61A Lecture 11

Friday, September 23

A Function with Behavior That Varies Over Time

```
Let's model a bank account that has a balance of $100
```

A Function with Behavior That Varies Over Time

Let's model a bank account that has a balance of $100

```
>>> withdraw(25)
```

Argument:
amount to withdraw

A Function with Behavior That Varies Over Time

Let's model a bank account that has a balance of $100

Return value:
remaining balance

```
>>> withdraw(25)
75
```

Argument:
amount to withdraw

A Function with Behavior That Varies Over Time

Let's model a bank account that has a balance of $100

Return value:
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>>> withdraw(25)
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Argument:
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```
>>> withdraw(25)
```

Second withdrawal
of the same amount

A Function with Behavior That Varies Over Time

Let's model a bank account that has a balance of $100

Return value: remaining balance

```
>>> withdraw(25)
75
```

Argument: amount to withdraw

Different return value!

```
>>> withdraw(25)
50
```

Second withdrawal of the same amount

A Function with Behavior That Varies Over Time

Let's model a bank account that has a balance of $100

Return value:
remaining balance

Different
return value!

```
>>> withdraw(25)
75

>>> withdraw(25)
50

>>> withdraw(60)
```

Argument:
amount to withdraw

Second withdrawal
of the same amount

A Function with Behavior That Varies Over Time

Let's model a bank account that has a balance of $100

Return value: remaining balance

Argument: amount to withdraw

```
>>> withdraw(25)
75

>>> withdraw(25)
50

>>> withdraw(60)
'Insufficient funds'
```

Different return value!

Second withdrawal of the same amount

A Function with Behavior That Varies Over Time

Let's model a bank account that has a balance of $100

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>>> withdraw(25)
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>>> withdraw(25)
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'Insufficient funds'

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Return value: remaining balance

Argument: amount to withdraw

Different return value!

Second withdrawal of the same amount

A Function with Behavior That Varies Over Time

Let's model a bank account that has a balance of $100

Return value: remaining balance

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'Insufficient funds'

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Different return value!

Second withdrawal of the same amount

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Second withdrawal of the same amount

Where's this balance stored?

A Function with Behavior That Varies Over Time

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Different return value!

Second withdrawal of the same amount

Where's this balance stored?

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>>> withdraw = make_withdraw(100)
```

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Return value: remaining balance

Argument: amount to withdraw

Different return value!

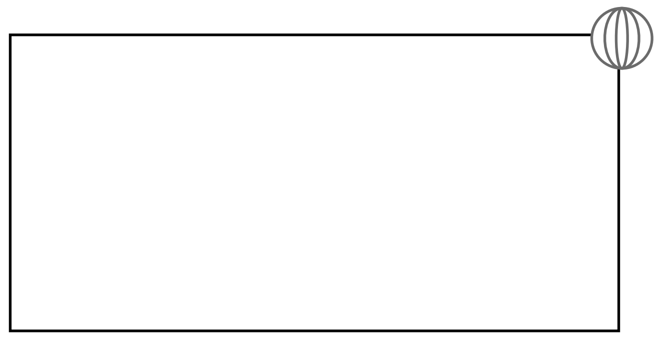
Second withdrawal of the same amount

Where's this balance stored?

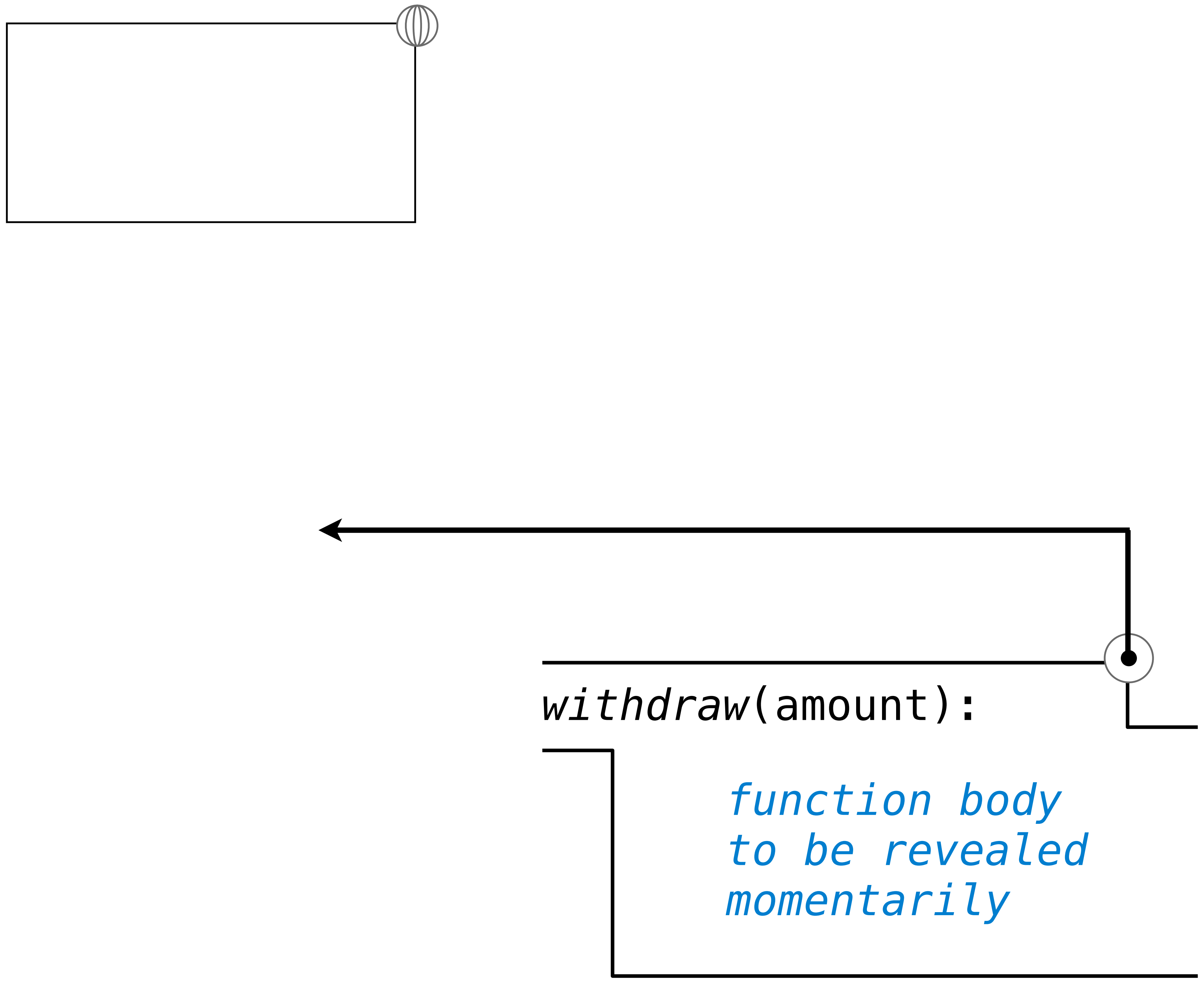
```
>>> withdraw = make_withdraw(100)
```

Within the function!

Persistent Local State



Persistent Local State



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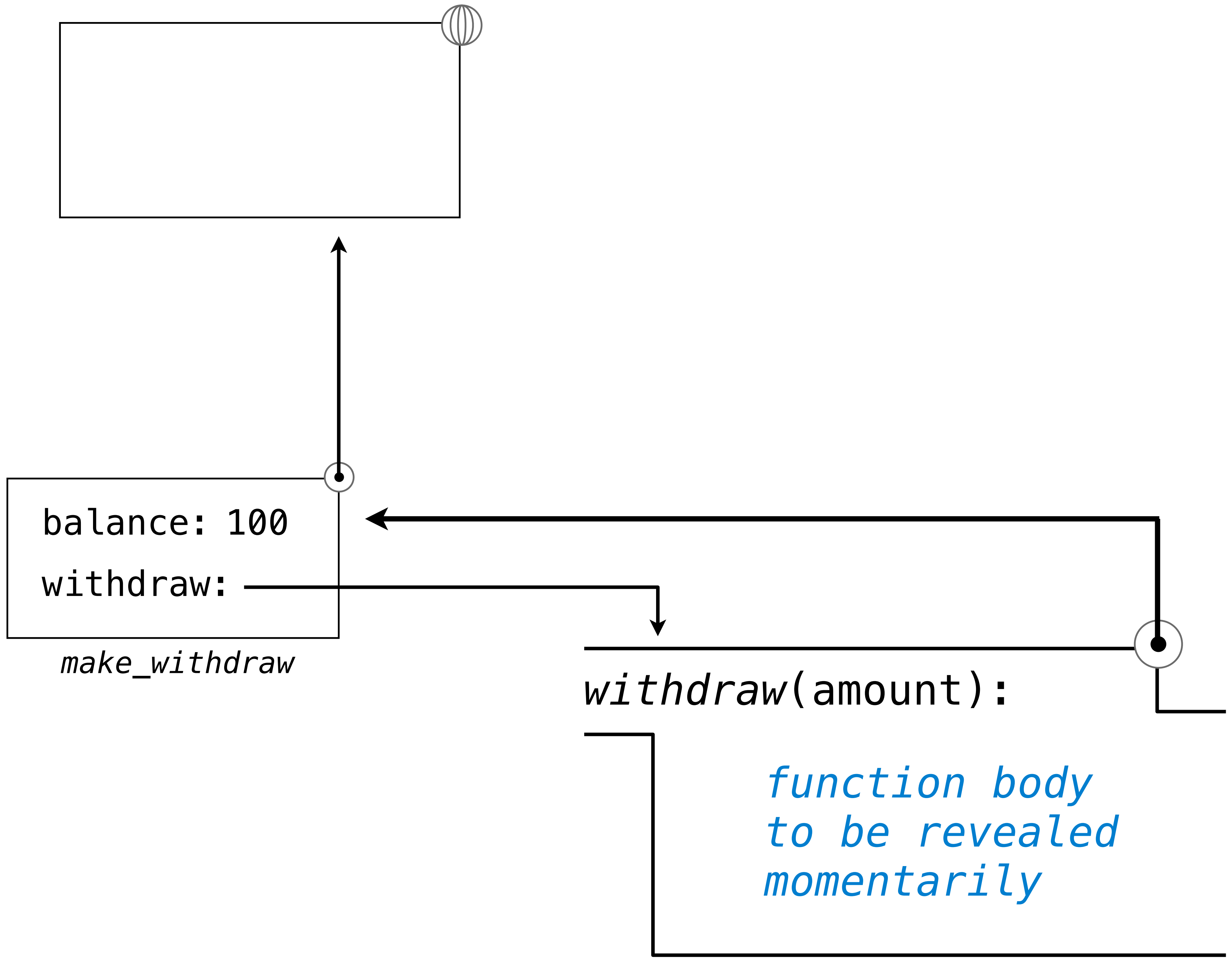

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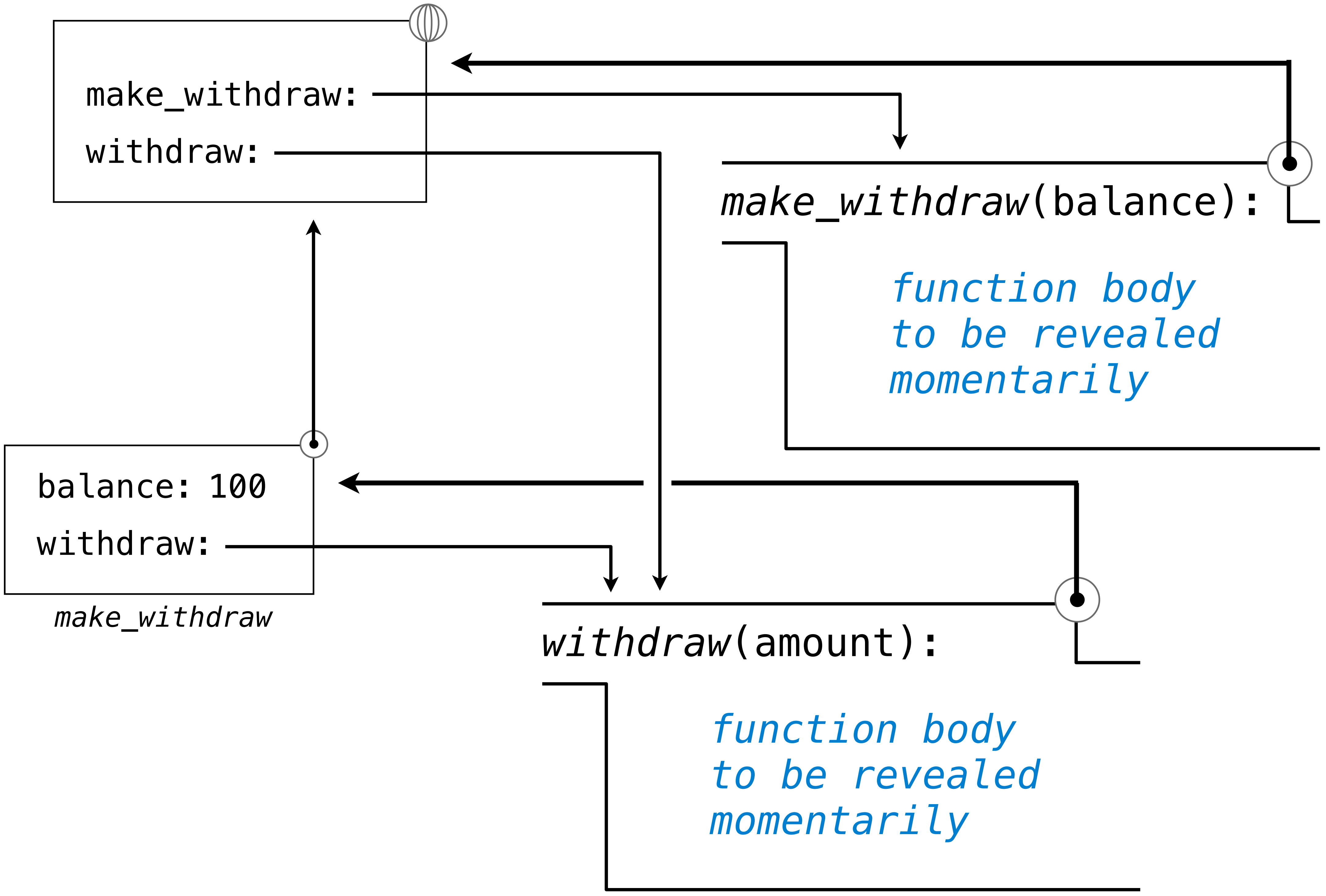

Local State via Non-Local Assignment

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def make_withdraw(balance):
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    """Return a withdraw function with a starting balance."""
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Declare the name "balance" nonlocal

Local State via Non-Local Assignment

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def make_withdraw(balance):
    """Return a withdraw function with a starting balance."""
    def withdraw(amount):
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        if amount > balance:
```

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Local State via Non-Local Assignment

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def make_withdraw(balance):
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    def withdraw(amount):
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        if amount > balance:
            return 'Insufficient funds'
        balance = balance - amount
```

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Re-bind balance where it was bound previously

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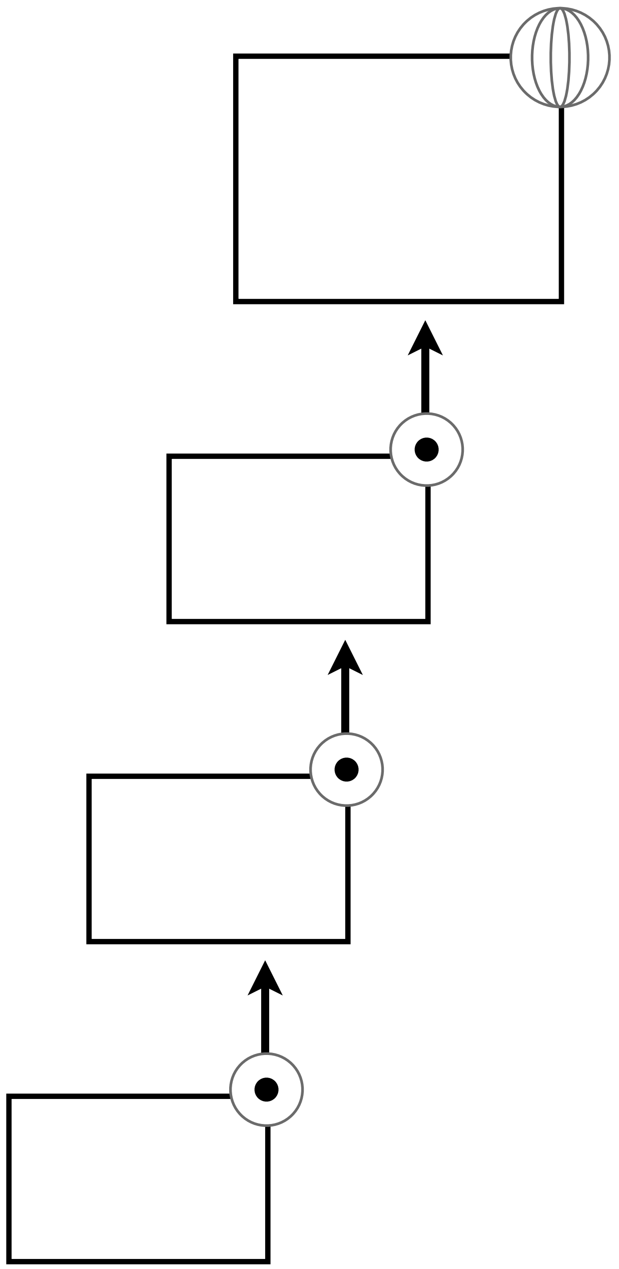
Demo

Local, Non-Local, and Global Frames



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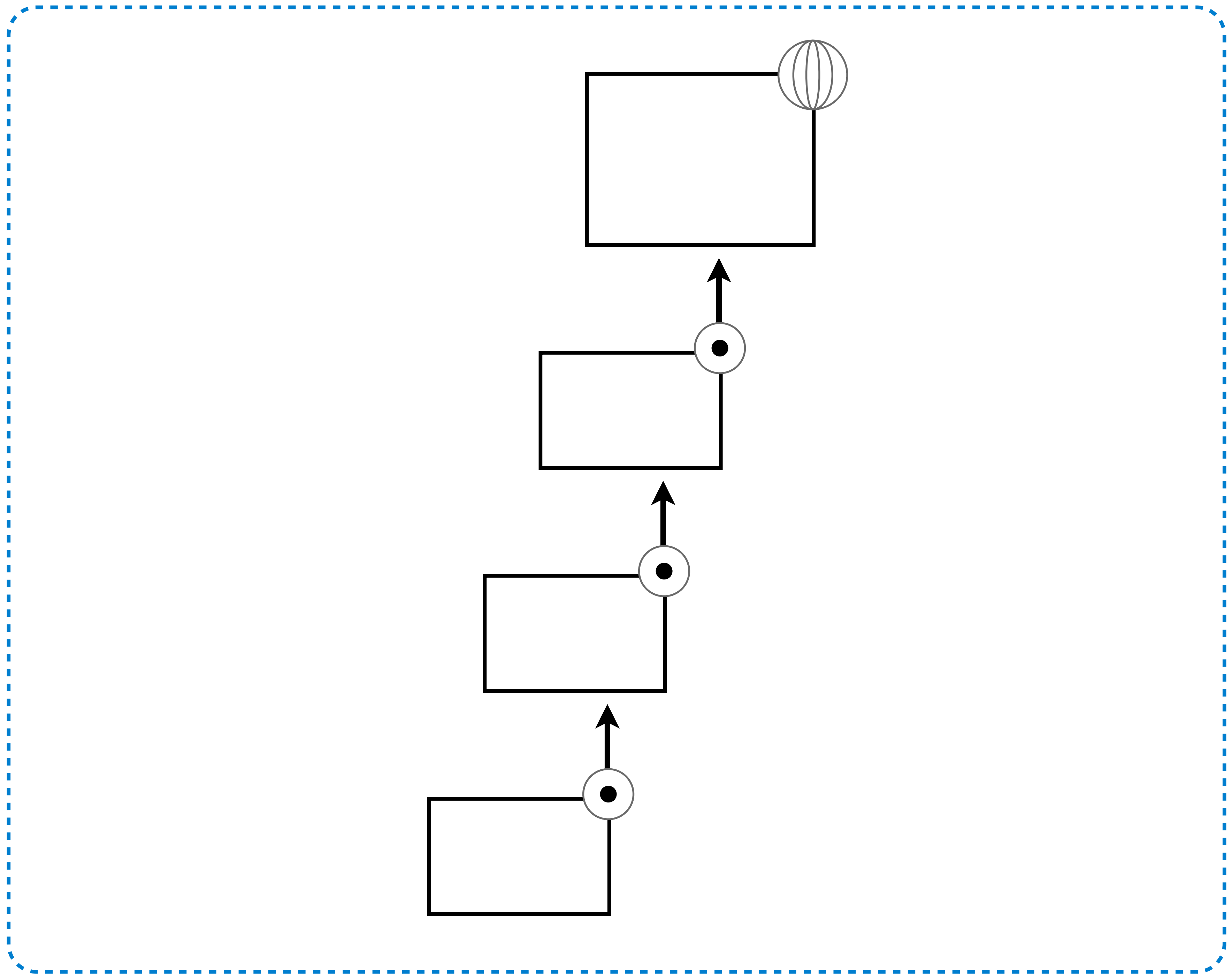
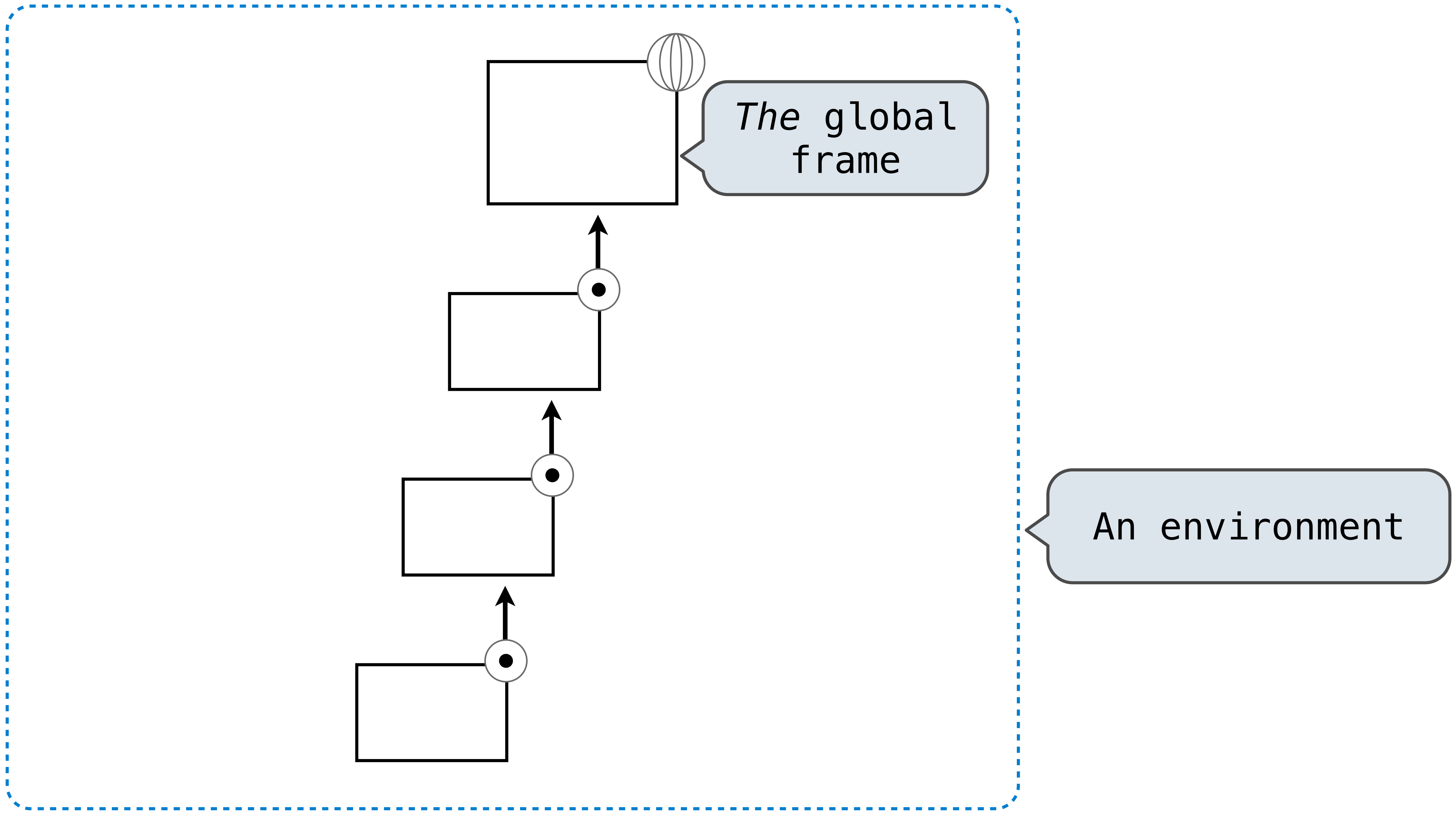


An environment

Local, Non-Local, and Global Frames



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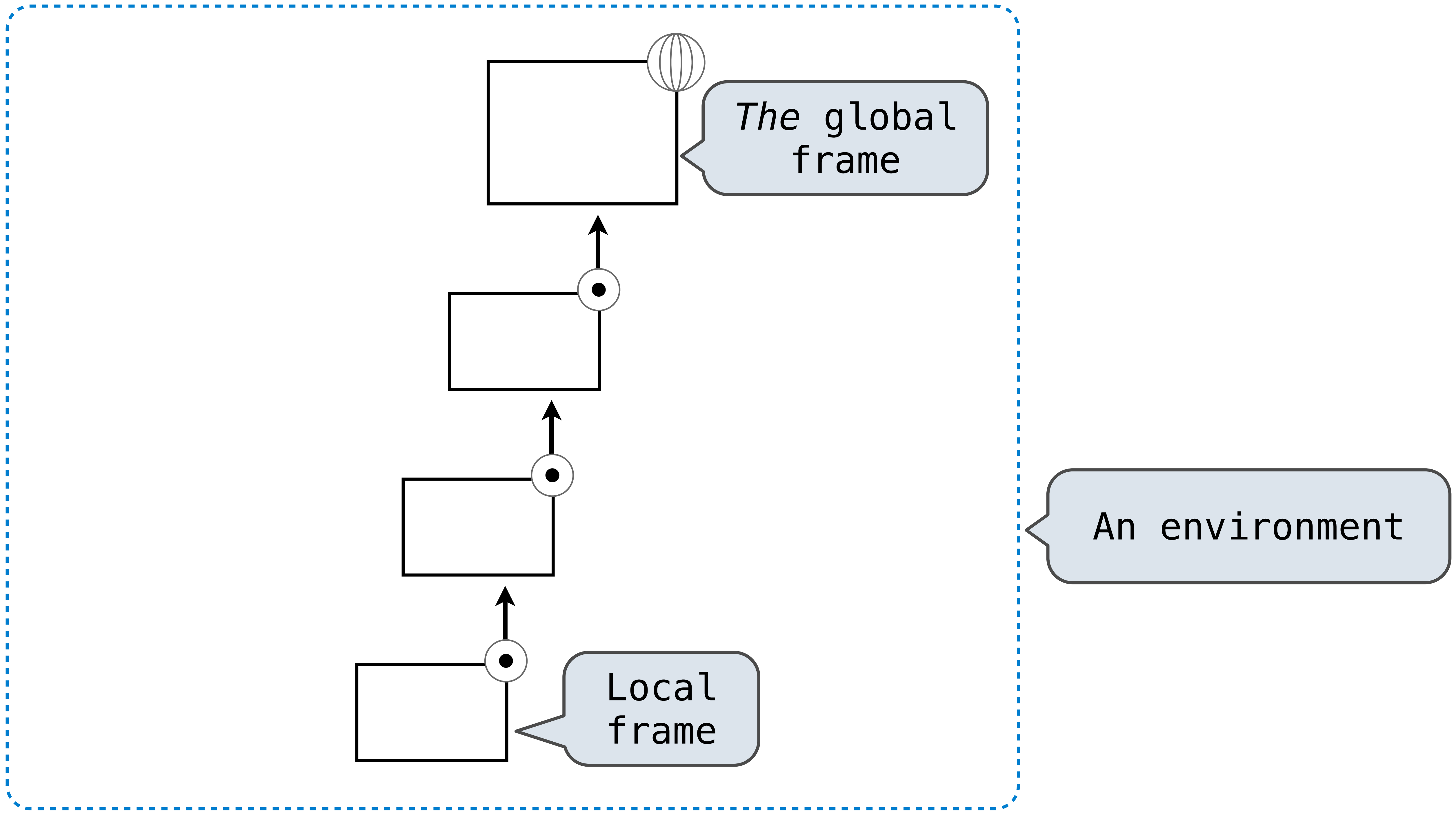

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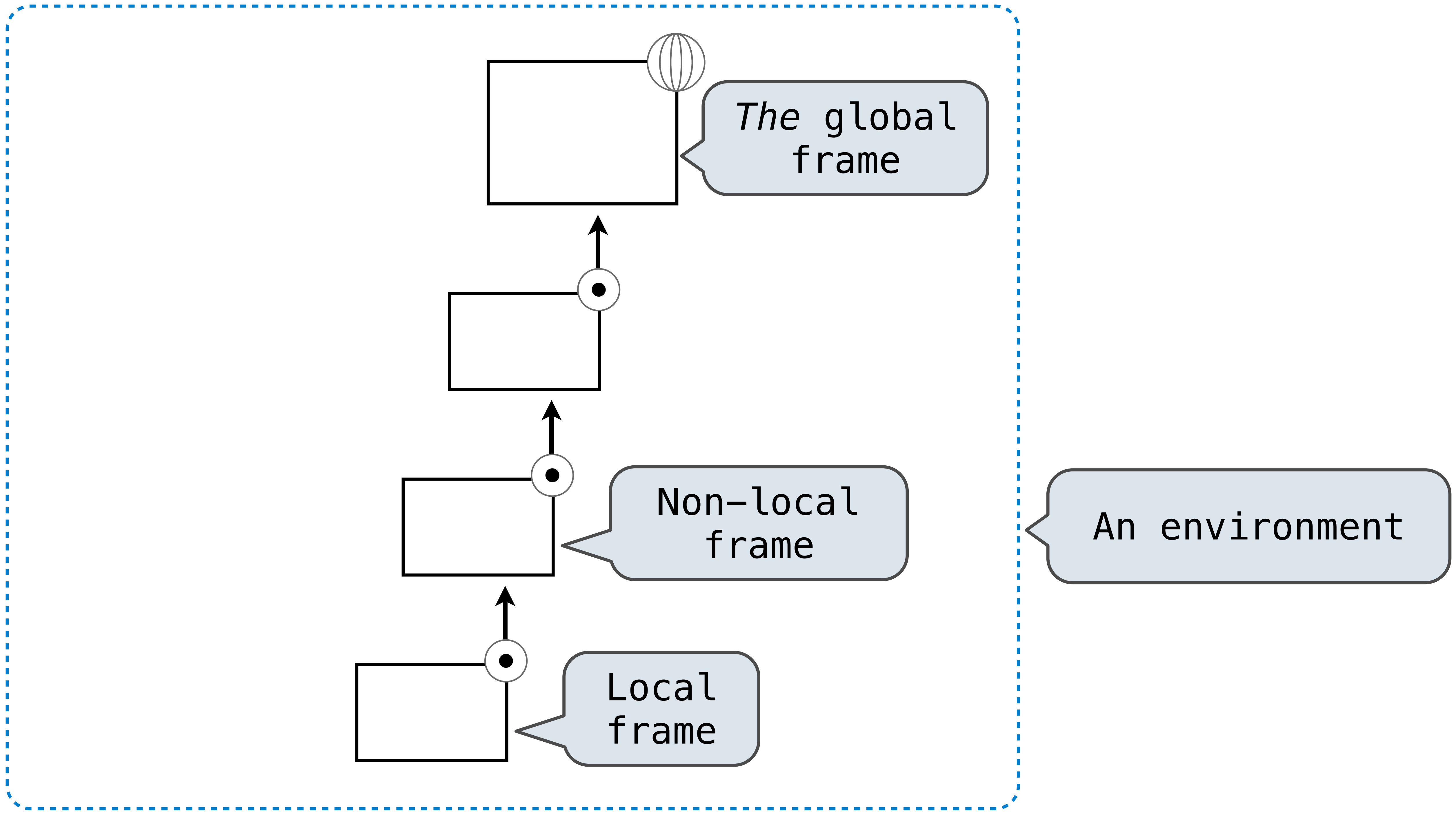

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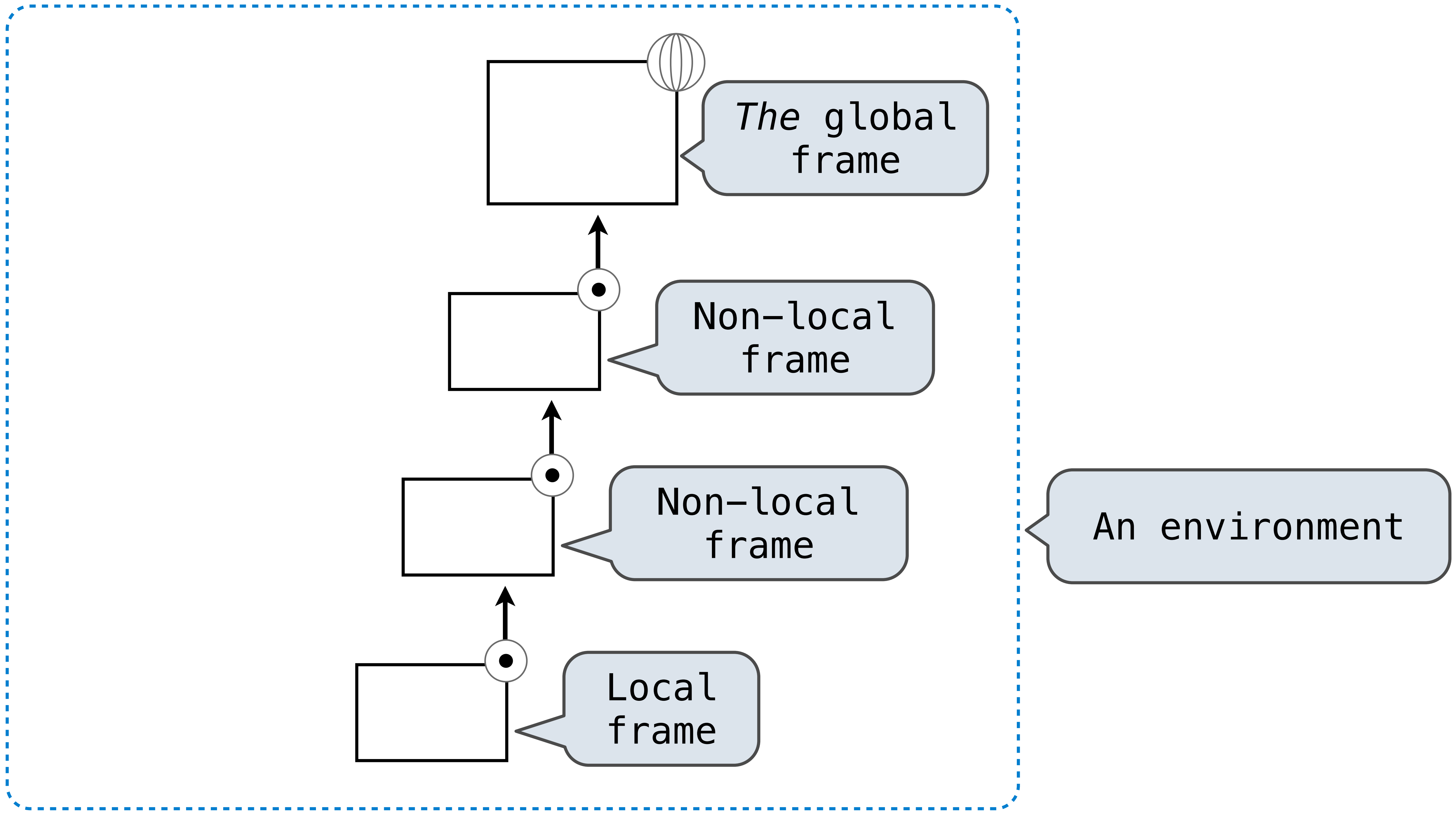

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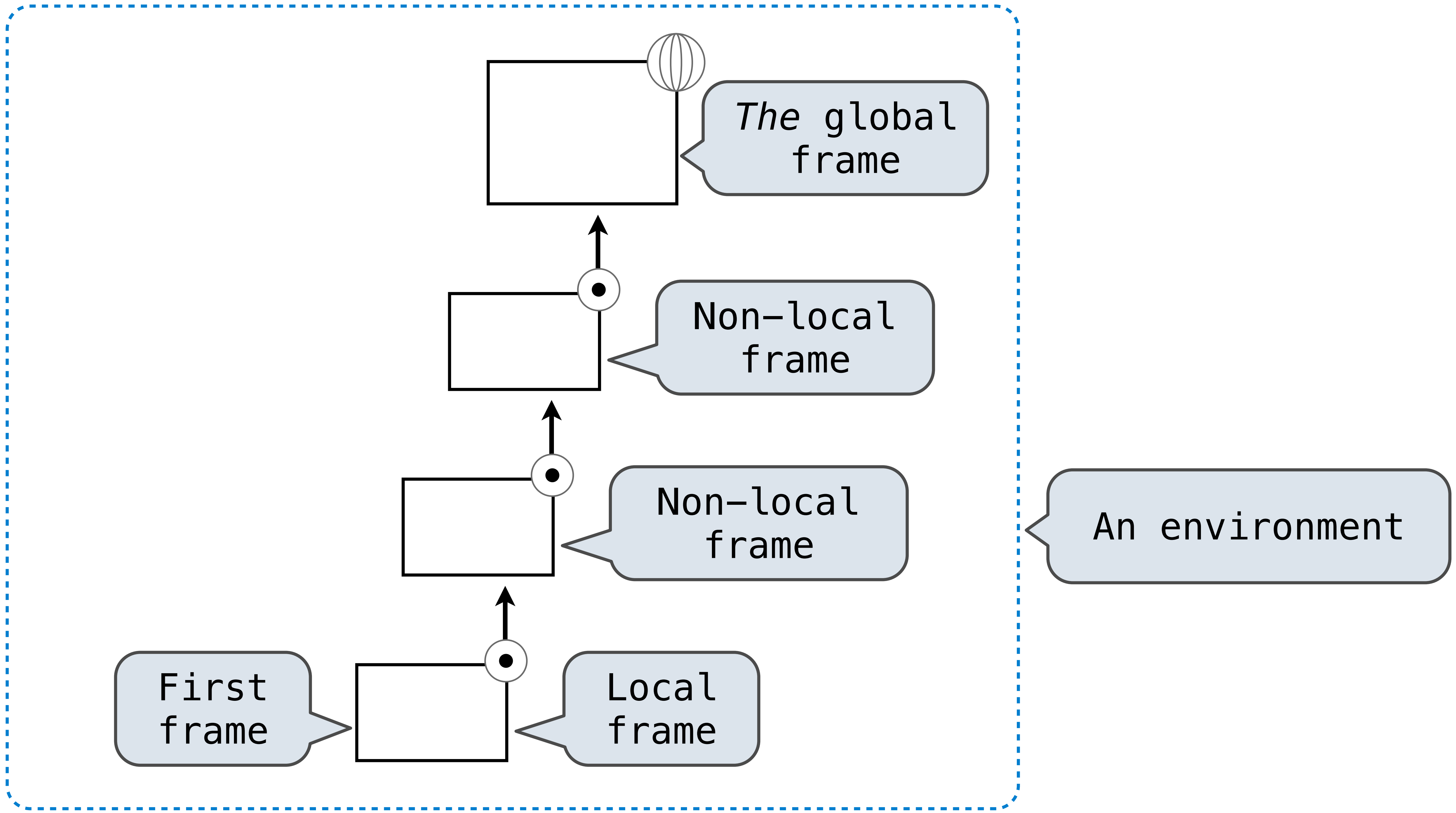

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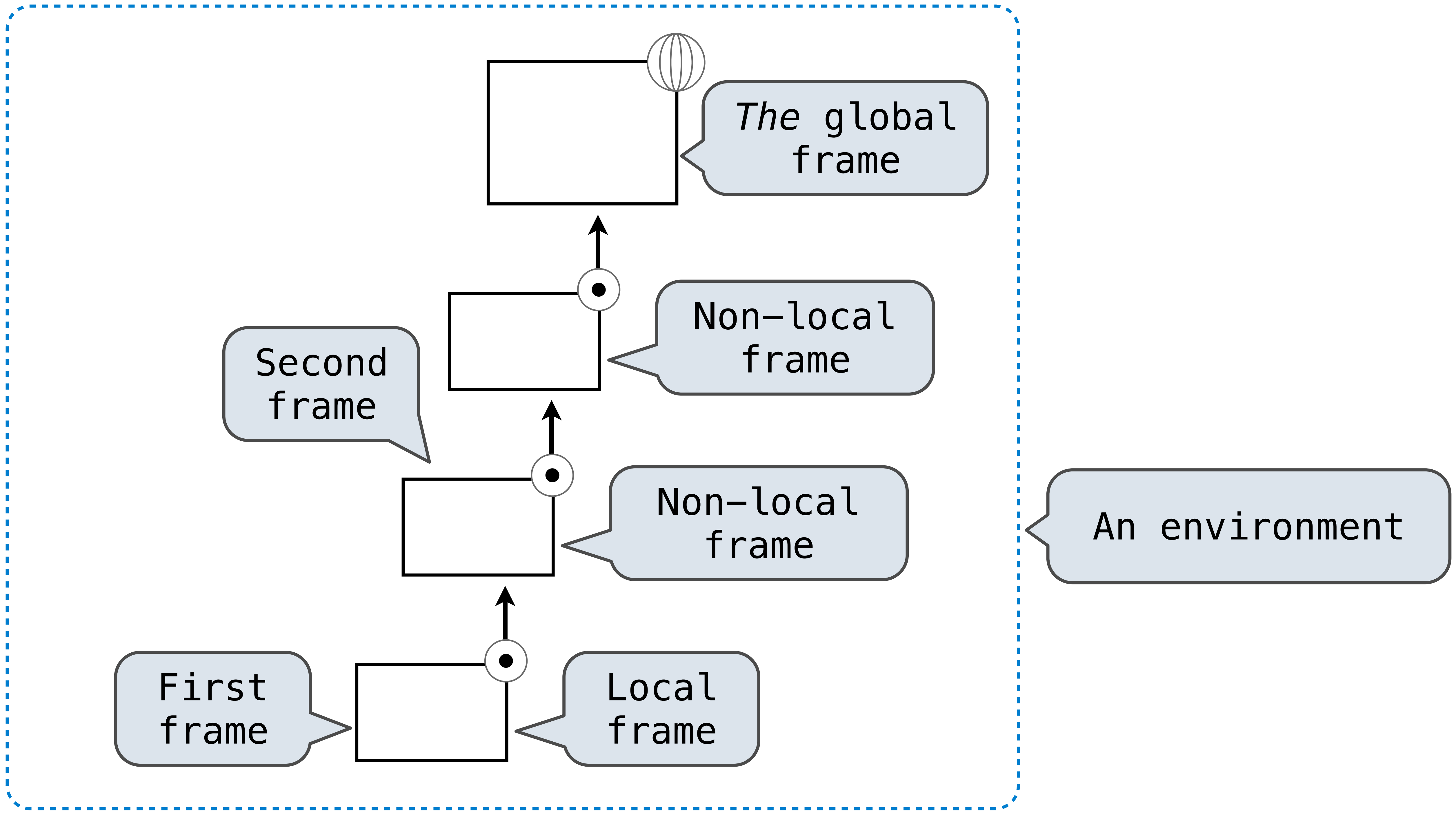

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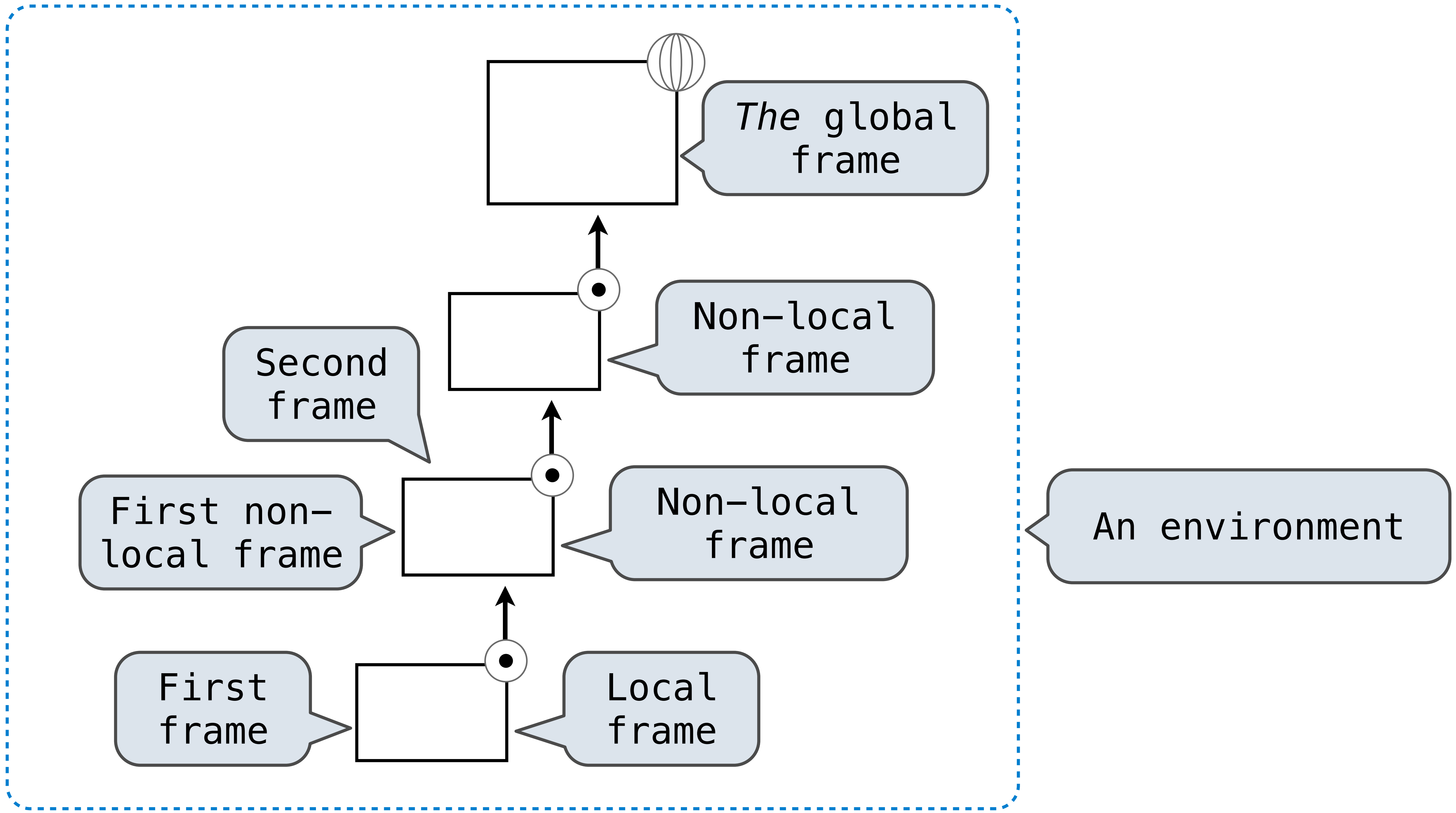

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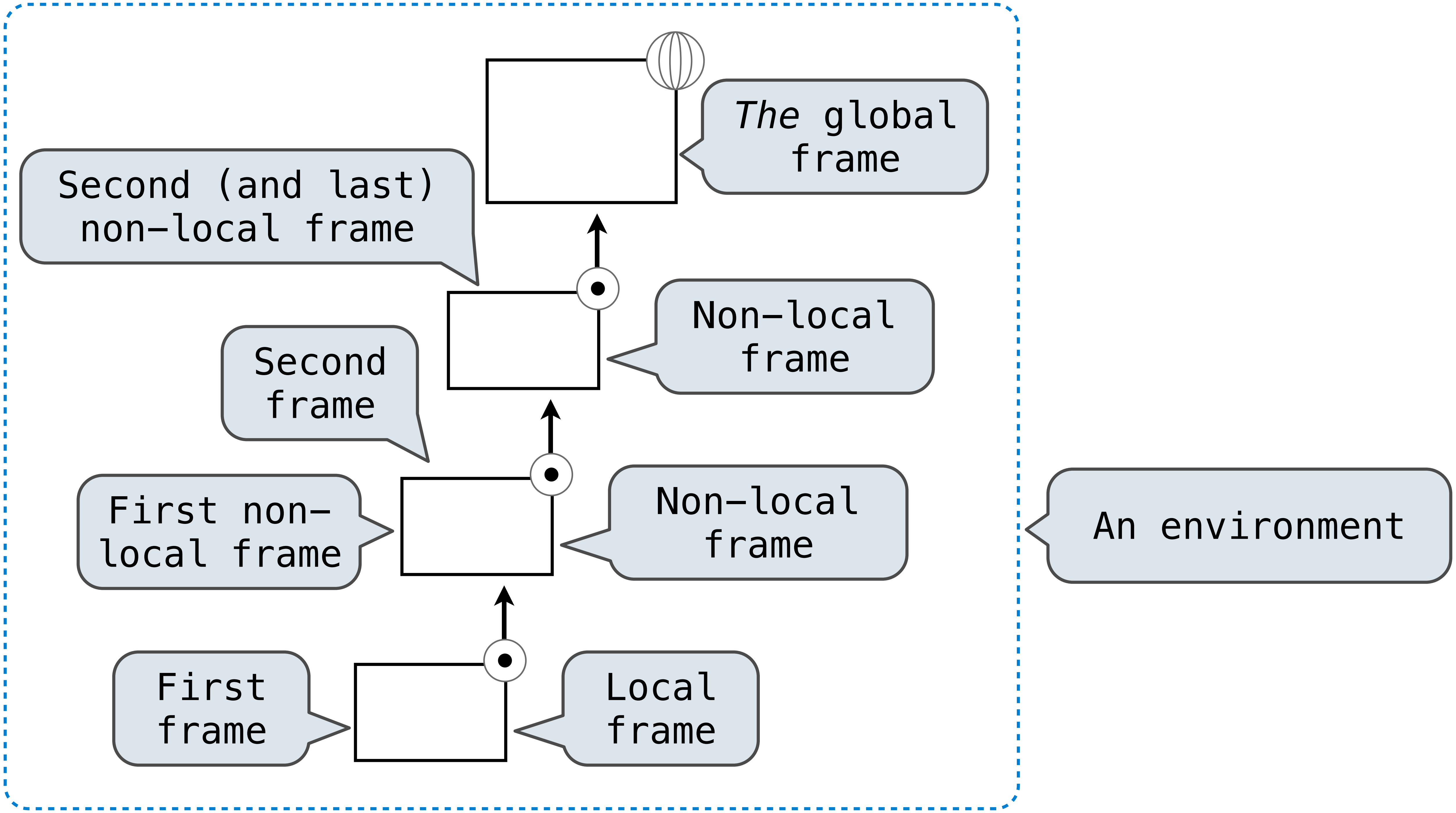

The Effect of Nonlocal Statements

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http://www.python.org/dev/peps/pep-3104/

The Many Meanings of Assignment Statements

```
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The Many Meanings of Assignment Statements

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The Many Meanings of Assignment Statements

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Status	Effect
• No nonlocal statement • "x" **is not** bound locally	Create a new binding from name "x" to object 2 in the first frame of the current environment.

The Many Meanings of Assignment Statements

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x = 2
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The Many Meanings of Assignment Statements

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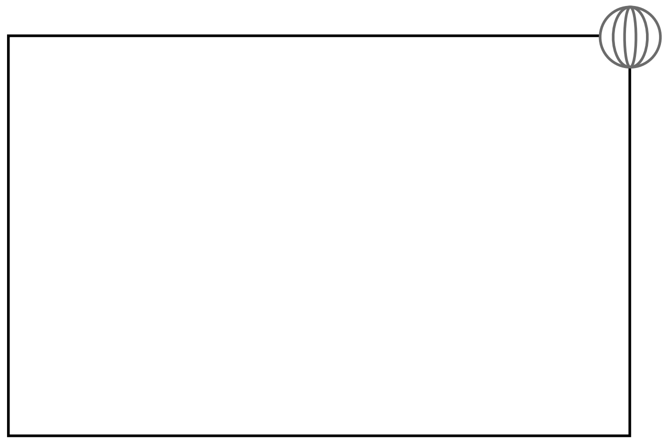
Assignment Review: Teenage Mutant Ninja Turtles



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def mutant(y):
    y, x = y+1, y+2
    return ninja(y)/2

def ninja(x):
    return x + 2

def turtle(x):
    return x * y + 2

y, ninja = 5, turtle

mutant(y)
```

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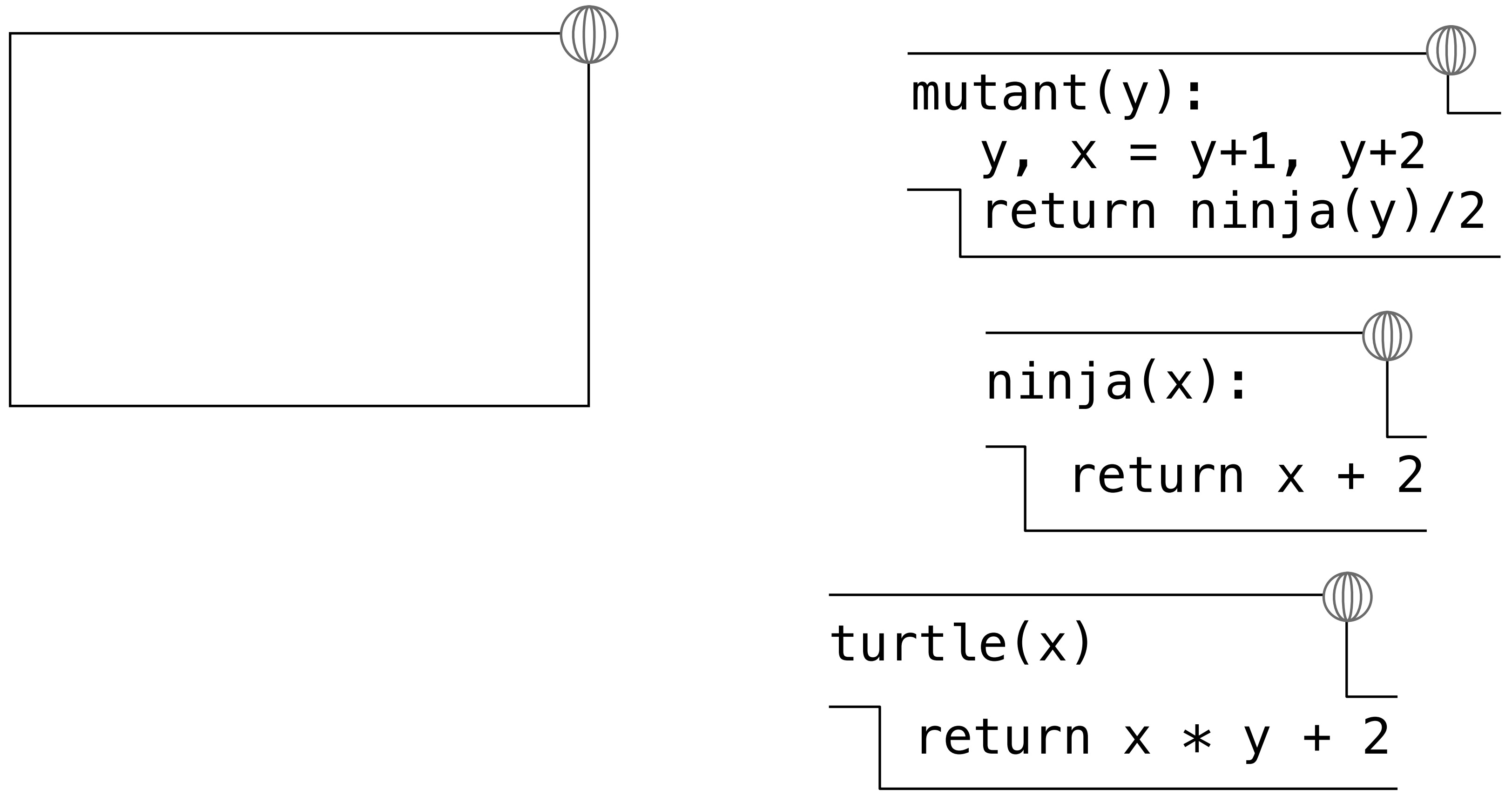

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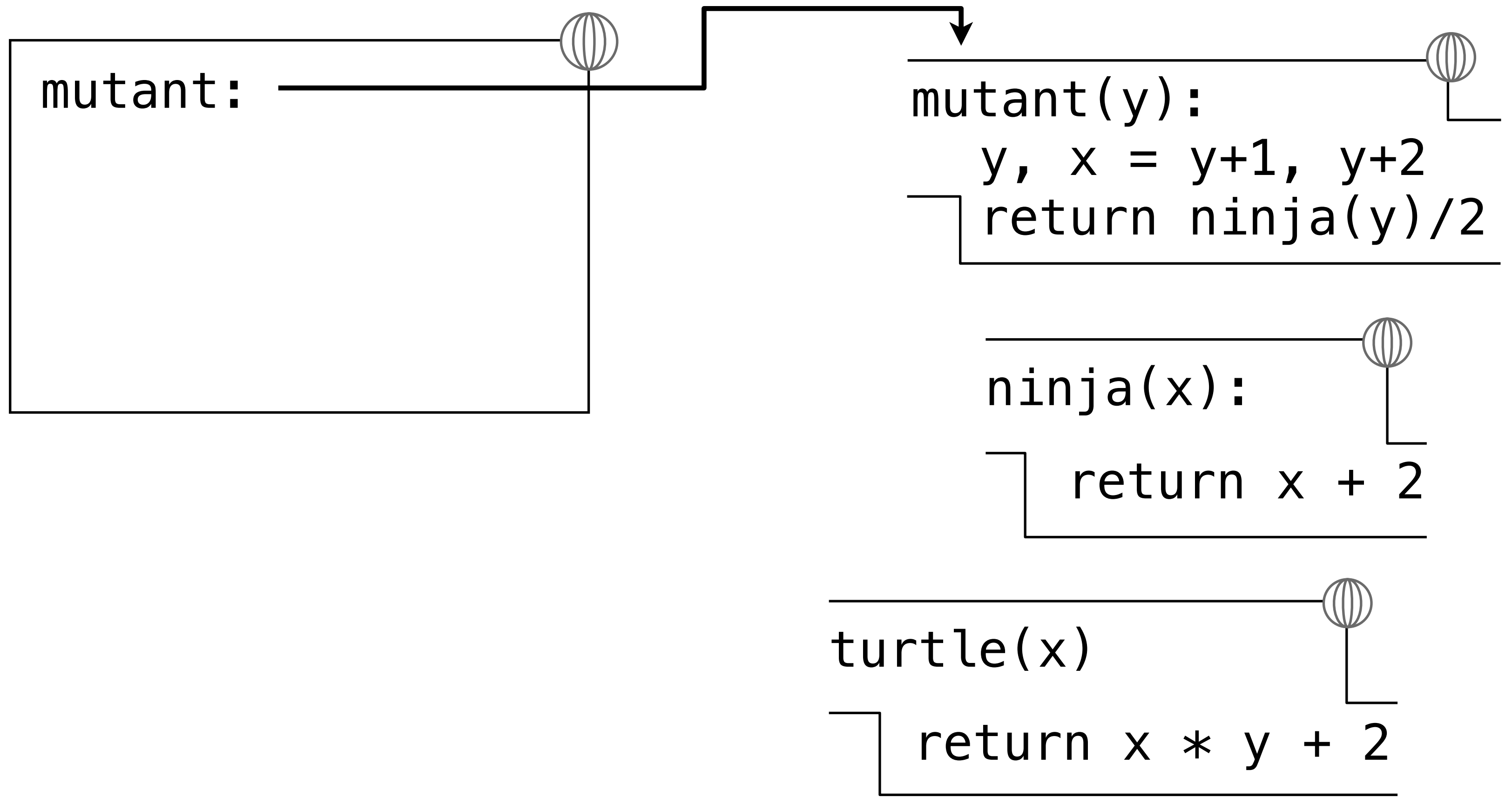

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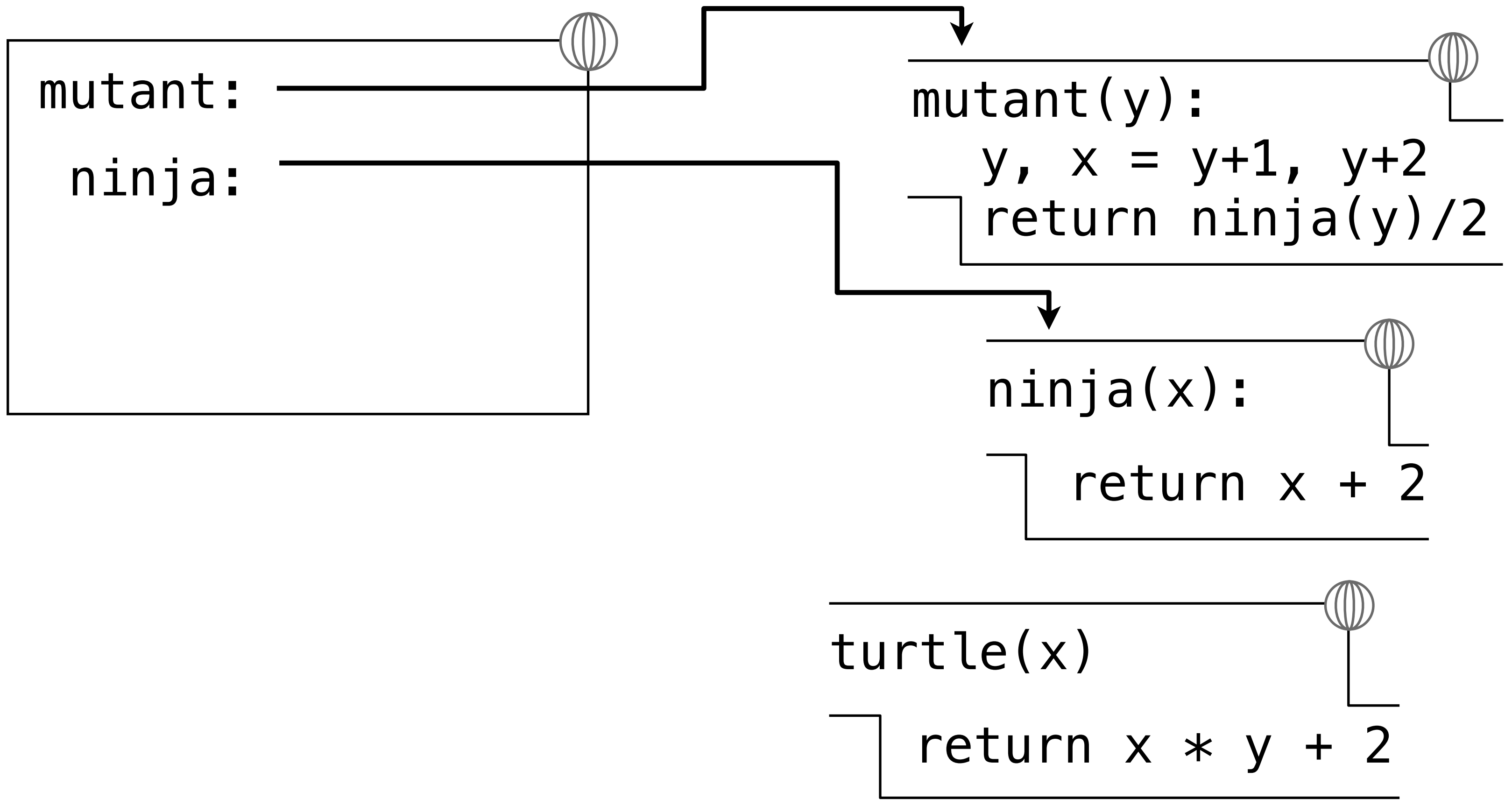

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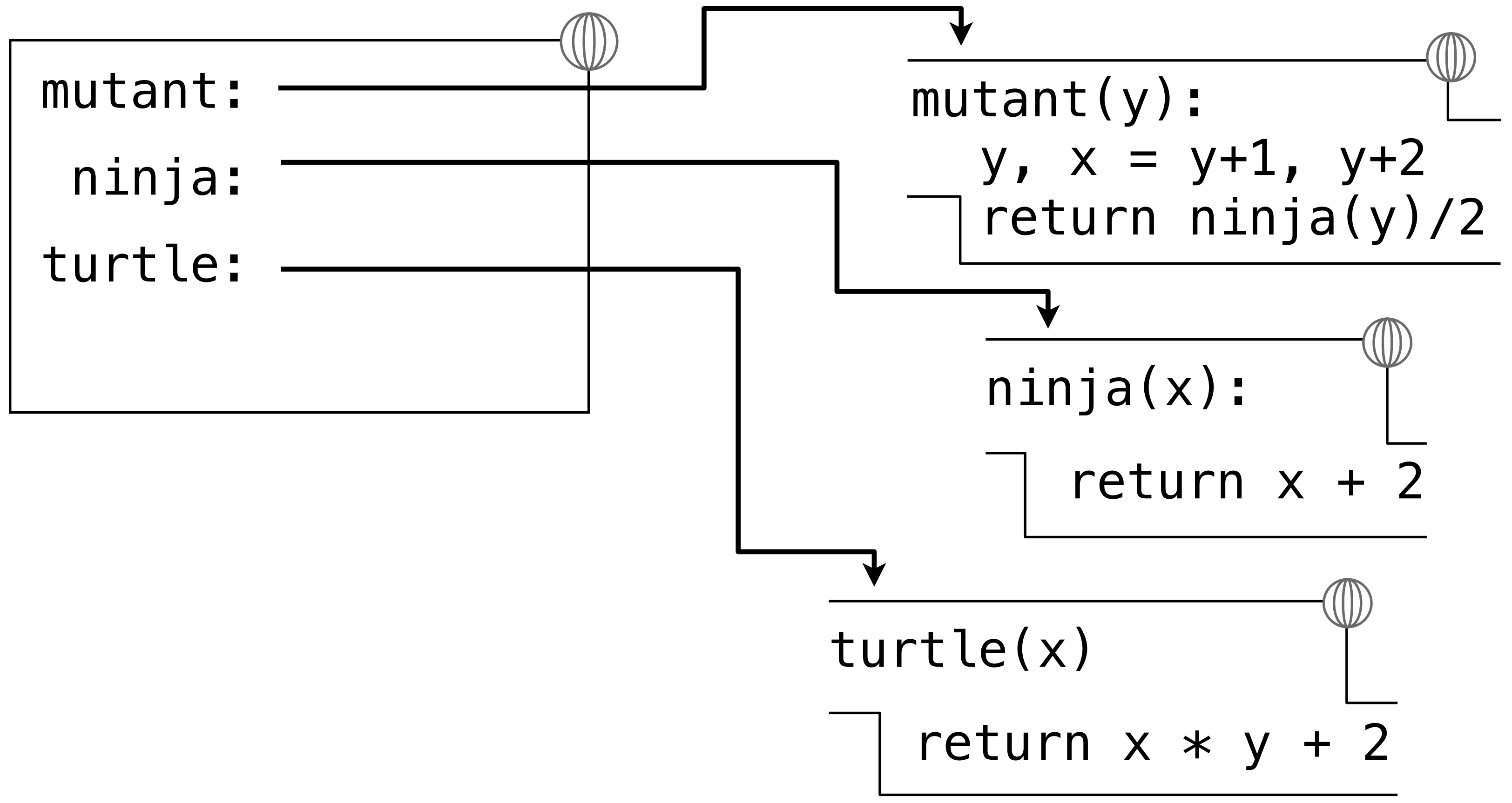

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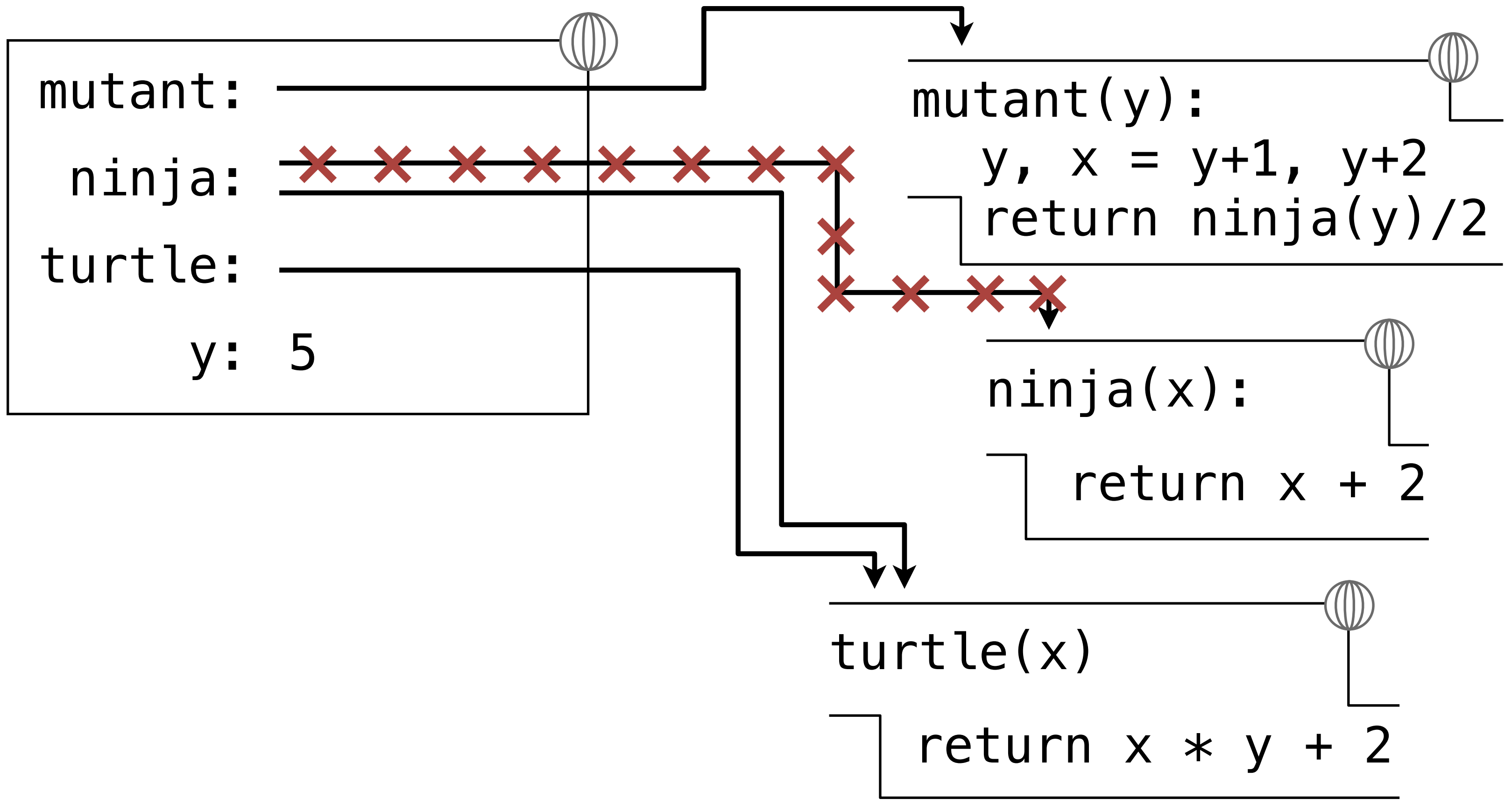

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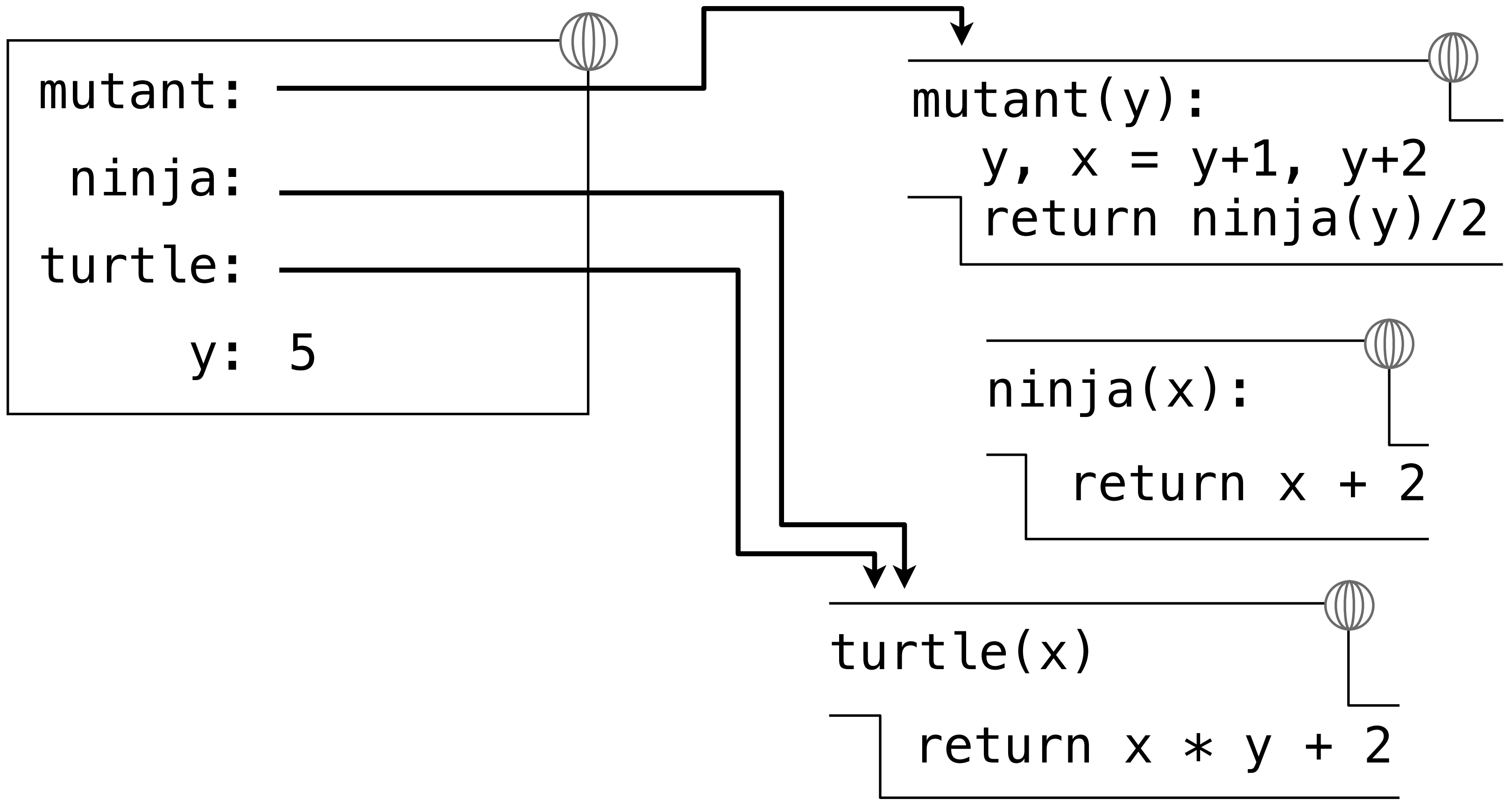

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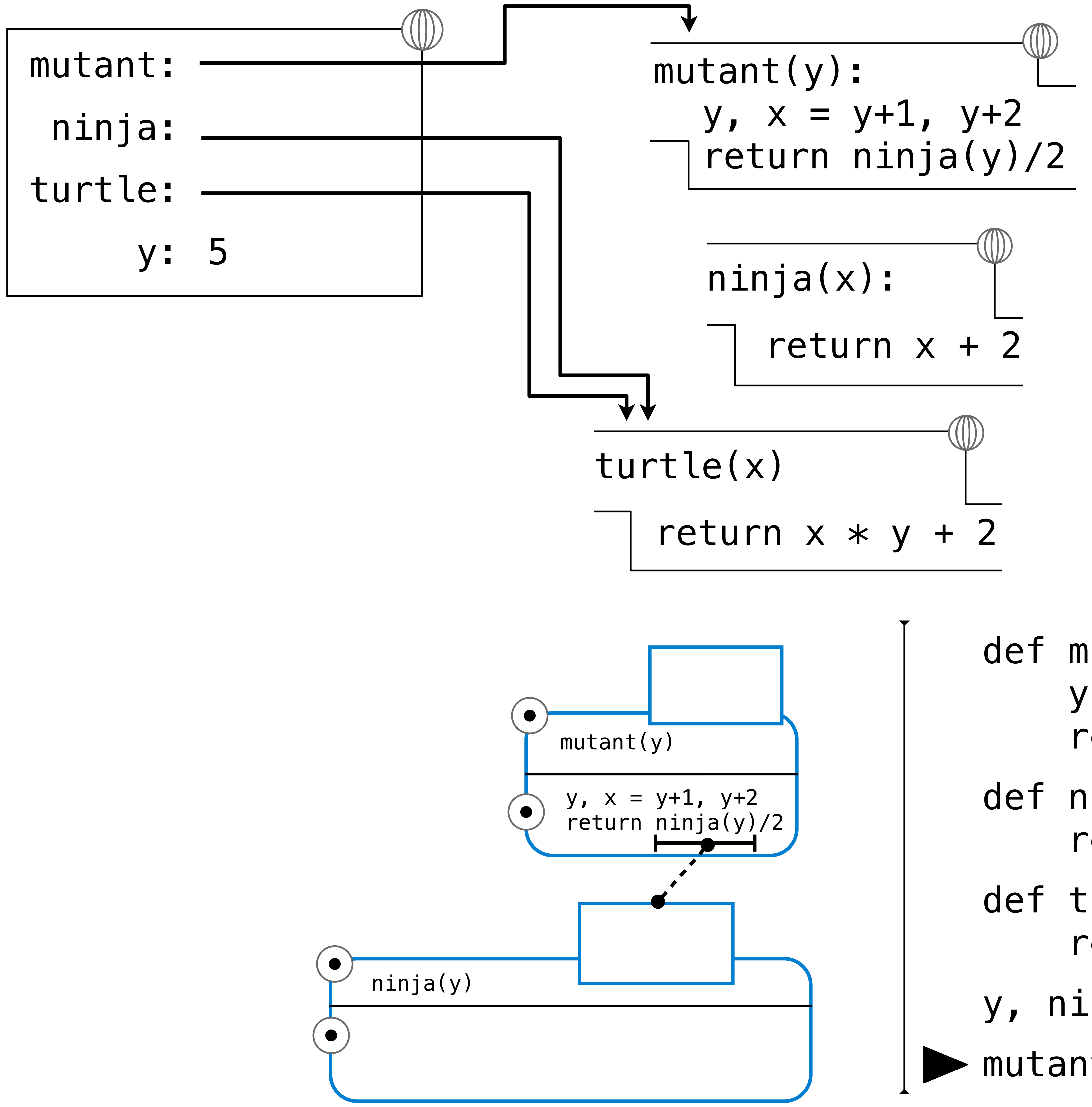

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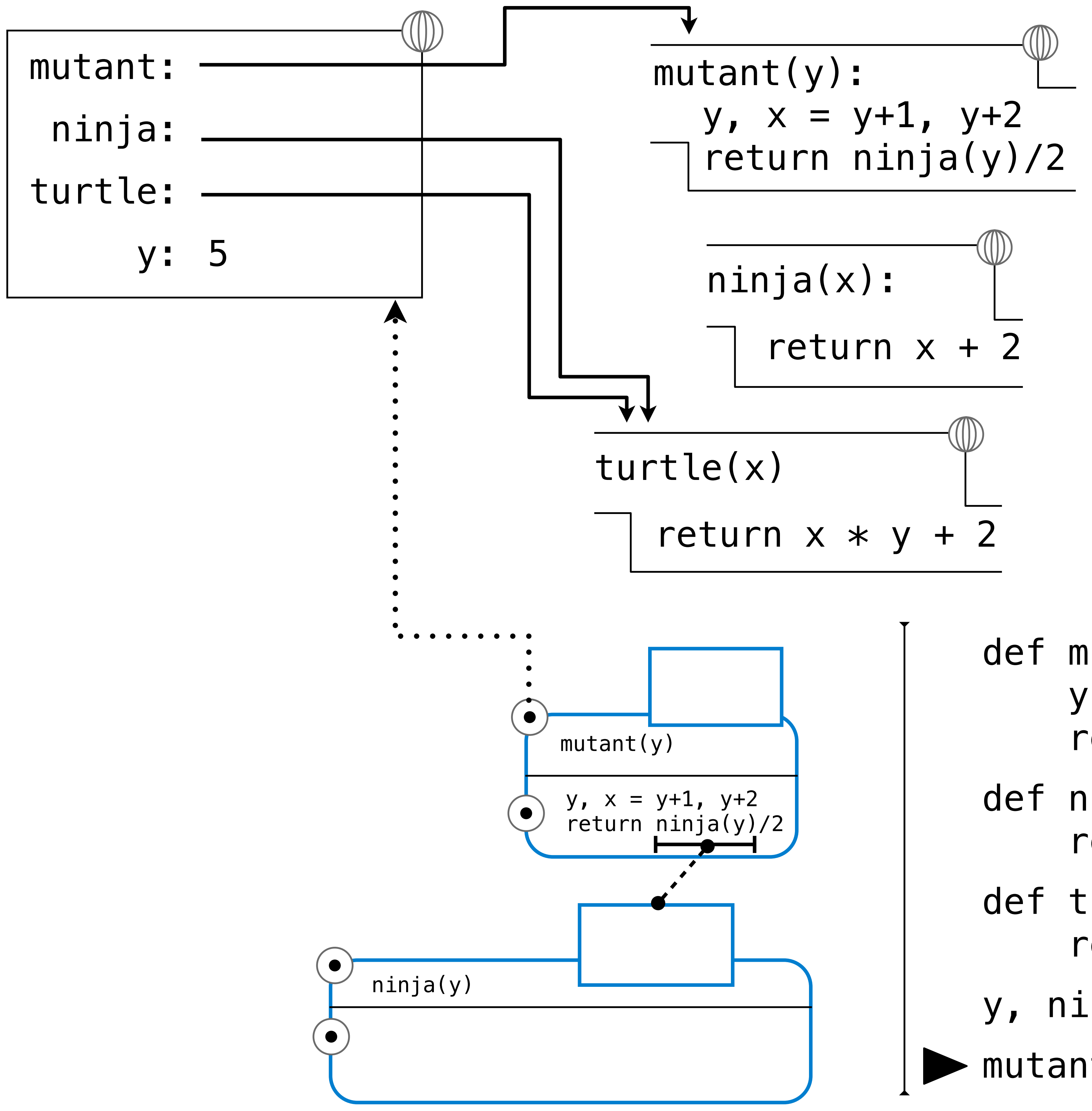

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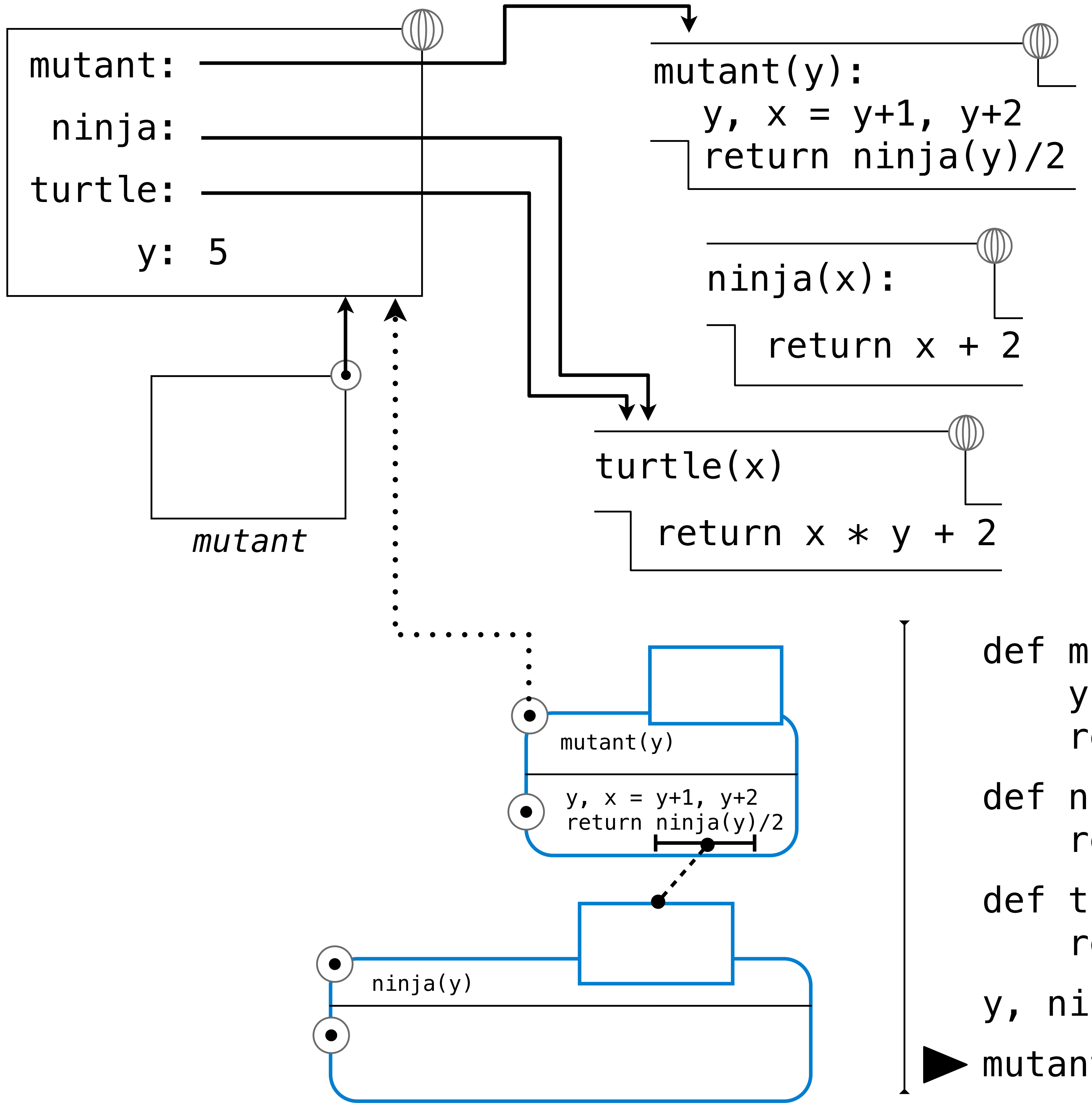

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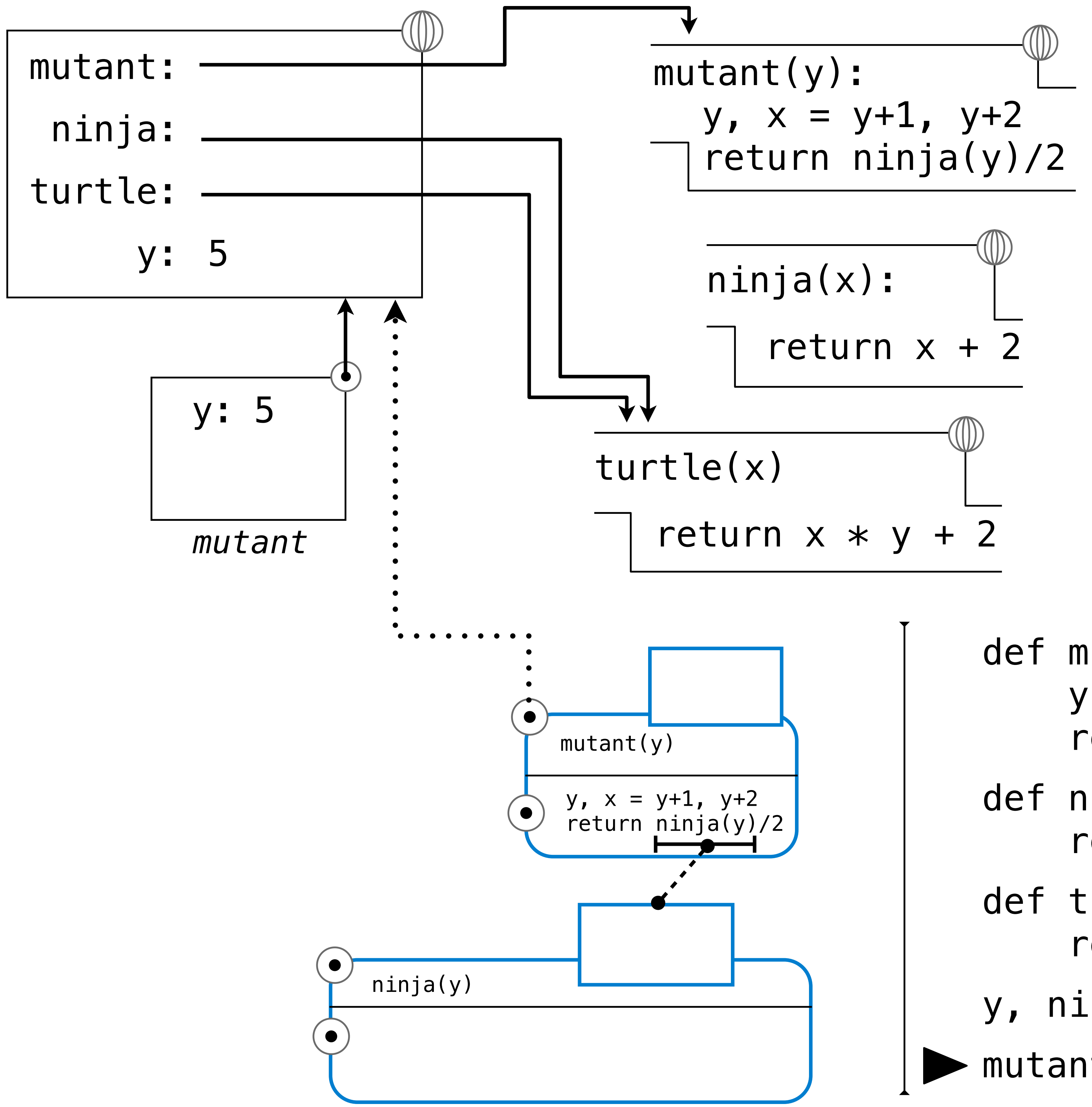

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def ninja(x):
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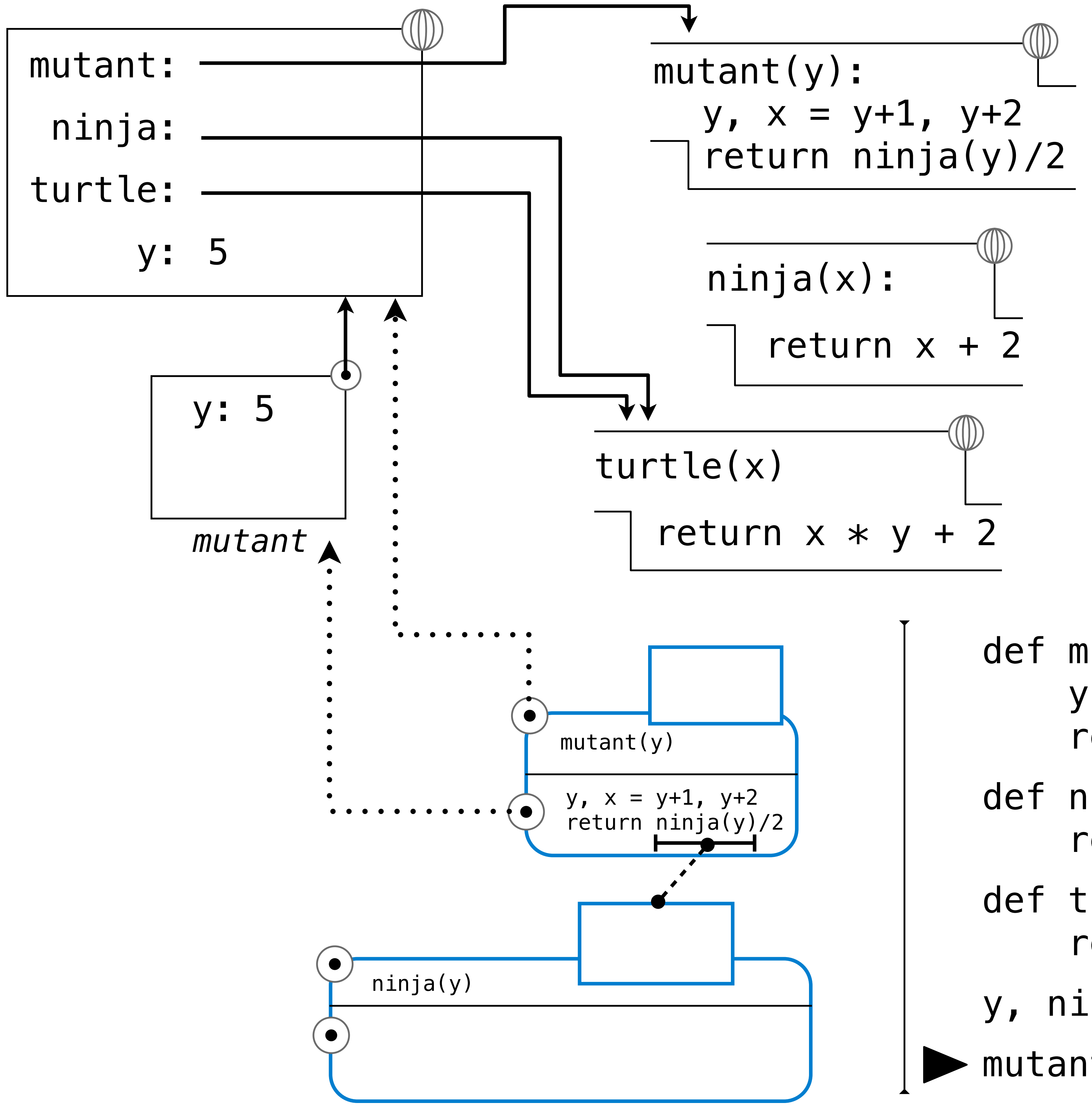
def turtle(x):
    return x * y + 2

y, ninja = 5, turtle

mutant(y)
```

Assignment Review: Teenage Mutant Ninja Turtles



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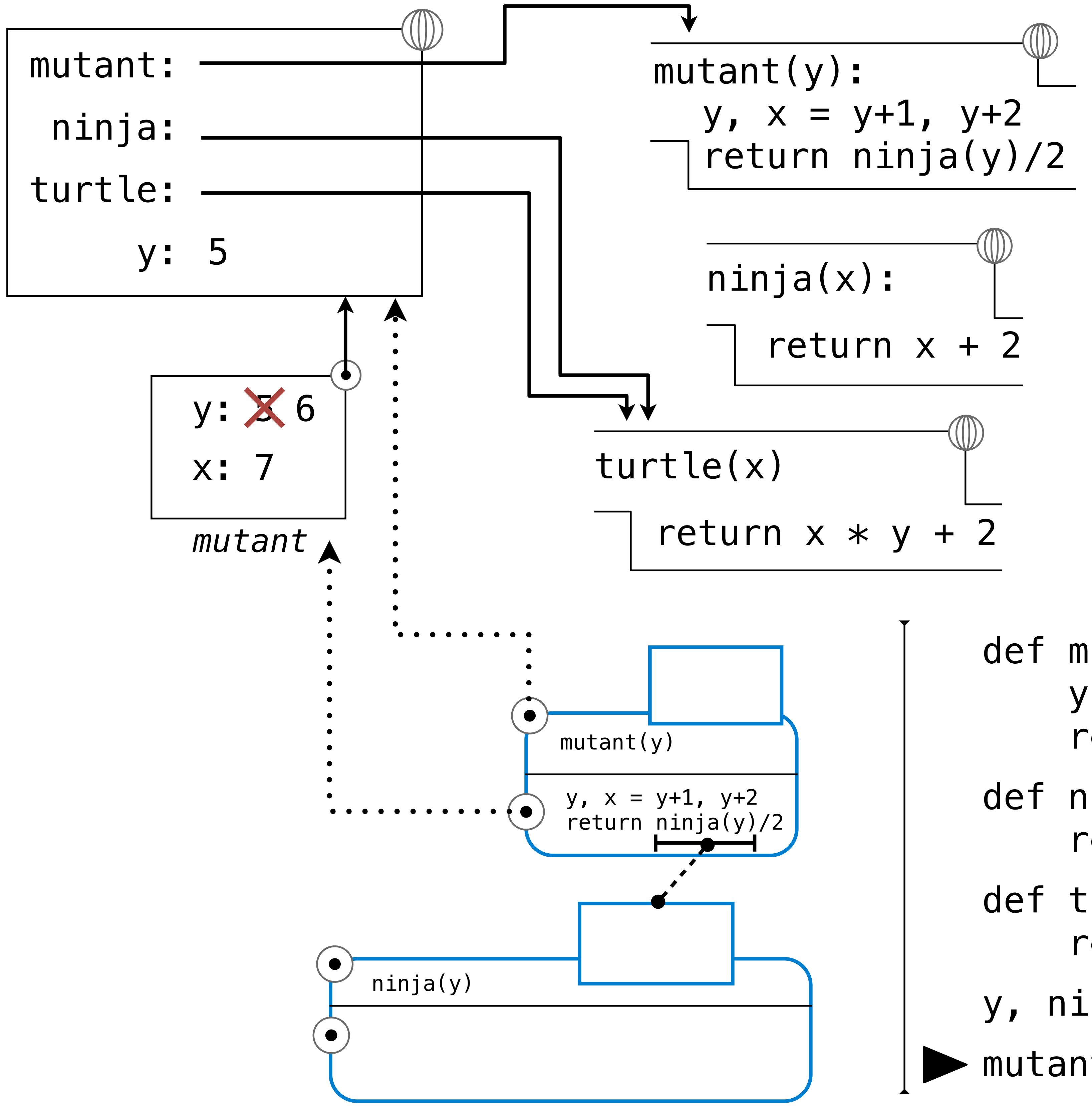
Assignment Review: Teenage Mutant Ninja Turtles



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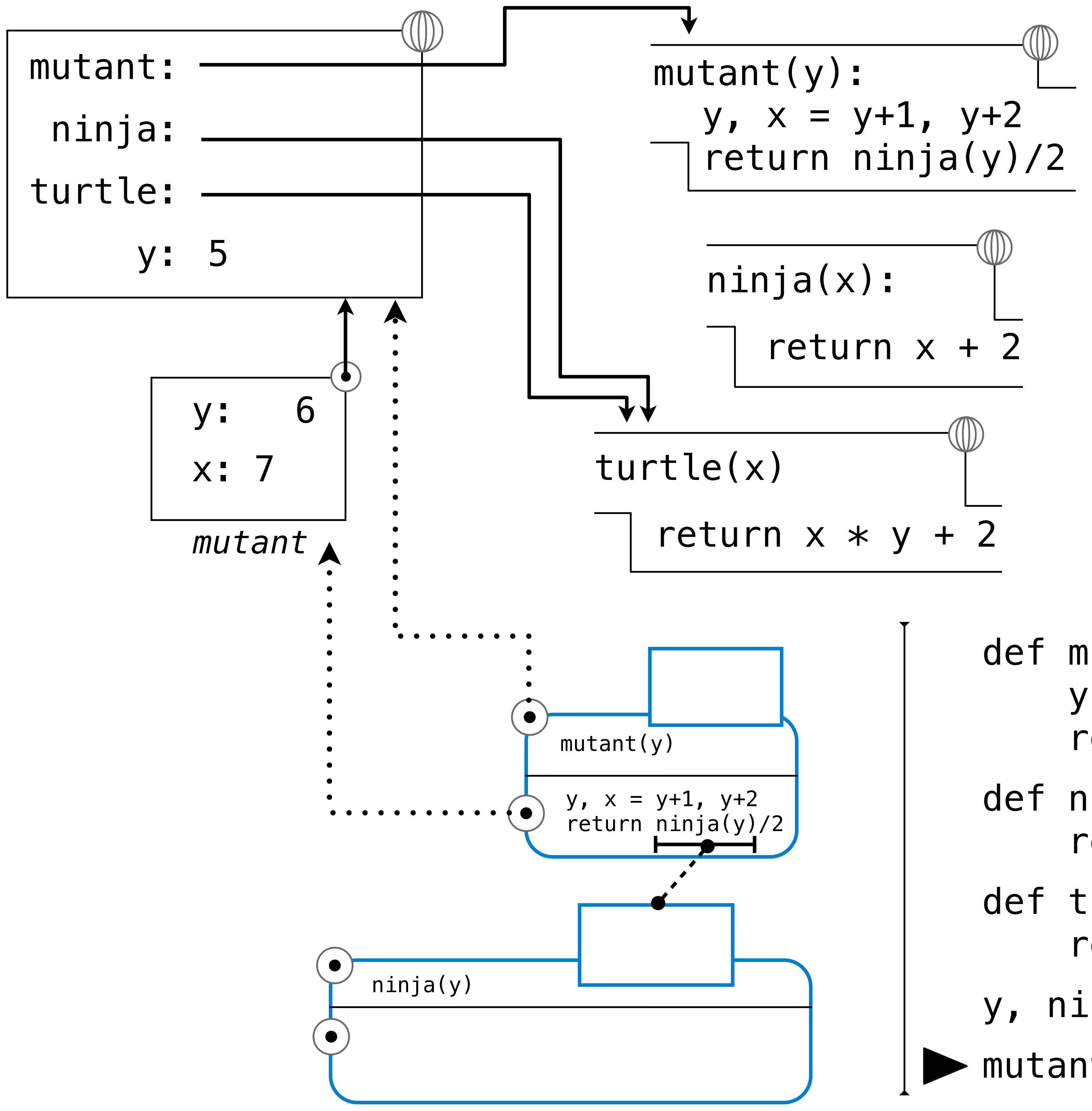
Assignment Review: Teenage Mutant Ninja Turtles



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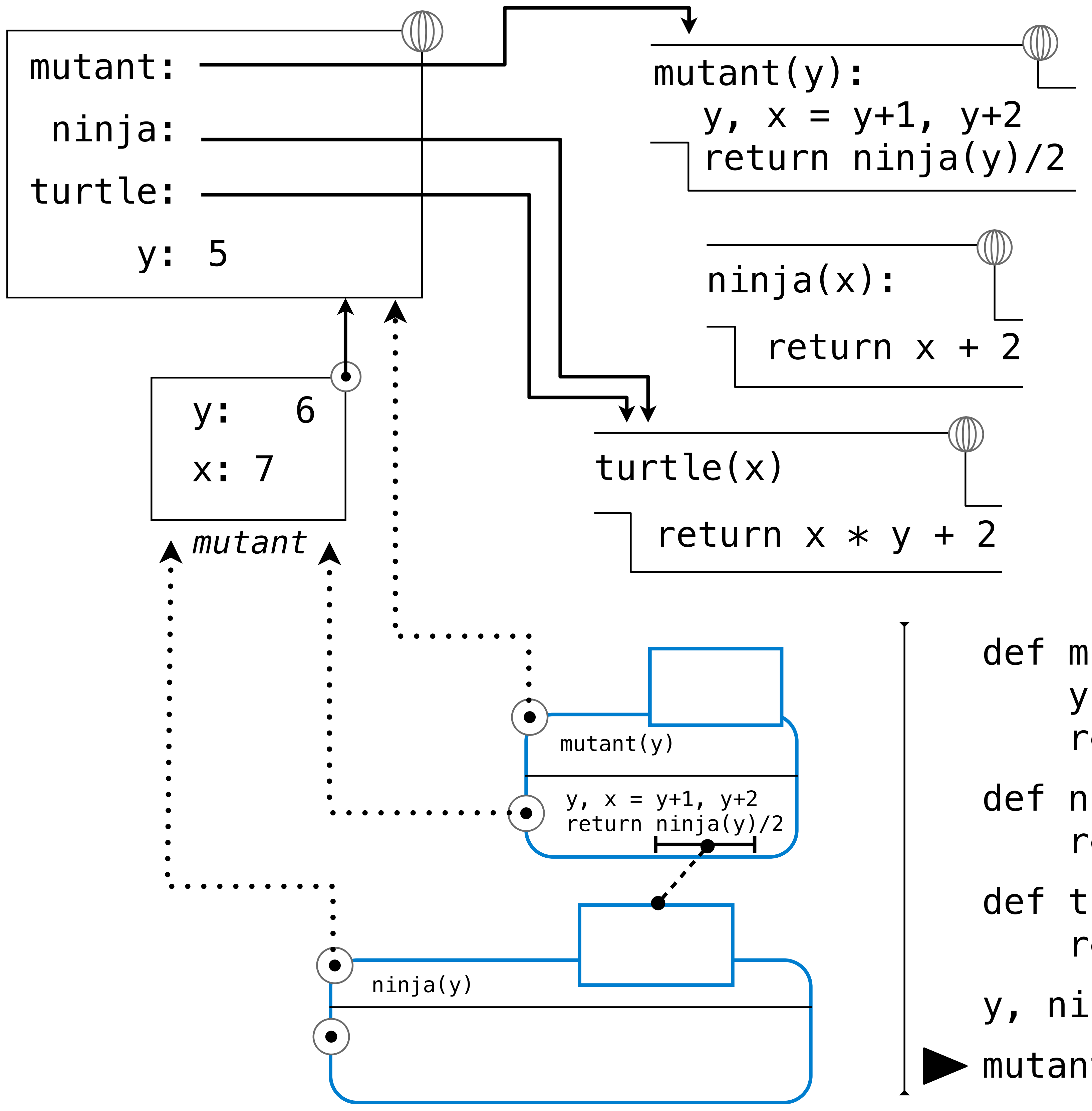
Assignment Review: Teenage Mutant Ninja Turtles



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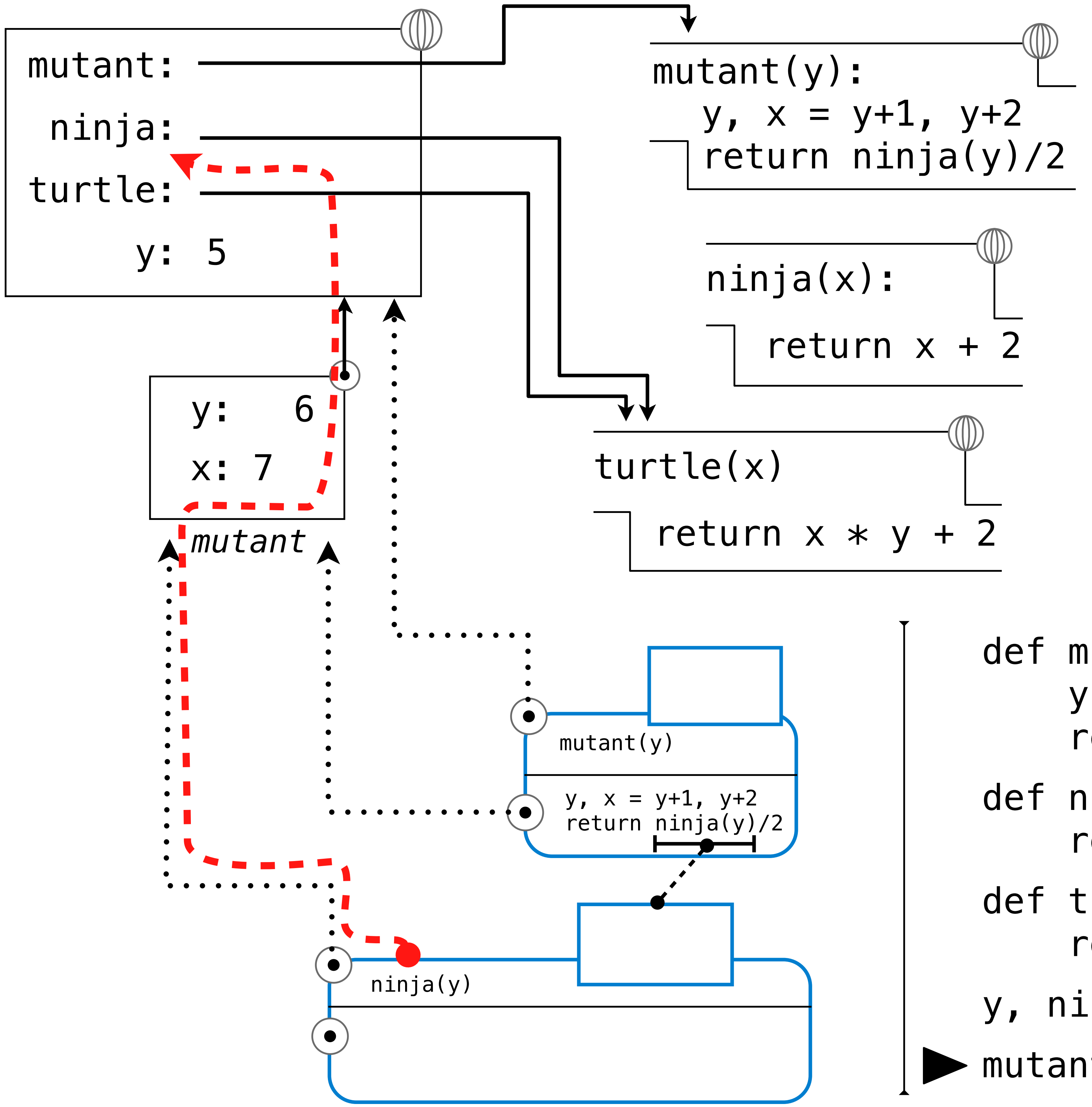
Assignment Review: Teenage Mutant Ninja Turtles



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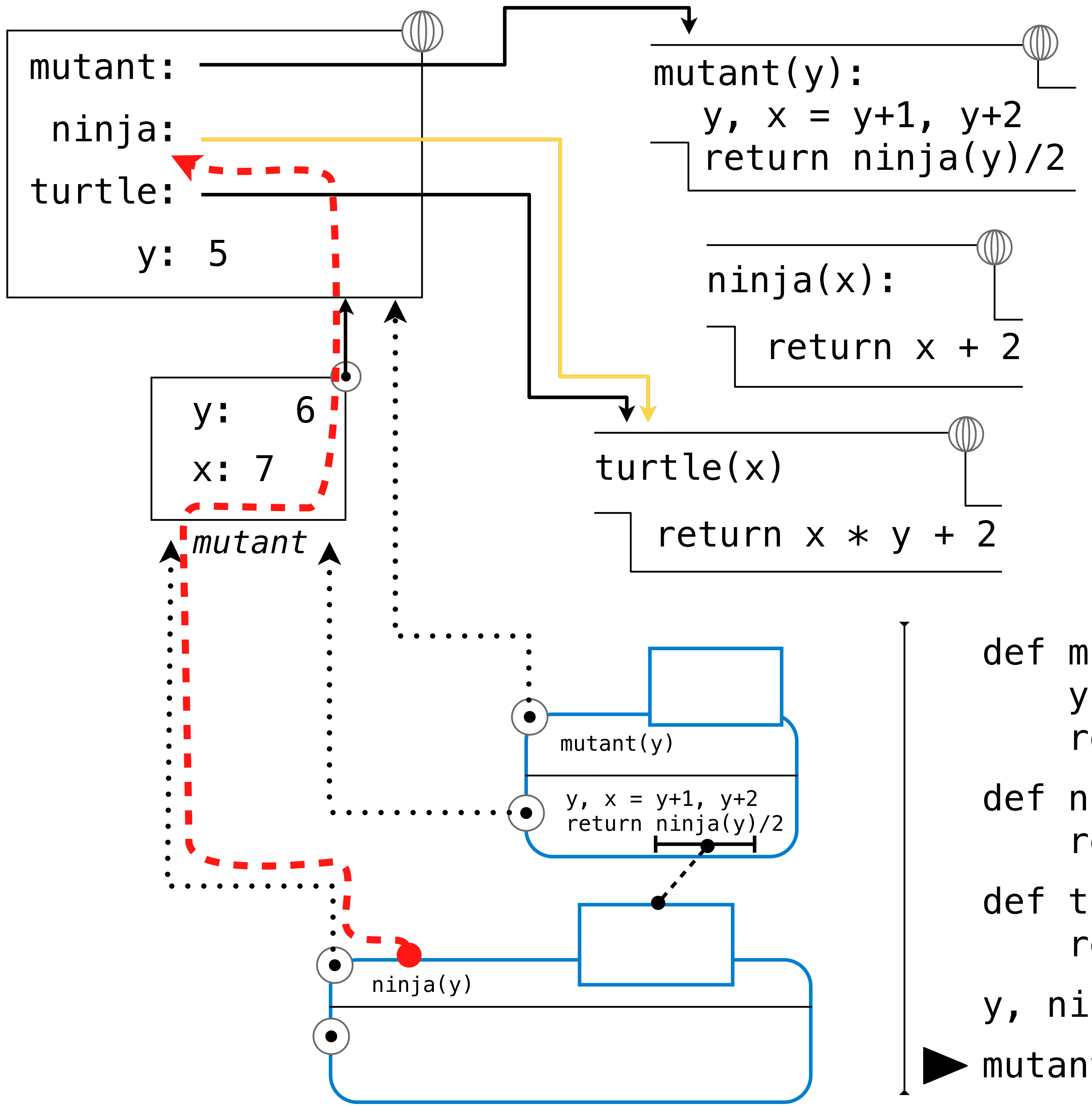
Assignment Review: Teenage Mutant Ninja Turtles



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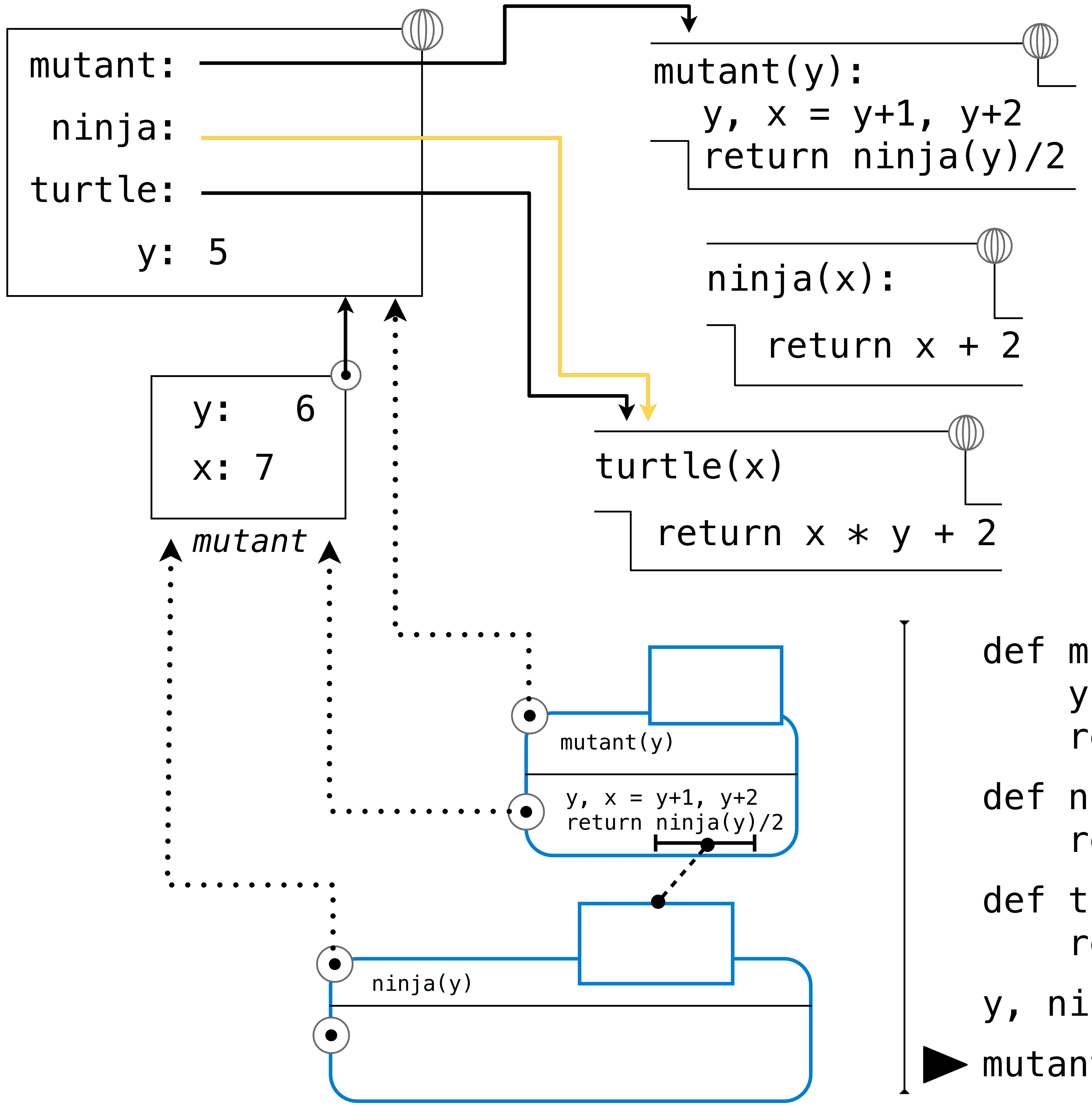
Assignment Review: Teenage Mutant Ninja Turtles



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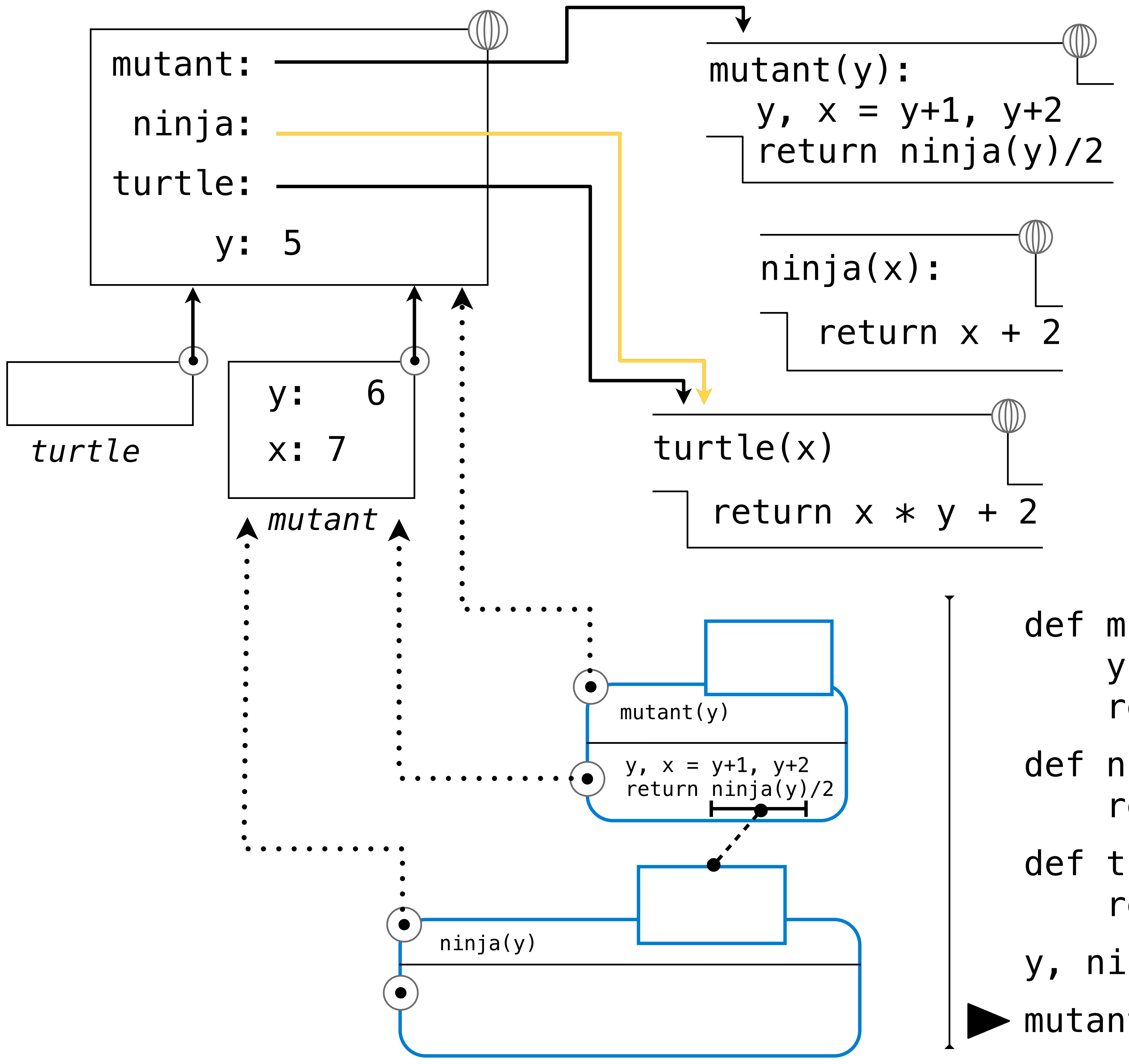
Friday, September 23, 2011

Assignment Review: Teenage Mutant Ninja Turtles



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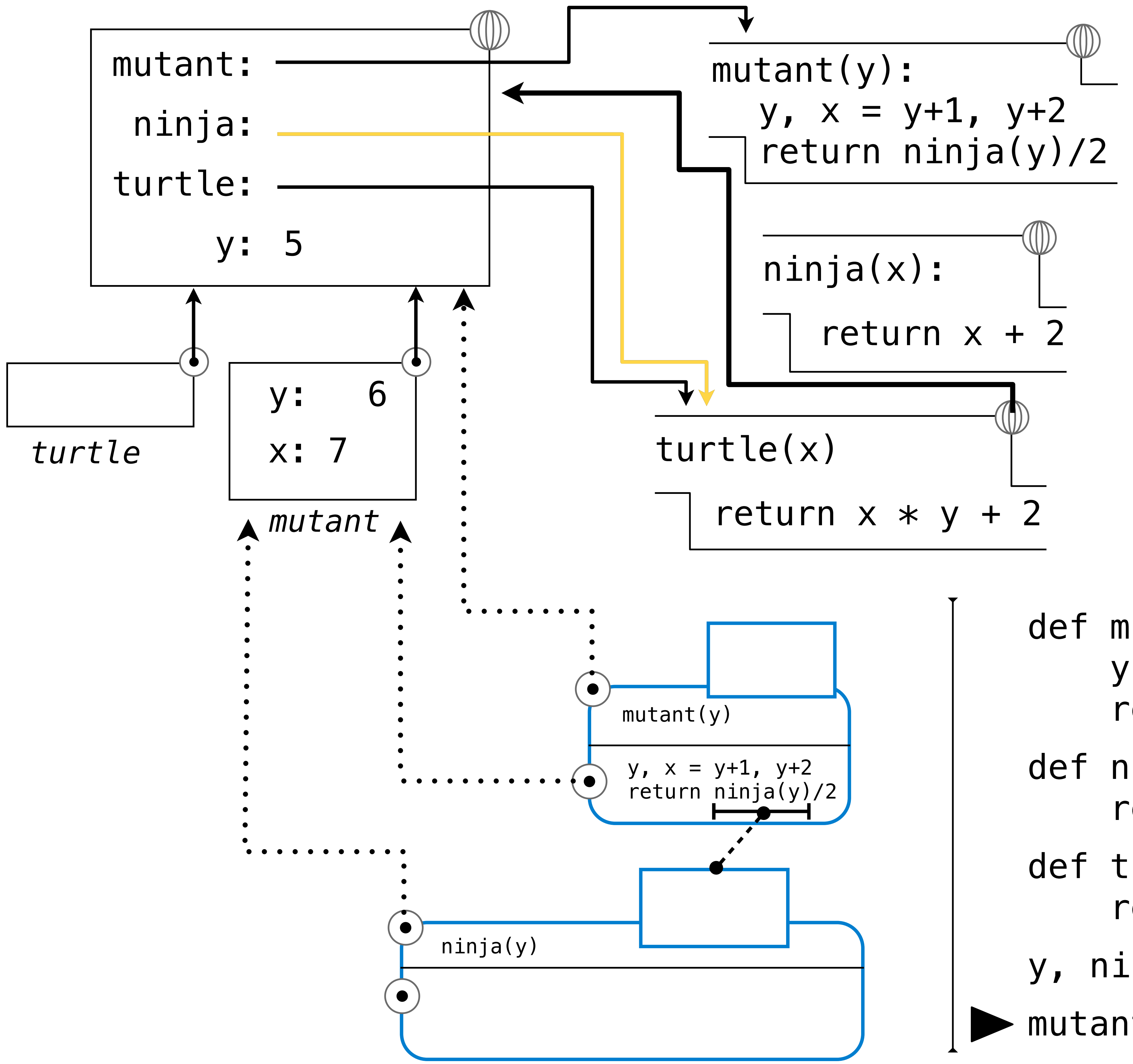
Assignment Review: Teenage Mutant Ninja Turtles



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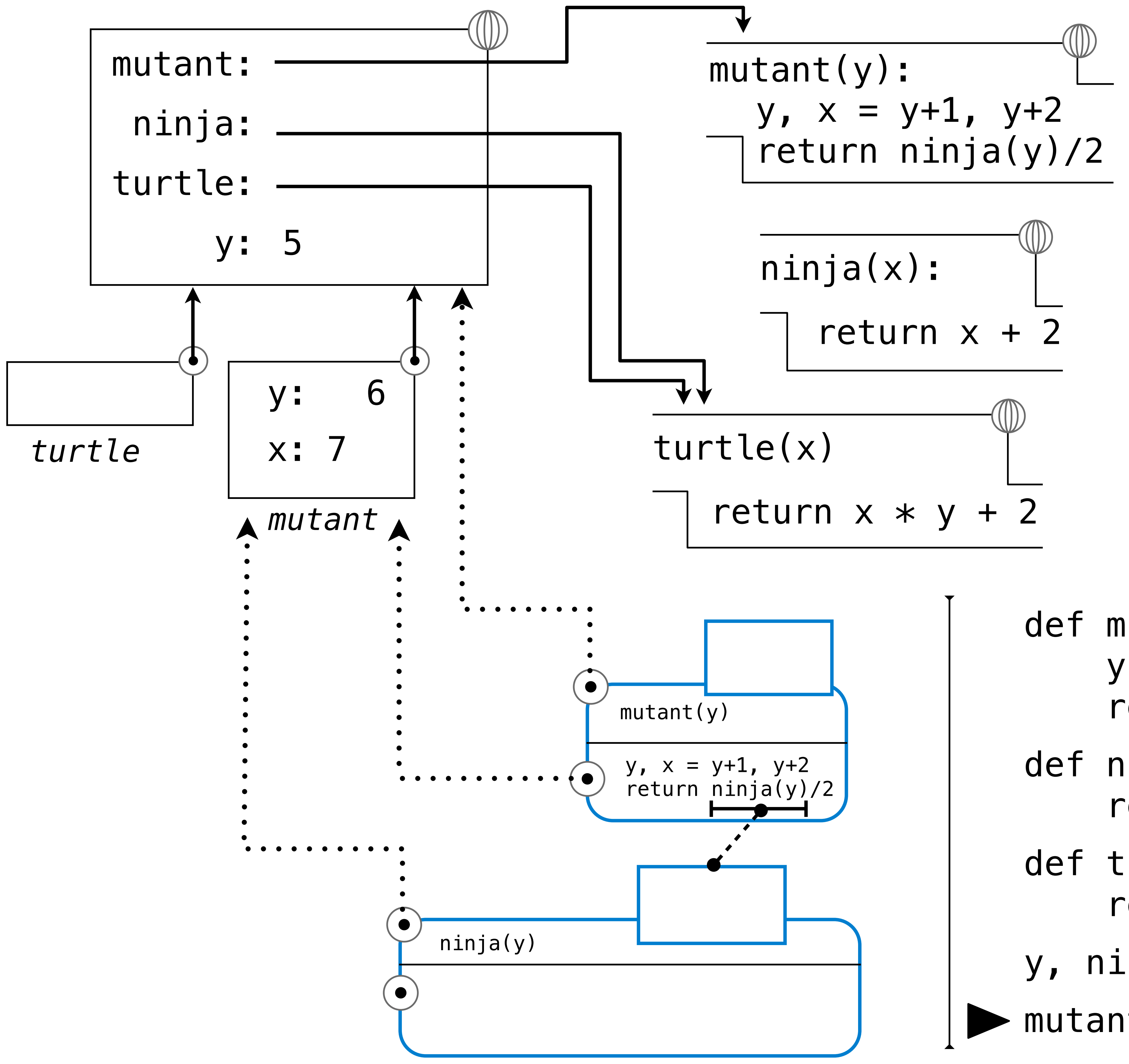
Assignment Review: Teenage Mutant Ninja Turtles



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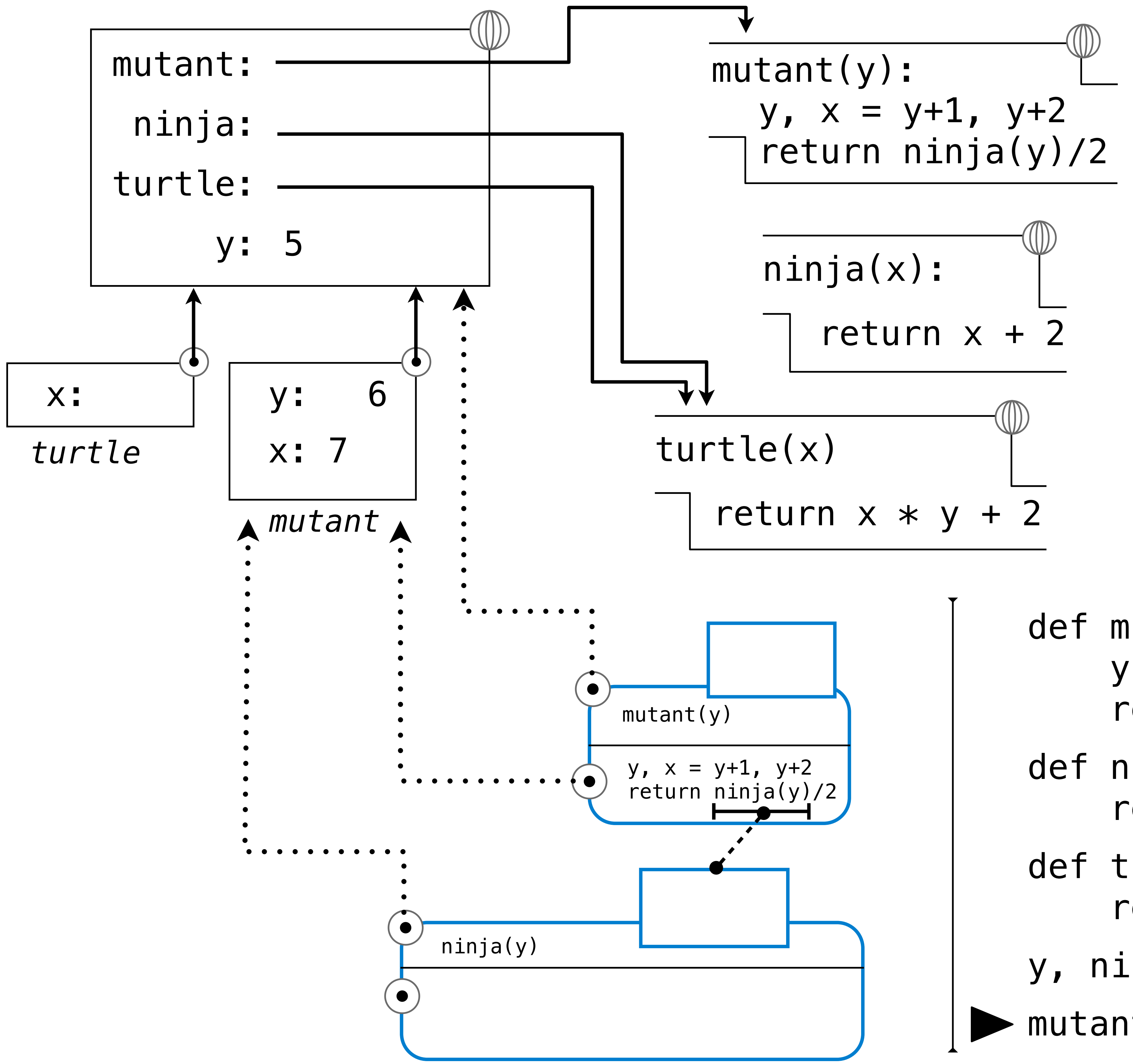
Assignment Review: Teenage Mutant Ninja Turtles



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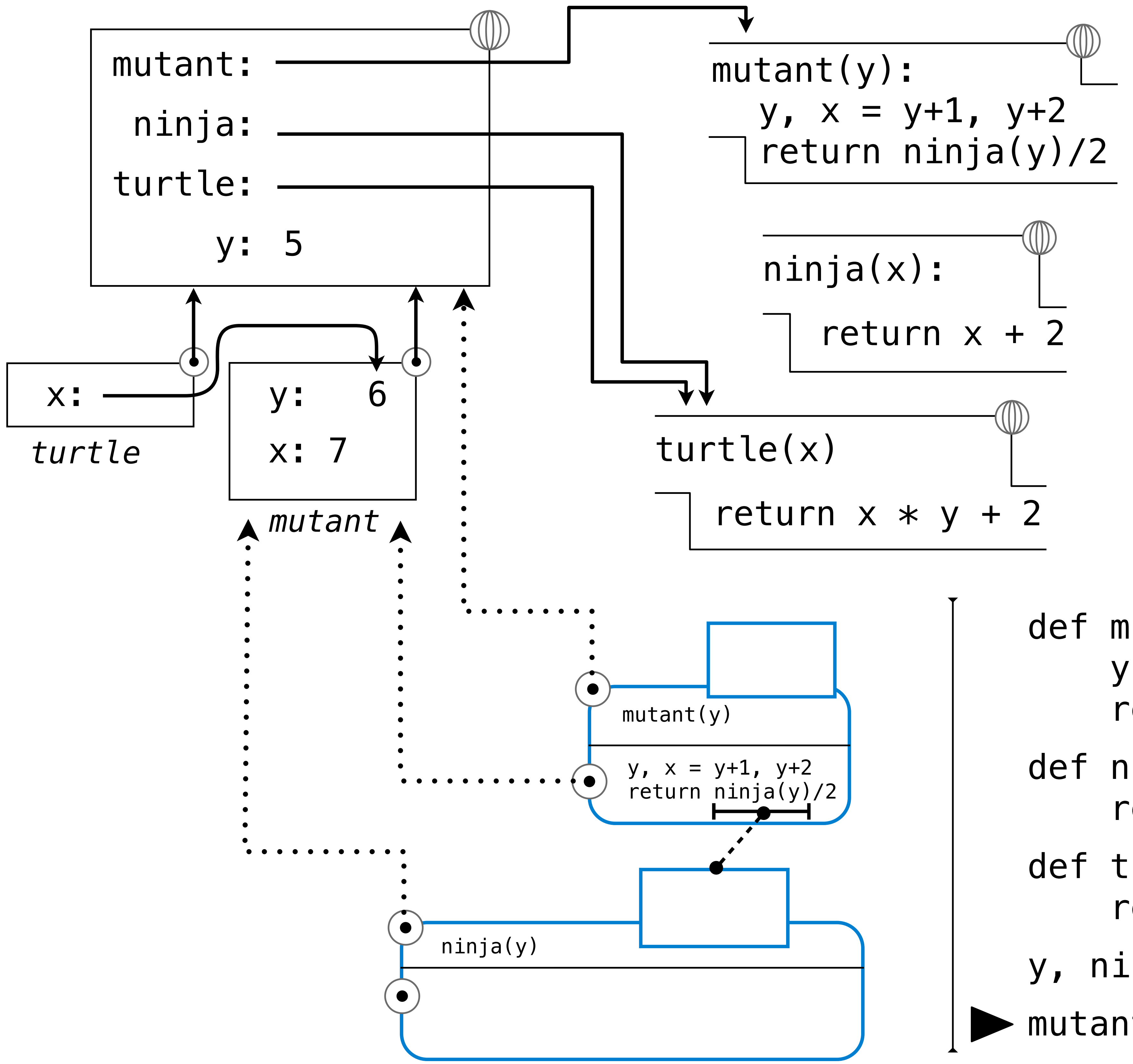
Assignment Review: Teenage Mutant Ninja Turtles



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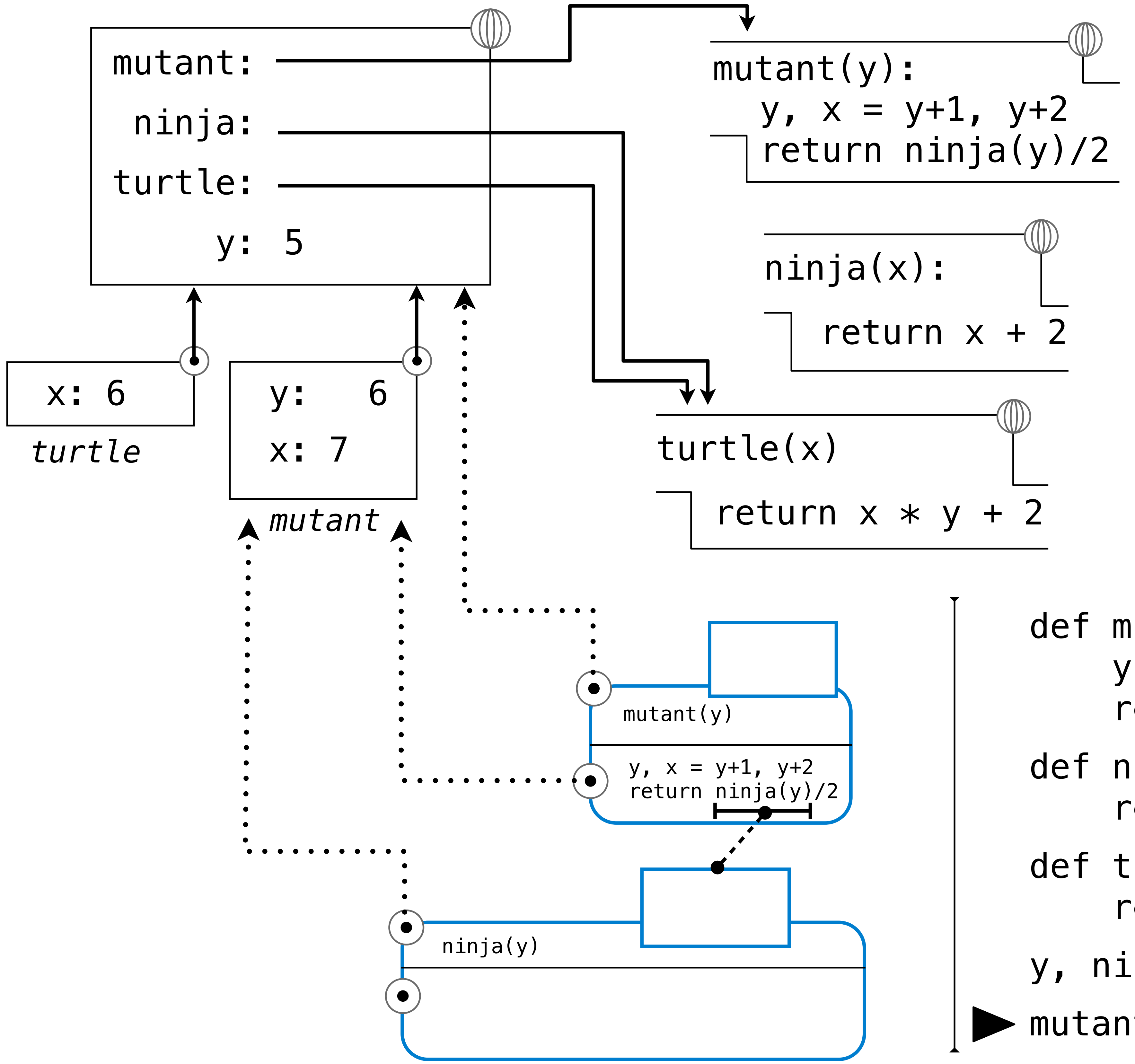
Assignment Review: Teenage Mutant Ninja Turtles



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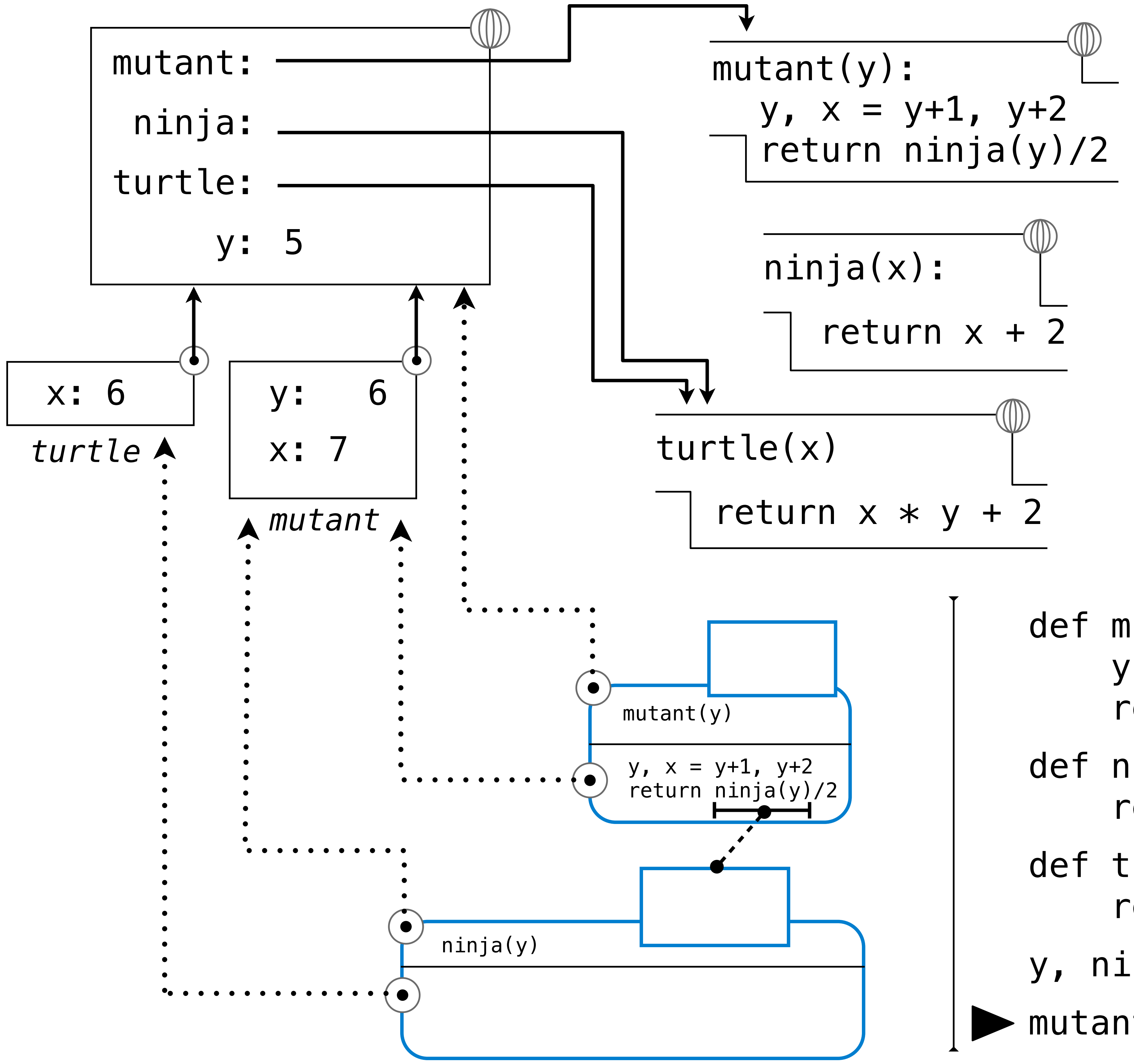
Assignment Review: Teenage Mutant Ninja Turtles



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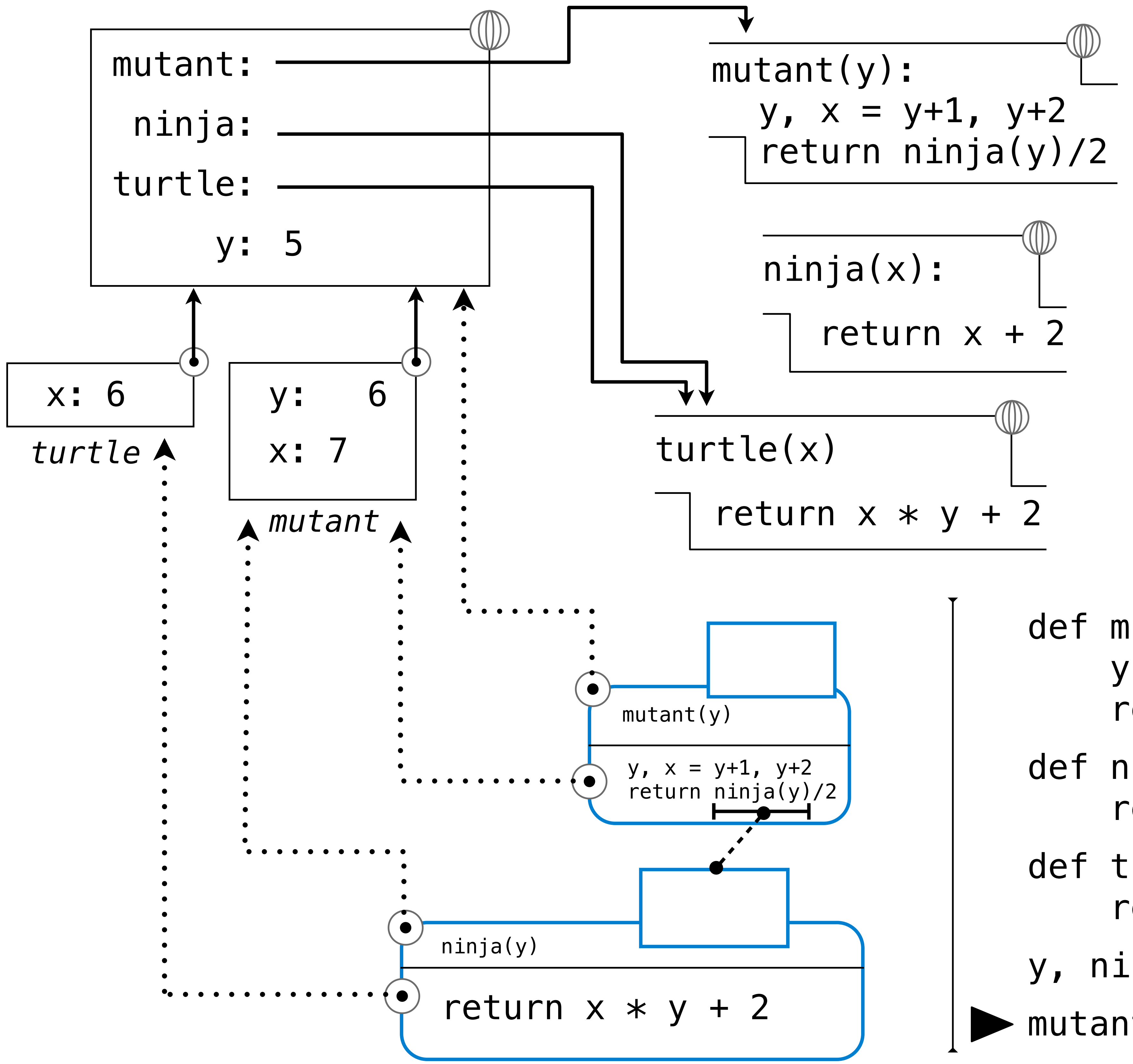
Assignment Review: Teenage Mutant Ninja Turtles



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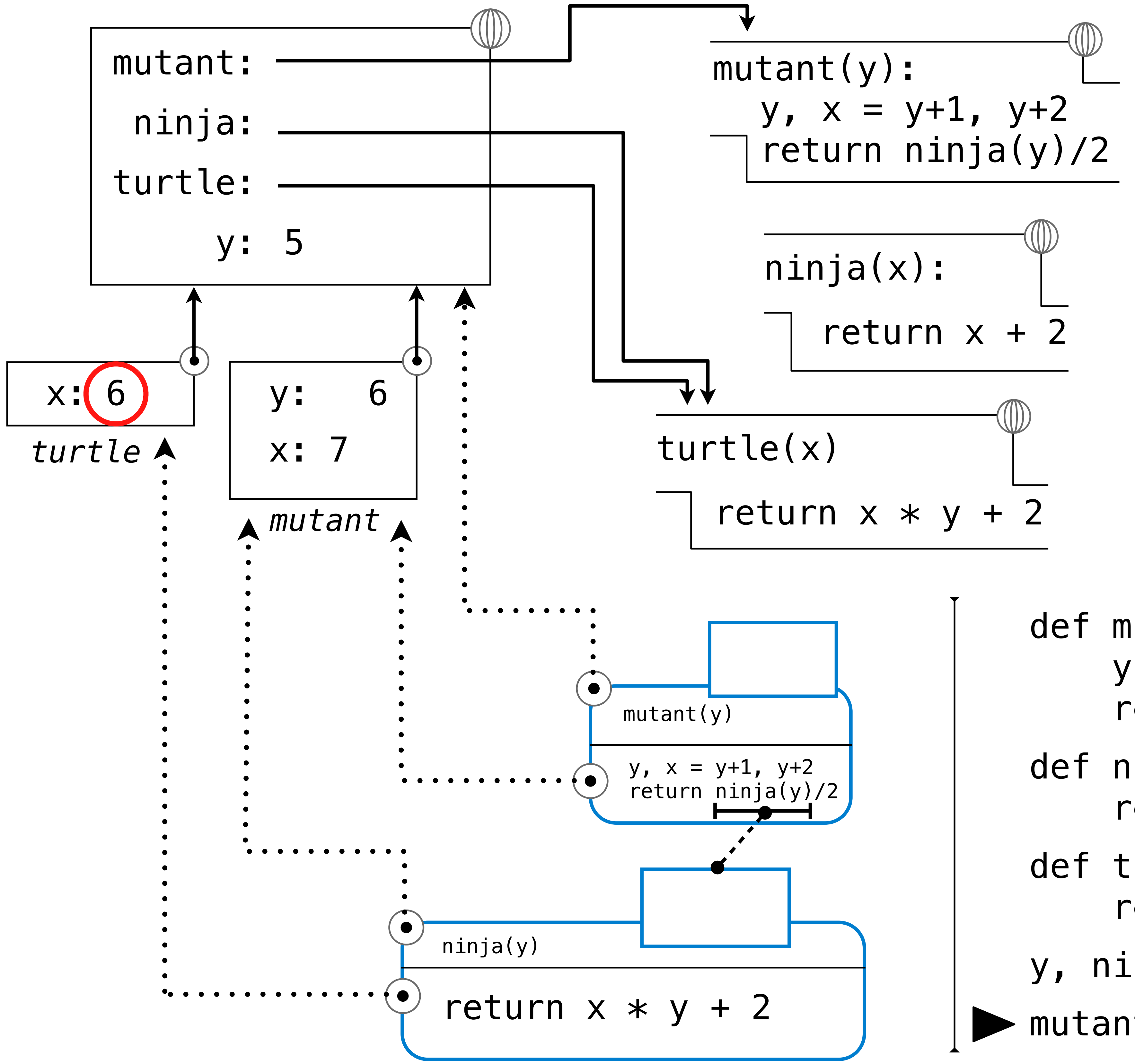
Assignment Review: Teenage Mutant Ninja Turtles



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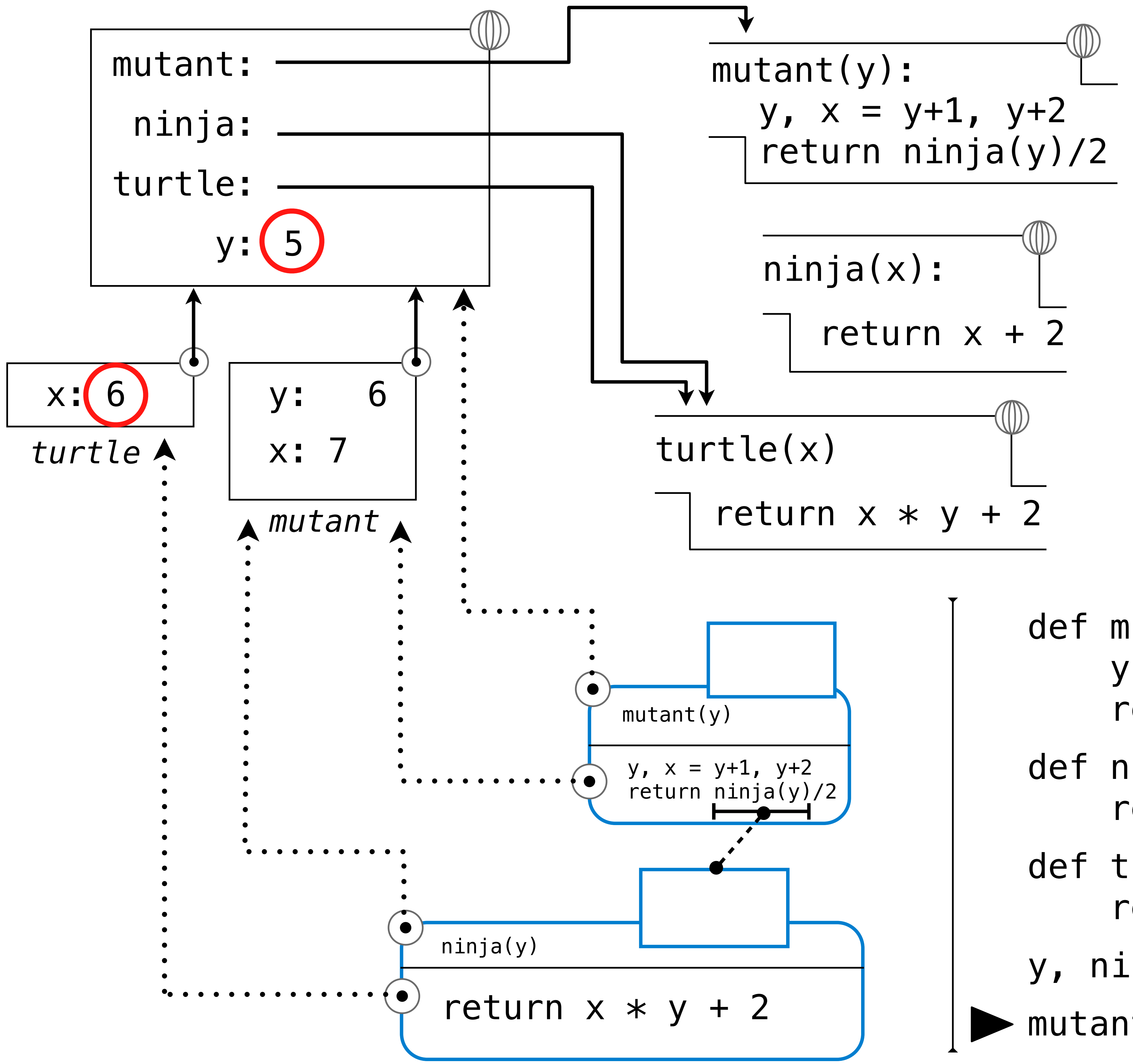
Assignment Review: Teenage Mutant Ninja Turtles



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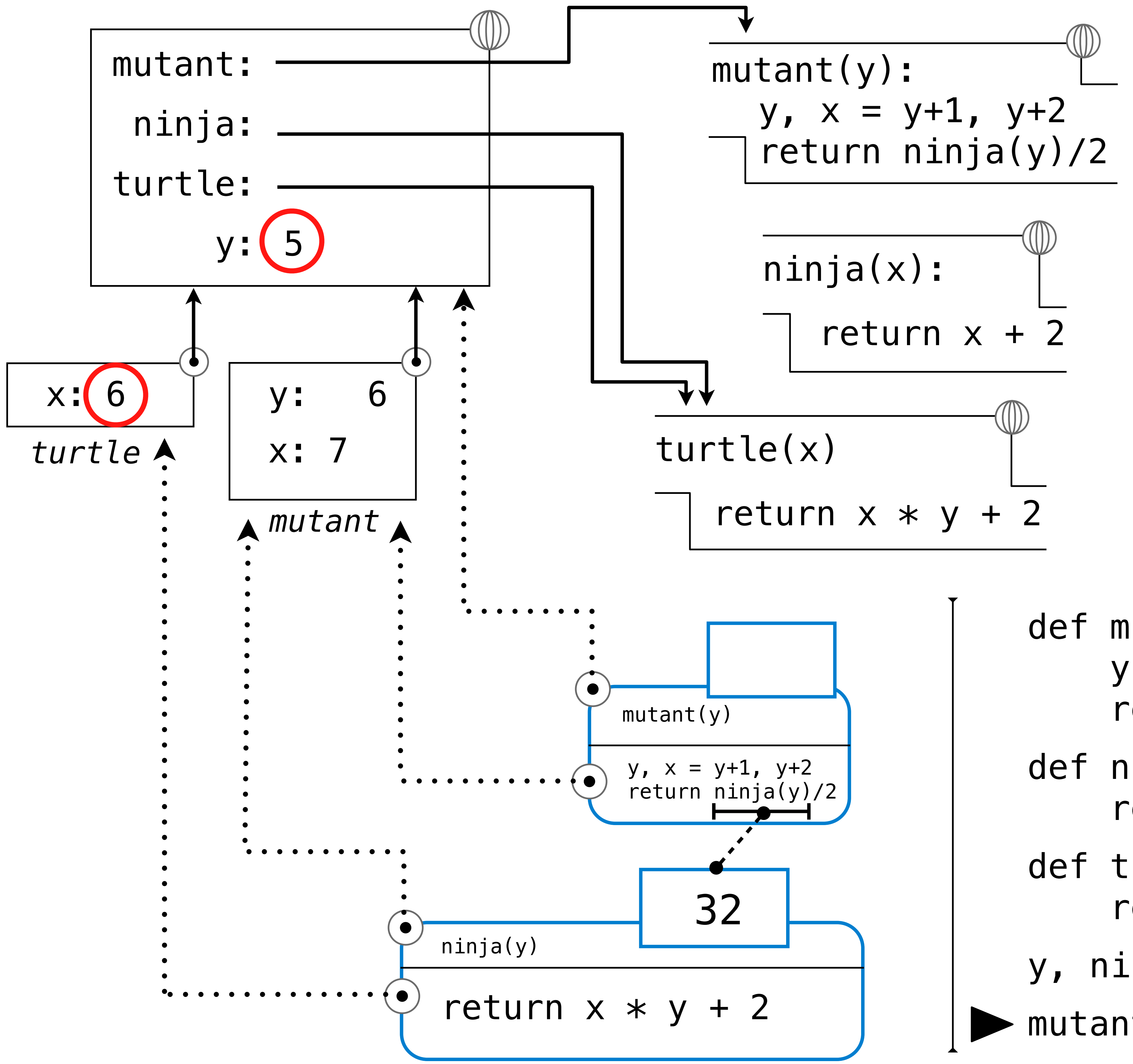
Assignment Review: Teenage Mutant Ninja Turtles



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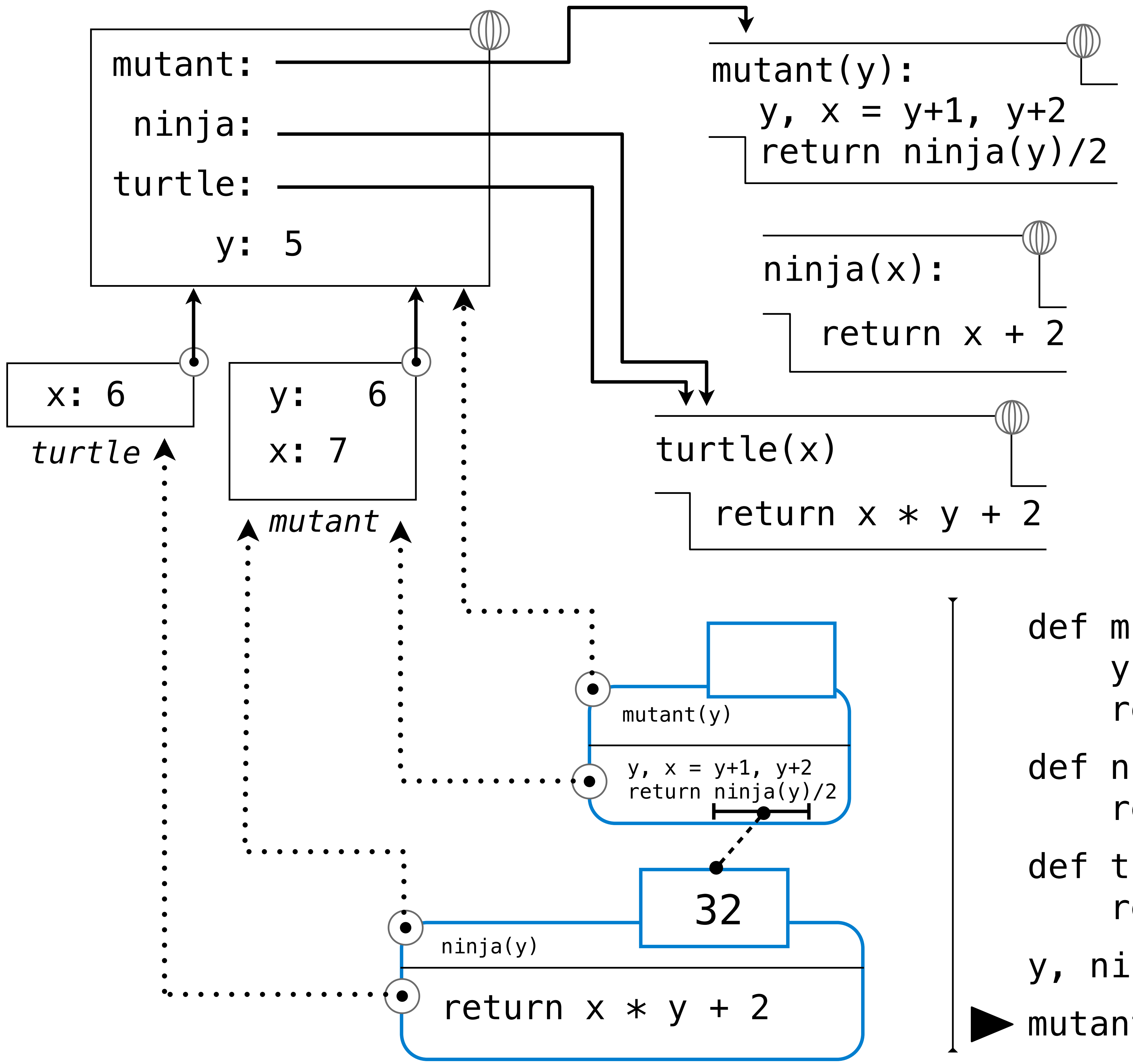
Assignment Review: Teenage Mutant Ninja Turtles



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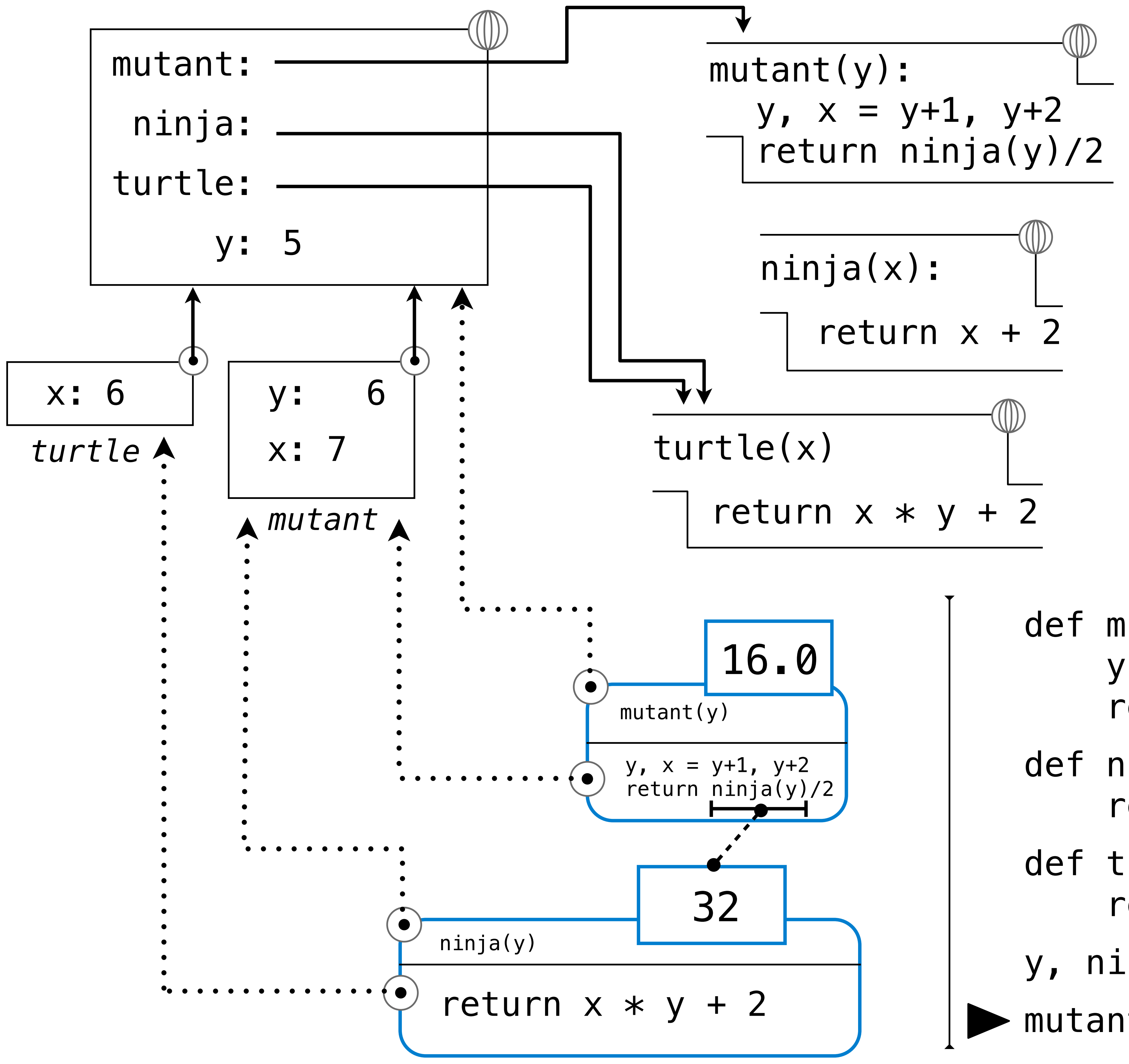
Assignment Review: Teenage Mutant Ninja Turtles



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Assignment Review: Teenage Mutant Ninja Turtles

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def turtle(x):
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y, ninja = 5, turtle

mutant(y)
```

Assignment Review: Teenage Mutant Ninja Turtles

- Bind mutant, ninja, and turtle to their respective functions

```
def mutant(y):
    y, x = y+1, y+2
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y, ninja = 5, turtle

mutant(y)
```

Assignment Review: Teenage Mutant Ninja Turtles

- Bind mutant, ninja, and turtle to their respective functions
- Simultaneously: bind y to 5 and ninja to the *turtle* function

```
def mutant(y):
    y, x = y+1, y+2
    return ninja(y)/2

def ninja(x):
    return x + 2

def turtle(x):
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y, ninja = 5, turtle

mutant(y)
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Assignment Review: Teenage Mutant Ninja Turtles

- Bind mutant, ninja, and turtle to their respective functions
- Simultaneously: bind y to 5 and ninja to the *turtle* function

Intrinsic function name

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def mutant(y):
    y, x = y+1, y+2
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def ninja(x):
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def turtle(x):
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y, ninja = 5, turtle

mutant(y)
```

Assignment Review: Teenage Mutant Ninja Turtles

- Bind mutant, ninja, and turtle to their respective functions
- Simultaneously: bind y to 5 and ninja to the *turtle* function
- Apply the *mutant* function *to 5*

Intrinsic function name

```
def mutant(y):
    y, x = y+1, y+2
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def ninja(x):
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def turtle(x):
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y, ninja = 5, turtle

mutant(y)
```

Assignment Review: Teenage Mutant Ninja Turtles

- Bind mutant, ninja, and turtle to their respective functions
- Simultaneously: bind y to 5 and ninja to the *turtle* function
- Apply the *mutant* function *to 5*
  - In the first frame, bind y to 6 and x to 7

Intrinsic function name

```
def mutant(y):
    y, x = y+1, y+2
    return ninja(y)/2

def ninja(x):
    return x + 2

def turtle(x):
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y, ninja = 5, turtle

mutant(y)
```

Assignment Review: Teenage Mutant Ninja Turtles

- Bind mutant, ninja, and turtle to their respective functions
- Simultaneously: bind y to 5 and ninja to the *turtle* function
- Apply the *mutant* function *to 5*
  - In the first frame, bind y to 6 and x to 7
  - Look up ninja, which is bound to the *turtle* function

Intrinsic function name

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def mutant(y):
    y, x = y+1, y+2
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def ninja(x):
    return x + 2

def turtle(x):
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y, ninja = 5, turtle

mutant(y)
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Assignment Review: Teenage Mutant Ninja Turtles

- Bind mutant, ninja, and turtle to their respective functions
- Simultaneously: bind y to 5 and ninja to the *turtle* function
- Apply the *mutant* function *to 5*
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  - Look up ninja, which is bound to the *turtle* function
  - Look up y, which is bound to 6

Intrinsic function name

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    y, x = y+1, y+2
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def ninja(x):
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def turtle(x):
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y, ninja = 5, turtle

mutant(y)
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Assignment Review: Teenage Mutant Ninja Turtles

- Bind mutant, ninja, and turtle to their respective functions
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  - In the first frame, bind y to 6 and x to 7
  - Look up ninja, which is bound to the *turtle* function
  - Look up y, which is bound to 6
  - Apply the *turtle* function to 6

Intrinsic function name

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y, ninja = 5, turtle

mutant(y)
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Assignment Review: Teenage Mutant Ninja Turtles

- Bind mutant, ninja, and turtle to their respective functions
- Simultaneously: bind y to 5 and ninja to the *turtle* function
- Apply the *mutant* function *to 5*
  - In the first frame, bind y to 6 and x to 7
  - Look up ninja, which is bound to the *turtle* function
  - Look up y, which is bound to 6
  - Apply the *turtle* function to 6
    - Look up x, which is bound to 6 in the local frame

Intrinsic function name

```
def mutant(y):
    y, x = y+1, y+2
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def ninja(x):
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def turtle(x):
    return x * y + 2

y, ninja = 5, turtle

mutant(y)
```

Assignment Review: Teenage Mutant Ninja Turtles

- Bind mutant, ninja, and turtle to their respective functions
- Simultaneously: bind y to 5 and ninja to the *turtle* function
- Apply the *mutant* function *to 5*
  - In the first frame, bind y to 6 and x to 7
  - Look up ninja, which is bound to the *turtle* function
  - Look up y, which is bound to 6
  - Apply the *turtle* function to 6
    - Look up x, which is bound to 6 in the local frame
    - Look up y, which is bound to 5 in the global frame

Intrinsic function name

```
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def ninja(x):
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def turtle(x):
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y, ninja = 5, turtle

mutant(y)
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Assignment Review: Teenage Mutant Ninja Turtles

- Bind mutant, ninja, and turtle to their respective functions
- Simultaneously: bind y to 5 and ninja to the *turtle* function
- Apply the *mutant* function *to 5*
    - In the first frame, bind y to 6 and x to 7
    - Look up ninja, which is bound to the *turtle* function
    - Look up y, which is bound to 6
    - Apply the *turtle* function to 6
        - Look up x, which is bound to 6 in the local frame
        - Look up y, which is bound to 5 in the global frame
        - Return 6 * 5 + 2 = 32

Intrinsic function name

```
def mutant(y):
    y, x = y+1, y+2
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def ninja(x):
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def turtle(x):
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y, ninja = 5, turtle

mutant(y)
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Assignment Review: Teenage Mutant Ninja Turtles

- Bind mutant, ninja, and turtle to their respective functions
- Simultaneously: bind y to 5 and ninja to the *turtle* function

Intrinsic function name

- Apply the *mutant* function *to 5*
  - In the first frame, bind y to 6 and x to 7
  - Look up ninja, which is bound to the *turtle* function
  - Look up y, which is bound to 6
  - Apply the *turtle* function to 6
    - Look up x, which is bound to 6 in the local frame
    - Look up y, which is bound to 5 in the global frame
    - Return 6 * 5 + 2 = 32
  - Return 32 / 2 = 16.0

```
def mutant(y):
    y, x = y+1, y+2
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def turtle(x):
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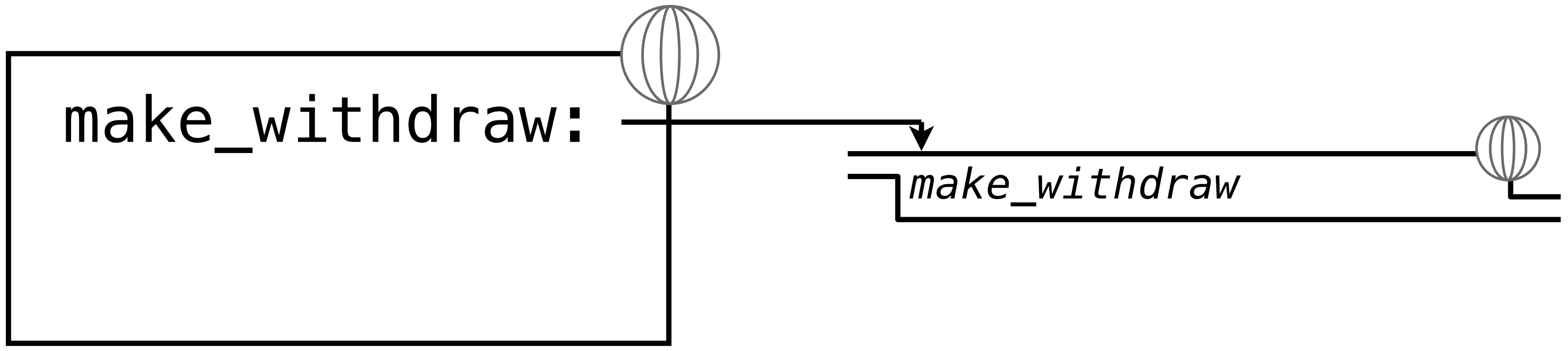
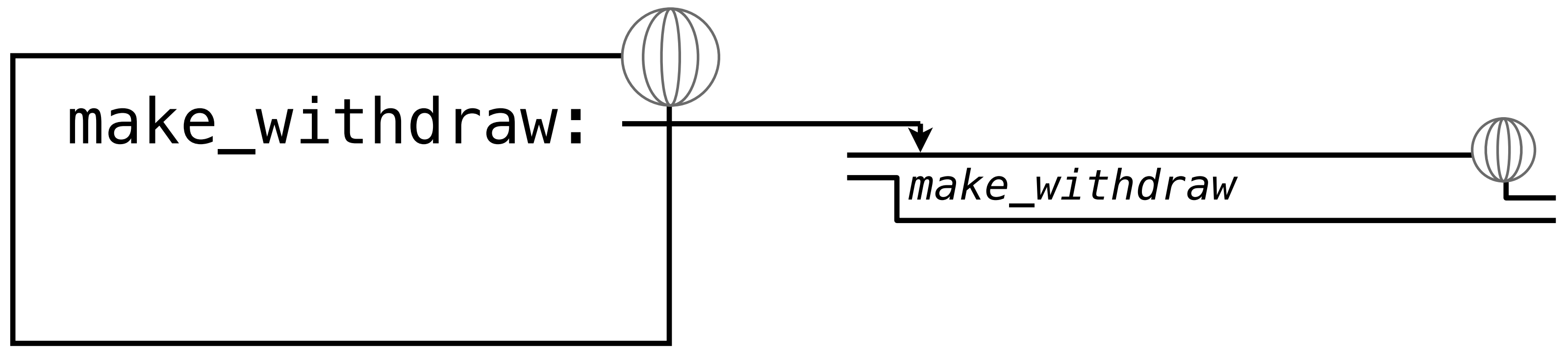
y, ninja = 5, turtle

mutant(y)
```

Environment Diagram of Withdraw

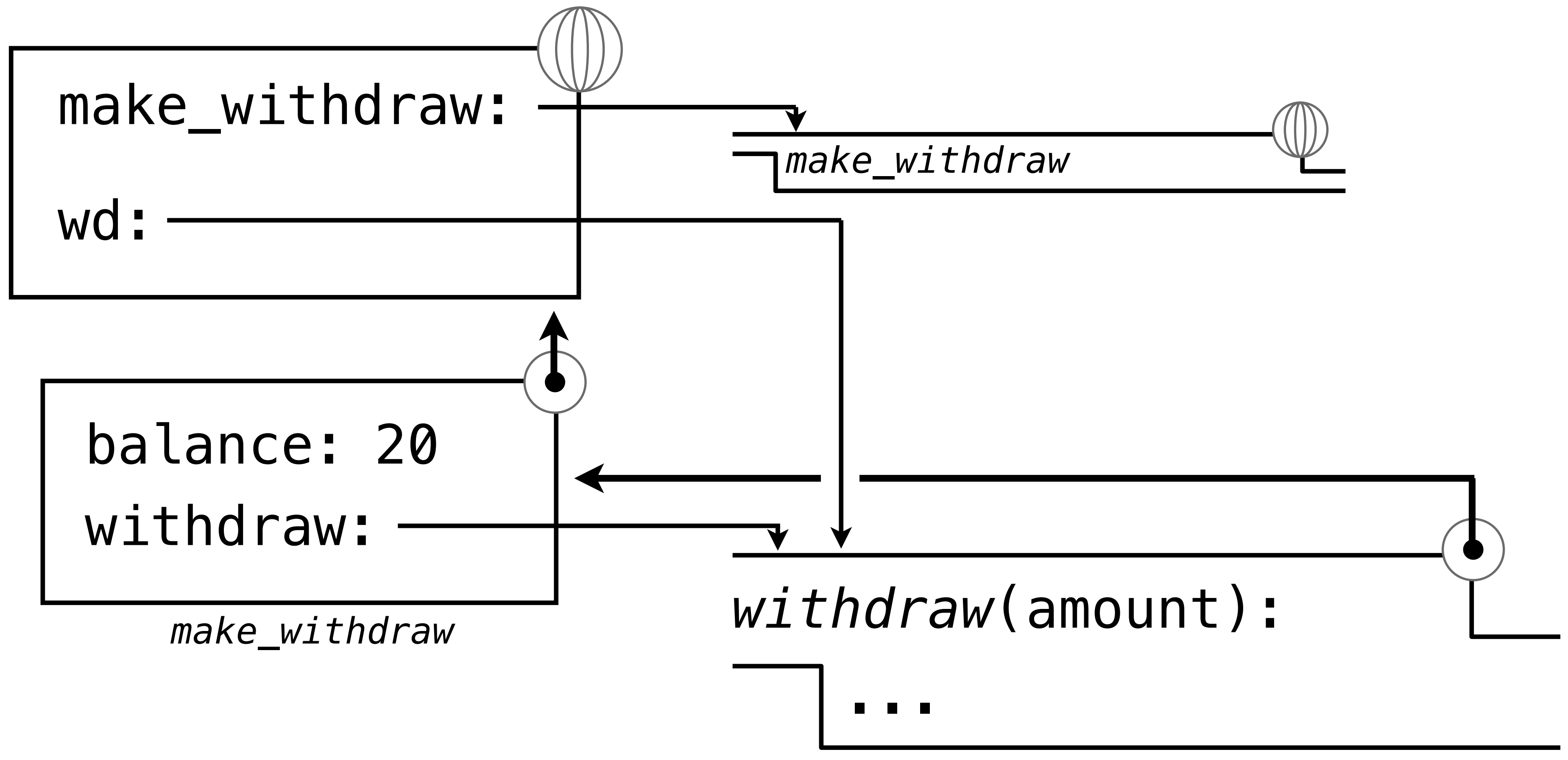


Environment Diagram of Withdraw



```
wd = make_withdraw(20)
wd(5)
```

Environment Diagram of Withdraw



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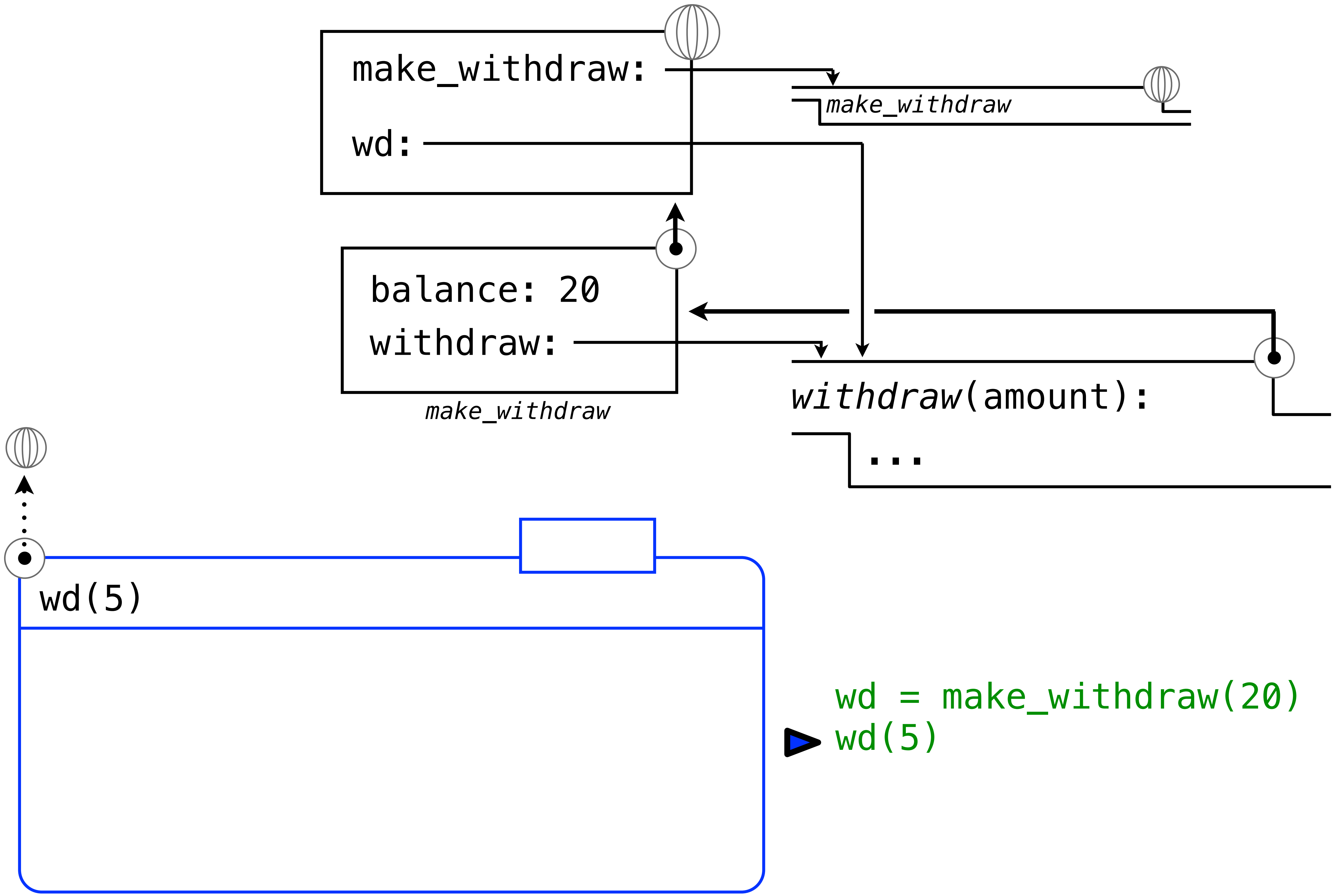

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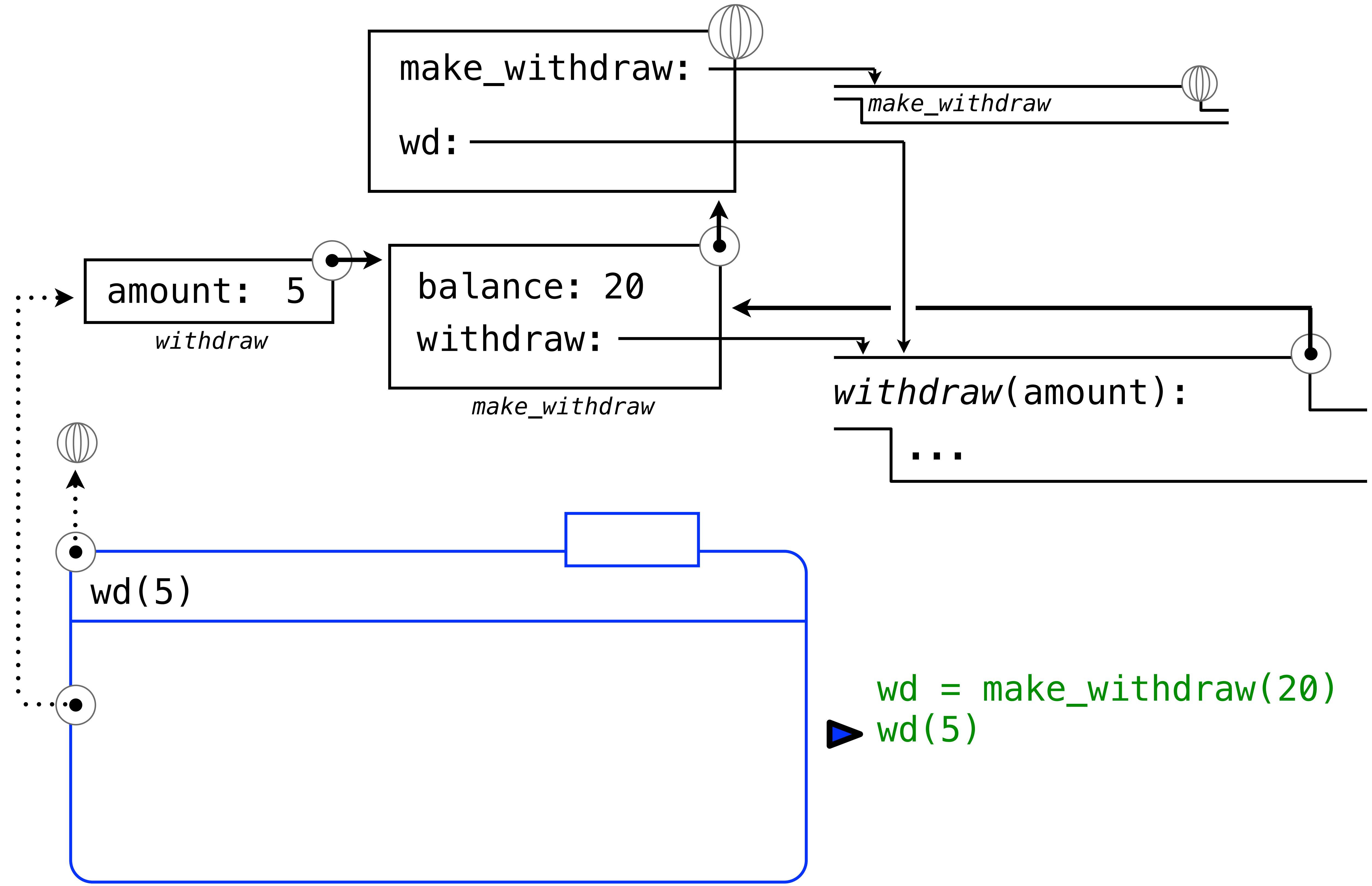

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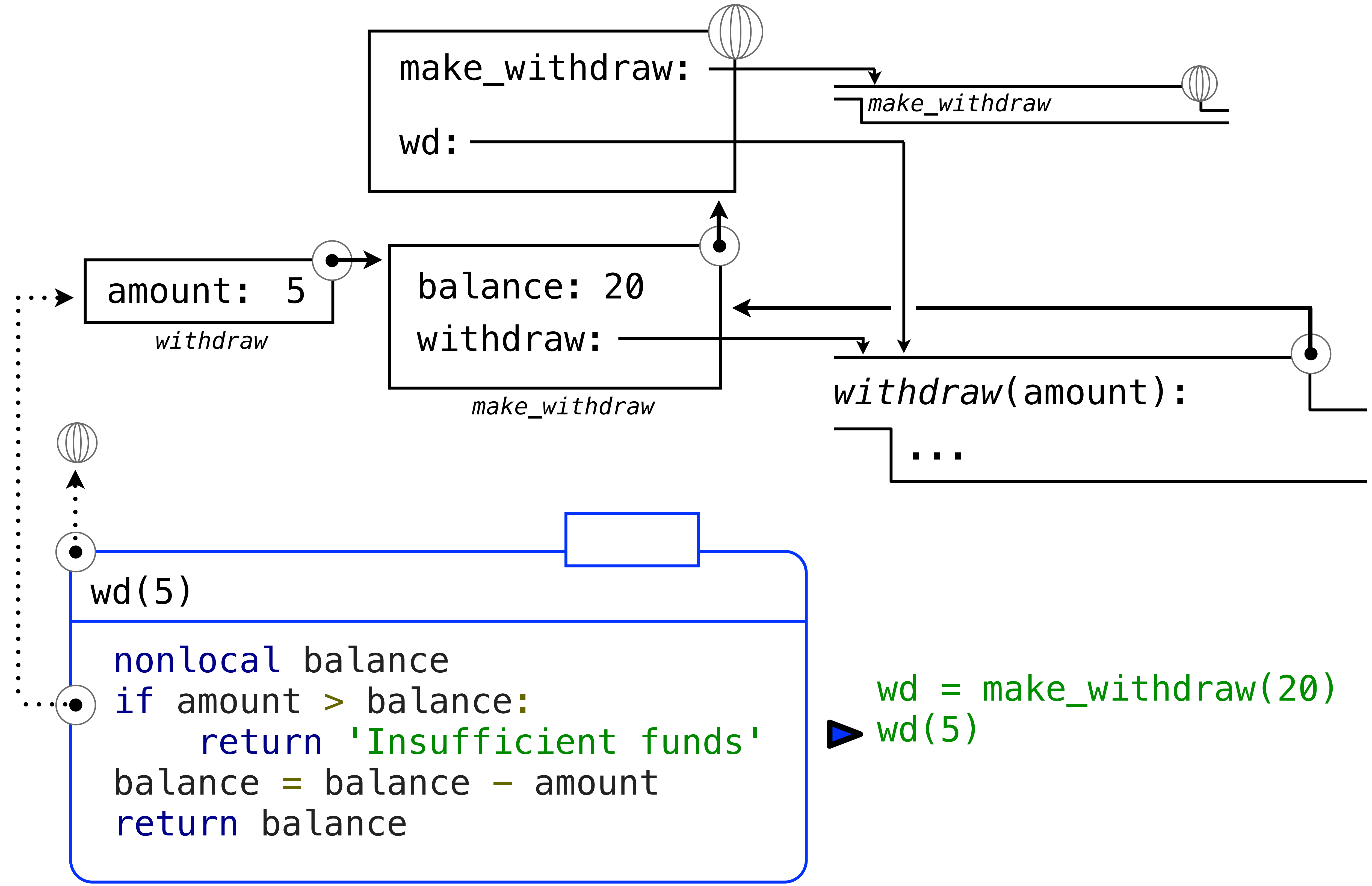

```
nonlocal balance
if amount > balance:
    return 'Insufficient funds'
balance = balance - amount
return balance
```

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wd(5)
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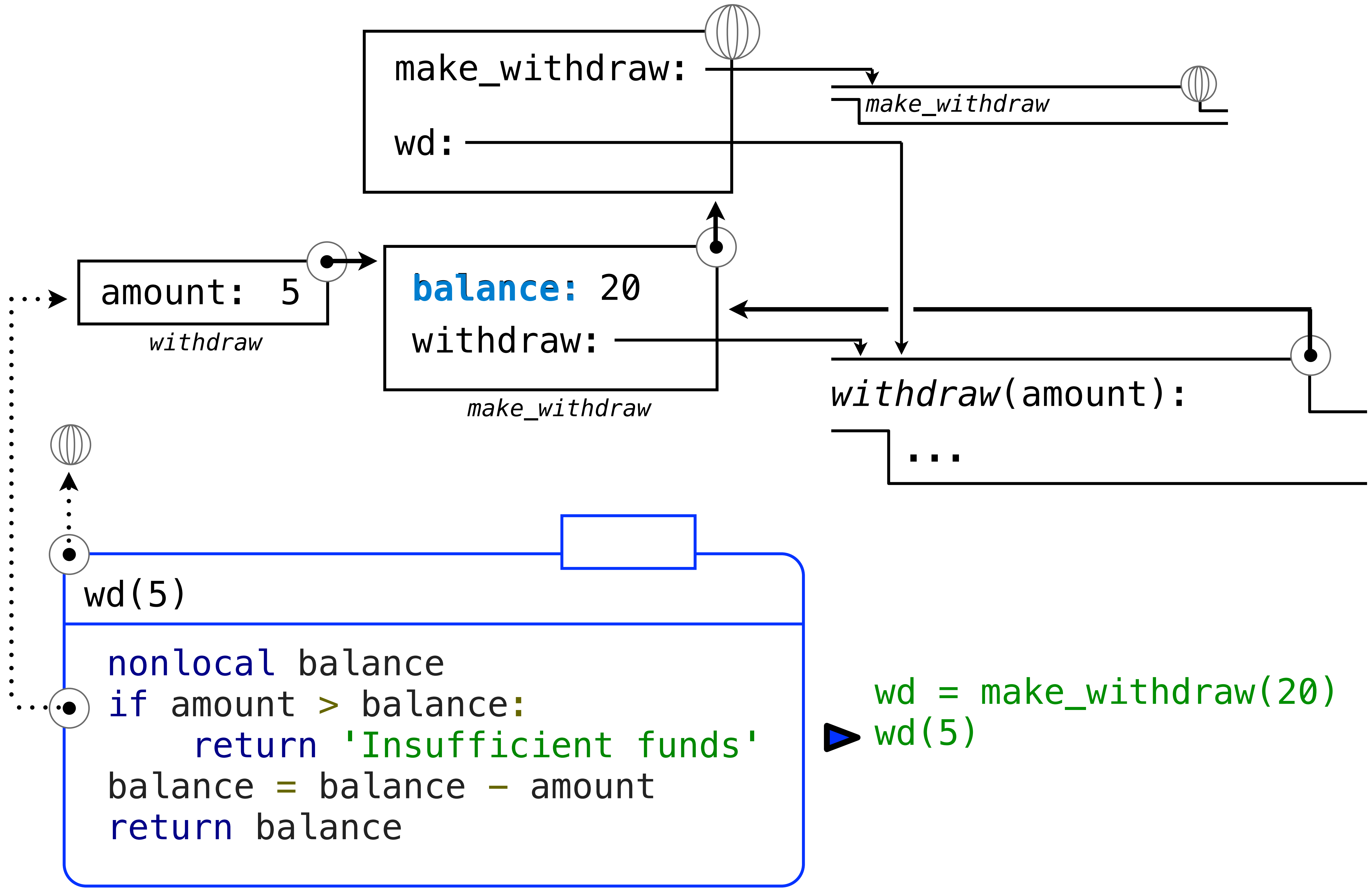
Environment Diagram of Withdraw



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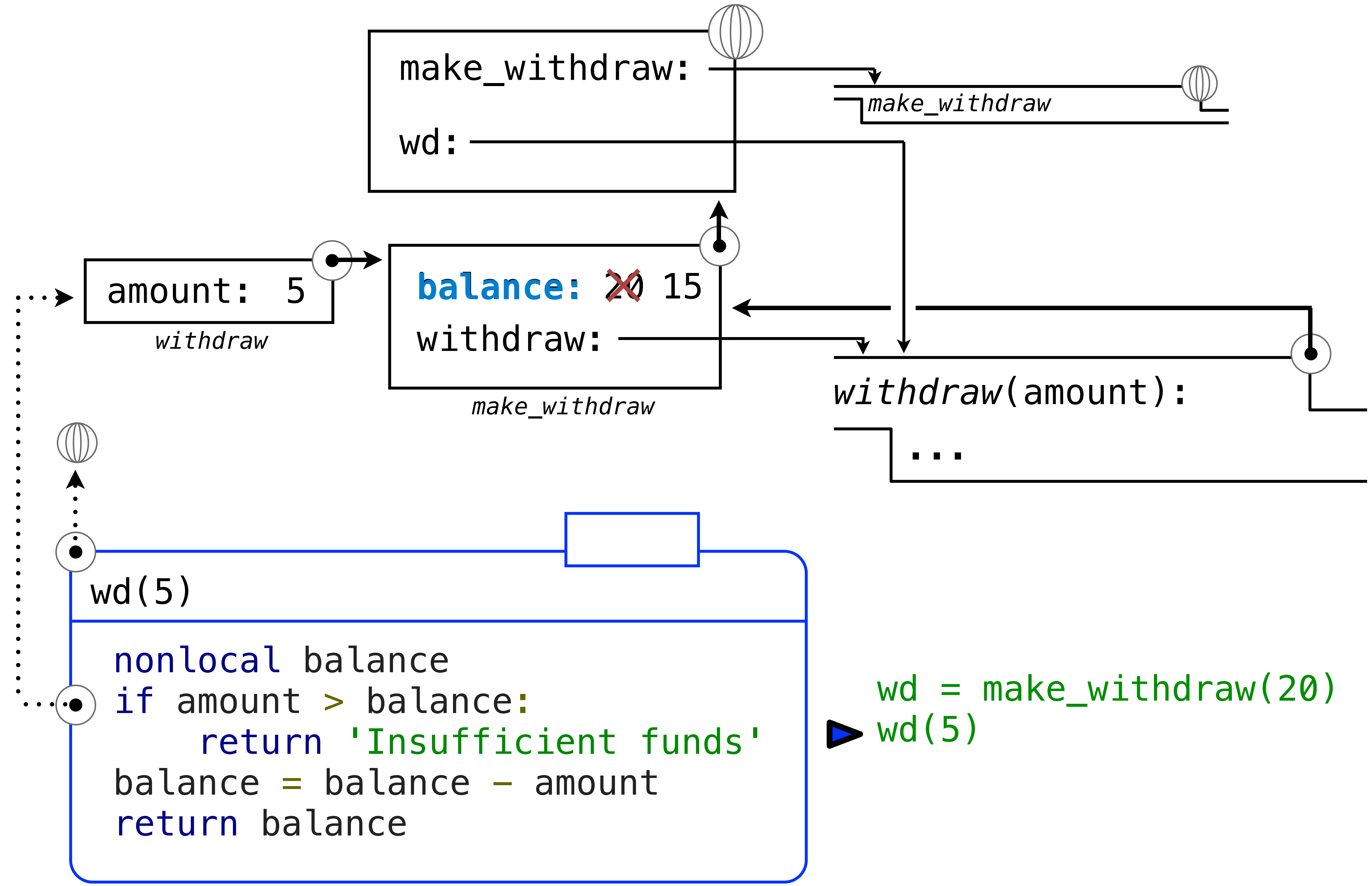

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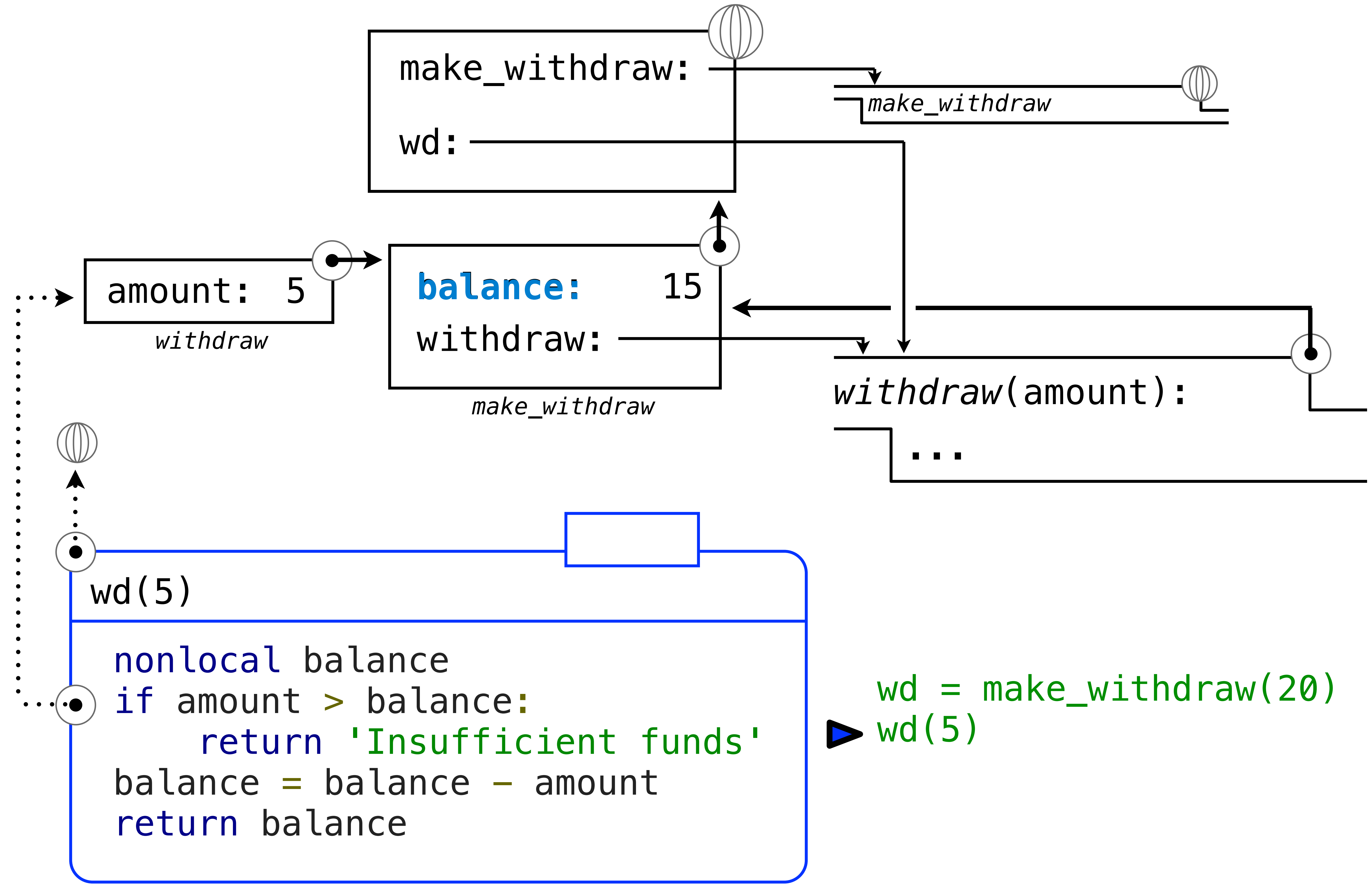

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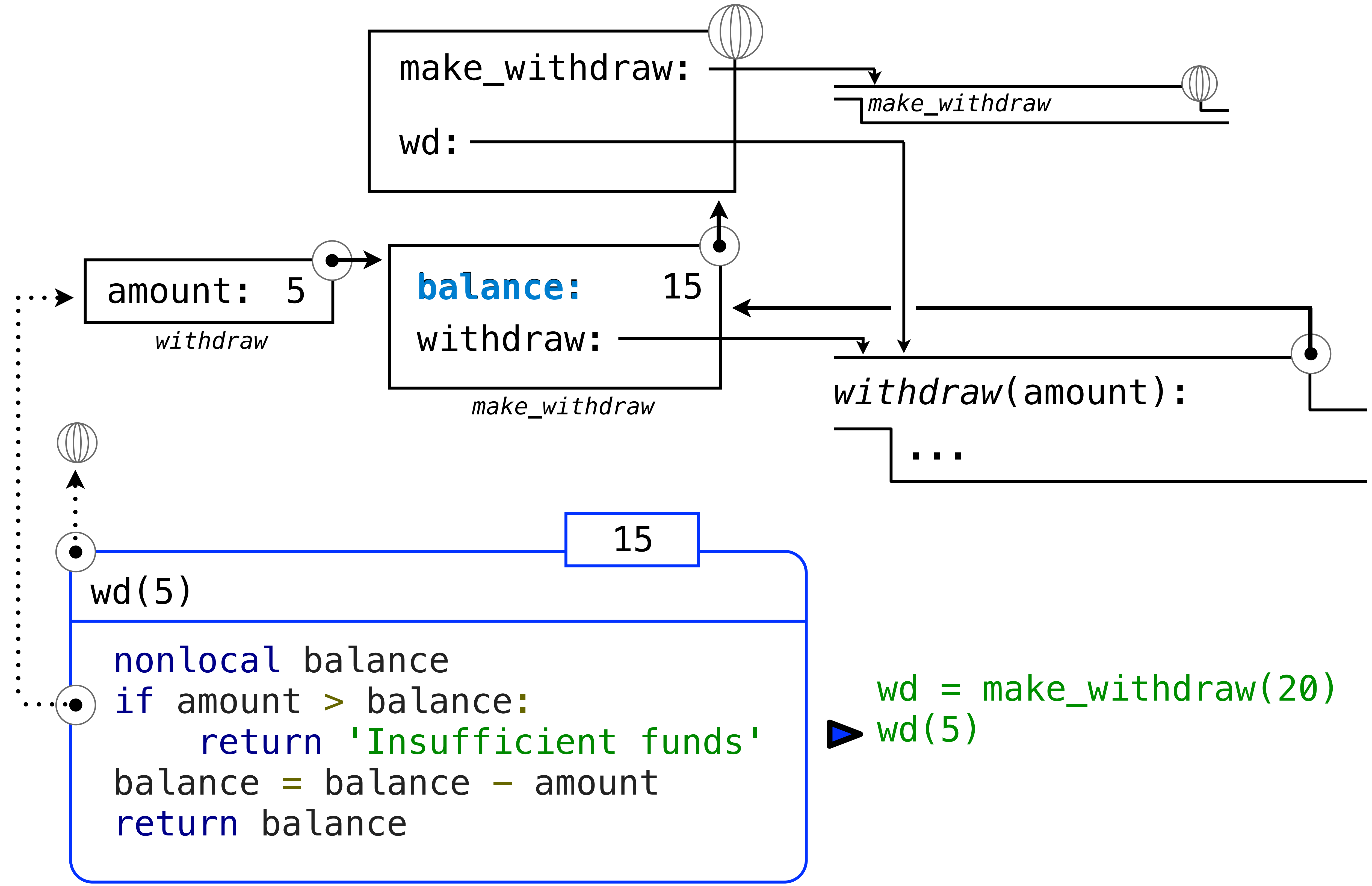

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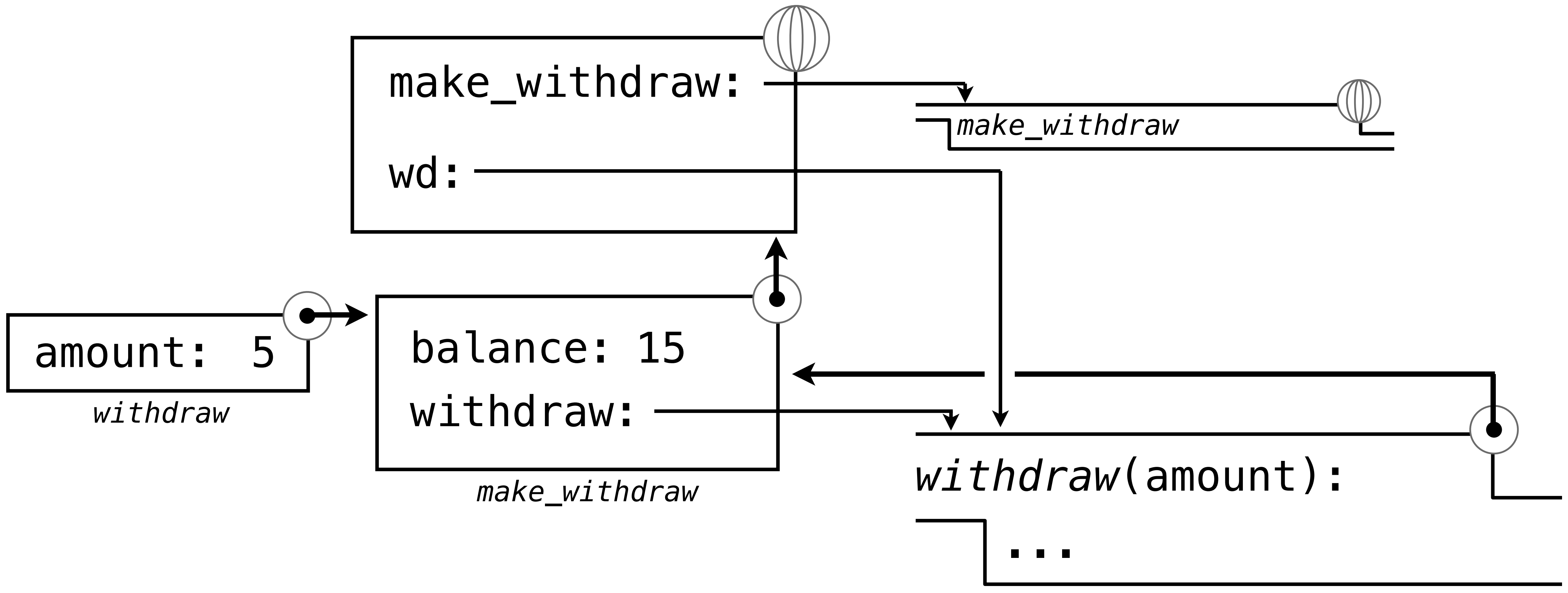

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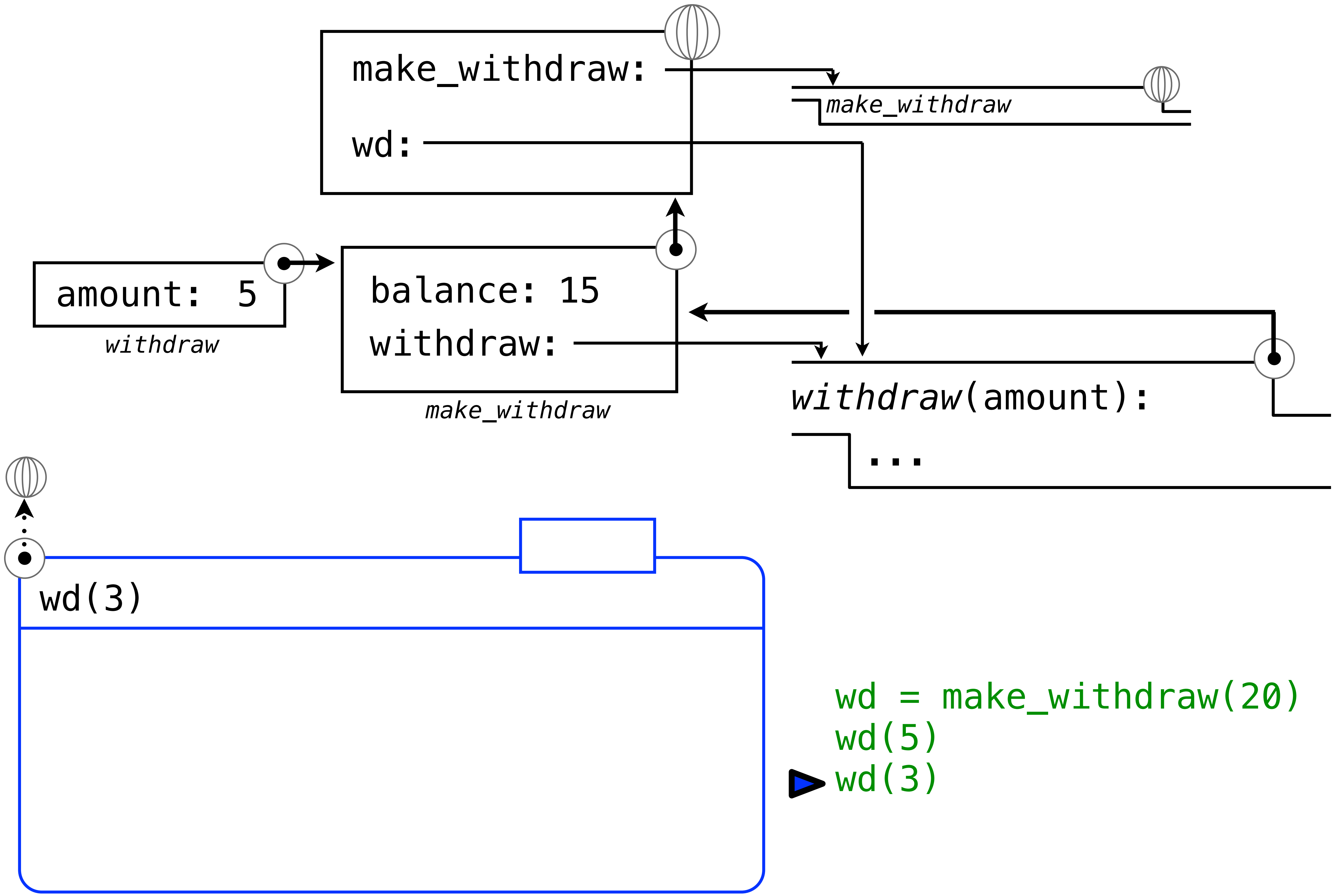

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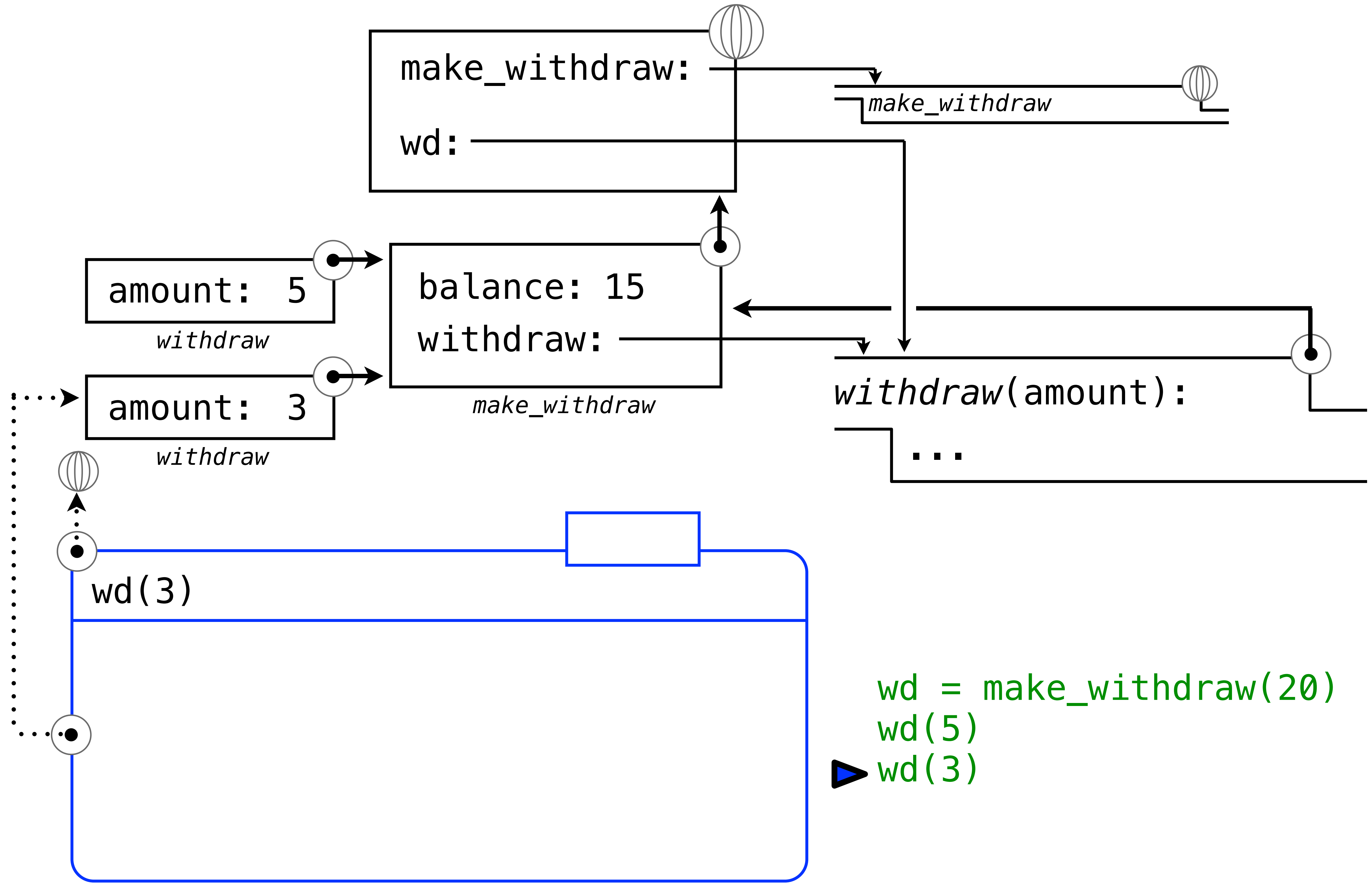

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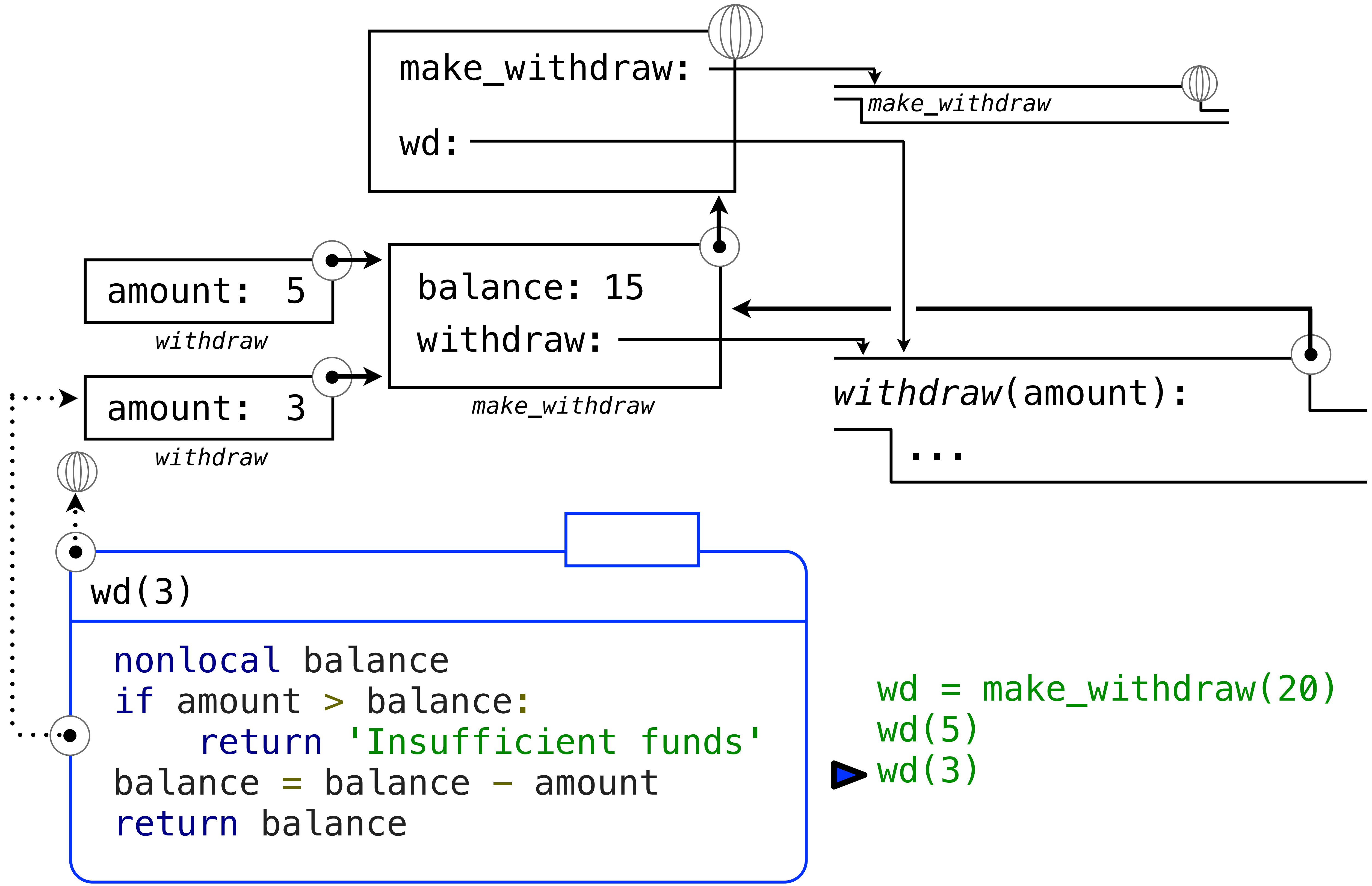

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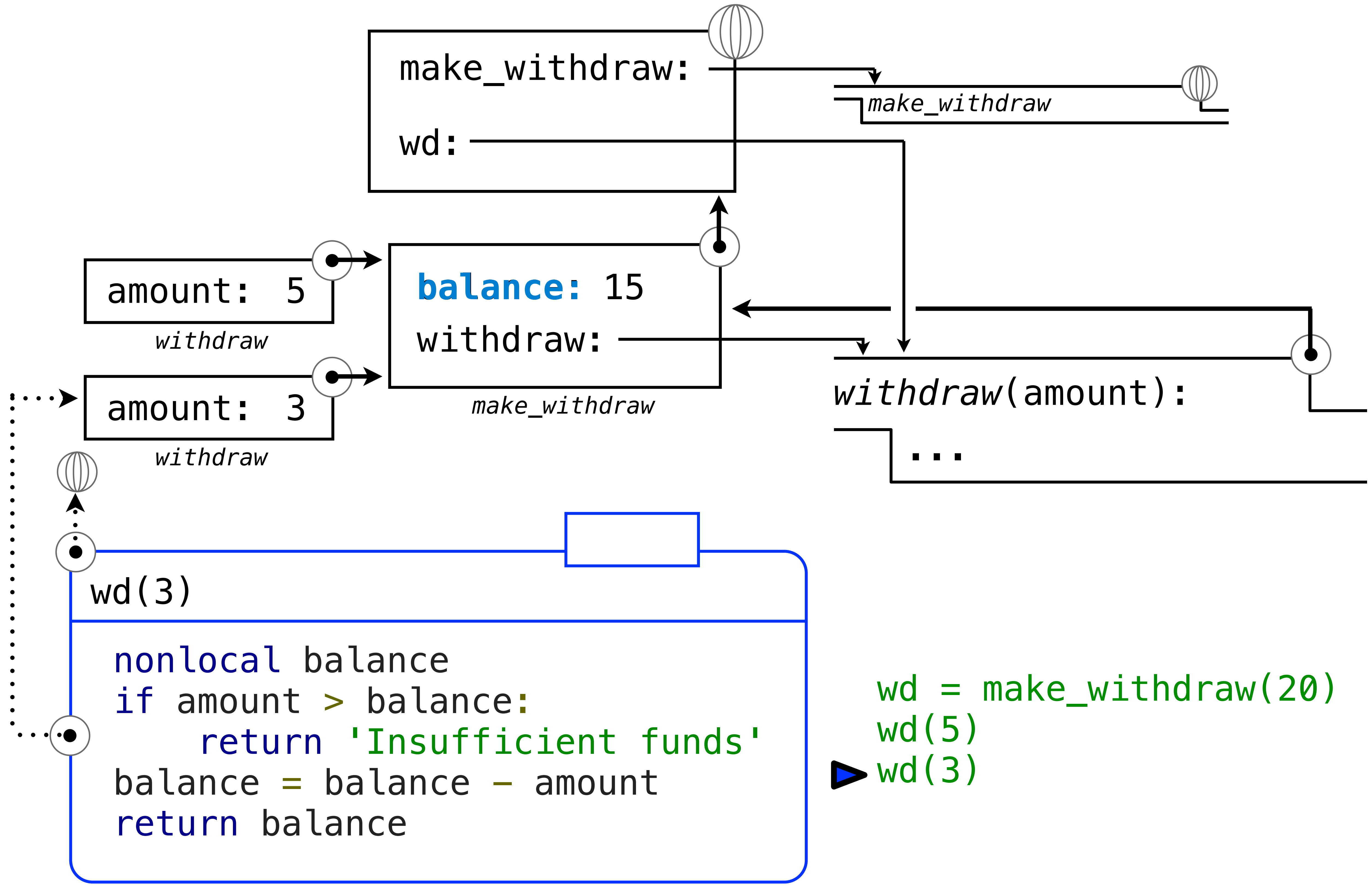

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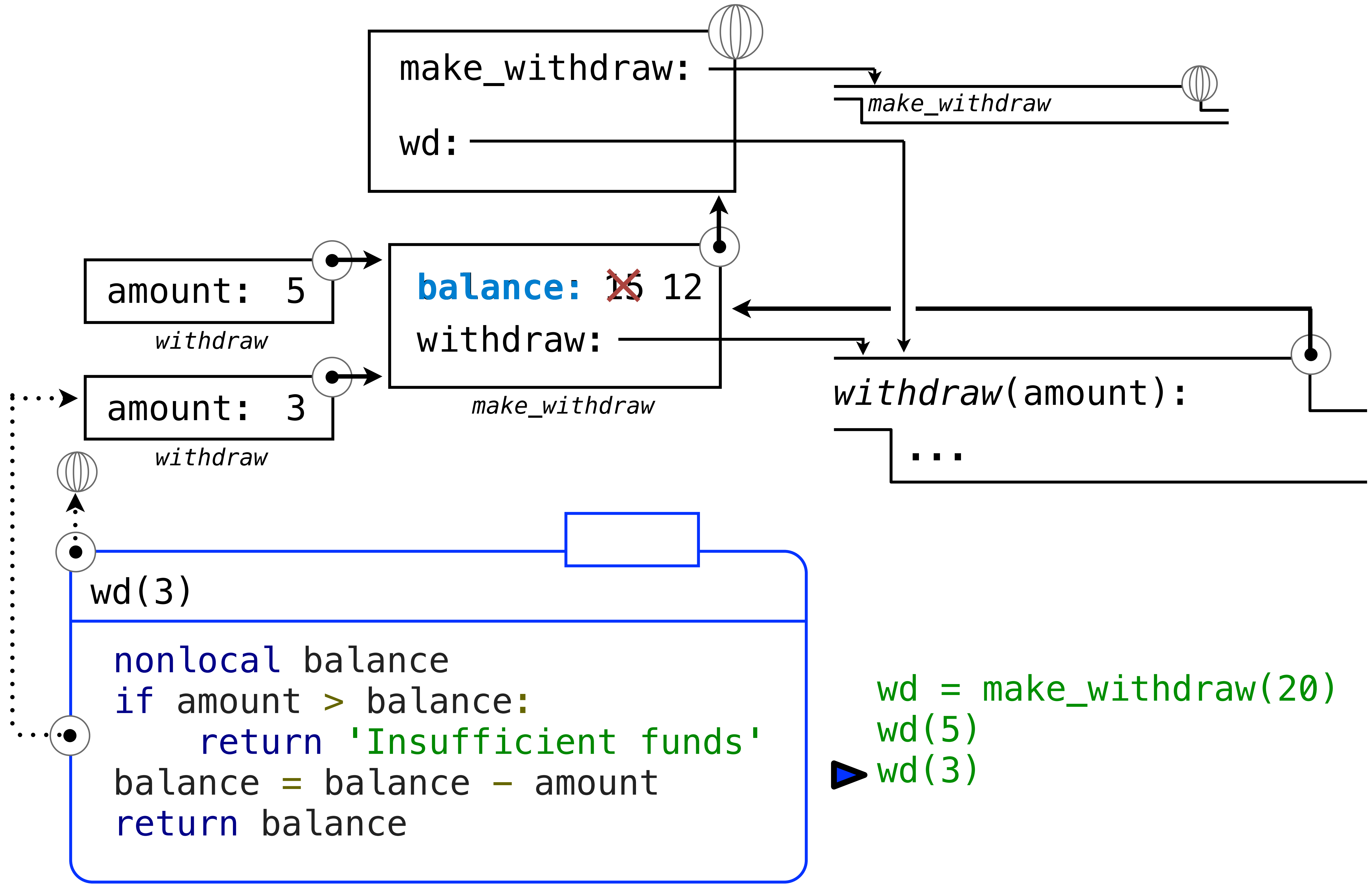

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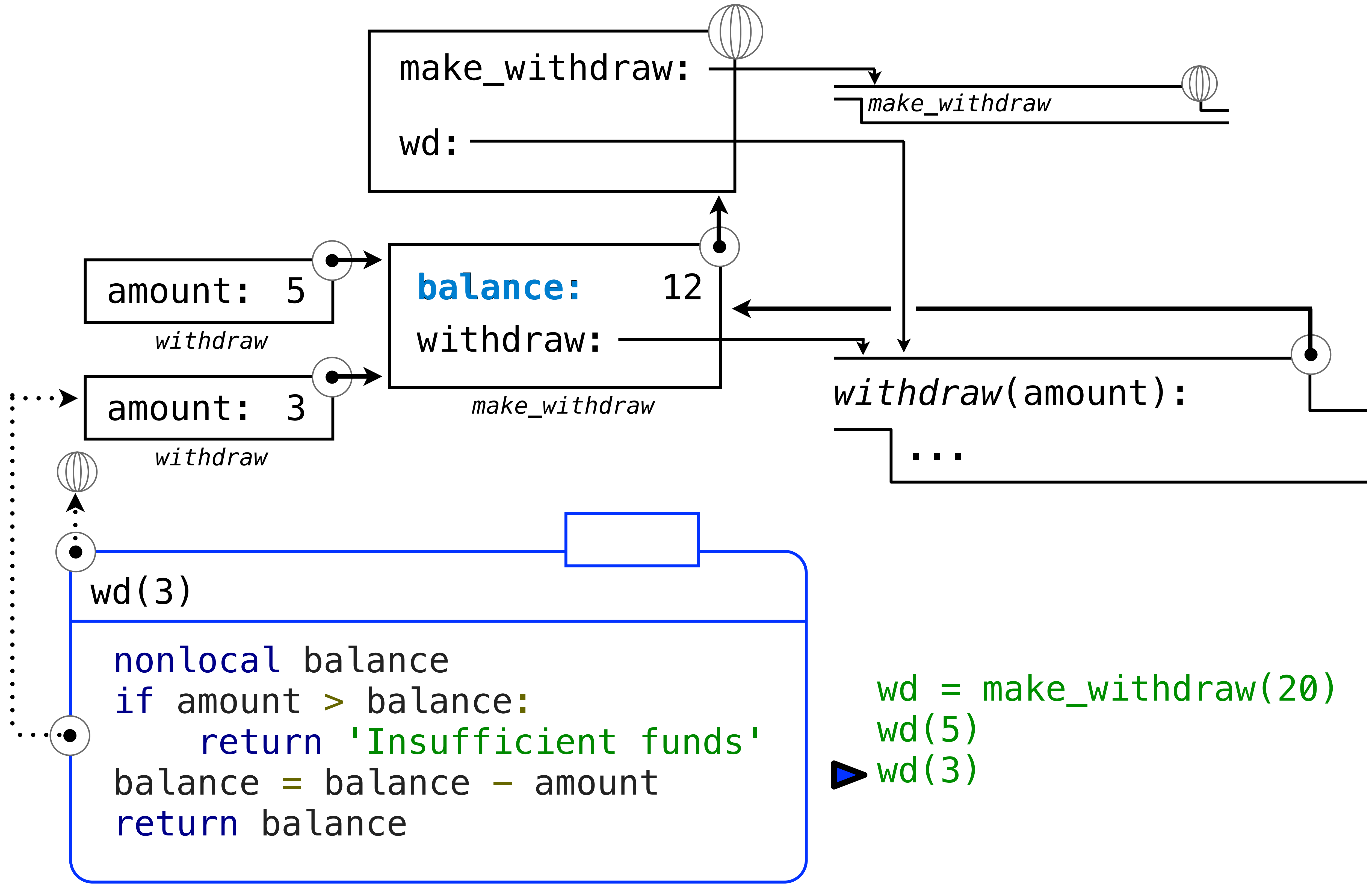

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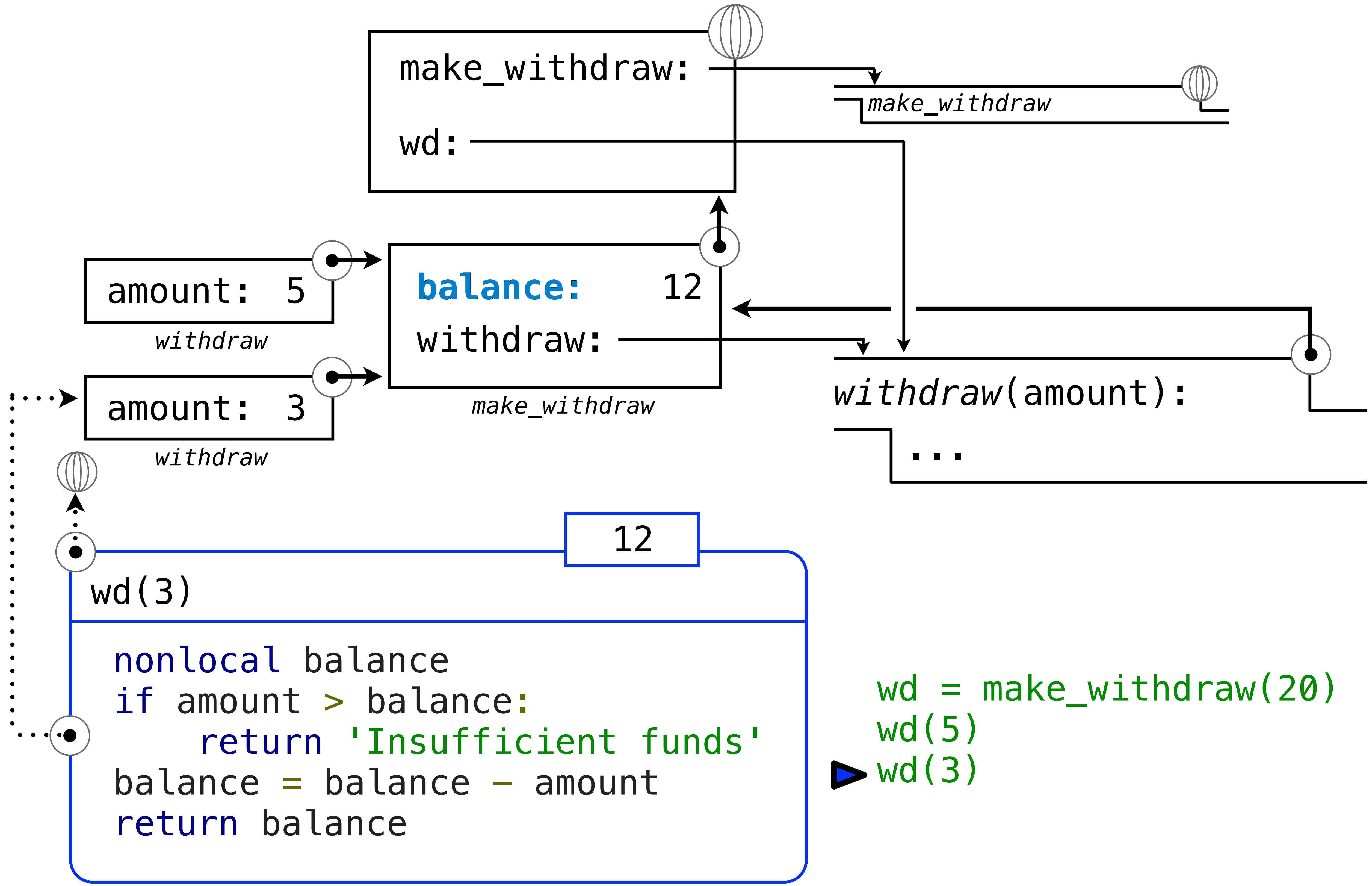

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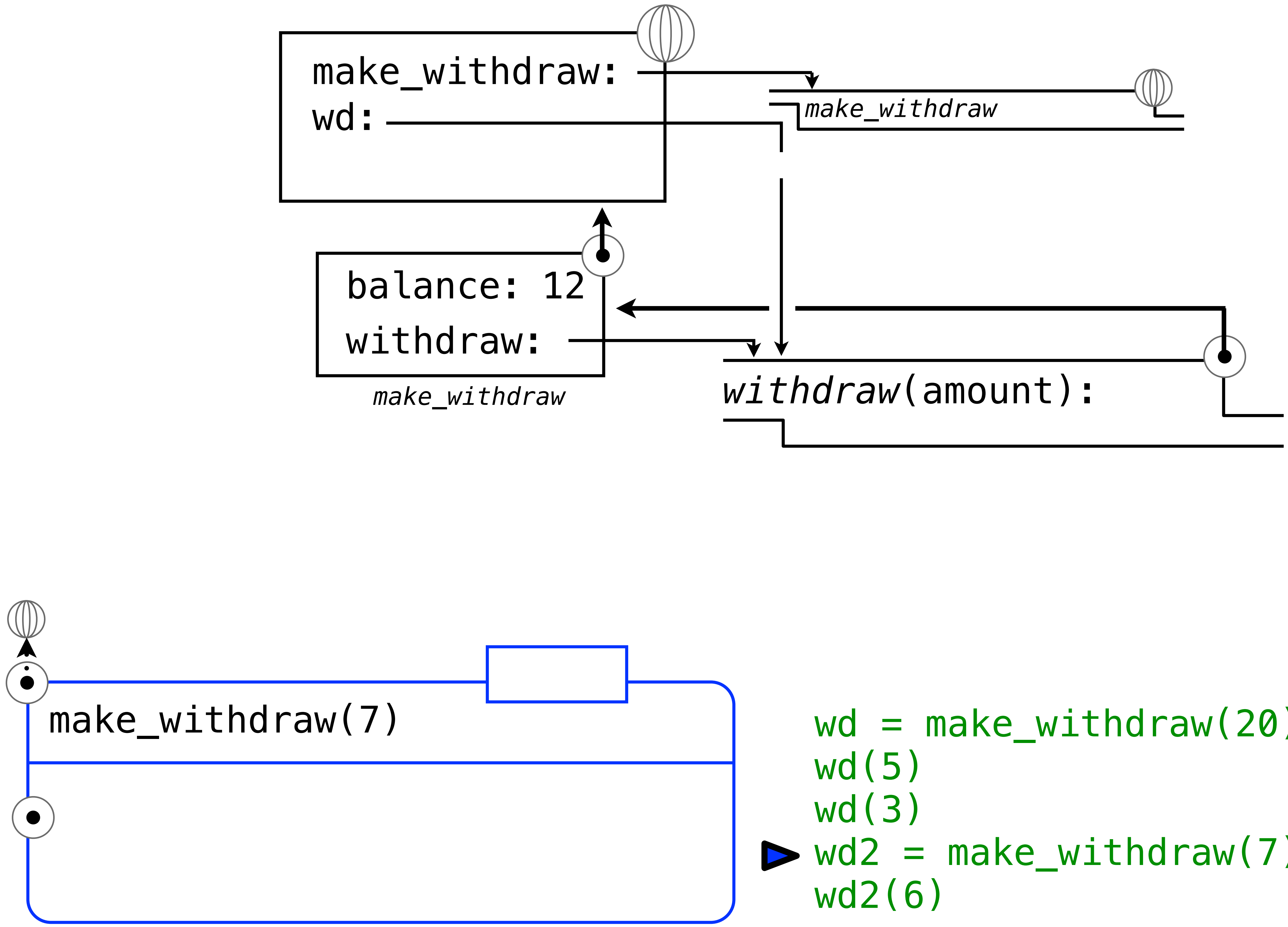

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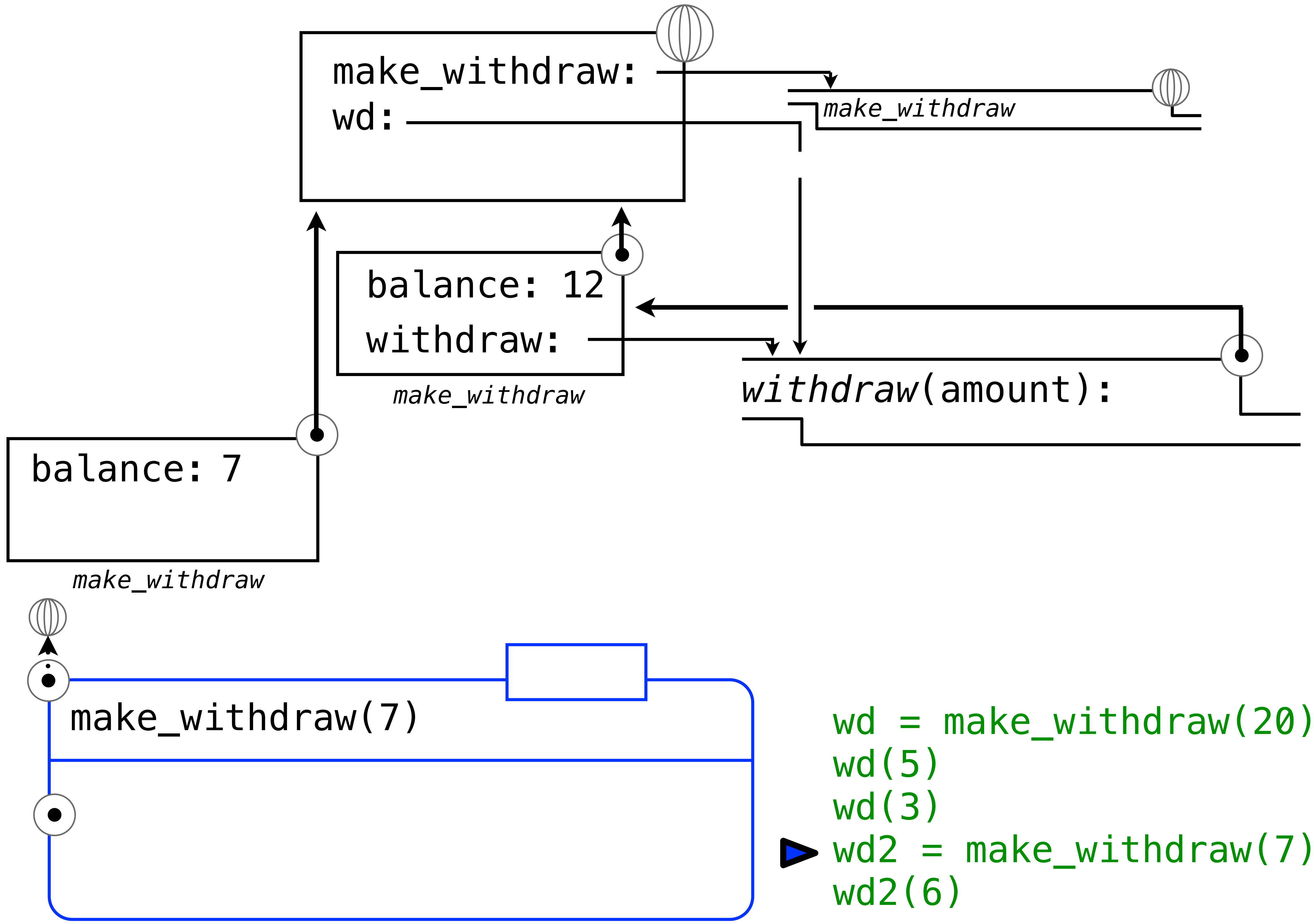

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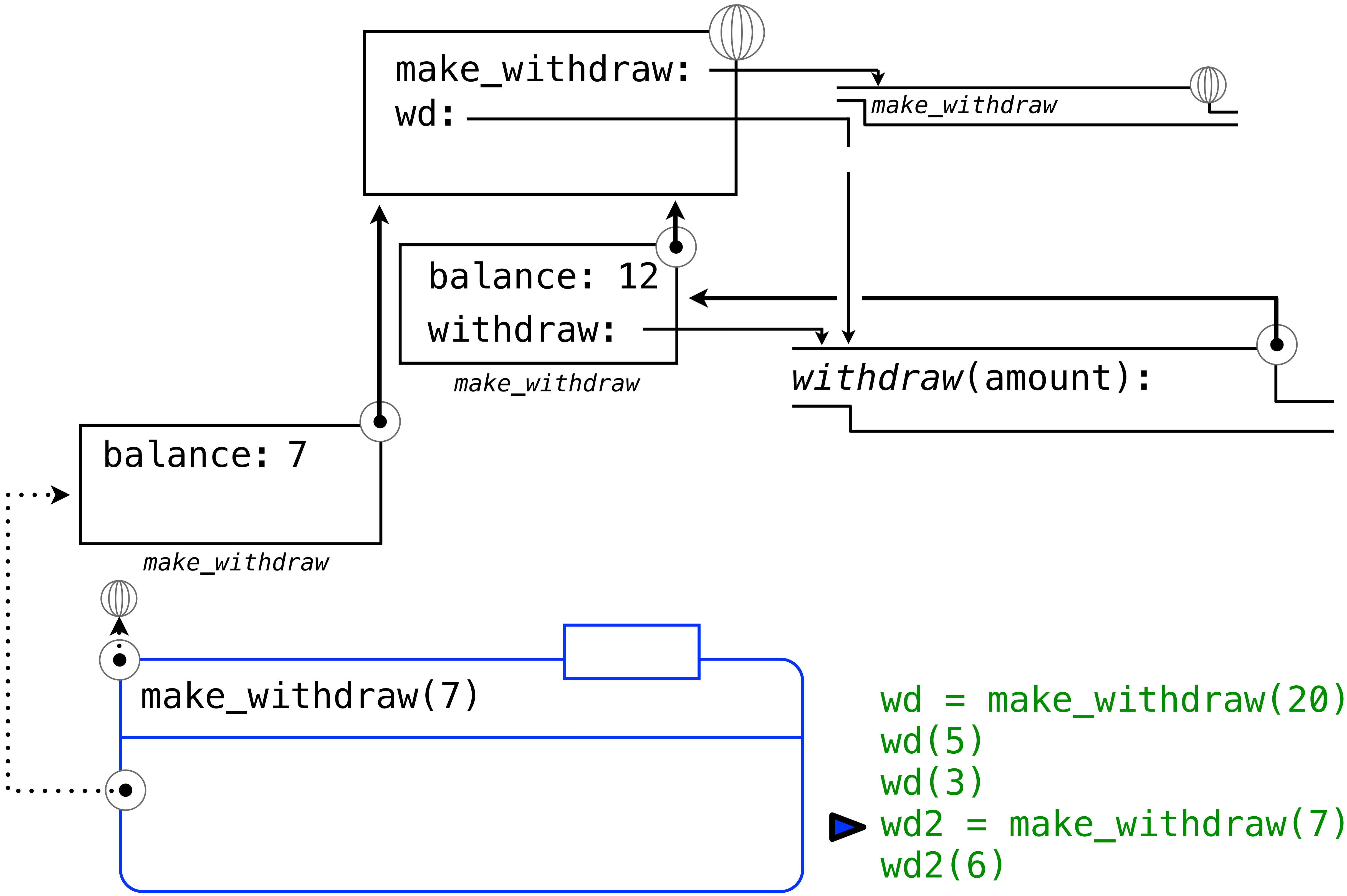

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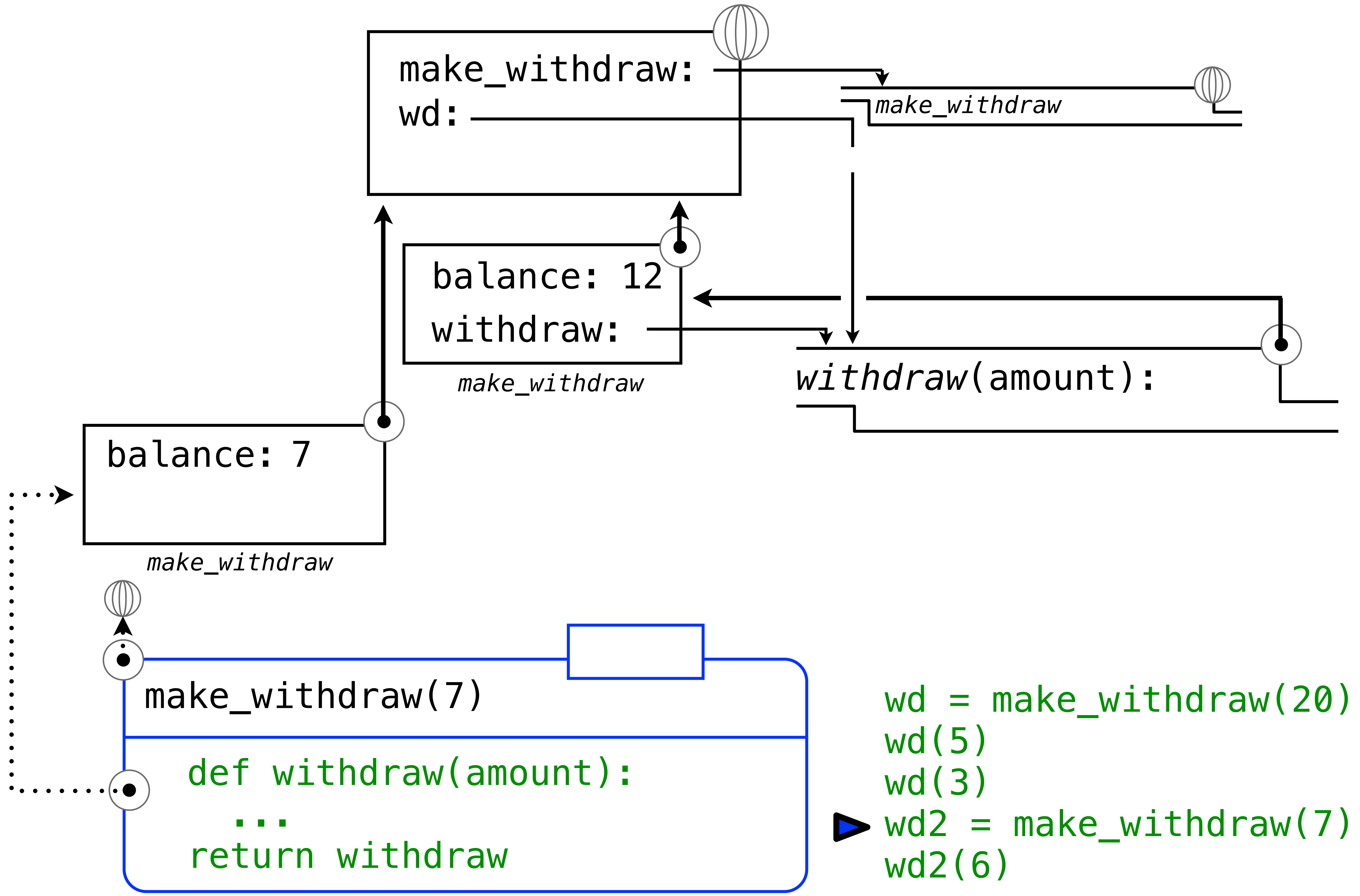

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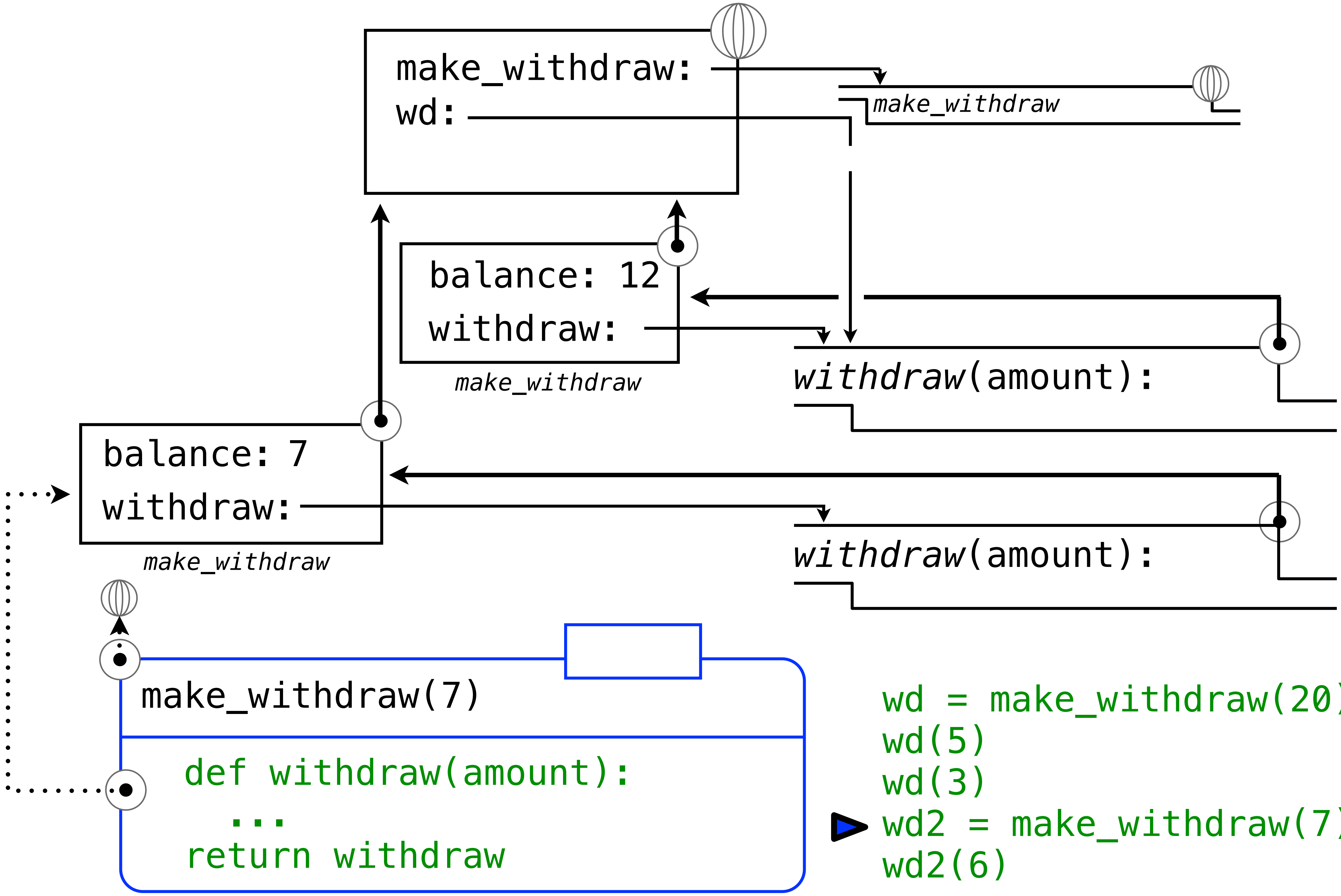

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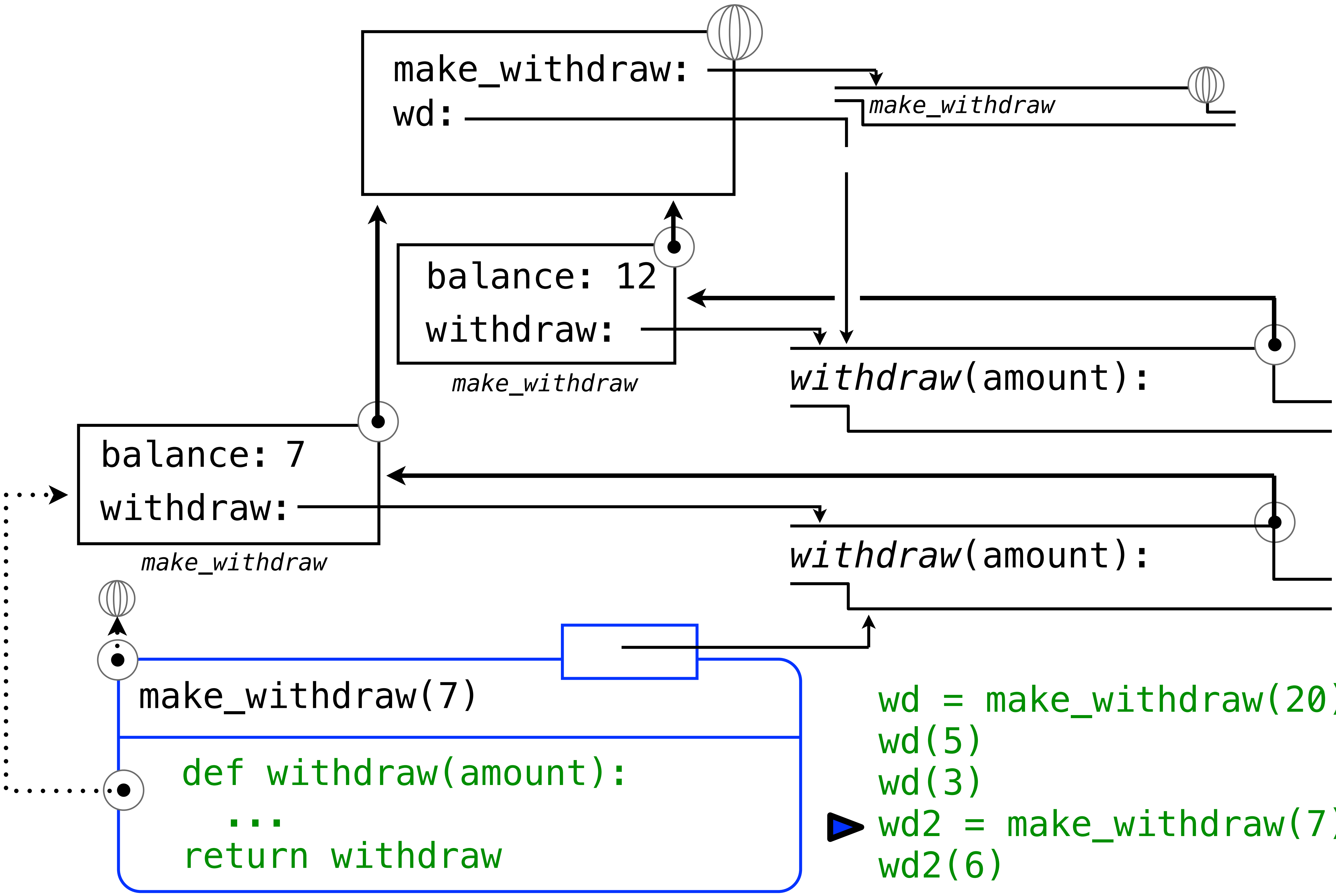

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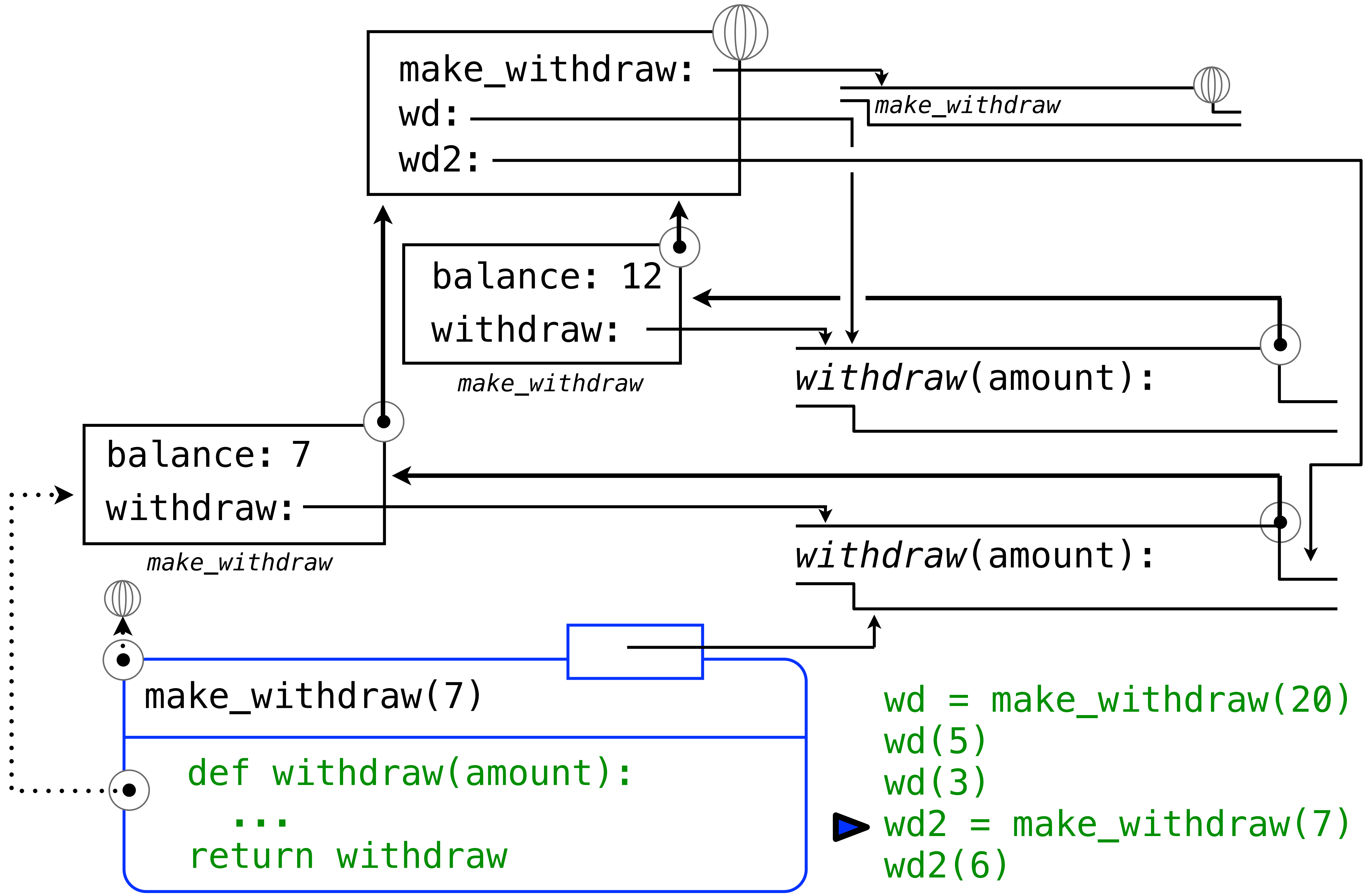

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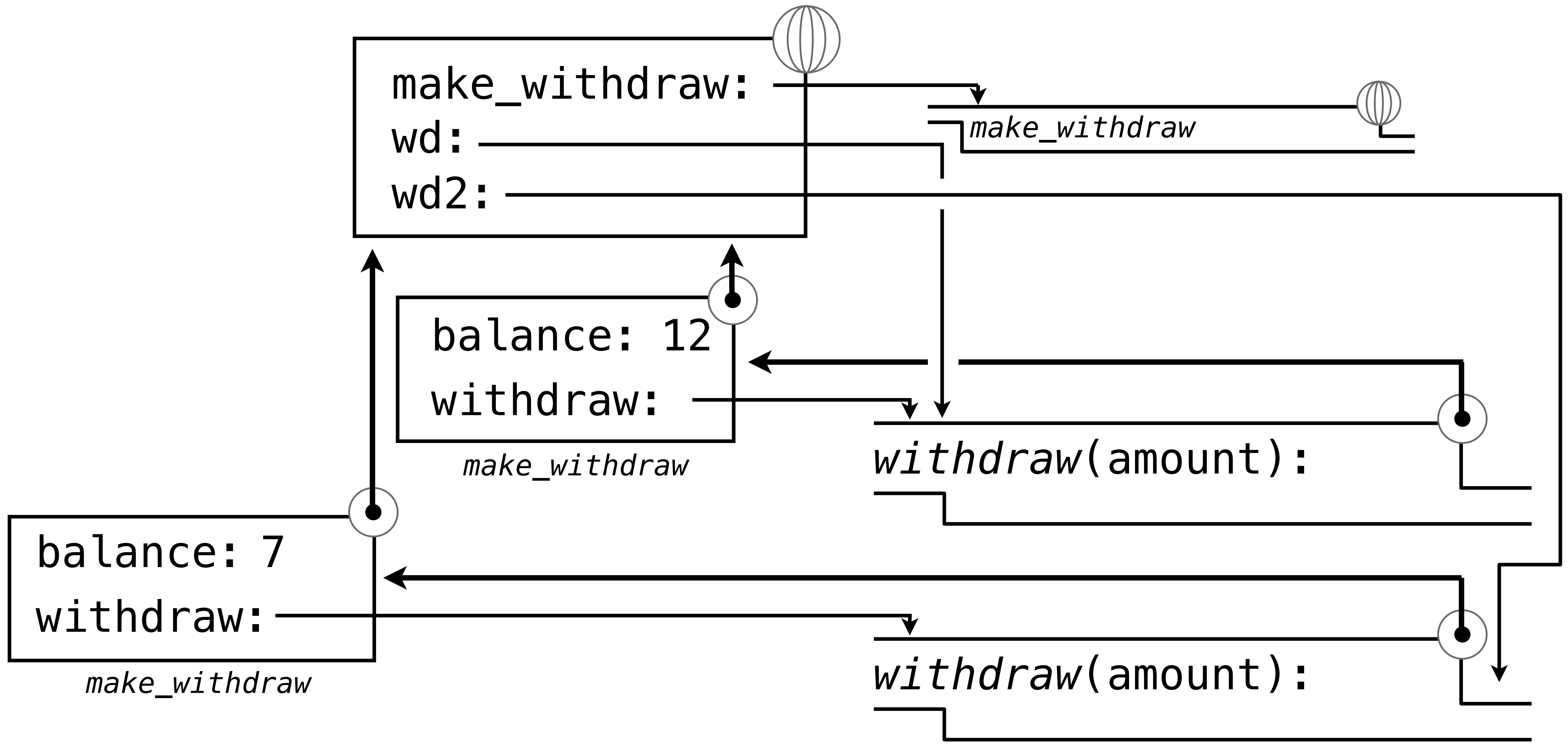

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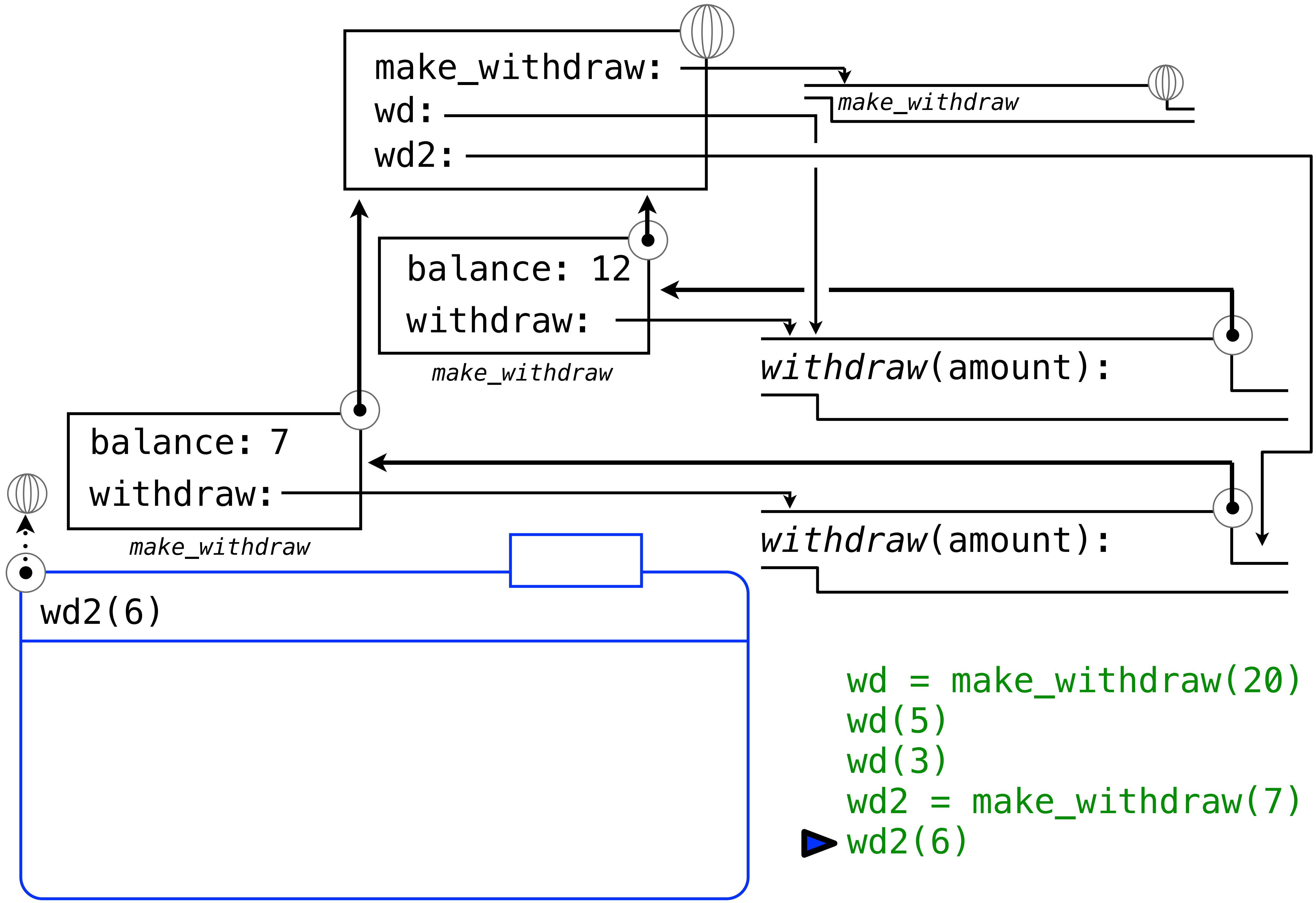

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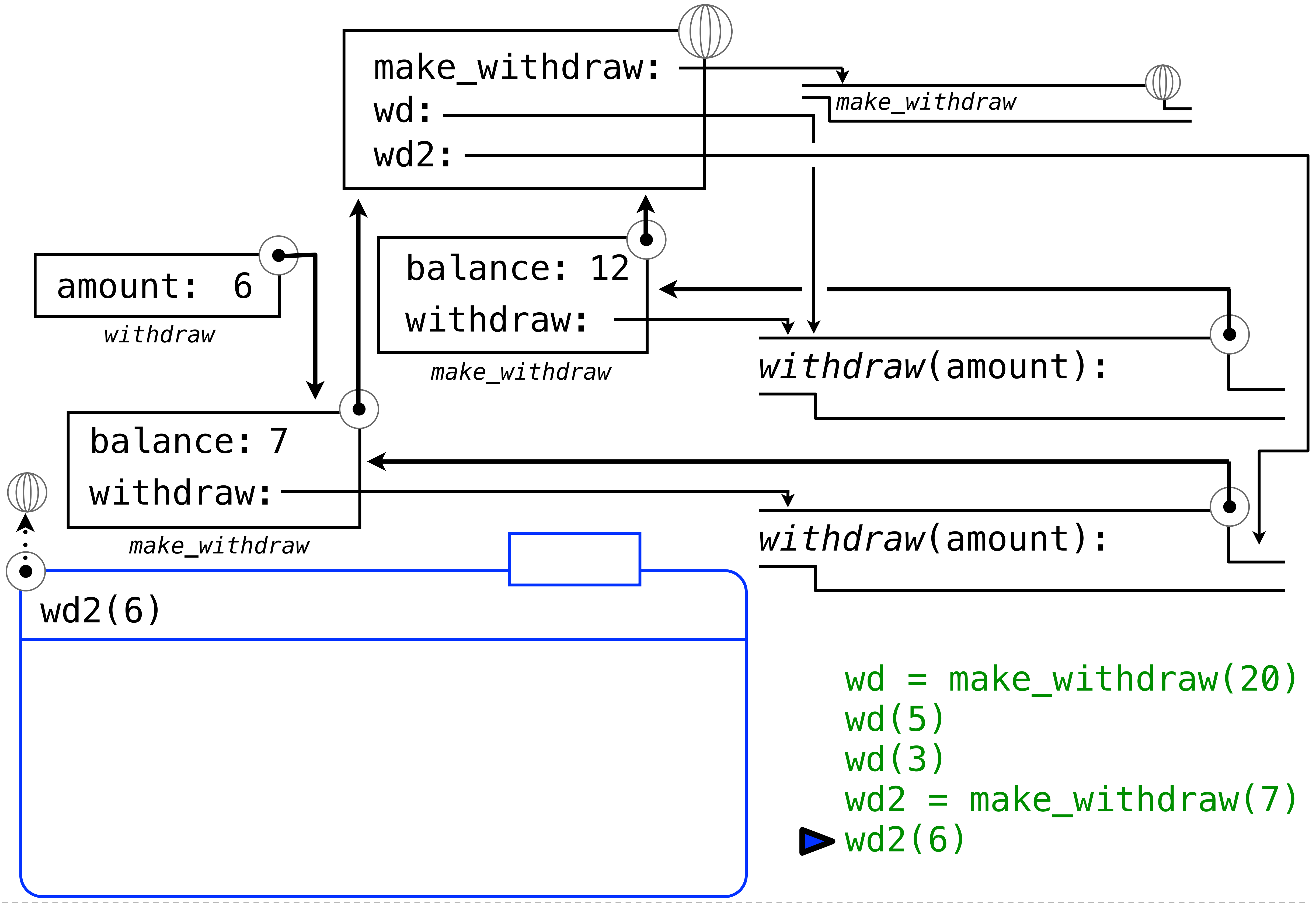

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Friday, September 23, 2011

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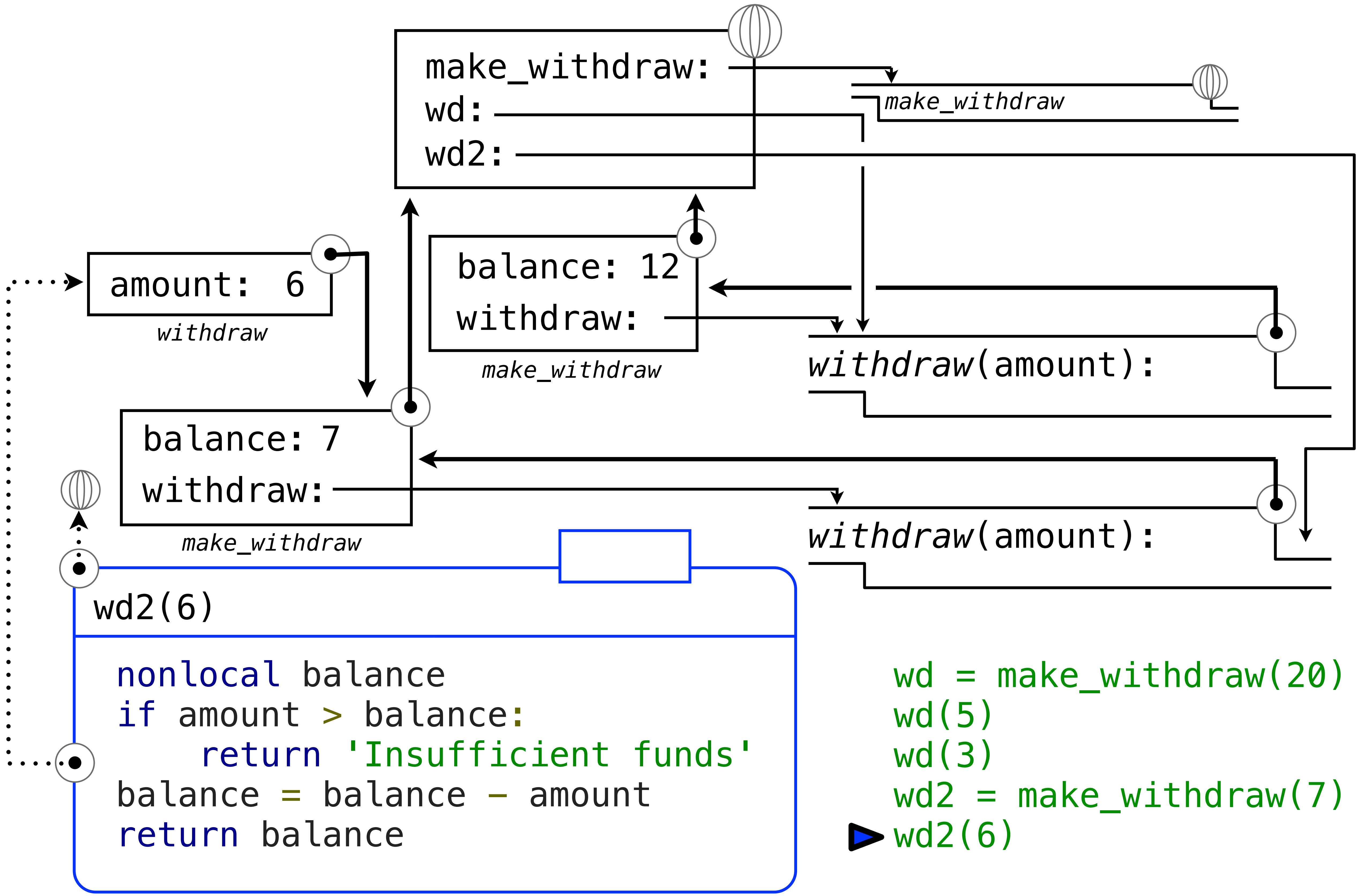

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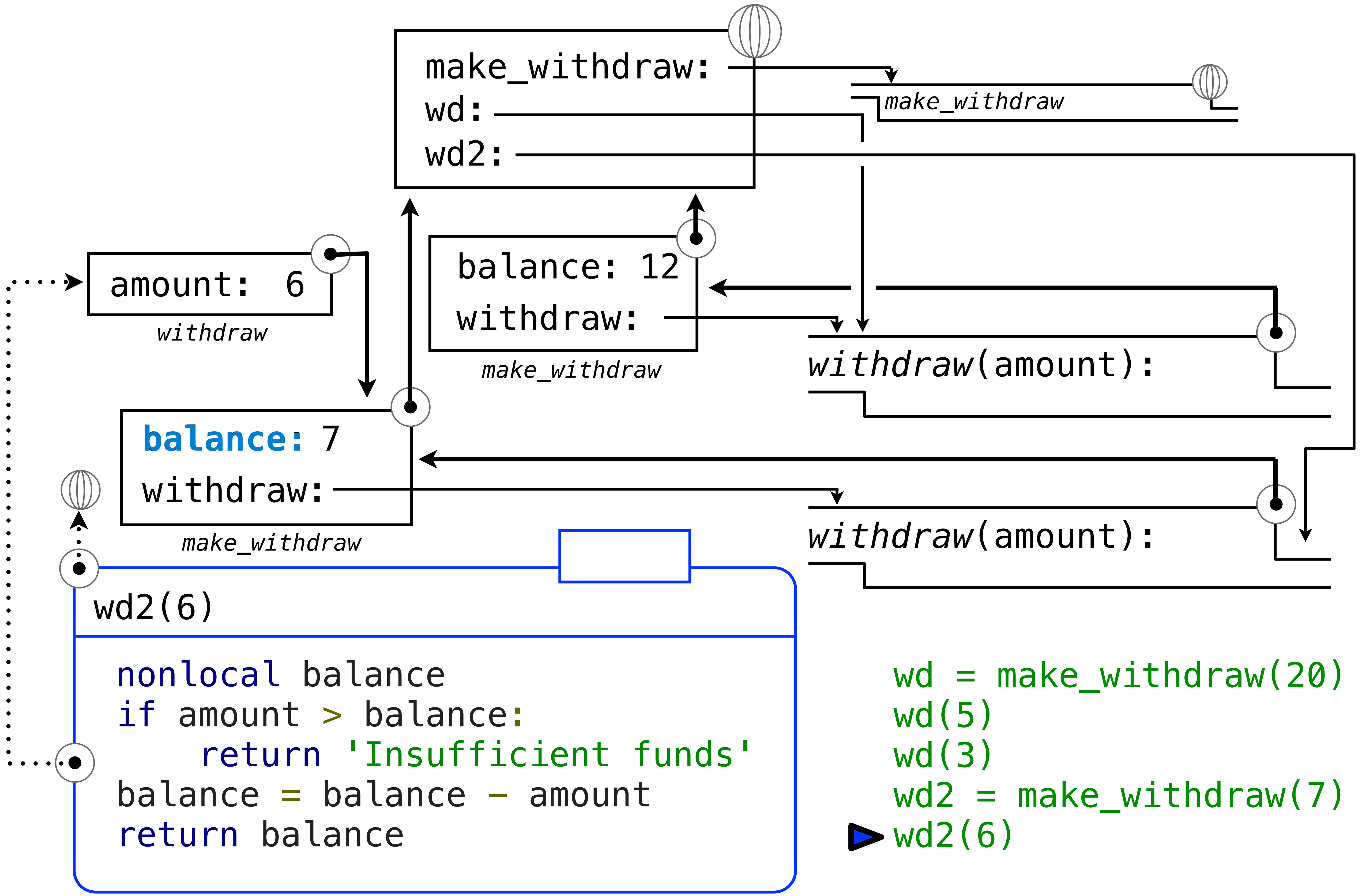

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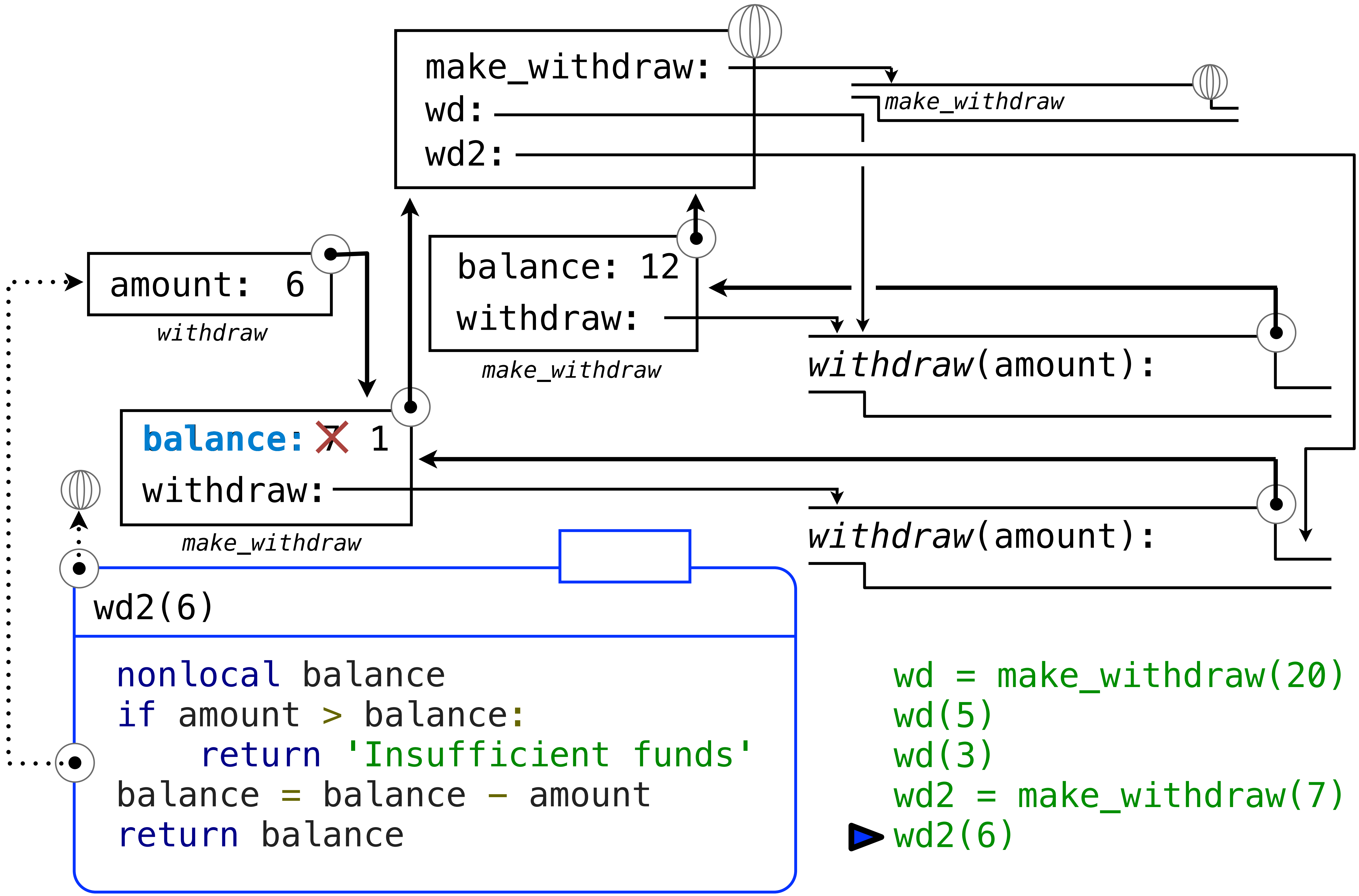

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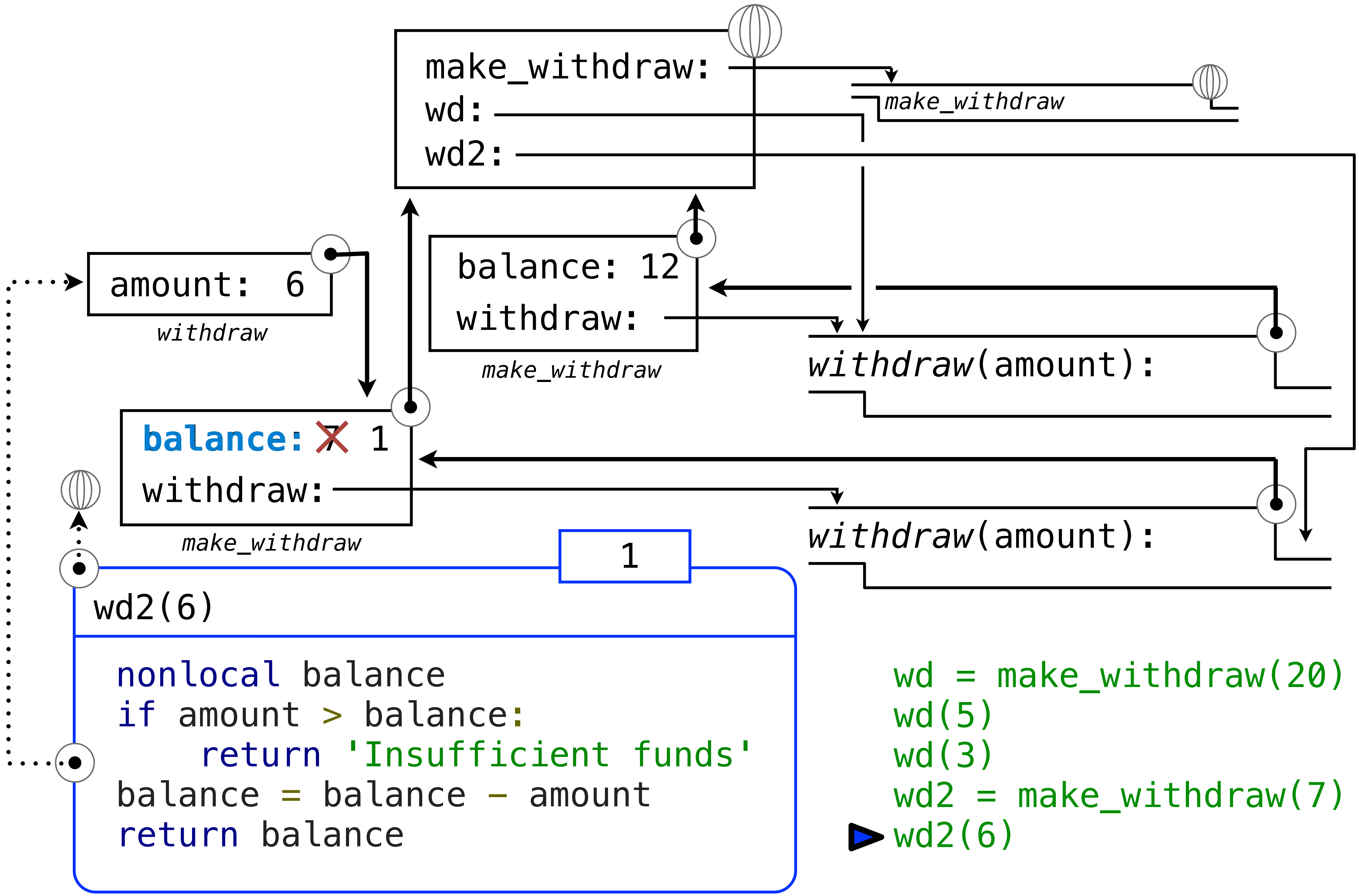

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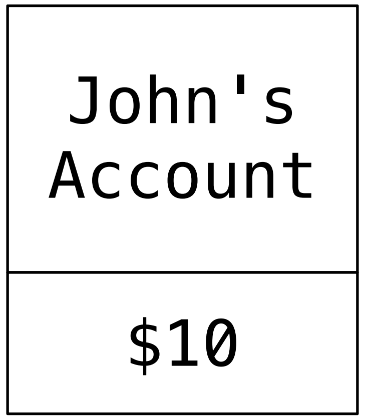

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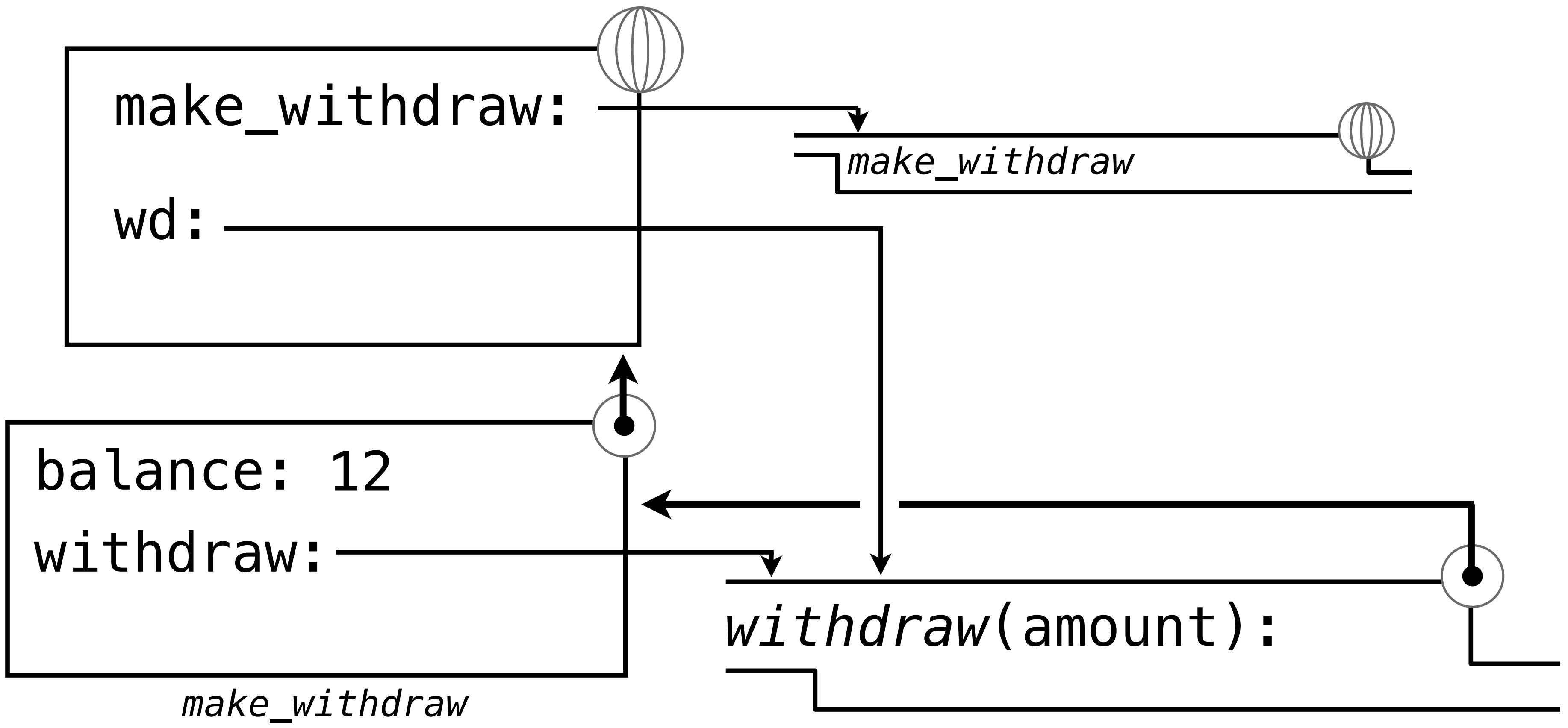
$10
Steven's Account
$1,000,000

Multiple References to a Single Withdraw Function



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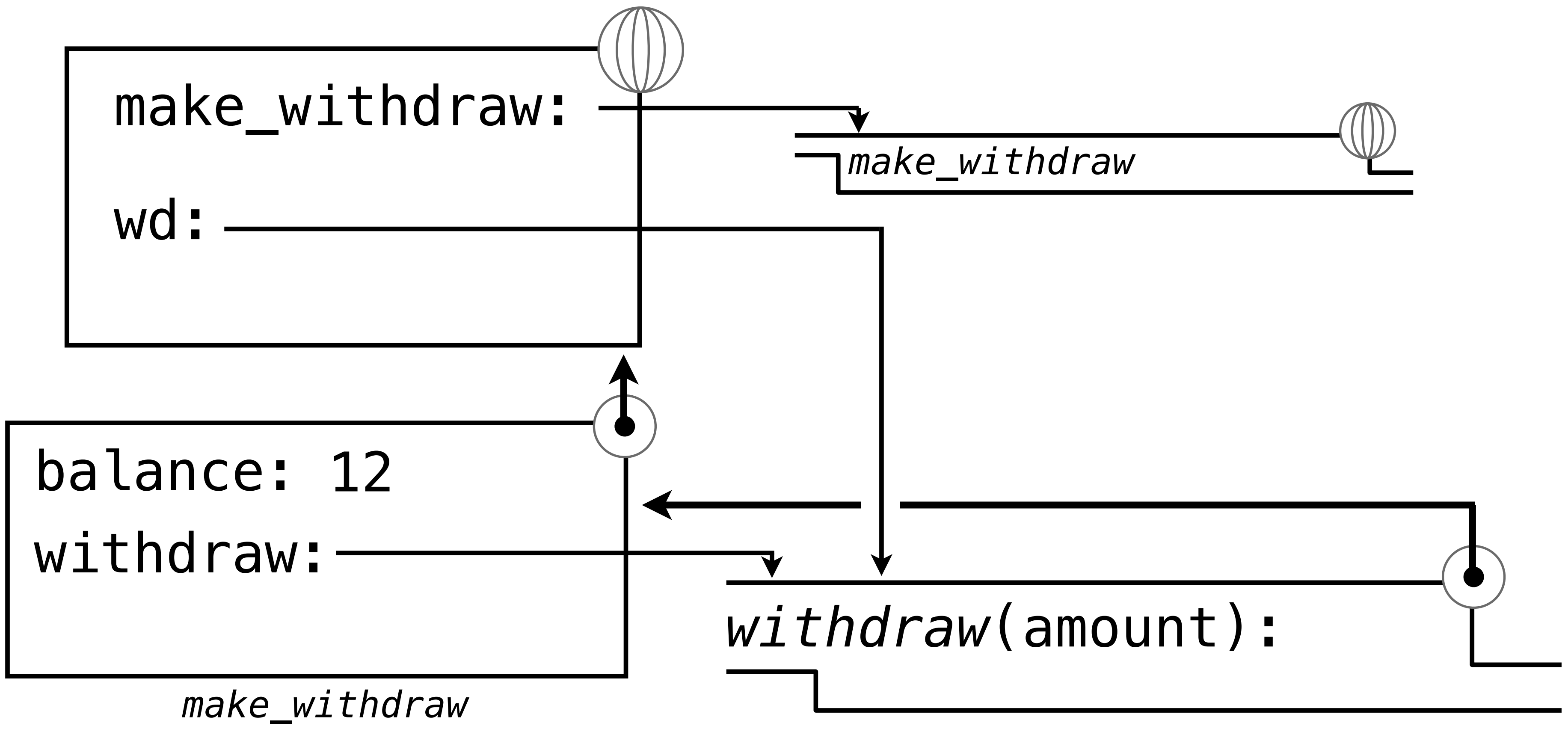

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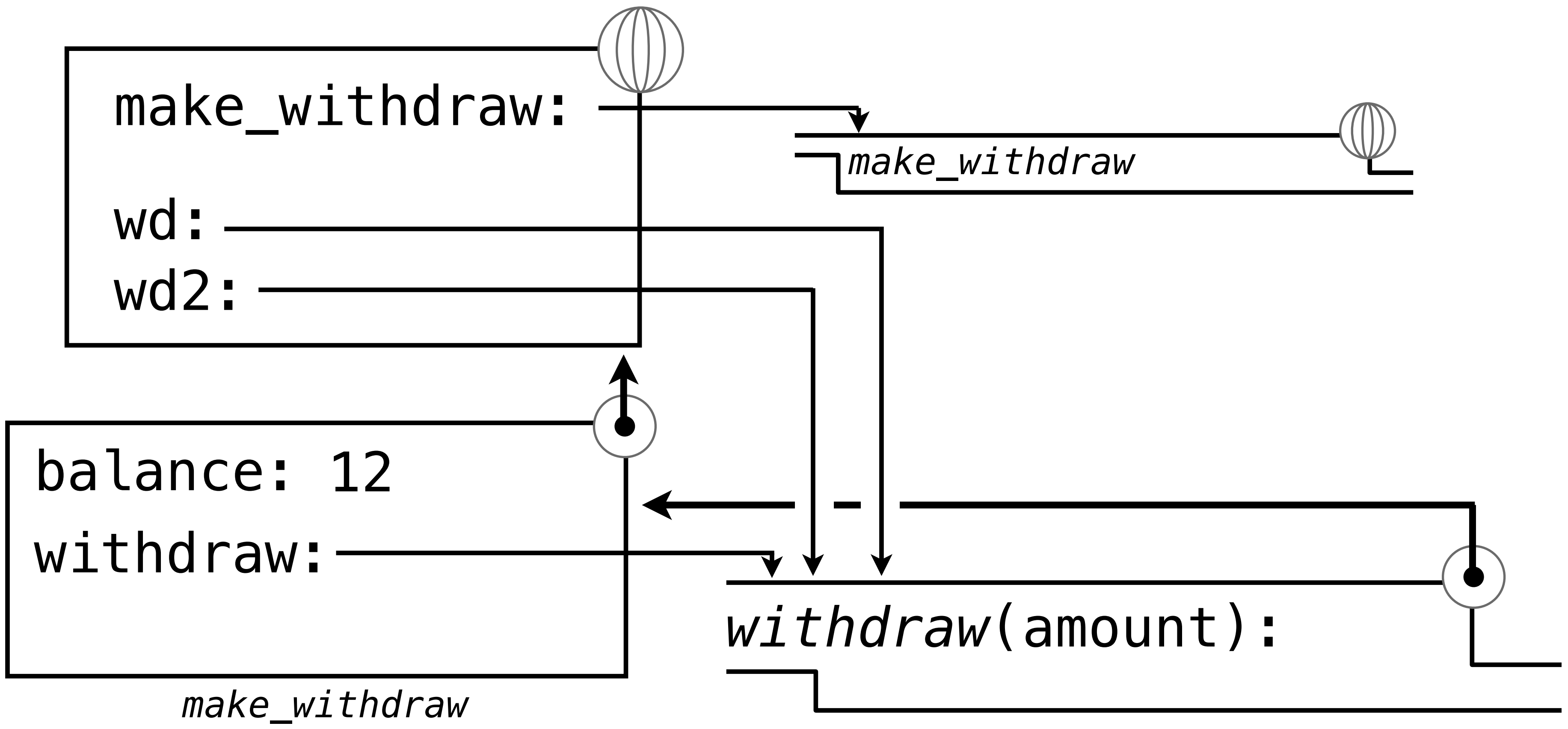

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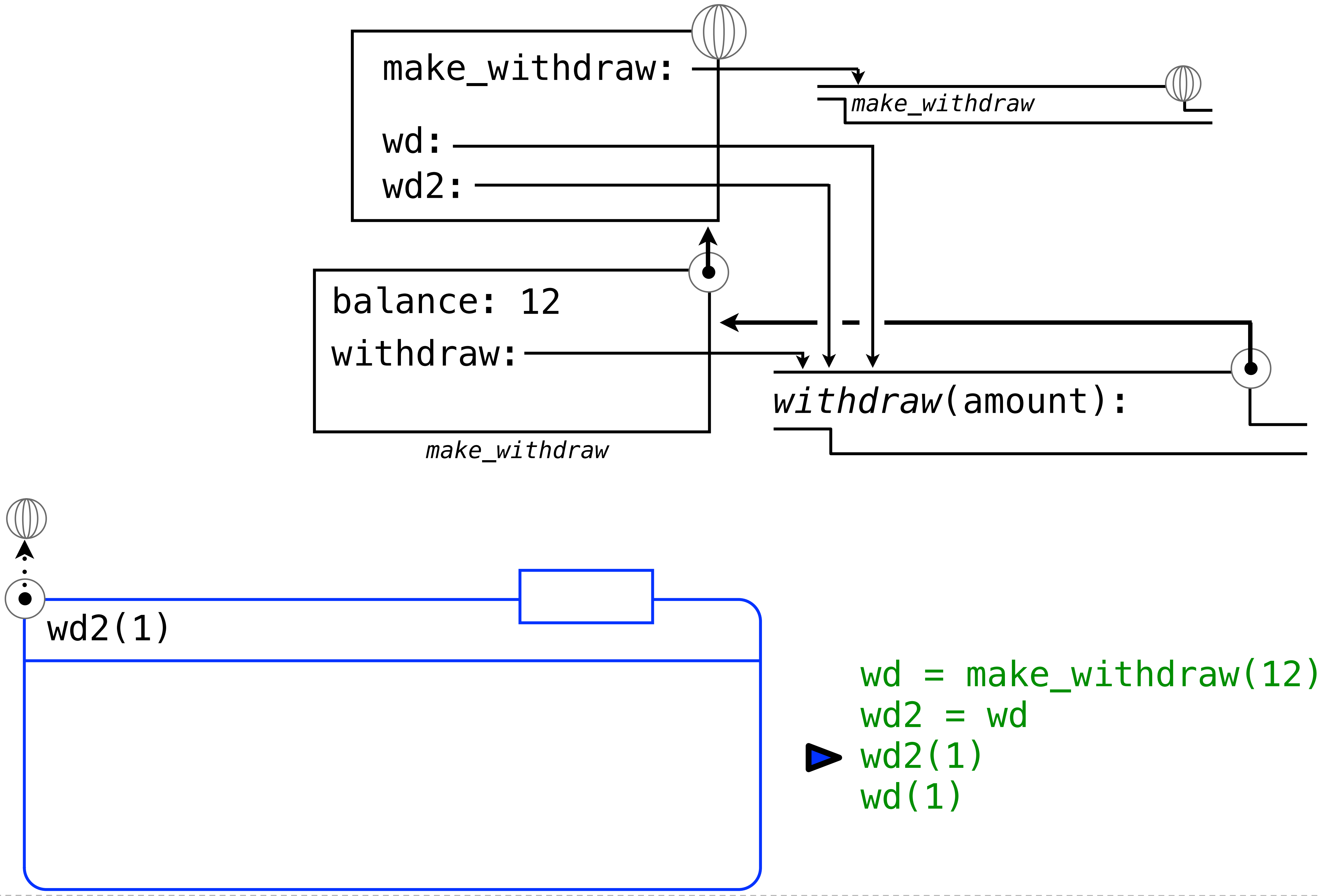

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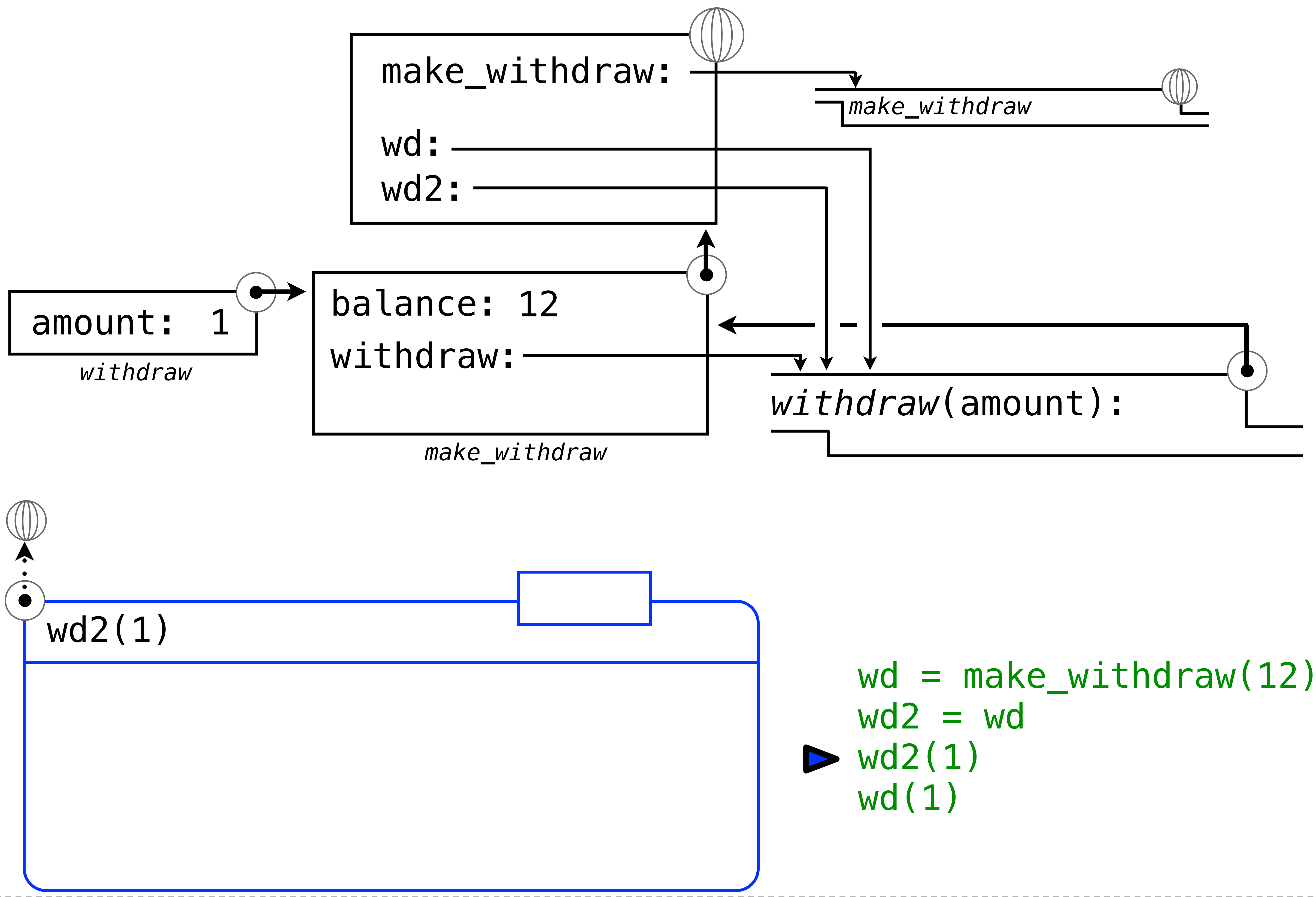

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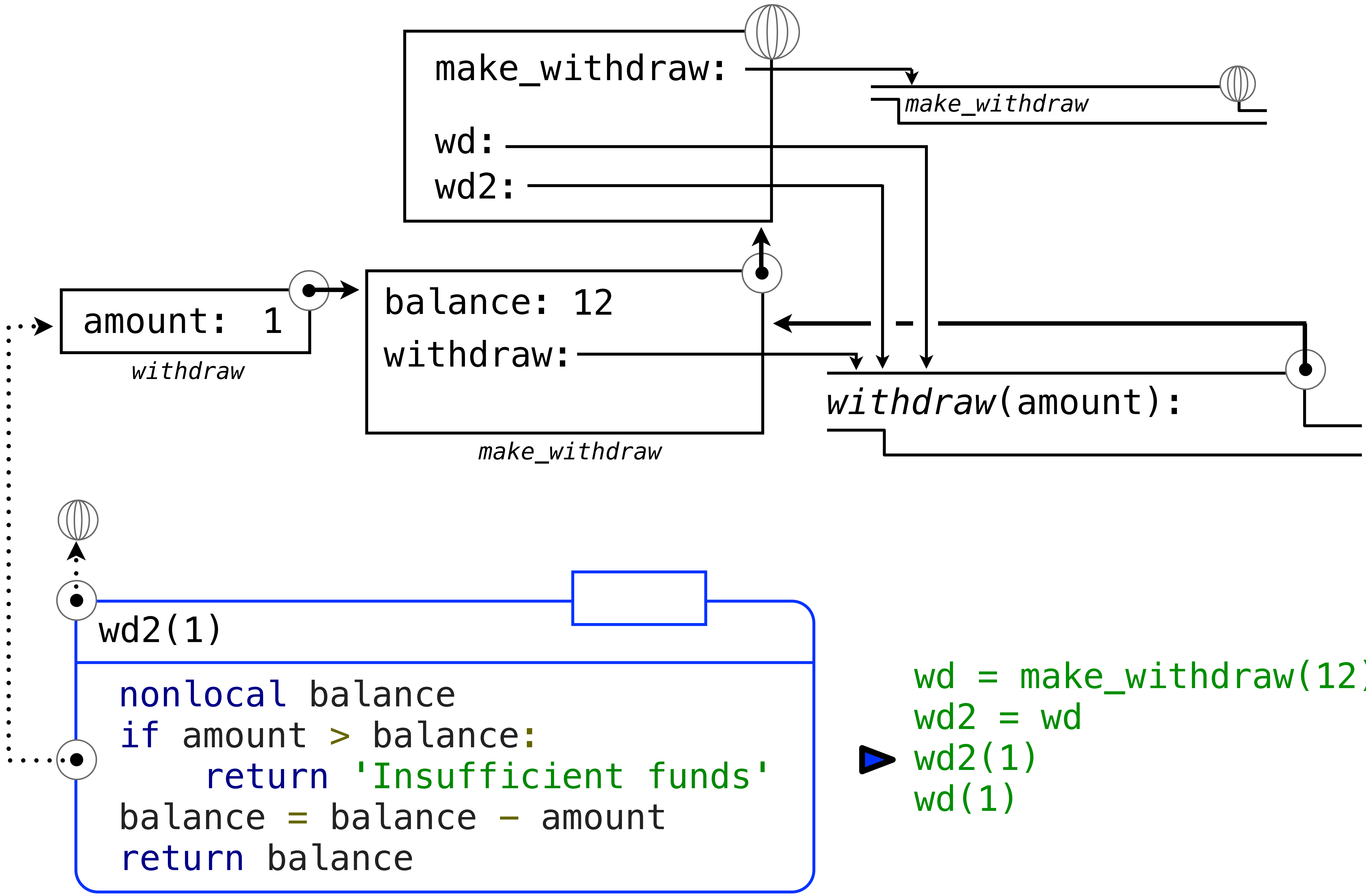

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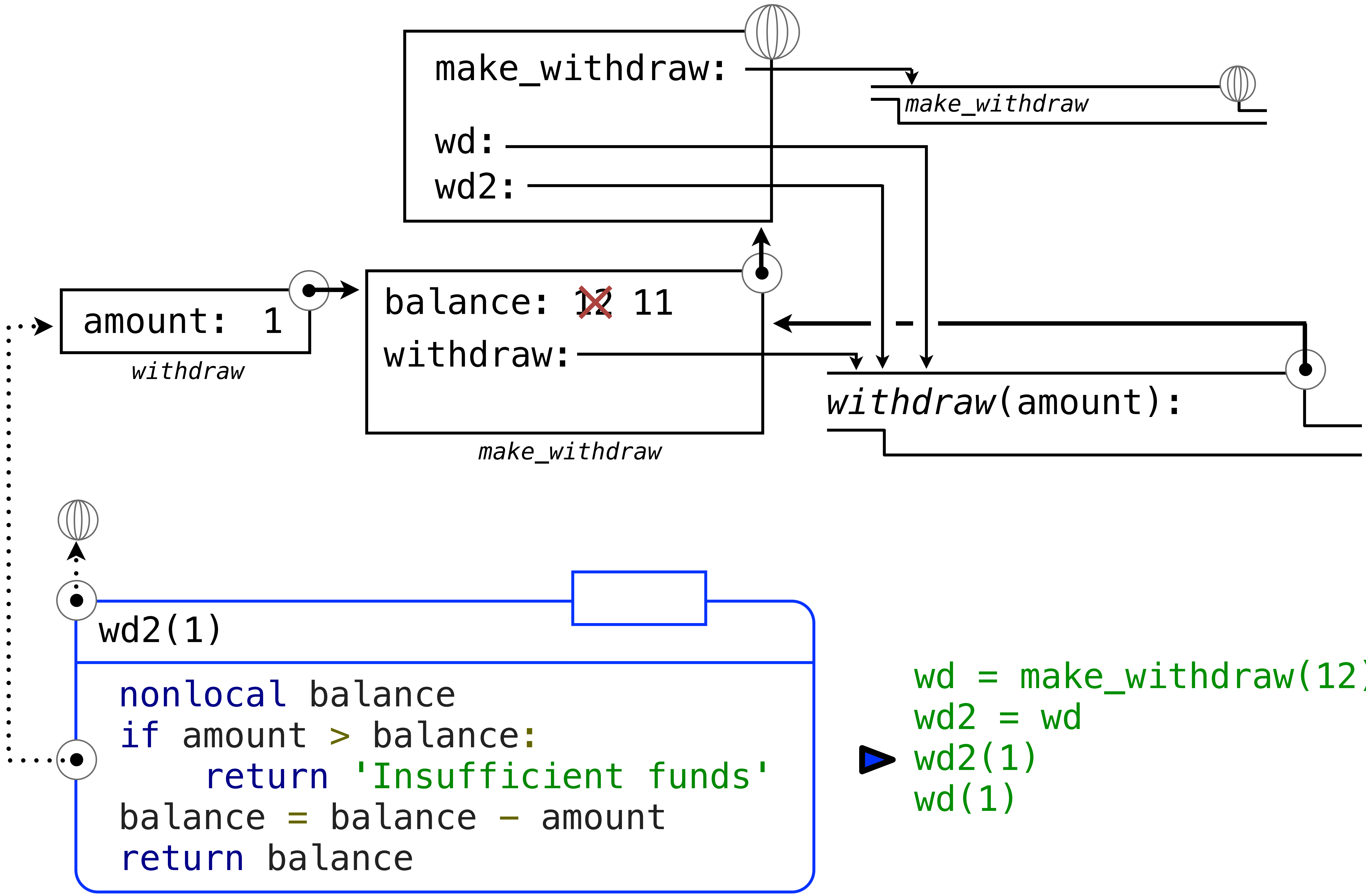

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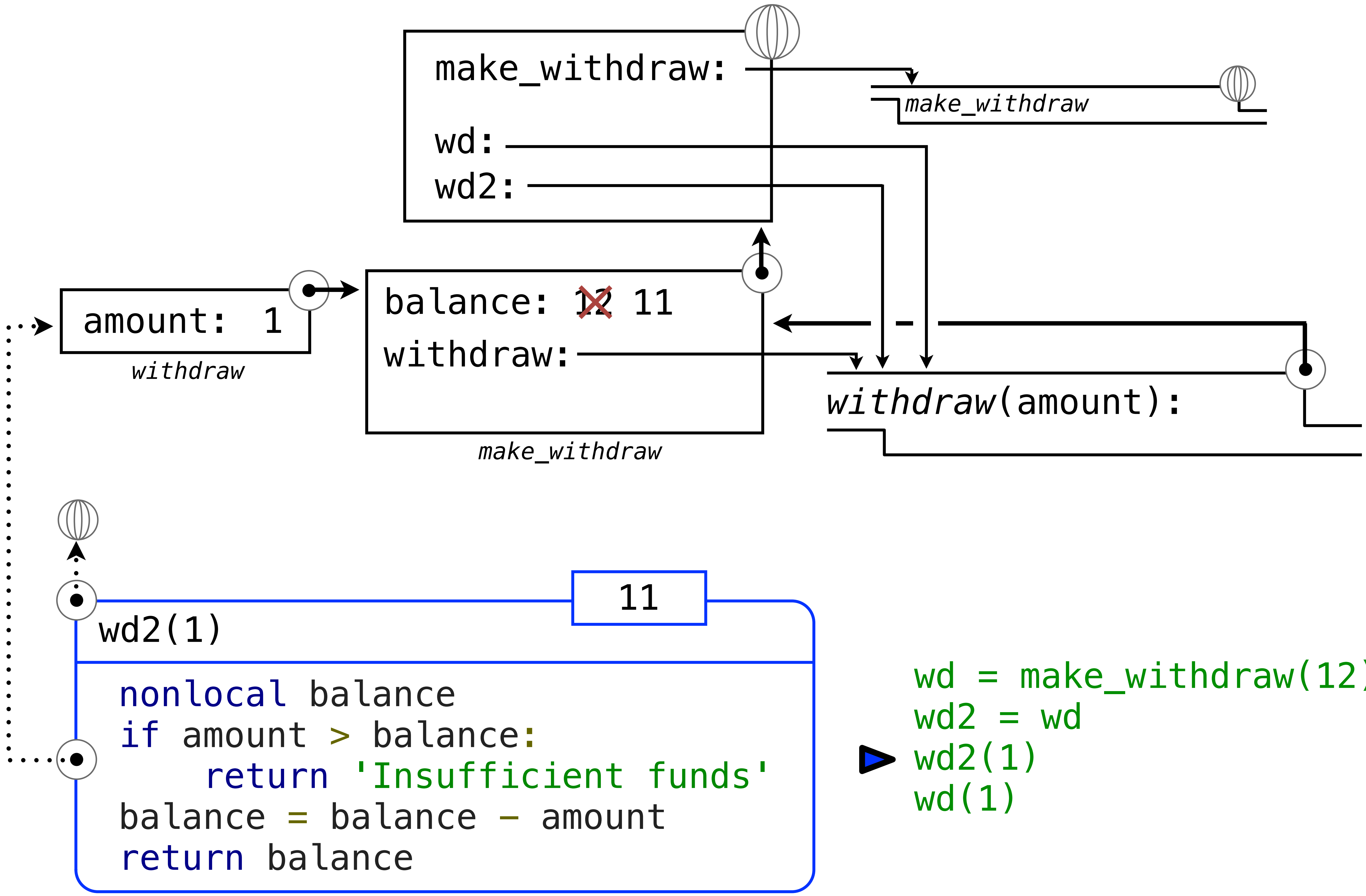

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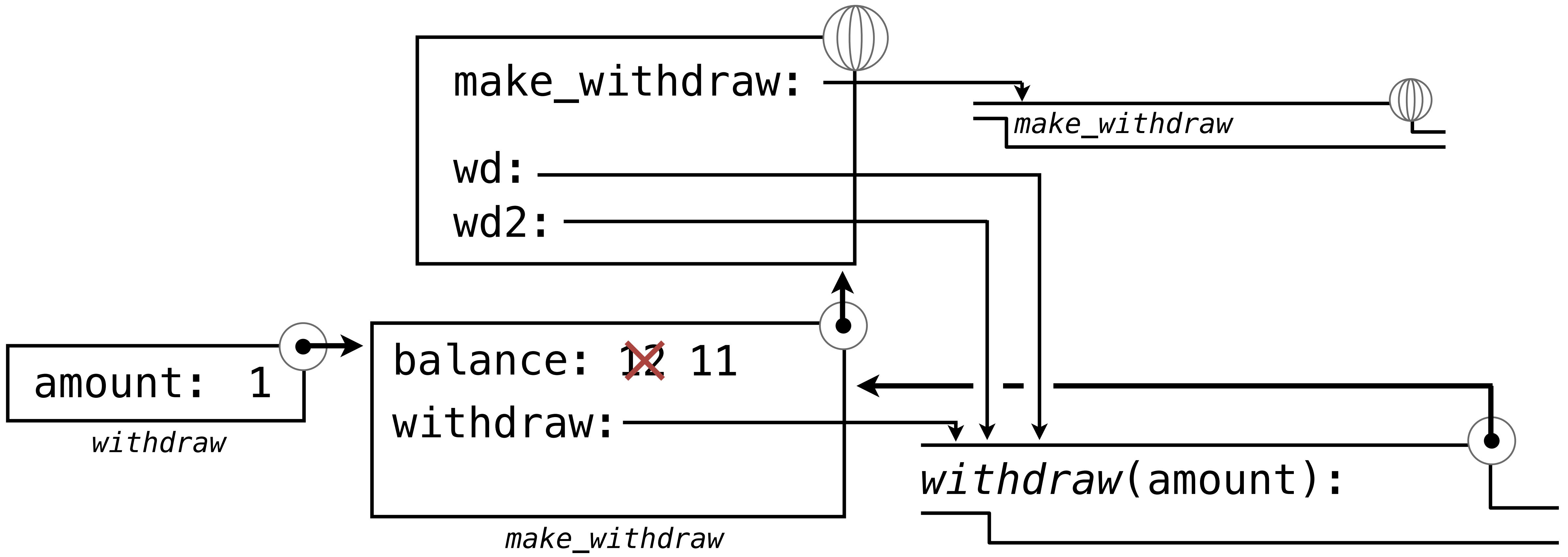

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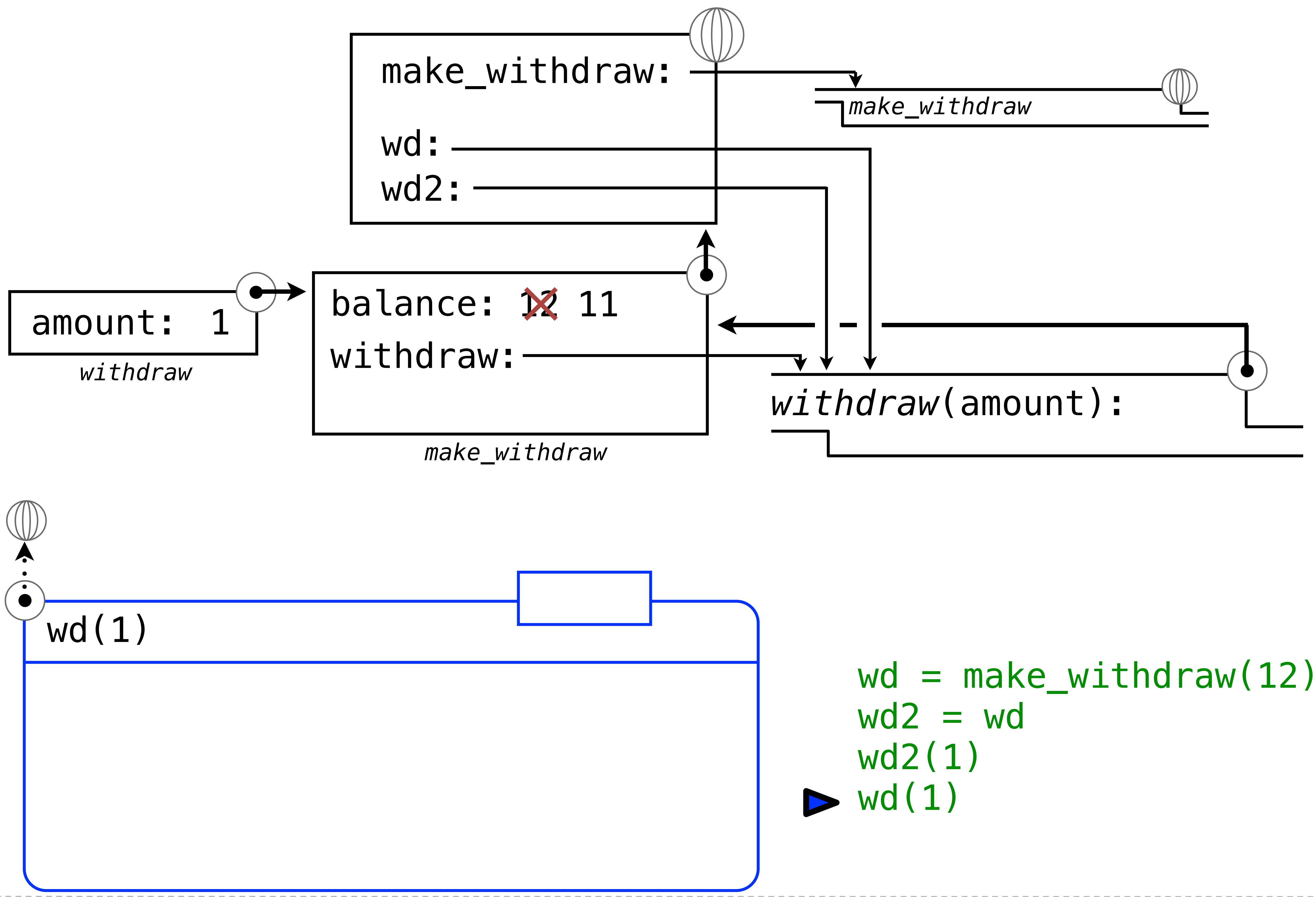

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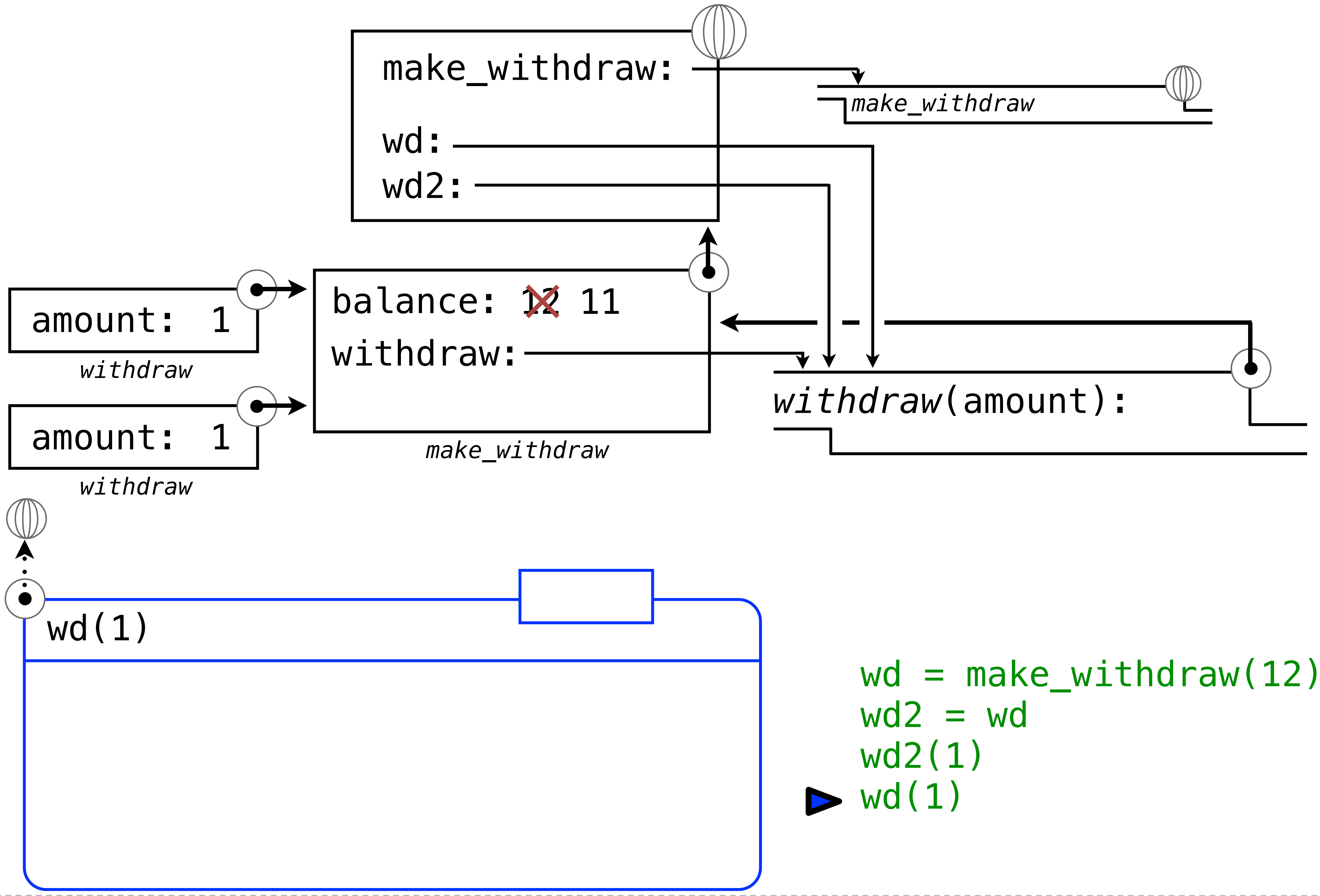

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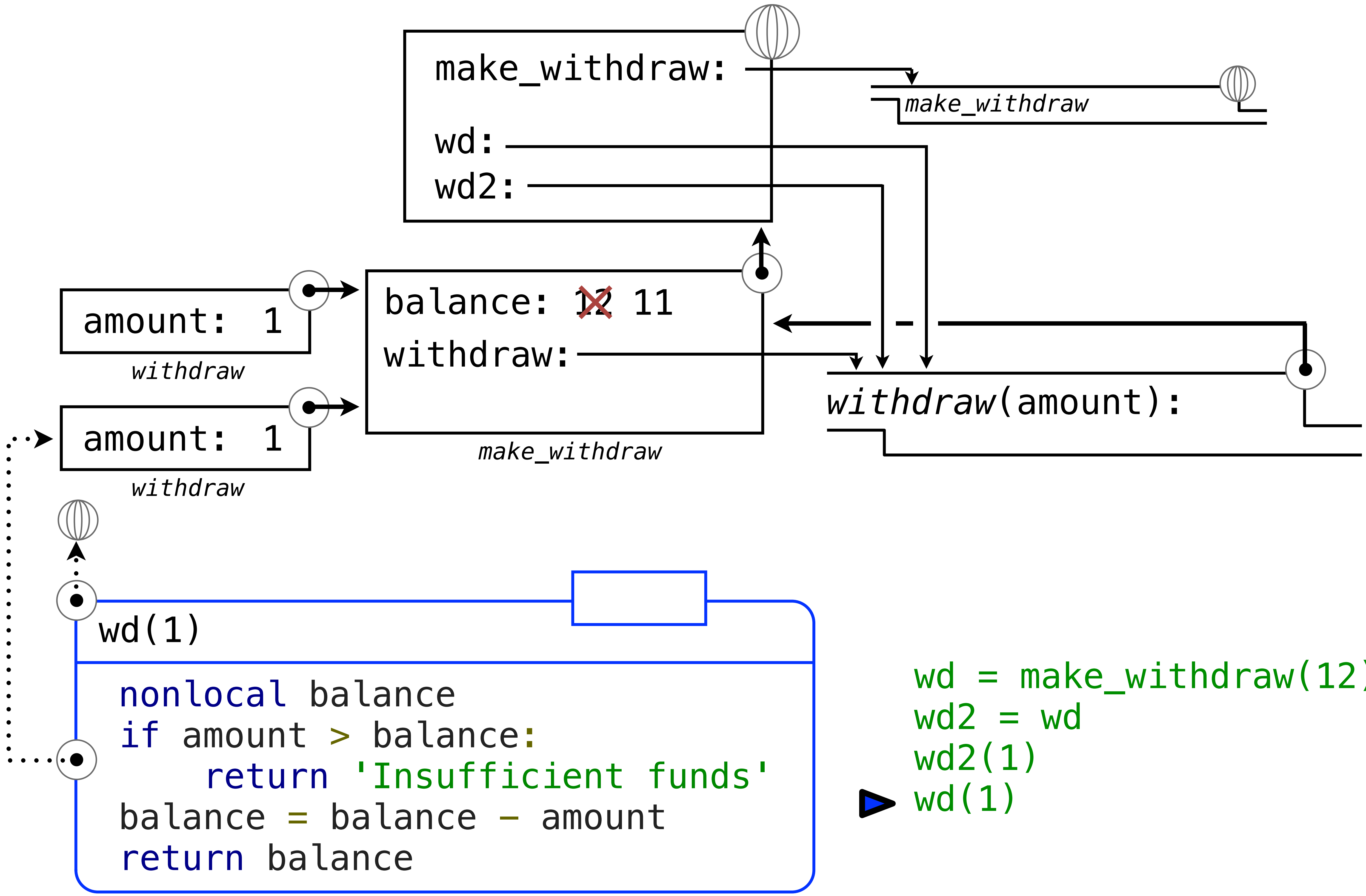

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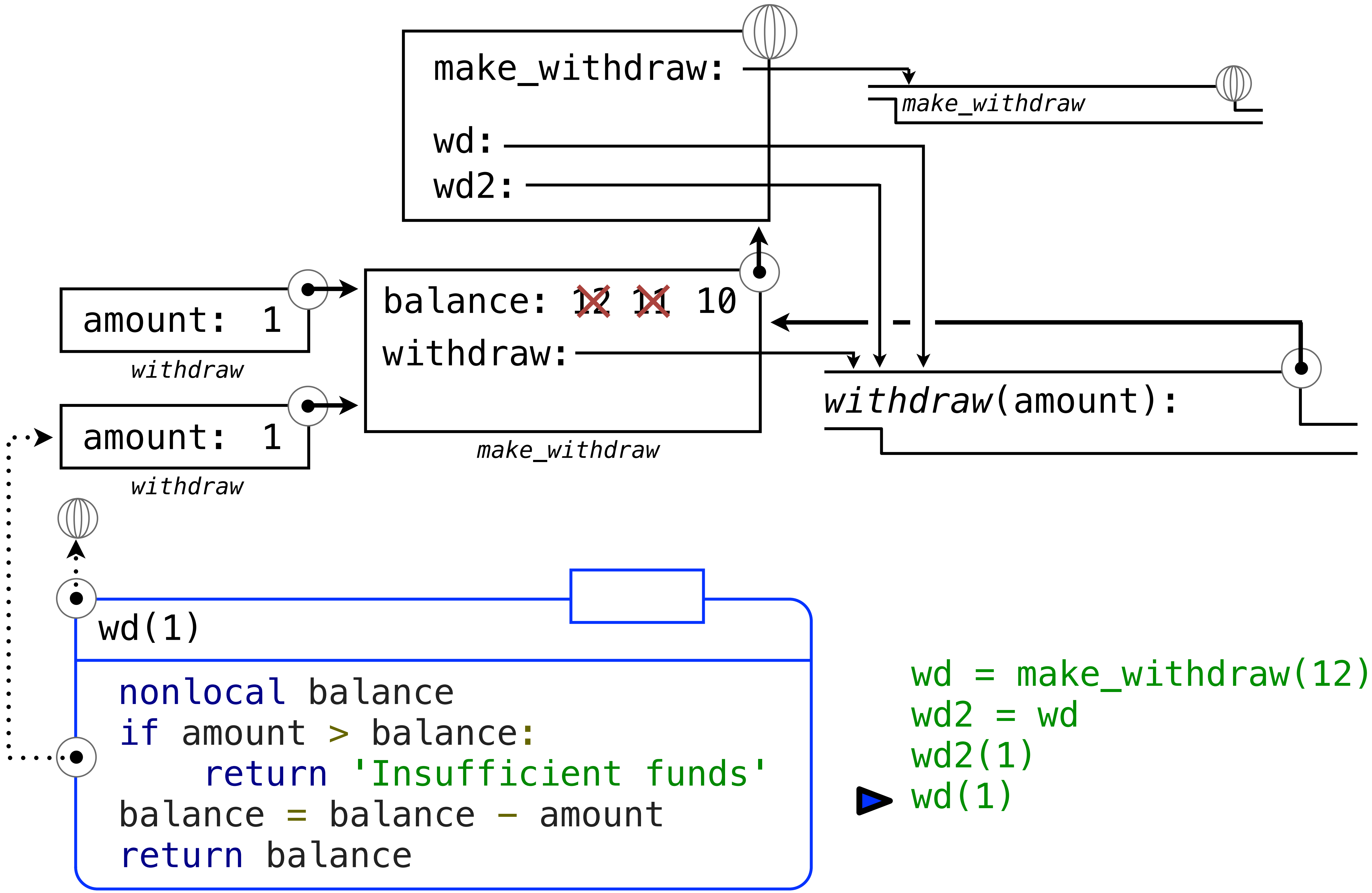

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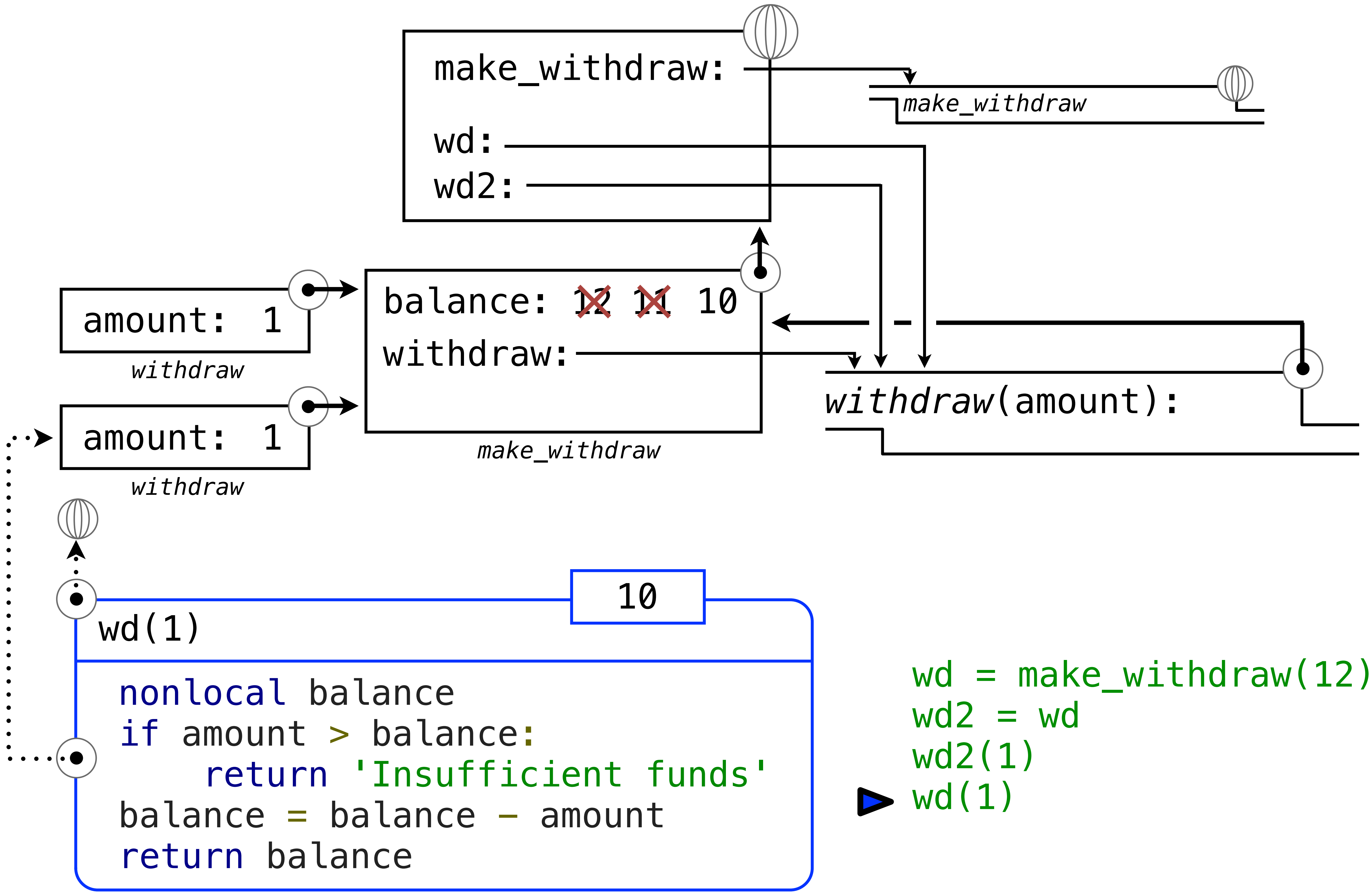

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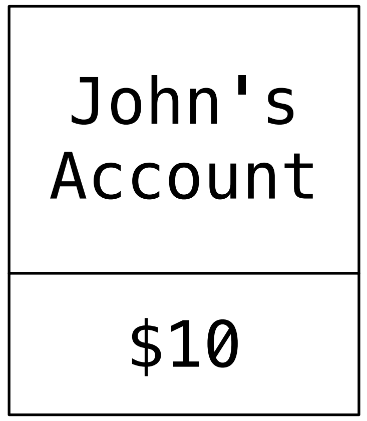

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- Two separately defined functions are not the same, because **changes to one may not be reflected in the other.**