# Warming Up

Write a program that, given letters, finds all anagrams

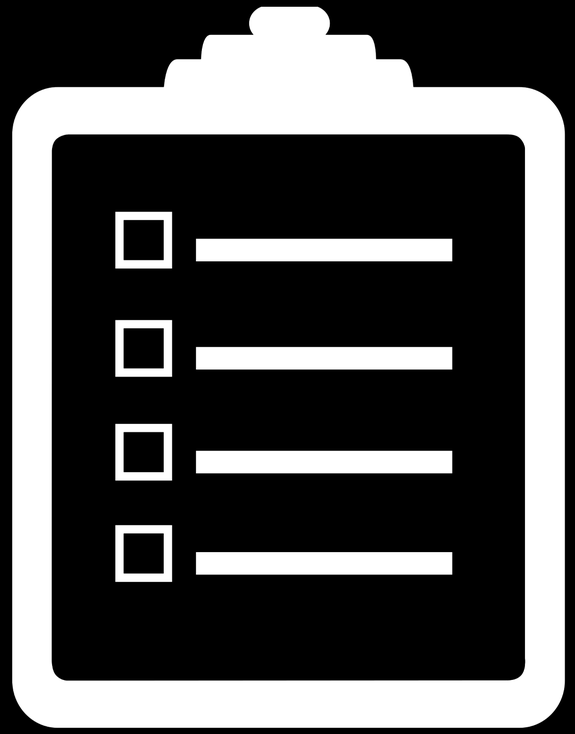
```
$ python anagrammer.py
Letters? hnopty
Anagram(s): PYTHON, PHYTON
Letters? sulpcpusl
Anagram(s): None
```

Key insight: The sorted letters of any two anagrams are the same: {sorted letters: set of anagrams}

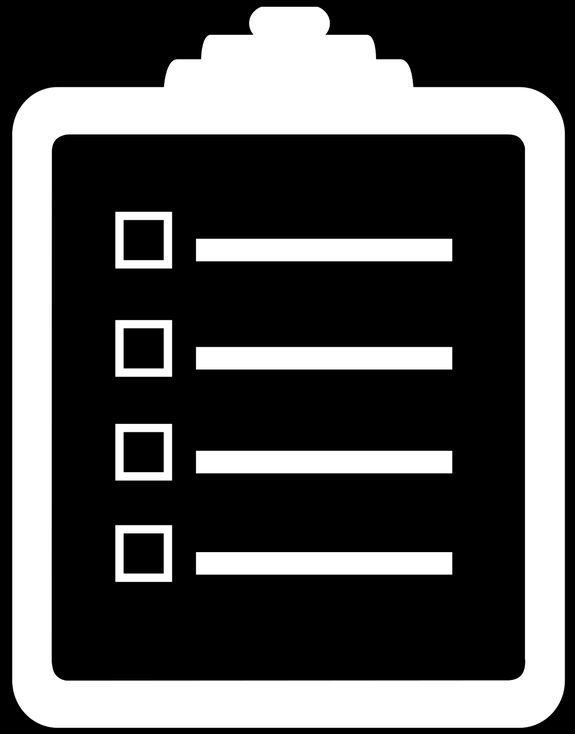
# Functions

January 22, 2019

# Agenda

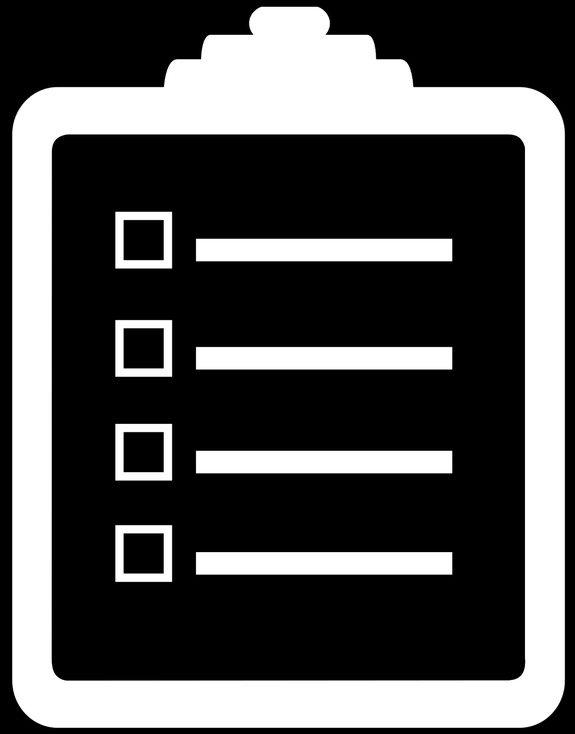


# Agenda



Recap of Last Week

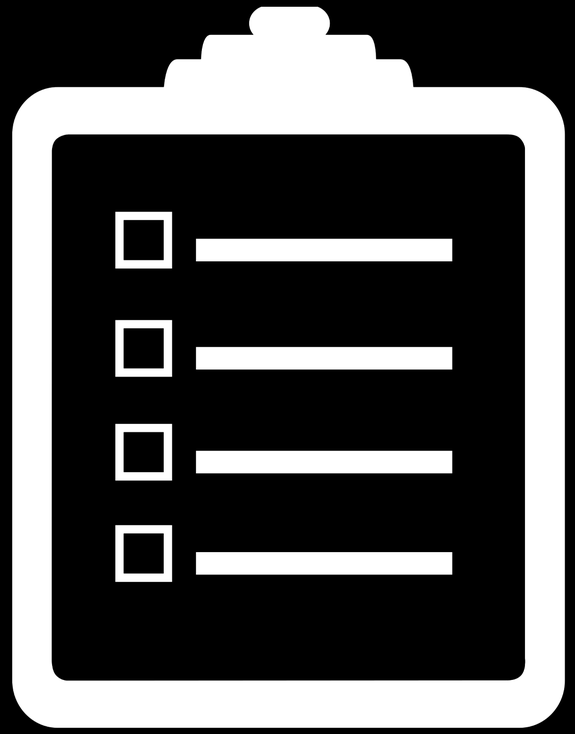
# Agenda



Recap of Last Week

Inside Python Functions

# Agenda

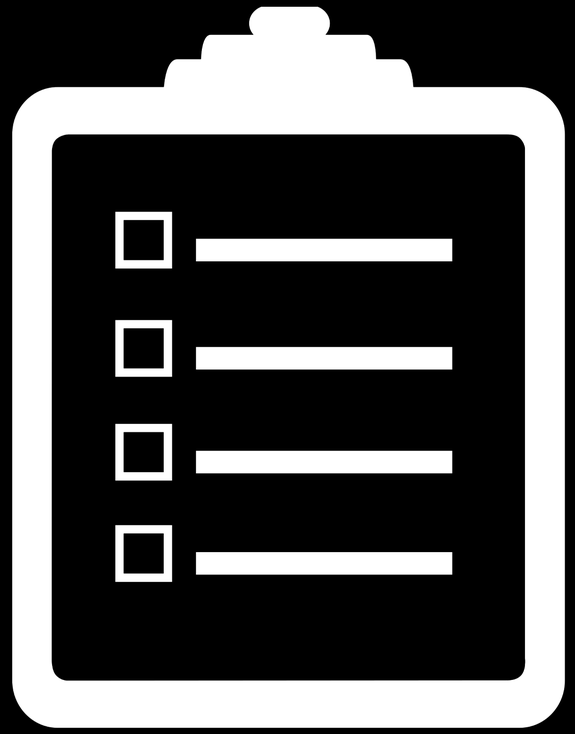


Recap of Last Week

Inside Python Functions

Keyword Arguments

# Agenda



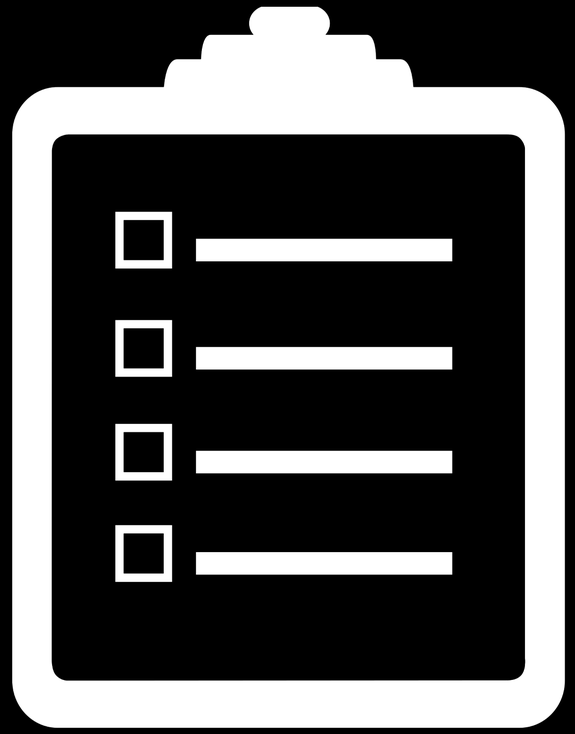
Recap of Last Week

Inside Python Functions

Keyword Arguments

Variadic Arguments

# Agenda



Recap of Last Week

Inside Python Functions

Keyword Arguments

Variadic Arguments

First-Class Functions

# Recap

# Data Structures

# Data Structures

- Lists `[items]`

# Data Structures

Lists `[items]`

Dictionaries `{key: value}`

# Data Structures

Lists `[items]`

Dictionaries `{key: value}`

Tuples `(frozen, sequence)`

# Data Structures

Lists `[items]`

Dictionaries `{key: value}`

Tuples `(frozen, sequence)`

Sets `{unique, hashable, values}`

# Data Structures

Lists `[items]`

Dictionaries `{key: value}`

Tuples `(frozen, sequence)`

Sets `{unique, hashable, values}`

Comprehensions `[f(xs) for xs in iter]`

# Warming Up: 10 Minutes

# Warming Up: 10 Minutes

Write a program that, given letters, finds all anagrams

```
$ python anagrammer.py
```

# Warming Up: 10 Minutes

Write a program that, given letters, finds all anagrams

```
$ python anagrammer.py
Letters? hnopty
Anagram(s): PYTHON, PHYTON
```

# Warming Up: 10 Minutes

Write a program that, given letters, finds all anagrams

```
$ python anagrammer.py
Letters? hnopty
Anagram(s): PYTHON, PHYTON
Letters? sulpcpusl
Anagram(s): None
```

# Warming Up: 10 Minutes

Write a program that, given letters, finds all anagrams

```
$ python anagrammer.py
Letters? hnopty
Anagram(s): PYTHON, PHYTON
Letters? sulpcpusl
Anagram(s): None
```

Key insight: The sorted letters of any two anagrams are the same: {sorted letters: set of anagrams}

# Familiar Functions

# Recall

The `def` keyword is used to define a new function

```
def fn_name(param1, param2):
    value = do_something()
    return value
```

# Basic Functions: Nuances

# Return

# Return

All functions return *some* value

# Return

All functions return *some* value

Even if that value is **None**

# Return

All functions return *some* value

- Even if that value is `None`

No `return` statement or just `return` implicitly returns `None`

# Return

All functions return *some* value

Even if that value is **`None`**

No **`return`** statement or just **`return`** implicitly returns **`None`**

The interpreter suppresses printing `None`

# Return

All functions return *some* value

Even if that value is **`None`**

No **`return`** statement or just **`return`** implicitly returns **`None`**

Returning multiple values

The interpreter suppresses printing `None`

# Return

All functions return *some* value

- Even if that value is **`None`**

No **`return`** statement or just **`return`** implicitly returns **`None`**

Returning multiple values

- You can use a tuple! In some cases, use a **`namedtuple`**

The interpreter suppresses printing `None`

# Return

All functions return *some* value

- Even if that value is **`None`**

No **`return`** statement or just **`return`** implicitly returns **`None`**

Returning multiple values

- You can use a tuple! In some cases, use a **`namedtuple`**

The interpreter suppresses printing `None`

```
return value1, value2, value3
```

# Return

All functions return *some* value

- Even if that value is **`None`**

No **`return`** statement or just **`return`** implicitly returns **`None`**

The interpreter suppresses printing `None`

Returning multiple values

- You can use a tuple! In some cases, use a **`namedtuple`**

```
return value1, value2, value3
```

Be careful! Callers may not expect a tuple as a return value

# Function Execution and Scopes

# Function Execution and Scopes

Function execution introduces a new local symbol table (scope)

Think of baggage tags and suitcases: a new baggage area

# Function Execution and Scopes

Function execution introduces a new local symbol table (scope)

Think of baggage tags and suitcases: a new baggage area

Variable assignments (L-values) `x = 5`

# Function Execution and Scopes

Function execution introduces a new local symbol table (scope)

Think of baggage tags and suitcases: a new baggage area

Variable assignments (L-values) `x = 5`

Add entry to local symbol table (or overwrite an existing entry)

# Function Execution and Scopes

Function execution introduces a new local symbol table (scope)

Think of baggage tags and suitcases: a new baggage area

Variable assignments (L-values) `x = 5`

Add entry to local symbol table (or overwrite an existing entry)

Variable references (R-values) `print(y)`

# Function Execution and Scopes

Function execution introduces a new local symbol table (scope)

- Think of baggage tags and suitcases: a new baggage area

Variable assignments (L-values) `x = 5`

- Add entry to local symbol table (or overwrite an existing entry)

Variable references (R-values) `print(y)`

- First, look in local symbol table

# Function Execution and Scopes

Function execution introduces a new local symbol table (scope)

- Think of baggage tags and suitcases: a new baggage area

Variable assignments (L-values) `x = 5`

- Add entry to local symbol table (or overwrite an existing entry)

Variable references (R-values) `print(y)`

- First, look in local symbol table
- Next, check symbol tables of enclosing functions (unusual)

# Function Execution and Scopes

Function execution introduces a new local symbol table (scope)

- Think of baggage tags and suitcases: a new baggage area

Variable assignments (L-values) `x = 5`

- Add entry to local symbol table (or overwrite an existing entry)

Variable references (R-values) `print(y)`

- First, look in local symbol table
- Next, check symbol tables of enclosing functions (unusual)
- Then, search global (top-level) symbol table

# Function Execution and Scopes

Function execution introduces a new local symbol table (scope)

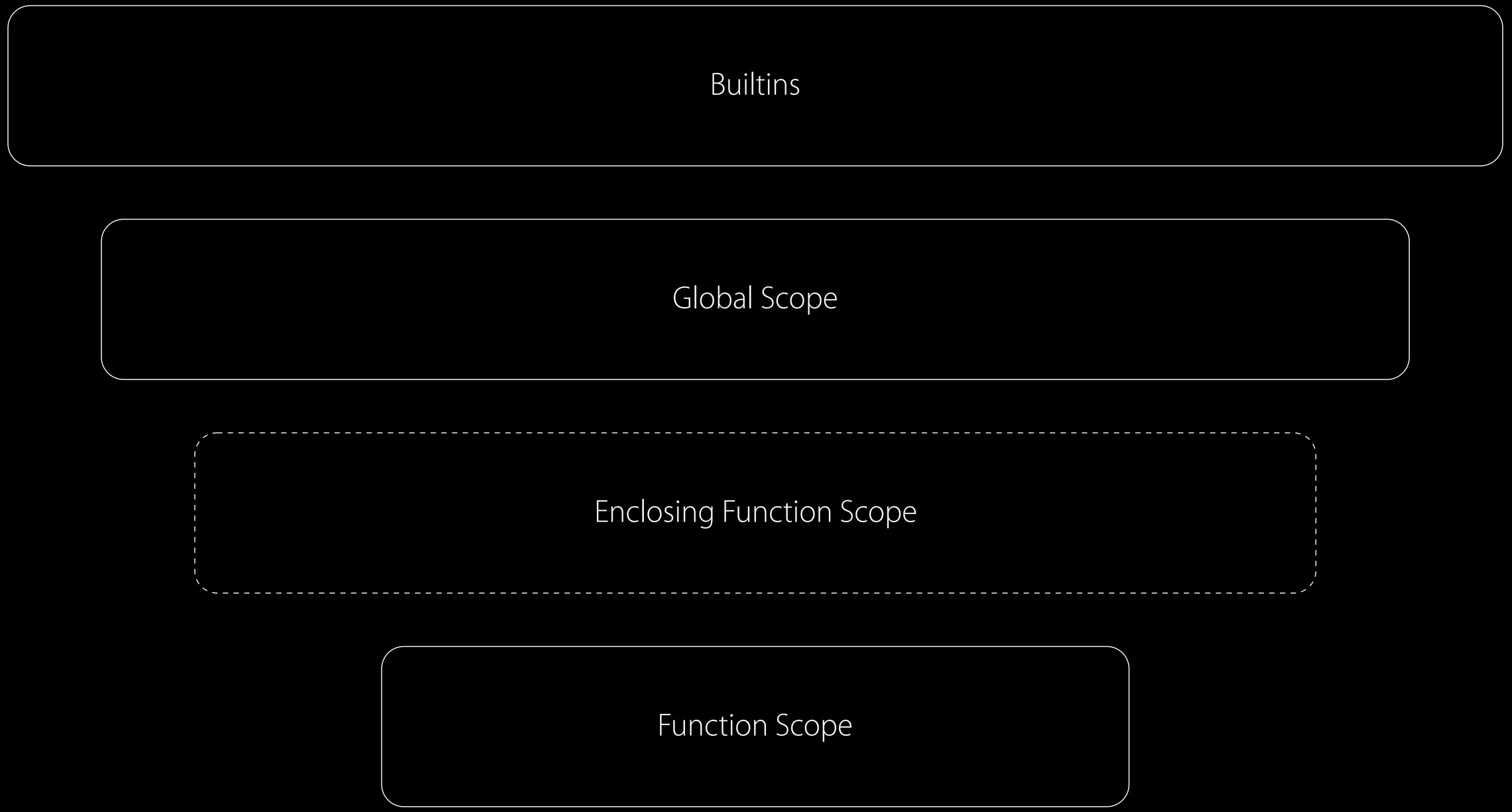
- Think of baggage tags and suitcases: a new baggage area

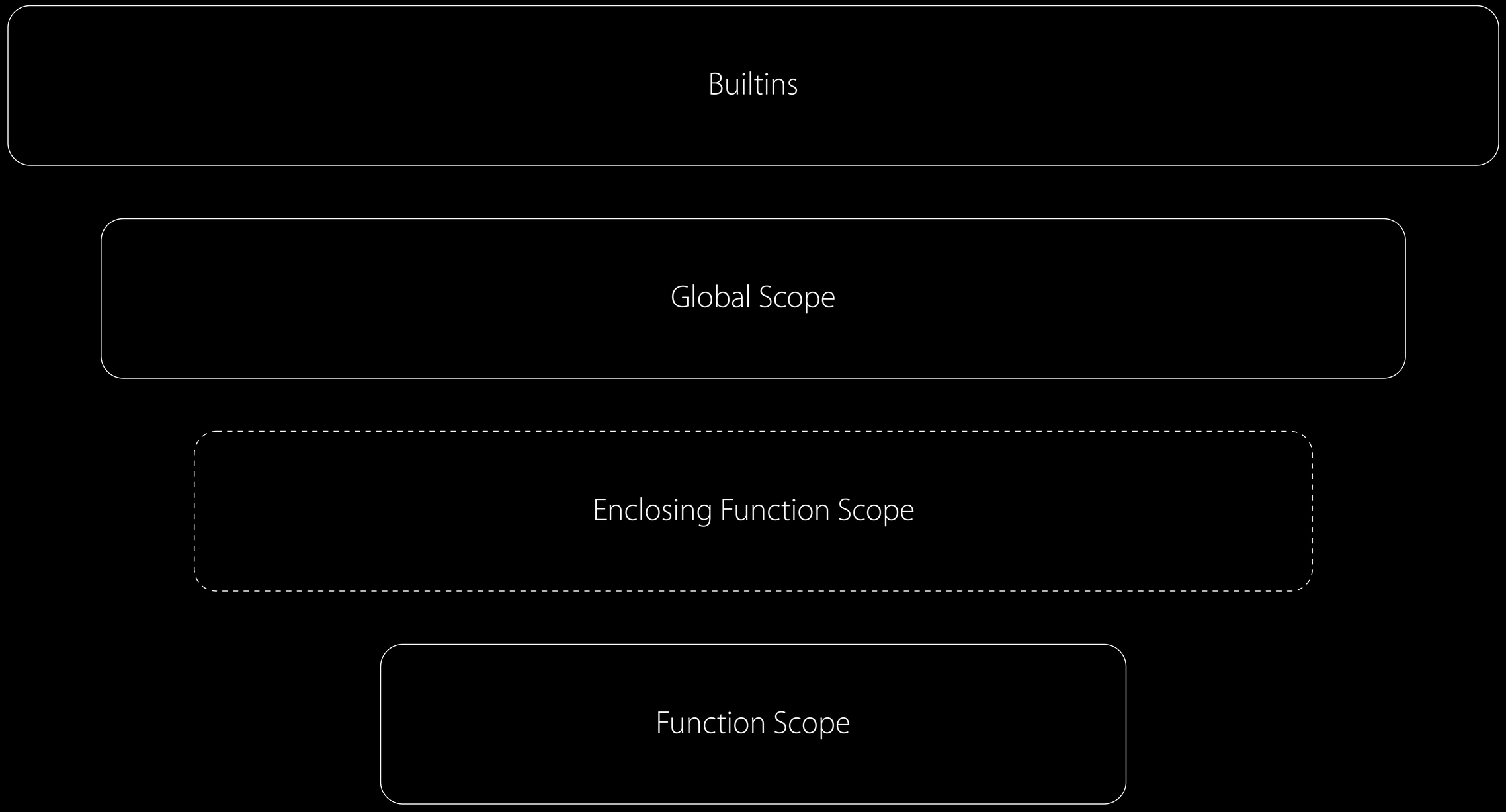
Variable assignments (L-values) `x = 5`

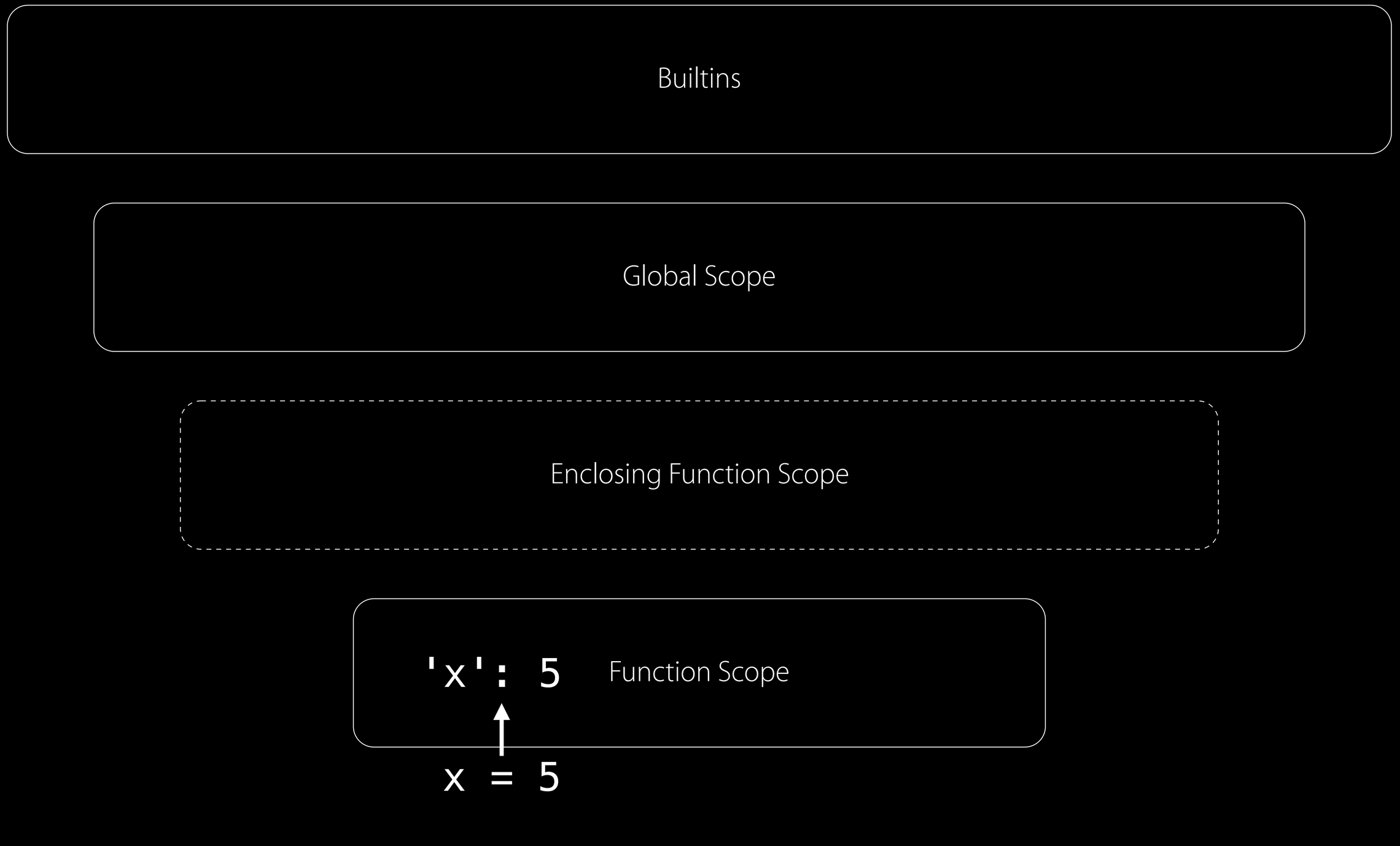
- Add entry to local symbol table (or overwrite an existing entry)

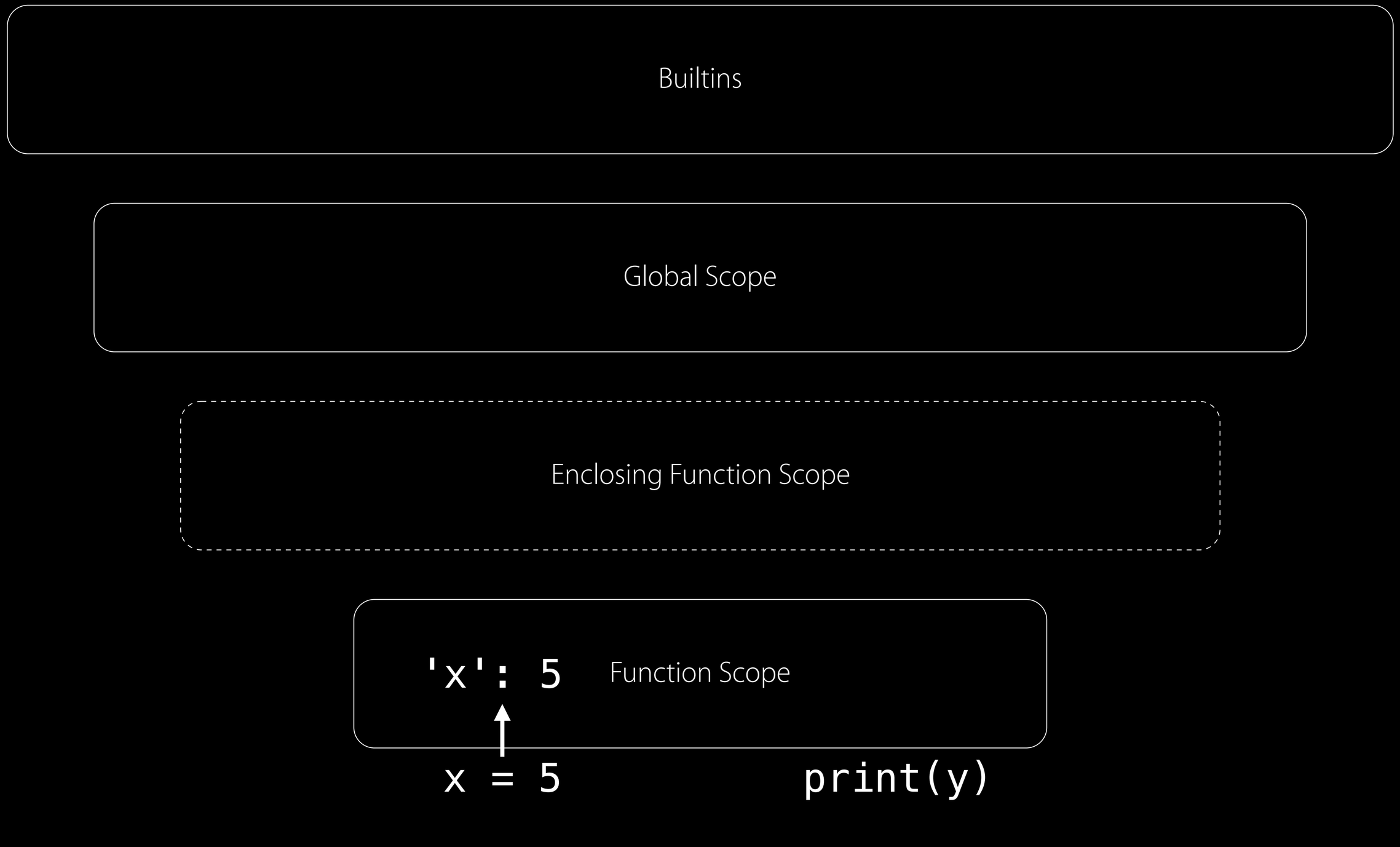
Variable references (R-values) `print(y)`

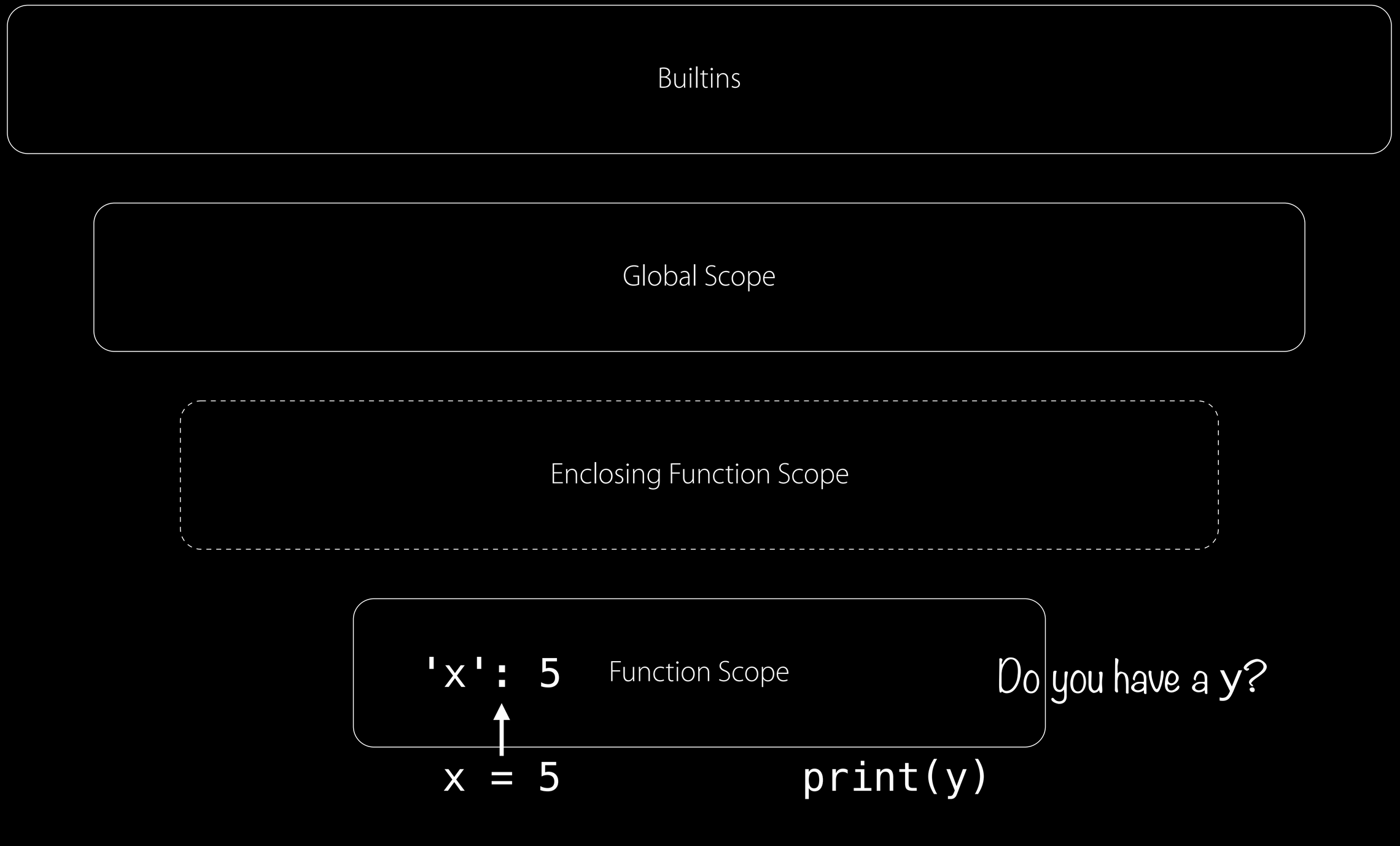
- First, look in local symbol table
- Next, check symbol tables of enclosing functions (unusual)
- Then, search global (top-level) symbol table
- Finally, check builtin symbols (`print`, `input`, etc)

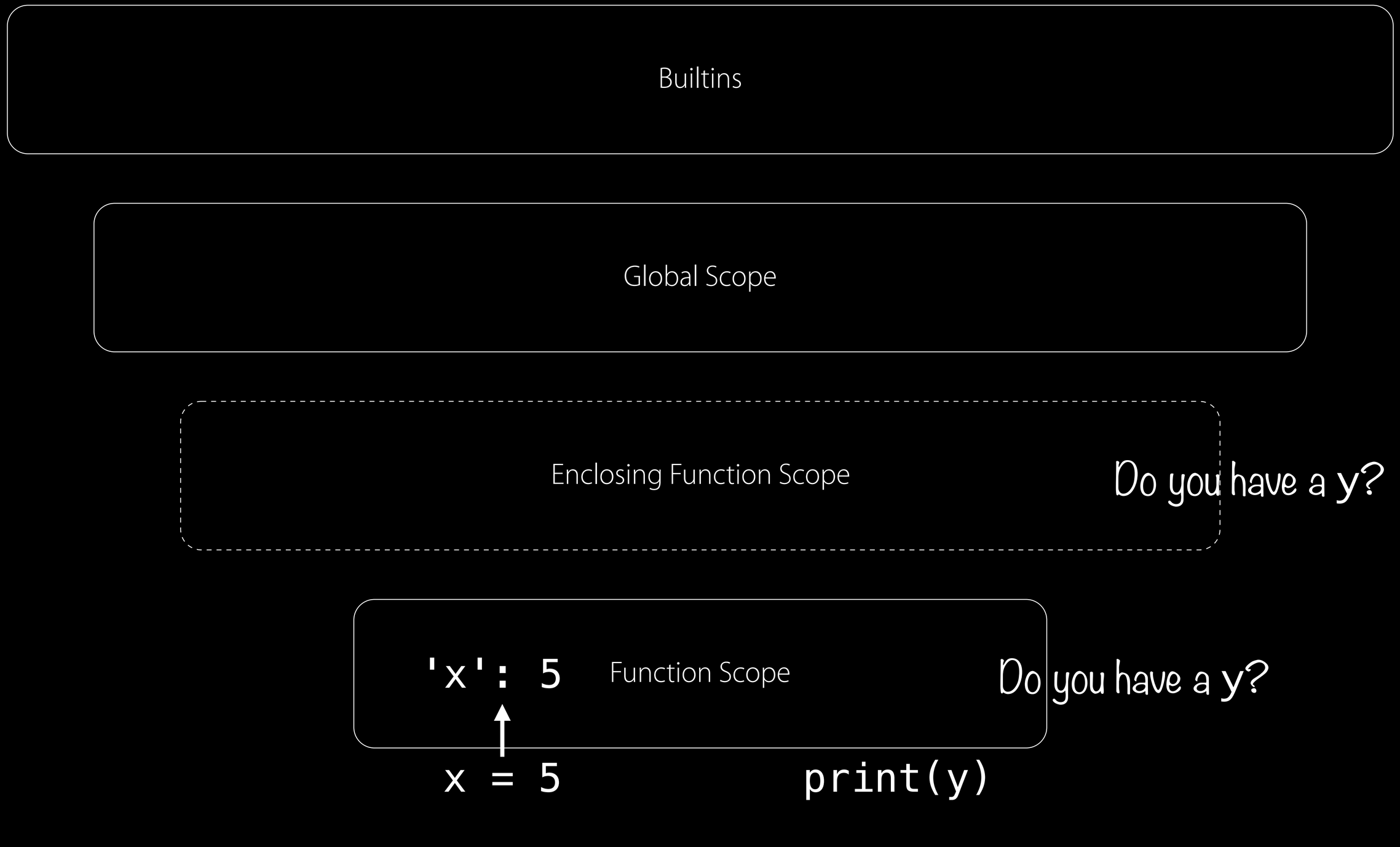

Builtins
Global Scope
Enclosing Function Scope
Function Scope

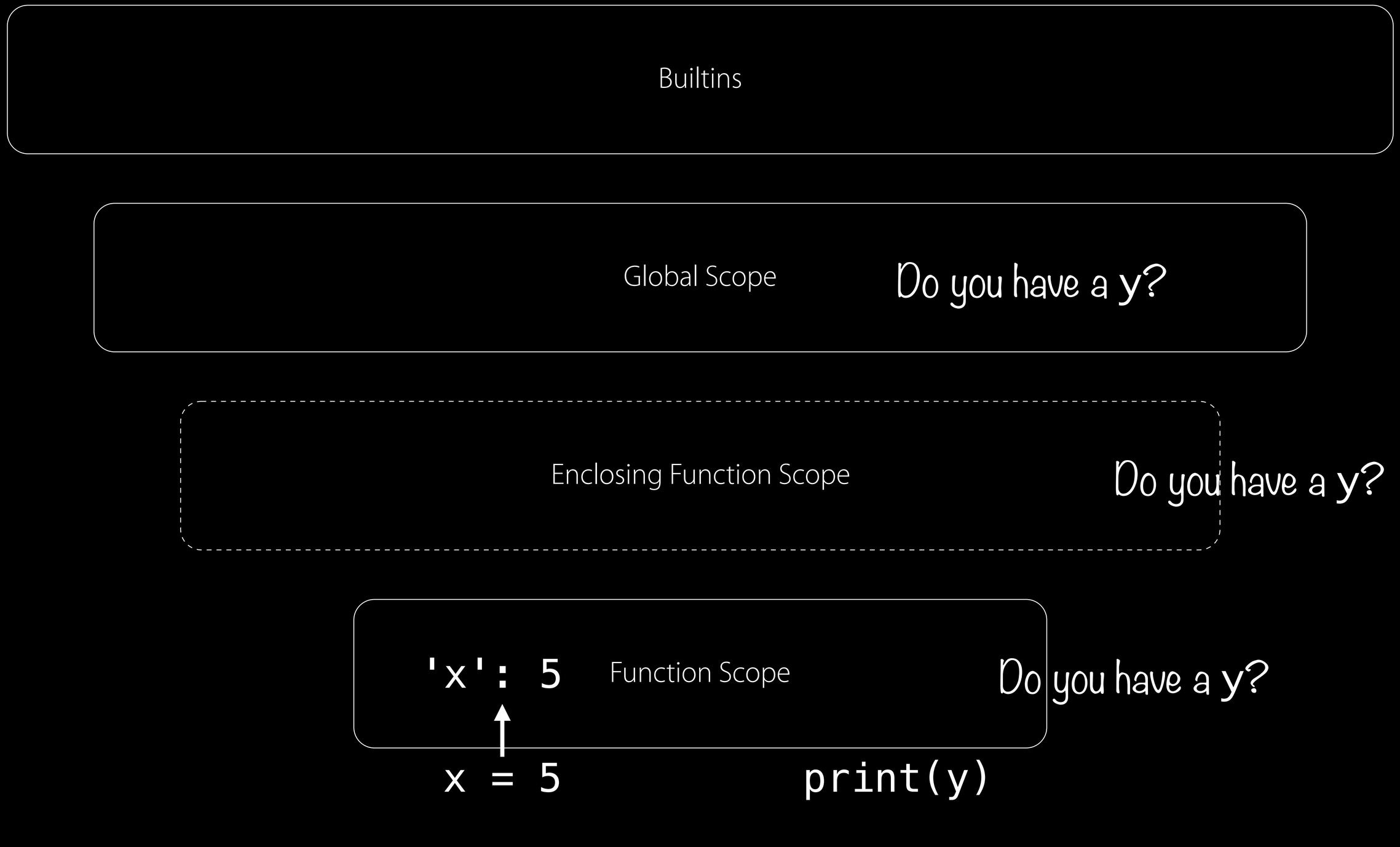

Builtins
Global Scope
Enclosing Function Scope
Function Scope
x = 5

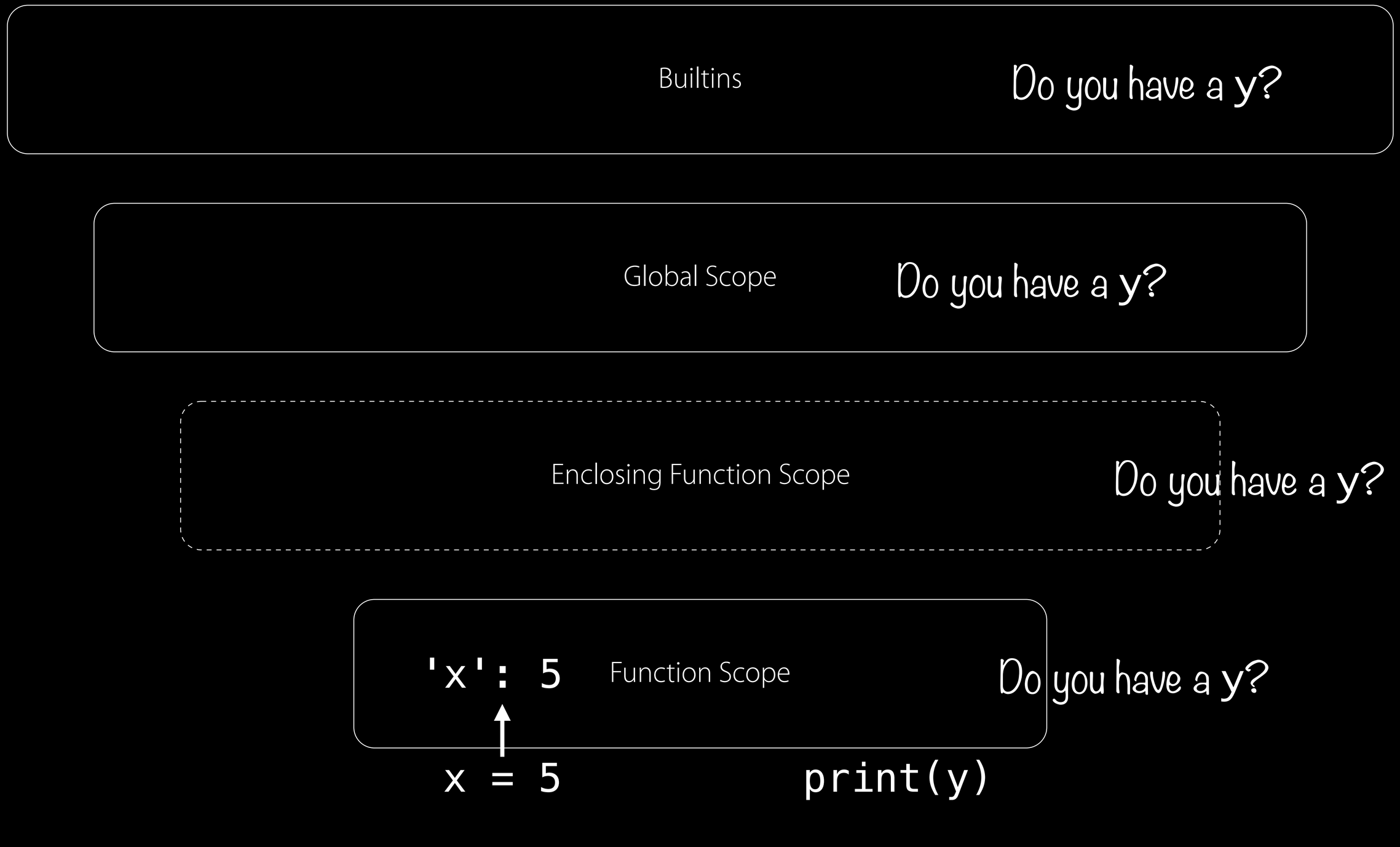

Builtins
Global Scope
Enclosing Function Scope
'x': 5
Function Scope
x = 5

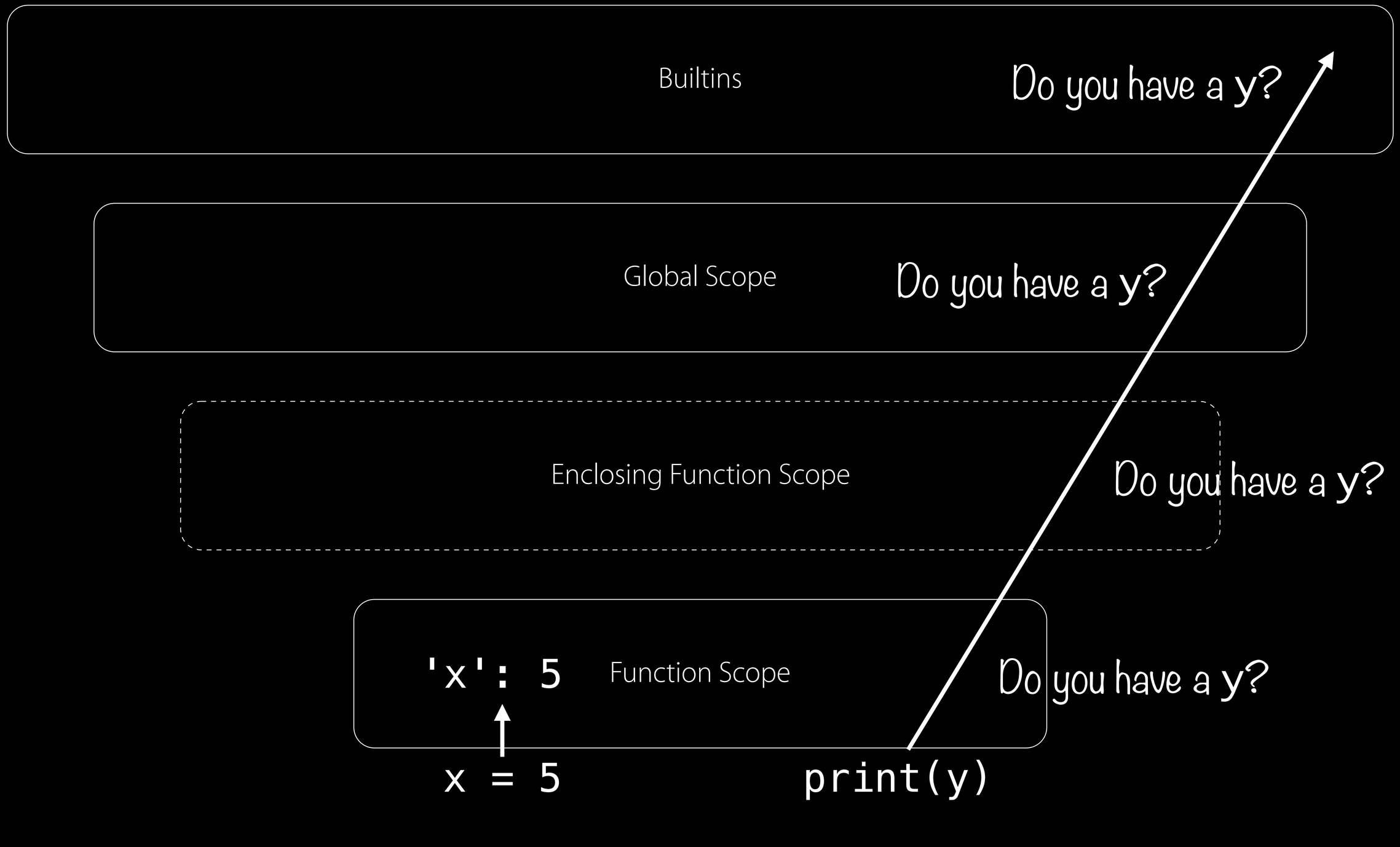

Builtins
Global Scope
Enclosing Function Scope
'x': 5
Function Scope
x = 5
print(y)

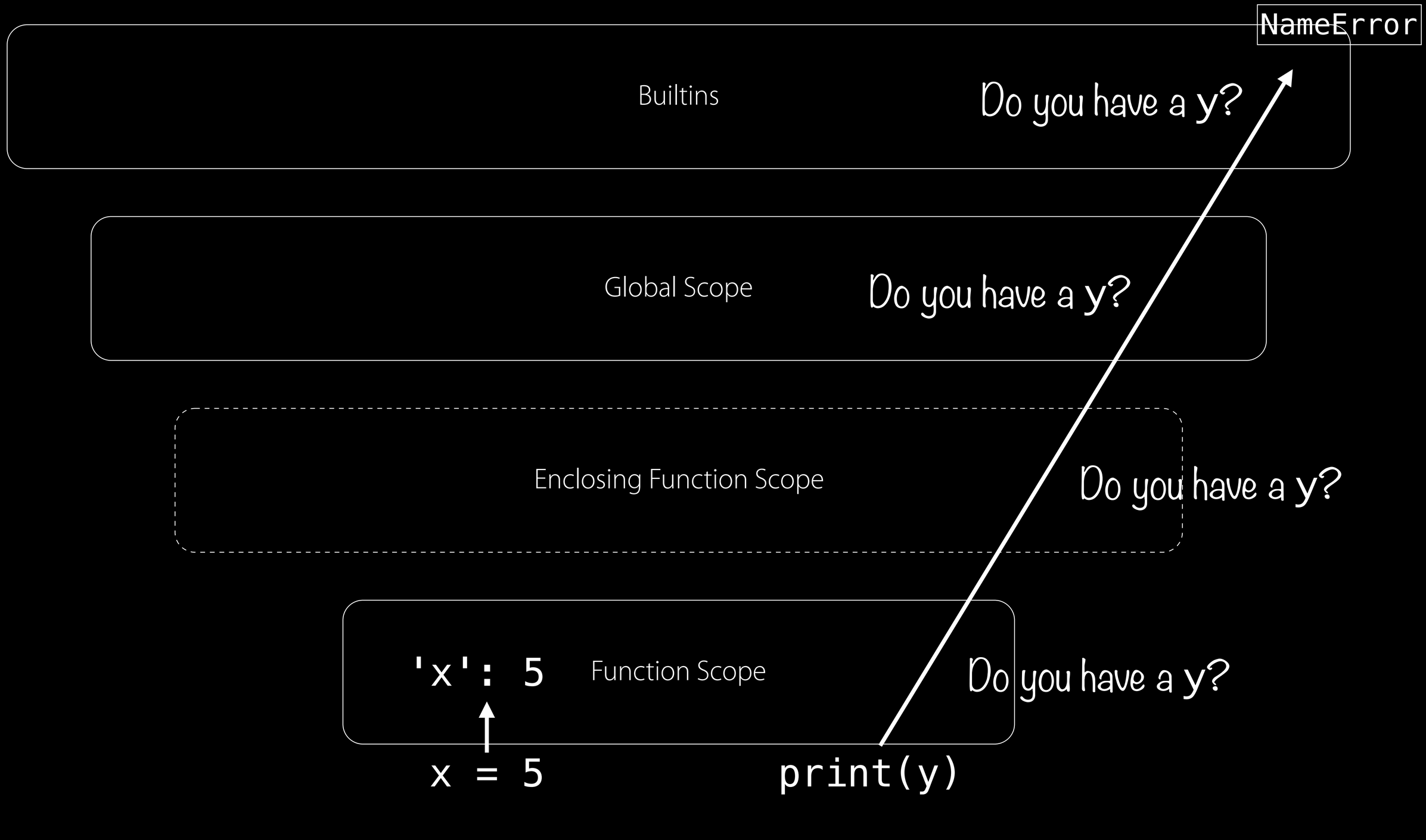

Builtins
Global Scope
Enclosing Function Scope
'x': 5
Function Scope
Do you have a y?
x = 5
print(y)


Builtins
Global Scope
Enclosing Function Scope
Do you have a y?
'x': 5
Function Scope
Do you have a y?
x = 5
print(y)


Builtins
Global Scope
Do you have a y?
Enclosing Function Scope
Do you have a y?
'x': 5
Function Scope
Do you have a y?
x = 5
print(y)


Builtins
Do you have a y?
Global Scope
Do you have a y?
Enclosing Function Scope
Do you have a y?
'x': 5
Function Scope
Do you have a y?
x = 5
print(y)


Builtins
Do you have a y?
Global Scope
Do you have a y?
Enclosing Function Scope
Do you have a y?
'x': 5
Function Scope
Do you have a y?
x = 5
print(y)


NameError
Builtins
Do you have a y?
Global Scope
Do you have a y?
Enclosing Function Scope
Do you have a y?
'x': 5
Function Scope
Do you have a y?
x = 5
print(y)

# Local Function Scope

# Local Function Scope

```
x = 2
def foo(y):
    z = 5
    print(locals())
    print(globals()['x'])
    print(x, y, z)
```

# Local Function Scope

```
x = 2
def foo(y):
    z = 5
    print(locals())
    print(globals()['x'])
    print(x, y, z)

foo(3)
```

# Local Function Scope

```
x = 2
def foo(y):
    z = 5
    print(locals())
    print(globals()['x'])
    print(x, y, z)

foo(3)
# prints {'y': 3, 'z': 5}
```

# Local Function Scope

```
x = 2
def foo(y):
    z = 5
    print(locals())
    print(globals()['x'])
    print(x, y, z)

foo(3)
# prints {'y': 3, 'z': 5}
# print 2
```

# Local Function Scope

```
x = 2
def foo(y):
    z = 5
    print(locals())
    print(globals()['x'])
    print(x, y, z)

foo(3)
# prints {'y': 3, 'z': 5}
# print 2
# prints 2, 3, 5
```

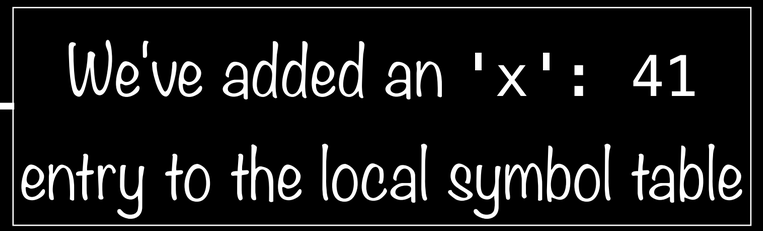
# Local Function Scope

# Local Function Scope

```
x = 2
def foo(y):
    x = 41
    z = 5
    print(locals())
    print(globals()['x'])
    print(x, y, z)
```

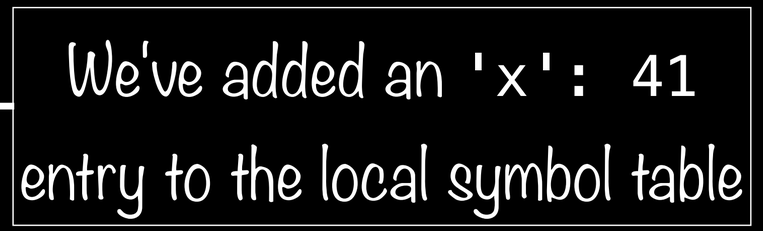
# Local Function Scope

```
x = 2
def foo(y):
    x = 41
    z = 5
    print(locals())
    print(globals()['x'])
    print(x, y, z)
```



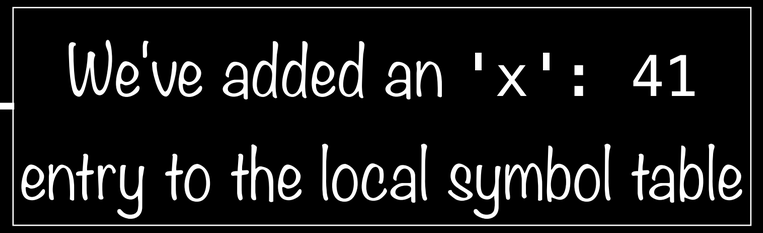
# Local Function Scope

```
x = 2
def foo(y):
    x = 41
    z = 5
    print(locals())
    print(globals()['x'])
    print(x, y, z)

foo(3)
```



# Local Function Scope

```
x = 2
def foo(y):
    x = 41
    z = 5
    print(locals())
    print(globals()['x'])
    print(x, y, z)

foo(3)
# prints {'x': 41, 'y': 3, 'z': 5}
```



# Local Function Scope

```
x = 2
def foo(y):
    x = 41
    z = 5
    print(locals())
    print(globals()['x'])
    print(x, y, z)

foo(3)
# prints {'x': 41, 'y': 3, 'z': 5}
# print 2
```

We've added an `'x': 41` entry to the local symbol table

# Local Function Scope

```
x = 2
def foo(y):
    x = 41
    z = 5
    print(locals())
    print(globals()['x'])
    print(x, y, z)

foo(3)
# prints {'x': 41, 'y': 3, 'z': 5}
# print 2
# prints 41, 3, 5
```

We've added an `'x': 41` entry to the local symbol table

# If / For Scope

# If / For Scope

Notably, only* function definitions define new scopes

*Also classes... kinda (Wk 5)

# If / For Scope

Notably, only* function definitions define new scopes

`if` statements, `for` loops, `while` loops, `with` statements, etc

*Also classes... kinda (Wk 5)

# If / For Scope

Notably, only* function definitions define new scopes

`if` statements, `for` loops, `while` loops, `with` statements, etc

Do *not* introduce a new scope

*Also classes... kinda (Wk 5)

# If / For Scope

Notably, only* function definitions define new scopes

`if` statements, `for` loops, `while` loops, `with` statements, etc

Do *not* introduce a new scope

```
if success:
    desc = 'Winner!'
else:
    desc = 'Loser :('
print(desc)
```

*Also classes... kinda (Wk 5)

# Pass-By-Value or Pass-By-Reference?

# Pass-By-Value or Pass-By-Reference?

Variables *are* copied into function's local symbol table

But variables are just references to objects!

# Pass-By-Value or Pass-By-Reference?

Variables *are* copied into function's local symbol table

- But variables are just references to objects!

Best to think of it as *pass-by-object-reference*

- If a mutable object is passed, caller will see changes

# Pass-By-Value or Pass-By-Reference?

Variables *are* copied into function's local symbol table

But variables are just references to objects!

Best to think of it as *pass-by-object-reference*

If a mutable object is passed, caller will see changes

Baggage tags in one area can point to suitcases in another

# Default Parameters

# Default / Named Parameters

# Default / Named Parameters

Specify a default value for one or more parameters

# Default / Named Parameters

Specify a default value for one or more parameters

Called with fewer arguments than it is defined to allow

# Default / Named Parameters

Specify a default value for one or more parameters

Called with fewer arguments than it is defined to allow

Usually used to provide "settings" for the function

# Default / Named Parameters

Specify a default value for one or more parameters

Called with fewer arguments than it is defined to allow

Usually used to provide "settings" for the function

Why?

# Default / Named Parameters

Specify a default value for one or more parameters

- Called with fewer arguments than it is defined to allow

Usually used to provide "settings" for the function

Why?

- Presents a simplified interface for a function

# Default / Named Parameters

Specify a default value for one or more parameters

- Called with fewer arguments than it is defined to allow

Usually used to provide "settings" for the function

Why?

- Presents a simplified interface for a function
- Provides reasonable defaults for parameters

# Default / Named Parameters

Specify a default value for one or more parameters

- Called with fewer arguments than it is defined to allow

Usually used to provide "settings" for the function

Why?

- Presents a simplified interface for a function
- Provides reasonable defaults for parameters
- Declares intent to caller that parameters are "extra"

```
def ask_yn(prompt,
           retries=4,
           complaint='...'):
```

Required parameter `prompt`

```
def ask_yn(prompt,
           retries=4,
           complaint='...'):
```

Required parameter `prompt`

```
def ask_yn(prompt,
           retries=4,
           complaint='...'):
```

Optional parameter `retries`
defaults to 4

Required parameter `prompt`

```
def ask_yn(prompt,
           retries=4,
           complaint='...'):
```

Optional parameter `retries`
defaults to 4

Optional parameter `complaint`
defaults to some message

# Keyword Arguments

# Keyword Arguments

```
def ask_yn(prompt, retries=4, complaint='Enter Y/N!'):
```

# Keyword Arguments

```
def ask_yn(prompt, retries=4, complaint='Enter Y/N!'):
    for i in range(retries):
```

# Keyword Arguments

```
def ask_yn(prompt, retries=4, complaint='Enter Y/N!'):
    for i in range(retries):
        ok = input(prompt)
```

# Keyword Arguments

```
def ask_yn(prompt, retries=4, complaint='Enter Y/N!'):
    for i in range(retries):
        ok = input(prompt)
        if ok in ('Y', 'y'):
            return True
        if ok in ('N', 'n'):
            return False
```

# Keyword Arguments

```
def ask_yn(prompt, retries=4, complaint='Enter Y/N!'):
    for i in range(retries):
        ok = input(prompt)
        if ok in ('Y', 'y'):
            return True
        if ok in ('N', 'n'):
            return False
        print(complaint)
```

# Keyword Arguments

```
def ask_yn(prompt, retries=4, complaint='Enter Y/N!'):
    for i in range(retries):
        ok = input(prompt)
        if ok in ('Y', 'y'):
            return True
        if ok in ('N', 'n'):
            return False
        print(complaint)
    return False
```

# Examples

# Examples

```
print(…, sep=' ', end='\n', file=sys.stdout, flush=False)
```

# Examples

```
print(…, sep=' ', end='\n', file=sys.stdout, flush=False)
range(start, stop, step=1)
```

# Examples

```
print(…, sep=' ', end='\n', file=sys.stdout, flush=False)
range(start, stop, step=1)
enumerate(iter, start=0)
```

# Examples

```
print(…, sep=' ', end='\n', file=sys.stdout, flush=False)
range(start, stop, step=1)
enumerate(iter, start=0)
int(x, base=10)
```

# Examples

```
print(…, sep=' ', end='\n', file=sys.stdout, flush=False)
range(start, stop, step=1)
enumerate(iter, start=0)
int(x, base=10)
pow(x, y, z=None)
```

# Examples

```
print(…, sep=' ', end='\n', file=sys.stdout, flush=False)
range(start, stop, step=1)
enumerate(iter, start=0)
int(x, base=10)
pow(x, y, z=None)
seq.sort(*, key=None, reverse=None)
```

# Examples

```
print(…, sep=' ', end='\n', file=sys.stdout, flush=False)
range(start, stop, step=1)
enumerate(iter, start=0)
int(x, base=10)
pow(x, y, z=None)
seq.sort(*, key=None, reverse=None)

subprocess.Popen(args, bufsize=-1, executable=None,
stdin=None, stdout=None, stderr=None, preexec_fn=None,
close_fds=True, shell=False, cwd=None, env=None,
universal_newlines=None, startupinfo=None,
creationflags=0, restore_signals=True,
start_new_session=False, pass_fds=(), encoding=None,
errors=None, text=None)
```

# Examples

```
print(…, sep=' ', end='\n', file=sys.stdout, flush=False)
range(start, stop, step=1)
enumerate(iter, start=0)
int(x, base=10)
pow(x, y, z=None)
seq.sort(*, key=None, reverse=None)

subprocess.Popen(args, bufsize=-1, executable=None,
stdin=None, stdout=None, stderr=None, preexec_fn=None,
close_fds=True, shell=False, cwd=None, env=None,
universal_newlines=None, startupinfo=None,
creationflags=0, restore_signals=True,
start_new_session=False, pass_fds=(), encoding=None,
errors=None, text=None)
```

Wow...

```
ask_yn(prompt, retries=4, complaint='...')
```

# ask_yn(prompt, retries=4, complaint='...')

```
# Call with only the mandatory argument
ask_yn('Really quit?')
```

```
ask_yn(prompt, retries=4, complaint='...')
```

```
# Call with only the mandatory argument
ask_yn('Really quit?')

# Call with one keyword argument
ask_yn('OK to overwrite the file?', retries=2)
```

# ask_yn(prompt, retries=4, complaint='...')

```
# Call with only the mandatory argument
ask_yn('Really quit?')

# Call with one keyword argument
ask_yn('OK to overwrite the file?', retries=2)

# Call with one keyword argument – in any order!
ask_yn('Update status?', complaint='Just Y/N')
```

# ask_yn(prompt, retries=4, complaint='...')

```
# Call with only the mandatory argument
ask_yn('Really quit?')

# Call with one keyword argument
ask_yn('OK to overwrite the file?', retries=2)

# Call with one keyword argument – in any order!
ask_yn('Update status?', complaint='Just Y/N')

# Call with all of the keyword arguments
ask_yn('Send text?', retries=2, complaint='Y/N please!')
```

# Dead Parrot

# Dead Parrot

```
def parrot(voltage, state='a stiff', action='voom',
           type='Norwegian Blue'):
```

# Dead Parrot

```
def parrot(voltage, state='a stiff', action='voom',
           type='Norwegian Blue'):
    print("-- This parrot wouldn't", action, end=' ')
    print("if you put", voltage, "volts through it.")
```

# Dead Parrot

```
def parrot(voltage, state='a stiff', action='voom',
           type='Norwegian Blue'):
    print("-- This parrot wouldn't", action, end=' ')
    print("if you put", voltage, "volts through it.")
    print("-- Lovely plumage, the", type)
```

# Dead Parrot

```
def parrot(voltage, state='a stiff', action='voom',
           type='Norwegian Blue'):
    print("-- This parrot wouldn't", action, end=' ')
    print("if you put", voltage, "volts through it.")
    print("-- Lovely plumage, the", type)
    print("-- It's", state, "!")
```

# Valid Calls

```
def parrot(voltage, state='…', action='…', type='…')
```

# Valid Calls

```
def parrot(voltage, state='…', action='…', type='…')

# 1 positional argument
parrot(1000)
```

# Valid Calls

```
def parrot(voltage, state='…', action='…', type='…')

# 1 positional argument
parrot(1000)
# 1 keyword argument
parrot(voltage=1000)
```

# Valid Calls

```
def parrot(voltage, state='…', action='…', type='…')

# 1 positional argument
parrot(1000)
# 1 keyword argument
parrot(voltage=1000)
# 2 keyword arguments
parrot(voltage=1000000, action='VOOOOOM')
```

# Valid Calls

```
def parrot(voltage, state='…', action='…', type='…')

# 1 positional argument
parrot(1000)
# 1 keyword argument
parrot(voltage=1000)
# 2 keyword arguments
parrot(voltage=1000000, action='VOOOOOM')
# 2 keyword arguments
parrot(action='VOOOOOM', voltage=1000000)
```

# Valid Calls

```
def parrot(voltage, state='…', action='…', type='…')

# 1 positional argument
parrot(1000)
# 1 keyword argument
parrot(voltage=1000)
# 2 keyword arguments
parrot(voltage=1000000, action='VOOOOOM')
# 2 keyword arguments
parrot(action='VOOOOOM', voltage=1000000)
# 3 positional arguments
parrot('a million', 'bereft of life', 'jump')
```

# Valid Calls

```
def parrot(voltage, state='…', action='…', type='…')

# 1 positional argument
parrot(1000)
# 1 keyword argument
parrot(voltage=1000)
# 2 keyword arguments
parrot(voltage=1000000, action='VOOOOOM')
# 2 keyword arguments
parrot(action='VOOOOOM', voltage=1000000)
# 3 positional arguments
parrot('a million', 'bereft of life', 'jump')
# 1 positional, 1 keyword
parrot('a thousand', state='pushing up the daisies')
```

# Invalid Calls

```
def parrot(voltage, state='…', action='…', type='…')
```

# Invalid Calls

```
def parrot(voltage, state='…', action='…', type='…')

# required argument missing
parrot()
```

# Invalid Calls

```
def parrot(voltage, state='…', action='…', type='…')

# required argument missing
parrot()
# non-keyword argument after a keyword argument
parrot(voltage=5.0, 'dead')
```

# Invalid Calls

```
def parrot(voltage, state='…', action='…', type='…')

# required argument missing
parrot()
# non-keyword argument after a keyword argument
parrot(voltage=5.0, 'dead')
# duplicate value for the same argument
parrot(110, voltage=220)
```

# Invalid Calls

```
def parrot(voltage, state='…', action='…', type='…')

# required argument missing
parrot()
# non-keyword argument after a keyword argument
parrot(voltage=5.0, 'dead')
# duplicate value for the same argument
parrot(110, voltage=220)
# unknown keyword argument
parrot(actor='John Cleese')
```

# Rules about Function Calls

# Rules about Function Calls

Keyword arguments must follow positional arguments

# Rules about Function Calls

Keyword arguments must follow positional arguments

All keyword arguments must identify some parameter

# Rules about Function Calls

Keyword arguments must follow positional arguments

All keyword arguments must identify some parameter

    Even positional ones

# Rules about Function Calls

Keyword arguments must follow positional arguments

All keyword arguments must identify some parameter

    Even positional ones

No parameter may receive a value more than once

# Rules about Function Calls

Keyword arguments must follow positional arguments

All keyword arguments must identify some parameter

    Even positional ones

No parameter may receive a value more than once

```
def fn(a): print(a)
fn(0, a=0)
```

# Rules about Function Calls

Keyword arguments must follow positional arguments

All keyword arguments must identify some parameter

Even positional ones

No parameter may receive a value more than once

```
def fn(a): print(a)
fn(0, a=0)
```

Not allowed!
Multiple values of a

# Variadic Positional Arguments

# Variadic Positional Arguments

# Variadic Positional Arguments

A parameter of form `*args` captures excess positional args

# Variadic Positional Arguments

A parameter of form `*args` captures excess positional args

These excess arguments are bundled into an `args` tuple

# Variadic Positional Arguments

A parameter of form `*args` captures excess positional args

These excess arguments are bundled into an `args` tuple

Why?

# Variadic Positional Arguments

A parameter of form `*args` captures excess positional args

- These excess arguments are bundled into an `args` tuple

Why?

- Call functions with any number of positional arguments

# Variadic Positional Arguments

A parameter of form `*args` captures excess positional args

- These excess arguments are bundled into an `args` tuple

Why?

- Call functions with any number of positional arguments
- Capture all arguments to forward to another handler

# Variadic Positional Arguments

A parameter of form `*args` captures excess positional args

- These excess arguments are bundled into an `args` tuple

Why?

- Call functions with any number of positional arguments
- Capture all arguments to forward to another handler
  - Used in subclasses, proxies, and decorators

# Variadic Positional Arguments

A parameter of form `*args` captures excess positional args

- These excess arguments are bundled into an `args` tuple

Why?

- Call functions with any number of positional arguments
- Capture all arguments to forward to another handler
  - Used in subclasses, proxies, and decorators

```
print(*objects, sep=' ', end='\n', file=…, flush=False)
```

# Variadic Positional Arguments

# Variadic Positional Arguments

```
# Suppose we want a product function that works as so:
product(3, 5)  # => 15
product(3, 4, 2)  # => 24
product(3, 5, scale=10)  # => 150
```

# Variadic Positional Arguments

```
# Suppose we want a product function that works as so:
product(3, 5)  # => 15
product(3, 4, 2)  # => 24
product(3, 5, scale=10)  # => 150


# product accepts any number of arguments
def product(*nums, scale=1):
```

# Variadic Positional Arguments

```
# Suppose we want a product function that works as so:
product(3, 5)  # => 15
product(3, 4, 2)  # => 24
product(3, 5, scale=10)  # => 150


# product accepts any number of arguments
def product(*nums, scale=1):
    p = scale
    for n in nums:
        p *= n
    return p
```

# Variadic Positional Arguments

```
# Suppose we want a product function that works as so:
product(3, 5)  # => 15
product(3, 4, 2)  # => 24
product(3, 5, scale=10)  # => 150


# product accepts any number of arguments
def product(*nums, scale=1):
    p = scale
    for n in nums:
        p *= n
    return p
```

Named parameters after `*args` are 'keyword-only' arguments (why?)

# Unpacking Variadic Positional Arguments

# Unpacking Variadic Positional Arguments

```
# Suppose we want to find 2 * 3 * 5 * 7 * … up to 100
def is_prime(n):  pass  # Some implementation
```

# Unpacking Variadic Positional Arguments

```
# Suppose we want to find 2 * 3 * 5 * 7 * … up to 100
def is_prime(n):  pass  # Some implementation

# Extract all the primes
primes = [number for number in range(2, 100)
          if is_prime(number)]
```

# Unpacking Variadic Positional Arguments

```
# Suppose we want to find 2 * 3 * 5 * 7 * … up to 100
def is_prime(n):  pass  # Some implementation

# Extract all the primes
primes = [number for number in range(2, 100)
          if is_prime(number)]

# primes == [2, 3, 5, …]
print(product(*primes))  # equiv. to product(2, 3, 5, …)
```

# Unpacking Variadic Positional Arguments

```
# Suppose we want to find 2 * 3 * 5 * 7 * … up to 100
def is_prime(n):  pass  # Some implementation

# Extract all the primes
primes = [number for number in range(2, 100)
          if is_prime(number)]

# primes == [2, 3, 5, …]
print(product(*primes))  # equiv. to product(2, 3, 5, …)
```

The syntax `*seq` unpacks a sequence into its constituent components

# Variadic Keyword Arguments

# Variadic Keyword Arguments

# Variadic Keyword Arguments

A parameter of the form `**kwargs` captures all excess keyword arguments

# Variadic Keyword Arguments

A parameter of the form `**kwargs` captures all excess keyword arguments

- These excess arguments are bundled into a `kwargs` dict

# Variadic Keyword Arguments

A parameter of the form `**kwargs` captures all excess keyword arguments

These excess arguments are bundled into a `kwargs` dict

Why?

# Variadic Keyword Arguments

A parameter of the form `**kwargs` captures all excess keyword arguments

- These excess arguments are bundled into a `kwargs` dict

Why?

- Allow arbitrary named parameters, usually for configuration

# Variadic Keyword Arguments

A parameter of the form `**kwargs` captures all excess keyword arguments

- These excess arguments are bundled into a `kwargs` dict

Why?

- Allow arbitrary named parameters, usually for configuration
- Similar: capture all arguments to forward to another handler

# Variadic Keyword Arguments

A parameter of the form `**kwargs` captures all excess keyword arguments

- These excess arguments are bundled into a `kwargs` dict

Why?

- Allow arbitrary named parameters, usually for configuration
- Similar: capture all arguments to forward to another handler
  - Used in subclasses, proxies, and decorators

# Variadic Keyword Arguments

# Variadic Keyword Arguments

```
authorize(
    "If music be the food of love, play on.",
    playwright="Shakespeare",
    act=1,
    scene=1,
    speaker="Duke Orsino"
)
```

# Variadic Keyword Arguments

```
authorize(
    "If music be the food of love, play on.",
    playwright="Shakespeare",
    act=1,
    scene=1,
    speaker="Duke Orsino"
)

# > If music be the food of love, play on.
# ----------------------------------------
# act: 1
# scene: 1
# speaker: Duke Orsino
# playwright: Shakespeare
```

# Variadic Keyword Arguments

# Variadic Keyword Arguments

```
def authorize(quote, **speaker_info):
```

# Variadic Keyword Arguments

```
def authorize(quote, **speaker_info):
    print(">", quote)
    print("—" * (len(quote) + 2))
    for k, v in speaker_info.items():
        print(k, v, sep=': ')
```

# Variadic Keyword Arguments

```
def authorize(quote, **speaker_info):
    print(">", quote)
    print("—" * (len(quote) + 2))
    for k, v in speaker_info.items():
        print(k, v, sep=': ')
```

```
speaker_info = {
  'act': 1,
  'scene': 1,
  'speaker': "Duke Orsino",
  'playwright': "Shakespeare"
}
```

# Unpacking Variadic Keyword Arguments

# Unpacking Variadic Keyword Arguments

```
info = {
    'sonnet': 18,
    'line': 1,
    'author': "Shakespeare"
}
```

# Unpacking Variadic Keyword Arguments

```
info = {
    'sonnet': 18,
    'line': 1,
    'author': "Shakespeare"
}

authorize("Shall I compare thee to a summer's day", **info)
```

# Unpacking Variadic Keyword Arguments

```
info = {
    'sonnet': 18,
    'line': 1,
    'author': "Shakespeare"
}

authorize("Shall I compare thee to a summer's day", **info)

# > Shall I compare thee to a summer's day
# ----------------------------------------
# line: 1
# sonnet: 18
# author: Shakespeare
```

# Example: Formatting Strings

```
fstr.format(*args, **kwargs)
```

All positional arguments go into `args`

```
fstr.format(*args, **kwargs)
```

All positional arguments go into `args`

```
fstr.format(*args, **kwargs)
```

All keyword arguments go into `kwargs`

fstr.format(*args, **kwargs)

# fstr.format(*args, **kwargs)

```
# {n} refers to the nth positional argument in `args`
"First, thou shalt count to {0}".format(3)
```

# fstr.format(*args, **kwargs)

```
# {n} refers to the nth positional argument in `args`
"First, thou shalt count to {0}".format(3)
```

```
args = (3, )
```

# fstr.format(*args, **kwargs)

```
# {n} refers to the nth positional argument in `args`
"First, thou shalt count to {0}".format(3)
"{0} shalt thou not count, neither count thou {1},
excepting that thou then proceed to {2}".format(4, 2, 3)
```

```
args = (3, )
```

# fstr.format(*args, **kwargs)

```
# {n} refers to the nth positional argument in `args`
"First, thou shalt count to {0}".format(3)
"{0} shalt thou not count, neither count thou {1},
excepting that thou then proceed to {2}".format(4, 2, 3)
```

`args = (3, )`

`args = (4, 2, 3)`

# fstr.format(*args, **kwargs)

```
# {n} refers to the nth positional argument in `args`
"First, thou shalt count to {0}".format(3)
"{0} shalt thou not count, neither count thou {1},
excepting that thou then proceed to {2}".format(4, 2, 3)

# {key} refers to the optional argument bound by key
"lobbest thou thy {weapon} towards thy foe".format(
    weapon="Holy Hand Grenade of Antioch"
)
```

```
args = (3, )
```

```
args = (4, 2, 3)
```

# fstr.format(*args, **kwargs)

```
# {n} refers to the nth positional argument in `args`
"First, thou shalt count to {0}".format(3)
"{0} shalt thou not count, neither count thou {1},
excepting that thou then proceed to {2}".format(4, 2, 3)

# {key} refers to the optional argument bound by key
"lobbest thou thy {weapon} towards thy foe".format(
    weapon="Holy Hand Grenade of Antioch"
)
```

`args = (3, )`

`args = (4, 2, 3)`

`kwargs = {"weapon": "Holy Hand Grenade of Antioch"}`

# Complicated Example

# Complicated Example

```
"{0}{b}{1}{a}{0}{2}".format(
    5, 8, 9, a='z', b='x'
)
```

# Complicated Example

```
"{0}{b}{1}{a}{0}{2}".format(
    5, 8, 9, a='z', b='x'
)
```

```
args = (5, 8, 9)
kwargs = {'a':'z', 'b':'x'}
```

# Complicated Example

```
"{0}{b}{1}{a}{0}{2}".format(
    5, 8, 9, a='z', b='x'
)
# => 5x8z59
```

```
args = (5, 8, 9)
kwargs = {'a':'z', 'b':'x'}
```

# Cute Trick: Unpacking Variadic Keyword Arguments

# Cute Trick: Unpacking Variadic Keyword Arguments

```
x = 3
foo = 'fighter'
y = 4
learn = 2, 'fly'
z = 5
```

# Cute Trick: Unpacking Variadic Keyword Arguments

```
x = 3
foo = 'fighter'
y = 4
learn = 2, 'fly'
z = 5
```

local symbol table

```
{
        'x': 3,
        'foo': 'fighter',
        'y': 4,
        'learn': (2, 'fly'),
        'z': 5, …
}
```

# Cute Trick: Unpacking Variadic Keyword Arguments

```
x = 3
foo = 'fighter'
y = 4
learn = 2, 'fly'
z = 5
```

local symbol table

```
{
    'x': 3,
    'foo': 'fighter',
    'y': 4,
    'learn': (2, 'fly'),
    'z': 5, …
}
```

```
print("{z}^2 = {x}^2 + {y}^2".format(x=x, y=y, z=z))
```

# Cute Trick: Unpacking Variadic Keyword Arguments

```
x = 3
foo = 'fighter'
y = 4
learn = 2, 'fly'
z = 5
```

local symbol table

```
{
    'x': 3,
    'foo': 'fighter',
    'y': 4,
    'learn': (2, 'fly'),
    'z': 5, …
}
```

```
print("{z}^2 = {x}^2 + {y}^2".format(x=x, y=y, z=z))
print("{z}^2 = {x}^2 + {y}^2".format(**locals()))
```

# Cute Trick: Unpacking Variadic Keyword Arguments

```
x = 3
foo = 'fighter'
y = 4
learn = 2, 'fly'
z = 5
```

local symbol table

```
{
    'x': 3,
    'foo': 'fighter',
    'y': 4,
    'learn': (2, 'fly'),
    'z': 5, …
}
```

```
print("{z}^2 = {x}^2 + {y}^2".format(x=x, y=y, z=z))
print("{z}^2 = {x}^2 + {y}^2".format(**locals()))
# Equivalent to .format(x=3, foo='fighter', y=4, ...)
```

# Cute Trick: Unpacking Variadic Keyword Arguments

```
x = 3
foo = 'fighter'
y = 4
learn = 2, 'fly'
z = 5
```

local symbol table

```
{
    'x': 3,
    'foo': 'fighter',
    'y': 4,
    'learn': (2, 'fly'),
    'z': 5, …
}
```

```
print("{z}^2 = {x}^2 + {y}^2".format(x=x, y=y, z=z))
print("{z}^2 = {x}^2 + {y}^2".format(**locals()))
# Equivalent to .format(x=3, foo='fighter', y=4, ...)
```

f-strings (`f""`) do something like this!

# Putting it All Together

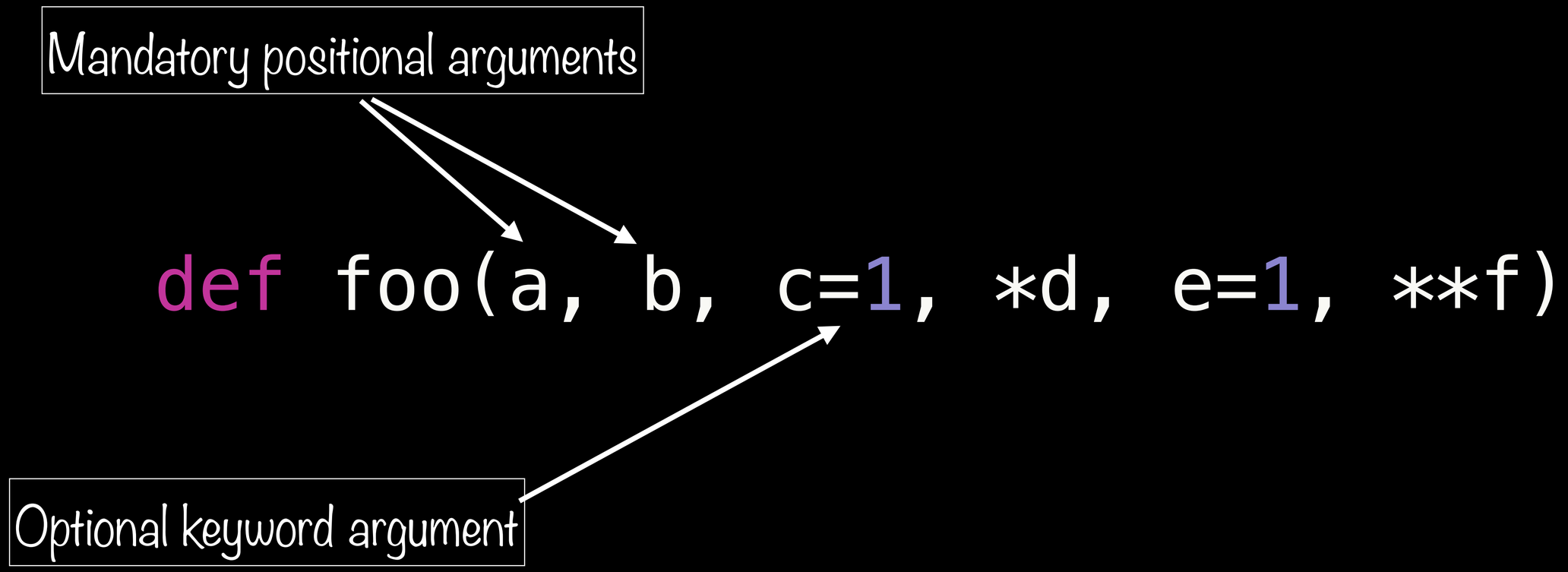
# A Valid Python Function Definition

```
def foo(a, b, c=1, *d, e=1, **f)
```

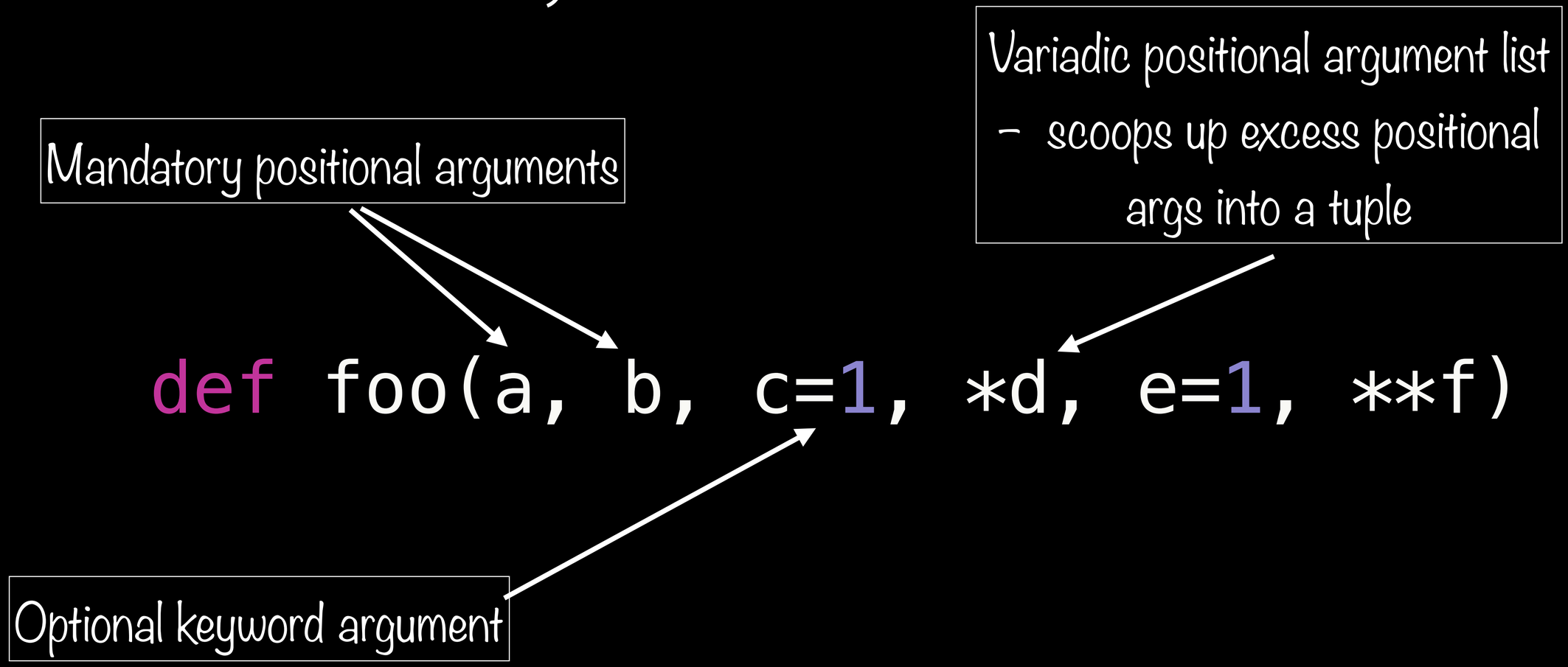
# A Valid Python Function Definition


```
def foo(a, b, c=1, *d, e=1, **f)
```

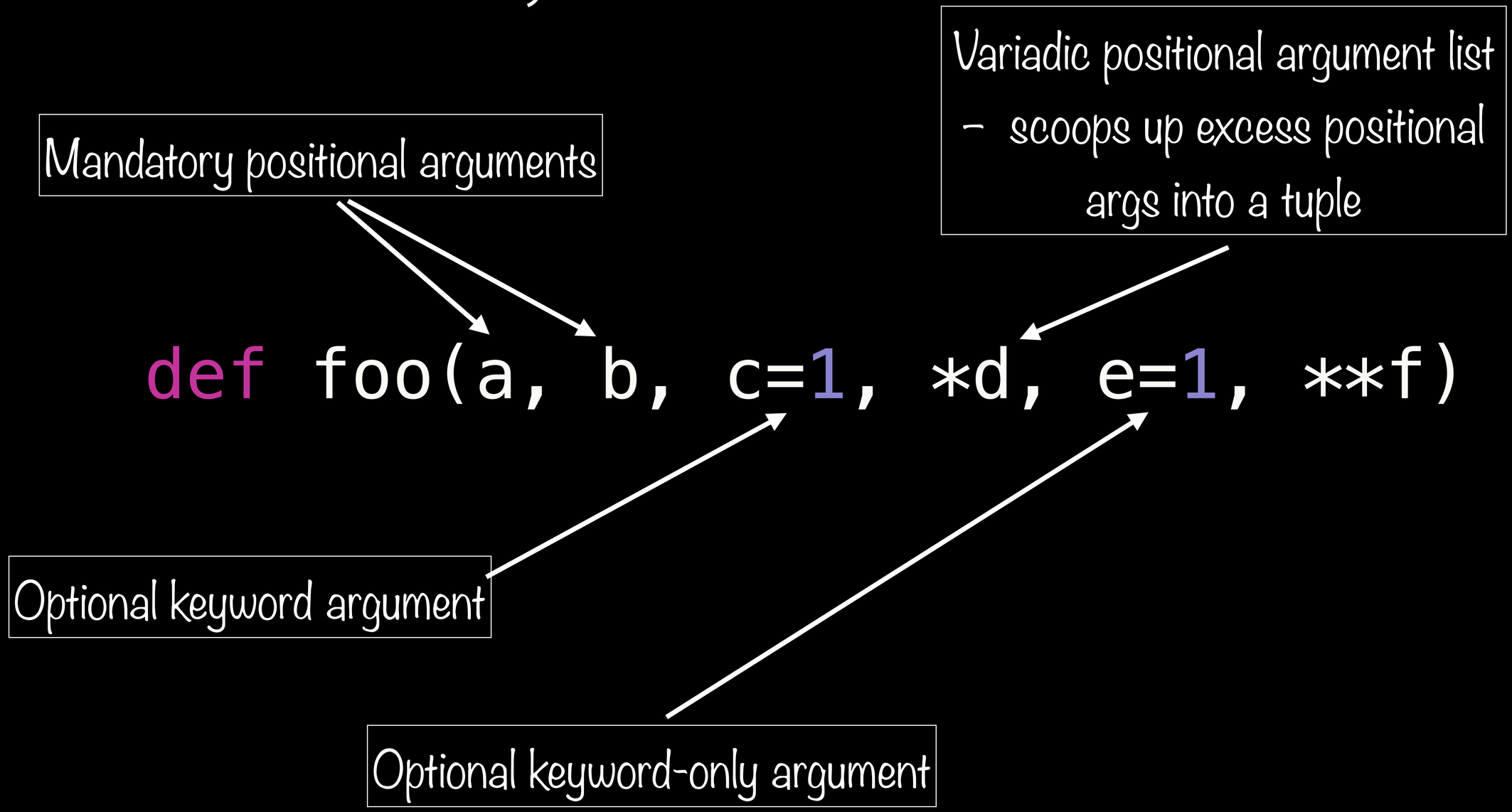
# A Valid Python Function Definition



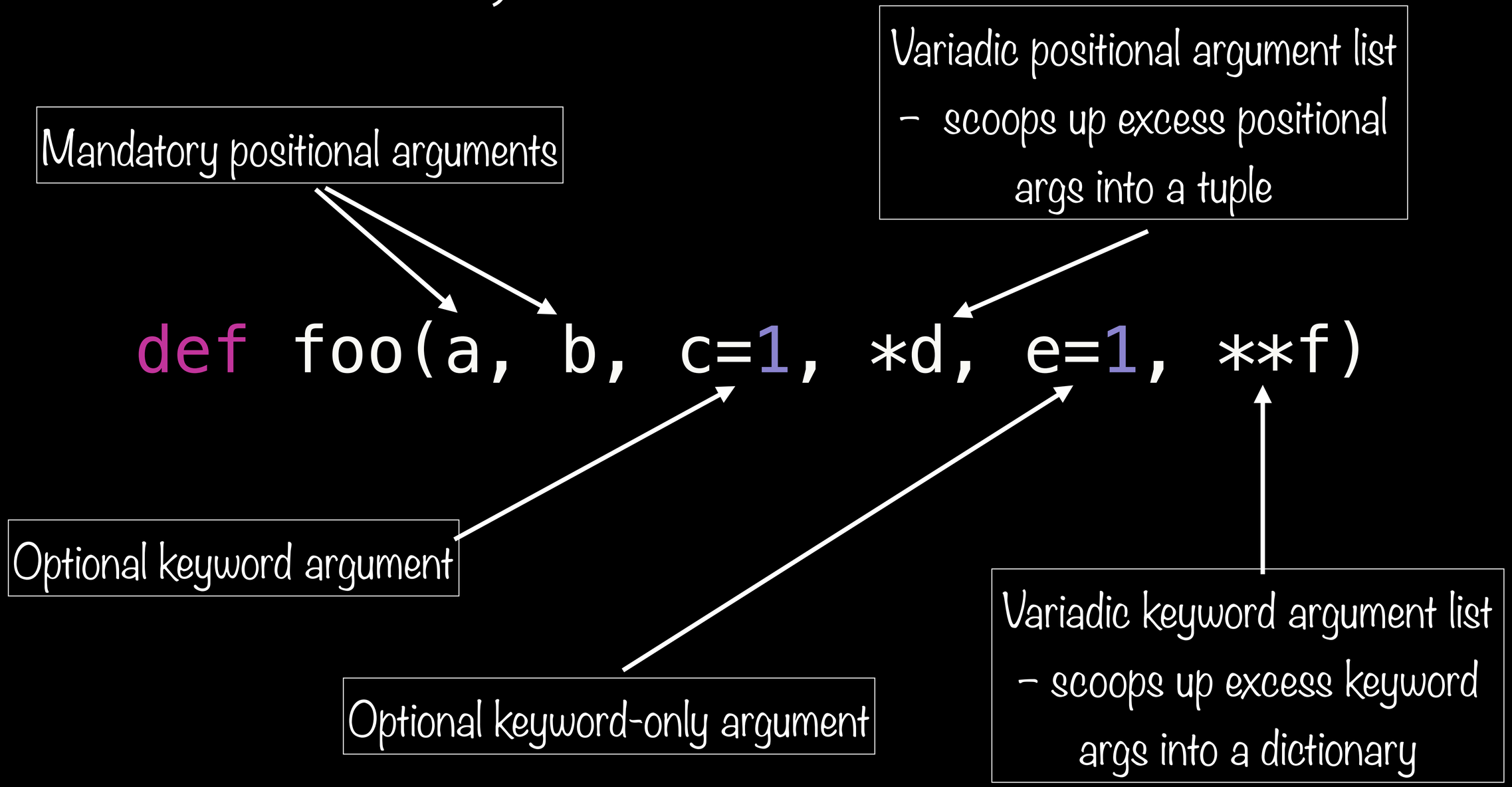
# A Valid Python Function Definition



# A Valid Python Function Definition



# A Valid Python Function Definition



# Time Out for Announcements

# Logistics

# Logistics

**Office Hours** Sam (after class/by appointment)

# Logistics

**Office Hours** Sam (after class/by appointment)

**Assignments** A0 and A1

# Logistics

**Office Hours** Sam (after class/by appointment)

**Assignments** A0 and A1

**Enrollment** Waitlist spots!

# Logistics

**Office Hours** Sam (after class/by appointment)

**Assignments** A0 and A1

**Enrollment** Waitlist spots!

**Lab Clarification** Labelled by week (Lab 2 for Week 2).

# Back to Python!

# Aside: Code Style

# Function Comments

# Function Comments

The first string literal *inside* a function body is a docstring

# Function Comments

The first string literal *inside* a function body is a docstring

- First line: one-line summary of the function

# Function Comments

The first string literal *inside* a function body is a docstring

- First line: one-line summary of the function
- Subsequent lines: extended description of function

# Function Comments

The first string literal *inside* a function body is a docstring

- First line: one-line summary of the function
- Subsequent lines: extended description of function

Describe parameters (value / expected type) and return

# Function Comments

- The first string literal *inside* a function body is a docstring
  - First line: one-line summary of the function
  - Subsequent lines: extended description of function
- Describe parameters (value / expected type) and return
  - Many standards have emerged (javadoc, reST, Google)

# Function Comments

- The first string literal *inside* a function body is a docstring
  - First line: one-line summary of the function
  - Subsequent lines: extended description of function
- Describe parameters (value / expected type) and return
  - Many standards have emerged (javadoc, reST, Google)
  - Just be consistent!

# Function Comments

- The first string literal *inside* a function body is a docstring
  - First line: one-line summary of the function
  - Subsequent lines: extended description of function
- Describe parameters (value / expected type) and return
  - Many standards have emerged (javadoc, reST, Google)
  - Just be consistent!
- The usual rules apply too! List pre-/post-conditions, if any.

# Example: Function Docstrings

# Example: Function Docstrings

```
def my_function():
```

# Example: Function Docstrings

```
def my_function():
    """Summary line: do nothing, but document it.

    Description: No, really, it doesn't do anything.
    """
    pass
```

# Example: Function Docstrings

```
def my_function():
    """Summary line: do nothing, but document it.

    Description: No, really, it doesn't do anything.
    """
    pass

print(my_function.__doc__)
```

# Example: Function Docstrings

```
def my_function():
    """Summary line: do nothing, but document it.

    Description: No, really, it doesn't do anything.
    """
    pass

print(my_function.__doc__)

# Summary line: Do nothing, but document it.
#
#     Description: No, really, it doesn't do anything.
```

# Example: Function Docstrings

```
def my_function():
    """Summary line: do nothing, but document it.

    Description: No, really, it doesn't do anything.
    """
    pass

print(my_function.__doc__)

# Summary line: Do nothing, but document it.
#
#     Description: No, really, it doesn't do anything.
```

More: PEP 257

# General Good Practices

# General Good Practices

**Spacing** Use 4 spaces to indent. Don't use tabs.

# General Good Practices

**Spacing** Use 4 spaces to indent. Don't use tabs.

Use blank lines to separate functions and logical sections inside functions.

# General Good Practices

**Spacing** Use 4 spaces to indent. Don't use tabs.

Use blank lines to separate functions and logical sections inside functions.

Use spaces around operators and after commas, but not directly inside delimiters

# General Good Practices

**Spacing** Use 4 spaces to indent. Don't use tabs.

Use blank lines to separate functions and logical sections inside functions.

Use spaces around operators and after commas, but not directly inside delimiters

```
a = f(1, 2) + g(3, 4)
```

# General Good Practices

**Spacing** Use 4 spaces to indent. Don't use tabs.

Use blank lines to separate functions and logical sections inside functions.

Use spaces around operators and after commas, but not directly inside delimiters

```
a = f(1, 2) + g(3, 4)
```

**Commenting** Comment all nontrivial functions.

# General Good Practices

**Spacing** Use 4 spaces to indent. Don't use tabs.

Use blank lines to separate functions and logical sections inside functions.

Use spaces around operators and after commas, but not directly inside delimiters

```
a = f(1, 2) + g(3, 4)
```

**Commenting** Comment all nontrivial functions.

Add header comments at the top of files before any imports.

# General Good Practices

**Spacing** Use 4 spaces to indent. Don't use tabs.

Use blank lines to separate functions and logical sections inside functions.

Use spaces around operators and after commas, but not directly inside delimiters

```
a = f(1, 2) + g(3, 4)
```

**Commenting** Comment all nontrivial functions.

Add header comments at the top of files before any imports.

If possible, put comments on a line of their own.

# General Good Practices

**Spacing** Use 4 spaces to indent. Don't use tabs.

Use blank lines to separate functions and logical sections inside functions.

Use spaces around operators and after commas, but not directly inside delimiters

```
a = f(1, 2) + g(3, 4)
```

**Commenting** Comment all nontrivial functions.

Add header comments at the top of files before any imports.

If possible, put comments on a line of their own.

More: PEP 8

# General Good Practices

# General Good Practices

**Naming**

Use snake_case for variables/functions; CamelCase for classes; CAPS_CASE for constants

# General Good Practices

**Naming**

Use snake_case for variables/functions; CamelCase for classes; CAPS_CASE for constants

**Decomposition and Logic**

Same as in 106s. Simple is better than complex. Seek abstractions and clean design.

# General Good Practices

**Naming**

Use snake_case for variables/functions; CamelCase for classes; CAPS_CASE for constants

**Decomposition and Logic**

Same as in 106s. Simple is better than complex. Seek abstractions and clean design.

**Automated Code Style Checking**

# General Good Practices

**Naming**

Use snake_case for variables/functions; CamelCase for classes; CAPS_CASE for constants

**Decomposition and Logic**

Same as in 106s. Simple is better than complex. Seek abstractions and clean design.

**Automated Code Style Checking**

Use PyLintOnline

Captures mechanical violations (naming, spacing); more advanced suggestions.

# General Good Practices

**Naming**

Use snake_case for variables/functions; CamelCase for classes; CAPS_CASE for constants

**Decomposition and Logic**

Same as in 106s. Simple is better than complex. Seek abstractions and clean design.

**Automated Code Style Checking**

Use PyLintOnline

- Captures mechanical violations (naming, spacing); more advanced suggestions.

Use `pycodestyle`

- Command line tool; install with `pip install pycodestyle`

# General Good Practices

**Naming**

Use snake_case for variables/functions; CamelCase for classes; CAPS_CASE for constants

**Decomposition and Logic**

Same as in 106s. Simple is better than complex. Seek abstractions and clean design.

**Automated Code Style Checking**

Use PyLintOnline

- Captures mechanical violations (naming, spacing); more advanced suggestions.

Use `pycodestyle`

- Command line tool; install with `pip install pycodestyle`

More: PEP 8

# Automatic Help with Python Linting

- Use PyLintOnline
  - Captures mechanical violations (naming, spacing)
  - Suggests (some) structural changes
- Use **`pycodestyle`**
  - Installed with pip install pycodestyle
  - Useful as a sanity check - sometimes overwhelming.

# Remember the Zen of Python

# First-Class Functions

# First-Class Functions

# First-Class Functions

```
def echo(arg): return arg
```

# First-Class Functions

```
def echo(arg): return arg

type(echo)  # <class 'function'>
```

# First-Class Functions

```
def echo(arg): return arg

type(echo)  # <class 'function'>
hex(id(echo))  # 0x1003c2bf8
```

# First-Class Functions

```
def echo(arg): return arg

type(echo)  # <class 'function'>
hex(id(echo))  # 0x1003c2bf8
print(echo)  # <function echo at 0x1003c2bf8>
```

# First-Class Functions

```
def echo(arg): return arg

type(echo)  # <class 'function'>
hex(id(echo))  # 0x1003c2bf8
print(echo)  # <function echo at 0x1003c2bf8>

foo = echo
```

# First-Class Functions

```
def echo(arg): return arg

type(echo)  # <class 'function'>
hex(id(echo))  # 0x1003c2bf8
print(echo)  # <function echo at 0x1003c2bf8>

foo = echo
hex(id(foo))  # 0x1003c2bf8
```

# First-Class Functions

```
def echo(arg): return arg

type(echo)  # <class 'function'>
hex(id(echo))  # 0x1003c2bf8
print(echo)  # <function echo at 0x1003c2bf8>

foo = echo
hex(id(foo))  # 0x1003c2bf8
print(foo)  # <function echo at 0x1003c2bf8>
```

# First-Class Functions

```
def echo(arg): return arg

type(echo)  # <class 'function'>
hex(id(echo))  # 0x1003c2bf8
print(echo)  # <function echo at 0x1003c2bf8>

foo = echo
hex(id(foo))  # 0x1003c2bf8
print(foo)  # <function echo at 0x1003c2bf8>

isinstance(echo, object)  # => True
```

# Functions are Objects

# Questions

# Questions

What can you do with function objects?

# Questions

What can you do with function objects?

What attributes does a function object possess?

# Questions

What can you do with function objects?

What attributes does a function object possess?

Can I pass a function as a parameters to other functions?

# Questions

What can you do with function objects?

What attributes does a function object possess?

Can I pass a function as a parameters to other functions?

Can a function return another function?

# Questions

What can you do with function objects?

What attributes does a function object possess?

Can I pass a function as a parameters to other functions?

Can a function return another function?

How can I modify a function object?

# Questions

What can you do with function objects?

What attributes does a function object possess?

Can I pass a function as a parameters to other functions?

Can a function return another function?

How can I modify a function object?

**WE MUST GO DEEPER (lab)**

# Summary

# Reference

# Reference

All functions return *some* value (possibly None)

# Reference

All functions return *some* value (possibly None)

Functions define scopes via symbol tables

# Reference

All functions return *some* value (possibly None)

Functions define scopes via symbol tables

Parameters are passed by object reference

# Reference

All functions return *some* value (possibly None)

Functions define scopes via symbol tables

Parameters are passed by object reference

Functions can have optional keyword arguments

# Reference

All functions return *some* value (possibly None)

Functions define scopes via symbol tables

Parameters are passed by object reference

Functions can have optional keyword arguments

Functions can take a variable number of args and kwargs

# Reference

All functions return *some* value (possibly None)

Functions define scopes via symbol tables

Parameters are passed by object reference

Functions can have optional keyword arguments

Functions can take a variable number of args and kwargs

Use docstrings and good style

# Reference

All functions return *some* value (possibly None)

Functions define scopes via symbol tables

Parameters are passed by object reference

Functions can have optional keyword arguments

Functions can take a variable number of args and kwargs

Use docstrings and good style

Functions are objects too (?!)