Discussion 02

Environment Diagrams and Recursion

```python
n = 7
def f(x):
   n = 8
   return x + 1
def g(x):
   n = 9
   def h():
      return x + 1
   return h
def f(f, x):
   return f(x + n)
f = f(g, n)
g = (lambda y: y())(f)
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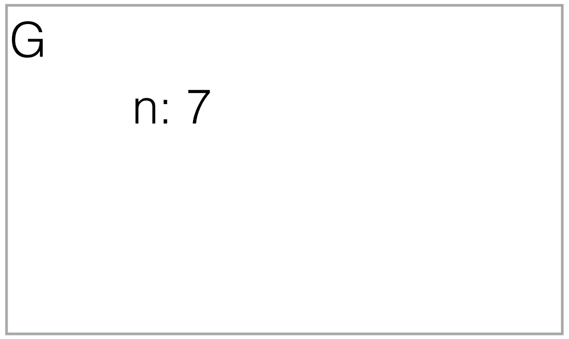

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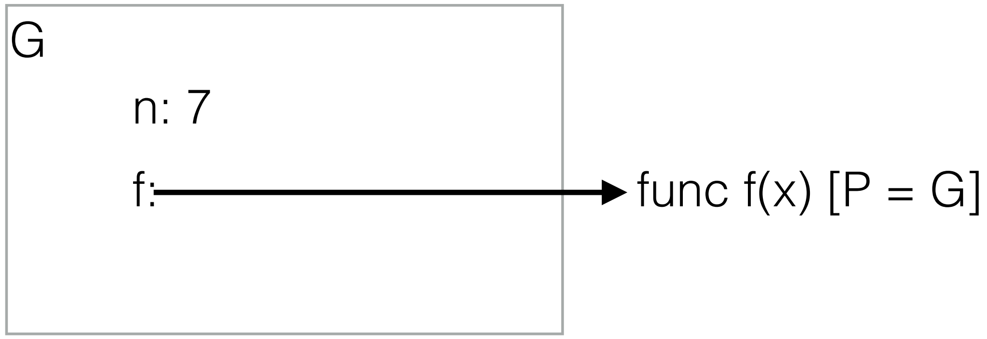

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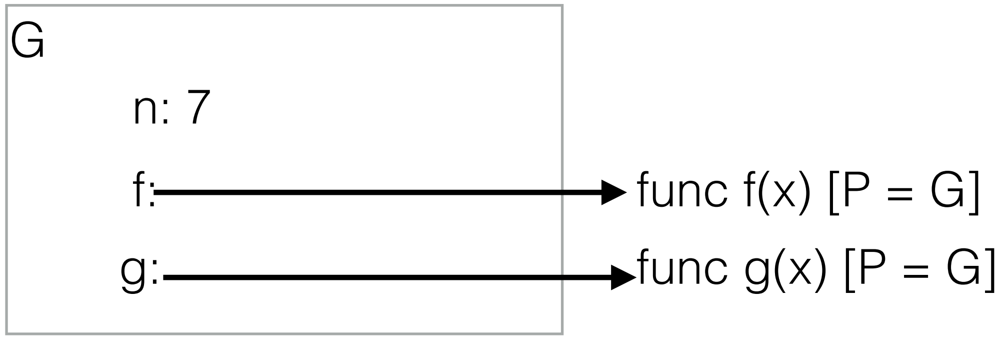

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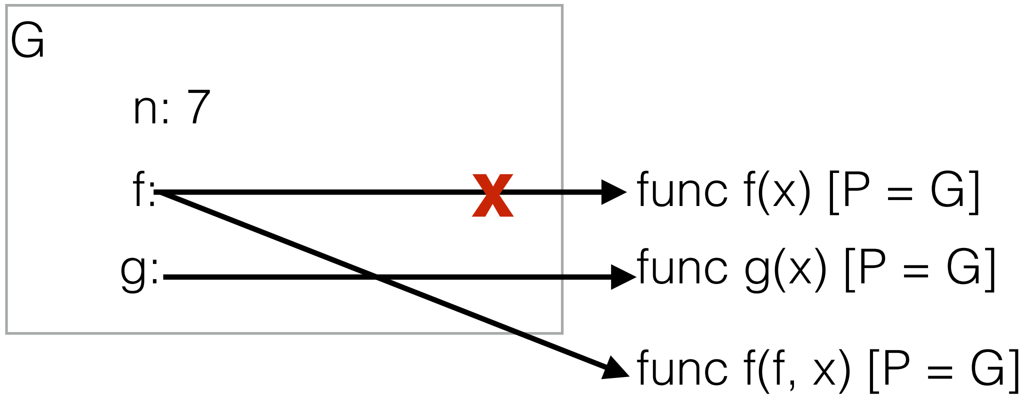

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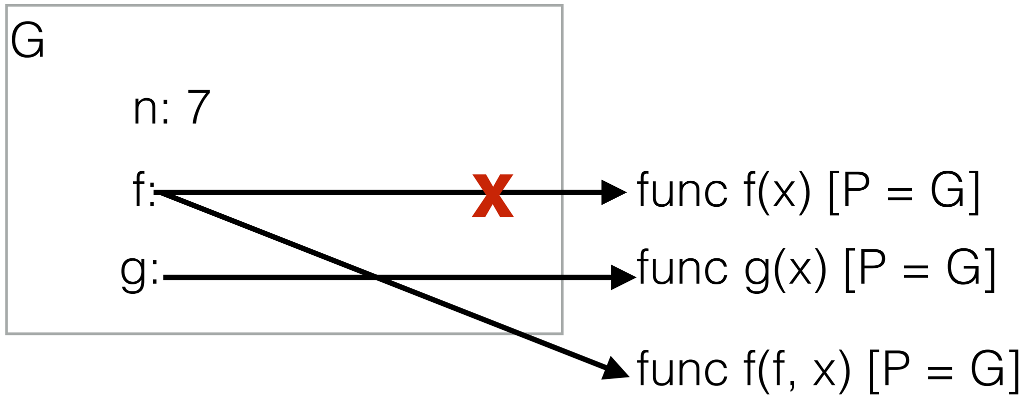

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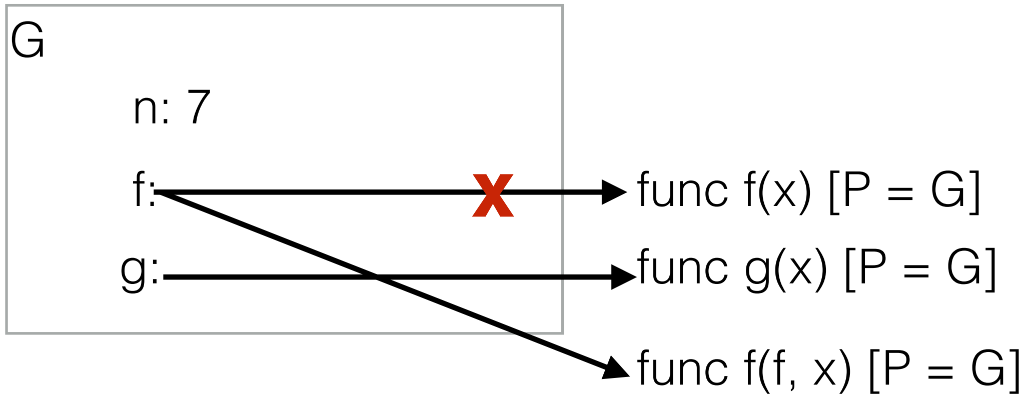

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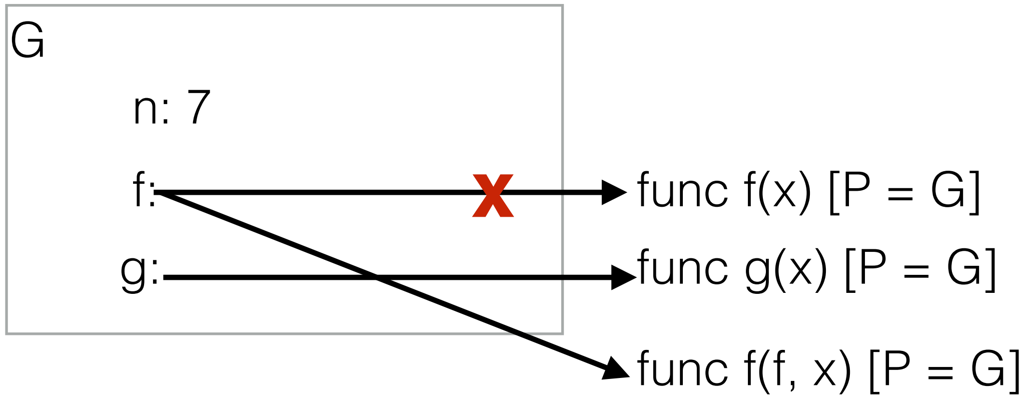

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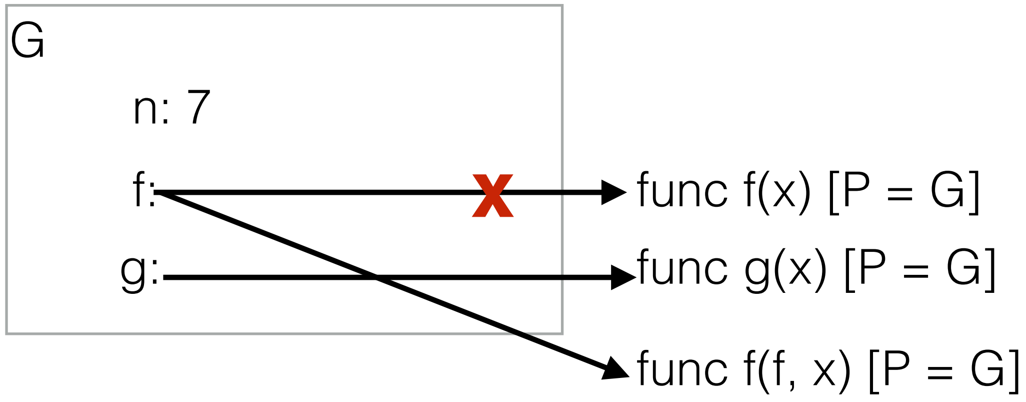

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f1

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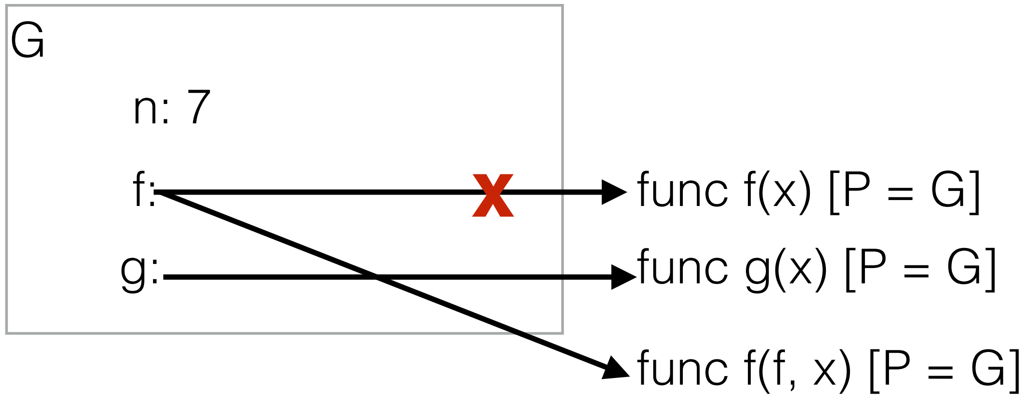

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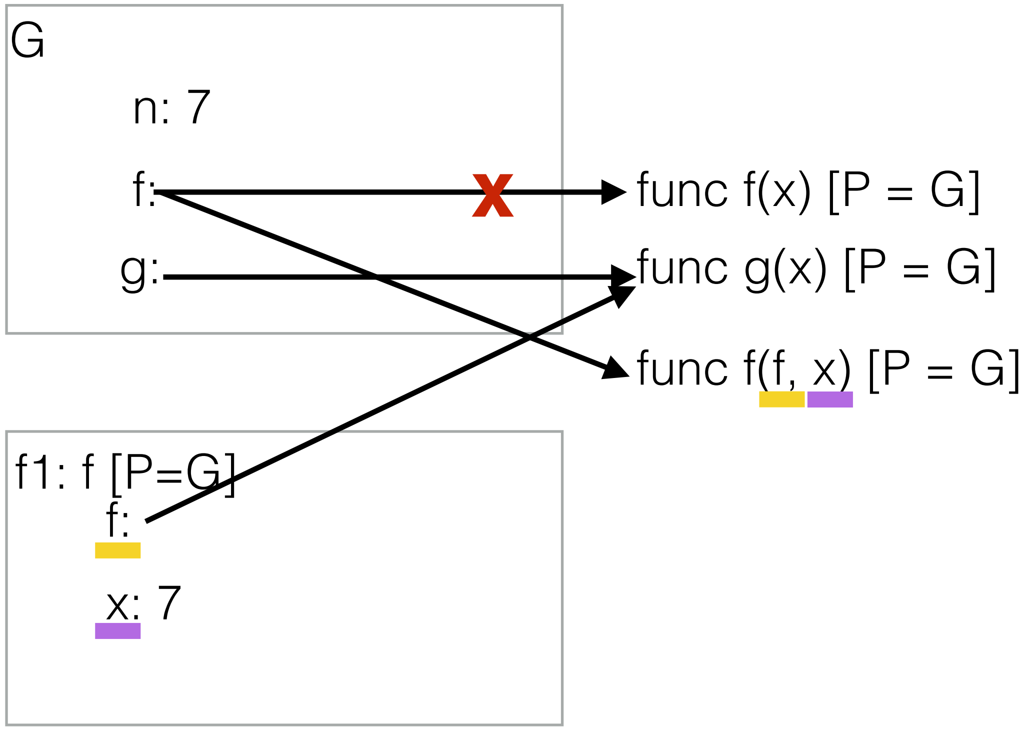

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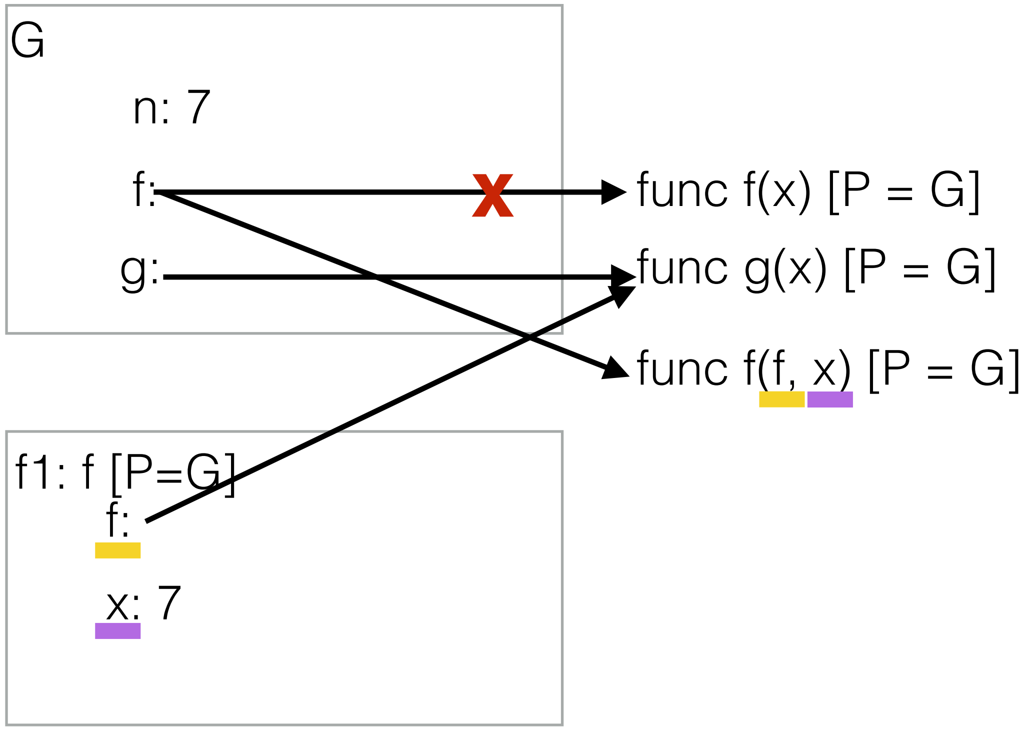

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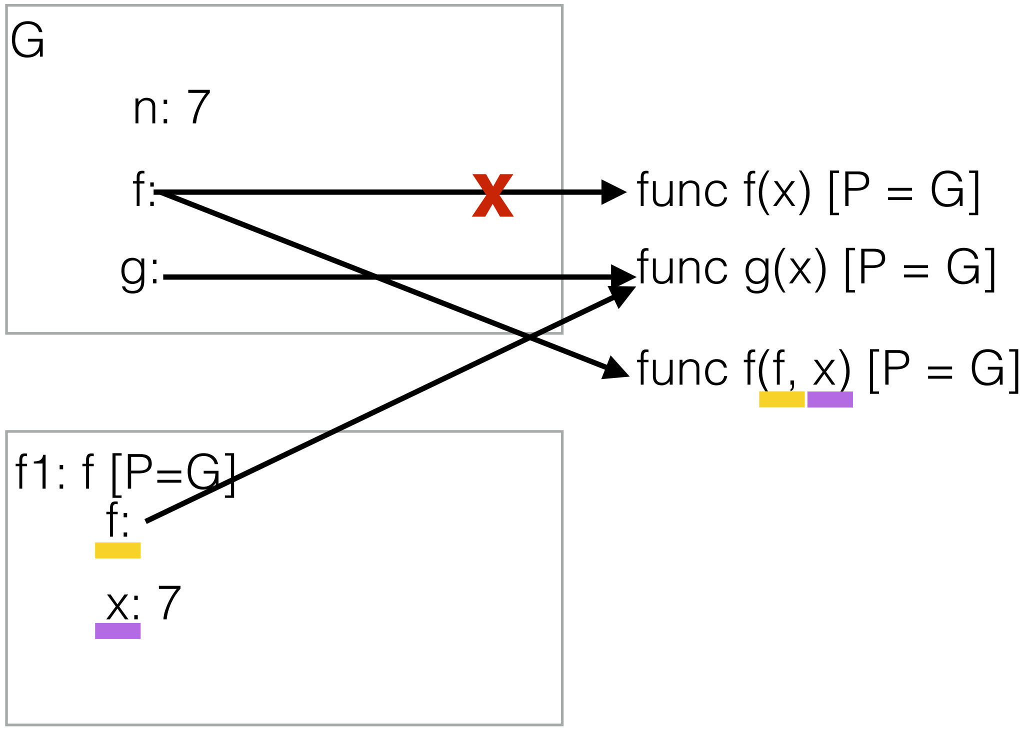

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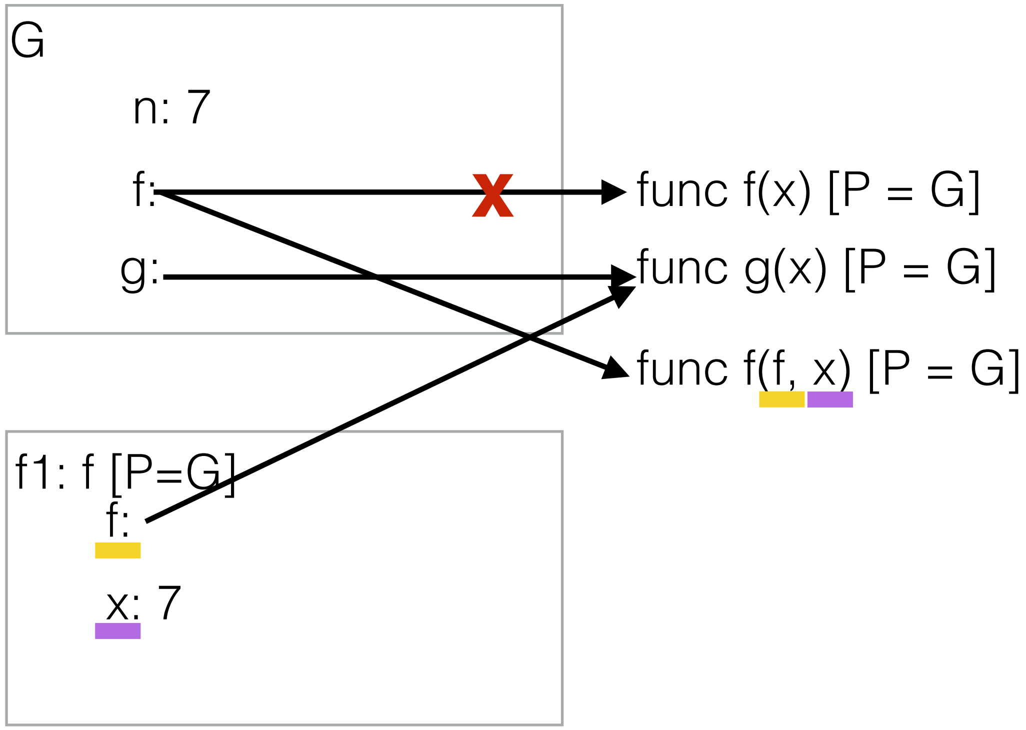
note that x is also just passed in and we must look up n in G



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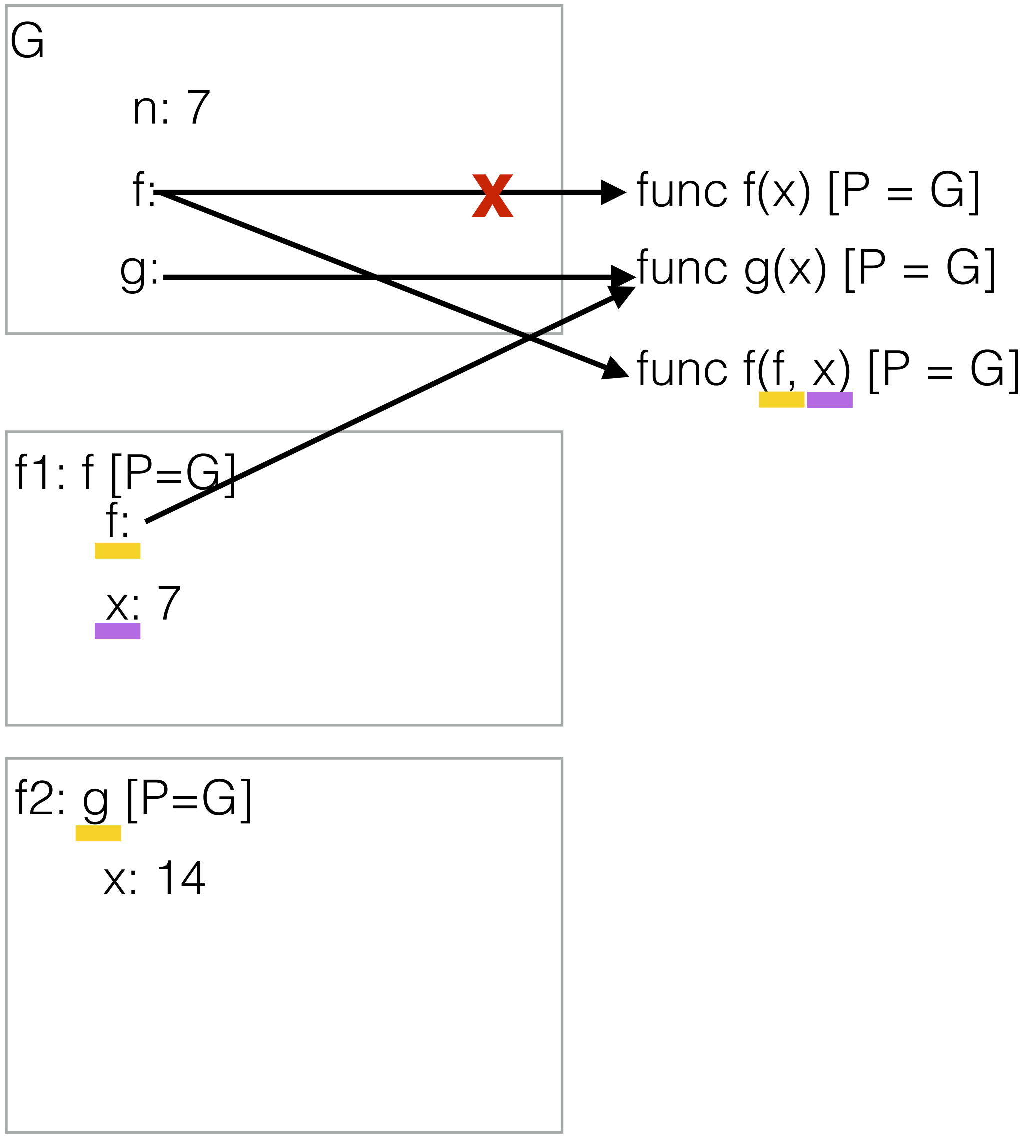

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f1: f [P=G]

f:

x: 7

f2: g [P=G]

x: 14

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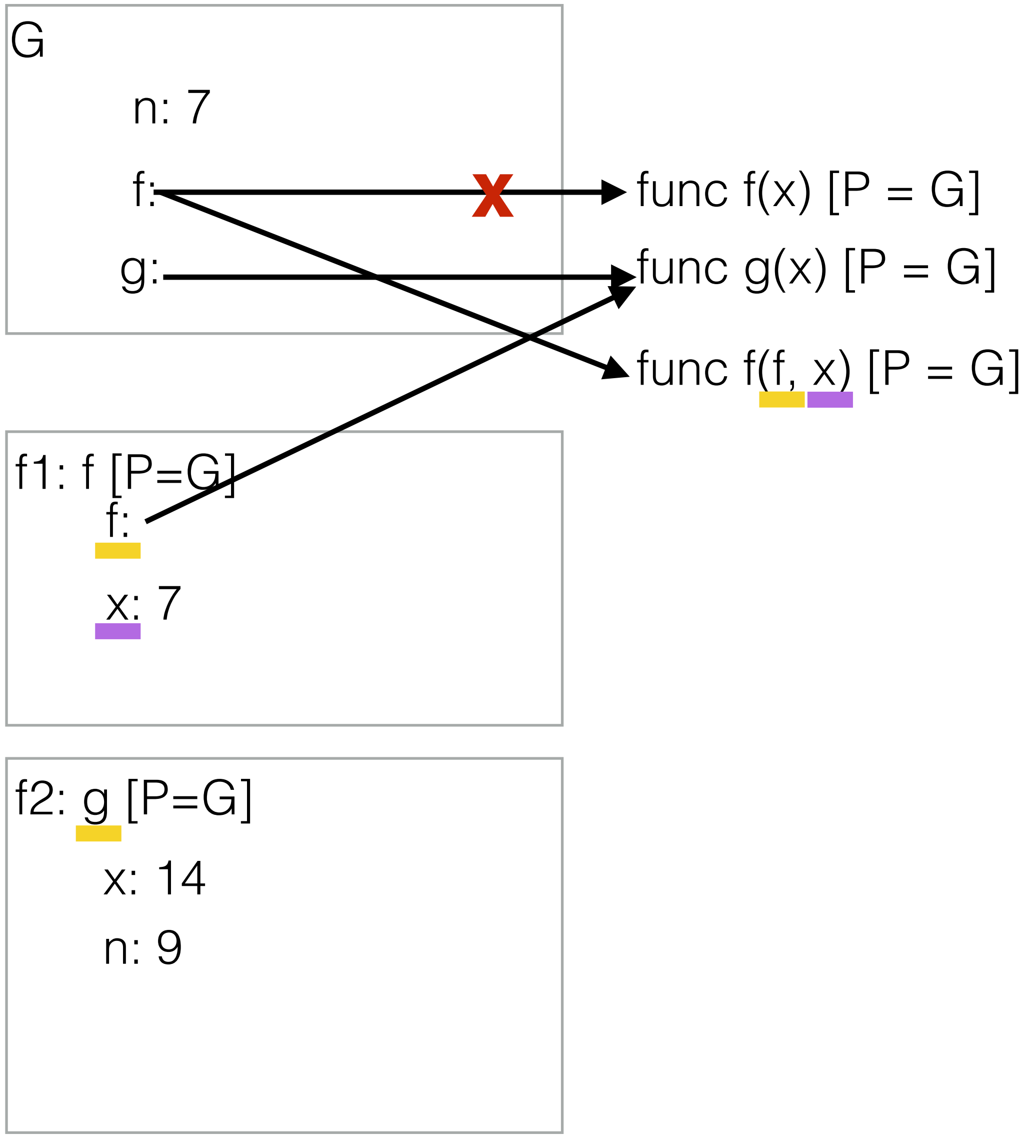

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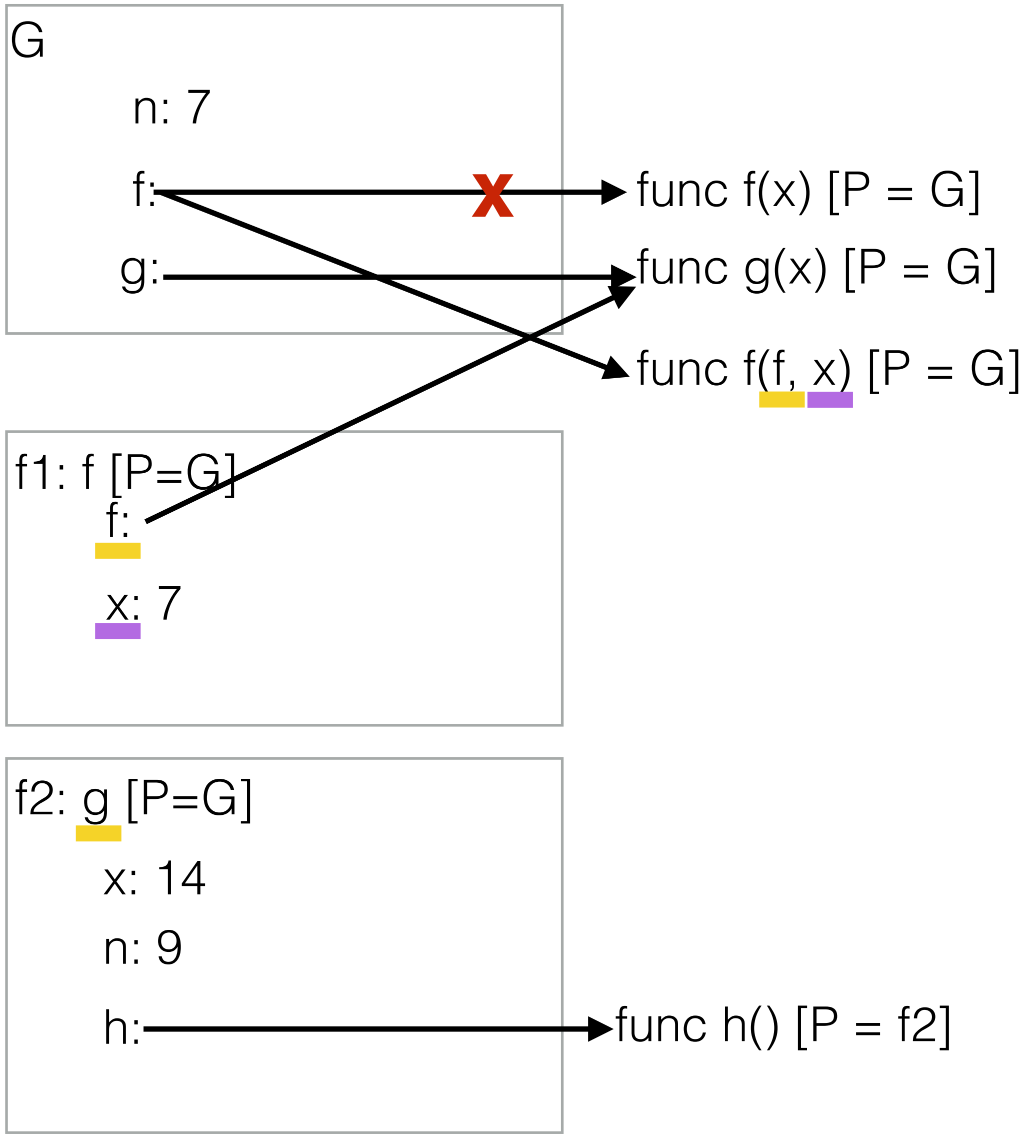

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f1: f [P=G]
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n: 9
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func h() [P = f2]

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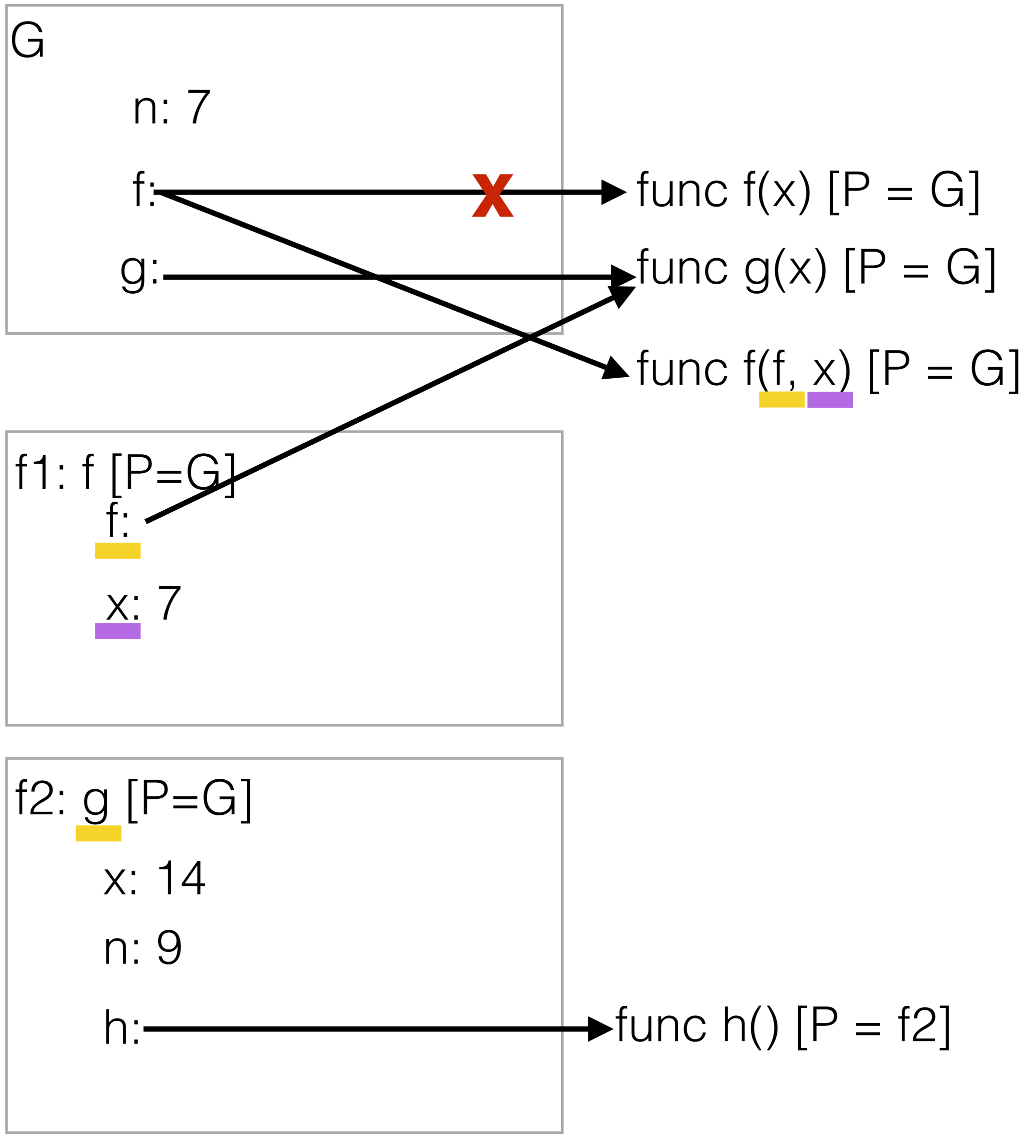
Checkpoint: why is the parent of h, f2?



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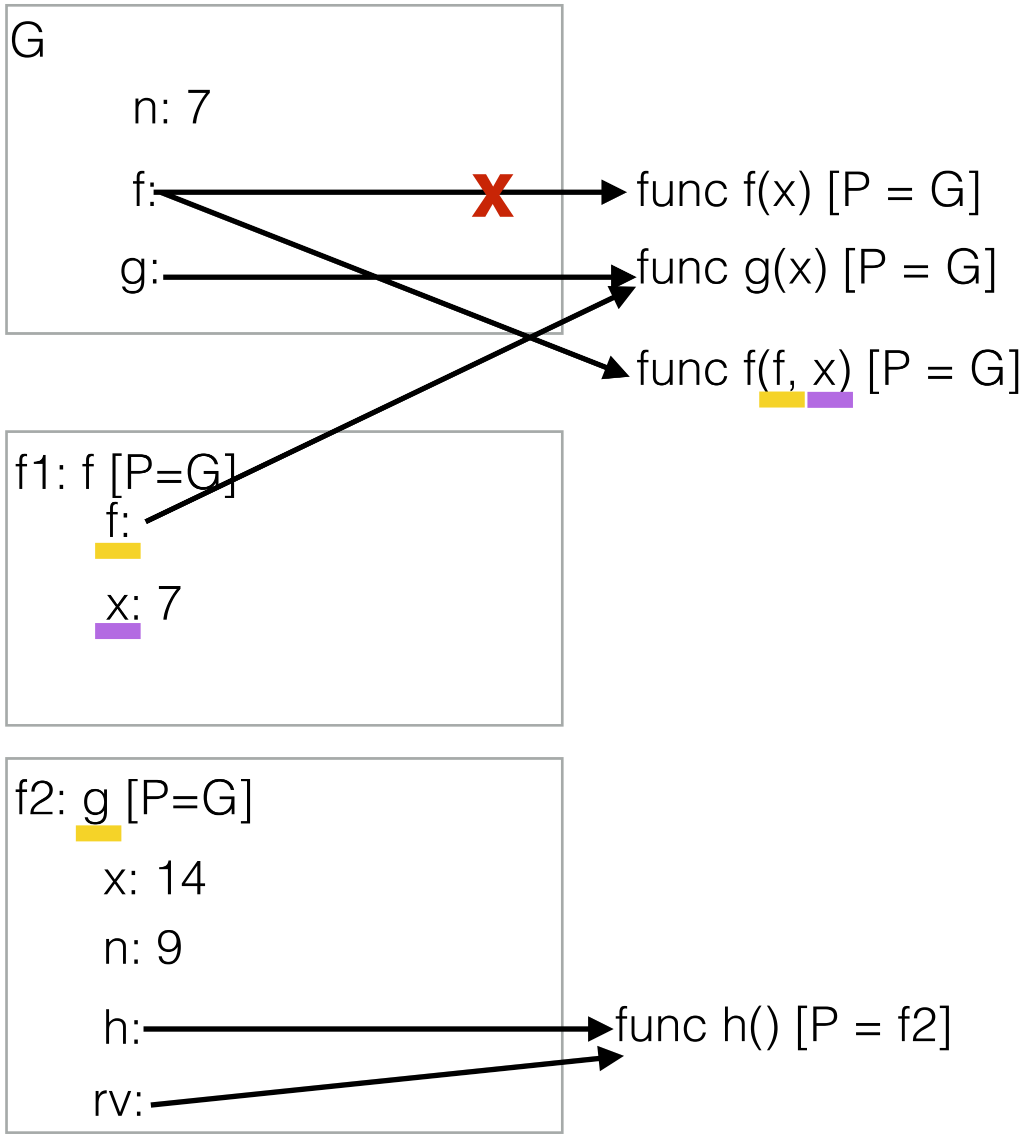

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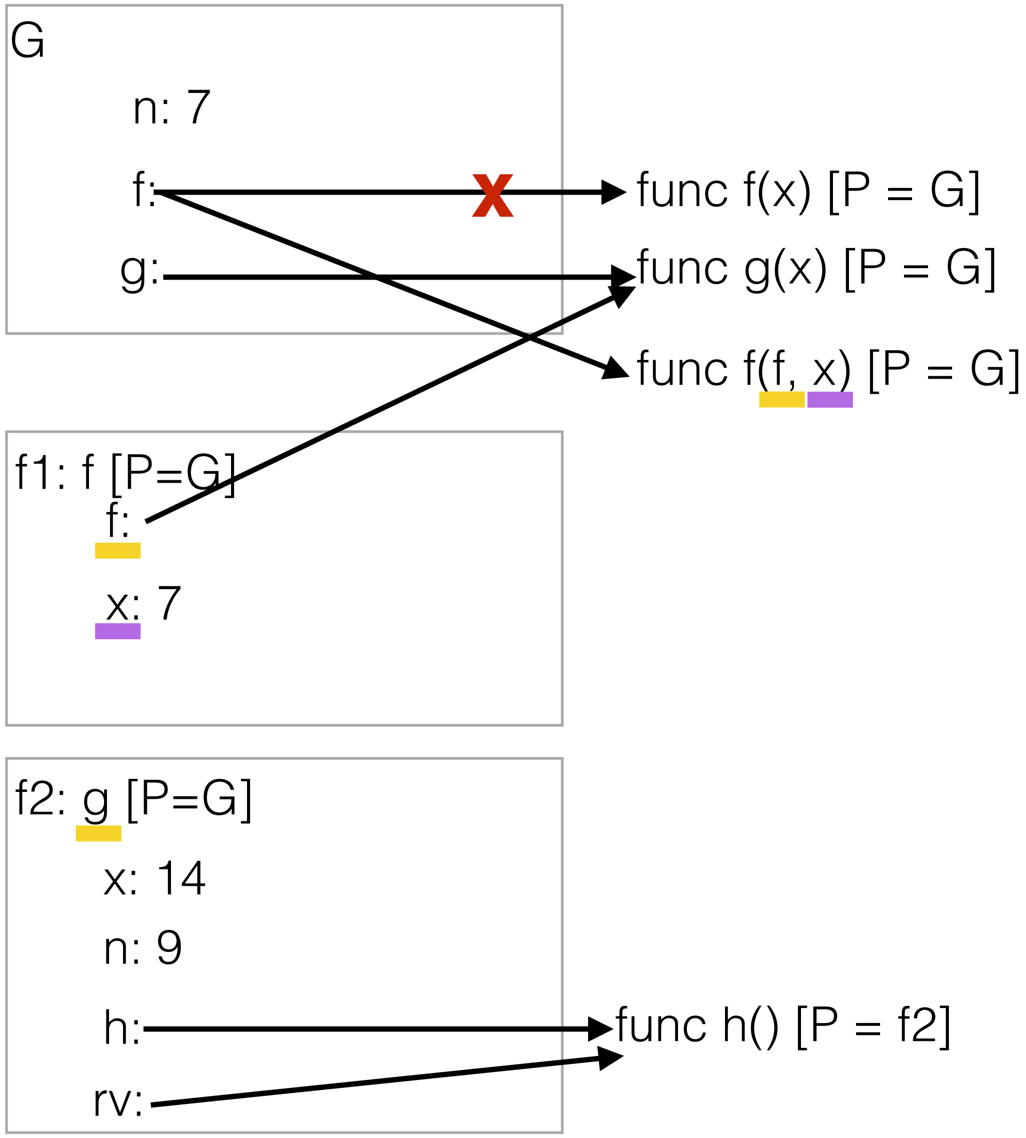
what type of thing do we return? (hint: what the difference between h and h()?)



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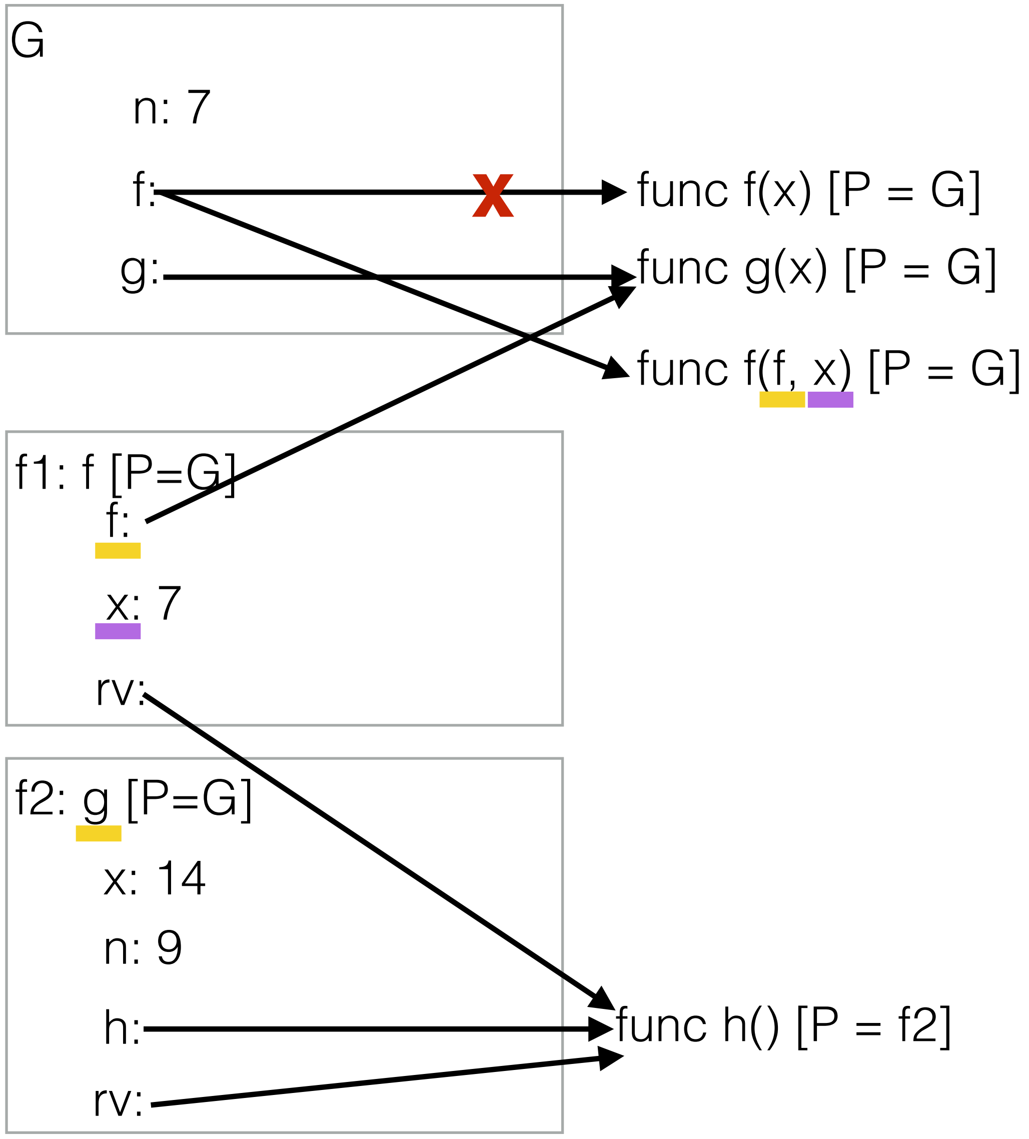

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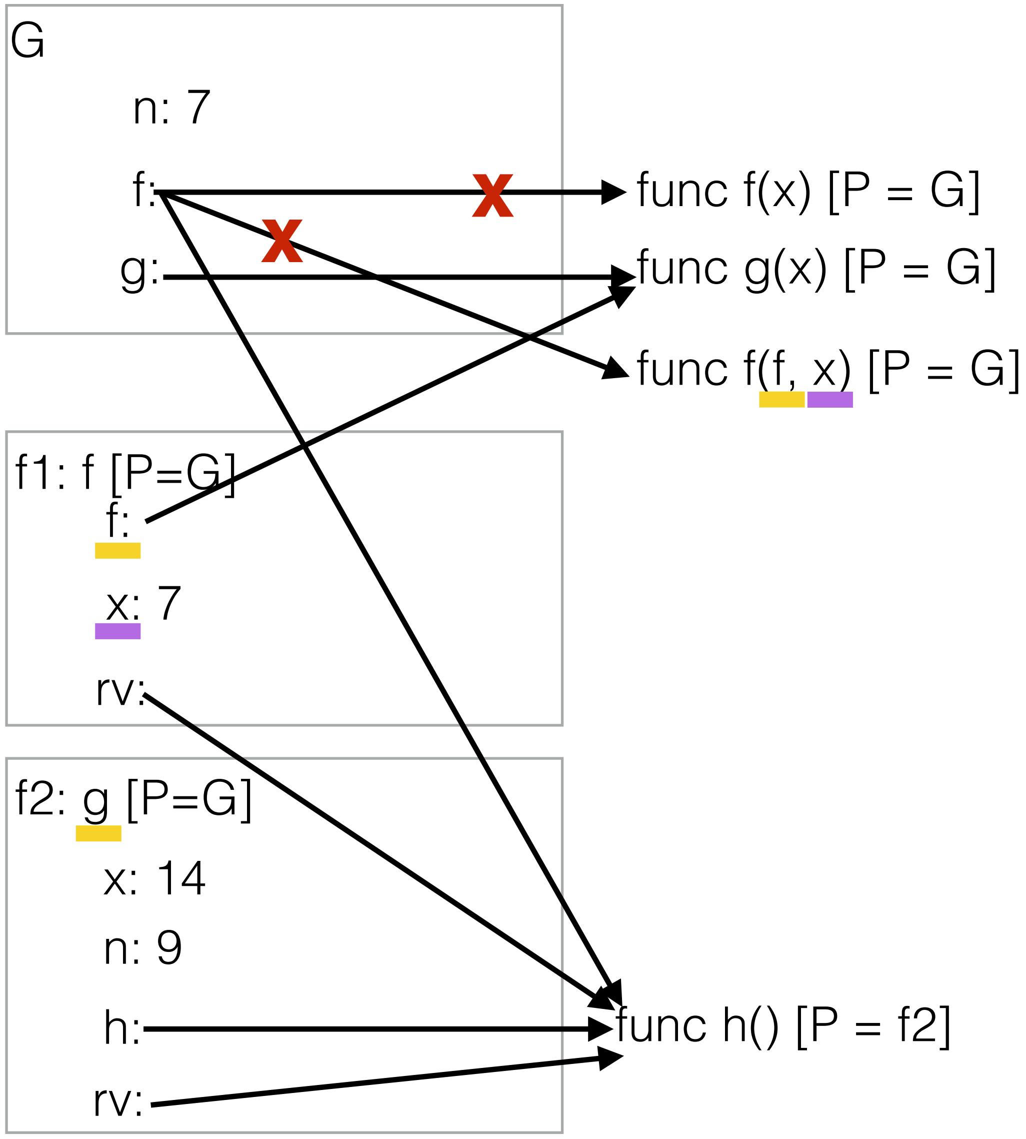
whatever this function evaluates to is what we return in f1. leave an indication that this is where you will return to after completing f2
evaluate operator and operands
note that the operator is f, which is the name of the parameter we just passed in
note that x is also just passed in and we must look up n in G

Checkpoint: why is the parent of h, f2?

what type of thing do we return? (hint: what the difference between h and h()?)



```
n = 7

def f(x):

    n = 8

    return x + 1

def g(x):

    n = 9

    def h():

        return x + 1

    return h

def f(f, x):

    return f(x + n)

f = f(g, n)

g = (lambda y: y())(f)
```

f2

f1

assignment statement! Evaluate the RHS, then bind the value to the name on the LHS in the current frame

function call!

evaluate f
look for what the name g is bound to in the current frame
evaluate g
look for what the name g is bound to in the current frame
evaluate n
look for what the name n is bound to in the current frame
DO NOT OPEN A NEW FRAME UNTIL YOU EVALUATE THE OPERATOR AND OPERANDS

Leave an indication that this is where in the code you will come back to after completing the function call

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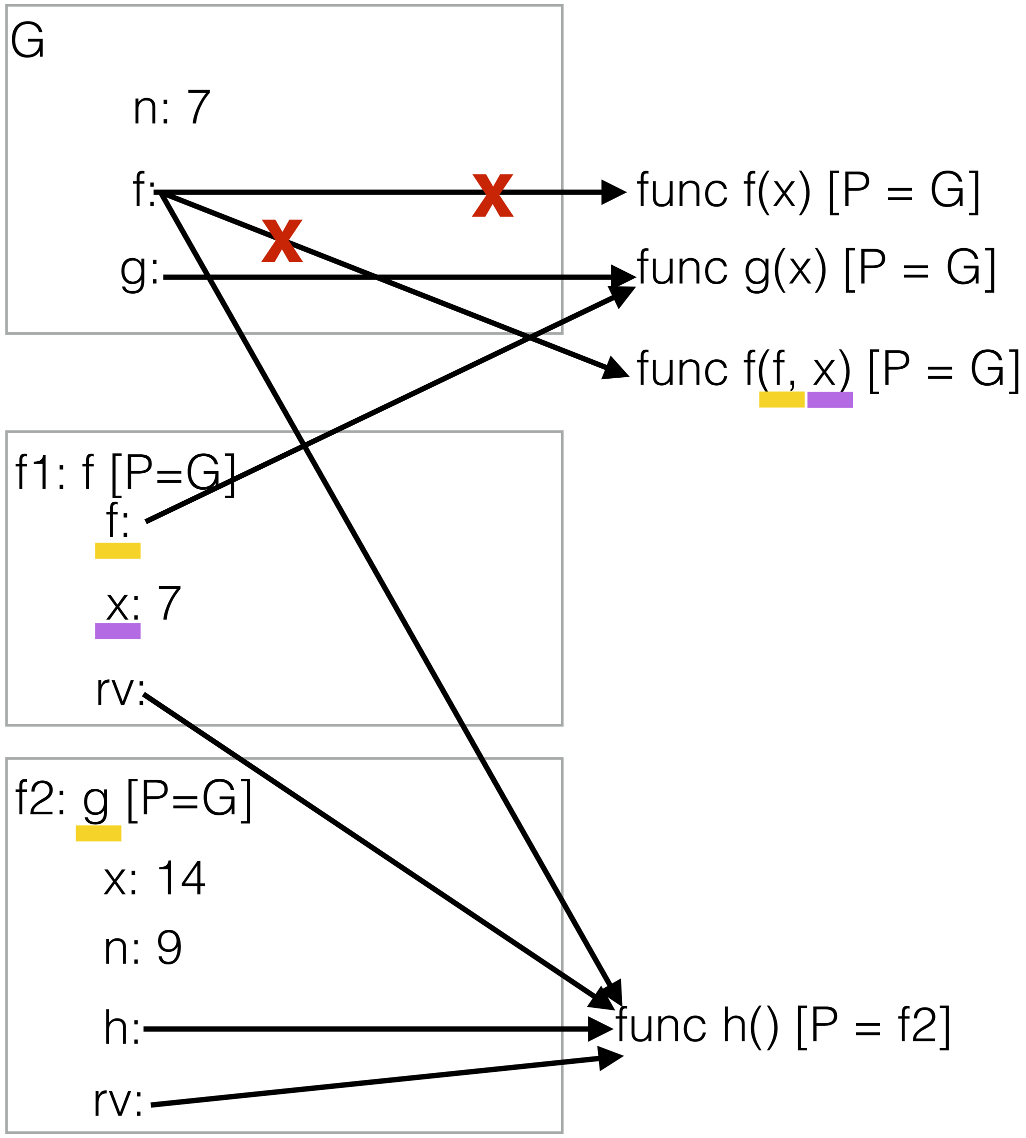

G
n: 7
f:
g:
func f(x) [P = G]
func g(x) [P = G]
func f(f, x) [P = G]

f1: f [P=G]
f:
x: 7
rv:

f2: g [P=G]
x: 14
n: 9
h:
rv:
func h() [P = f2]

```
n = 7

def f(x):

    n = 8

    return x + 1

def g(x):

    n = 9

    def h():

        return x + 1

    return h

def f(f, x):

    return f(x + n)  f2

f = f(g, n)  f1

g = (lambda y: y())(f)
```

assignment statement! Evaluate the RHS, then bind the value to the name on the LHS in the current frame

function call!

evaluate f
look for what the name g is bound to in the current frame
evaluate g
look for what the name g is bound to in the current frame
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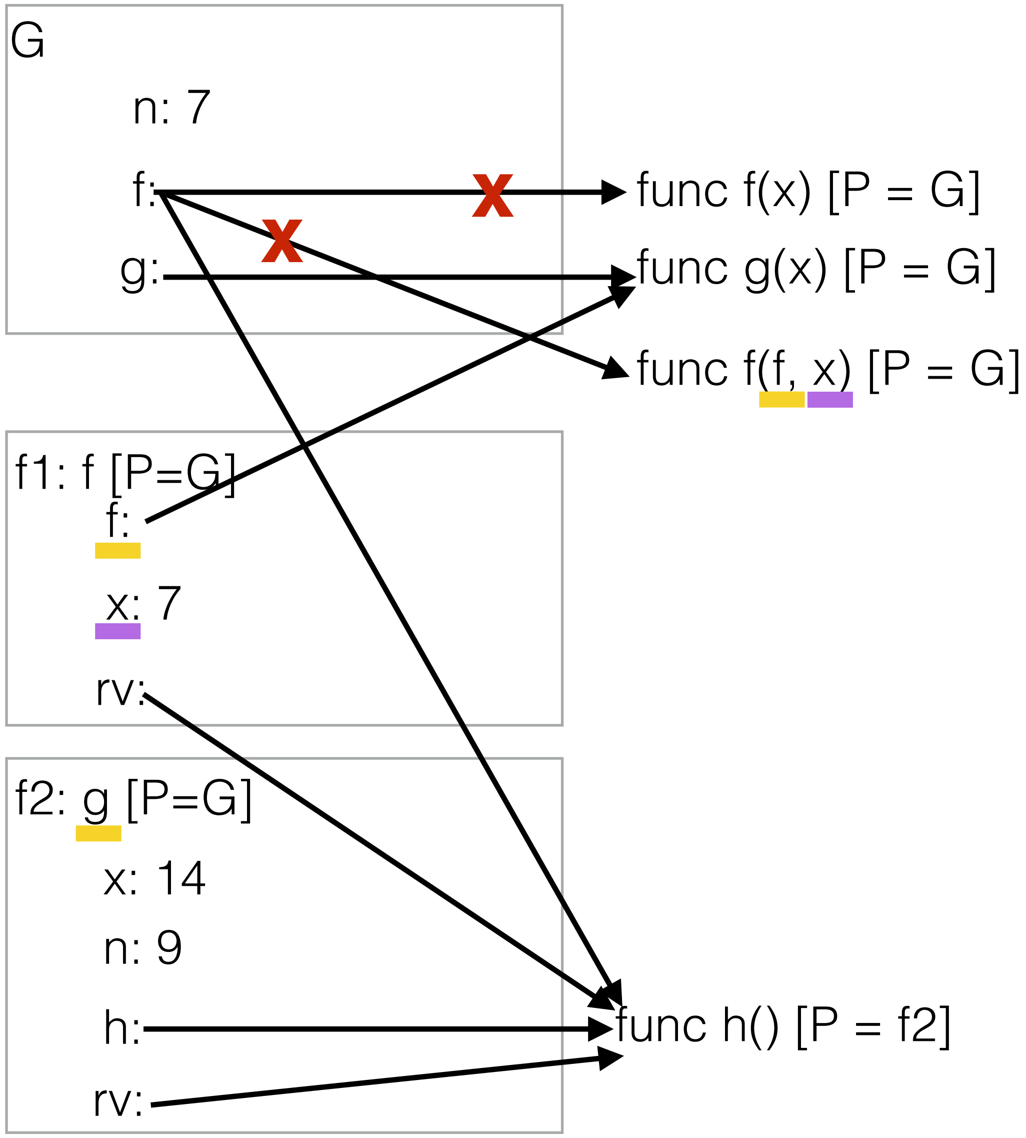
note that x is also just passed in and we must look up n in G

Checkpoint: why is the parent of h, f2?

what type of thing do we return? (hint: what the difference between h and h()?)

what does it mean to evaluate a lambda?



```
n = 7

def f(x):

    n = 8

    return x + 1

def g(x):

    n = 9

    def h():

        return x + 1

    return h

def f(f, x):

    return f(x + n) f2

f = f(g, n)  f1

g = (lambda y: y())(f)
```

assignment statement! Evaluate the RHS, then bind the value to the name on the LHS in the current frame

function call!

evaluate f
look for what the name g is bound to in the current frame
evaluate g
look for what the name g is bound to in the current frame
evaluate n
look for what the name n is bound to in the current frame
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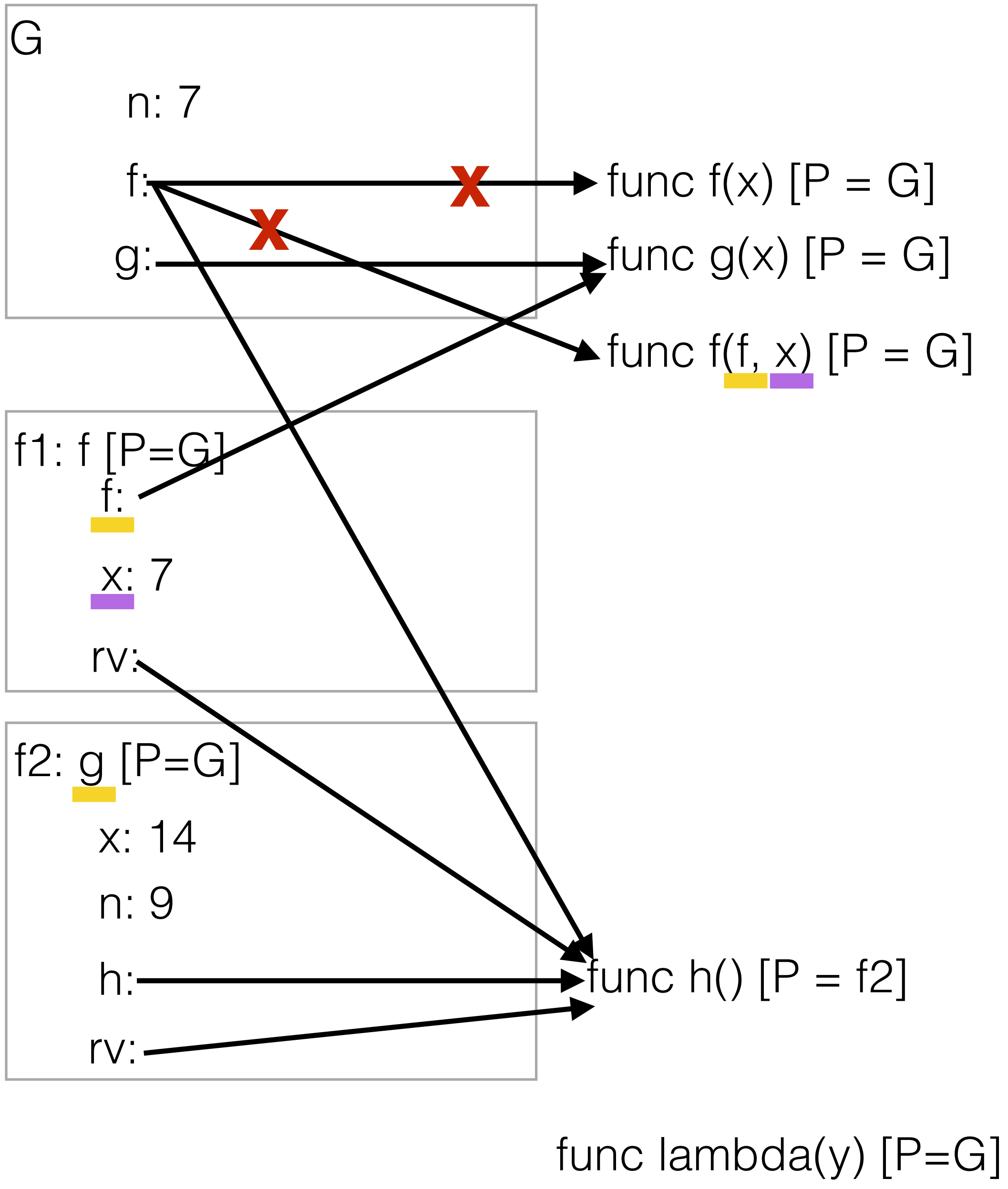
Checkpoint: why is the parent of h, f2?

what type of thing do we return? (hint: what the difference between h and h()?)

what does it mean to evaluate a lambda?



G
n: 7
f:
g:

func f(x) [P = G]
func g(x) [P = G]
func f(f, x) [P = G]

f1: f [P=G]
f:
x: 7
rv:

f2: g [P=G]
x: 14
n: 9
h:
rv:

func h() [P = f2]

func lambda(y) [P=G]

```
n = 7
def f(x):
    n = 8
    return x + 1
def g(x):
    n = 9
    def h():
        return x + 1
    return h
def f(f, x):
    return f(x + n)  f2
f = f(g, n)  f1
g = (lambda y: y())(f)
```

assignment statement! Evaluate the RHS, then bind the value to the name on the LHS in the current frame

function call!

evaluate f
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evaluate g
look for what the name g is bound to in the current frame
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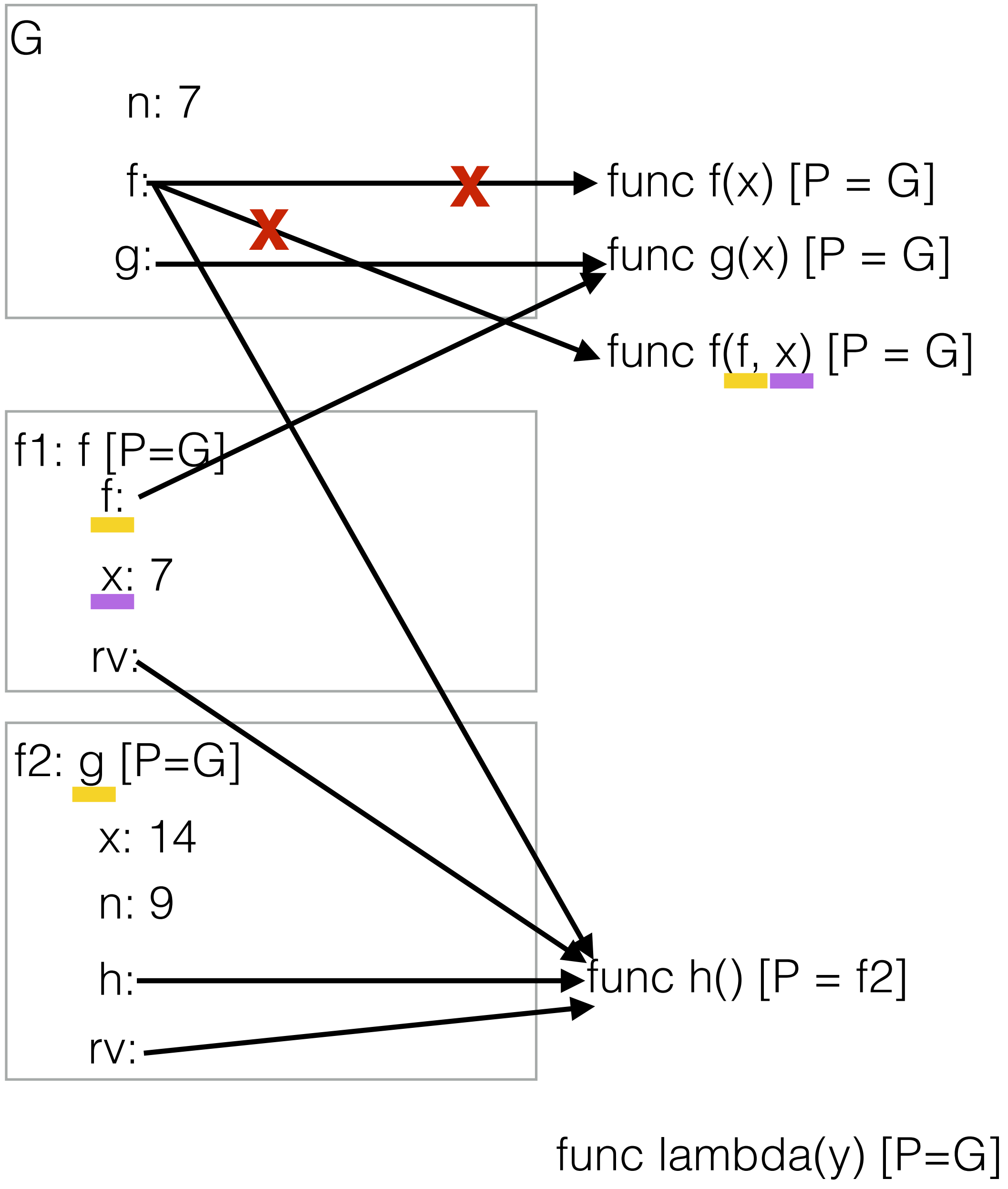
note that x is also just passed in and we must look up n in G

Checkpoint: why is the parent of h, f2?

what type of thing do we return? (hint: what the difference between h and h()?)

what does it mean to evaluate a lambda?
we just assigned f to point to the function h, so we pass in the function h as y



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n = 7

def f(x):

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    n = 9

    def h():

        return x + 1

    return h

def f(f, x):

    return f(x + n) f2

f = f(g, n)   f1

g = (lambda y: y())(f)
```

assignment statement! Evaluate the RHS, then bind the value to the name on the LHS in the current frame

function call!

evaluate f
look for what the name g is bound to in the current frame
evaluate g
look for what the name g is bound to in the current frame
evaluate n
look for what the name n is bound to in the current frame
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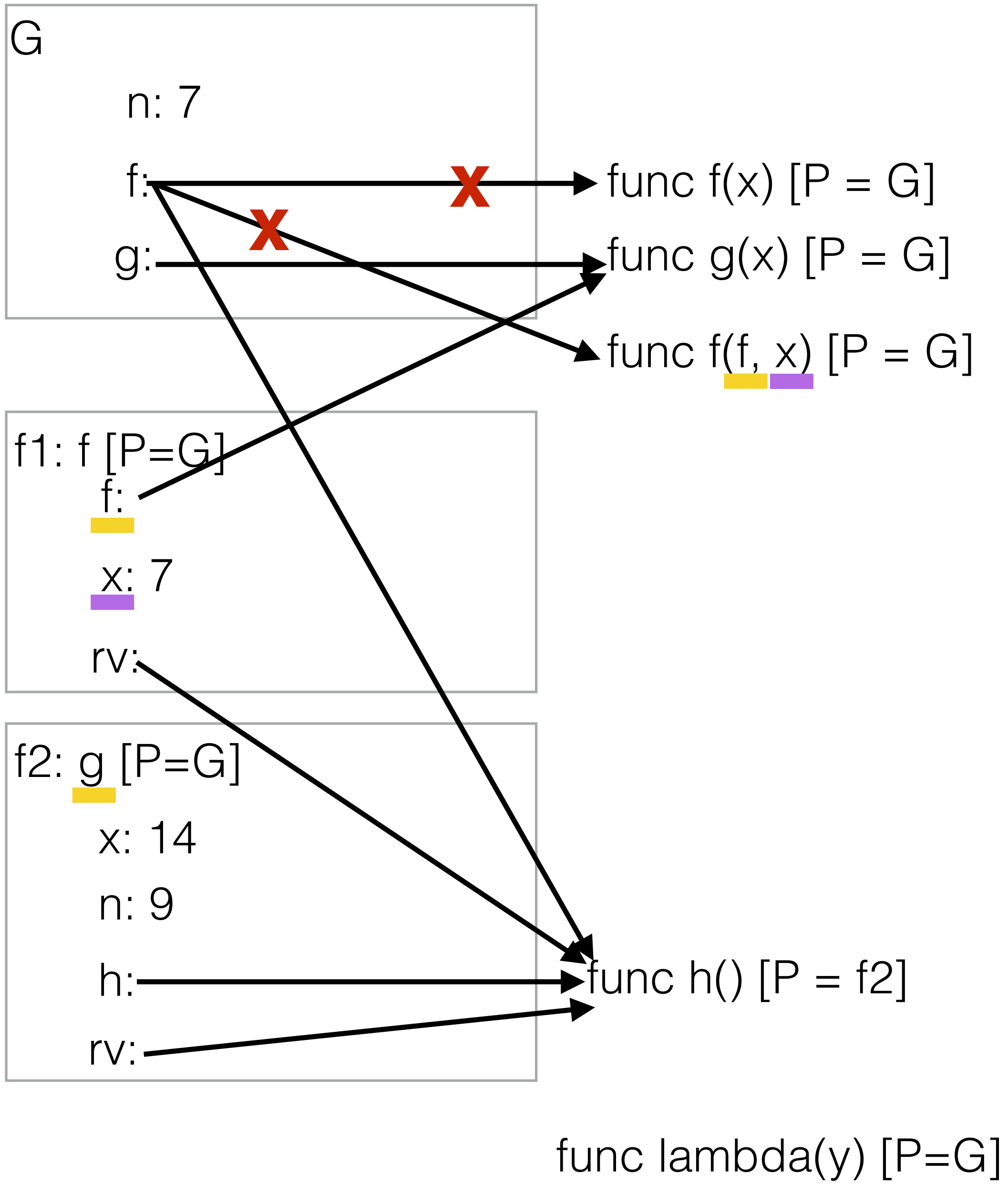
we just assigned f to point to the function h, so we pass in the function h as y
Checkpoint: why is lambda's parent G?



```
n = 7

def f(x):

    n = 8

    return x + 1

def g(x):

    n = 9

    def h():

        return x + 1

    return h

def f(f, x):

    return f(x + n) f2

f = f(g, n)    f1

g = (lambda y: y())(f)
                   f3
```

assignment statement! Evaluate the RHS, then bind the value to the name on the LHS in the current frame

function call!

evaluate f
look for what the name g is bound to in the current frame
evaluate g
look for what the name g is bound to in the current frame
evaluate n
look for what the name n is bound to in the current frame
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evaluate operator and operands

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note that x is also just passed in and we must look up n in G

Checkpoint: why is the parent of h, f2?

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we just assigned f to point to the function h, so we pass in the function h as y
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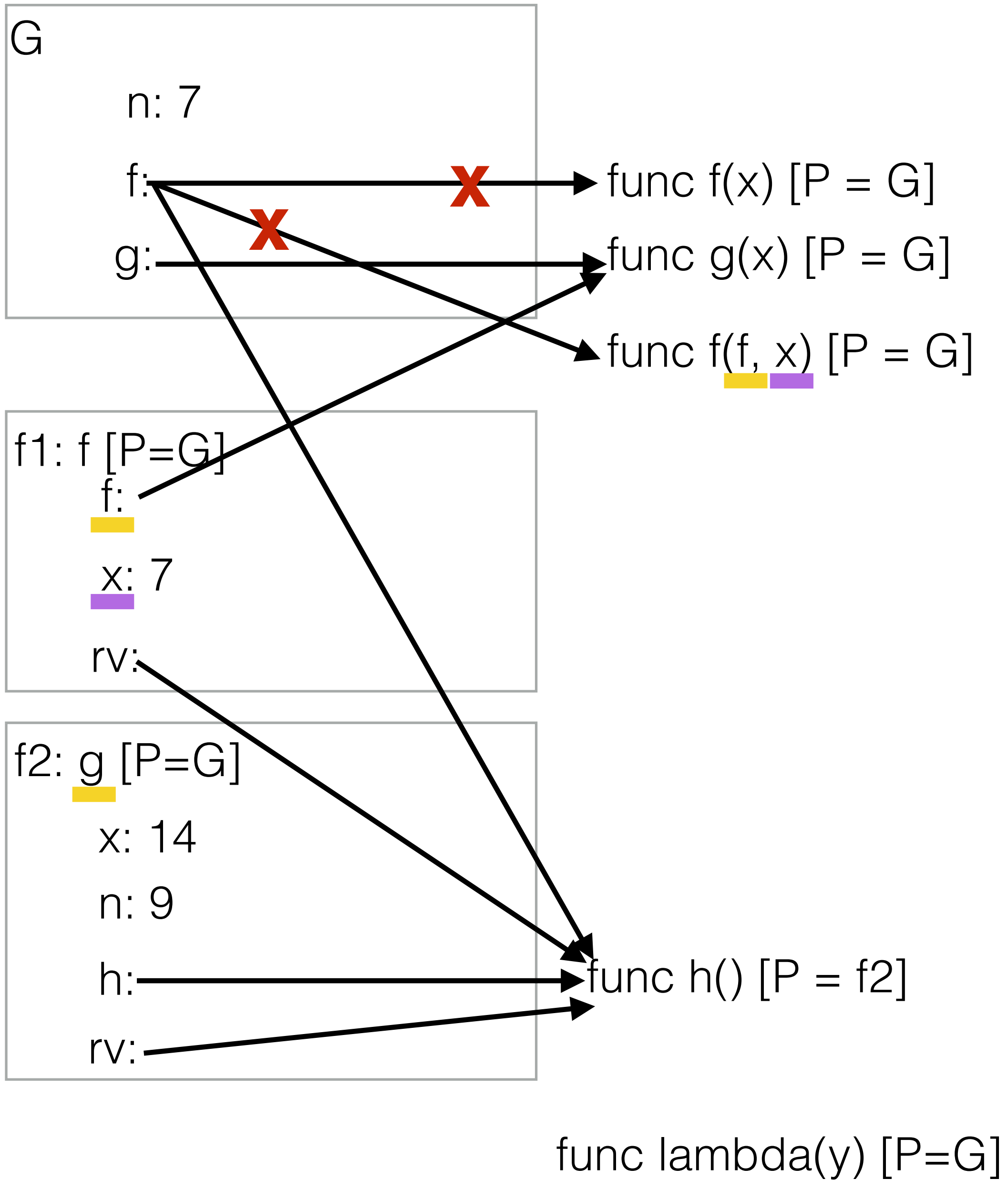


```
n = 7
def f(x):
    n = 8
    return x + 1
def g(x):
    n = 9
    def h():
        return x + 1
    return h
def f(f, x):
    return f(x + n)   f2
f = f(g, n)   f1
g = (lambda y: y())(f)
                     f3
```

assignment statement! Evaluate the RHS, then bind the value to the name on the LHS in the current frame

function call!

evaluate f

look for what the name g is bound to in the current frame

evaluate g

look for what the name g is bound to in the current frame

evaluate n

look for what the name n is bound to in the current frame

DO NOT OPEN A NEW FRAME UNTIL YOU EVALUATE THE OPERATOR AND OPERANDS

Leave an indication that this is where in the code you will come back to after completing the function call

After opening the new frame, bind the parameter names in the function signature (f, x) to the values we just evaluated

whatever this function evaluates to is what we return in f1. leave an indication that this is where you will return to after completing f2

evaluate operator and operands

note that the operator is f, which is the name of the parameter we just passed in

note that x is also just passed in and we must look up n in G

Checkpoint: why is the parent of h, f2?

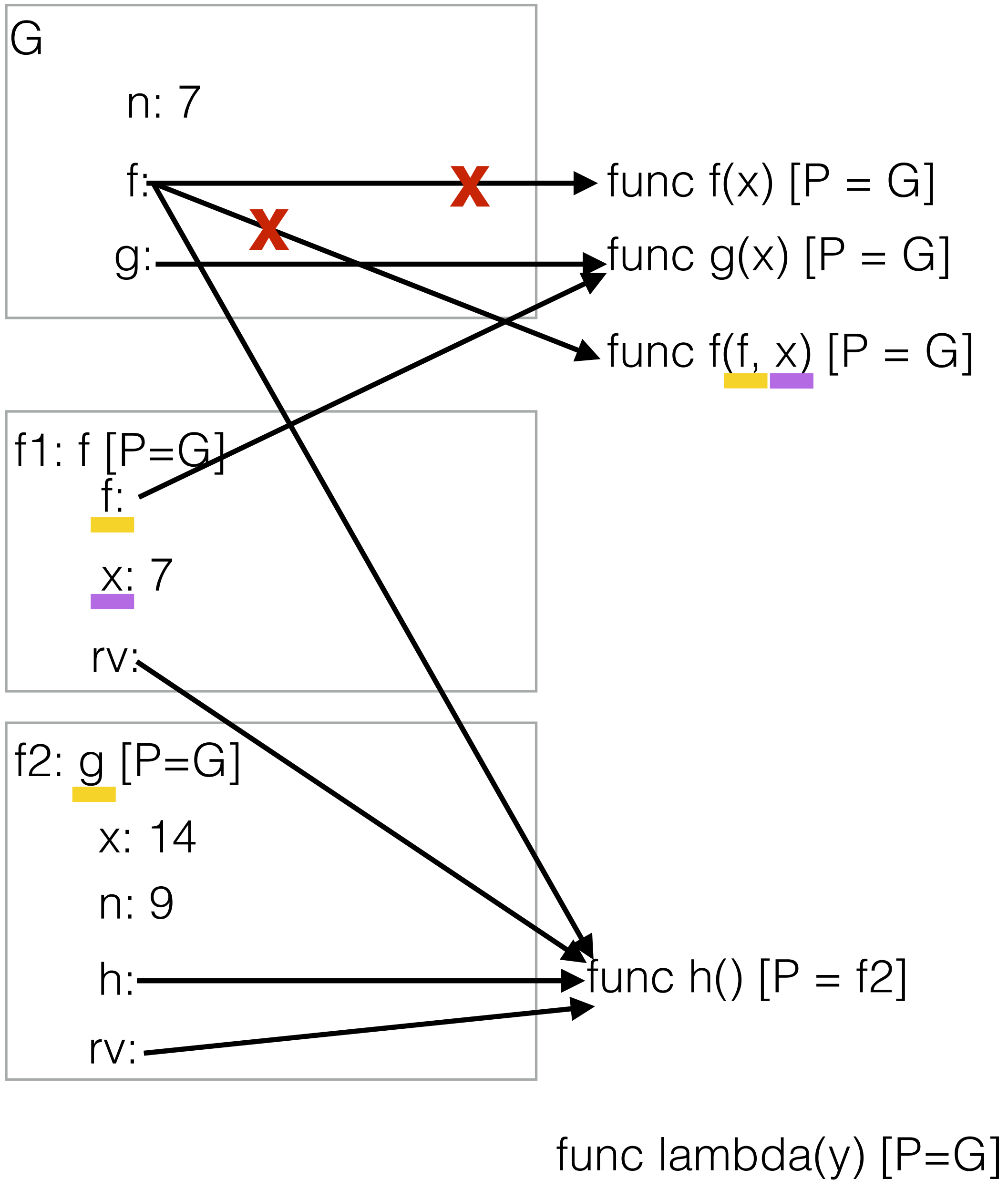
what type of thing do we return? (hint: what the difference between h and h()?)

what does it mean to evaluate a lambda?

we just assigned f to point to the function h, so we pass in the function h as y

Checkpoint: why is lambda's parent G?

we have a function call, leave a mark where to return to once you complete f3



```
n = 7

def f(x):

    n = 8

    return x + 1

def g(x):

    n = 9

    def h():

        return x + 1

    return h

def f(f, x):

    return f(x + n) f2

f = f(g, n)  f1

g = (lambda y: y())(f)
                   f3
```

assignment statement! Evaluate the RHS, then bind the value to the name on the LHS in the current frame

function call!

evaluate f
look for what the name g is bound to in the current frame
evaluate g
look for what the name g is bound to in the current frame
evaluate n
look for what the name n is bound to in the current frame
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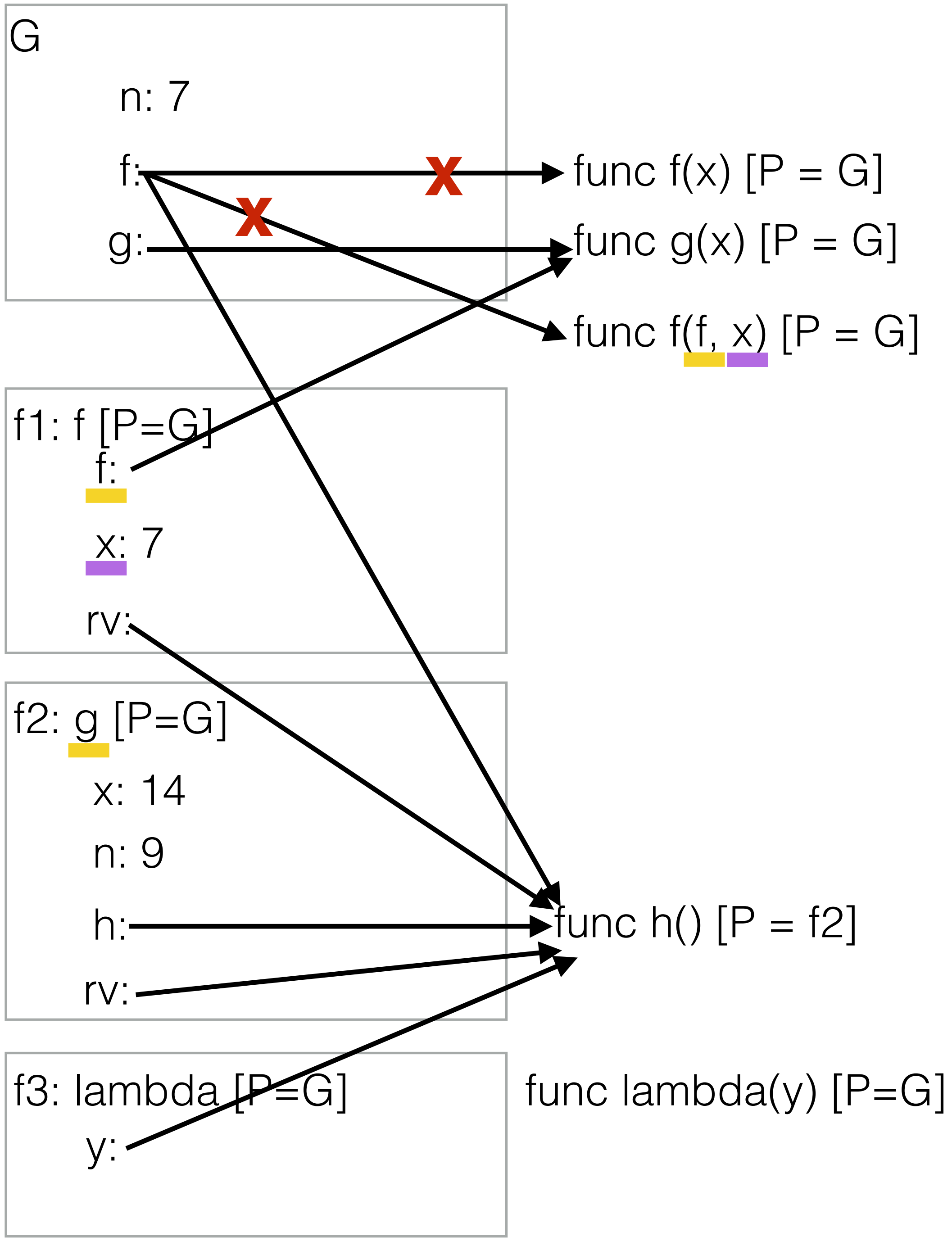
note that x is also just passed in and we must look up n in G

Checkpoint: why is the parent of h, f2?

what type of thing do we return? (hint: what the difference between h and h()?)

what does it mean to evaluate a lambda?
we just assigned f to point to the function h, so we pass in the function h as y
Checkpoint: why is lambda's parent G?
we have a function call, leave a mark where to return to once you complete f3



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n = 7

def f(x):

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    return x + 1

def g(x):

    n = 9

    def h():

        return x + 1

    return h

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f = f(g, n)  f1

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assignment statement! Evaluate the RHS, then bind the value to the name on the LHS in the current frame

function call!

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look for what the name g is bound to in the current frame
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Checkpoint: why is the parent of h, f2?

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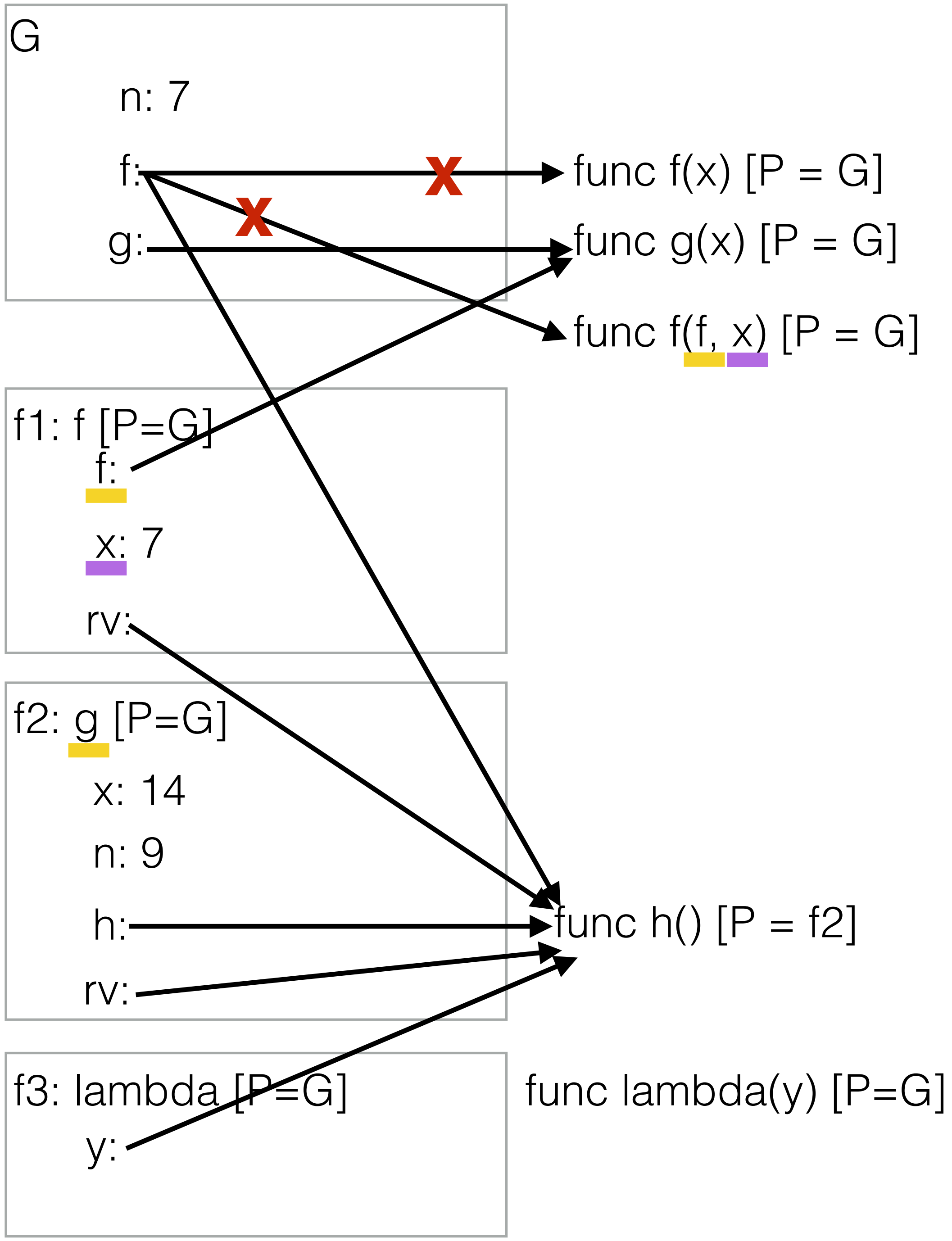
what does this lambda do? whats the body of the lambda? try converting the lambda to a normal def statement



G
n: 7
f:
g:
func f(x) [P = G]
func g(x) [P = G]
func f(f, x) [P = G]

f1: f [P=G]
f:
x: 7
rv:

f2: g [P=G]
x: 14
n: 9
h:
rv:
func h() [P = f2]

f3: lambda [P=G]
y:
func lambda(y) [P=G]

```
n = 7

def f(x):

    n = 8

    return x + 1

def g(x):

    n = 9

    def h():

        return x + 1

    return h

def f(f, x):

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f = f(g, n)  f1

g = (lambda y: y())(f)
                f4  f3
```

assignment statement! Evaluate the RHS, then bind the value to the name on the LHS in the current frame

function call!

evaluate f

look for what the name g is bound to in the current frame

evaluate g

look for what the name g is bound to in the current frame

evaluate n

look for what the name n is bound to in the current frame

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After opening the new frame, bind the parameter names in the function signature (f, x) to the values we just evaluated

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evaluate operator and operands

note that the operator is f, which is the name of the parameter we just passed in

note that x is also just passed in and we must look up n in G

Checkpoint: why is the parent of h, f2?

what type of thing do we return? (hint: what the difference between h and h()?)

what does it mean to evaluate a lambda?

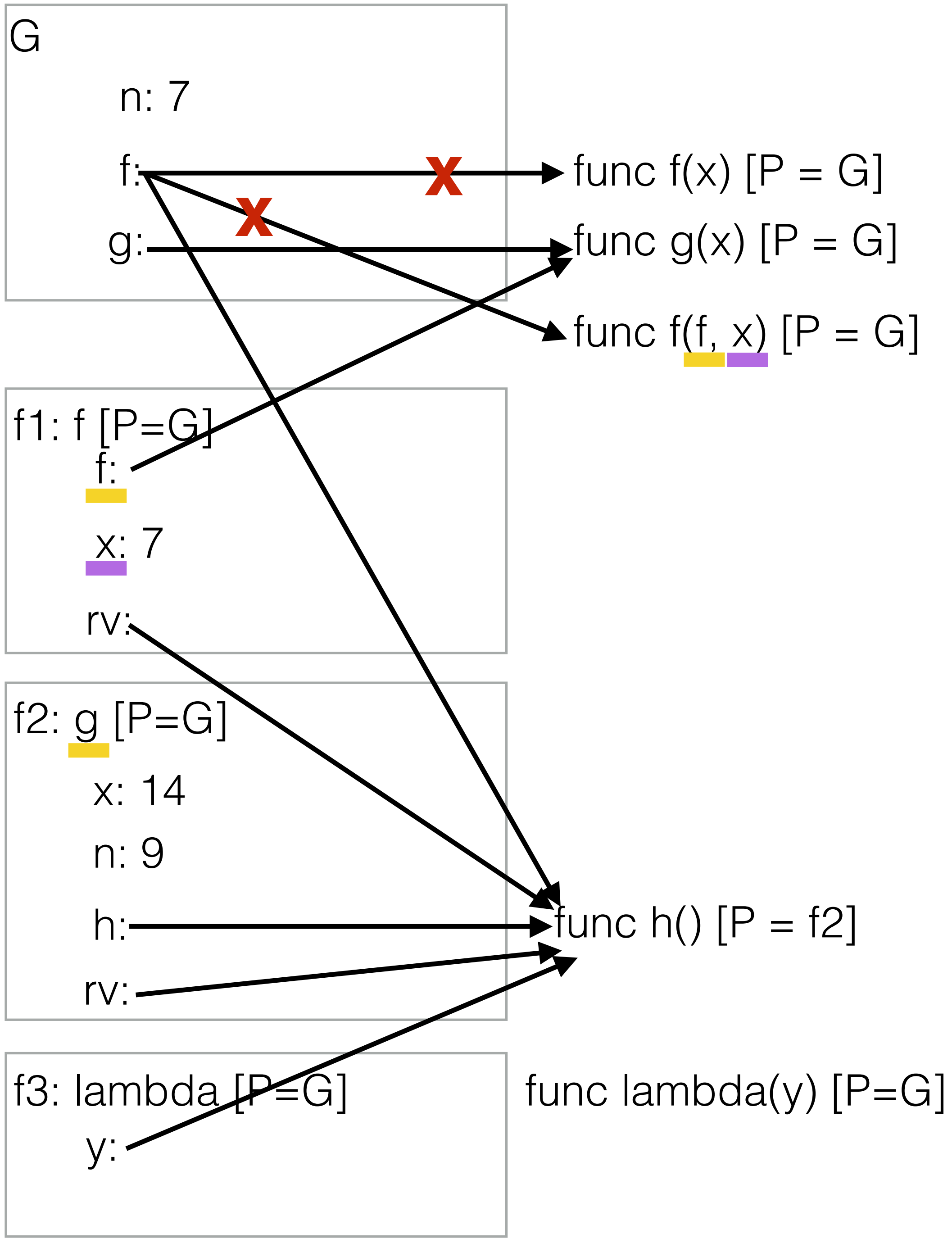
we just assigned f to point to the function h, so we pass in the function h as y

Checkpoint: why is lambda's parent G?

we have a function call, leave a mark where to return to once you complete f3

what does this lambda do? whats the body of the lambda? try converting the lambda to a normal def statement

we have another function call, leave a mark where to return to once you complete f4



```
n = 7

def f(x):

    n = 8

    return x + 1

def g(x):

    n = 9

    def h():

        return x + 1

    return h

def f(f, x):

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f = f(g, n)  f1

g = (lambda y: y())(f)
                 f4   f3
```

assignment statement! Evaluate the RHS, then bind the value to the name on the LHS in the current frame

function call!

evaluate f
look for what the name g is bound to in the current frame
evaluate g
look for what the name g is bound to in the current frame
evaluate n
look for what the name n is bound to in the current frame
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evaluate operator and operands

note that the operator is f, which is the name of the parameter we just passed in
note that x is also just passed in and we must look up n in G

Checkpoint: why is the parent of h, f2?

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what does it mean to evaluate a lambda?
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Checkpoint: why is lambda's parent G?
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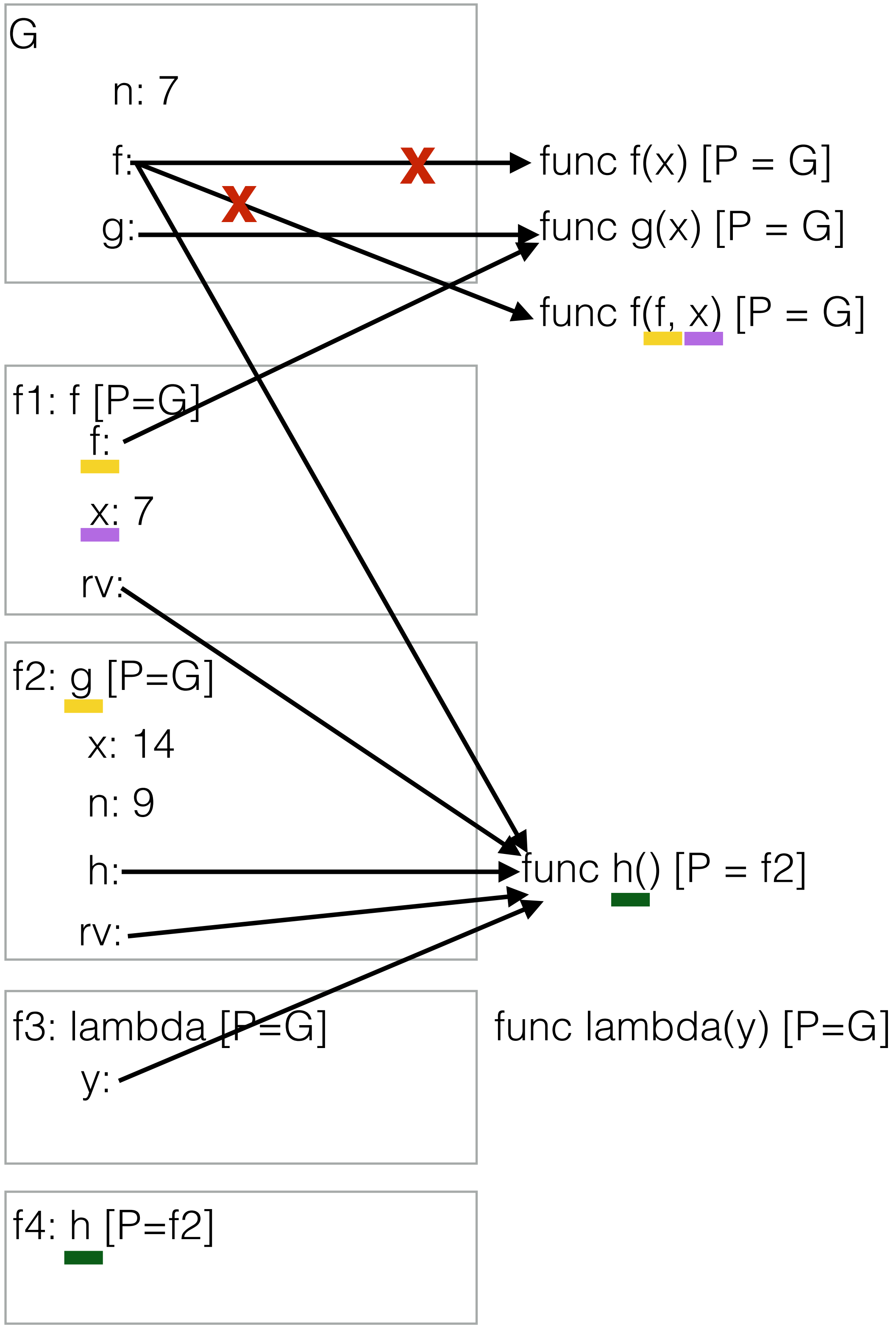
what does this lambda do? whats the body of the lambda? try converting the lambda to a normal def statement

we have another function call, leave a mark where to return to once you complete f4

y is really h, and h just adds x and 1 and returns the sum. we can find x in f2 since that is the parent of h



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def f(x):

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    return x + 1

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    n = 9

    def h():

        return x + 1

    return h

def f(f, x):

    return f(x + n) f2

f = f(g, n)  f1

g = (lambda y: y())(f)
                 f4   f3
```

assignment statement! Evaluate the RHS, then bind the value to the name on the LHS in the current frame

function call!

evaluate f
look for what the name g is bound to in the current frame
evaluate g
look for what the name g is bound to in the current frame
evaluate n
look for what the name n is bound to in the current frame
DO NOT OPEN A NEW FRAME UNTIL YOU EVALUATE THE OPERATOR AND OPERANDS

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After opening the new frame, bind the parameter names in the function signature (f, x) to the values we just evaluated
whatever this function evaluates to is what we return in f1. leave an indication that this is where you will return to after completing f2
evaluate operator and operands
note that the operator is f, which is the name of the parameter we just passed in
note that x is also just passed in and we must look up n in G

Checkpoint: why is the parent of h, f2?

what type of thing do we return? (hint: what the difference between h and h()?)
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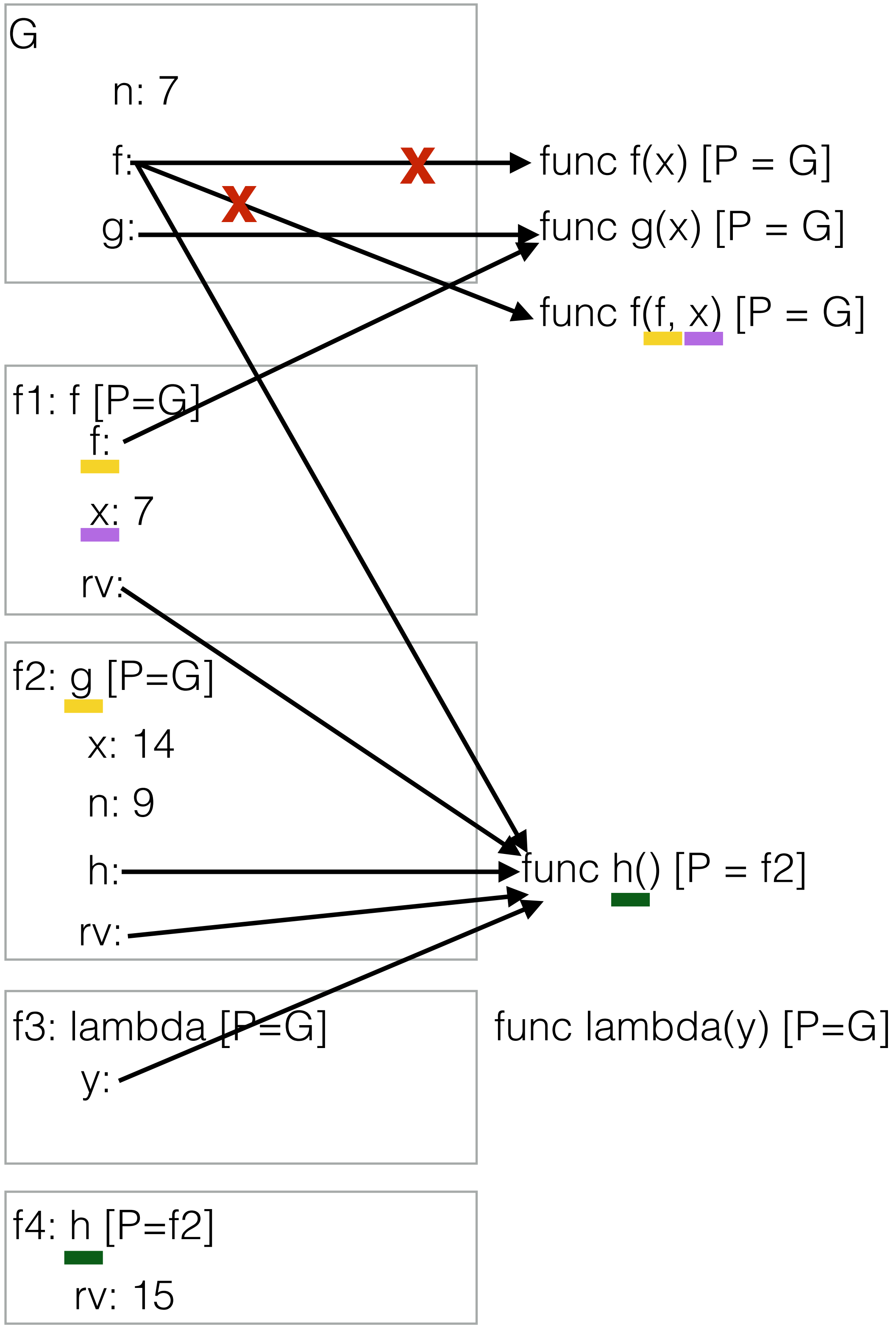

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    n = 9
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    return h
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    return f(x + n) f2
f = f(g, n)  f1
g = (lambda y: y())(f)
               f4   f3
```

assignment statement! Evaluate the RHS, then bind the value to the name on the LHS in the current frame

function call!

evaluate f

look for what the name g is bound to in the current frame

evaluate g

look for what the name g is bound to in the current frame

evaluate n

look for what the name n is bound to in the current frame

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Leave an indication that this is where in the code you will come back to after completing the function call

After opening the new frame, bind the parameter names in the function signature (f, x) to the values we just evaluated

whatever this function evaluates to is what we return in f1. leave an indication that this is where you will return to after completing f2

evaluate operator and operands

note that the operator is f, which is the name of the parameter we just passed in

note that x is also just passed in and we must look up n in G

Checkpoint: why is the parent of h, f2?

what type of thing do we return? (hint: what the difference between h and h()?)

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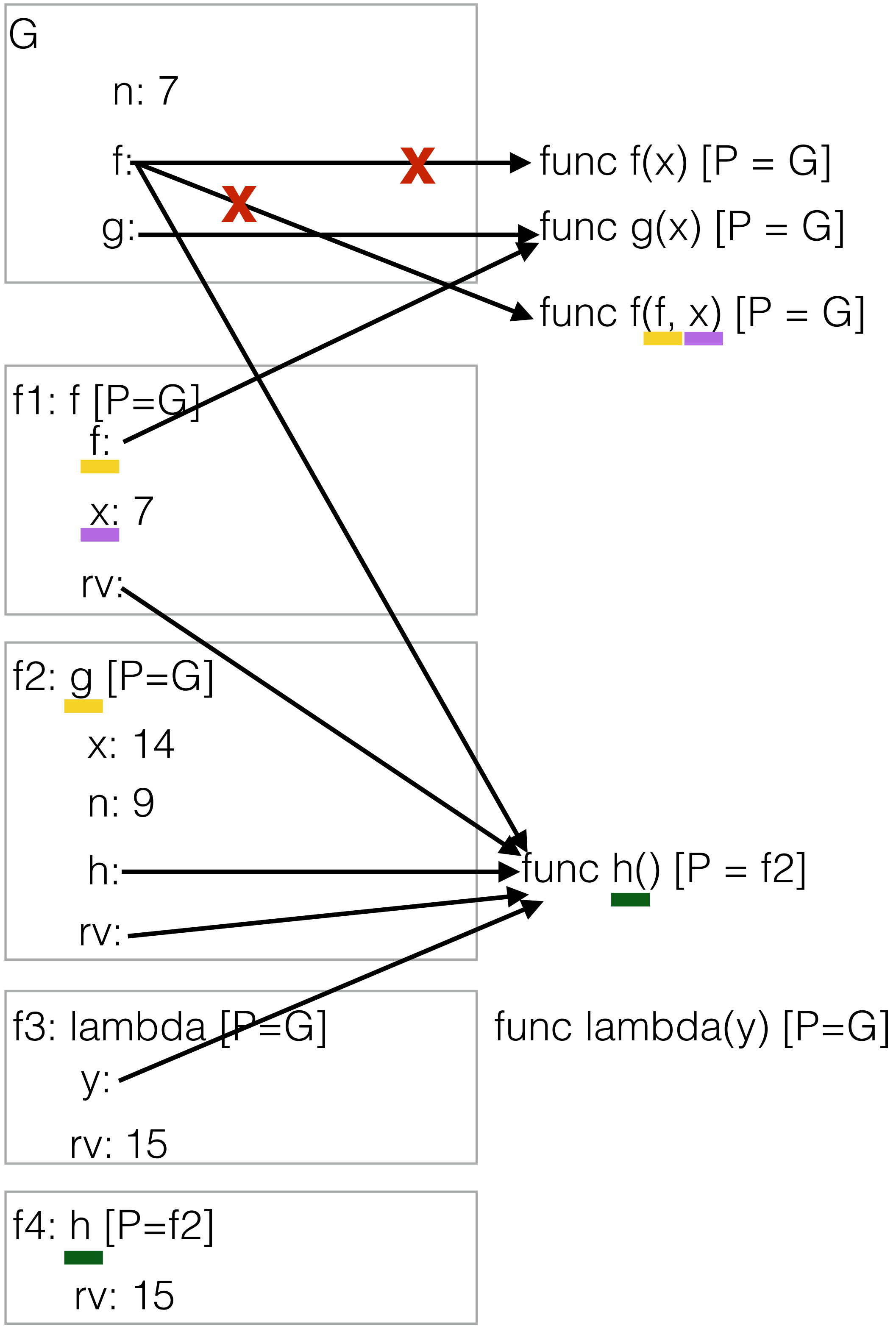


G
n: 7
f:
g:

func f(x) [P = G]
func g(x) [P = G]
func f(f, x) [P = G]

f1: f [P=G]
f:
x: 7
rv:

f2: g [P=G]
x: 14
n: 9
h:
rv:

func h() [P = f2]

f3: lambda [P=G]
y:
rv: 15

func lambda(y) [P=G]

f4: h [P=f2]
rv: 15

```
n = 7
def f(x):
    n = 8
    return x + 1
def g(x):
    n = 9
    def h():
        return x + 1
    return h
def f(f, x):
    return f(x + n)
f = f(g, n)
g = (lambda y: y())(f)
```

f2

f1

f4 f3

assignment statement! Evaluate the RHS, then bind the value to the name on the LHS in the current frame

function call!

evaluate f

look for what the name g is bound to in the current frame

evaluate g

look for what the name g is bound to in the current frame

evaluate n

look for what the name n is bound to in the current frame

DO NOT OPEN A NEW FRAME UNTIL YOU EVALUATE THE OPERATOR AND OPERANDS

Leave an indication that this is where in the code you will come back to after completing the function call

After opening the new frame, bind the parameter names in the function signature (f, x) to the values we just evaluated

whatever this function evaluates to is what we return in f1. leave an indication that this is where you will return to after completing f2

evaluate operator and operands

note that the operator is f, which is the name of the parameter we just passed in

note that x is also just passed in and we must look up n in G

Checkpoint: why is the parent of h, f2?

what type of thing do we return? (hint: what the difference between h and h()?)

what does it mean to evaluate a lambda?

we just assigned f to point to the function h, so we pass in the function h as y

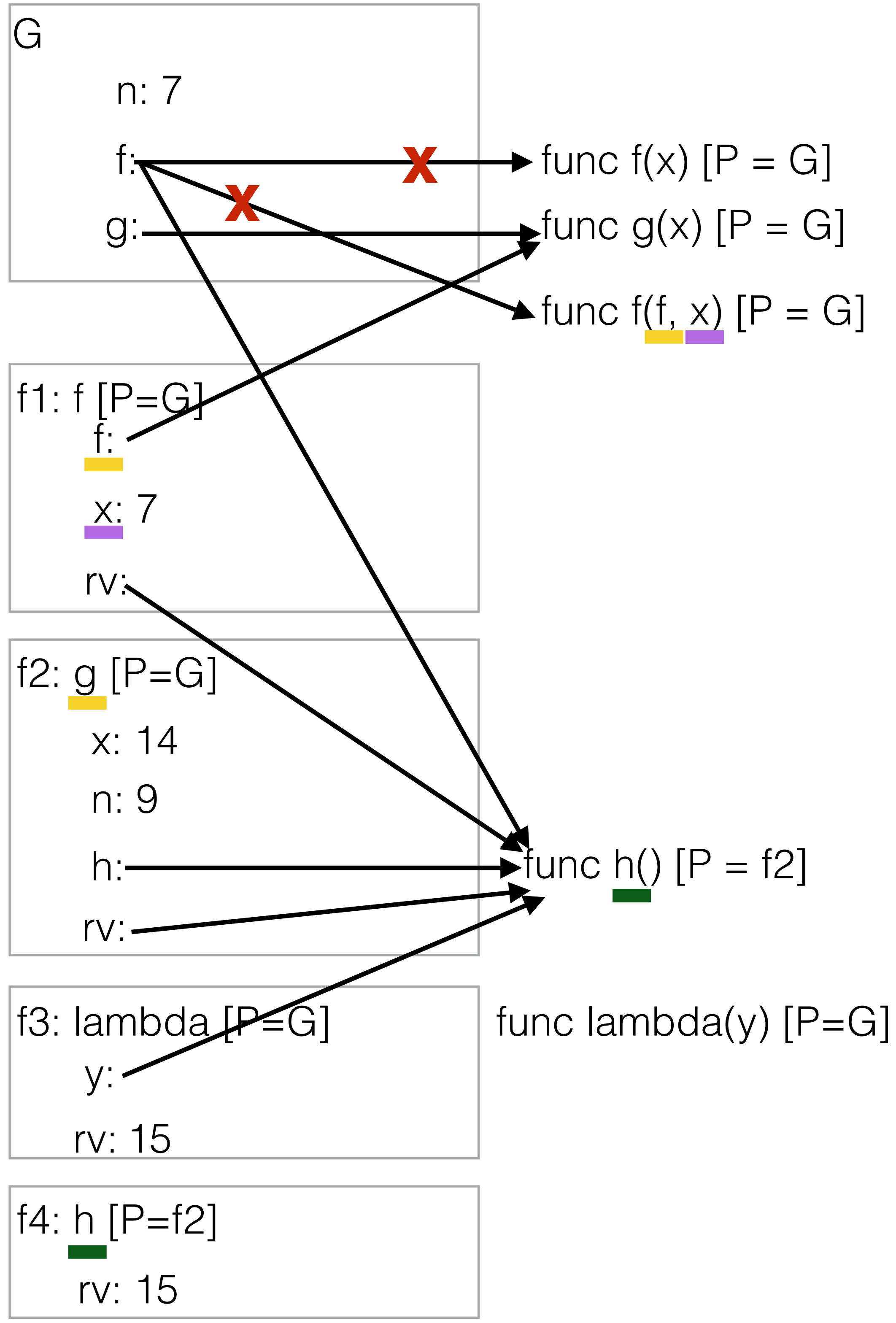
Checkpoint: why is lambda's parent G?

we have a function call, leave a mark where to return to once you complete f3

what does this lambda do? whats the body of the lambda? try converting the lambda to a normal def statement

we have another function call, leave a mark where to return to once you complete f4

y is really h, and h just adds x and 1 and returns the sum. we can find x in f2 since that is the parent of h



remember to return back to where we left marks. the last thing to do is assign the value of the function call to the name g in G

```
n = 7

def f(x):

    n = 8

    return x + 1

def g(x):

    n = 9

    def h():

        return x + 1

    return h

def f(f, x):

    return f(x + n) f2

f = f(g, n)  f1

g = (lambda y: y())(f)
                f4    f3
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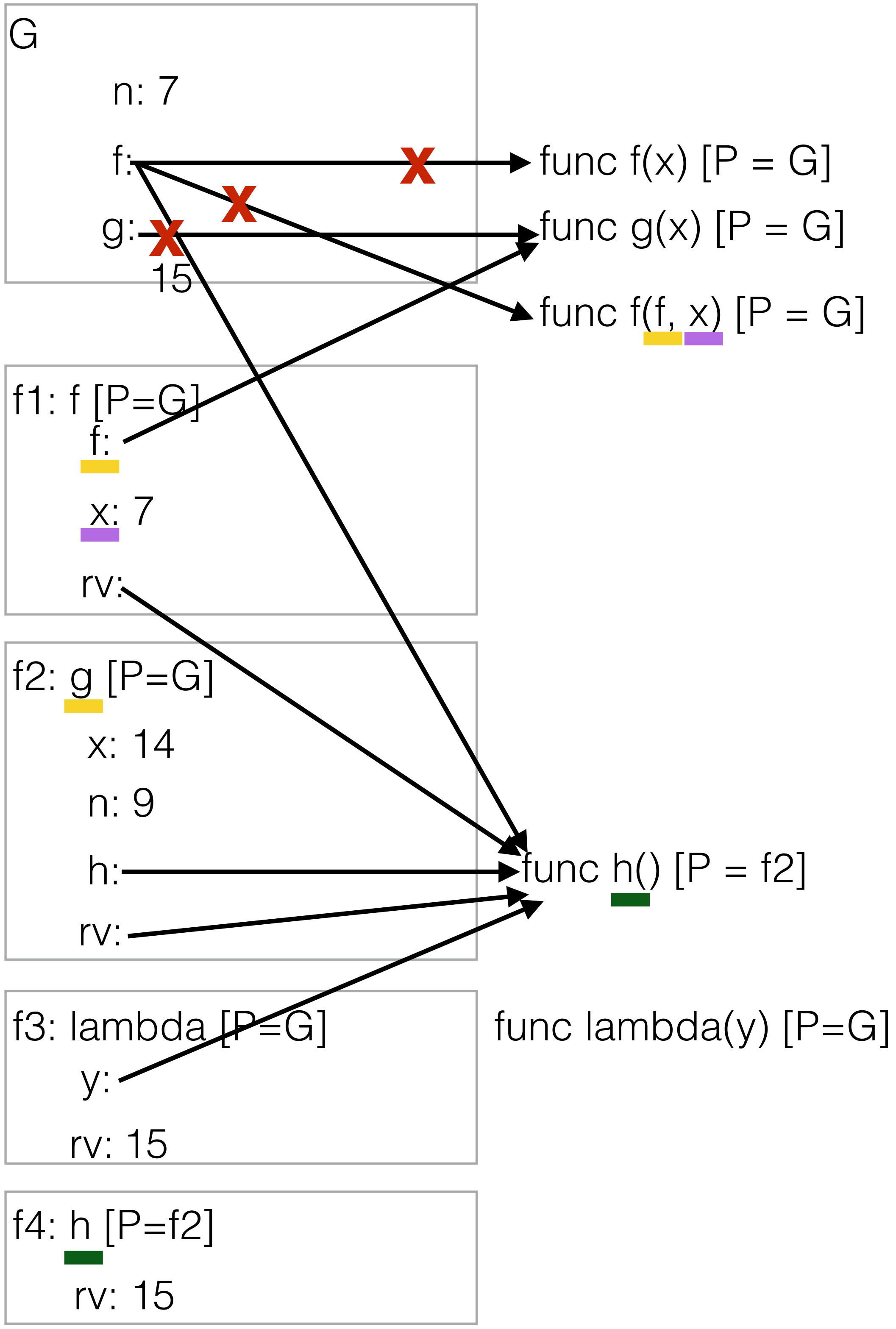

G
n: 7
f:
g:
15
func f(x) [P = G]
func g(x) [P = G]
func f(f, x) [P = G]

f1: f [P=G]
f:
x: 7
rv:

f2: g [P=G]
x: 14
n: 9
h:
rv:
func h() [P = f2]

f3: lambda [P=G]
y:
rv: 15
func lambda(y) [P=G]

f4: h [P=f2]
rv: 15

remember to return back to where we left marks. the last thing to do is assign the value of the function call to the name g in G

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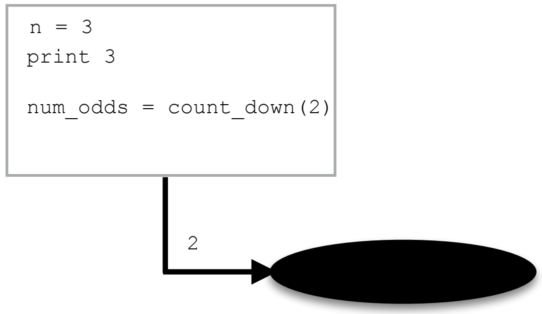

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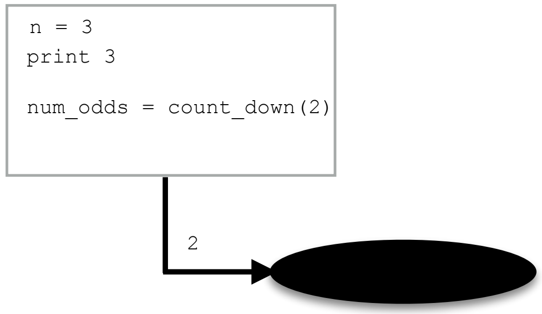

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n = 3
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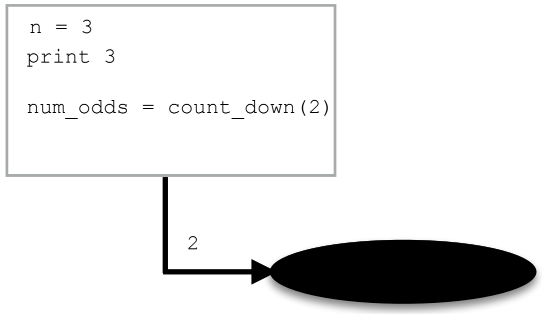

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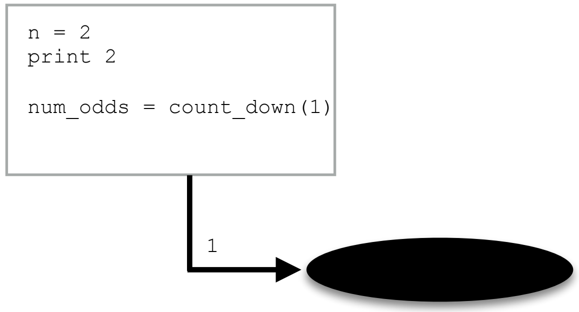

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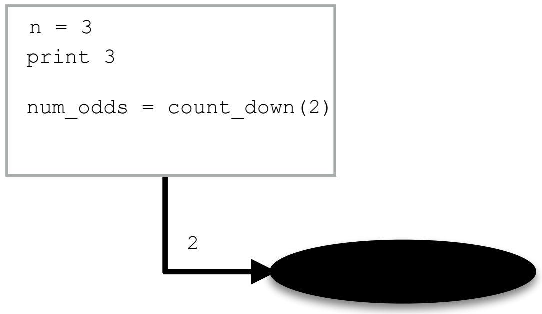

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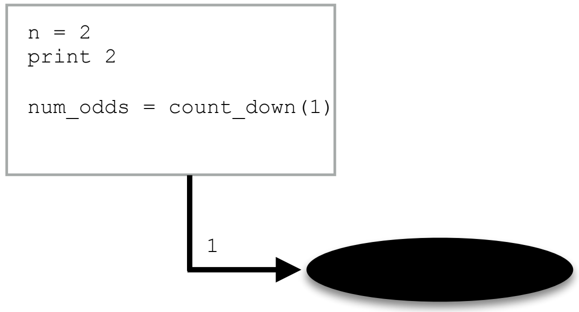

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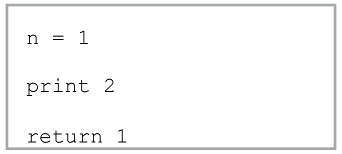

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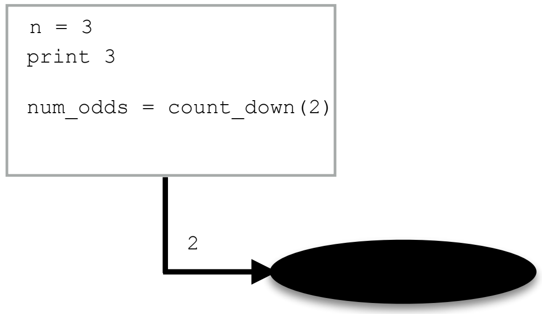
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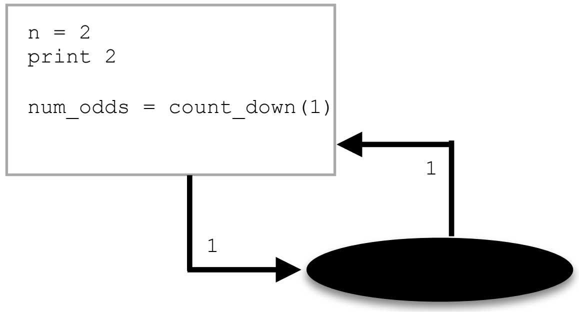
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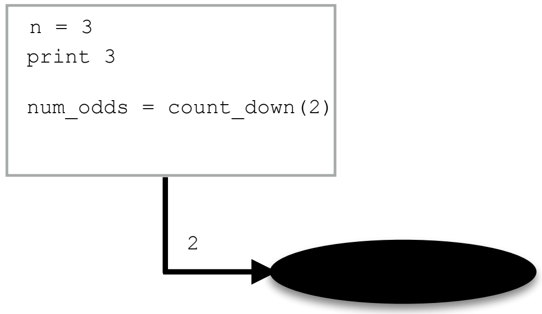
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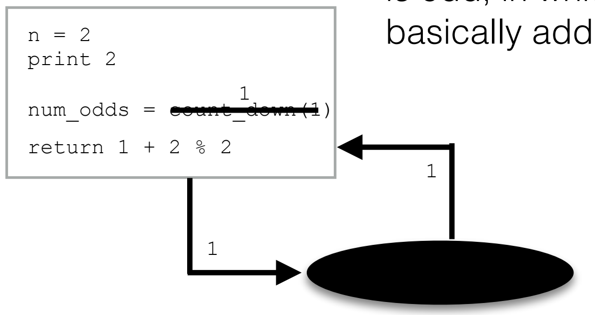
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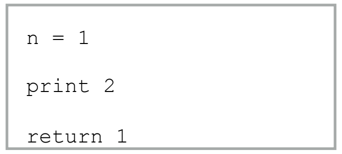
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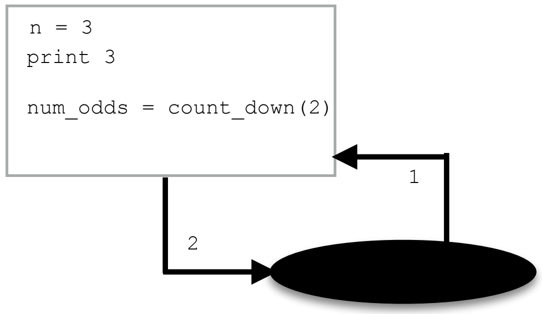

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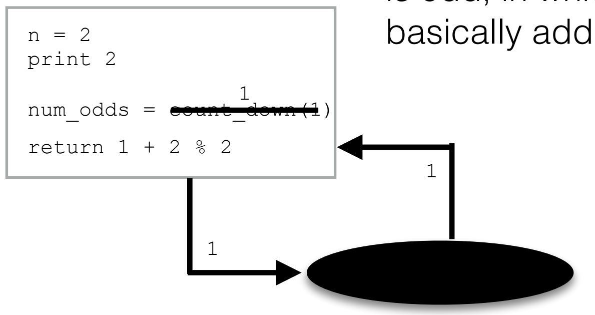

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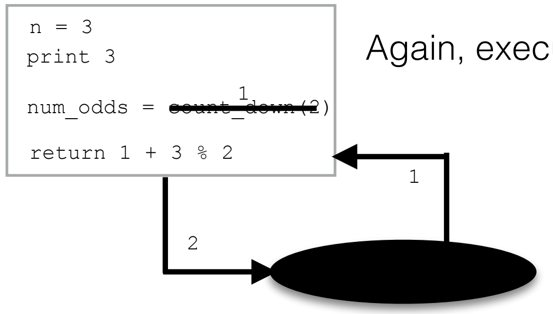

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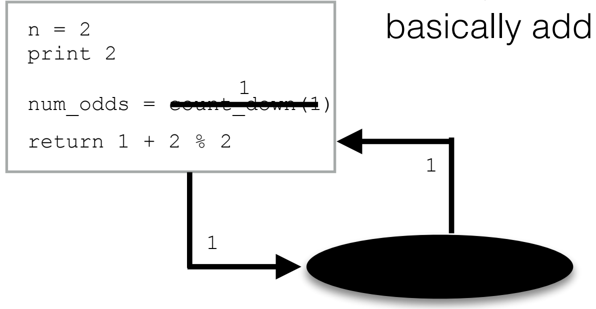

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