Executable Grammars in Newspeak

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Parser Combinators

- Long history in Functional Programming
- Operators of BNF are functions from (grammar) productions to productions
- Productions are isomorphic to parsers
- Build parser by writing out BNF!

Parser Combinators

BNF

*id = letter (letter | digit) **

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*id = letter (letter | digit) **

Newspeak

id = letter, (letter | digit) star.

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*id = letter (letter | digit) **

Newspeak

id = letter, (letter | digit) star.

Javanese

id = letter().seq(letter().or(digit()).star());

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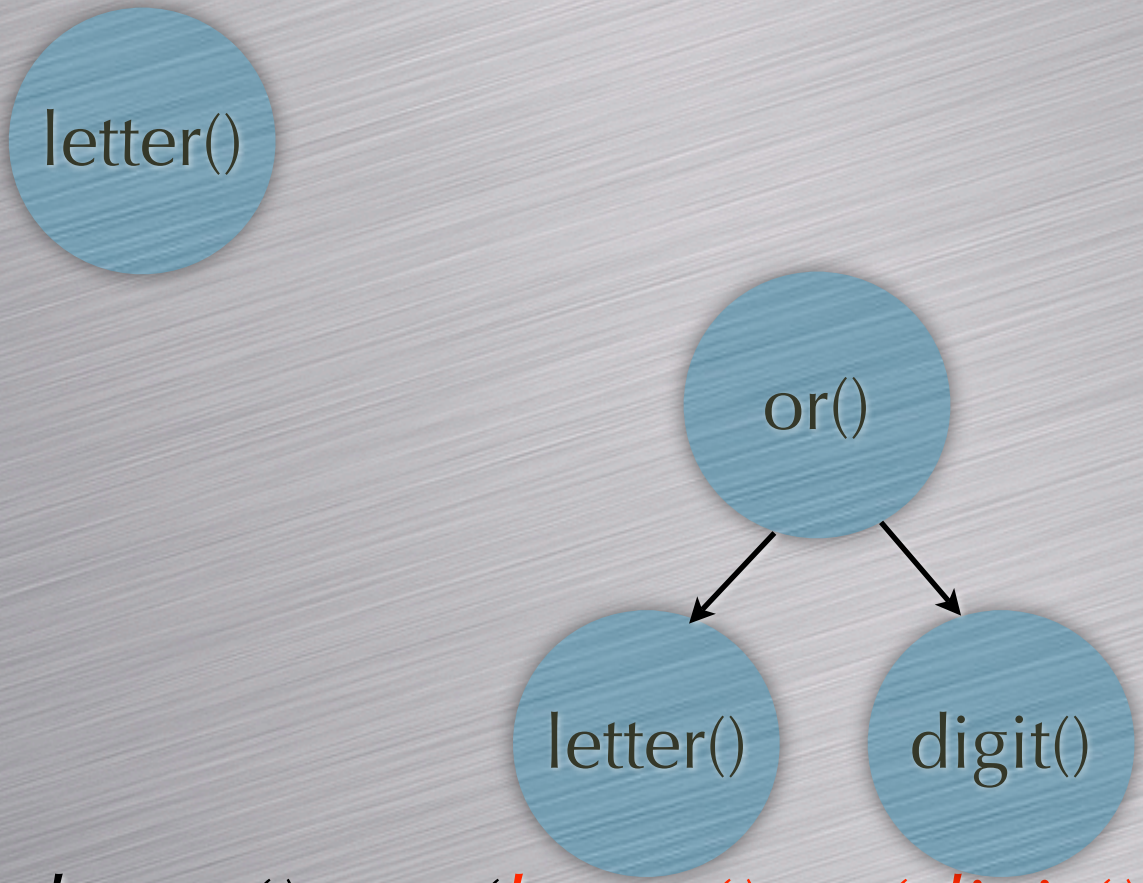

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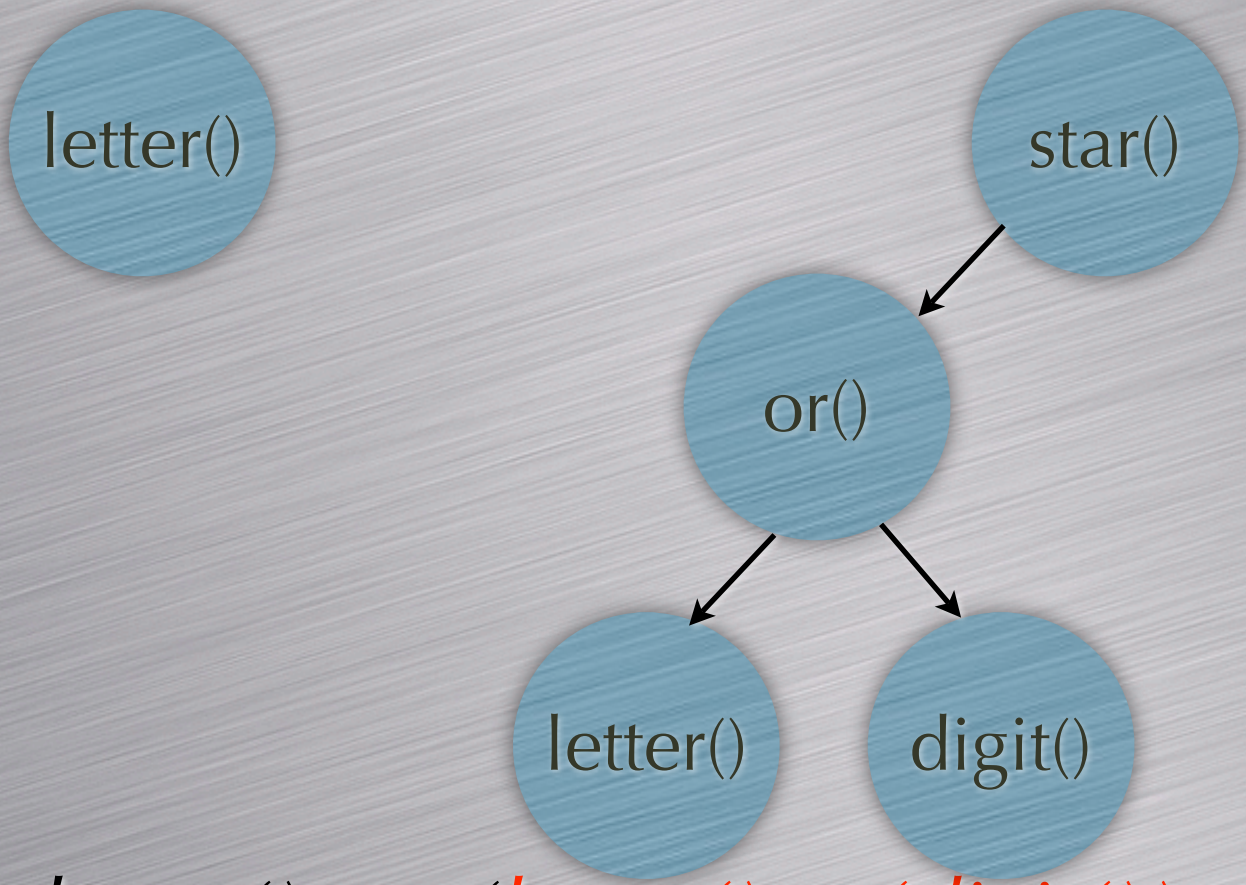

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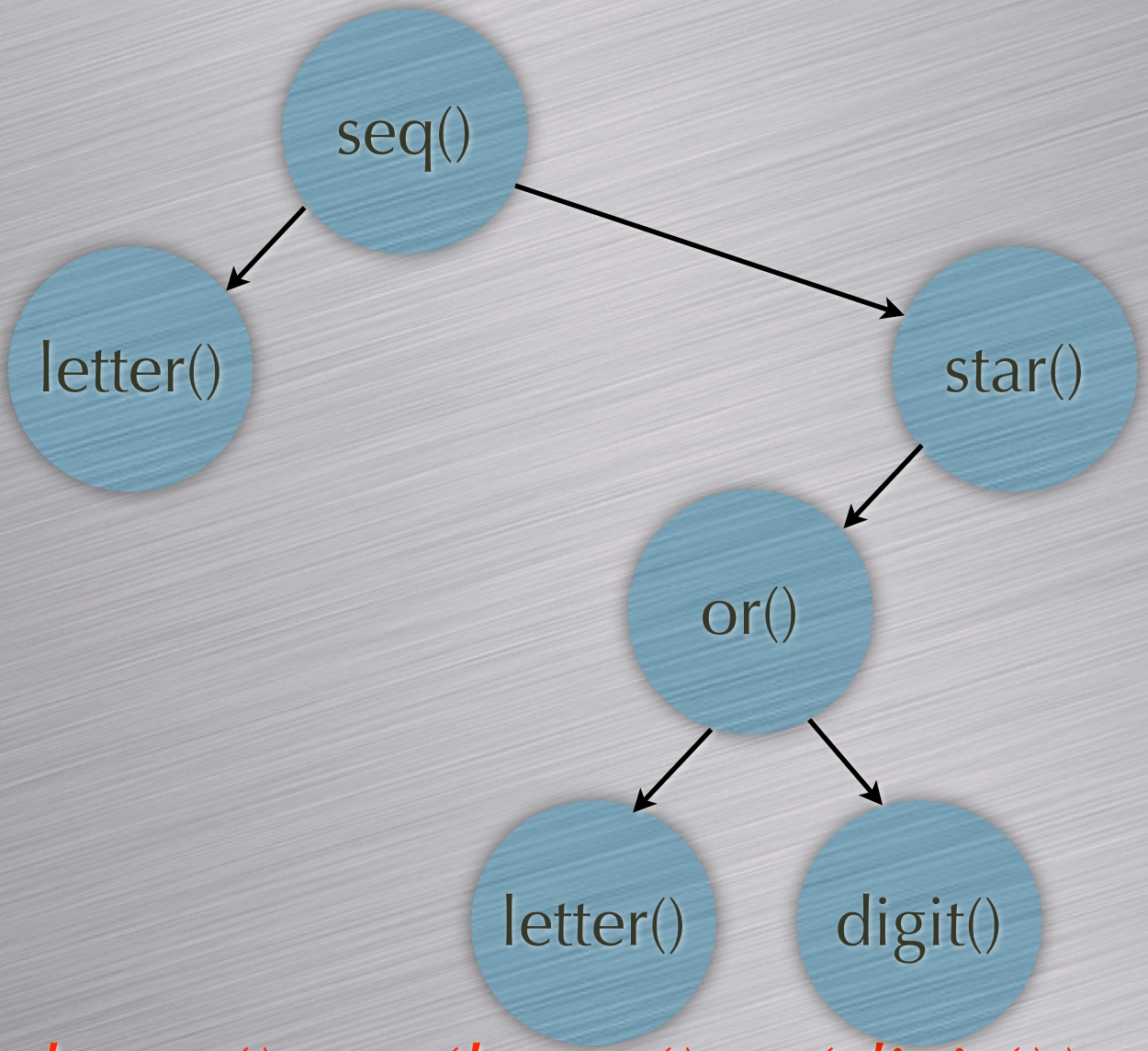

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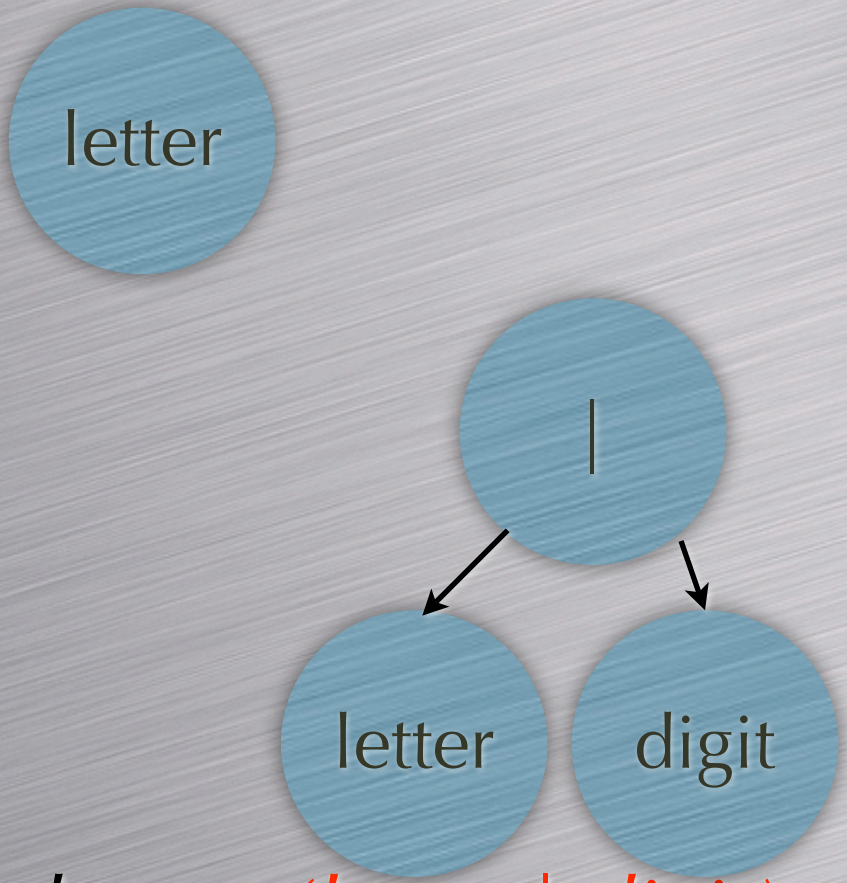

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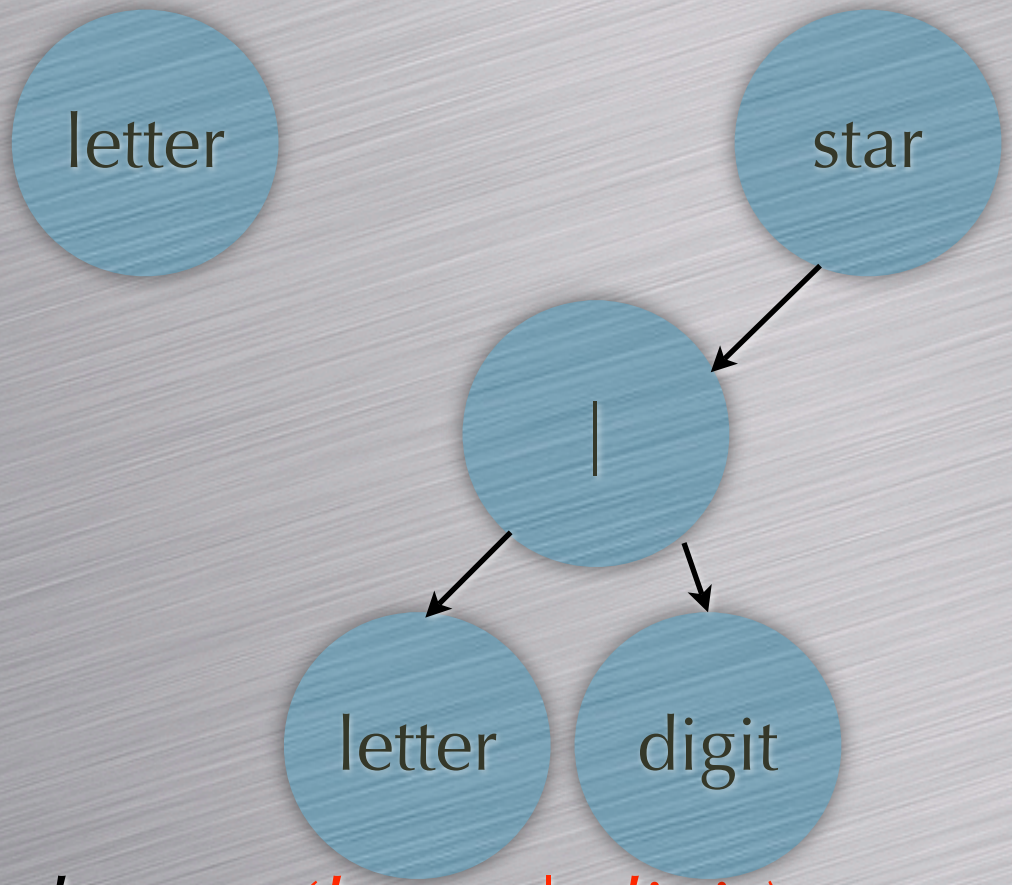

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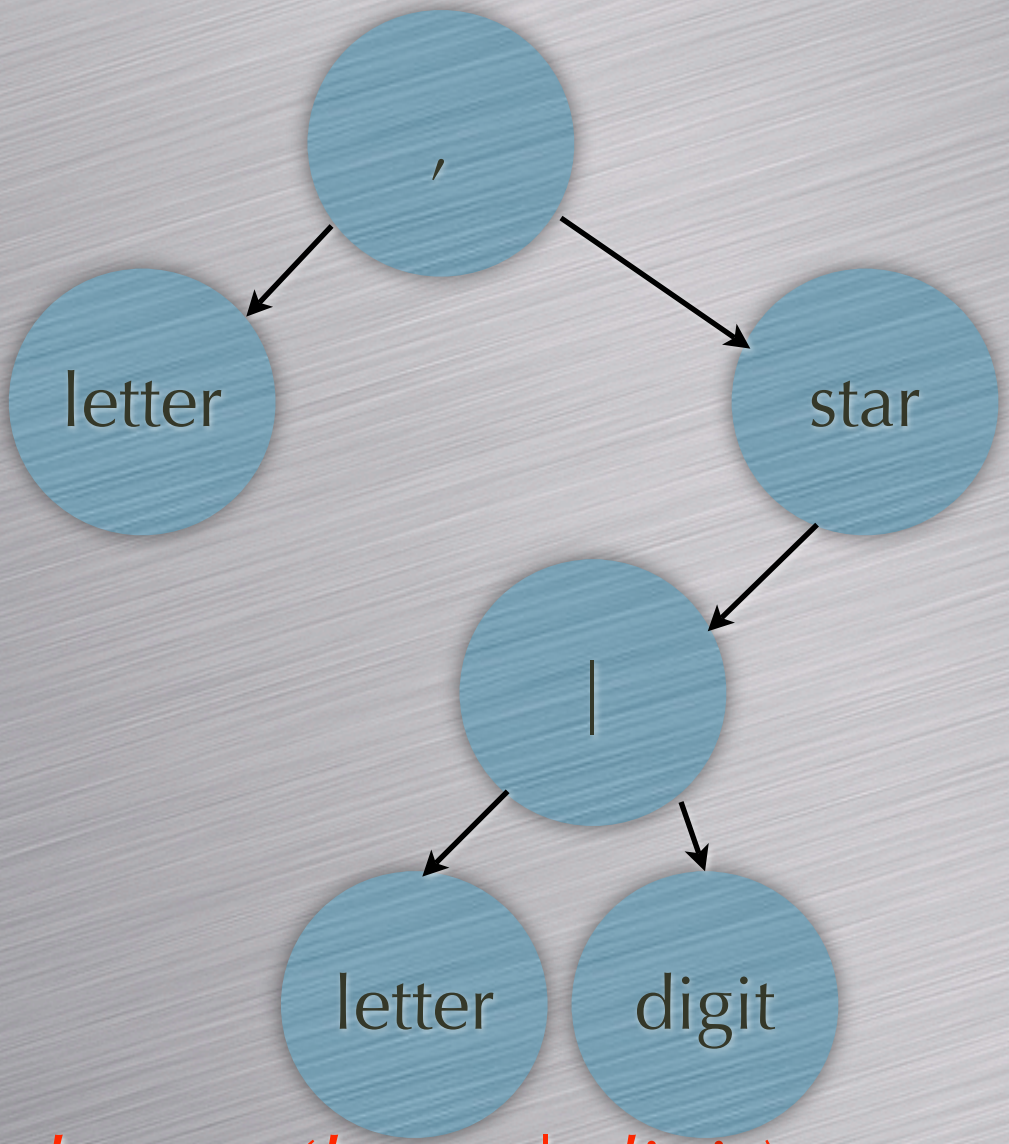
How it Works



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Why is this Ugly?

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vs.

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id = letter().seq(letter().or(digit()).star());
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vs.

```
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```

Why is it Ugly?

A programming language is low level when its programs require attention to the irrelevant

- Alan Perlis

A Complete Grammar

```
class ExampleGrammar1 = ExecutableGrammar (
|
digit = charBetween: $0 and: $9.
letter = (charBetween: $a and:$z) |
         (charBetween: $A and:$Z).
id = letter, (letter | digit) star.
identifier = tokenFor: id.
hat = tokenFromChar: $^.
expression = identifier.
returnStatement = hat, expression.
|
)()
```

Building an AST

```
returnStat = hat, expression
                    wrapper:[:caret : expr |
                                ReturnStat on: expr
                    ]
```

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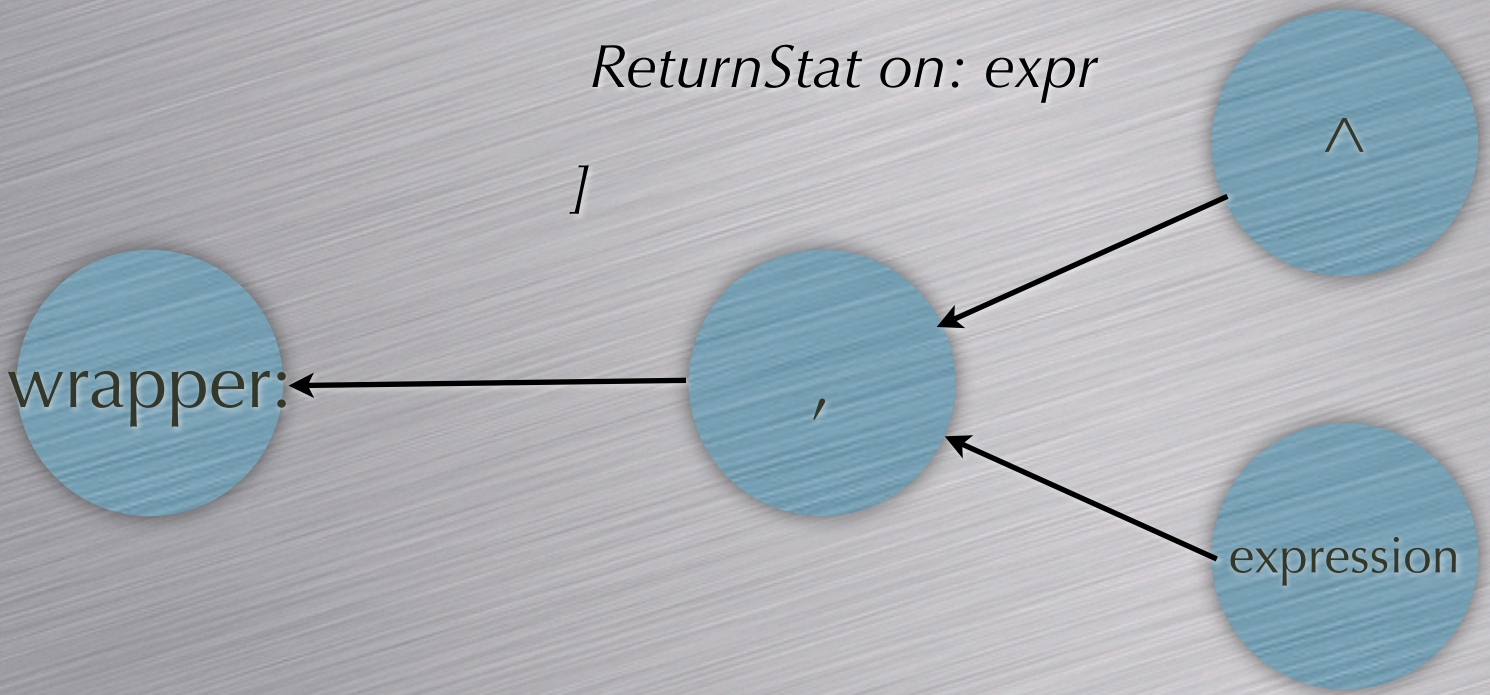


Grammar

```
returnStat = hat, expression

        wrapper:[:caret : expr |

                ReturnStat on: expr

        ]
```

AST construction

```
returnStat = hat, expression

                wrapper:[:caret : expr |

                        ReturnStat on: expr

                ]
```

Factor out Grammar

Superclass (pure grammar specification):

returnStat = hat, expression

Subclass (AST builder):

```
returnStat = (

        super returnStat

            wrapper:[:caret : expr |

                ReturnStat on: expr

            ] )
```

Modular Parser

```
class ExampleParser1= ExampleGrammar1 () (
  id = (
    ^super id
      wrapper:[:fst :snd | fst asString, (String withAll: snd)]
  )
 identifier = (
    ^super identifier
      wrapper:[:v |VariableAST new name: v token;
                                  start: v start; end: v end].
  )
  returnStatement = (
    ^super returnStatement
      wrapper:[:r :e | ReturnStatAST new expr:e;
                                  start: r start; end: e end].
)
```

Extending a Grammar

```
class ExampleGrammar2 = ExampleGrammar1 (
|
if = tokenFromSymbol:#if.
then = tokenFromSymbol:#then.
else = tokenFromSymbol:#else.
ifStatement = if, expression, then, statement, else, statement.
statement = ifStatement | returnStatement.
|
)()
```

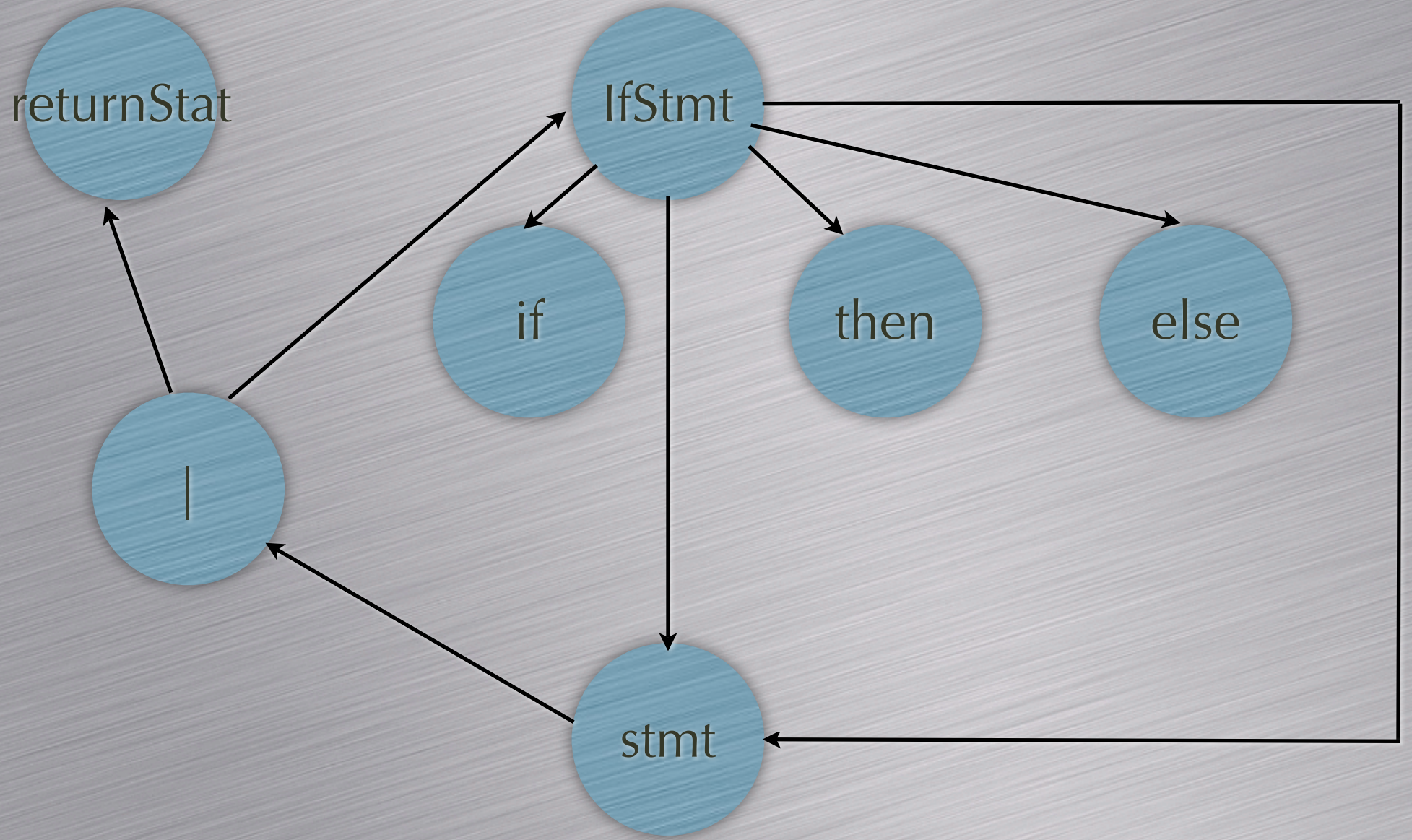
Mutual Recursion

ifStatement = if, expression, then, statement,

else, statement.

statement = ifStatement | returnStatement.

Mutual Recursion



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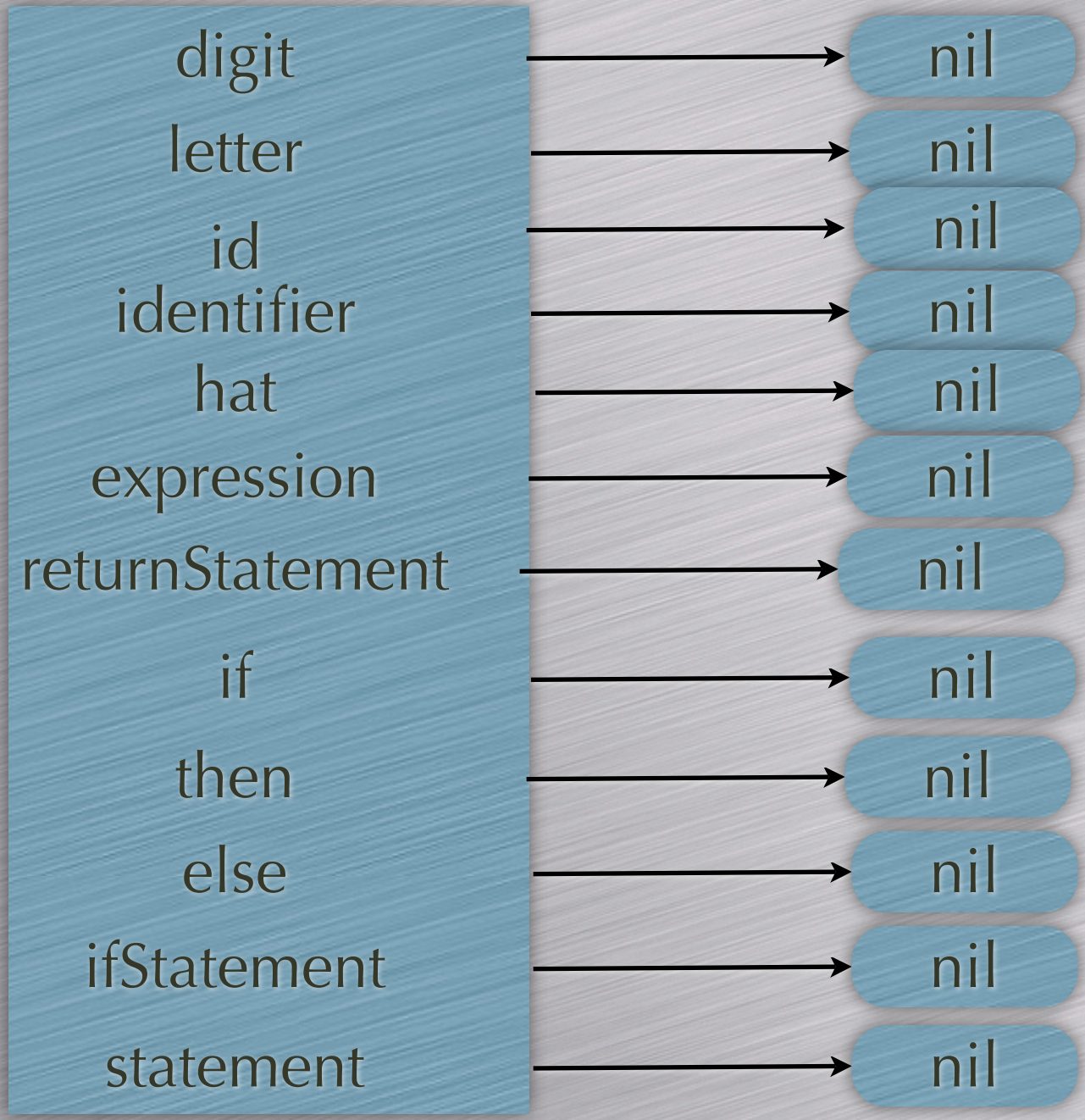

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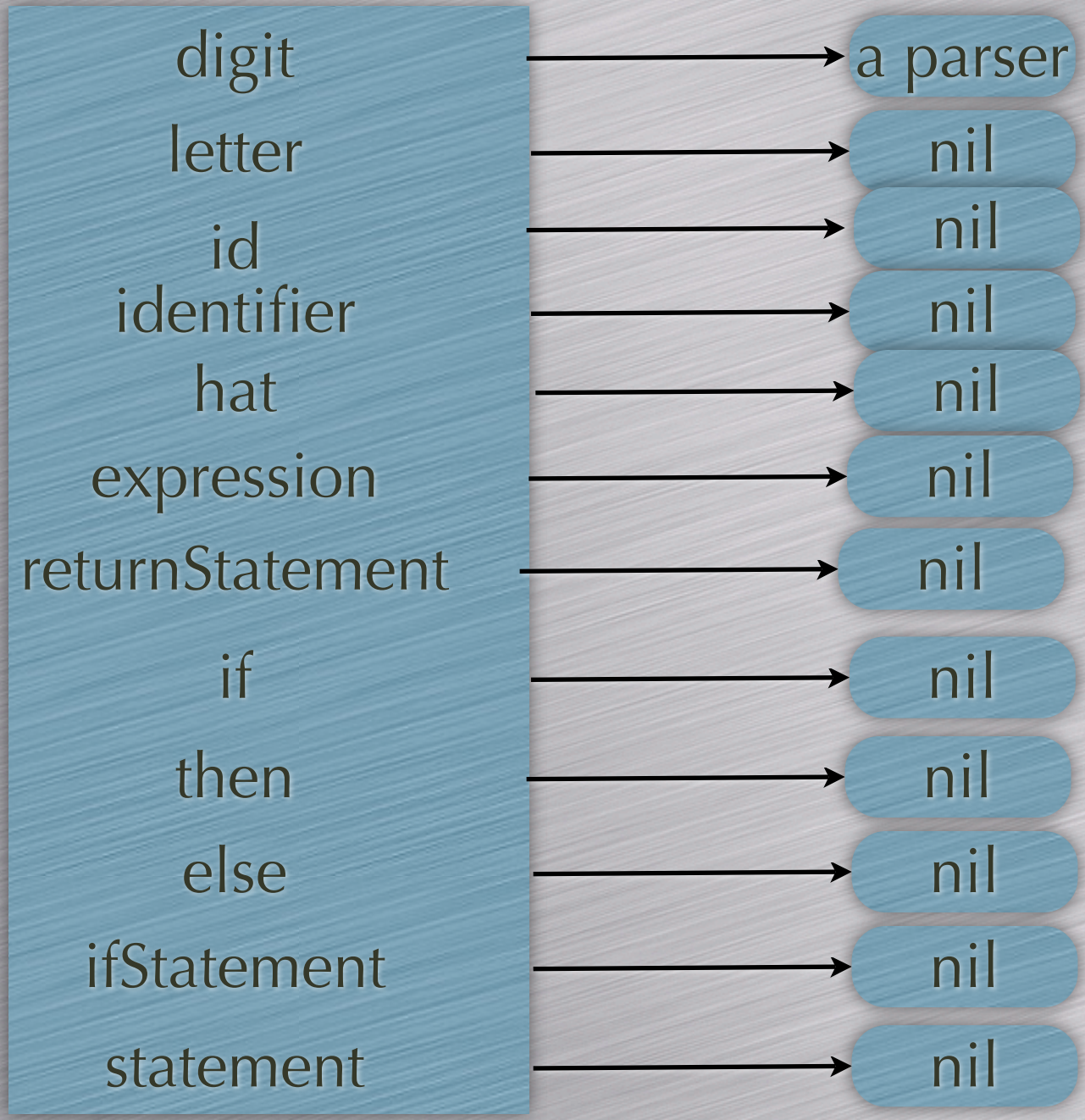

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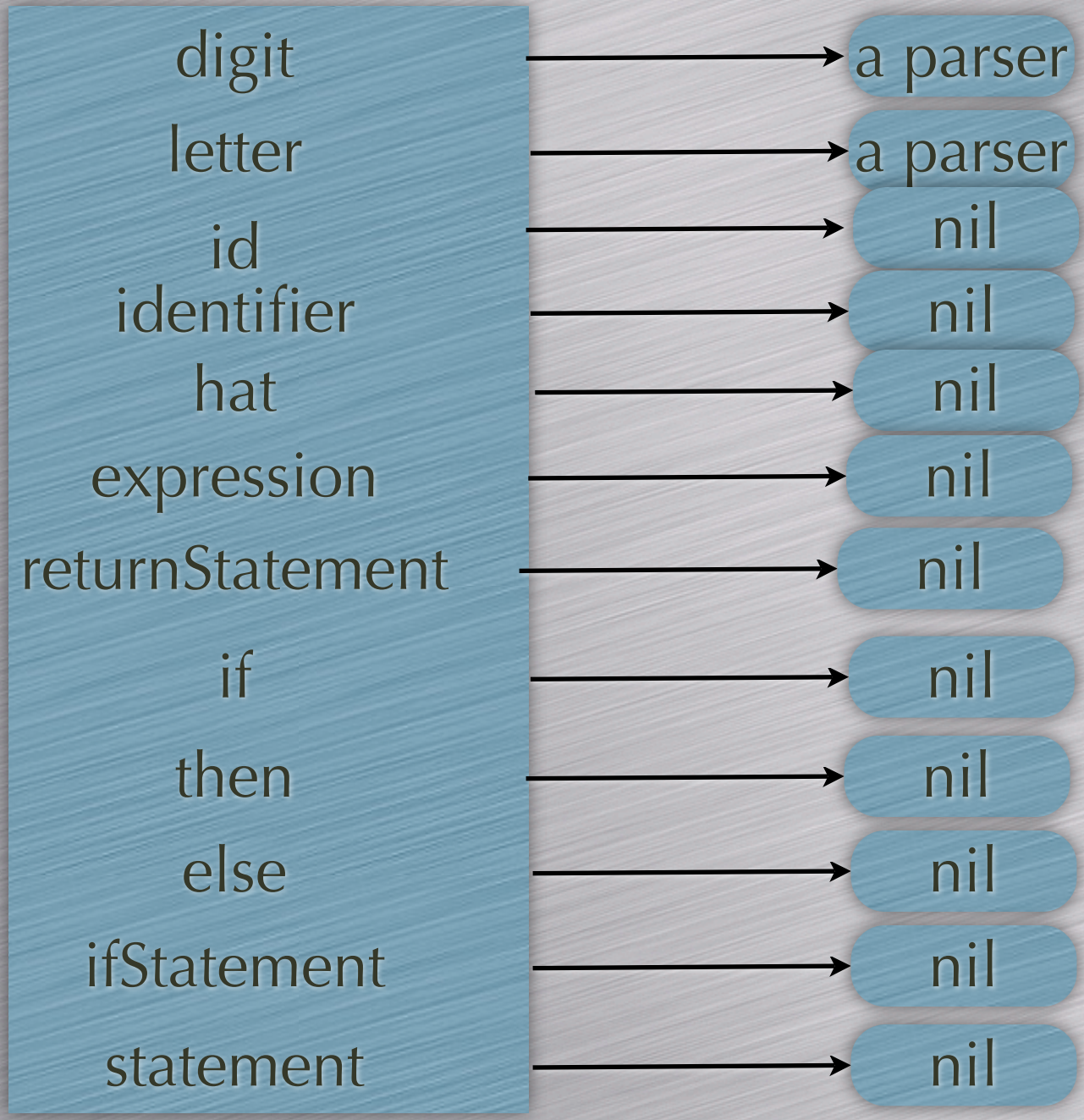

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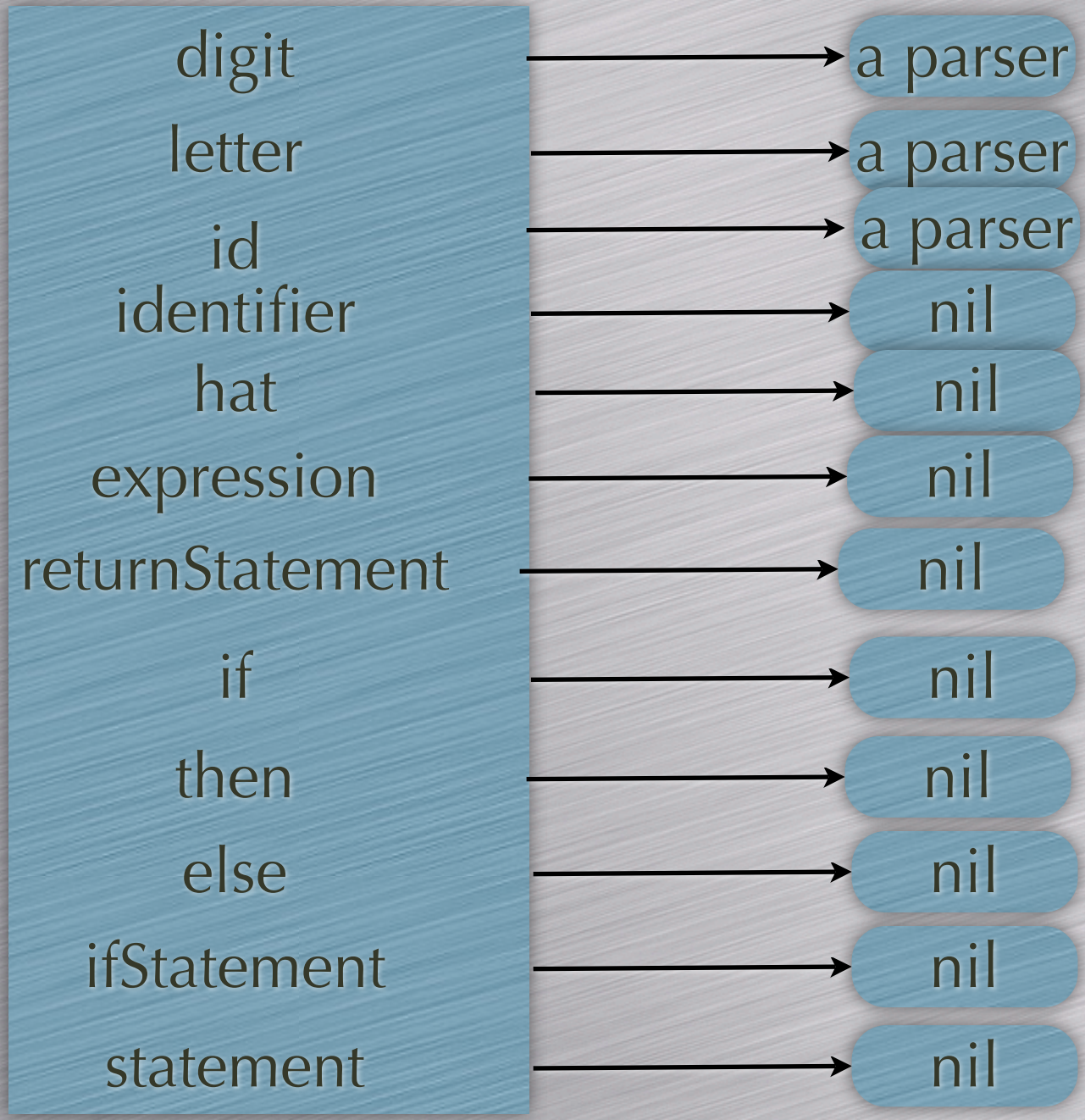

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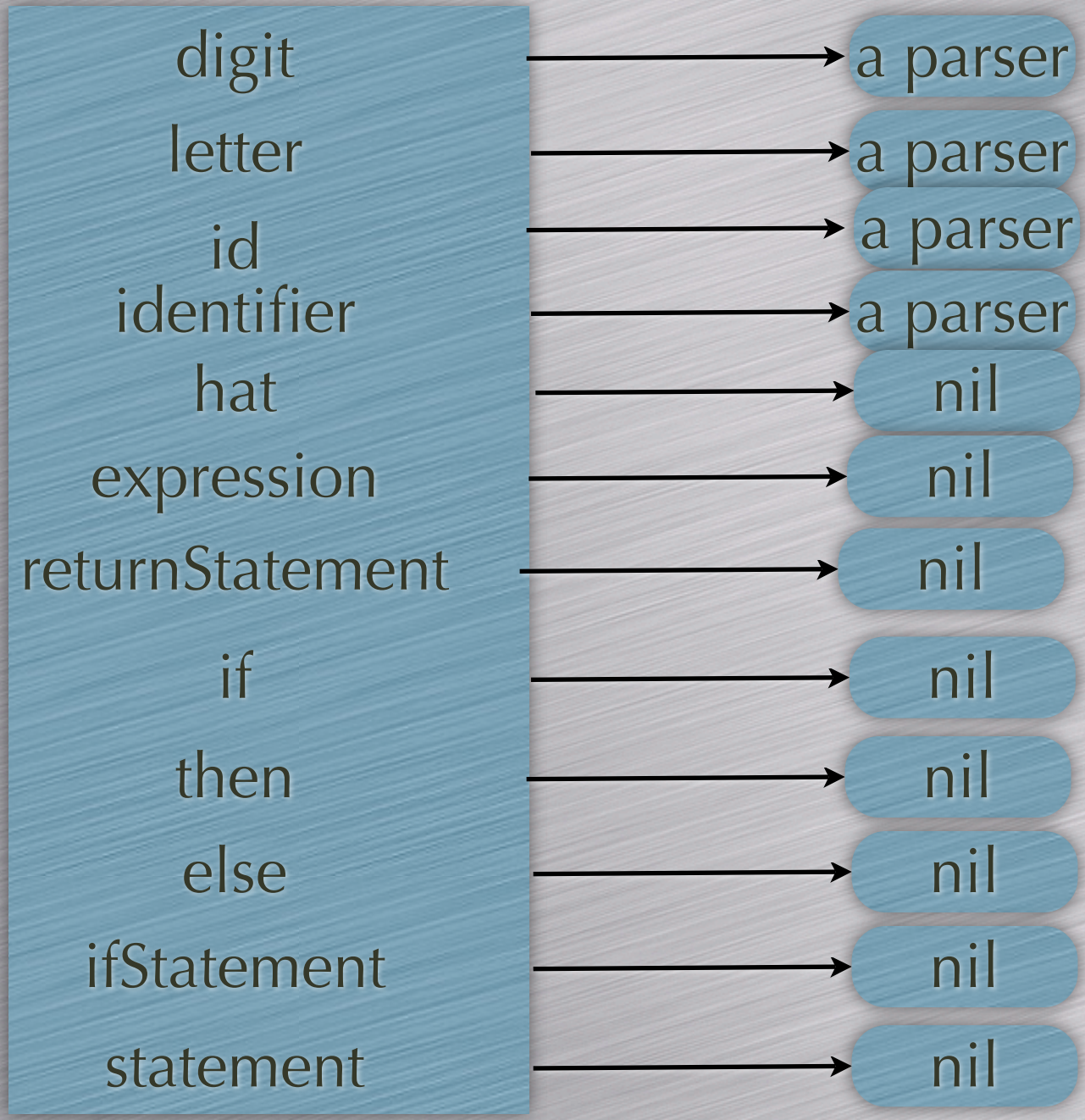

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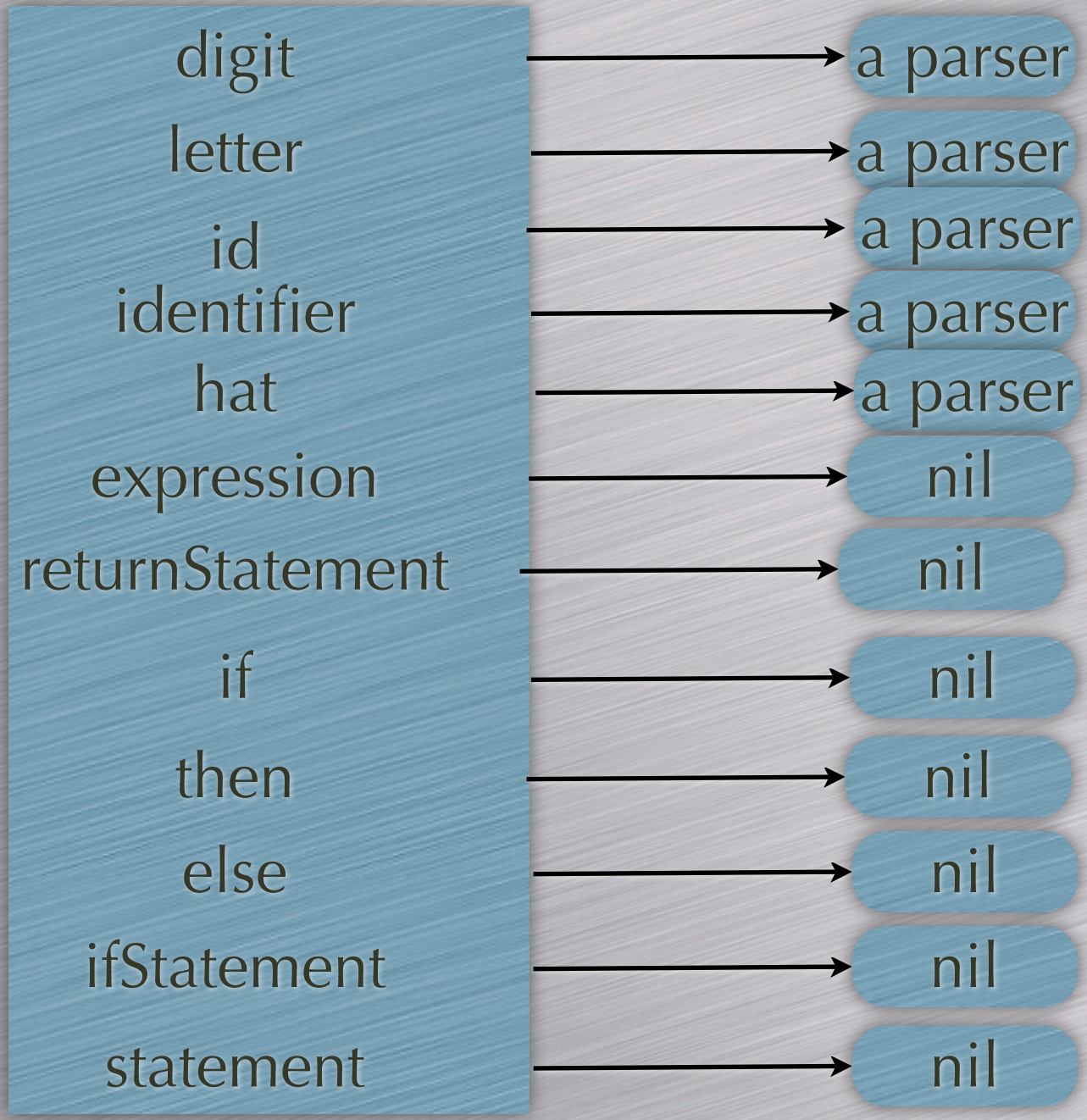

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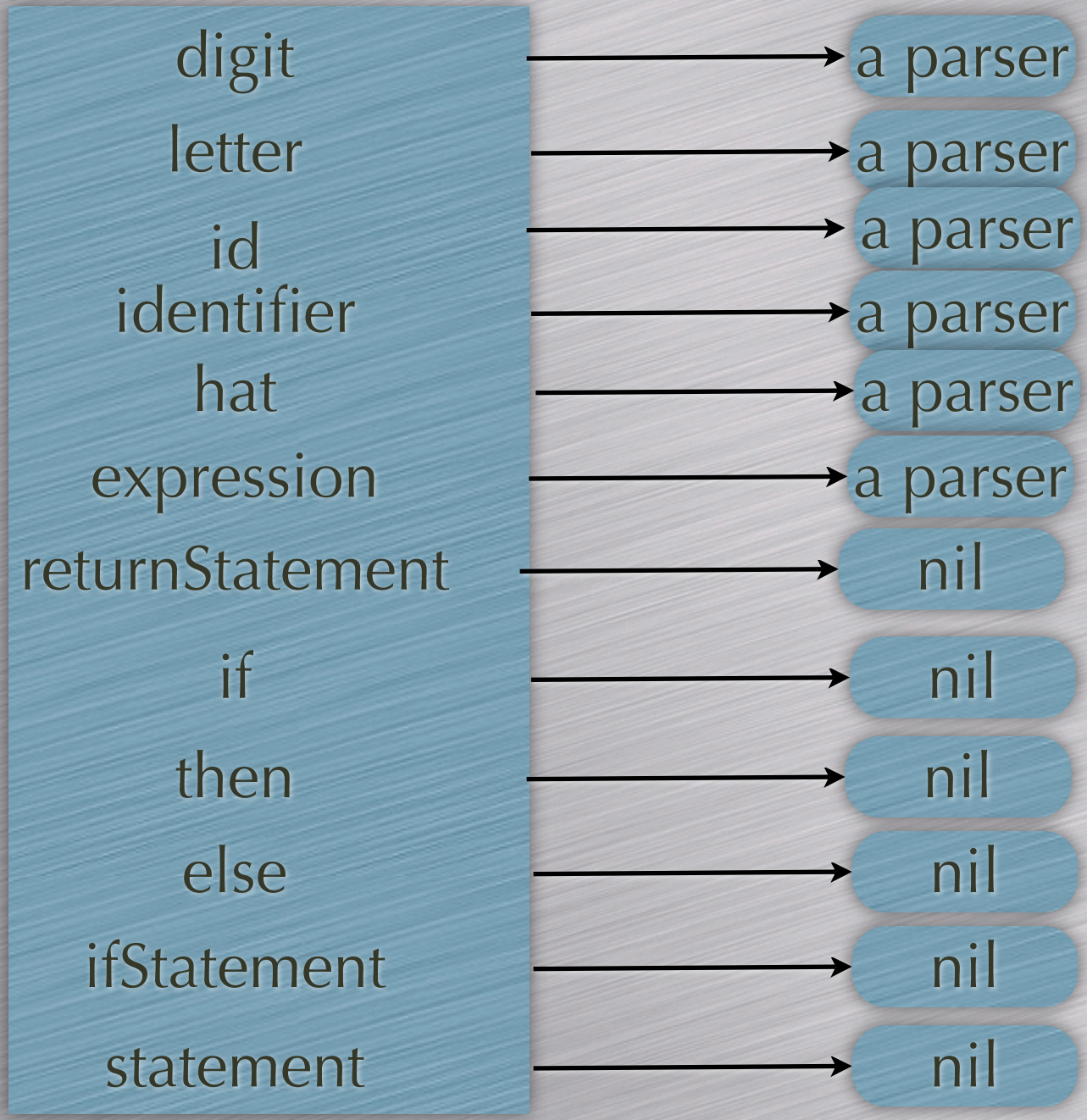

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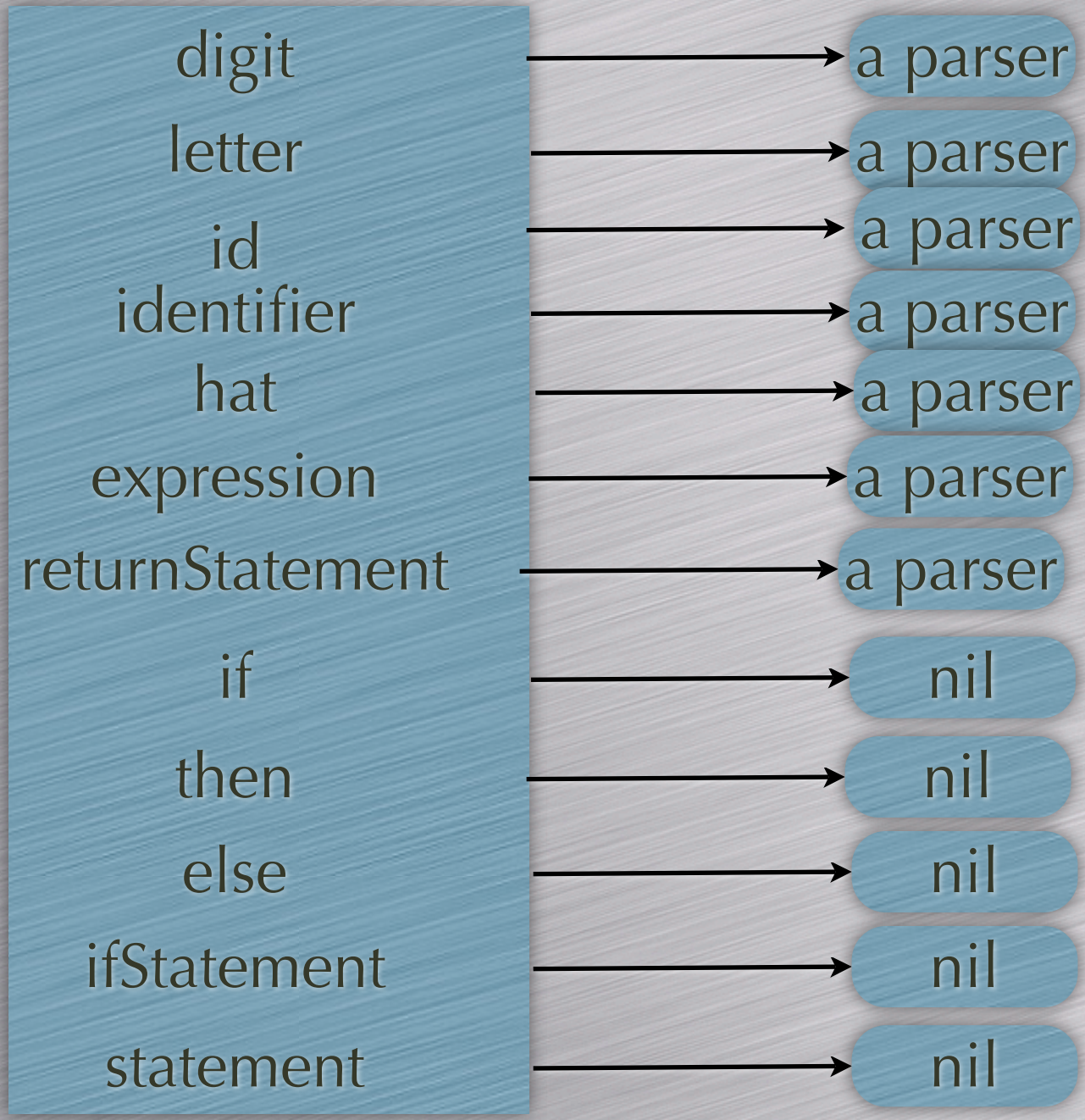

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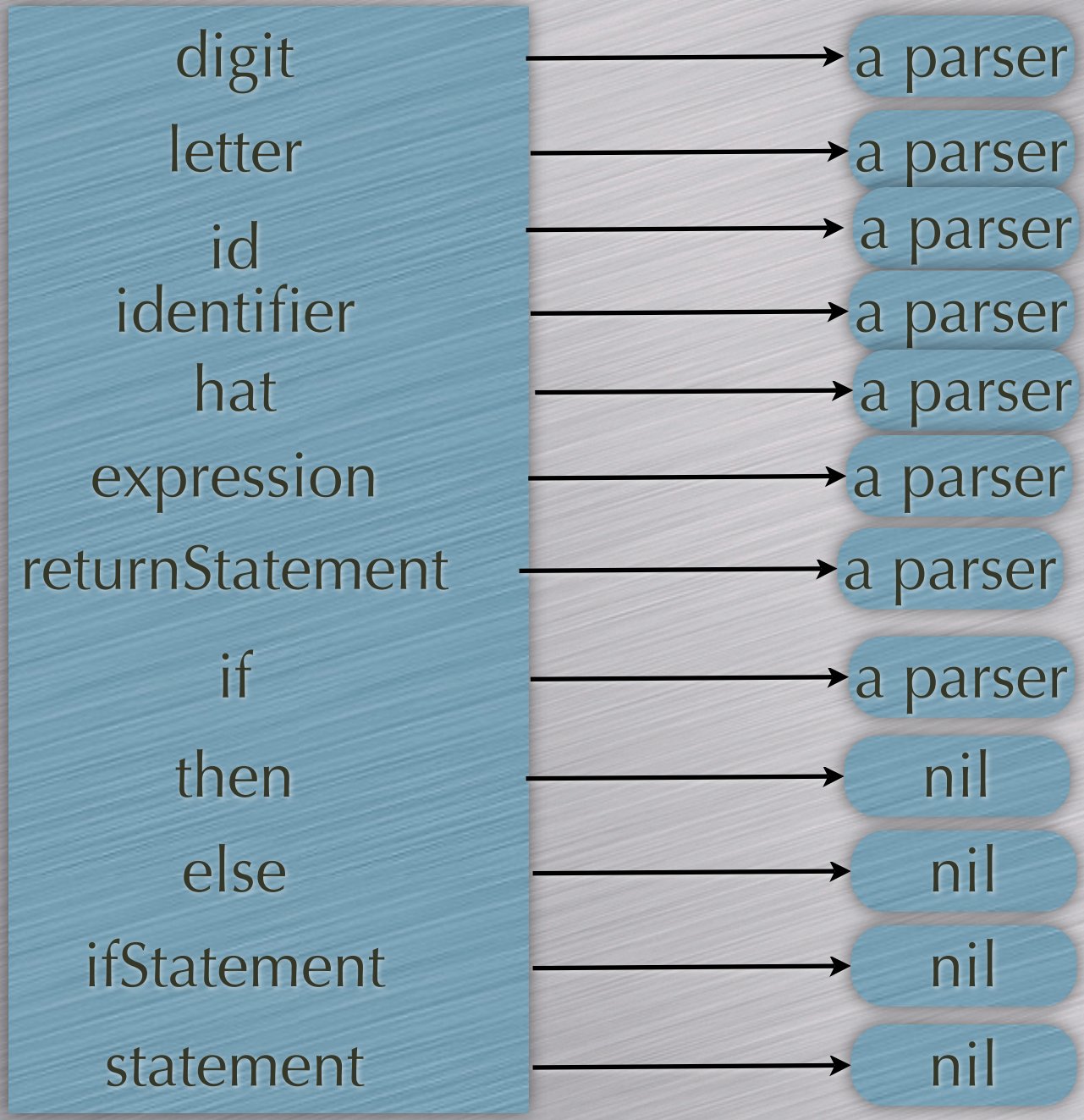

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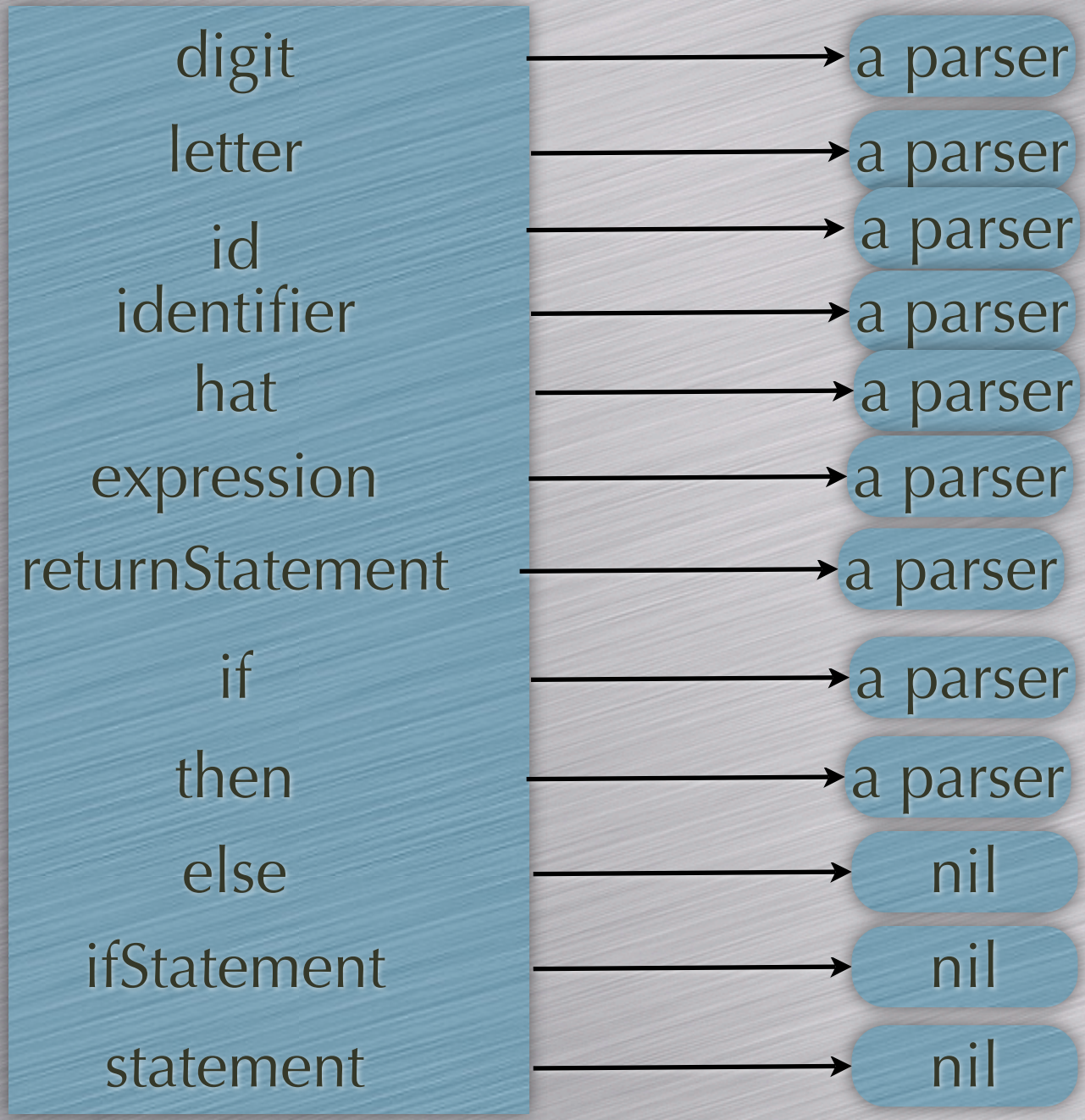

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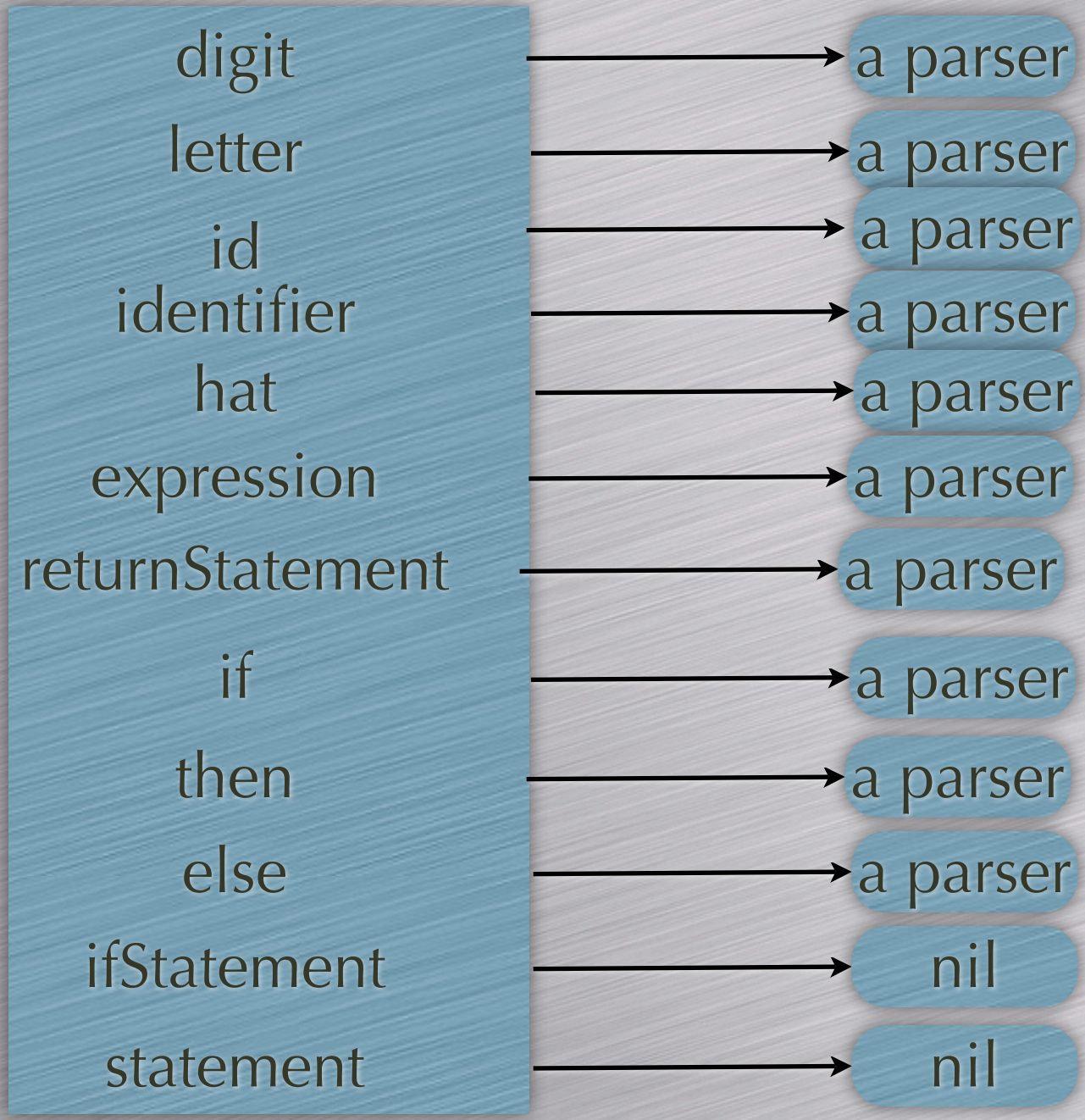

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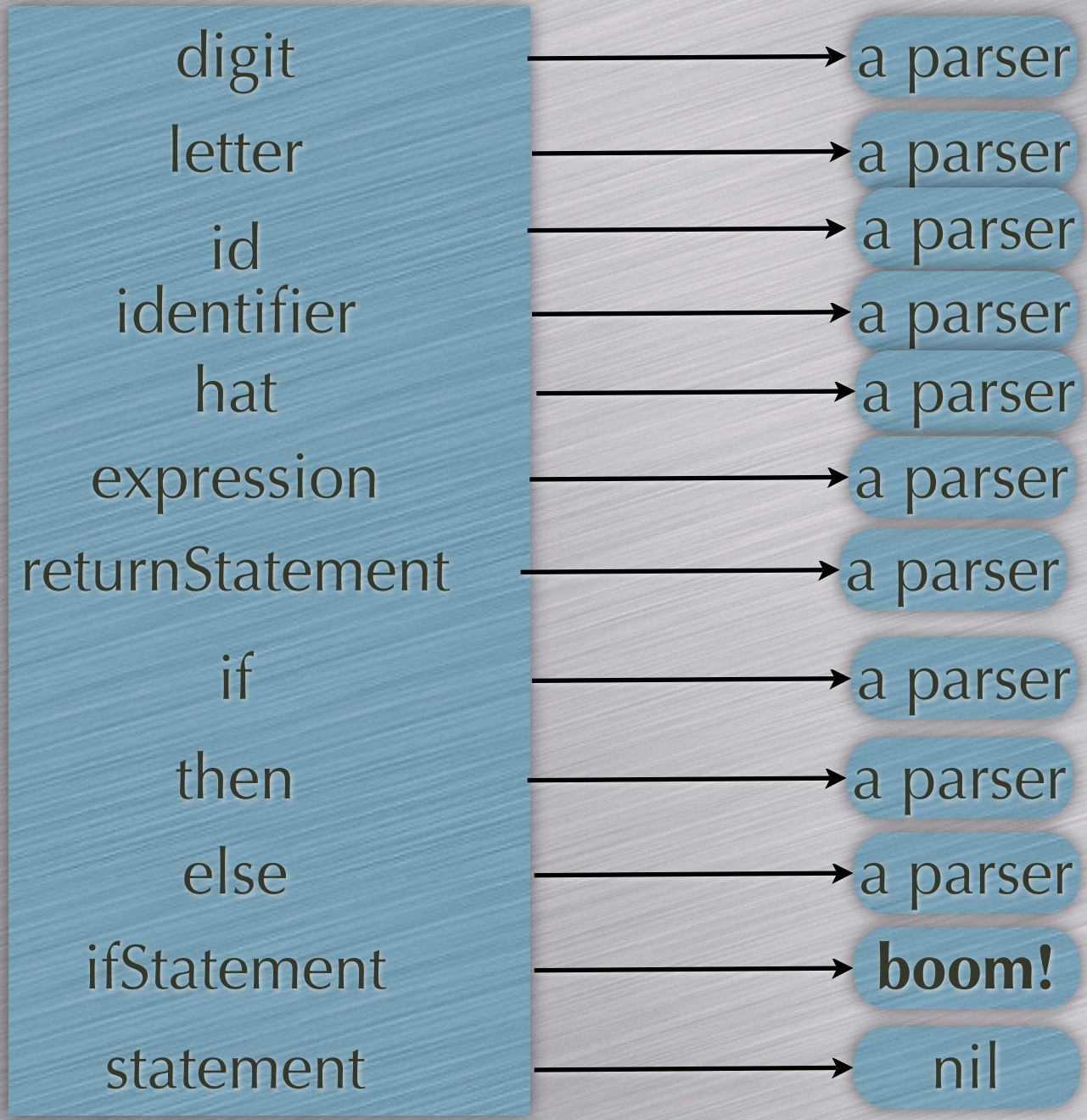

Mutual Recursion

- Addressed with laziness in Haskell
- Can be addressed with closures

ifStatement = if, [expression], [then], [statement],

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Being Reflective rather than Lazy

Use Reflection instead of Laziness.

Framework initializes all slots to “stand-in” parsers which act as forward references

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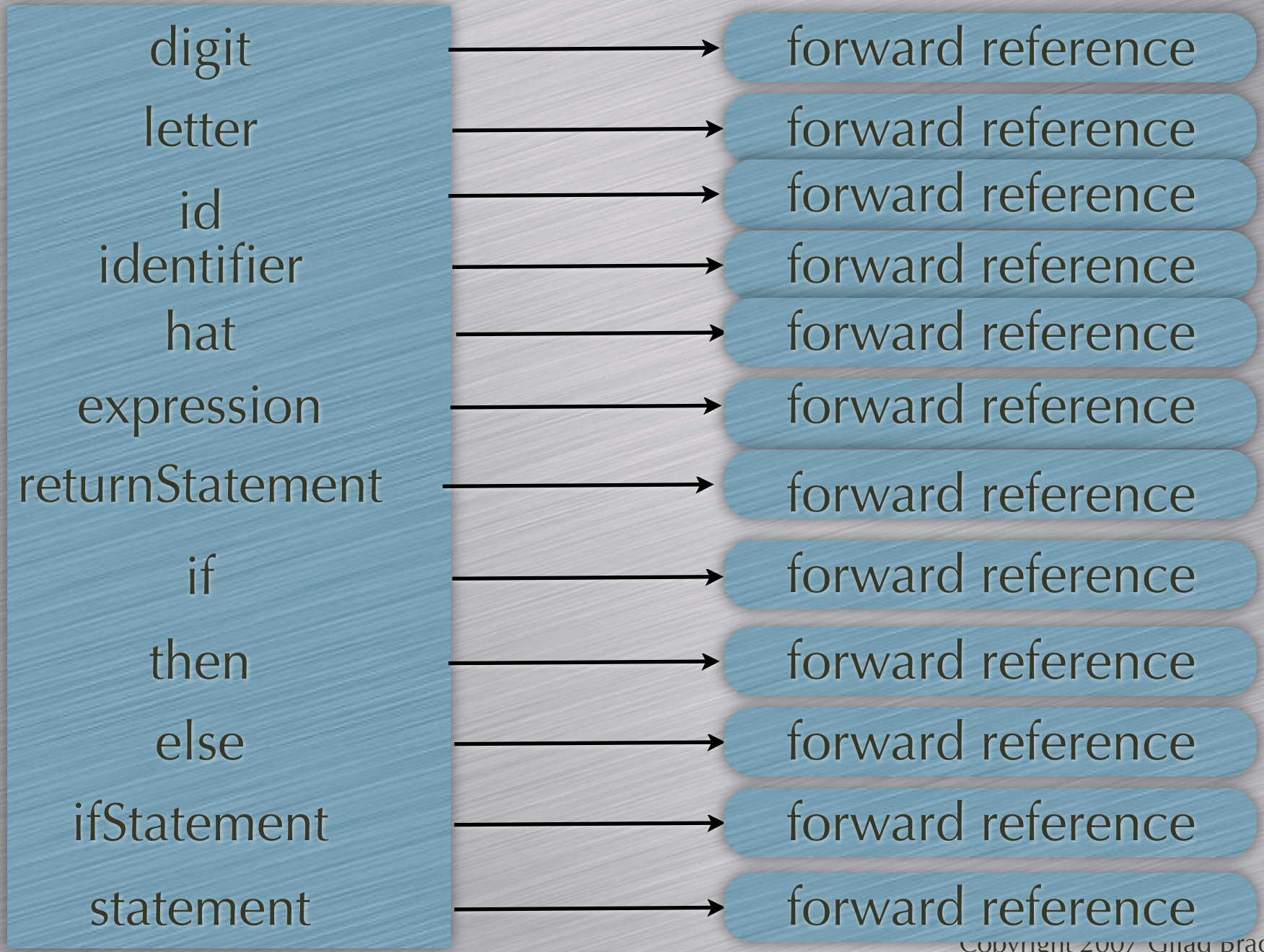

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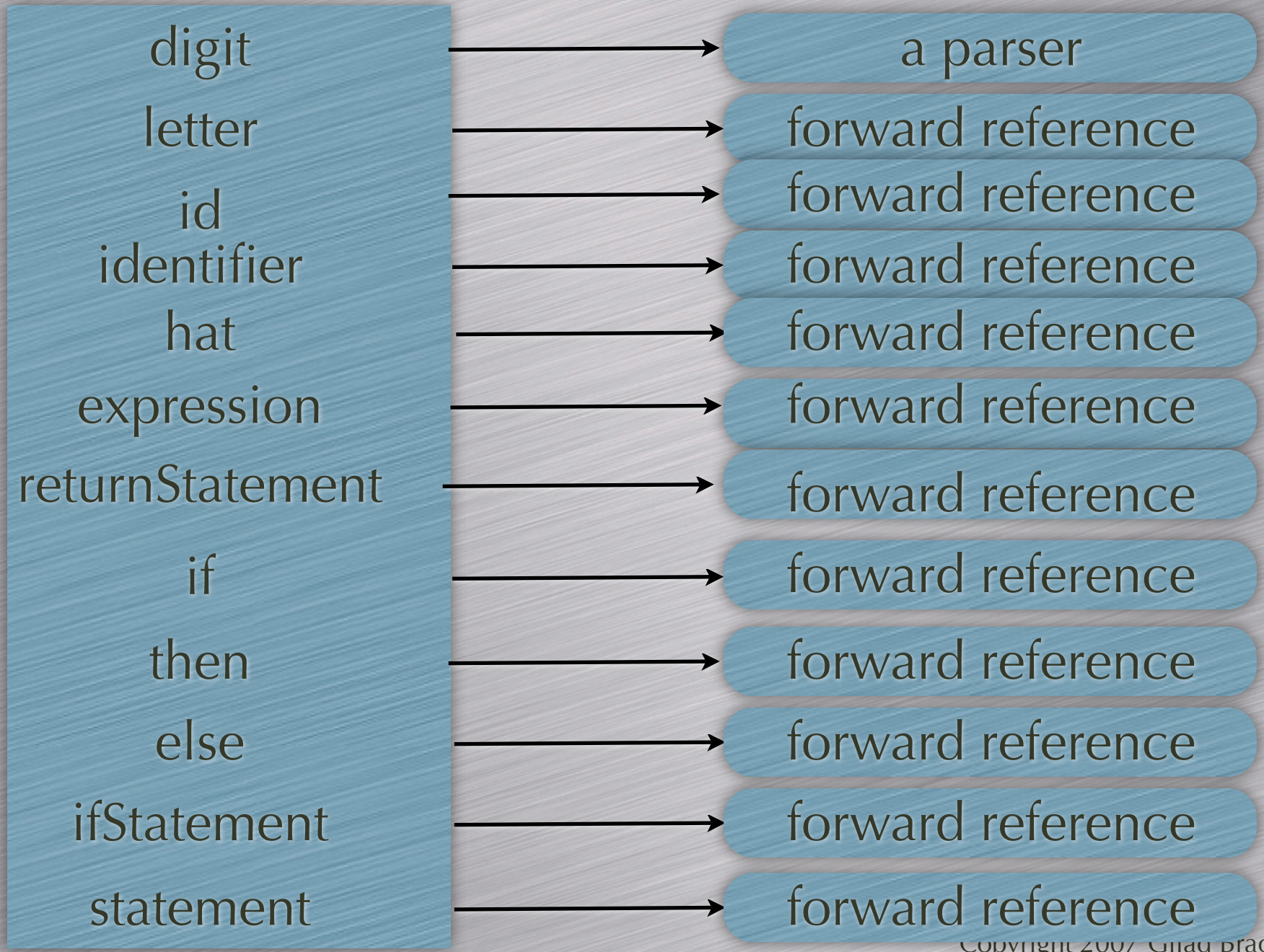

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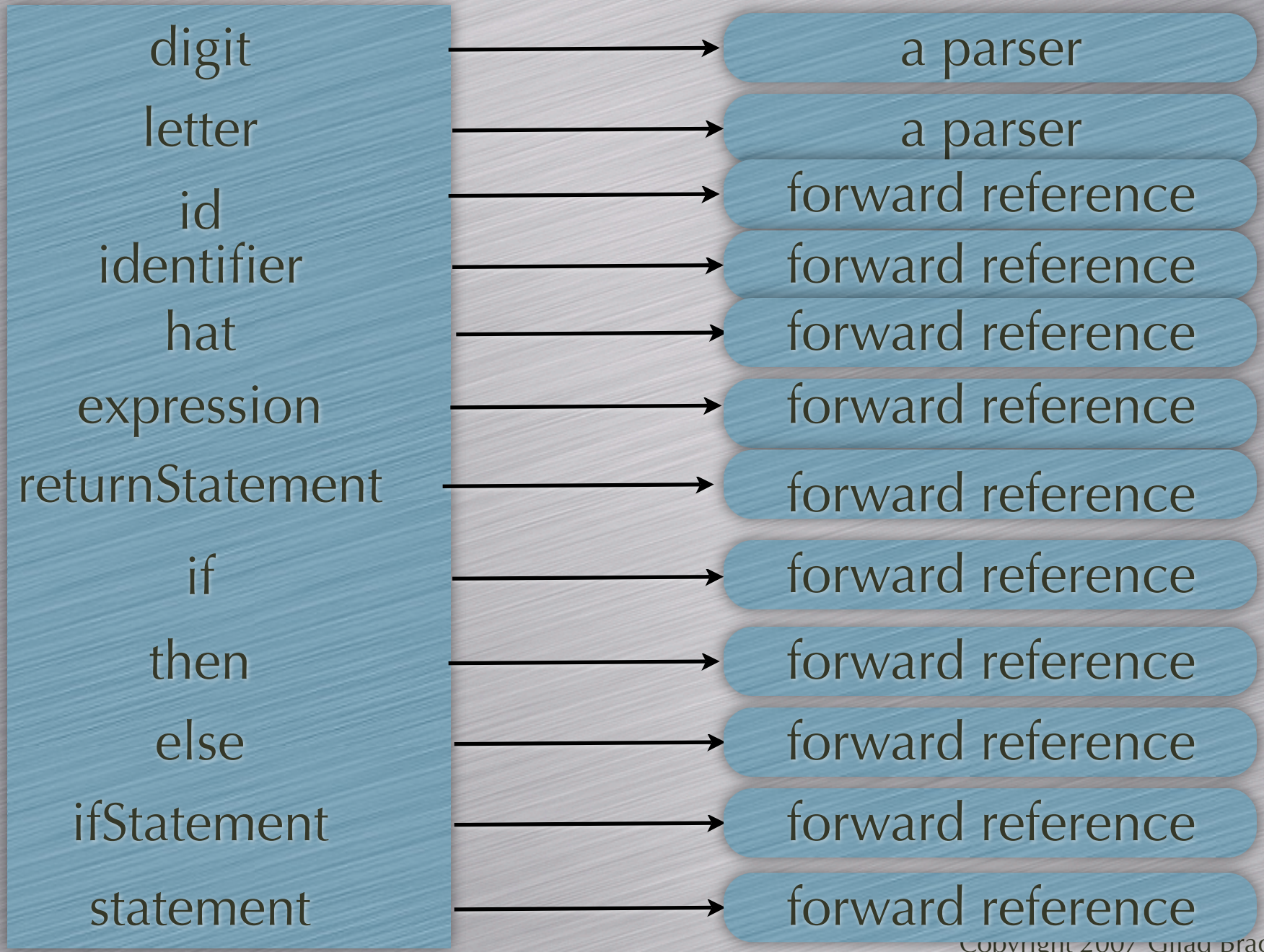

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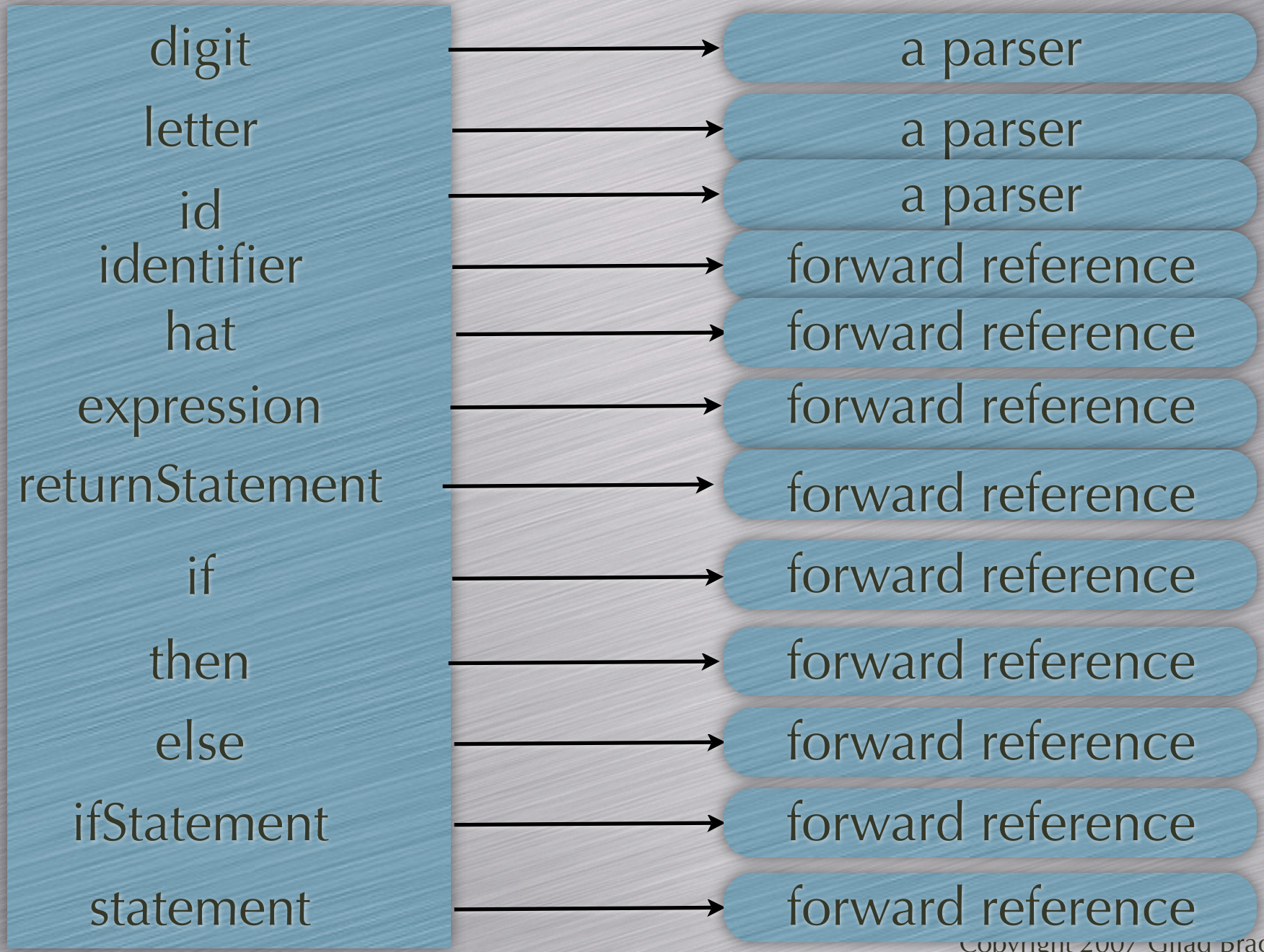

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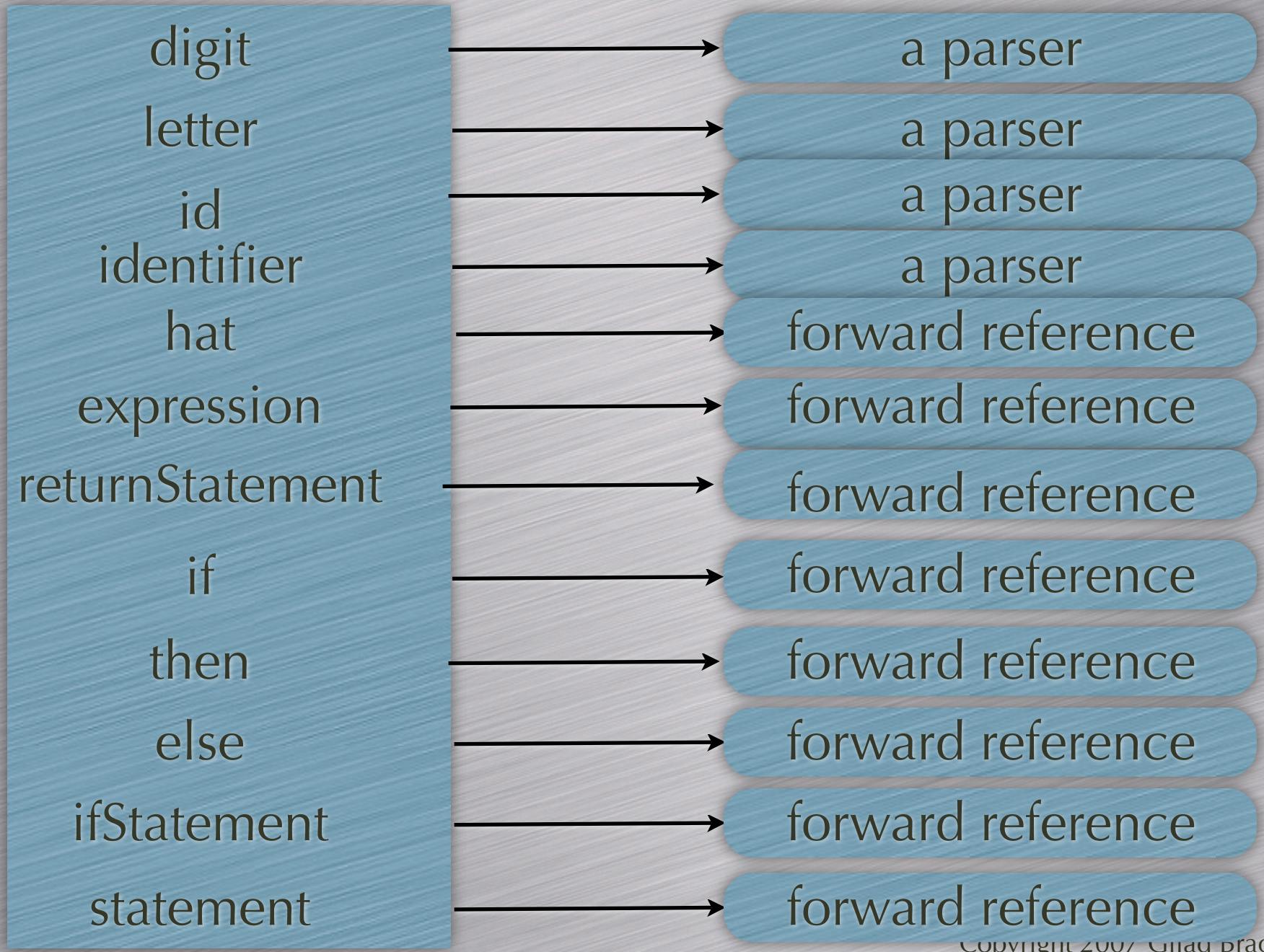

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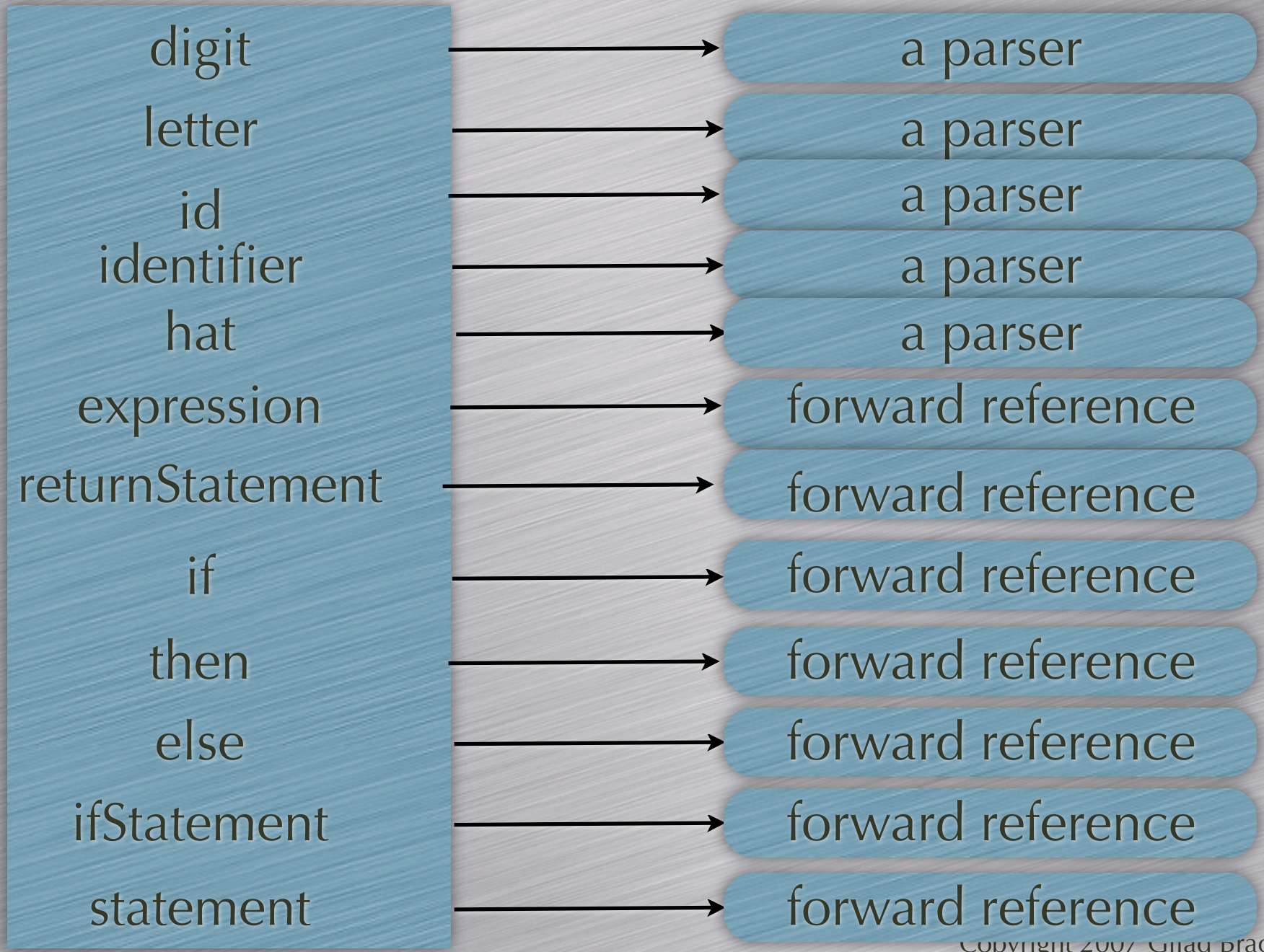

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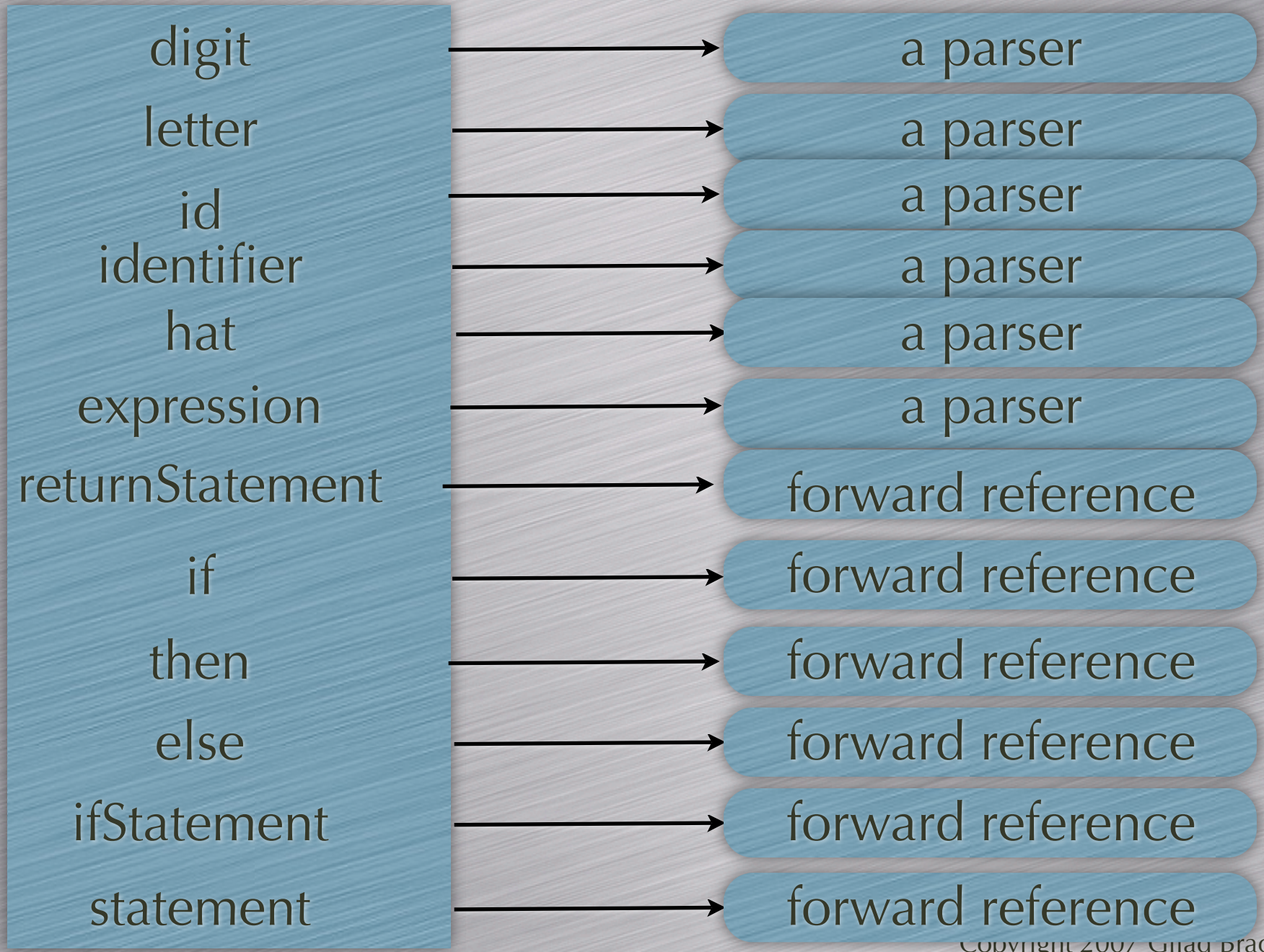

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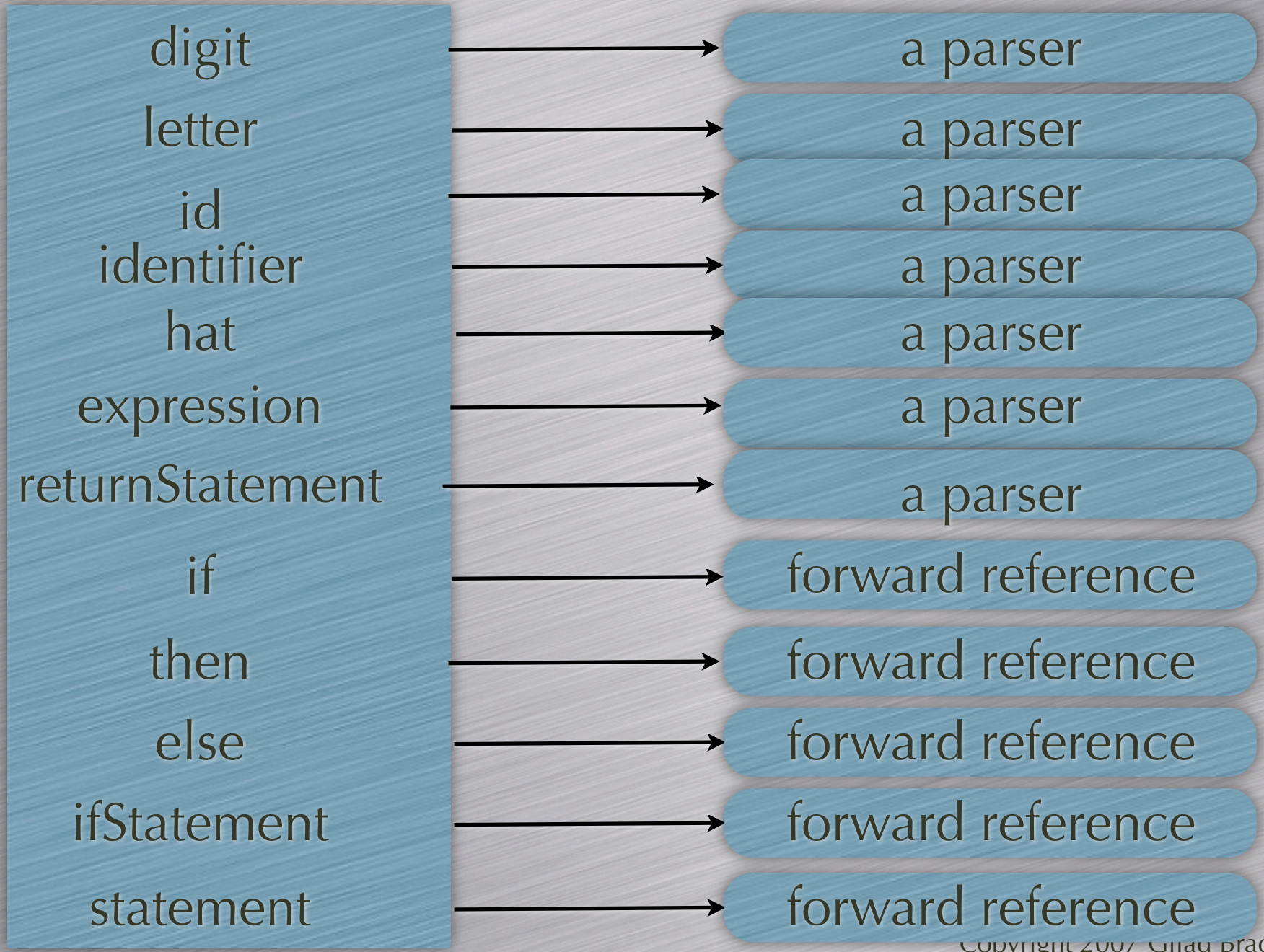

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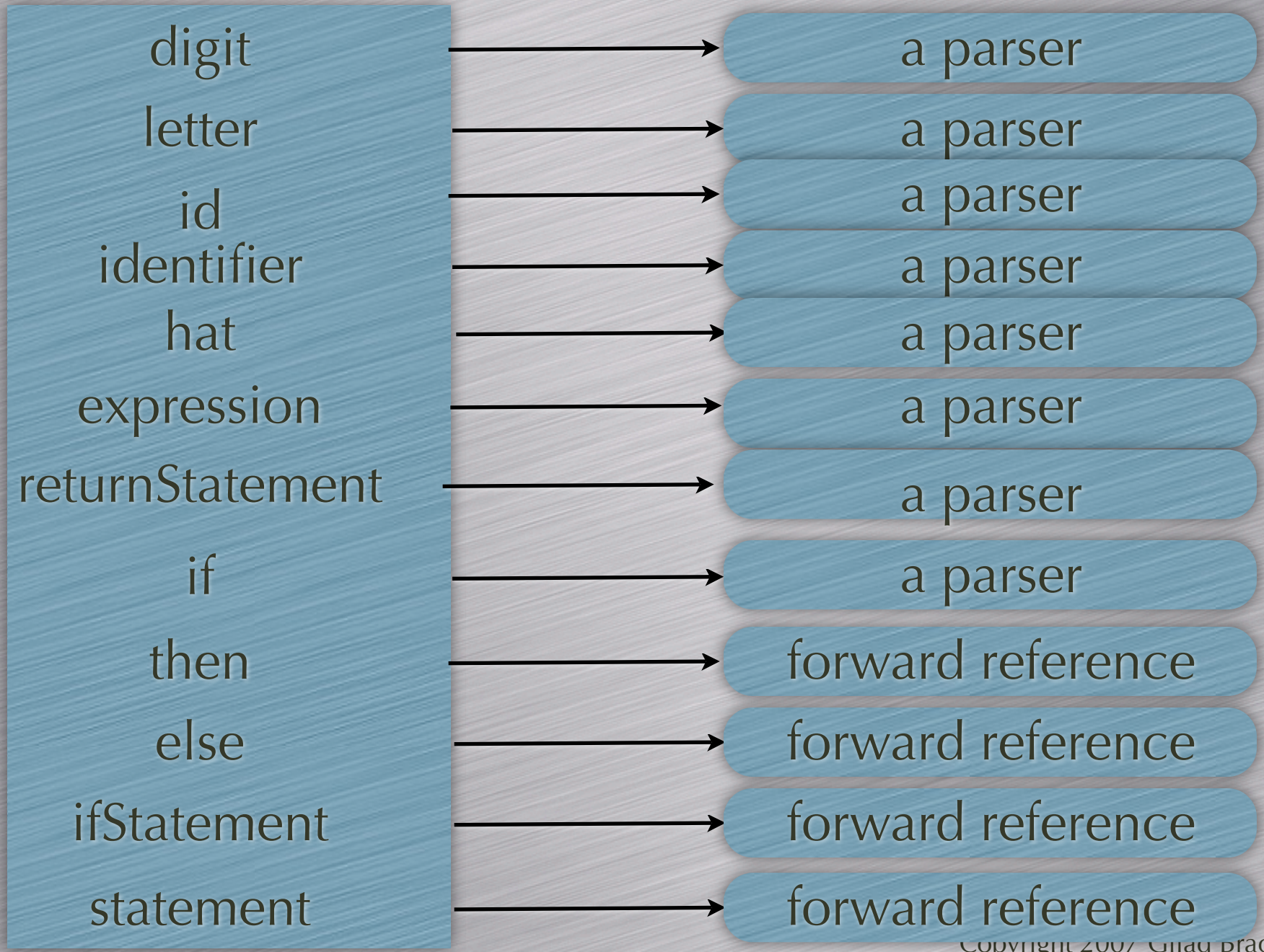

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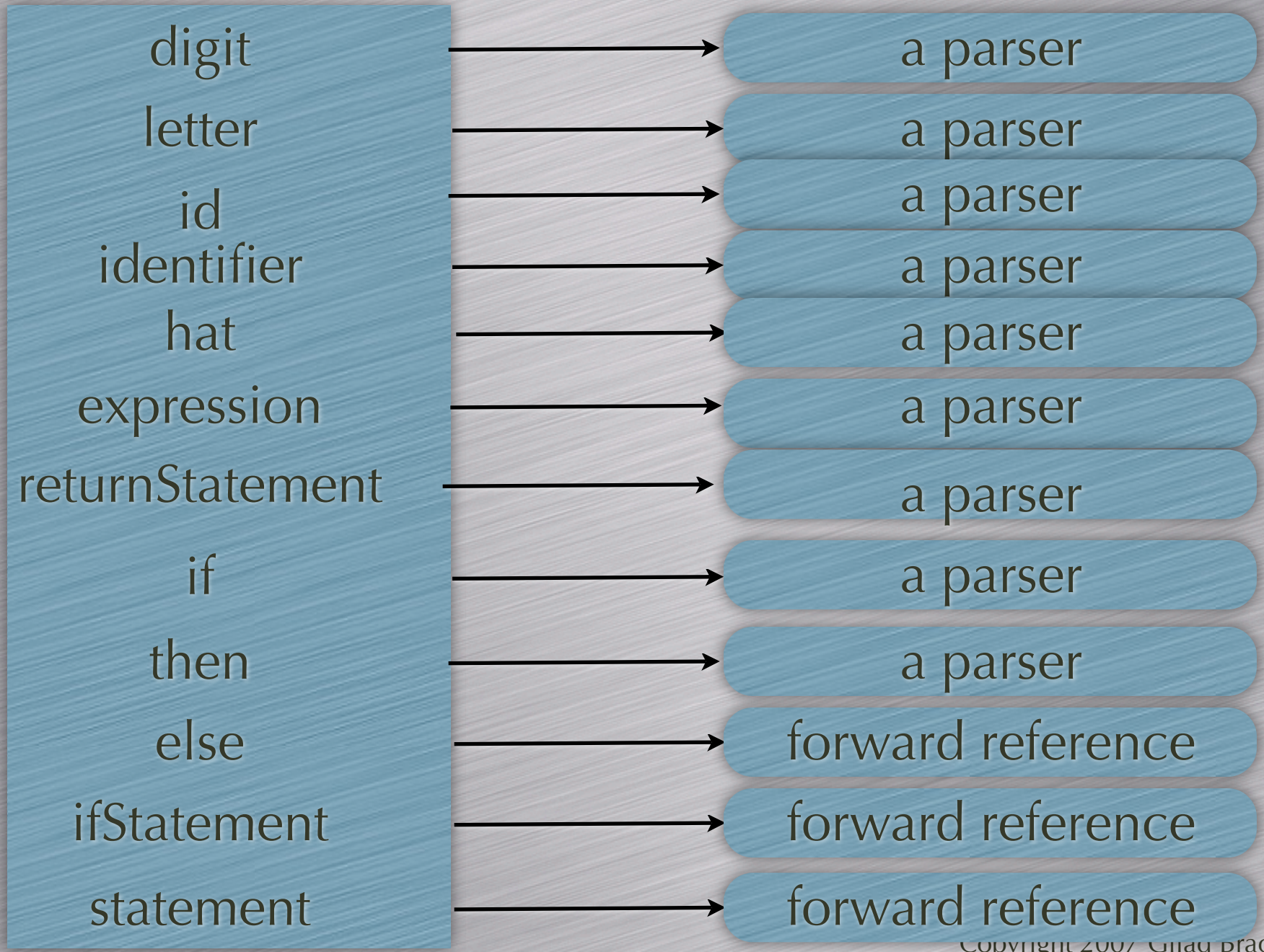

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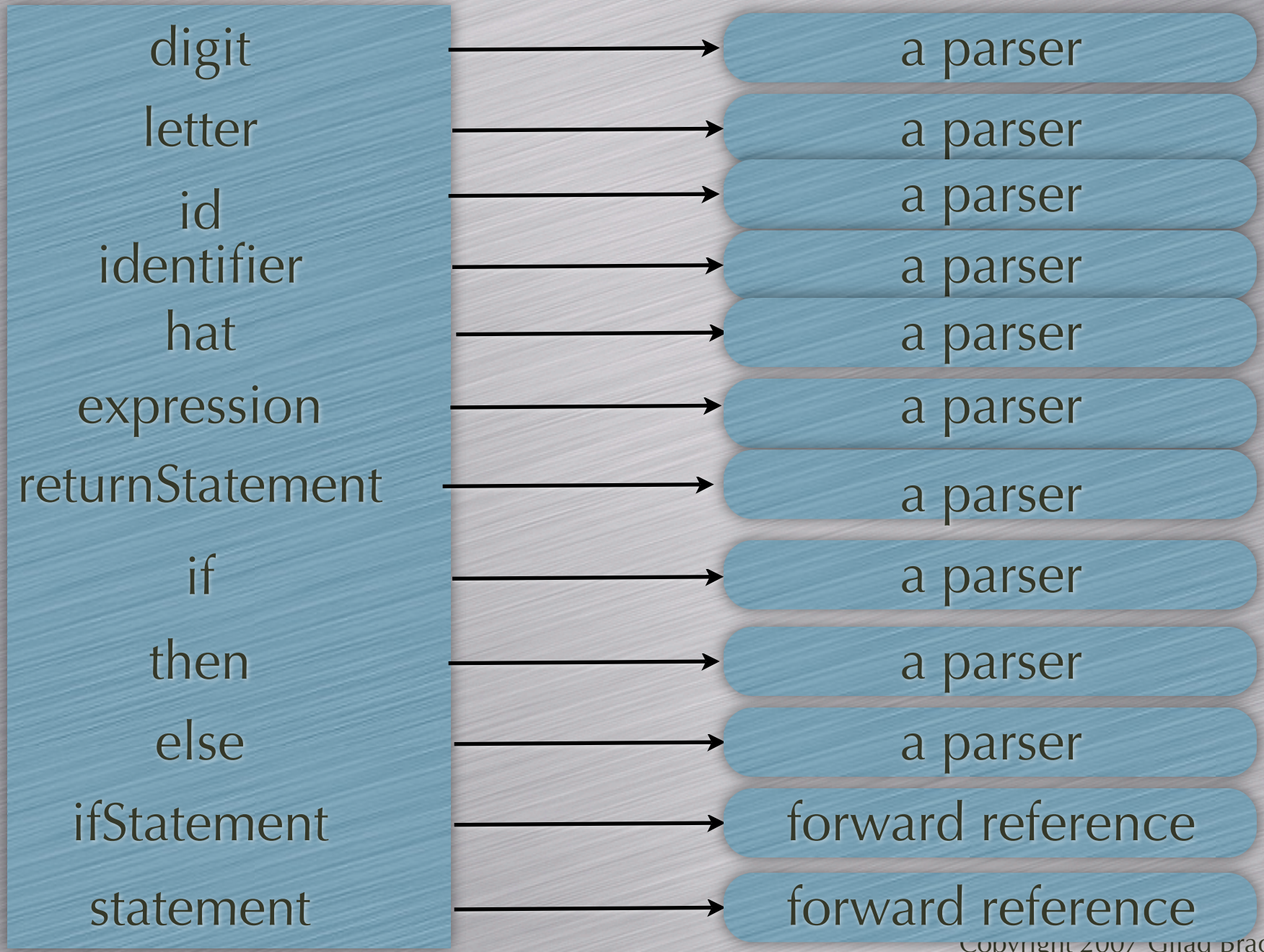

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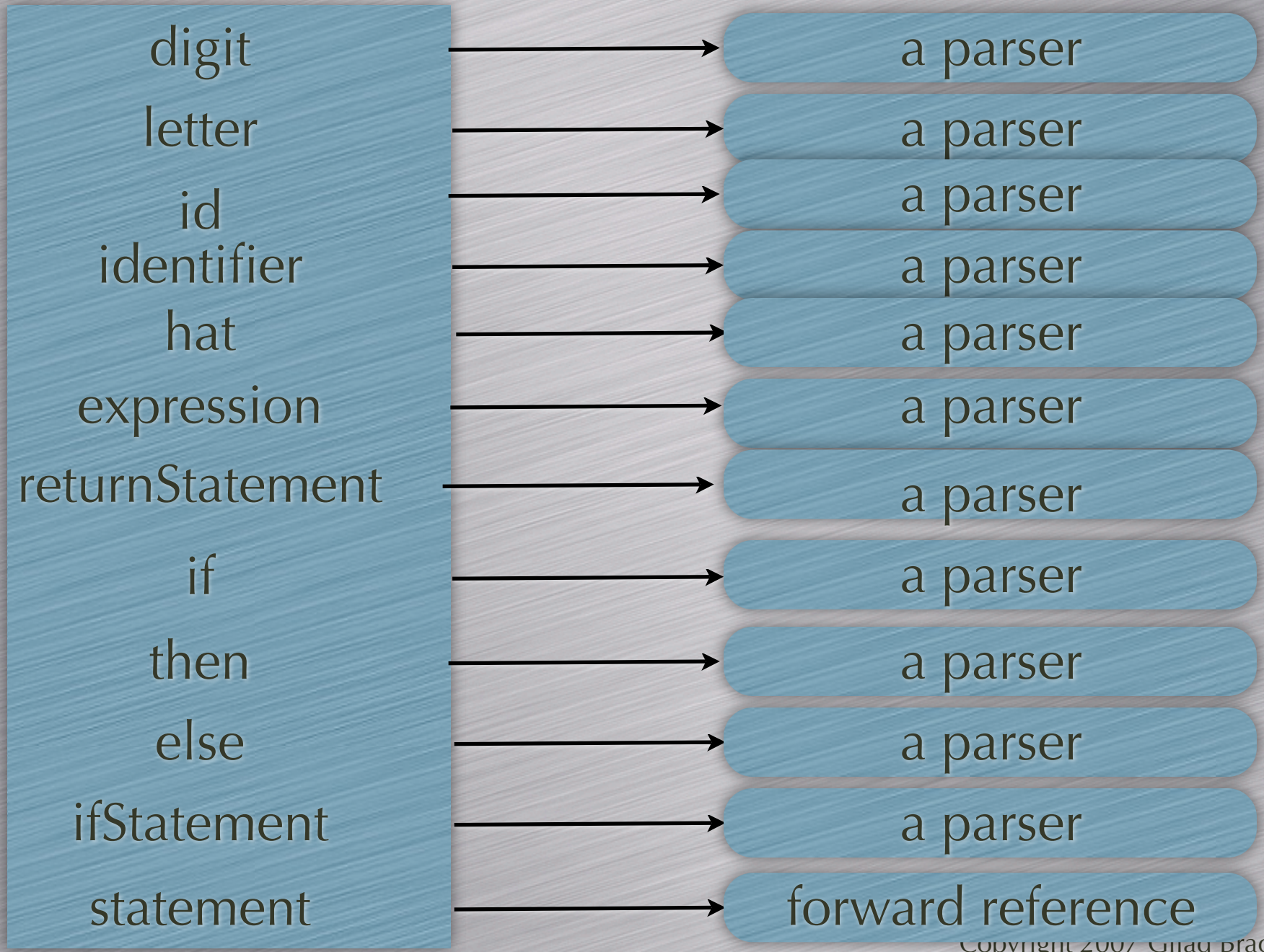

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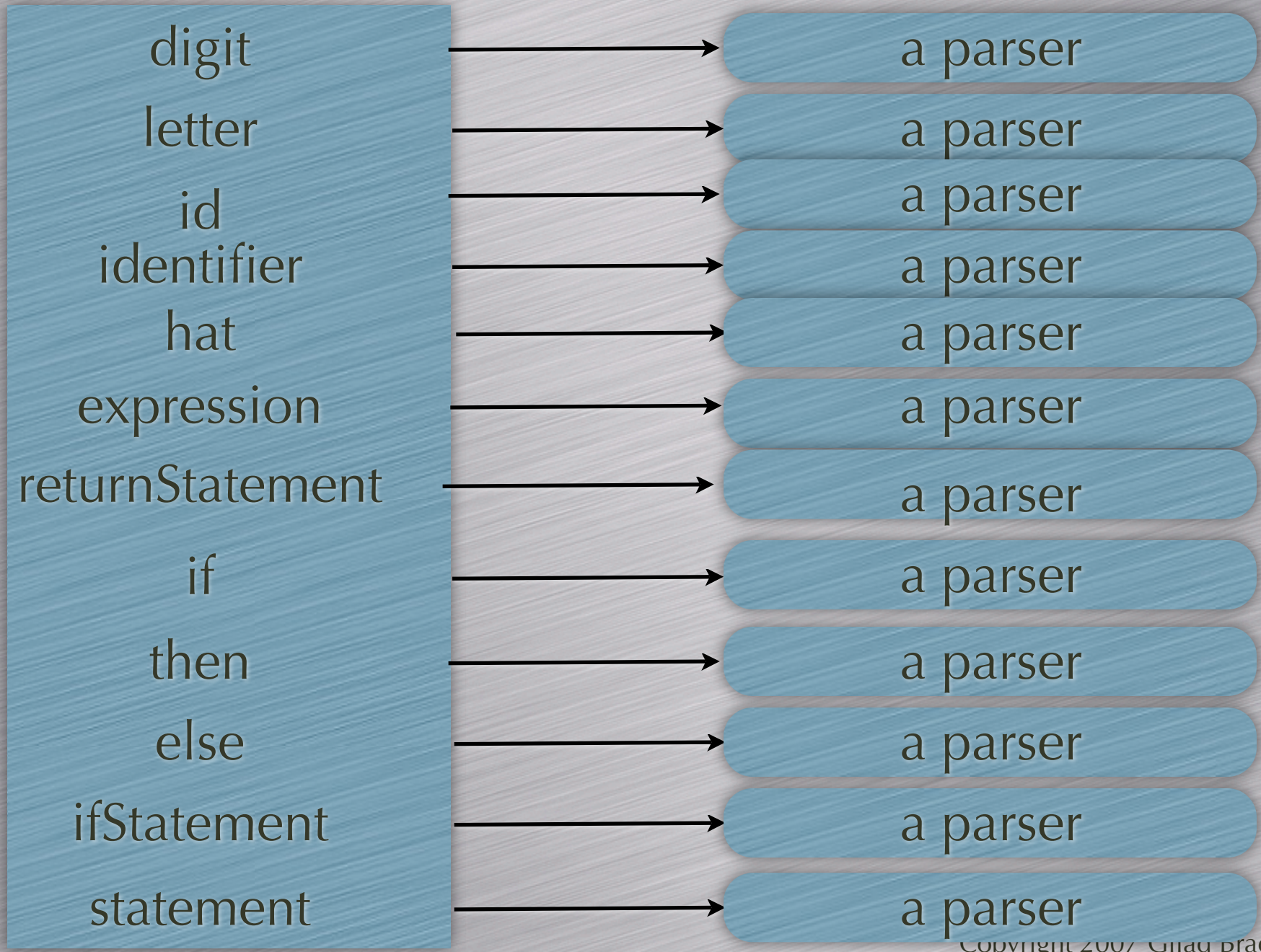

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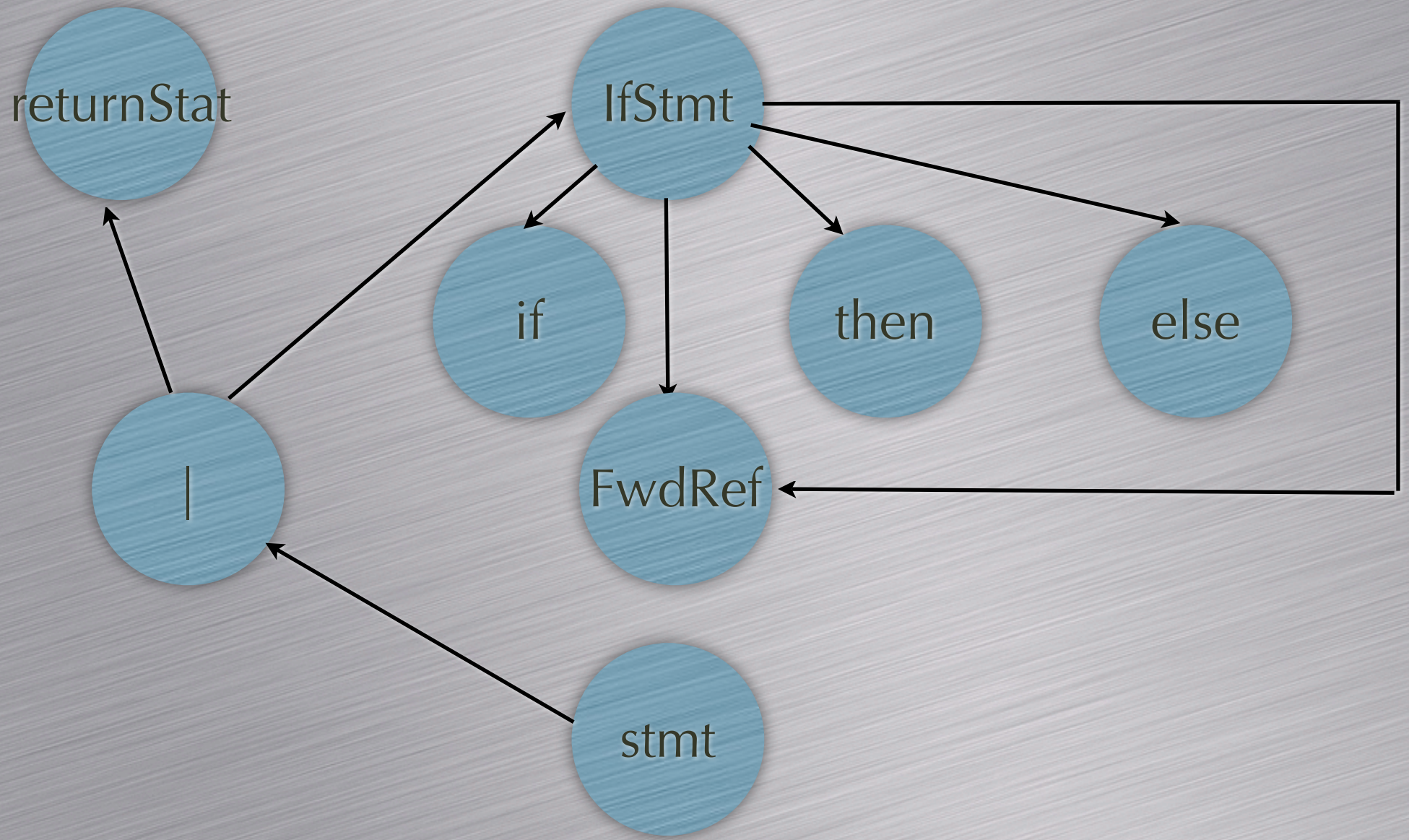


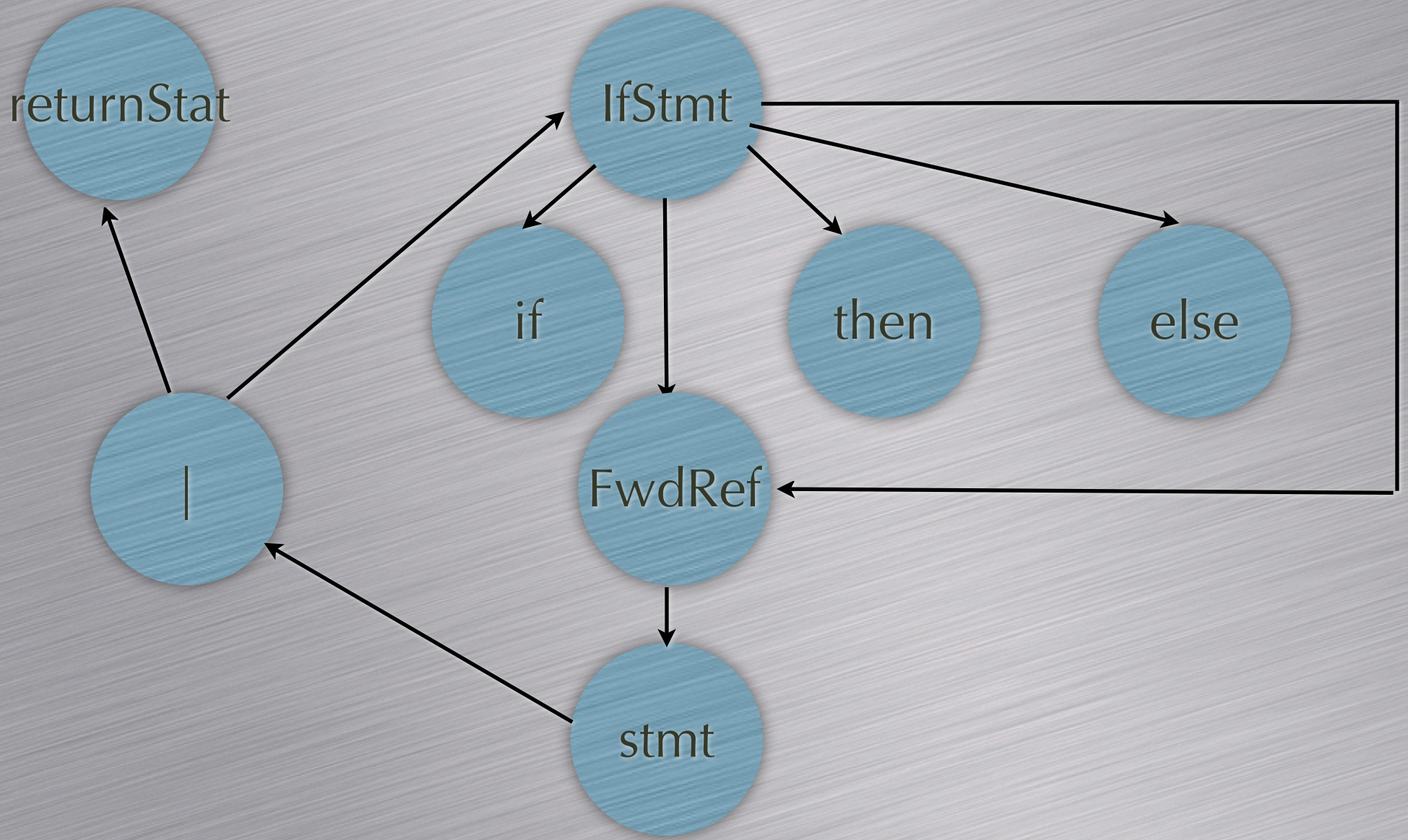
Being Reflective rather than Lazy

Use Reflection instead of Laziness.

Framework initializes all slots to “stand-in” parsers which act as forward references

When grammar is completely initialized, stand-ins are connected to originals and forward calls to them

Mutual Recursion



The Mirror is mightier than the Sloth

One can simulate a degree of laziness using reflection, but no amount of laziness will give us any reflection at all

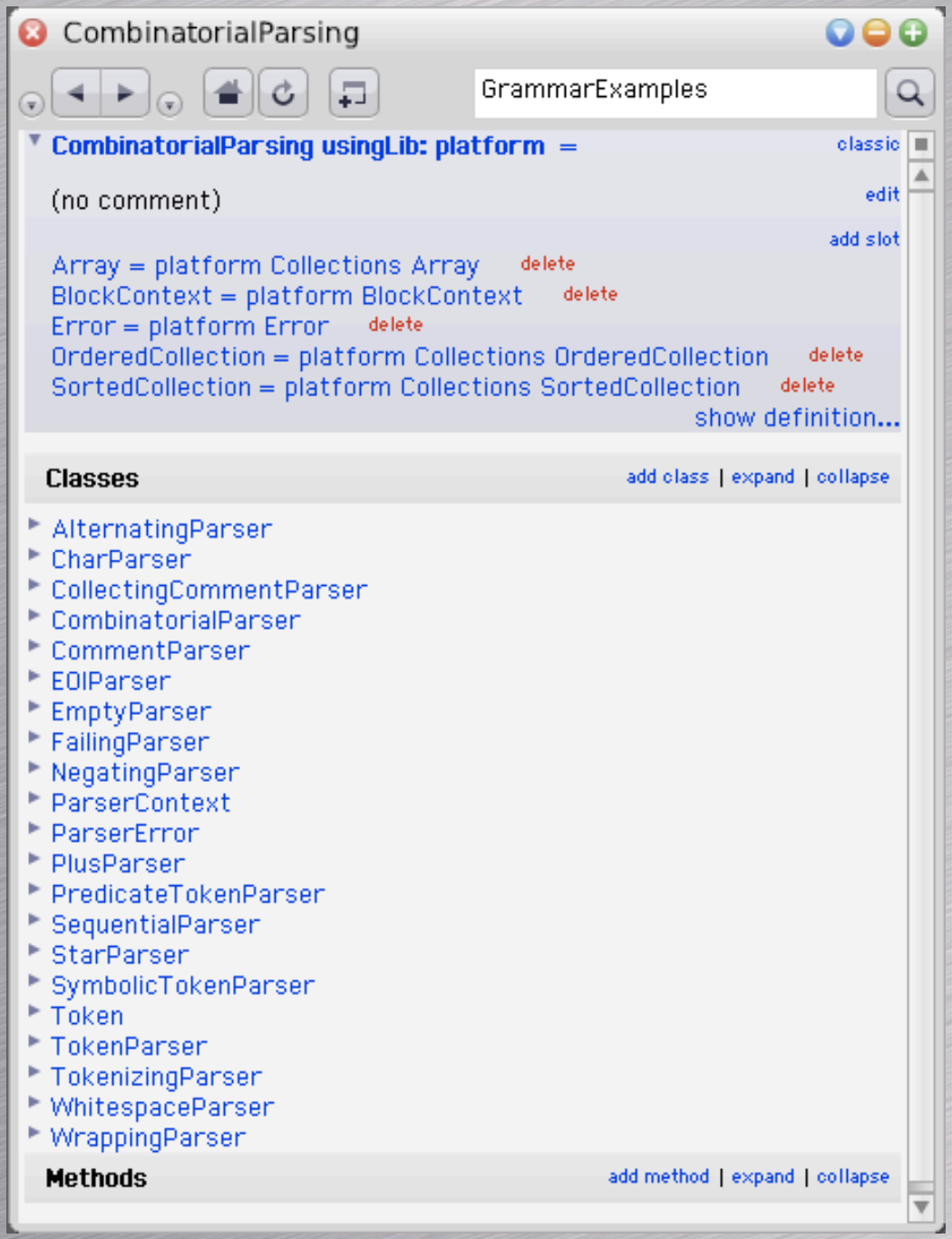
Composing Parsers

```
class ExampleParser2 = ExampleParser1 mixin |>
                                        ExampleGrammar2 ()
(
  ifStatement = (
    ^super ifStatement
      wrapper:[:ifKw :e :thenKw :s1 :elseKw :s2 |
                  IfStatAST new cond: e;
                                  trueBranch: s1;
                                  falseBranch: s2;
                                  start: ifKw start;
                                  end: s2 end
                ]
  )
)
```

Grammar is shared executable specification

- Shareable among several IDEs/ compilers that require distinct ASTs
- Shareable among other language tools: syntax colorizers, postprocessing tools

The Library

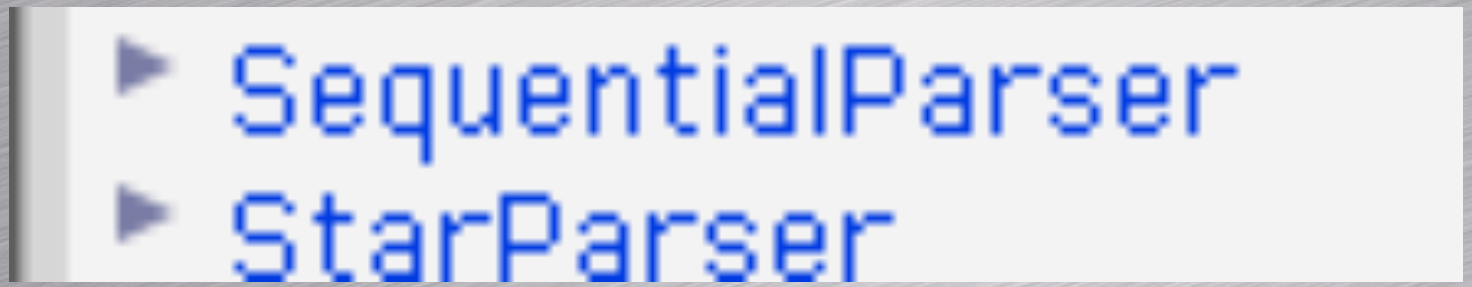


Nested Classes

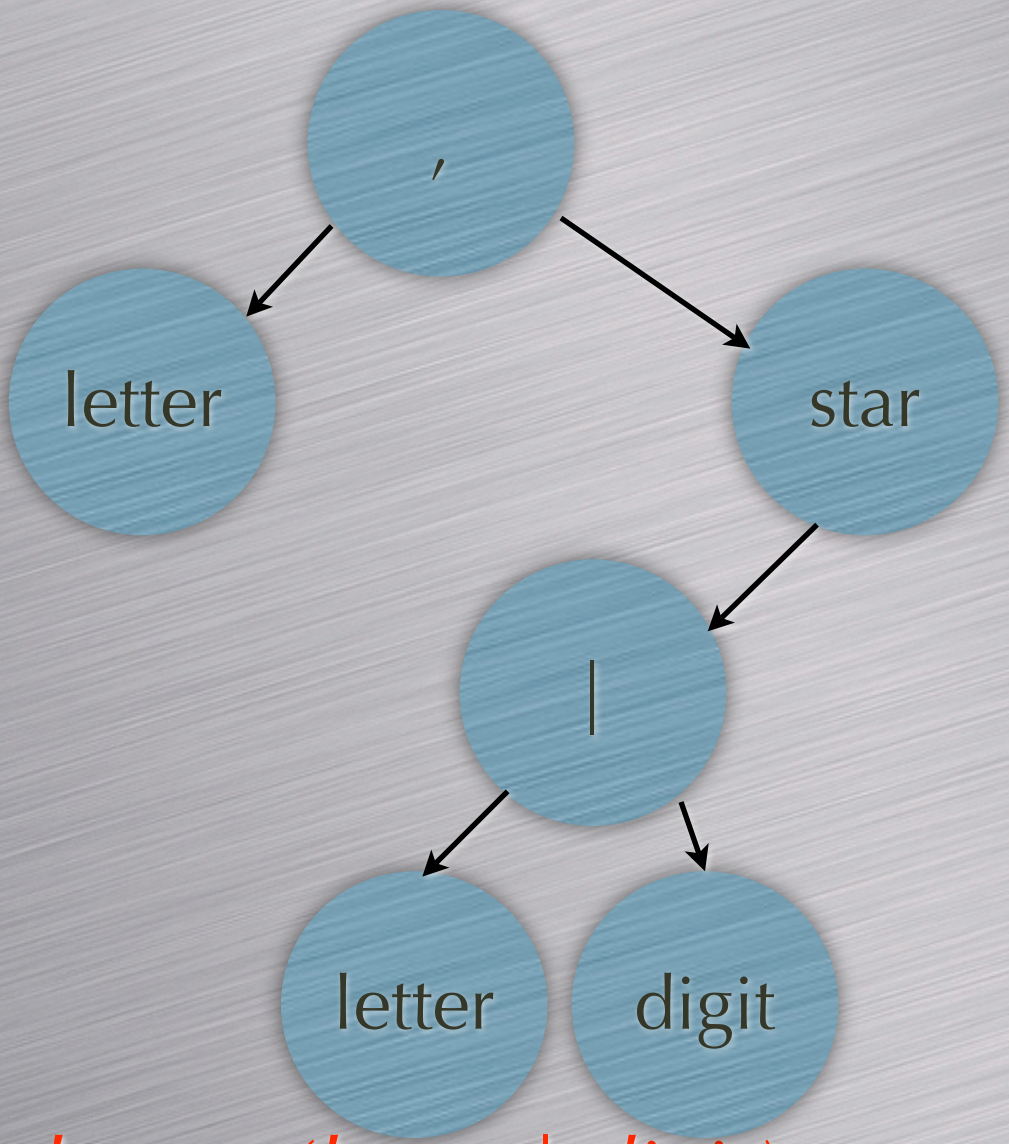
Classes add class | expand | collapse

- AlternatingParser
- CharParser
- CollectingCommentParser
- CombinatorialParser
- CommentParser
- EOIParser
- EmptyParser
- FailingParser
- NegatingParser
- ParserContext
- ParserError
- PlusParser
- PredicateTokenParser
- SequentialParser
- StarParser
- SymbolicTokenParser
- Token
- TokenParser
- TokenizingParser
- WhitespaceParser
- WrappingParser

Nested Classes In Detail



How it Works



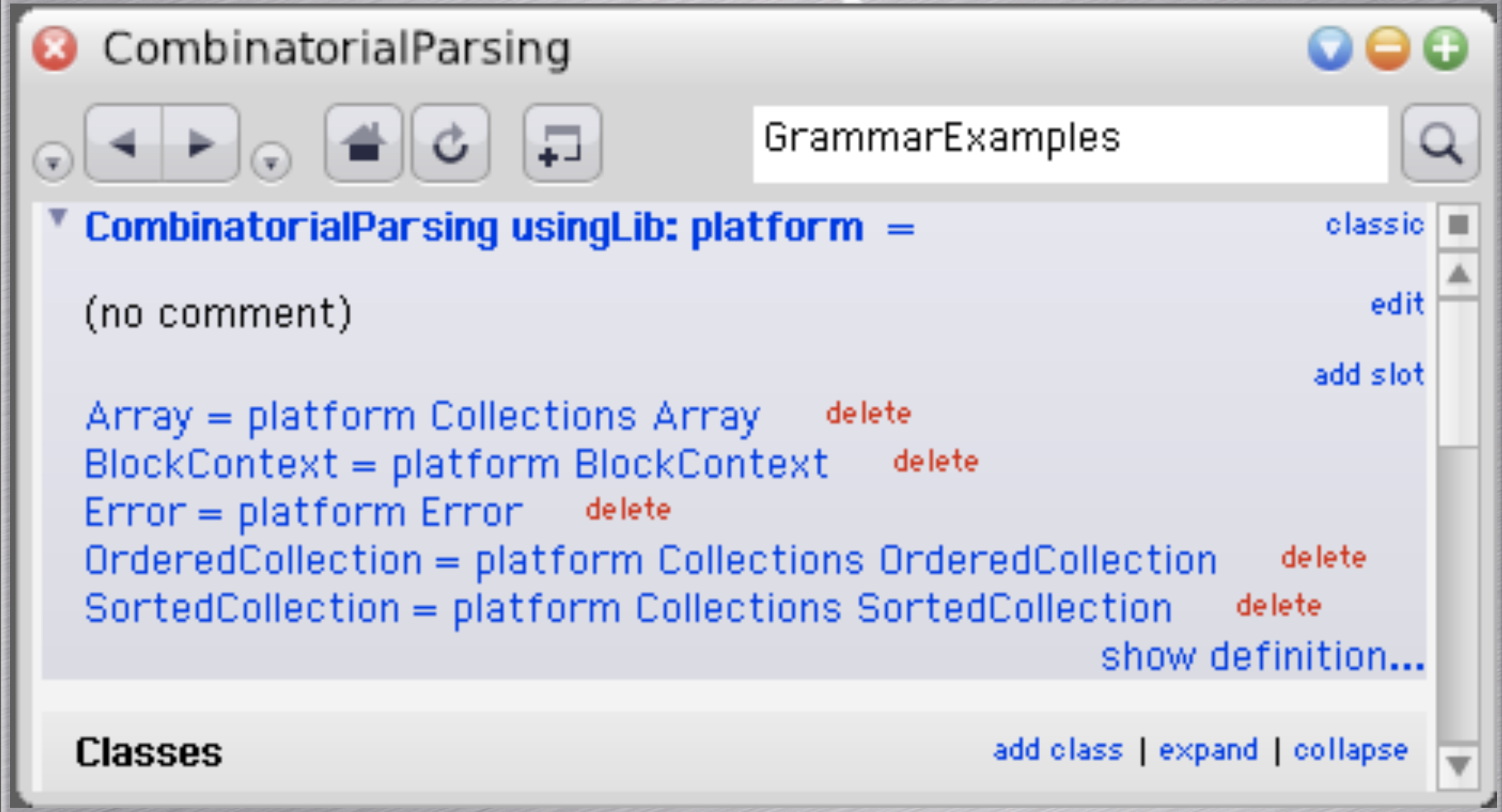
id = letter, (letter | digit) star.

Modules

```
class CombinatorialParsing usingLib: platform = (...)(
  class AlternatingParser = CombinatorialParser (...)(...)

  public class CombinatorialParser = ()( ...
     | p = (^AlternatingParser either: self or: p)
    ....
  )
  ....
)
```

Modules up Close



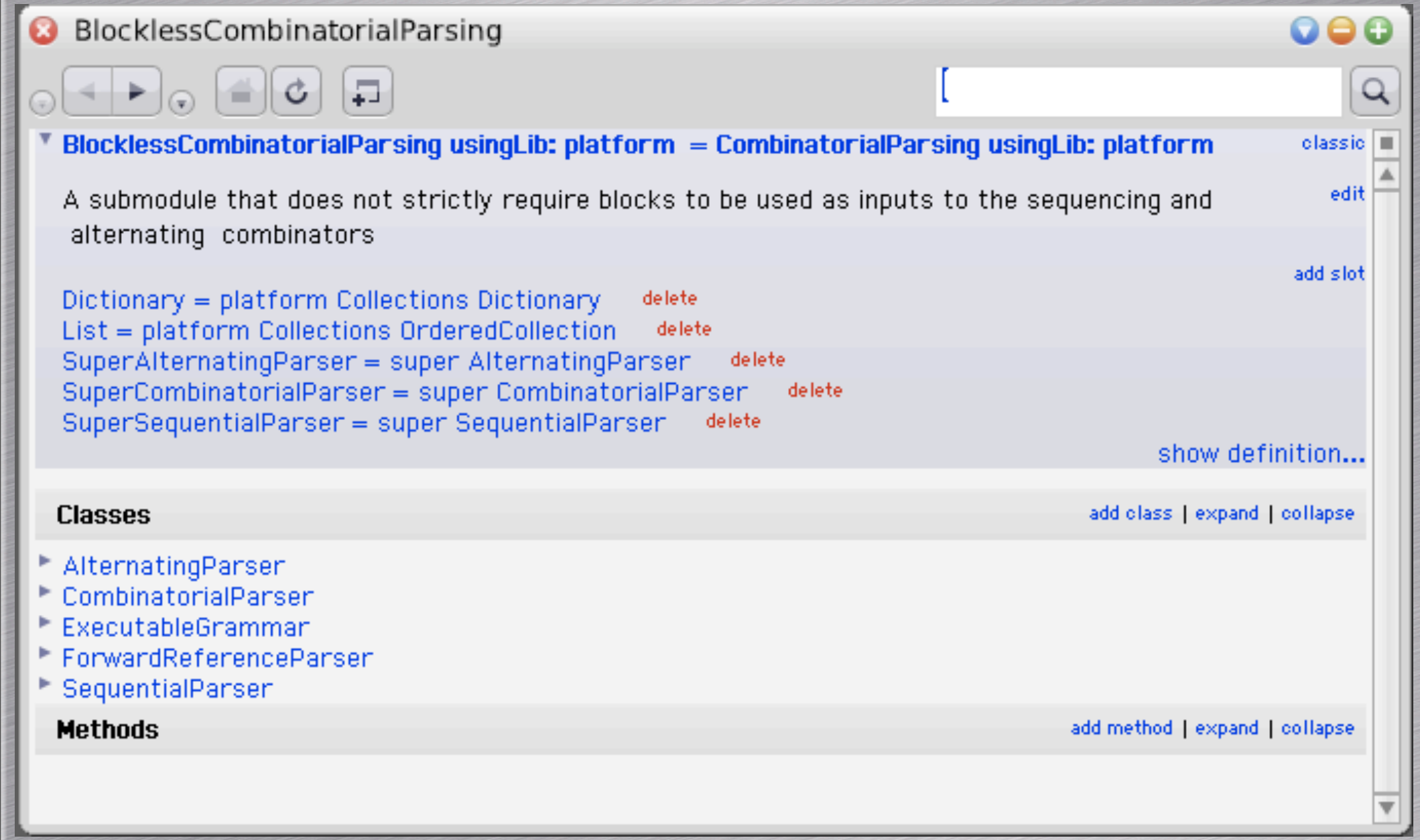
But, this version uses Closures

ifStatement = if, [expression], [then], [statement],

[else], [statement].

statement = ifStatement | [returnStatement].

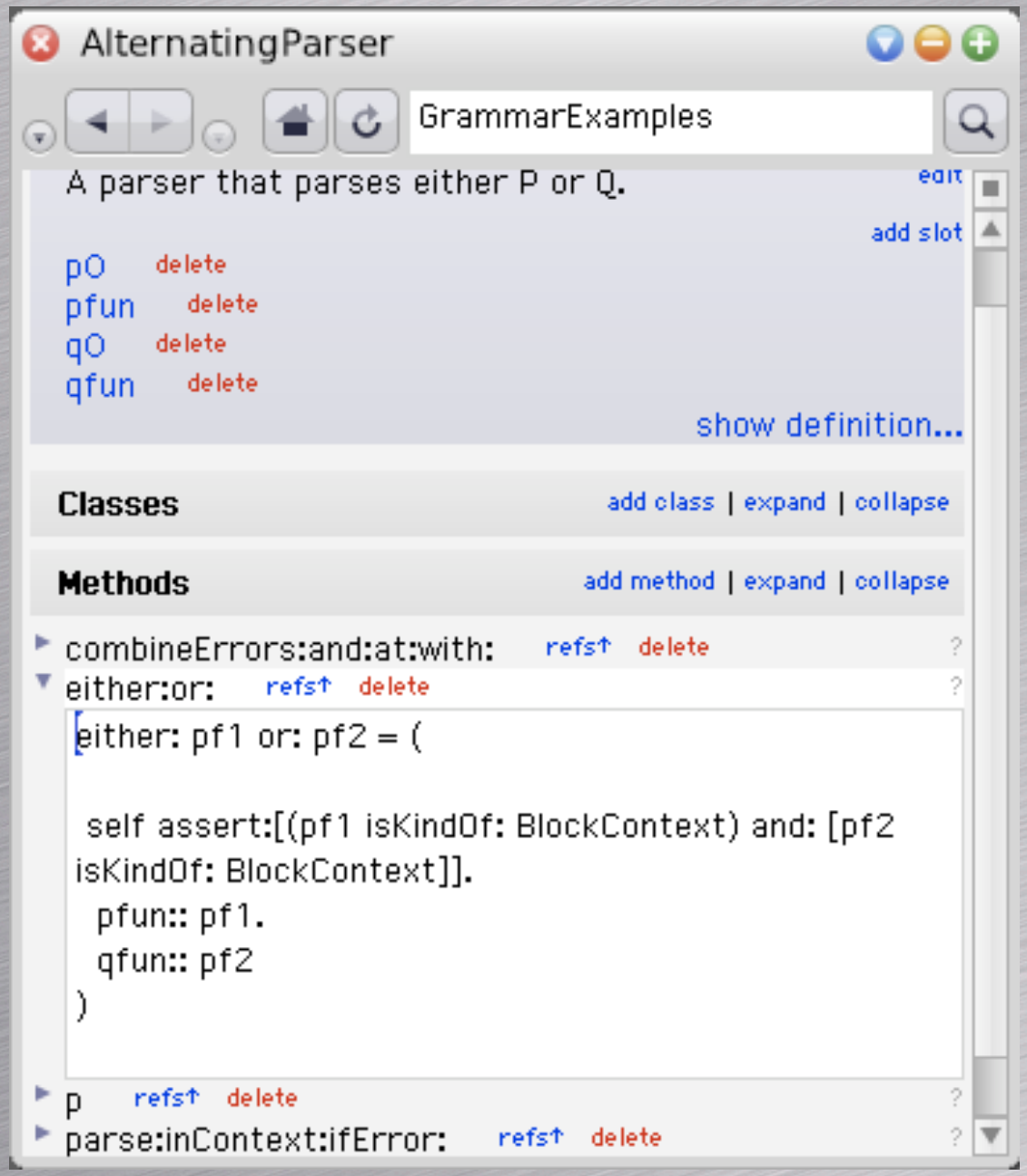
Closureless Version



Hierarchy Inheritance

```
class BlocklessCombinatorialParsing usingLib: platform =
   CombinatorialParsing usingLib: platform (
    | SuperCombinatorialParser = super CombinatorialParser.
      SuperAlternatingParser = super AlternatingParser.
    .....
    |
) (
   public CombinatorialParser = SuperCombinatorialParser ( ...
   )
   public AlternatingParser = SuperAlternatingParser( ... ) ( ... )
....
   public ExecutableGrammar =  CombinatorialParser (...) (...)
)
```

Closureful Alternation

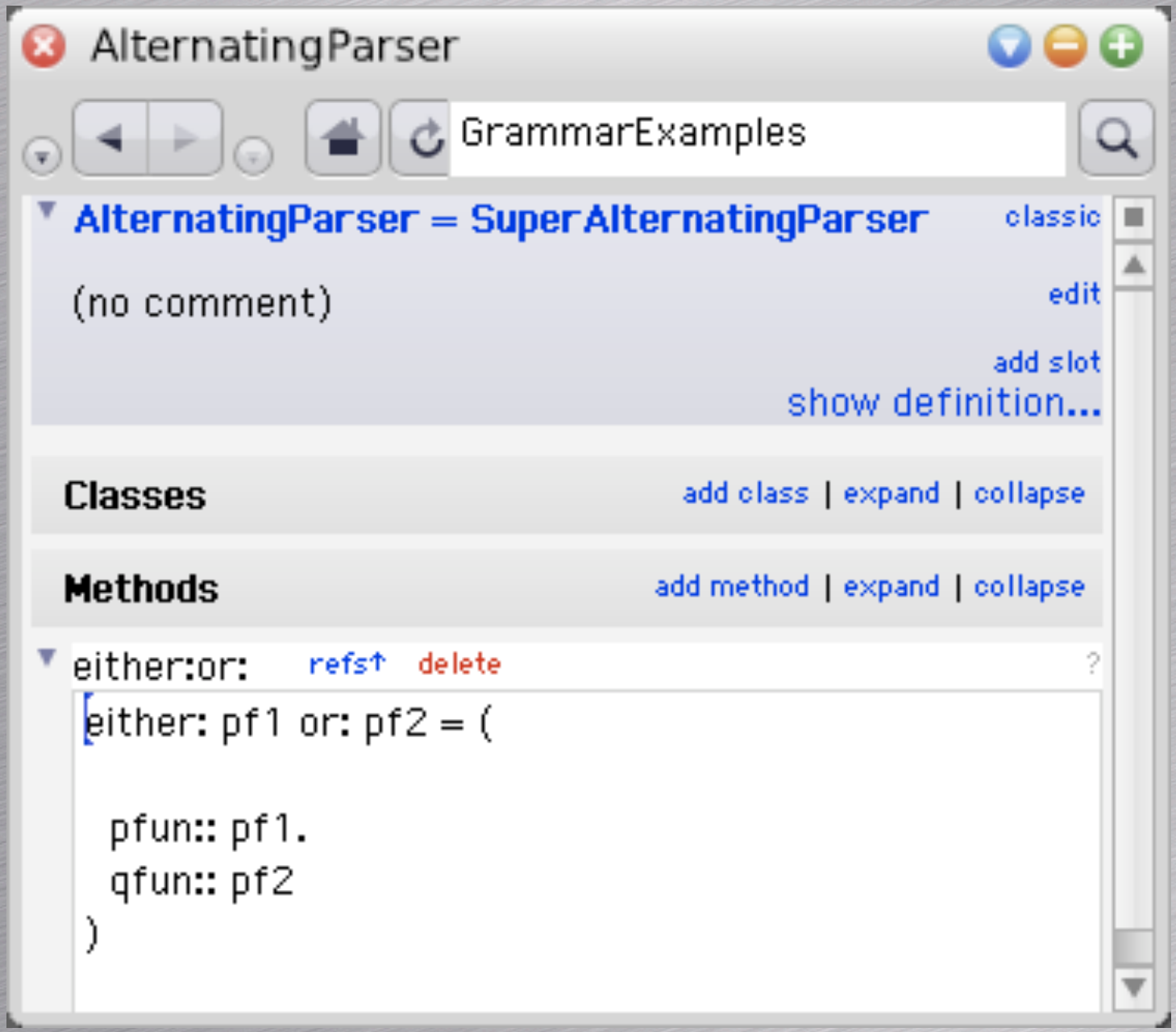


Closure Version

```
either: pf1 or: pf2 = (

 self assert:[(pf1 isKindOf: BlockContext) and: [pf2
isKindOf: BlockContext]].
  pfun:: pf1.
  qfun:: pf2
)
```

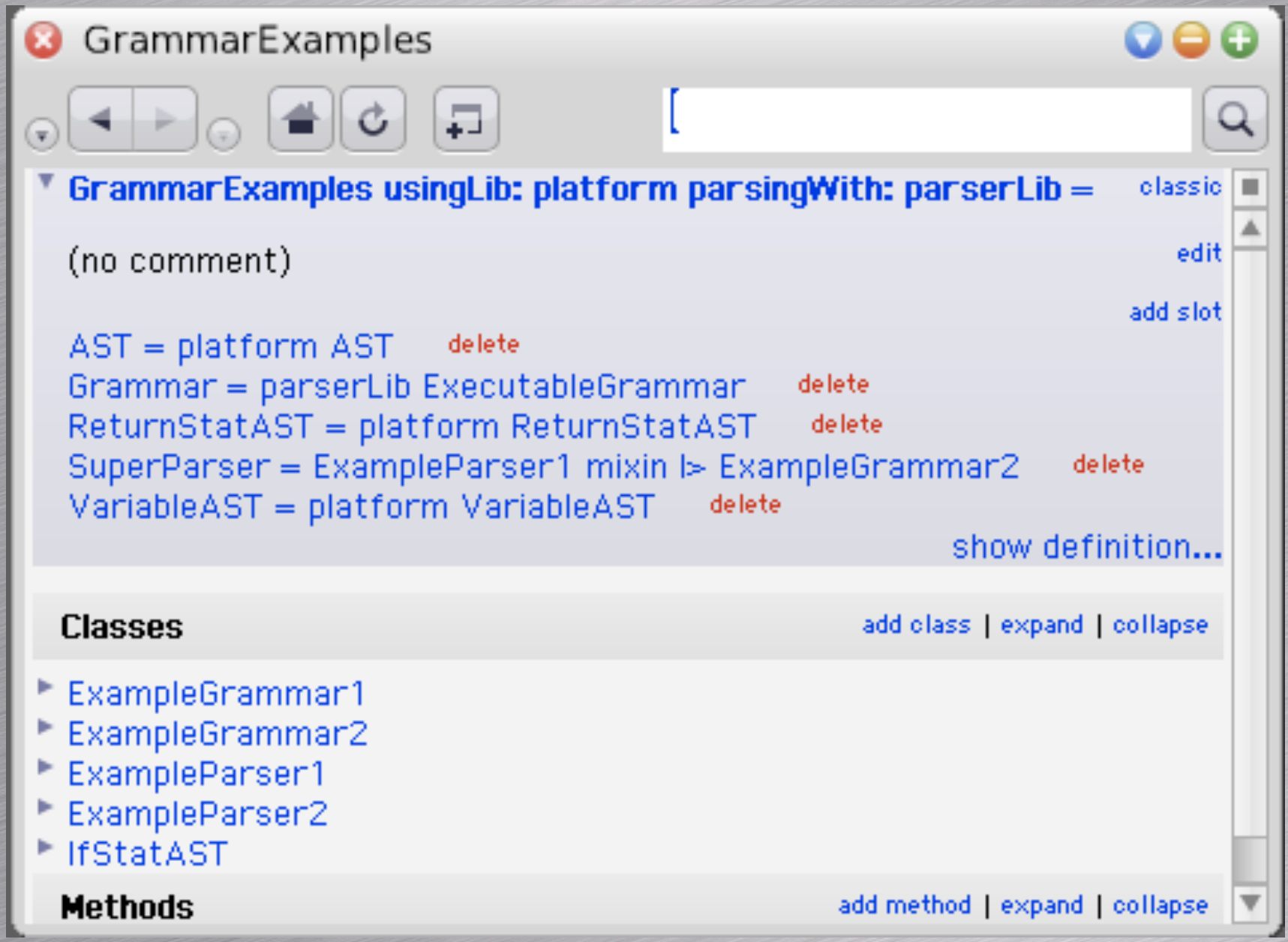
Closureless Alternation



Hierarchy Inheritance

```
class FullBNFParsing usingLib: platform =
   CombinatorialParsing usingLib: platform (
      | SuperParser = super CombinatorialParser. |
) (
   CombinatorialParser = SuperParser (
      | p =  ( ... )
   )
   BacktrackingParser = ( ... ) ( ... )
)
```

Modules Using Modules



Modules using Modules

```
class GrammarExamples
   using: platform parsingWith: parserLib =
 ( |
      Grammar = parserLib ExecutableGrammar.
      SuperParser = ExampleParser1 mixin |>
                                        ExampleGrammar2.
       List = platform Collections OrderedCollection.
    |
 )
(
   ExampleGrammar1 = Grammar ( ... ) (
   ....
    )
 )
```

Side by Side Modules

```
platform:: Platform new.

m1:: GrammarExamples
        using: platform
      parsingWith: (BlocklessCombinatorialParsing
                              usingLib: platform)

m2:: GrammarExamples
        using: platform
      parsingWith: (PackratParsing usingLib: platform)
```

Improving Readability

```
class ExampleGrammar1 = ExecutableGrammar (
|
digit = charBetween: $0 and: $9.
letter = (charBetween: $a and:$z) |
         (charBetween: $A and:$Z).
id = letter, (letter | digit) star.
identifier = tokenFor: id.
hat = tokenFromChar: $^.
expression = identifier.
returnStatement = hat, expression.
|
)()
```

A Modest Facelift

```
class ExampleGrammar3 = ExecutableGrammar (
|
digit = $0 - $9.
letter = ($a - $z) | ($A - $Z).
id = letter, (letter | digit) star.
identifier = tokenFor: id.
expression = identifier.
returnStatement = $^, expression.
|
)()
```

Before

```
class ExampleGrammar2 = ExampleGrammar1 (
|
if = tokenFromSymbol:#if.
then = tokenFromSymbol:#then.
else = tokenFromSymbol:#else.
ifStatement = if, expression, then, statement, else, statement.
statement = ifStatement | returnStatement.
|
)()
```

After

```
class ExampleGrammar3 = ExampleGrammar4 (
|
ifStatement = #if, expression, #then, statement, #else,
statement.
statement = ifStatement | returnStatement.
|
)()
```

Dirty Tricks?

```
class ExecutableGrammar usingLib: platform =
                CombinatorialParsing usingLib: platform (
|
PlatformCharacter = super Character.
Character = PlatformCharacter mixin |> CharacterParser.
Symbol = super Symbol mixin |> SymbolParser.
....
|
)()
```

Related Work

- Too much to survey; some highlights:
  - Parsec (Haskell parser combinator library)
  - Swierstra et al.
  - Sparsec (Scala parser combinator library)
  - PEGs (Ford, POPL04, ICFP)
  - Tedir (Plesner-Hansen's masters thesis)
  - Ometa (OOPLA 07 DLS)

Related Work

- Message-based programming: Smalltalk, Self
- Virtual Types: Beta, gBeta, Scala
- Modules: ML, Units
- Side-by-Side deployment: OSGi
- Hierarchy inheritance: Ossher & Harrisson ..

Conclusions

- Clean syntax and reflection allow effective embedding of BNF as a DSL in Newspeak
- Inheritance and dynamic typing make it easy to separate grammar from processing; huge SE benefits
- Message based programming supports strong component style modularity + class hierarchy inheritance