CS61A Lecture 15

Amir Kamil

UC Berkeley

February 25, 2013

Announcements

- HW5 due on Wednesday
- Trends project out
  - Partners are required; find one in lab or on Piazza
  - Will not work in IDLE
  - New bug submission policy; see Piazza

The Sequence Abstraction

red, orange, yellow, green, blue, indigo, violet.

0 , 1 , 2 , 3 , 4 , 5 , 6 .

There isn't just one sequence type (in Python or in general)

This abstraction is a collection of behaviors:

Length. A sequence has a finite length.

Element selection. A sequence has an element corresponding to any non-negative integer index less than its length, starting at 0 for the first element.

The sequence abstraction is shared among several types, including tuples.

Recursive Lists

Constructor:

```
def rlist(first, rest):
    """Return a recursive list from its first element and
    the rest."""
```

Selectors:

```
def first(s):
    """Return the first element of recursive list s."""

def rest(s):
    """Return the remaining elements of recursive list s."""
```

Behavior condition(s):

If a recursive list **`s`** is constructed from a first element **`f`** and a recursive list **`r`**, then

- **`first(s)`** returns **`f`**, and
- **`rest(s)`** returns **`r`**, which is a recursive list.

Implementing Recursive Lists Using Pairs

1 , 2 , 3 , 4

A recursive list is a pair

tuple | tuple | tuple | tuple

0: 1, 1: → | 0: 2, 1: → | 0: 3, 1: → | 0: 4, 1: None

None represents the empty list

The first element of the pair is the first element of the list

The second element of the pair is the rest of the list

Example: http://goo.gl/fVhbF

Implementing the Sequence Abstraction

Implementing the Sequence Abstraction

Length. A sequence has a finite length.

Element selection. A sequence has an element corresponding to any non-negative integer index less than its length, starting at 0 for the first element.

Implementing the Sequence Abstraction

```
def len_rlist(s):
    """Return the length of recursive list s."""
    if s == empty_rlist:
        return 0
    return 1 + len_rlist(rest(s))
```

Length. A sequence has a finite length.

Element selection. A sequence has an element corresponding to any non-negative integer index less than its length, starting at 0 for the first element.

Implementing the Sequence Abstraction

```
def len_rlist(s):
    """Return the length of recursive list s."""
    if s == empty_rlist:
        return 0
    return 1 + len_rlist(rest(s))

def getitem_rlist(s, i):
    """Return the element at index i of recursive list s."""
    if i == 0:
        return first(s)
    return getitem_rlist(rest(s), i - 1)
```

Length. A sequence has a finite length.

Element selection. A sequence has an element corresponding to any non-negative integer index less than its length, starting at 0 for the first element.

Python Sequence Abstraction

Python Sequence Abstraction

Built-in sequence types provide the following behavior

Python Sequence Abstraction

Built-in sequence types provide the following behavior

Type-specific constructor	`>>> a = (1, 2, 3)` `>>> b = tuple([4, 5, 6, 7])`
Length	`>>> len(a), len(b)` `(3, 4)`
Element selection	`>>> a[1], b[-1]` `(2, 7)`
Slicing	`>>> a[1:3], b[1:1], a[:2], b[1:]` `((2, 3), (), (1, 2), (5, 6, 7))`
Membership	`>>> 2 in a, 4 in a, 4 not in b` `(True, False, False)`

Python Sequence Abstraction

Built-in sequence types provide the following behavior

Type-specific constructor	`>>> a = (1, 2, 3)` `>>> b = tuple([4, 5, 6, 7])`
Length	`>>> len(a), len(b)` `(3, 4)`
Element selection	`>>> a[1], b[-1]` `(2, 7)`
Slicing	`>>> a[1:3], b[1:1], a[:2], b[1:]` `((2, 3), (), (1, 2), (5, 6, 7))`
Membership	`>>> 2 in a, 4 in a, 4 not in b` `(True, False, False)`

A list; more on this later

Python Sequence Abstraction

Built-in sequence types provide the following behavior

Type-specific constructor	`>>> a = (1, 2, 3)` `>>> b = tuple([4, 5, 6, 7])`
Length	`>>> len(a), len(b)` `(3, 4)`
Element selection	`>>> a[1], b[-1]` `(2, 7)`
Slicing	`>>> a[1:3], b[1:1], a[:2], b[1:]` `((2, 3), (), (1, 2), (5, 6, 7))`
Membership	`>>> 2 in a, 4 in a, 4 not in b` `(True, False, False)`

A list; more on this later

Count from the end; -1 is last element

Sequence Iteration

Sequence Iteration

Python has a special statement for iterating over the elements in a sequence

Sequence Iteration

Python has a special statement for iterating over the elements in a sequence

```
def count(s, value):
    total = 0




    for elem in s:
        if elem == value:
            total += 1
    return total
```

Sequence Iteration

Python has a special statement for iterating over the elements in a sequence

```
def count(s, value):
    total = 0
    for elem in s:
        if elem == value:
            total += 1
    return total
```

Name bound in the first frame of the current environment

For Statement Execution Procedure

For Statement Execution Procedure

```
for <name> in <expression>:
    <suite>
```

For Statement Execution Procedure

```
for <name> in <expression>:
    <suite>
```

1. Evaluate the header `<expression>`, which must yield an iterable value.

For Statement Execution Procedure

```
for <name> in <expression>:
    <suite>
```

1. Evaluate the header `<expression>`, which must yield an iterable value.
2. For each element in that sequence, in order:
   A. Bind `<name>` to that element in the first frame of the current environment.
   B. Execute the `<suite>`.

Sequence Unpacking in For Statements

Sequence Unpacking in For Statements

```
>>> pairs = ((1, 2), (2, 2), (2, 3), (4, 4))

>>> same_count = 0
```

Sequence Unpacking in For Statements

A sequence of fixed-length sequences

```
>>> pairs = ((1, 2), (2, 2), (2, 3), (4, 4))

>>> same_count = 0
```

Sequence Unpacking in For Statements

A sequence of fixed-length sequences

```
>>> pairs = ((1, 2), (2, 2), (2, 3), (4, 4))

>>> same_count = 0

>>> for x, y in pairs:
        if x == y:
            same_count = same_count + 1

>>> same_count
2
```

Sequence Unpacking in For Statements

A sequence of fixed-length sequences

```
>>> pairs = ((1, 2), (2, 2), (2, 3), (4, 4))

>>> same_count = 0
```

A name for each element in a fixed-length sequence

```
>>> for x, y in pairs:
        if x == y:
            same_count = same_count + 1

>>> same_count
2
```

Sequence Unpacking in For Statements

A sequence of fixed-length sequences

```
>>> pairs = ((1, 2), (2, 2), (2, 3), (4, 4))

>>> same_count = 0
```

A name for each element in a fixed-length sequence

Each name is bound to a value, as in multiple assignment

```
>>> for x, y in pairs:
        if x == y:
            same_count = same_count + 1

>>> same_count
2
```

The Range Type

The Range Type

A range is a sequence of consecutive integers.*

The Range Type

A range is a sequence of consecutive integers.*

* Ranges can actually represent more general integer sequences.

The Range Type

A range is a sequence of consecutive integers.*

```
..., -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, ...
```

* Ranges can actually represent more general integer sequences.

The Range Type

A range is a sequence of consecutive integers.*

```
..., -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, ...
```

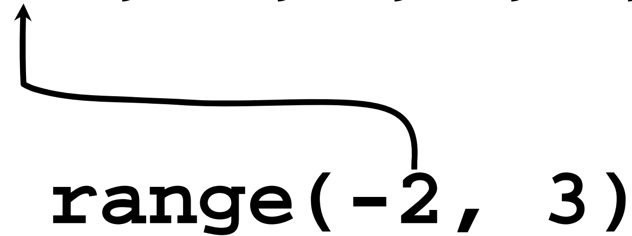
```
range(-2, 3)
```

* Ranges can actually represent more general integer sequences.

The Range Type

A range is a sequence of consecutive integers.*

```
..., -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, ...
```



```
range(-2, 3)
```

* Ranges can actually represent more general integer sequences.

The Range Type

A range is a sequence of consecutive integers.*

```
..., -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, ...
```

```
range(-2, 3)
```

* Ranges can actually represent more general integer sequences.

The Range Type

A range is a sequence of consecutive integers.*

```
..., -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, ...
```

```
range(-2, 3)
```

* Ranges can actually represent more general integer sequences.

The Range Type

A range is a sequence of consecutive integers.*

```
..., -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, ...
```

```
range(-2, 3)
```

Length: ending value - starting value

* Ranges can actually represent more general integer sequences.

The Range Type

A range is a sequence of consecutive integers.*

```
..., -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, ...
```

```
range(-2, 3)
```

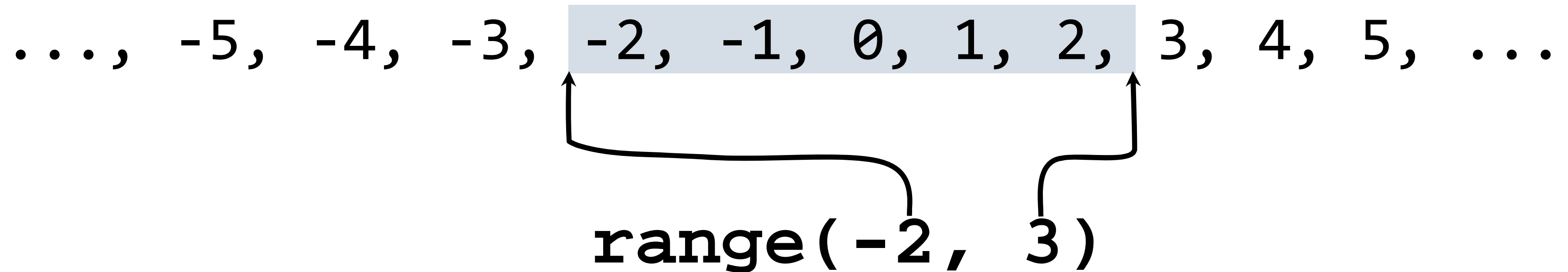
Length: ending value - starting value

Element selection: starting value + index

* Ranges can actually represent more general integer sequences.

The Range Type

A range is a sequence of consecutive integers.*



Length: ending value - starting value

Element selection: starting value + index

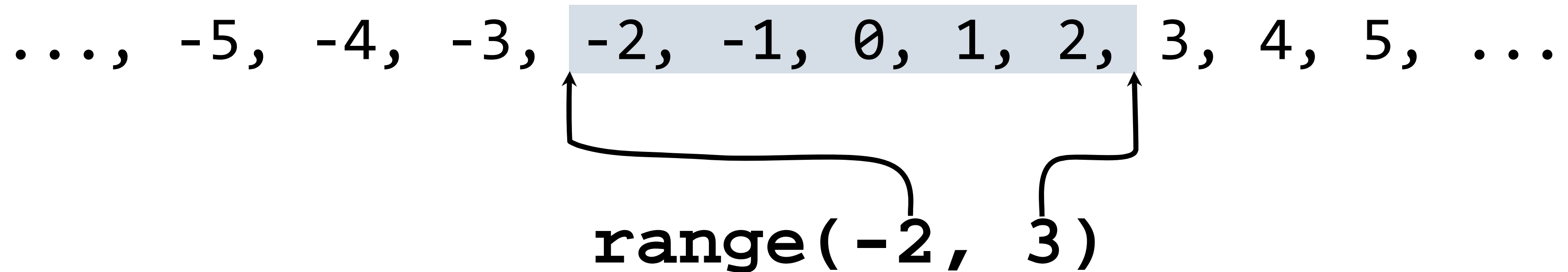
```
>>> tuple(range(-2, 3))
(-2, -1, 0, 1, 2)

>>> tuple(range(4))
(0, 1, 2, 3)
```

* Ranges can actually represent more general integer sequences.

The Range Type

A range is a sequence of consecutive integers.*



Length: ending value - starting value

Element selection: starting value + index

```
>>> tuple(range(-2, 3))
(-2, -1, 0, 1, 2)

>>> tuple(range(4))
(0, 1, 2, 3)
```

Tuple constructor

* Ranges can actually represent more general integer sequences.

The Range Type

A range is a sequence of consecutive integers.*

```
..., -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, ...
```

```
range(-2, 3)
```

Length: ending value - starting value

Element selection: starting value + index

```
>>> tuple(range(-2, 3))
(-2, -1, 0, 1, 2)
```

Tuple constructor

```
>>> tuple(range(4))
(0, 1, 2, 3)
```

With a 0 starting value

* Ranges can actually represent more general integer sequences.

String Literals

String Literals

```
>>> 'I am string!'
'I am string!'
>>> "I've got an apostrophe"
"I've got an apostrophe"
>>> '您好'
'您好'
```

String Literals

```
>>> 'I am string!'
'I am string!'
>>> "I've got an apostrophe"
"I've got an apostrophe"
>>> '您好'
'您好'
```

Single- and double-quoted strings are equivalent

String Literals

```
>>> 'I am string!'
'I am string!'
>>> "I've got an apostrophe"
"I've got an apostrophe"
>>> '您好'
'您好'
```

Single- and double-quoted strings are equivalent

```
>>> """The Zen of Python
claims, Readability counts.
Read more: import this."""
'The Zen of Python\nclaims, Readability counts.\nRead more: import this.'
```

String Literals

```
>>> 'I am string!'
'I am string!'
>>> "I've got an apostrophe"
"I've got an apostrophe"
>>> '您好'
'您好'
```

Single- and double-quoted strings are equivalent

```
>>> """The Zen of Python
claims, Readability counts.
Read more: import this."""
'The Zen of Python\nclaims, Readability counts.\nRead
more: import this.'
```

A backslash "escapes" the following character

String Literals

```
>>> 'I am string!'
'I am string!'
>>> "I've got an apostrophe"
"I've got an apostrophe"
>>> '您好'
'您好'
```

Single- and double-quoted strings are equivalent

```
>>> """The Zen of Python
claims, Readability counts.
Read more: import this."""
'The Zen of Python\nclaims, Readability counts.\nRead more: import this.'
```

A backslash "escapes" the following character

"Line feed" character represents a new line

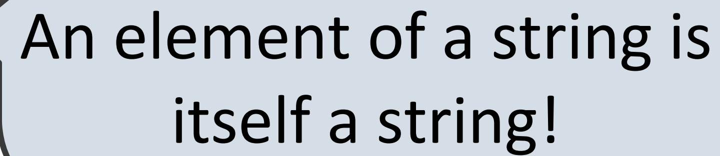
Strings Are Sequences

Strings Are Sequences

```
>>> city = 'Berkeley'
>>> len(city)
8
>>> city[3]
'k'
```

Strings Are Sequences

```
>>> city = 'Berkeley'
>>> len(city)
8
>>> city[3]
'k'
```



Strings Are Sequences

```
>>> city = 'Berkeley'
>>> len(city)
8
>>> city[3]
'k'
```

An element of a string is itself a string!

The **`in`** and **`not in`** operators match substrings

Strings Are Sequences

```
>>> city = 'Berkeley'
>>> len(city)
8
>>> city[3]
'k'
```

An element of a string is itself a string!

The **`in`** and **`not in`** operators match substrings

```
>>> 'here' in "Where's Waldo?"
True
```

Strings Are Sequences

```
>>> city = 'Berkeley'
>>> len(city)
8
>>> city[3]
'k'
```

An element of a string is itself a string!

The **`in`** and **`not in`** operators match substrings

```
>>> 'here' in "Where's Waldo?"
True
```

Why? Working with strings, we care about words, not characters

Sequence Arithmetic

Sequence Arithmetic

Some Python sequences support arithmetic operations

Sequence Arithmetic

Some Python sequences support arithmetic operations

```
>>> city = 'Berkeley'
>>> city + ', CA'
'Berkeley, CA'
```

Sequence Arithmetic

Some Python sequences support arithmetic operations

```
>>> city = 'Berkeley'
>>> city + ', CA'
'Berkeley, CA'
```

Sequence Arithmetic

Some Python sequences support arithmetic operations

```
>>> city = 'Berkeley'
>>> city + ', CA'
'Berkeley, CA'

>>> "Don't repeat yourself! " * 2
"Don't repeat yourself! Don’t repeat yourself! "
```

Concatenate

Sequence Arithmetic

Some Python sequences support arithmetic operations

```
>>> city = 'Berkeley'
>>> city + ', CA'
'Berkeley, CA'

>>> "Don't repeat yourself! " * 2
"Don't repeat yourself! Don’t repeat yourself! "
```

Concatenate

Repeat twice

Sequence Arithmetic

Some Python sequences support arithmetic operations

```
>>> city = 'Berkeley'
>>> city + ', CA'
'Berkeley, CA'
```

Concatenate

```
>>> "Don't repeat yourself! " * 2
"Don't repeat yourself! Don’t repeat yourself! "
```

Repeat twice

```
>>> (1, 2, 3) * 3
(1, 2, 3, 1, 2, 3, 1, 2, 3)

>>> (1, 2, 3) + (4, 5, 6, 7)
(1, 2, 3, 4, 5, 6, 7)
```

Sequences as Conventional Interfaces

Sequences as Conventional Interfaces

We can apply a function to every element in a sequence

Sequences as Conventional Interfaces

We can apply a function to every element in a sequence

This is called *mapping* the function over the sequence

Sequences as Conventional Interfaces

We can apply a function to every element in a sequence

This is called *mapping* the function over the sequence

```
>>> fibs = tuple(map(fib, range(8)))
>>> fibs
(0, 1, 1, 2, 3, 5, 8, 13)
```

Sequences as Conventional Interfaces

We can apply a function to every element in a sequence

This is called *mapping* the function over the sequence

```
>>> fibs = tuple(map(fib, range(8)))
>>> fibs
(0, 1, 1, 2, 3, 5, 8, 13)
```

We can extract elements that satisfy a given condition

Sequences as Conventional Interfaces

We can apply a function to every element in a sequence

This is called *mapping* the function over the sequence

```
>>> fibs = tuple(map(fib, range(8)))
>>> fibs
(0, 1, 1, 2, 3, 5, 8, 13)
```

We can extract elements that satisfy a given condition

```
>>> even_fibs = tuple(filter(is_even, fibs))
>>> even_fibs
(0, 2, 8)
```

Sequences as Conventional Interfaces

We can apply a function to every element in a sequence

This is called *mapping* the function over the sequence

```
>>> fibs = tuple(map(fib, range(8)))
>>> fibs
(0, 1, 1, 2, 3, 5, 8, 13)
```

We can extract elements that satisfy a given condition

```
>>> even_fibs = tuple(filter(is_even, fibs))
>>> even_fibs
(0, 2, 8)
```

We can compute the sum of all elements

Sequences as Conventional Interfaces

We can apply a function to every element in a sequence

This is called *mapping* the function over the sequence

```
>>> fibs = tuple(map(fib, range(8)))
>>> fibs
(0, 1, 1, 2, 3, 5, 8, 13)
```

We can extract elements that satisfy a given condition

```
>>> even_fibs = tuple(filter(is_even, fibs))
>>> even_fibs
(0, 2, 8)
```

We can compute the sum of all elements

```
>>> sum(even_fibs)
10
```

Sequences as Conventional Interfaces

We can apply a function to every element in a sequence

This is called *mapping* the function over the sequence

```
>>> fibs = tuple(map(fib, range(8)))
>>> fibs
(0, 1, 1, 2, 3, 5, 8, 13)
```

We can extract elements that satisfy a given condition

```
>>> even_fibs = tuple(filter(is_even, fibs))
>>> even_fibs
(0, 2, 8)
```

We can compute the sum of all elements

```
>>> sum(even_fibs)
10
```

Both **`map`** and **`filter`** produce an iterable, not a sequence

Iterables

Iterables

Iterables provide access to some elements in order but do not provide length or element selection

Iterables

Iterables provide access to some elements in order but do not provide length or element selection

Python-specific construct; more general than a sequence

Iterables

Iterables provide access to some elements in order but do not provide length or element selection

Python-specific construct; more general than a sequence

Many built-in functions take iterables as argument

Iterables

Iterables provide access to some elements in order but do not provide length or element selection

Python-specific construct; more general than a sequence

Many built-in functions take iterables as argument

`tuple`	Construct a tuple containing the elements
`map`	Construct a map that results from applying the given function to each element
`filter`	Construct a filter with elements that satisfy the given condition
`sum`	Return the sum of the elements
`min`	Return the minimum of the elements
`max`	Return the maximum of the elements

Iterables

Iterables provide access to some elements in order but do not provide length or element selection

Python-specific construct; more general than a sequence

Many built-in functions take iterables as argument

`tuple`	Construct a tuple containing the elements
`map`	Construct a map that results from applying the given function to each element
`filter`	Construct a filter with elements that satisfy the given condition
`sum`	Return the sum of the elements
`min`	Return the minimum of the elements
`max`	Return the maximum of the elements

For statements also operate on iterable values.

Generator Expressions

Generator Expressions

One large expression that combines mapping and filtering to produce an iterable

Generator Expressions

One large expression that combines mapping and filtering to produce an iterable

```
(<map exp> for <name> in <iter exp> if <filter exp>)
```

Generator Expressions

One large expression that combines mapping and filtering to produce an iterable

```
(<map exp> for <name> in <iter exp> if <filter exp>)
```

- Evaluates to an iterable.

Generator Expressions

One large expression that combines mapping and filtering to produce an iterable

```
(<map exp> for <name> in <iter exp> if <filter exp>)
```

- Evaluates to an iterable.
- <iter exp> is evaluated when the generator expression is evaluated.

Generator Expressions

One large expression that combines mapping and filtering to produce an iterable

```
(<map exp> for <name> in <iter exp> if <filter exp>)
```

- Evaluates to an iterable.
- <iter exp> is evaluated when the generator expression is evaluated.
- Remaining expressions are evaluated when elements are accessed.

Generator Expressions

One large expression that combines mapping and filtering to produce an iterable

```
(<map exp> for <name> in <iter exp> if <filter exp>)
```

- Evaluates to an iterable.
- <iter exp> is evaluated when the generator expression is evaluated.
- Remaining expressions are evaluated when elements are accessed.

No-filter version: `(<map exp> for <name> in <iter exp>)`

Generator Expressions

One large expression that combines mapping and filtering to produce an iterable

```
(<map exp> for <name> in <iter exp> if <filter exp>)
```

- Evaluates to an iterable.
- <iter exp> is evaluated when the generator expression is evaluated.
- Remaining expressions are evaluated when elements are accessed.

No-filter version: `(<map exp> for <name> in <iter exp>)`

Precise evaluation rule introduced in Chapter 4.

Reducing a Sequence

Reducing a Sequence

Reduce is a higher-order generalization of max, min, and sum.

Reducing a Sequence

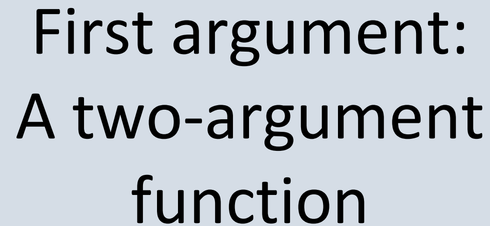
Reduce is a higher-order generalization of max, min, and sum.

```
>>> from operator import mul
>>> from functools import reduce
>>> reduce(mul, (1, 2, 3, 4, 5), 1)
120
```

Reducing a Sequence

Reduce is a higher-order generalization of max, min, and sum.

```
>>> from operator import mul
>>> from functools import reduce
>>> reduce(mul, (1, 2, 3, 4, 5), 1)
120
```



Reducing a Sequence

Reduce is a higher-order generalization of max, min, and sum.

```
>>> from operator import mul
>>> from functools import reduce
>>> reduce(mul, (1, 2, 3, 4, 5), 1)
120
```

First argument: A two-argument function

Second argument: an iterable object

Reducing a Sequence

Reduce is a higher-order generalization of max, min, and sum.

```
>>> from operator import mul
>>> from functools import reduce
>>> reduce(mul, (1, 2, 3, 4, 5), 1)
120
```

First argument: A two-argument function

Second argument: an iterable object

Optional initial value as third argument

Reducing a Sequence

Reduce is a higher-order generalization of max, min, and sum.

```
>>> from operator import mul
>>> from functools import reduce
>>> reduce(mul, (1, 2, 3, 4, 5), 1)
120
```

First argument: A two-argument function

Second argument: an iterable object

Optional initial value as third argument

Like accumulate from Homework 2, but with iterables

Reducing a Sequence

Reduce is a higher-order generalization of max, min, and sum.

```
>>> from operator import mul
>>> from functools import reduce
>>> reduce(mul, (1, 2, 3, 4, 5), 1)
120
```

First argument: A two-argument function

Second argument: an iterable object

Optional initial value as third argument

Like accumulate from Homework 2, but with iterables

```
def accumulate(combiner, start, n, term):
    return reduce(combiner,
                  map(term, range(1, n + 1)),
                  start)
```

More Functions on Iterables (Bonus)

Create an iterable of fixed-length sequences

```
>>> a, b = (1, 2, 3), (4, 5, 6, 7)
>>> for x, y in zip(a, b):
...     print(x + y)
...
5
7
9
```

Produces tuples with one element from each argument, up to length of smallest argument

The **`itertools`** module contains many useful functions for working with iterables

```
>>> from itertools import product, combinations
>>> tuple(product(a, b[:2]))
((1, 4), (1, 5), (2, 4), (2, 5), (3, 4), (3, 5))
>>> tuple(combinations(a, 2))
((1, 2), (1, 3), (2, 3))
```