



Accelerating Information Technology Innovation

<http://aiti.mit.edu>

Kenya Summer 2011
Lecture 05 – Functions

Weather forecast in Nairobi

Saturday  21°C

Sunday  19°C

Monday  23°C

Tuesday  26°C

...

$$f = \frac{9}{5} c + 32$$

Temperature in Fahrenheit

Temperature in Celsius

Converting Celsius to Fahrenheit

$$f = \frac{9}{5} c + 32$$

```
tempC = 21
tempF = ((9.0 / 5.0) * tempC) + 32.0
print 'Saturday:', tempF, 'F'
```

Saturday: 69.80000000000001 F

But we want the whole forecast, not just one day

```
temp_sat_C = 21 # Saturday's forecast in C
temp_sun_C = 19 # Sunday's forecast in C
temp_mon_C = 23 # Monday's forecast in C
temp_tues_C = 26 # Tuesday's forecast in C...
```

Converting Celsius to Fahrenheit

```
temp_sat_C = 21 # Saturday's forecast in C
temp_sun_C = 19 # Sunday's forecast in C
temp_mon_C = 23 # Monday's forecast in C
...
temp_sat_F = ((9.0 / 5.0) * temp_sat_C) + 32.0
print 'Saturday:', temp_sat_F, 'F'
temp_sun_F = ((9.0 / 5.0) * temp_sun_C) + 32.0
print 'Sunday:', temp_sun_F, 'F'
temp_mon_F = ((9.9 / 5.0) * temp_mon_C) + 33.0
print 'Monday:', temp_mon_F, 'F'
...
```

Repetitive!

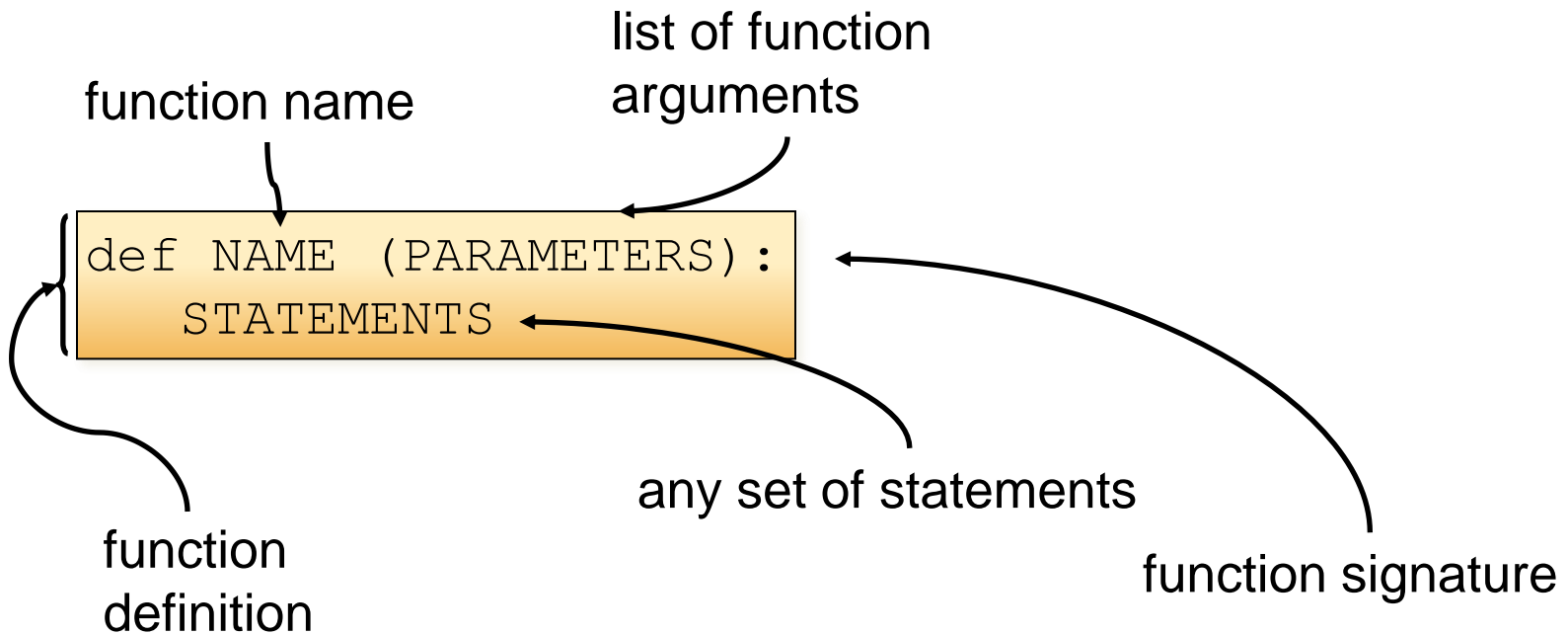
Easy to make mistakes

What if we want to spell out 'Fahrenheit'
instead of 'F'?
Must change everywhere!

Functions

Functions

- A **function** is a sequence of statements that has been given a name.



Defining a function

function name,
follows same naming
rules as variables

name for each parameter

```
def print_as_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    print f, 'F'
```

function body

Calling a function

c starts with the same initial value as temp_sat_C had

```
def print_as_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```

function call

argument passed into function

Flow of execution

```
def print_as_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```

Program execution always starts at the first line that is **not** a statement inside a function

Flow of execution

```
def print_as_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    print f, 'F'
```

```
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```

Function calls are like
detours in the execution flow.

Flow of execution

```
def print_as_fahrenheit(c):  
    f = (9.0 / 5.0) * c + 32.0  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```

Flow of execution

```
def print_as_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    print f, 'F'  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```

69.800000000000001 F

Flow of execution

```
def print_as_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```



69.800000000000001 F

Different numbers of parameters

```
def print_as_fahrenheit (c, day):  
    f = ((9.0 / 5.0) * c) + 32.0  
    print day + ':', f, 'F'
```

```
print_as_fahrenheit(21, 'Saturday')
```

```
Saturday: 69.800000000000001 F
```

```
def print_forecast_intro():  
    print 'Welcome to your weather forecast!'
```

```
print_forecast_intro()
```

```
Welcome to your weather forecast!
```

Different numbers of parameters

```
def print_as_fahrenheit (c, day):  
    f = ((9.0 / 5.0) * c) + 32.0  
    print day + ':', f, 'F'
```

- What happens here?

```
print_as_fahrenheit(21)
```

`TypeError: print_as_fahrenheit() takes exactly 2 arguments (1 given)`

```
print_as_fahrenheit(21, 'Saturday', 'Sunday')
```

`TypeError: print_as_fahrenheit() takes exactly 2 arguments (3 given)`

```
print_as_fahrenheit('Saturday', 21)
```

`TypeError: can't multiply sequence by non-int of type 'float'`

Returning a value

```
def convert_to_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    return f
```

return statement

```
return EXPRESSION
```

A return statement ends
the function immediately.

any expression, or nothing

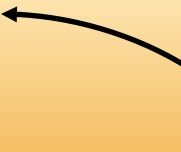
What is the output here?

```
def convert_to_fahrenheit(c):  
    print 'Celsius:' + c  
    f = ((9.0 / 5.0) * c) + 32.0  
    return f  
    print 'Fahrenheit:' + f  
  
convert_to_fahrenheit(27)
```

Celsius: 27

More than one return statement

```
def absolute_value(c):  
    if c < 0:  
        return -c  
    else:  
        return c
```



If c is negative, the function returns here.

More than one return statement

```
def absolute_value(c):  
    if c < 0:  
        return -c  
    return c
```

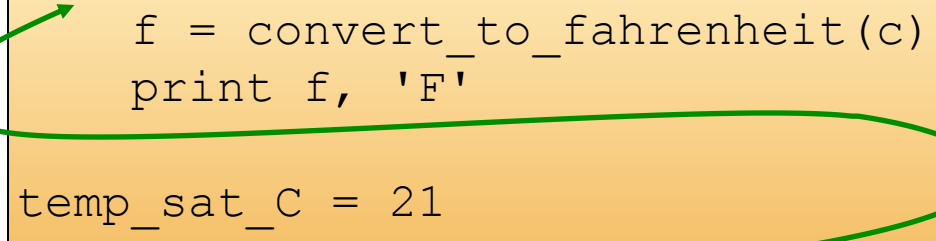
Good rule: Every path through the function must have a return statement. If you don't add one, Python will add one for you that returns nothing (the value None).

Functions can call functions

```
def convert_to_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    return f  
  
def print_as_fahrenheit(c):  
    f = convert_to_fahrenheit(c)  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```

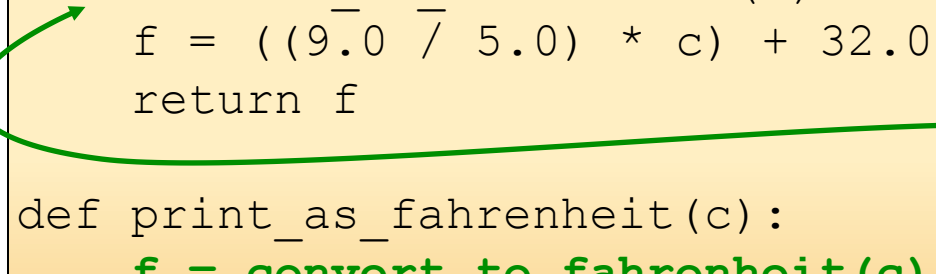
Functions can call functions

```
def convert_to_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    return f  
  
def print_as_fahrenheit(c):  
    f = convert_to_fahrenheit(c)  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```



Functions can call functions

```
def convert_to_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    return f  
  
def print_as_fahrenheit(c):  
    f = convert_to_fahrenheit(c)  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```

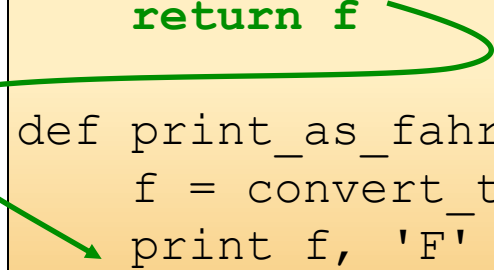


Functions can call functions

```
def convert_to_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    return f  
  
def print_as_fahrenheit(c):  
    f = convert_to_fahrenheit(c)  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```

Functions can call functions

```
def convert_to_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    return f  
  
def print_as_fahrenheit(c):  
    f = convert_to_fahrenheit(c)  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```

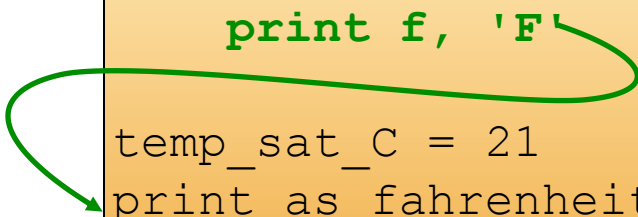
A diagram consisting of two green arrows. The first arrow starts at the `return f` line in the `convert_to_fahrenheit` function and points to the `f = convert_to_fahrenheit(c)` line in the `print_as_fahrenheit` function. The second arrow starts at the `print f, 'F'` line in the `print_as_fahrenheit` function and points back to the `return f` line in the `convert_to_fahrenheit` function, illustrating the return value being passed back to the caller.

Functions can call functions

```
def convert_to_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    return f
```

```
def print_as_fahrenheit(c):  
    f = convert_to_fahrenheit(c)  
    print f, 'F'
```

```
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```



Functions can call functions

```
def convert_to_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    return f  
  
def print_as_fahrenheit(c):  
    f = convert_to_fahrenheit(c)  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```



80.6 F

What is wrong here?

this function has to be defined before it is called

```
temp_sat_C = 21
print_as_fahrenheit(temp_sat_C)

def print_as_fahrenheit(c):
    f = convert_to_fahrenheit(c)
    print f, 'F'

def convert_to_fahrenheit(c):
    f = ((9.0 / 5.0) * c) + 32.0
    return f
```

NameError: name
'print_as_fahrenheit'
is not defined

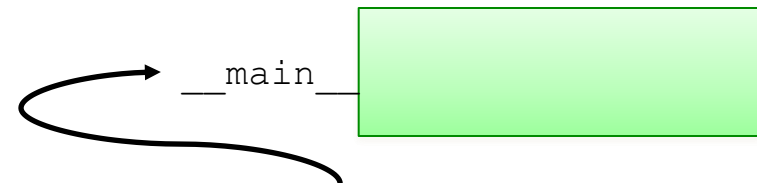
what about this one?

The two functions are in the same level. Therefore, one function can call the other functions even if it is defined after the calling function.

Scoping in functions

- A **stack diagram** keeps track of where each variable is defined, and its value.

```
def convert_to_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    return f  
  
def print_as_fahrenheit(c):  
    f = convert_to_fahrenheit(c)  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```

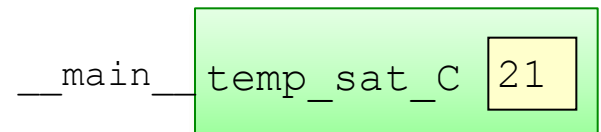


Each function call gets its own **stack frame**.

Scoping in functions

- A **stack diagram** keeps track of where each variable is defined, and its value.

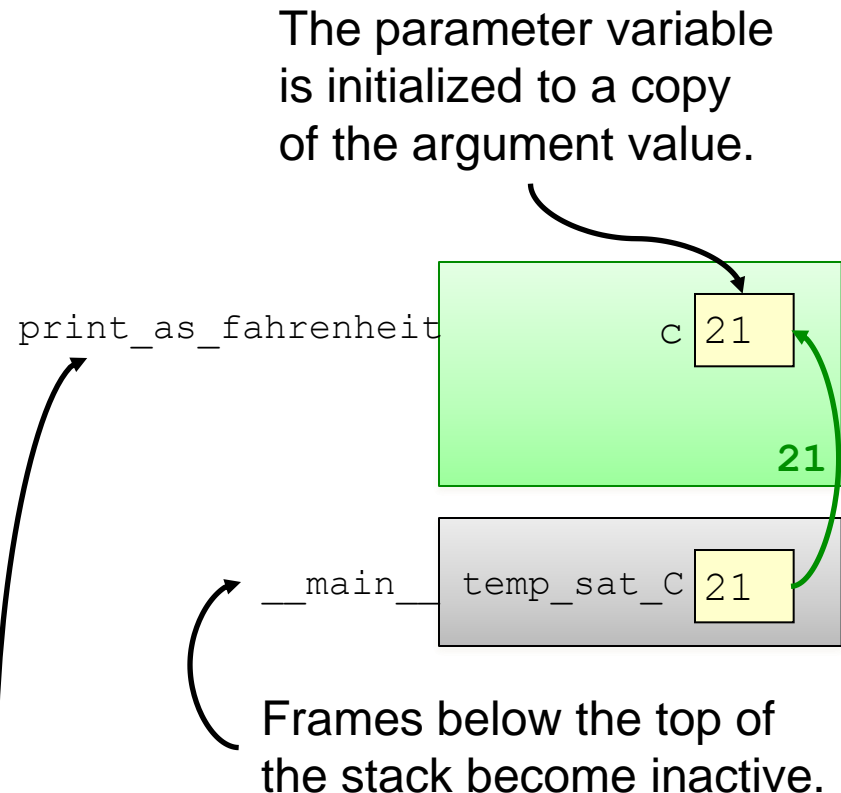
```
def convert_to_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    return f  
  
def print_as_fahrenheit(c):  
    f = convert_to_fahrenheit(c)  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```



Scoping in functions

- A **stack diagram** keeps track of where each variable is defined, and its value.

```
def convert_to_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    return f  
  
def print_as_fahrenheit(c):  
    f = convert_to_fahrenheit(c)  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```



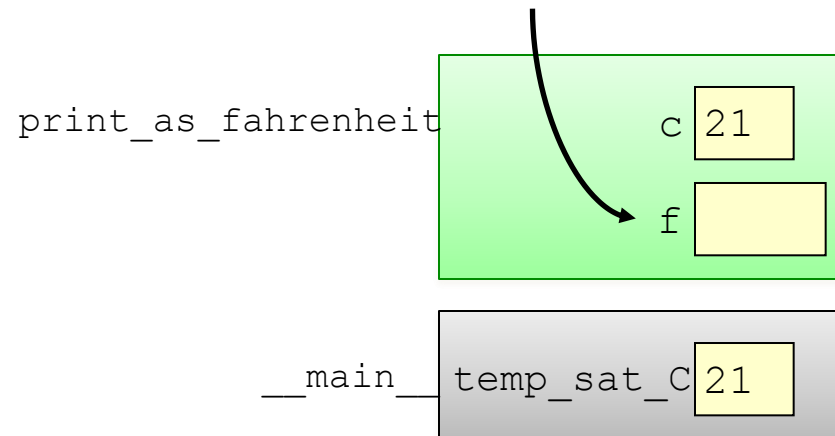
A new frame is added to the top of stack.

Scoping in functions

- A **stack diagram** keeps track of where each variable is defined, and its value.

```
def convert_to_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    return f  
  
def print_as_fahrenheit(c):  
    f = convert_to_fahrenheit(c)  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```

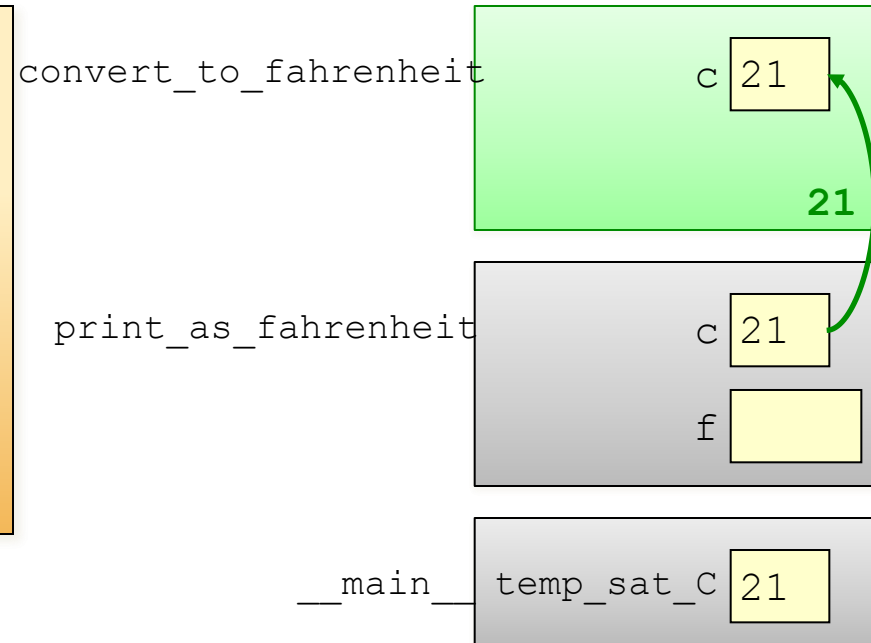
Variables defined inside the function are called **local variables**.



Scoping in functions

- A **stack diagram** keeps track of where each variable is defined, and its value.

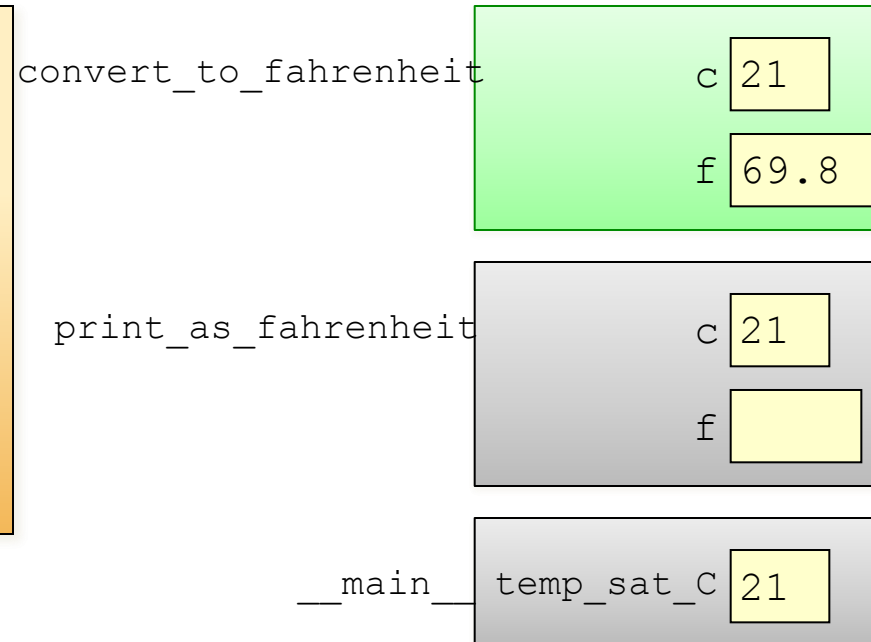
```
def convert_to_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    return f  
  
def print_as_fahrenheit(c):  
    f = convert_to_fahrenheit(c)  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```



Scoping in functions

- A **stack diagram** keeps track of where each variable is defined, and its value.

```
def convert_to_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    return f  
  
def print_as_fahrenheit(c):  
    f = convert_to_fahrenheit(c)  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```

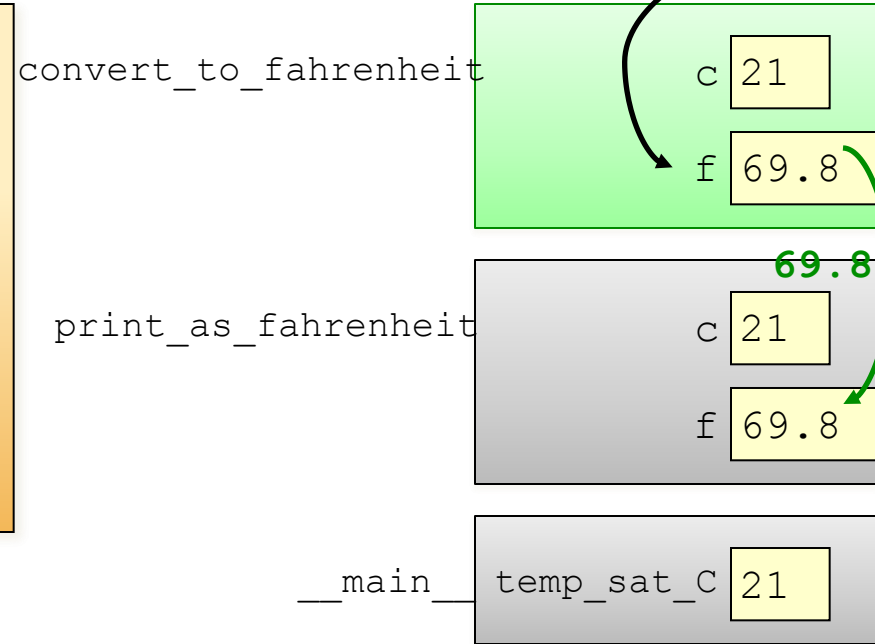


Scoping in functions

The return value is passed back to the function's caller.

- A **stack diagram** keeps track of where each variable is defined, and its value.

```
def convert_to_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    return f  
  
def print_as_fahrenheit(c):  
    f = convert_to_fahrenheit(c)  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```

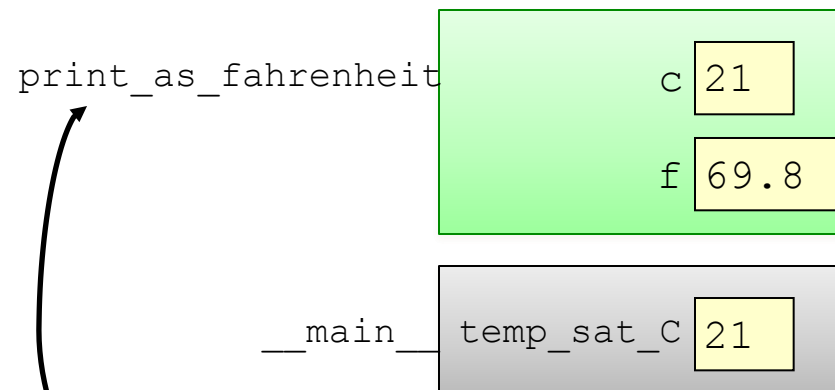


Scoping in functions

- A **stack diagram** keeps track of where each variable is defined, and its value.

```
def convert_to_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    return f  
  
def print_as_fahrenheit(c):  
    f = convert_to_fahrenheit(c)  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```

When a function returns,
its stack frame is
popped off the stack.

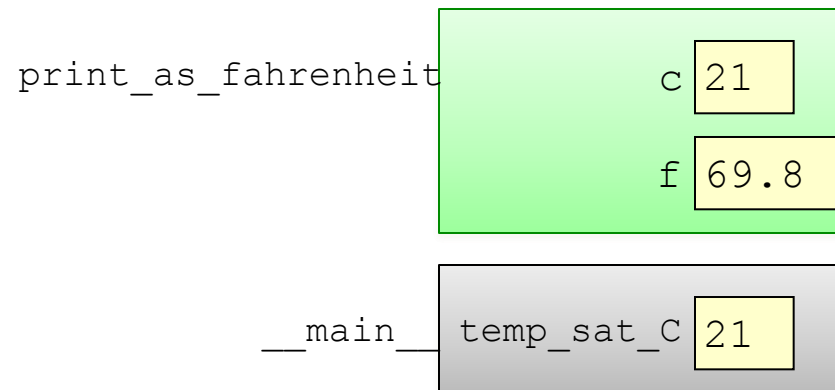


The stack frame for
the calling function
is now active again.

Scoping in functions

- A **stack diagram** keeps track of where each variable is defined, and its value.

```
def convert_to_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    return f  
  
def print_as_fahrenheit(c):  
    f = convert_to_fahrenheit(c)  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```

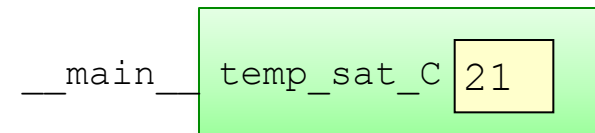


69.8 F

Scoping in functions

- A **stack diagram** keeps track of where each variable is defined, and its value.

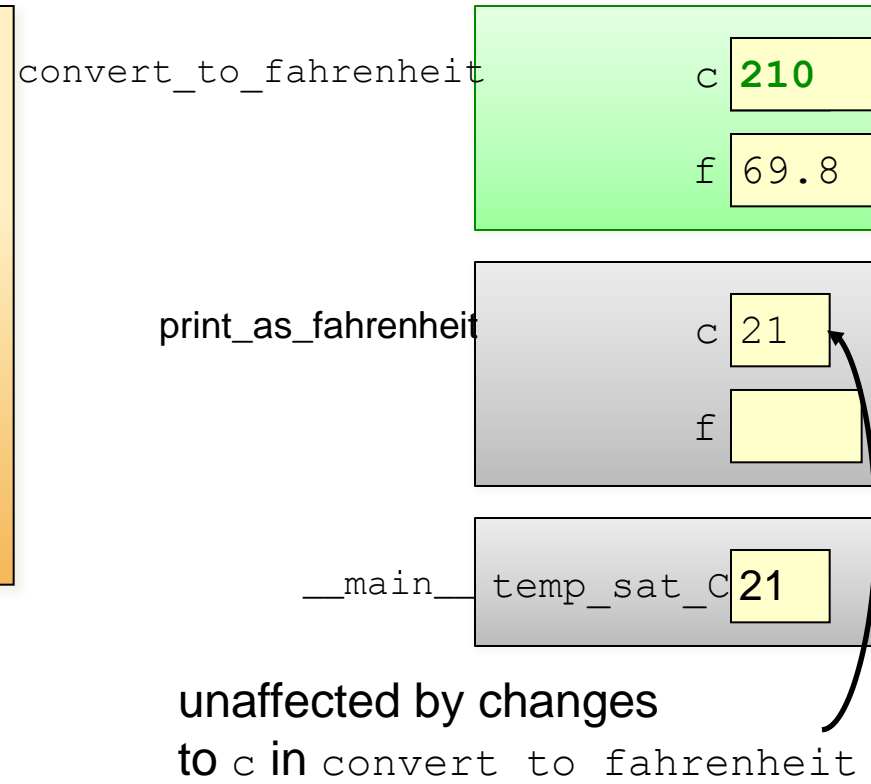
```
def convert_to_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    return f  
  
def print_as_fahrenheit(c):  
    f = convert_to_fahrenheit(c)  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```



Tricky issues with scoping

- Changes to a variable in the current scope do not affect variables in other scopes.

```
def convert_to_fahrenheit(c):  
    f = ((9.0 / 5.0) * c) + 32.0  
    c = c * 10  
    return f  
  
def print_as_fahrenheit(c):  
    f = convert_to_fahrenheit(c)  
    print f, 'F'  
  
temp_sat_C = 21  
print_as_fahrenheit(temp_sat_C)
```



Why use functions?

- **Generalization:** the same code can be used more than once, with parameters to allow for differences.

BEFORE

```
temp_sat_F = ((9.0 / 5.0) * 21) + 32.0
print 'Saturday:', temp_sat_F, 'F'

temp_sun_F = ((9.0 / 5.0) * 19) + 32.0
print 'Sunday:', temp_sun_F, 'F'

temp_mon_F = ((9.9 / 5.0) * 23) + 33.0
print 'Monday:', temp_mon_F, 'F'
```

Would not have made this typo.

AFTER

```
def print_as_fahrenheit(c, day):
    f = ((9.0 / 5.0) * c) + 32.0
    print day + ':', f, 'F'

print_as_fahrenheit(21, 'Saturday')
print_as_fahrenheit(19, 'Sunday')
print_as_fahrenheit(23, 'Monday')
```

Only type these lines once.

Why use functions?

- **Maintenance:** much easier to make changes.

BEFORE

```
temp_sat_F = ((9.0 / 5.0) * 21) + 32.0
print 'Saturday:', temp_sat_F, 'F'

temp_sun_F = ((9.0 / 5.0) * 19) + 32.0
print 'Sunday:', temp_sun_F, 'F'

temp_mon_F = ((9.9 / 5.0) * 23) + 33.0
print 'Monday:', temp_mon_F, 'F'
```

AFTER

```
def print_as_fahrenheit(c, day):
    f = ((9.0 / 5.0) * c) + 32.0
    print day + ':', f, 'F'

print_as_fahrenheit(21, 'Saturday')
print_as_fahrenheit(19, 'Sunday')
print_as_fahrenheit(23, 'Monday')
```

Can change to
"Fahrenheit" with
only one change.

Why use functions?

- **Encapsulation:** much easier to read and debug!

BEFORE

```
temp_sat_F = ((9.0 / 5.0) * 21) + 32.0
print 'Saturday:', temp_sat_F, 'F'

temp_sun_F = ((9.0 / 5.0) * 19) + 32.0
print 'Sunday:', temp_sun_F, 'F'

temp_mon_F = ((9.9 / 5.0) * 23) + 33.0
print 'Monday:', temp_mon_F, 'F'
```

What are we doing here?

Oh, printing as Fahrenheit!

AFTER

```
def print_as_fahrenheit(c, day):
    f = ((9.0 / 5.0) * c) + 32.0
    print day + ':', f, 'F'

print_as_fahrenheit(21, 'Saturday')
print_as_fahrenheit(19, 'Sunday')
print_as_fahrenheit(23, 'Monday')
```