

Analyzing function calls

Stack diagrams - allow us to visualize the memory and state of the program

Steps for writing stack diagrams:

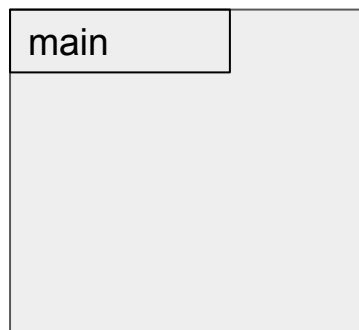
1. Pause when you see the function call
2. Create a stack frame for the called function
 - a. parameters allocated
 - b. local variables in scope stored here
3. Copy argument values to parameters
4. Execute the function, line by line, until the return
5. Send back the return value
6. Pop the function off the stack
7. Resume the calling function

Tip: Use Python Tutor to check your answers!

Exercise - add.py

Function Stack

Heap



A screenshot of the Atom code editor. The title bar shows the file path: `add.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom`. The menu bar includes File, Edit, View, Selection, Find, Packages, and Help. The editor has tabs for `add.py`, `add2.py`, `add3.py`, `tip.py`, and `fancify.py`. The `add.py` file contains the following Python code:

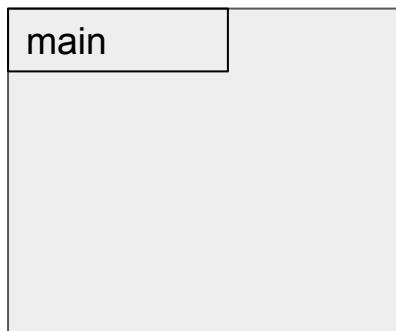
```
1  """
2  A program that adds two numbers using a function
3  """
4
5  def add(x,y):
6      print(x, y)
7      return x + y
8
9  def main():
10     n = 2
11     out = add(n, 4)
12     print(out)
13
14  main()
15
```

A red rectangular box highlights the `main()` call on line 14. The status bar at the bottom shows `add.py 15:1`, `LF N UTF-8 Python`, and `0 files`.

Exercise - add.py

Function Stack

Heap



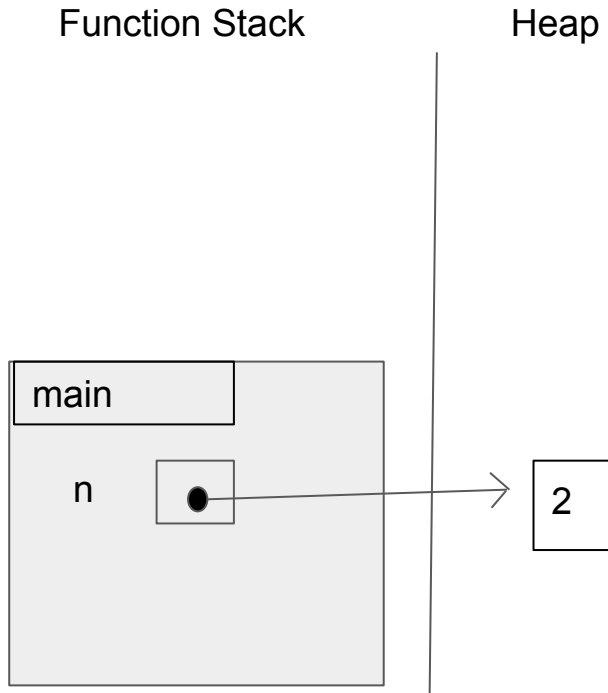
```
add.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom
File Edit View Selection Find Packages Help

add.py  add2.py  add3.py  tip.py  fancify.py

1  """
2  A program that adds two numbers using a function
3  """
4
5  def add(x,y):
6      print(x, y)
7      return x + y
8
9  def main():
10     n = 2
11     out = add(n, 4)
12     print(out)
13
14     main()
15
```

add.py 15:1 LF N UTF-8 Python 0 files

Exercise - add.py



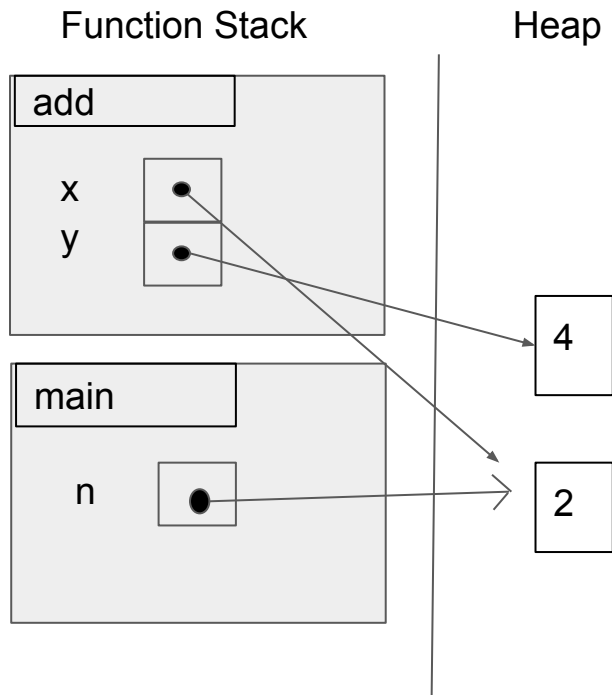
```
add.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom
File Edit View Selection Find Packages Help

add.py  add2.py  add3.py  tip.py  fancify.py

1  """
2  A program that adds two numbers using a function
3  """
4
5  def add(x,y):
6      print(x, y)
7      return x + y
8
9  def main():
10     > n = 2
11     out = add(n, 1)
12     print(out)
13
14     main()
15
```

add.py 15:1 LF N UTF-8 Python 0 files

Exercise - add.py



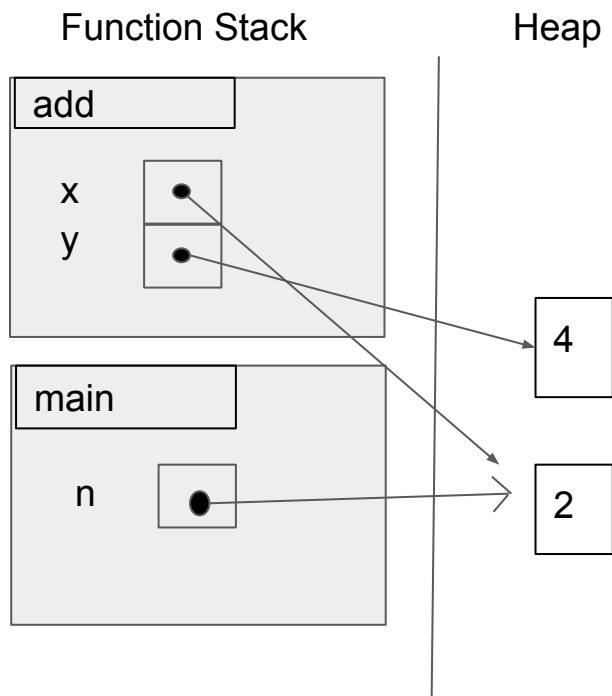
```
add.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom
File Edit View Selection Find Packages Help

add.py  add2.py  add3.py  tip.py  fancify.py

1  """
2  A program that adds two numbers using a function
3  """
4
5  def add(x,y):
6      print(x, y)
7      return x + y
8
9  def main():
10     n = 2
11     out = add(n, 4)
12     print(out)
13
14  main()
15
```

add.py 15:1 LF N UTF-8 Python 0 files

Exercise - add.py



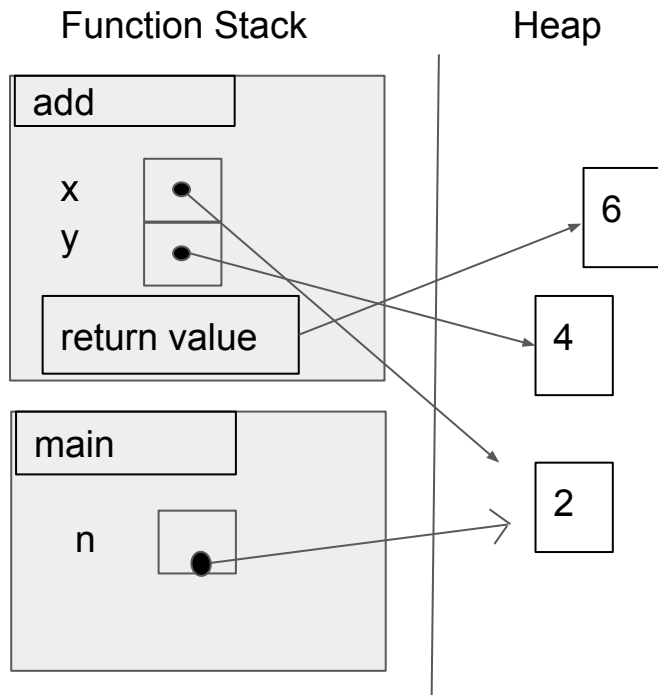
```
add.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom
File Edit View Selection Find Packages Help

add.py  add2.py  add3.py  tip.py  fancify.py

1  """
2  A program that adds two numbers using a function
3  """
4
5  def add(x,y):
6      print(x, y)
7      return x + y
8
9  def main():
10     n = 2
11     out = add(n, 4)
12     print(out)
13
14     main()
15
```

add.py 15:1 LF N UTF-8 Python 0 files

Exercise - add.py



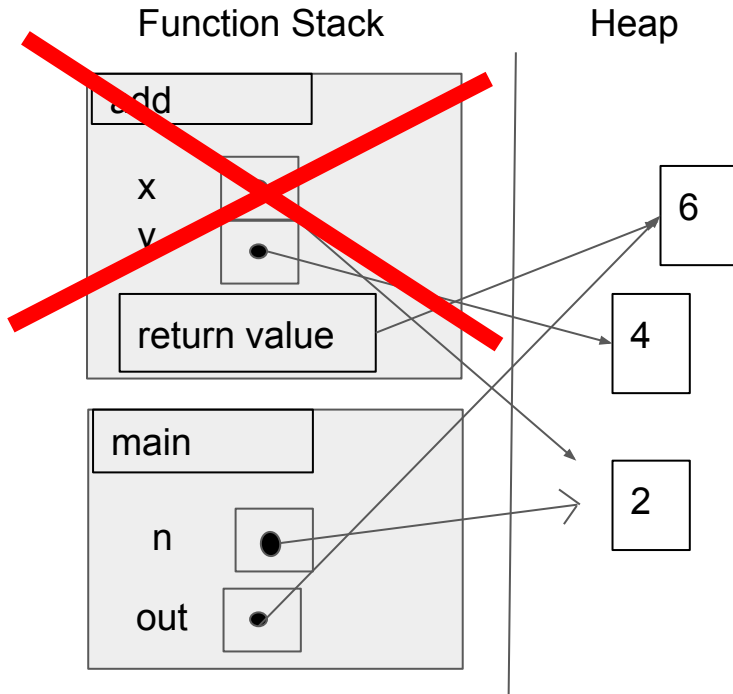
```
add.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom
File Edit View Selection Find Packages Help

add.py  add2.py  add3.py  tip.py  fancify.py

1  """
2  A program that adds two numbers using a function
3  """
4
5  def add(x,y):
6      print(x, y)
7      return x + y
8
9  def main():
10     n = 2
11     out = add(n, 4)
12     print(out)
13
14     main()
15
```

add.py 15:1 LF N UTF-8 Python 0 files

Exercise - add.py



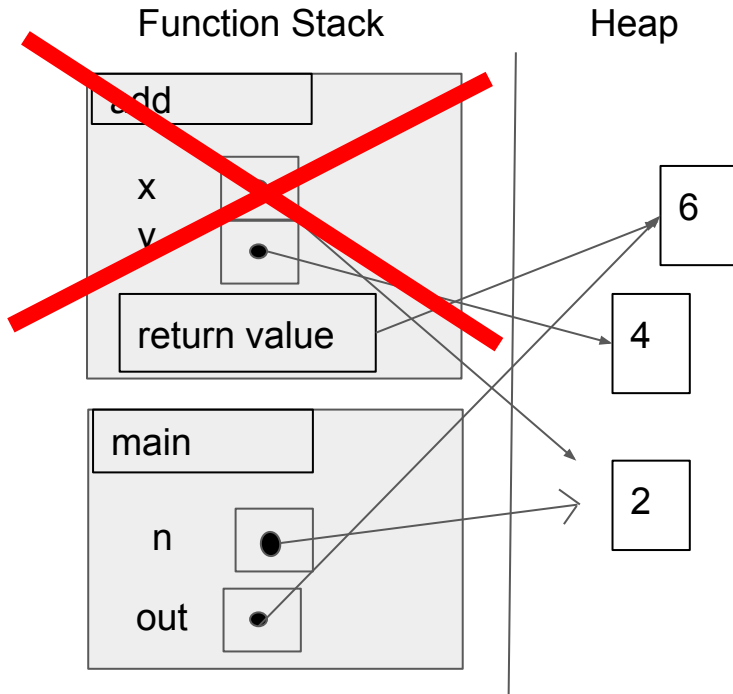
```
add.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom
File Edit View Selection Find Packages Help

add.py  add2.py  add3.py  tip.py  fancify.py

1  """
2  A program that adds two numbers using a function
3  """
4
5  def add(x,y):
6      print(x, y)
7      return x + y
8
9  def main():
10     n = 2
11     out = add(n, 4)
12     print(out)
13
14     main()
15
```

add.py 15:1 LF N UTF-8 Python 0 files

Exercise - add.py



```
add.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom
File Edit View Selection Find Packages Help

add.py  add2.py  add3.py  tip.py  fancify.py

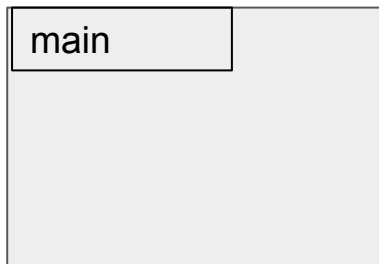
1  """
2  A program that adds two numbers using a function
3  """
4
5  def add(x,y):
6      print(x, y)
7      return x + y
8
9  def main():
10     n = 2
11     out = add(n, 4)
12     print(out)
13
14     main()
15
```

add.py 15:1 LF N UTF-8 Python 0 files

Exercise - add2.py

Function Stack

Heap



A screenshot of the Atom code editor. The title bar shows the file path: `add2.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom`. The menu bar includes `File Edit View Selection Find Packages Help`. The tab bar shows several files: `add.py`, `add2.py` (selected), `add3.py`, `tip.py`, and `fancy.py`. The code area displays the following Python code:

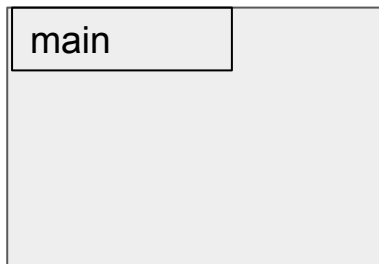
```
1 """
2 A program that adds two numbers using a function
3 """
4
5 def add(x,y):
6     print(x, y)
7     return x + y
8
9 def main():
10     x = 2
11     x = add(x, x)
12     print(x)
13
14 main()
15
```

A red rectangular box highlights the line `main()` at line 14. The status bar at the bottom shows `add2.py 15:1`, `LF`, `O`, `UTF-8`, `Python`, and `0 files`.

Exercise - add2.py

Function Stack

Heap

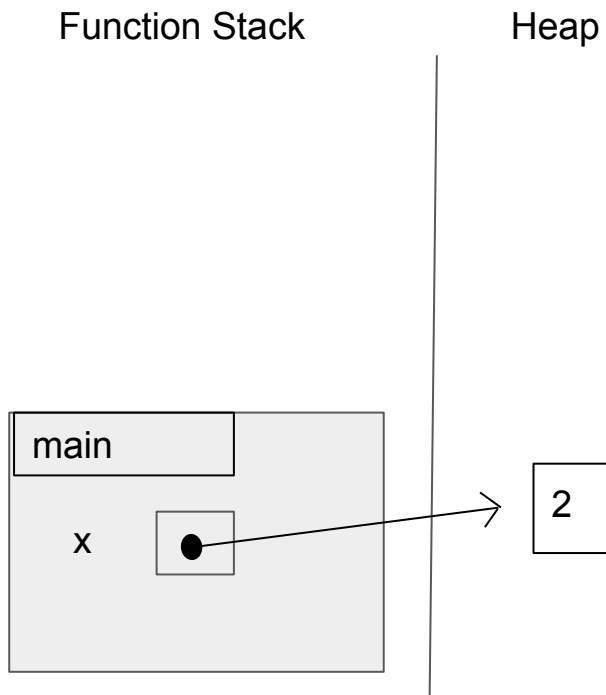


A screenshot of the Atom code editor. The title bar shows the file path: `add2.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom`. The menu bar includes `File`, `Edit`, `View`, `Selection`, `Find`, `Packages`, and `Help`. The tab bar shows several open files: `add.py`, `add2.py` (selected), `add3.py`, `tip.py`, and `fancify.py`. The code editor displays the following Python code:

```
1  """
2  A program that adds two numbers using a function
3  """
4
5  def add(x,y):
6      print(x, y)
7      return x + y
8
9  def main():
10     x = 2
11     x = add(x, x)
12     print(x)
13
14  main()
15
```

The line `def main():` on line 9 is highlighted with a red rectangular box. The status bar at the bottom shows `add2.py 15:1`, `LF`, `O`, `UTF-8`, `Python`, and `0 files`.

Exercise - add2.py



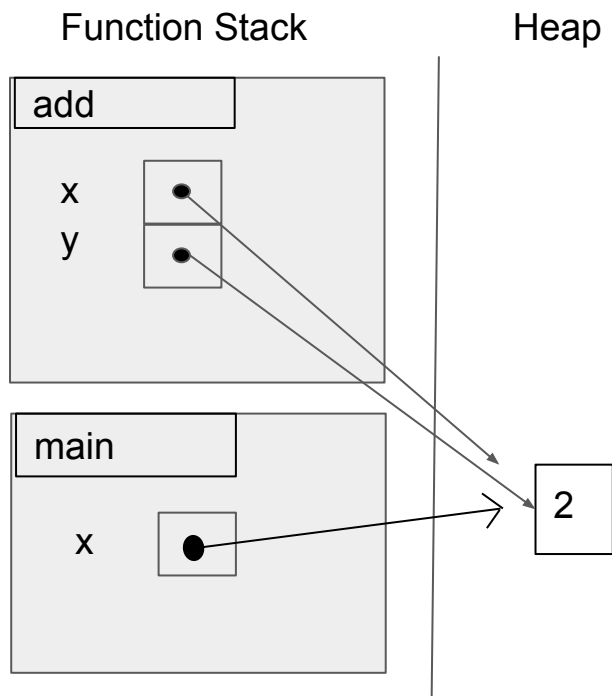
```
add2.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom
File Edit View Selection Find Packages Help

add.py | add2.py | add3.py | tip.py | fancify.py

1  """
2  A program that adds two numbers using a function
3  """
4
5  def add(x,y):
6      print(x, y)
7      return x + y
8
9  def main():
10     x = 2
11     x = add(x, x)
12     print(x)
13
14     main()
15
```

add2.py 15:1 LF O UTF-8 Python 0 files

Exercise - add2.py



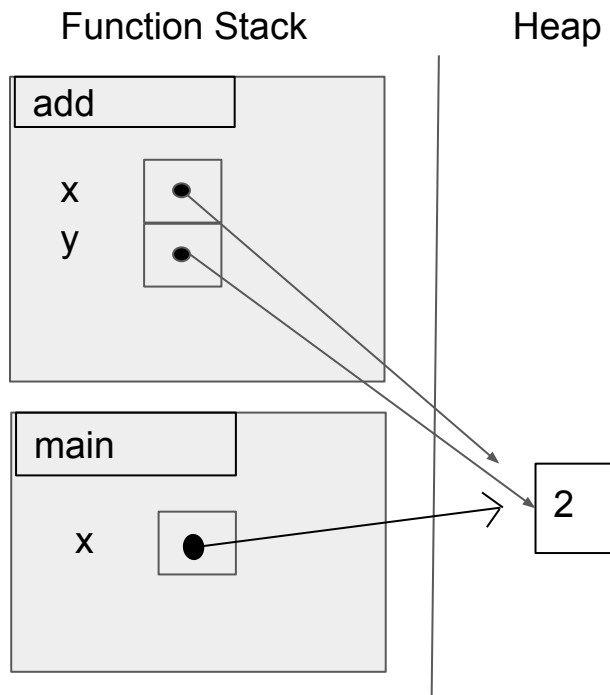
```
add2.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom
File Edit View Selection Find Packages Help

add.py | add2.py | add3.py | tip.py | fancify.py

1 """
2 A program that adds two numbers using a function
3 """
4
5 def add(x,y):
6     print(x, y)
7     return x + y
8
9 def main():
10     x = 2
11     x = add(x, x)
12     print(x)
13
14 main()
15
```

add2.py 15:1 LF O UTF-8 Python 0 files

Exercise - add2.py



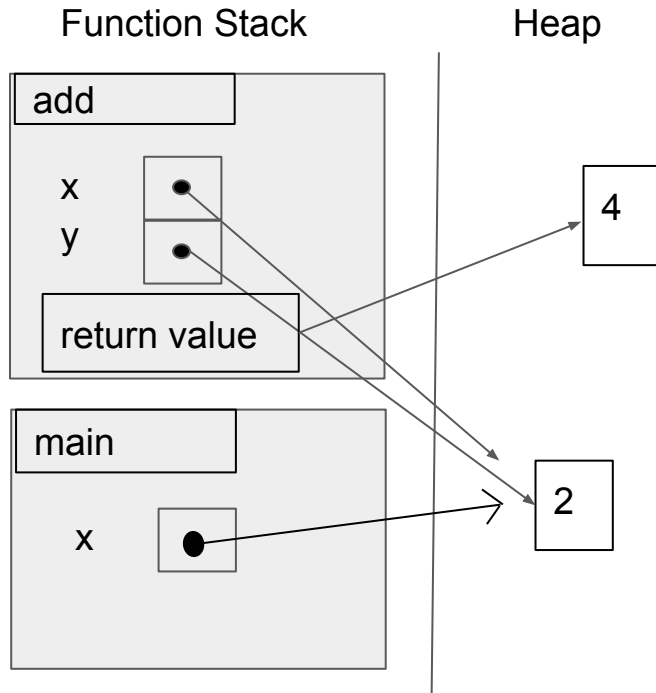
```
add2.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom
File Edit View Selection Find Packages Help

add.py | add2.py | add3.py | tip.py | fancify.py

1 """
2 A program that adds two numbers using a function
3 """
4
5 def add(x,y):
6     print(x, y)
7     return x + y
8
9 def main():
10     x = 2
11     x = add(x, x)
12     print(x)
13
14 main()
15
```

add2.py 15:1 LF O UTF-8 Python 0 files

Exercise - add2.py

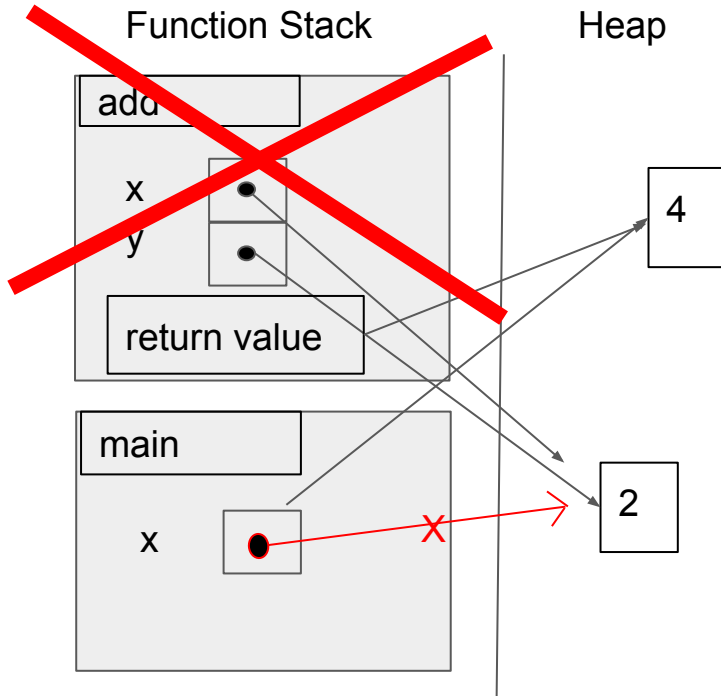


```
add2.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom
File Edit View Selection Find Packages Help
add.py add2.py add3.py tip.py fancify.py

1 """
2 A program that adds two numbers using a function
3 """
4
5 def add(x,y):
6     print(x, y)
7     return x + y
8
9 def main():
10     x = 2
11     x = add(x, x)
12     print(x)
13
14 main()
15
```

add2.py 15:1 LF O UTF-8 Python 0 files

Exercise - add2.py



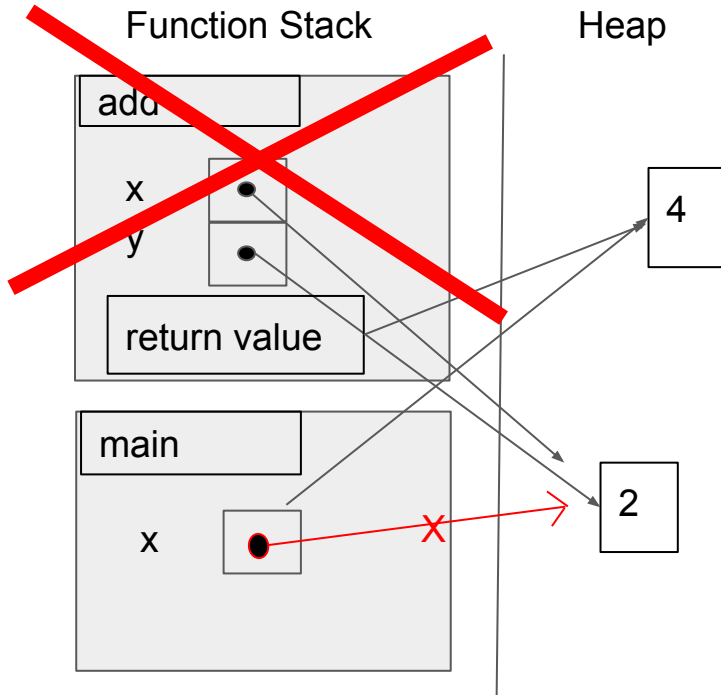
```
add2.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom
File Edit View Selection Find Packages Help

add.py | add2.py | add3.py | tip.py | fancify.py

1 """
2 A program that adds two numbers using a function
3 """
4
5 def add(x,y):
6     print(x, y)
7     return x + y
8
9 def main():
10     x = 2
11     x = add(x, x)
12     print(x)
13
14 main()
15
```

add2.py 15:1 LF O UTF-8 Python 0 files

Exercise - add2.py



```
add2.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom
File Edit View Selection Find Packages Help

add.py | add2.py | add3.py | tip.py | fancify.py

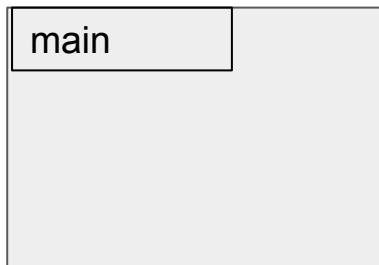
1 """
2 A program that adds two numbers using a function
3 """
4
5 def add(x,y):
6     print(x, y)
7     return x + y
8
9 def main():
10     x = 2
11     x = add(x, x)
12     print(x)
13
14 main()
15
```

add2.py 15:1 LF O UTF-8 Python 0 files

Exercise - add3.py

Function Stack

Heap

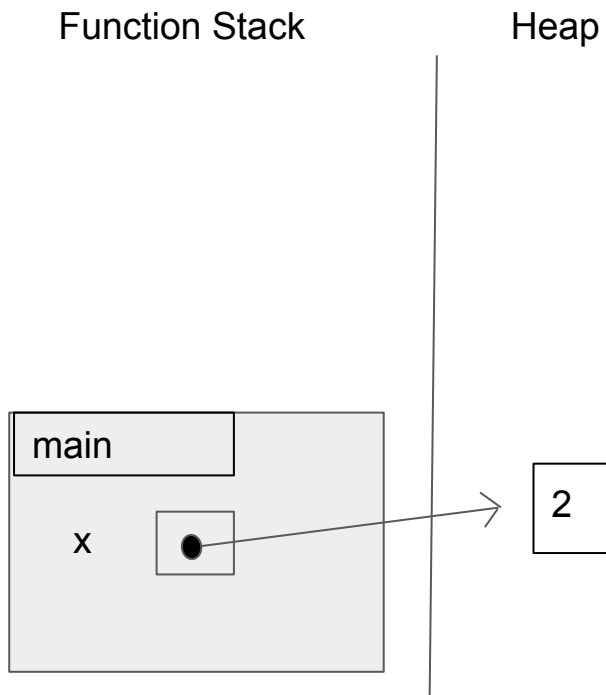


A screenshot of the Atom code editor. The title bar shows the file path: `add3.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom`. The menu bar includes File, Edit, View, Selection, Find, Packages, and Help. The tab bar shows several files: `add.py`, `add2.py`, `add3.py` (selected), `tip.py`, `fancify.py`, and `addVal.py`. The code editor displays the following Python code:

```
1 """
2 A program that adds two numbers using a function
3 """
4
5 def add(x,y):
6     x = 10
7     print(x, y)
8     return x + y
9
10 def main():
11     x = 2
12     out = add(x, x)
13     print(x, out)
14
15 main()
16
```

The code block for `def main():` (lines 10-13) is highlighted with a red rectangle. The status bar at the bottom shows `add3.py 8:9`, `LF N UTF-8 Python`, and `0 files`.

Exercise - add3.py



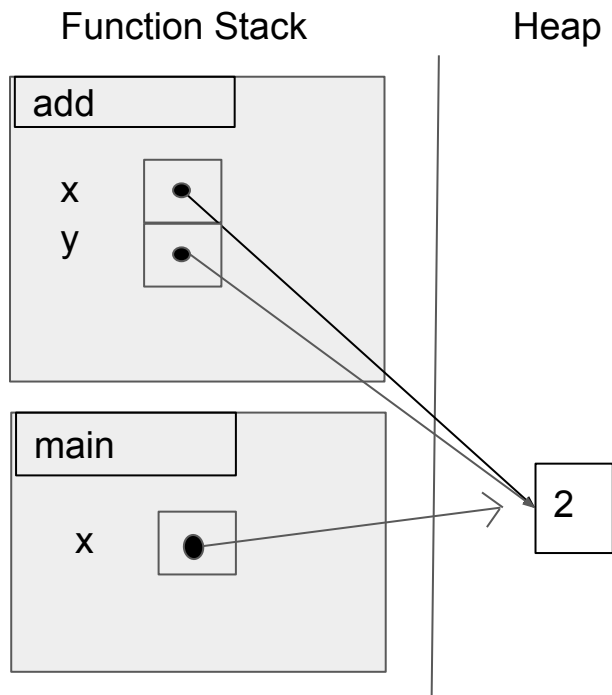
```
add3.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom
File Edit View Selection Find Packages Help

add.py  add2.py  add3.py  tip.py  fancify.py  addVal.py

1  """
2  A program that adds two numbers using a function
3  """
4
5  def add(x,y):
6      x = 10
7      print(x, y)
8      return x + y
9
10 def main():
11     x = 2
12     out = add(x, x)
13     print(x, out)
14
15 main()
16

add3.py  8:9  LF  N  UTF-8  Python  0 files
```

Exercise - add3.py



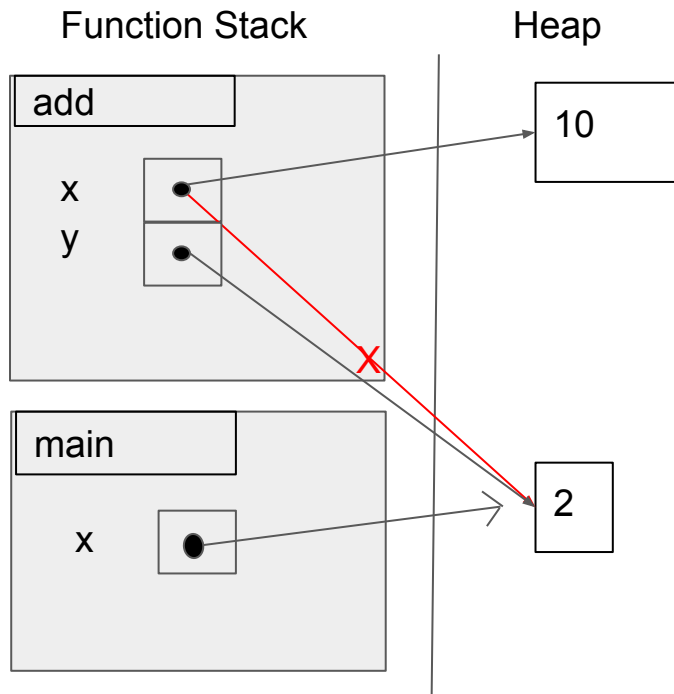
```
add3.py -- ~/CS21/cs21-devel/examples/inclass/w05 -- Atom
File Edit View Selection Find Packages Help

add.py  add2.py  add3.py  tip.py  fancify.py  addVal.py

1  """
2  A program that adds two numbers using a function
3  """
4
5  def add(x,y):
6      x = 10
7      print(x, y)
8      return x + y
9
10 def main():
11     x = 2
12     out = add(x, x)
13     print(x, out)
14
15 main()
16
```

add3.py 8:9 LF N UTF-8 Python 0 files

Exercise - add3.py



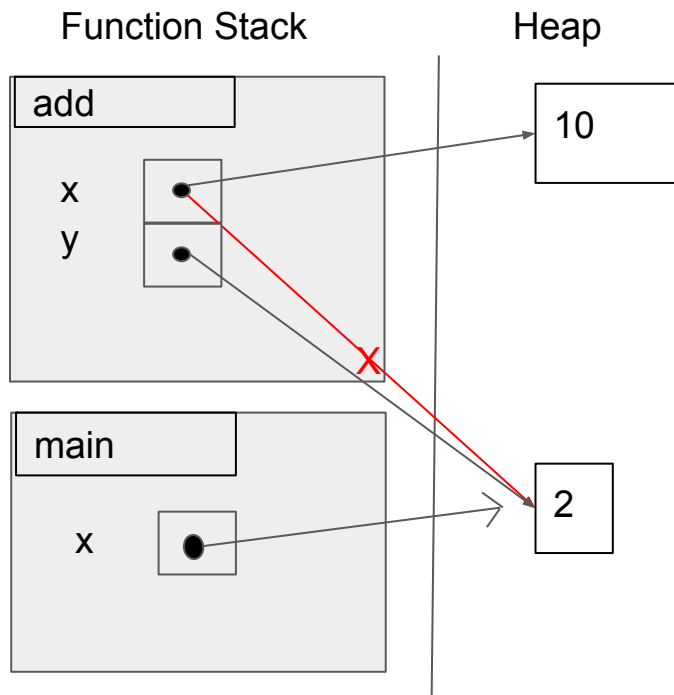
```
add3.py -- ~/CS21/cs21-devel/examples/inclass/w05 -- Atom
File Edit View Selection Find Packages Help

add.py  add2.py  add3.py  tip.py  fancify.py  addVal.py

1  """
2  A program that adds two numbers using a function
3  """
4
5  def add(x, y):
6      x = 10
7      print(x, y)
8      return x + y
9
10 def main():
11     x = 2
12     out = add(x, x)
13     print(x, out)
14
15 main()
16
```

add3.py 8:9 LF N UTF-8 Python 0 files

Exercise - add3.py



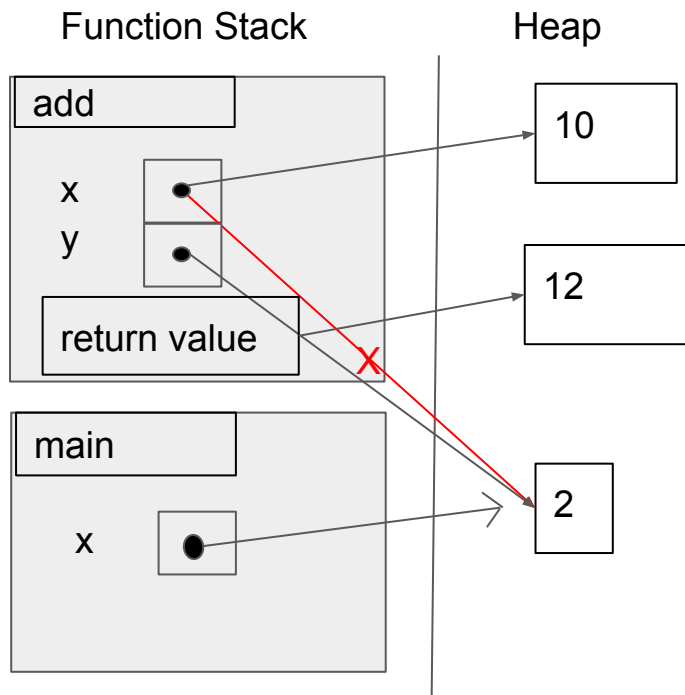
```
add3.py -- ~/CS21/cs21-devel/examples/inclass/w05 -- Atom
File Edit View Selection Find Packages Help

add.py  add2.py  add3.py  tip.py  fancify.py  addVal.py

1  """
2  A program that adds two numbers using a function
3  """
4
5  def add(x,y):
6      x = 10
7      print(x, y)
8      return x + y
9
10 def main():
11     x = 2
12     out = add(x, x)
13     print(x, out)
14
15 main()
16

add3.py  8:9  LF  N  UTF-8  Python  0 files
```

Exercise - add3.py



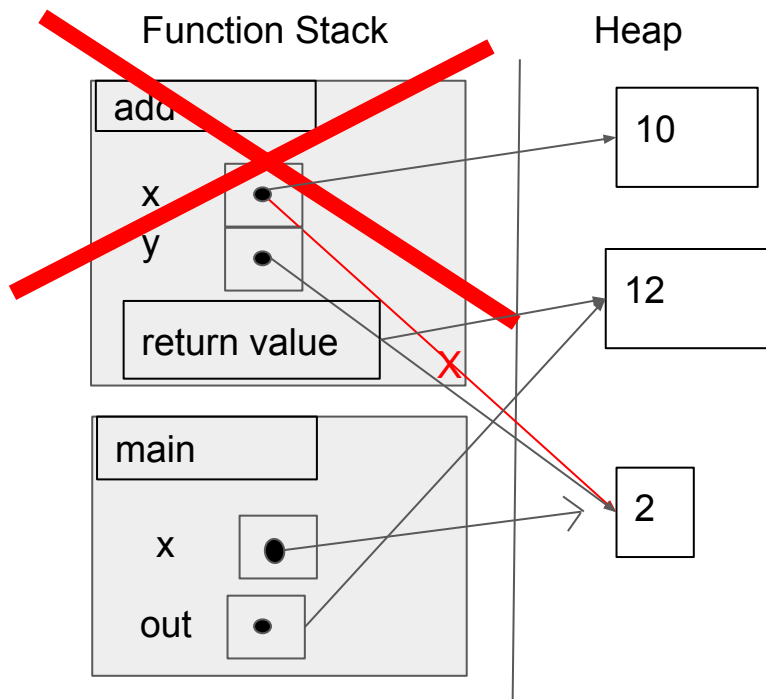
```
add3.py -- ~/CS21/cs21-devel/examples/inclass/w05 -- Atom
File Edit View Selection Find Packages Help

add.py  add2.py  add3.py  tip.py  fancify.py  addVal.py

1  """
2  A program that adds two numbers using a function
3  """
4
5  def add(x,y):
6      x = 10
7      print(x, y)
8      return x + y
9
10 def main():
11     x = 2
12     out = add(x, x)
13     print(x, out)
14
15 main()
16

add3.py  8:9  LF  N  UTF-8  Python  0 files
```

Exercise - add3.py



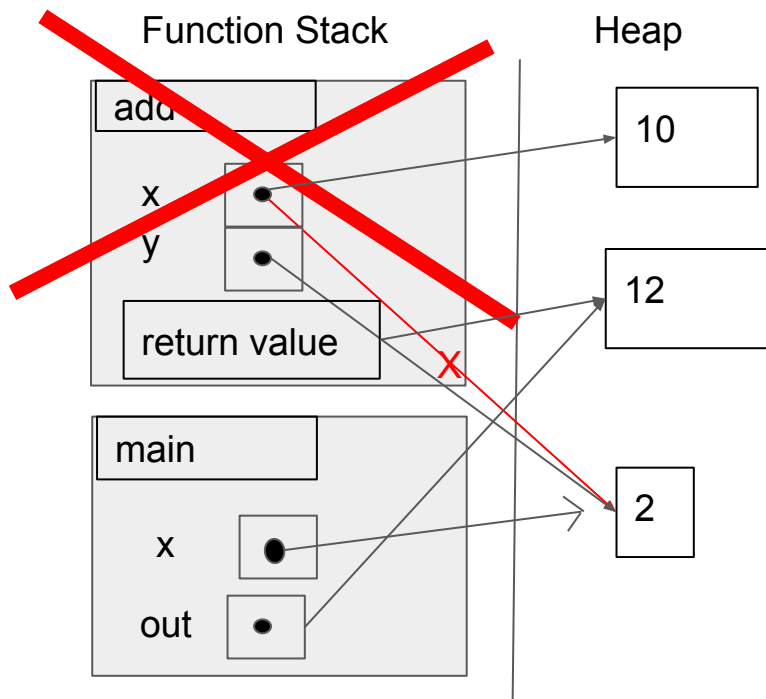
```
add3.py -- ~/CS21/cs21-devel/examples/inclass/w05 -- Atom
File Edit View Selection Find Packages Help

add.py  add2.py  add3.py  tip.py  fancify.py  addVal.py

1  """
2  A program that adds two numbers using a function
3  """
4
5  def add(x,y):
6      x = 10
7      print(x, y)
8      return x + y
9
10 def main():
11     x = 2
12     out = add(x, x)
13     print(x, out)
14
15 main()
16
```

Note that x has the same value in main() after add() returns!

Exercise - add3.py



The screenshot shows the `add3.py` file open in the Atom text editor. The code is as follows:

```
1 """  
2 A program that adds two numbers using a function  
3 """  
4  
5 def add(x,y):  
6     x = 10  
7     print(x, y)  
8     return x + y  
9  
10 def main():  
11     x = 2  
12     out = add(x, x)  
13     print(x, out)  
14  
15 main()  
16
```

A red rectangle highlights the lines `13 print(x, out)` and `14` in the `main` function.

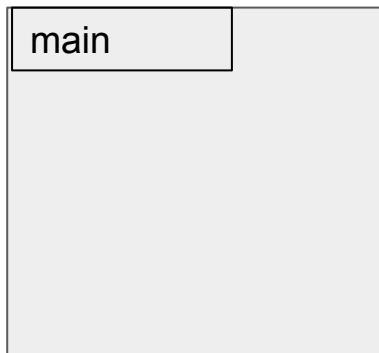
At the bottom of the editor window, the status bar shows: `add3.py 8:9`, `LF N UTF-8 Python`, and `0 files`.

Note that x has the same value in `main()` after `add()` returns!

Exercise - tip.py

Function Stack

Heap



A screenshot of the Atom code editor. The title bar shows the file path: `tip.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom`. The editor has several tabs: `add.py`, `add2.py`, `add3.py`, `tip.py` (selected), and `fancify.py`. The code in `tip.py` is as follows:

```
1 """
2 A program that computes the total cost with tip using a function
3 """
4
5 def compute_total(amount, tip_percent):
6     tip = amount * tip_percent
7     total = amount + tip
8     return total
9
10 def main():
11     cost = float(input("Enter the cost: "))
12     percent = 0.1
13     total_cost = compute_total(cost, percent)
14     print("The total cost is", total_cost)
15
16 main()
17
```

The `def main():` line (line 10) is highlighted with a red rectangular box. The status bar at the bottom shows `tip.py 12:18`, `LF`, `N`, `UTF-8`, `Python`, and `0 files`.

Exercise - tip.py

Function Stack

Heap



tip.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom

File Edit View Selection Find Packages Help

add.py add2.py add3.py tip.py fancify.py

```
1 """
2 A program that computes the total cost with tip using a function
3 """
4
5 def compute_total(amount, tip_percent):
6     tip = amount * tip_percent
7     total = amount + tip
8     return total
9
10 def main():
11     cost = float(input("Enter the cost: "))
12     percent = 0.1
13     total_cost = compute_total(cost, percent)
14     print("The total cost is", total_cost)
15
16 main()
17
```

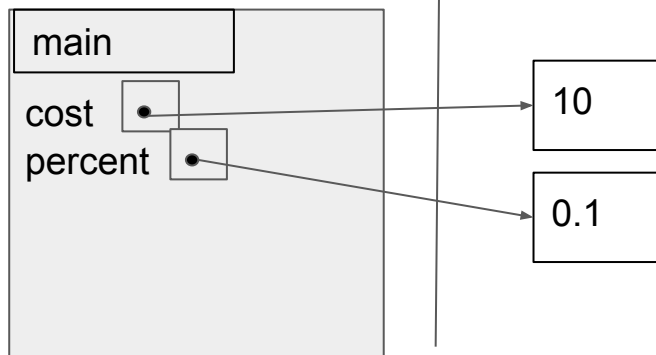
Assume cost = 10

tip.py 12:18 LF N UTF-8 Python 0 files

Exercise - tip.py

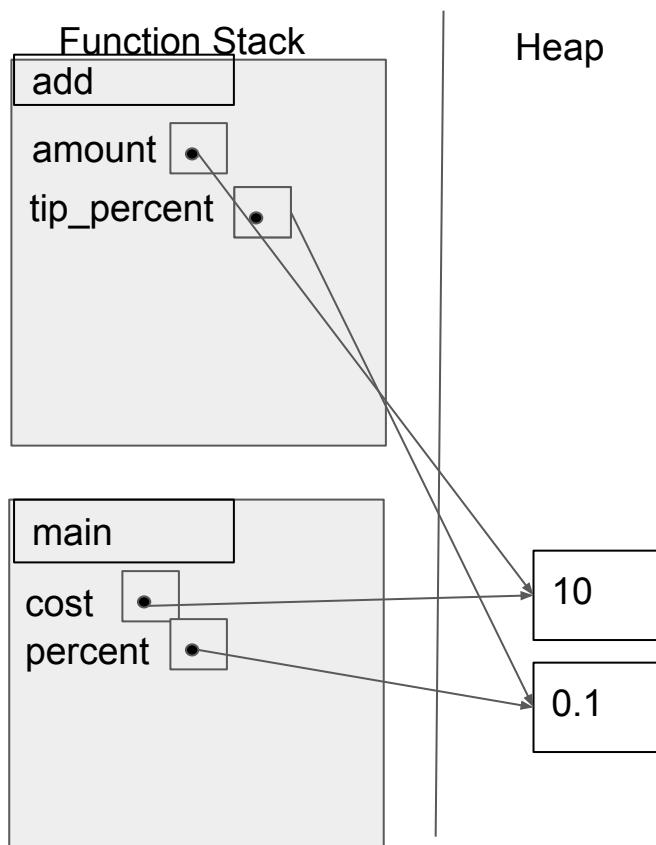
Function Stack

Heap



```
tip.py — ~/CS21/cs21-devel/examples/inclass/w05 — Atom
File Edit View Selection Find Packages Help
add.py add2.py add3.py tip.py fancify.py
1 """
2 A program that computes the total cost with tip using a function
3 """
4
5 def compute_total(amount, tip_percent):
6     tip = amount * tip_percent
7     total = amount + tip
8     return total
9
10 def main():
11     cost = float(input("Enter the cost: "))
12     percent = 0.1
13     total_cost = compute_total(cost, percent)
14     print("The total cost is", total_cost)
15
16 main()
17
```

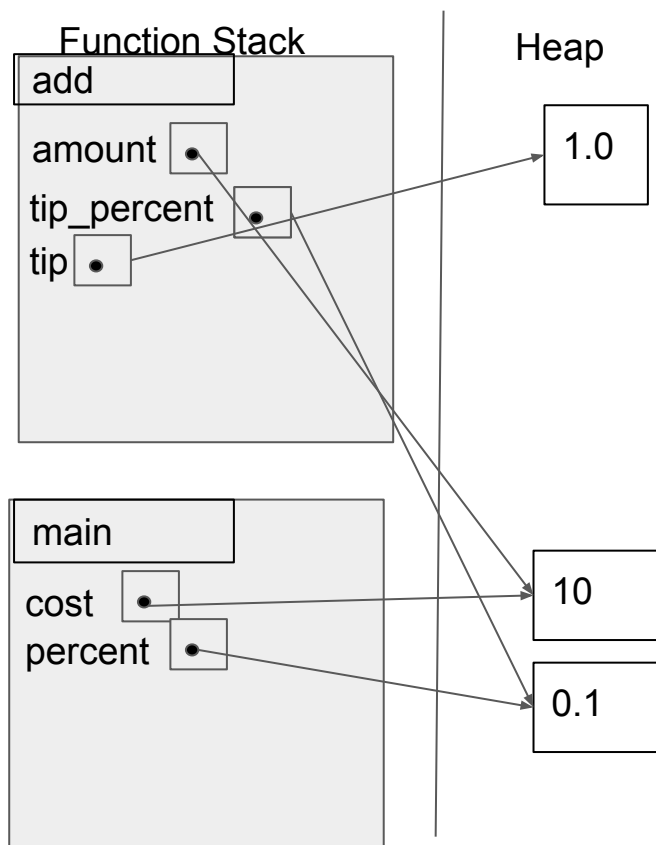
Exercise - tip.py



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Exercise - tip.py



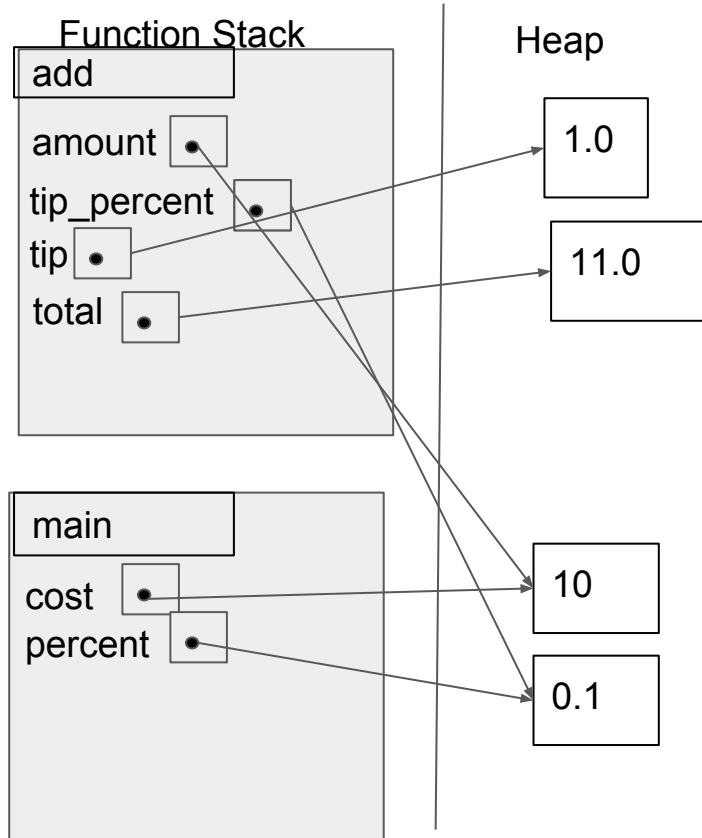
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Exercise - tip.py



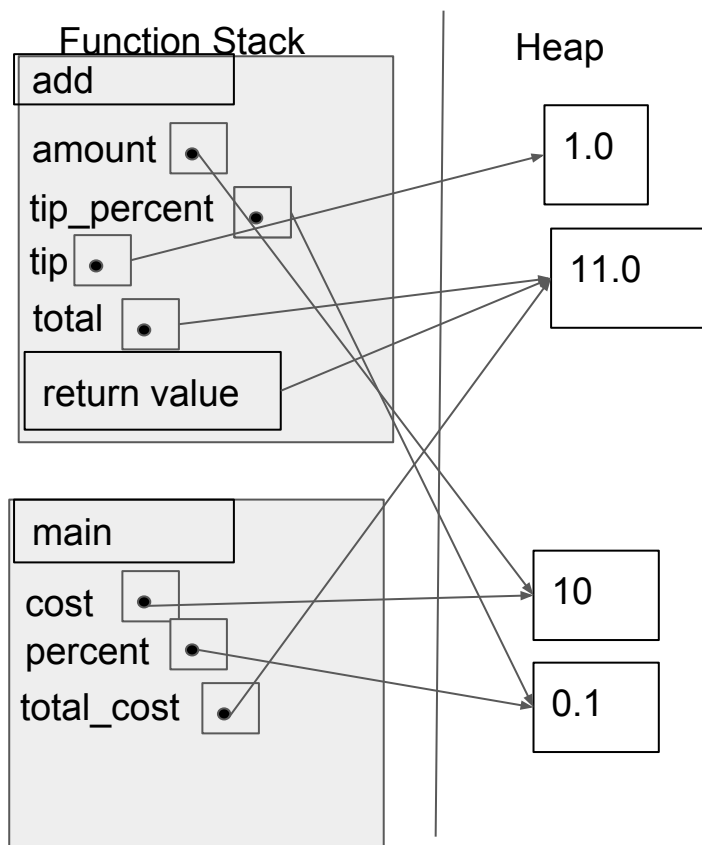
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Exercise - tip.py



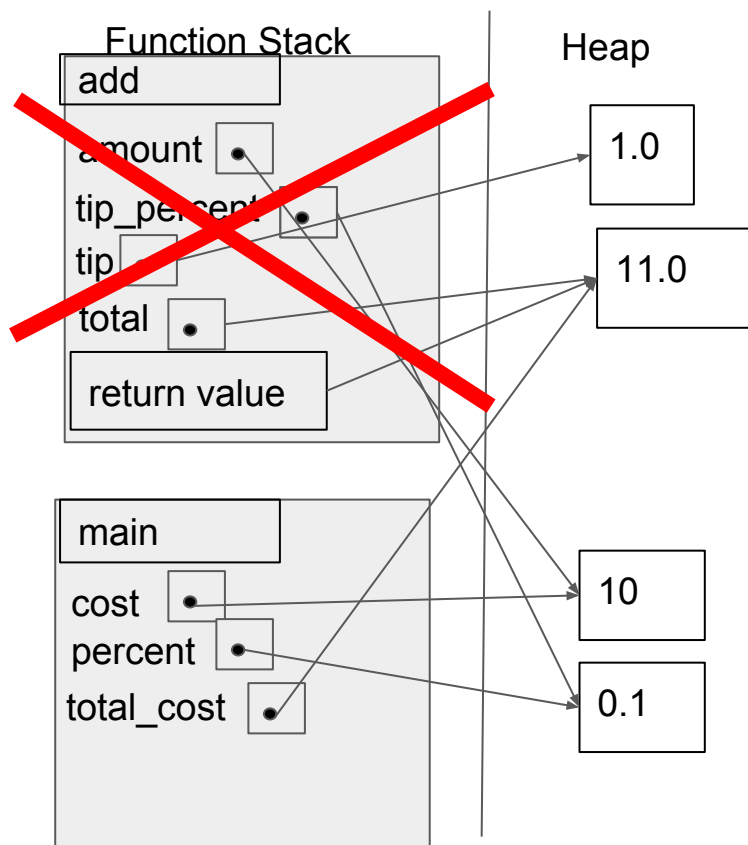
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Exercise - tip.py



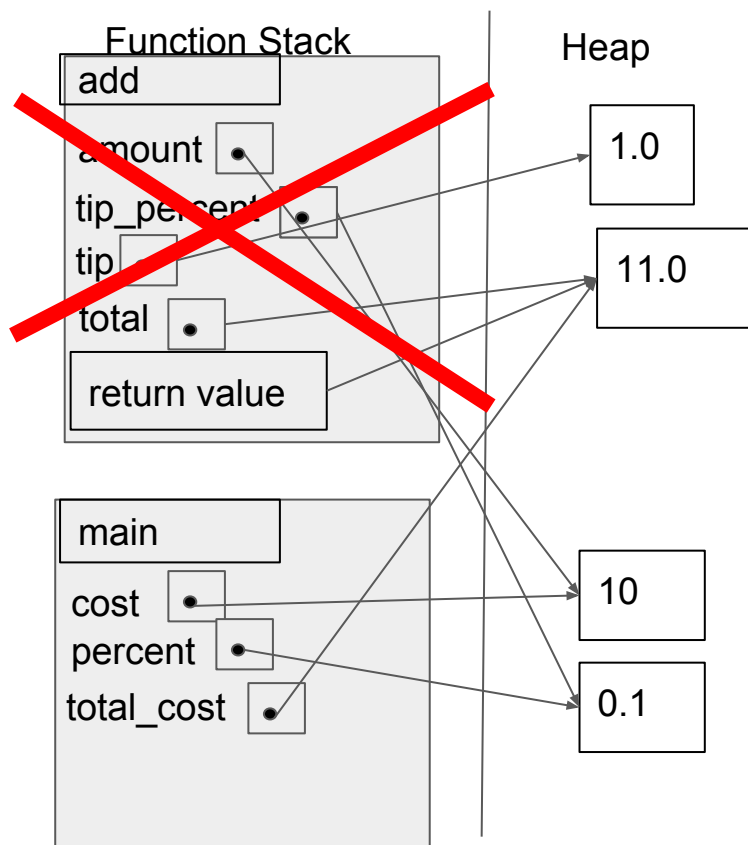
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