Yhc: The York Haskell Compiler

By
Tom Shackell

What?

- Yhc is a rewrite of the back end of the nhc98 system.
- The back-end of the compiler is replaced.
- The runtime system is replaced.
- The instruction set is different.
- The Prelude is heavily modified.

Why?

- It was written to address some issues with the nhc98 back end.
- In particular: The high bit problem.
- Also as an experiment: Can we make nhc98 more portable?

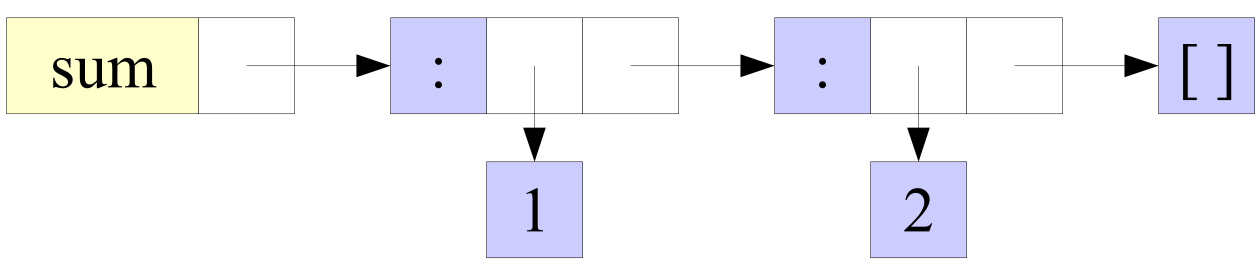
The High Bit Problem

Graph Reduction

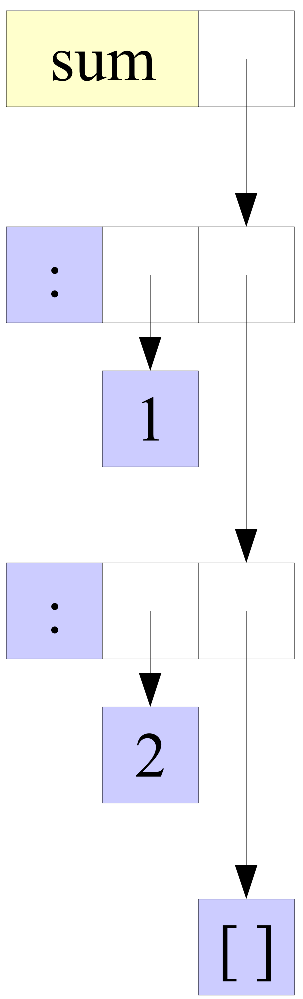
- Lazy functional languages are usually implemented using graph reduction.
- Haskell expressions are represented by graphs.

```
sum :: [Int] -> Int
sum []     = 0
sum (x:xs) = x + sum xs
```

- The expression 'sum [1,2]' might be represented by the graph:



Reduction



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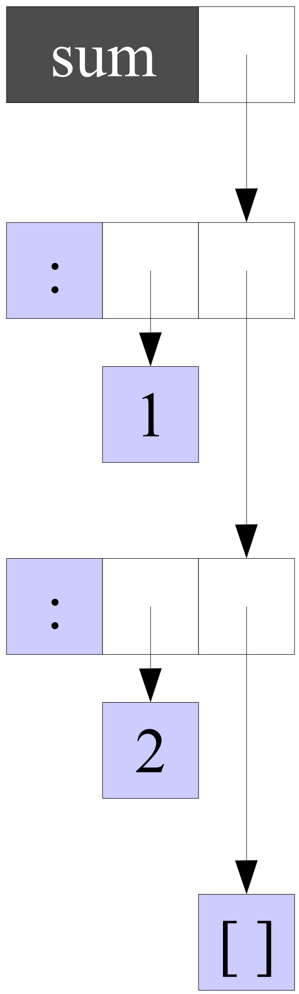

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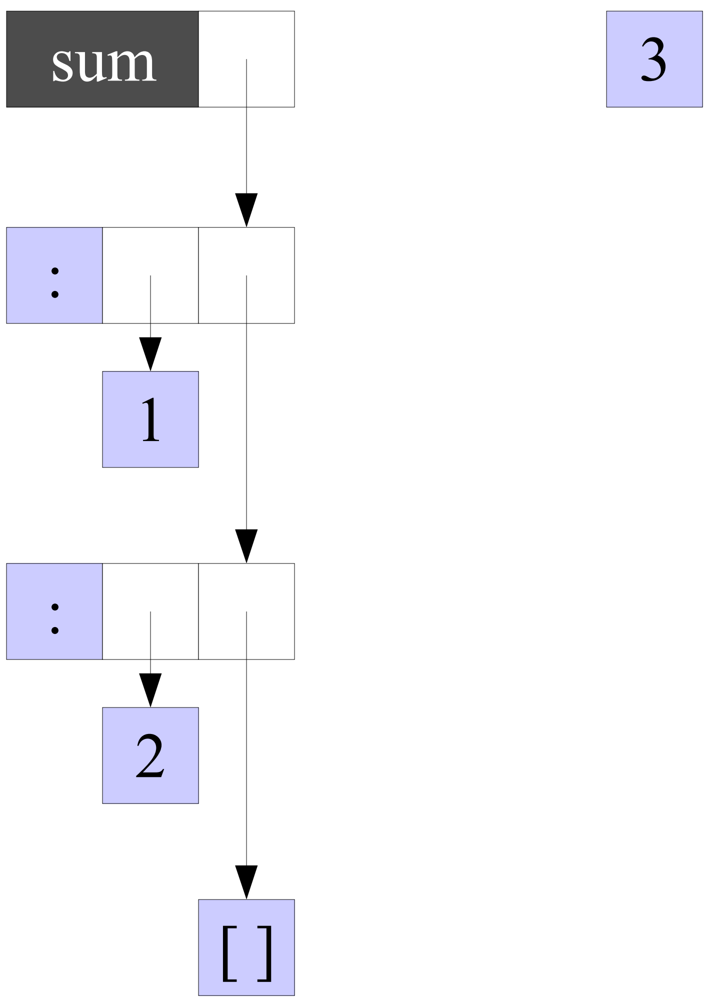
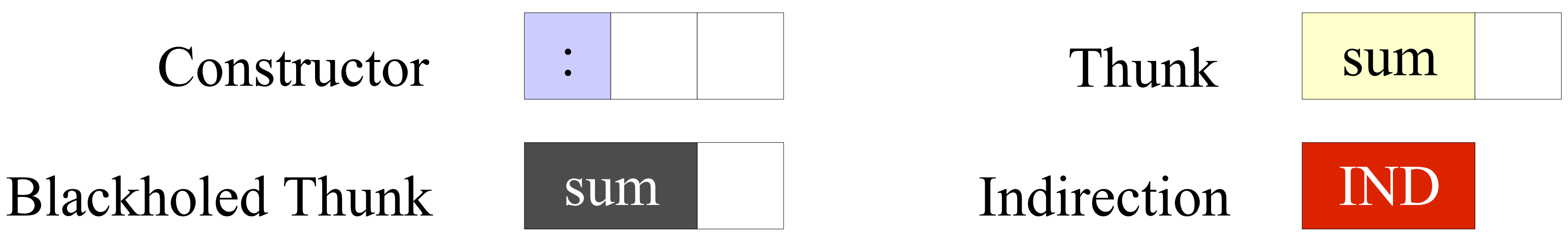


Reduction

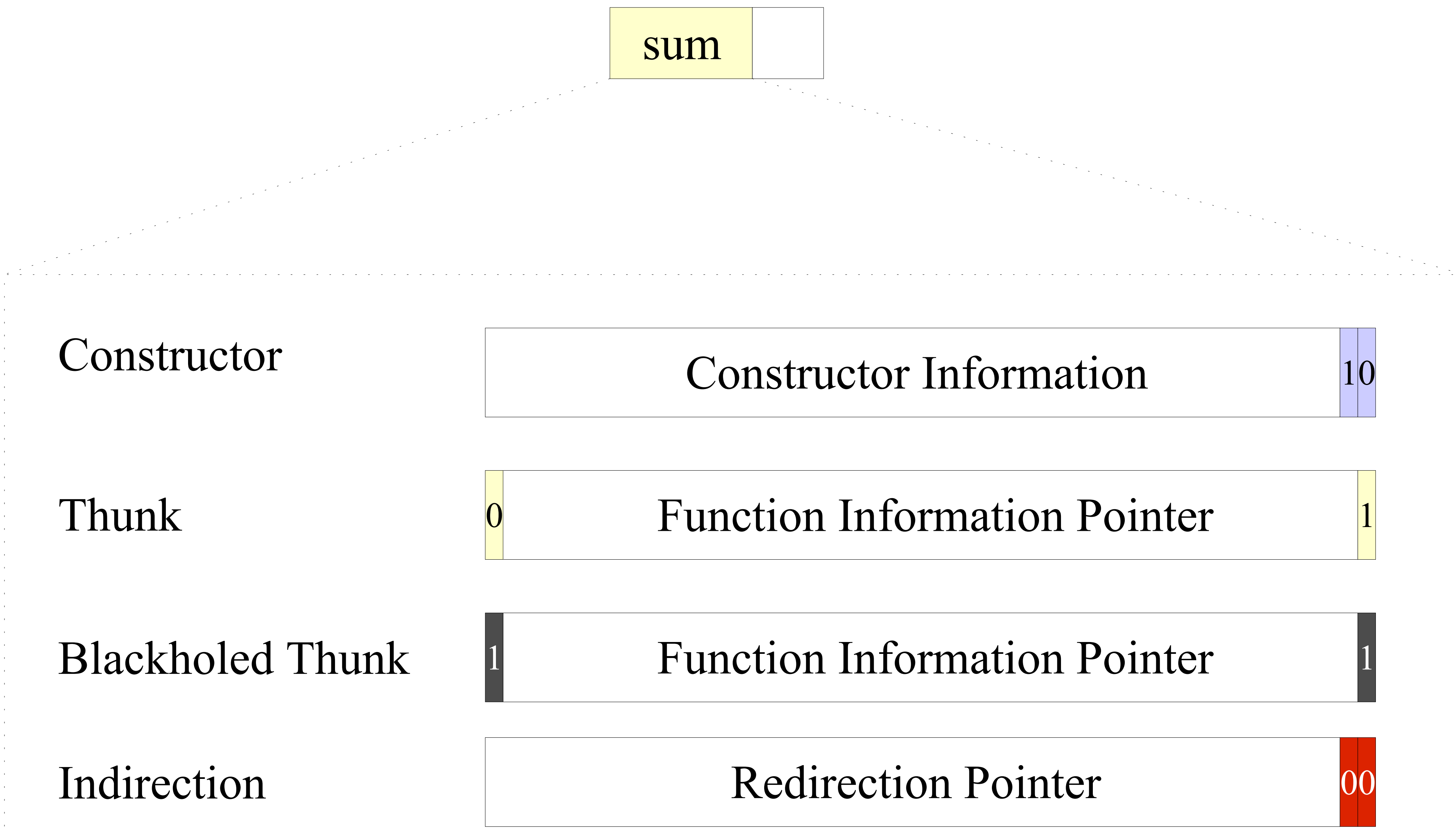
Heap Node

We can see there are 4 types of graph node



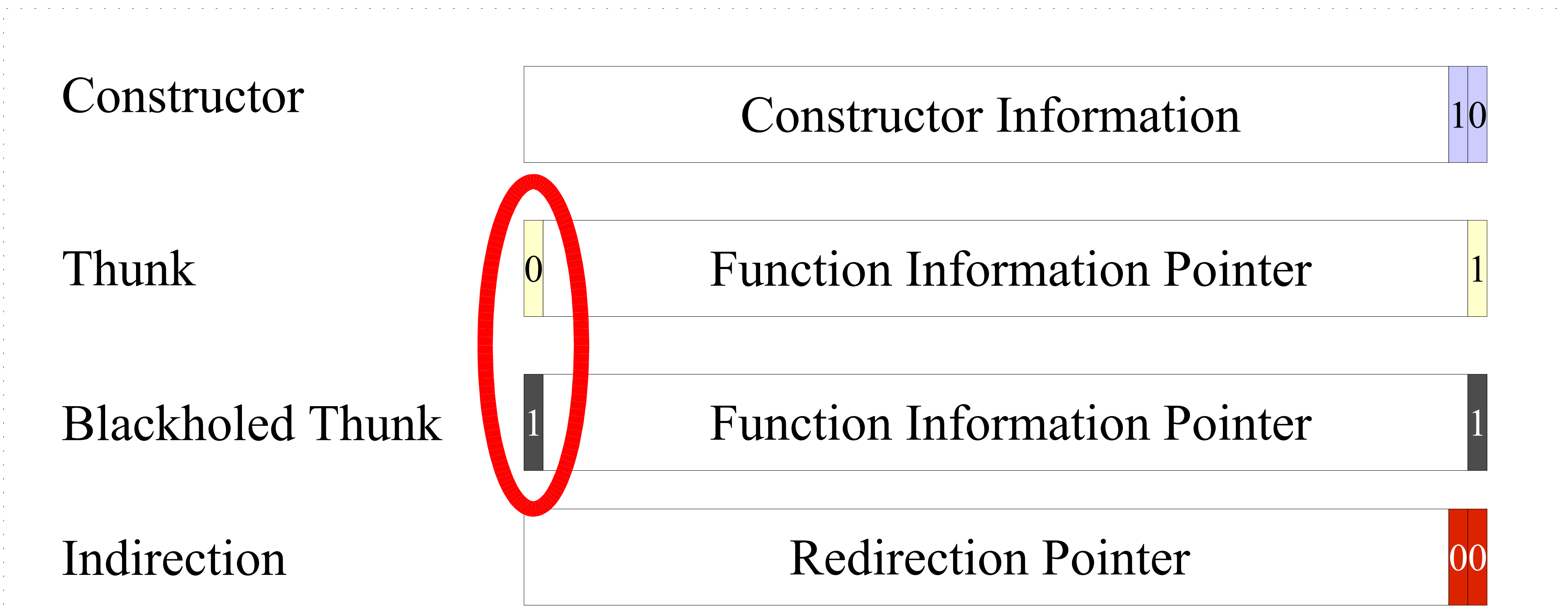
In nhc and Yhc these graph nodes are represented with 4 types of heap node

Heap Nodes in nhc



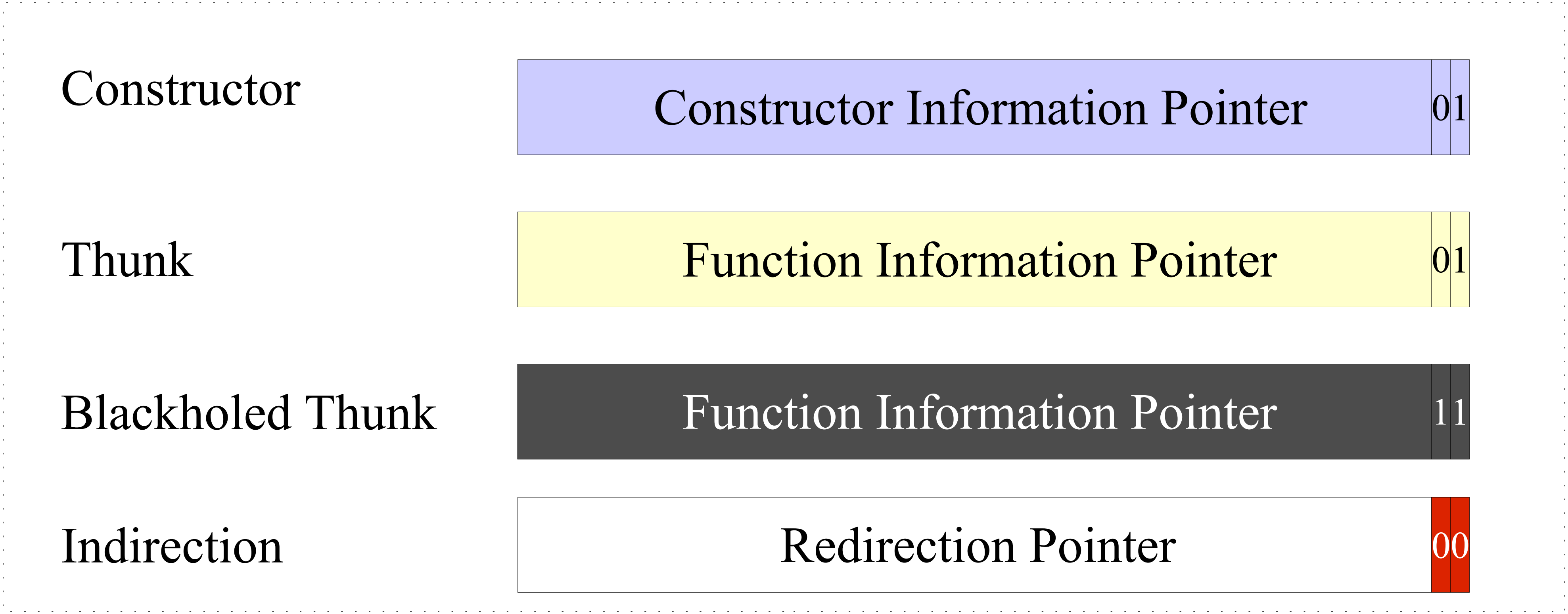
The “High Bit” problem

- nhc assumes that it can use the topmost bit of a pointer to store information.
- This is not always the case: many modern Linux-x86 kernels allocate memory in addresses too high to fit in 31bits.



Heap Nodes in Yhc

- Yhc makes sure that all FInfo structures are 4 byte aligned. Freeing up a bit at the bottom for Thunk nodes.
- It also represents constructors by using a pointer to the information about the constructor, rather than encoding the information into the heap word.



Instruction Sets

- The instruction set for Yhc is much simpler than for nhc.
- Both are based on stack machines.
- However, nhc has instructions for directly manipulating both the heap and the stack.
- Where as Yhc only directly manipulates the stack.

Instructions

```
main :: IO ()
main = putStrLn (show 42)
```

nhc instructions

```
main():
  HEAP_CVAL show
  HEAP_INT 42
  PUSH_HEAP
  HEAP_CVAL putStrLn
  HEAP_OFF -3
  RETURN_EVAL
```

Yhc instructions

```
main():
  PUSH_INT 42
  MK_AP show
  MK_AP putStrLn
  RETURN_EVAL
```

nhc instructions

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main():
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Stack

Heap

Constants

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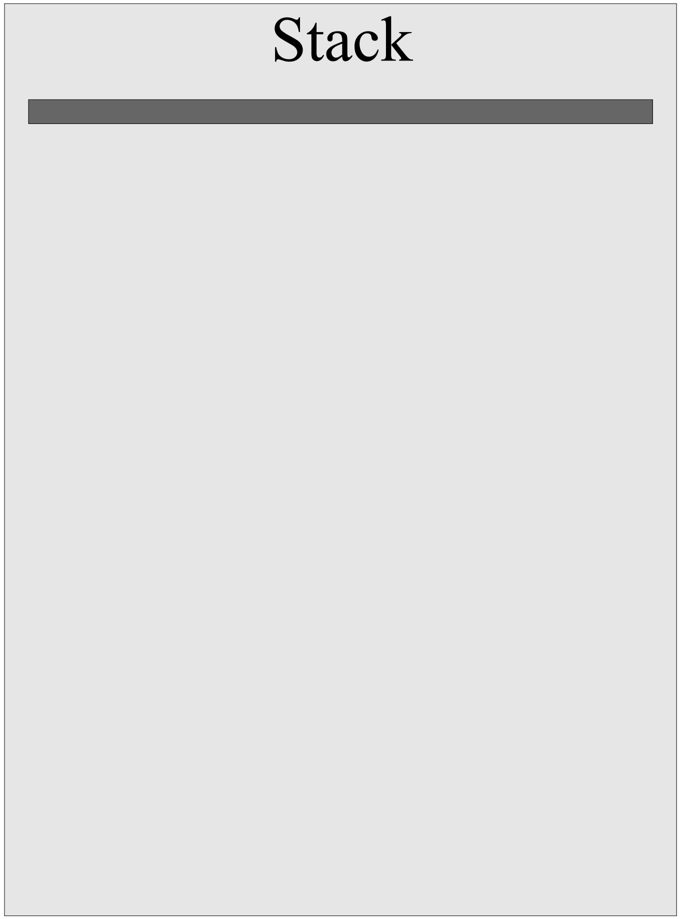

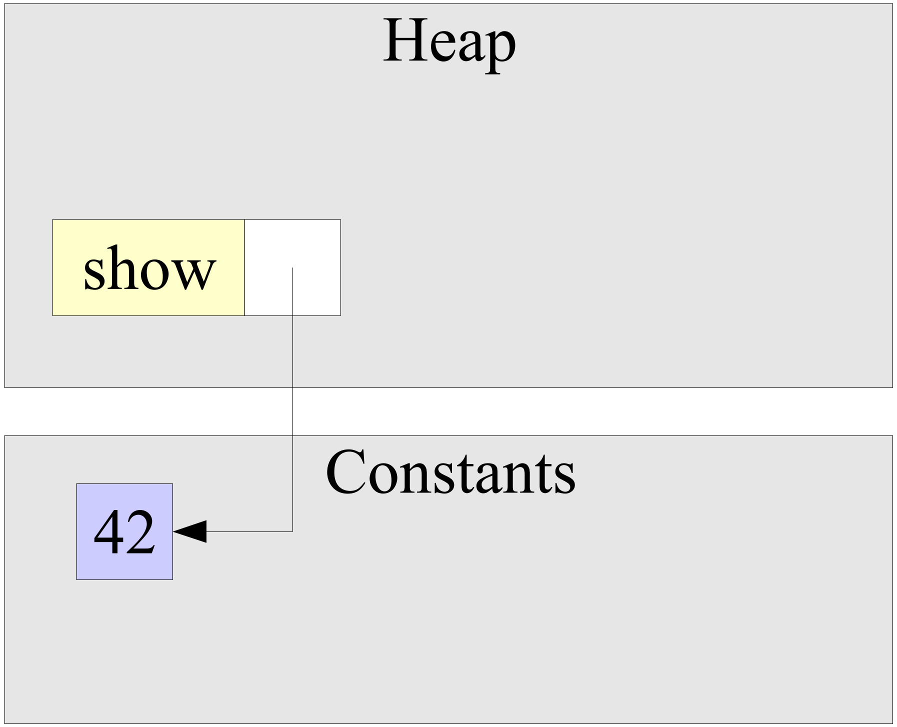

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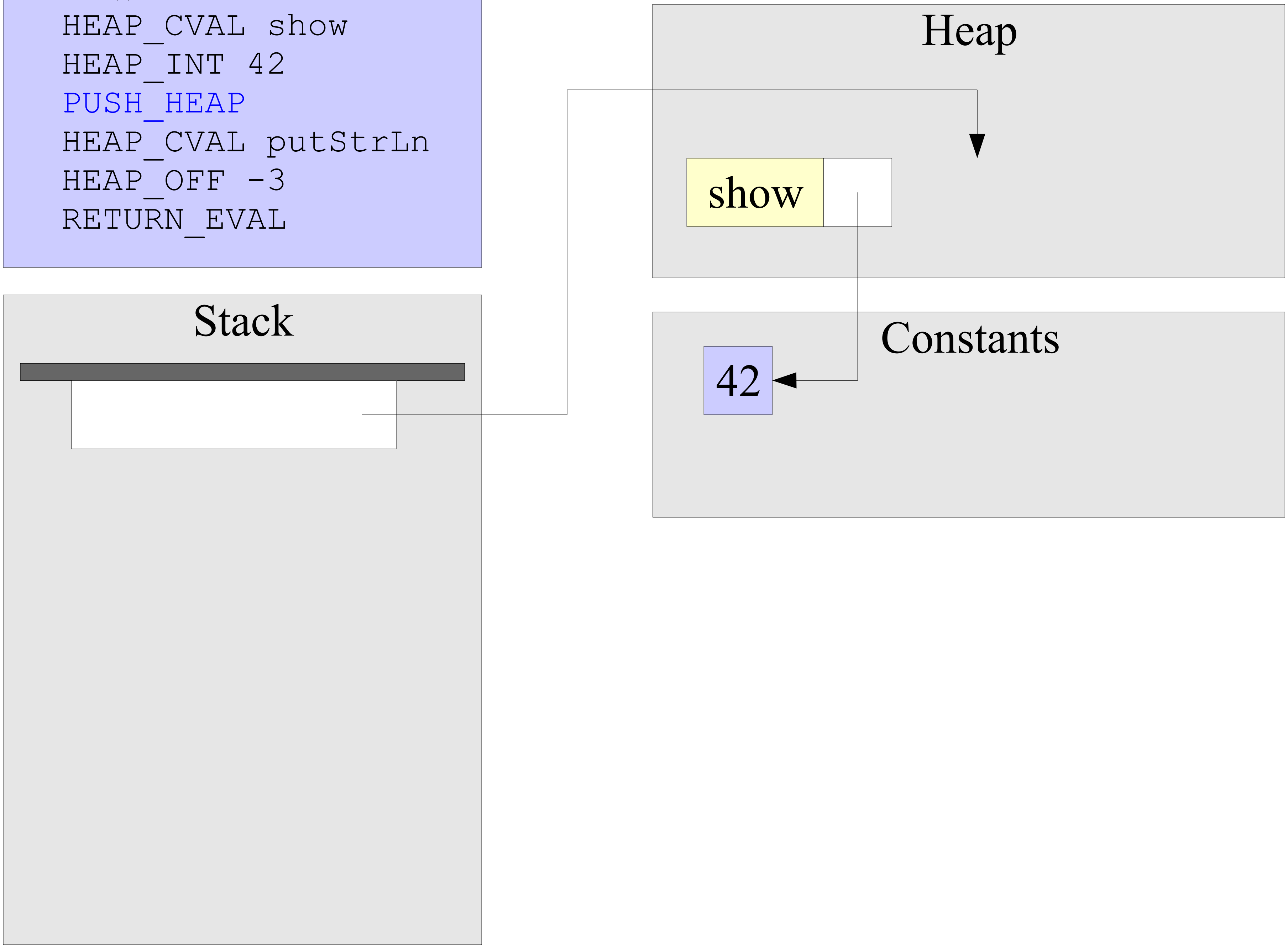

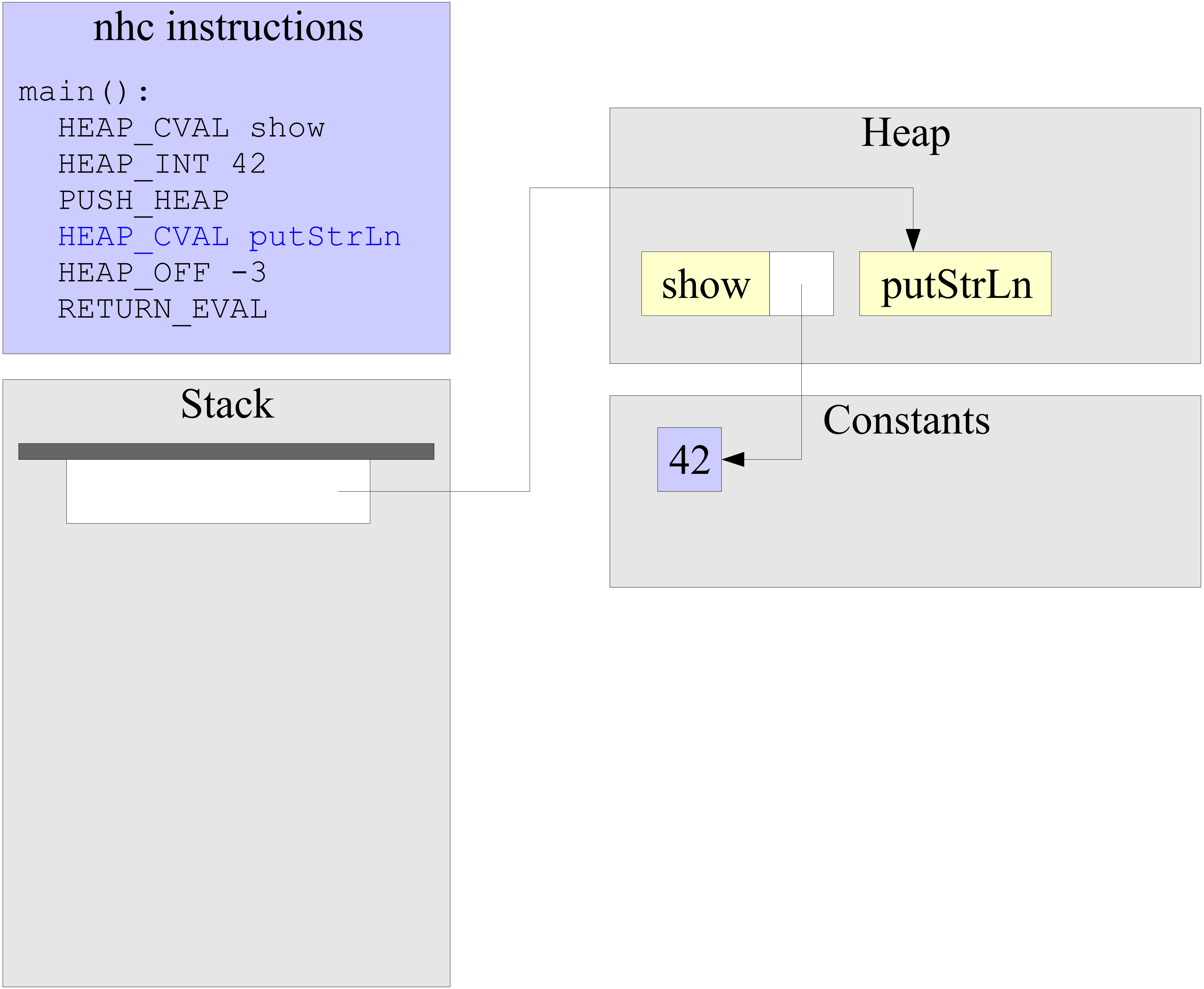
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Constants
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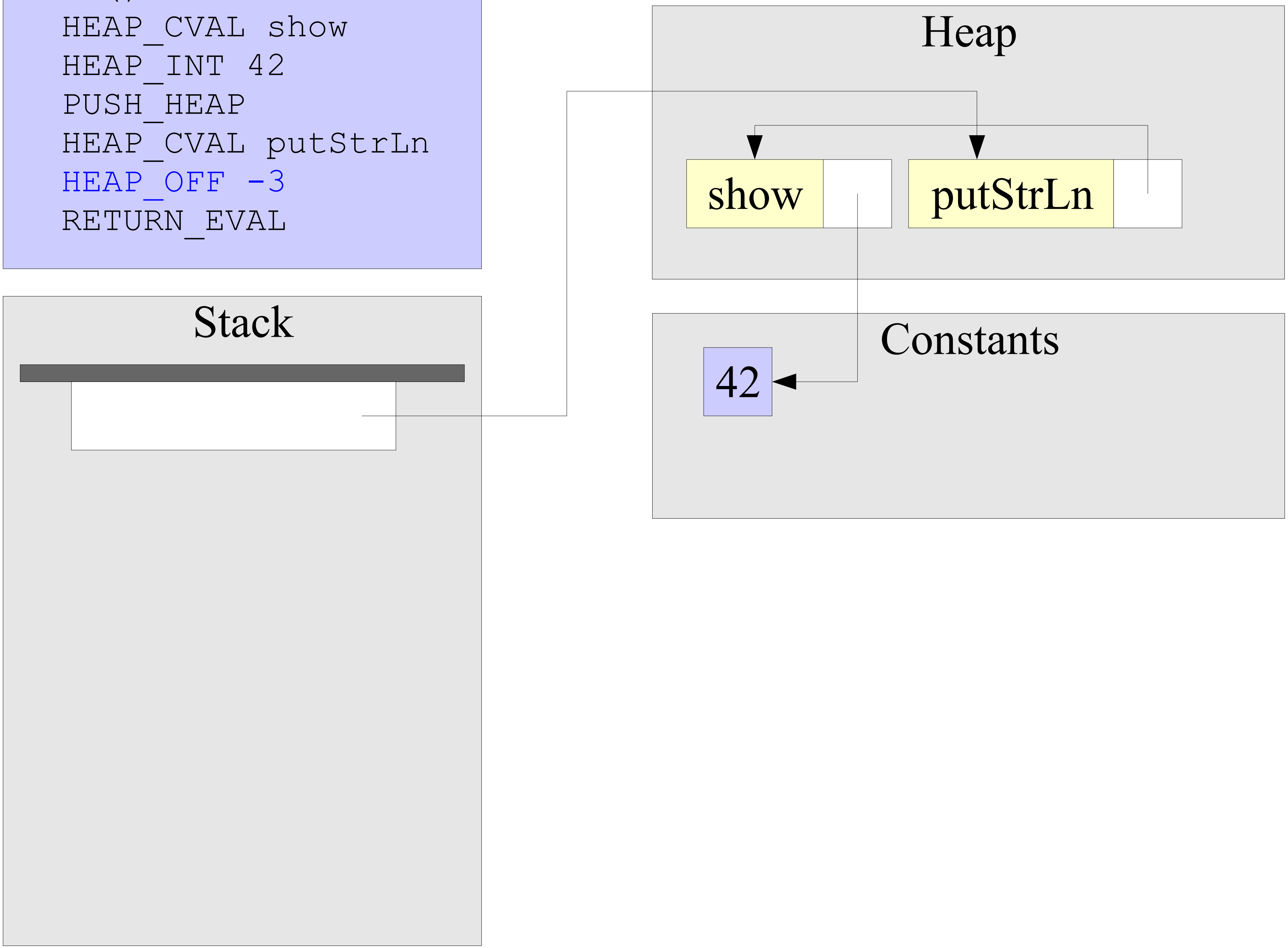

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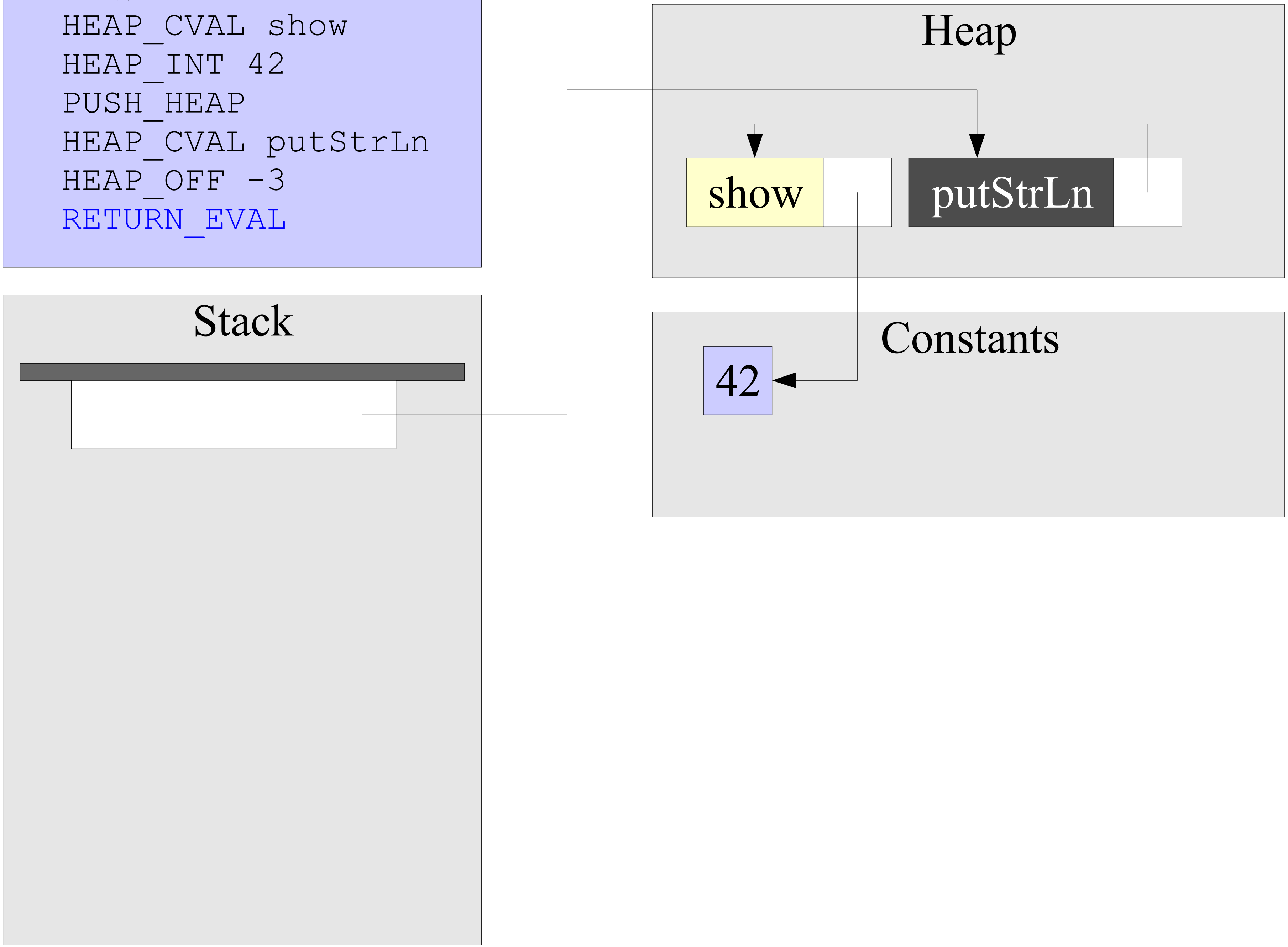

Yhc instructions

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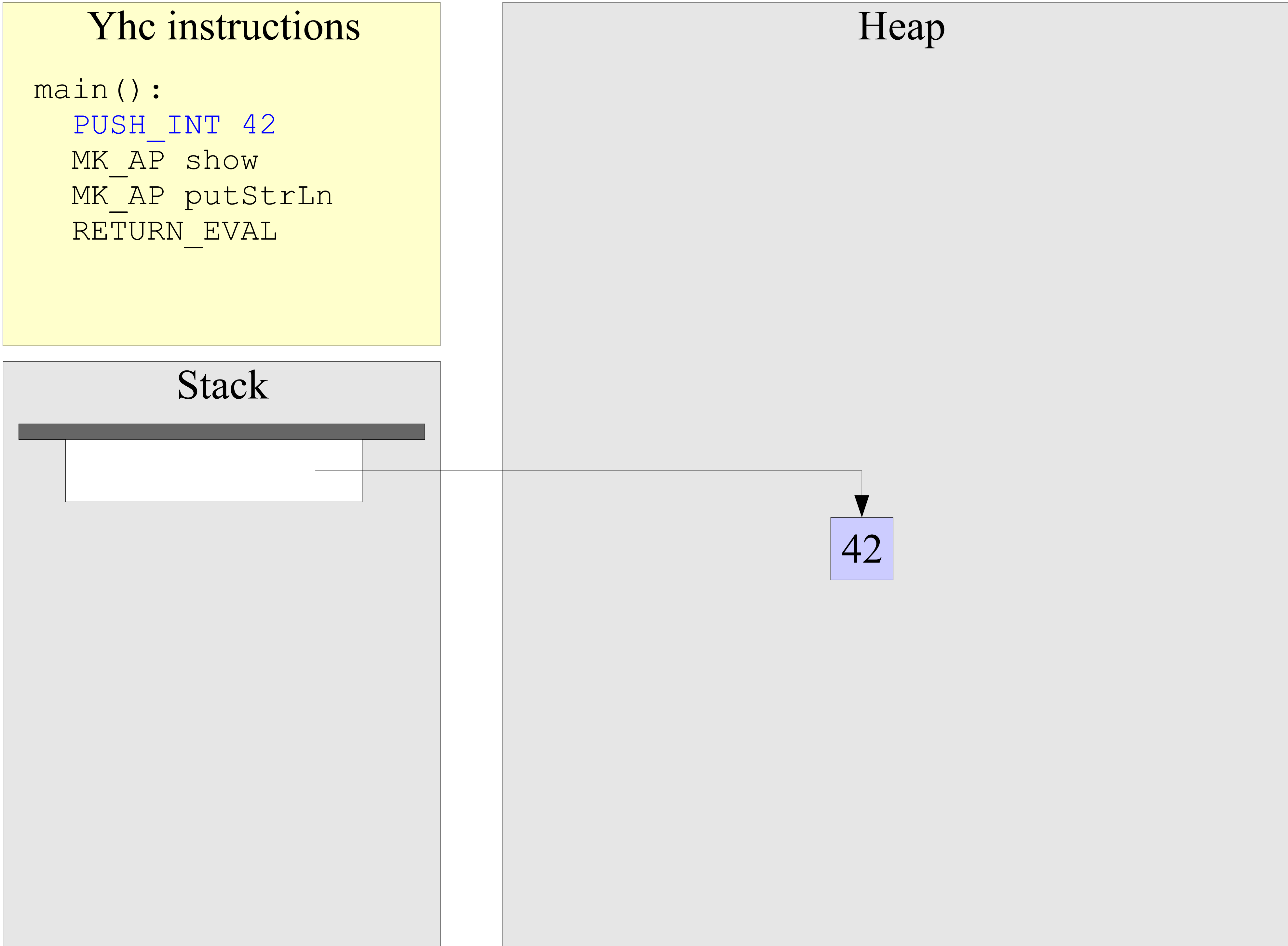

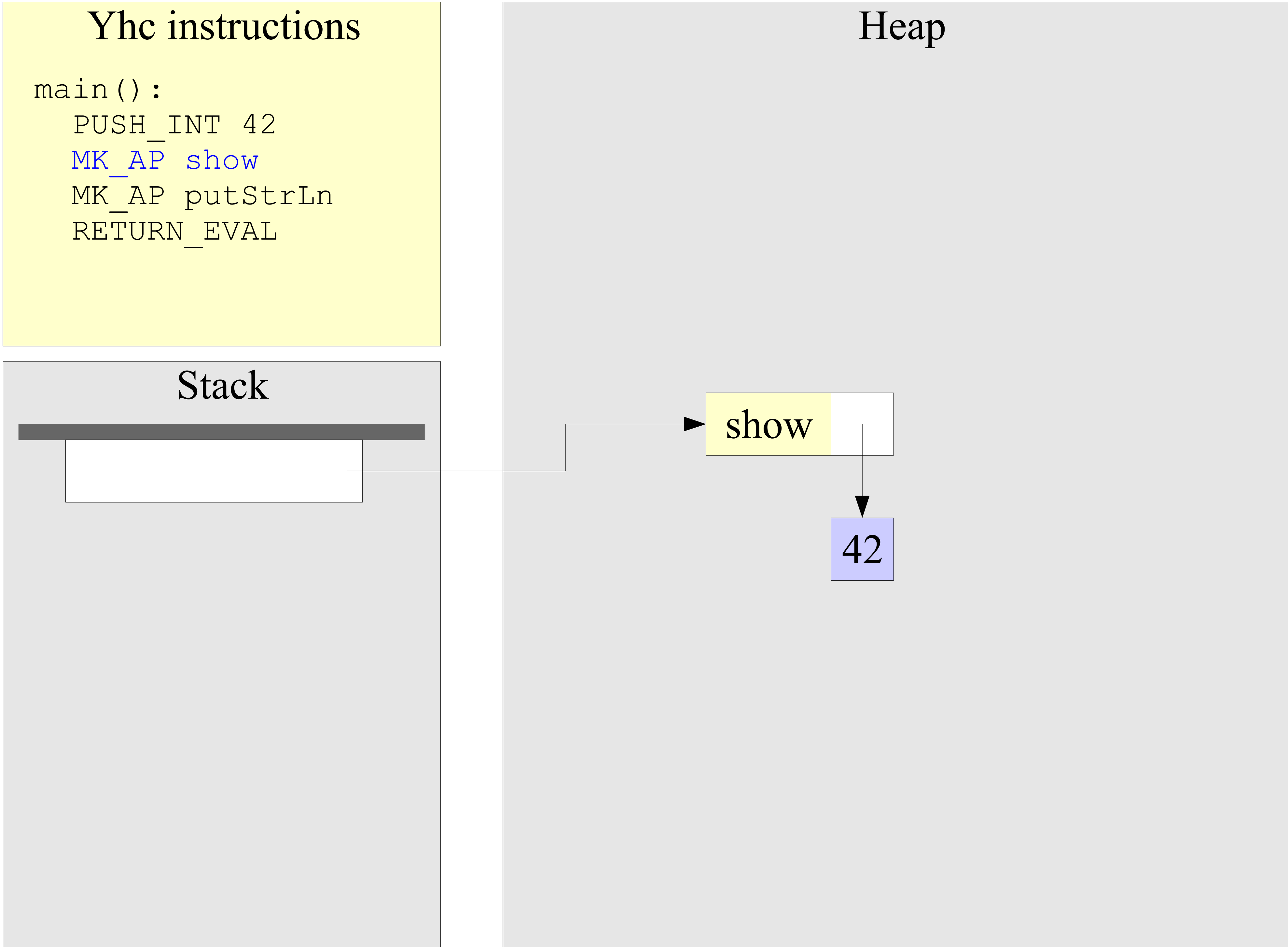
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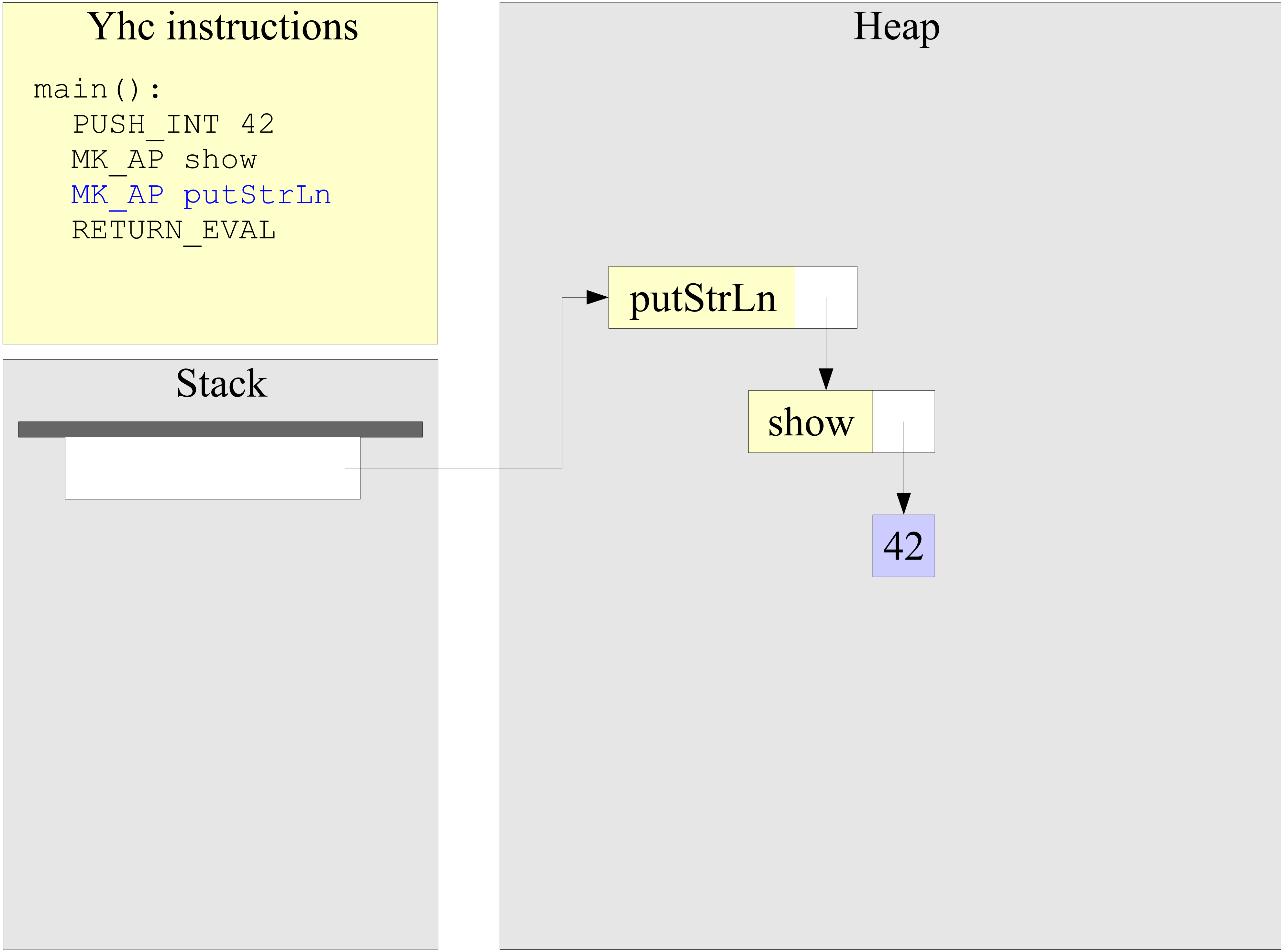

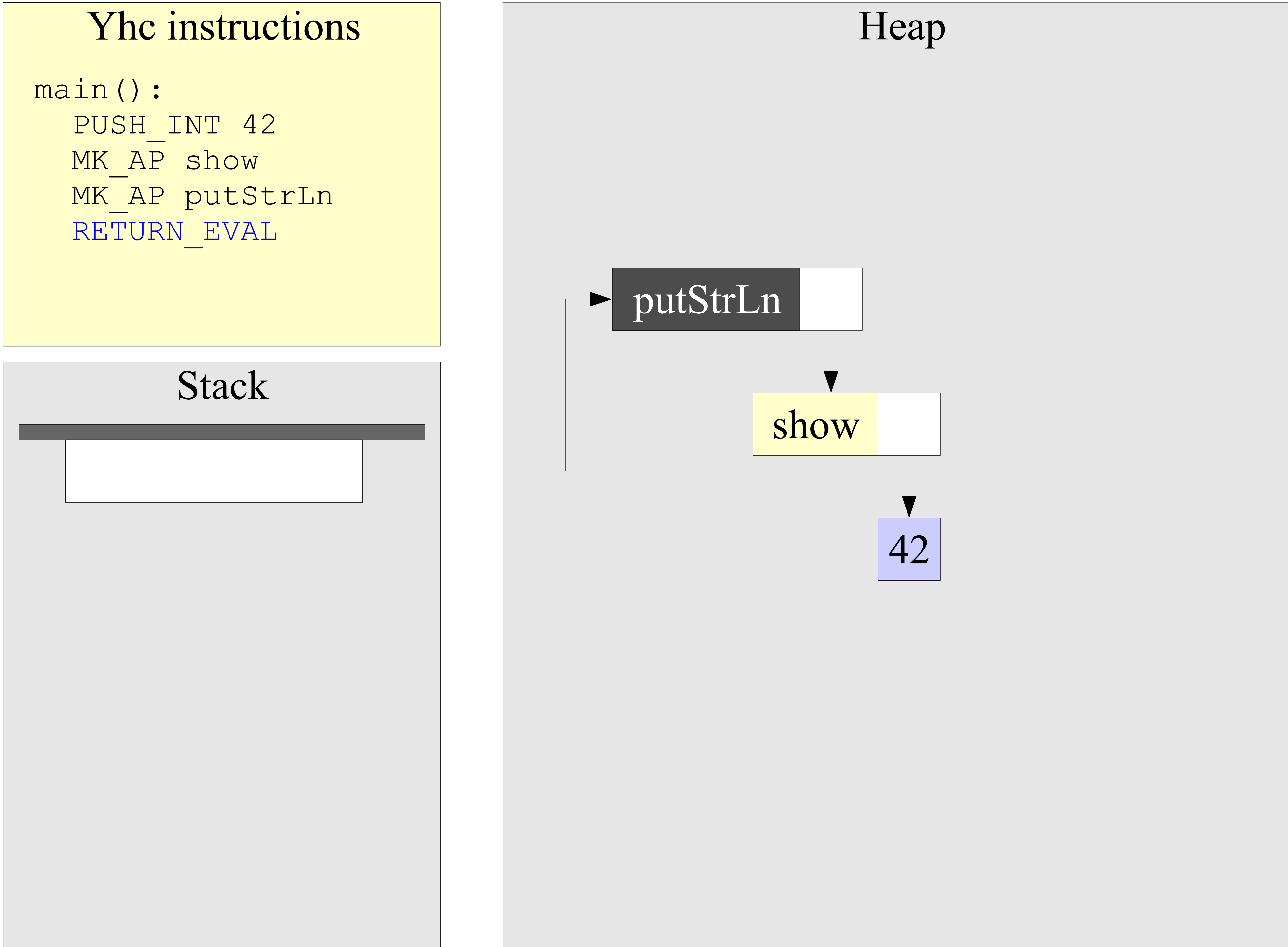
Yhc instructions
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Stack
Heap
putStrLn
show
42

Comparison

- Yhc uses less instructions to do the same thing.
- Because it doesn't have to have explicit movements between heap and stack.
- ... and because it can reference other nodes implicitly rather than using explicit heap offsets.
- Yhc instructions are also smaller
- Because it has more 'specializations'
- ... and again, because heap references are implicit
- These two factors make Yhc about 20% faster than nhc

Improving Portability

Bytecode in nhc

- nhc compiles Haskell functions into a bytecode for an abstract machine that manipulates graphs: The G-Machine.
- The bytecode is placed in a C source file, using an array of bytes. The C source file is then compiled and linked with the nhc interpreter to form an executable.

```
unsigned char[] FN_Prelude_46sum = {
   NEEDHEAP_I32, HEAP_CVAL_I3, HEAP_ARG, 1, HEAP_CVAL_I4,
   HEAP_ARG, 1, HEAP_CVAL_I5, HEAP_OFF_N1, 3, HEAP_CADR_N1, 1,
   PUSH_HEAP, HEAP_CVAL_P1, 6, HEAP_OFF_N1, 8, HEAP_OFF_N1, 5,
   RETURN, ENDCODE
};
```

Portable?

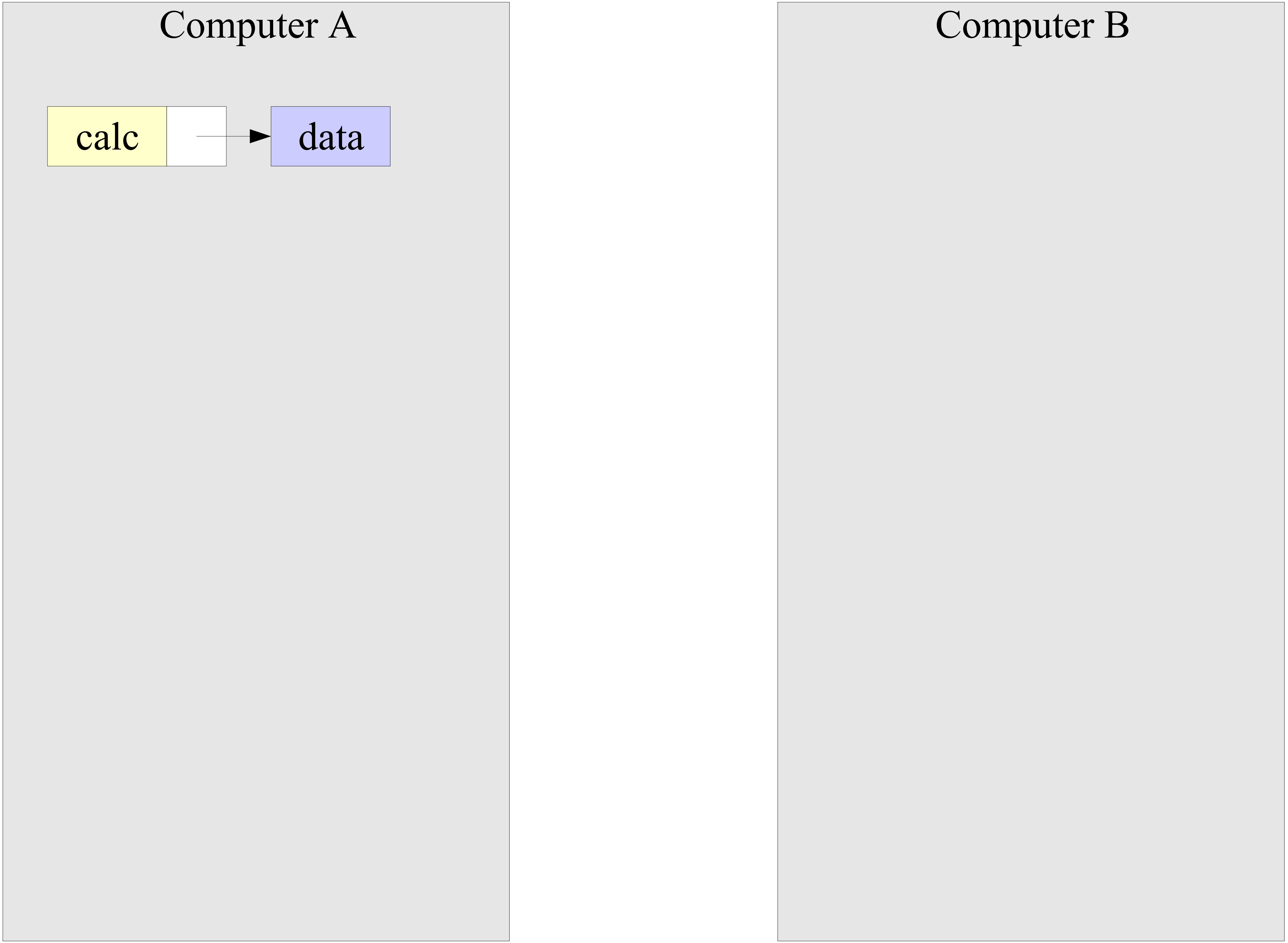
- The C code is portable, isn't it?
- Yes, but:
- It creates a dependency on a C compiler.
- There are issues with the nuances of various C compilers.
- The bytecode can't be loaded dynamically.

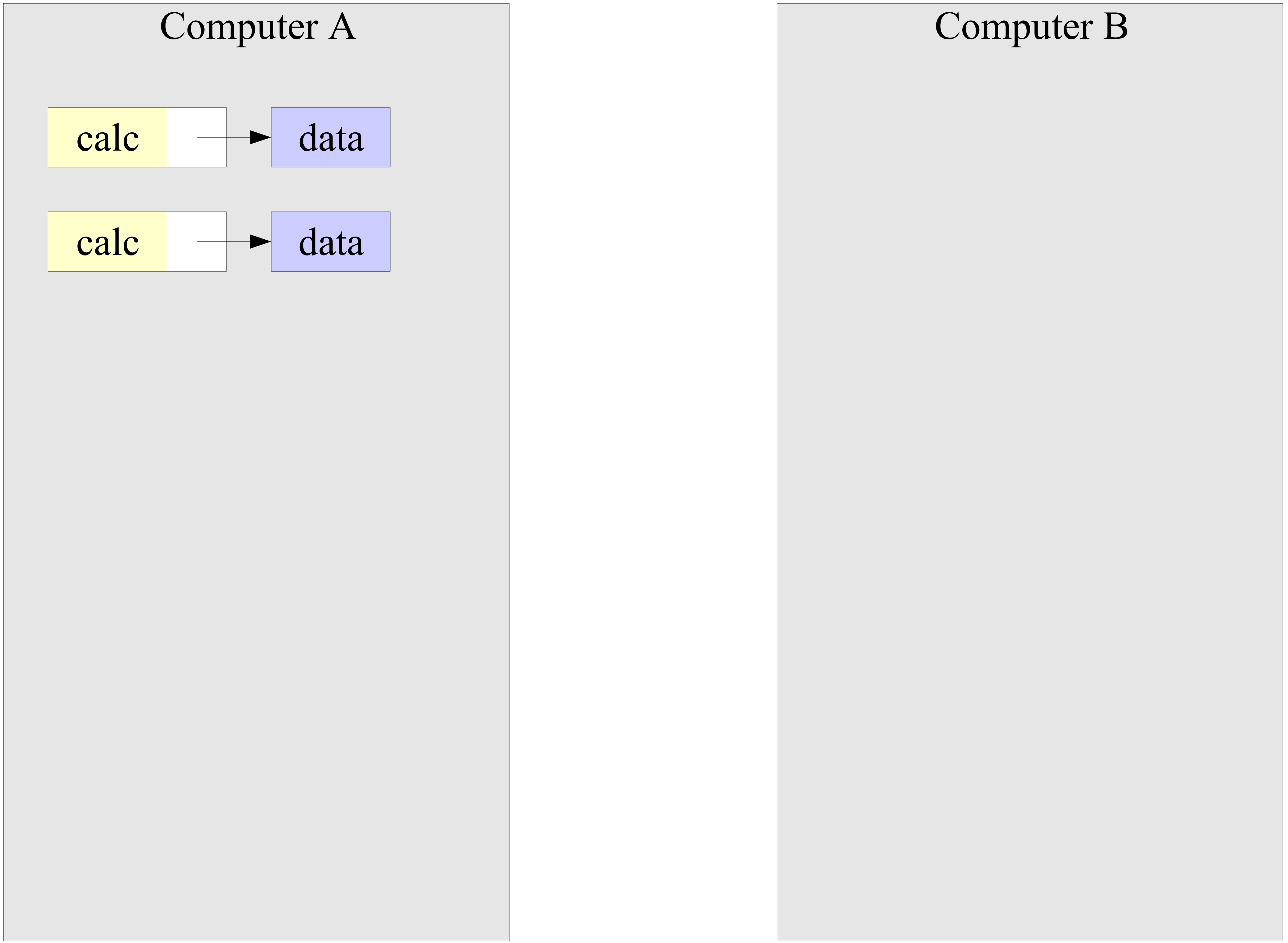
Improved Portability.

- Yhc also compiles Haskell functions into bytecode instructions for a G-Machine.
- However, Yhc places the bytecodes in a separate file which is then loaded by the interpretter at runtime. Similar to Java's classfile system.
- More portable, but it means Yhc has to do its own linking.

More Portable Still?

- Can we extend portability to include portability over a network?
- Then we could take a closure on one machine and have it run on another machine.
- Not implemented yet, but some interesting ideas.


Computer A
calc
data
Computer B



Computer A
calc
data
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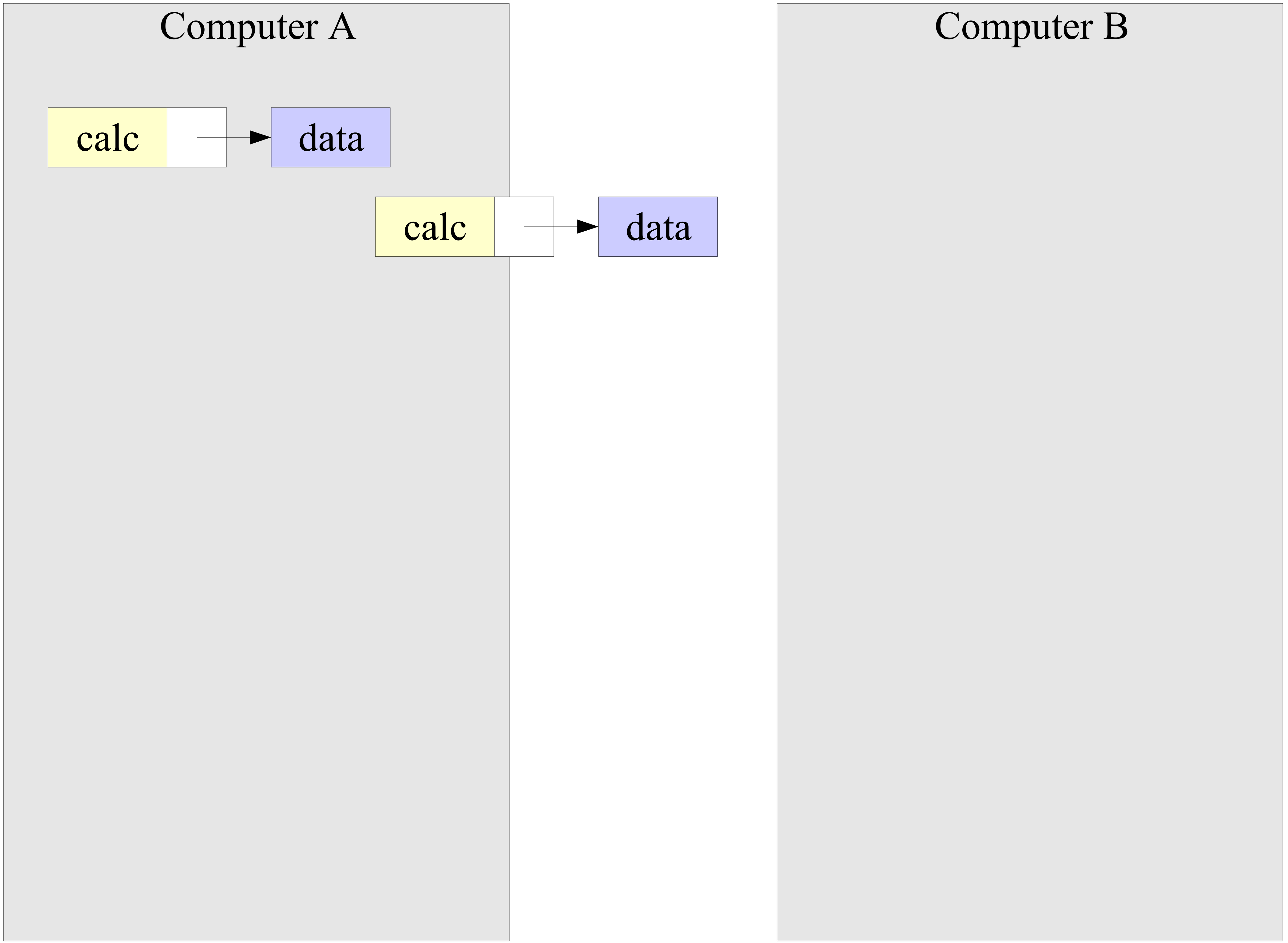
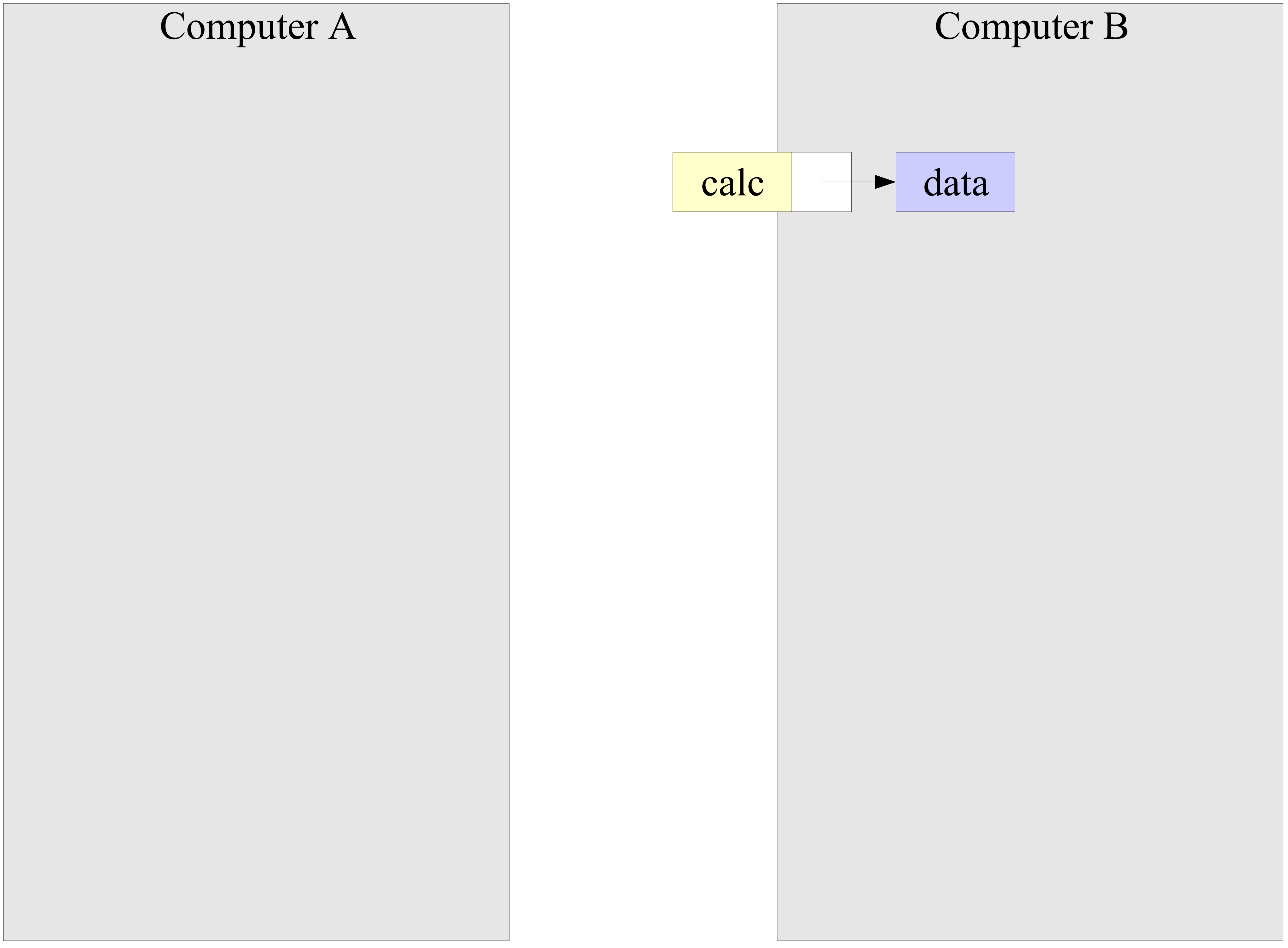

Computer A
Computer B
calc
data
calc
data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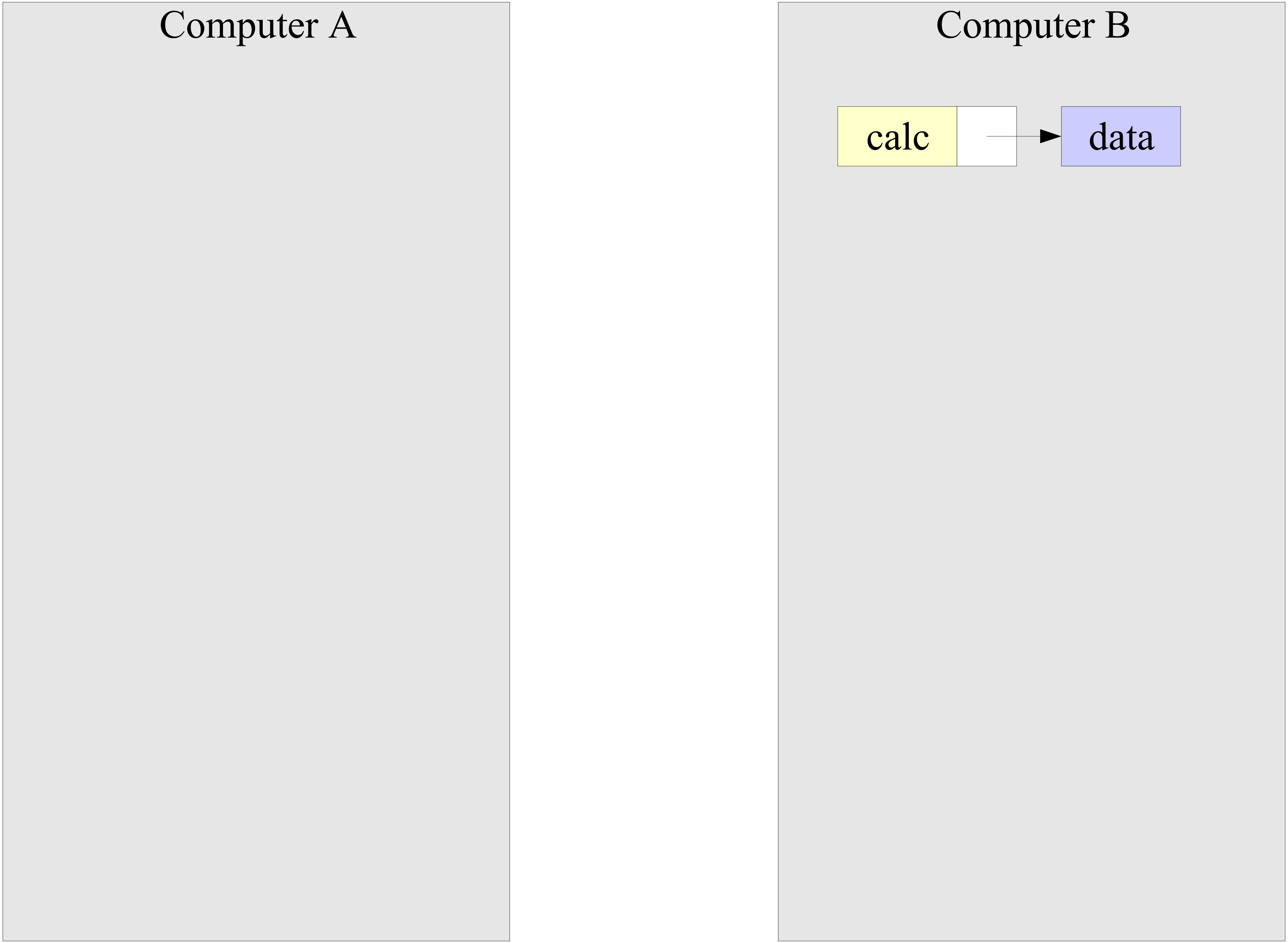
data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calc
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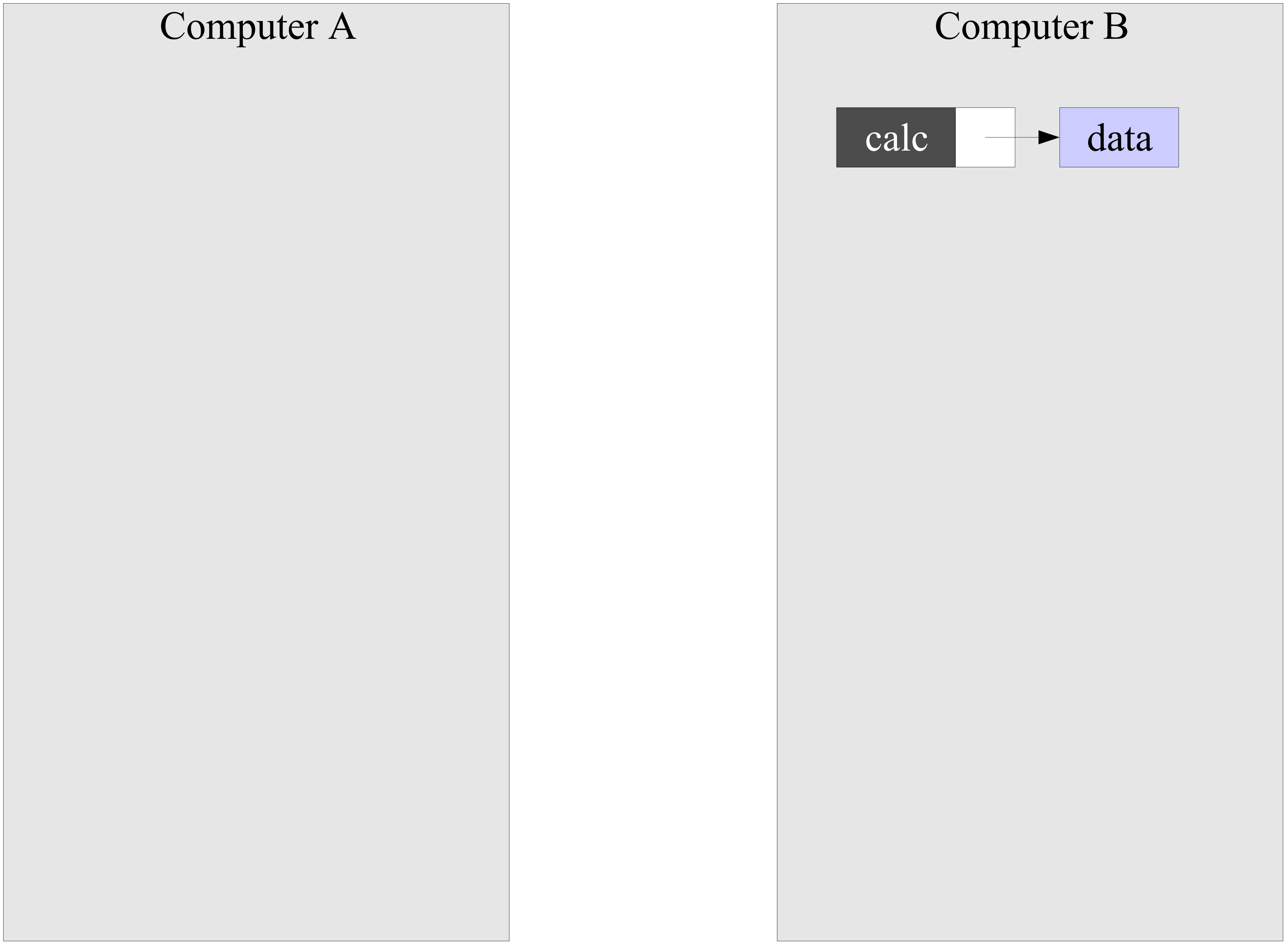
Computer A
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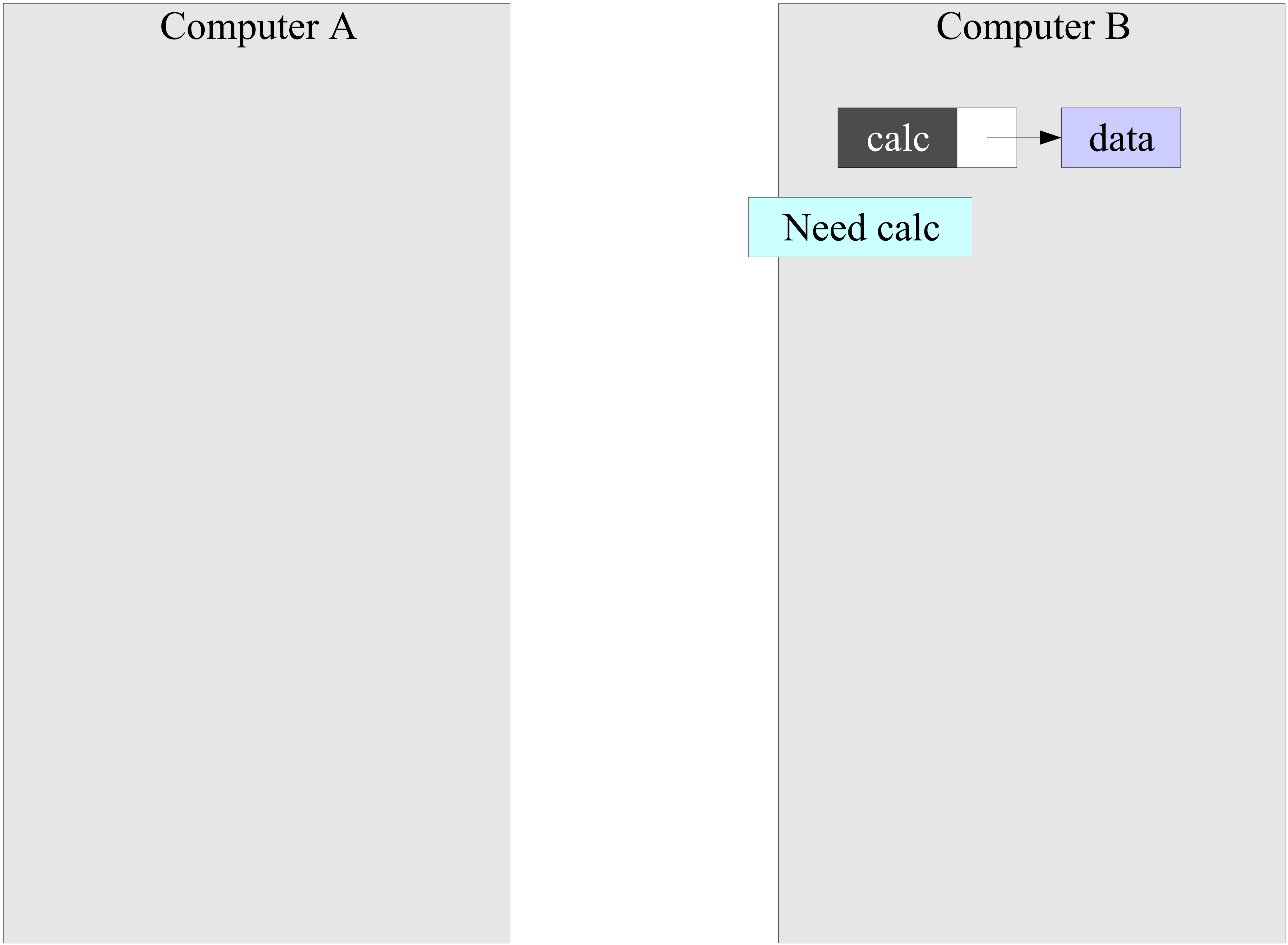
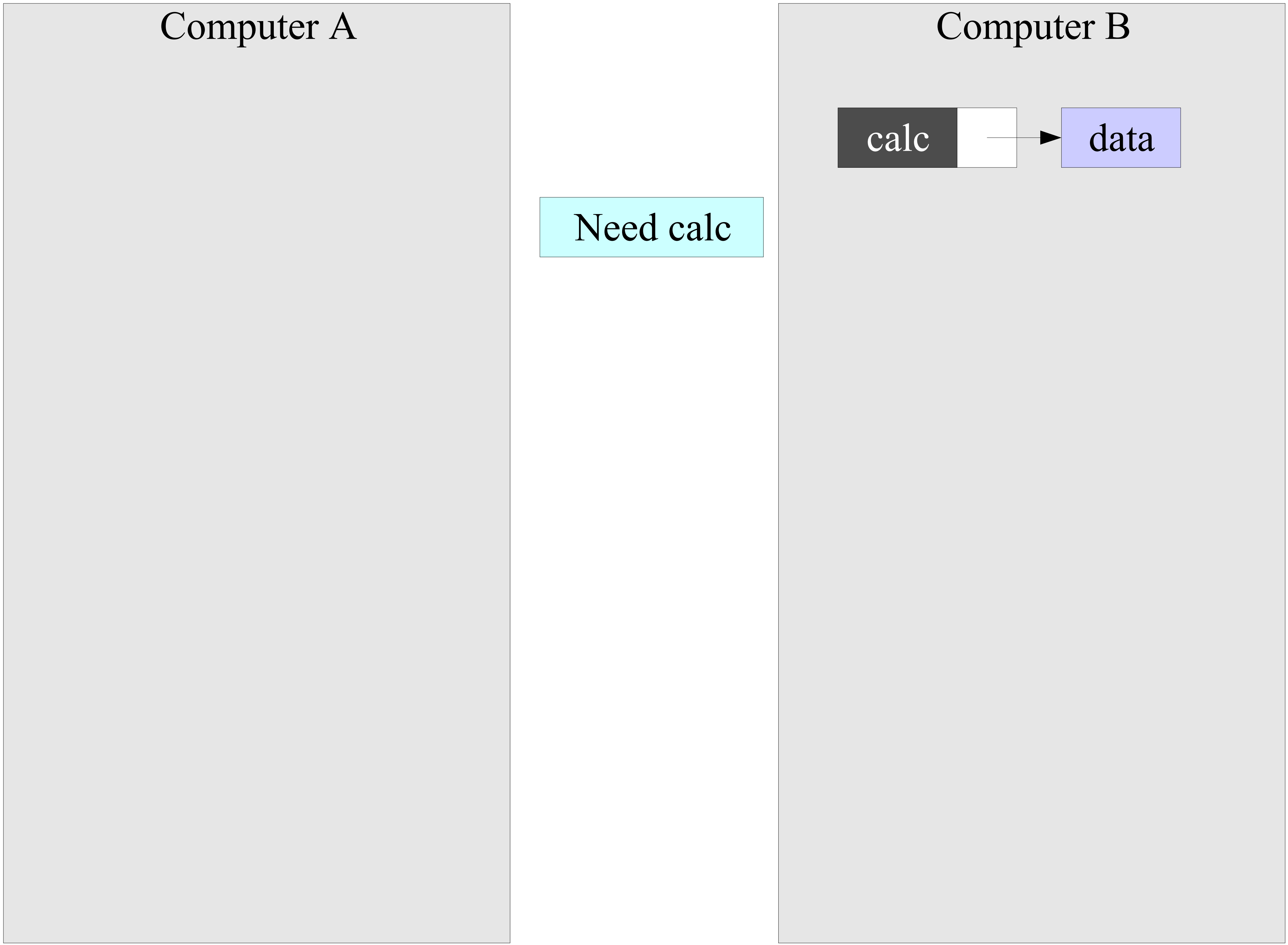

Computer A
Computer B
calc
data
Need calc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Computer B
calc
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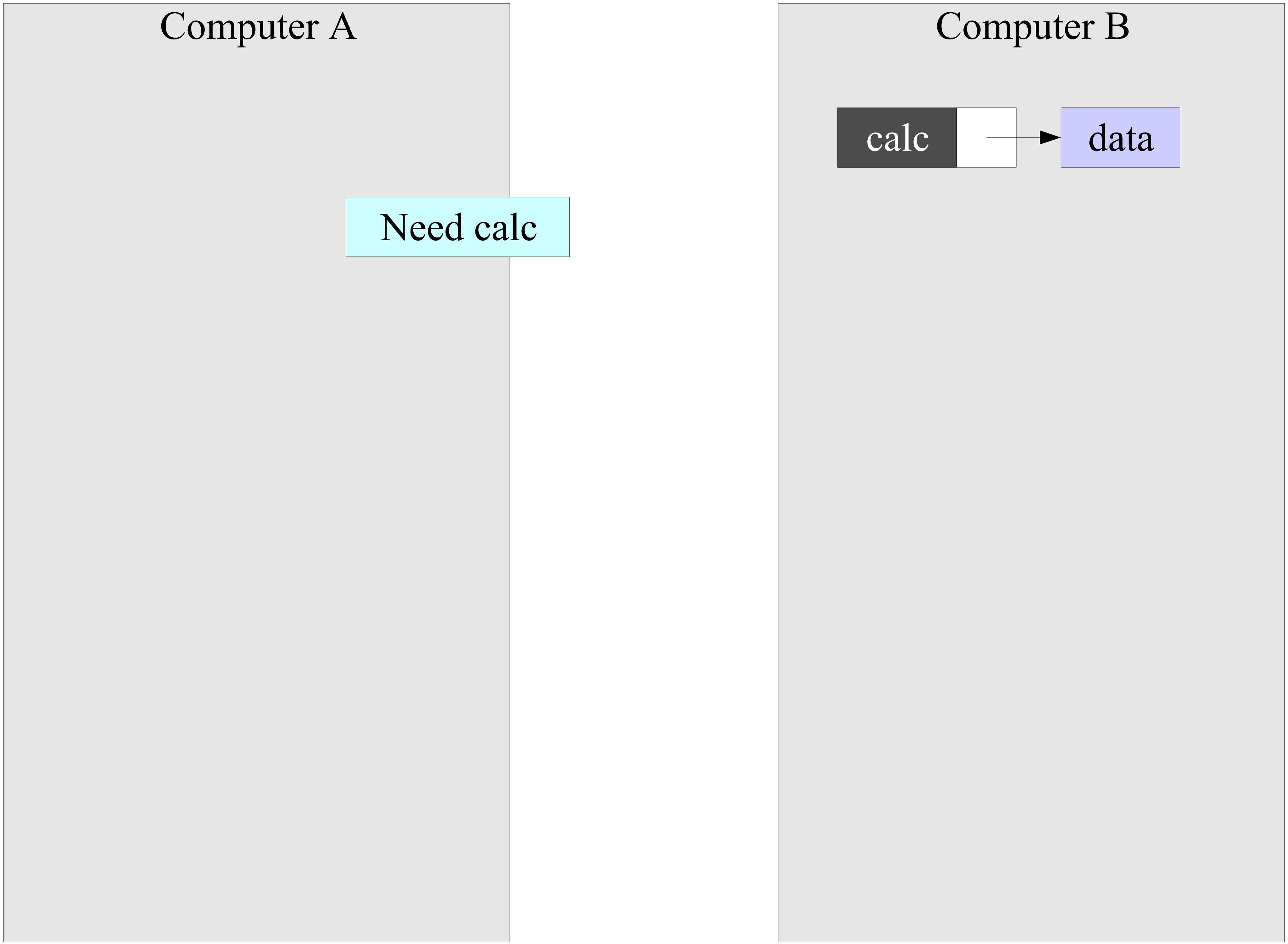
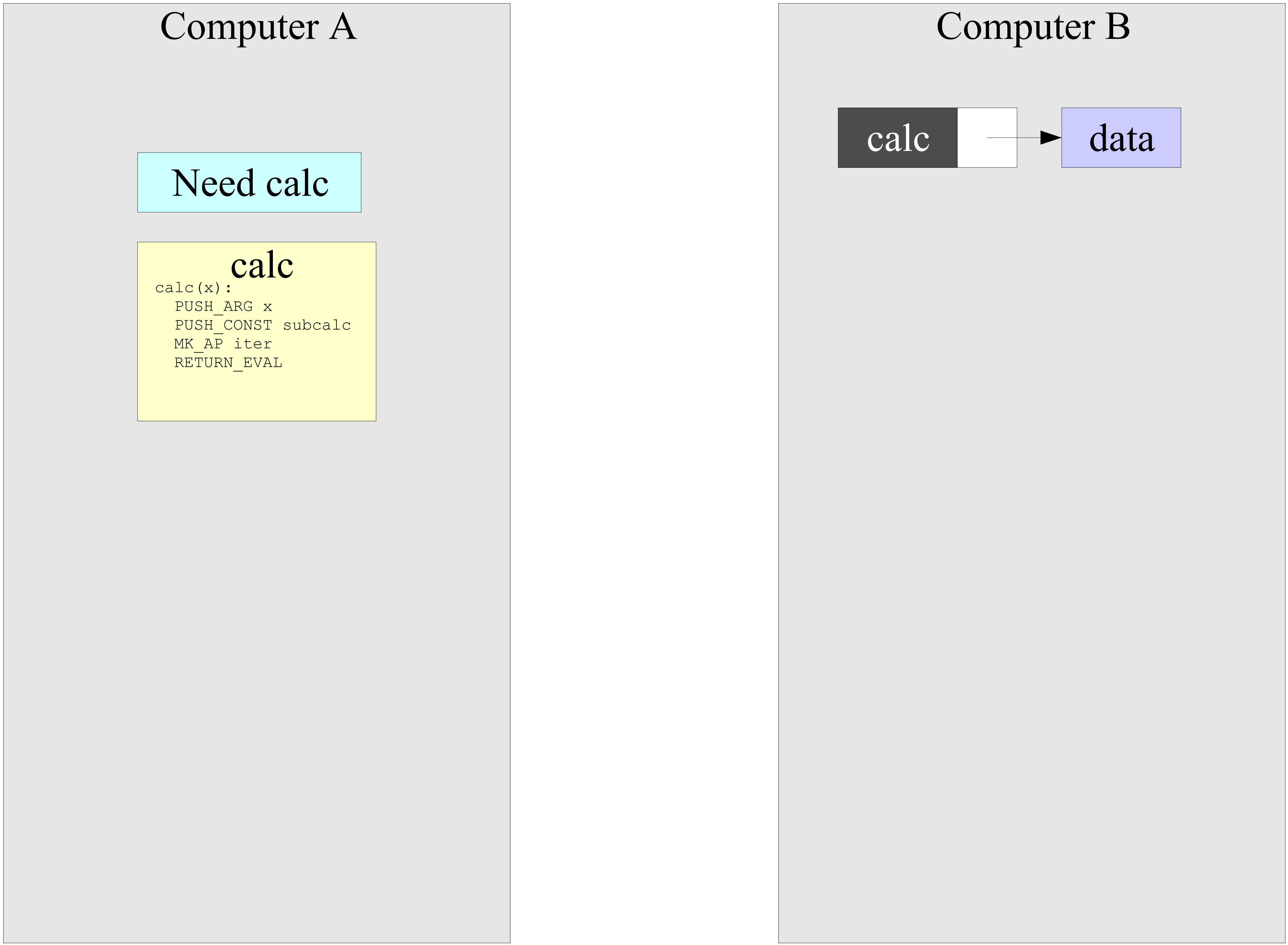
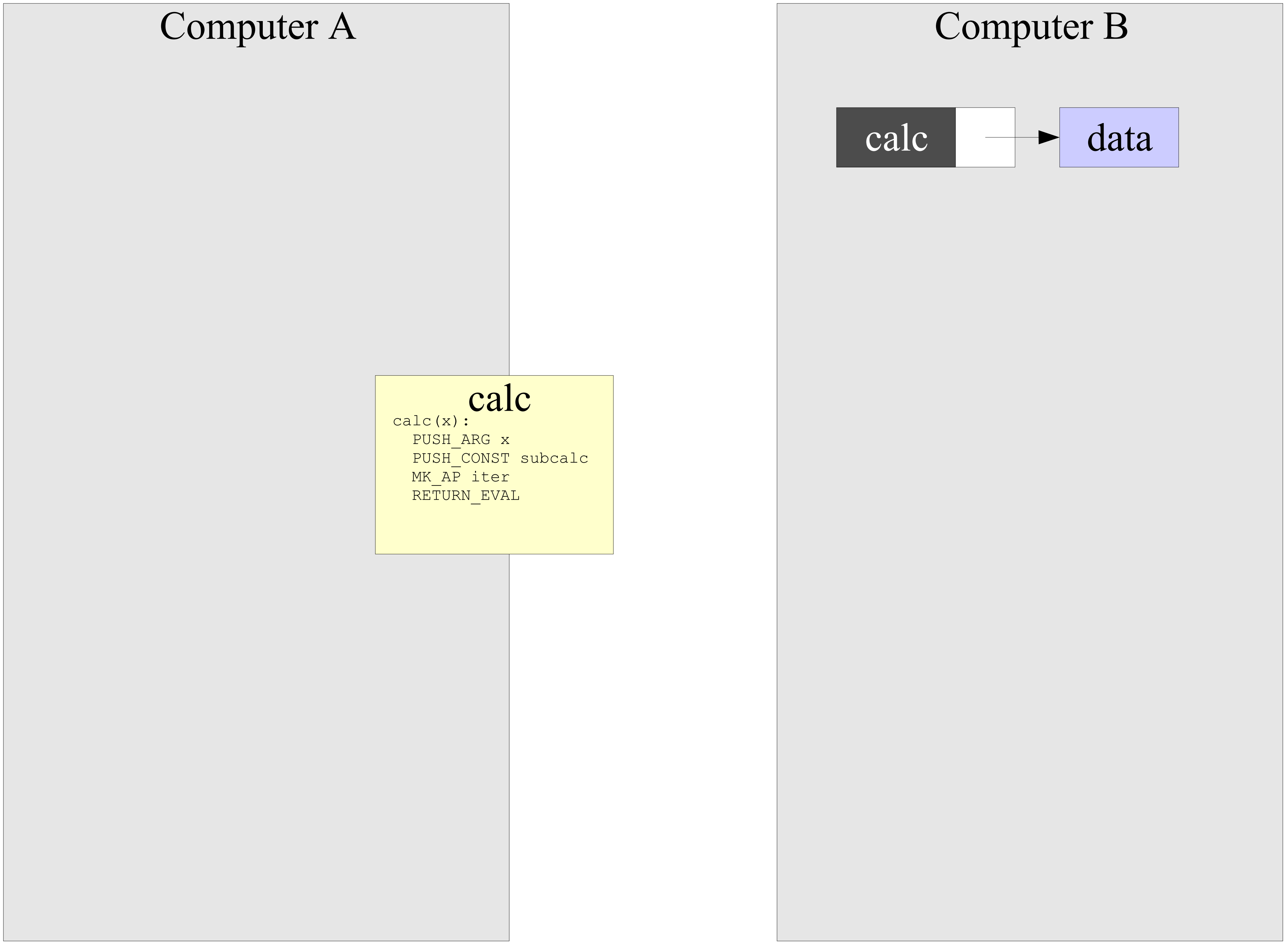

Computer A
Need calc
Computer B
calc
data



Computer A
Need calc
calc
calc(x):
PUSH_ARG x
PUSH_CONST subcalc
MK_AP iter
RETURN_EVAL
Computer B
calc
data



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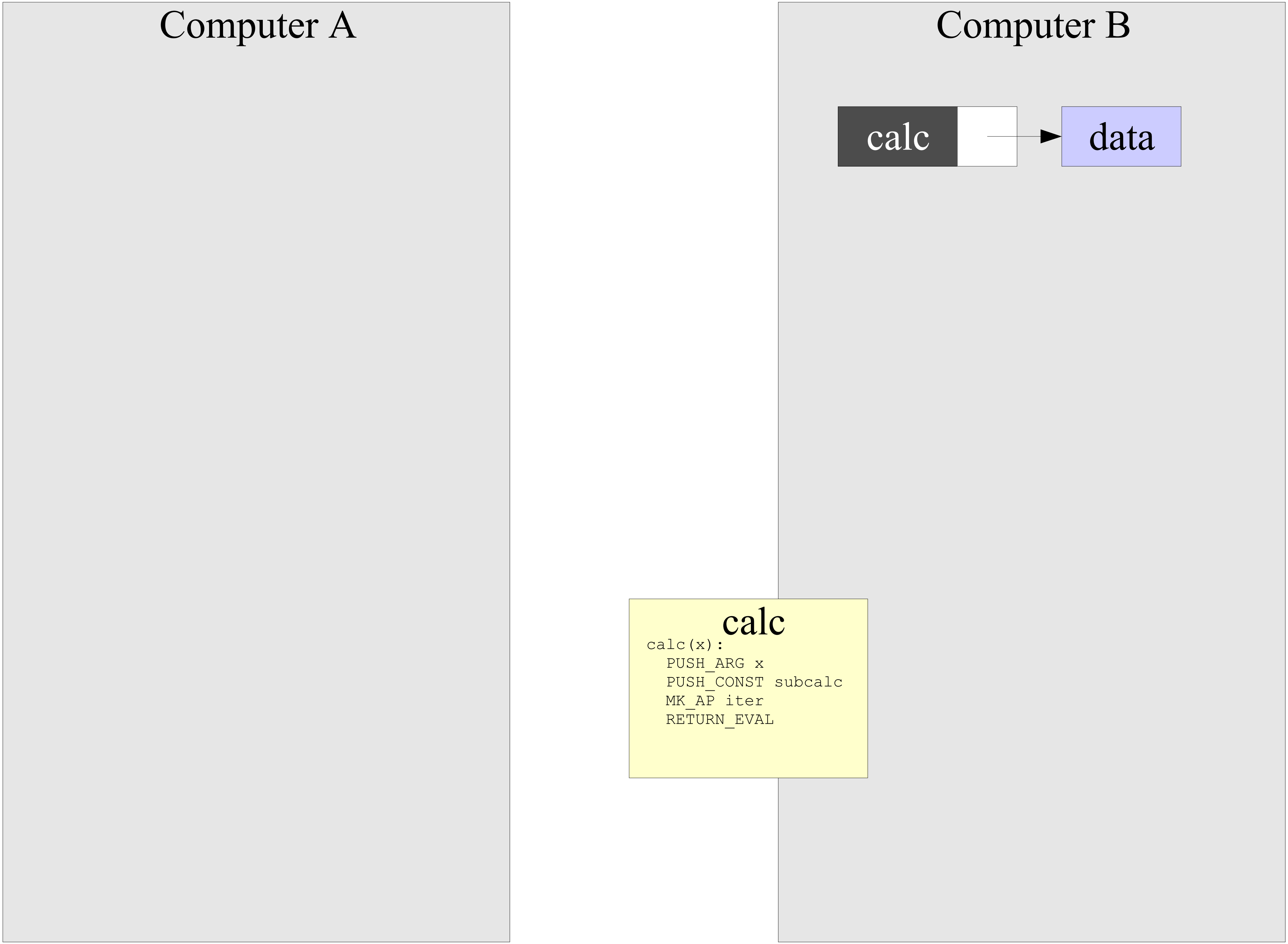
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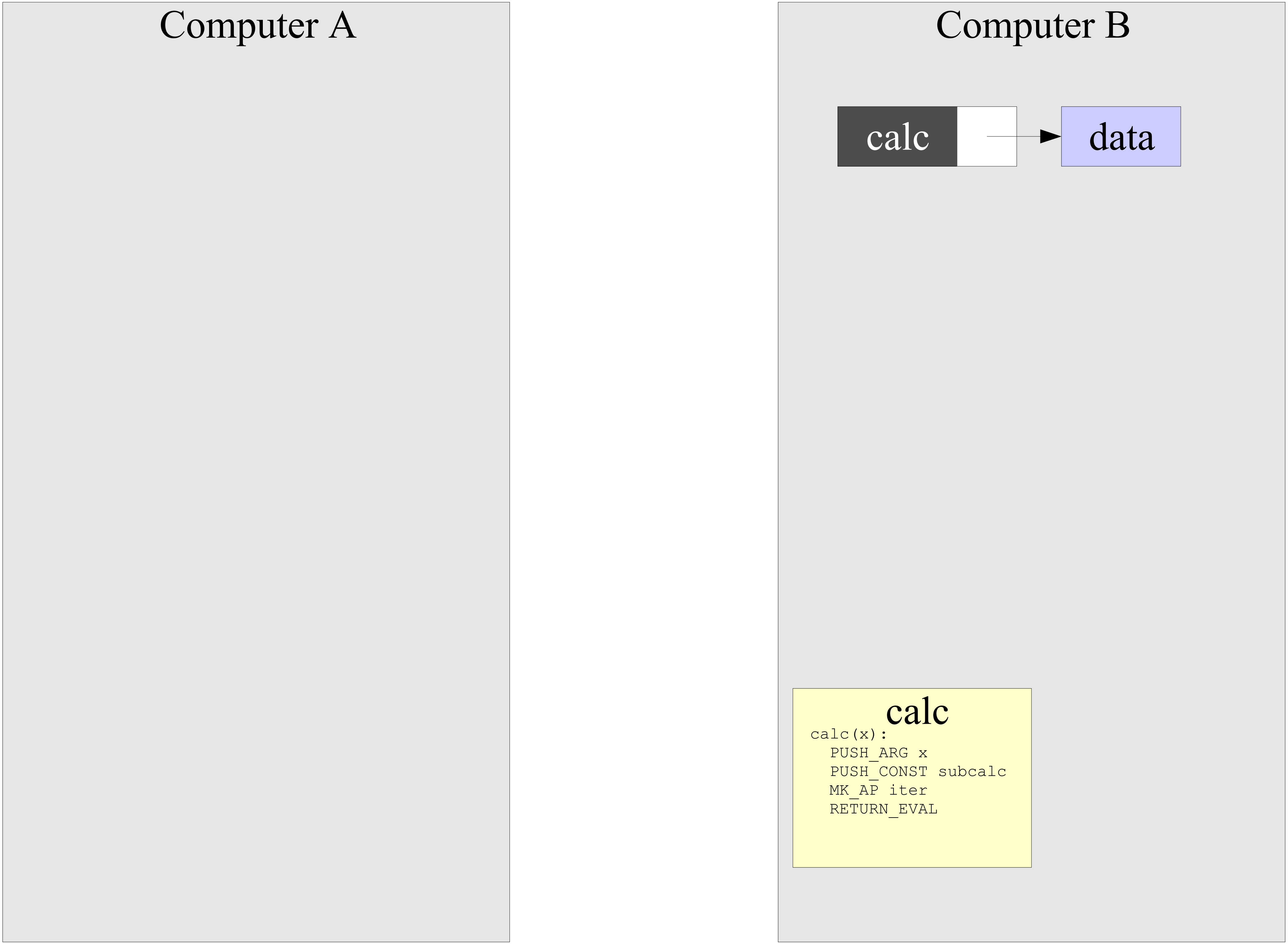
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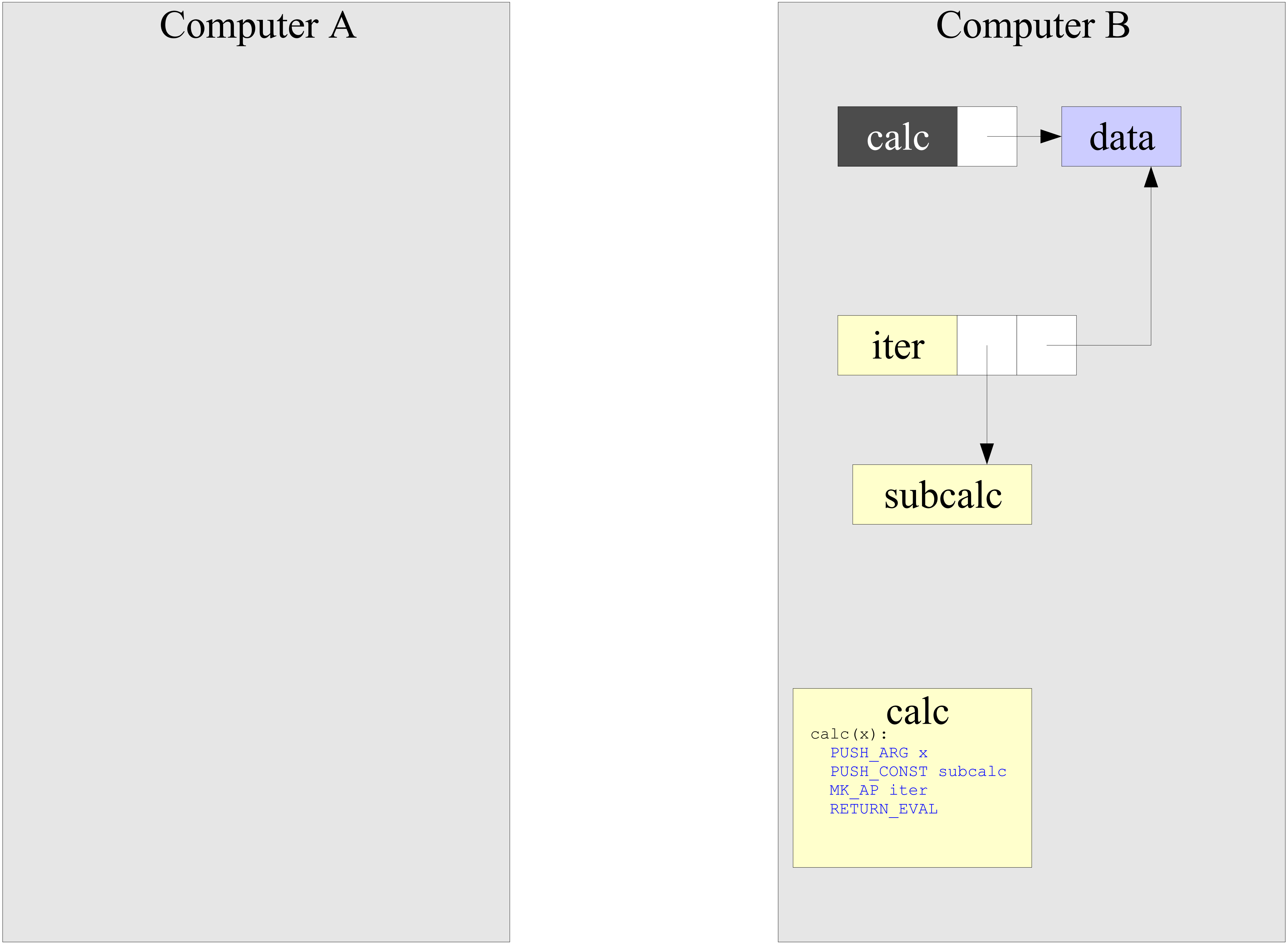
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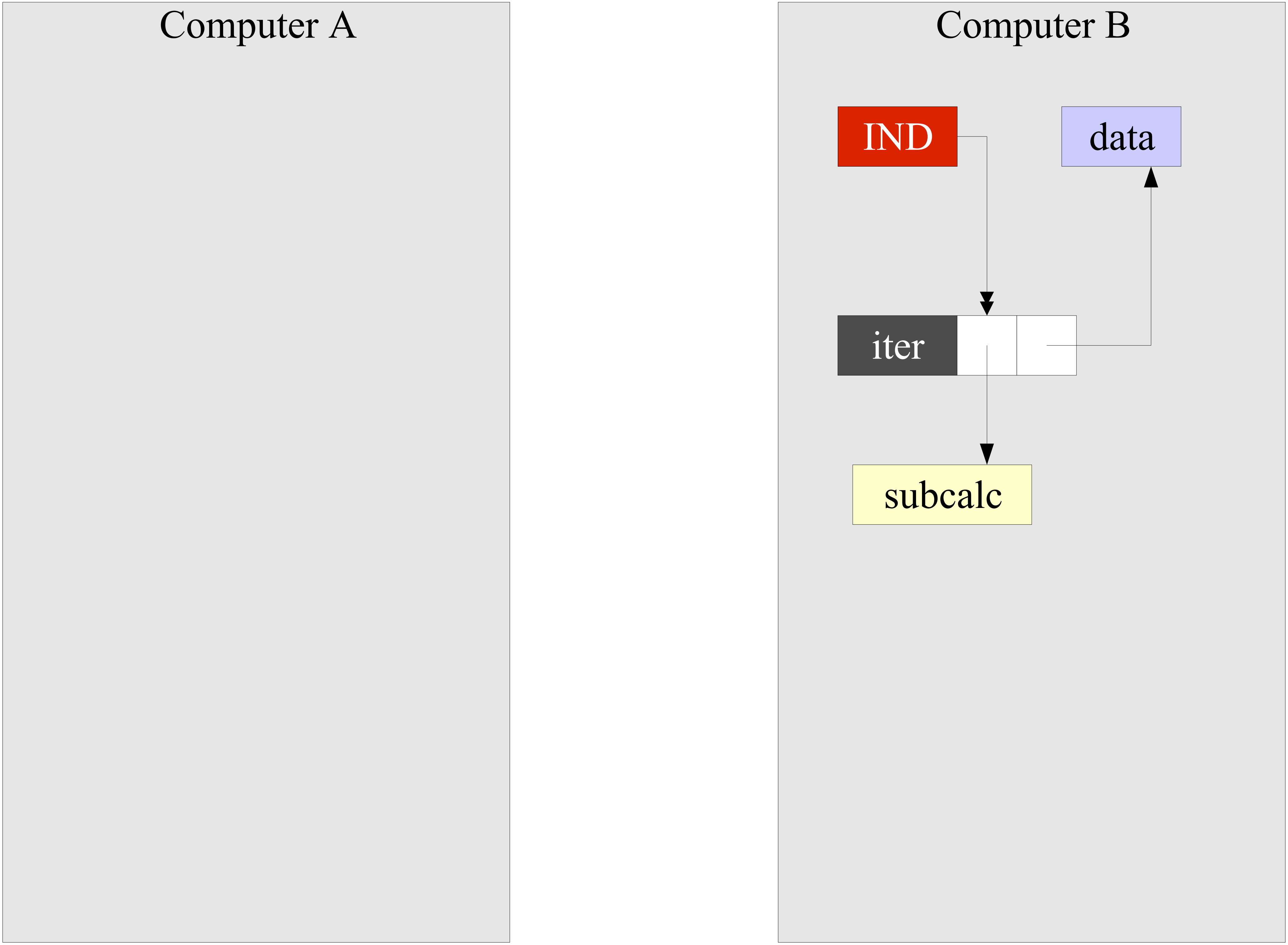

Computer A
Computer B
IND
data
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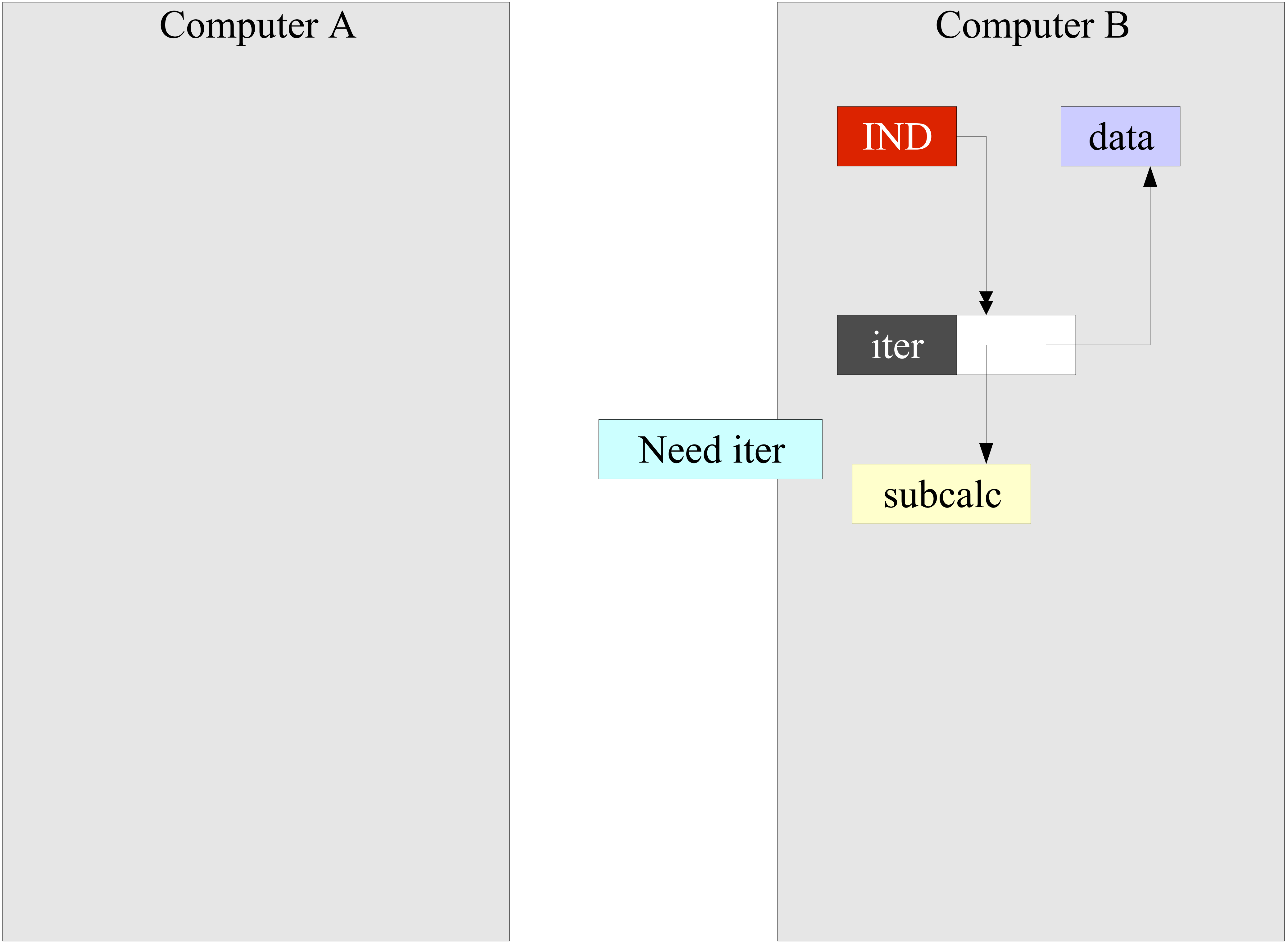
subcalc



Computer A
Computer B
IND
data
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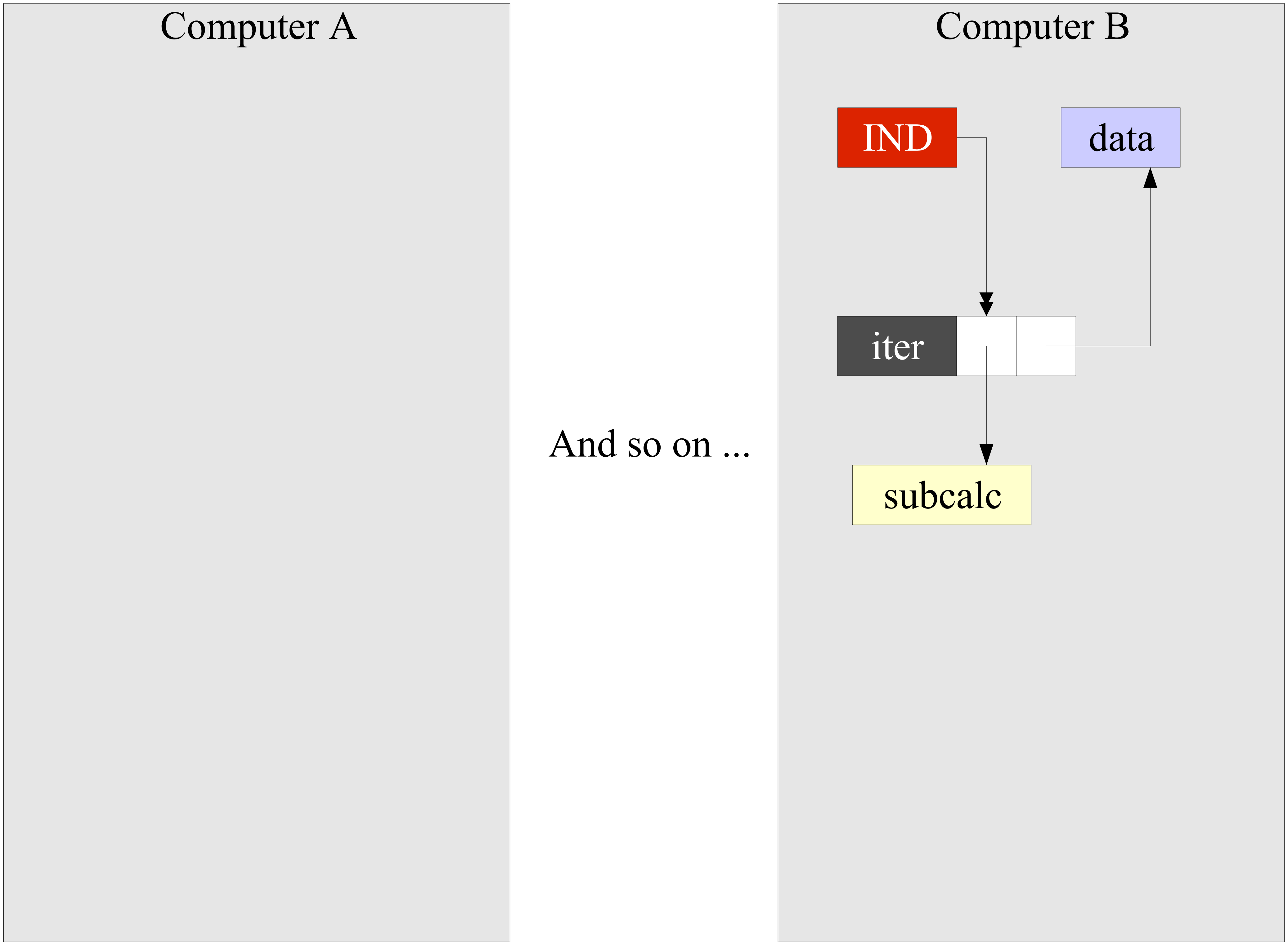
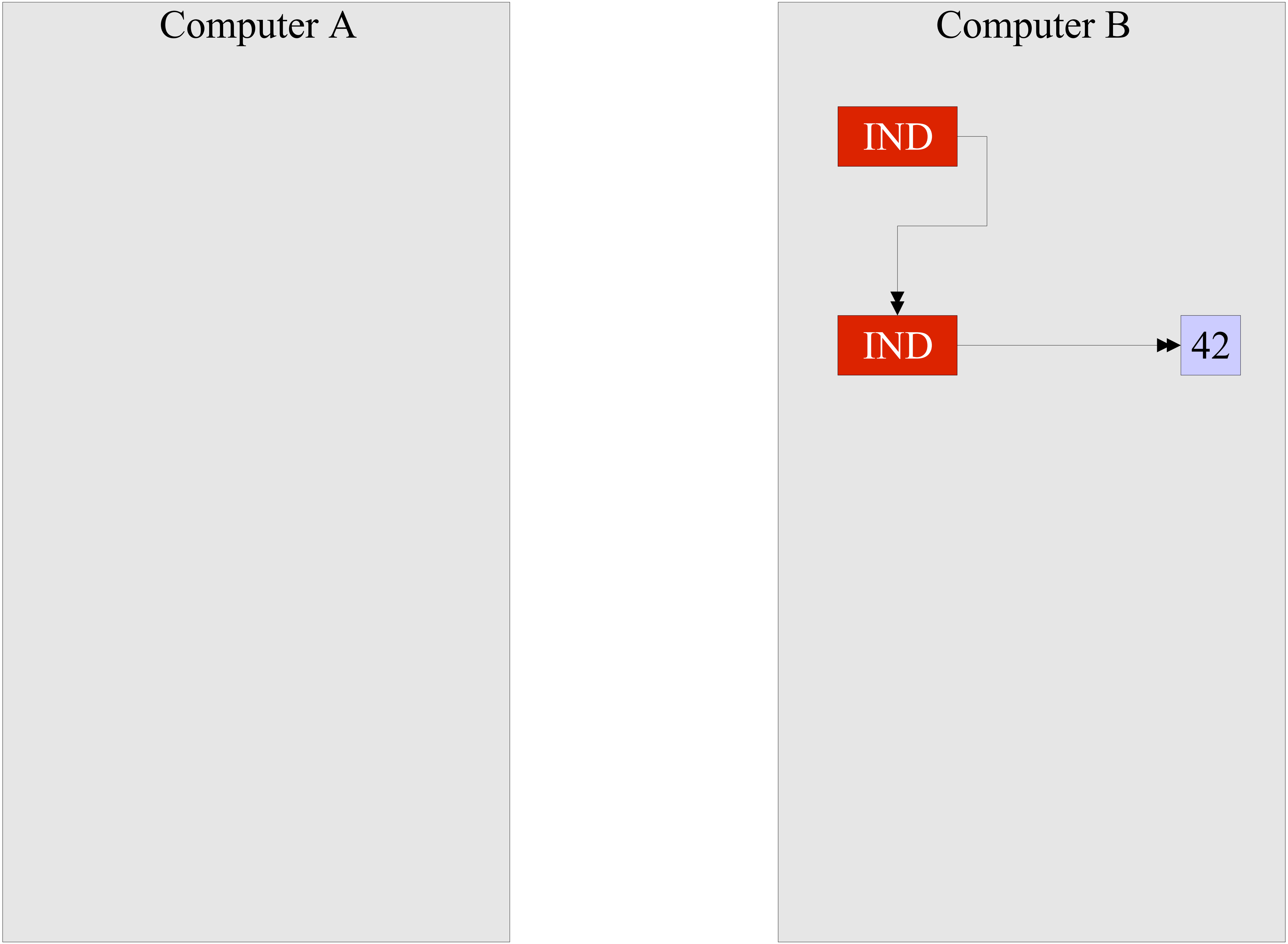
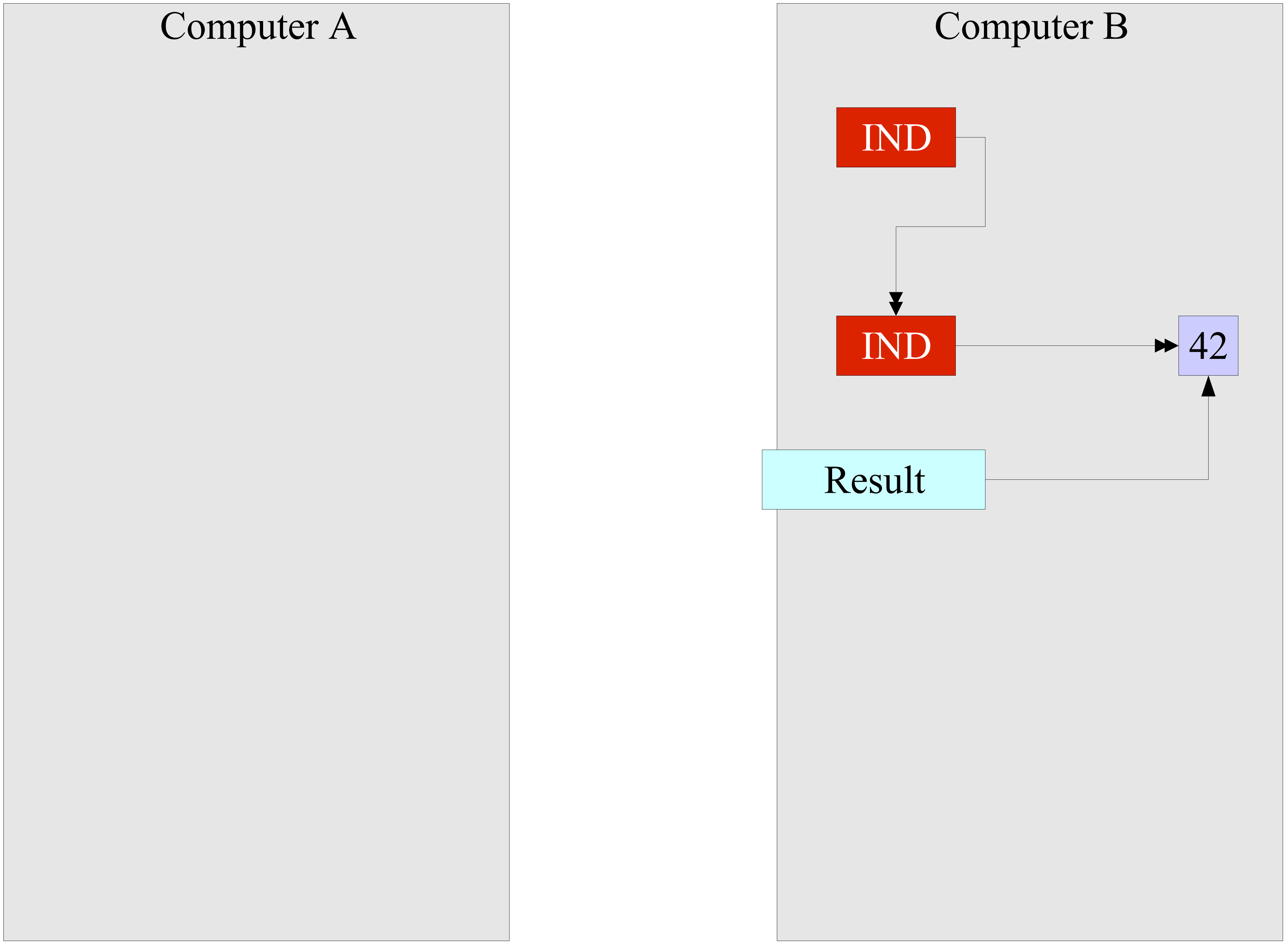
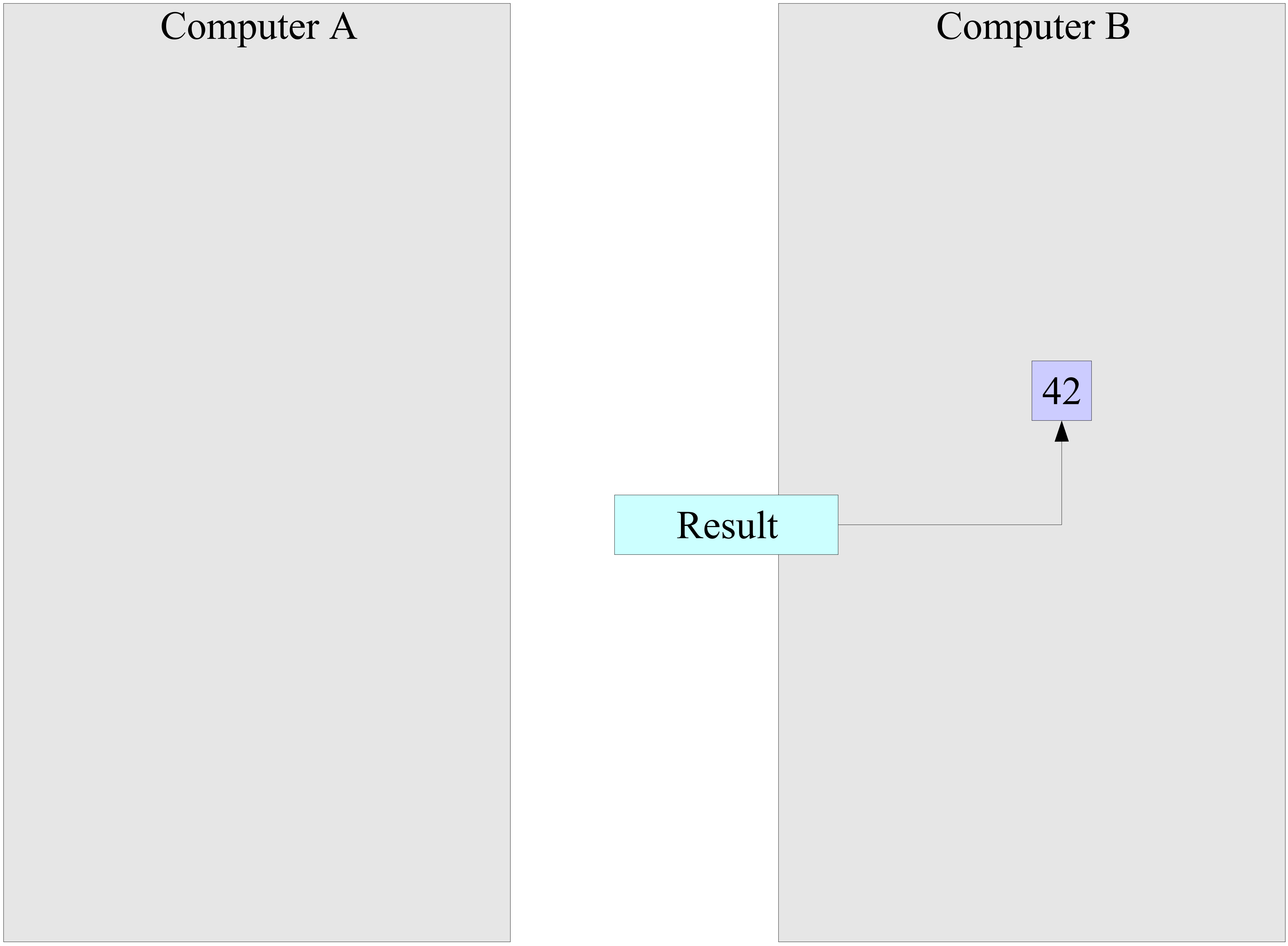
Need iter
subcalc


Computer A
Computer B
IND
data
iter
subcalc
And so on ...


Computer A
Computer B
IND
IND
42



Computer A
Computer B
IND
IND
42
Result


Computer A
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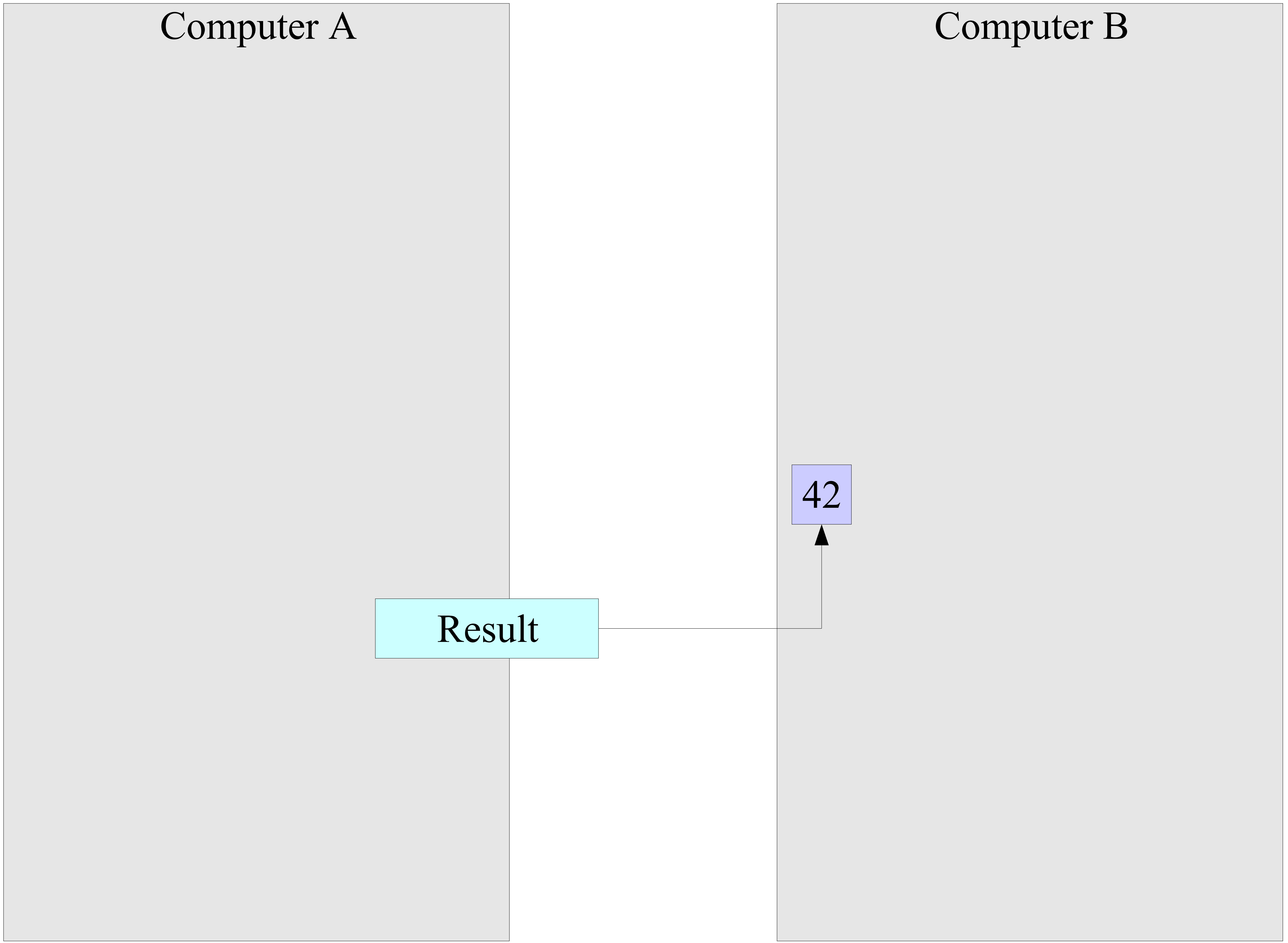
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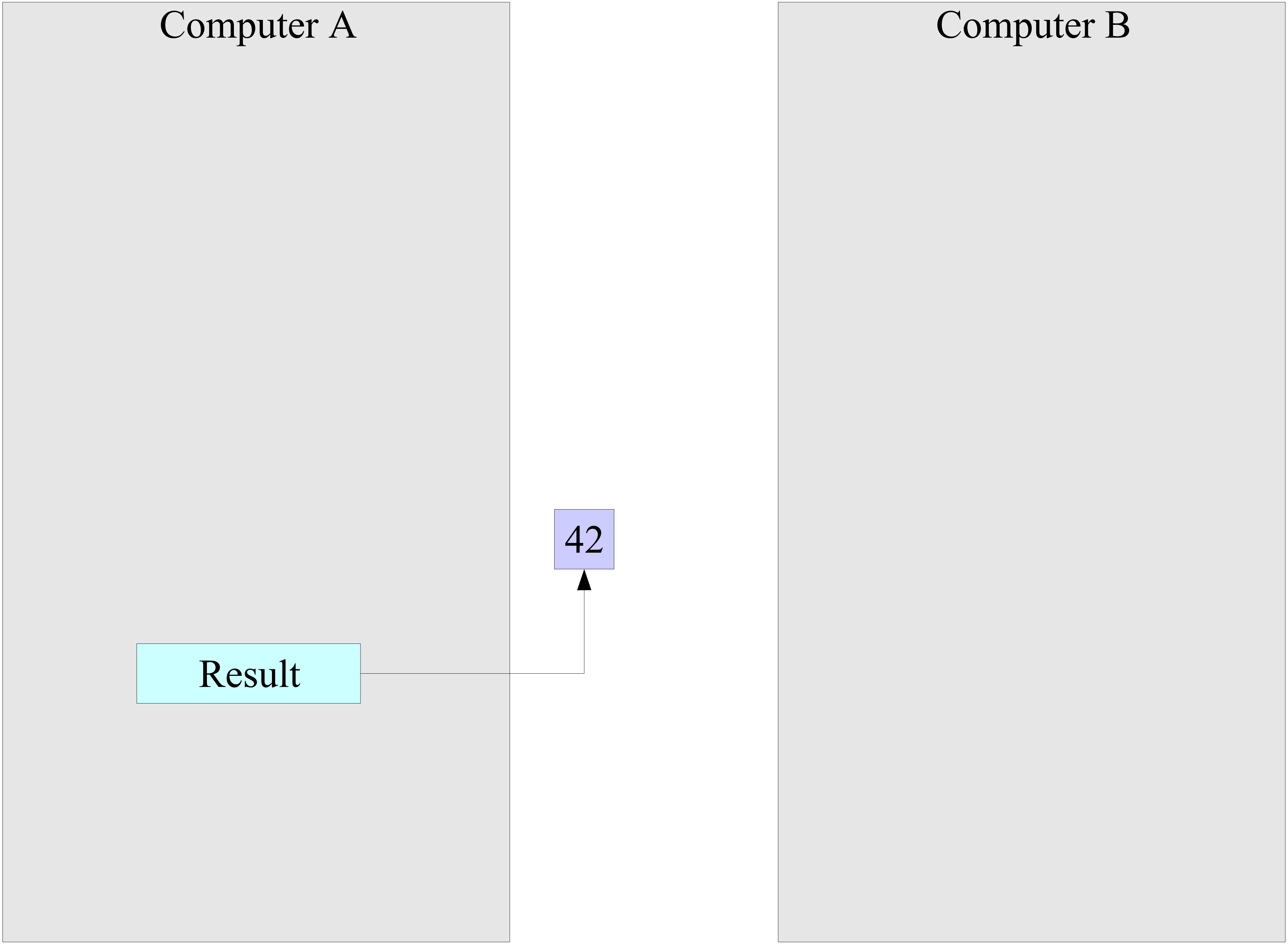
Computer A
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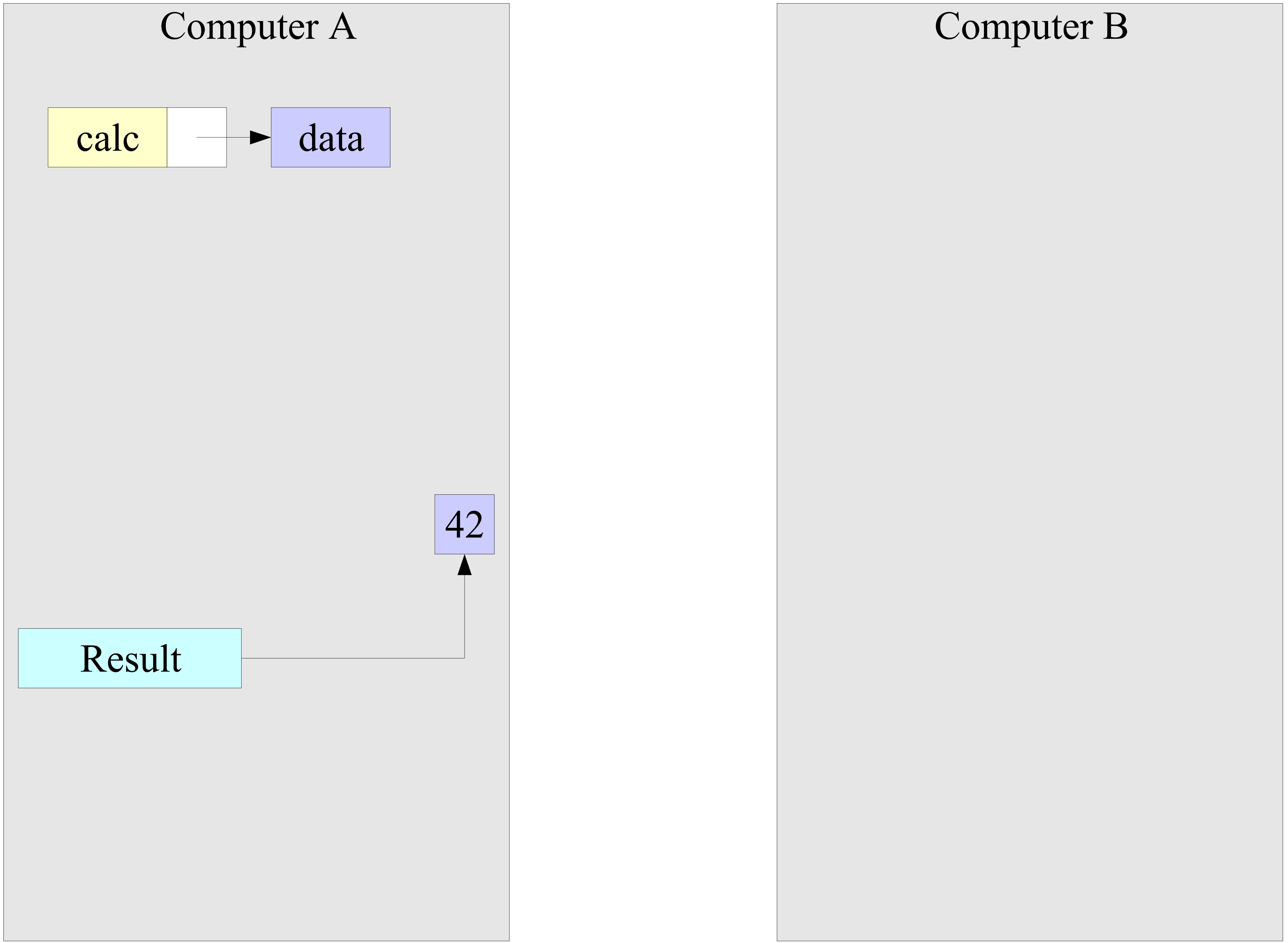
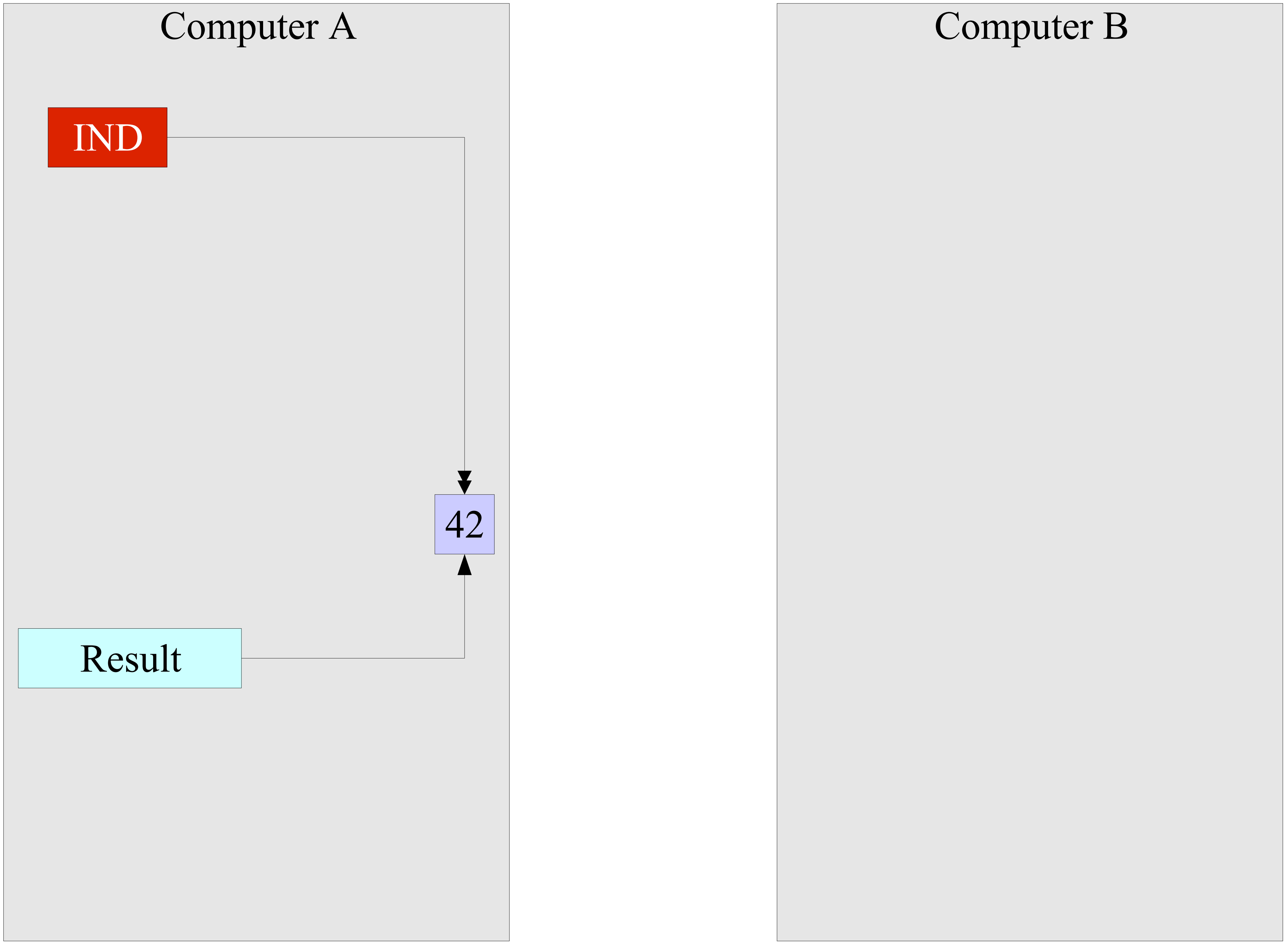

Computer A
Computer B
calc
data
42
Result


Computer A
Computer B
IND
42
Result

Challenges

- Needs concurrency to be useful.
- Complicates Garbage collection.
- Level of granularity versus laziness.
- Possible architecture differences.

Other Things!

- Other people have written various interpretters and backends for Yhc bytecode: Java, Python, .NET
- ... and various related tools such as interactive interpretters.
- I'm also using Yhc to do my Hat G-Machine work.

Questions?