CSC 108H: Introduction to Computer Programming

Summer 2012

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Administration

- Exercise 2 is due tomorrow.
  - .Extended one day due to midterms.
- First assignment is up.
  - Will cover it today.
- Midterm will be Jun 28th, at 6:00.
  - In BA 2185/BA 2195
- Help Centre is still open.
  - BA 2270.

List Review

- Lists are a new type we used to store an array of variables.
  - Created with:

    list_name = [list_elt0, ..., list_eltn]
  - Elements are referenced with

    list_name[elt_#]
  - Empty lists are allowed.
  - Lists can have changing lengths and are heterogenous.
- Lists and strings can be sliced.

List Questions

```
x = [1,2]
y = [0,2,4,6,8]
```

- What do these expressions evaluate to?

```
x[0] + y[-3]

y[0:1]
```

```
x[y[0]:]

y[-2:5]

y.append([])

y[5]
```

List Questions

```
x = [1,2]
y = [0,2,4,6,8]
```

- What do these expressions evaluate to?

```
x[0] + y[-3]
5
y[0:1]
0
x[y[0]:]
[1, 2]
y[-2:5]
[6,8]
y.append([])
None
y[5]
[]
```

Aliasing/Mutability Review

- Lists are mutable.
  - That is, one can change the value of a list element or append/remove items from a list without needing to create a new list.
  - To capture this, we view a list as a list of memory addresses in our memory model.
  - Changing a list element is modifying the memory address that list element points to.
- This means lists have aliasing problems.
  - Where one has multiple variables referring to the same list, and modifying one of these lists affects all of them.

Aliasing Questions

- How many different lists are there at the end of this execution?

```
def foo(x)
    x.append(1)
    return x.pop()
x = []
y = x[:]
y.append(1)
```

```
y.pop()
foo(x)
z = y
foo(y)
a = foo(x)
```

Aliasing Questions

- How many different lists are there at the end of this execution?

```
def foo(x)
    x.append(1)
    return x.pop()
x = []
y = x[:]
y.append(1)
y.pop()
foo(x)
z = y
foo(y)
a = foo(x)
```

2, x and y are separate lists, z is aliased with y.

For Loop Review

- The format of a for loop is:

```
for list_elt in list_name:
    block
```

- The block is executed once for each element in the list.
  - list_elt refers to each list element in turn.
  - So the block code uses a different variable each time.
- Unravelling loops is a useful tool.

Unravel these Loops

```
x = [0,1,2]
y = 0
for i in x:
    y+=2
```

```
x = range(4,10,2)
for i in x:
    print i
```

Unravel these Loops

```
x = [0,1,2]
y = 0
for i in x:
    y+=2
i = x[0]
y += 2
i = x[1]
y += 2
i = x[2]
y += 2
```

```
x = range(4,10,2)
for i in x:
    print i
i = x[0]
print i
i = x[1]
print i
i = x[2]
print i
```

Lists and Relational Operators

- != and == are defined on lists.
  - Two lists are defined to be equal if each element is equal, and they're in the same places.
  - Not based on memory addresses.
  - So y == y[:] evaluates to True.

Nested Lists

- Lists are heterogenous, and often one wants each list element to be another list.
  - Used to represent matrices, tiles, spreadsheet cells, etc.
- To access an element in a nested list, one uses multiple square brackets.

  `list_name[list1_#][list2_#]...`
- The closest brackets to the name are evaluated first.

Nested Lists

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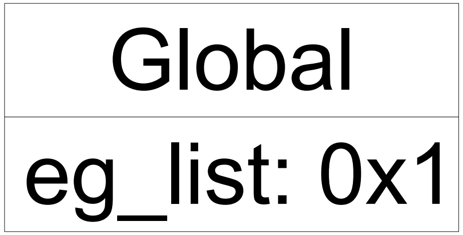
list_name[list1_#][list2_#]...
```

- The closest brackets to the name are evaluated first.

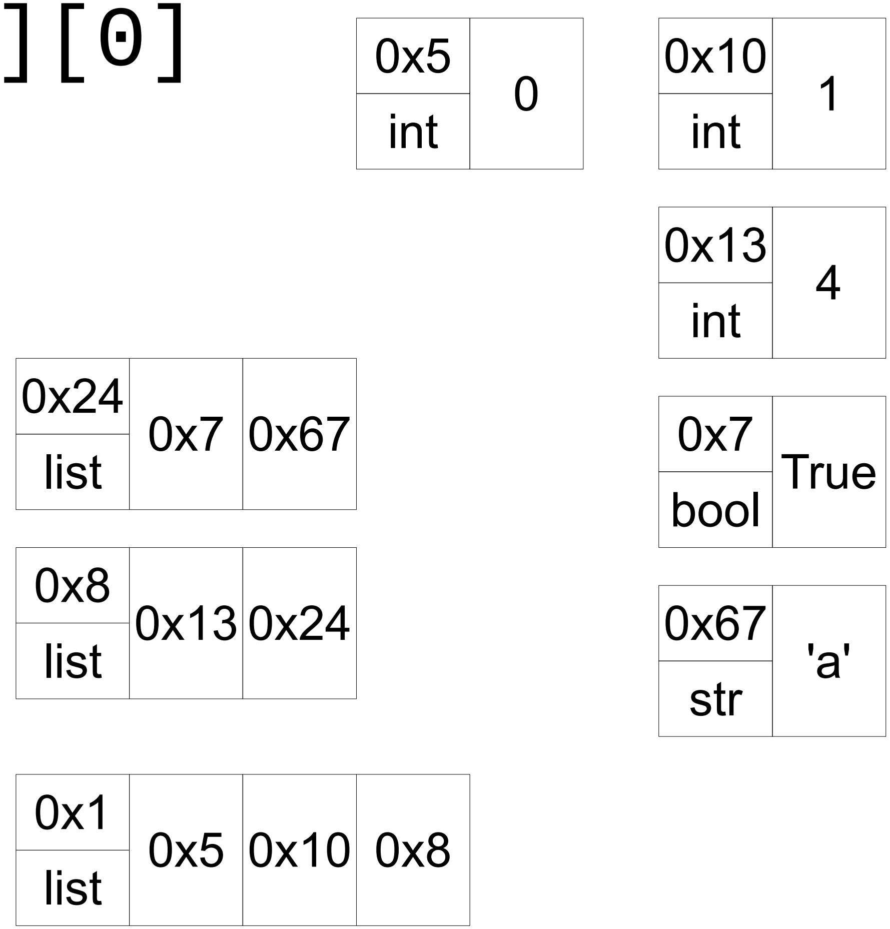
Nested Lists and the Memory Model

```
eg_list = [0,1,[4, [True, 'a']]]
print eg_list[2][1][0]
```



Global

eg_list: 0x1



0x5 int 0

0x10 int 1

0x13 int 4

0x24 list 0x7 0x67

0x7 bool True

0x8 list 0x13 0x24

0x67 str 'a'

0x1 list 0x5 0x10 0x8

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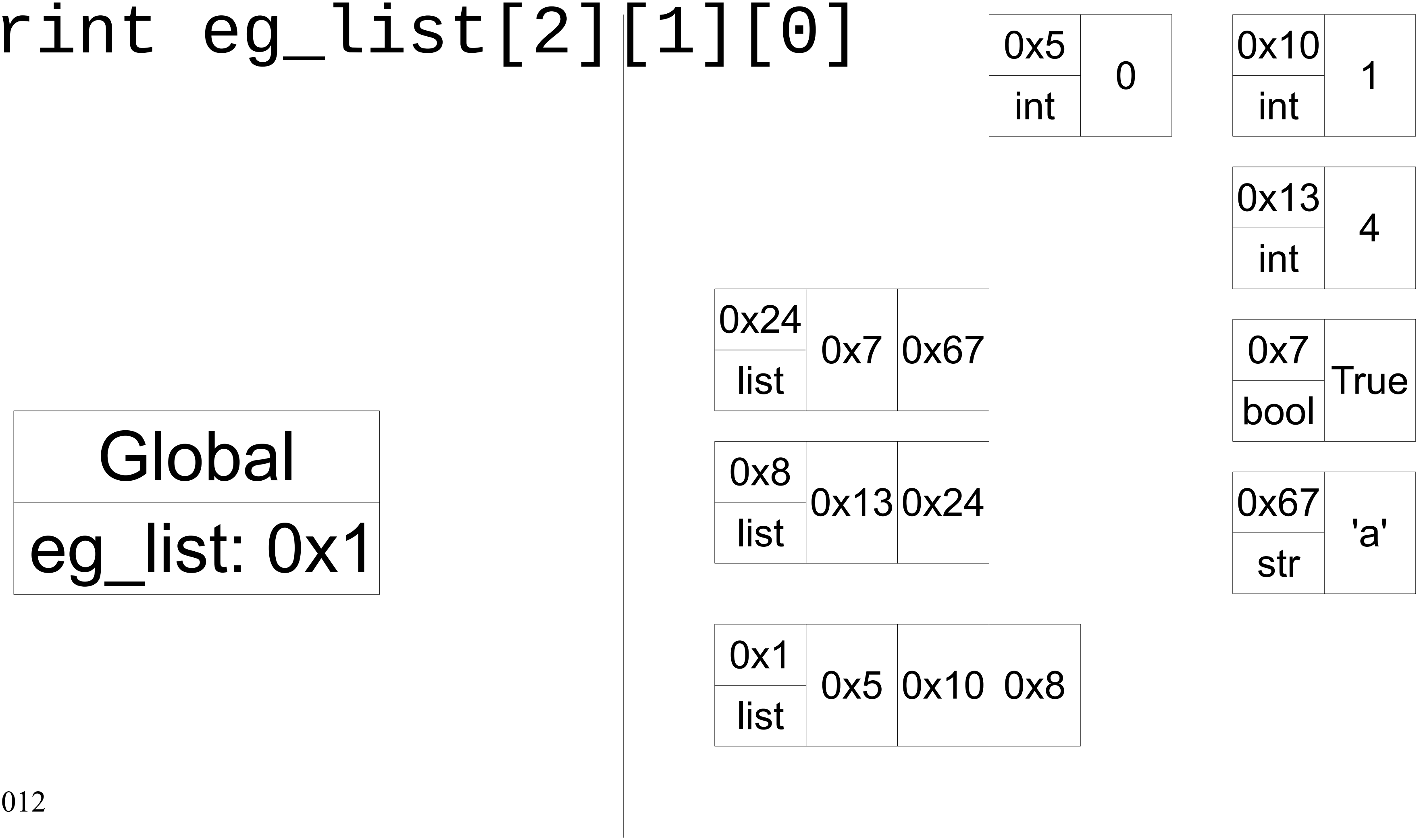

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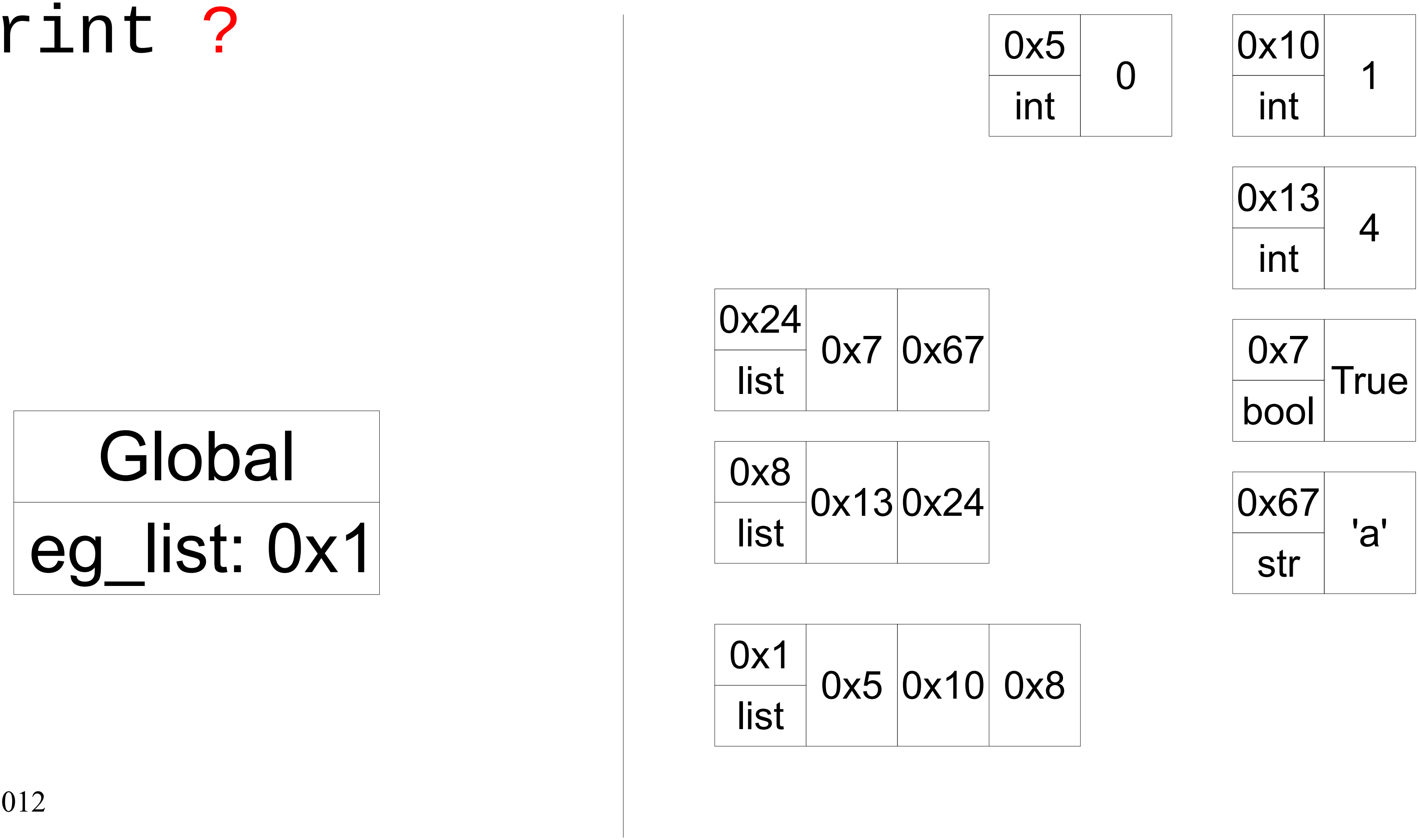
Nested Lists and the Memory Model

```
eg_list = [0,1,[4, [True, 'a']]]
→ print ?
```



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eg_list: 0x1

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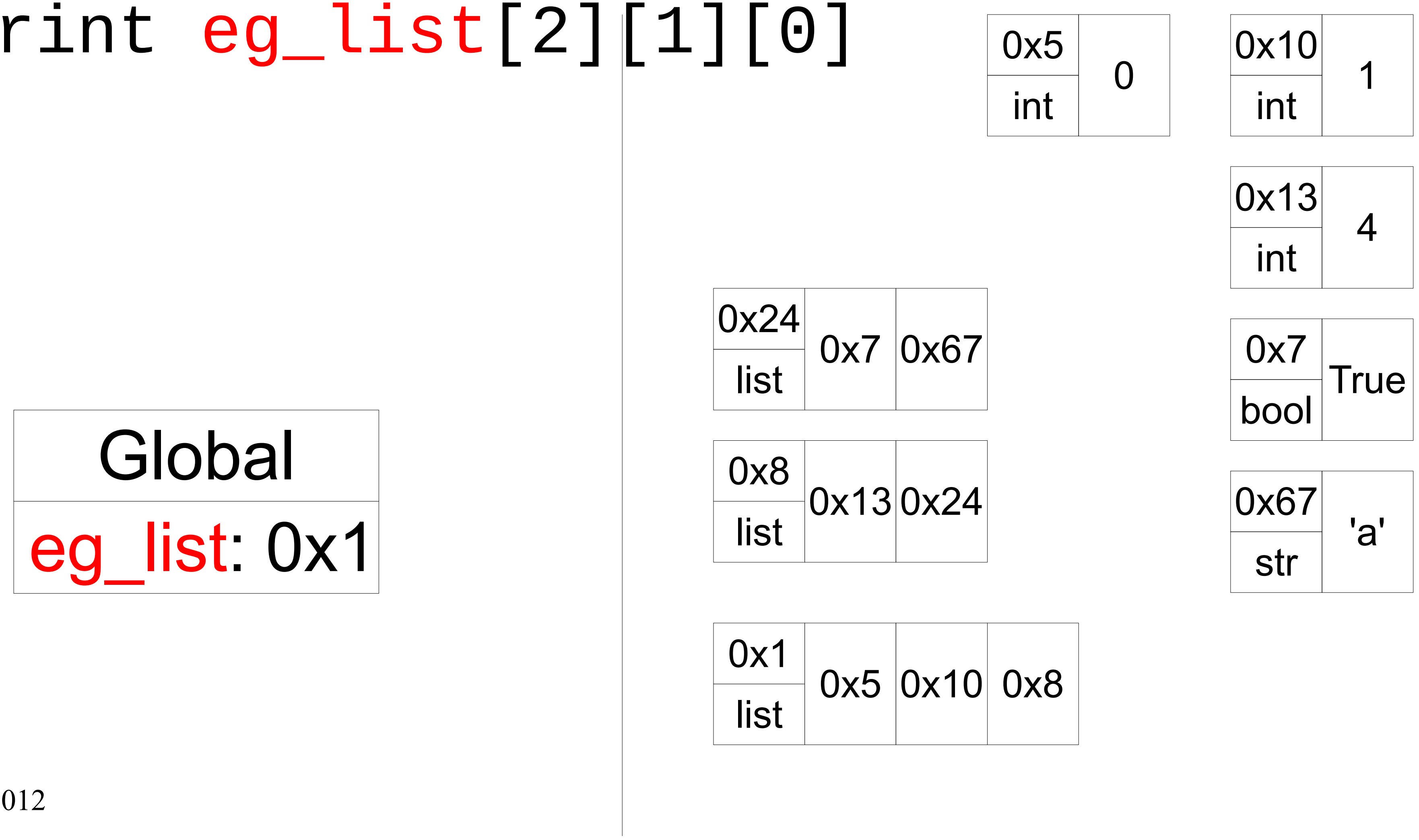

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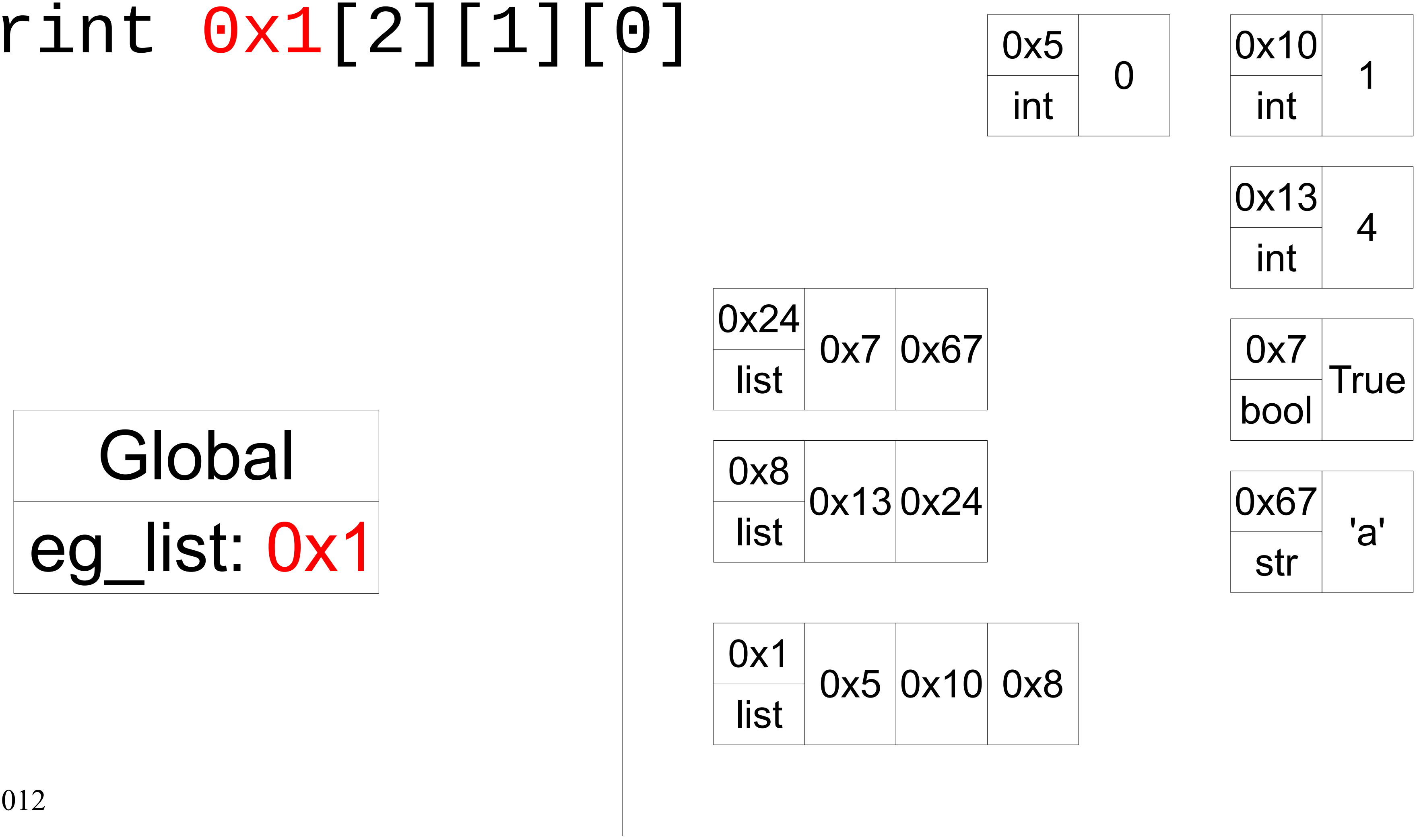

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Nested Lists and the Memory Model

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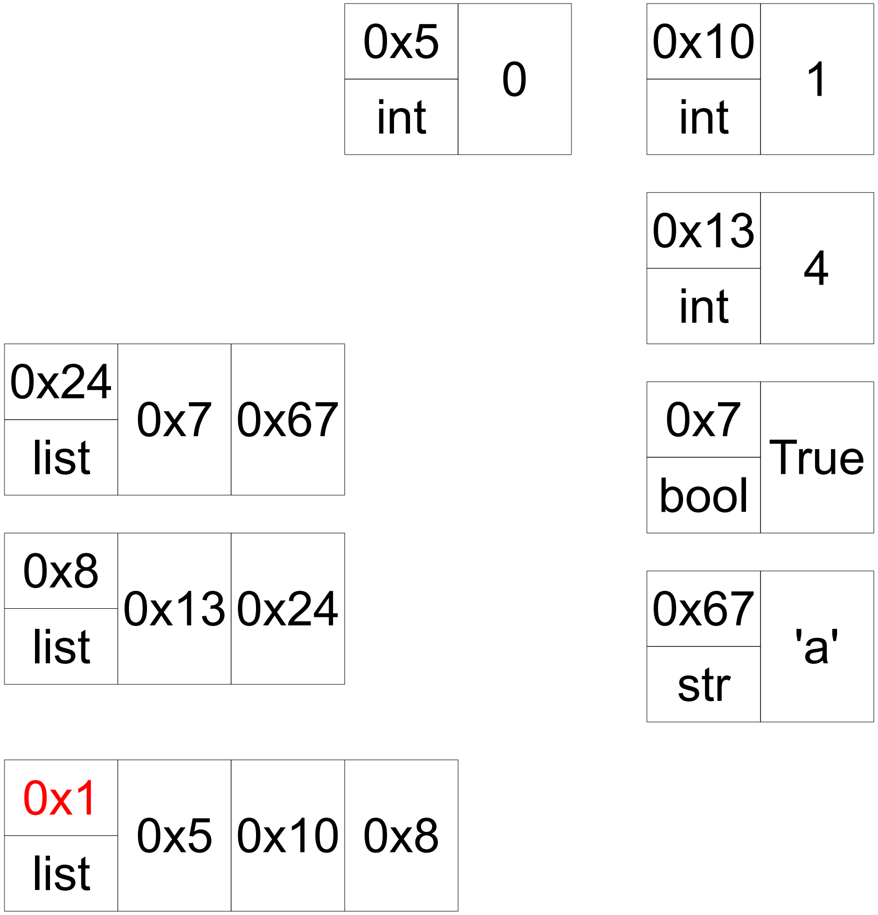

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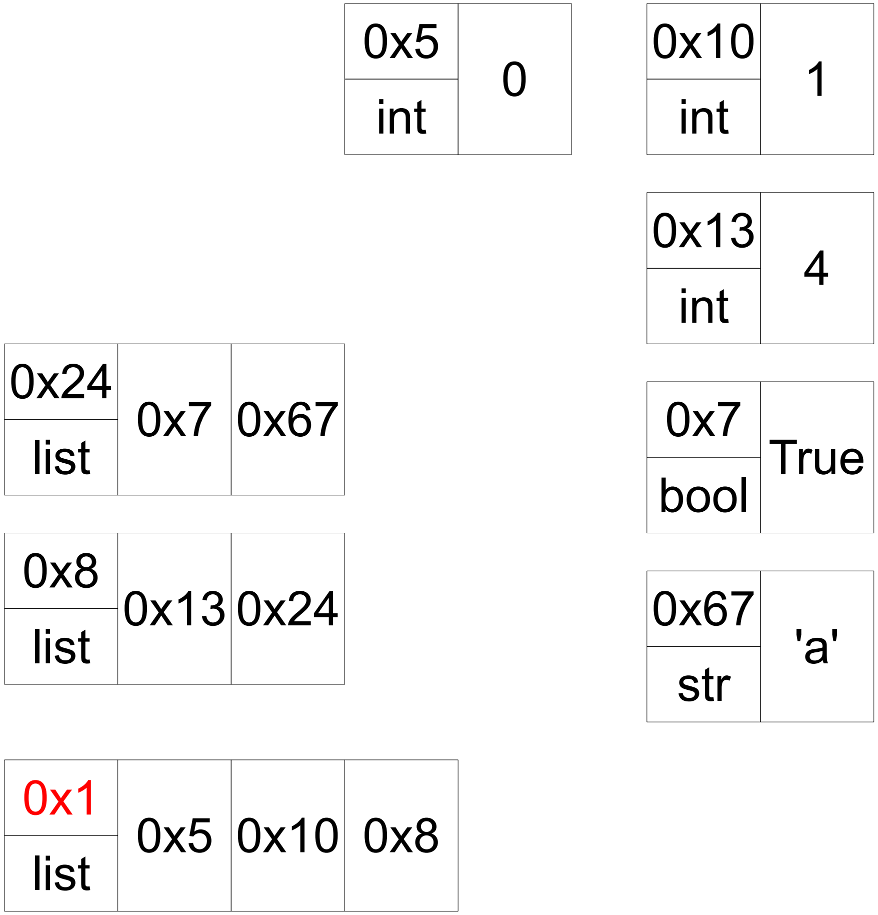

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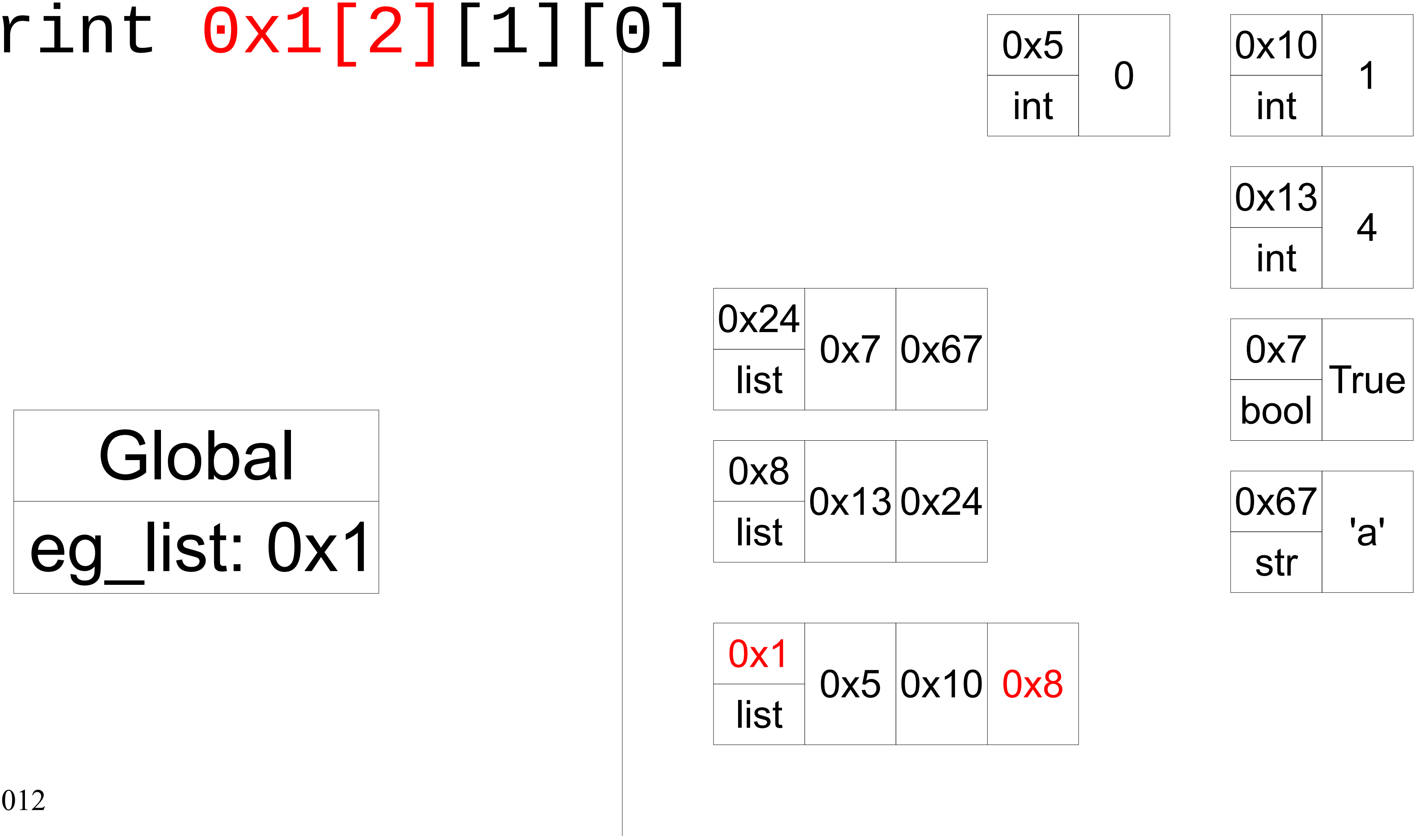

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Nested Lists and the Memory Model

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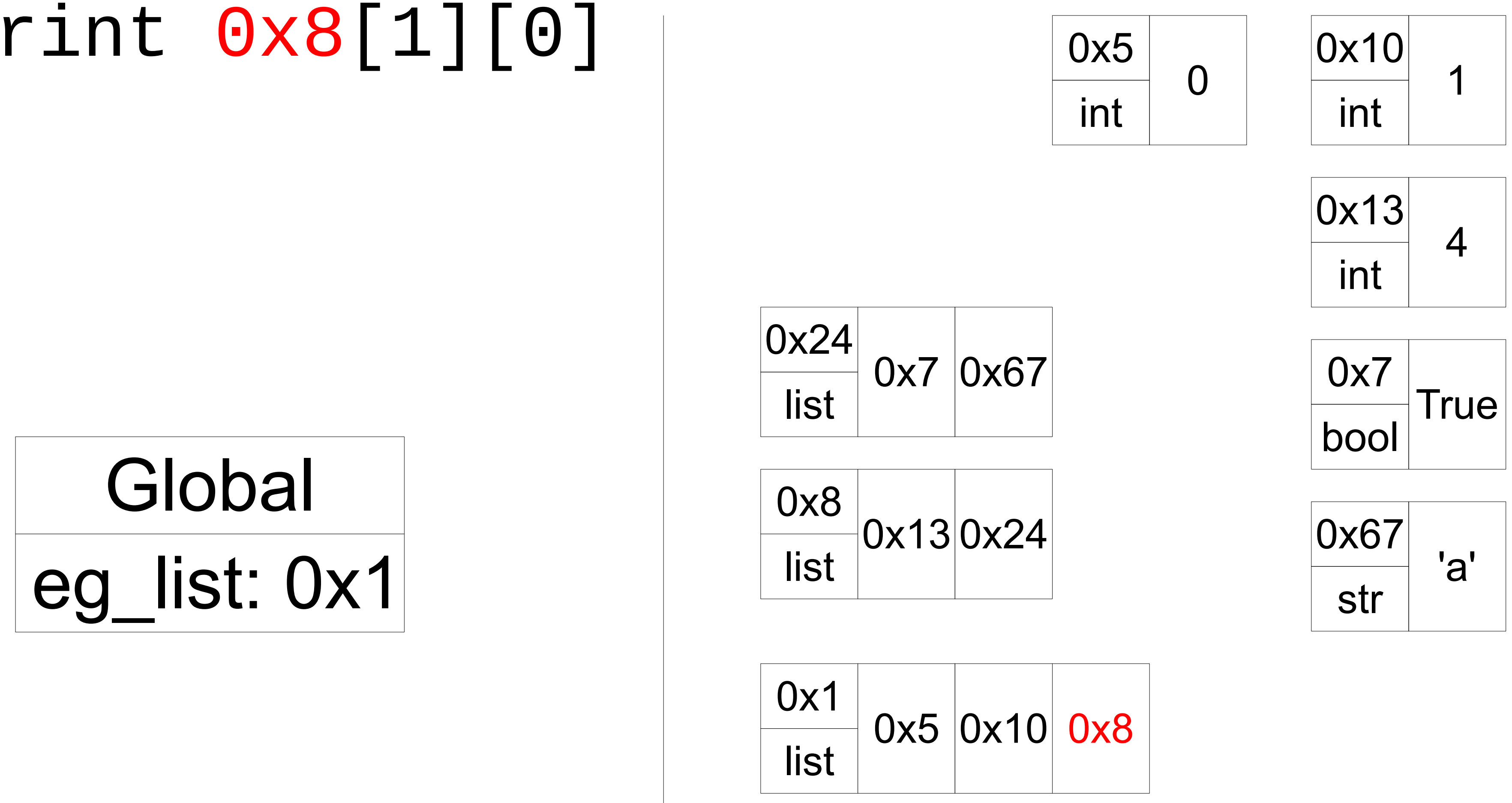
→ print 0x8[1][0]
```



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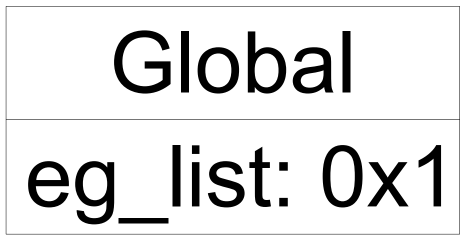
```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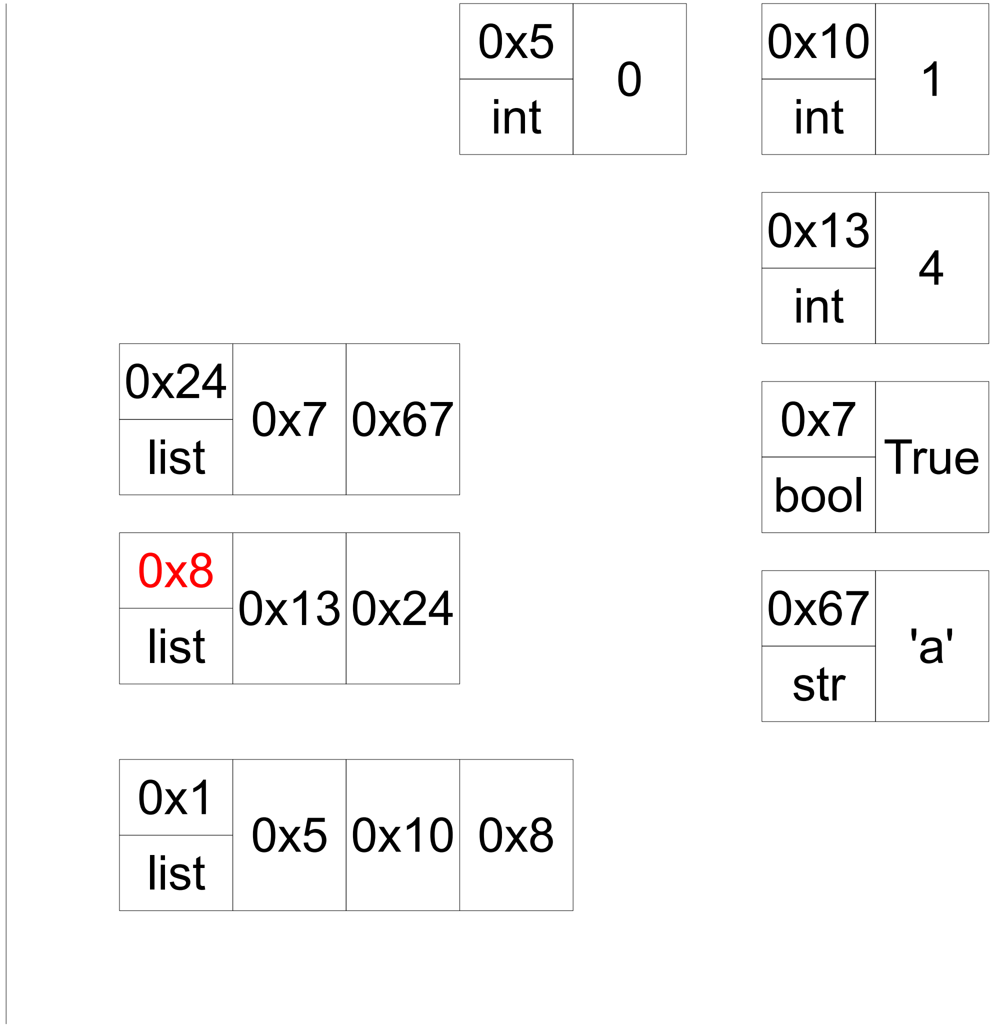
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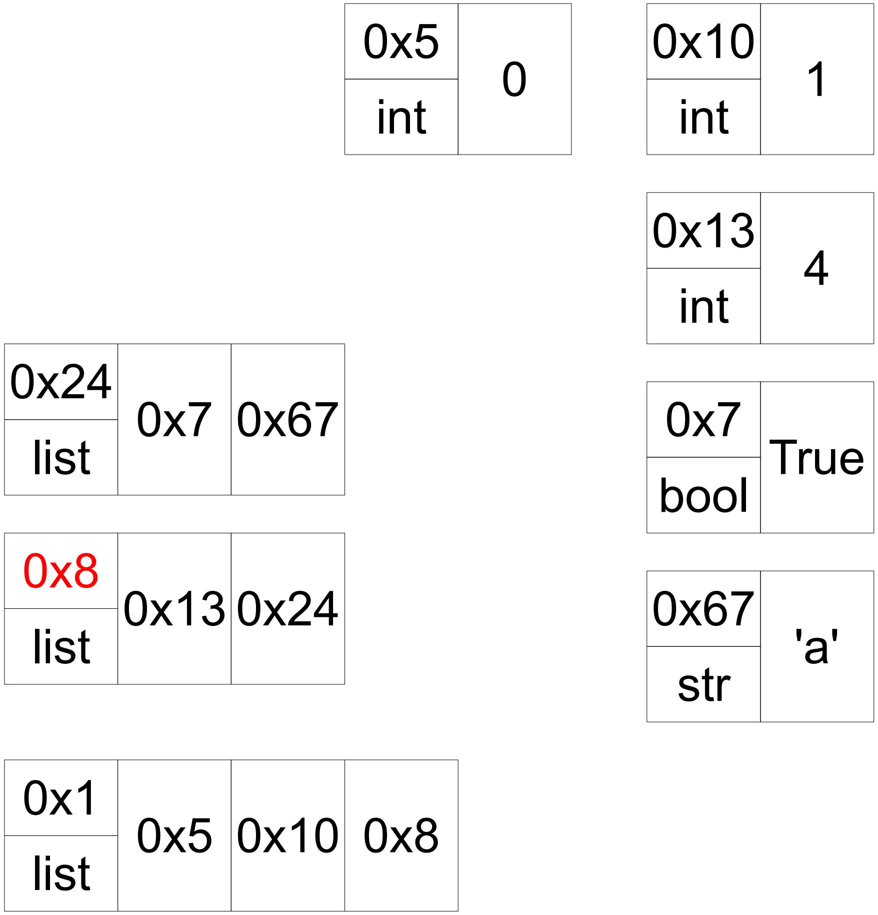

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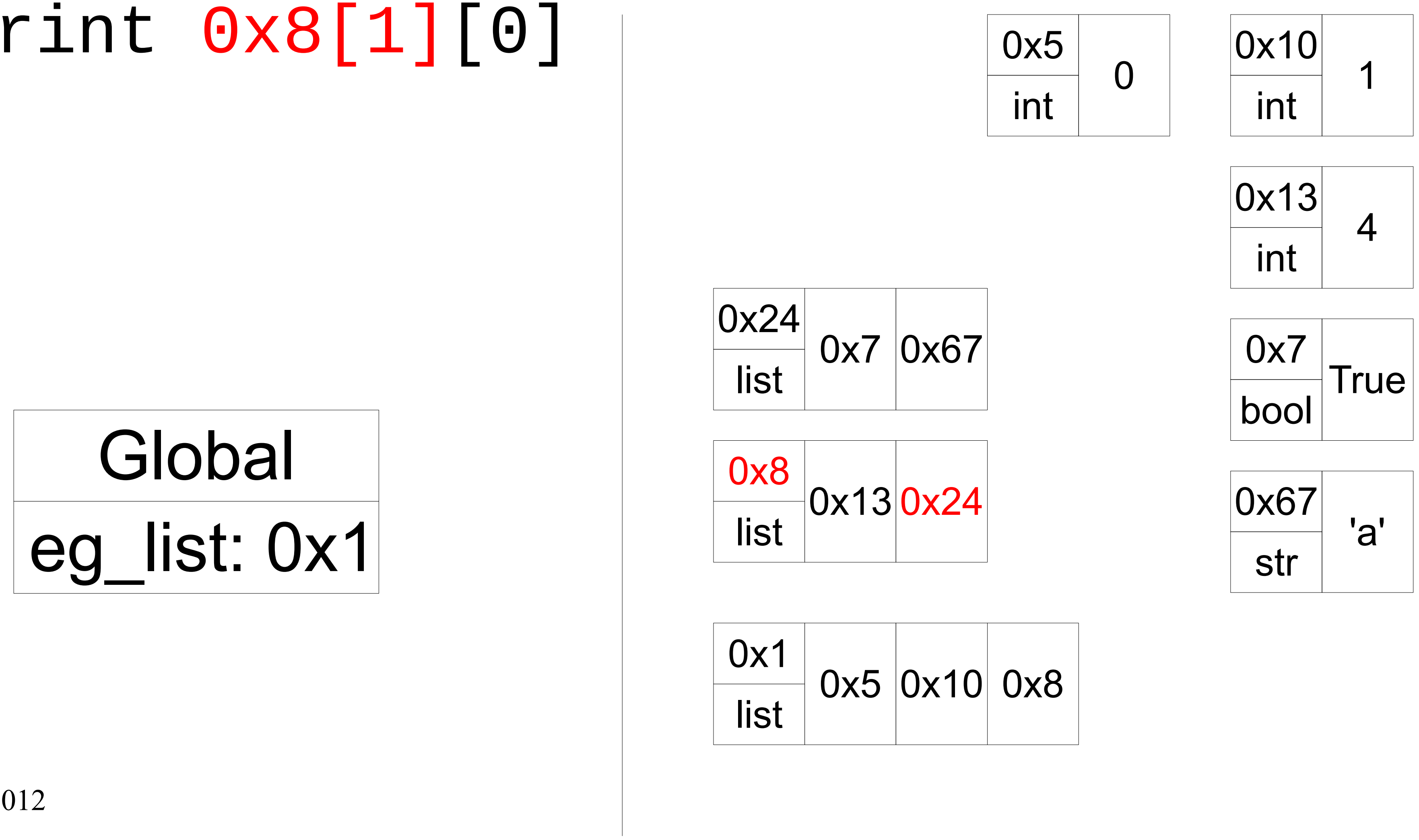

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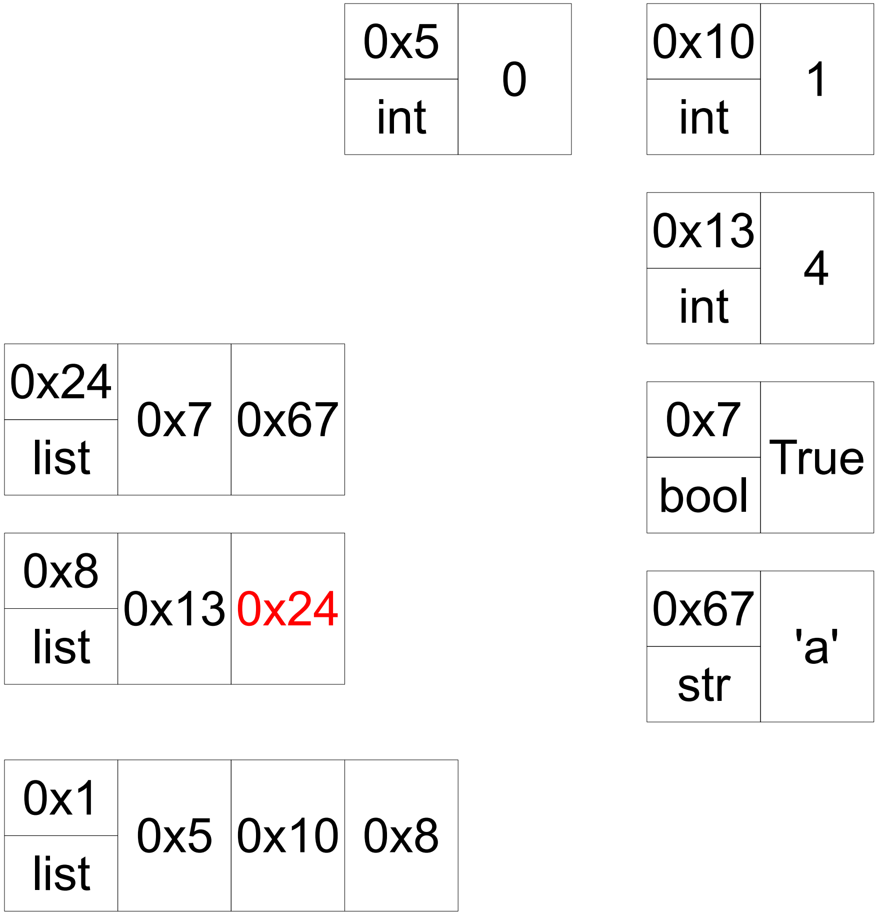

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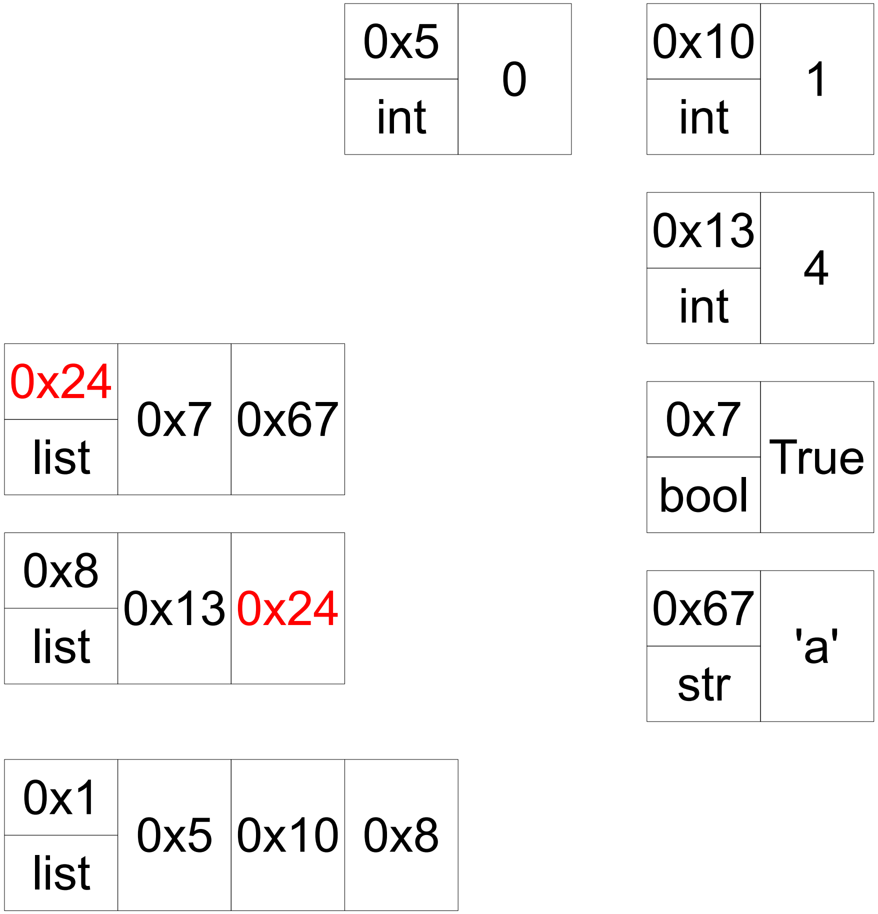

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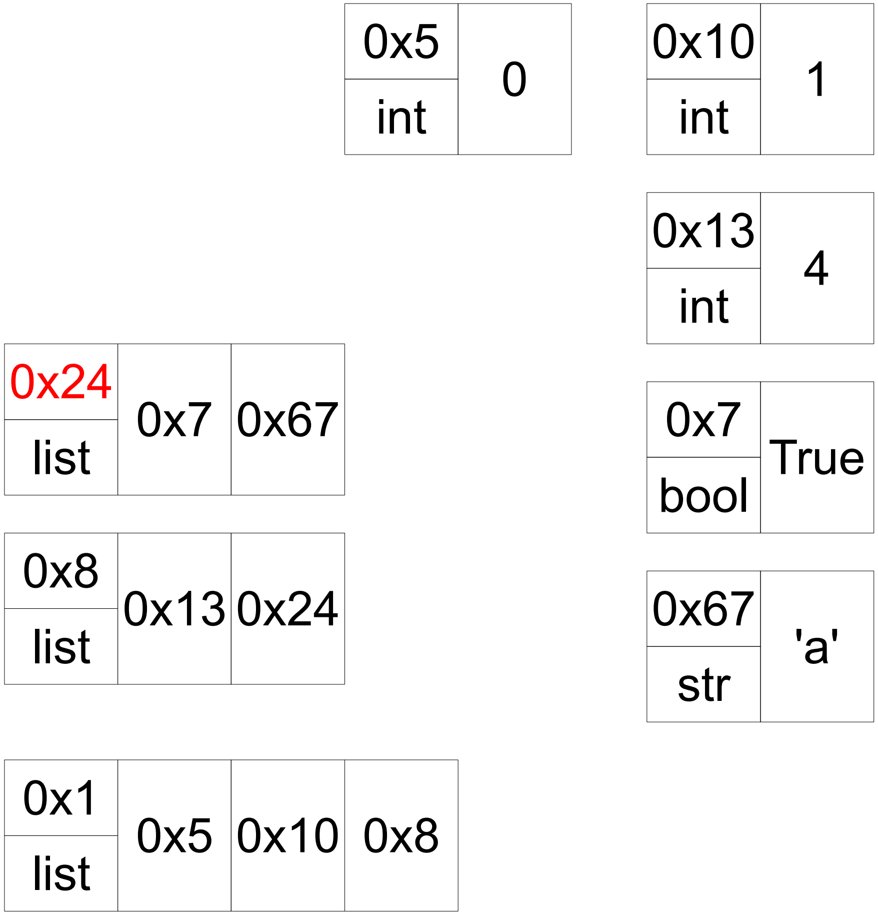

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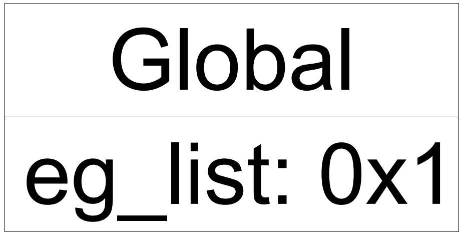

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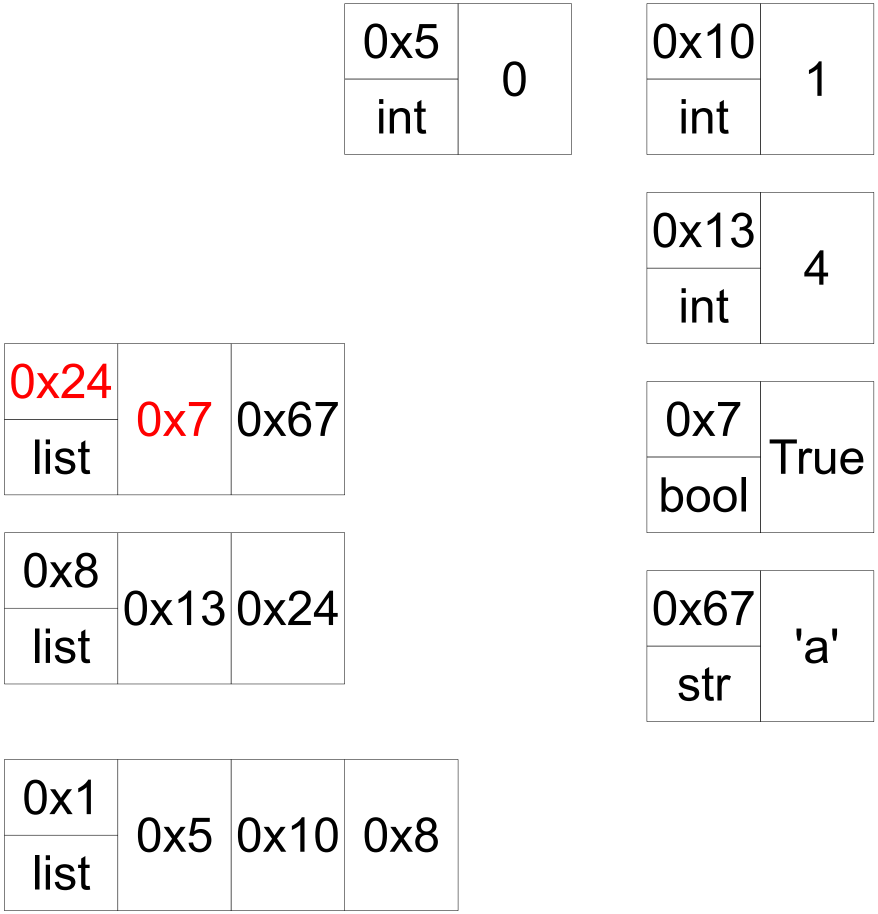

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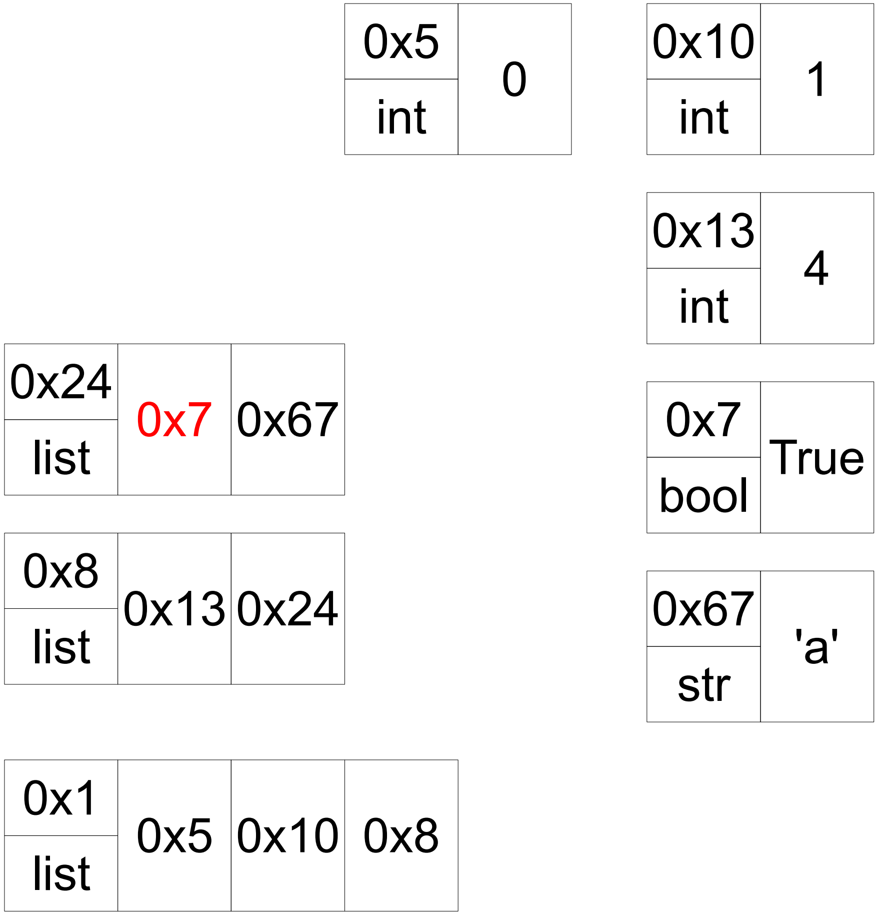

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Nested Lists and the Memory Model

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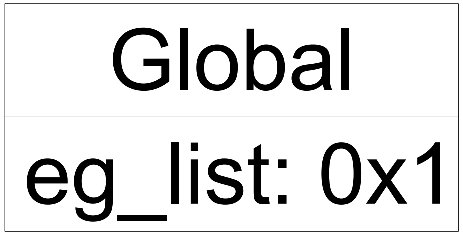

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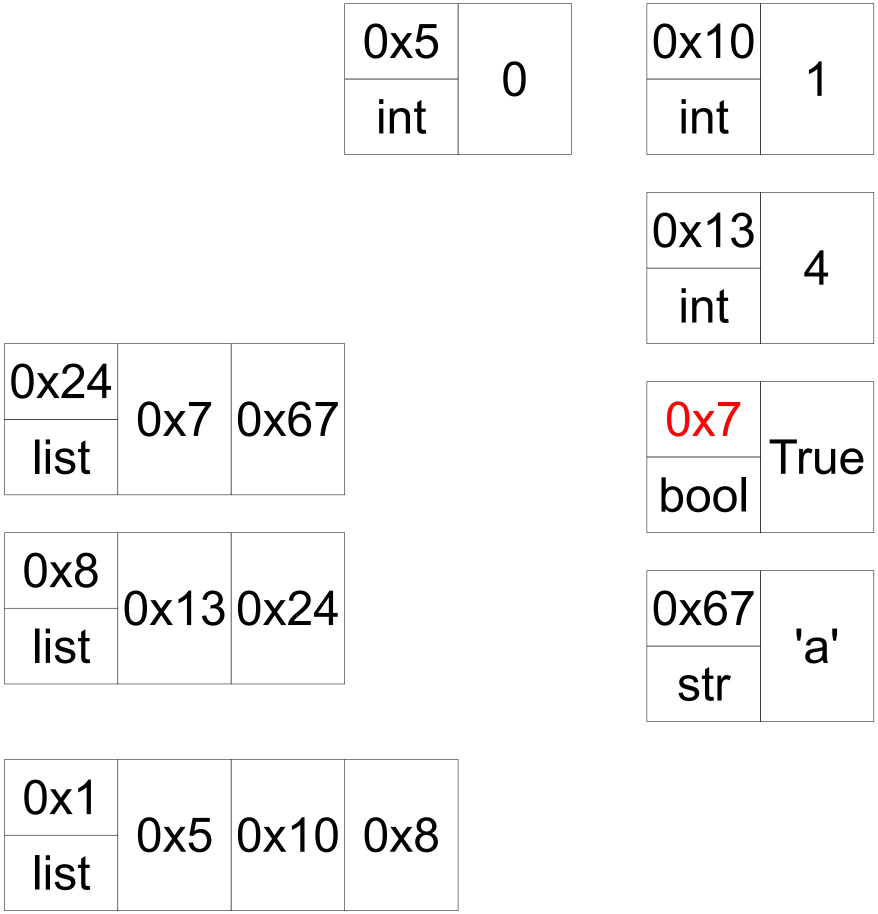

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Nested Lists and the Memory Model

```
eg_list = [0,1,[4, [True, 'a']]]
print 0x7
```

Global
eg_list: 0x1

0x5	0
int	

0x10	1
int	

0x13	4
int	

0x24	0x7	0x67
list		

0x7	True
bool	

0x8	0x13	0x24
list		

0x67	'a'
str	

0x1	0x5	0x10	0x8
list			

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Nested Lists and the Memory Model

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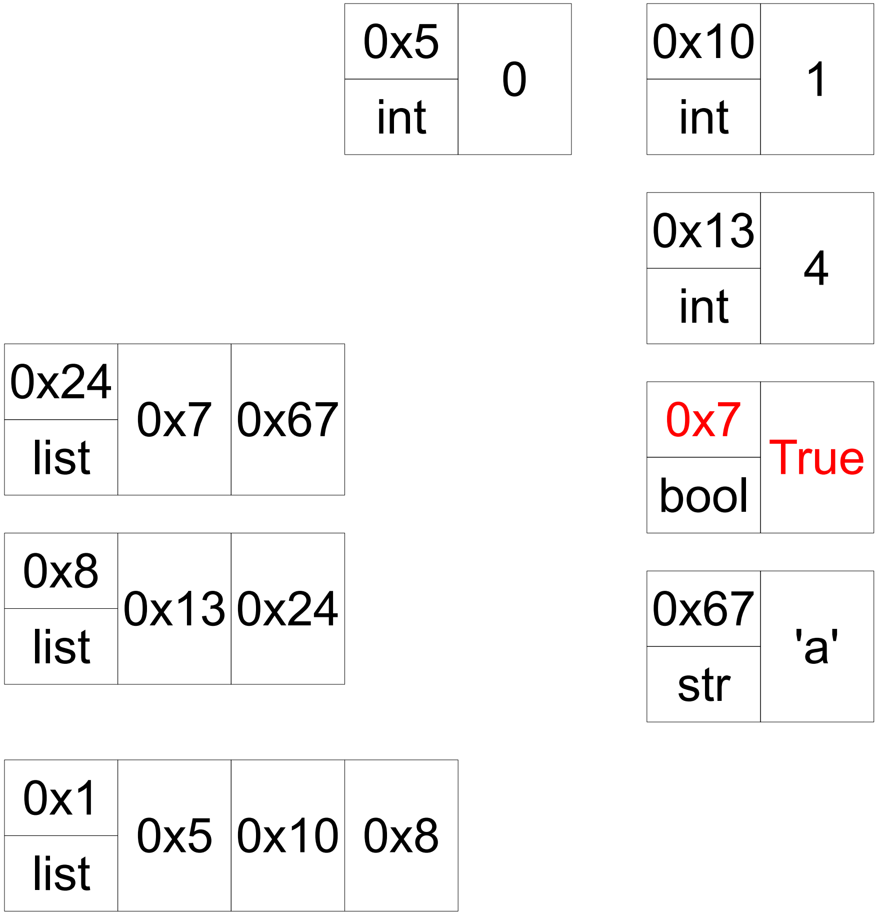
eg_list: 0x1



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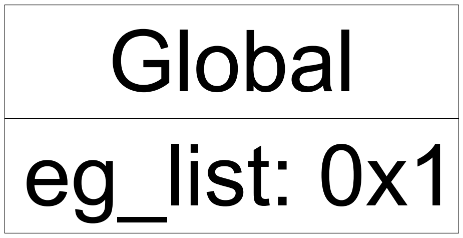
Nested Lists and the Memory Model

```
eg_list = [0,1,[4, [True, 'a']]]
print True
```



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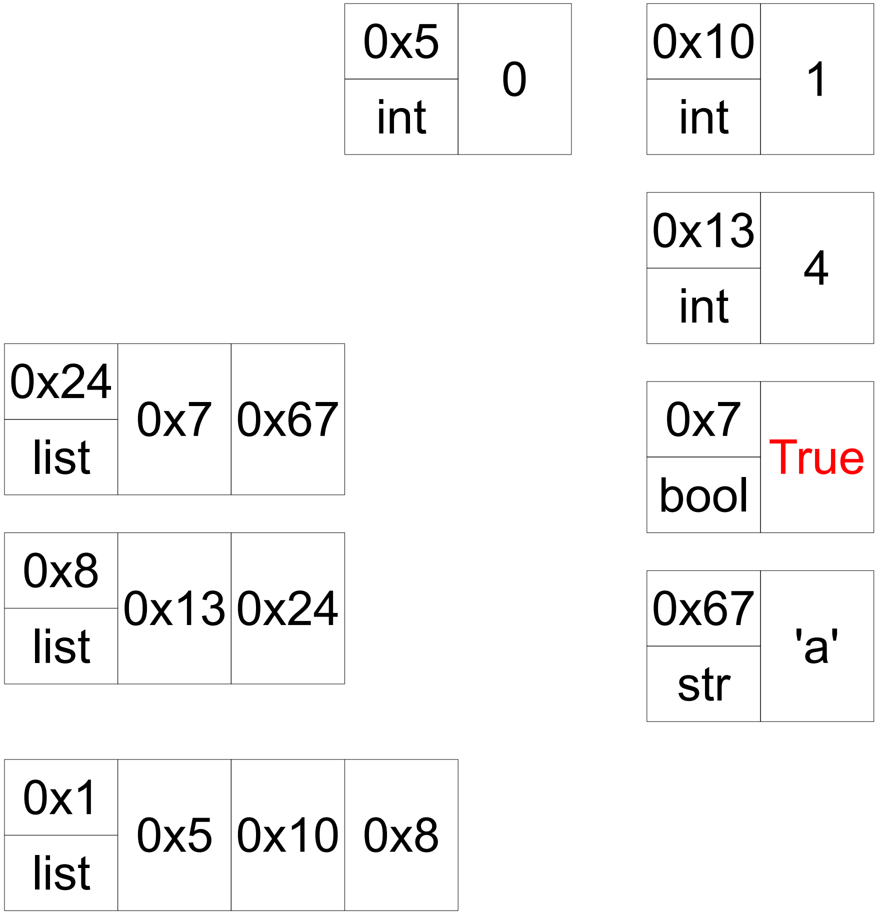

0x5 / int	0

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0x8 / list	0x13	0x24

0x1 / list	0x5	0x10	0x8

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Evaluate the Boolean Expressions

```
x = [1,2]
y = [x,x,2,x]
y[0][0] = 12
y[0] == y[3]

x == y[1]
```

```
x = [1,2]
y = [x[:],x[:],2,x]
y[0][0] = 12
y[0] == y[3]

x == y[1]
```

Evaluate the Boolean Expressions

```
x = [1,2]
y = [x,x,2,x]
y[0][0] = 12
y[0] == y[3]
True
x == y[1]
True
```

```
x = [1,2]
y = [x[:],x[:],2,x]
y[0][0] = 12
y[0] == y[3]
False
x == y[1]
True
```

Tuples

- Similar to lists, but not mutable.
  - So they cannot be changed once they are initialised.
  - Aliasing is not a problem
  - Faster.
- Syntax for creating tuples is like that of lists, but with parentheses instead of square brackets.
- Syntax for accessing tuple elements is like that of lists.

Tuples

- Syntax for creating a tuple:

```
tuple_name = (elt0, elt1, ..., eltn)
```

  - Note that this is ambiguous for a single element.
  - `a = (10)` could be an integer or tuple

- Syntax for accessing a tuple element:

```
tuple_name[elt#]
```

Tuples

- Syntax for creating a tuple:

  `tuple_name = (elt0, elt1, ..., eltn)`

  - Note that this is ambiguous for a single element.
  - `a = (10)` could be an integer or tuple
  - `a = (10,)` is unambiguous.
- Syntax for accessing a tuple element:

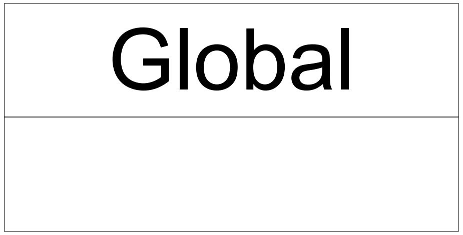
  `tuple_name[elt#]`

Assignment Statements

- Evaluate the right side first!
- Variables can be thought of as look up tables.
- The point of an assignment statement is to connect a memory location to a variable name.
- This means that one needs to evaluate the right side first, before one can do anything else.

Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(x)
```



Assignment Statements & Memory Model

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   def f(x):
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Global
x: ?

Assignment Statements & Memory Model

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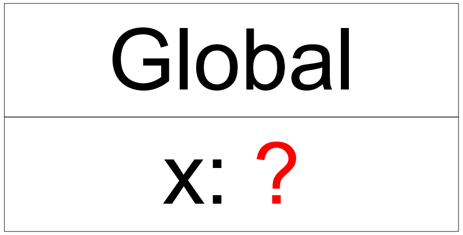

Global

x: ?

Assignment Statements & Memory Model

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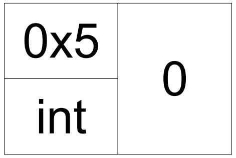
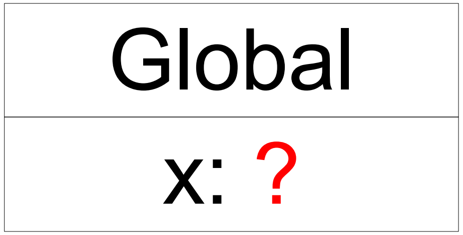
```





Assignment Statements & Memory Model

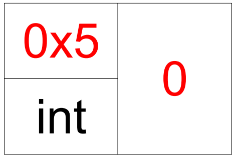
```
    def f(x):
        return x + 4
→   x = 0
    x = 13 + 4
    x = x + f(4)
    x = 10 + f(x)
```

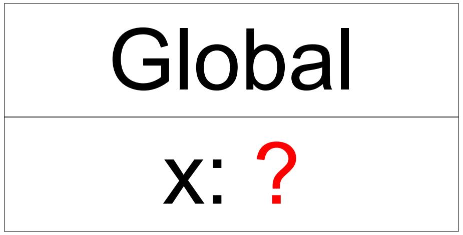
0x5	0
int	

Global
x: ?

Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0x5
x = 13 + 4
x = x + f(4)
x = 10 + f(x)
```





Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(x)
```

0x5	0
int	

Global
x: 0x5

Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
→ x = 13 + 4
x = x + f(4)
x = 10 + f(x)
```

Global
x: 0x5

0x5	0
int	

Assignment Statements & Memory Model

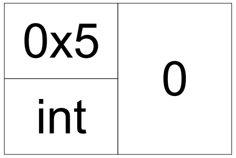
```
  def f(x):
        return x + 4
  x = 0
→ x = 13 + 4
  x = x + f(4)
  x = 10 + f(x)
```

0x5	0
int	

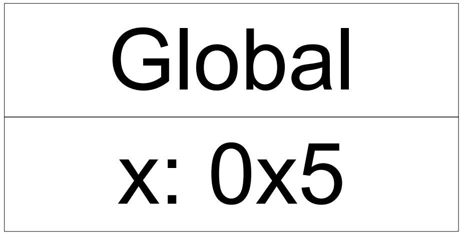
Global
x: 0x5

Assignment Statements & Memory Model

```
   def f(x):
       return x + 4
   x = 0
→  x = ?
   x = x + f(4)
   x = 10 + f(x)
```



0x5 | int | 0



Global

x: 0x5

Assignment Statements & Memory Model

```
  def f(x):
      return x + 4
  x = 0
→ x = 13 + 4
  x = x + f(4)
  x = 10 + f(x)
```

Global
x: 0x5

0x5	0
int	

0x3	13
int	

Assignment Statements & Memory Model

```
  def f(x):
      return x + 4
  x = 0
→ x = 13 + 4
  x = x + f(4)
  x = 10 + f(x)
```

0x5	0
int	

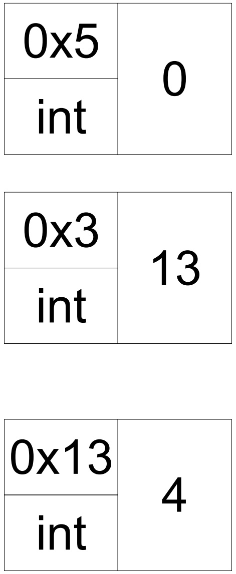
0x3	13
int	

Global
x: 0x5

Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
→ x = 13 + 4
x = x + f(4)
x = 10 + f(x)
```

Global
x: 0x5



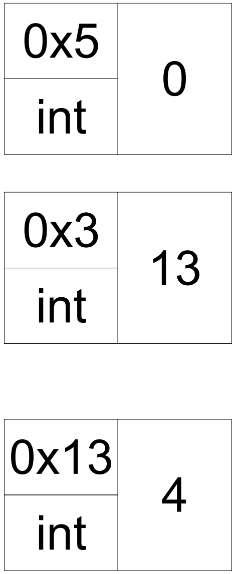
0x5	0
int	

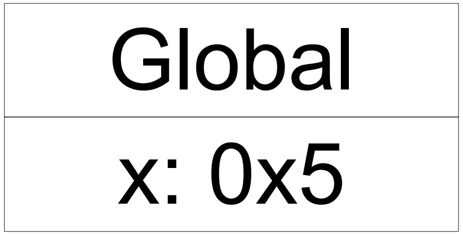
0x3	13
int	

0x13	4
int	

Assignment Statements & Memory Model

```
  def f(x):
      return x + 4
  x = 0
→ x = 13 + 4
  x = x + f(4)
  x = 10 + f(x)
```





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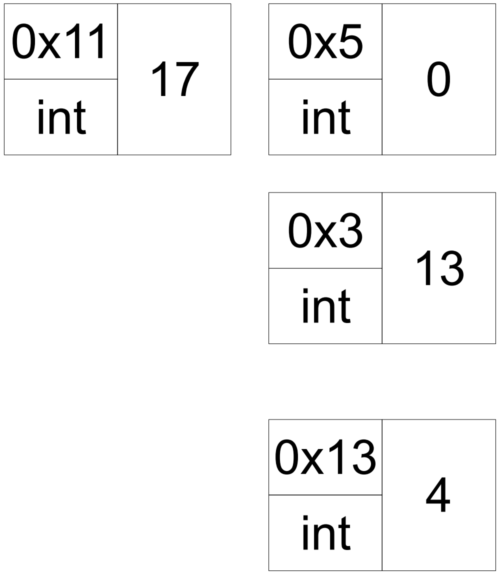
Assignment Statements & Memory Model

```
    def f(x):
        return x + 4
    x = 0
──► x = 13 + 4
    x = x + f(4)
    x = 10 + f(x)
```



0x11 17 int

0x5 0 int

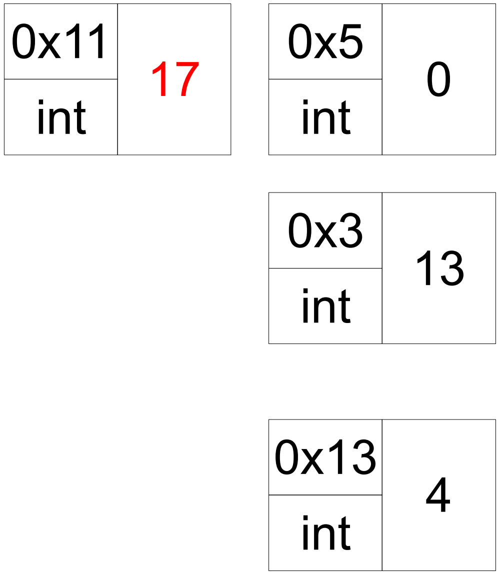
0x3 13 int

0x13 4 int

Global
x: 0x5

Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
x = 17
x = x + f(4)
x = 10 + f(x)
```



0x11	17
int	

0x5	0
int	

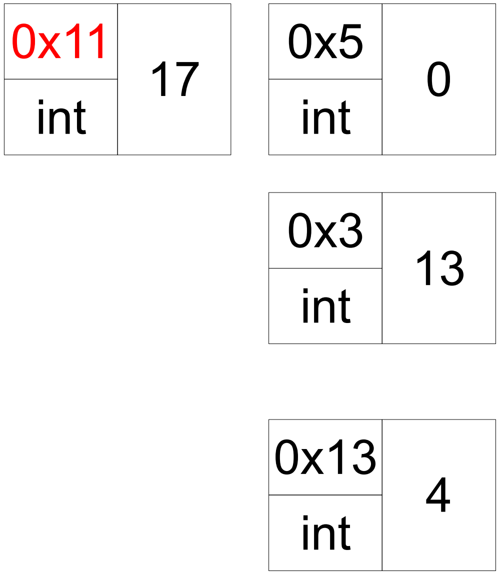
0x3	13
int	

0x13	4
int	

Global
x: 0x5

Assignment Statements & Memory Model

```
   def f(x):
       return x + 4
   x = 0
→  x = 0x11
   x = x + f(4)
   x = 10 + f(x)
```



0x11 | int | 17

0x5 | int | 0

0x3 | int | 13

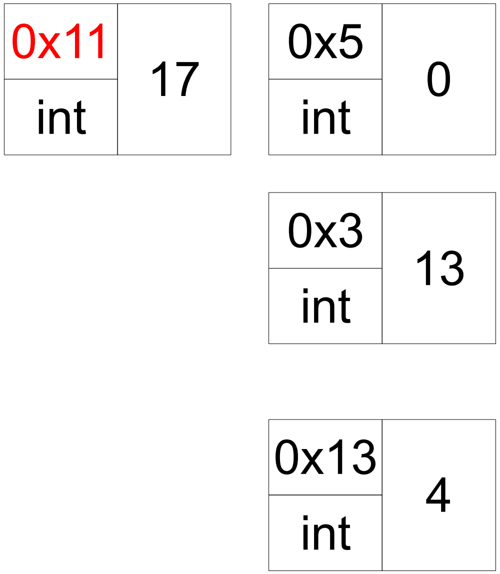
0x13 | int | 4

Global
x: 0x5

Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
x = 0x11
x = x + f(4)
x = 10 + f(x)
```

Global
x: 0x11



0x11 int 17

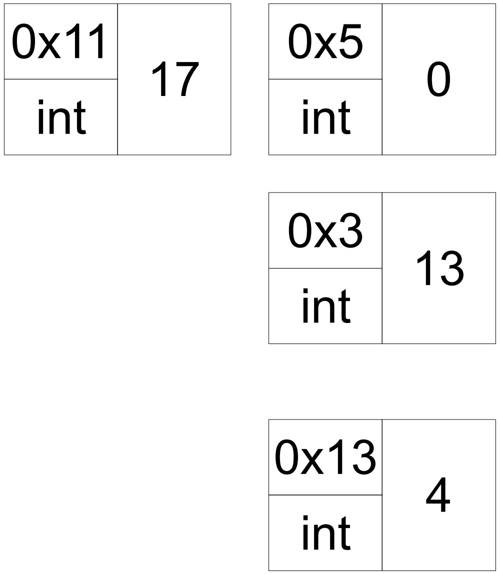
0x5 int 0

0x3 int 13

0x13 int 4

Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(x)
```

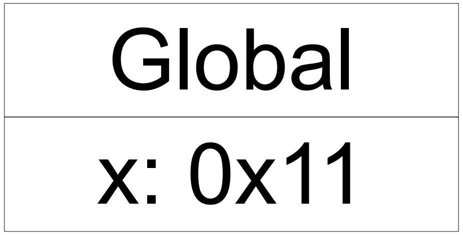


0x11	17
int	

0x5	0
int	

0x3	13
int	

0x13	4
int	



Global
x: 0x11

Assignment Statements & Memory Model

```
   def f(x):
       return x + 4
   x = 0
   x = 13 + 4
►  x = x + f(4)
   x = 10 + f(x)
```

0x11	17
int	

0x5	0
int	

0x3	13
int	

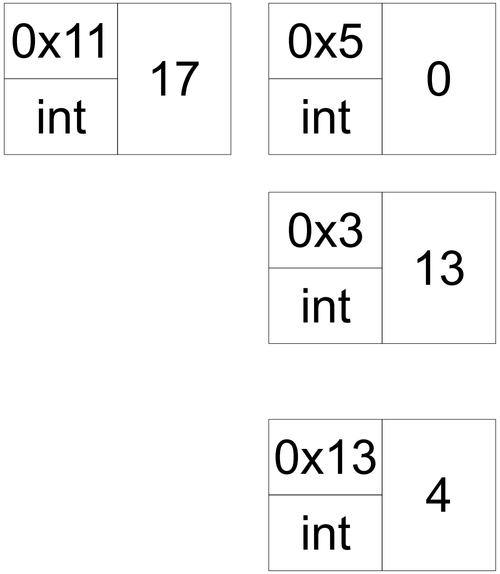
0x13	4
int	

Global
x: 0x11

Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(x)
```

Global
x: 0x11



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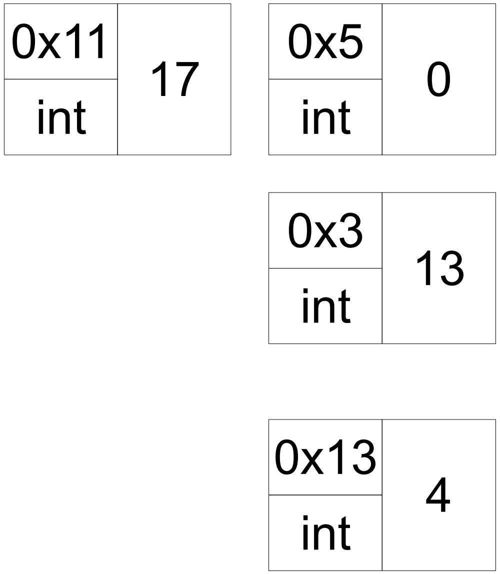
Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
→ x = x + f(4)
x = 10 + f(x)
```



0x11 int	17

0x5 int	0

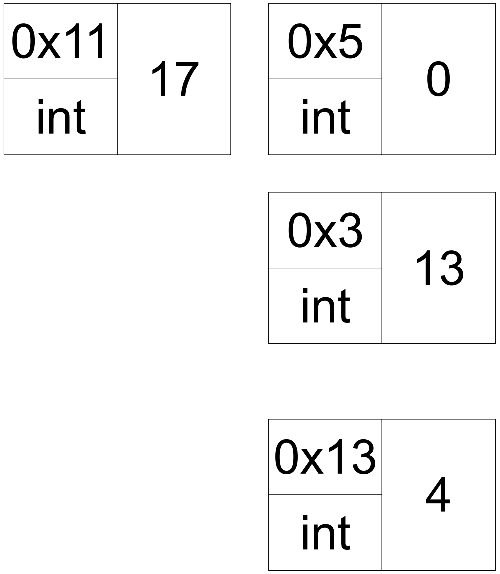
0x3 int	13

0x13 int	4

Global
x: 0x11

Assignment Statements & Memory Model

```
  def f(x):
      return x + 4
  x = 0
  x = 13 + 4
→ x = x + f(4)
  x = 10 + f(x)
```



0x11	17
int	

0x5	0
int	

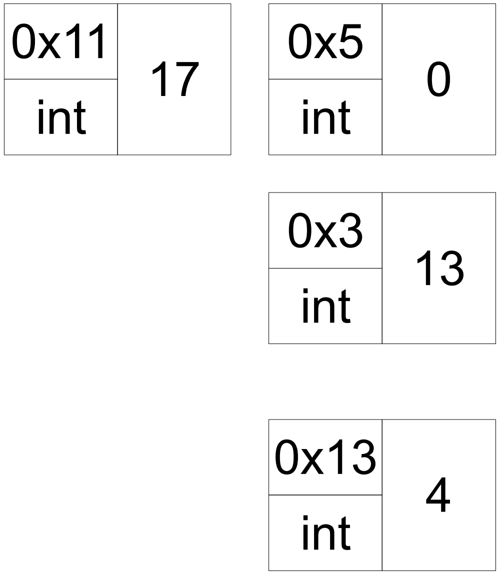
0x3	13
int	

0x13	4
int	

Global
x: 0x11

Assignment Statements & Memory Model

```
  def f(x):
      return x + 4
  x = 0
  x = 13 + 4
→ x = 0x11 + f(4)
  x = 10 + f(x)
```



0x11 int 17

0x5 int 0

0x3 int 13

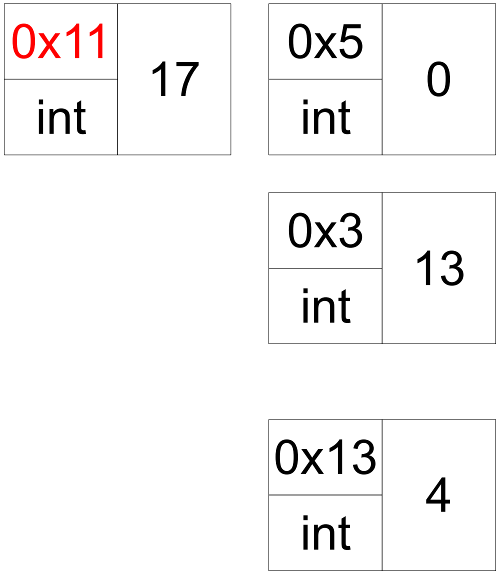
0x13 int 4

Global
x: 0x11

Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = 0x11 + f(4)
x = 10 + f(x)
```

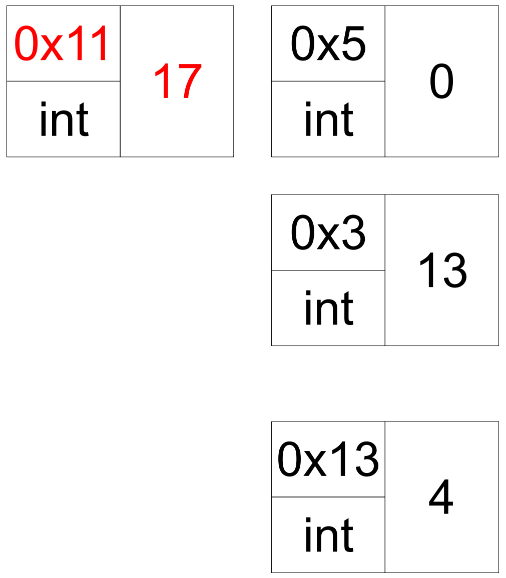
Global
x: 0x11



Assignment Statements & Memory Model

```
     def f(x):
         return x + 4
     x = 0
     x = 13 + 4
──►  x = 17 + f(4)
     x = 10 + f(x)
```

Global
x: 0x11



0x11 | int | 17

0x5 | int | 0

0x3 | int | 13

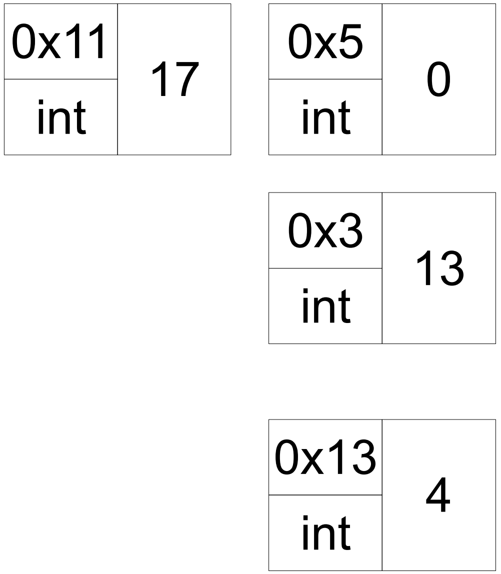
0x13 | int | 4

June 14 2012

Assignment Statements & Memory Model

```
    def f(x):
        return x + 4
    x = 0
    x = 13 + 4
──► x = 17 + f(4)
    x = 10 + f(x)
```

Global
x: 0x11

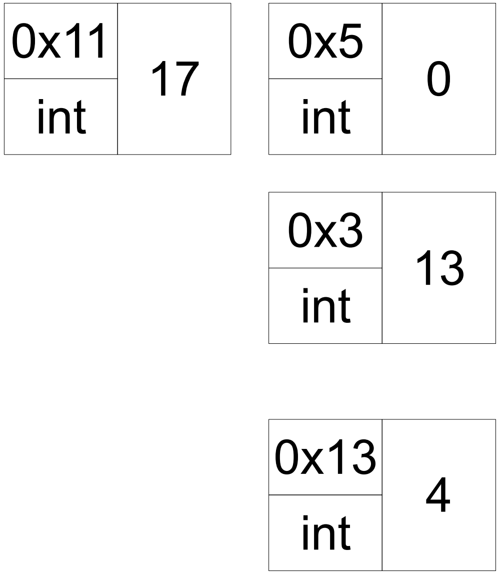


0x11	int	17
0x5	int	0
0x3	int	13
0x13	int	4

June 14 2012

Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = 17 + f(4)
x = 10 + f(x)
```



0x11
int
17

0x5
int
0

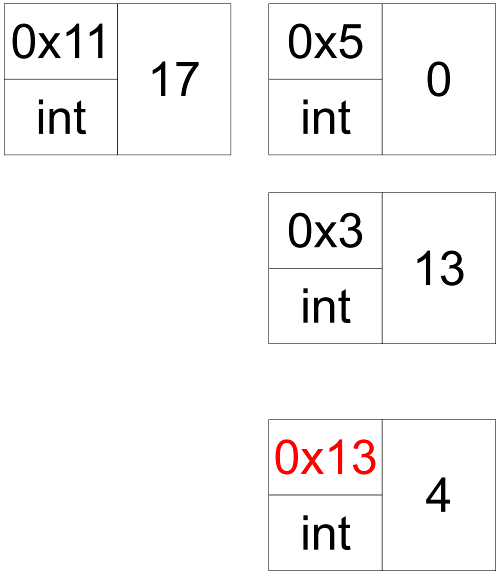
0x3
int
13

0x13
int
4

Global
x: 0x11

Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = 17 + f(0x13)
x = 10 + f(x)
```



0x11	17
int	

0x5	0
int	

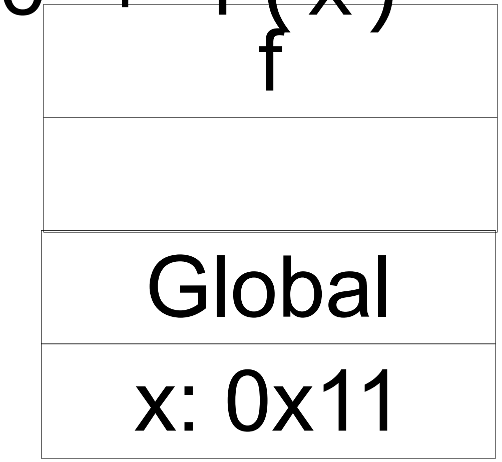
0x3	13
int	

0x13	4
int	

Global
x: 0x11

Assignment Statements & Memory Model

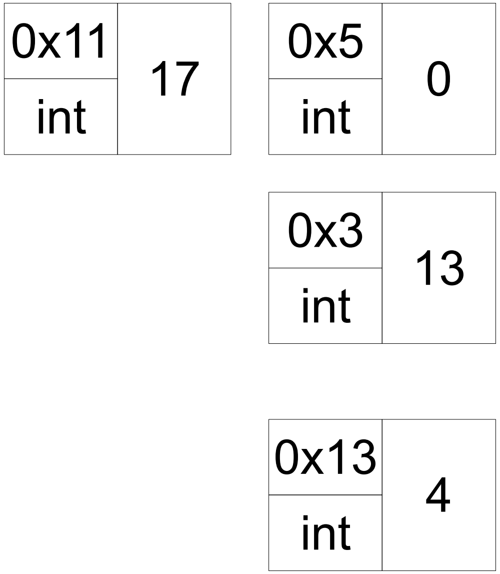
```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = 17 + f(0x13)
x = 10 + f(x)
```



f

Global

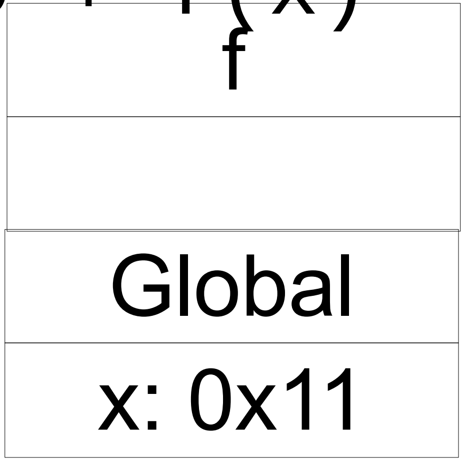
x: 0x11



0x11 int	17		0x5 int	0
			0x3 int	13
			0x13 int	4

Assignment Statements & Memory Model

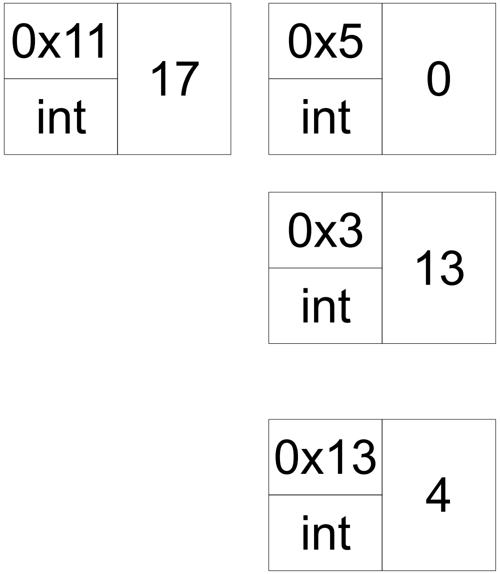
```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = 17 + f(0x13)
x = 10 + f(x)
```



f

Global

x: 0x11



0x11 int 17

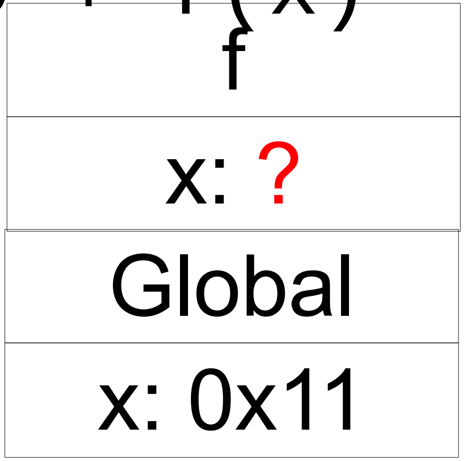
0x5 int 0

0x3 int 13

0x13 int 4

Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = 17 + f(0x13)
x = 10 + f(x)
```

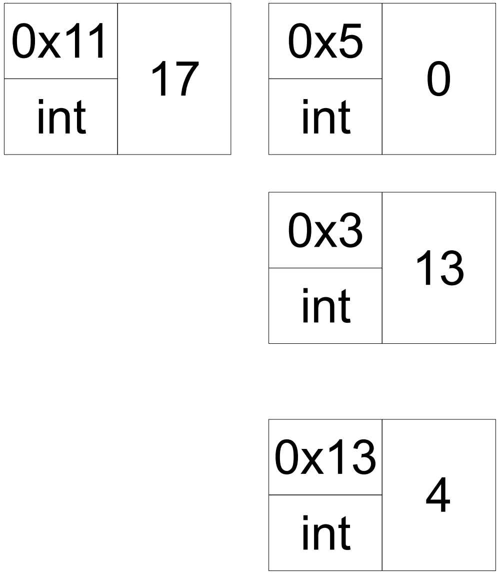


f

x: ?

Global

x: 0x11



0x11 int 17

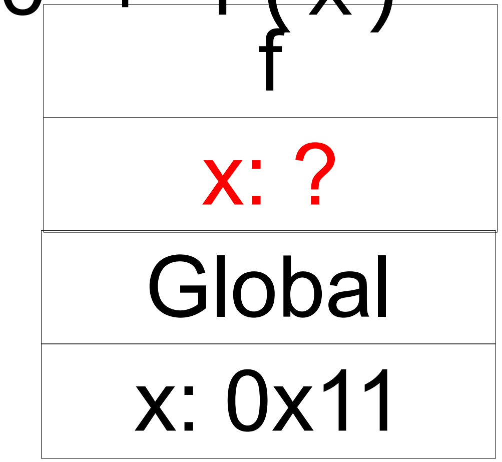
0x5 int 0

0x3 int 13

0x13 int 4

Assignment Statements & Memory Model

```
  def f(x):
      return x + 4
  x = 0
  x = 13 + 4
► x = 17 + f(0x13)
  x = 10 + f(x)
```

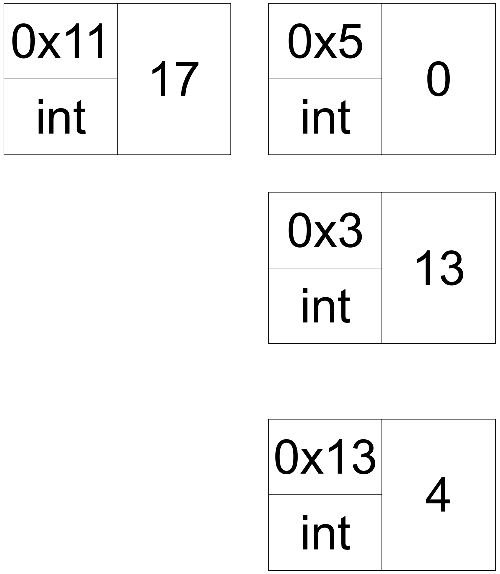


f

x: ?

Global

x: 0x11



0x11 int	17

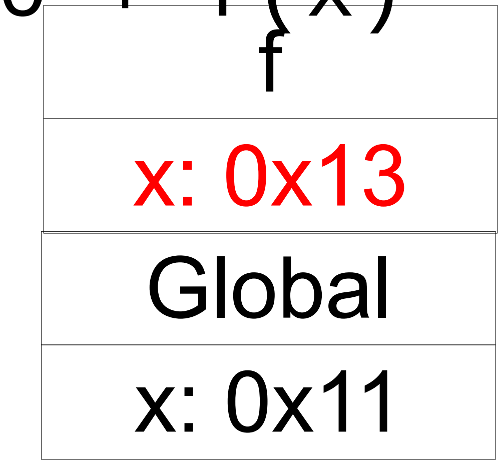
0x5 int	0

0x3 int	13

0x13 int	4

Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = 17 + f(0x13)
x = 10 + f(x)
```

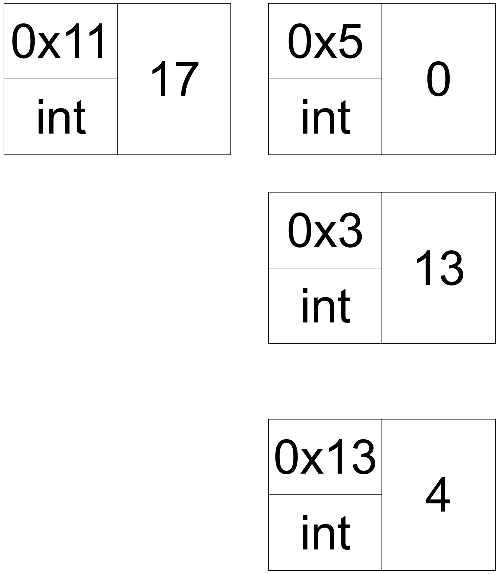


f

x: 0x13

Global

x: 0x11



0x11 int 17

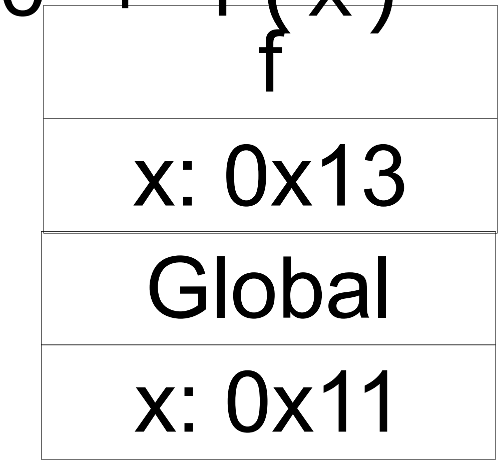
0x5 int 0

0x3 int 13

0x13 int 4

Assignment Statements & Memory Model

```
  def f(x):
→     return x + 4
  x = 0
  x = 13 + 4
  x = 17 + f(4)
  x = 10 + f(x)
```

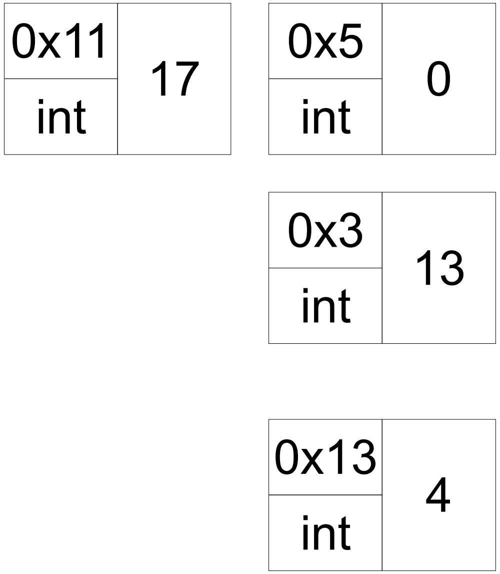


f

x: 0x13

Global

x: 0x11



0x11 int 17

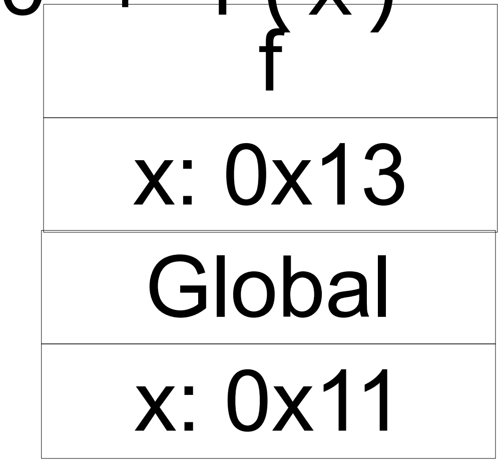
0x5 int 0

0x3 int 13

0x13 int 4

Assignment Statements & Memory Model

```
    def f(x):
→       return x + 4
    x = 0
    x = 13 + 4
    x = 17 + f(4)
    x = 10 + f(x)
```

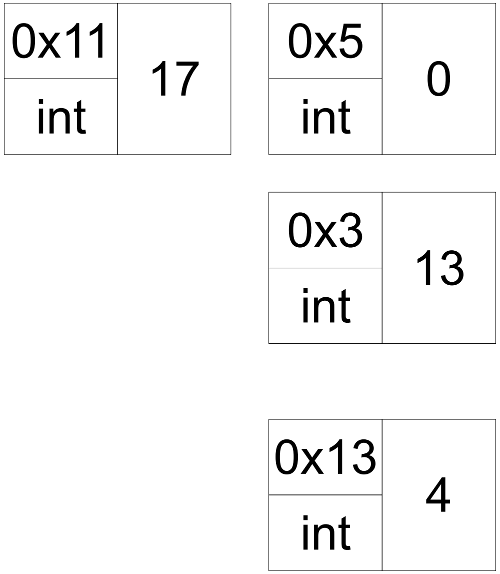


f

x: 0x13

Global

x: 0x11



0x11 int 17

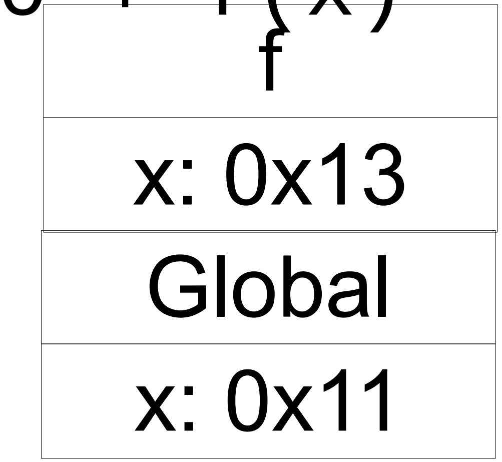
0x5 int 0

0x3 int 13

0x13 int 4

Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = 17 + f(4)
x = 10 + f(x)
```

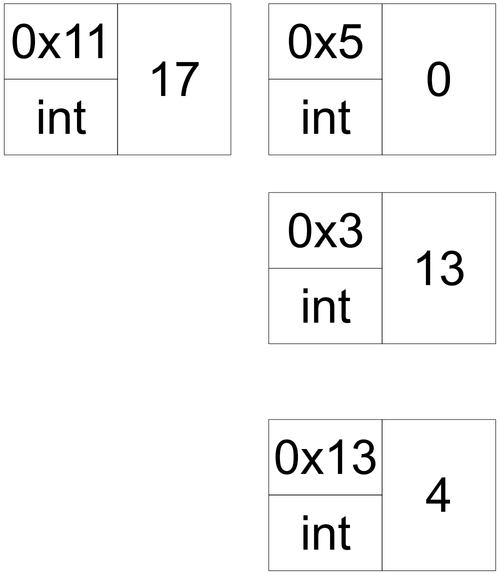


f

x: 0x13

Global

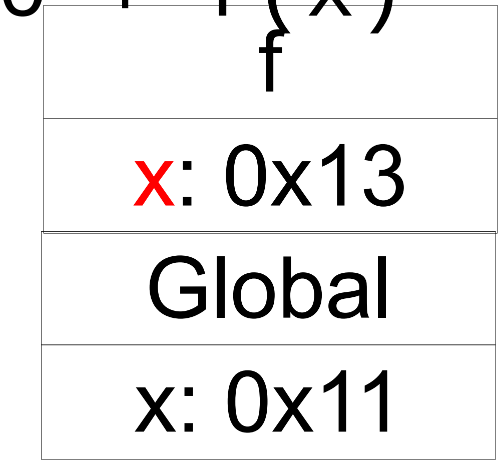
x: 0x11



0x11	17		0x5	0
int			int	
			0x3	13
			int	
			0x13	4
			int	

Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = 17 + f(4)
x = 10 + f(x)
```

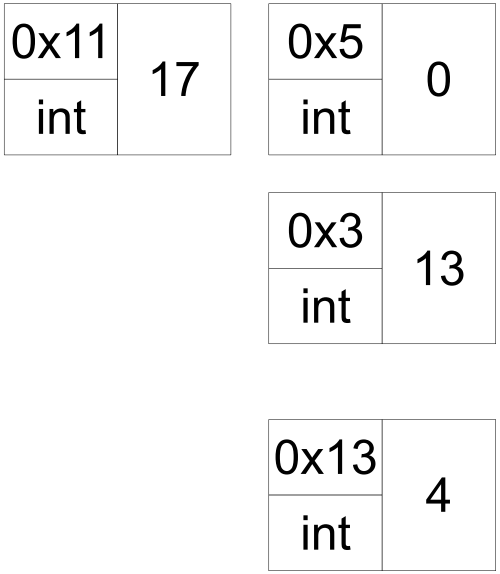


f

x: 0x13

Global

x: 0x11



0x11 int	17

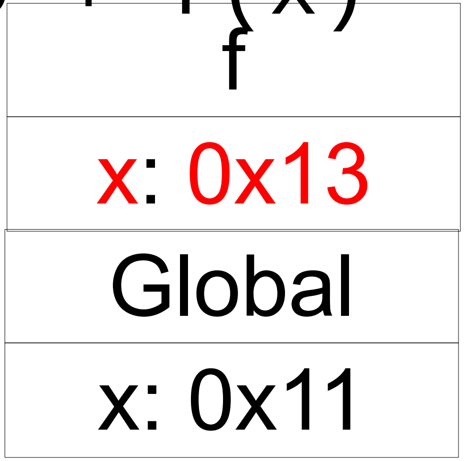
0x5 int	0

0x3 int	13

0x13 int	4

Assignment Statements & Memory Model

```
def f(x):
→   return x + 4
x = 0
x = 13 + 4
x = 17 + f(4)
x = 10 + f(x)
```

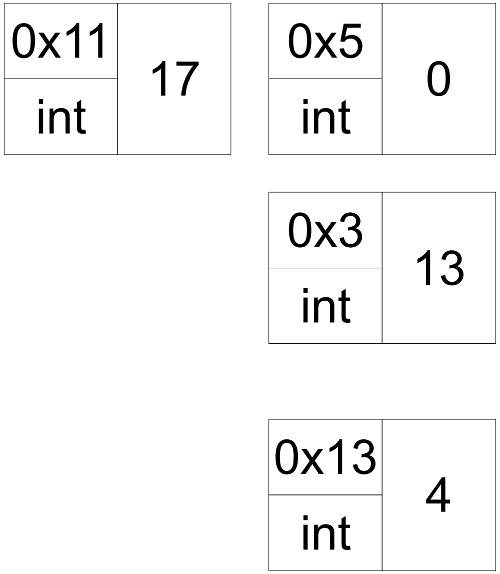


f

x: 0x13

Global

x: 0x11



0x11	17
int	

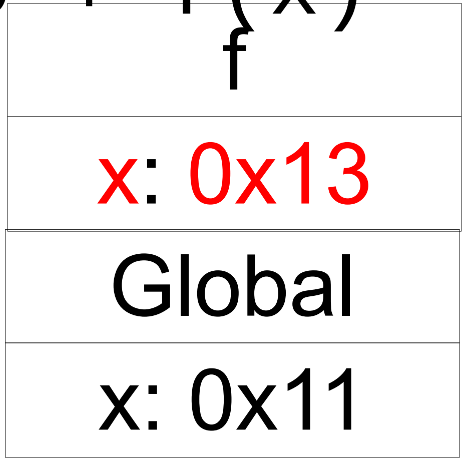
0x5	0
int	

0x3	13
int	

0x13	4
int	

Assignment Statements & Memory Model

```
def f(x):
    return 0x13 + 4
x = 0
x = 13 + 4
x = 17 + f(4)
x = 10 + f(x)
```

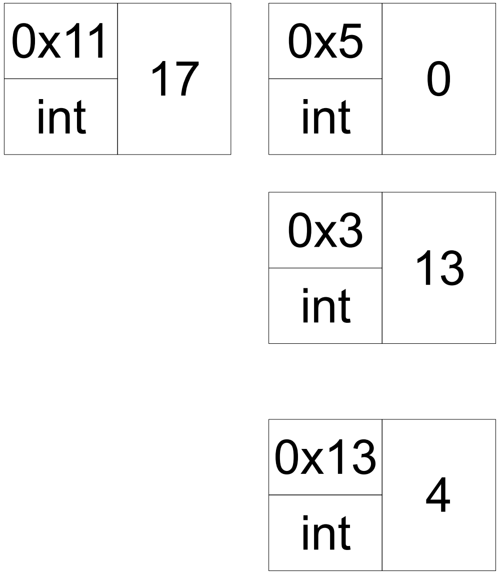


f

x: 0x13

Global

x: 0x11



0x11 int 17

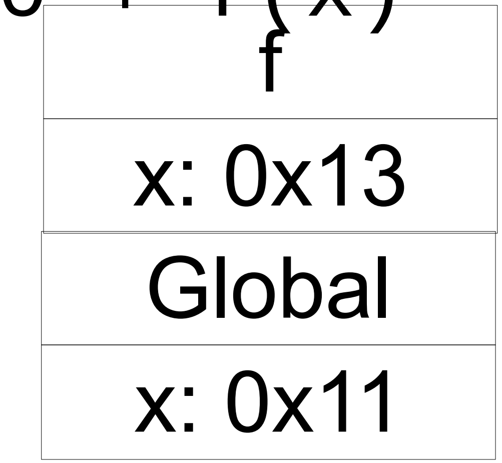
0x5 int 0

0x3 int 13

0x13 int 4

Assignment Statements & Memory Model

```
def f(x):
    return 0x13 + 4
x = 0
x = 13 + 4
x = 17 + f(4)
x = 10 + f(x)
```

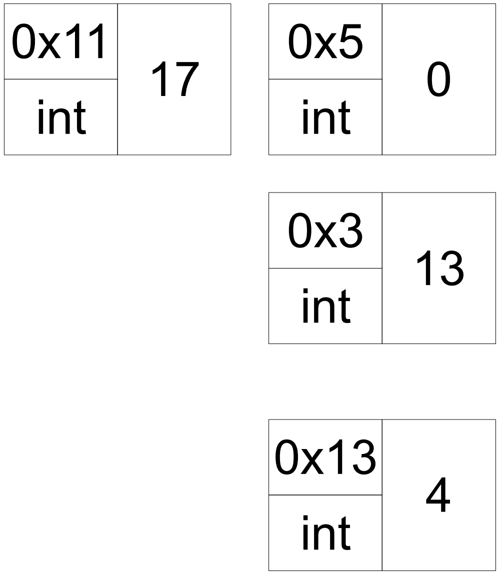


f

x: 0x13

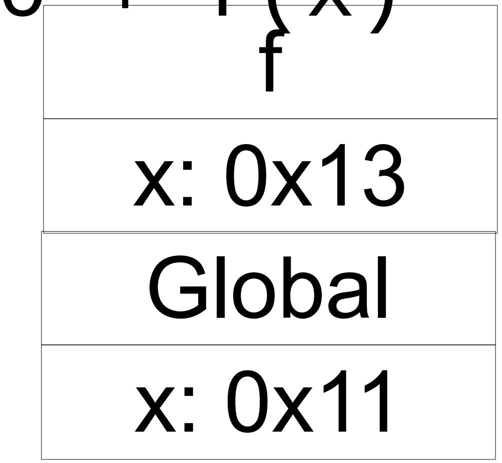
Global

x: 0x11



Assignment Statements & Memory Model

```
def f(x):
    return 0x13 + 4
x = 0
x = 13 + 4
x = 17 + f(4)
x = 10 + f(x)
```

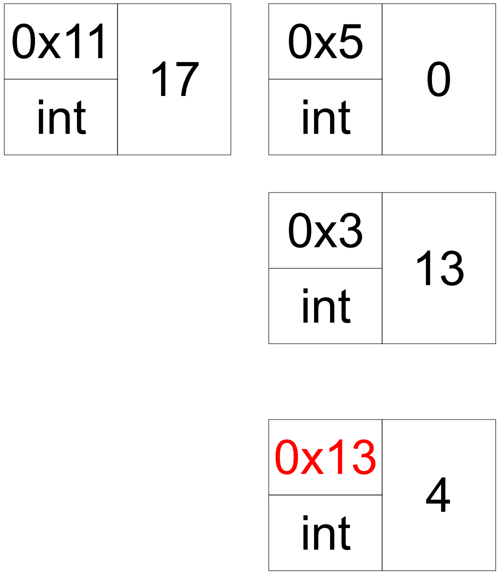


f

x: 0x13

Global

x: 0x11



0x11
int
17

0x5
int
0

0x3
int
13

0x13
int
4

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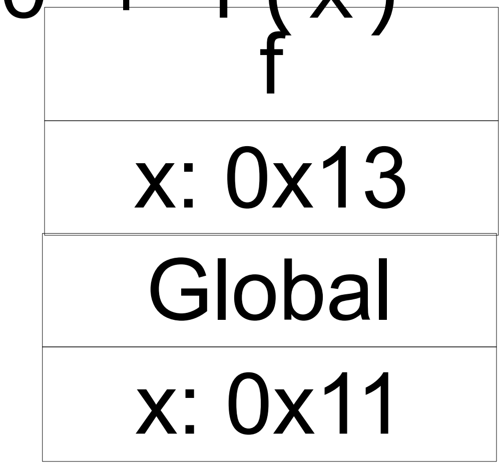
Assignment Statements & Memory Model

```
def f(x):
→   return 4 + 4
x = 0
x = 13 + 4
x = 17 + f(4)
x = 10 + f(x)
```

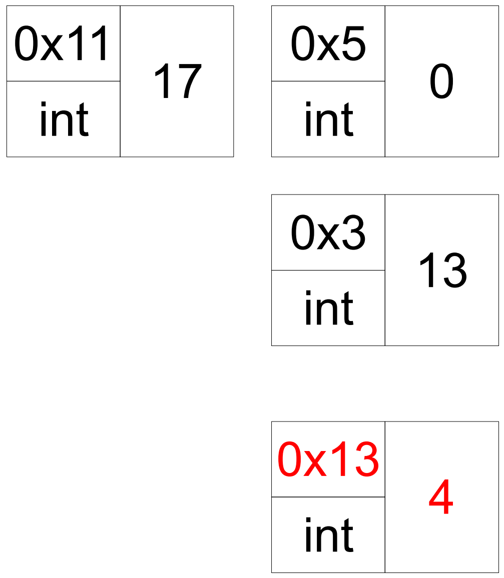


f

x: 0x13

Global

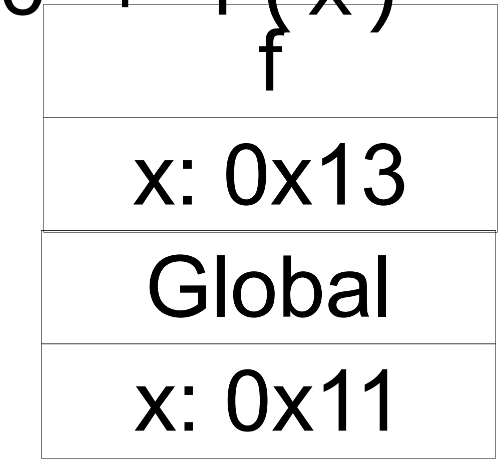
x: 0x11



0x11	int	17
0x5	int	0
0x3	int	13
0x13	int	4

Assignment Statements & Memory Model

```
def f(x):
→       return 4 + 4
x = 0
x = 13 + 4
x = 17 + f(4)
x = 10 + f(x)
```

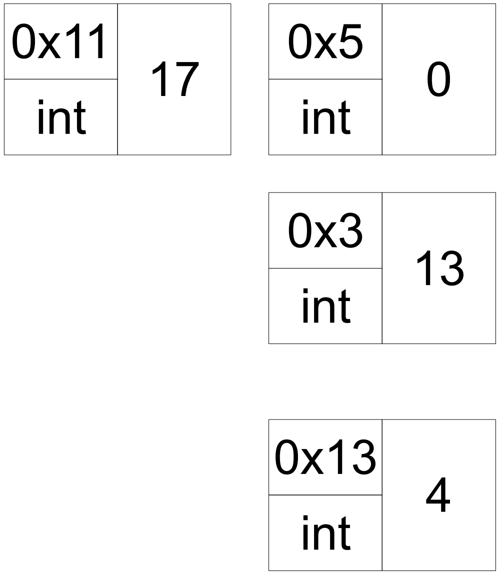


f

x: 0x13

Global

x: 0x11



0x11 int 17

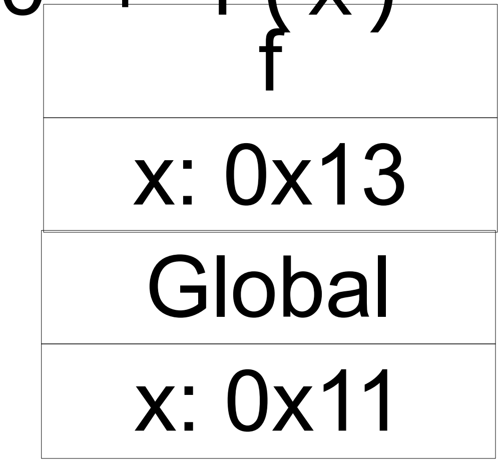
0x5 int 0

0x3 int 13

0x13 int 4

Assignment Statements & Memory Model

```
def f(x):
    return 4 + 4
x = 0
x = 13 + 4
x = 17 + f(4)
x = 10 + f(x)
```

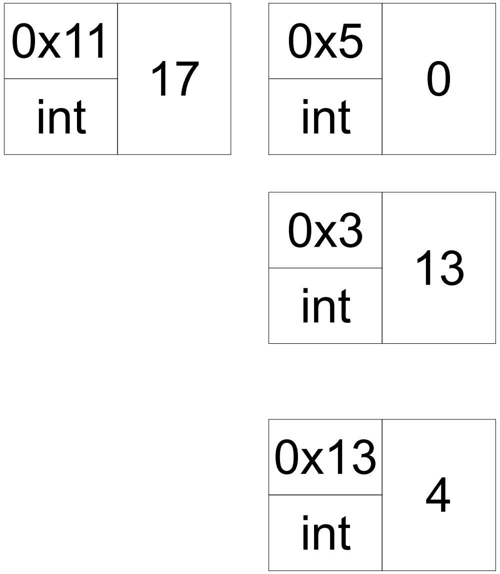


f

x: 0x13

Global

x: 0x11



0x11 int 17

0x5 int 0

0x3 int 13

0x13 int 4

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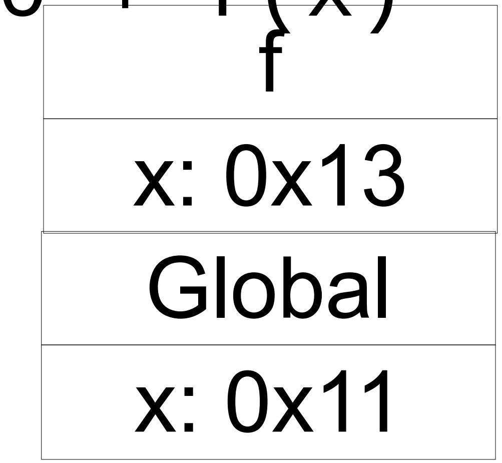
Assignment Statements & Memory Model

```
def f(x):
    return 8
x = 0
x = 13 + 4
x = 17 + f(4)
x = 10 + f(x)
```

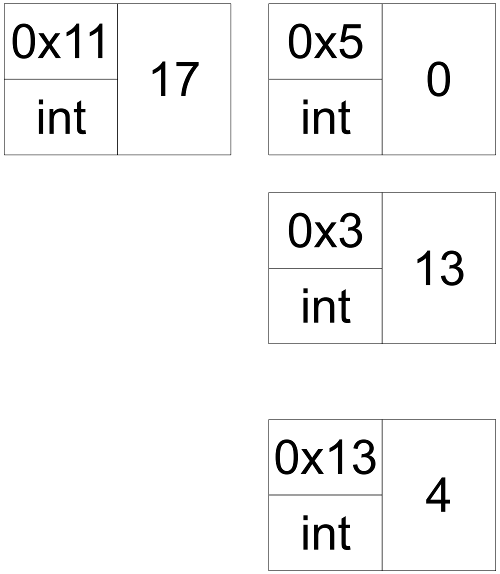


f

x: 0x13

Global

x: 0x11



0x11 int	17

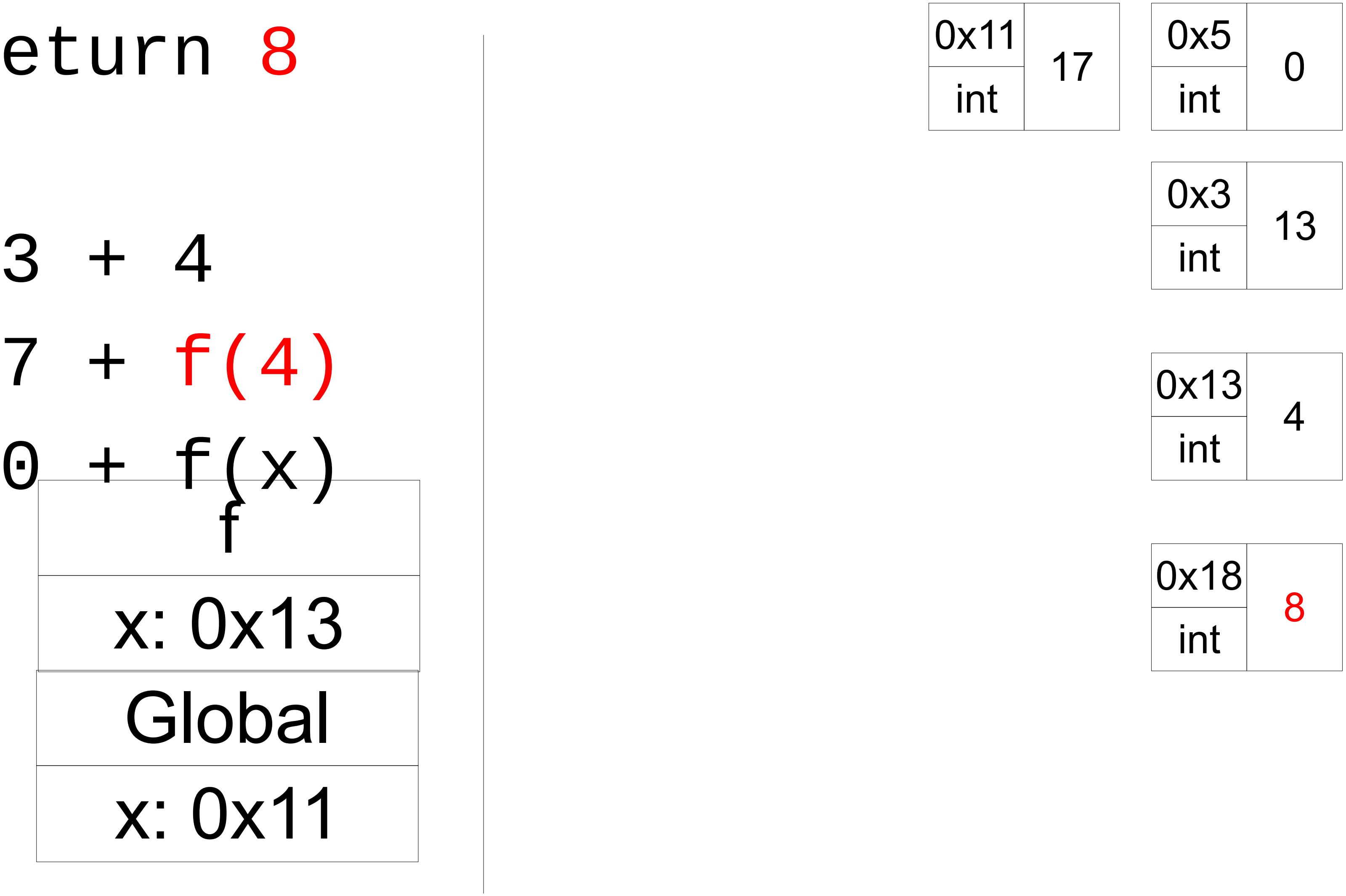
0x5 int	0

0x3 int	13

0x13 int	4

Assignment Statements & Memory Model

```
def f(x):
    return 8
x = 0
x = 13 + 4
x = 17 + f(4)
x = 10 + f(x)
```



f

x: 0x13

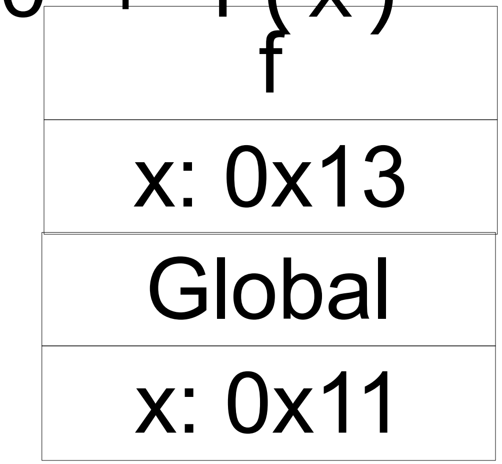
Global

x: 0x11

0x11 int	17	
0x5 int	0	
0x3 int	13	
0x13 int	4	
0x18 int	8	

Assignment Statements & Memory Model

```
def f(x):
    return 0x18
x = 0
x = 13 + 4
x = 17 + f(4)
x = 10 + f(x)
```

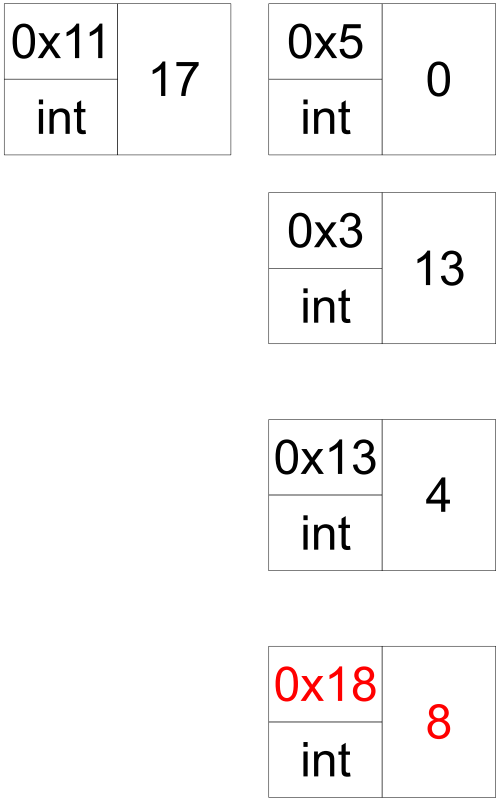


f

x: 0x13

Global

x: 0x11



0x11	int	17
0x5	int	0
0x3	int	13
0x13	int	4
0x18	int	8

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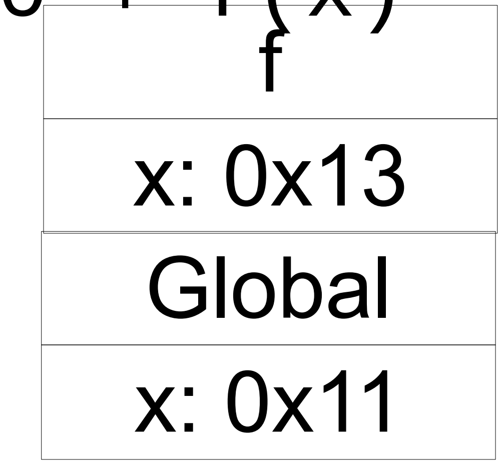
Assignment Statements & Memory Model

```
def f(x):
    return 0x18
x = 0
x = 13 + 4
x = 17 + f(4)
x = 10 + f(x)
```

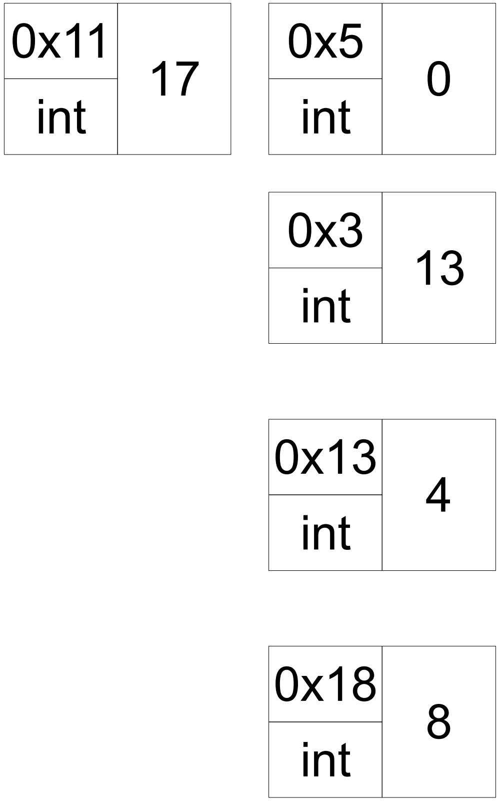


f

x: 0x13

Global

x: 0x11



0x11 int	17

0x5 int	0

0x3 int	13

0x13 int	4

0x18 int	8

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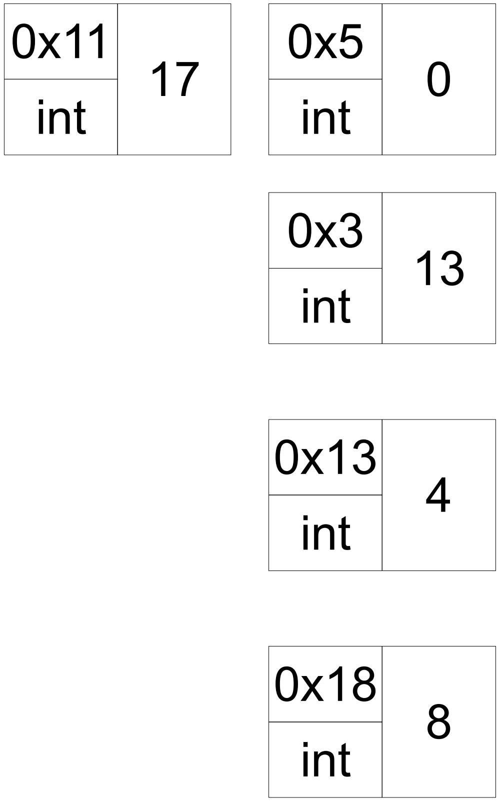
Assignment Statements & Memory Model

```
def f(x):
    return 0x18
x = 0
x = 13 + 4
x = 17 + 0x18
x = 10 + f(x)
```

Global
x: 0x11



0x11 | int | 17

0x5 | int | 0

0x3 | int | 13

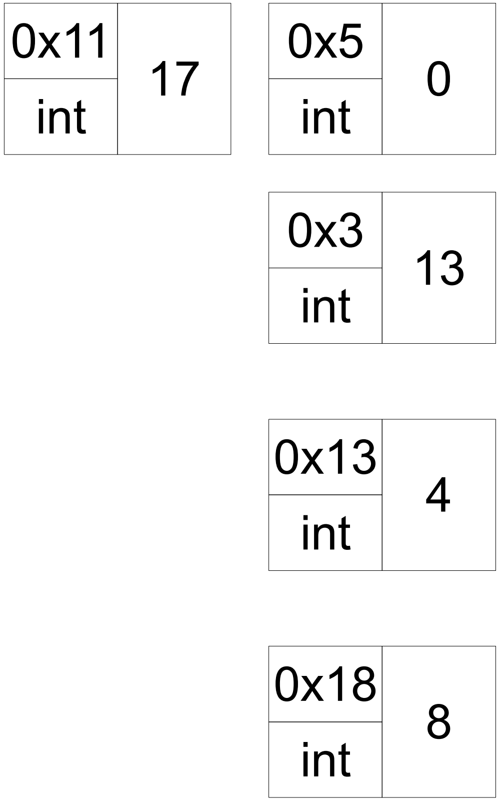
0x13 | int | 4

0x18 | int | 8

Assignment Statements & Memory Model

```
  def f(x):
      return 0x18
  x = 0
  x = 13 + 4
→ x = 17 + 0x18
  x = 10 + f(x)
```

Global
x: 0x11

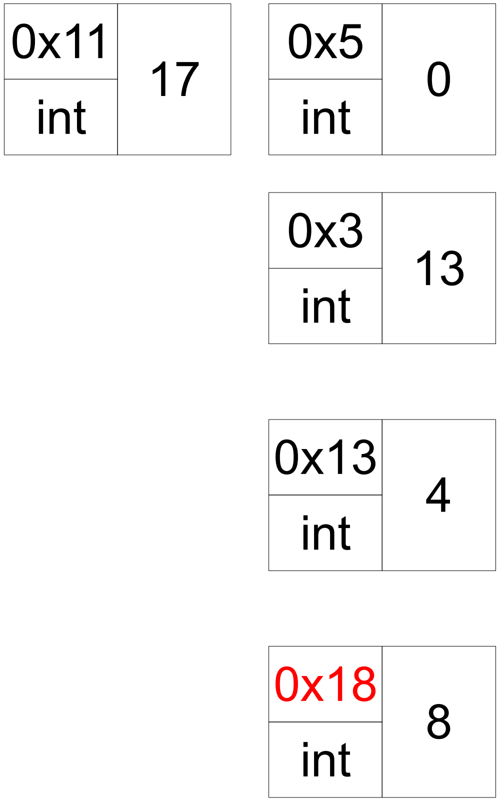


0x11	int	17
0x5	int	0
0x3	int	13
0x13	int	4
0x18	int	8

Assignment Statements & Memory Model

```
def f(x):
    return 0x18
x = 0
x = 13 + 4
x = 17 + 0x18
x = 10 + f(x)
```

Global
x: 0x11



0x11	17
int	

0x5	0
int	

0x3	13
int	

0x13	4
int	

0x18	8
int	

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Assignment Statements & Memory Model

```
  def f(x):
      return 0x18
  x = 0
  x = 13 + 4
→ x = 17 + 0x18
  x = 10 + f(x)
```

Global
x: 0x11

0x11	17
int	

0x5	0
int	

0x3	13
int	

0x13	4
int	

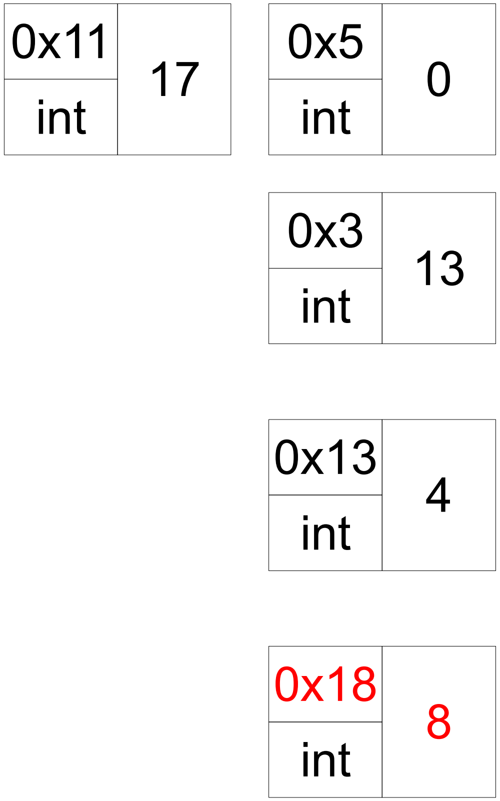
0x18	8
int	

Assignment Statements & Memory Model

```
  def f(x):
      return 0x18
  x = 0
  x = 13 + 4
→ x = 17 + 8
  x = 10 + f(x)
```

Global

x: 0x11



0x11 int 17

0x5 int 0

0x3 int 13

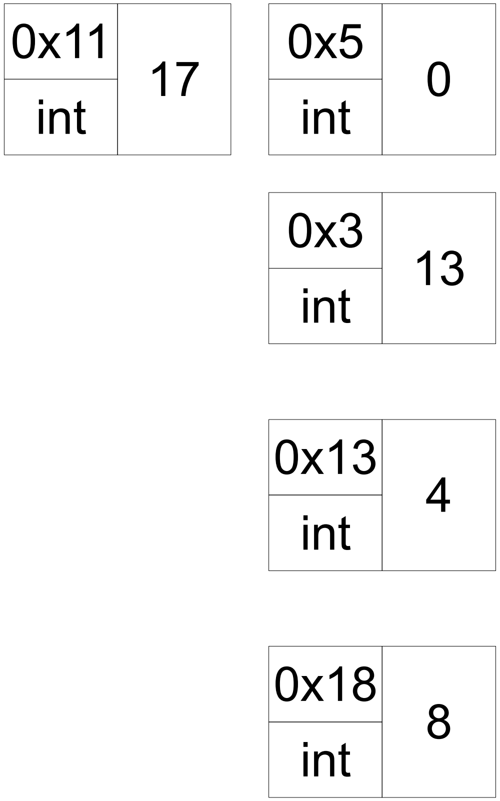
0x13 int 4

0x18 int 8

Assignment Statements & Memory Model

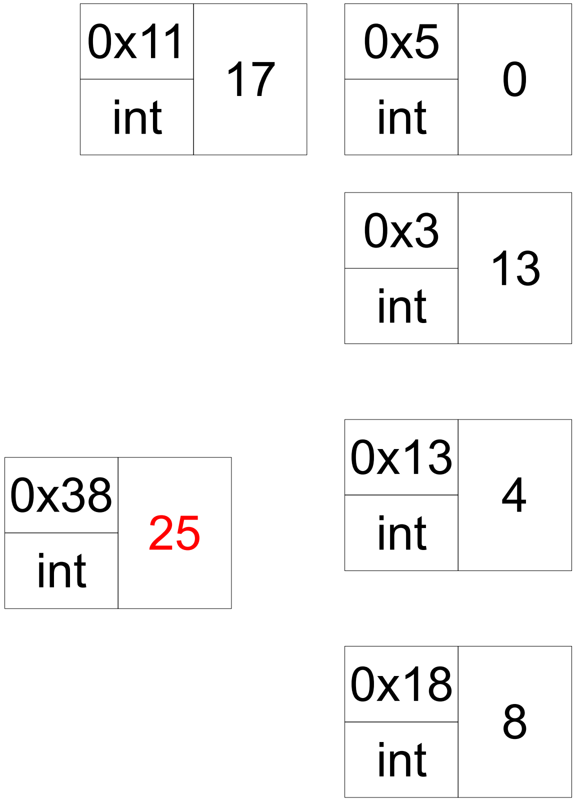
```
def f(x):
    return 0x18
x = 0
x = 13 + 4
x = 17 + 8
x = 10 + f(x)
```

Global
x: 0x11



Assignment Statements & Memory Model

```
def f(x):
    return 0x18
x = 0
x = 13 + 4
x = 25
x = 10 + f(x)
```

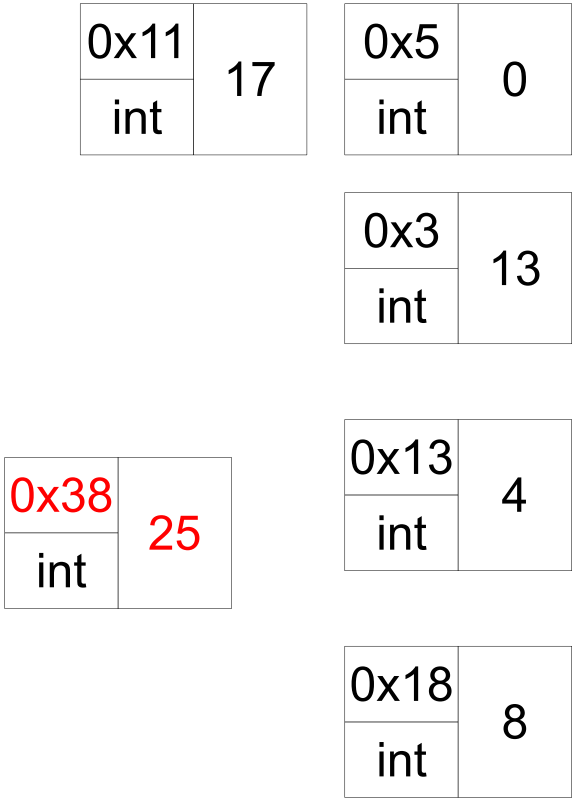


Global

x: 0x11

Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = 25
x = 10 + f(x)
```



0x11 int 17

0x5 int 0

0x3 int 13

0x38 int 25

0x13 int 4

0x18 int 8

Global
x: 0x11

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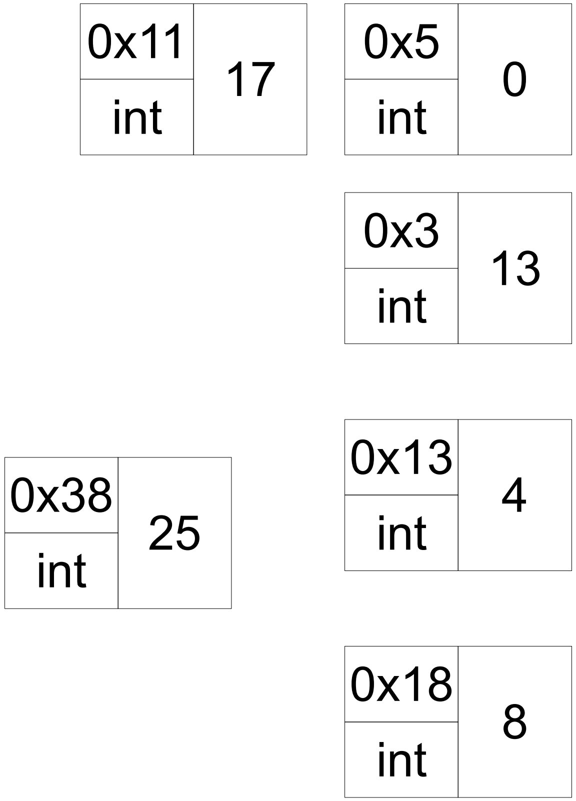
Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = 0x38
x = 10 + f(x)
```

Global
x: 0x11



0x11 int 17

0x5 int 0

0x3 int 13

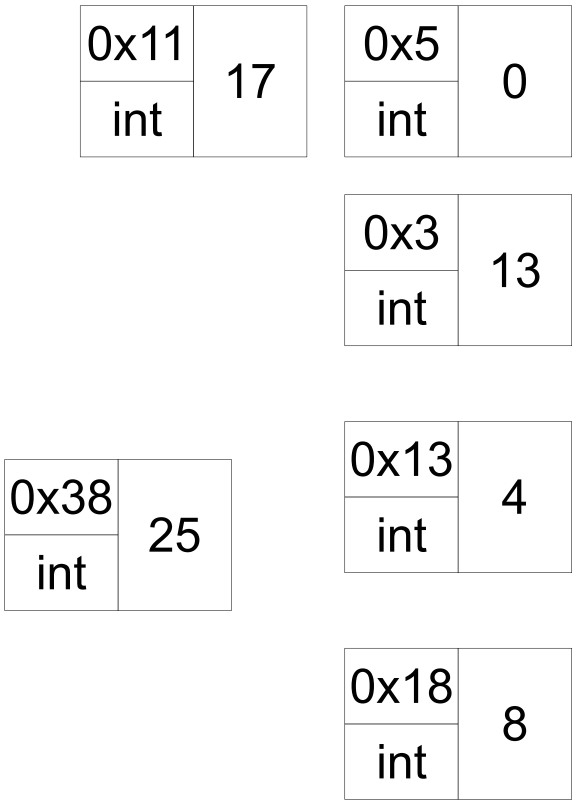
0x38 int 25

0x13 int 4

0x18 int 8

Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = 0x38
x = 10 + f(x)
```



0x11 | int | 17

0x5 | int | 0

0x3 | int | 13

0x38 | int | 25

0x13 | int | 4

0x18 | int | 8

Global
x: 0x11

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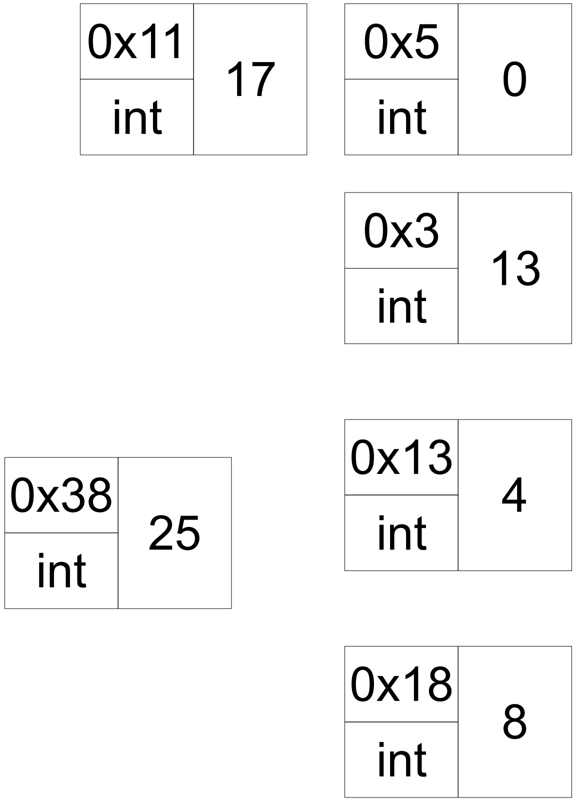
Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = 0x38
x = 10 + f(x)
```



0x11 | int | 17

0x5 | int | 0

0x3 | int | 13

0x38 | int | 25

0x13 | int | 4

0x18 | int | 8

Global

x: 0x38

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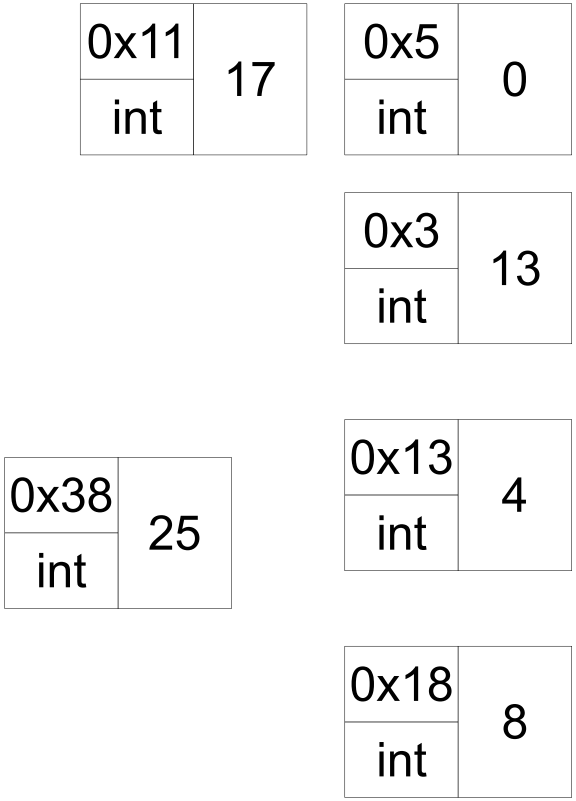
Assignment Statements & Memory Model

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(x)
```



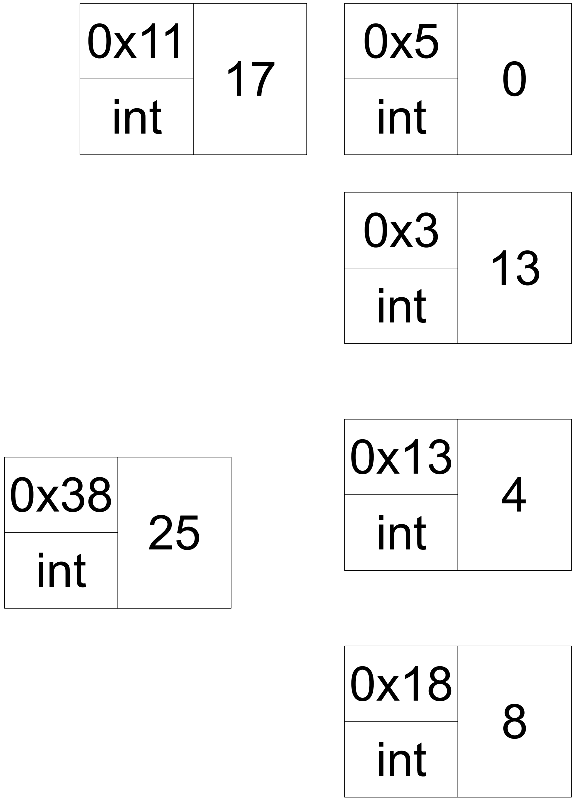
Global
x: 0x38

Break, the first.

Do all the steps to evaluate the last line.

```
  def f(x):
      return x + 4
  x = 0
  x = 13 + 4
  x = x + f(4)
→ x = 10 + f(x)
```

Global
x: 0x38



0x11 | int | 17

0x5 | int | 0

0x3 | int | 13

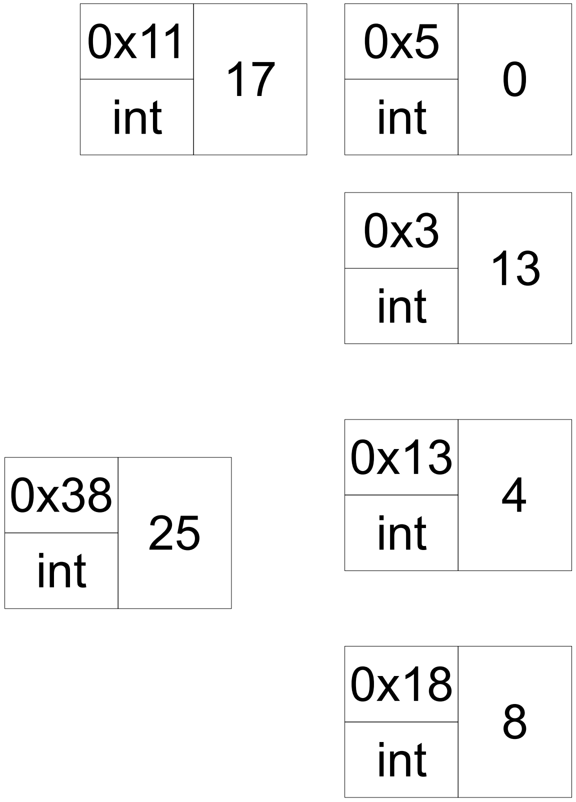
0x38 | int | 25

0x13 | int | 4

0x18 | int | 8

Do all the steps to evaluate the last line.

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(x)
```



0x11 int 17

0x5 int 0

0x3 int 13

0x38 int 25

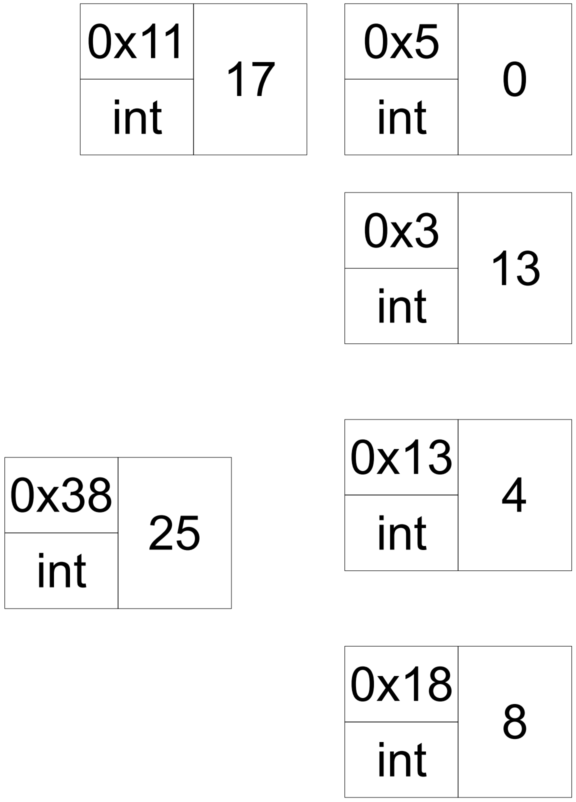
0x13 int 4

0x18 int 8

Global
x: 0x38

Do all the steps to evaluate the last line.

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(x)
```



0x11 int	17

0x5 int	0

0x3 int	13

0x38 int	25

0x13 int	4

0x18 int	8

Global
x: 0x38

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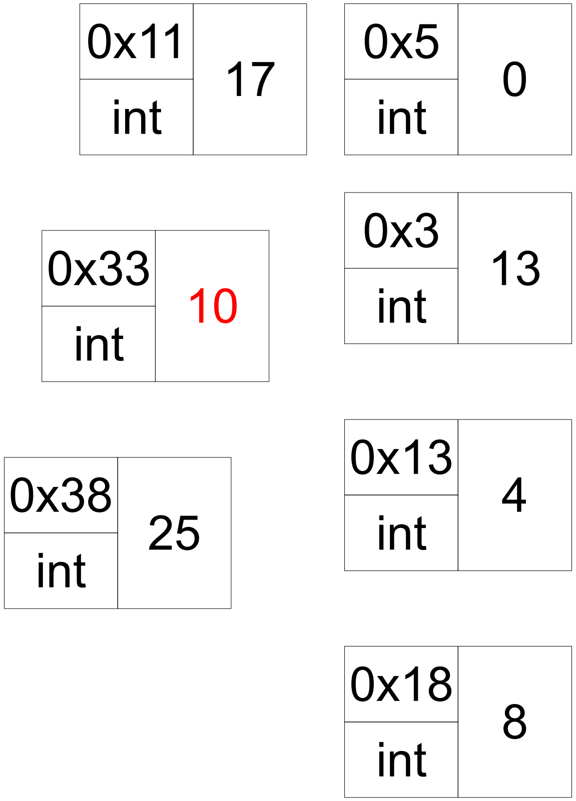
Do all the steps to evaluate the last line.

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(x)
```

Global
x: 0x38



0x11 int 17

0x5 int 0

0x33 int 10

0x3 int 13

0x38 int 25

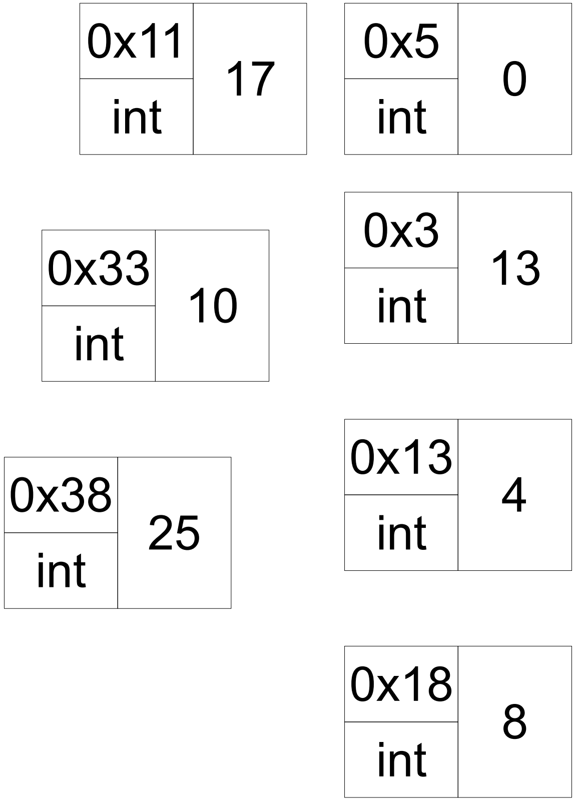
0x13 int 4

0x18 int 8

Do all the steps to evaluate the last line.

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(x)
```

Global
x: 0x38



0x11 int 17

0x5 int 0

0x33 int 10

0x3 int 13

0x38 int 25

0x13 int 4

0x18 int 8

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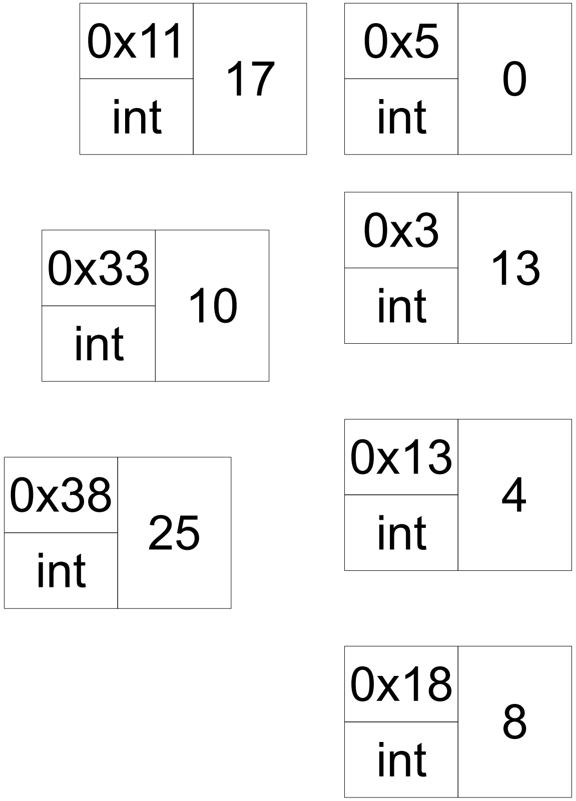
Do all the steps to evaluate the last line.

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(x)
```

Global

x: 0x38



0x11 int 17

0x5 int 0

0x33 int 10

0x3 int 13

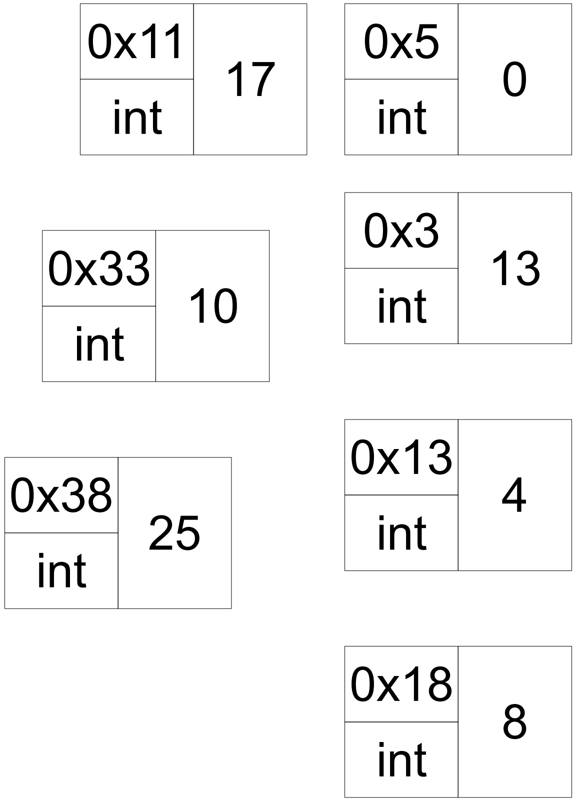
0x38 int 25

0x13 int 4

0x18 int 8

Do all the steps to evaluate the last line.

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(x)
```



0x11 int 17

0x5 int 0

0x33 int 10

0x3 int 13

0x38 int 25

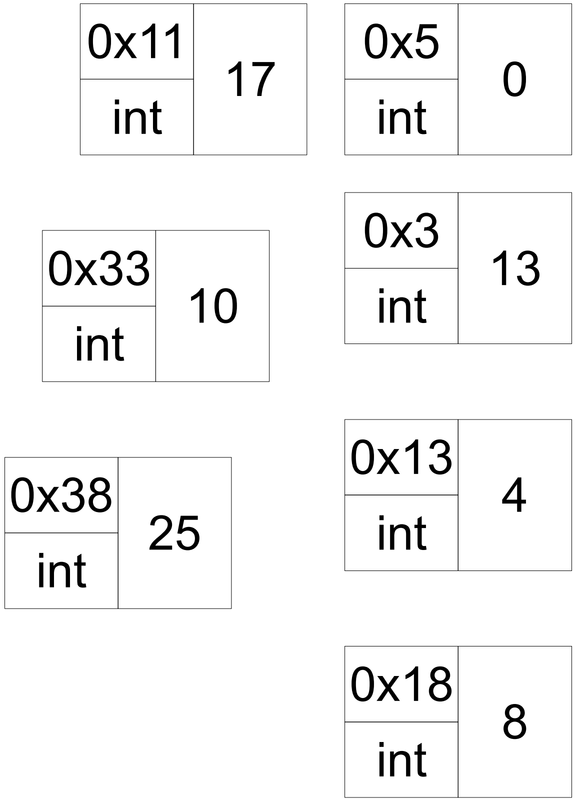
0x13 int 4

0x18 int 8

Global
x: 0x38

Do all the steps to evaluate the last line.

```
    def f(x):
        return x + 4
    x = 0
    x = 13 + 4
    x = x + f(4)
──► x = 10 + f(0x38)
```



0x11 int 17

0x5 int 0

0x33 int 10

0x3 int 13

0x38 int 25

0x13 int 4

0x18 int 8

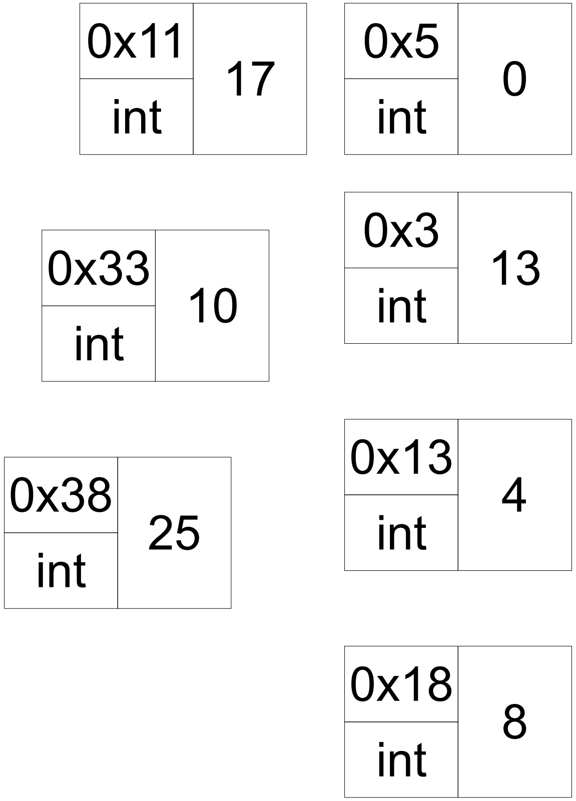
Global
x: 0x38

June 14 2012

Do all the steps to evaluate the last line.

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```

Global
x: 0x38



0x11 int 17

0x5 int 0

0x33 int 10

0x3 int 13

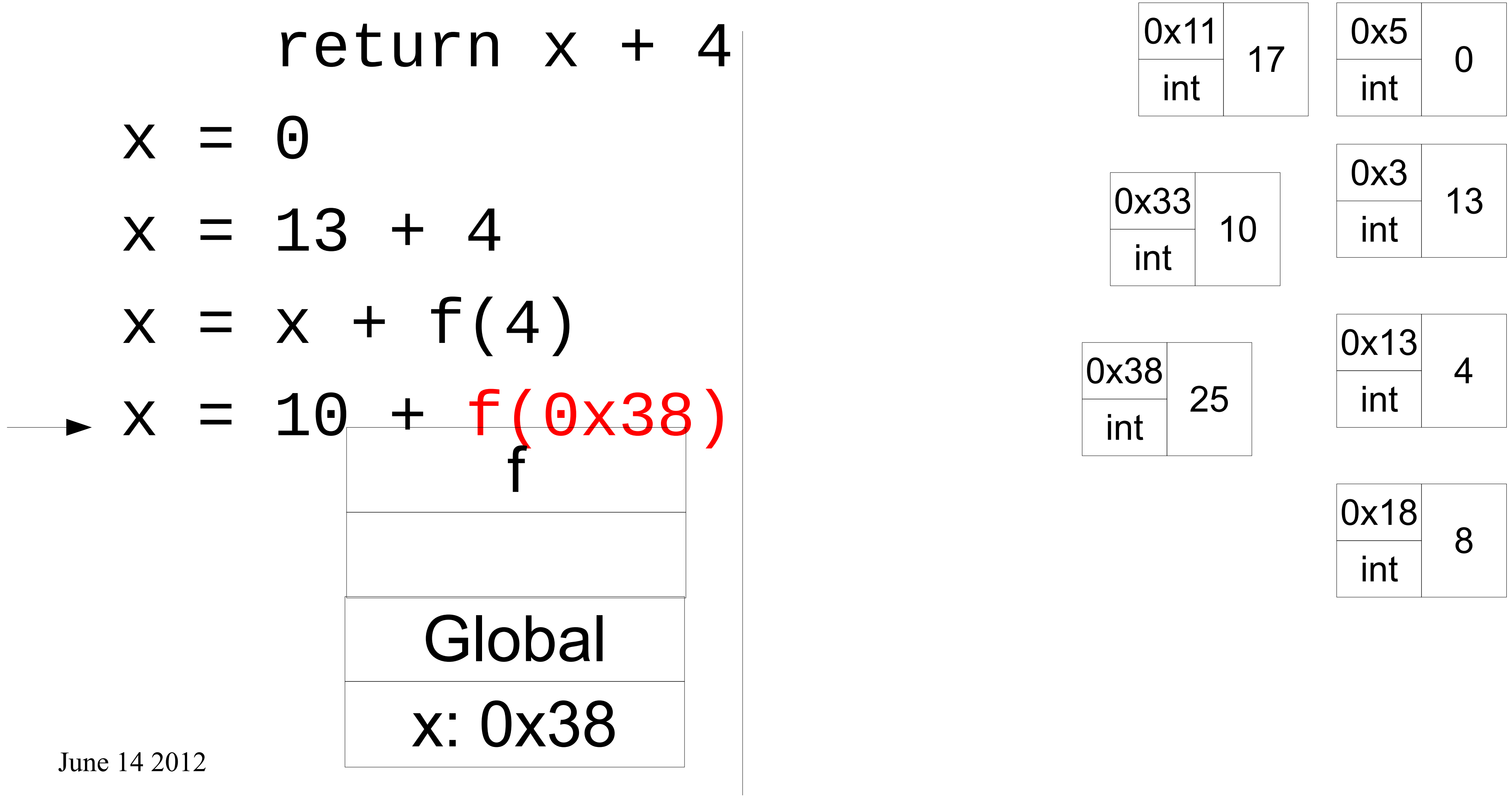
0x38 int 25

0x13 int 4

0x18 int 8

Do all the steps to evaluate the last line.

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```



f

Global

x: 0x38

0x11 int 17

0x5 int 0

0x33 int 10

0x3 int 13

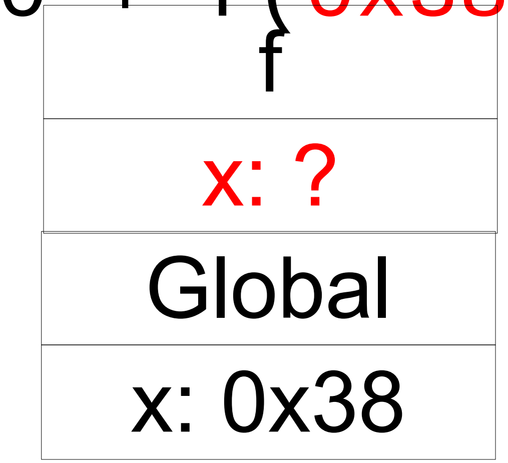
0x38 int 25

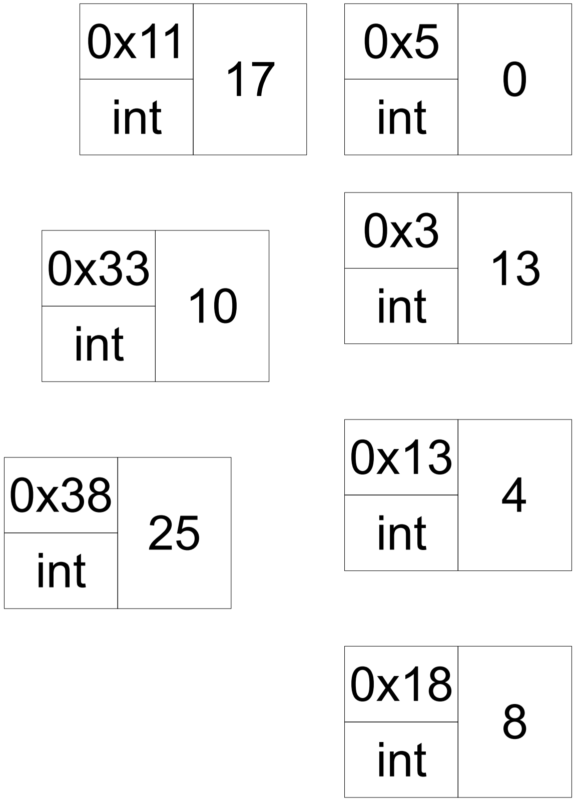
0x13 int 4

0x18 int 8

Do all the steps to evaluate the last line.

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```





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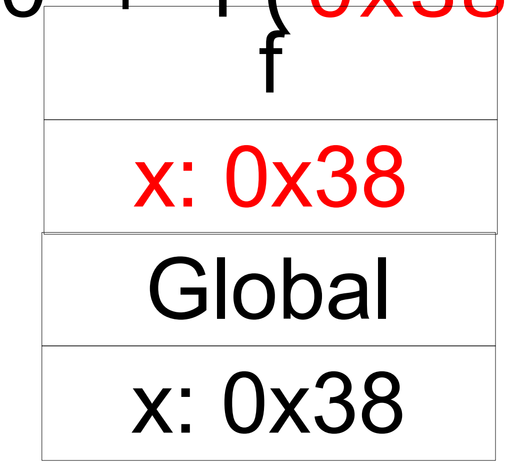
Do all the steps to evaluate the last line.

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```

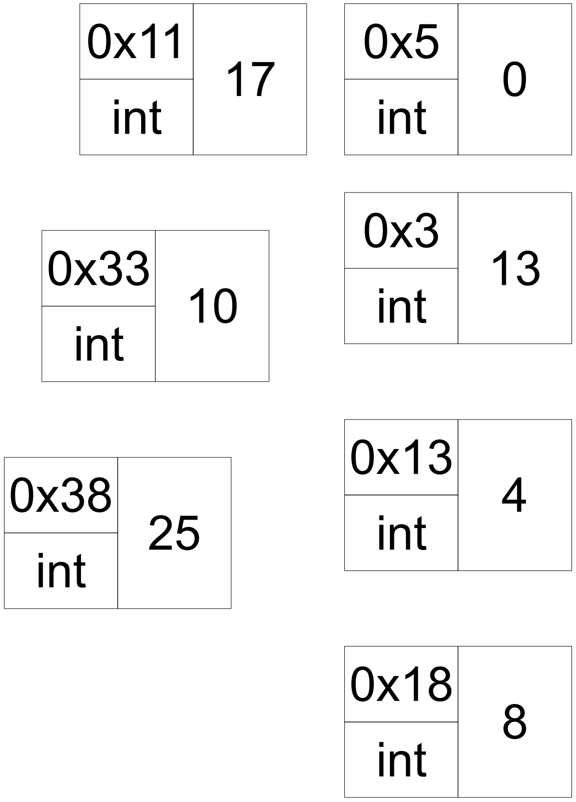


f

x: 0x38

Global

x: 0x38



0x11 int 17

0x5 int 0

0x33 int 10

0x3 int 13

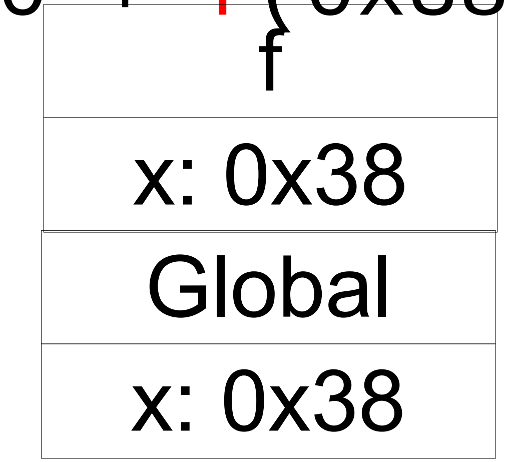
0x38 int 25

0x13 int 4

0x18 int 8

Do all the steps to evaluate the last line.

```
def f(x):
→       return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```

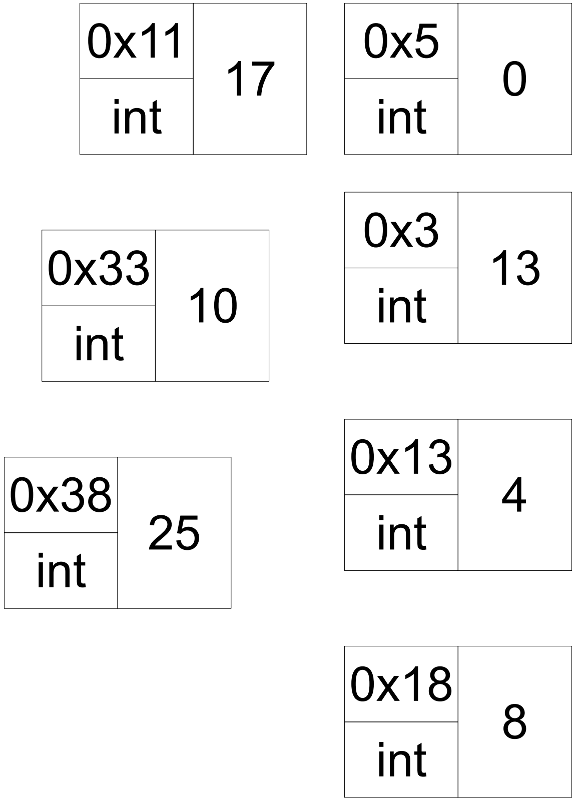


f

x: 0x38

Global

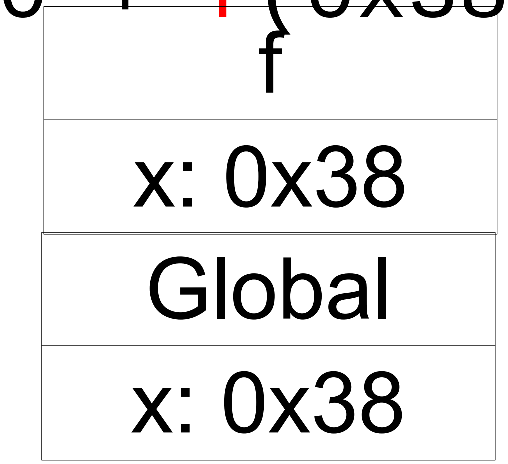
x: 0x38



0x11	int	17
0x5	int	0
0x33	int	10
0x3	int	13
0x38	int	25
0x13	int	4
0x18	int	8

Do all the steps to evaluate the last line.

```
def f(x):
→   return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```

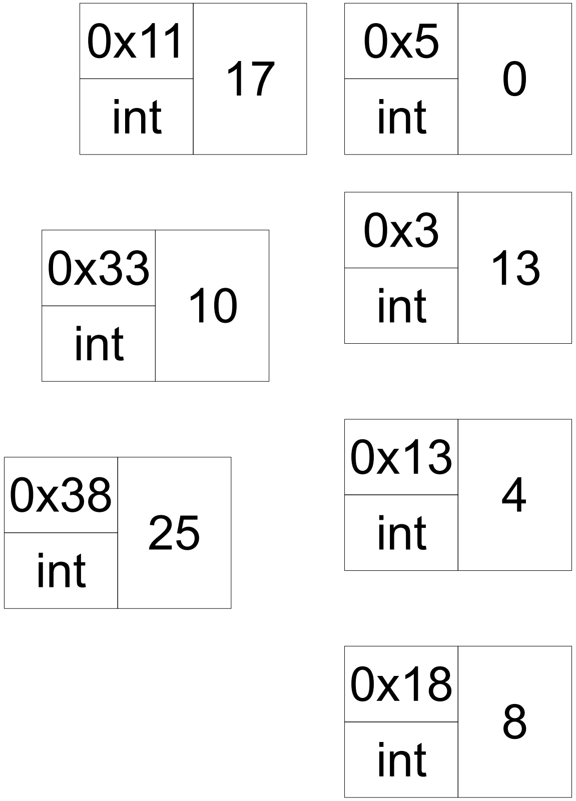


f

x: 0x38

Global

x: 0x38



0x11 int 17

0x5 int 0

0x33 int 10

0x3 int 13

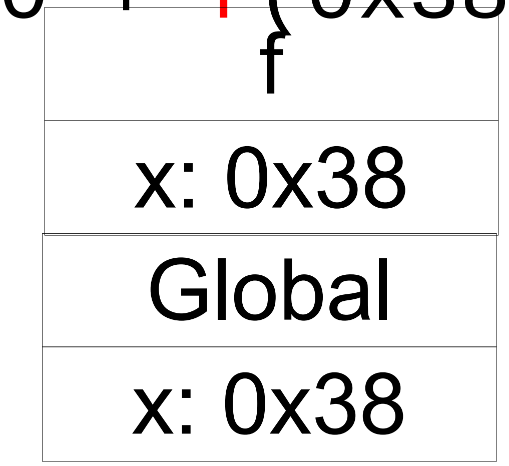
0x38 int 25

0x13 int 4

0x18 int 8

Do all the steps to evaluate the last line.

```
def f(x):
→   return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```

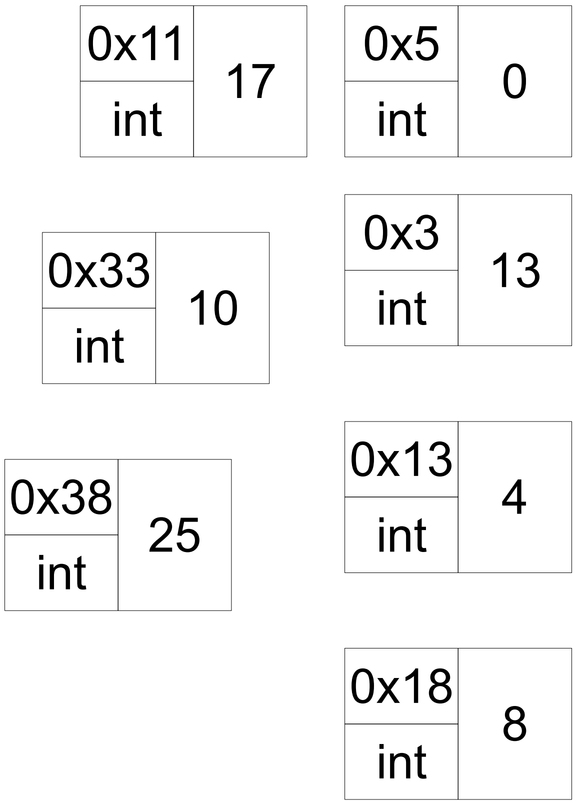


f

x: 0x38

Global

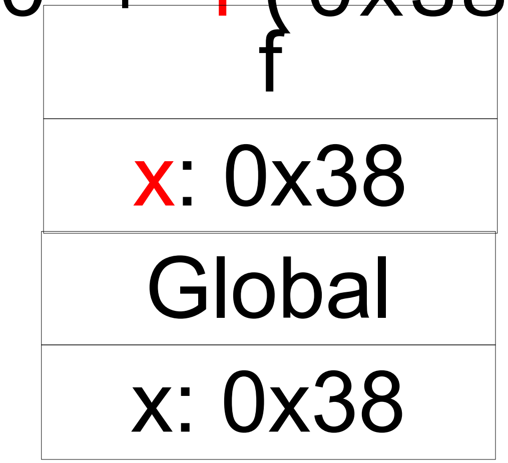
x: 0x38



0x11	int	17
0x5	int	0
0x33	int	10
0x3	int	13
0x38	int	25
0x13	int	4
0x18	int	8

Do all the steps to evaluate the last line.

```
def f(x):
→   return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```

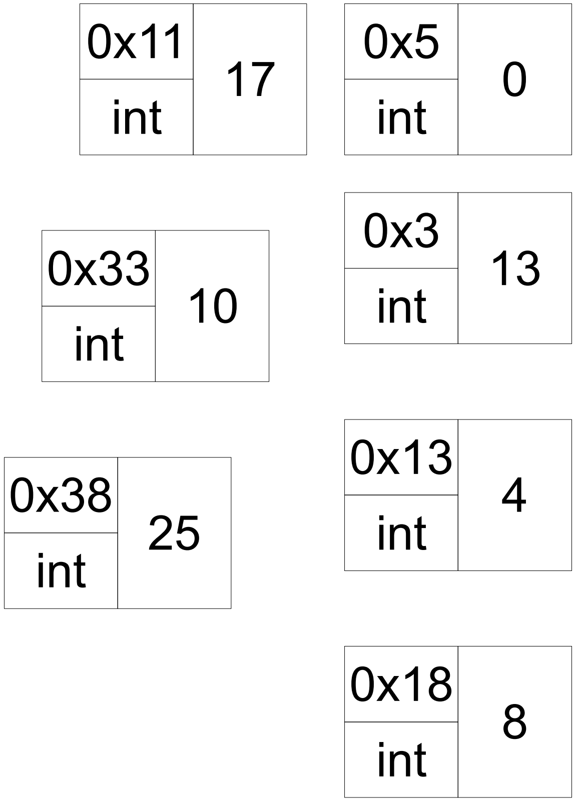


f

x: 0x38

Global

x: 0x38



0x11	int	17
0x5	int	0
0x33	int	10
0x3	int	13
0x38	int	25
0x13	int	4
0x18	int	8

Do all the steps to evaluate the last line.

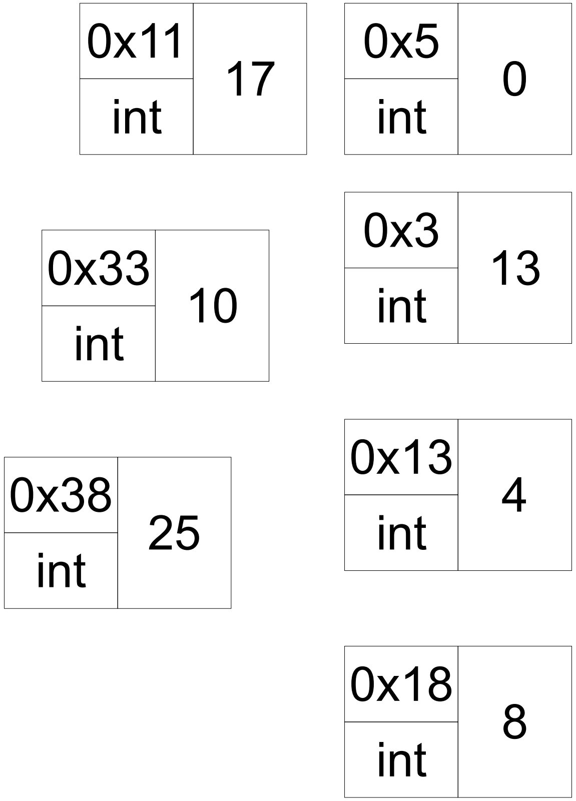
```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```

f

x: 0x38

Global

x: 0x38



0x11 | int | 17

0x5 | int | 0

0x33 | int | 10

0x3 | int | 13

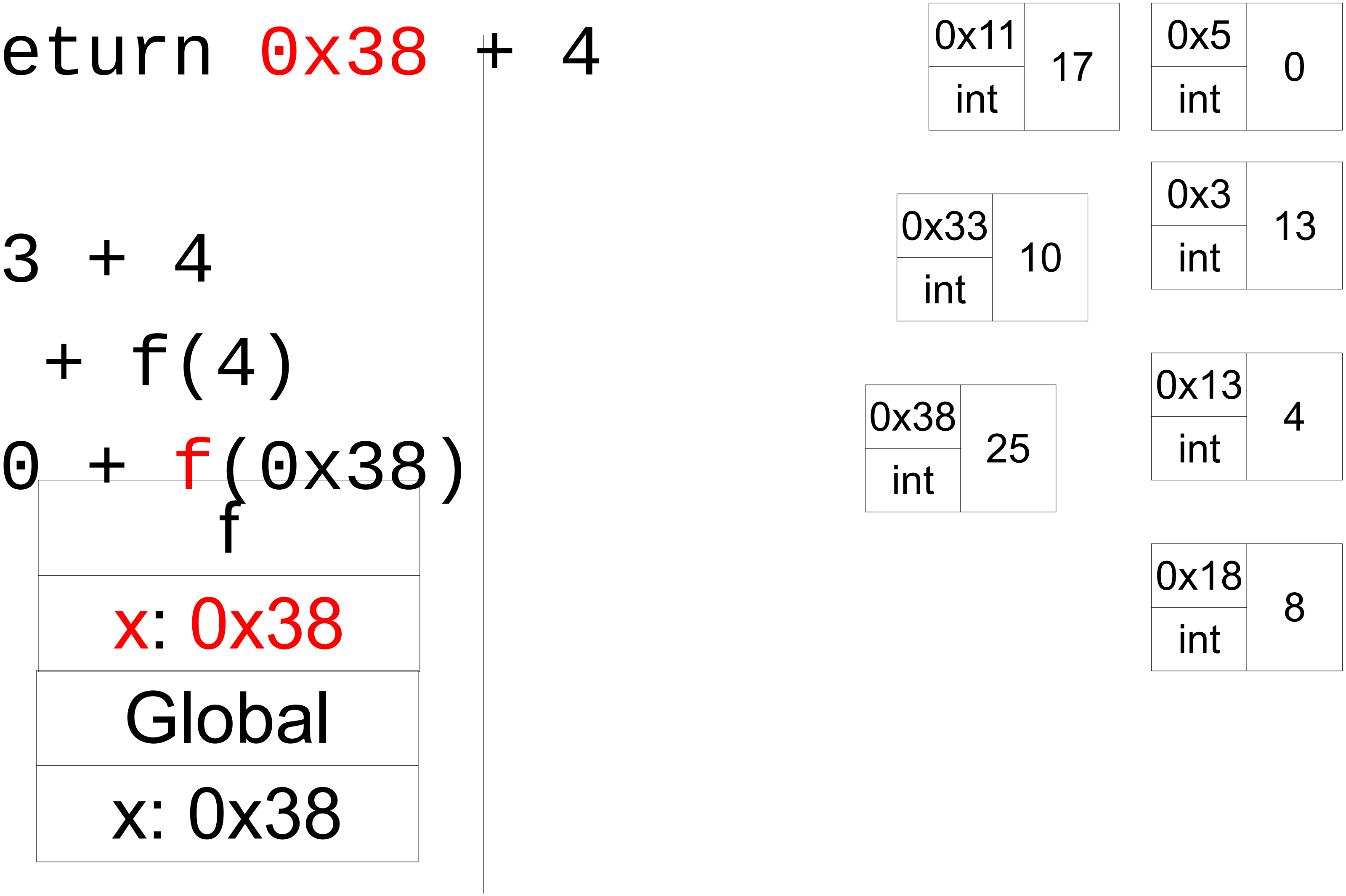
0x38 | int | 25

0x13 | int | 4

0x18 | int | 8

Do all the steps to evaluate the last line.

```
def f(x):
→   return 0x38 + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```



f

x: 0x38

Global

x: 0x38

0x11 int 17

0x5 int 0

0x33 int 10

0x3 int 13

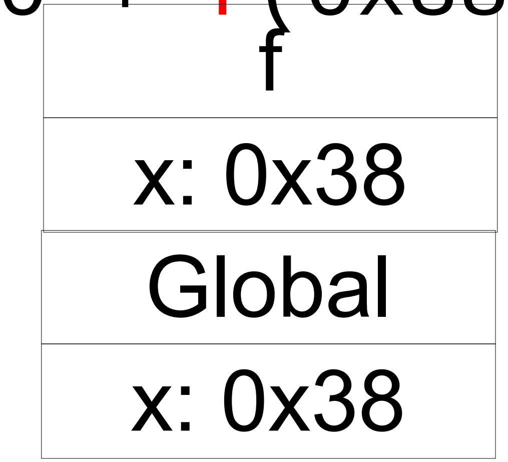
0x38 int 25

0x13 int 4

0x18 int 8

Do all the steps to evaluate the last line.

```
def f(x):
→    return 0x38 + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```

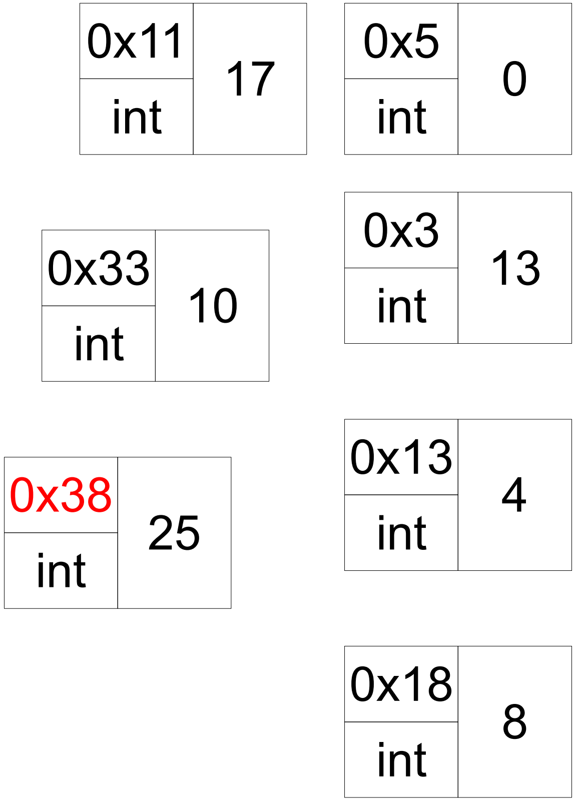


f

x: 0x38

Global

x: 0x38



0x11 int 17

0x5 int 0

0x33 int 10

0x3 int 13

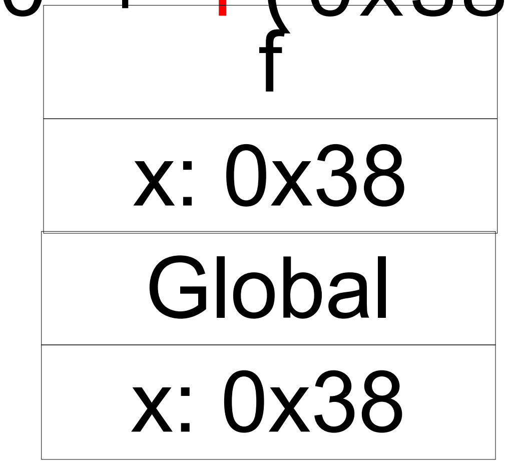
0x38 int 25

0x13 int 4

0x18 int 8

Do all the steps to evaluate the last line.

```
def f(x):
→   return 0x38 + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```

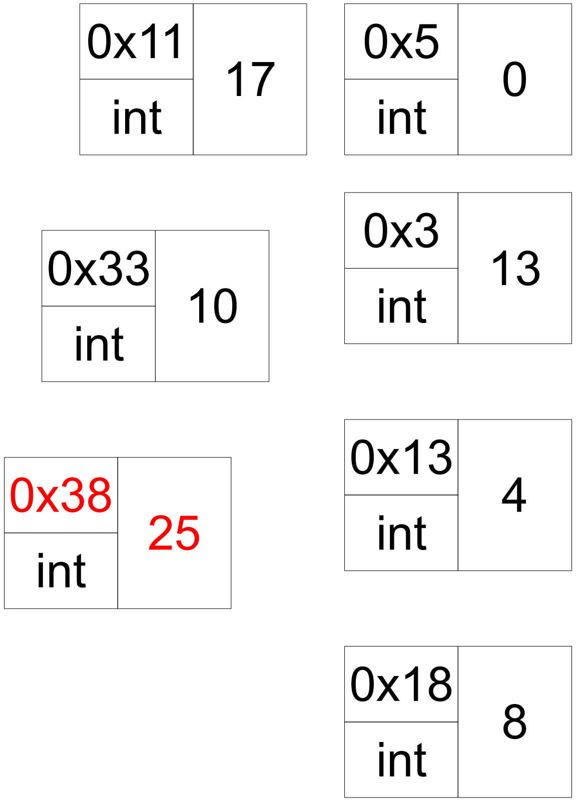


f

x: 0x38

Global

x: 0x38



0x11 int 17

0x5 int 0

0x33 int 10

0x3 int 13

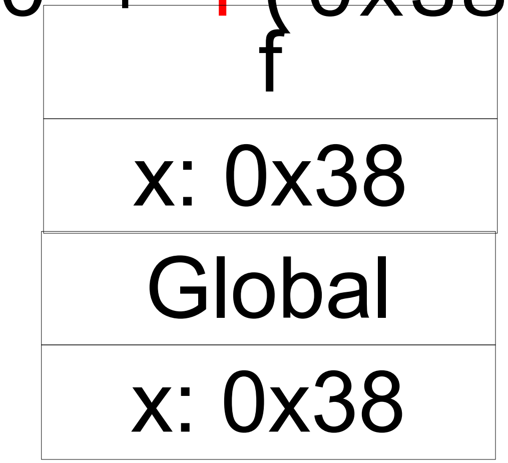
0x38 int 25

0x13 int 4

0x18 int 8

Do all the steps to evaluate the last line.

```
def f(x):
→    return 25 + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```

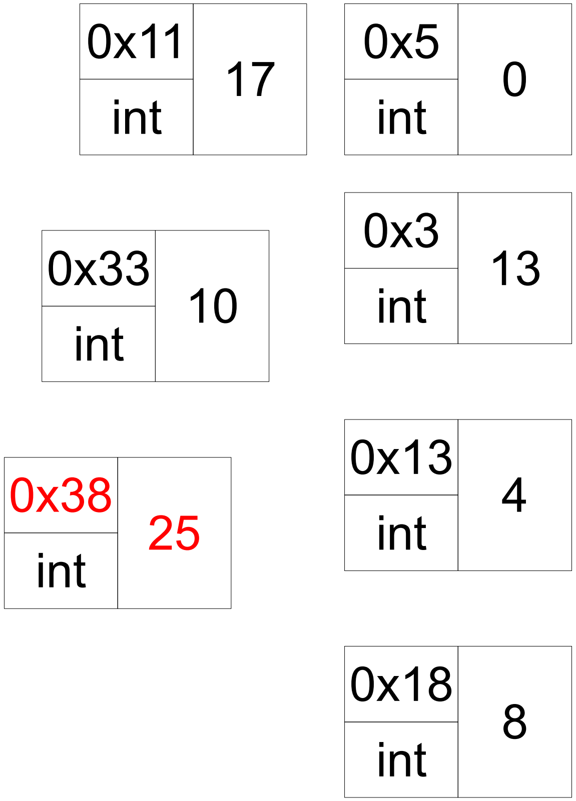


f

x: 0x38

Global

x: 0x38



0x11	int	17
0x5	int	0
0x33	int	10
0x3	int	13
0x38	int	25
0x13	int	4
0x18	int	8

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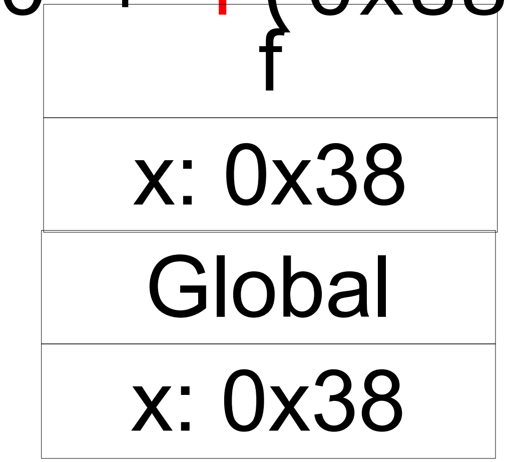
Do all the steps to evaluate the last line.

```
def f(x):
→   return 25 + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```

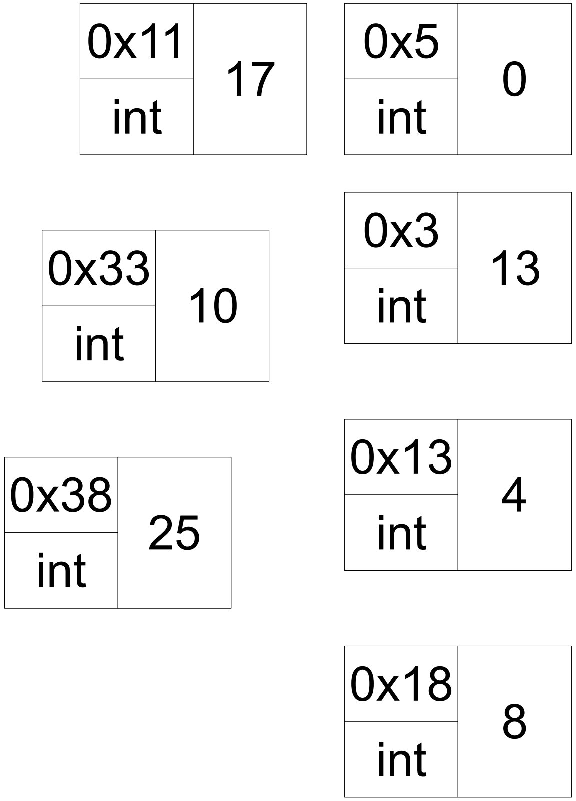


f

x: 0x38

Global

x: 0x38



0x11 int 17

0x5 int 0

0x33 int 10

0x3 int 13

0x38 int 25

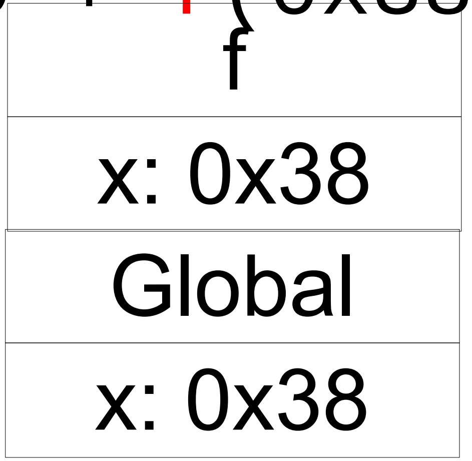
0x13 int 4

0x18 int 8

June 14 2012

Do all the steps to evaluate the last line.

```
def f(x):
→   return 25 + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```

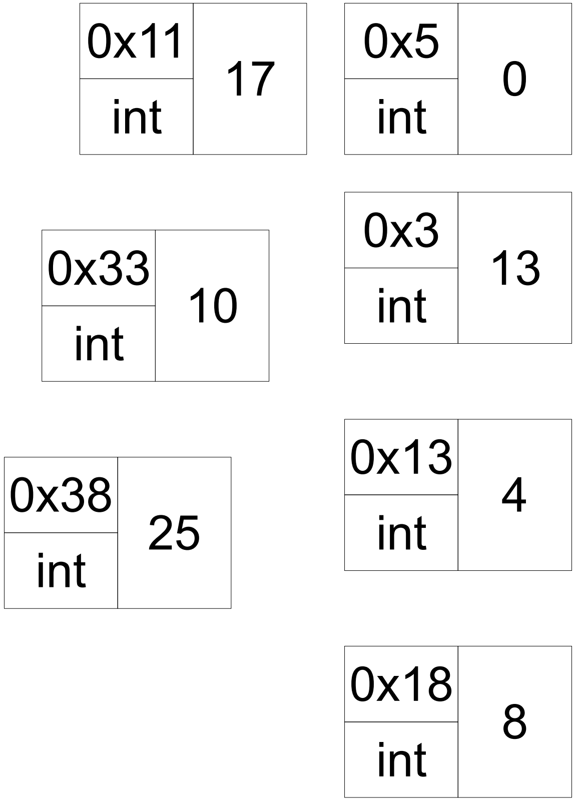


f

x: 0x38

Global

x: 0x38



0x11	17
int	

0x5	0
int	

0x33	10
int	

0x3	13
int	

0x38	25
int	

0x13	4
int	

0x18	8
int	

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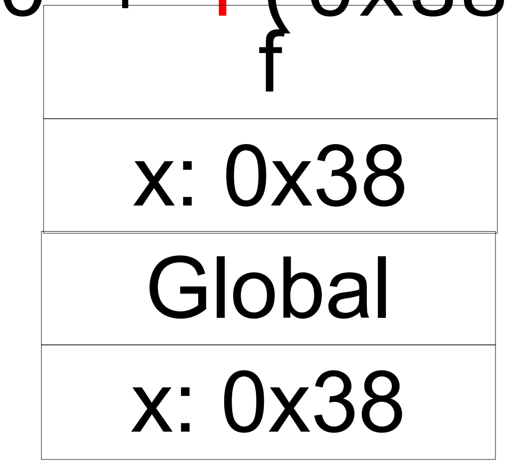
Do all the steps to evaluate the last line.

```
def f(x):
→   return 29
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```

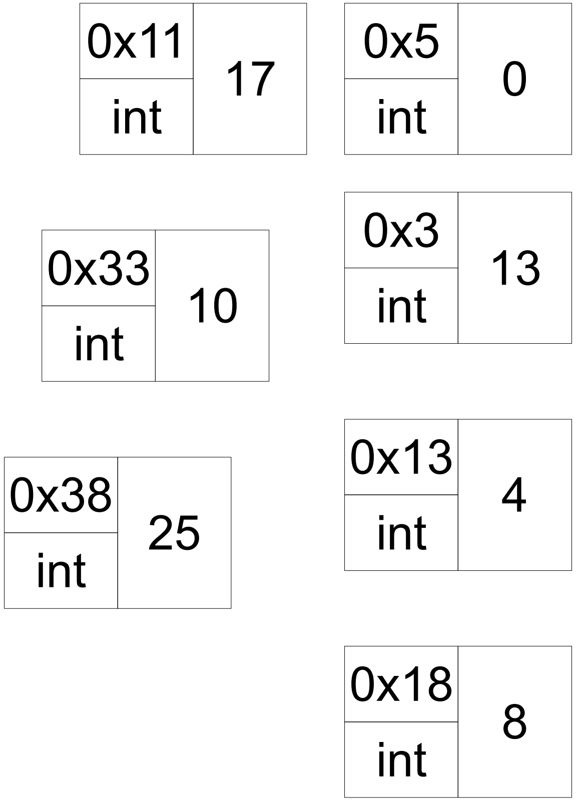


f

x: 0x38

Global

x: 0x38



0x11 int 17

0x5 int 0

0x33 int 10

0x3 int 13

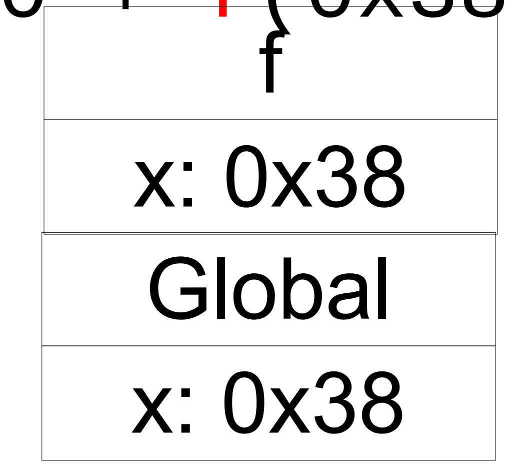
0x38 int 25

0x13 int 4

0x18 int 8

Do all the steps to evaluate the last line.

```
def f(x):
→   return 29
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```

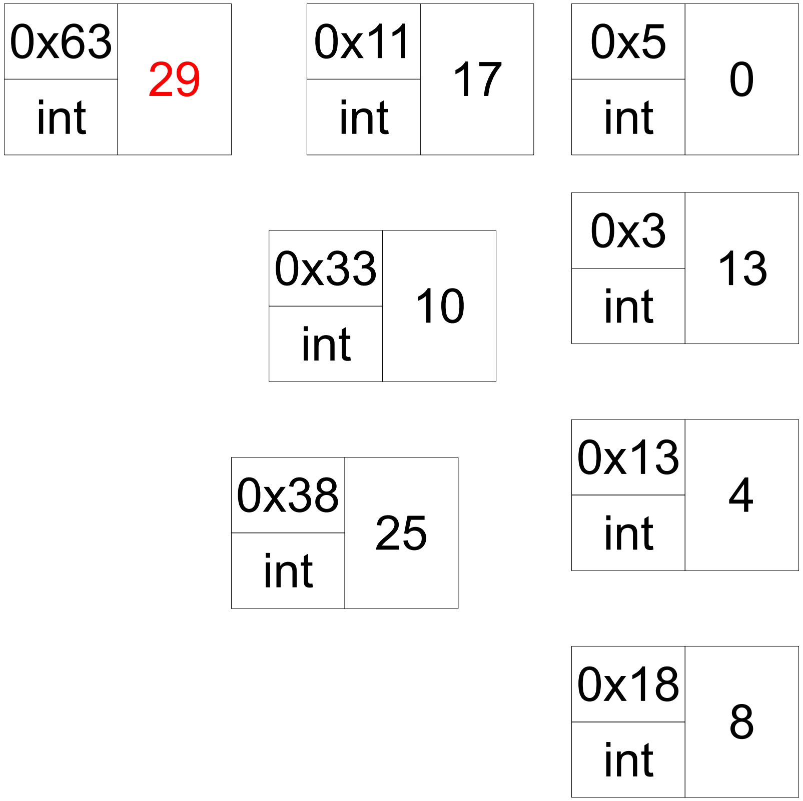


f

x: 0x38

Global

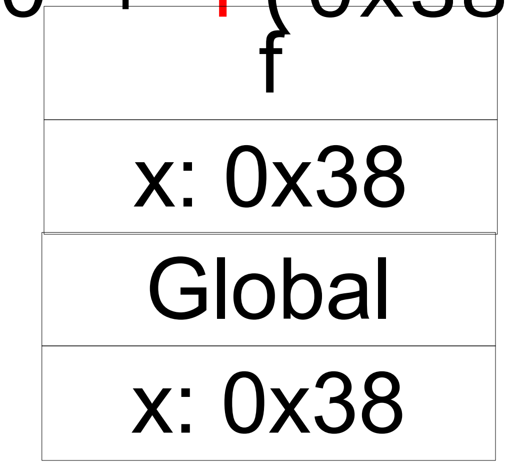
x: 0x38



0x63	int	29
0x11	int	17
0x5	int	0
0x33	int	10
0x3	int	13
0x38	int	25
0x13	int	4
0x18	int	8

Do all the steps to evaluate the last line.

```
def f(x):
→   return 29
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```

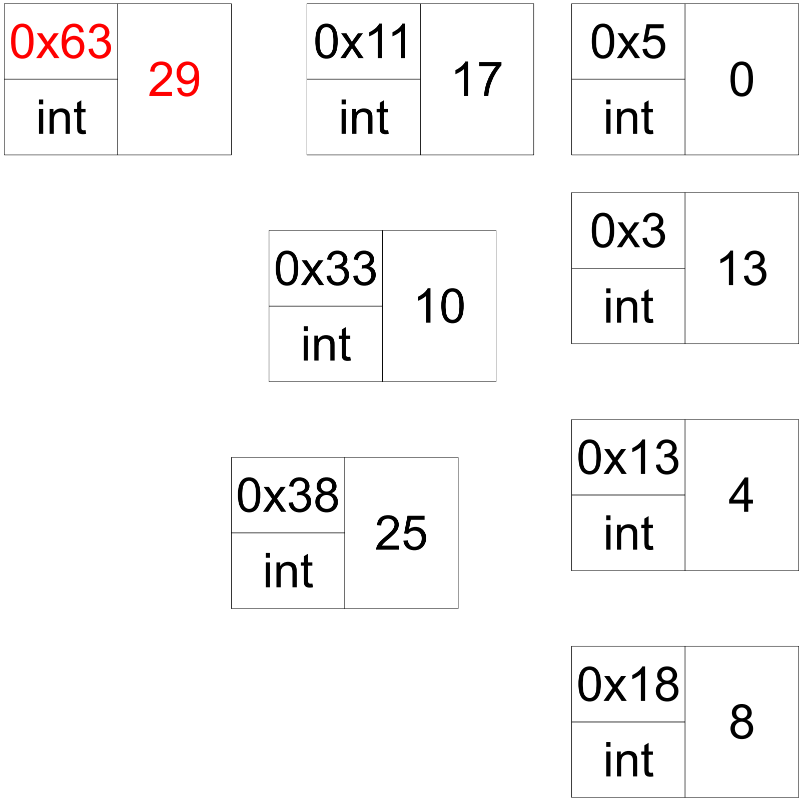


f

x: 0x38

Global

x: 0x38



0x63 int 29

0x11 int 17

0x5 int 0

0x33 int 10

0x3 int 13

0x38 int 25

0x13 int 4

0x18 int 8

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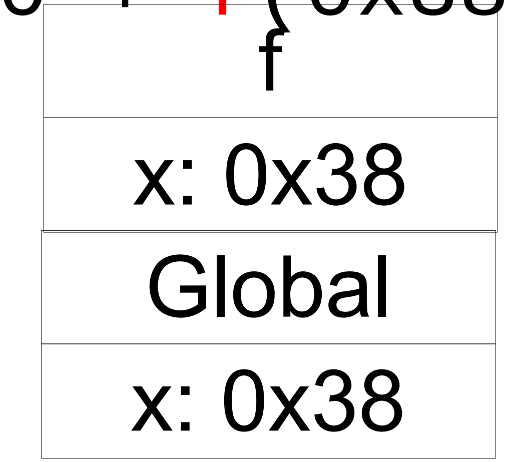
Do all the steps to evaluate the last line.

```
def f(x):
→     return 0x63
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```

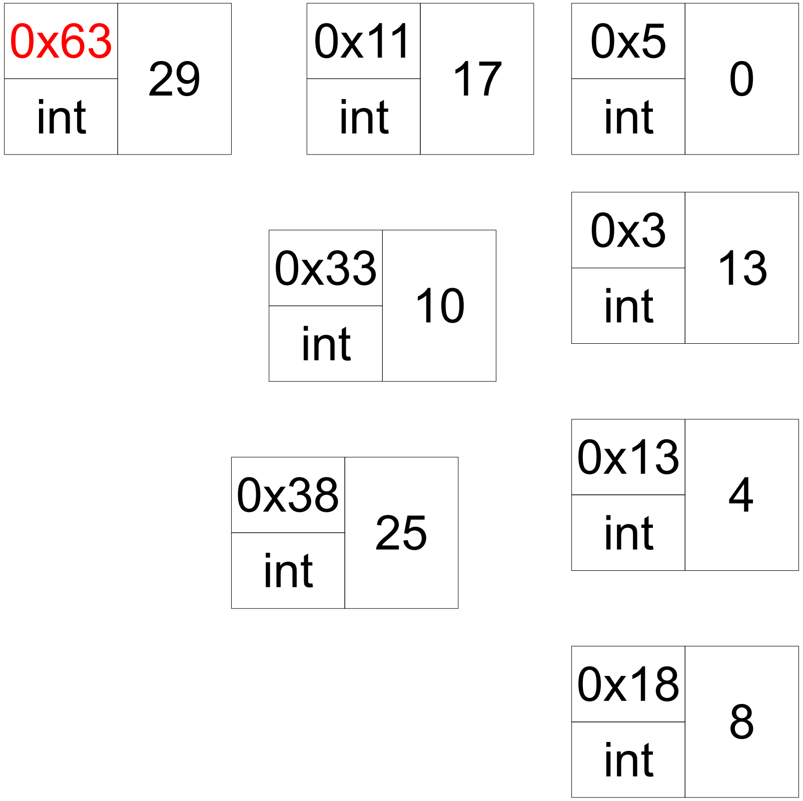


f

x: 0x38

Global

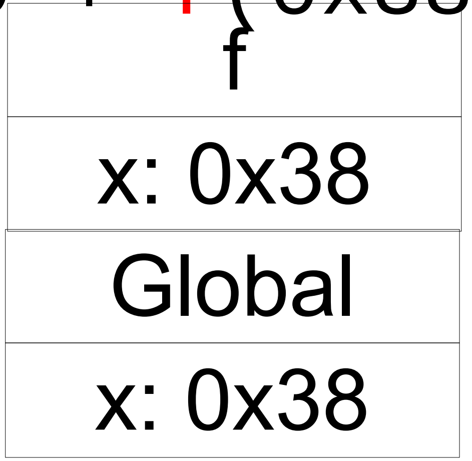
x: 0x38



0x63	int	29
0x11	int	17
0x5	int	0
0x33	int	10
0x3	int	13
0x38	int	25
0x13	int	4
0x18	int	8

Do all the steps to evaluate the last line.

```
def f(x):
→    return 0x63
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(0x38)
```

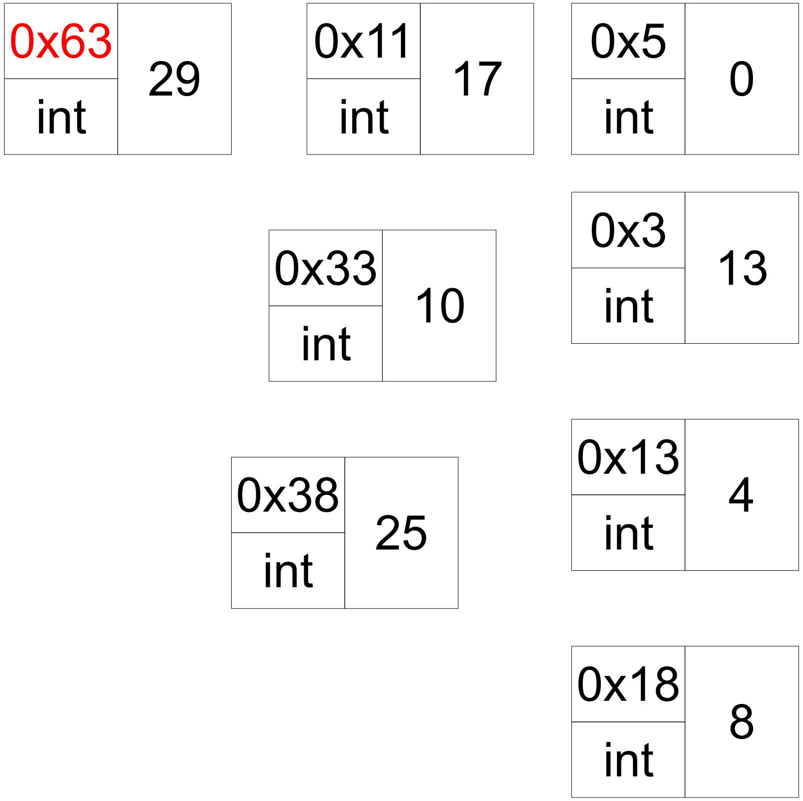


f

x: 0x38

Global

x: 0x38



0x63 int 29

0x11 int 17

0x5 int 0

0x33 int 10

0x3 int 13

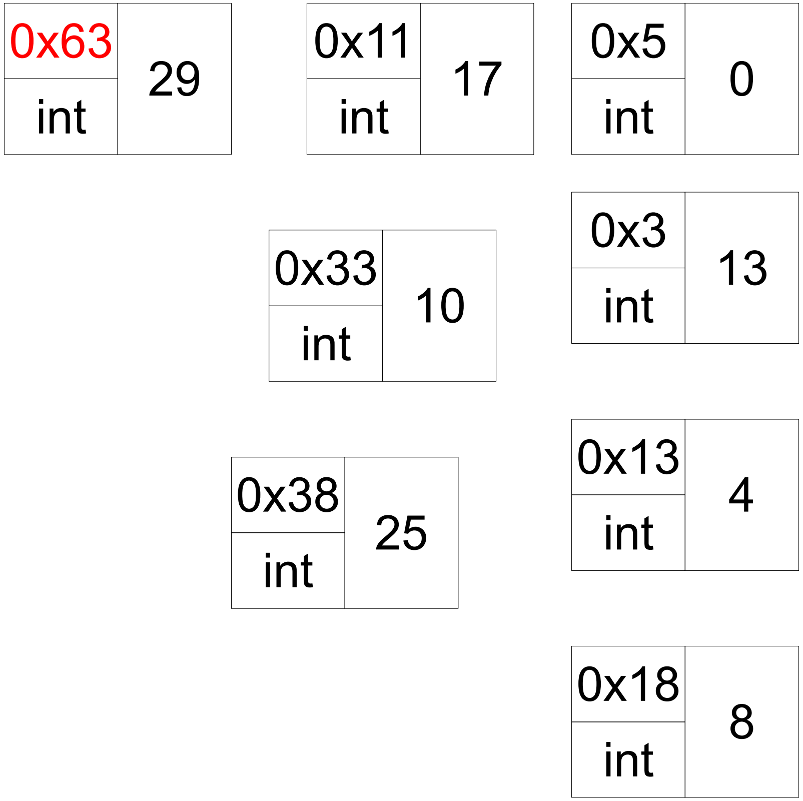
0x38 int 25

0x13 int 4

0x18 int 8

Do all the steps to evaluate the last line.

```
def f(x):
→   return 0x63
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + 0x63
```



0x63 int 29

0x11 int 17

0x5 int 0

0x3 int 13

0x33 int 10

0x13 int 4

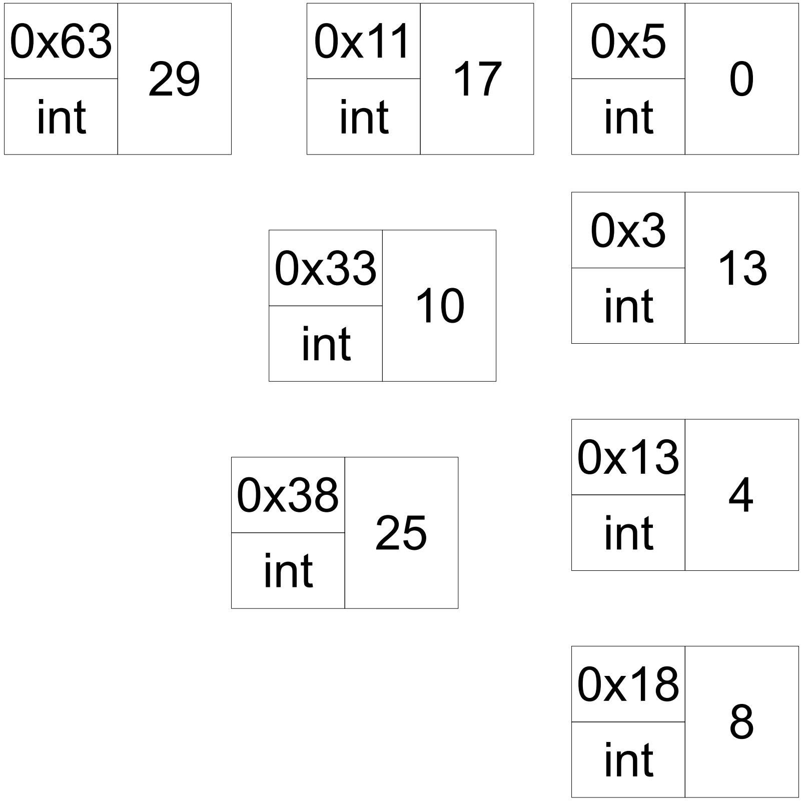
0x38 int 25

0x18 int 8

Global
x: 0x38

Do all the steps to evaluate the last line.

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + 0x63
```



0x63 int 29

0x11 int 17

0x5 int 0

0x33 int 10

0x3 int 13

0x38 int 25

0x13 int 4

0x18 int 8

Global
x: 0x38

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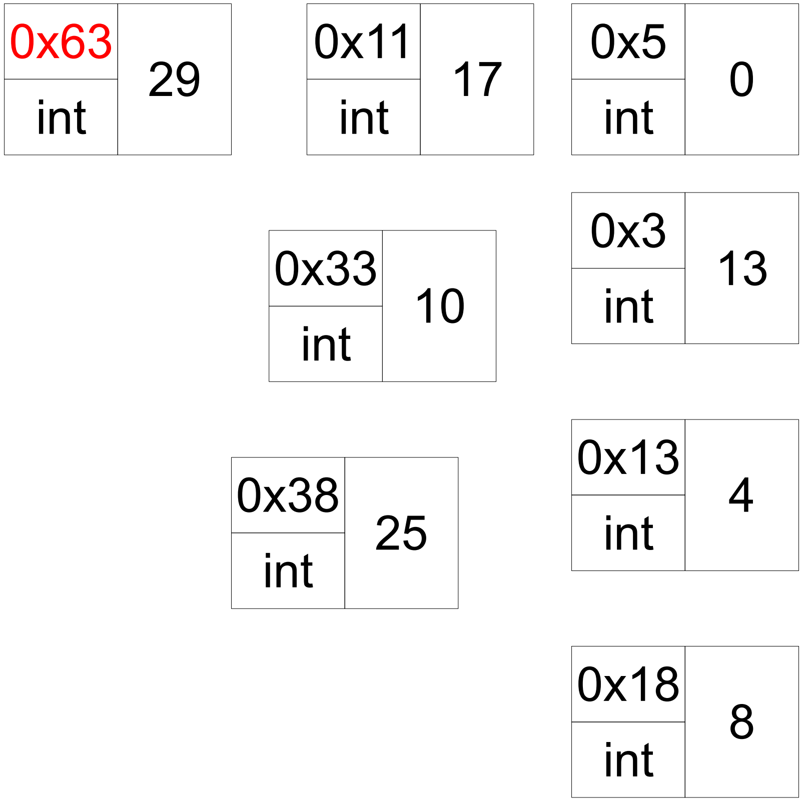
Do all the steps to evaluate the last line.

```
  def f(x):
      return x + 4
  x = 0
  x = 13 + 4
  x = x + f(4)
→ x = 10 + 0x63
```



0x63 | int | 29

0x11 | int | 17

0x5 | int | 0

0x33 | int | 10

0x3 | int | 13

0x38 | int | 25

0x13 | int | 4

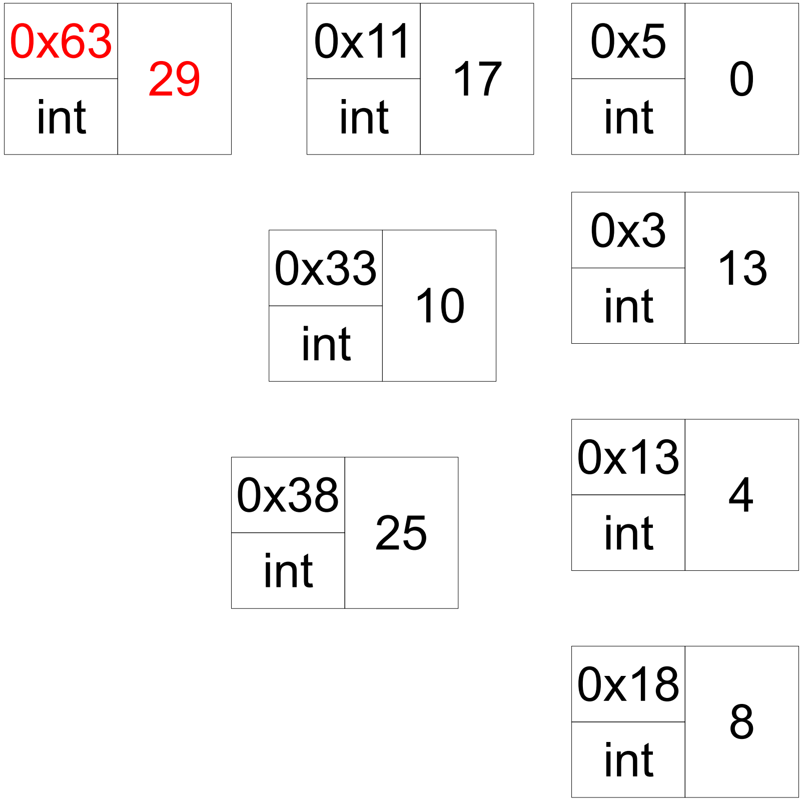
0x18 | int | 8

Global
x: 0x38

June 14 2012

Do all the steps to evaluate the last line.

```
   def f(x):
       return x + 4
   x = 0
   x = 13 + 4
   x = x + f(4)
→  x = 10 + 29
```



0x63	29
int	

0x11	17
int	

0x5	0
int	

0x33	10
int	

0x3	13
int	

0x38	25
int	

0x13	4
int	

0x18	8
int	

Global
x: 0x38

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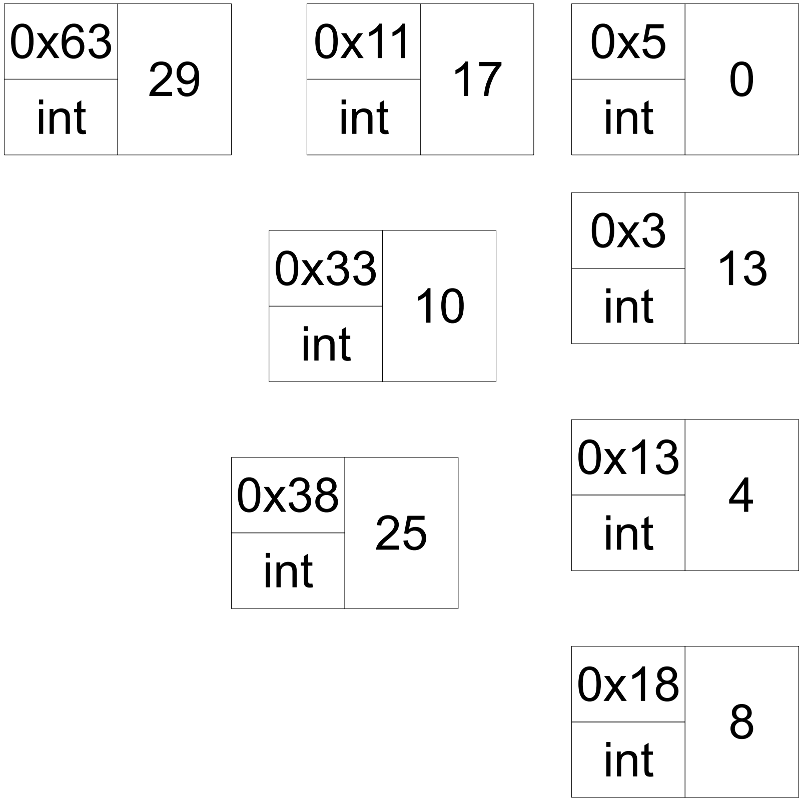
Do all the steps to evaluate the last line.

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
→ x = 10 + 29
```



0x63 int 29

0x11 int 17

0x5 int 0

0x33 int 10

0x3 int 13

0x38 int 25

0x13 int 4

0x18 int 8

Global
x: 0x38

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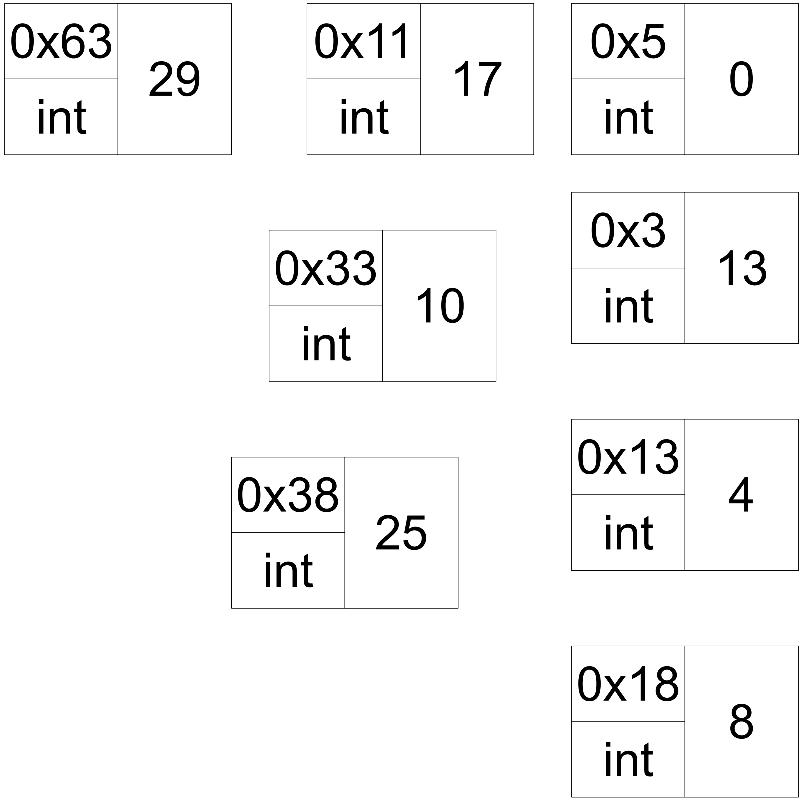
Do all the steps to evaluate the last line.

```
  def f(x):
      return x + 4
  x = 0
  x = 13 + 4
  x = x + f(4)
→ x = 39
```



0x63	int	29
0x11	int	17
0x5	int	0
0x33	int	10
0x3	int	13
0x38	int	25
0x13	int	4
0x18	int	8

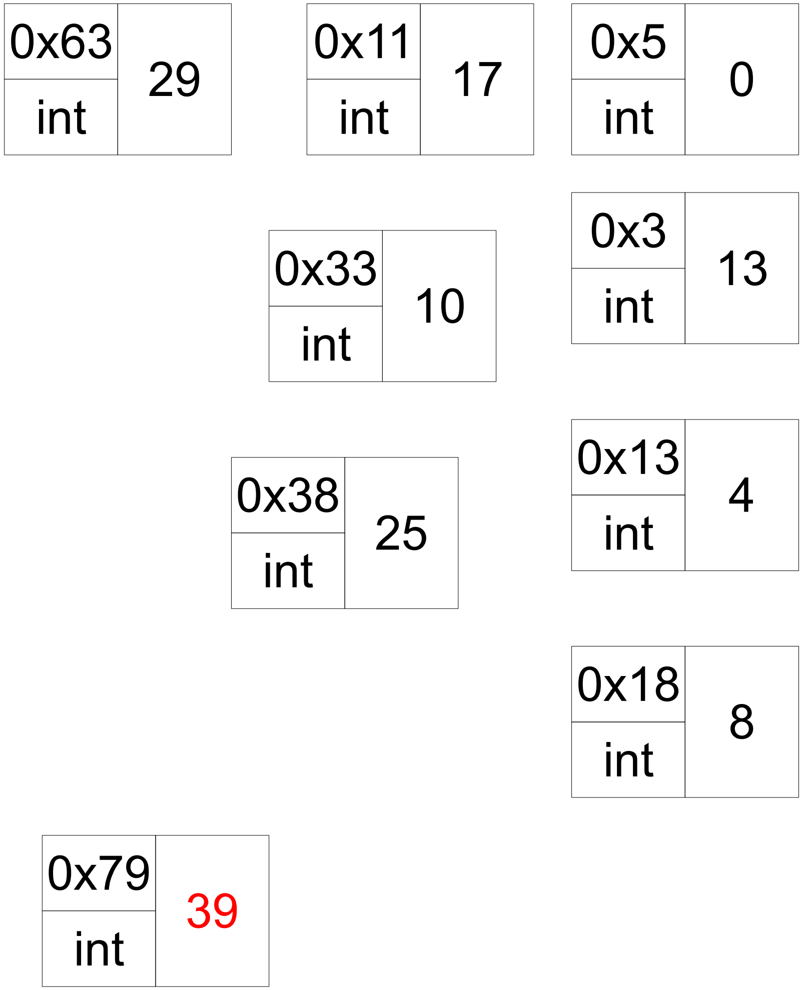
Global
x: 0x38

June 14 2012

Do all the steps to evaluate the last line.

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 39
```

Global
x: 0x38



0x63 int 29

0x11 int 17

0x5 int 0

0x33 int 10

0x3 int 13

0x38 int 25

0x13 int 4

0x18 int 8

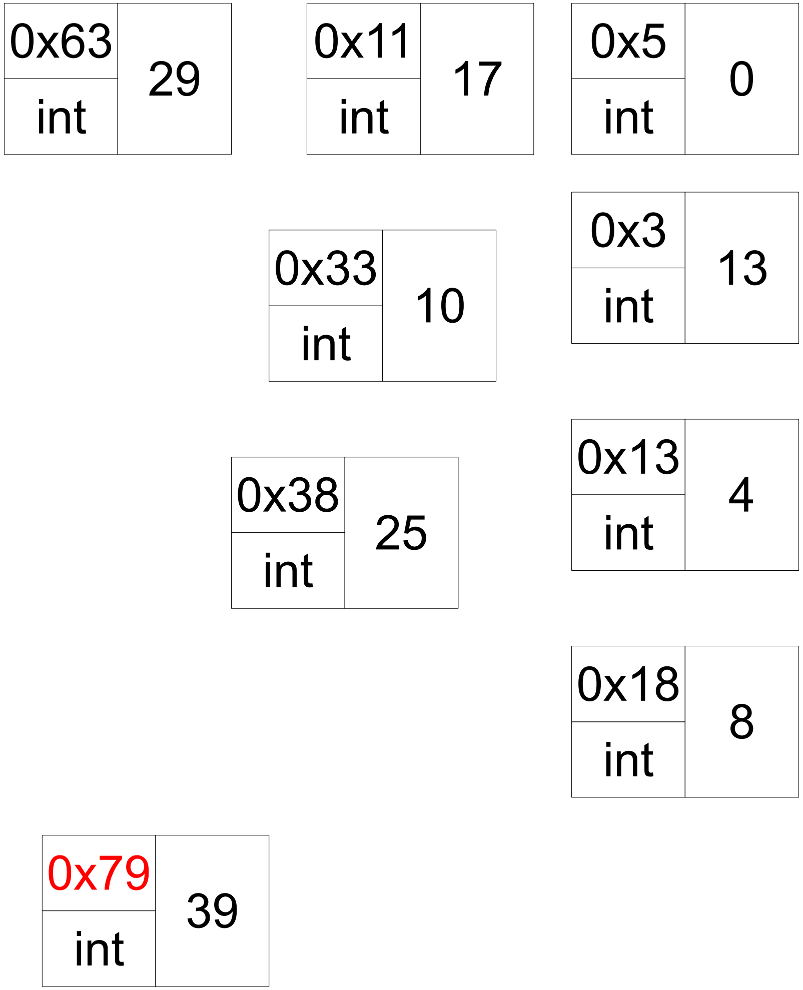
0x79 int 39

Do all the steps to evaluate the last line.

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 0x79
```

→

Global
x: 0x38



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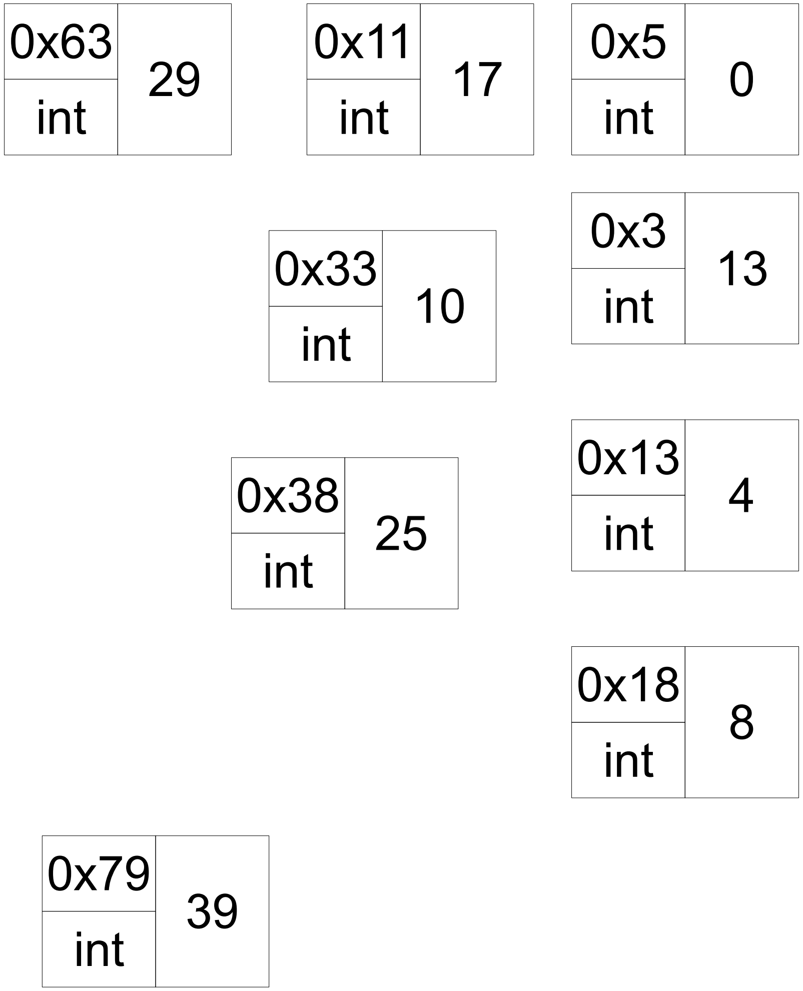
Do all the steps to evaluate the last line.

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 0x79
```

Global

x: 0x79



0x63 int 29

0x11 int 17

0x5 int 0

0x3 int 13

0x33 int 10

0x38 int 25

0x13 int 4

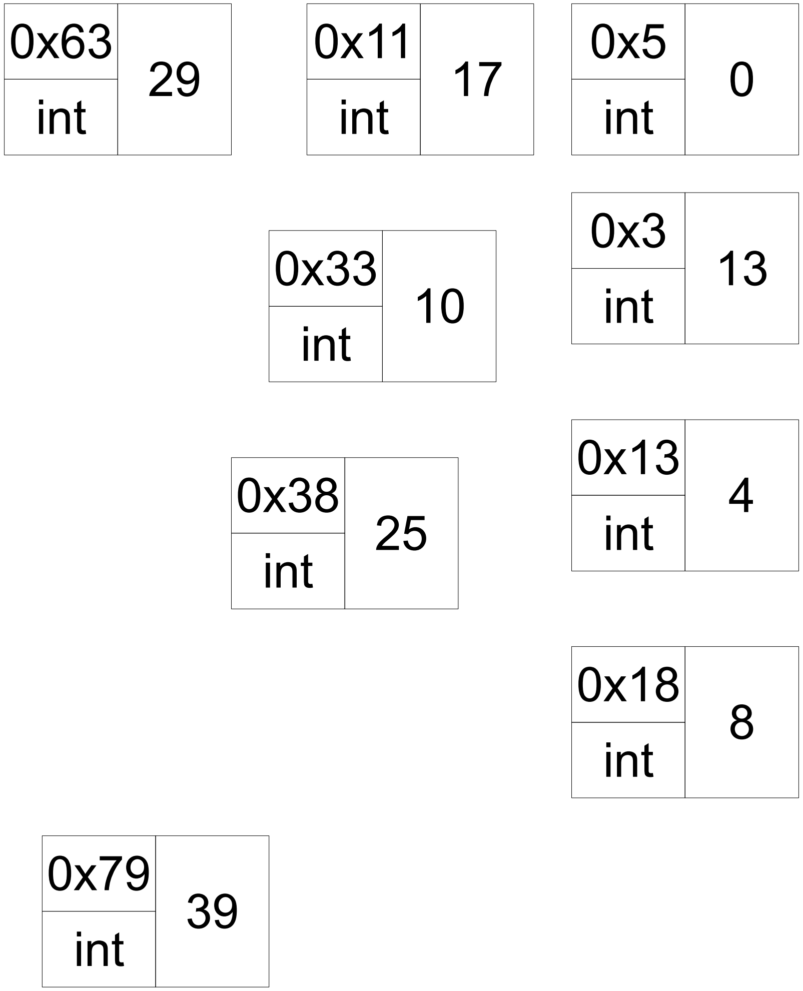
0x18 int 8

0x79 int 39

Do all the steps to evaluate the last line.

```
def f(x):
    return x + 4
x = 0
x = 13 + 4
x = x + f(4)
x = 10 + f(x)
```

Global
x: 0x79



June 14 2012

While Loops

- For Loops are great if we know how many times we want to loop over something.
  - In other cases, not so great.
  - If you want to enforce a legal input, for example
  - If you're playing a game and don't know how many turns there will be.
  - If we want to loop indefinitely.
- In these cases we use a while loop.

While loop syntax

```
while condition:
    block
```

- The `condition` evaluates to a boolean variable.
- The `block` is executed so long as the condition is true.
- If the `condition` is `False` the first time the while loop is seen, the `block` is never executed.

Unravelling While Loops

- We saw that for loops can be unravelled to make the program simpler to analyse, albeit longer.
- While loops are more complicated and are not always possible to be unravelled.
  - For eg. if the number of times the block is executed is dependent on user input.
- So to analyse them we need to use other tools.
  - Debugger, visualiser, hand simulation, etc.

While vs. For

- Every for loop can be written as a while loop.
- Not ever while loop can be written as a for loop:

```
while True:
    block
```

- How do we choose between while and for?

While vs. For

- Every for loop can be written as a while loop.
- Not ever while loop can be written as a for loop:

```
while True:
      block
```

- How do we choose between while and for?
  - for is simpler.
  - In general we prefer simpler loops, as they are easier to read.

While vs. For

- While loops are used when:
  - We want infinite loops.
  - We want to loop some number of times that we can't predict.
  - That is, we want to loop until some condition is met.

How many times does the while block get executed?

```
i = 0
while i<4:
    i+=1
```

```
x = +ve # > 1
def foo(x)
    for i in range(x):
        if i*i == x:
            return True
    return False
while not(foo(x)):
    x-=1
```

How many times does the while block get executed?

```
i = 0
while i<4:
    i+=1
```

- 4 times, once for i = 0,1,2,3

```
x = +ve # > 1
def foo(x)
    for i in range(x):
        if i*i == x:
            return True
    return False
while not(foo(x)):
    x-=1
```

- Once for every amount that x is larger than the largest square number <= x.

Docstrings

- Recall that the first line of a docstring contains type information.
  - Specifically it tells us the parameter types and the expected output type.
  - `'''(parameter types) -> output type'''`

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  - `'''(parameter types) -> output type'''`
- If we want to return multiple things, we wrap them with a tuple and use the following format
  - `'''(parameter types) -> (output types)'''`
  - `'''(NoneType) -> (int, str, list)'''`

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- Changing your docstring does not change your function in anyway.

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Indentation

- I have been using indented blocks a lot when giving python syntax.

```
for item in list:
    block
```

Indentation

- I have been using indented blocks a lot when giving python syntax.

```
while condition:
    block
```

Indentation

- I have been using indented blocks a lot when giving python syntax.

```
if condition:
    block1
else:
    block2
```

Indentation

- I have been using indented blocks a lot when giving python syntax.

```
def foo(parameters):
    block
```

Indentation

- I have been using indented blocks a lot when giving python syntax.

```
def foo(parameters):
    block
```

- I want to make it explicit that these blocks last as long as the indentation is at least one tab.
  - It can be more, because blocks can contain sub blocks.

Sub-blocks

```
def foo(parameters):
    block
        sub-block
    block
```

Sub-blocks

```
def foo(x):
    if (x%2 == 0):
        sub-block
    block
```

- Recall:

```
if condition:
    block1
```

Sub-blocks

```
def foo(x):
    if (x%2 == 0):
        sub-block
    block
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Sub-blocks

```
def foo(x):
     if (x%2 == 0):
          sub-block
     block
```

- Recall:

```
if condition:
     block1
```

Sub-blocks

```
def foo(x):
    if (x%2 == 0):
        print 'even'
    print 'odd'
```

Indentation

- I have been using indented blocks a lot when giving python syntax.

  ```
  def foo(parameters):
      block
  ```

- I want to make it explicit that these blocks last as long as the indentation is at least one tab.
  - It can be more, because blocks can contain sub blocks.
- When you stop indenting the block ends.

Indentation

- When you stop indenting the block ends.

```
def foo(parameters):
    block1
block2
    block3
```

- Blocks 1, 2 and 3 are all different, and only block 1 is inside the function definition.
- If the last line of block2 is not something that expects a block to follow it, block 3 is illegal.

Indentation

- When you stop indenting the block ends.

  White space does not count as ending a block.

  ```
  def foo(parameters):
      block1

      block3
  ```

- Here block 1 and block 3 are considered to be part of the same block, regardless of whether or not the empty line contains spaces/tabs/etc.

Indentation

- When you stop indenting the block ends.

  White space does not count as ending a block.

```
def foo(parameters):
    block1


    block3
```

- Here block 1 and block 3 are considered to be part of the same block, regardless of whether or not the empty line contains spaces/tabs/etc.
  - Note that this may vary depending on the IDE.

Break, the second

Convert these to while loops.

```
for x in eg_list:
    print x
```

```
for x in range(len(eg_list)):
    print x
```

Convert these to while loops.

```
for x in eg_list:
    print x
```

```
for x in
range(len(eg_list)):
    print x
```

```
x = 0
while x < len(eg_list):
    print eg_list[x]
    x += 1
```

```
x = 0
while x < len(eg_list):
    print x
    x += 1
```

Files.

- So far we've seen some basic file stuff.
- Media opens files
- The testing script for Assignment 1 opens a file.

Files as types.

- Python has a type used to deal with files.
- There are four main things we want to do with files:
  - Figure out how to open them.
  - Figure out how to read them.
  - Figure out how to write to them.
  - Figure out how to close them.

Opening files.

- Can hardcode the filename in the code.
  - Like done in the script for assignment 1.
- Can ask the user for a file name using raw_input()
- Some modules have their own builtin functions for opening files.
  - `media` has `choose_file()` which opens a dialog window.

Opening files.

- Once we have a filename we can call open:

  `open(filename, 'r')` – for reading (this is the default mode).

  `open(filename, 'w')` – for writing (erases the contents of a file).

  `open(filename, 'a')` – for appending (keeps the contents of the file).

- This function returns a new object, a file object.

Reading Files.

- The most basic way is the read the whole file into a string:

  `filename.read()` - returns a string that is the contents of the entire file.

  - Not recommended for big files.

- Can read a single line of the file.

  `filename.readline()` - reads a line of the filename.

  - A subsequent call the readline() will read the next line of the file, the first line is lost.

Reading Files.

- Can read a fixed number of characters.

  `filename.read(10)` – will read 10 characters.

  - If you call it again, it will start reading from the place after the characters that it has read.

- Can read the file a line at a time.

  ```
  for line in filename:
       print line
  ```

- Note that the string `split` method is often very useful.

Writing to Files.

- Write to files using:

```
filename.write(“This is a string”)
```

- Multiple writes are concatenated.
- Need to open a file in append or write mode to write to it.
- Append mode will add the strings to the end of the file.

Closing Files.

- Close a file with:

```
filename.close()
```

- Generally a good idea.
- Frees up system resources.

Assignment 1

June 23 2011

Lab Review

- Next weeks lab covers:
  - slicing
  - nested lists
  - while loops