ {case l~"+"~r ⇒ Plus(l,r)  }

            | expr ~ "-" ~ expr ^^ {case l~"-"~r ⇒ Minus(l,r) }

            | expr ~ "*" ~ expr ^^ {case l~”*"~r ⇒ Times(l,r) }

            | expr ~ "/" ~ expr ^^ {case l~”/"~r ⇒ Divide(l,r)}

            | wholeNumber       ^^ {s ⇒ Num(s.toInt)} )

}
```

Warning: associativity / precedence

build.sbt

```
libraryDependencies += "org.scala-lang.modules" %% "scala-parser-combinators" % "1.0.4"
```

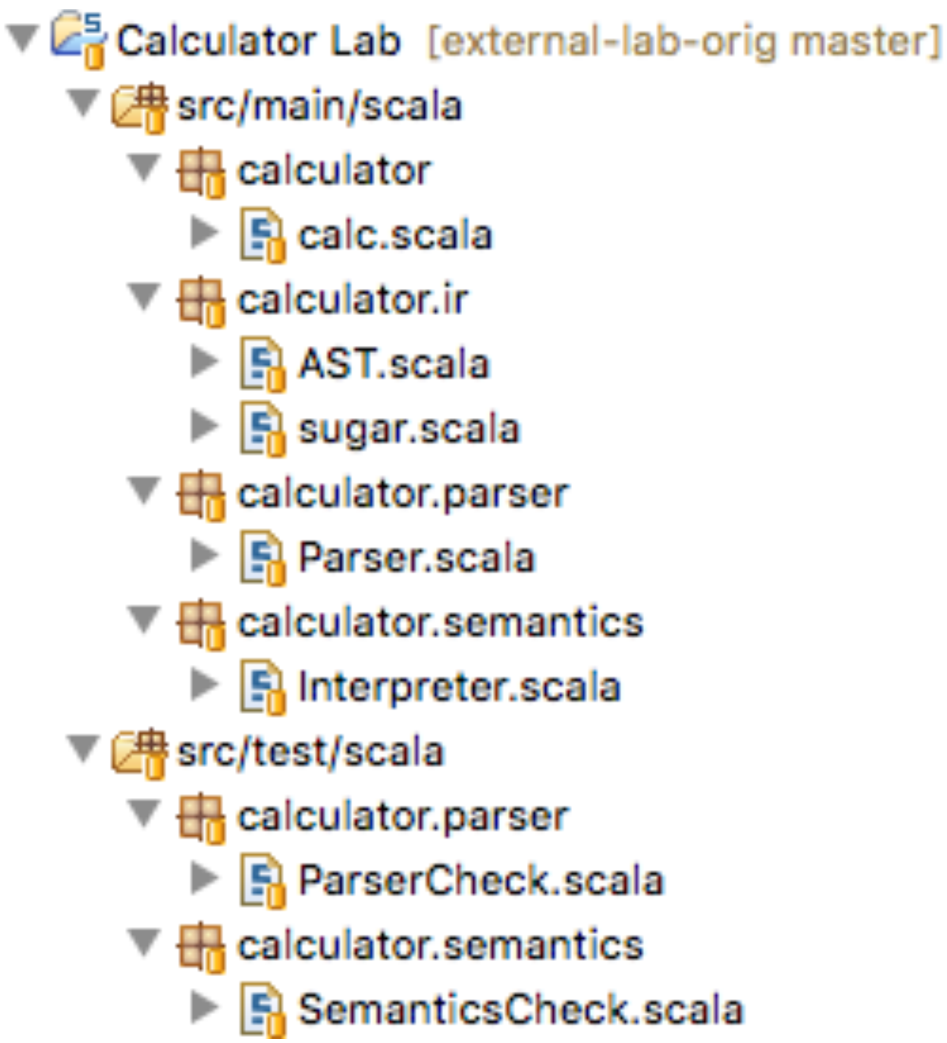
A less ambiguous grammar

The "lower-down" the operation, the higher its precedence.

```
               n ∈ 𝒵
expr ::=
         expr    +    term
       | expr    -    term
       | fact

term ::=
         term    *    fact
       | term    /    fact
       | fact

fact ::=
         n | ( expr )
```

```scala
sealed abstract class Expr

case class Plus(left: Expr, right: Expr) extends Expr

case class Sub(left: Expr, right: Expr)  extends Expr

case class Mult(left: Expr, right: Expr) extends Expr

case class Div(left: Expr, right: Expr)  extends Expr

case class Num(n: Int)                   extends Expr
```

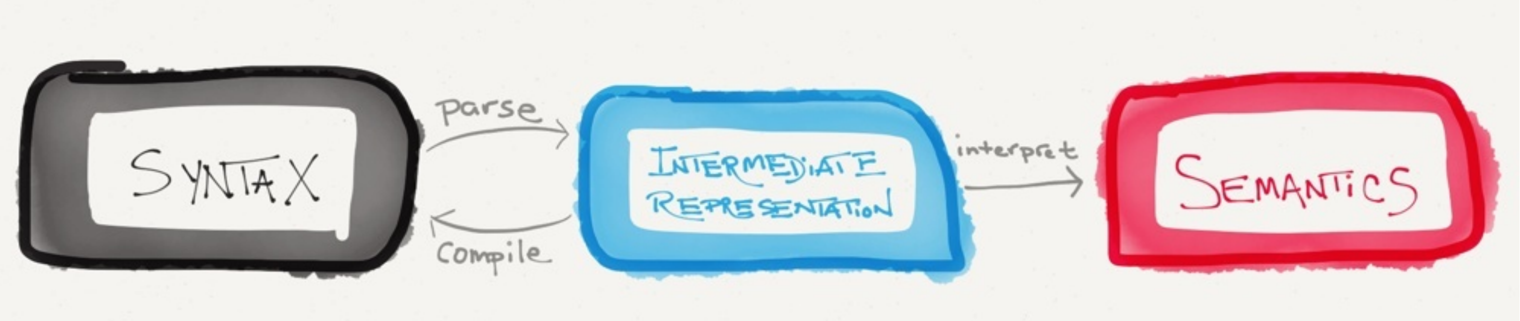
A Scala architecture for languages



```
▼ Calculator Lab [external-lab-orig master]
  ▼ src/main/scala
    ▼ calculator
      ▶ calc.scala
    ▼ calculator.ir
      ▶ AST.scala
      ▶ sugar.scala
    ▼ calculator.parser
      ▶ Parser.scala
    ▼ calculator.semantics
      ▶ Interpreter.scala
  ▼ src/test/scala
    ▼ calculator.parser
      ▶ ParserCheck.scala
    ▼ calculator.semantics
      ▶ SemanticsCheck.scala
```

Read-Eval-Print-Loop (**REPL**)

```
libraryDependencies += "org.scala-lang" % "scala-compiler" % scalaVersion.value
```



parser combinators

case classes

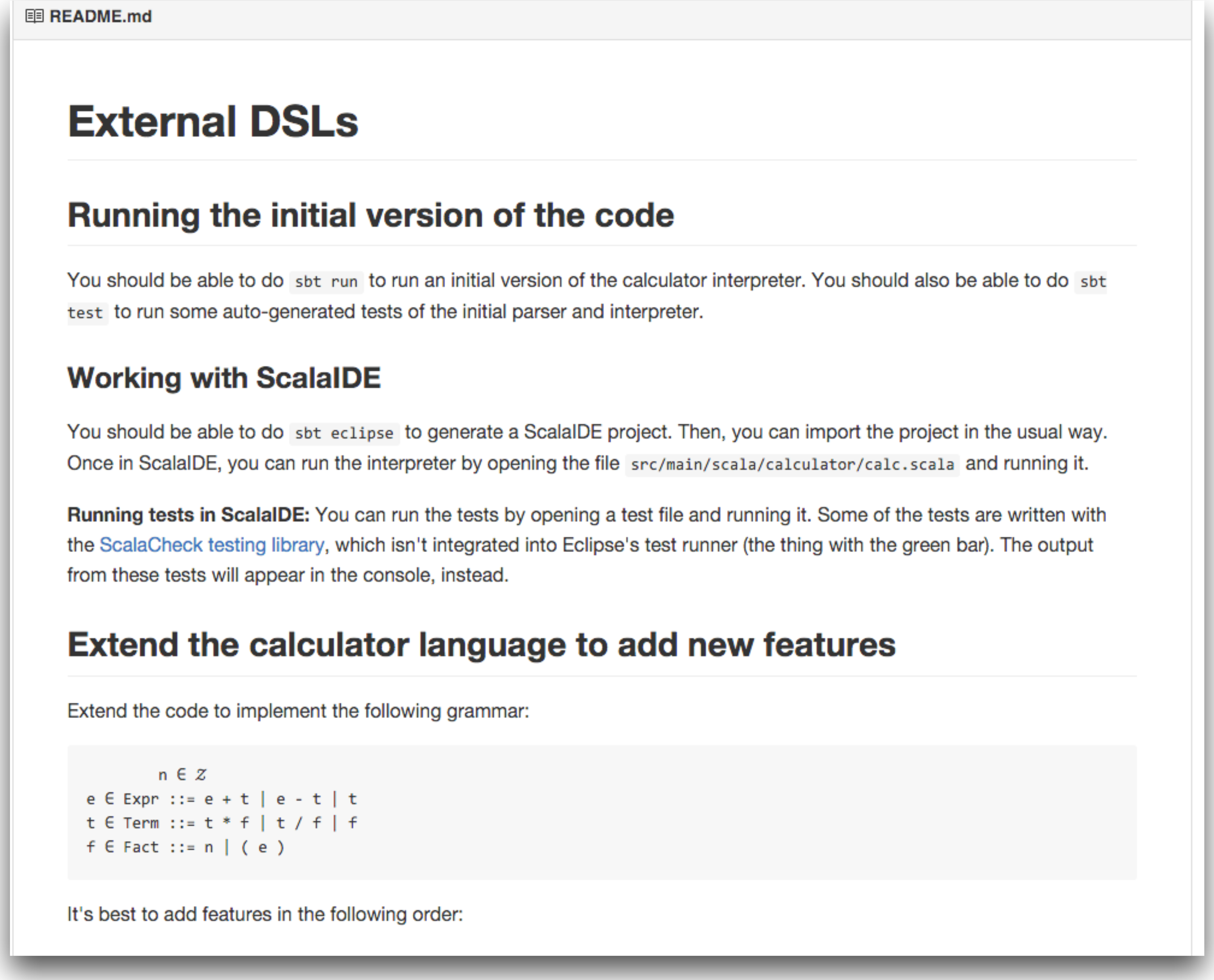
functions & pattern matching

tests

```
libraryDependencies += "org.scalacheck" %% "scalacheck" % "1.13.0" % "test"
libraryDependencies += "org.scalatest" %% "scalatest" % "2.2.6" % "test"
```

Let’s practice!

With a grammar that fixes the associativity / precedence problems



README.md

External DSLs

Running the initial version of the code

You should be able to do `sbt run` to run an initial version of the calculator interpreter. You should also be able to do `sbt test` to run some auto-generated tests of the initial parser and interpreter.

Working with ScalaIDE

You should be able to do `sbt eclipse` to generate a ScalaIDE project. Then, you can import the project in the usual way. Once in ScalaIDE, you can run the interpreter by opening the file `src/main/scala/calculator/calc.scala` and running it.

Running tests in ScalaIDE: You can run the tests by opening a test file and running it. Some of the tests are written with the ScalaCheck testing library, which isn't integrated into Eclipse's test runner (the thing with the green bar). The output from these tests will appear in the console, instead.

Extend the calculator language to add new features

Extend the code to implement the following grammar:

```
         n ∈ ℤ
e ∈ Expr ::= e + t | e - t | t
t ∈ Term ::= t * f | t / f | f
f ∈ Fact ::= n | ( e )
```

It's best to add features in the following order: