61A Lecture 3

Friday, September 6

Announcements

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- Project 1 posted this Friday, due Thursday 9/19 at 11:59pm.
  - Demo during next lecture

Multiple Environments

Life Cycle of a User-Defined Function

What happens?

Def statement:

Call expression:

Calling/Applying:

Life Cycle of a User-Defined Function

What happens?

Def statement:

```
>>> def square( x ):
        return mul(x, x)
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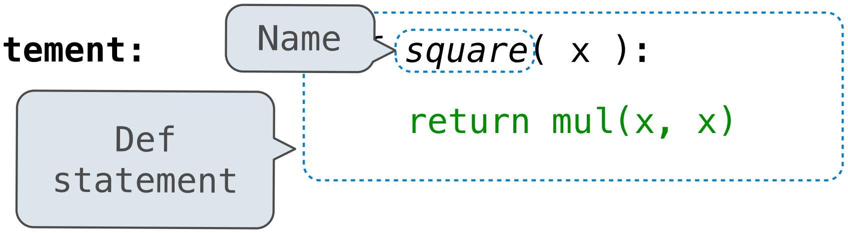

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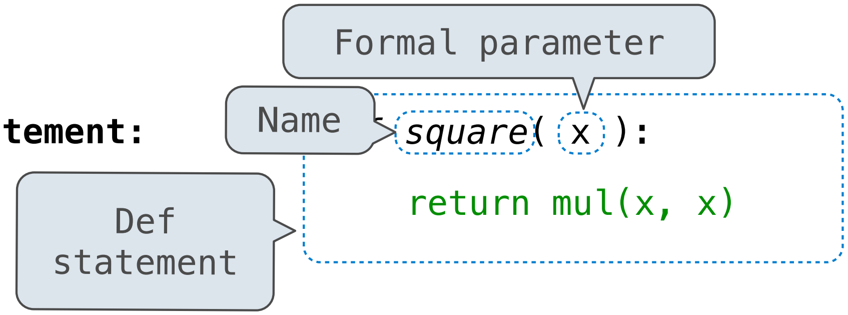

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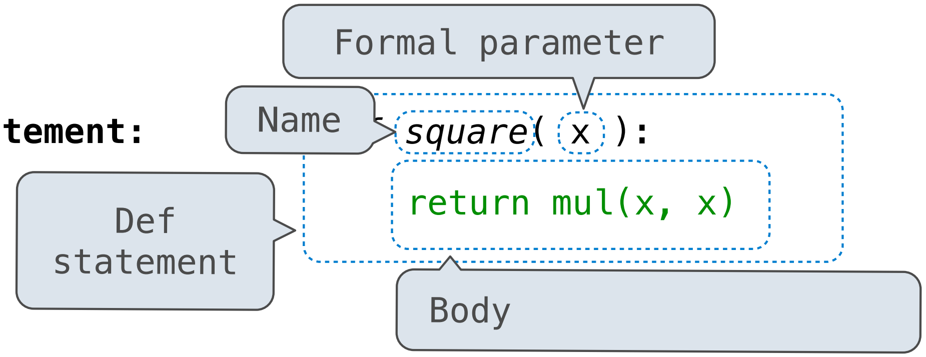

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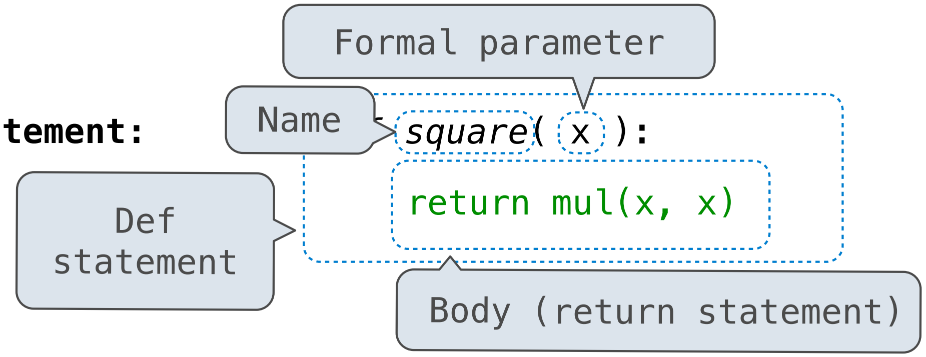

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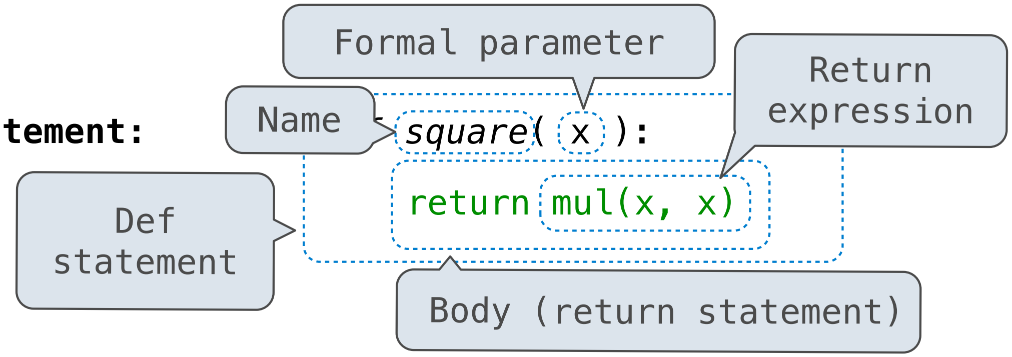

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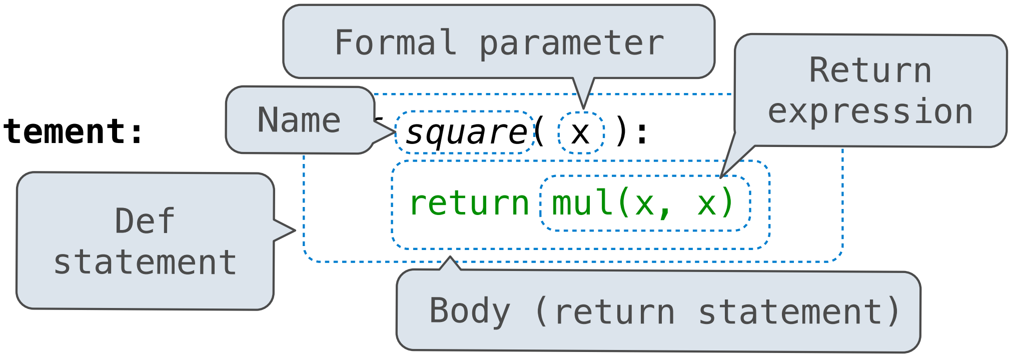

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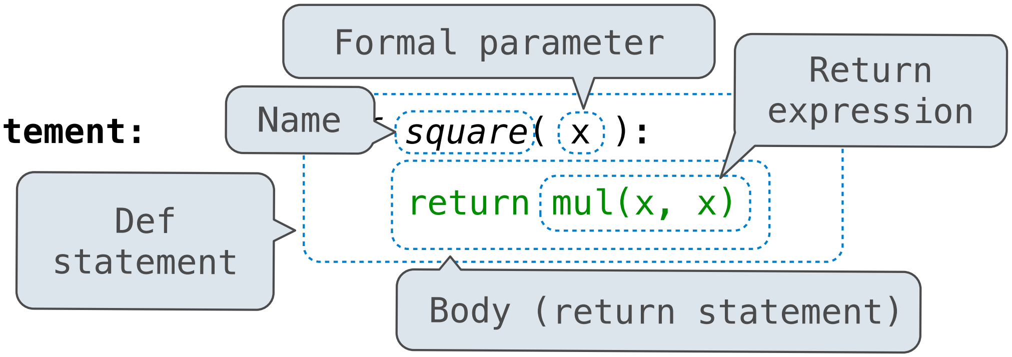

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Name bound to that function in the current frame

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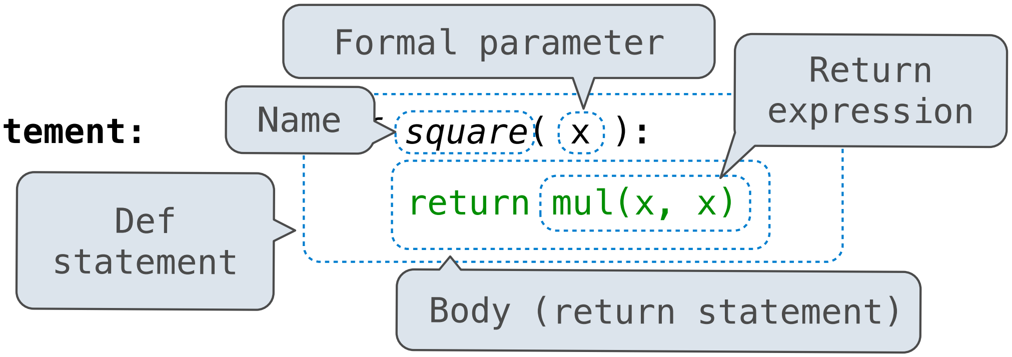

Formal parameter

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Return expression

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Def statement

Body (return statement)

What happens?

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Name bound to that function in the current frame

Call expression:

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square(2+2)
```

Calling/Applying:

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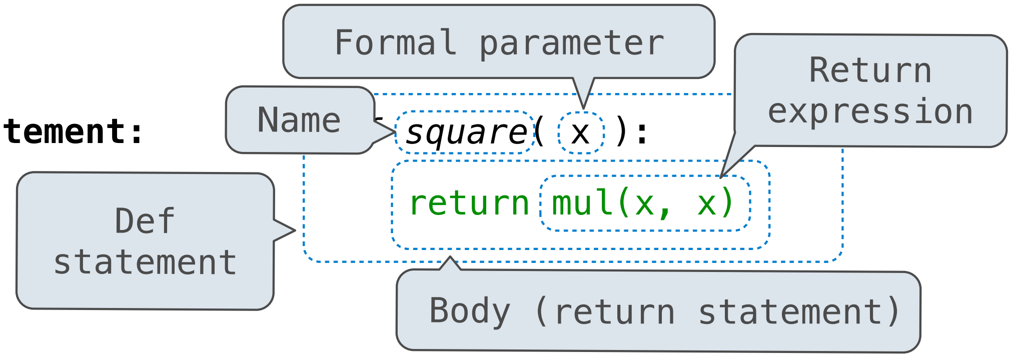

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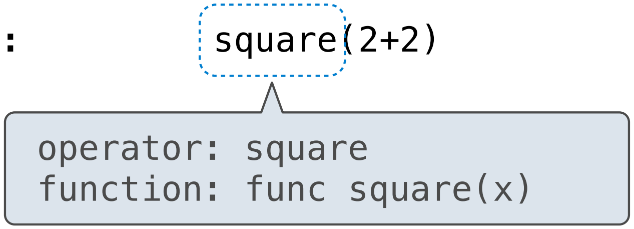

```
square(2+2)
```

```
operator: square
function: func square(x)
```

Calling/Applying:

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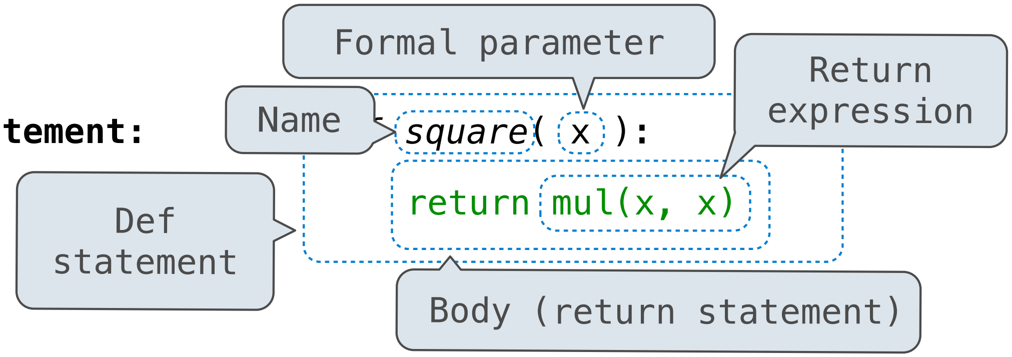

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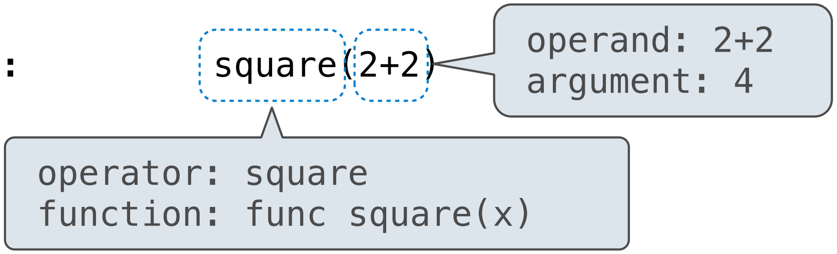

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square(2+2)
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operand: 2+2
argument: 4

operator: square
function: func square(x)

Calling/Applying:

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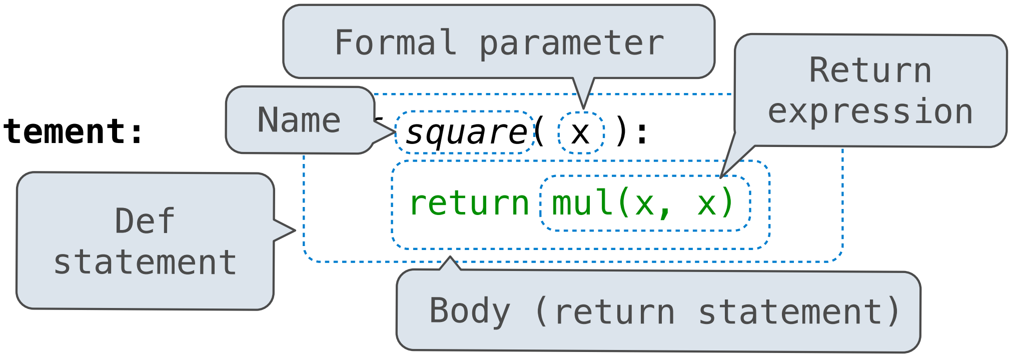

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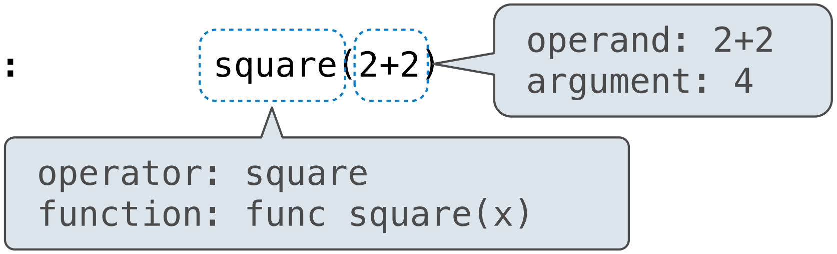

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operand: 2+2
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Operator & operands evaluated

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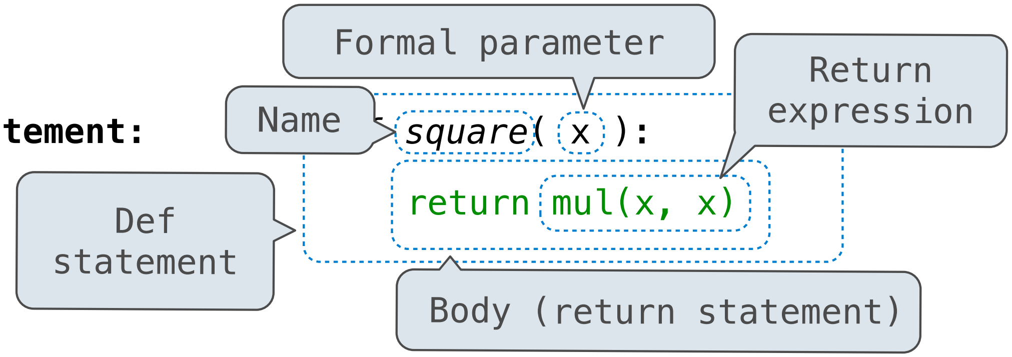

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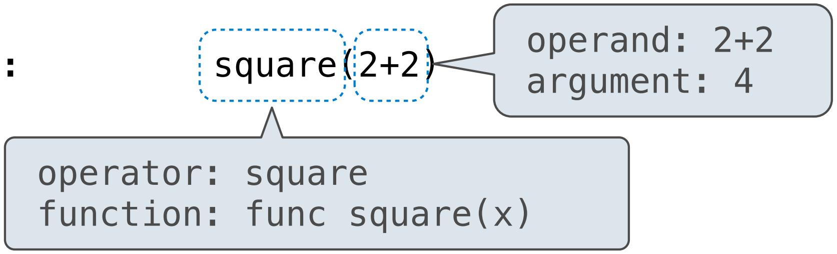

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Operator & operands evaluated

Function (value of operator) called on arguments (values of operands)

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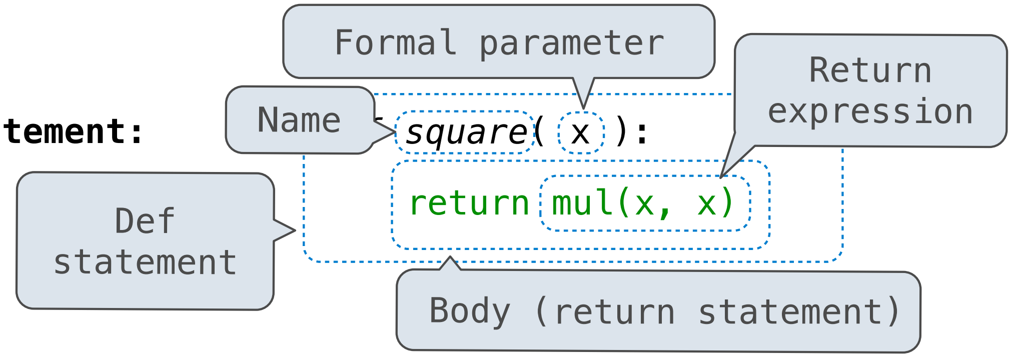

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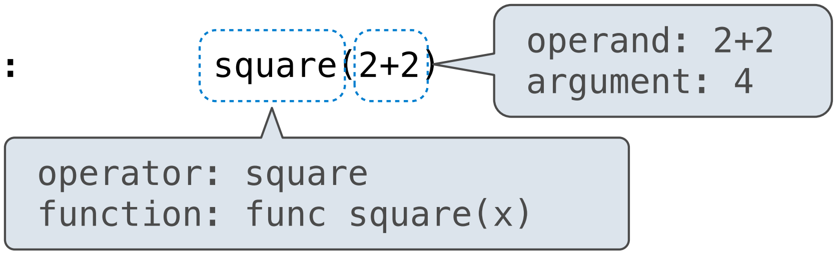

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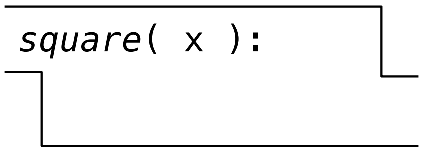

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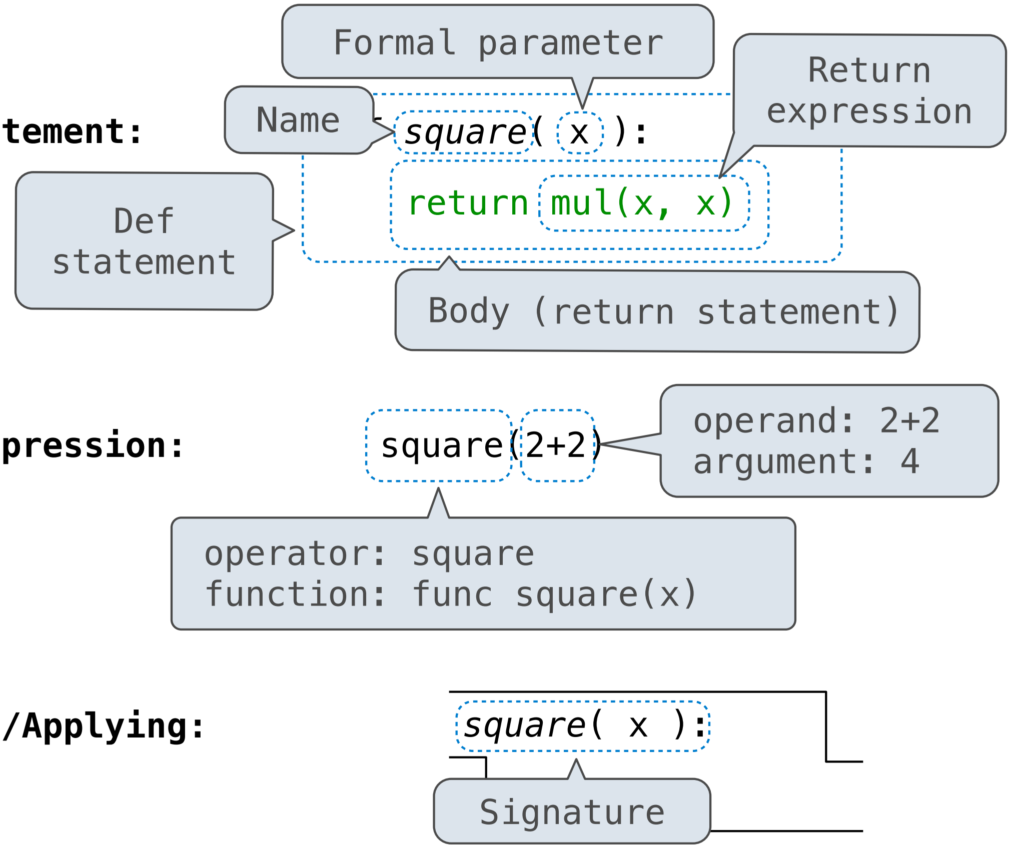

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operand: 2+2
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Operator & operands evaluated

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Calling/Applying:

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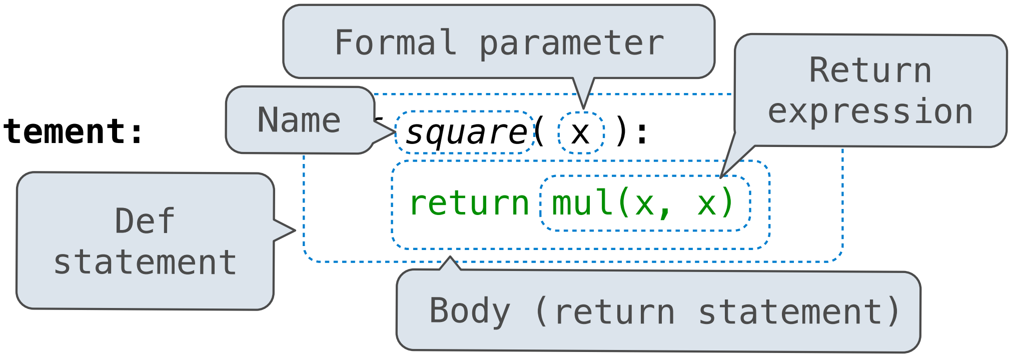

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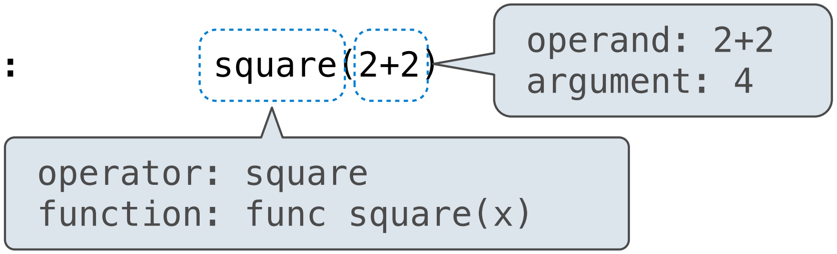

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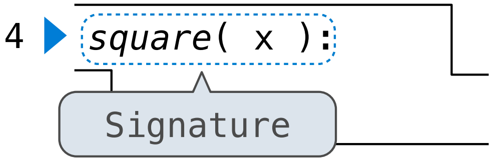
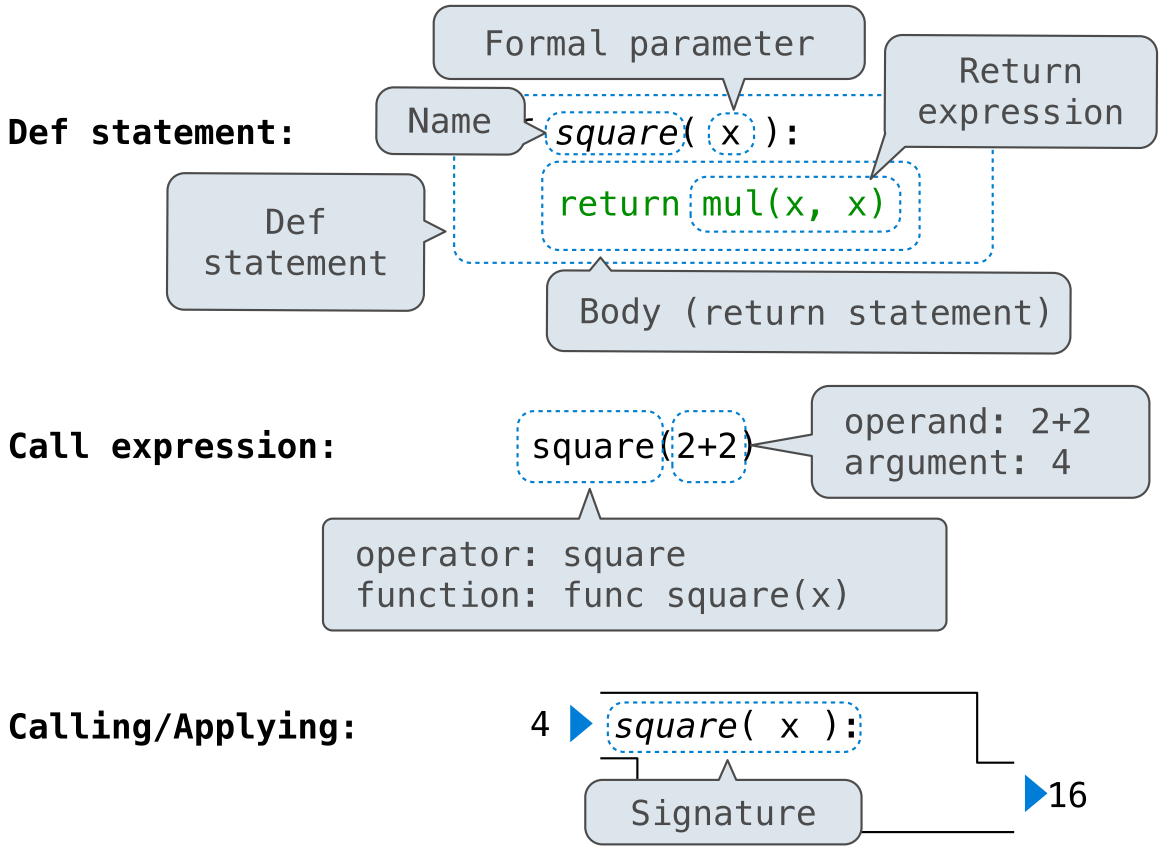


4 ▶ *square*(x):

Signature

Life Cycle of a User-Defined Function



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square( x ):
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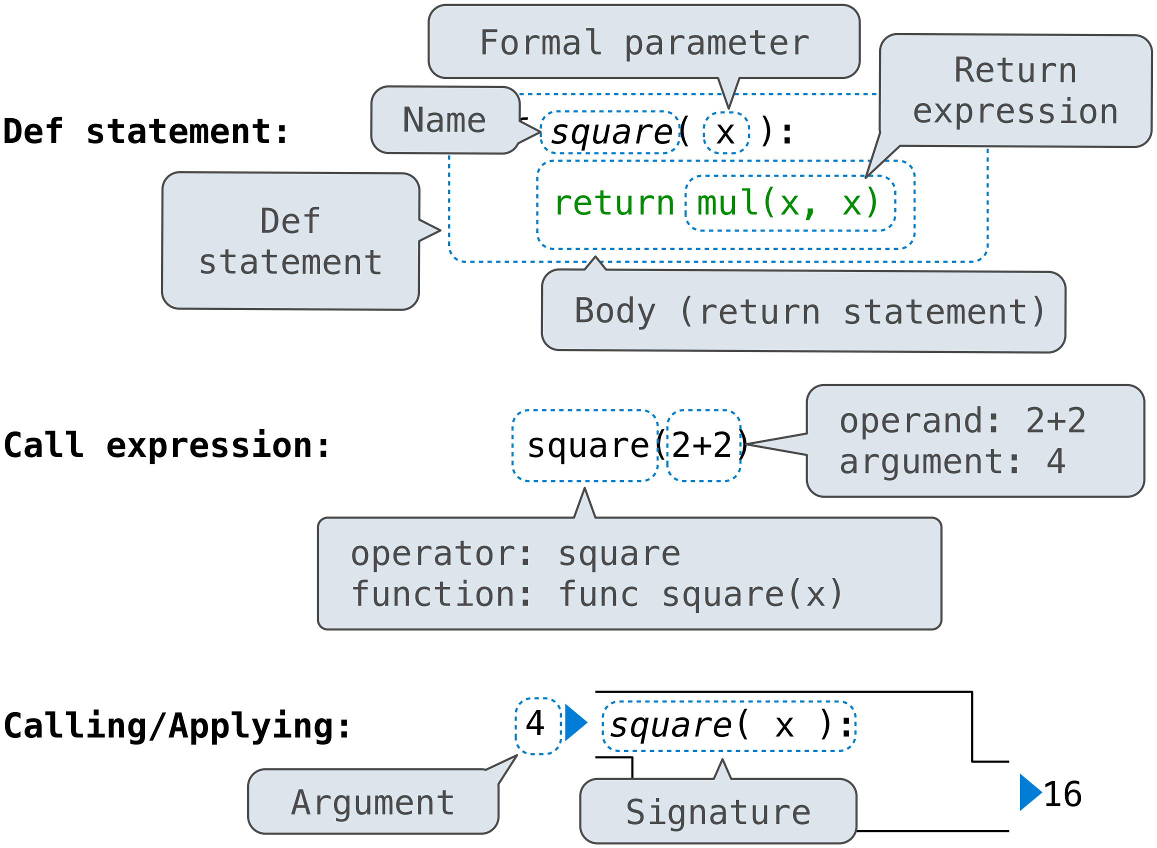

Def statement:

Formal parameter

Name

Return expression

Def statement

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square( x ):
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Body (return statement)

Call expression:

```
square(2+2)
```

operand: 2+2
argument: 4

operator: square
function: func square(x)

Calling/Applying:

4

```
square( x ):
```

16

Argument

Signature

What happens?

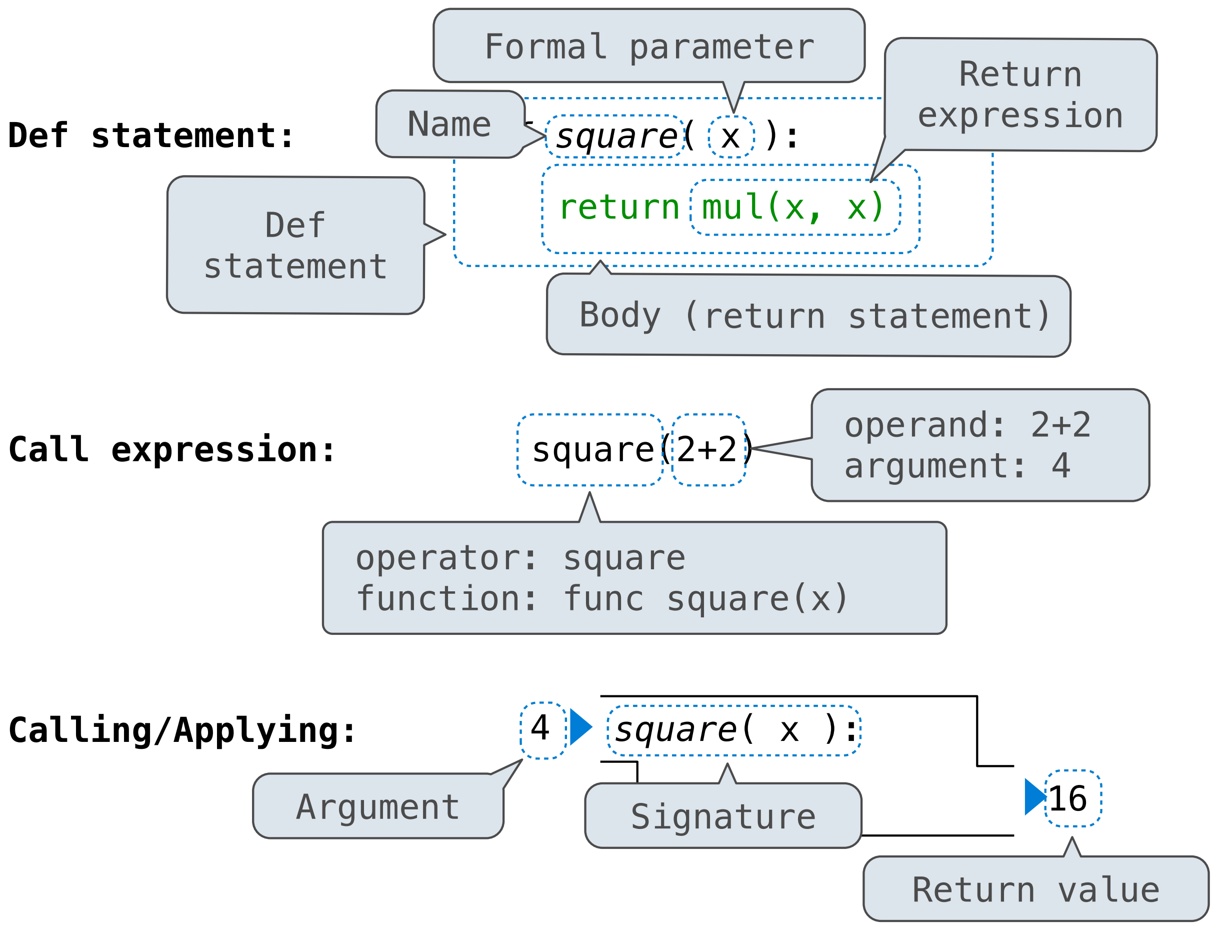
A new function is created!

Name bound to that function in the current frame

Operator & operands evaluated

Function (value of operator) called on arguments (values of operands)

Life Cycle of a User-Defined Function



Def statement:

Name

Formal parameter

Return expression

Def statement

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Body (return statement)

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square( x ):
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16

Argument

Signature

Return value

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Operator & operands evaluated

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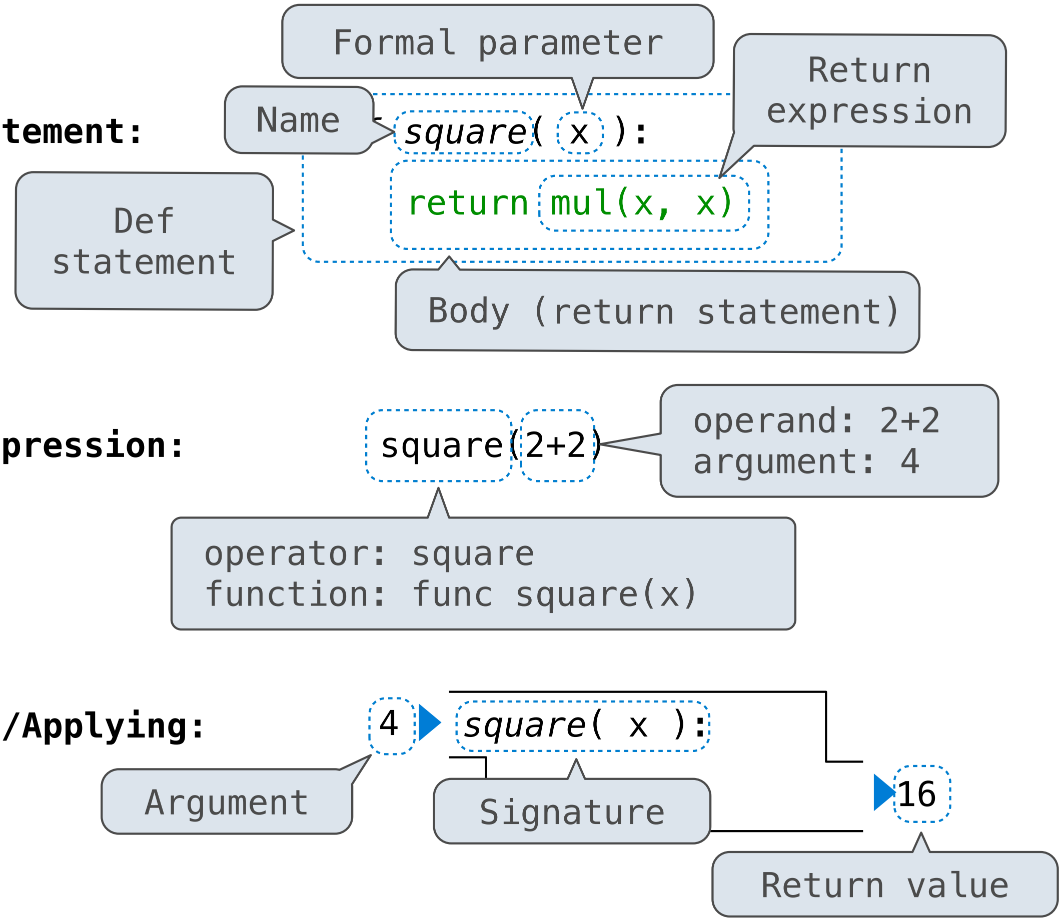
Life Cycle of a User-Defined Function



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Formal parameter

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Return expression

Def statement

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Argument

Signature

Return value

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A new function is created!

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Operator & operands evaluated

Function (value of operator)
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A new frame is created!

Life Cycle of a User-Defined Function

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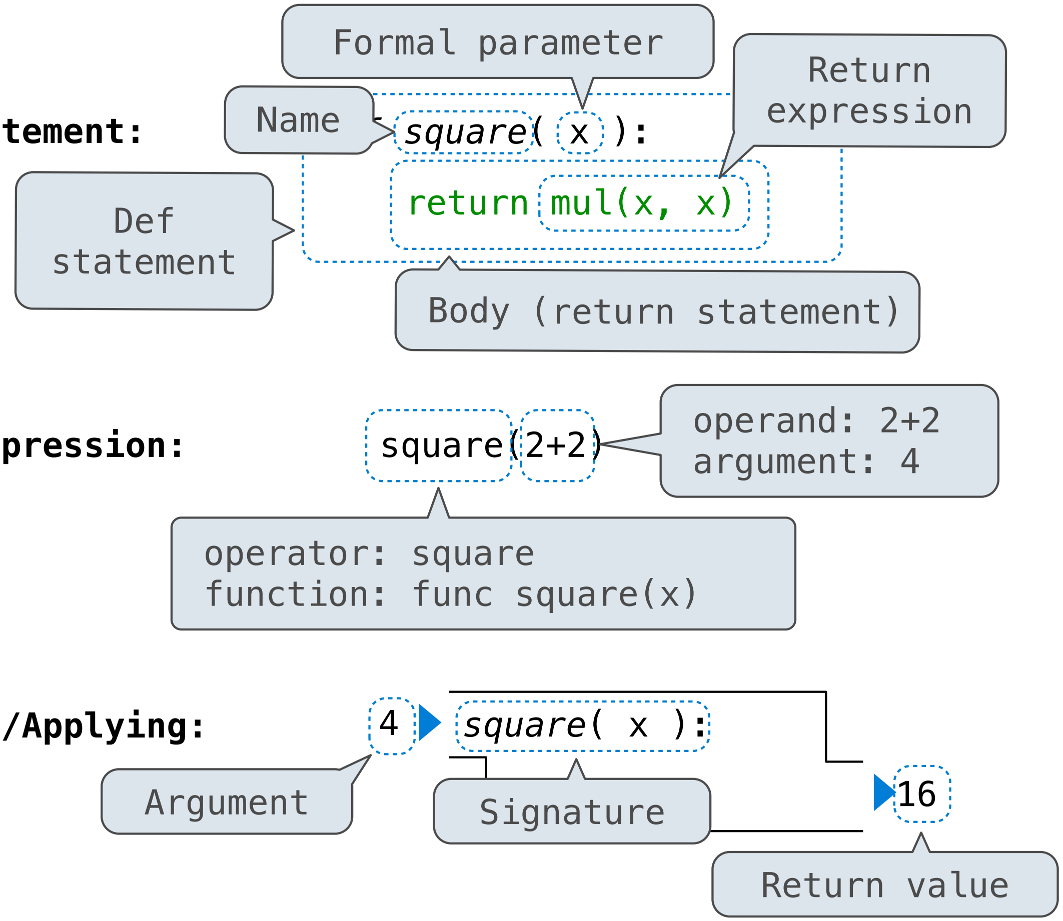

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Name bound to that function
in the current frame

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Function (value of operator)
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Calling/Applying:

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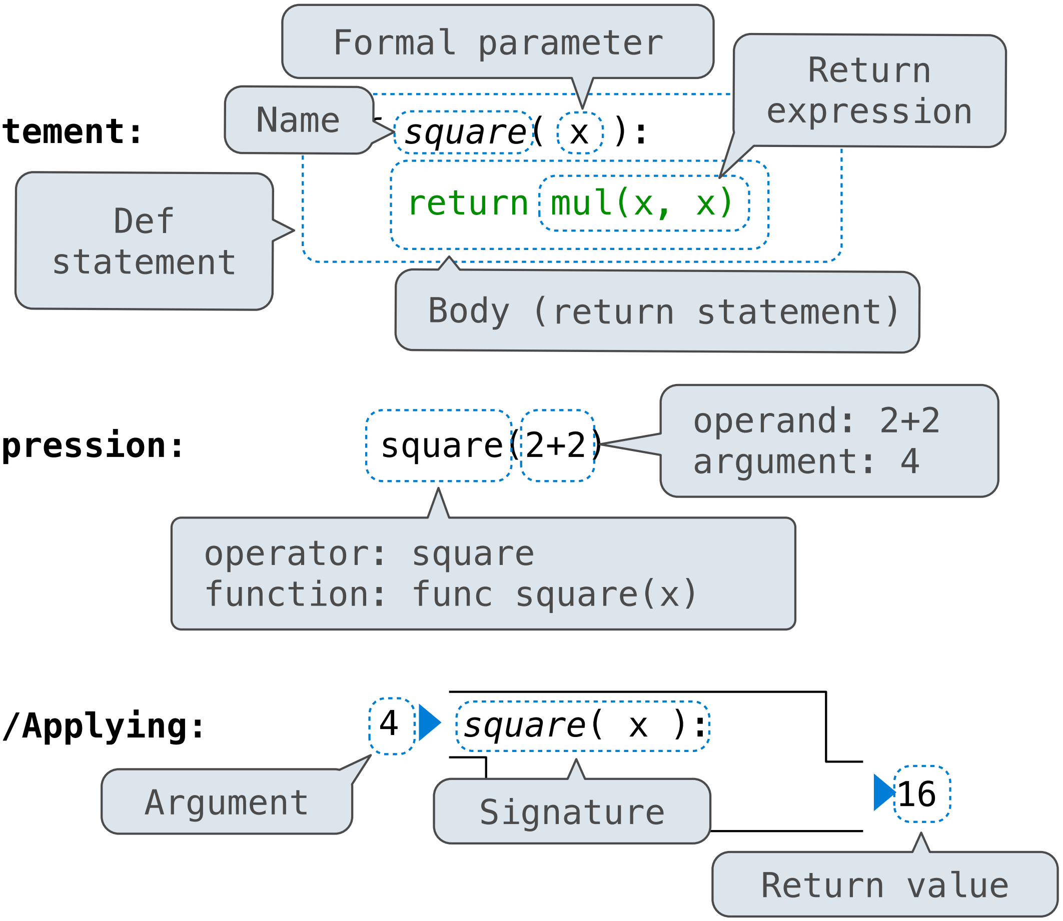
4 square( x ): 16
```

A new frame is created!

Parameters bound to arguments

Life Cycle of a User-Defined Function



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Calling/Applying:

```
4 ▶ square( x ): ▶ 16
```

Argument

Signature

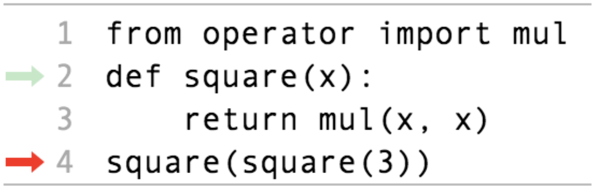
Return value

A new frame is created!

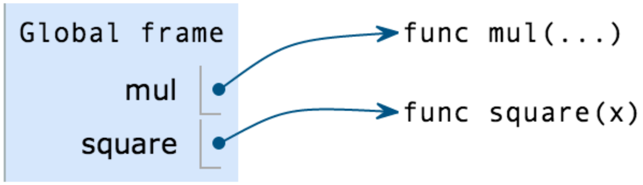
Parameters bound to arguments

Body is executed in that new environment

Multiple Environments in One Diagram!



```
from operator import mul
def square(x):
    return mul(x, x)
square(square(3))
```



Example: http://goo.gl/XVtEms

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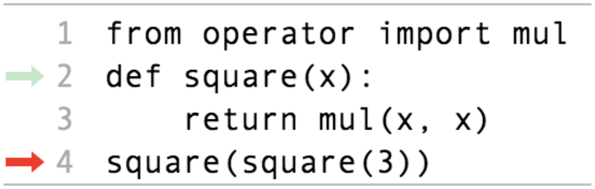

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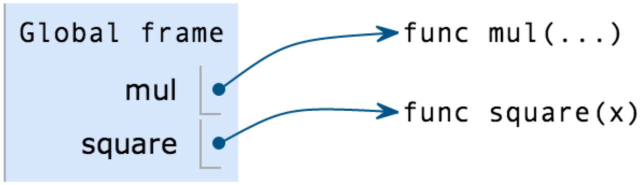

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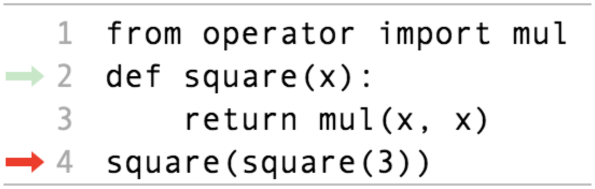

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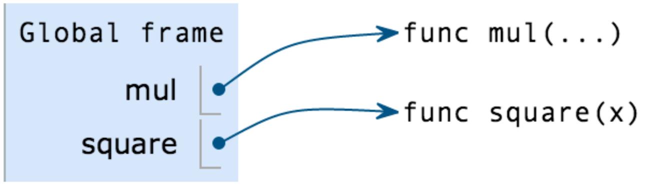

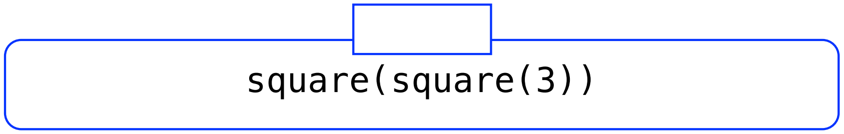

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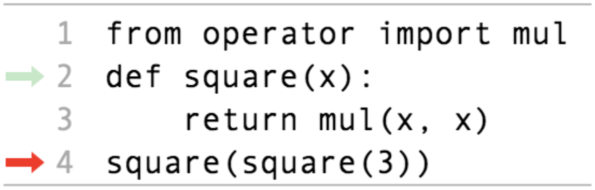

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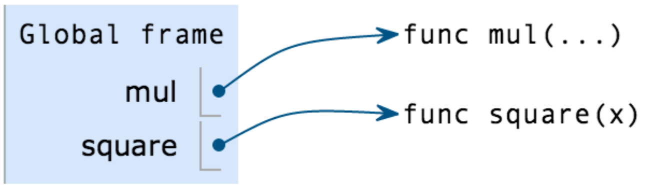

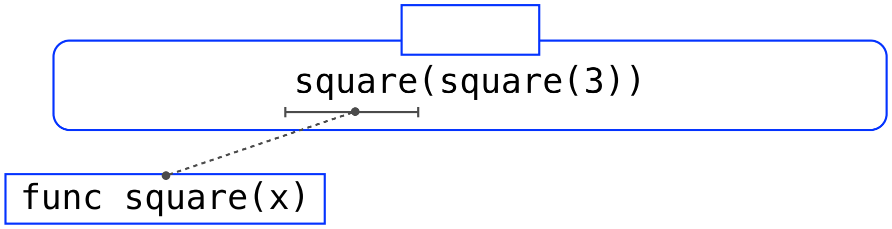

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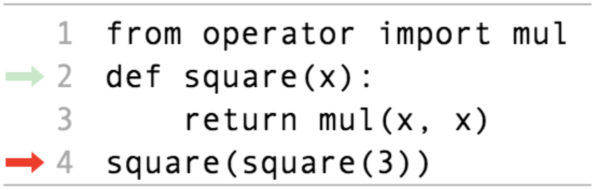

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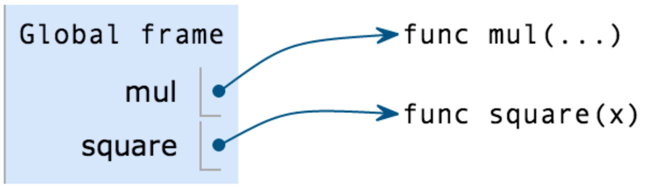

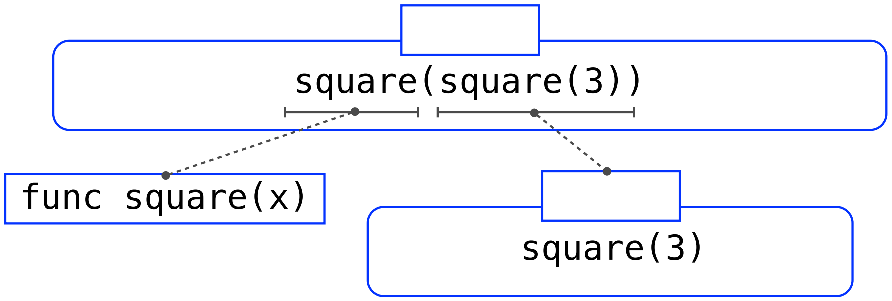

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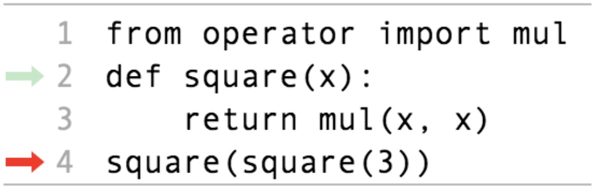

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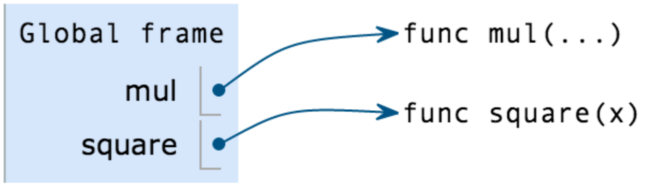
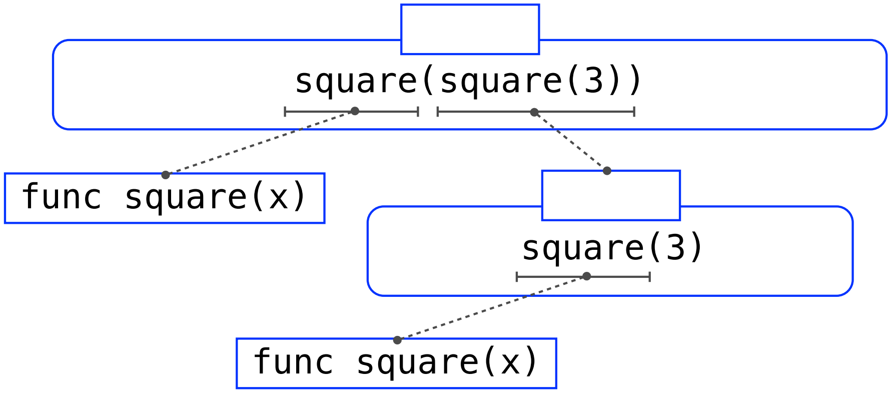
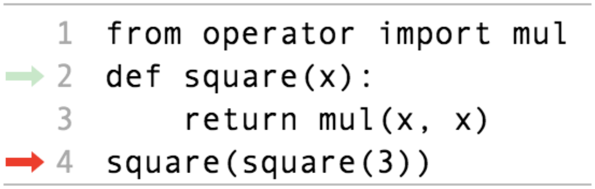




Example: http://goo.gl/XVtEms

Multiple Environments in One Diagram!



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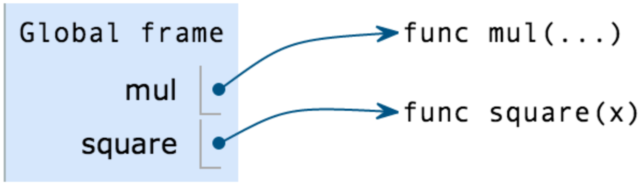

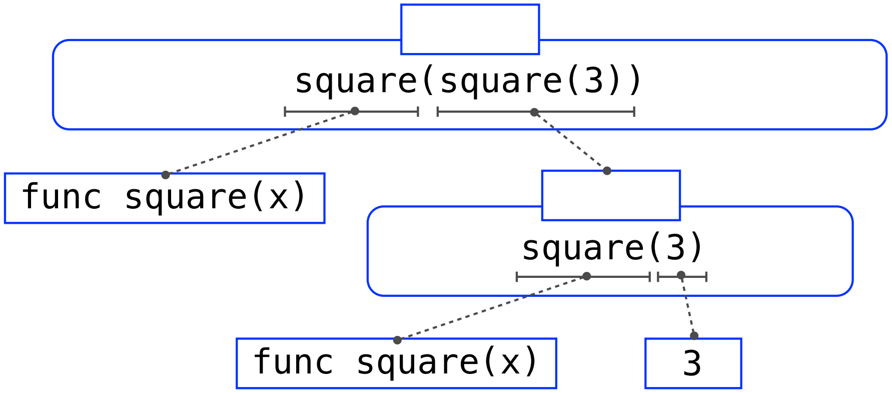

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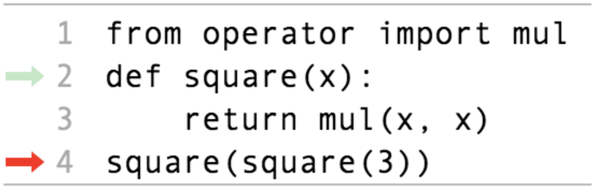

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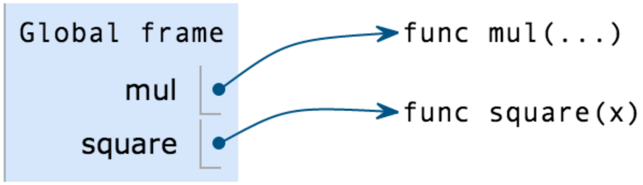

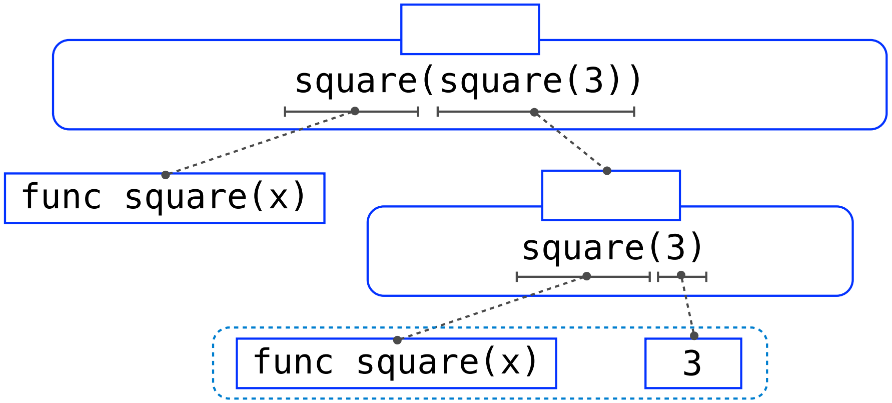

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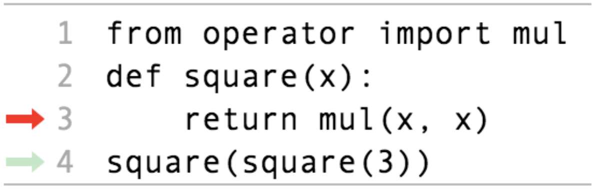

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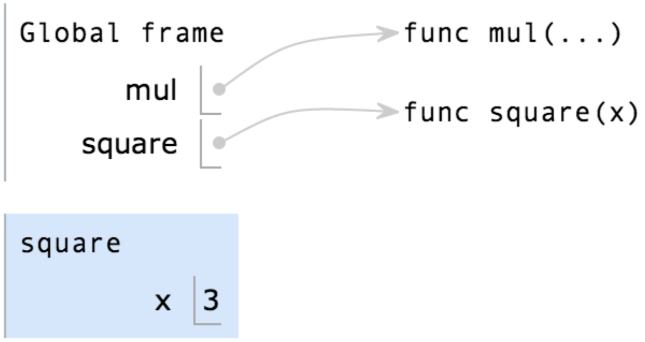

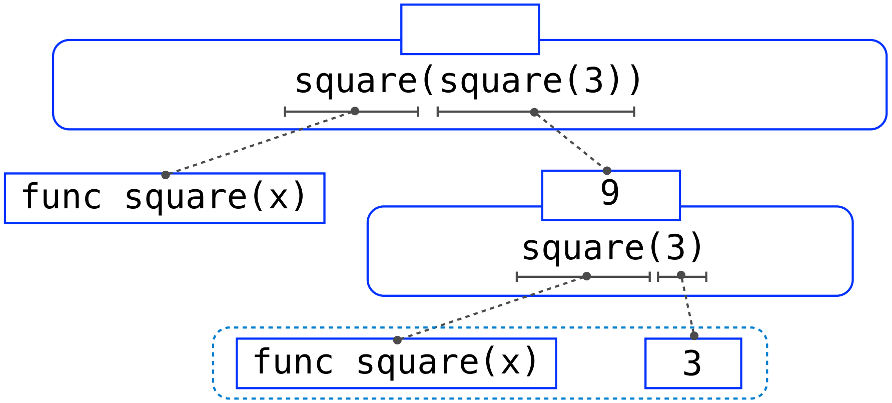

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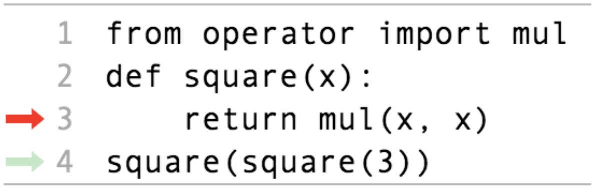

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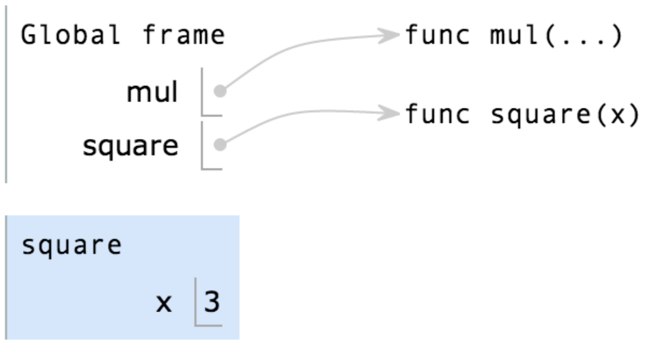

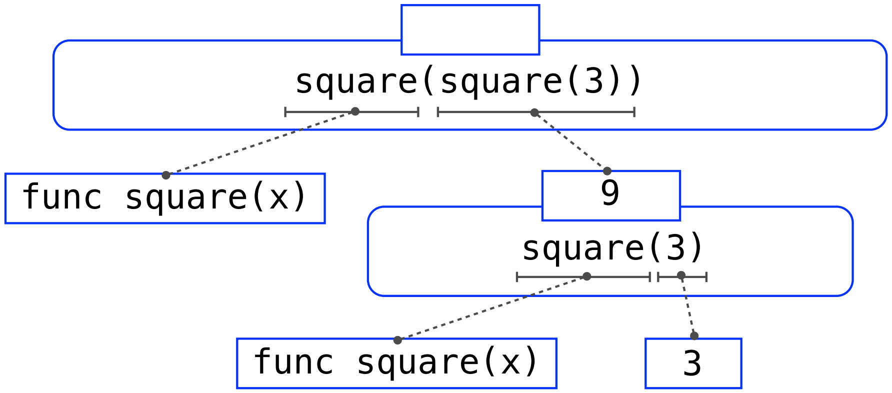

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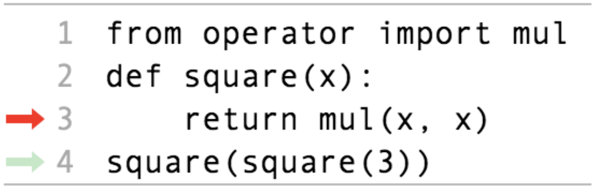

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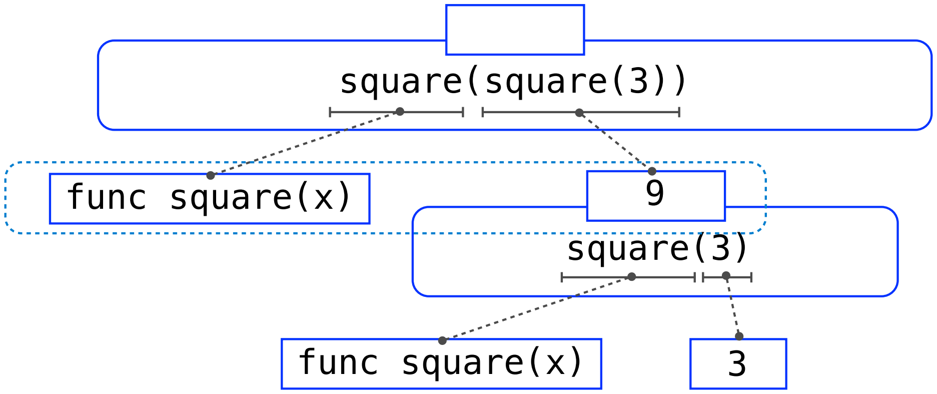

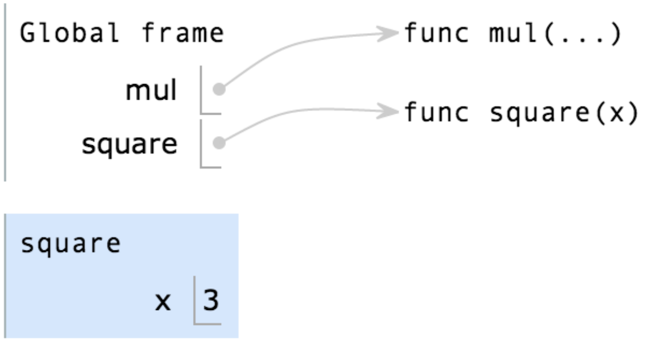

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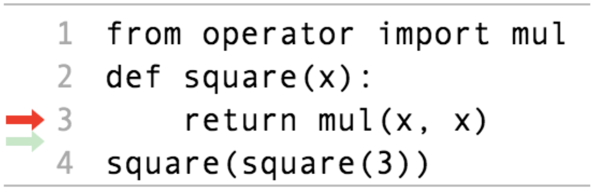

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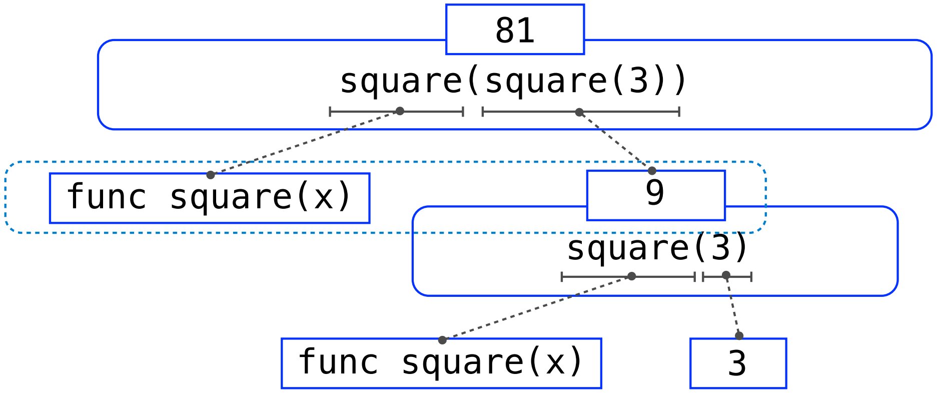

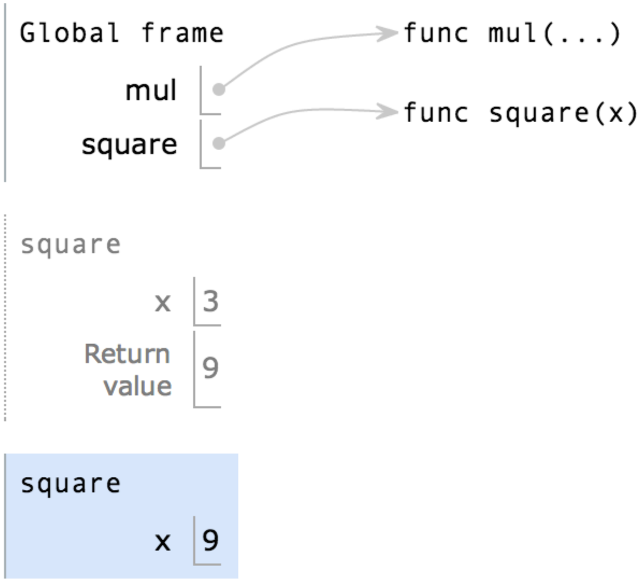

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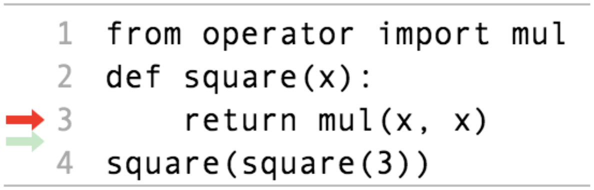

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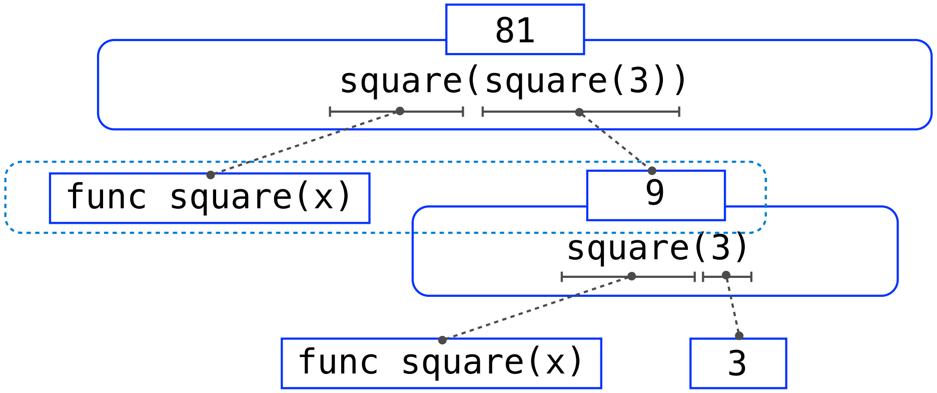

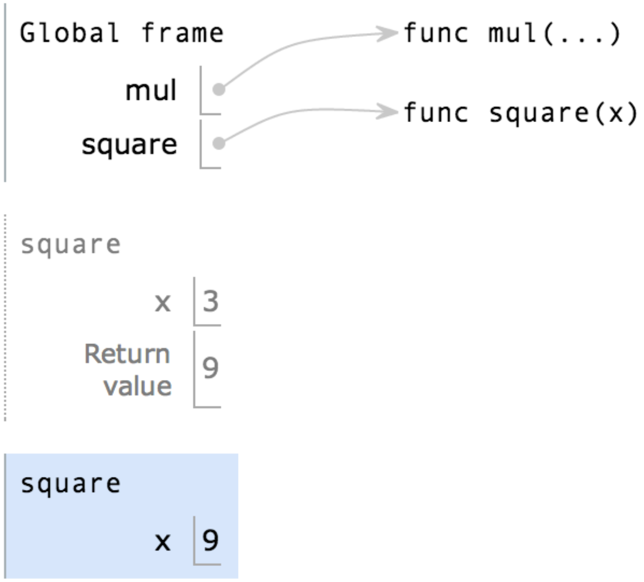

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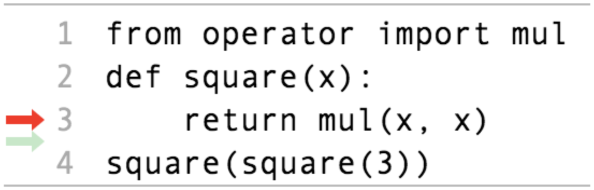

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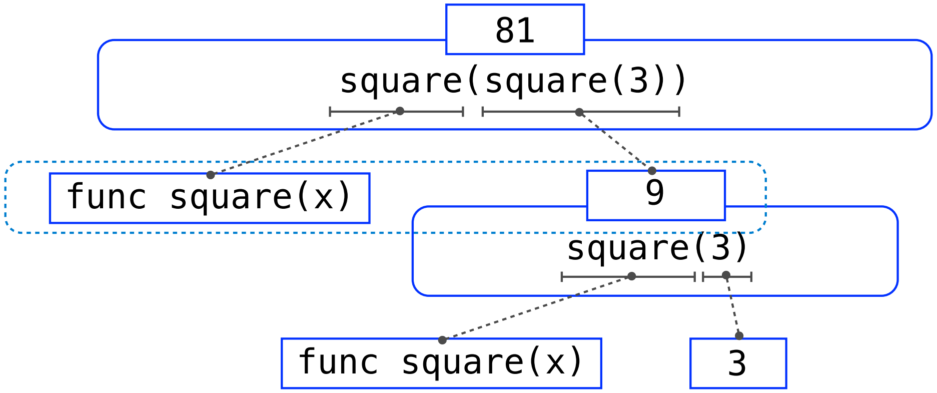

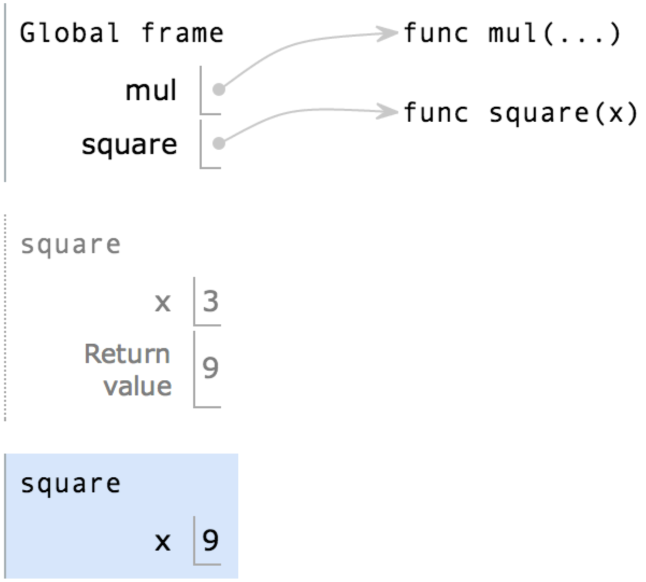

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- The global frame alone
- A local, then the global frame

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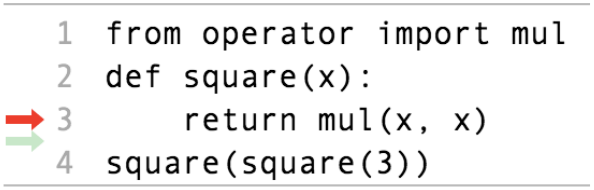

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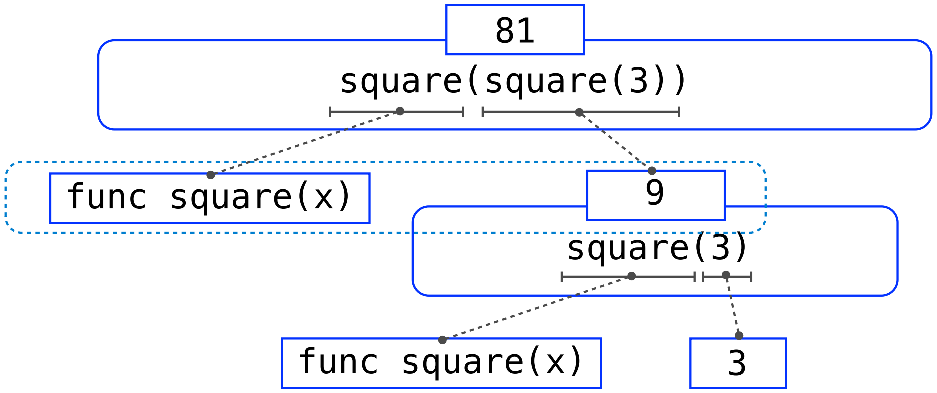

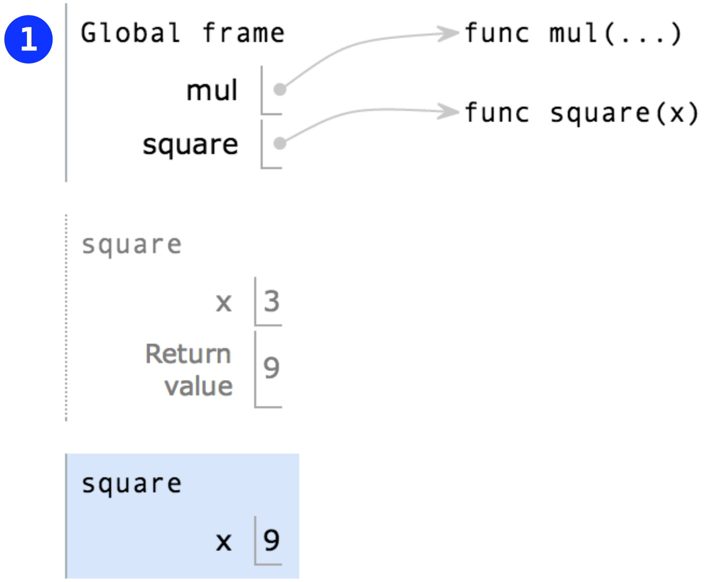

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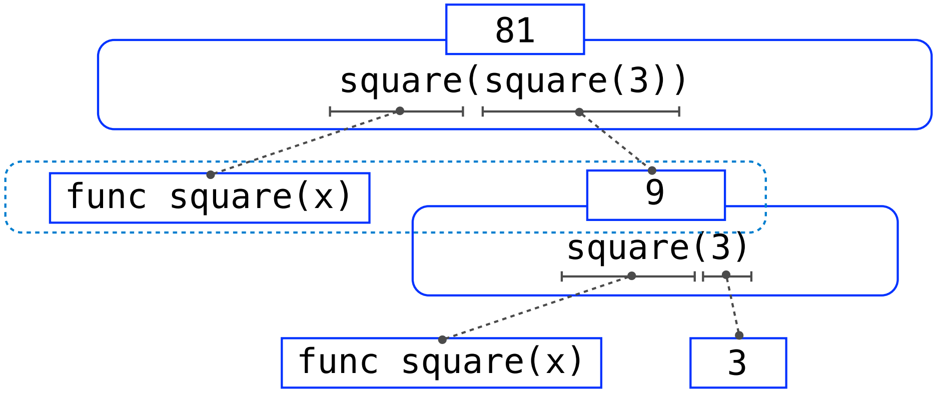

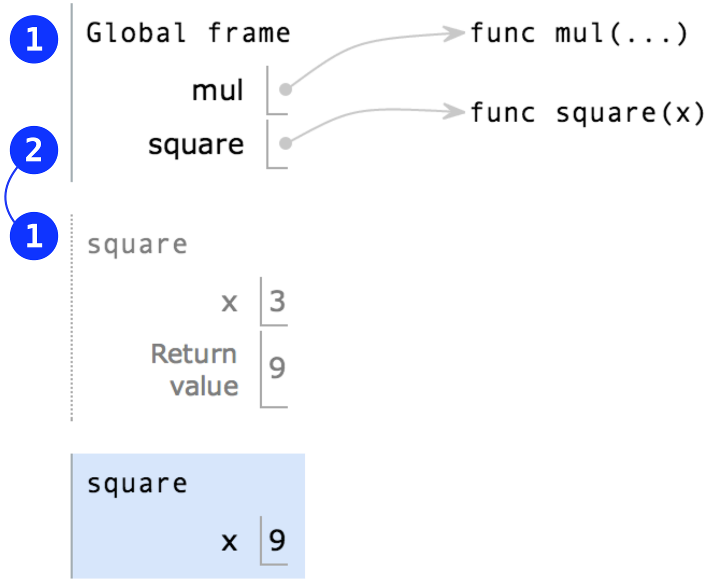

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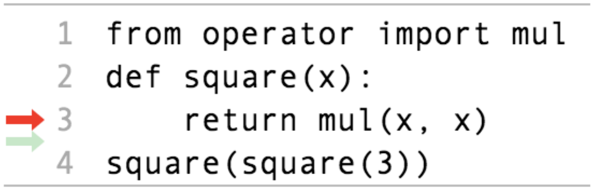

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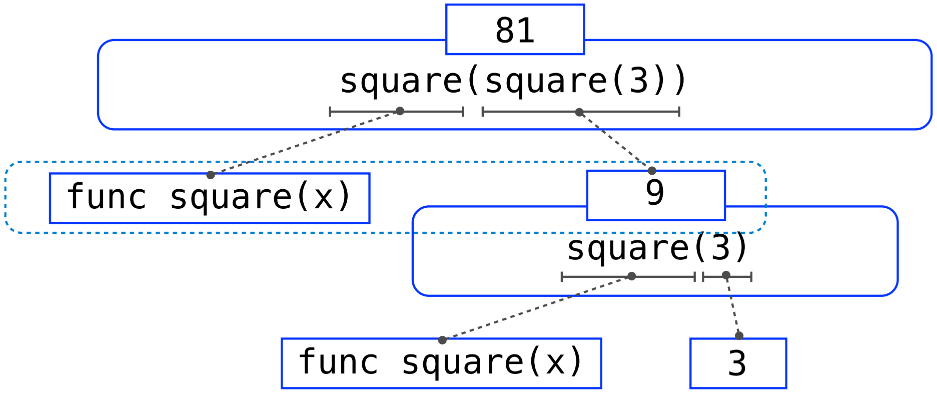

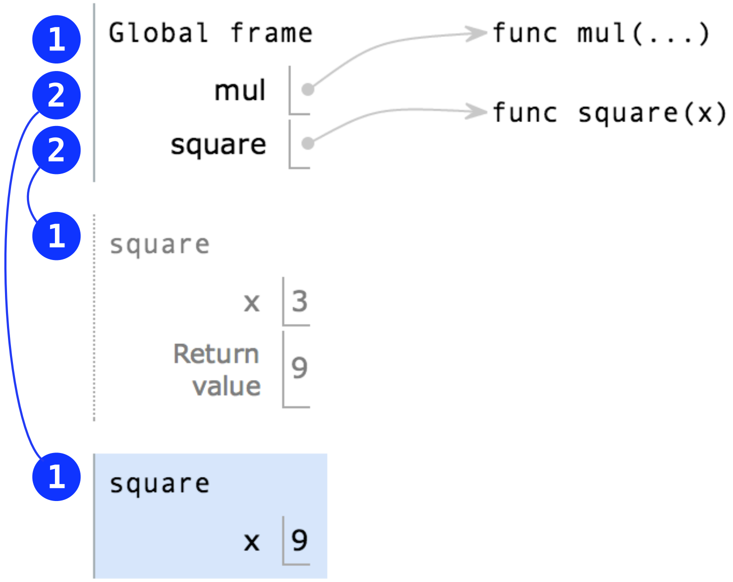

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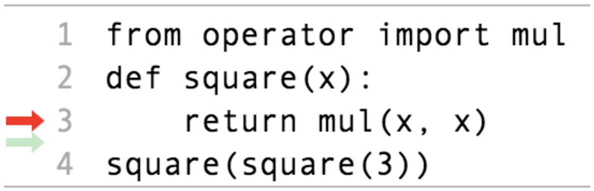
Names Have No Meaning Without Environments



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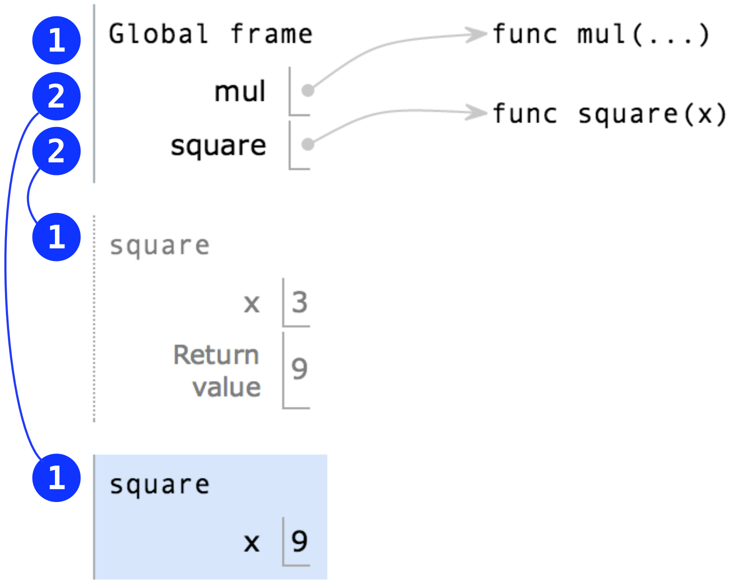

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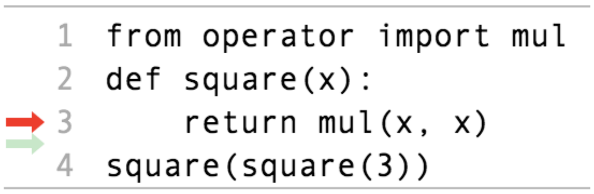

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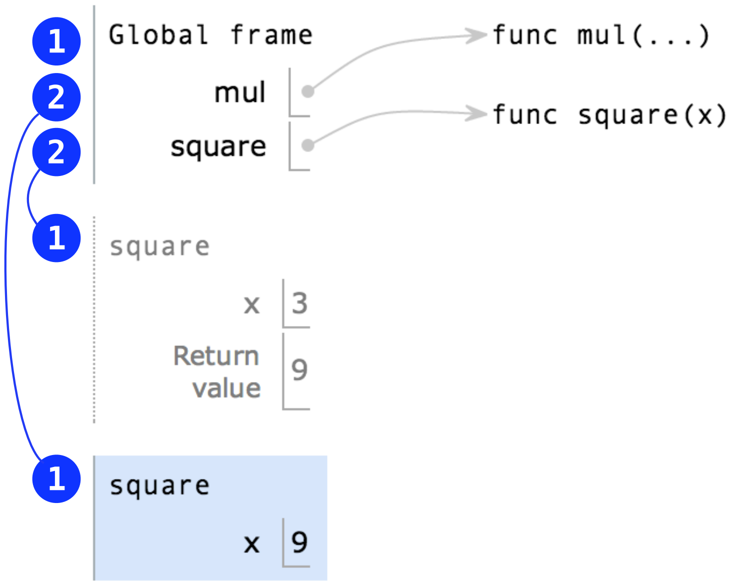

Every expression is evaluated in the context of an environment.

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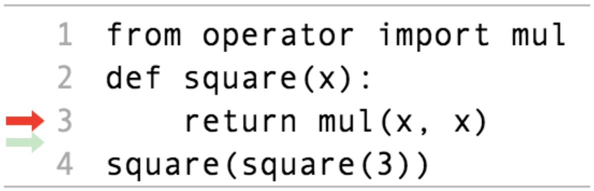

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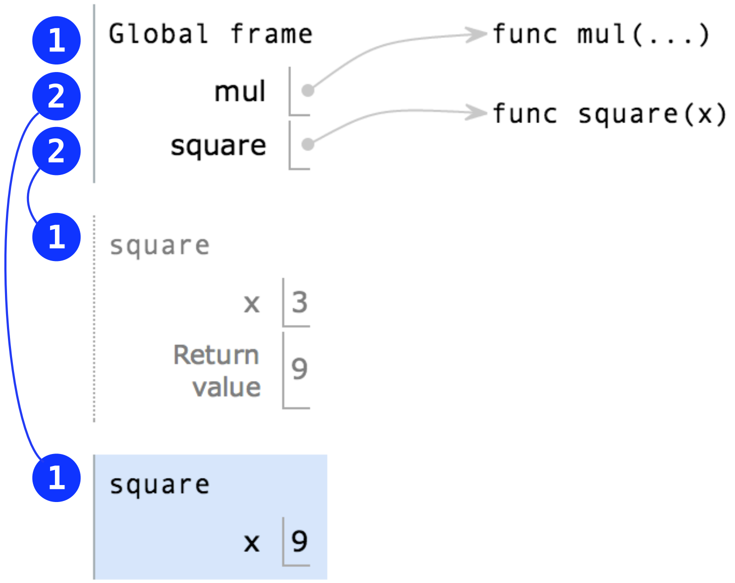

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A name evaluates to the value bound to that name in the earliest frame of the current environment in which that name is found.

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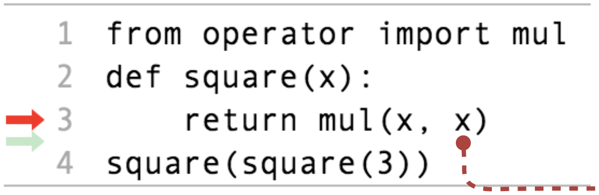

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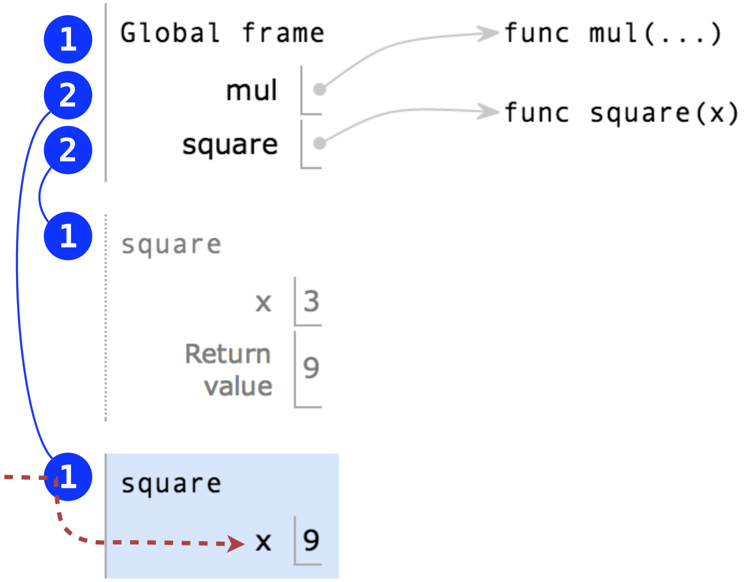

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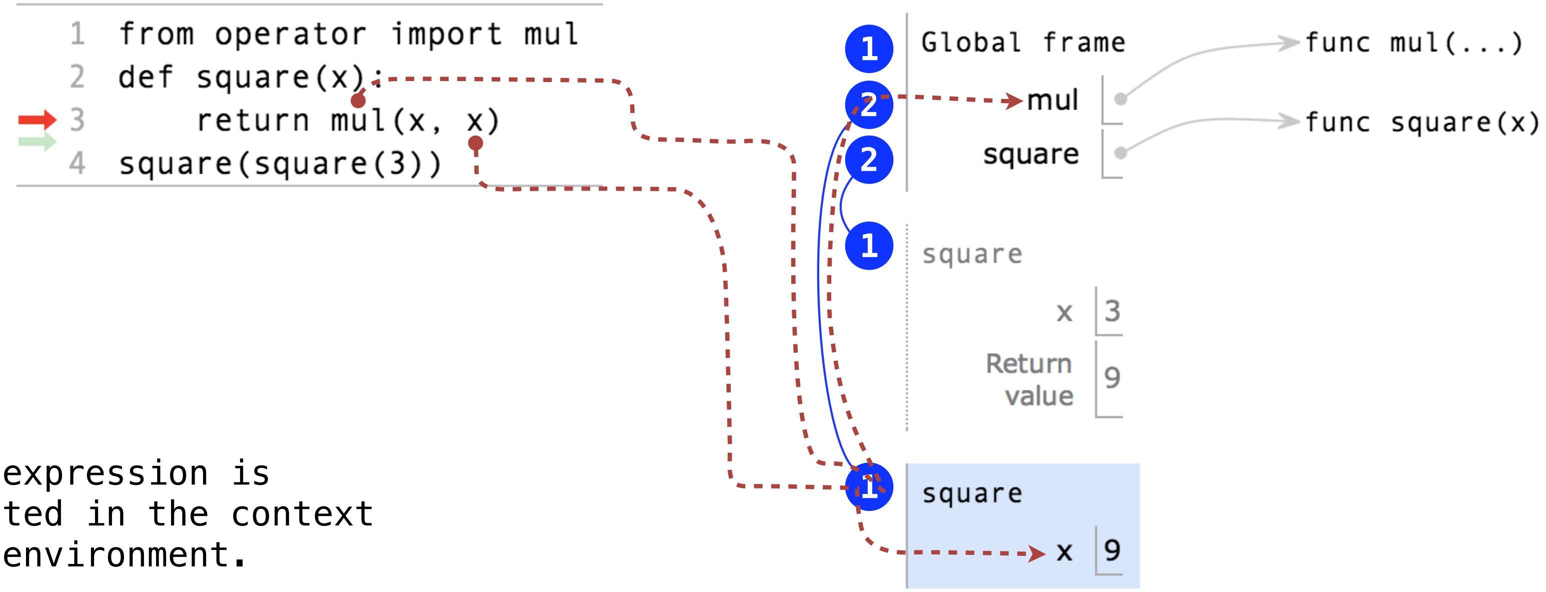

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Miscellaneous Python Features

Operators

Multiple Return Values

Docstrings

Doctests

Default Arguments

(Demo)

Conditional Statements

Statements

Statements

A ***statement*** is executed by the interpreter to perform an action

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Compound statements:

```
<header>:
    <statement>
    <statement>
    ...
<separating header>:
    <statement>
    <statement>
    ...
...
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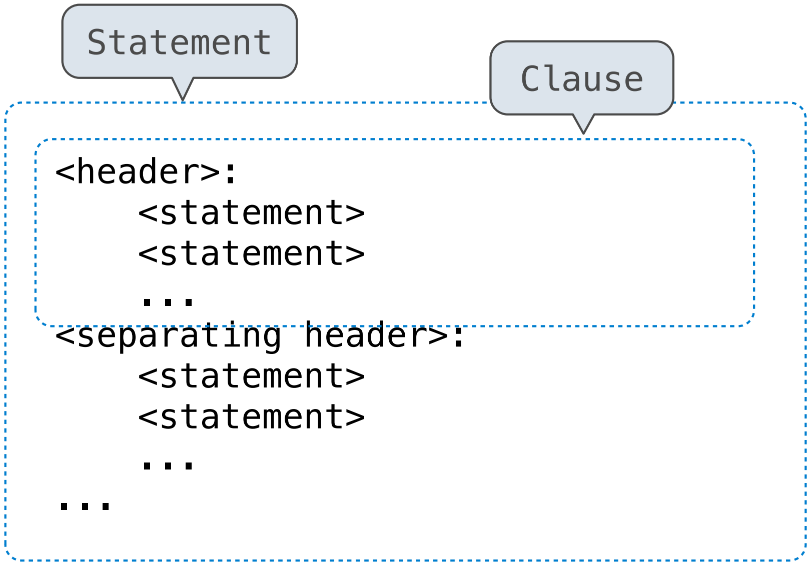

Statement

Clause

```
<header>:
    <statement>
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<separating header>:
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    ...
...
```

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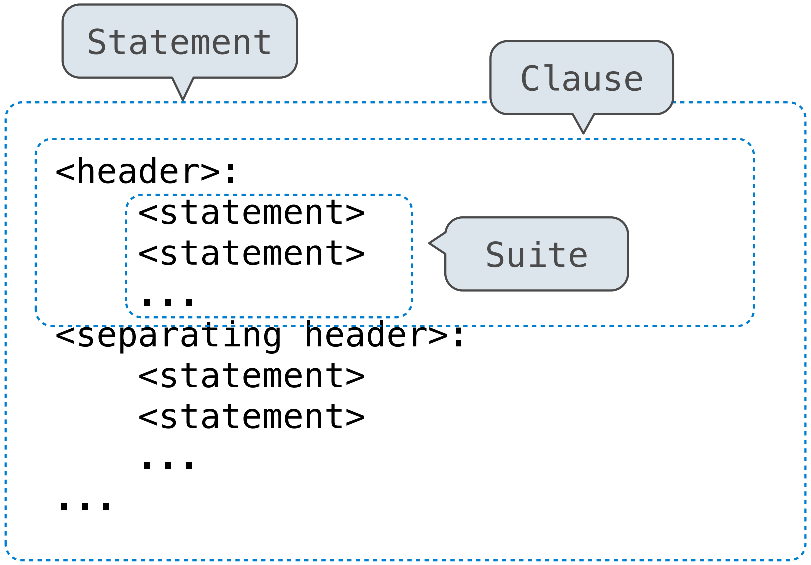

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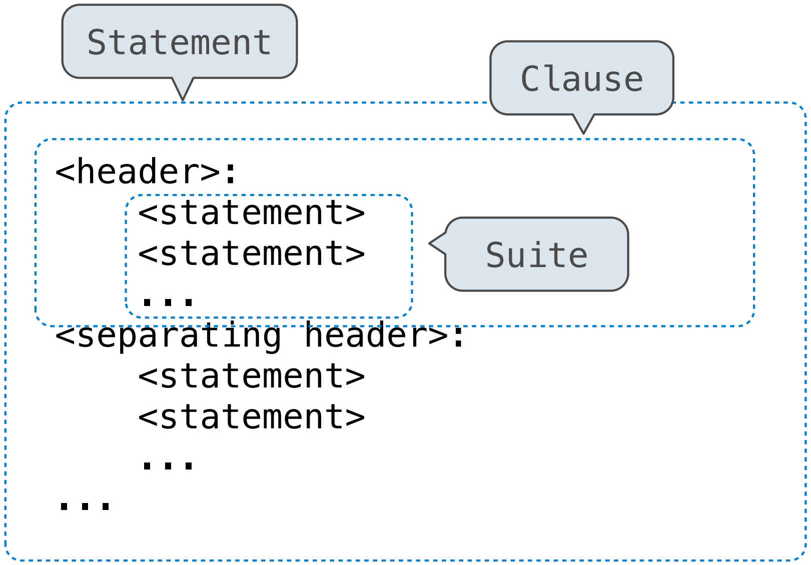

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The first header determines a statement’s type

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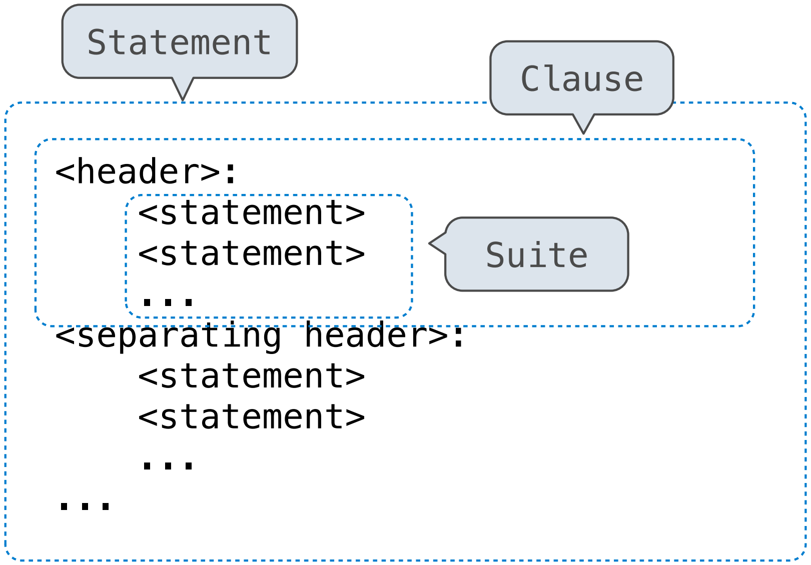

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The header of a clause “controls” the suite that follows

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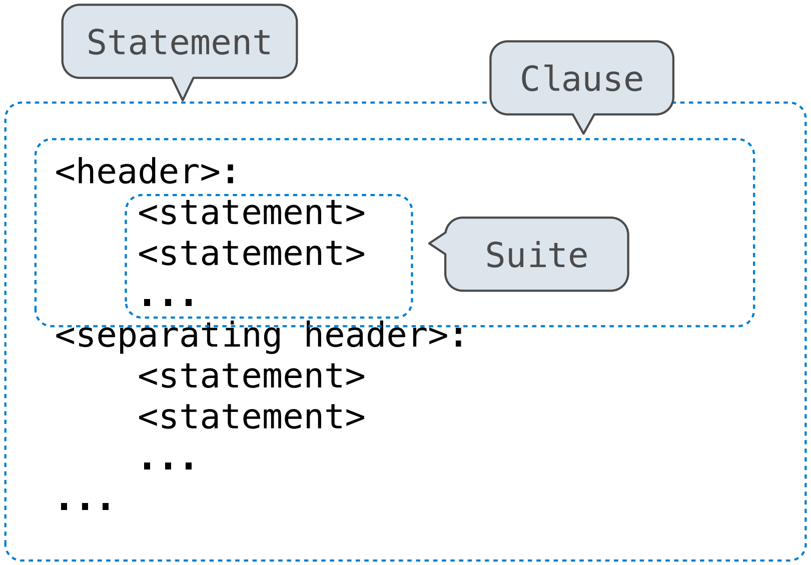

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    ...
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    <statement>
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The header of a clause "controls" the suite that follows

def statements are compound statements

Compound Statements

Compound statements:

```
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    <statement>
    ...
<separating header>:
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    ...
...
```

Suite

Compound Statements

Compound statements:

```
<header>:
    <statement>
    <statement>
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    <statement>
    ...
...
```

Suite

A suite is a sequence of statements

Compound Statements

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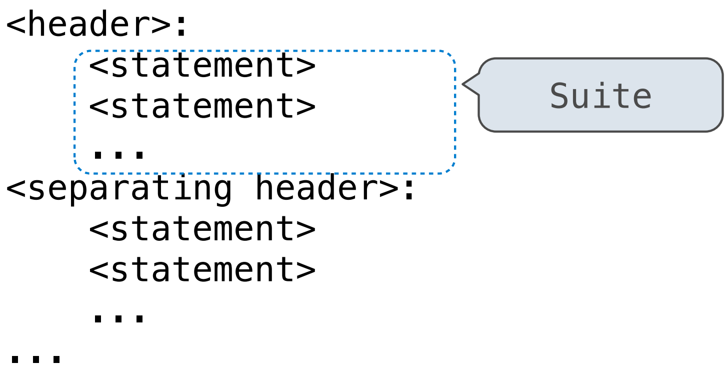

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    <statement>
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    <statement>
    <statement>
    ...
...
```

Suite

A suite is a sequence of statements

To "execute" a suite means to execute its sequence of statements, in order

Compound Statements

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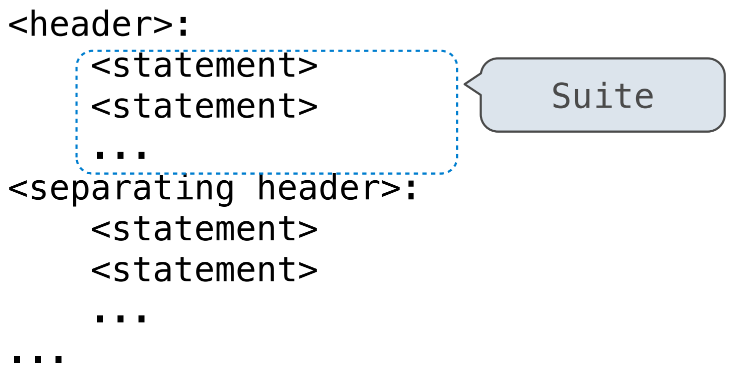

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    ...
<separating header>:
    <statement>
    <statement>
    ...
...
```

Suite

A suite is a sequence of statements

To “execute” a suite means to execute its sequence of statements, in order

Execution Rule for a sequence of statements:

- Execute the first statement
- Unless directed otherwise, execute the rest

Conditional Statements

(Demo)

Conditional Statements

(Demo)

```python
def absolute_value(x):
    """Return the absolute value of x."""
    if x < 0:
        return -x
    elif x == 0:
        return 0
    else:
        return x
```

Conditional Statements

(Demo)

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def absolute_value(x):
    """Return the absolute value of x."""
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```

1 statement,
3 clauses,
3 headers,
3 suites

Conditional Statements

(Demo)

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Execution rule for conditional statements:

Conditional Statements

(Demo)

1 statement,
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    if x < 0:
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```

Execution rule for conditional statements:

Each clause is considered in order.

1. Evaluate the header's expression.

2. If it is a true value,
   execute the suite & skip the remaining clauses.

Conditional Statements

(Demo)

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1 statement,
3 clauses,
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Execution rule for conditional statements:

Each clause is considered in order.

1. Evaluate the header's expression.

2. If it is a true value,
   execute the suite & skip the remaining clauses.

Syntax Tips

Conditional Statements

(Demo)

```
def absolute_value(x):
    """Return the absolute value of x."""
    if x < 0:
        return -x
    elif x == 0:
        return 0
    else:
        return x
```

1 statement,
3 clauses,
3 headers,
3 suites

Execution rule for conditional statements:

Each clause is considered in order.

1. Evaluate the header's expression.
2. If it is a true value,
   execute the suite & skip the remaining clauses.

Syntax Tips

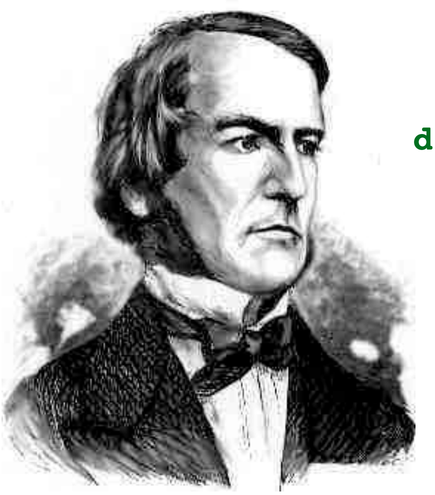
1. Always starts with "if" clause.
2. Zero or more "elif" clauses.
3. Zero or one "else" clause,
   always at the end.

Boolean Contexts

George Boole

```
def absolute_value(x):
    """Return the absolute value of x."""
    if x < 0:
        return -x
    elif x == 0:
        return 0
    else:
        return x
```

Boolean Contexts



George Boole

```
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    if x < 0:
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    else:
        return x
```

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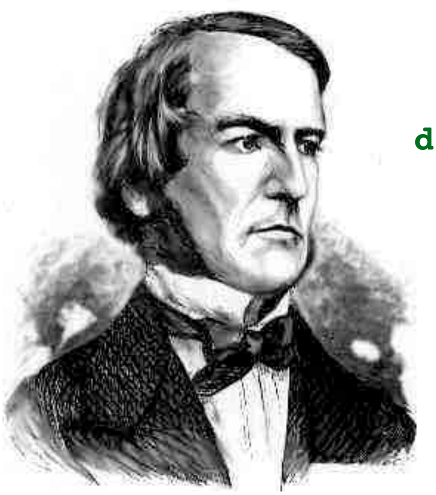

George Boole

```
def absolute_value(x):
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    if x < 0:
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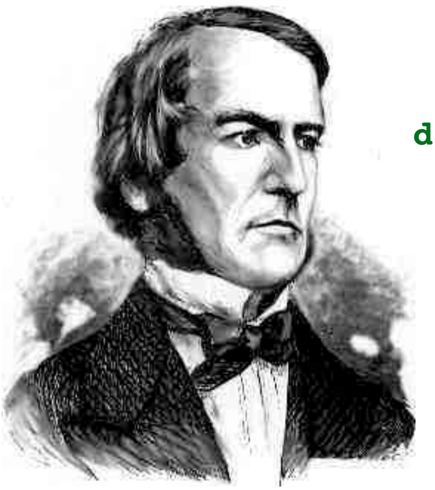
```

Two boolean contexts

Boolean Contexts



George Boole

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    if x < 0:
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    else:
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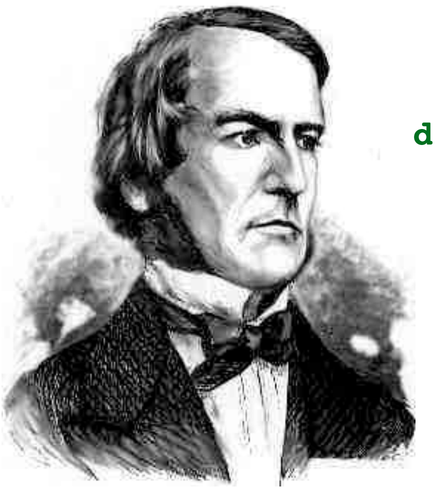
```

Two boolean contexts

False values in Python: False, 0, '', None

Boolean Contexts



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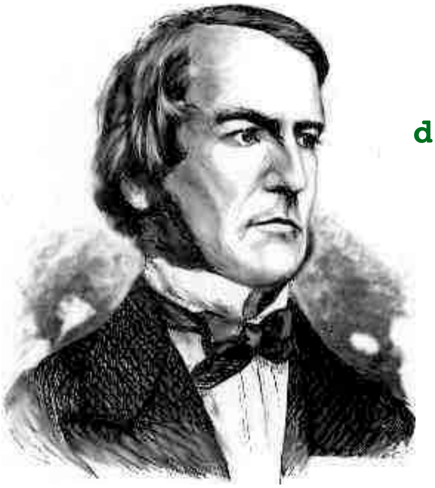
Two boolean contexts

False values in Python: False, 0, '', None   *(more to come)*

Boolean Contexts



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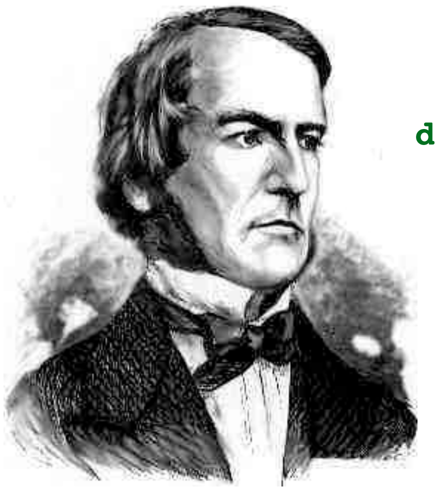
Two boolean contexts

False values in Python: False, 0, '', None *(more to come)*

True values in Python: Anything else (True)

Boolean Contexts



George Boole

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Two boolean contexts

False values in Python: False, 0, '', None *(more to come)*

True values in Python: Anything else (True)

Read Section 1.5.4!

Reading: http://composingprograms.com/pages/15-control.html#conditional-statements

Iteration

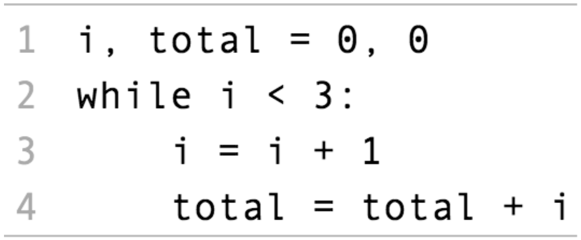
While Statements

(Demo)

Example: http://goo.gl/0d2cjF

While Statements

(Demo)

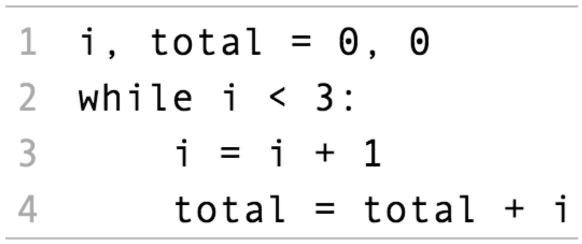


```
i, total = 0, 0
while i < 3:
    i = i + 1
    total = total + i
```

Example: http://goo.gl/0d2cjF

While Statements

(Demo)



```
i, total = 0, 0
while i < 3:
    i = i + 1
    total = total + i
```

Execution rule for while statements:

1. Evaluate the header’s expression.

2. If it is a true value,
   execute the (*whole*) suite,
   then return to step 1.

Example: http://goo.gl/0d2cjF

While Statements

George Boole

(Demo)

```
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While Statements

George Boole

(Demo)

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While Statements

George Boole

(Demo)

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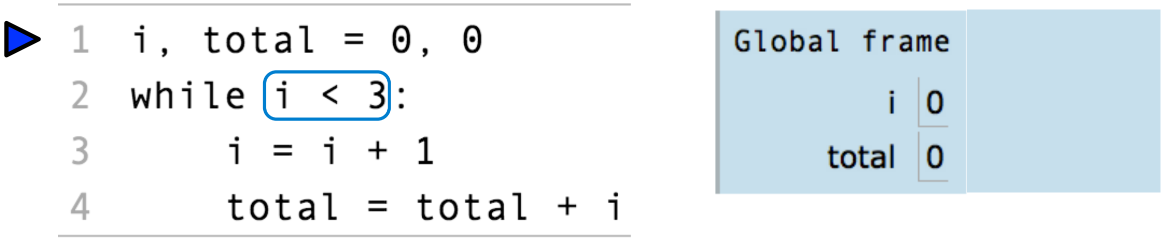
While Statements

George Boole

(Demo)



```
i, total = 0, 0
while i < 3:
    i = i + 1
    total = total + i
```

Global frame

i	0
total	0

Execution rule for while statements:

1. Evaluate the header’s expression.

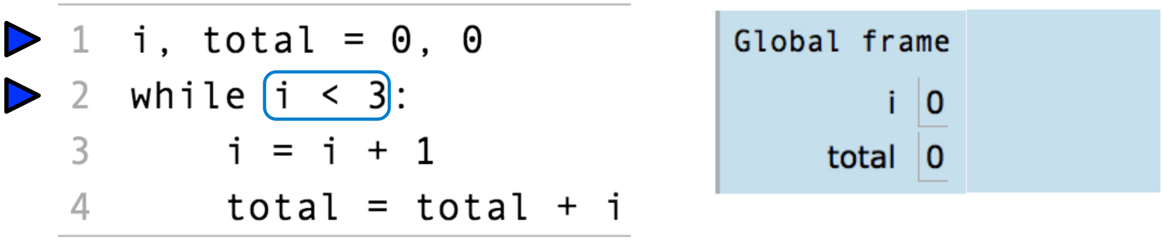
2. If it is a true value,
   execute the (*whole*) suite,
   then return to step 1.

Example: http://goo.gl/0d2cjF

While Statements

George Boole

(Demo)



```
i, total = 0, 0
while i < 3:
    i = i + 1
    total = total + i
```

Global frame

i	0
total	0

Execution rule for while statements:

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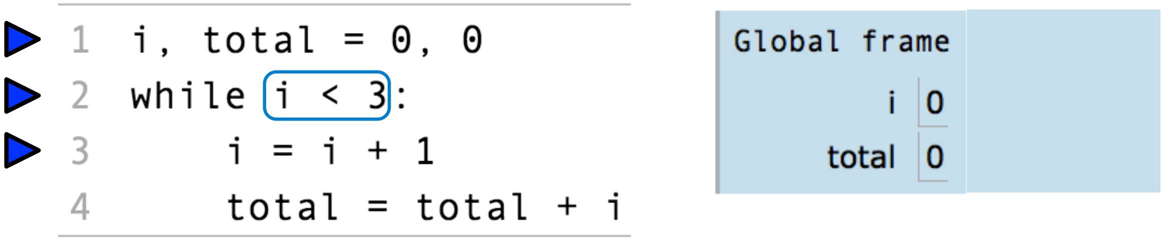
Example: http://goo.gl/0d2cjF

While Statements

George Boole

(Demo)



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i, total = 0, 0
while i < 3:
    i = i + 1
    total = total + i
```

Global frame

i	0
total	0

Execution rule for while statements:

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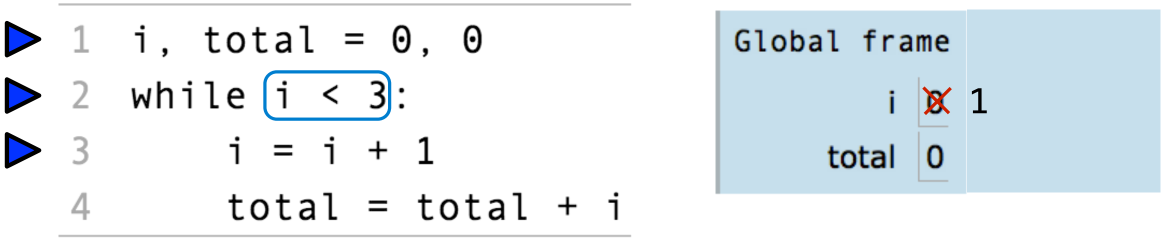
While Statements

George Boole

(Demo)



```
i, total = 0, 0
while i < 3:
    i = i + 1
    total = total + i
```

Global frame

i ~~0~~ 1

total 0

Execution rule for while statements:

1. Evaluate the header's expression.

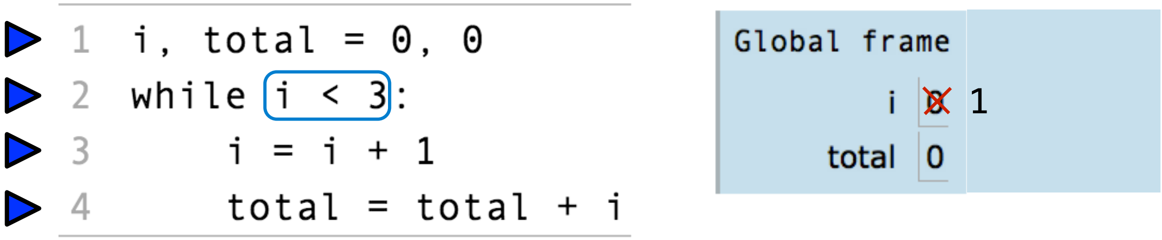
2. If it is a true value, execute the (*whole*) suite, then return to step 1.

Example: http://goo.gl/0d2cjF

While Statements

George Boole

(Demo)



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while i < 3:
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    total = total + i
```

Global frame

i ~~0~~ 1

total 0

Execution rule for while statements:

1. Evaluate the header’s expression.

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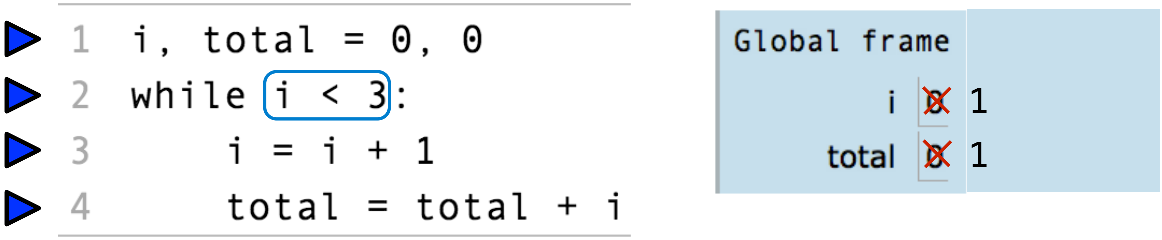
While Statements

George Boole

(Demo)



```
i, total = 0, 0
while i < 3:
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    total = total + i
```

Global frame

i ~~0~~ 1

total ~~0~~ 1

Execution rule for while statements:

1. Evaluate the header's expression.

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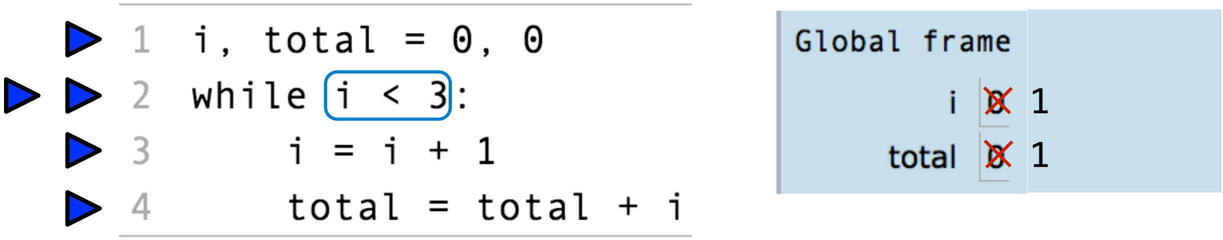
While Statements

George Boole

(Demo)



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i, total = 0, 0
while i < 3:
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    total = total + i
```

Global frame

i ~~0~~ 1

total ~~0~~ 1

Execution rule for while statements:

1. Evaluate the header's expression.

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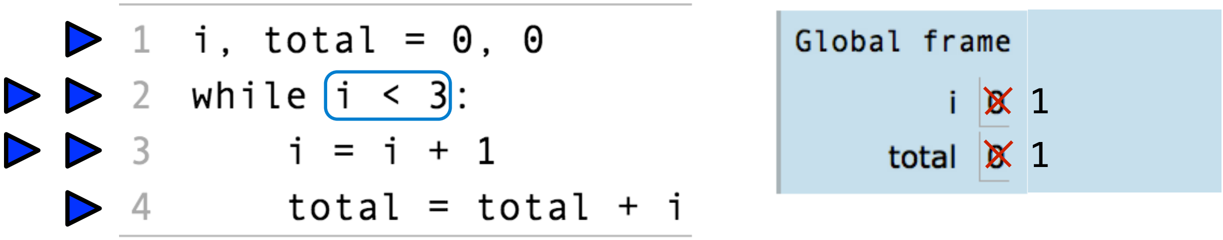
While Statements

George Boole

(Demo)



```
i, total = 0, 0
while i < 3:
    i = i + 1
    total = total + i
```

Global frame

i	~~0~~ 1
total	~~0~~ 1

Execution rule for while statements:

1. Evaluate the header’s expression.

2. If it is a true value,
   execute the (*whole*) suite,
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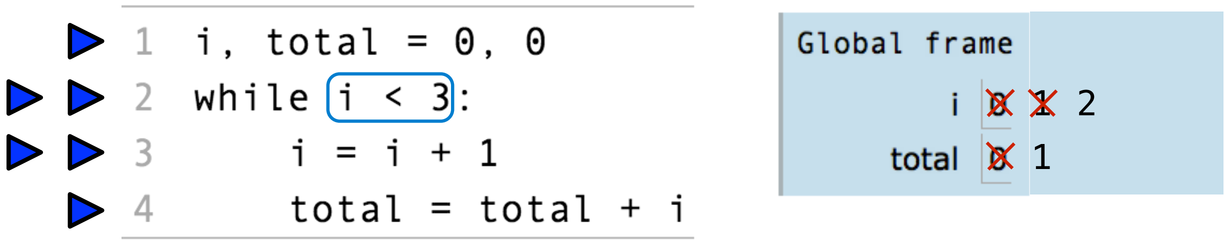
While Statements

George Boole

(Demo)



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while i < 3:
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    total = total + i
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Execution rule for while statements:

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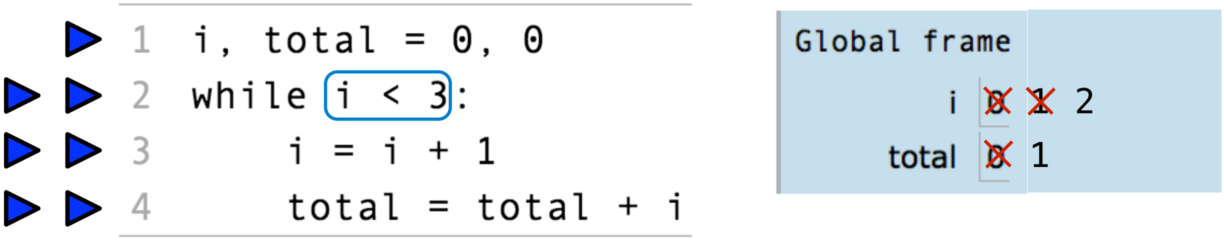
While Statements

George Boole

(Demo)



```
i, total = 0, 0
while i < 3:
    i = i + 1
    total = total + i
```

Global frame

i	~~0~~ ~~1~~ 2
total	~~0~~ 1

Execution rule for while statements:

1. Evaluate the header's expression.

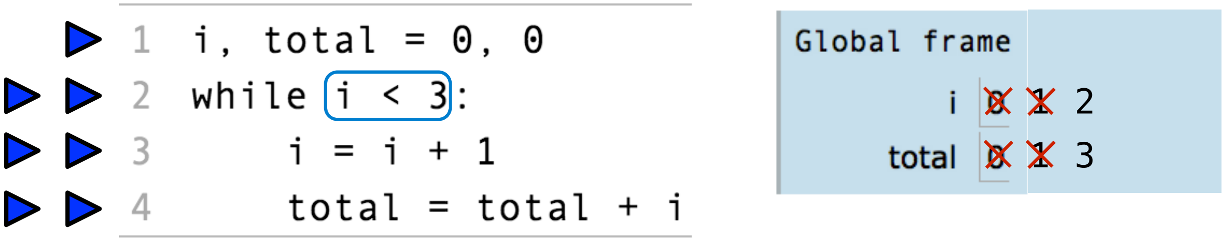
2. If it is a true value, execute the (*whole*) suite, then return to step 1.

Example: http://goo.gl/0d2cjF

While Statements

George Boole

(Demo)



```
i, total = 0, 0
while i < 3:
    i = i + 1
    total = total + i
```

Global frame

i	~~0~~ ~~1~~ 2
total	~~0~~ ~~1~~ 3

Execution rule for while statements:

1. Evaluate the header’s expression.

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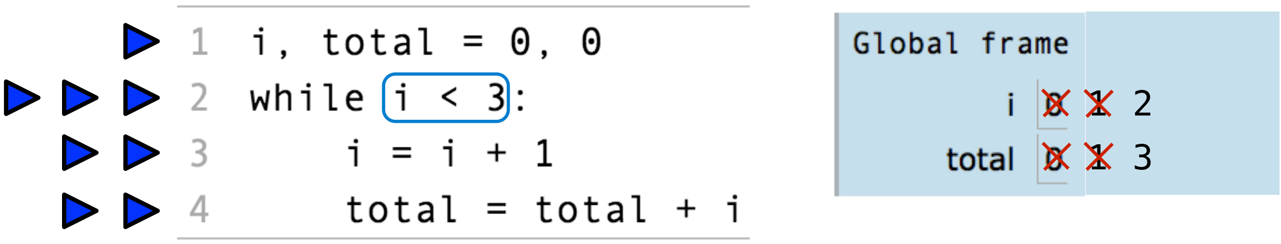
While Statements

George Boole

(Demo)



```
i, total = 0, 0
while i < 3:
    i = i + 1
    total = total + i
```

Global frame

i	~~0~~ ~~1~~ 2
total	~~0~~ ~~1~~ 3

Execution rule for while statements:

1. Evaluate the header’s expression.

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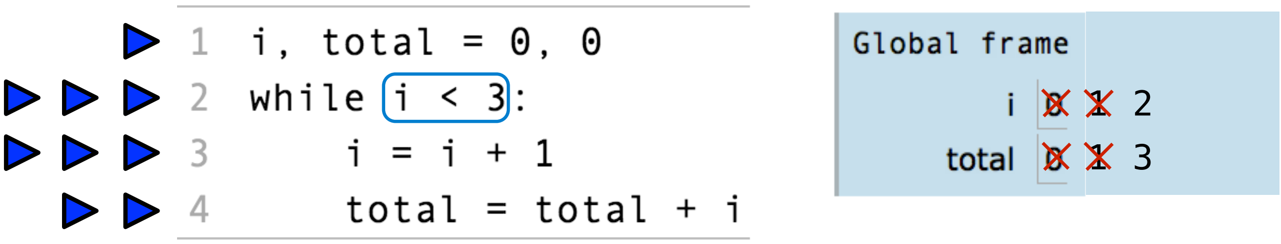
While Statements

George Boole

(Demo)



```
i, total = 0, 0
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    total = total + i
```

Global frame

i ~~0~~ ~~1~~ 2

total ~~0~~ ~~1~~ 3

Execution rule for while statements:

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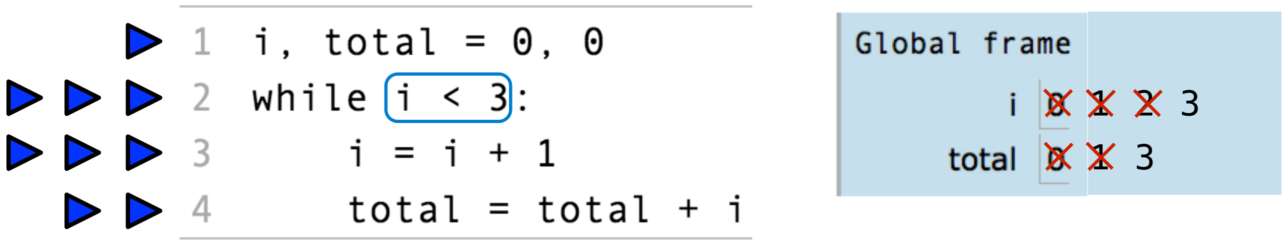
While Statements

George Boole

(Demo)



```
i, total = 0, 0
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```

Global frame

i ~~0~~ ~~1~~ ~~2~~ 3

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Execution rule for while statements:

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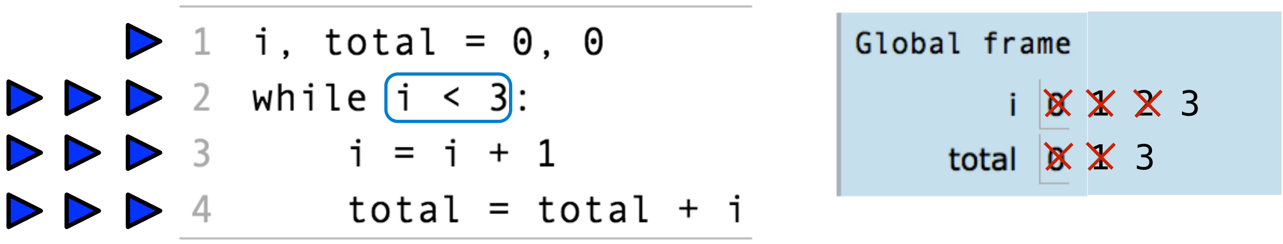
While Statements

George Boole

(Demo)



```
i, total = 0, 0
while i < 3:
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    total = total + i
```

Global frame

i ~~0~~ ~~1~~ ~~2~~ 3

total ~~0~~ ~~1~~ 3

Execution rule for while statements:

1. Evaluate the header’s expression.

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Example: http://goo.gl/0d2cjF

While Statements

George Boole

(Demo)

```
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while i < 3:
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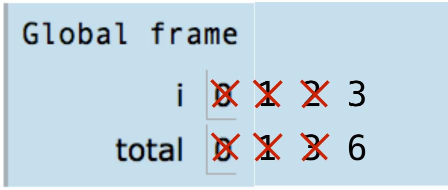
```



Global frame

i ~~0~~ ~~1~~ ~~2~~ 3

total ~~0~~ ~~1~~ ~~3~~ 6

Execution rule for while statements:

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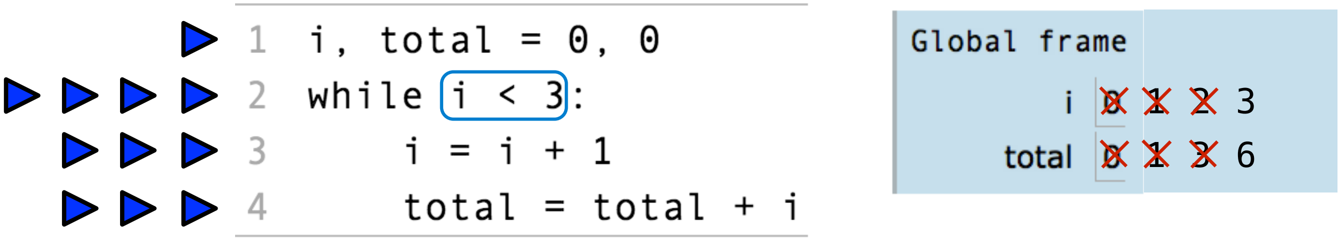
Example: http://goo.gl/0d2cjF

While Statements

George Boole

(Demo)



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i, total = 0, 0
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Global frame

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total ~~0~~ ~~1~~ ~~3~~ 6

Execution rule for while statements:

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Discussion Question

```
Complete the following definition by placing an expression in ________________________.
```

Example: http://goo.gl/38ch3o

Discussion Question

Complete the following definition by placing an expression in ______________________________.

```
def choose(total, selection):
```

Example: http://goo.gl/38ch3o

Discussion Question

Complete the following definition by placing an expression in ______________________.

```
def choose(total, selection):
    """Return the number of ways to choose SELECTION items from TOTAL.
```

Example: http://goo.gl/38ch3o

Discussion Question

Complete the following definition by placing an expression in ________________________.

```
def choose(total, selection):
    """Return the number of ways to choose SELECTION items from TOTAL.

    choose(n, k) is typically defined in math as:  n! / (n-k)! / k!
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Example: http://goo.gl/38ch3o

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```

$$\frac{n \cdot (n-1) \cdot (n-2) \cdot \ \ldots \ \cdot (n-k+1)}{k \cdot (k-1) \cdot (k-2) \cdot \ \ldots \ \cdot 2 \cdot 1}$$

Example: http://goo.gl/38ch3o

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    >>> choose(5, 2)
    10
```

$$\frac{n \cdot (n-1) \cdot (n-2) \cdot \ \ldots \ \cdot (n-k+1)}{k \cdot (k-1) \cdot (k-2) \cdot \ \ldots \ \cdot 2 \cdot 1}$$

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    >>> choose(5, 2)
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    >>> choose(20, 6)
    38760
    """
```

$$\frac{n \cdot (n-1) \cdot (n-2) \cdot \ \ldots \ \cdot (n-k+1)}{k \cdot (k-1) \cdot (k-2) \cdot \ \ldots \ \cdot 2 \cdot 1}$$

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    >>> choose(20, 6)
    38760
    """
    ways = 1
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$$\frac{n \cdot (n-1) \cdot (n-2) \cdot \ \ldots \ \cdot (n-k+1)}{k \cdot (k-1) \cdot (k-2) \cdot \ \ldots \ \cdot 2 \cdot 1}$$

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    """Return the number of ways to choose SELECTION items from TOTAL.

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    10
    >>> choose(20, 6)
    38760
    """
    ways = 1
    selected = 0
```

$$\frac{n \cdot (n-1) \cdot (n-2) \cdot \ \ldots \ \cdot (n-k+1)}{k \cdot (k-1) \cdot (k-2) \cdot \ \ldots \ \cdot 2 \cdot 1}$$

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    >>> choose(5, 2)
    10
    >>> choose(20, 6)
    38760
    """
    ways = 1
    selected = 0
    while selected < selection:
```

$$\frac{n \cdot (n-1) \cdot (n-2) \cdot \ \ldots \ \cdot (n-k+1)}{k \cdot (k-1) \cdot (k-2) \cdot \ \ldots \ \cdot 2 \cdot 1}$$

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    38760
    """
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    selected = 0
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$$\frac{n \cdot (n-1) \cdot (n-2) \cdot \ \ldots \ \cdot (n-k+1)}{k \cdot (k-1) \cdot (k-2) \cdot \ \ldots \ \cdot 2 \cdot 1}$$

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Example: http://goo.gl/38ch3o

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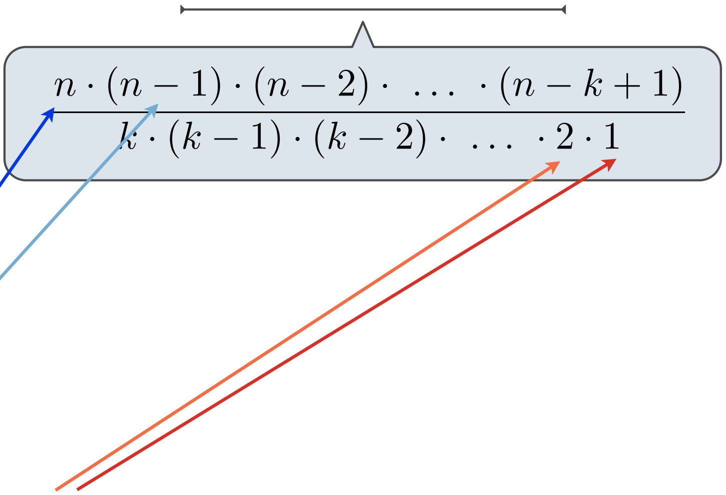

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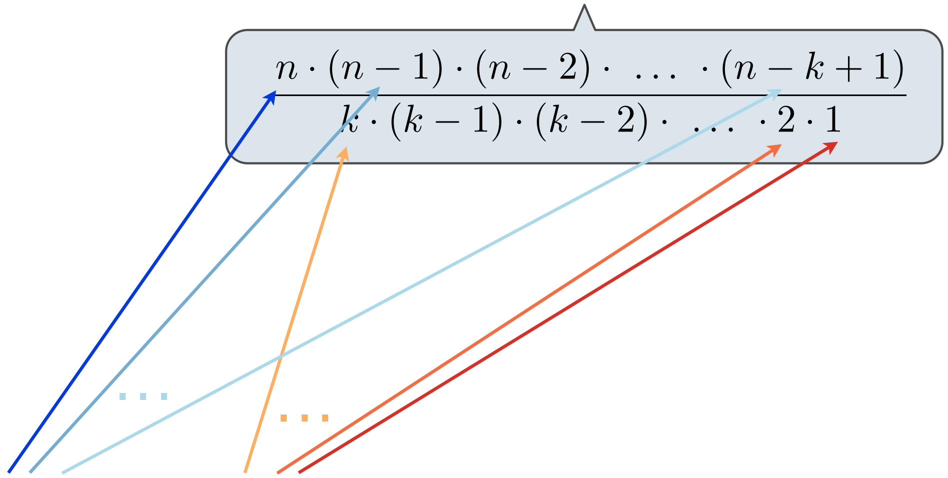

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