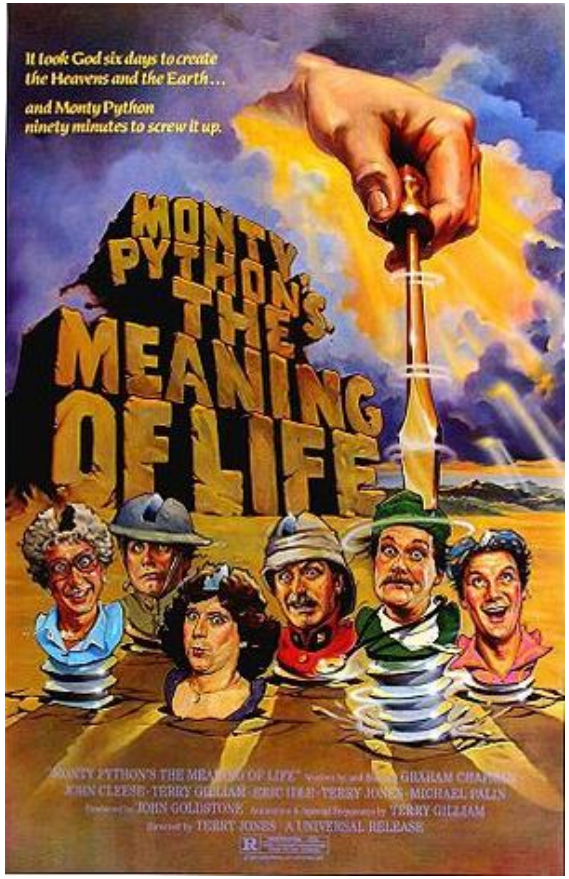
Functional Programming

- Functions are objects
- Lambda notation
- Functional programming
- Closure, map, filter, reduce



function definition

IMPERATIVE

```
function factI (n)
  local accumulator = 1
  for i = 1,n do
    accum = accumulator*i
  end
  return accum
end
```

Variable

trace of execution

factI(4) =
accumulator = 1
i = 1 accumulator = 1 * 1
i = 2 accumulator = 1 * 2
i = 3 accumulator = 2 * 3
i = 4 accumulator = 6 * 4
return 24

function definition

FUNCTIONAL

```
function factR (n)
  if n == 1 then
    return 1
  else
    return n*factR(n-1)
  end
end
```

No variables
Just param...
use recursion 4 loops

trace of execution

```
factR(4) =
4 * factR(3) =
      3 * factR(2) =
            2 * factR(1) =
                  1
            1
      2
6
24
```

Functions are first-class objects

Functions can be used as any other data type, eg:

- Arguments to function
- Return values of functions
- Assigned to variables
- Parts of tuples, lists, etc

```
>>> def square(x): return x*x
>>> def applier(q, x): return q(x)
>>> applier(square, 7)
49
```

Lambda Notation

Python's lambda creates anonymous functions

```
>>> lambda x: x + 1
<function <lambda> at 0x1004e6ed8>
>>> f = lambda x: x + 1
>>> f
<function <lambda> at 0x1004e6f50>
>>> f(100)
101
```

Lambda Notation

Be careful with the syntax

```
>>> f = lambda x,y: 2 * x + y
>>> f
<function <lambda> at 0x87d30>
>>> f(3, 4)
10
>>> v = lambda x: x*x(100)
>>> v
<function <lambda> at 0x87df0>
>>> v = (lambda x: x*x)(100)
>>> v
10000
```

Lambda Notation Limitations

- Note: only **one** expression in the lambda body; Its value is always returned
- The lambda expression must fit on one line!
- Lambda will probably be deprecated in future versions of python

  Guido is not a lambda fanboy

Functional programming

- Python supports functional programming idioms
- Built-ins for map, reduce, filter, closures, continuations, etc.
- These are often used with lambda

Example: composition

```
>>> def square(x):
        return x*x
>>> def twice(f):
        return lambda x: f(f(x))
>>> twice
<function twice at 0x87db0>
>>> quad = twice(square)
>>> quad
<function <lambda> at 0x87d30>
>>> quad(5)
625
```

Example: closure

```
>>> def counter(start=0, step=1):
        x = [start]
        def _inc():
            x[0] += step
            return x[0]
        return _inc
>>> c1 = counter()
>>> c2 = counter(100, -10)
>>> c1()
1
>>> c2()
90
```

map

```
>>> def add1(x): return x+1
>>> map(add1, [1,2,3,4])
[2, 3, 4, 5]
>>> map(lambda x: x+1, [1,2,3,4])
[2, 3, 4, 5]
>>> map(+, [1,2,3,4], [100,200,300,400])
map(+,[1,2,3,4],[100,200,300,400])
          ^
SyntaxError: invalid syntax
```

Example

```
>>> sentence = 'It is raining cats and dogs'
>>> words = sentence.split()
>>> print (words)
['It', 'is', 'raining', 'cats', 'and', 'dogs']

>>> lengths = map(lambda word: len(word), words)
>>> print (lengths)
[2, 2, 7, 4, 3, 4]
```

map

- + is an operator, not a function
- We can define a corresponding add function

```
>>> def add(x, y): return x+y
>>> map(add,[1,2,3,4],[100,200,300,400])
[101, 202, 303, 404]
```

- Or import the operator module

```
>>> from operator import *
>>> map(add, [1,2,3,4], [100,200,300,400])
[101, 202, 303, 404]
>>> map(sub, [1,2,3,4], [100,200,300,400])
[-99, -198, -297, -396]
```

filter function

- filter offers an elegant way to filter out all the elements of a list.
- In `filter(f,l)`
  - the 1st argument is a function f that returns a Boolean value, i.e. either True or False.
  - This function is applied to every element of the list *l*.
  - Only if f returns True will the element of the list be included in the result list.

filter function

```
>>> filter(odd, [1,2,3,4])
[1, 3]

>>> fib = [0,1,1,2,3,5,8,13,21,34,55]
>>> result = filter(lambda x: x % 2, fib)
>>> print (result)
[1, 1, 3, 5, 13, 21, 55]
>>> result = filter(lambda x: x % 2 == 0, fib)
>>> print result
[0, 2, 8, 34]
```

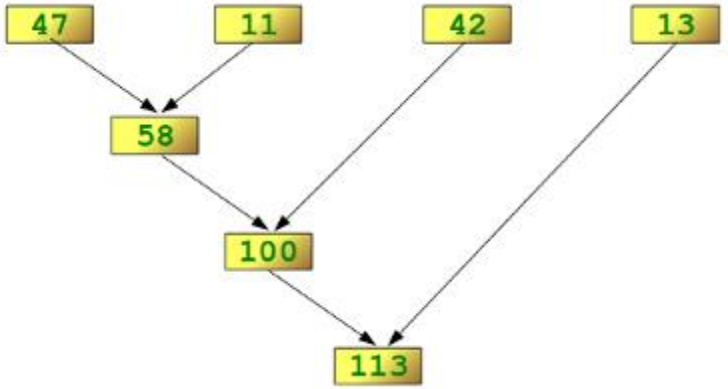
reduce function

- `reduce(func, seq)` continually applies the function `func()` to the sequence `seq`. It returns a single value.
- If seq = [s_1, s_2, s_3, ... , s_n], calling `reduce(func, seq)` works like this:
  - At first, the first two elements of `seq` will be applied to `func`, i.e. `func(s1,s2)`
  - The list on which `reduce()` works looks now like this: [func(s_1, s_2), s_3, ... , s_n]
- In the next step `func` will be applied on the previous result and the third element of the list, i.e. `func(func(s1, s2),s3)`
  - The list looks like this now: `[ func(func(s1, s2),s3), ... , sn ]`
- Continue like this until just one element is left and return this element as the result of `reduce()`

Illustration

```
>>> reduce(lambda x,y: x+y, [47,11,42,13])
113
```

- The following diagram shows the intermediate steps of the calculation:



reduce example

- Determining the maximum of a list of numerical values by using reduce:

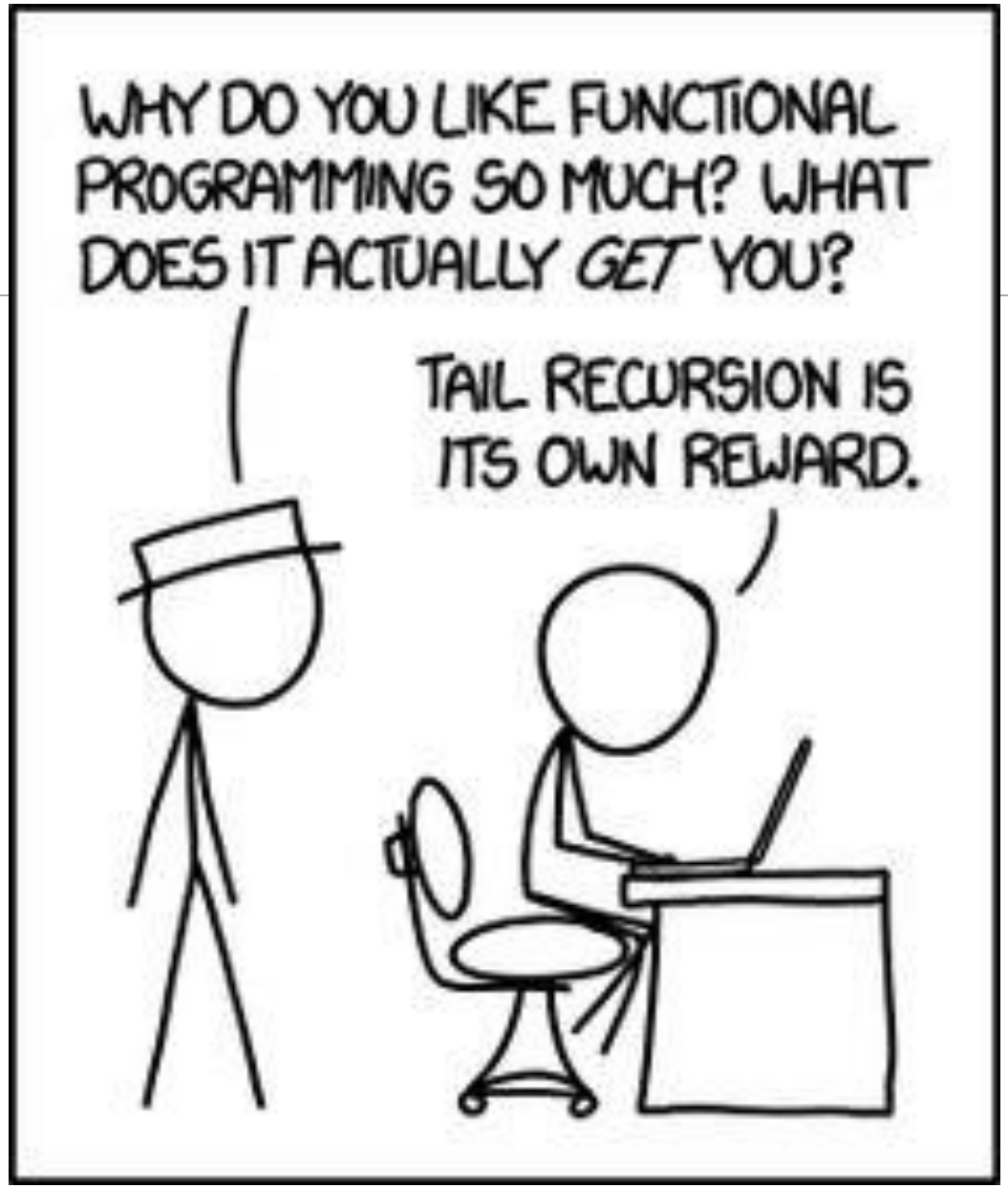
```
>>> f = lambda a,b: a if (a > b) else b
>>> reduce(f, [47,11,42,102,13])
102
>>>
```

- Calculating the sum of the numbers from 1 to 100:

```
>>> reduce(lambda x, y: x+y,range(1,101))
5050
```

filter, reduce

- The map, filter and reduce functions are also at risk of being dropped.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TAIL RECURSION IS ITS OWN REWARD.