C/CPS 506

Comparative Programming Languages

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Topic 2: Control flow & collections in Smalltalk

Ryerson University

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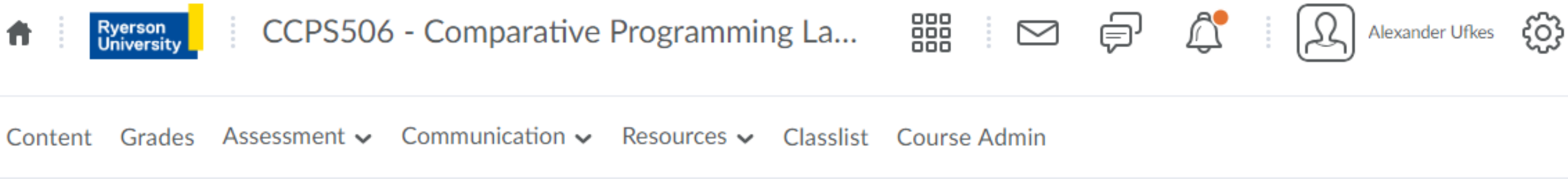
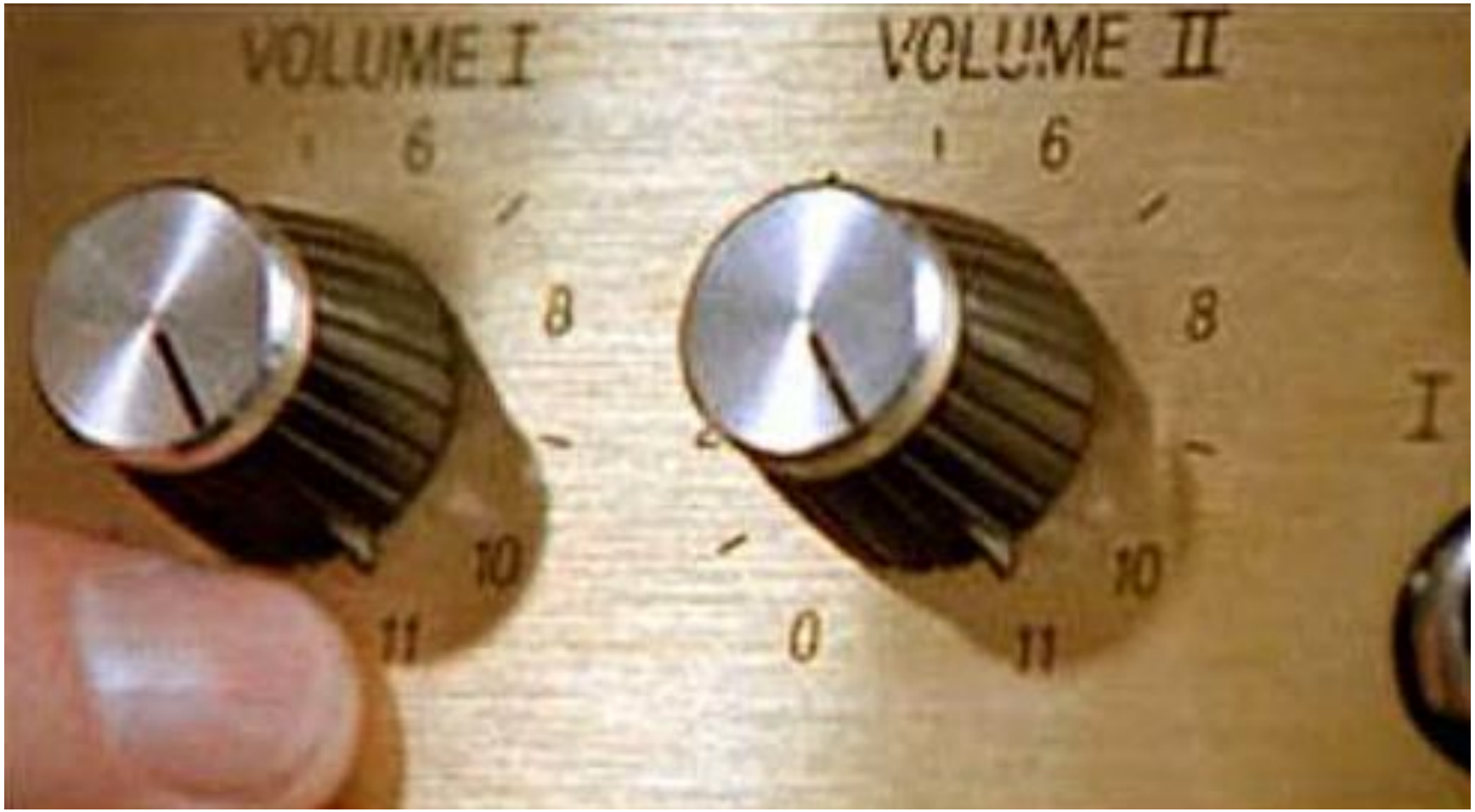


- Labs #1 & #2 posted
- Assignment description posted
- See D2L or outline for due dates

Let’s Get Started!

Smalltalk: OOP cranked up to 11



Objects in Smalltalk

Everything is an object. *Everything* is an instance of a corresponding class

A Smalltalk object can do exactly three things:

1. Hold state (assignment)
2. Receive a *message* (from itself or another object)
3. Send *message* (to itself or another object)

Message passing is **central** in Smalltalk.

Message Summary

Unary Messages:

```
sqrt, squared
  asInteger
  class, cr
floor, ceiling
sin, cos, tan
```

Any message without argument(s)

Binary Messages:

```
+, -, *, /
  //, \\
  =, ==,
<, <=, >, >=
```

Arithmetic, comparison, etc.

Keyword Messages:

```
  raisedTo:
bitAnd:, bitOr:
  show:
ifTrue:ifFalse:
```

Message with one or more arguments, ending in colon:

http://squeak.org/documentation/terse_guide/

Summary: Literals

```
| b x |
b := true.                  "true constant"
b := false.                 "false constant"
x := nil.                   "nil object constant"
x := 1.                     "integer constants"
x := 3.14.                  "float constants"
x := 2e-2.                  "fractional constants"
x := 16r0F.                 "hex constant"
x := -1.                    "negative constants"
x := 'Hello'.               "string constant"
x := 'I''m here'.           "single quote escape"
x := $A.                    "character constant"
x := $ .                    "character constant (space)"
x := #aSymbol.              "symbol constants"
x := #(3 2 1).              "array constants"
x := #('abc' 2 $a).         "mixing of types allowed"
```

Example: What is the Result?

Which messages are unary? Binary? Keywords?

```
3 factorial + 4 factorial between: 10 and: 100
```

1. factorial gets sent to 3, then 4.
2. + is sent to 6 with 24 as argument
3. between:and: sent to 30 with 10 and 100 as arguments

```
6 + 24 between: 10 and: 100

30 between: 10 and: 100

30 between: 10 and: 100
```

`true`

Continuing on…

Today

Continuing study of Smalltalk:

- Blocks, control flow
- Some Smalltalk collections

Blocks

Blocks

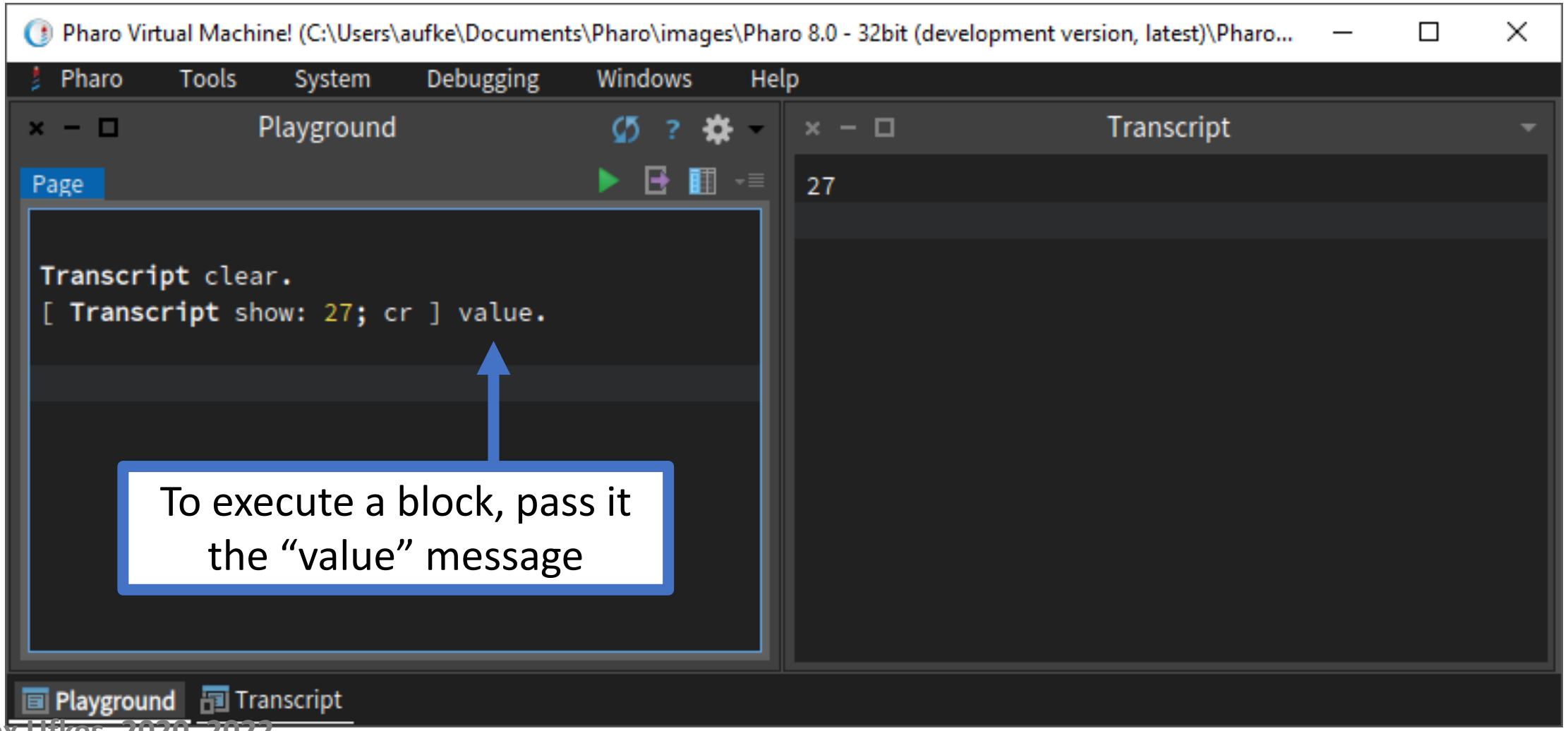
Defined with square brackets [ ]

Within the [ ] is Smalltalk code.

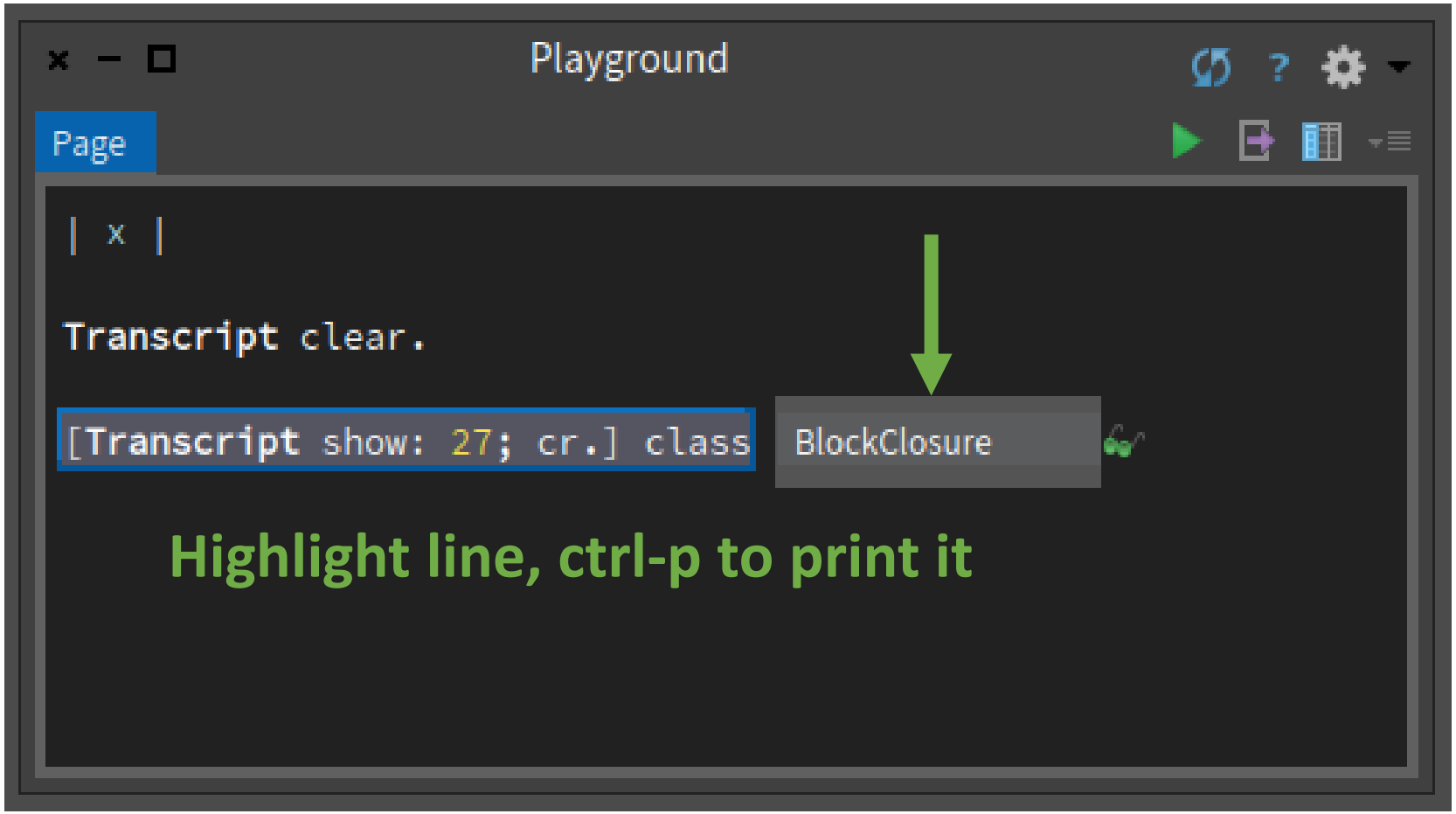
```
[ Transcript show: 27; cr ].
```

This block contains familiar code – we show the Integer 27 and do a carriage return.

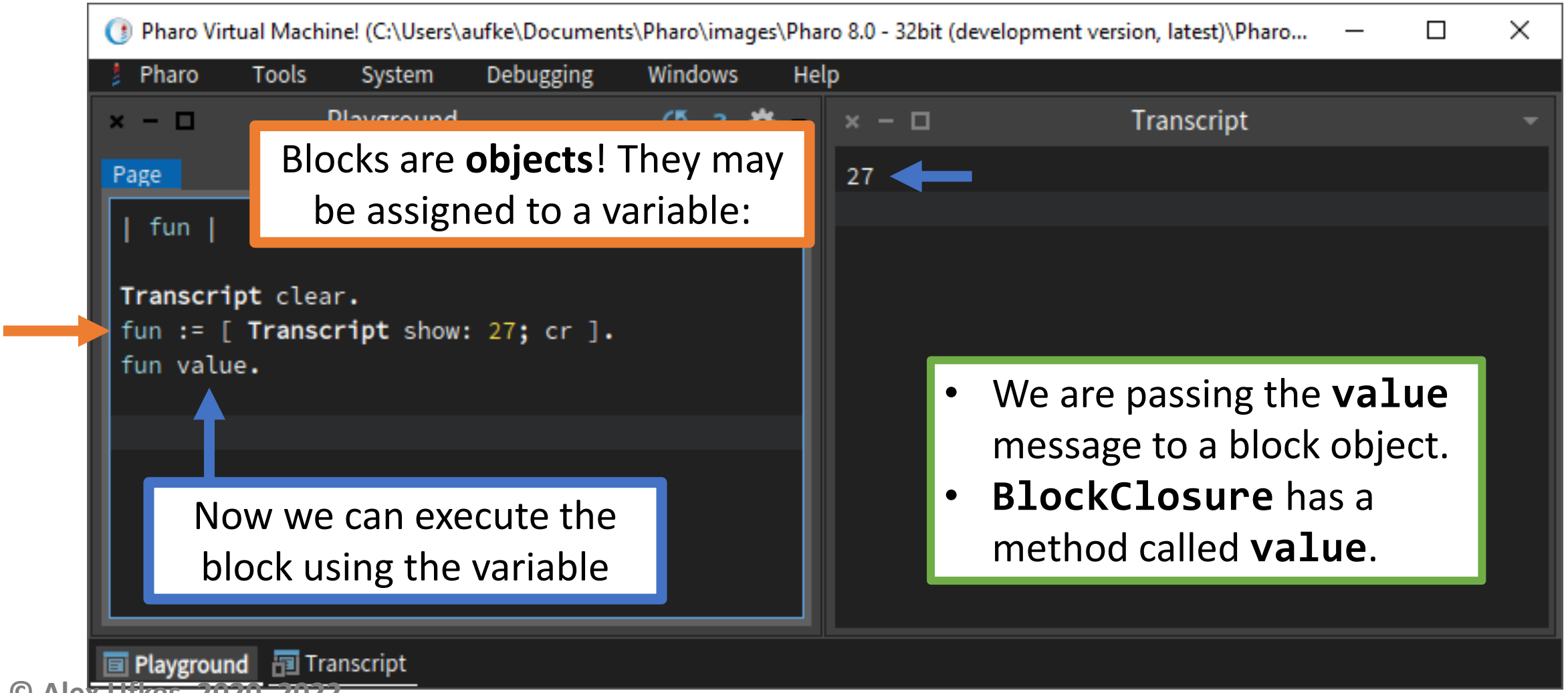
Blocks



Blocks are ***Objects***!



Blocks



Blocks as *Anonymous Functions*

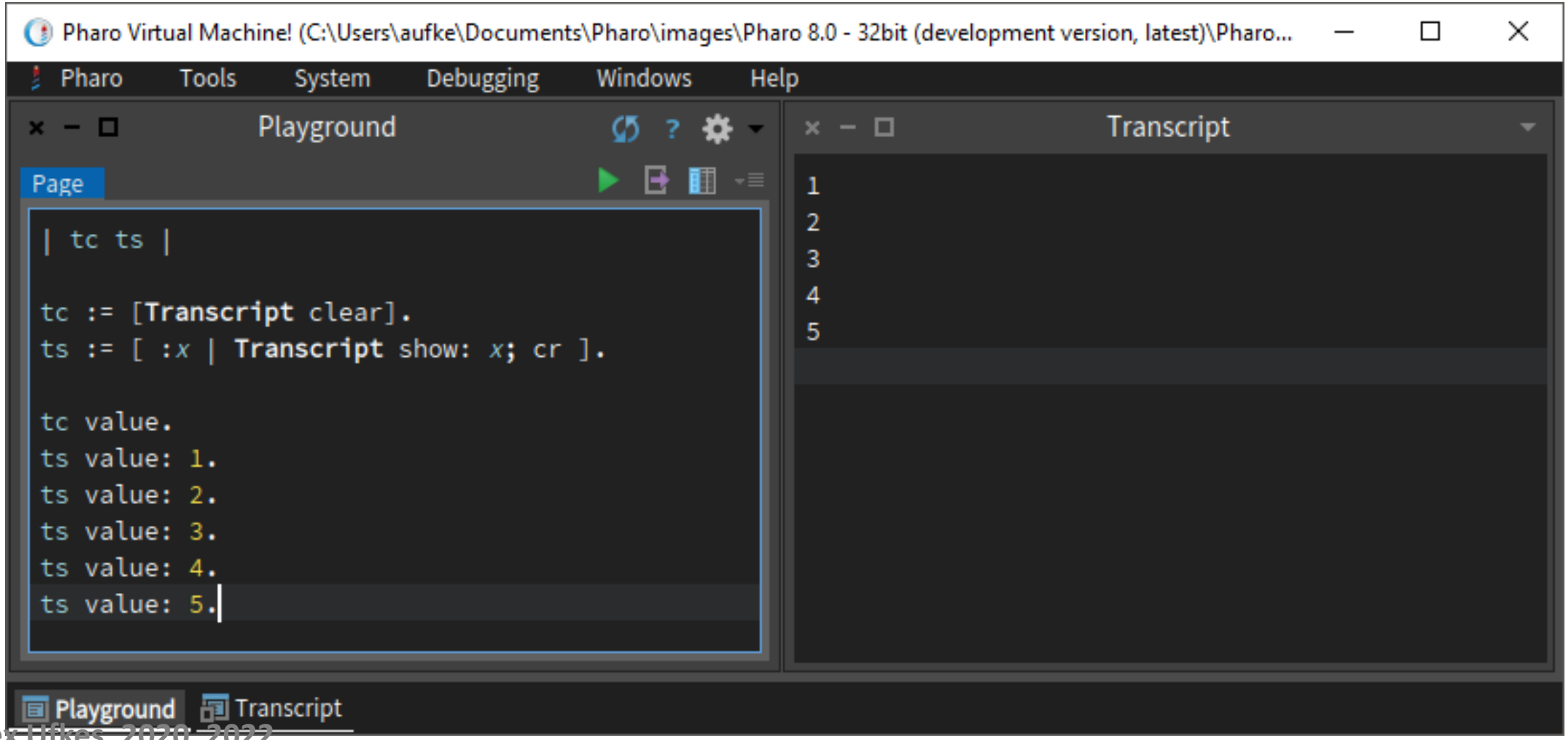
```
func := [ :x | Transcript show: x; cr. ].
```

- This is a parameter. Pharo allows up to **four**.
- *Think about why this limit of four might exist in practice.*

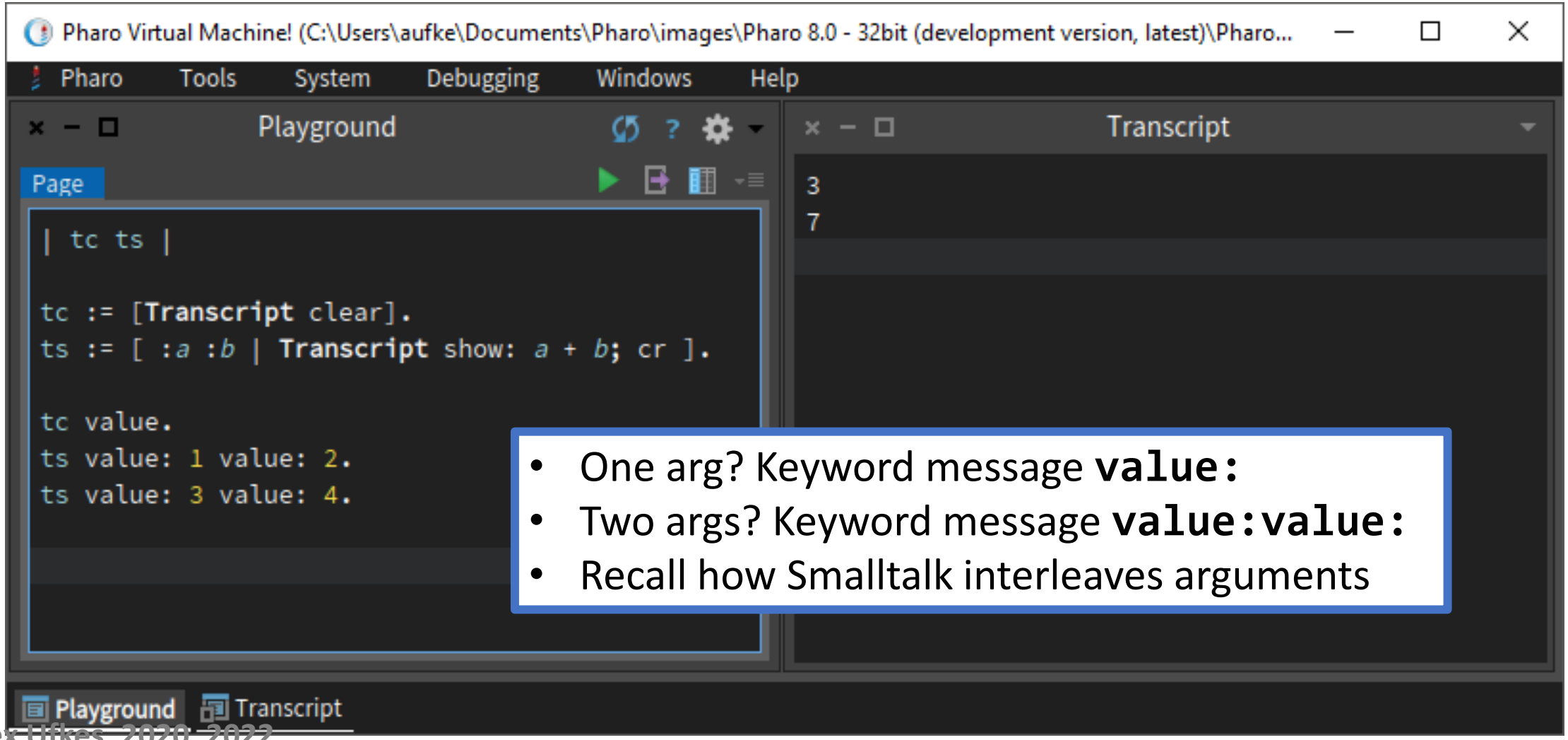
Argument(s) can be passed in when we send the keyword **`value:`** message (as opposed to the unary **`value`** message)

```
func value: 27.
```

Blocks with Arguments

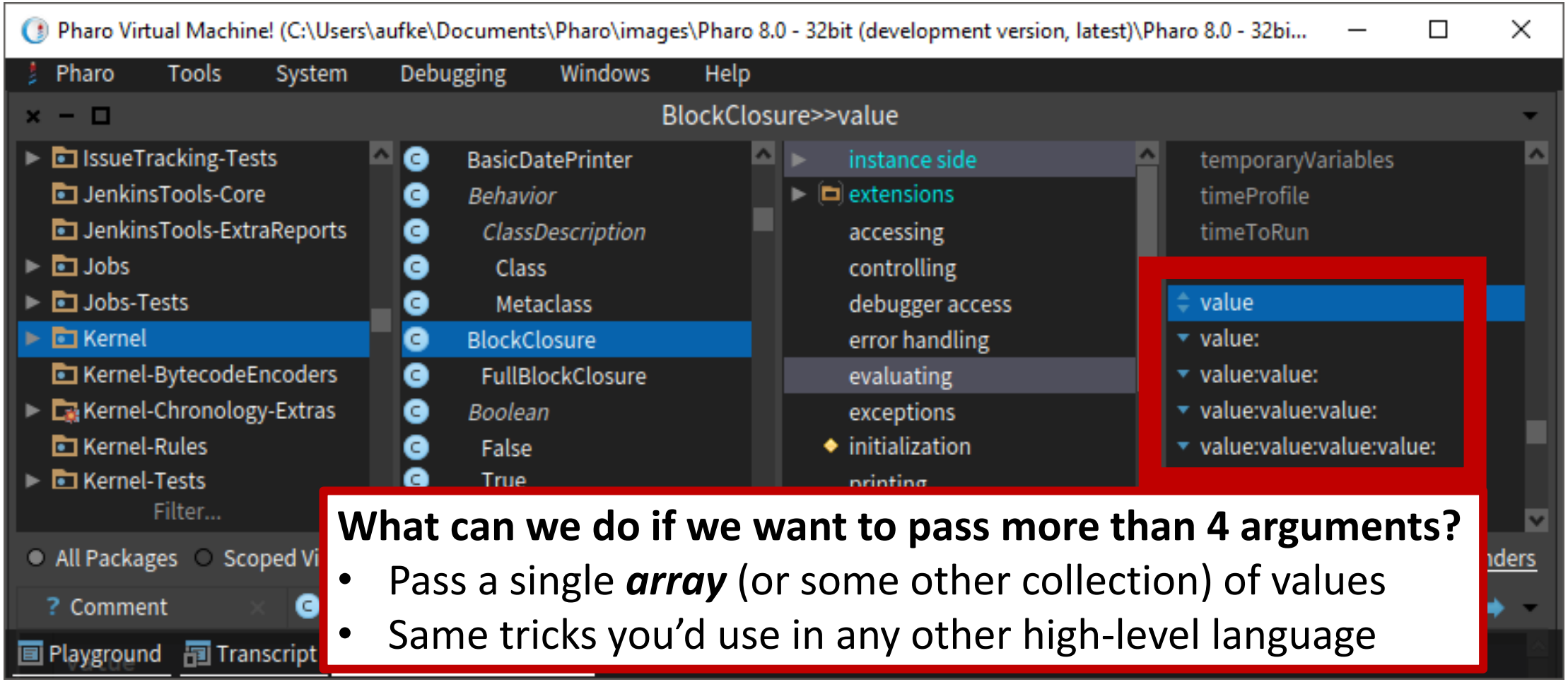


Blocks with Multiple Arguments



- One arg? Keyword message **`value:`**
- Two args? Keyword message **`value:value:`**
- Recall how Smalltalk interleaves arguments

value:value:value:value:value:value:value....



Reminder: Terminator VS Separator

```
func := [ :x | Transcript show: x; cr. ].
```

```
func := [ :x | Transcript show: x; cr ].
```

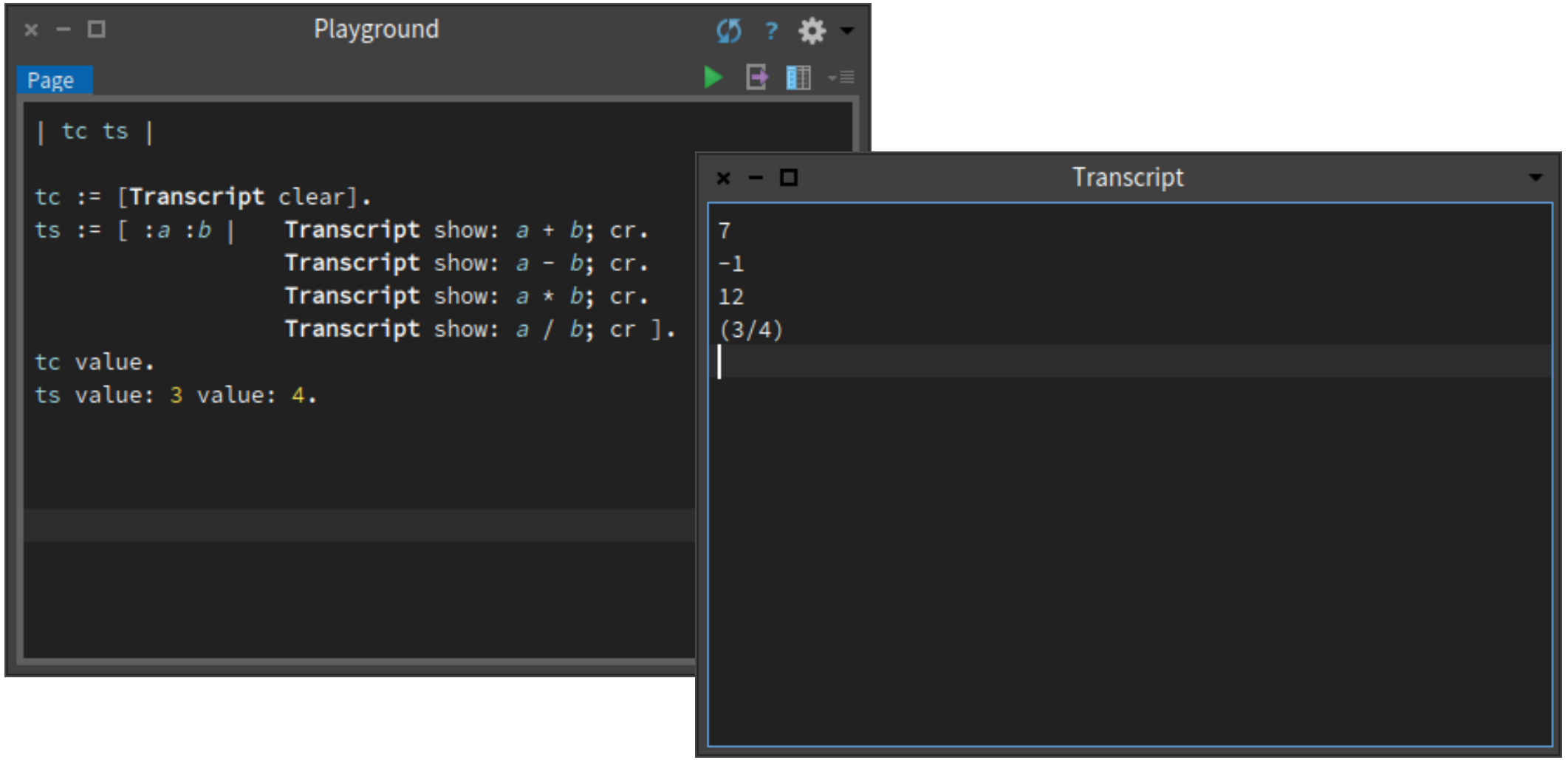
These both work. What's the difference, if any?

Reminder: Terminator VS Separator

In Java, semi-colon (;) is the statement ***terminator***.
In Smalltalk, period (.) is the statement ***separator***.

- Thus, we do not need a period after the last statement we're executing.
- This applies to blocks as well. Period not required after the last statement in a block
- Of course, it's not *illegal* to have it there, just redundant

Blocks: Multiple Statements



Nice blocks, what can you build with them?

Control Structures

Boolean Expressions

Control Structures: Branching/Selection

In Java we have syntax (reserved words) for selection:

```
if (x > y)
   System.out.println(“True”);
else
   System.out.println(“False”);
```

Control structures in Smalltalk do not have special syntax.

They are realized using blocks and message passing!

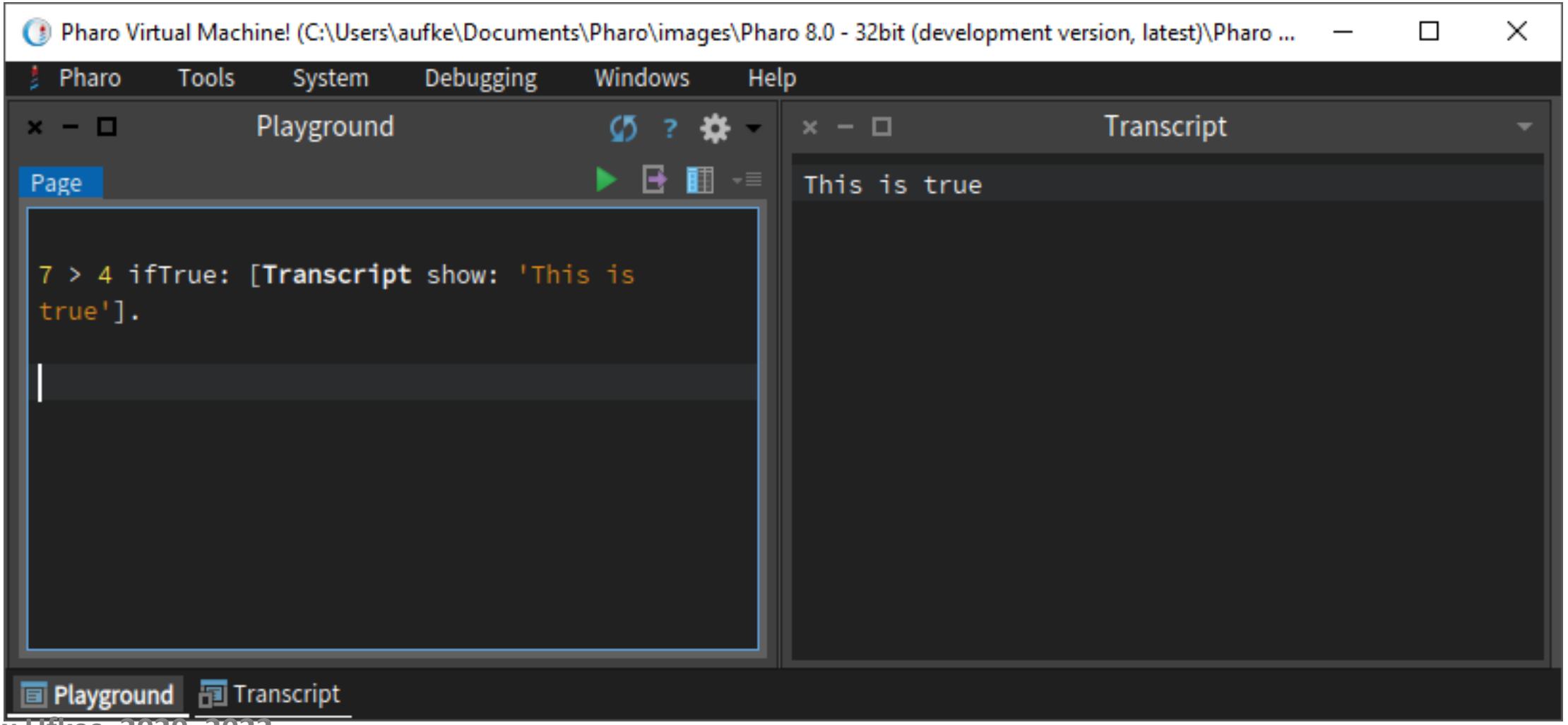
Control Structures: Branching/Selection

They are realized using **blocks** and **message passing**!

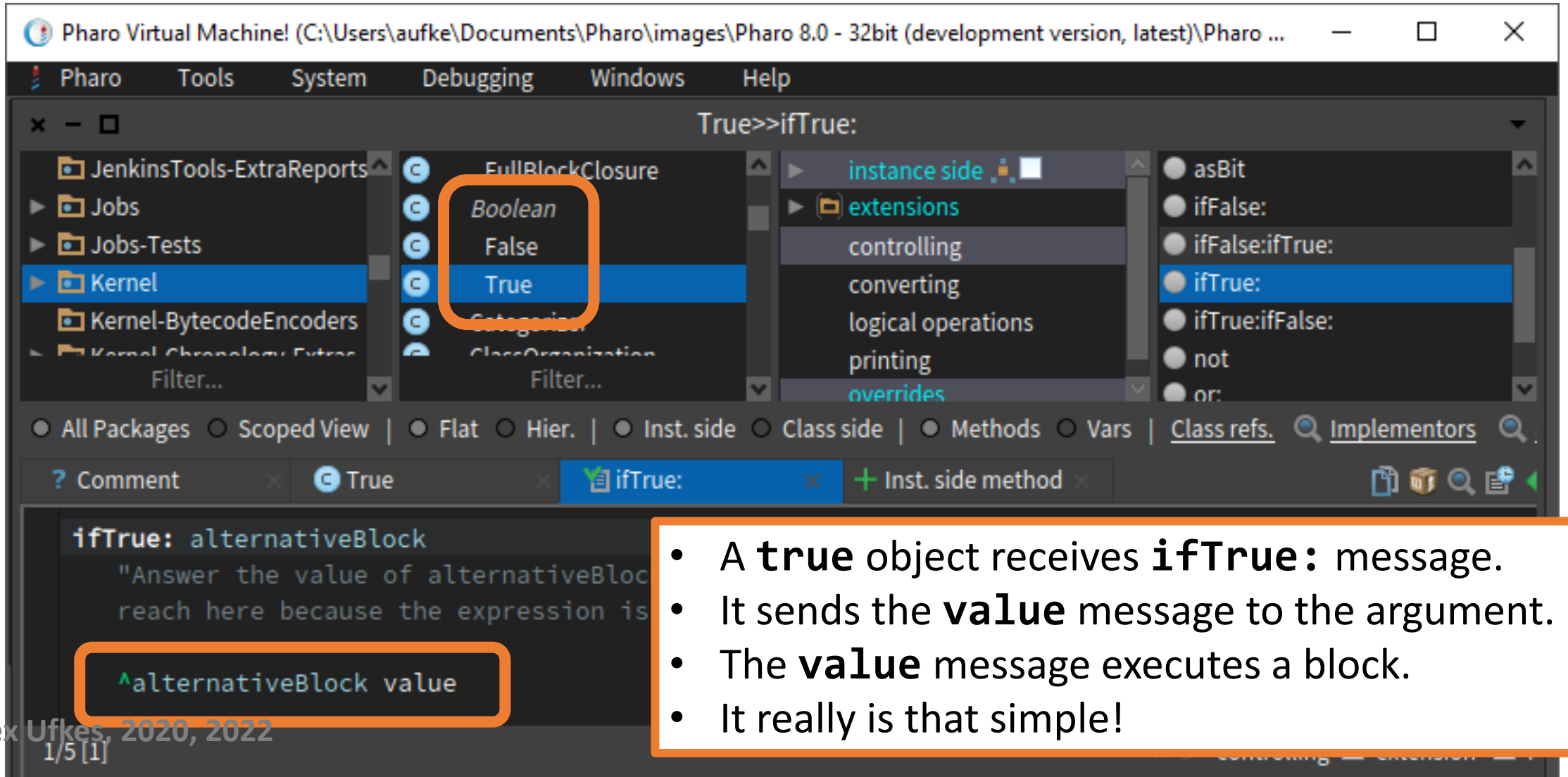
```
7 > 4 ifTrue: [Transcript show: 'This is true'].
```

1) **7 > 4** evaluated first (*why?*), results in Boolean object
2) **ifTrue:** message sent to Boolean object with BlockClosure argument **`[Transcript show: 'This is true']`**.
   - Suggests that a Boolean object (`true`, `false`) knows how to handle the **`ifTrue:`** message.
   - Who can guess what the **`ifTrue:`** method is going to do with its argument?

```
7 > 4 ifTrue: [Transcript show: 'This is true'].
```

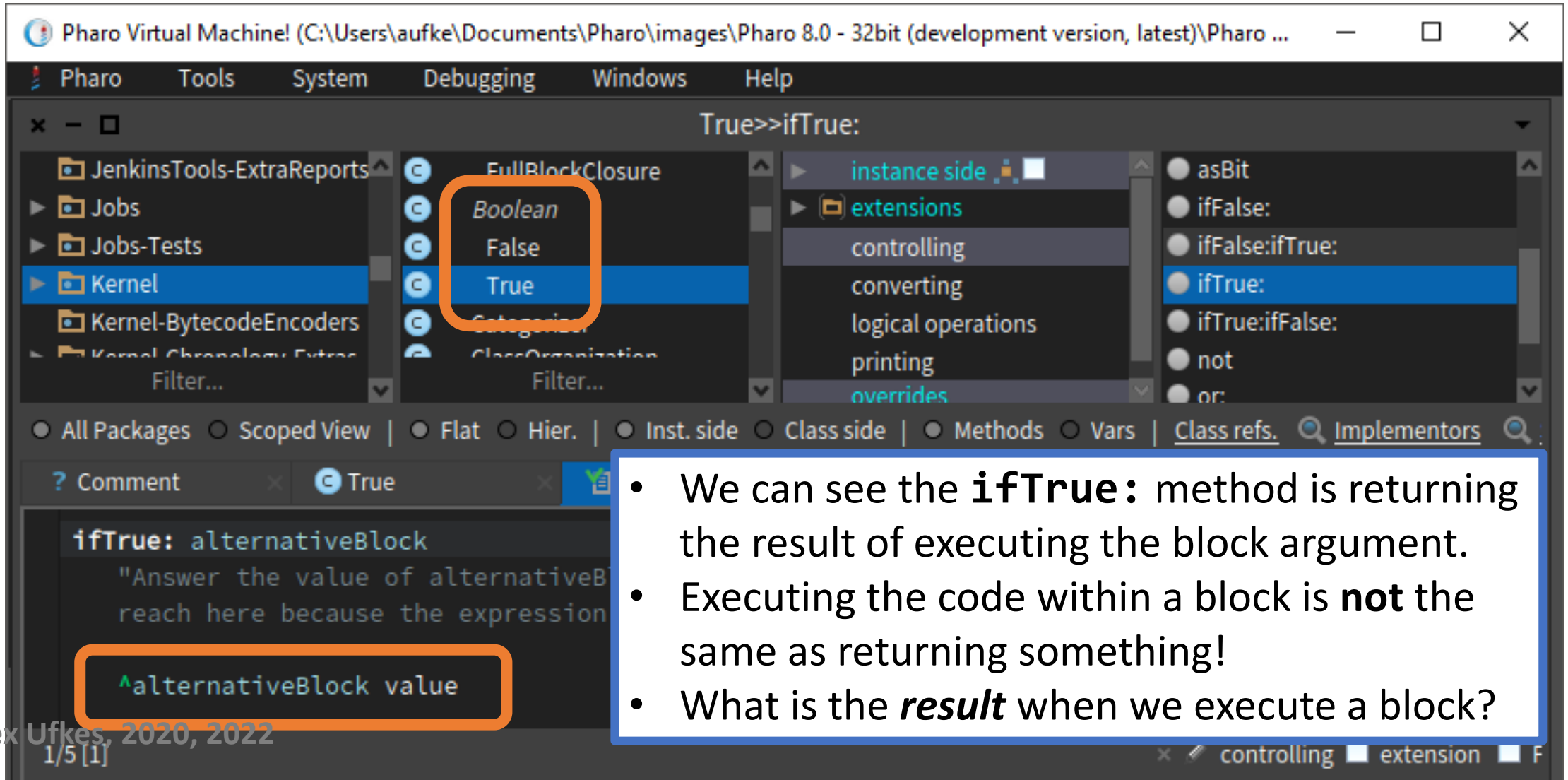


`ifTrue:` must be very complicated…



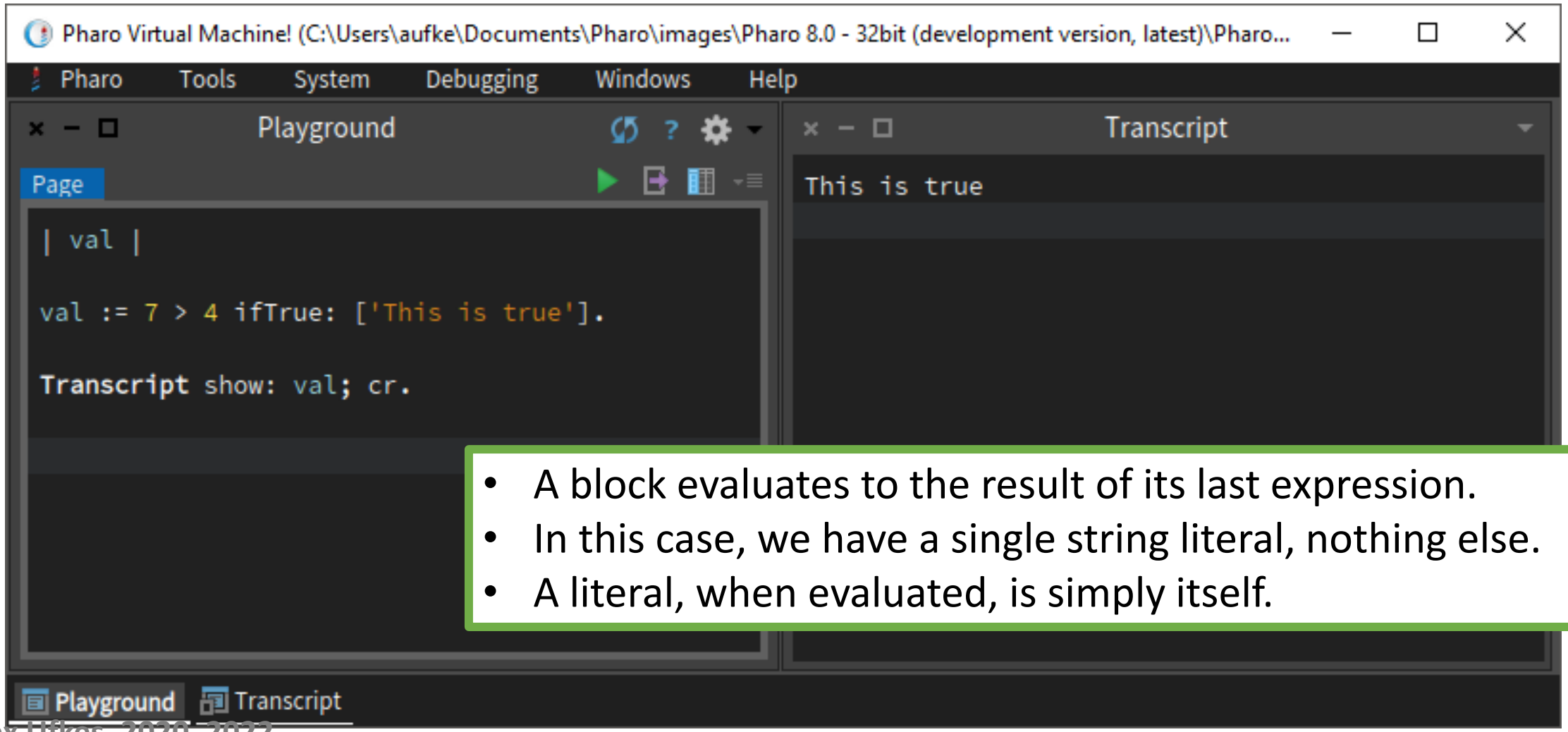
- A **`true`** object receives **`ifTrue:`** message.
- It sends the **`value`** message to the argument.
- The **`value`** message executes a block.
- It really is that simple!

`ifTrue:` must be very complicated…



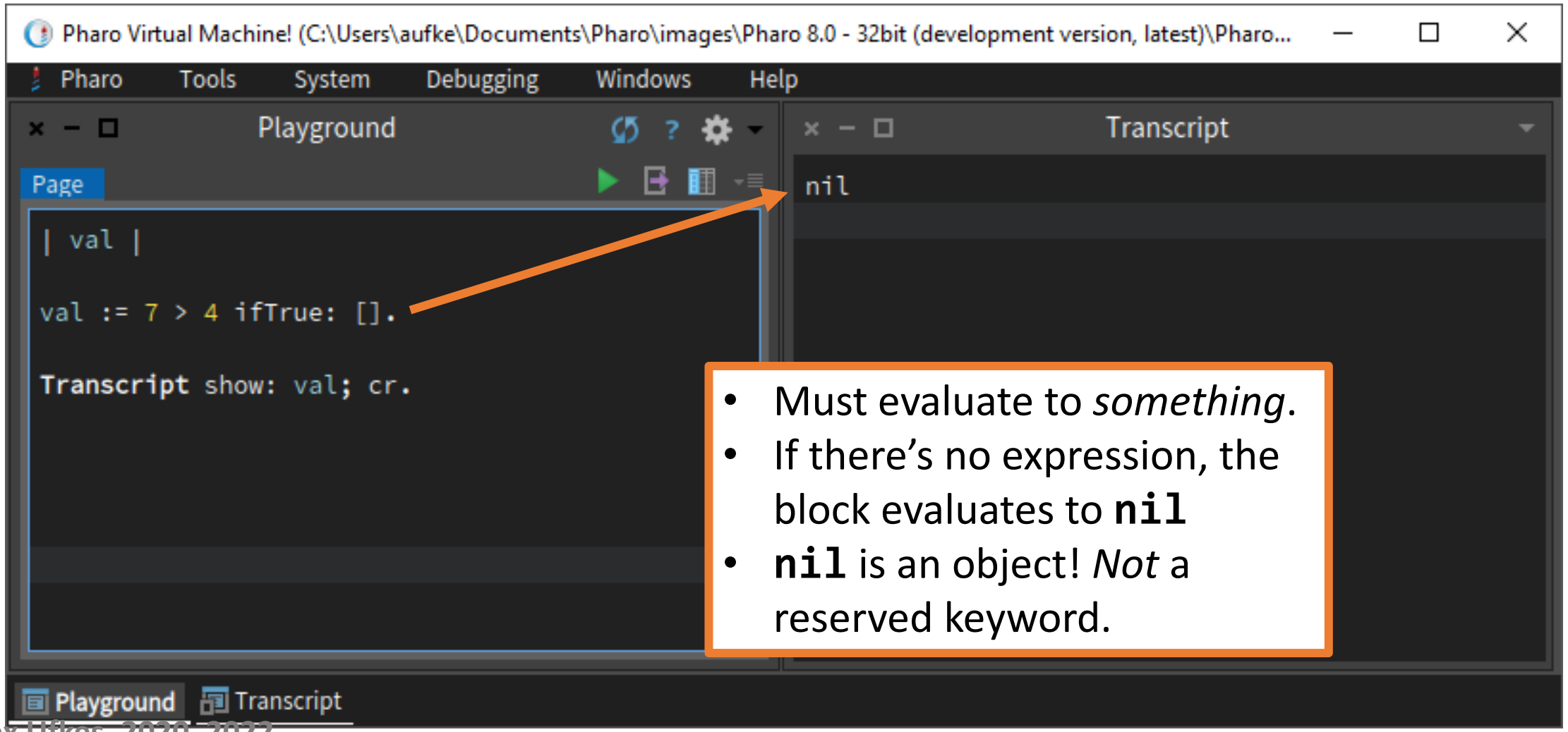
- We can see the **`ifTrue:`** method is returning the result of executing the block argument.
- Executing the code within a block is **not** the same as returning something!
- What is the ***result*** when we execute a block?

Evaluating Blocks



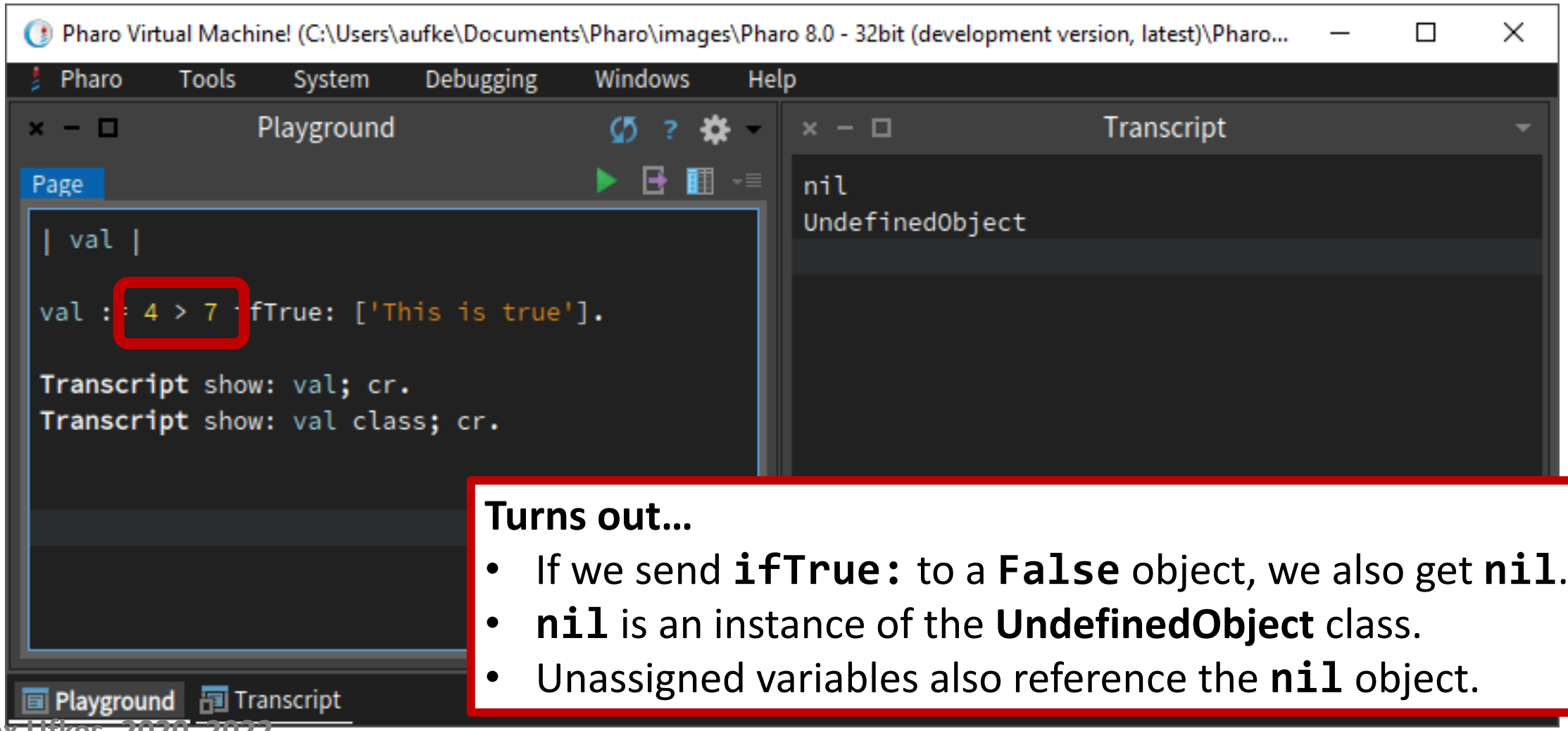
- A block evaluates to the result of its last expression.
- In this case, we have a single string literal, nothing else.
- A literal, when evaluated, is simply itself.

Evaluating Blocks



- Must evaluate to *something*.
- If there's no expression, the block evaluates to **`nil`**
- **`nil`** is an object! *Not* a reserved keyword.

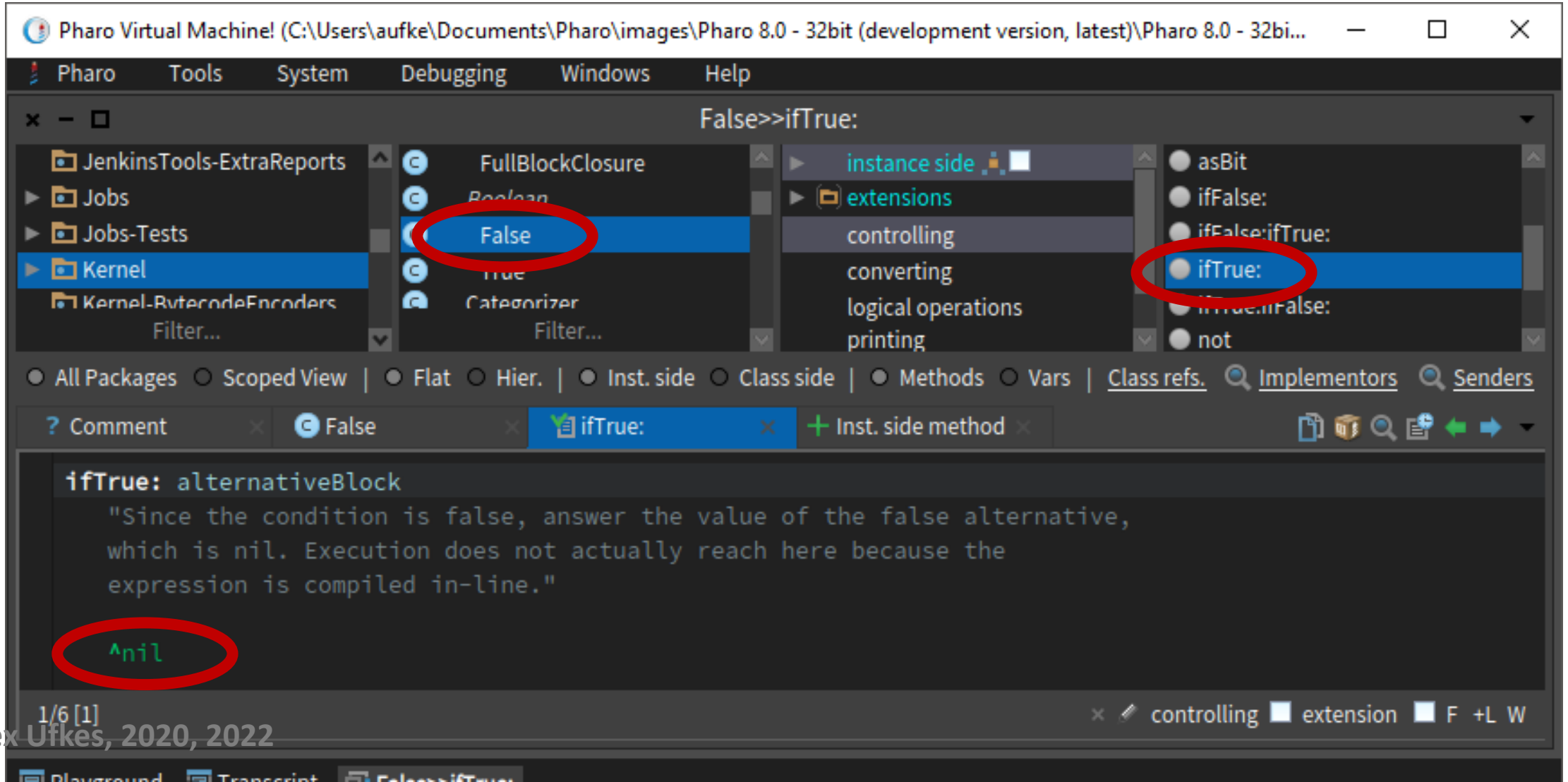
nil



Turns out…

- If we send **`ifTrue:`** to a **`False`** object, we also get **`nil`**.
- **`nil`** is an instance of the **UndefinedObject** class.
- Unassigned variables also reference the **`nil`** object.

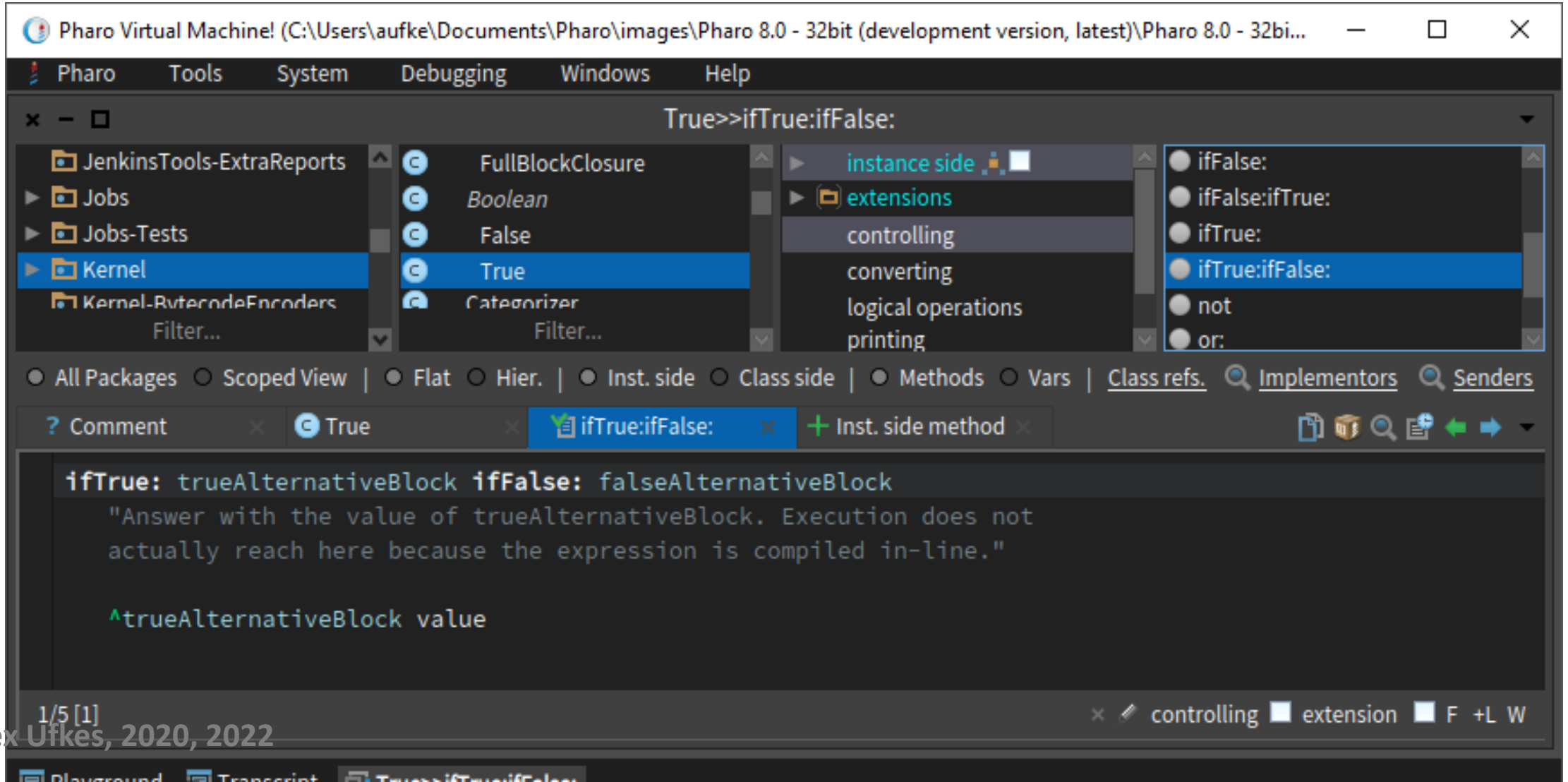
nil



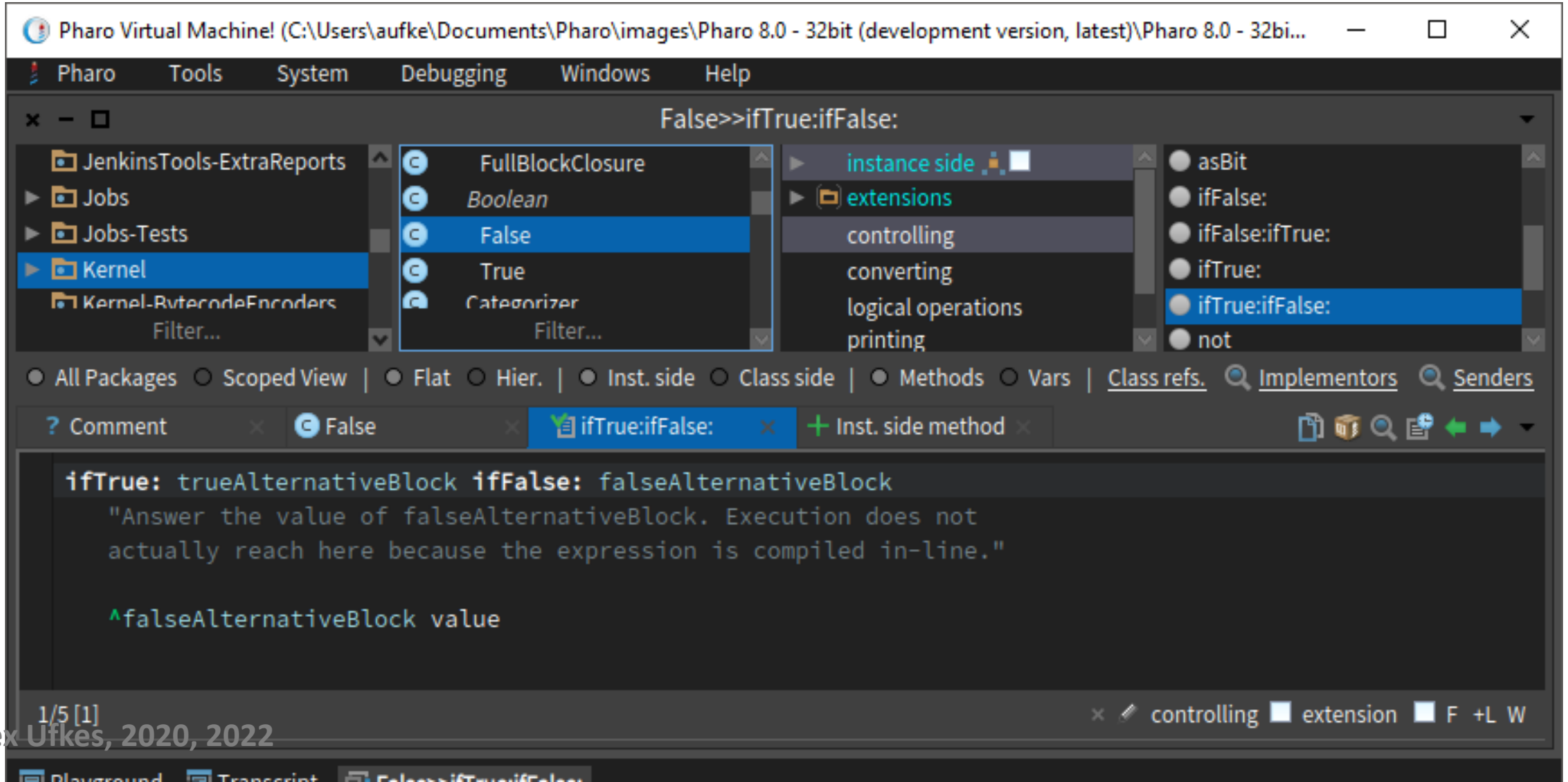
`ifTrue:ifFalse:`

- By now, we know this is a keyword message that takes two arguments. Both are blocks.
- The block that gets executed depends on whether the message is sent to a **`true`** object or a **`false`** object.

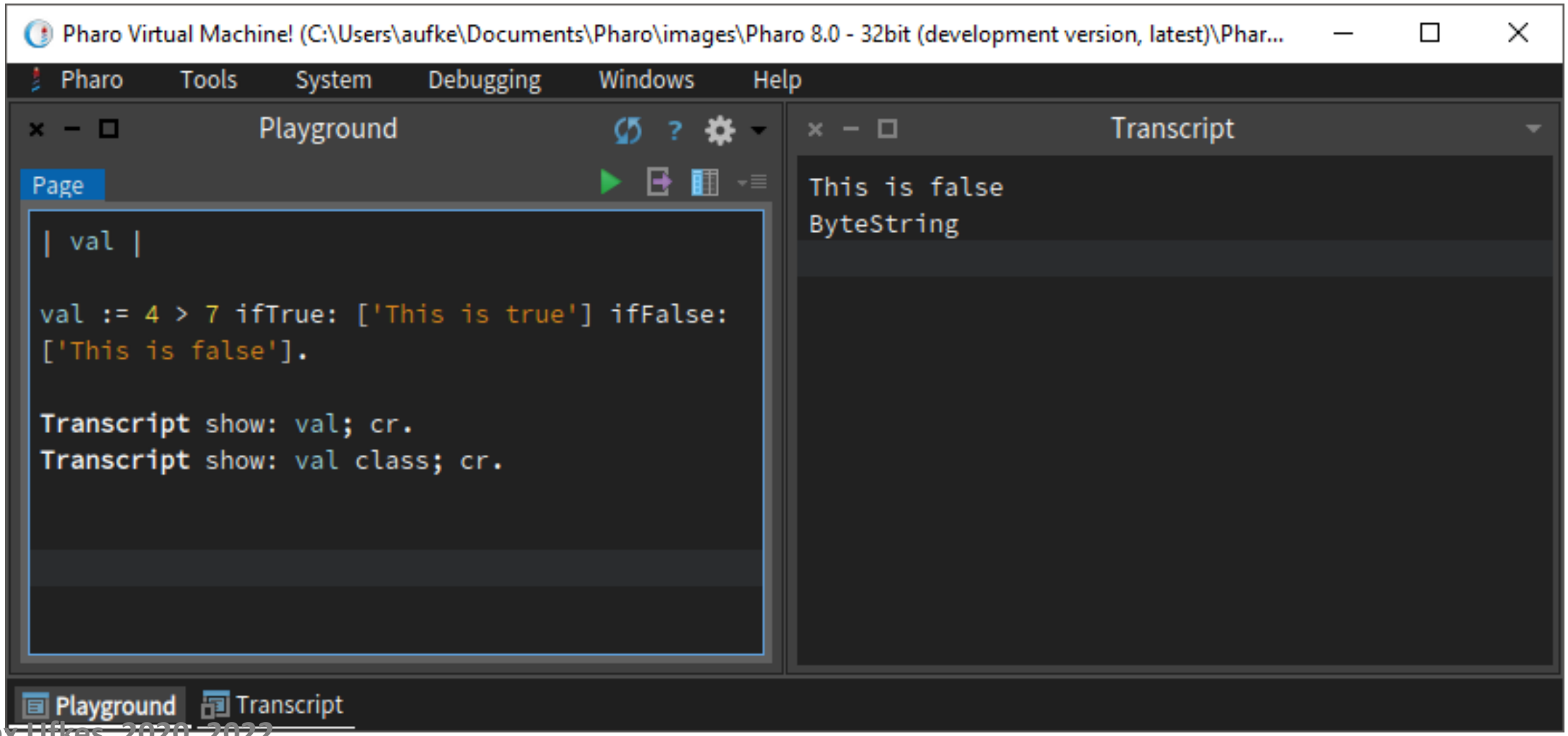
ifTrue:ifFalse:



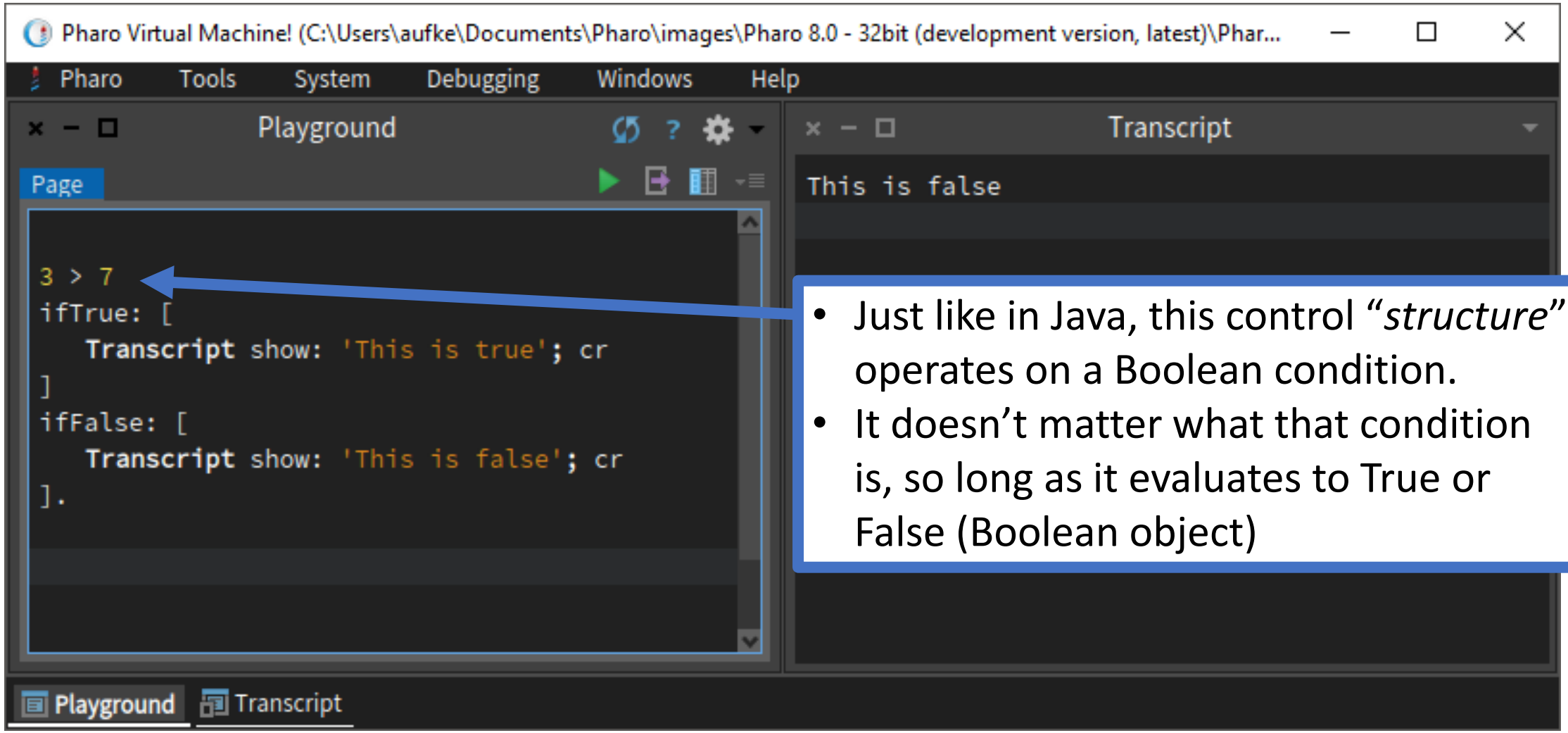
ifTrue:ifFalse:



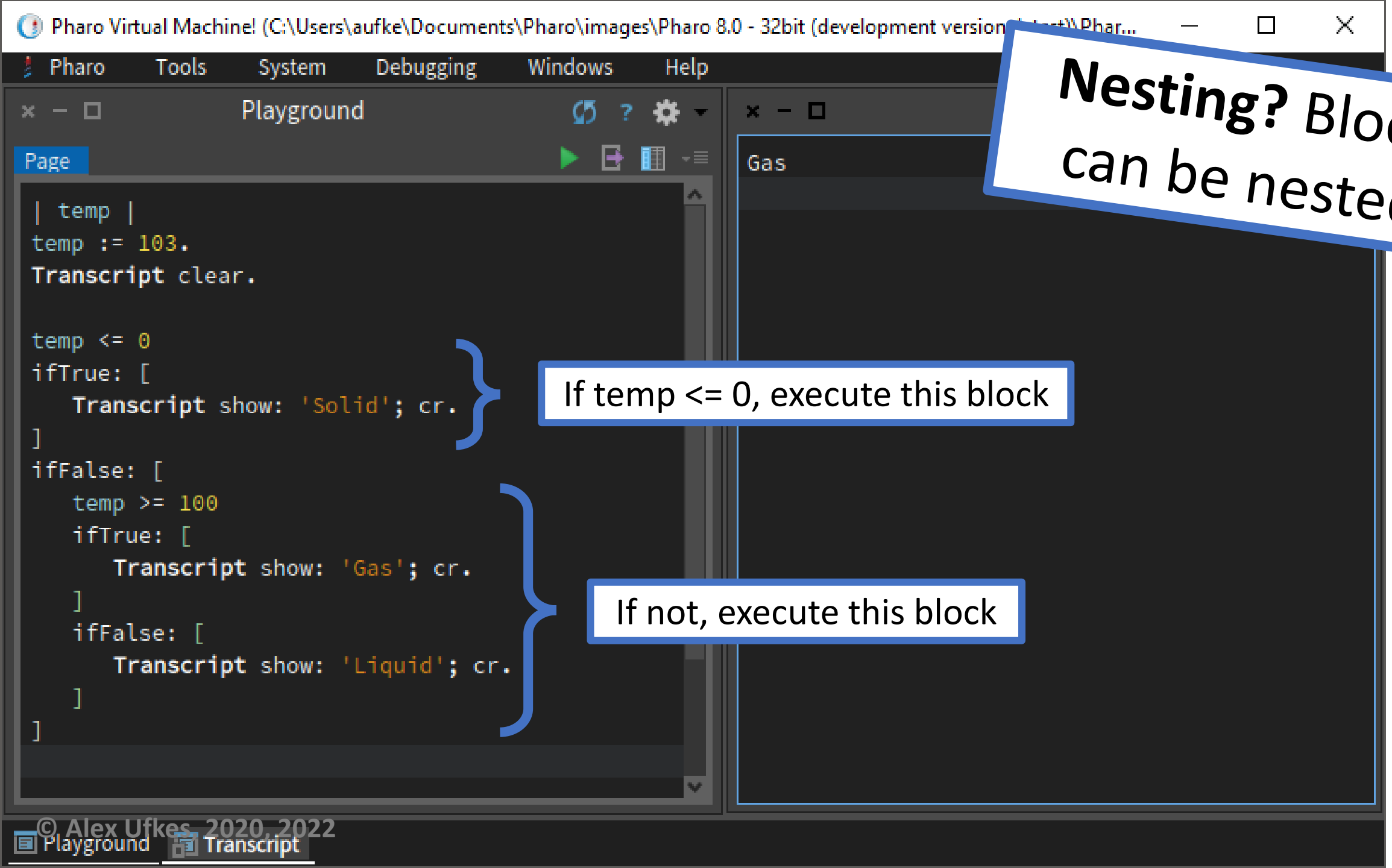
ifTrue:ifFalse:

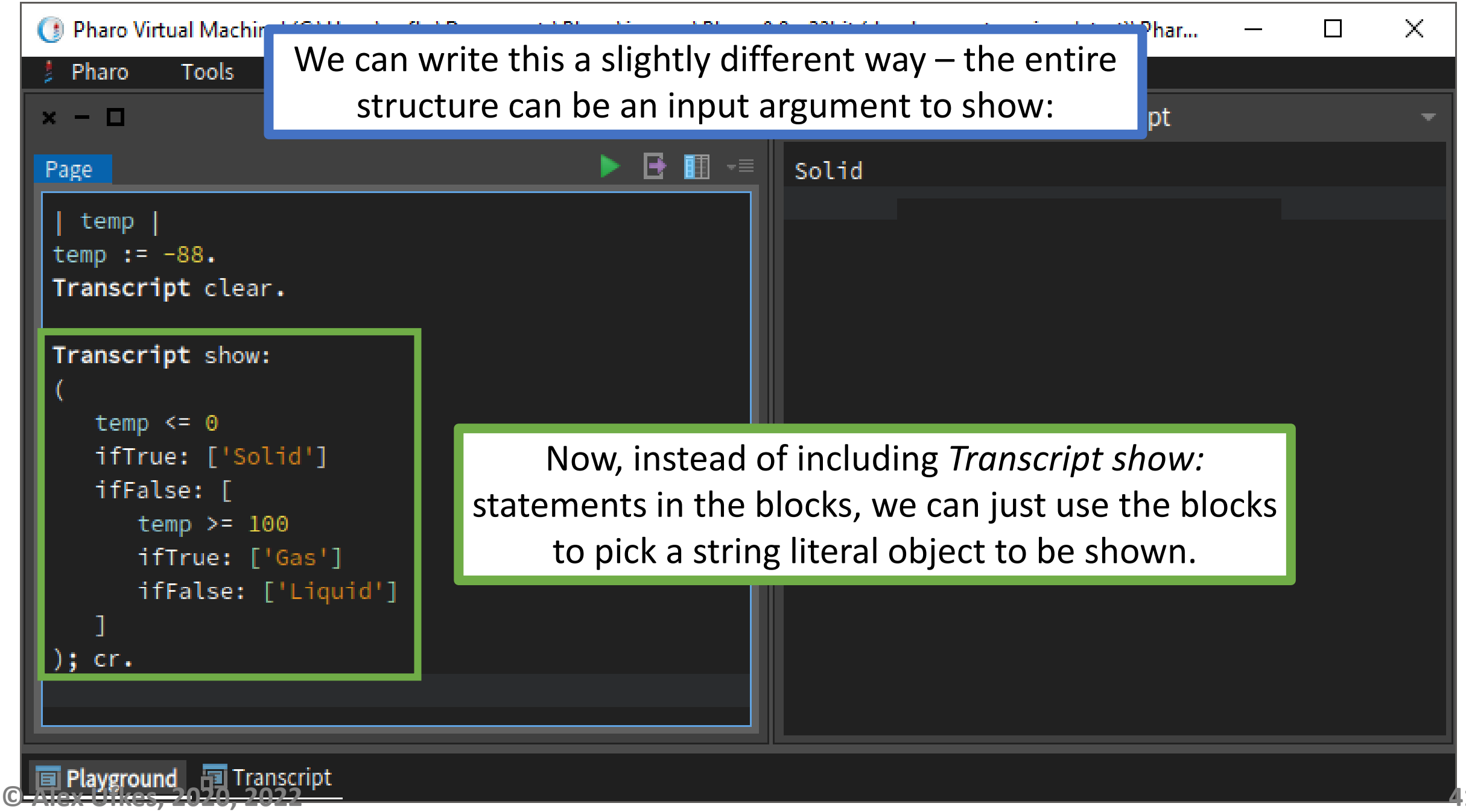


We can arrange the code to make the structure look more familiar:

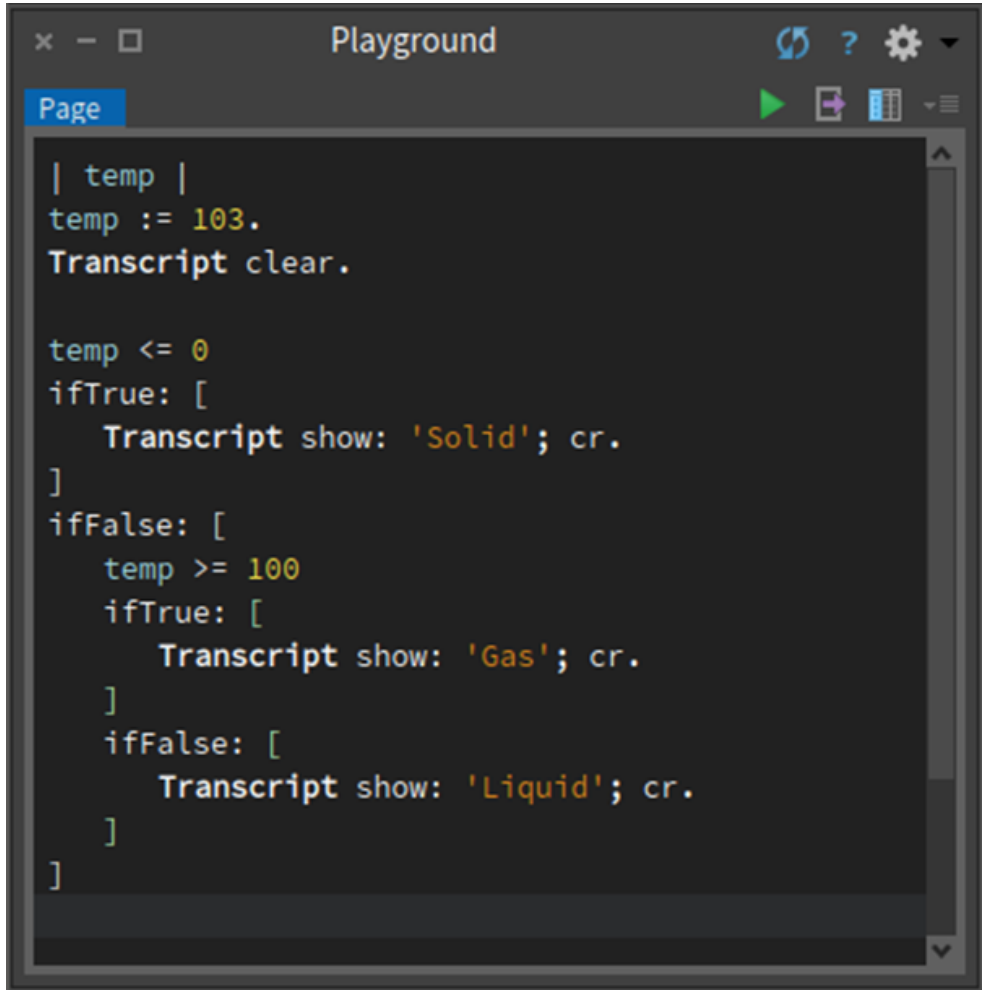


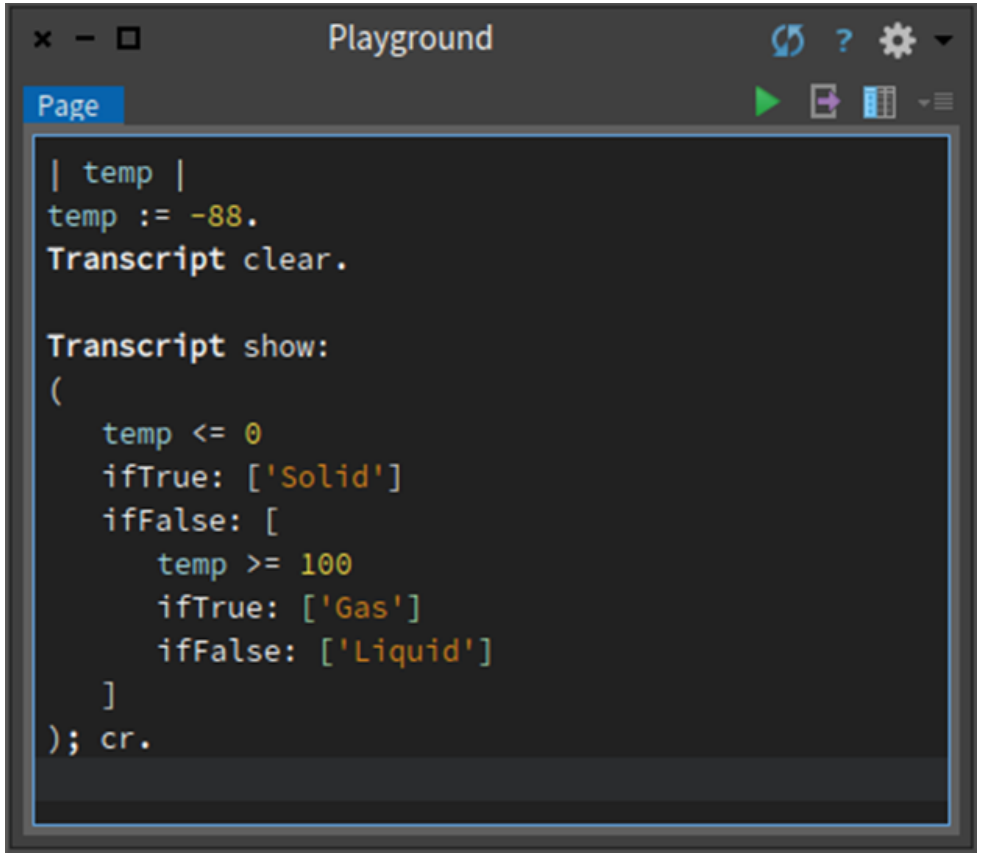
- Just like in Java, this control "*structure*" operates on a Boolean condition.
- It doesn't matter what that condition is, so long as it evaluates to True or False (Boolean object)





Different Syntax, Same Semantics





Different Syntax, Same Semantics

Playground

Page

```
| temp |
temp := -88.
Transcript clear.

Transcript show:
(
   temp <= 0
   ifTrue: ['Solid']
   ifFalse: [
      temp >= 100
      ifTrue: ['Gas']
      ifFalse: ['Liquid']
   ]
); cr.
```

Playground

Page

```
| temp result |
temp := -88.

result := temp <= 0 ifTrue: ['Solid']
   ifFalse: [ temp >= 100 ifTrue: ['Gas']
      ifFalse: ['Liquid'] ].

Transcript clear; show: result; cr.
```

This is great practice – rearrange code to be as small/efficient as possible. It will help you truly understand how the syntax works.

```
temp := 88.

temp <= 0 ifTrue: ['Solid'] ifFalse: [temp >= 100 ifTrue:
                                        ['Gas'] ifFalse: ['Liquid']].
```

Does not evaluate yet!

This goes first!

```
false ifTrue: ['Solid'] ifFalse: [temp >= 100 ifTrue: ['Gas']
                                              ifFalse: ['Liquid']].
```

Passed to false object

```
temp >= 100 ifTrue: ['Gas'] ifFalse: ['Liquid']
```

This goes first!

```
false ifTrue: ['Gas'] ifFalse: ['Liquid']
```

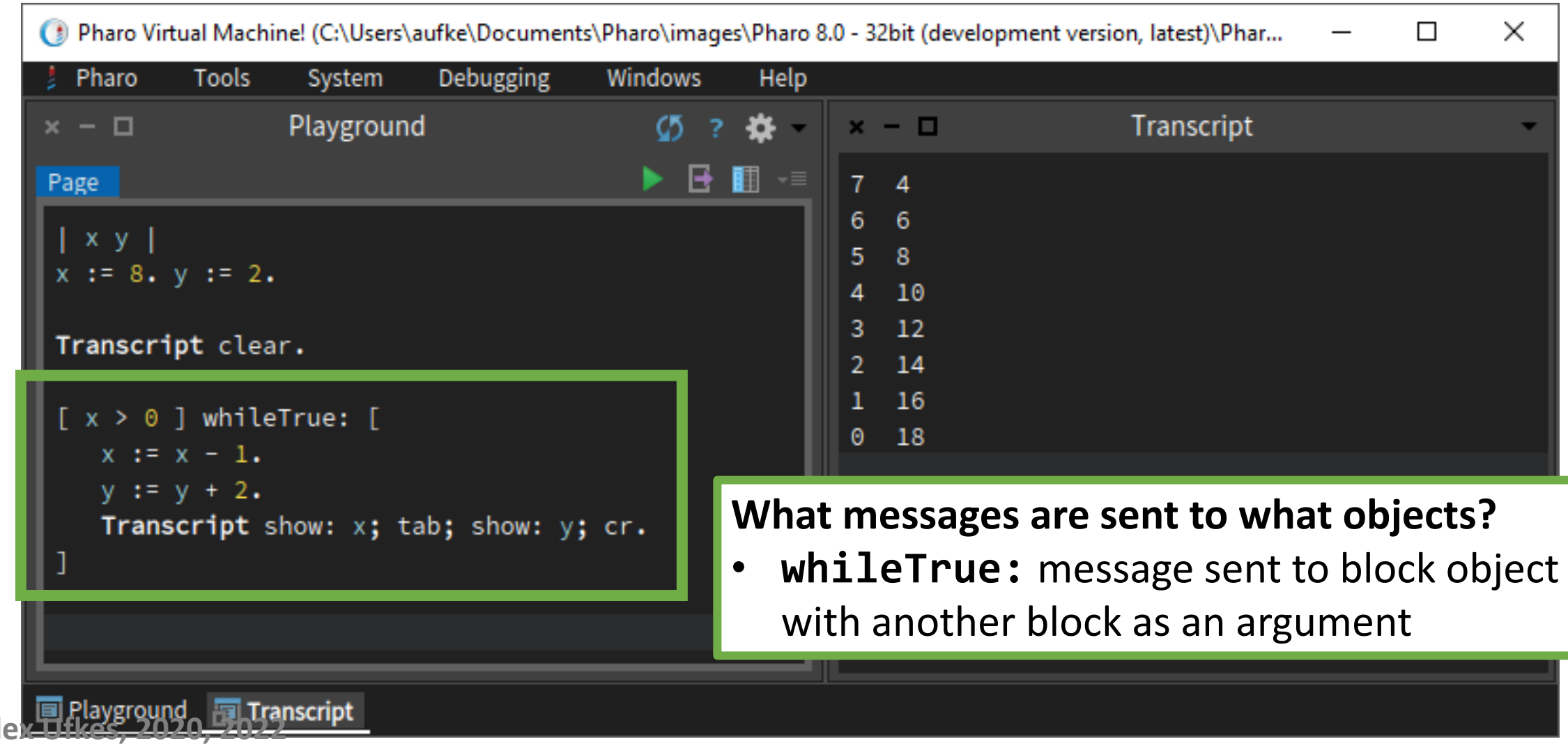
Passed to false object

```
false ifTrue: ['Gas'] ifFalse: ['Liquid'].
```


```
'Liquid'
```

Finally, when all the message passes have been evaluated, we're left with `'Liquid'`

Repetition Using Messages & Blocks



What messages are sent to what objects?

- **`whileTrue:`** message sent to block object with another block as an argument

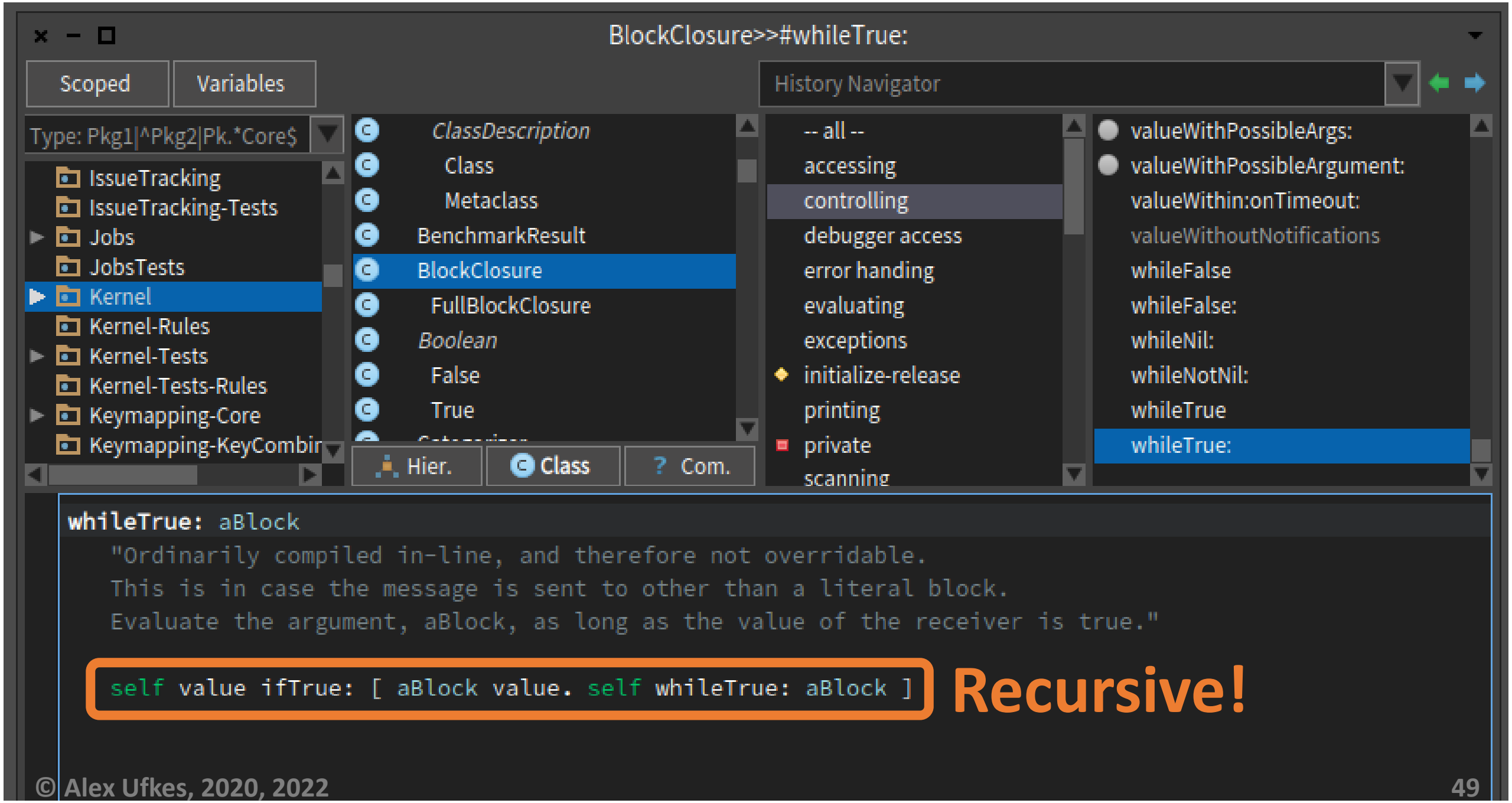
Repetition Using Messages & Blocks

```
[x > 0] whileTrue: [ x := x - 1. y := y + 2. ].
```

`whileTrue:` message sent to block containing Boolean expression x > 0

The BlockClosure class understands the `whileTrue:` message.

The argument that accompanies the `whileTrue:` message is a block containing the code to be repeated.



- Send ifTrue: message to Boolean
- Argument is a Block object

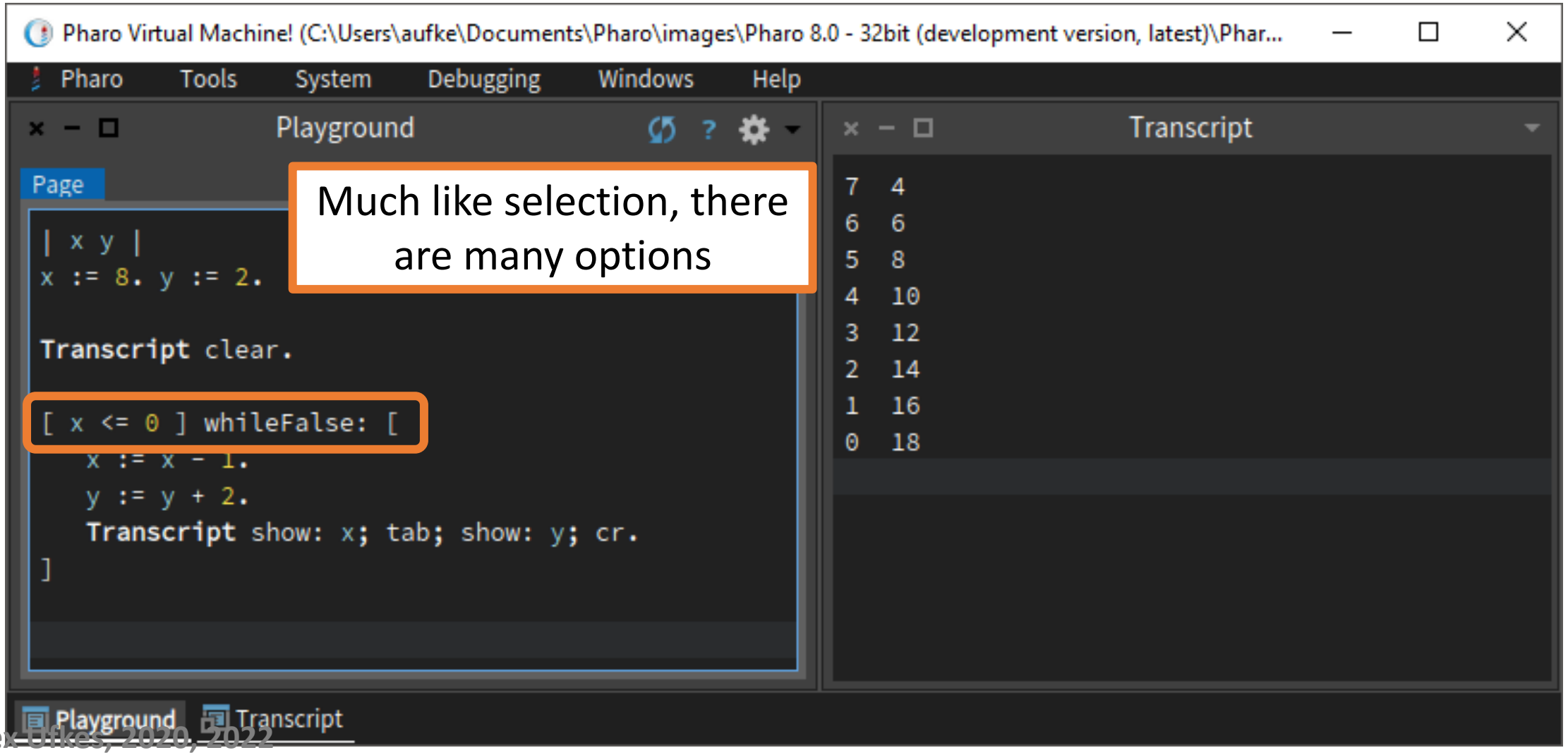
Finally, send **`whileTrue:`** once more to the same block, with the same argument.

```
self value ifTrue: [ aBlock value. self whileTrue: aBlock ]
```

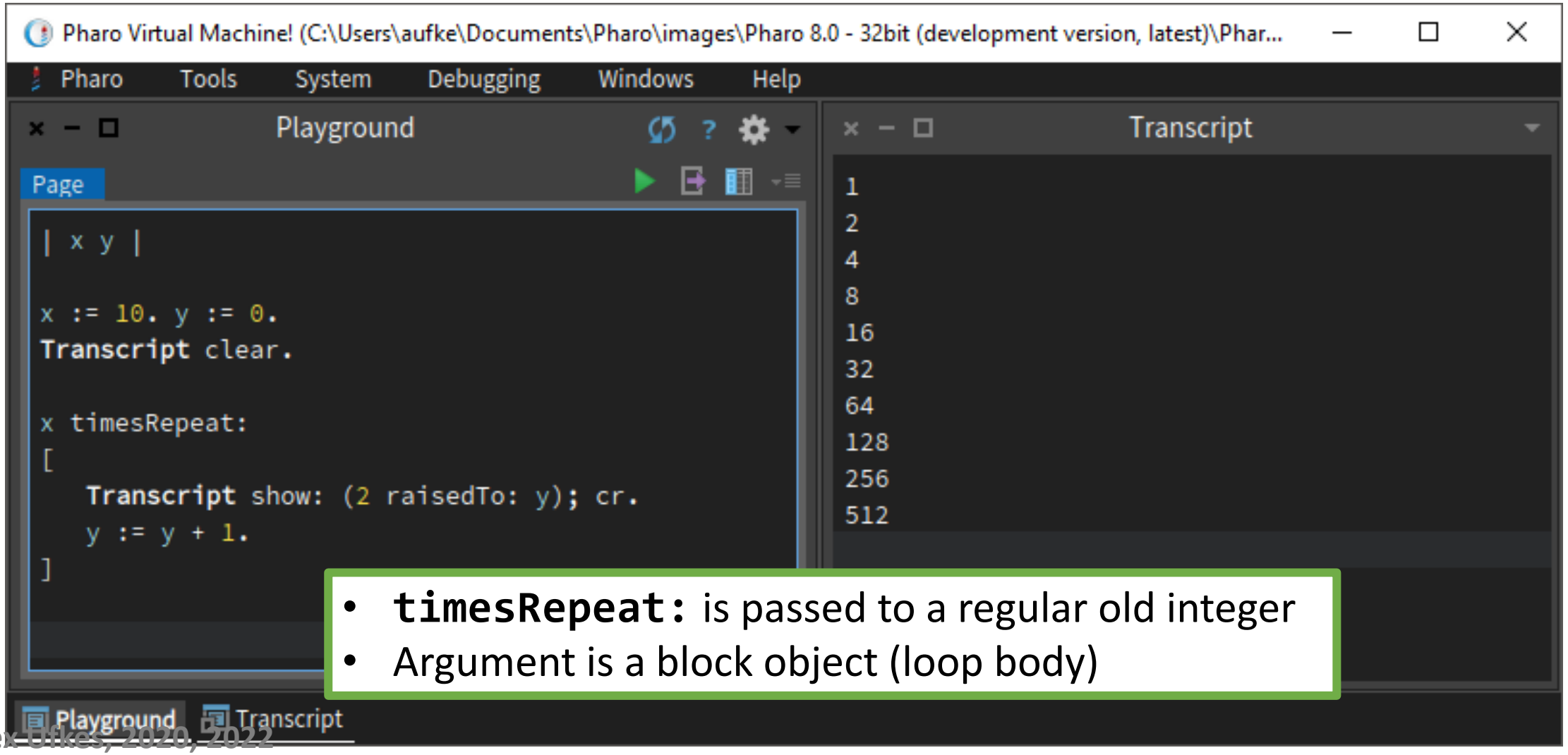
- Send value message to **`self`**, which executes it
- **`self`** evaluates to a Bool

- **`aBlock`** is the input argument first passed with the **`whileTrue:`** message
- We execute it once

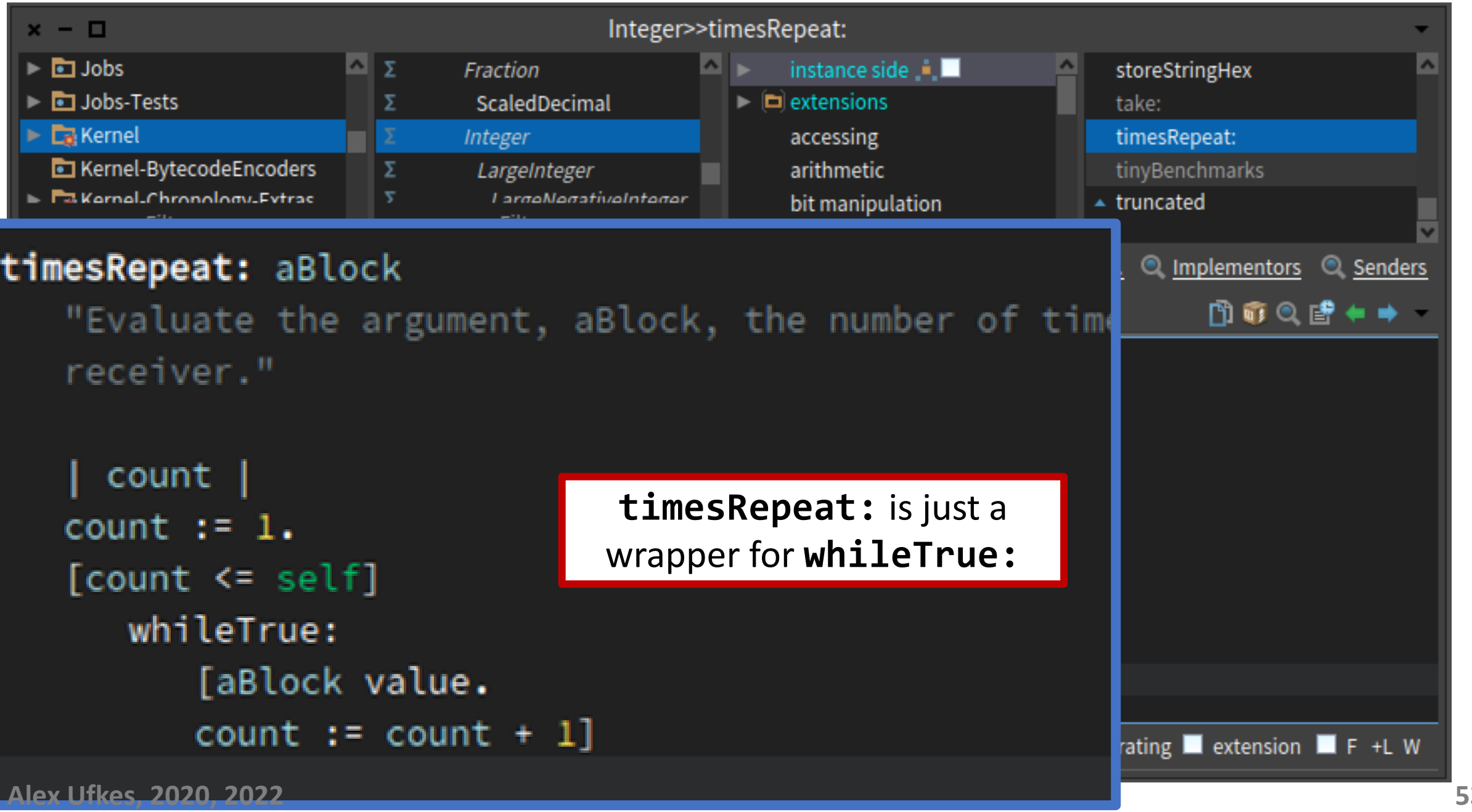
Repetition Using Messages & Blocks



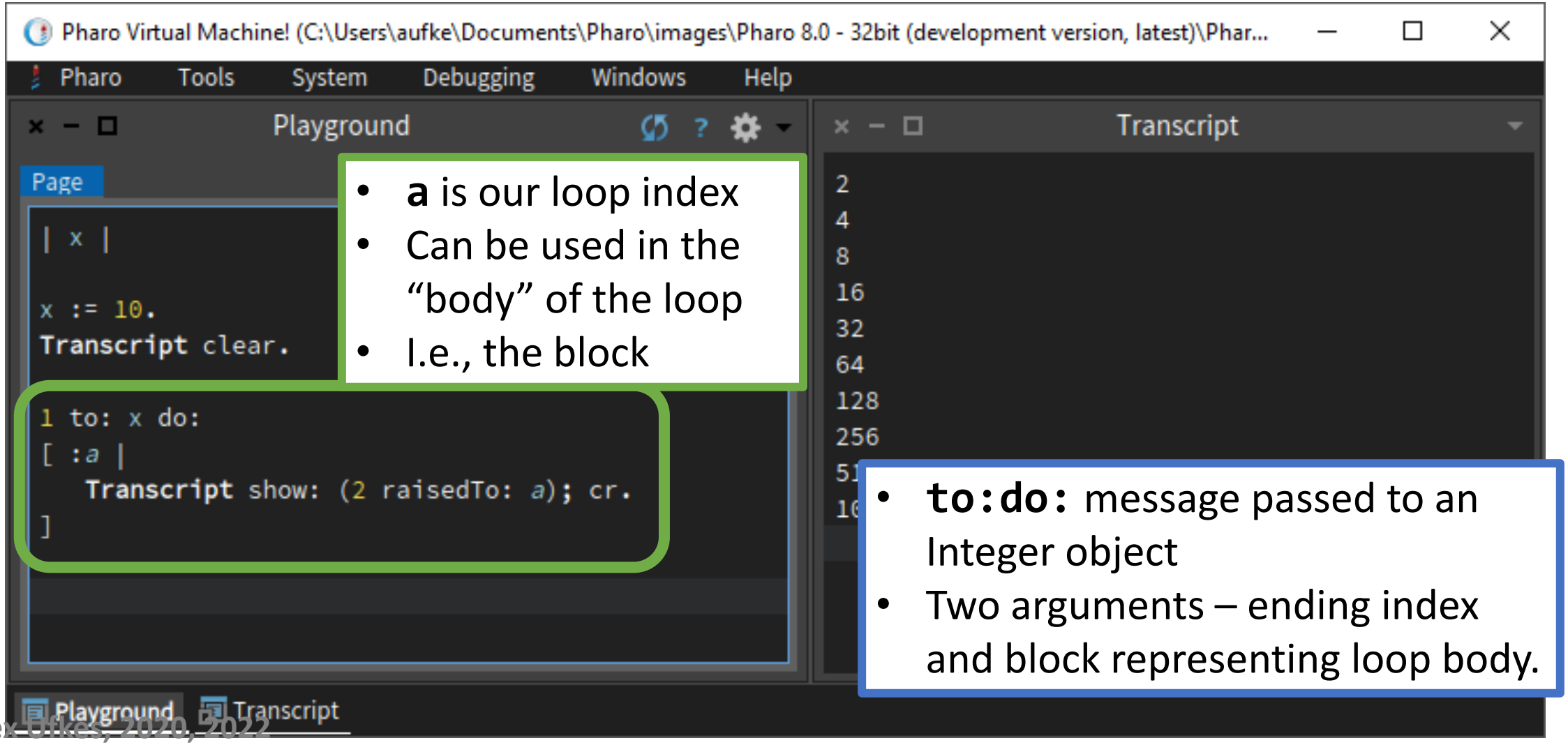
`timesRepeat:`



- **`timesRepeat:`** is passed to a regular old integer
- Argument is a block object (loop body)

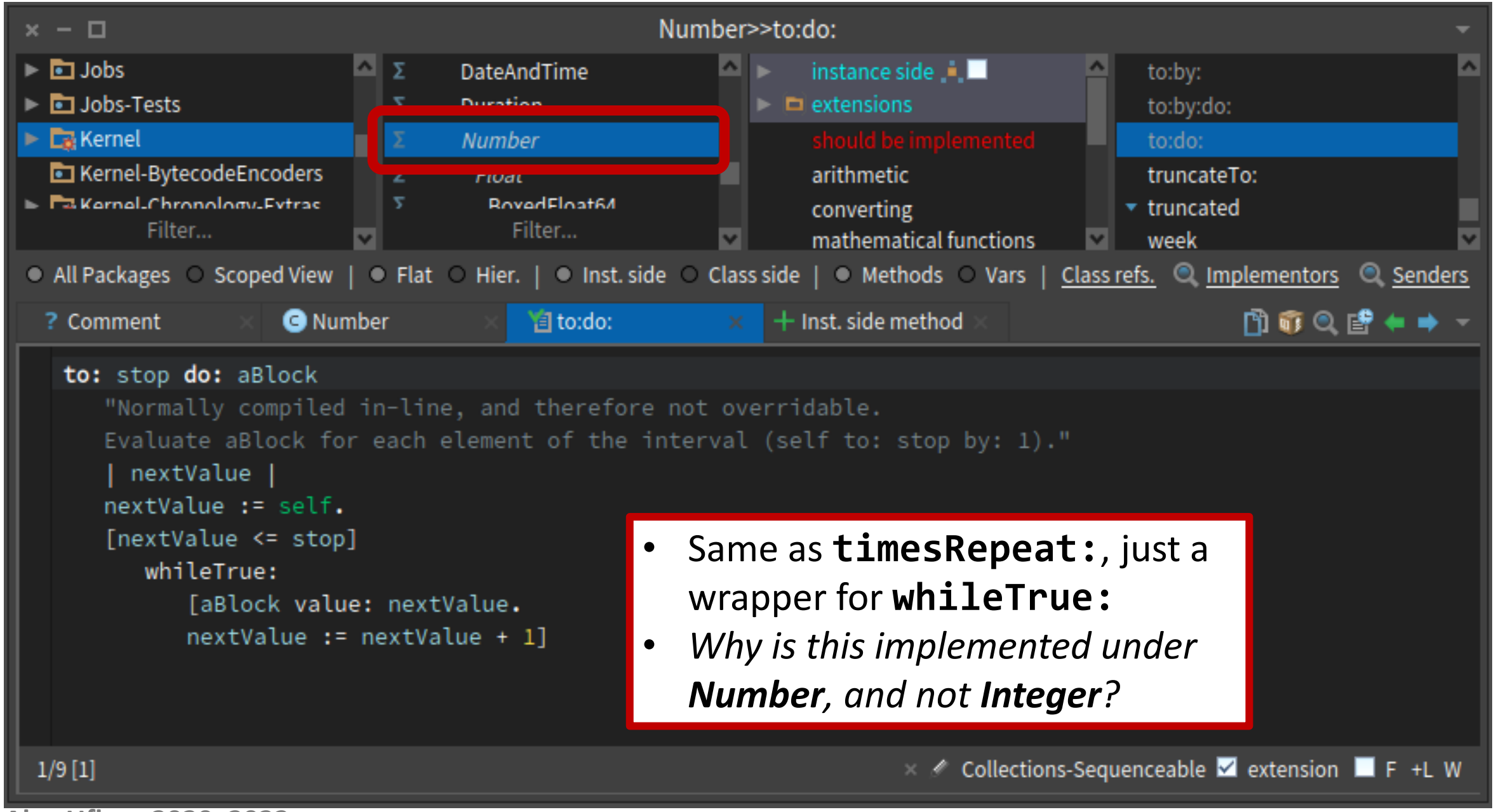


For-loop equivalent - `to:do:`



- **a** is our loop index
- Can be used in the "body" of the loop
- I.e., the block

- **`to:do:`** message passed to an Integer object
- Two arguments – ending index and block representing loop body.



- Same as **`timesRepeat:`**, just a wrapper for **`whileTrue:`**
- *Why is this implemented under **Number**, and not **Integer**?*

For-loop equivalent - `to:do:`

*Why is this implemented under **Number**, and not **Integer**?*

In the case of timesReapeat:

- We cannot execute a block 4.7 times.
- This makes no sense.

`x to: y do: […]`

- Will count from x to y by 1.
- We *can* count from 2.1 to 4.7.
- **2.1**, **3.1**, **4.1**, **5.1**

Iterate Over Arrays

- In Java we have a different version of for loop for safely iterating over arrays.
- Prevents us from accidentally going out of bounds.

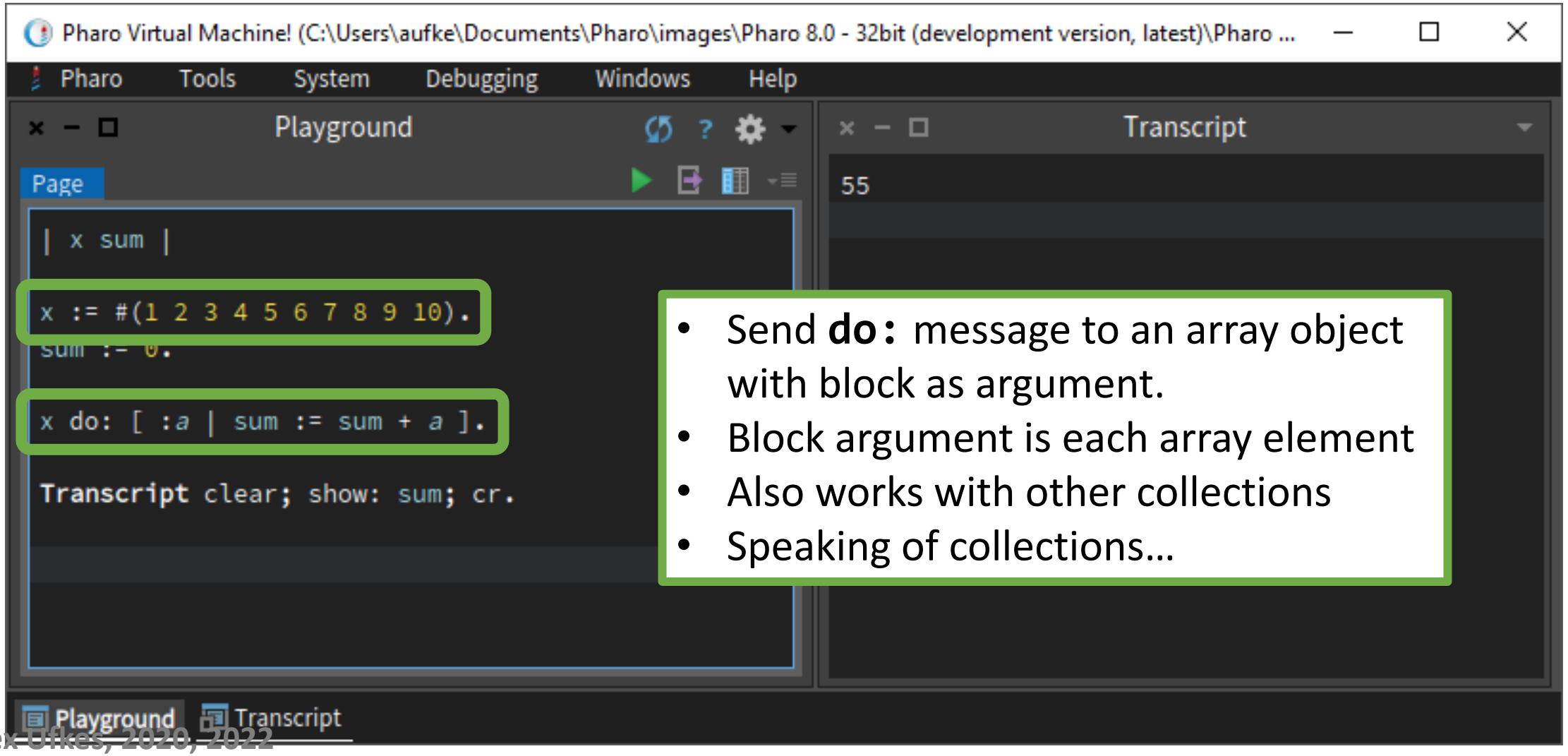
```
public static void main(String[] args)
{
    int[] nums = {-11, 68, 4, 0, 99};
    int sum = 0;

    for (int e : nums)
        sum += e;

        System.out.println(sum);
}
```

- **e** will take the value of each element in the array **nums**.
- Written this way, the loop will automatically go through each element in **nums**.
- Don't need to keep track of index or conditions, it's done for us.

Iterate Over Arrays



- Send **do:** message to an array object with block as argument.
- Block argument is each array element
- Also works with other collections
- Speaking of collections…

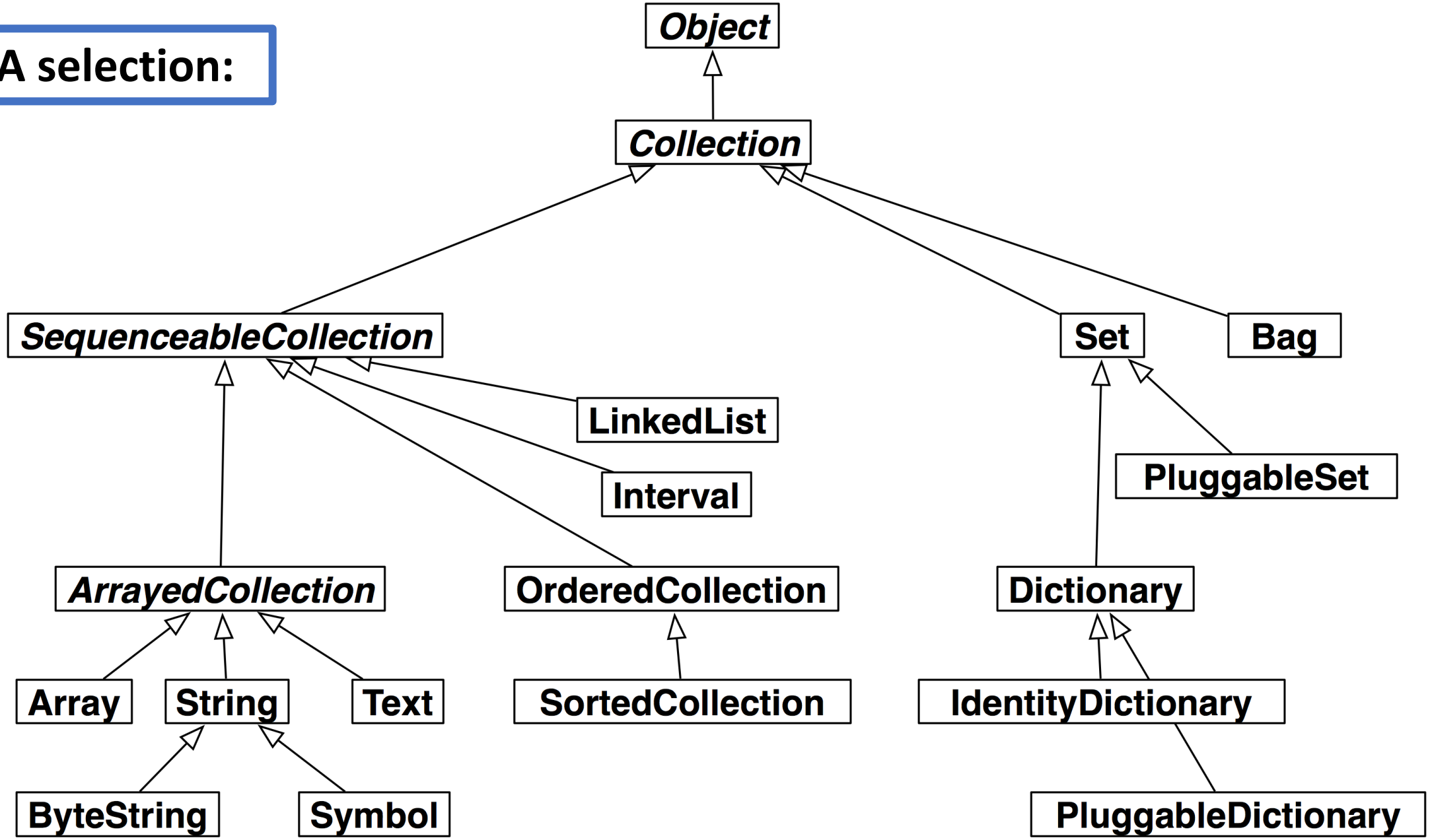
Smalltalk Collections

We've seen arrays.

In Java, we have things like ArrayLists, Vectors, LinkedLists, PriorityQueues, and so on.

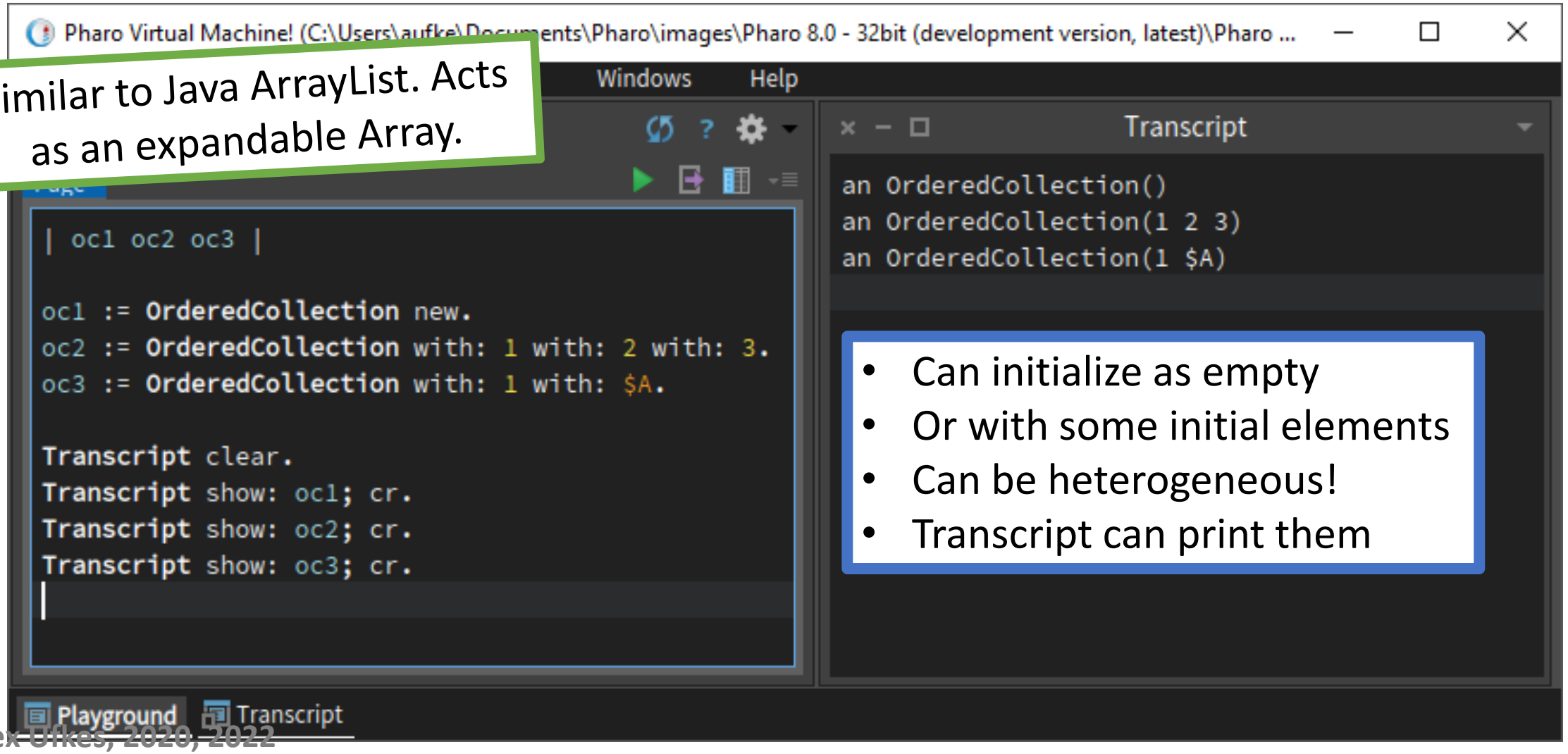
What about Smalltalk?

A selection:



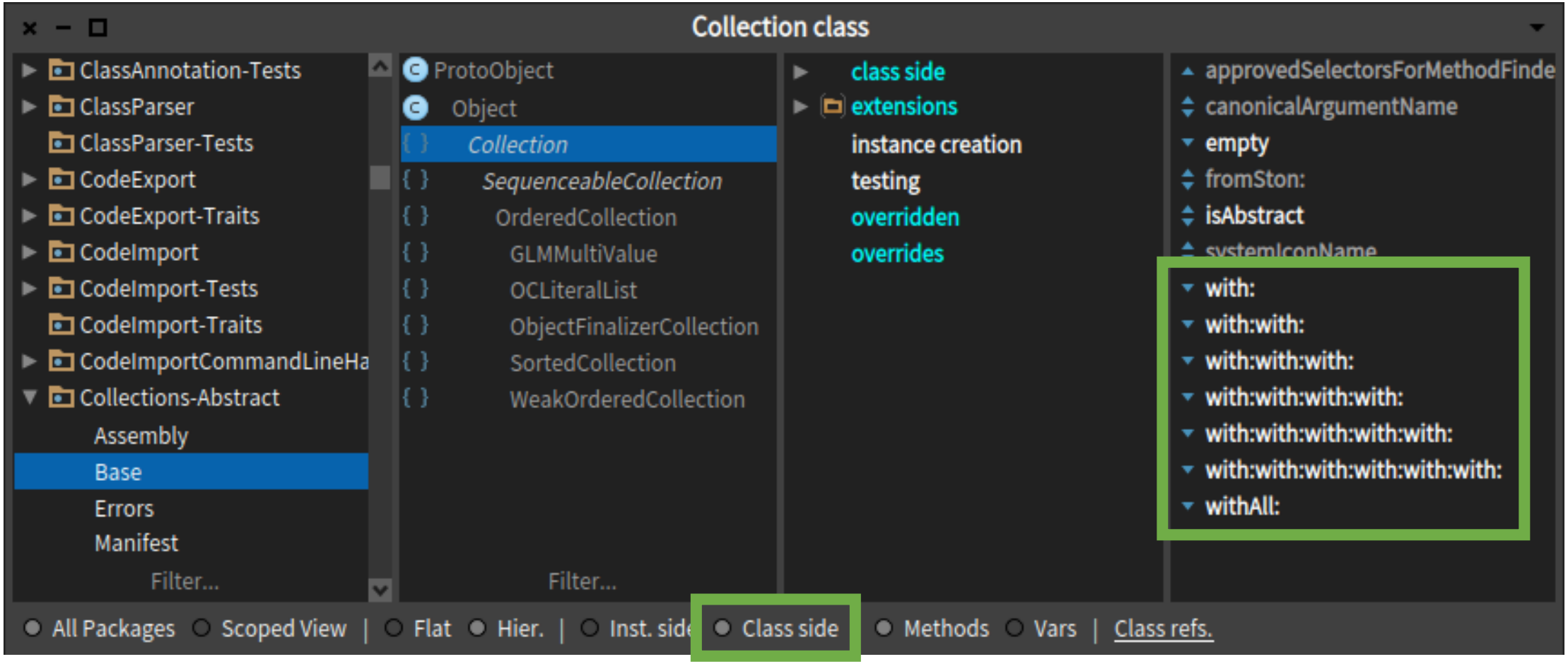
Ordered Collection

Similar to Java ArrayList. Acts as an expandable Array.

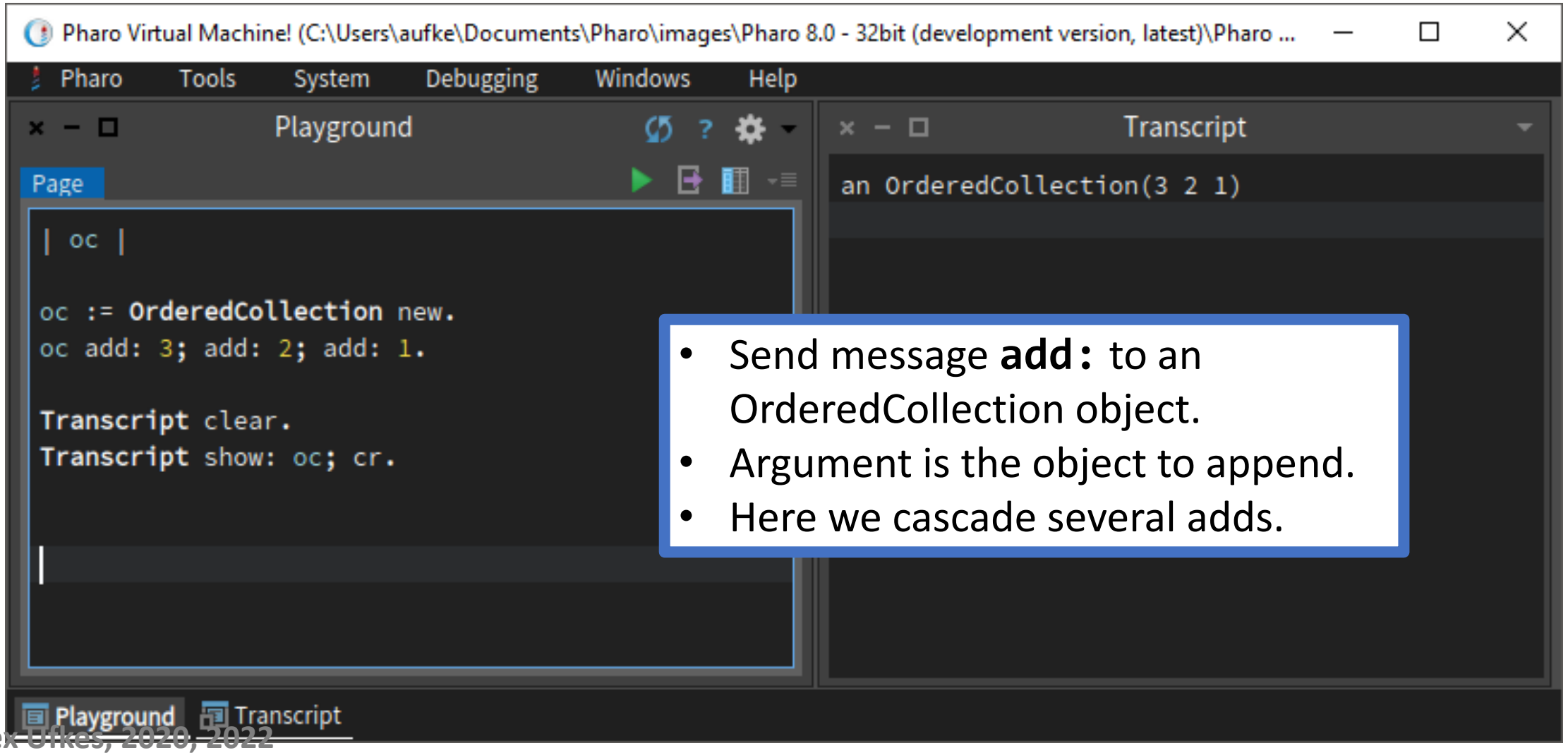


- Can initialize as empty
- Or with some initial elements
- Can be heterogeneous!
- Transcript can print them

with:with:with:with:with:with:with:...

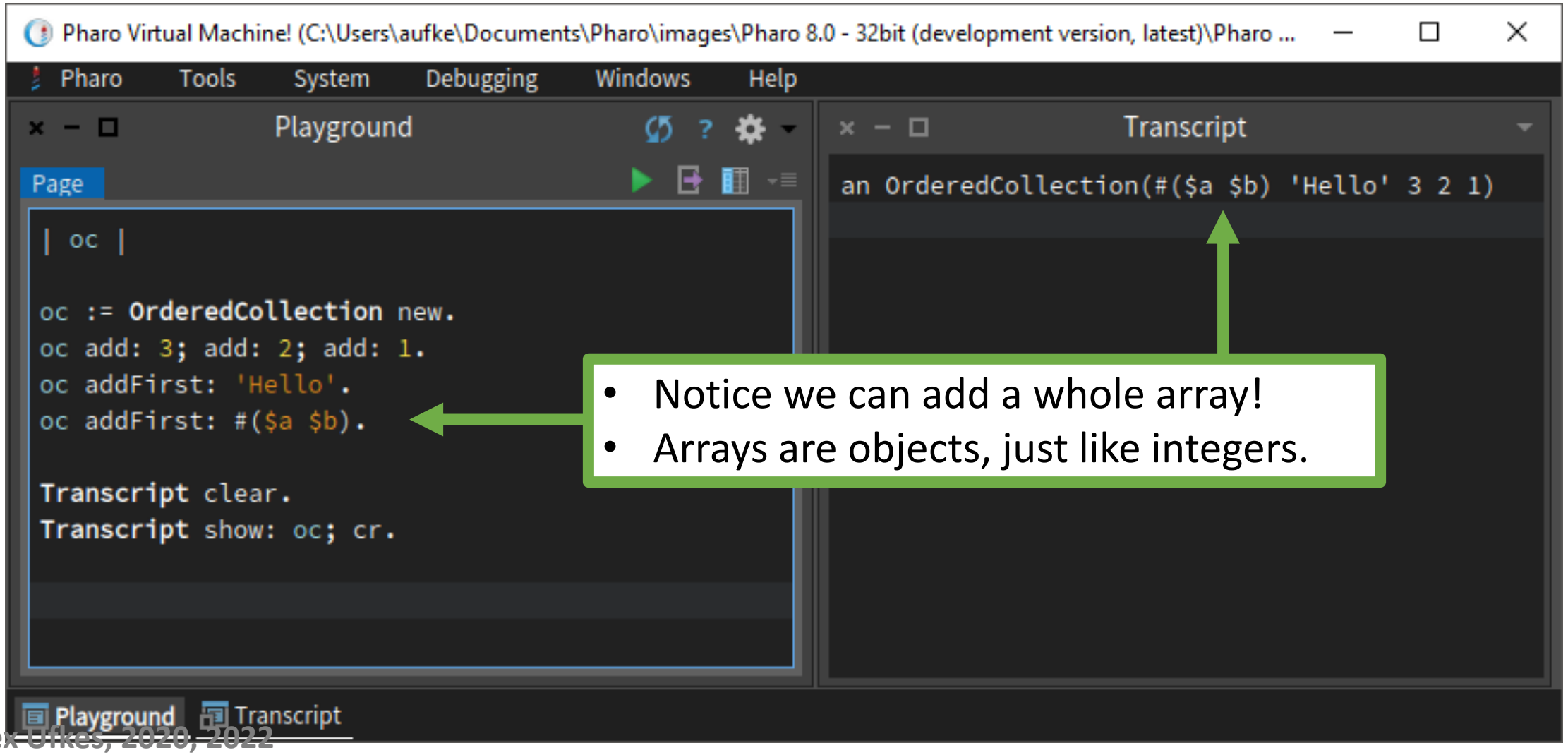


Ordered Collection: Add Elements

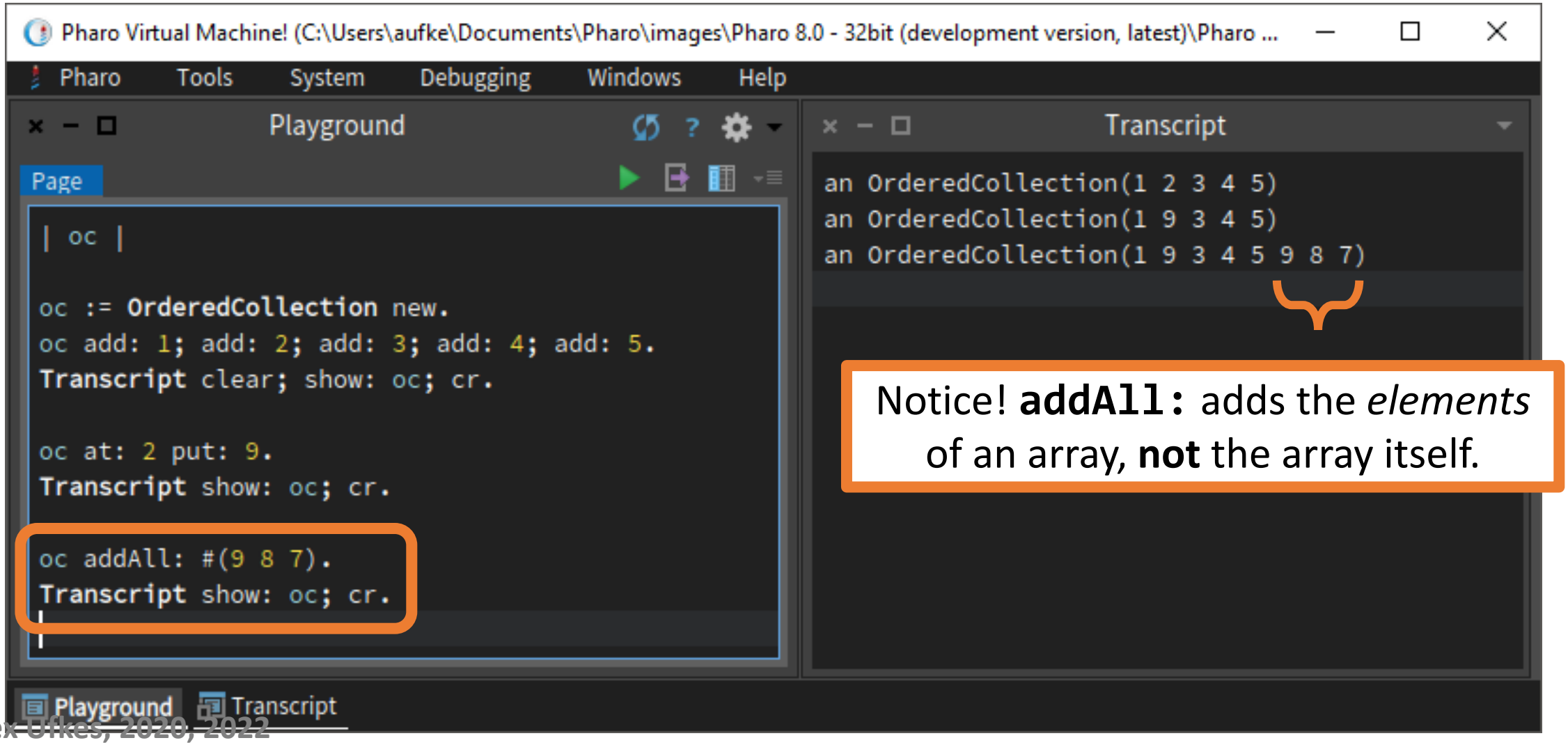


- Send message **add:** to an OrderedCollection object.
- Argument is the object to append.
- Here we cascade several adds.

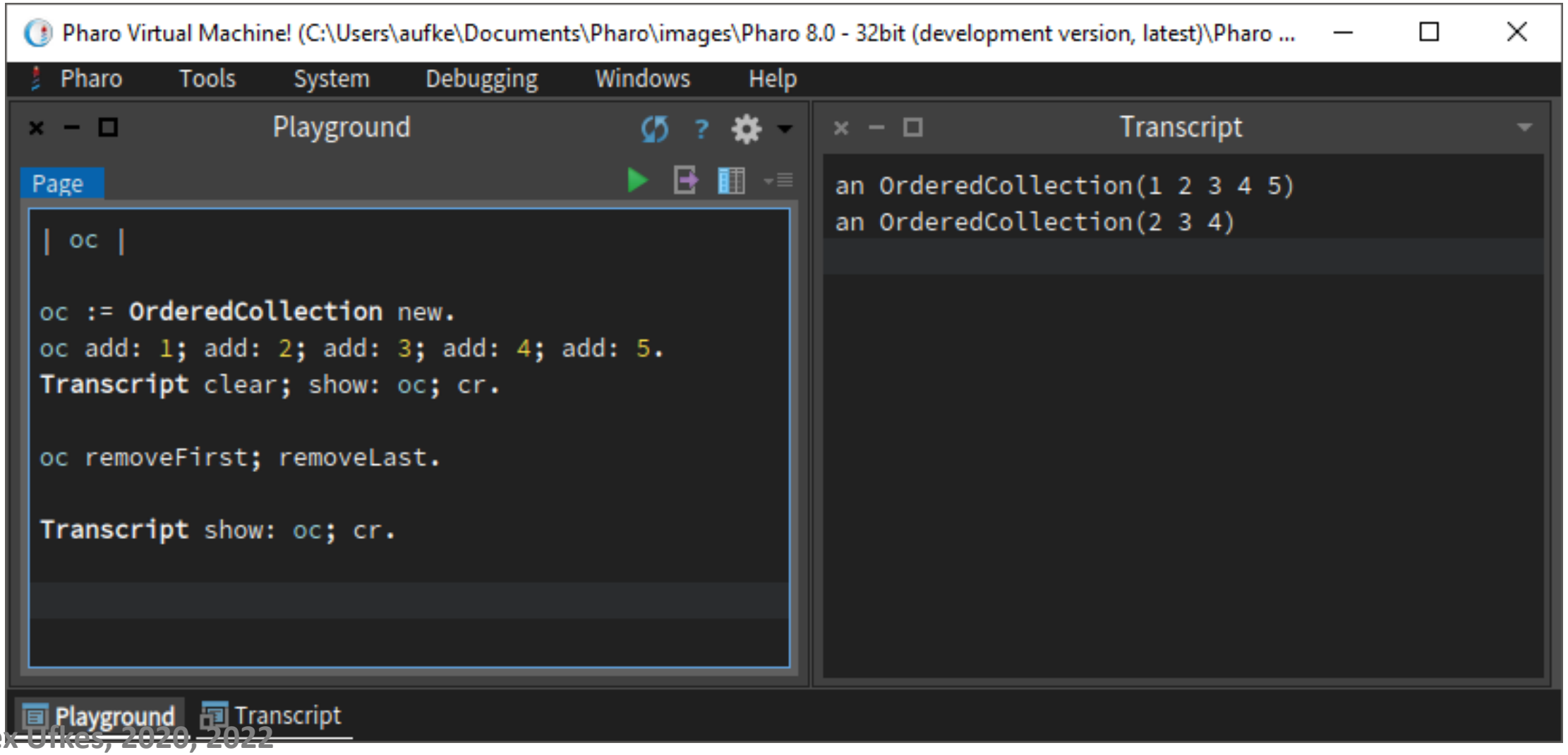
Ordered Collection: Add Elements



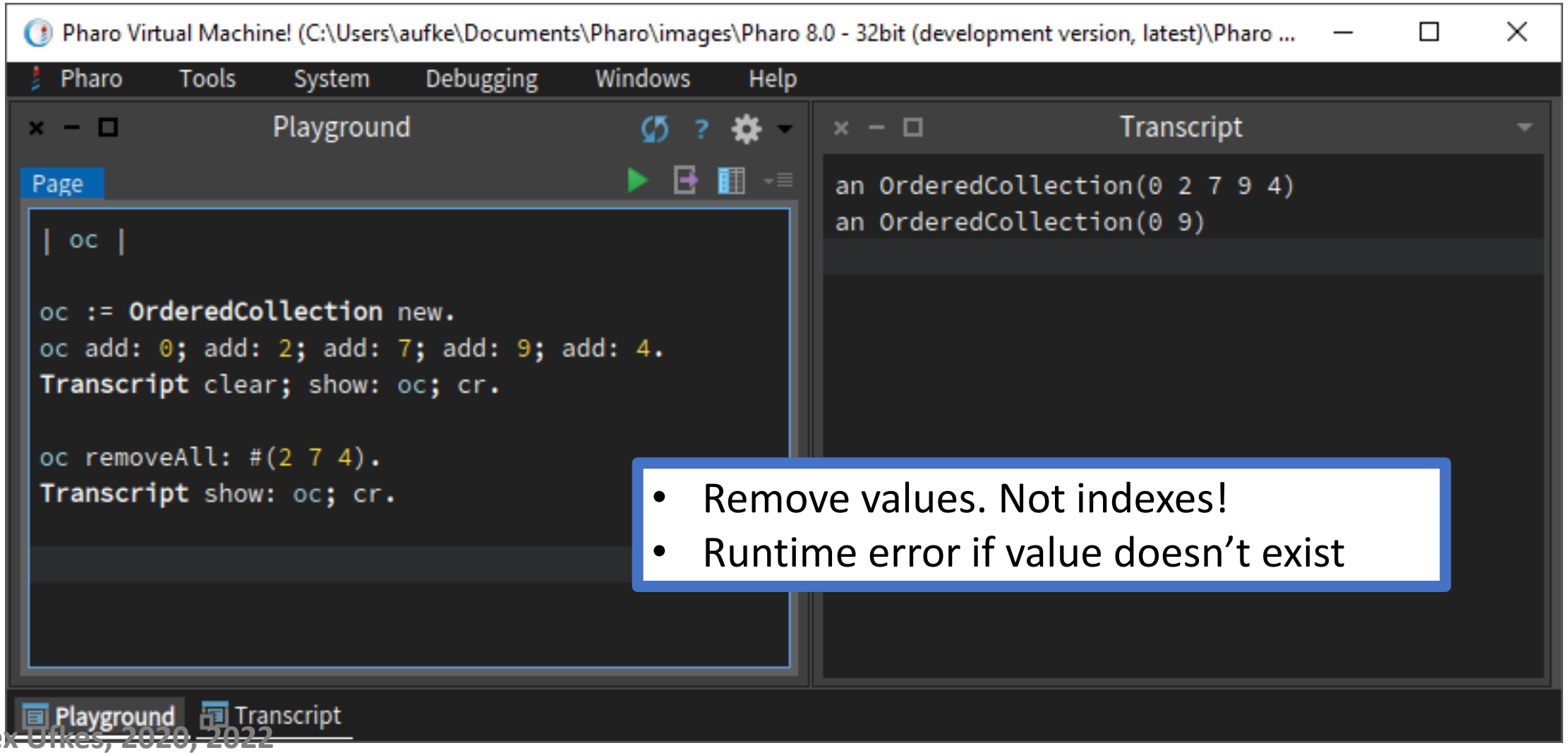
Ordered Collection: `at:put:`, `addAll:`



Ordered Collection: Removing

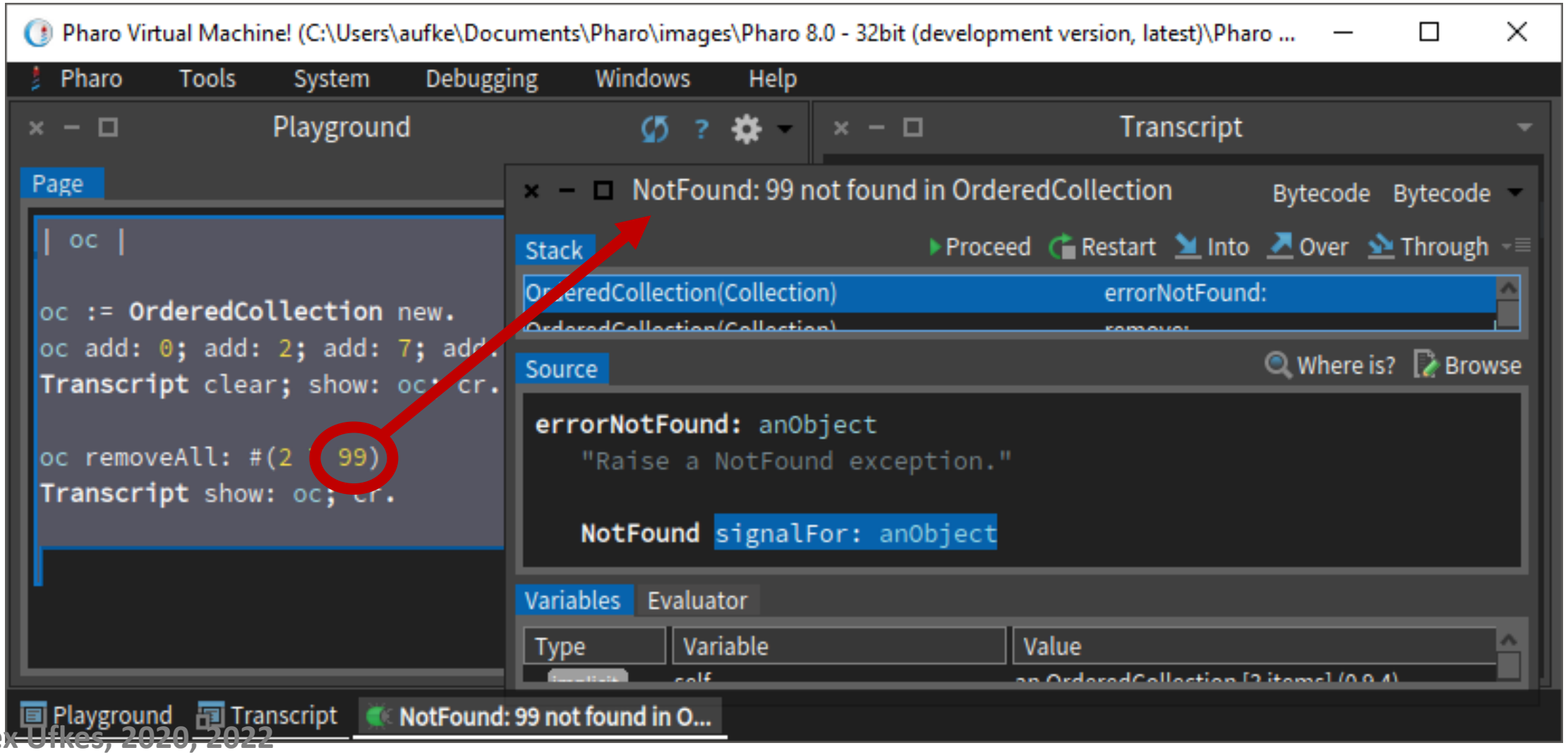


Ordered Collection: Removing



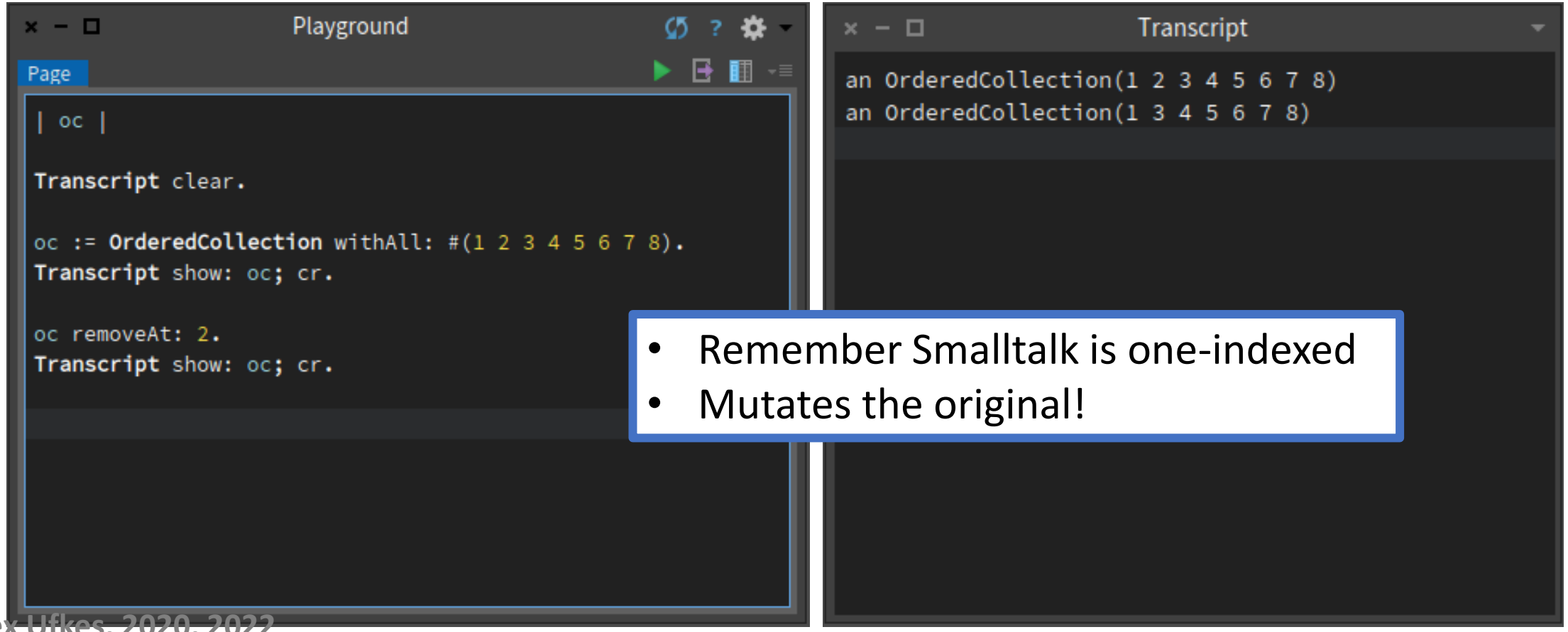
- Remove values. Not indexes!
- Runtime error if value doesn't exist

Ordered Collection: Removing



Remove by Index

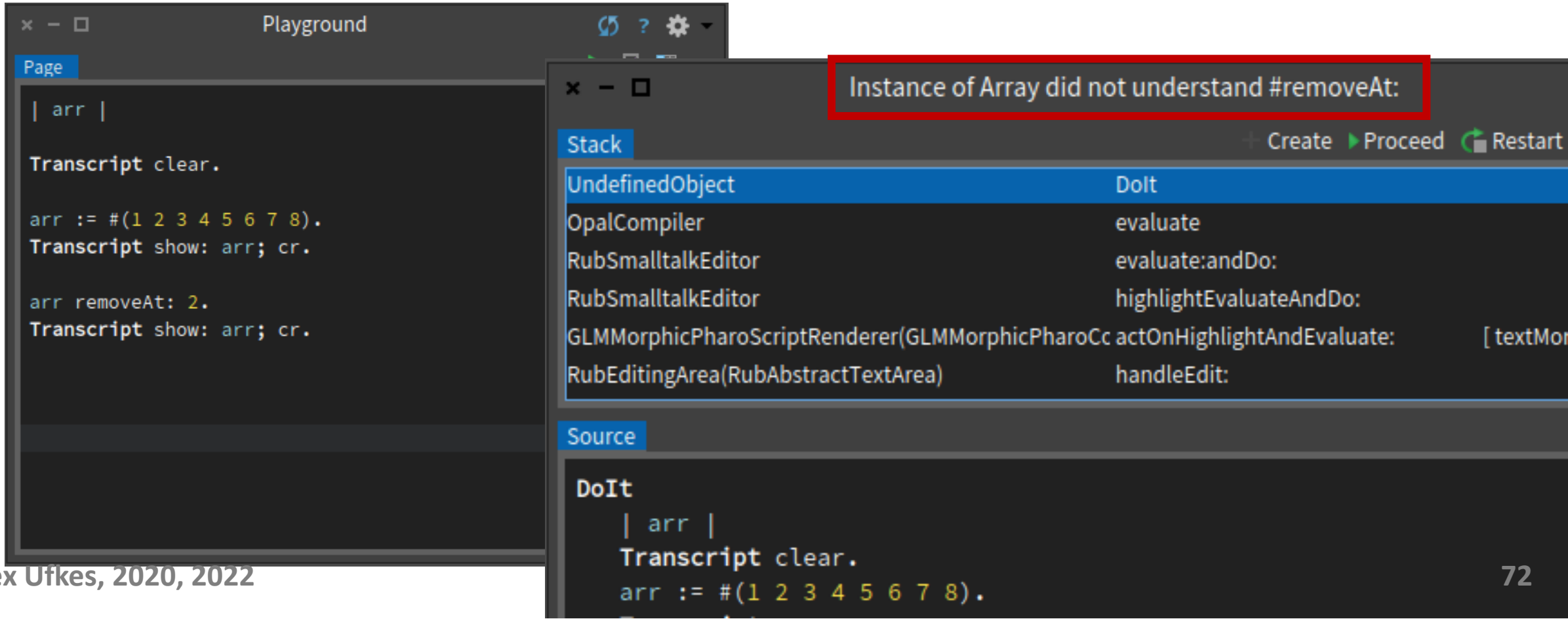
Can use **`removeAt:`**



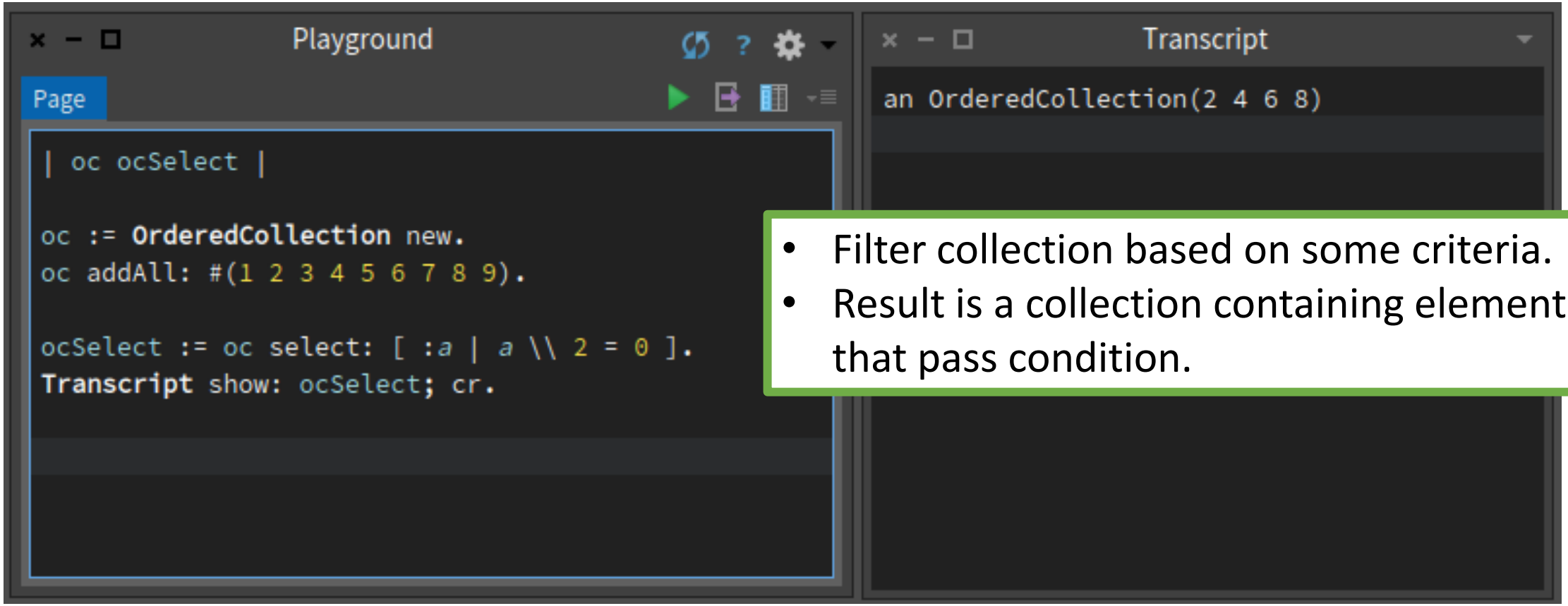
- Remember Smalltalk is one-indexed
- Mutates the original!

With Arrays?

No! Arrays cannot change size once created:

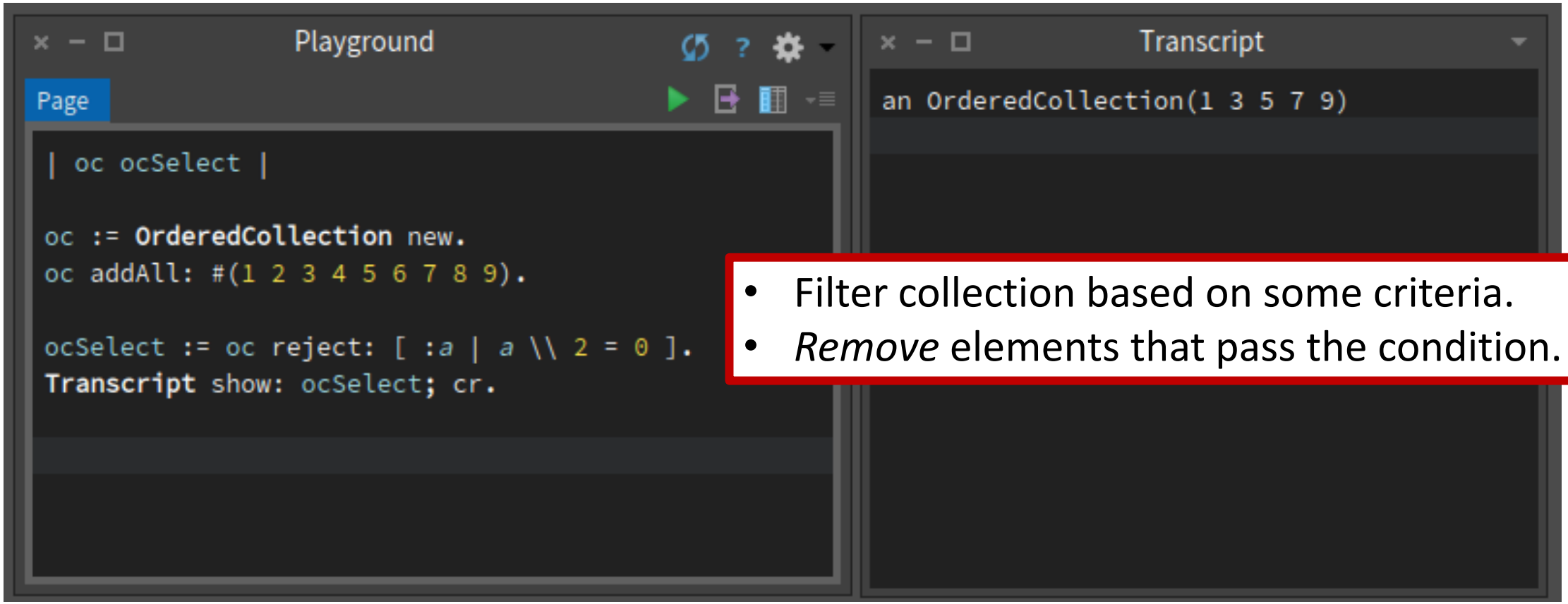


Ordered Collection: `select:`



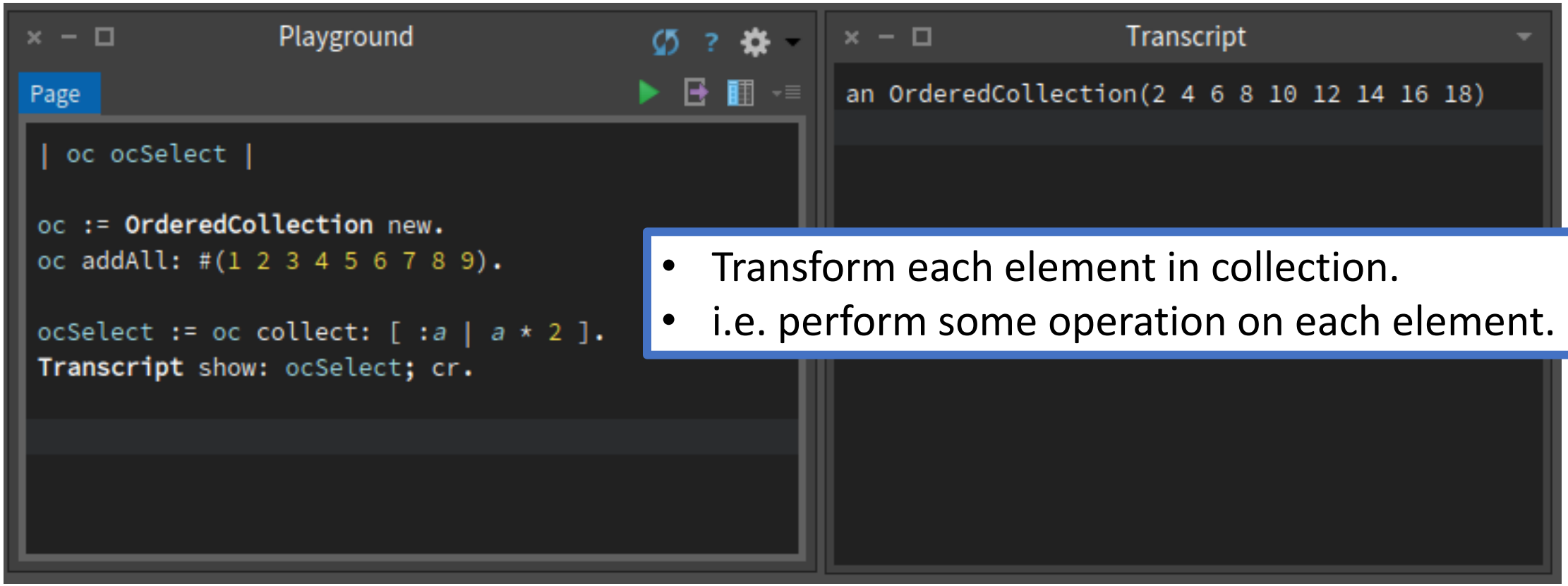
- Filter collection based on some criteria.
- Result is a collection containing elements that pass condition.

Ordered Collection: `reject:`



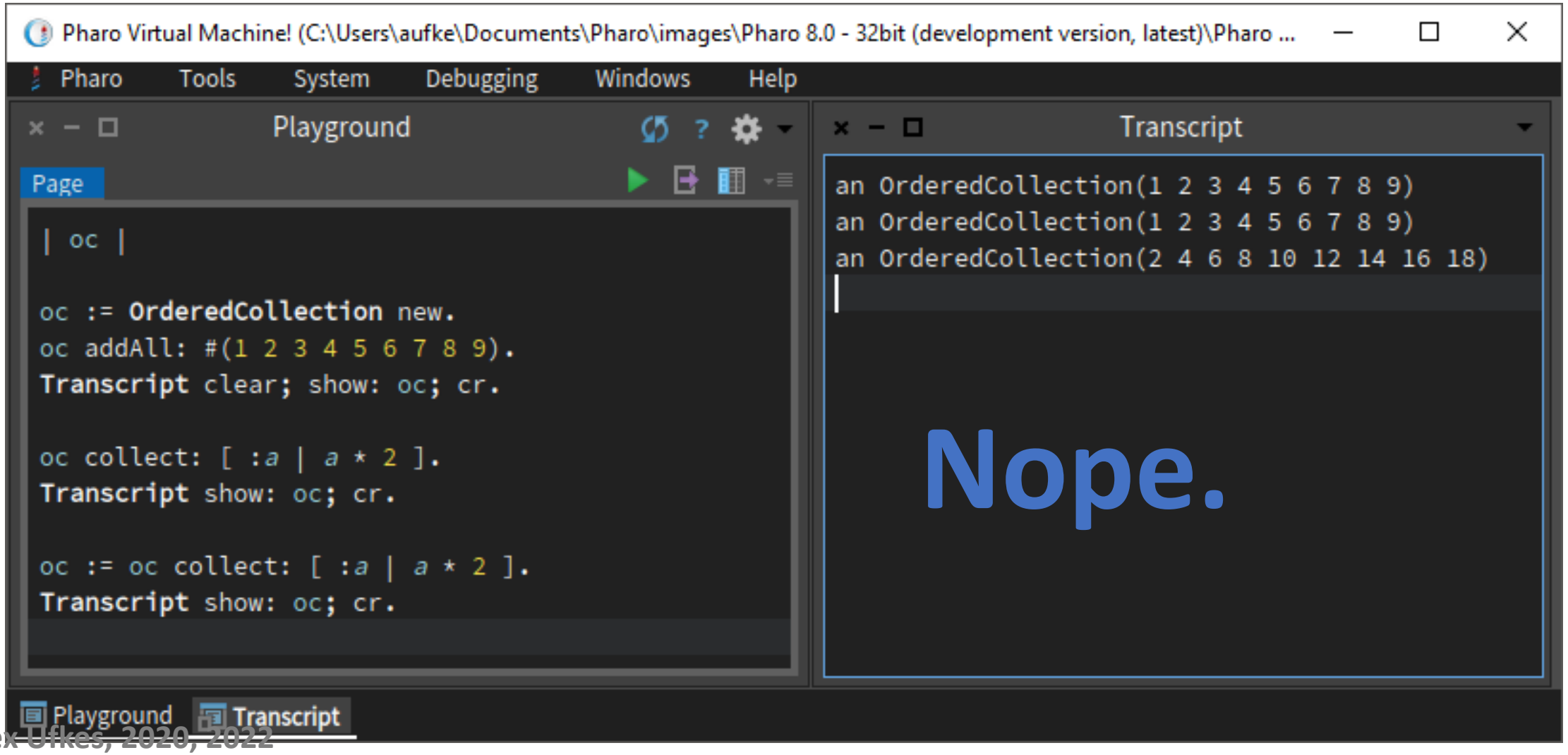
- Filter collection based on some criteria.
- *Remove* elements that pass the condition.

Ordered Collection: `collect:`



- Transform each element in collection.
- i.e. perform some operation on each element.

Are we mutating the original?



And More!

OrderedCollection

Acts like an expandable array

```
| b x y sum max |
x := OrderedCollection with: 4 with: 3 with: 2 with: 1.      "create collection with up to 4 elements"
x := OrderedCollection new.                                  "allocate collection"
x add: 3; add: 2; add: 1; add: 4; yourself.                  "add element to collection"
y := x addFirst: 5.                                          "add element at beginning of collection"
y := x removeFirst.                                          "remove first element in collection"
y := x addLast: 6.                                           "add element at end of collection"
y := x removeLast.                                           "remove last element in collection"
y := x addAll: #(7 8 9).                                     "add multiple elements to collection"
y := x removeAll: #(7 8 9).                                  "remove multiple elements from collection"
x at: 2 put: 3.                                              "set element at index"
y := x remove: 5 ifAbsent: [].                               "remove element from collection"
b := x isEmpty.                                              "test if empty"
y := x size.                                                 "number of elements"
y := x at: 2.                                                "retrieve element at index"
y := x first.                                                "retrieve first element in collection"
y := x last.                                                 "retrieve last element in collection"
b := x includes: 5.                                          "test if element is in collection"
y := x copyFrom: 2 to: 3.                                    "subcollection"
y := x indexOf: 3 ifAbsent: [0].                             "first position of element within collection"
y := x occurrencesOf: 3.                                     "number of times object in collection"
x do: [:a | Transcript show: a printString; cr].             "iterate over the collection"
b := x conform: [:a | (a >= 1) & (a <= 4)].                  "test if all elements meet condition"
y := x select: [:a | a > 2].                                 "return collection of elements that pass test"
y := x reject: [:a | a < 2].                                 "return collection of elements that fail test"
y := x collect: [:a | a + a].                                "transform each element for new collection"
y := x detect: [:a | a > 3] ifNone: [].                      "find position of first element that passes test"
sum := 0. x do: [:a | sum := sum + a]. sum.                  "sum elements"
sum := 0. 1 to: (x size) do: [:a | sum := sum + (x at: a)]. "sum elements"
sum := x inject: 0 into: [:a :c | a + c].                    "sum elements"
max := x inject: 0 into: [:a :c | (a > c)                    "find max element in collection"
    ifTrue: [a]
    ifFalse: [c]].
y := x shuffled.                                             "randomly shuffle collection"
y := x asArray.                                              "convert to array"
```

Sorted Collection

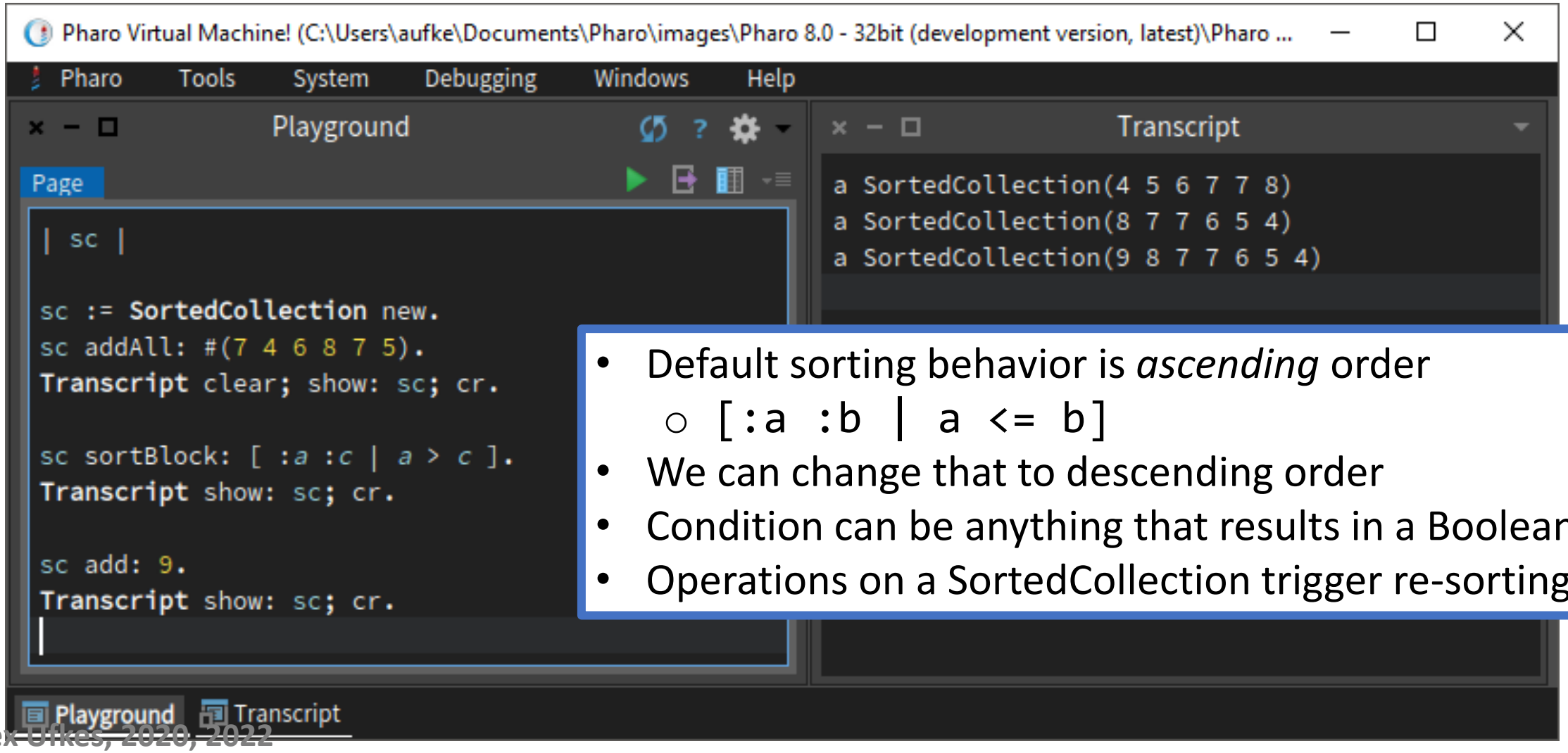
Similar to an OrderedCollection, but, you know, sorted.

Operations are all very similar to OrderedCollection, but here we can specify a *sorting criteria*:

```
[:a :c | a <= c]
```

- A block with two inputs, that implement a Boolean condition.

Sorted Collection



- Default sorting behavior is *ascending* order
  - `[:a :b | a <= b]`
- We can change that to descending order
- Condition can be anything that results in a Boolean
- Operations on a SortedCollection trigger re-sorting.

Sorted Collection

- Default sorting behavior is *ascending* order
  - `[:a :c | a <= c]`

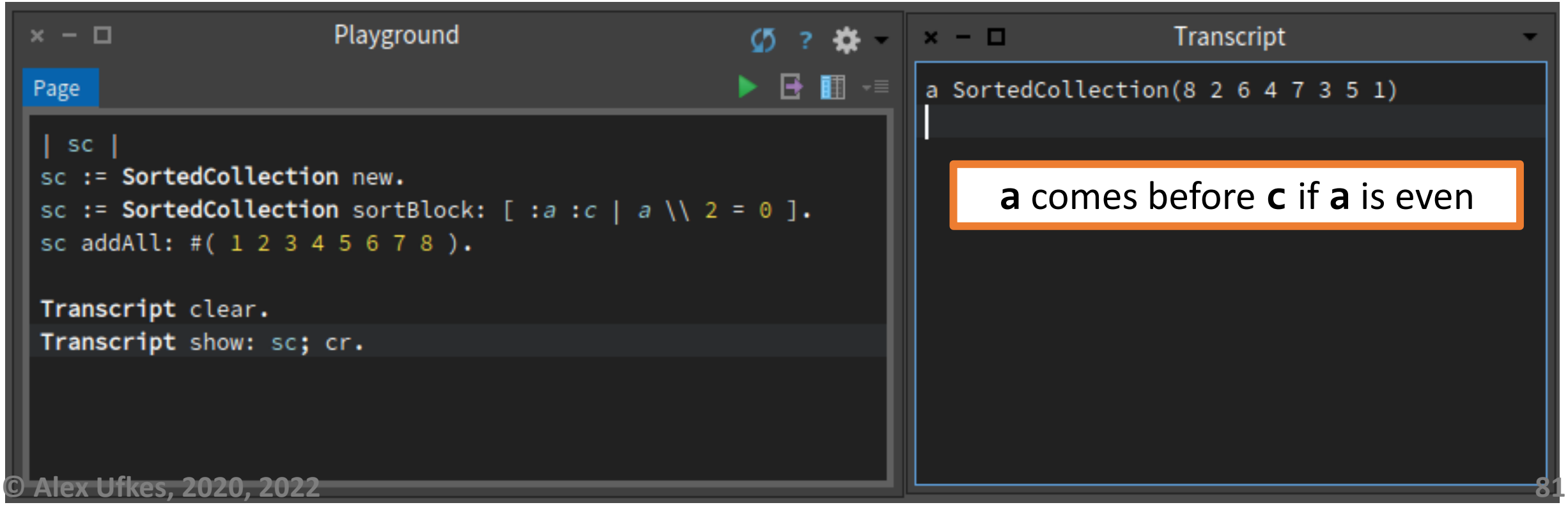
- This is a block that evaluates to Boolean when executed
- We're defining the condition for **a** appearing before **c** in the sequence
- Ascending order: **a** comes before **c** if **a** is less than or equal to **c**
- If block is true, **a** comes first.

This is just like implementing a **`compareTo()`** method in Java

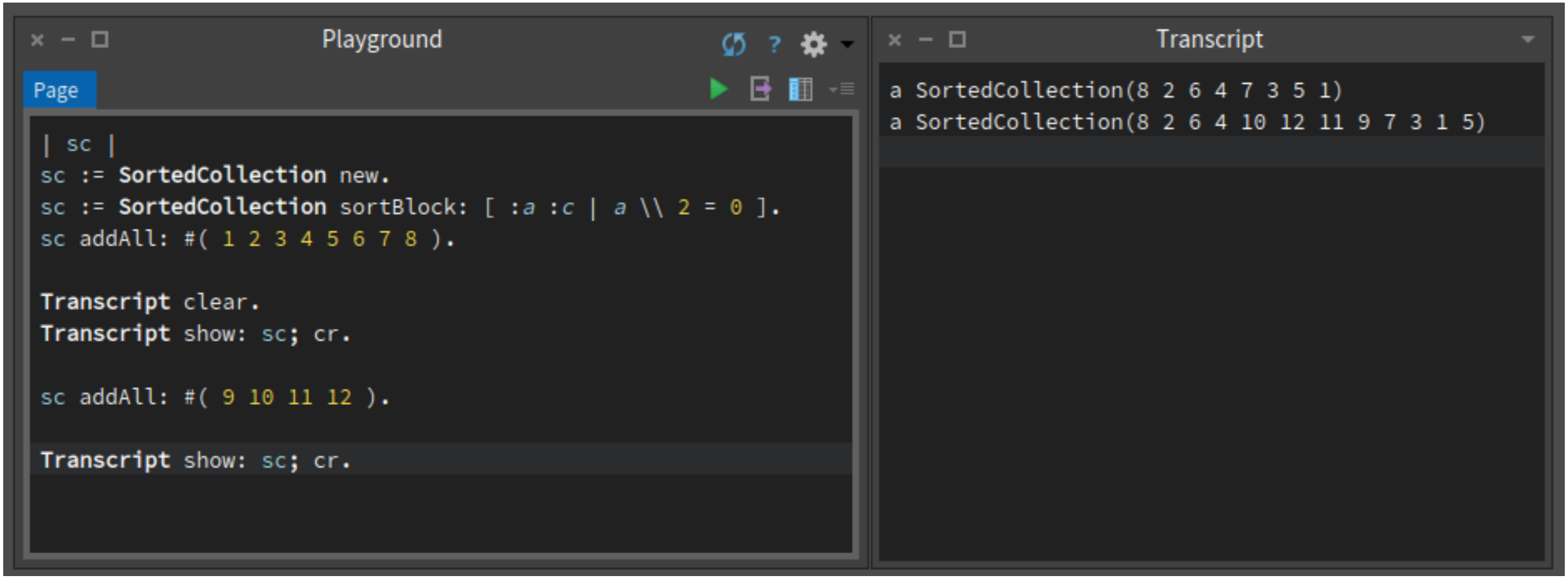
Sorted Collection

Silly sorting criteria?

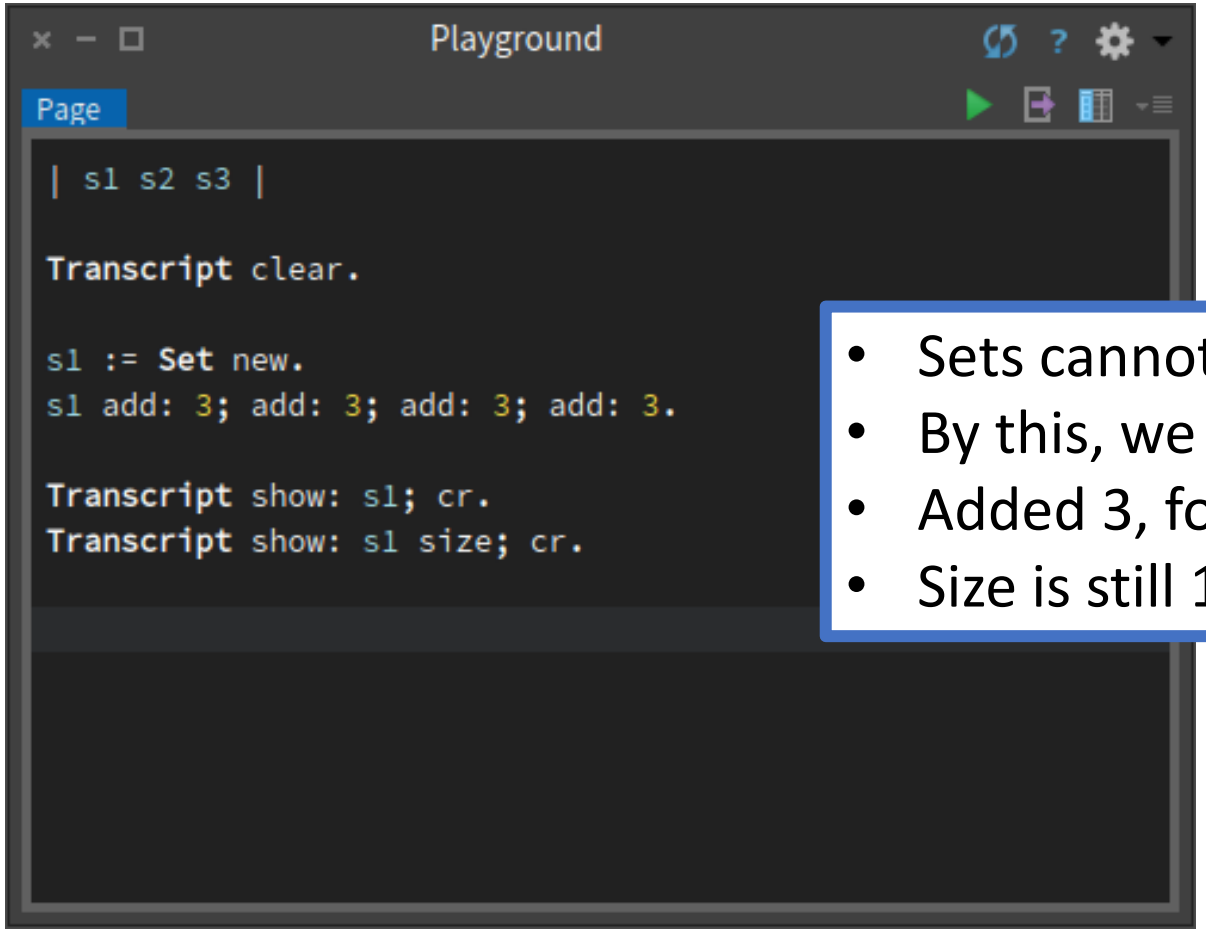
```
[:a :b | a \\ 2 = 0]
```

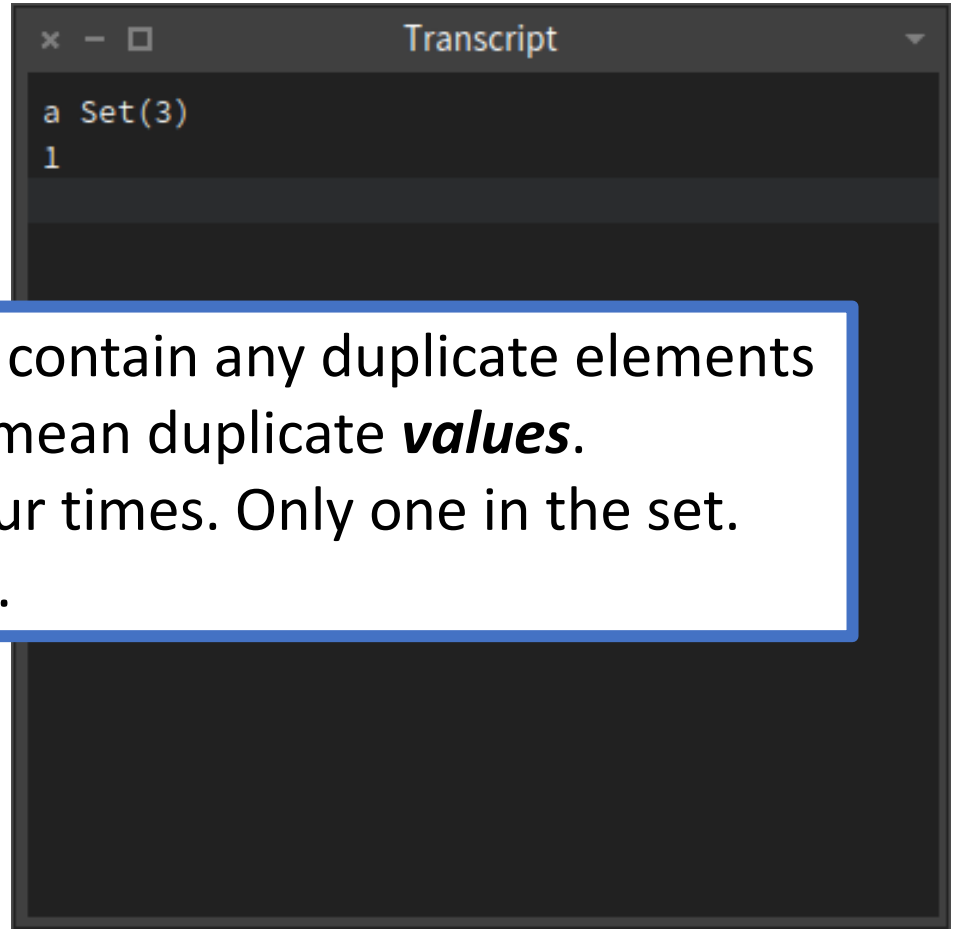


Modifying collection triggers re-sorting



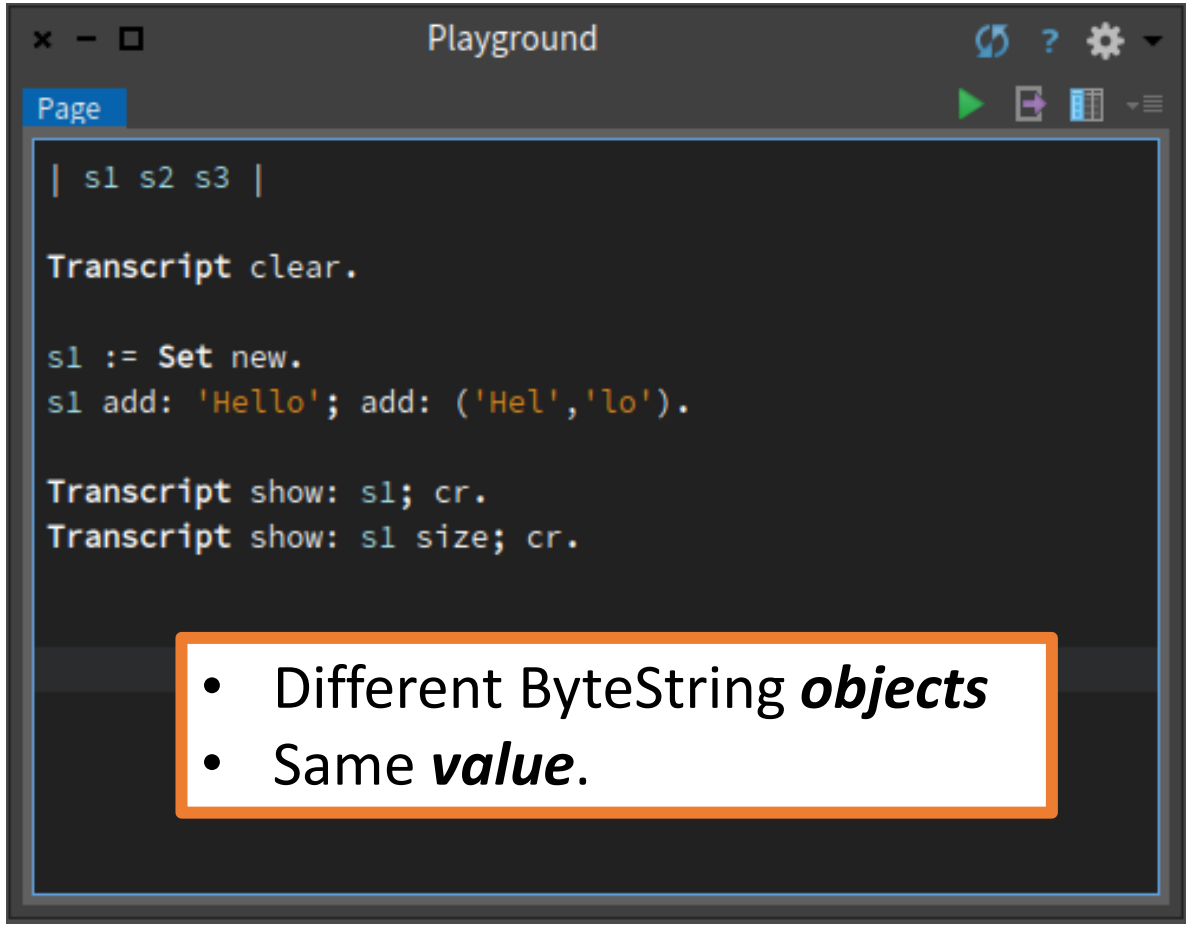
Collections: Sets



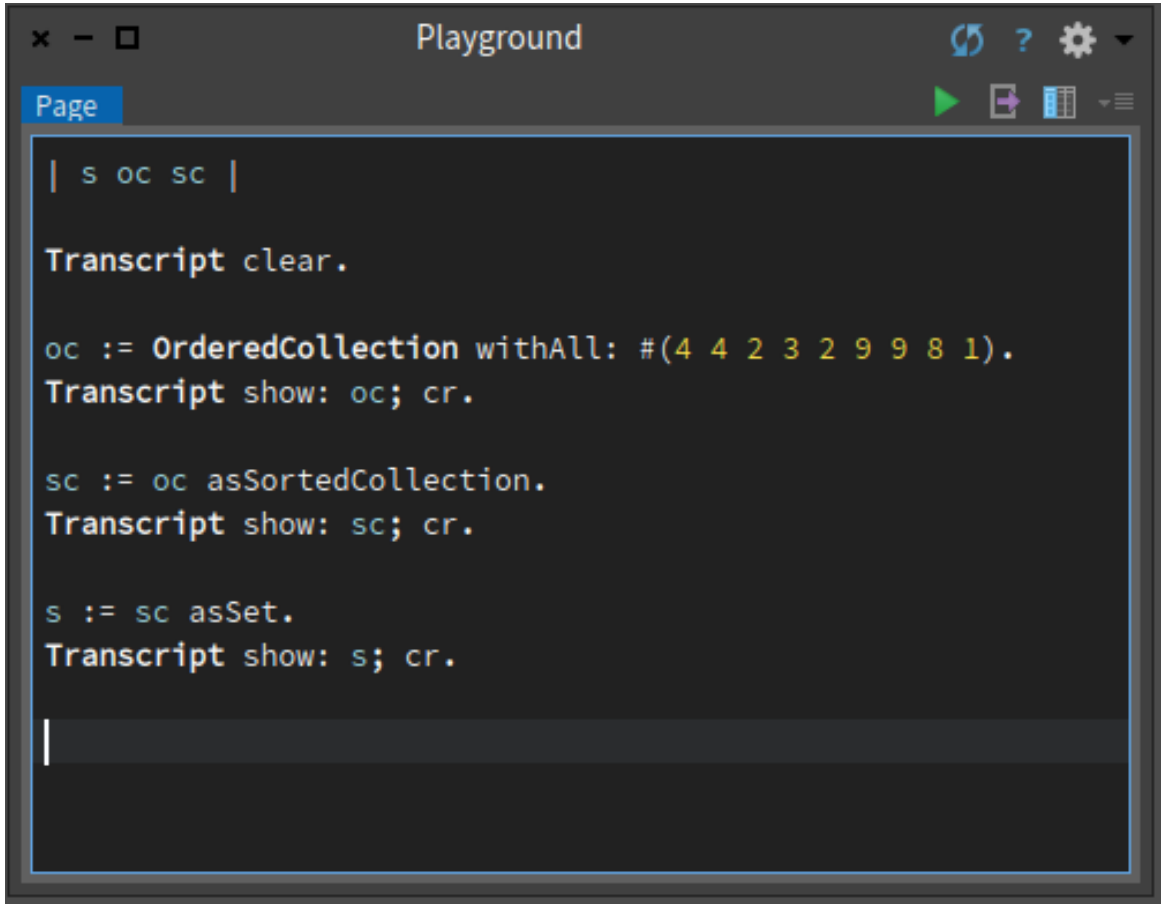


- Sets cannot contain any duplicate elements
- By this, we mean duplicate ***values***.
- Added 3, four times. Only one in the set.
- Size is still 1.

Collections: Sets

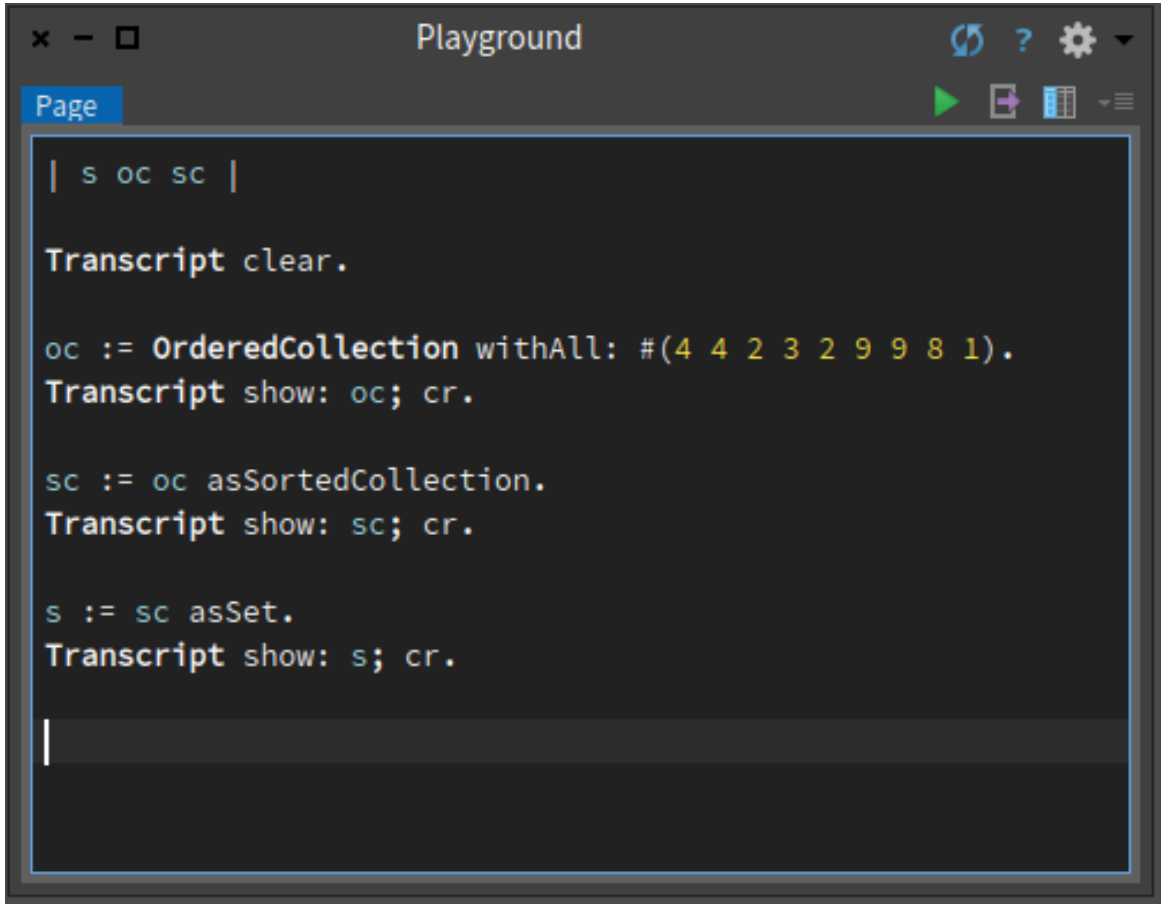


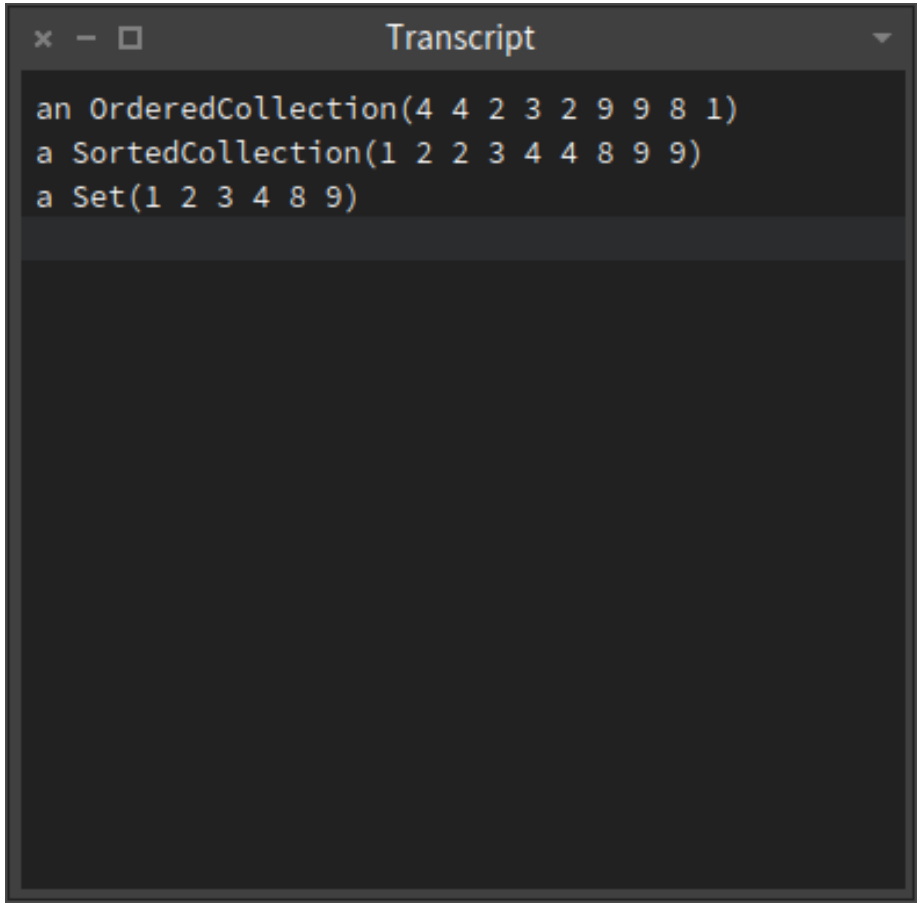
Collections: Sets



- We can convert back and forth between collection types.
- asSet, asSortedCollection, etc
- asInteger, asArray, lots of coercion messages.

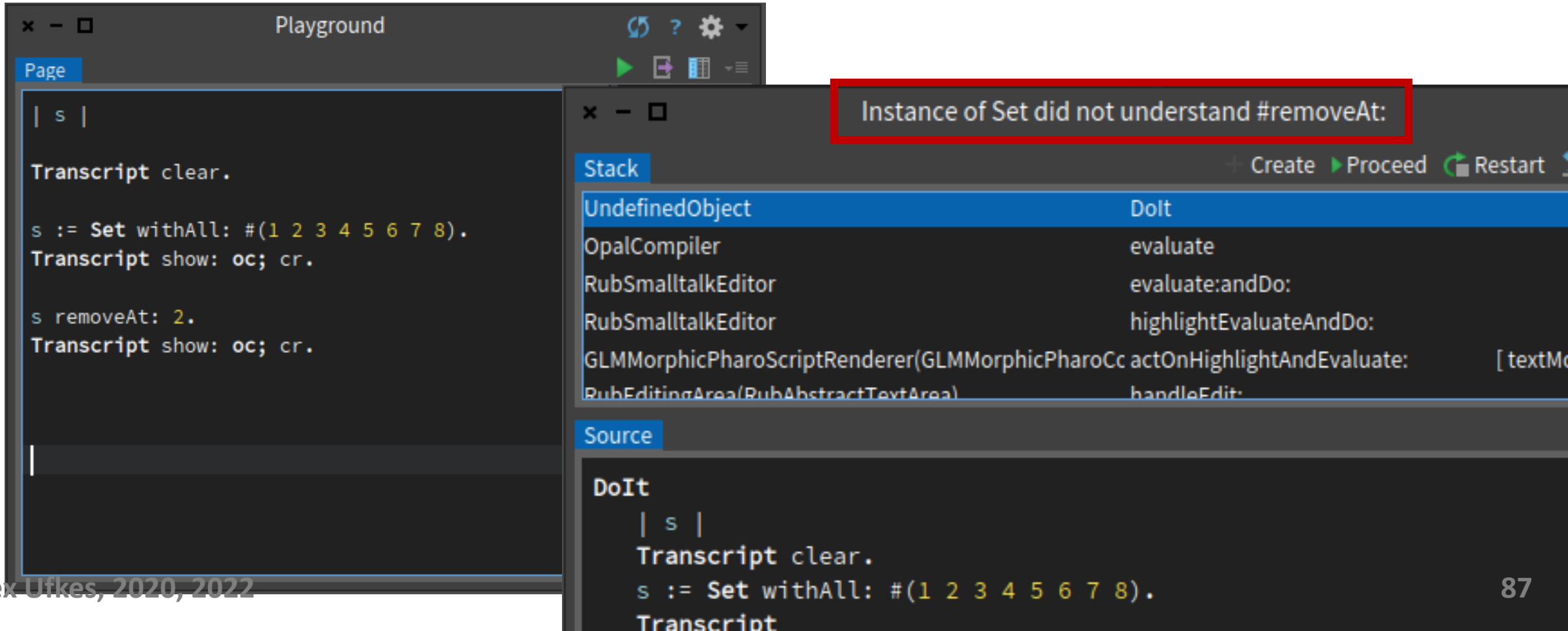
Collections: Sets



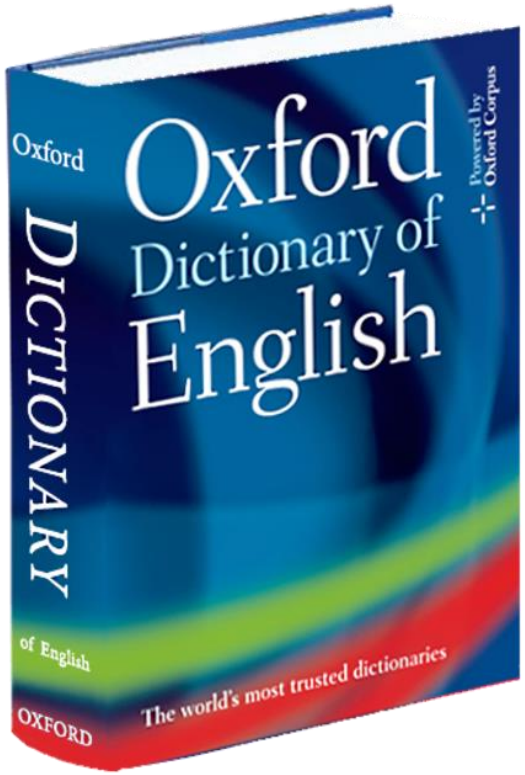


Remove by Index?

No! Sets do not have ***order***. They cannot be accessed by index:

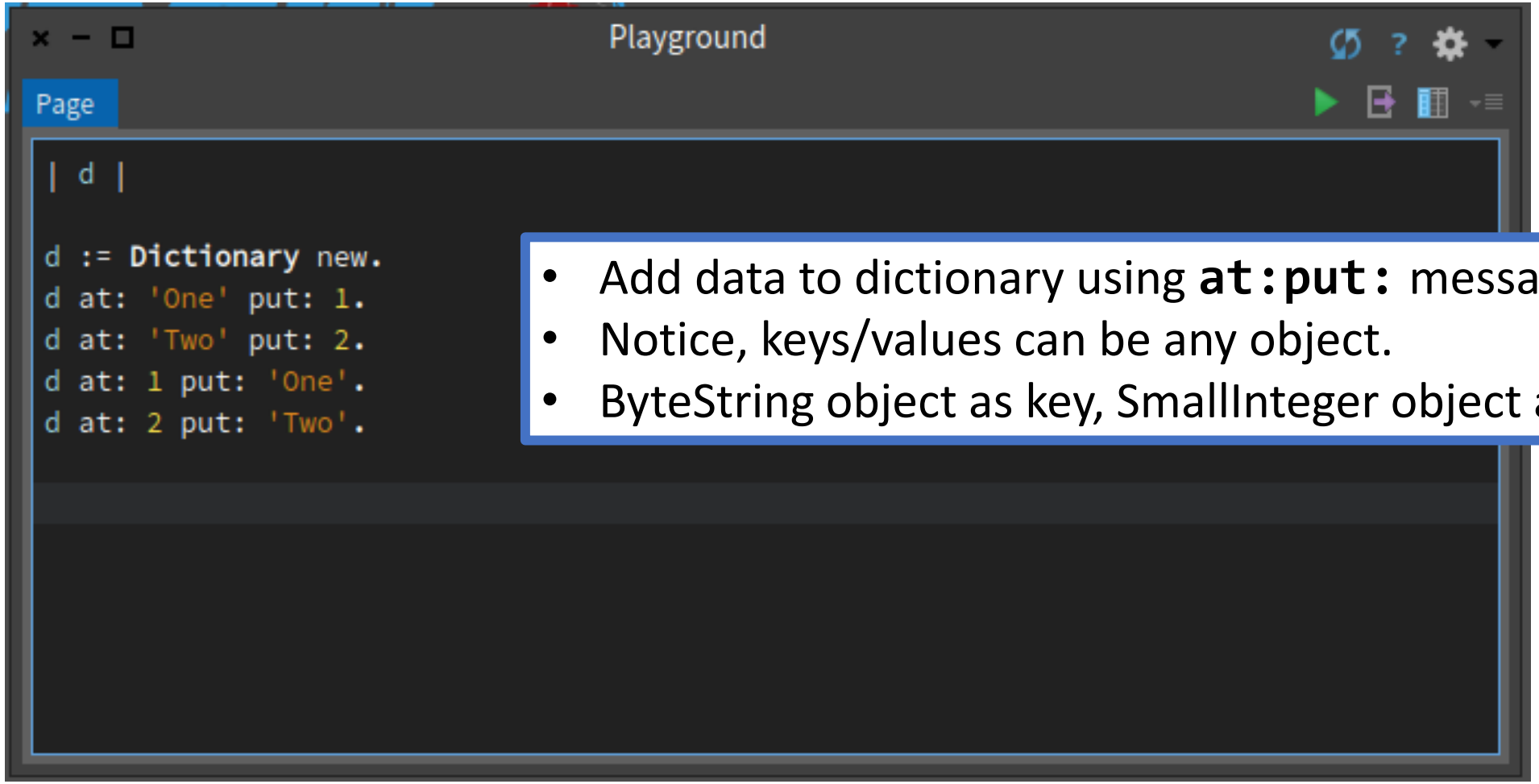


Dictionary



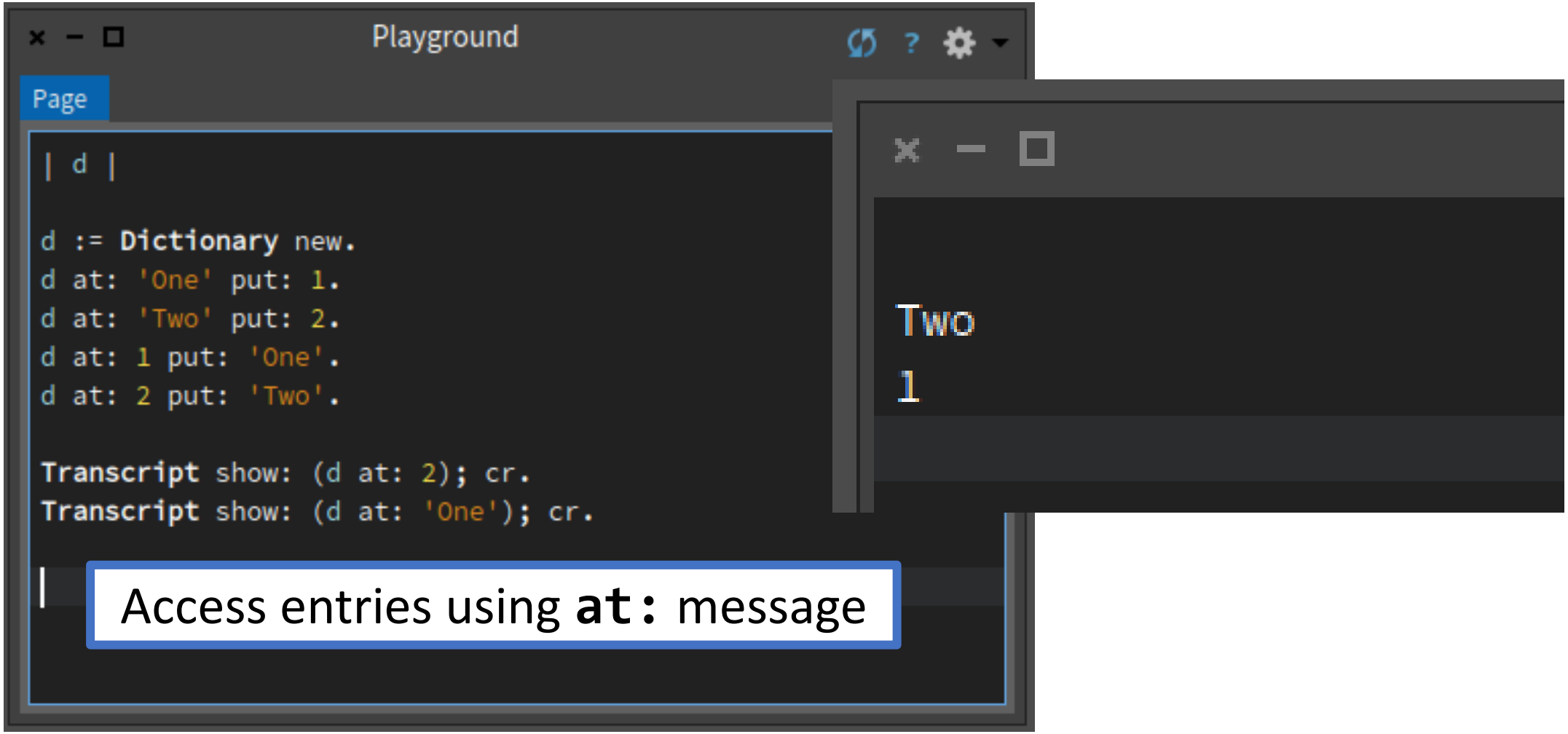
- Arrays are indexed with integers; Dictionaries are indexed with *any object at all.*
- You'll know exactly how this works if you learned Python in C/CPS 109
- Store key/value pairs, key can be anything.
- Very powerful, but we give up ordering (hash table implementation)

Dictionary: Adding Entries

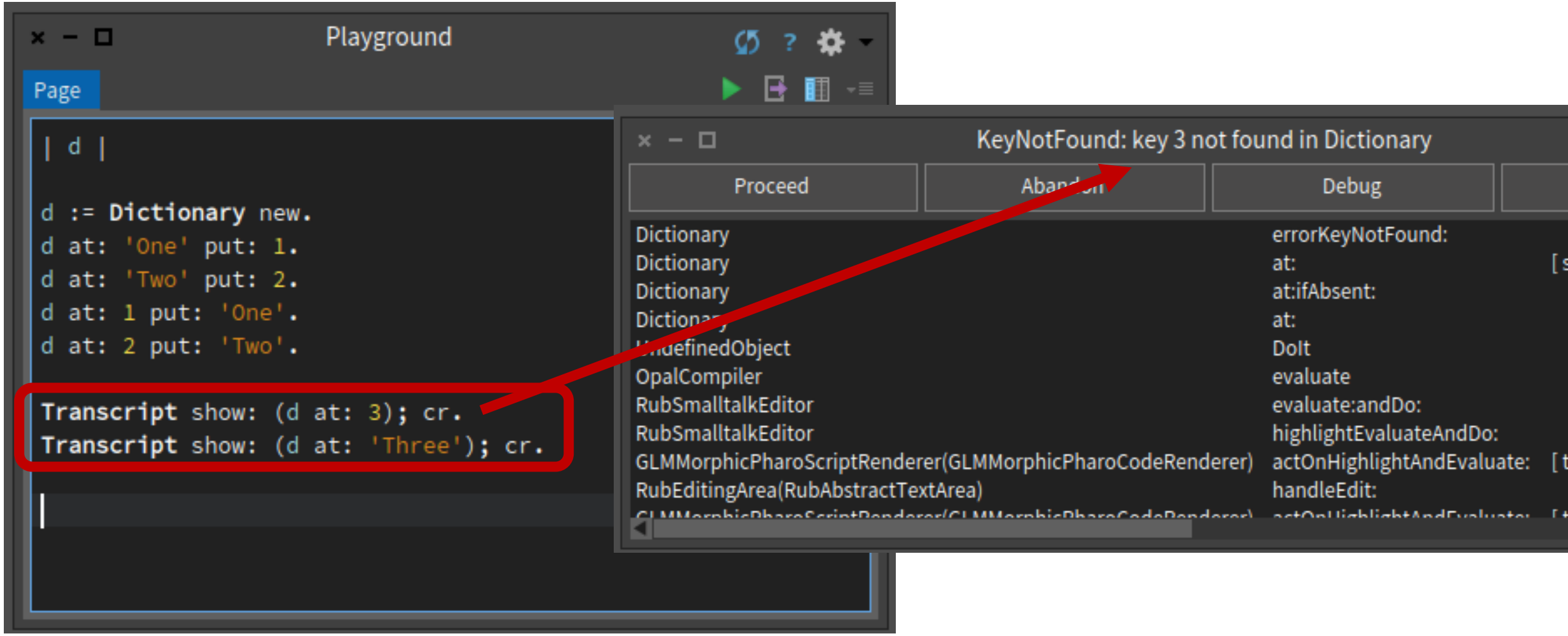


- Add data to dictionary using **`at:put:`** message
- Notice, keys/values can be any object.
- ByteString object as key, SmallInteger object as key.

Dictionary: Getting Value with Key

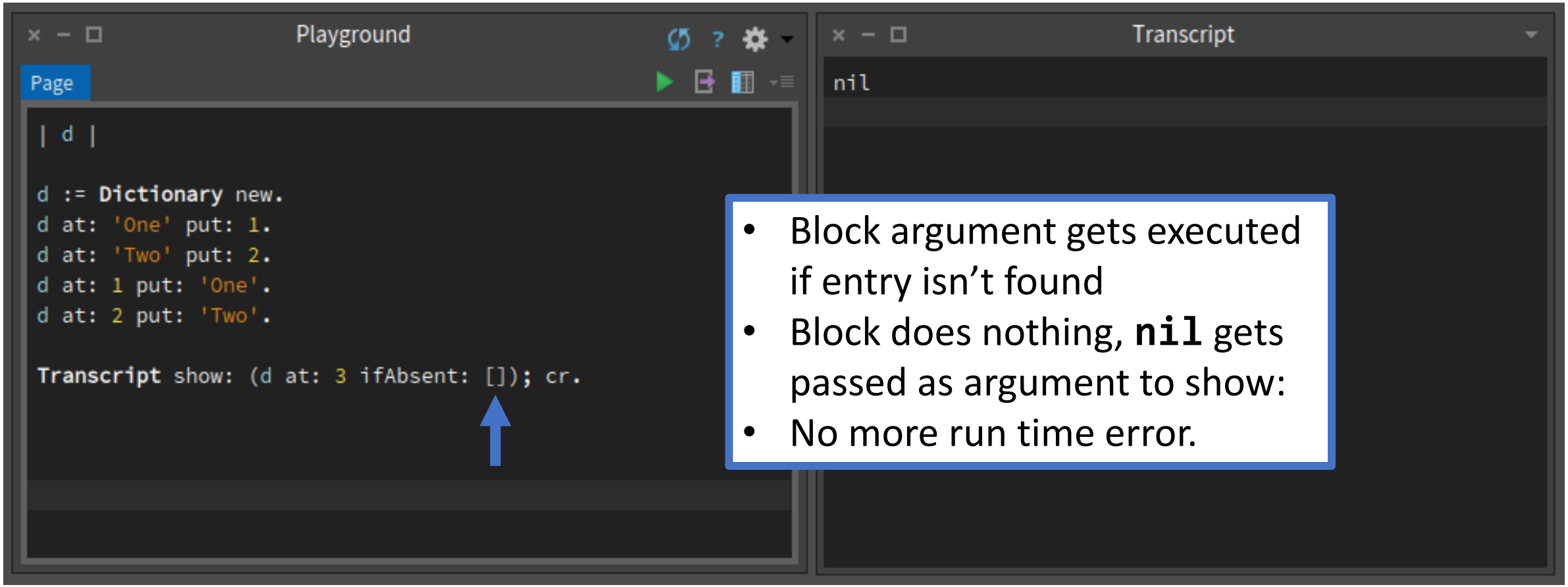


Dictionary: Key not Found?

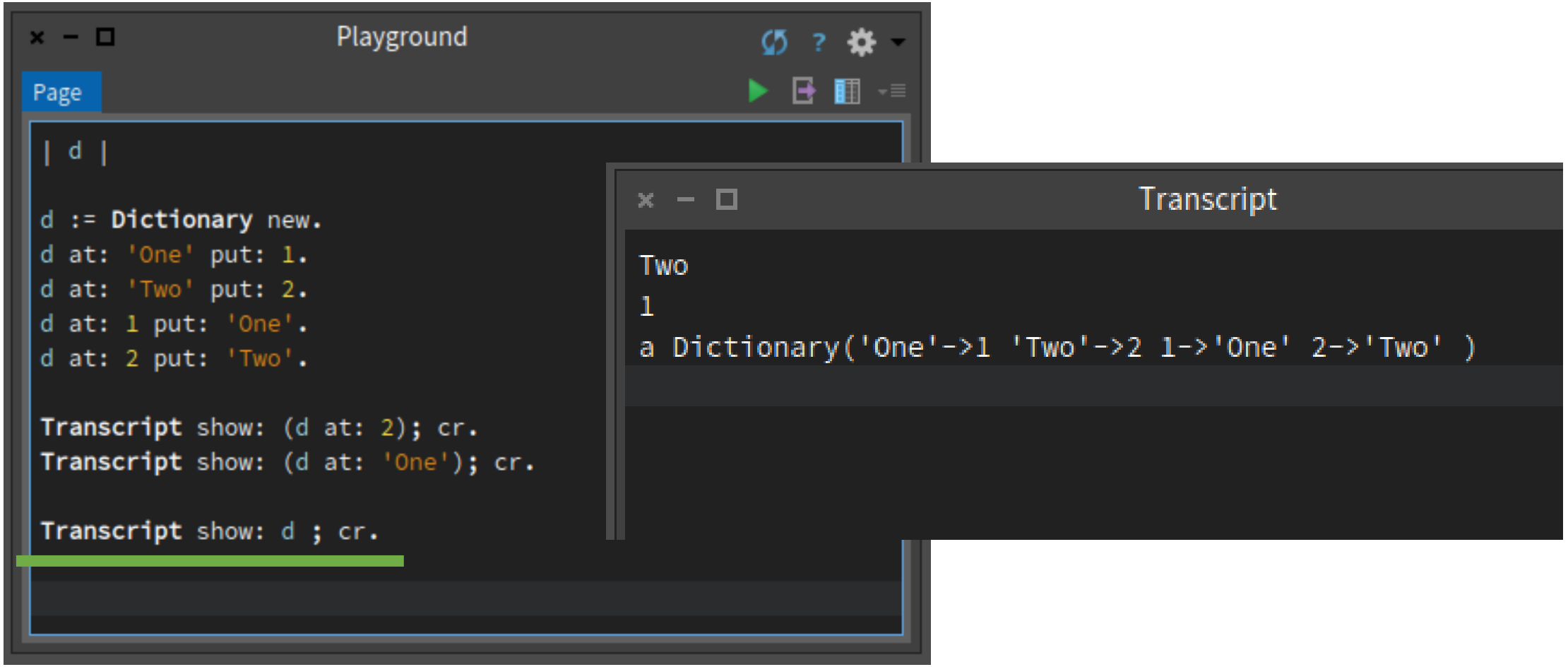


Not very graceful…

Try **`at:ifAbsent:`** instead



Dictionary: Printing



Identity Dictionary

- When searching for a key in a regular dictionary, the result of the **=** and **hash** messages are used.
- I.e., hash to index into table, compare key to resolve collision
  - *Remember hash tables from C/CPS 305*
- An *Identity Dictionary* uses **==** message, which checks if the key is the same ***object***
- Other than that, methods are the same
- Identity dictionary works great with symbols, less so with strings. Why?
  - Identical strings are *not necessarily* the same object!

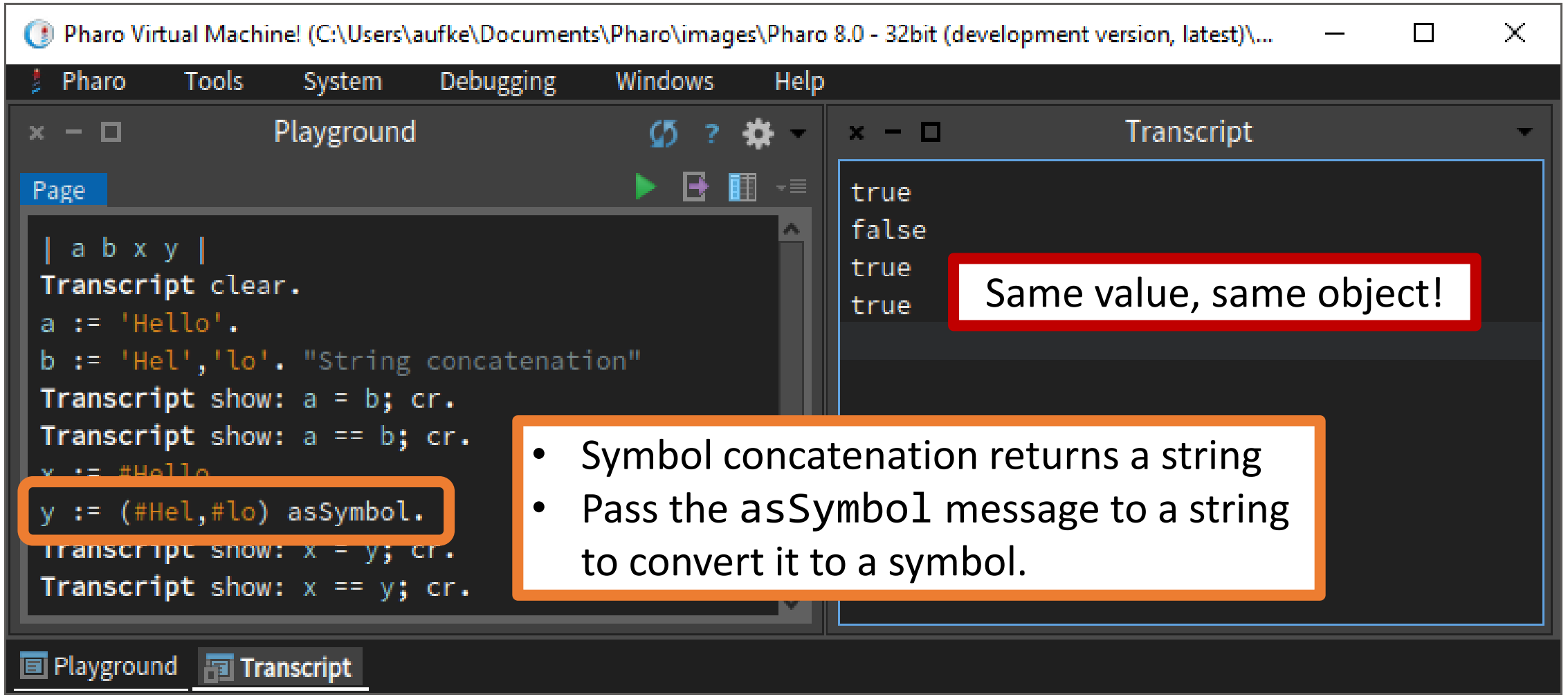
Symbol Reminder

Symbols:

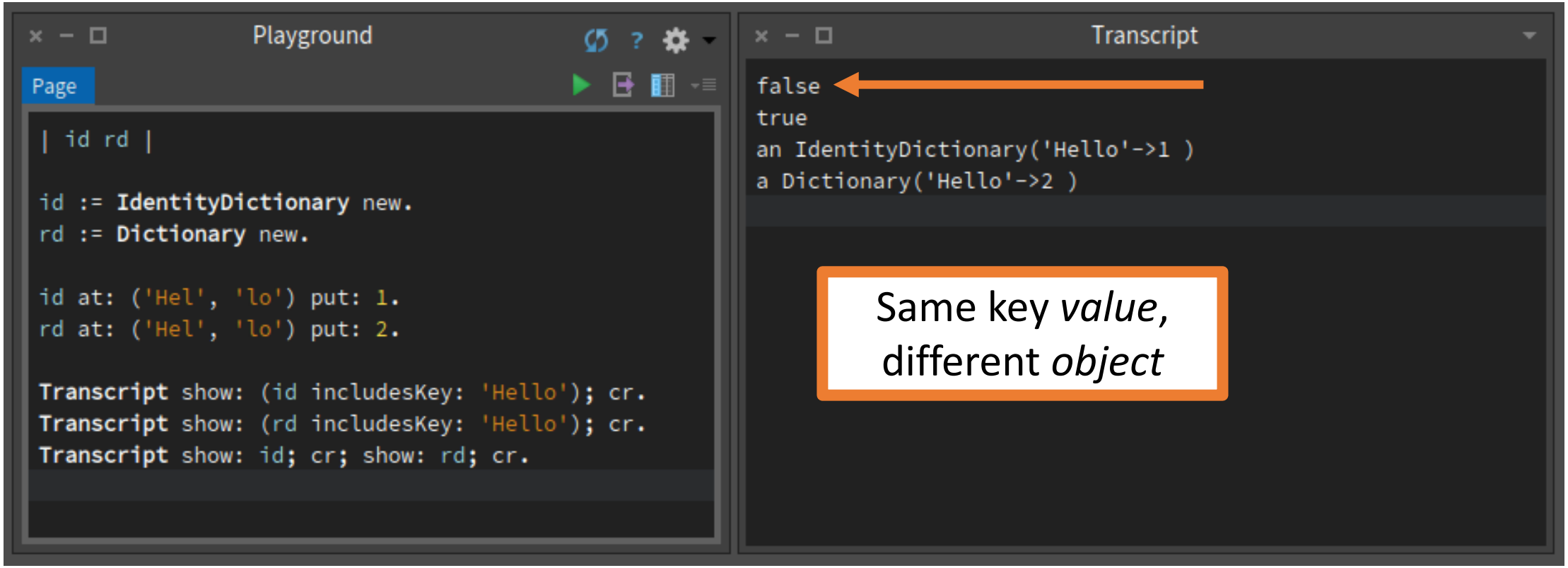
- # followed by string literal
  - **`#‘aSymbol’`** same as **`#aSymbol`** (no whitespace, quotes implied)
  - **`#‘symbol one’ #‘symbol two’`**
- Symbols are ***globally unique***. Strings are *not.*

Meaning:

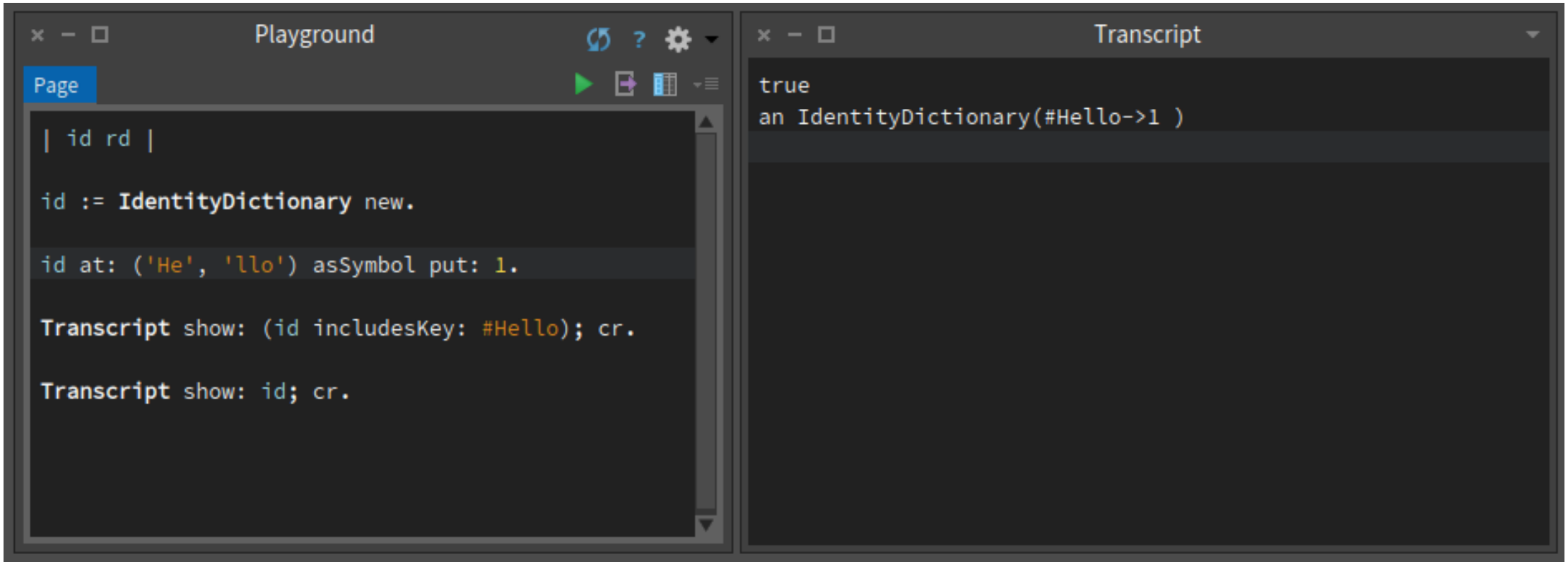
- Two *identical* (value) strings can exist as two *different* objects
- For every *unique* symbol value, there can be only *one* object.



Identity Dictionary



With Symbols?



Dictionaries

And much more!

```
| b x y sum max |
x := Dictionary new.                                          "allocate collection"
x add: #a->4; add: #b->3; add: #c->1; add: #d->2; yourself.   "add element to collection"
x at: #e put: 3.                                              "set element at index"
b := x isEmpty.                                               "test if empty"
y := x size.                                                  "number of elements"
y := x at: #a ifAbsent: [].                                   "retrieve element at index"
y := x keyAtValue: 3 ifAbsent: [].                            "retrieve key for given value with error block"
y := x removeKey: #e ifAbsent: [].                            "remove element from collection"
b := x includes: 3.                                           "test if element is in values collection"
b := x includesKey: #a.                                       "test if element is in keys collection"
y := x occurrencesOf: 3.                                      "number of times object in collection"
y := x keys.                                                  "set of keys"
y := x values.                                                "bag of values"
x do: [:a | Transcript show: a printString; cr].              "iterate over the values collection"
x keysDo: [:a | Transcript show: a printString; cr].          "iterate over the keys collection"
x associationsDo: [:a | Transcript show: a printString; cr]."iterate over the associations"
x keysAndValuesDo: [:aKey :aValue | Transcript                "iterate over keys and values"
   show: aKey printString; space;
   show: aValue printString; cr].
b := x conform: [:a | (a >= 1) & (a <= 4)].                   "test if all elements meet condition"
y := x select: [:a | a > 2].                                  "return collection of elements that pass test"
y := x reject: [:a | a < 2].                                  "return collection of elements that fail test"
y := x collect: [:a | a + a].                                 "transform each element for new collection"
y := x detect: [:a | a > 3] ifNone: [].                       "find position of first element that passes test"
sum := 0. x do: [:a | sum := sum + a]. sum.                   "sum elements"
sum := x inject: 0 into: [:a :c | a + c].                     "sum elements"
max := x inject: 0 into: [:a :c | (a > c)                     "find max element in collection"
   ifTrue: [a]
   ifFalse: [c]].
y := x asArray.                                               "convert to array"
y := x asOrderedCollection.                                   "convert to ordered collection"
y := x asSortedCollection.                                    "convert to sorted collection"
y := x asBag.                                                 "convert to bag collection"
y := x asSet.                                                 "convert to set collection"
```

Date

```
| b x y |
x := Date today.
x := Date dateAndTimeNow.
x := Date readFromString: '01/
x := Date newDay: 12 month: #J
x := Date fromDays: 36000.
y := Date dayOfWeek: #Monday.
y := Date indexOfMonth: #Janua
y := Date daysInMonth: 2 forYe
y := Date daysInYear: 1996.
y := Date nameOfDay: 1
y := Date nameOfMonth: 1.
y := Date leapYear: 1996.
y := x weekday.
y := x previous: #Monday.
y := x dayOfMonth.
y := x day.
y := x firstDayOfMonth.
y := x monthName.
y := x monthIndex.
y := x daysInMonth.
y := x year.
y := x daysInYear.
y := x daysLeftInYear.
y := x asSeconds.
y := x addDays: 10.
y := x subtractDays: 10.
y := x subtractDate: (Date tod
y := x printFormat: #(2 1 3 $/
b := (x <= Date today).
```

Time

```
| b x y |
x := Time now.
x := Time dateAndTimeNow.
x := Time readFromString: '3:4
x := Time fromSeconds: (60 * 6
y := Time millisecondClockValu
y := Time totalSeconds.
y := x seconds.
y := x minutes.
```

```
Smalltalk removeKey: #CMRDictionary ifAbsent:
```

Internal Stream

```
| b x ios |
ios := ReadStream on: 'Hello read stream'.
ios := ReadStream on: 'Hello read stream' from
[(x := ios nextLine) notNil]
   whileTrue: [Transcript show: x; cr].
ios position: 3.
ios position.
x := ios next.
x := ios peek.
x := ios contents.
b := ios atEnd.
ios position.
ios nextPutAll: 'Chris'.
x := ios next.
x := ios peek.
x := ios contents.
b := ios atEnd.
```

FileStream

```
| b x ios |
ios := FileStream newFileNamed: 'ios.txt'.
ios nextPut: $H; cr.
ios nextPutAll: 'Hello File'; cr.
'Hello File' printOn: ios.
'Hello File' storeOn: ios.
                              "total seconds sinc
                              "seconds past minut
                              "minutes past hour
```

There are many other classes for you to explore:

Interval

```
| b x y sum max |
x := Interval from: 5 to: 10.                    "create
x := 5 to: 10.
x := Interval from: 5 to: 10 by: 2.              "create
x := 5 to: 10 by: 2.
b := x isEmpty.                                  "test if
y := x size.                                     "number
x includes: 9.                                   "test if
x do: [:k | Transcript show: k printString; cr]. "iterate
b := x conform: [:a | (a >= 1) & (a <= 4)].      "test if
y := x select: [:a | a > 7].                     "return
                                                 "return
                                                 "transfo
                                                 "find po
                                                 "sum ele
                                                 "sum ele
                                                 "sum ele
                                                 "find ma
                                                 "convert
                                                 "convert
y := x asSortedCollection.                       "convert
y := x asBag.                                    "convert
y := x asSet.                                    "convert
```

Associations

```
| x y |
x := #myVar->'hello'.
y := x key.
y := x value.
```

Dictionaries

- `Dictionary`
- `IdentityDictionary`: uses identity test (`==` rather than `=`)

Topic 3: Summary

Continuing study of Smalltalk:

- More advanced syntax/semantics:
  - Blocks
  - Control “Structures”
  - Several Smalltalk collections