First Class Variables as AST Annotations

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Part I: The AST

- AST = **A**bstract **S**yntax **T**ree
- Tree Representation of the Method
- Based on the RB AST
- Used by all tools (refactoring, syntax-highlighting,…)

```
Smalltalk compiler parse: 'test ^(1+2)'
```

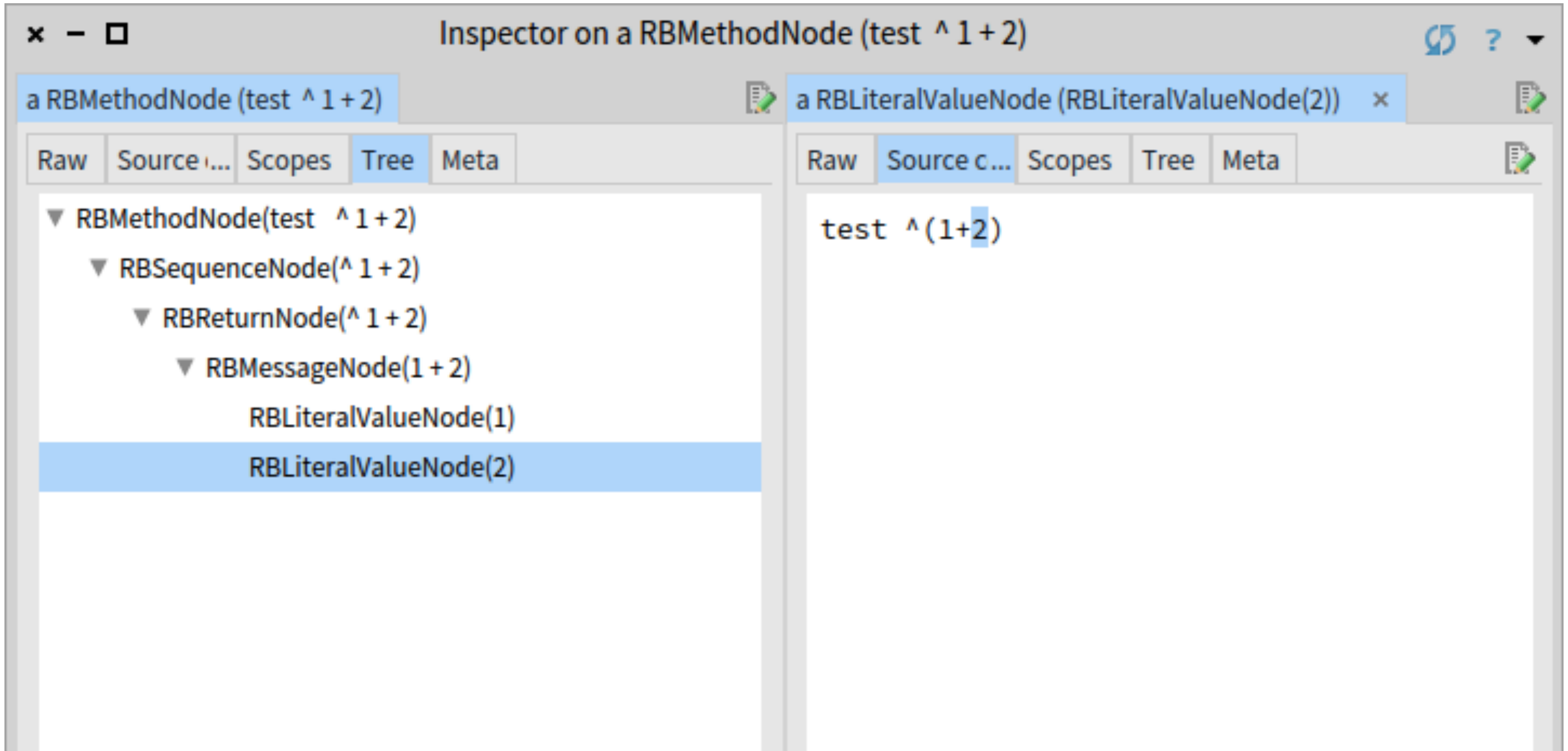
AST

• RBMethodNode	Root
• RBVariableNode	Variable (read and write)
• RBAssignmentNode	Assignment
• RBMessageNode	A Message (most of them)
• RBReturnNode	Return

Inspect a simple AST

- A very simple Example

```
Smalltalk compiler parse: 'test ^(1+2)'
```


Inspector on a RBMethodNode (test ^ 1 + 2)
a RBMethodNode (test ^ 1 + 2)
Raw
Source ...
Scopes
Tree
Meta
a RBLiteralValueNode (RBLiteralValueNode(2))
Raw
Source c...
Scopes
Tree
Meta

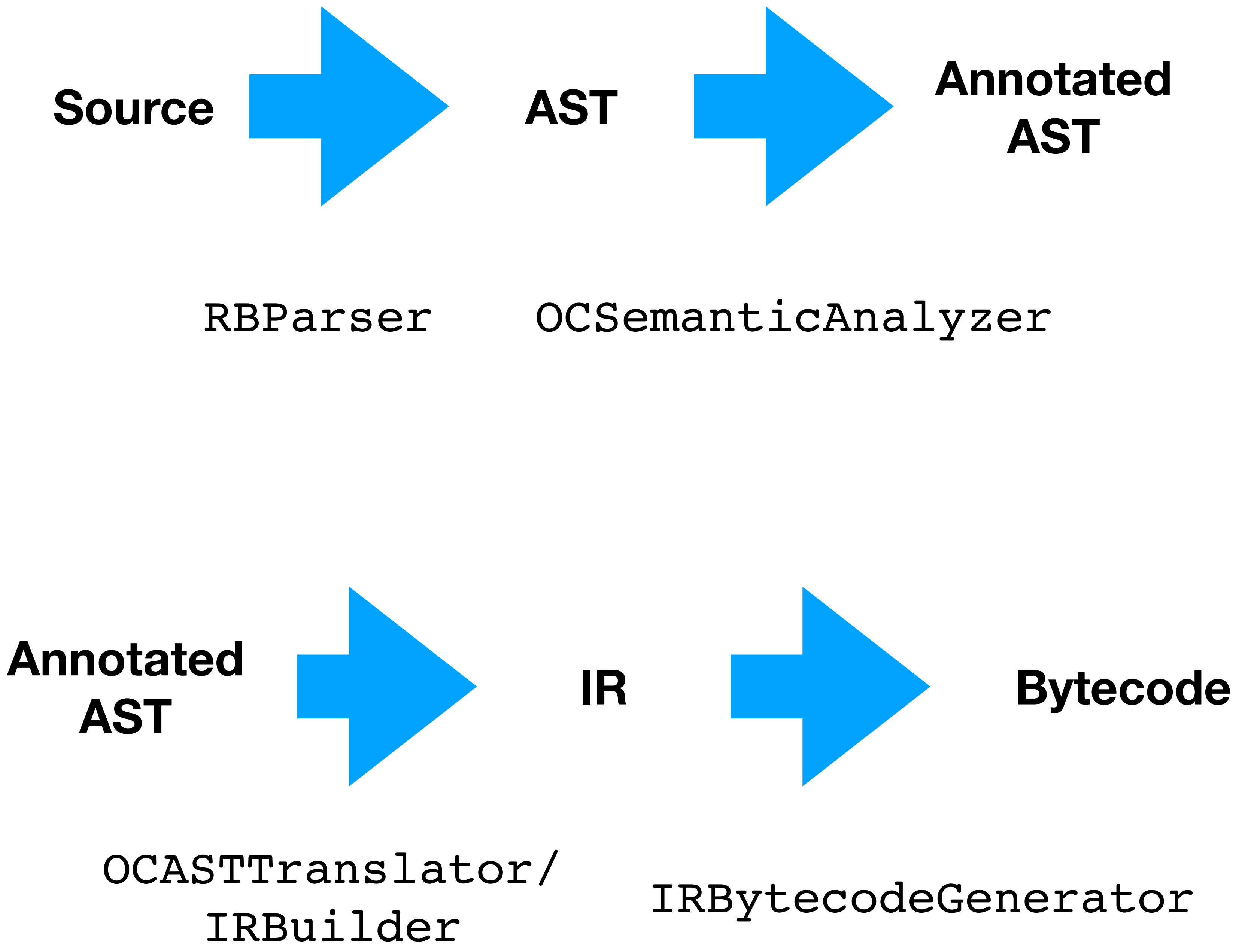
```
▼ RBMethodNode(test  ^ 1 + 2)
    ▼ RBSequenceNode(^ 1 + 2)
        ▼ RBReturnNode(^ 1 + 2)
            ▼ RBMessageNode(1 + 2)
                RBLiteralValueNode(1)
                RBLiteralValueNode(2)
```

```
test ^(1+2)
```

User: Tools

- Refactoring
- Breakpoints / Watchers
- Syntax Highlight / Code Completion
- AST based Menu in the Code Browser

User: The Compiler



Source → **AST** → **Annotated AST**

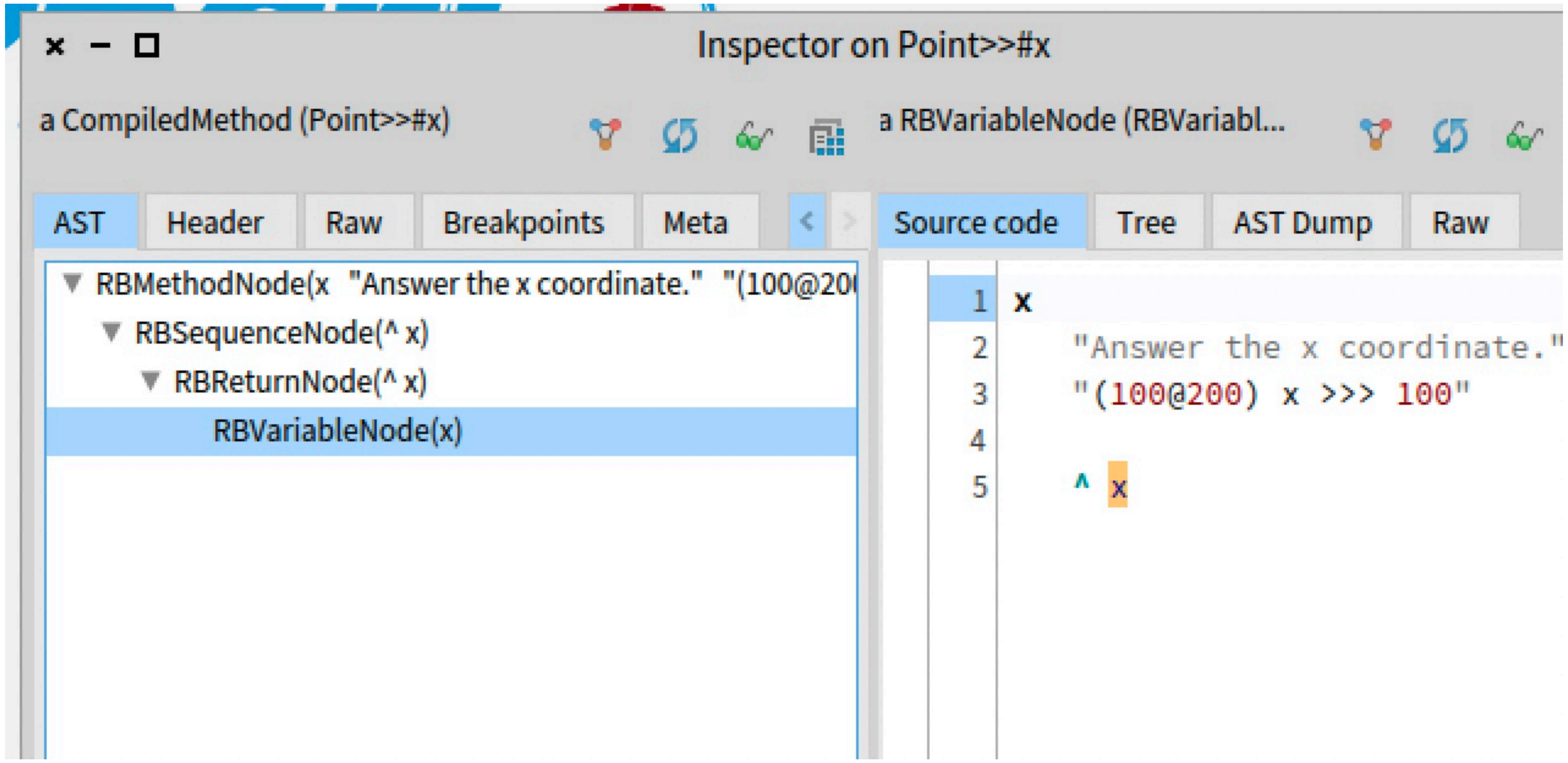
`RBParser` `OCSemanticAnalyzer`

Annotated AST → **IR** → **Bytecode**

`OCASTTranslator/ IRBuilder` `IRBytecodeGenerator`

Variables in the AST

- Example: (Point>>#x)



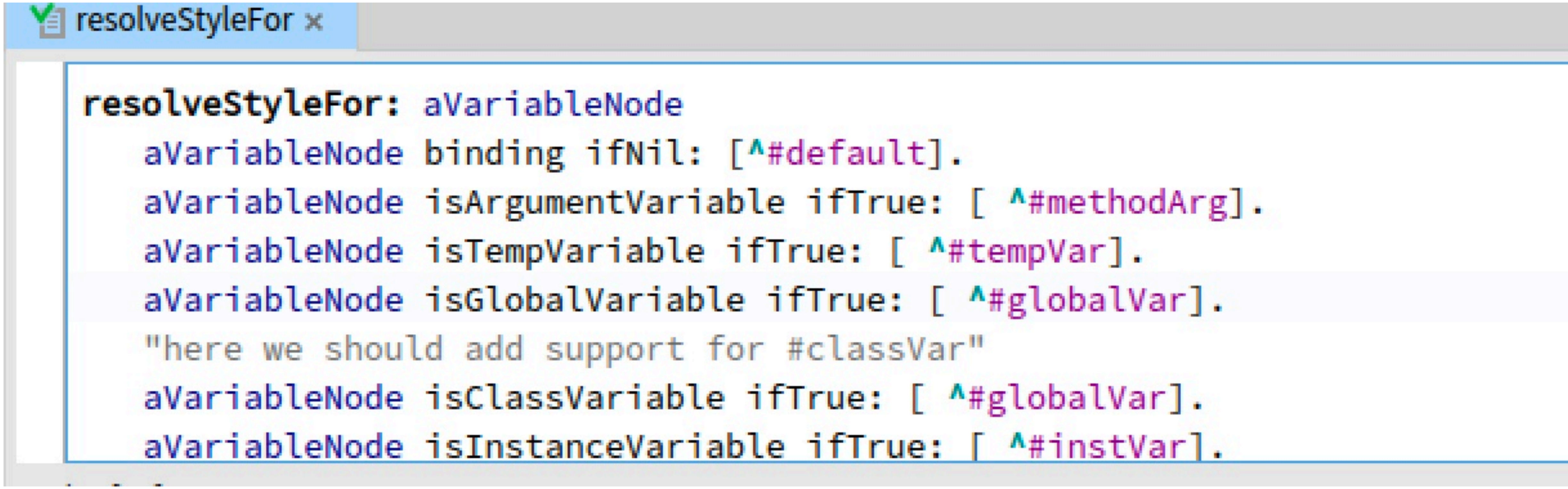
```
▼ RBMethodNode(x  "Answer the x coordinate."  "(100@20
   ▼ RBSequenceNode(^ x)
      ▼ RBReturnNode(^ x)
           RBVariableNode(x)
```

```
x
    "Answer the x coordinate."
    "(100@200) x >>> 100"

    ^ x
```

Problem: Kind of Variable?

- Example: SHRBTextStyler
    - Syntax highlighting needs to know which kind



```
resolveStyleFor: aVariableNode
   aVariableNode binding ifNil: [^#default].
   aVariableNode isArgumentVariable ifTrue: [ ^#methodArg].
   aVariableNode isTempVariable ifTrue: [ ^#tempVar].
   aVariableNode isGlobalVariable ifTrue: [ ^#globalVar].
   "here we should add support for #classVar"
   aVariableNode isClassVariable ifTrue: [ ^#globalVar].
   aVariableNode isInstanceVariable ifTrue: [ ^#instVar].
```

Variables in the AST

- Every definition, read and write gets one new instance of RBVariableNode (as we have to encode the parent for each differently)
  - We just know the name
  - SYNTAX, but no SEMANTICs
    - Kind? (temp or ivar)
    - Variables with same name can be different variables

To the Rescue: Name Analysis

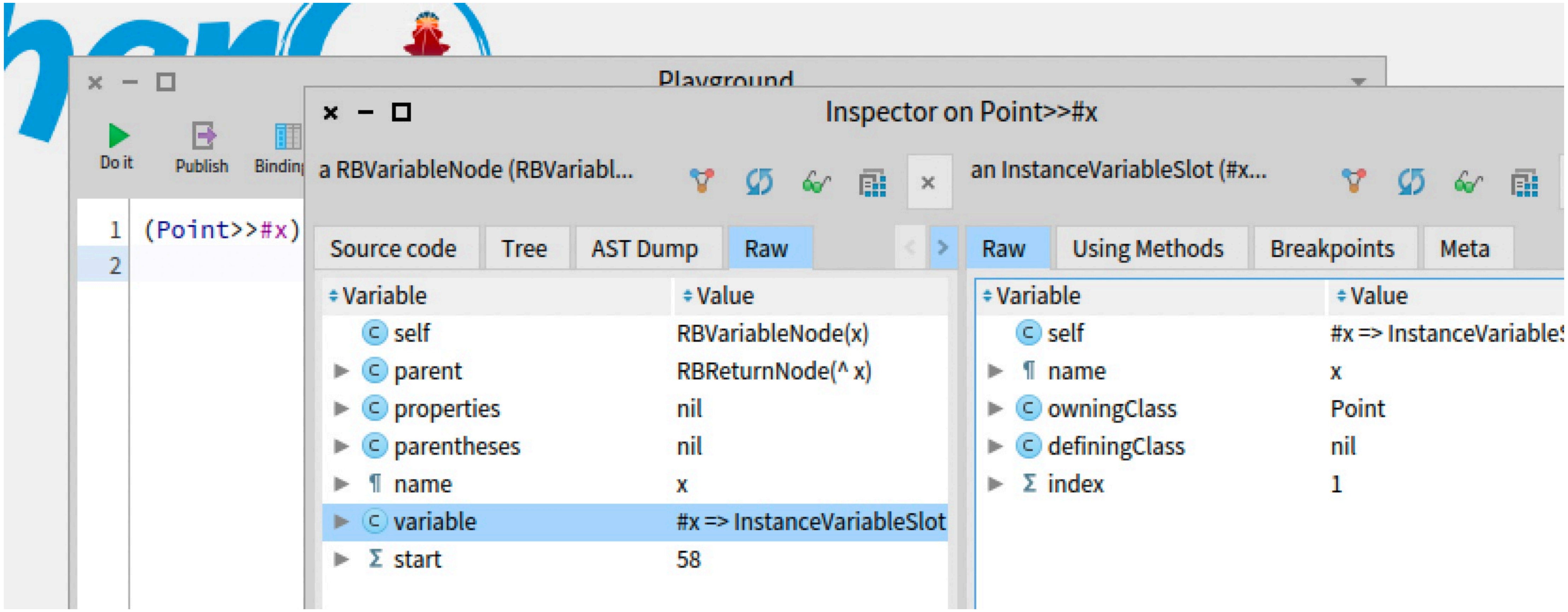
- We have to annotate the AST with information about Variables
- Block/Method: defined Variables are put in a Scope
    - Scopes know the parent Scope
- When we see a use, we loop up the variable in the Scope

Semantic Variables

- Every RBVariableNode gets a semantic variable annotation
    - Both the definition and all uses
- There is one instance for each variable that models
    - name
    - scope it was defined

Variables in the AST

- Example Again: (Point>>#x)
-



```
(Point>>#x)
```

Inspector on Point>>#x

a RBVariableNode (RBVariabl...

Variable	Value
self	RBVariableNode(x)
parent	RBReturnNode(^ x)
properties	nil
parentheses	nil
name	x
variable	#x => InstanceVariableSlot
start	58

an InstanceVariableSlot (#x...

Variable	Value
self	#x => InstanceVariable
name	x
owningClass	Point
definingClass	nil
index	1

Variables and Compilation

- Compiler just delegates to the Variable, e.g for instance Variables:

```
emitStore: methodBuilder
    "generate store bytecode"
    methodBuilder storeInstVar: index
```

- emitStore/emitValue: defined for each kind of Variables (global/temp/ivar)

Repeat:The AST

- AST = **A**bstract **S**yntax **T**ree
- Tree Representation of the Method
- Produced by the Parser (part of the Compiler)
- Used by all tools and the Compiler
- We need to model Variables semantically to make it useful

Now Step Back

Forget Part I
(for now)

Look at it from Reflective Point of View

PartII
First Class Variables

First: Variables in ST80

Instance Variables

- Defined by the Class (list of variable names)
- Can be read via the object:
- `instVarNamed:(put:)`, `#instVarAt:(put:)`
- Instance Variables have an offset in the Object
- Defined by the order of the defined vars in the Hierarchy

1@2 instVarNamed: 'x'

Temporary Variable

- Defined by a method or Block
    - Arguments are temps, too
- Can be read via the context
- `#tempNamed:, tempNamed:put:`

```
[| temp |  temp := 1. thisContext tempNamed:  'temp' ] value
```

- With Closures this is more complex than you ever want to know!

Globals

- Entries in the “Smalltalk globals” Dictionary
- Contain the value

```
Smalltalk globals at: #Object.
Object binding value.
```

- Can be read via the global Dictionary
- Access via #value / value: on the Association
- Class Vars and Pool Vars are just Associations from other Dictionaries

“Everything is an Object”

For Variables… not really

Globals/Class Vars

- Here we have at least the Association (#binding):

Object binding

- But there is no “GlobalVariable” class
  - No API other than #value:/#value
  - Classes define just names of variables

Instance Variables

- The class just knows the names

```
Point allInstVarNames
```

- There is no Object representing instance variables
- Classes define just names of variables
- Bytecode accesses by offset

Temporary Variables

- The methods know nothing. Even to know the variable name we need the compiler (and the source)

- There is no object representing temp Variables

- Reflective read and write is *hard* -> compiler needs to create extensive meta-data

Why Not Do Better?

- Every defined Variable is described a meta object
- Class Hierarchy: Variable

The Hierarchy

- Variable
  - LiteralVariable
    - ClassVariable
    - GlobalVariable
    - UndeclaredVariable
    - WorkspaceVariable
  - LocalVariable
    - ArgumentVariable
    - TemporaryVariable
  - ReservedVariable
    - SelfVariable
    - SuperVariable
    - ThisContextVariable
  - Slot

Example: vars of a class

- Get all Variables of a class
- Inspect it
- #usingMethods

```
Point instanceVariables
```

Instance Variable

- Read x in a Point

```
(Point instanceVariables first) read: (5@4)
```

- Write

```
point := 5@4.
(Point instanceVariables first) write: 100 to: point.
```

- read/write without sending a message to the object!

Globals

- Object binding class

- Object binding read

- We keep the Association API so the Global Variables can play the role of associations in the global dictionary.

Object binding usingMethods

Temporary Variables

- There are too many to allocate them all
- They are created on demand (with the AST)

```
((LinkedList>>#do:) temporaryVariableNamed: 'aLink')
```

#lookupVar:

- Every variable knows the scope is was defined in
- Every scope know the outer scope

```
(Point slotNamed: #x ) scope outerScope
```

- #lookupVar: looks up names along the scope

```
[ | temp |thisContext lookupVar: 'temp' ] value.

[ | temp |thisContext lookupVar: ‘Object' ] value
```

Debugger: Read Vars

- In the Debugger we to be able to read Variables from a DoIt.
- lookupVar, then readInContext works for all Variables!

```
[ | temp | temp :=1 . (thisContext lookupVar: 'temp')
              readInContext: thisContext] value
```

- If you know the context, you can read any variable
- DoItVariable: Nice names in DoIts (—> Show Us)

Part III: Putting it Together

- We have seen how Semantic Variables are needed to make the AST useful
- We have seen First Class Variables as part of the Reflective Model
- Do we really need the two?

Solution: Scope

- What is needed? Add the concept of Scope
    - Scope of a global is Smalltalk globals
    - Scope of an instance variable is the class
    - Scope of temp: method and block scope

Example: Point x

```
(Point slotNamed: #x) scope == Point

(Point lookupVar:  #x) == (Point slotNamed: #x)

(Point>>#x) ast variableNodes first variable == (Point slotNamed: #x)
```

What do we get?

- Simplified Name Analysis in the Compiler
- Open Compiler: Define your own kinds of Variables
- While fully integrated in the Reflective Model
  - Reflective Reading/Writing
  - All tools work for you own kinds of Variables

What we did not see…

- Define your own kinds of Variables (e.g. subclasses of Slot / ClassVariable)
- Fluid Class Definitions: How to create classes that use these variables
- How this enables DoIts with nice variable names
- Reflection: MetaLinks on Variables

Thanks…

- This is the work on *many* contributors from the Pharo Community

- Thanks for lots of interesting discussions, ideas, and code!

Questions?

- We have seen how the AST needs semantic variables to be useful
- We have seen First Class Variables as part of the Reflective model
- First Class Variables, with just adding the concept of a Scope, can serve as semantic annotations on the AST