CSCI 275: Programming Abstractions

Lecture 29: Parameter Passing

Fall 2024

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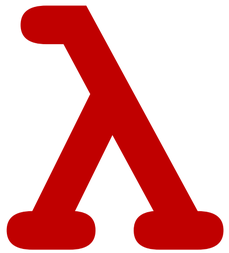
Slides from Molly Q Feldman



Exam next Wednesday

Monday will be a review day

Exam will be 24 hour take home exam, like the first exam

It will be designed to be completed in 50 minutes, you just get to pick when (and where) you want to do it

I'll be in my office during class time on Wednesday to answer exam-related questions

No lecture on Wednesday

More details on the exam on Monday

Parameter-passing mechanisms

Parameter Passing

Parameter passing mechanisms help us understand how values are passed between procedures

In essence: how do we associate the formal parameters with the arguments?

Two Major Approaches*

Call by value (CBV)

Arguments are evaluated in the caller's environment

Values are bound to parameters

Most languages you've used work this way

Call by name (CBN)

Arguments are not evaluated, passed "as is"

You can think about it as the "text" of the argument is passed and replaces the parameters in the function's body

```
((lambda (x) 5) (/ 1 0))
```

What will the result be in Call by Value?
In Call by Name?

A. CBV: 5
   CBN: 5

B. CBV: divide by zero error
   CBN: divide by zero error

C. CBV: divide by zero error
   CBN: 5

D. Something else

Thanks to “Design Concepts in Programming Languages” by Turbak, Gifford, and Sheldon for this example

```
(let* ([v 0]
       [f (lambda (x)
            (set! v (+ v 1))
            x)])
  (f (+ v 5)))
```

returns what in Racket?

A. 6

B. 5

C. 0

D. 1

E. Error

Call by Value Example in Racket

```
(let* ([v 0]
       [f (lambda (x)
            (set! v (+ v 1))
            x)])
  (f (+ v 5)))
```

`f` is called with value 5, so `x` is bound to 5

`v` is set to 1

`x` equal to `5` is returned

Call by Name Example in Racket

```
(let* ([v 0]
       [f (lambda (x)
            (set! v (+ v 1))
            x)])
  (f (+ v 5)))
```

The text of `f`'s body becomes the two expressions (by replacing `x` with the text of the argument)

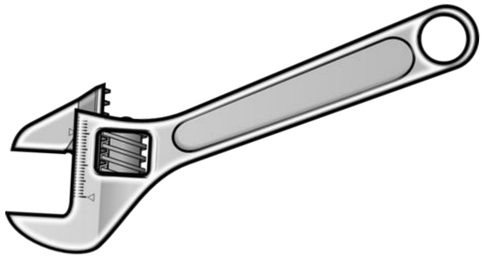
```
(set! v (+ v 1))
(+ v 5)
```

`v` is set to 1 and then *6* is returned

PL Theory vs. PL Practice

- When we talk about Call by Value or Call by Name in theory, we can have a nice conversation

- Language implementations make these types of formalisms real and therefore messy
  - This is why having a parameter passing discussion for Java is *hard*



PL Practice: Variations on CBV

Depending on the language at hand, many use a call by value approach or a related approach

Related approaches:

- Call by sharing
- Call by reference

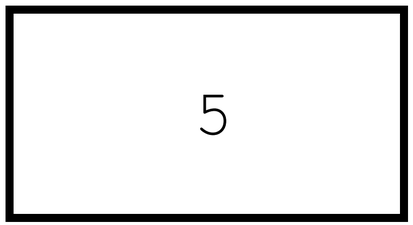
Most prevalent in languages with objects

These are *subtlety* different, so much so call by sharing tends to not be used as a term

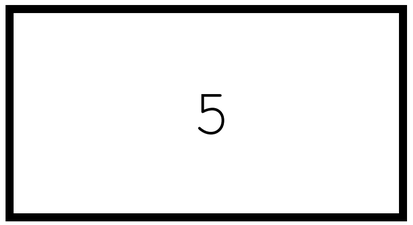
Basic principle: **the callee function gets a copy of what the caller supplies**

(Classic) Call by Value

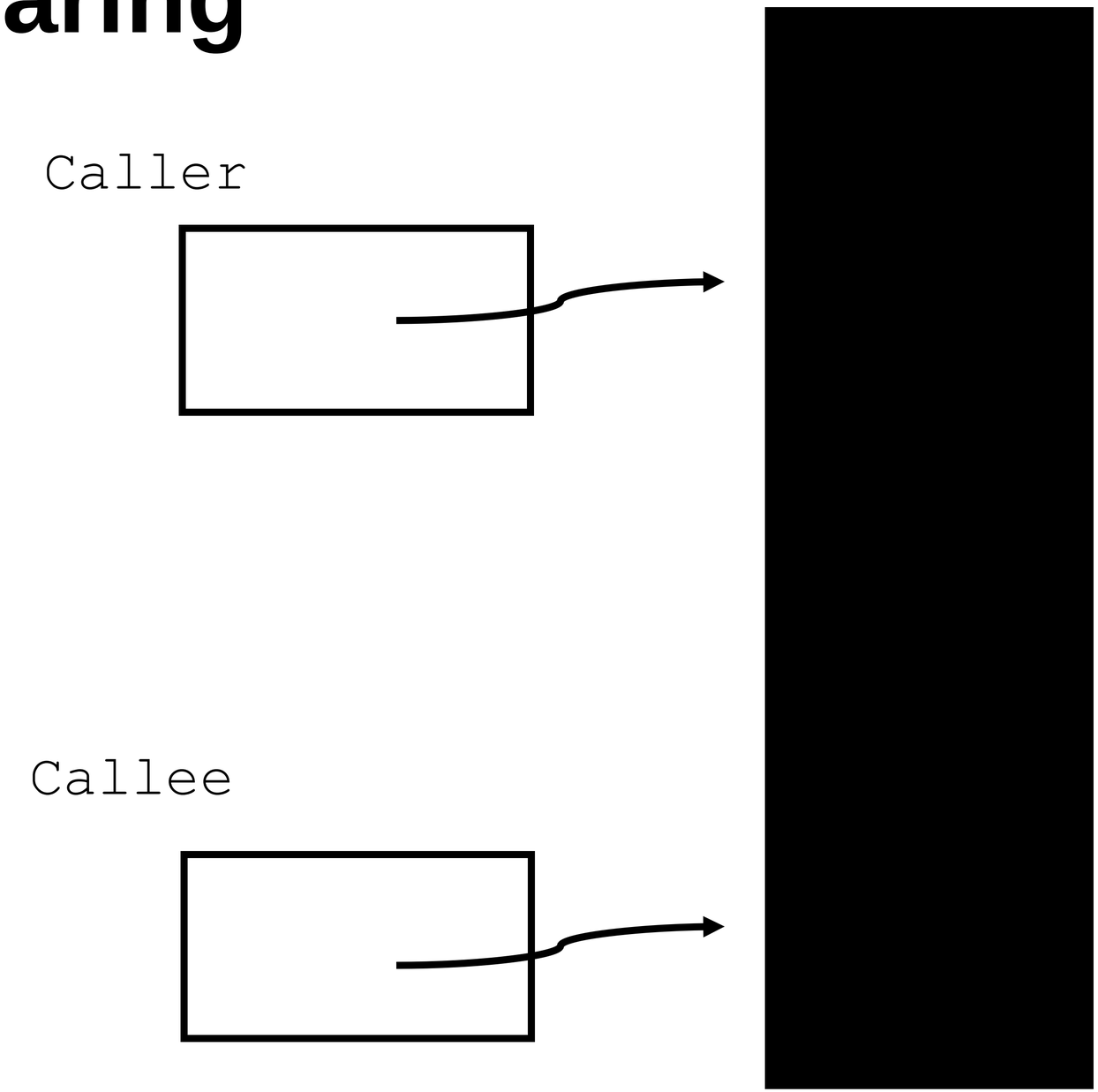
Caller



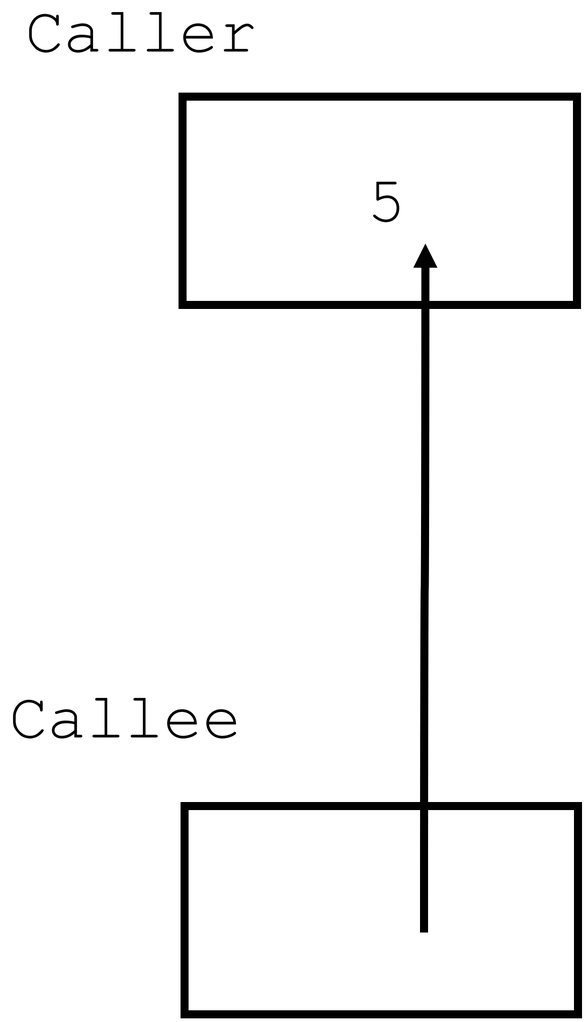
Callee



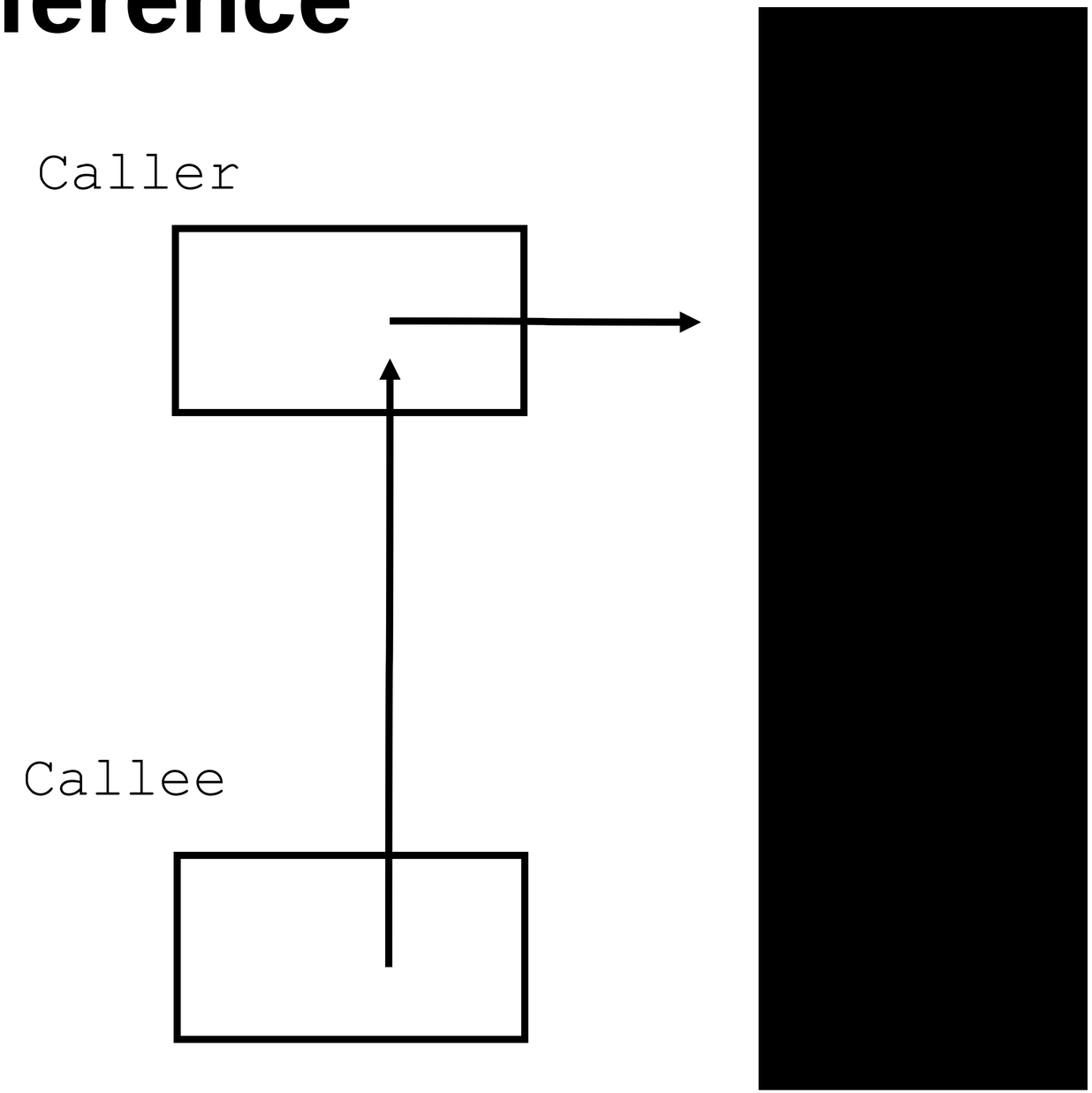
Call by Sharing



Call by Reference



Call by Reference



Call by Sharing versus Call by Reference

Call by Sharing is when you get your own copy of the pointer

- What's happening in Java and Python
- Can mutate the object, cannot replace it

Call by Reference is when you get a reference to the object (a "pointer to the value")

- What's happening in C++
- Can entirely replace the object

Call by Reference in C++

Python Tutor Example

https://pythontutor.com/render.html#code=%23include%20%3Ciostream%3E%0A%0Avoid%20change_value%28int%20%26x%29%20%7B%0A%20%20x%20%3D%2010%3B%0A%7D%0A%0Aint%20main%28%29%20%7B%0A%20%20int%20num%20%3D%200%3B%0A%20%20change_value%28num%29%3B%0A%20%20std%3A%3Acout%20%3C%3C%20num%20%3C%3C%20%22%5Cn%22%3B%0A%20%20return%200%3B%0A%7D&cumulative=false&curInstr=0&heapPrimitives=nevernest&mode=display&origin=opt-frontend.js&py=cpp_g%2B%2B9.3.0&rawInputLstJSON=%5B%5D&textReferences=false

Call by Sharing in Python

Python Tutor Example

https://pythontutor.com/render.html#code=def%20change_value%28lst%29%3A%0A%20%20%20%20lst.append%2825%29%0A%20%20%20%20lst%20%3D%20%5B1,%202,%203%5D%0A%0Adef%20main%28%29%3A%0A%20%20%20%20vals%20%3D%20%5B10,%2020,%2030%5D%0A%20%20%20%20change_value%28vals%29%0A%20%20%20%20print%28vals%29%0A%0Amain%28%29&cumulative=false&curInstr=0&heapPrimitives=nevernest&mode=display&origin=opt-frontend.js&py=3&rawInputLstJSON=%5B%5D&textReferences=false

Aside: Prof. Barbara Liskov

Institute Professor of Computer Science at the Massachusetts Institute of Technology

Researcher in **programming languages and systems:** what are the rules and proofs behind how we communicate with computers

Developed CLU, defines call by sharing in it’s manual

Turing Award Winner

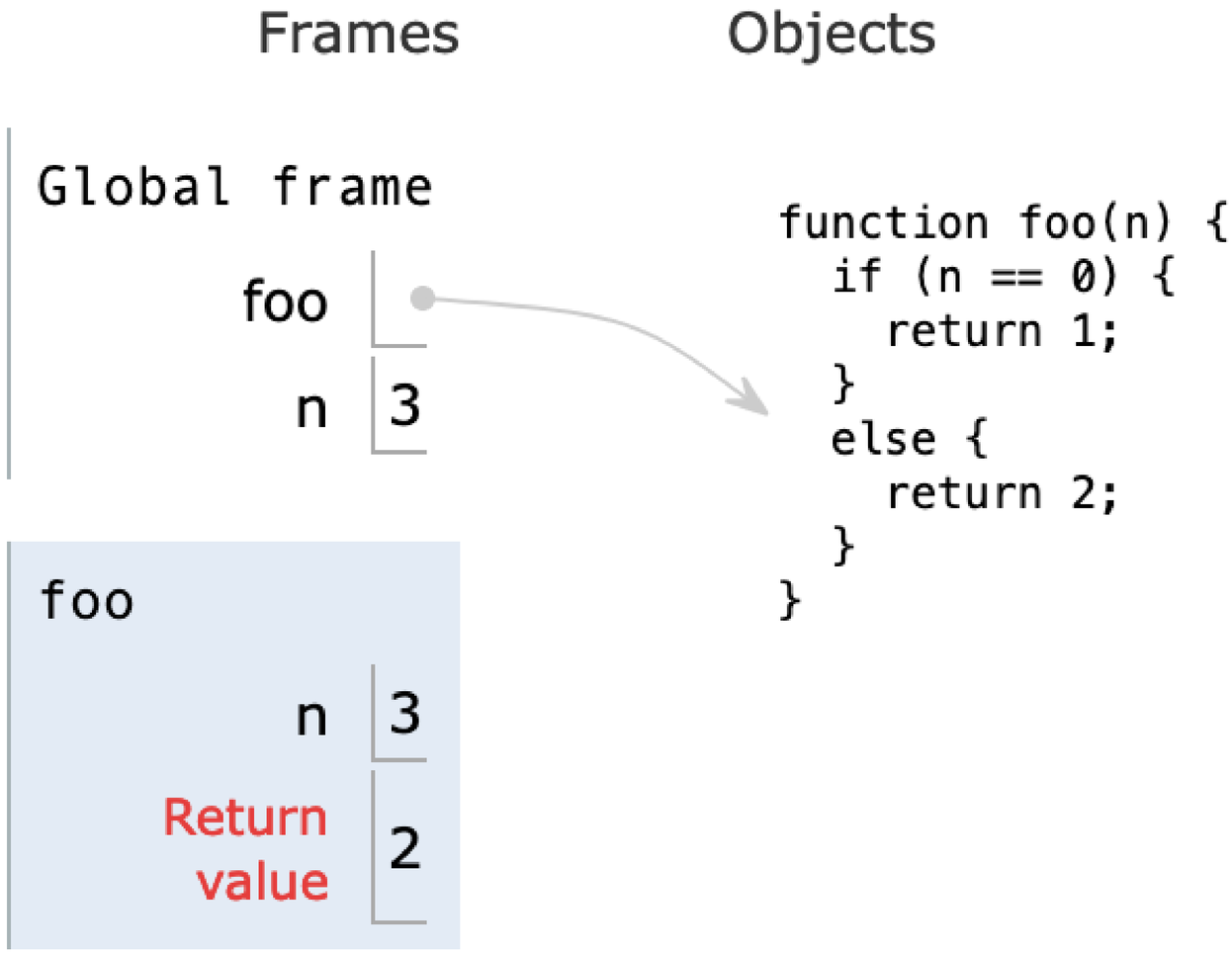
Parameter Passing *Is a Design Choice*

Different languages have made different choices!

Call by Value in JavaScript in PythonTutor

```
function foo(n) {
  if (n == 0) {
    return 1;
  }
  else {
    return 2;
  }
}

var n = 3;
foo(n);
```



https://pythontutor.com/visualize.html#mode=edit

Call by Name in TeX

TeX is a macro language for writing documents

```
\def\work#1#2{%
  All work and no play makes #1 a dull #2.\par}
 \work{Jack}{boy}
 \work{2+3}{5}
 \bye
```

All work and no play makes Jack a dull boy.
All work and no play makes 2+3 a dull 5.

Parameter Passing *Is a Design Choice*

With varying levels of precision and difficulty, we could make MiniScheme work with Call by Value, Call by Name, or Call by Reference

We **chose** classic Call by Value in our implementation when implementing lambdas

Example: if we wanted MiniScheme as CBN

We can make MiniScheme use Call by Name via function re-writing

- Don't evaluate arguments at all!
- In `(apply-proc p args)`, rewrite the procedure's body (which is a parse tree) replacing each use of a parameter with the parse tree for the corresponding argument