

# Python

## Lists

# Loops let us do things many times

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*Collections* let us store many values together

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*Collections* let us store many values together

Most popular collection is a *list*

Create using `[value, value, ...]`

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Get/set values using `var[index]`

Create using [value, value, ...]

Get/set values using var[index]

```
gases = ['He', 'Ne', 'Ar', 'Kr']  
print(gases)  
['He', 'Ne', 'Ar', 'Kr']
```

Create using [value, value, ...]

Get/set values using var[index]

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]
```

```
print(gases)
```

```
['He' , 'Ne' , 'Ar' , 'Kr' ]
```

```
print(gases[1])
```

```
Ne
```



# Index from 0, not 1

Index from 0, not 1

Reasons made sense for C in 1970...

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It's an error to try to access out of range

Index from 0, not 1

Reasons made sense for C in 1970...

It's an error to try to access out of range

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]  
print(gases[4])
```

***IndexError: list index out of range***

Use `len(list)` to get length of list

Use `len(list)` to get length of list

```
gases = ['He', 'Ne', 'Ar', 'Kr']  
print(len(gases))  
4
```

Use `len(list)` to get length of list

```
gases = ['He', 'Ne', 'Ar', 'Kr']  
print(len(gases))  
4
```

Returns 0 for the *empty list*

```
etheric = []  
print(len(etheric))  
0
```

Some negative indices work



Some negative indices work

`values[-1]` is last element, `values[-2]` next-to-last, ...

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`values[-1]` is last element, `values[-2]` next-to-last, ...

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]
```

Some negative indices work

`values[-1]` is last element, `values[-2]` next-to-last, ...

```
gases = ['He', 'Ne', 'Ar', 'Kr']  
print(gases[-1], gases[-4])  
Kr He
```

Some negative indices work

`values[-1]` is last element, `values[-2]` next-to-last, ...

```
gases = ['He', 'Ne', 'Ar', 'Kr']  
print(gases[-1], gases[-4])  
Kr He
```

`values[-1]` is much nicer than `values[len(values)-1]`

Some negative indices work

`values[-1]` is last element, `values[-2]` next-to-last, ...

```
gases = ['He', 'Ne', 'Ar', 'Kr']  
print(gases[-1], gases[-4])  
Kr He
```

`values[-1]` is much ~~nicer~~ than `values[len(values)-1]`

less error prone

*Mutable* : can change it after it is created

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```
gases = [ 'He' , 'Ne' , 'Ar' , 'K' ]    # last entry misspelled
```

*Mutable* : can change it after it is created

```
gases = [ 'He' , 'Ne' , 'Ar' , 'K' ]    # last entry misspelled  
gases[3] = 'Kr'
```



*Mutable* : can change it after it is created

```
gases = ['He', 'Ne', 'Ar', 'K']    # last entry misspelled
gases[3] = 'Kr'
print(gases)
['He', 'Ne', 'Ar', 'Kr']
```

*Mutable* : can change it after it is created

```
gases = ['He', 'Ne', 'Ar', 'K']    # last entry misspelled
gases[3] = 'Kr'
print(gases)
['He', 'Ne', 'Ar', 'Kr']
```

Location must exist before assignment

*Mutable* : can change it after it is created

```
gases = ['He', 'Ne', 'Ar', 'K']    # last entry misspelled
gases[3] = 'Kr'
print(gases)
['He', 'Ne', 'Ar', 'Kr']
```

Location must exist before assignment

```
gases = ['He', 'Ne', 'Ar', 'Kr']
```

*Mutable* : can change it after it is created

```
gases = ['He', 'Ne', 'Ar', 'K']    # last entry misspelled
gases[3] = 'Kr'
print(gases)
['He', 'Ne', 'Ar', 'Kr']
```

Location must exist before assignment

```
gases = ['He', 'Ne', 'Ar', 'Kr']
gases[4] = 'Xe'
```

***IndexError: list assignment index out of range***

*Heterogeneous* : can store values of many kinds

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```
helium = ['He', 2]
```

```
neon = ['Ne', 8]
```

*Heterogeneous* : can store values of many kinds

```
helium = ['He', 2]  
neon = ['Ne', 8]
```

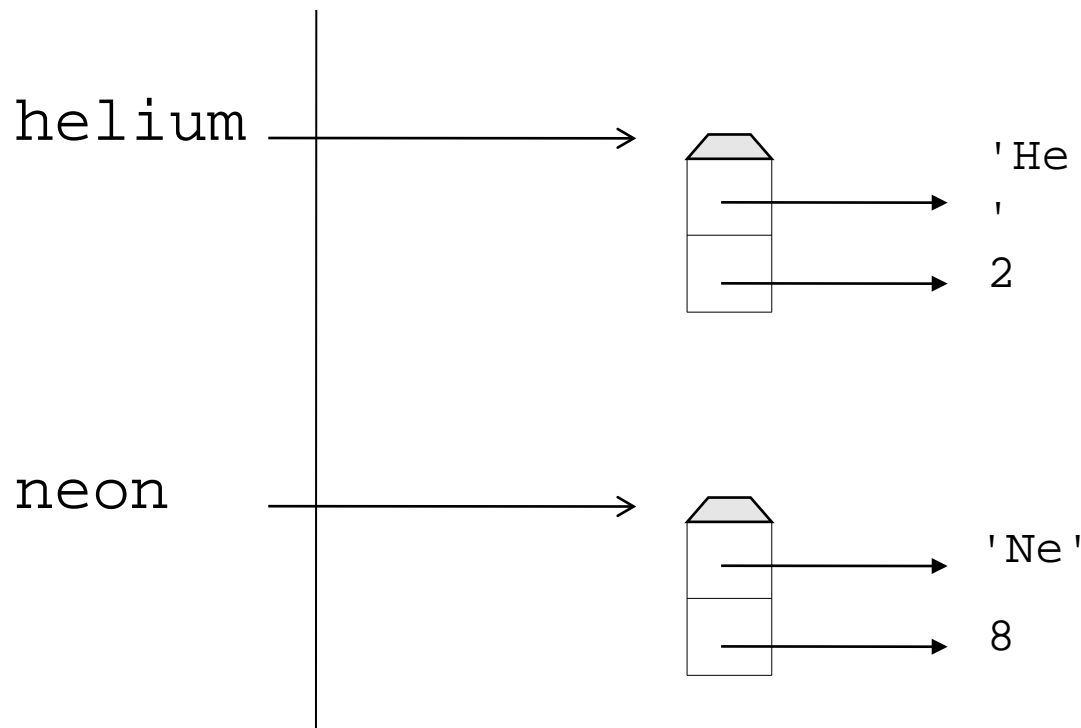
*[string, int]*



*Heterogeneous* : can store values of many kinds

```
helium = [ 'He', 2]
```

```
neon = [ 'Ne' , 8 ]
```



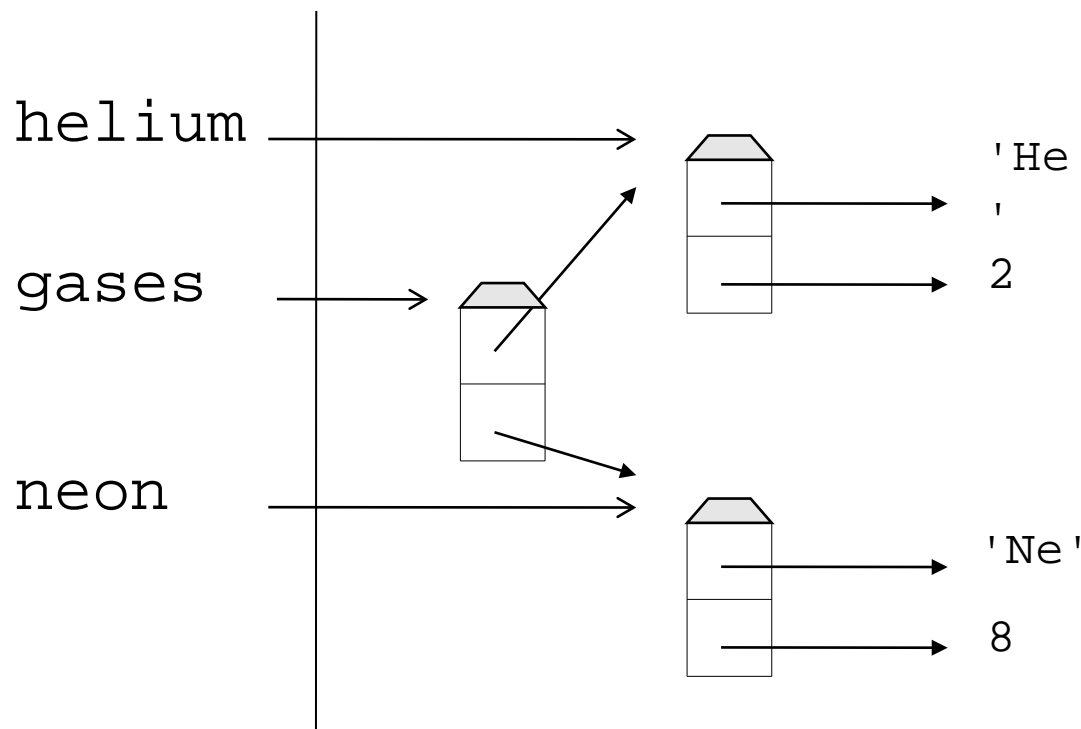


*Heterogeneous* : can store values of many kinds

```
helium = ['He', 2]  
neon = ['Ne', 8]  
gases = [helium, neon]
```

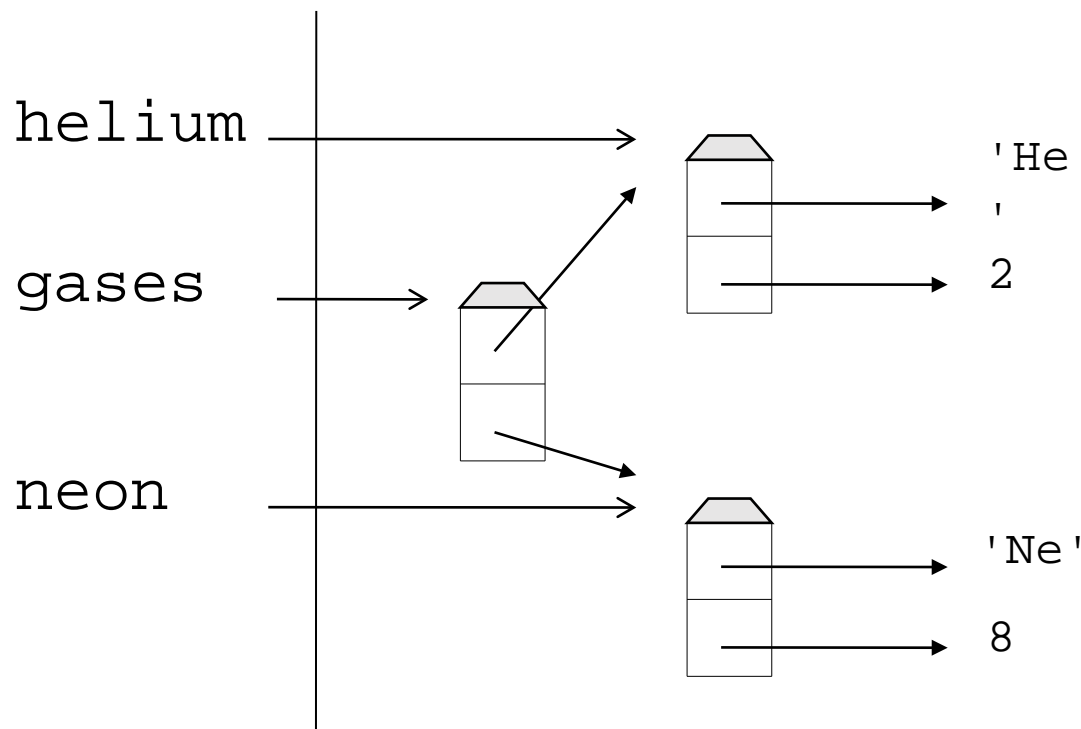
*Heterogeneous* : can store values of many kinds

```
helium = ['He', 2]  
neon = ['Ne', 8]  
gases = [helium, neon]
```



*Heterogeneous* : can store values of many kinds

```
helium = ['He', 2]  
neon = ['Ne', 8]  
gases = [helium, neon]
```



Devote a whole  
episode to this

# Loop over elements to "do all"

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Use `while` to step through all possible indices

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Use `while` to step through all possible indices

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]  
i = 0  
while i < len(gases):  
    print(gases[i])  
    i += 1
```

Loop over elements to "do all"

Use `while` to step through all possible indices

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]
```

```
i = 0 ← First legal index
```

```
while i < len(gases):  
    print(gases[i])  
    i += 1
```

Loop over elements to "do all"

Use `while` to step through all possible indices

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]  
i = 0  
while i < len(gases):  
    print(gases[i])  
    i += 1 ← Next index
```



Loop over elements to "do all"

Use `while` to step through all possible indices

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]
```

```
i = 0
```

```
while i < len(gases):
```

———— Defines set of legal indices

```
    print(gases[i])
```

```
    i += 1
```

Loop over elements to "do all"

Use `while` to step through all possible indices

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]  
i = 0  
while i < len(gases):  
    print(gases[i])  
    i += 1
```

*He*

*Ne*

*Ar*

*Kr*

Loop over elements to "do all"

Use `while` to step through all possible indices

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]  
i = 0  
while i < len(gases):  
    print(gases[i])  
    i += 1
```

*He*

*Ne*

*Ar*

*Kr*

Tedious to type in over and over again

Loop over elements to "do all"

Use `while` to step through all possible indices

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]  
i = 0  
while i < len(gases):  
    print(gases[i])  
    i += 1
```

*He*

*Ne*

*Ar*

*Kr*

Tedious to type in over and over again

And it's easy to forget the "`+= 1`" at the end

Use a **for** loop to access each value in turn

## Use a `for` loop to access each value in turn

```
gases = [ 'He', 'Ne', 'Ar', 'Kr' ]
```

```
for gas in gases:
```

```
print (gas)
```

 $He$  $Ne$ 

*Ar*

 $Kr$

Use a `for` loop to access each value in turn

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]  
for gas in gases:  
    print(gas)
```

*He*

*Ne*

*Ar*

*Kr*

Loop variable assigned each *value* in turn

## Use a `for` loop to access each value in turn

```
gases = ['He', 'Ne', 'Ar', 'Kr']
for gas in gases:
    print(gas)
```

 $He$ 

*Ne*

$$Ar$$
 $Kr$ 

## Loop variable assigned each *value* in turn

## Not each index



Use a `for` loop to access each value in turn

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]  
for gas in gases:  
    print(gas)
```

*He*

*Ne*

*Ar*

*Kr*

Loop variable assigned each *value* in turn

*Not* each index

Because that's the most common case

## Can delete entries entirely (shortens the list)

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```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]
```

Can delete entries entirely (shortens the list)

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]  
del gases[0]
```

Can delete entries entirely (shortens the list)

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]  
del gases[0]  
print(gases)  
[ 'Ne' , 'Ar' , 'Kr' ]
```

Can delete entries entirely (shortens the list)

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]  
del gases[0]  
print(gases)  
['Ne' , 'Ar' , 'Kr' ]  
del gases[2]
```

Can delete entries entirely (shortens the list)

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]  
del gases[0]  
print(gases)  
[ 'Ne' , 'Ar' , 'Kr' ]  
del gases[2]  
print(gases)  
[ 'Ne' , 'Ar' ]
```

Can delete entries entirely (shortens the list)

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]  
del gases[0]  
print(gases)  
[ 'Ne' , 'Ar' , 'Kr' ]  
del gases[2]  
print(gases)  
[ 'Ne' , 'Ar' ]
```

Yes, deleting an index that doesn't exist is an error



# Appending values to a list lengthens it

# Appending values to a list lengthens it

```
gases = [ ]
```

# Appending values to a list lengthens it

```
gases = []  
gases.append( 'He' )
```

# Appending values to a list lengthens it

```
gases = []  
gases.append( 'He' )  
gases.append( 'Ne' )
```

# Appending values to a list lengthens it

```
gases = []  
gases.append( 'He' )  
gases.append( 'Ne' )  
gases.append( 'Ar' )
```

## Appending values to a list lengthens it

```
gases = []  
gases.append( 'He' )  
gases.append( 'Ne' )  
gases.append( 'Ar' )  
print(gases)  
['He' , 'Ne' , 'Ar']
```

## Appending values to a list lengthens it

```
gases = []  
gases.append( 'He' )  
gases.append( 'Ne' )  
gases.append( 'Ar' )  
print( gases )  
[ 'He' , 'Ne' , 'Ar' ]
```

Most operations on lists are *methods*

Appending values to a list lengthens it

```
gases = []  
gases.append( 'He' )  
gases.append( 'Ne' )  
gases.append( 'Ar' )  
print( gases )  
[ 'He' , 'Ne' , 'Ar' ]
```

Most operations on lists are *methods*

A function that belongs to (and usually operates on)  
specific data



Appending values to a list lengthens it

```
gases = []  
gases.append( 'He' )  
gases.append( 'Ne' )  
gases.append( 'Ar' )  
print( gases )  
[ 'He' , 'Ne' , 'Ar' ]
```

Most operations on lists are *methods*

A function that belongs to (and usually operates on)  
specific data

thing . method ( args )

# Some useful list methods

## Some useful list methods

```
gases = [ 'He' , 'He' , 'Ar' , 'Kr' ] # 'He' is duplicated
```

## Some useful list methods

```
gases = [ 'He' , 'He' , 'Ar' , 'Kr' ] # 'He' is duplicated  
print(gases.count( 'He' ))  
2
```

## Some useful list methods

```
gases = [ 'He' , 'He' , 'Ar' , 'Kr' ] # 'He' is duplicated
print(gases.count( 'He' ))
2
print(gases.index( 'Ar' ))
2
```

## Some useful list methods

```
gases = [ 'He' , 'He' , 'Ar' , 'Kr' ] # 'He' is duplicated
print(gases.count( 'He' ))
2
print(gases.index( 'Ar' ))
2
gases.insert(1, 'Ne' )
```

## Some useful list methods

```
gases = [ 'He' , 'He' , 'Ar' , 'Kr' ] # 'He' is duplicated
print(gases.count( 'He' ))
2
print(gases.index( 'Ar' ))
2
gases.insert(1, 'Ne')
print(gases)
[ 'He' , 'Ne' , 'He' , 'Ar' , 'Kr' ]
```

# Two that are often used incorrectly



Two that are often used incorrectly

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]
```

## Two that are often used incorrectly

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]  
print(gases.sort() )  
None
```

## Two that are often used incorrectly

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]  
print(gases.sort() )
```

*None*

```
print(gases )  
[ 'Ar' , 'He' , 'Kr' , 'Ne' ]
```

## Two that are often used incorrectly

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]
```

```
print(gases.sort() )
```

*None*

```
print(gases )
```

*[ 'Ar' , 'He' , 'Kr' , 'Ne' ]*

```
print(gases.reverse() )
```

*None*

## Two that are often used incorrectly

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]
```

```
print(gases.sort())
```

*None*

```
print(gases)
```

*[ 'Ar' , 'He' , 'Kr' , 'Ne' ]*

```
print(gases.reverse())
```

*None*

```
print(gases)
```

*[ 'Ne' , 'Kr' , 'He' , 'Ar' ]*

## Two that are often used incorrectly

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]
```

```
print(gases.sort())
```

*None*

```
print(gases)
```

*[ 'Ar' , 'He' , 'Kr' , 'Ne' ]*

```
print(gases.reverse())
```

*None*

```
print(gases)
```

*[ 'Ne' , 'Kr' , 'He' , 'Ar' ]*

## A common bug

## Two that are often used incorrectly

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]
```

```
print(gases.sort())
```

*None*

```
print(gases)
```

*[ 'Ar' , 'He' , 'Kr' , 'Ne' ]*

```
print(gases.reverse())
```

*None*

```
print(gases)
```

*[ 'Ne' , 'Kr' , 'He' , 'Ar' ]*

## A common bug

`gases = gases.sort()` assigns `None` to `gases`

There is an alternative built-in function for sorting:

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]  
s_gases = sorted(gases)  
r_gases = sorted(gases, reverse=True)
```

```
print (gases )  
['He' , 'Ne' , 'Ar' , 'Kr' ]
```

```
print (s_gases)  
['Ar' , 'He' , 'Kr' , 'Ne' ]
```

```
print (r_gases)  
['Ne' , 'Kr' , 'He' , 'Ar' ]
```



# Use `in` to test for membership

# Use `in` to test for membership

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]
```

## Use **in** to test for membership

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]  
print( 'He' in gases )  
True
```

## Use `in` to test for membership

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]
```

```
print( 'He' in gases )
```

*True*

```
if 'Pu' in gases:
```

```
    print( 'But plutonium is not a gas!' )
```

```
else:
```

```
    print( 'The universe is well ordered.' )
```

## Use `in` to test for membership

```
gases = [ 'He' , 'Ne' , 'Ar' , 'Kr' ]
```

```
print( 'He' in gases )
```

*True*

```
if 'Pu' in gases:
```

```
    print( 'But plutonium is not a gas!' )
```

```
else:
```

```
    print( 'The universe is well ordered.' )
```

*The universe is well ordered.*

## Use range to construct a range of numbers

# Use range to construct a range of numbers

```
print(range(5))
```

```
range(0, 5)
```

Use `list(range)` to construct lists of numbers



Use `list(range)` to construct lists of numbers

```
print(list(range(5)))  
[0, 1, 2, 3, 4]
```

Use `list(range)` to construct lists of numbers

```
print(list(range(5)))  
[0, 1, 2, 3, 4]  
print(list(range(2, 6)))  
[2, 3, 4, 5]
```

Use `list(range())` to construct lists of numbers

```
print(list(range(5)))
```

```
[0, 1, 2, 3, 4]
```

```
print(list(range(2, 6)))
```

```
[2, 3, 4, 5]
```

```
print(list(range(0, 10, 3)))
```

```
[0, 3, 6, 9]
```

Use `list(range)` to construct lists of numbers

```
print(list(range(5)))  
[0, 1, 2, 3, 4]  
print(list(range(2, 6)))  
[2, 3, 4, 5]  
print(list(range(0, 10, 3)))  
[0, 3, 6, 9]  
print(list(range(10, 0)))  
[]
```

Sometimes you might need both the index and value while  
looping

Sometimes you might need both the index and value while looping.

You could use `range ( len ( gases ) )`

Sometimes you might need both the index and value while looping.

You could use `range(len(gases))`

```
gases = ['He', 'Ne', 'Ar', 'Kr']
```

```
for i in range(len(gases)):
    print(i, gases[i])
```

*0 He*

*1 Ne*

*2 Ar*

*3 Kr*

But there is a better way... `enumerate()`



But there is a better way... `enumerate()`

```
gases = ['He', 'Ne', 'Ar', 'Kr']
```

```
for i, gas in enumerate(gases):  
    print(i, gas)
```

*0 He*

*1 Ne*

*2 Ar*

*3 Kr*

But there is a better way... `enumerate()`

```
gases = ['He', 'Ne', 'Ar', 'Kr']
```

```
for i, gas in enumerate(gases):  
    print(i, gas)
```

```
0 He
```

```
1 Ne
```

```
2 Ar
```

```
3 Kr
```

A very common *idiom* in Python

# Python

## Slicing

Lists, strings, and tuples are all *sequences*

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Can be indexed by integers in the range  $0 \dots \text{len}(X) - 1$

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Can be indexed by integers in the range  $0 \dots \text{len}(X) - 1$

Can also be *sliced* using a range of indices

Lists, strings, and tuples are all *sequences*

Can be indexed by integers in the range  $0 \dots \text{len}(X) - 1$

Can also be *sliced* using a range of indices

```
>>> element = 'uranium'
>>>
```

0	1	2	3	4	5	6	7
u	r	a	n	i	u	m	
-7	-6	-5	-4	-3	-2	-1	

Lists, strings, and tuples are all *sequences*

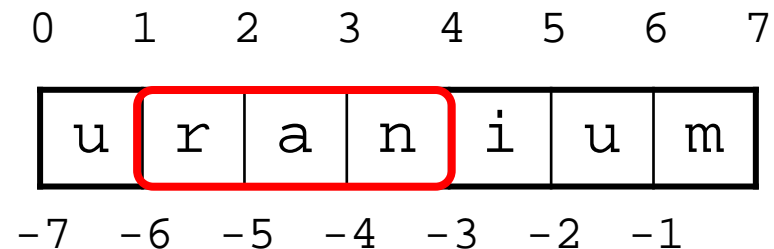
Can be indexed by integers in the range  $0 \dots \text{len}(X) - 1$

Can also be *sliced* using a range of indices

```
>>> element = 'uranium'
>>> print(element[1:4])
```

*ran*

```
>>>
```





Lists, strings, and tuples are all *sequences*

Can be indexed by integers in the range  $0 \dots \text{len}(X) - 1$

Can also be *sliced* using a range of indices

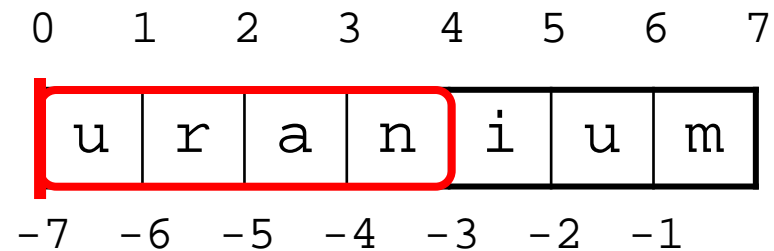
```
>>> element = 'uranium'
>>> print(element[1:4])
```

*uran*

```
>>> print(element[:4])
```

*uran*

```
>>>
```



Lists, strings, and tuples are all *sequences*

Can be indexed by integers in the range  $0 \dots \text{len}(X) - 1$

Can also be *sliced* using a range of indices

```
>>> element = 'uranium'
>>> print(element[1:4])
ran
>>> print(element[:4])
uran
>>> print(element[4:])
ium
>>>
```

0	1	2	3	4	5	6	7
u	r	a	n	i	u	m	
-7	-6	-5	-4	-3	-2	-1	

Lists, strings, and tuples are all *sequences*

Can be indexed by integers in the range  $0 \dots \text{len}(X) - 1$

Can also be *sliced* using a range of indices

```
>>> element = 'uranium'
>>> print(element[1:4])
uran
>>> print(element[:4])
uran
>>> print(element[4:])
ium
>>> print(element[-4:])
nium
>>>
```

0	1	2	3	4	5	6	7
u	r	a	n	i	u	m	
-7	-6	-5	-4	-3	-2	-1	

# Python checks bounds when indexing

Python checks bounds when indexing

But truncates when slicing

# Python checks bounds when indexing

## But truncates when slicing

```
>>> element = 'uranium'  
>>>
```

0	1	2	3	4	5	6	7
u	r	a	n	i	u	m	
-	-	-	-	-	-	-	
7	6	5	4	3	2	1	

# Python checks bounds when indexing

## But truncates when slicing

```
>>> element = 'uranium'
```

```
>>> print(element[400])
```

***IndexError: string index out of range***

```
>>>
```

0	1	2	3	4	5	6	7
u	r	a	n	i	u	m	
-	-	-	-	-	-	-	
7	6	5	4	3	2	1	

## But truncates when slicing

```
>>> print(element[400])
```

```
>>> print(element[1:400])
```

>>>

0	1	2	3	4	5	6	7
u	r	a	n	i	u	m	
-	-	-	-	-	-	-	
7	6	5	4	3	2	1	



So `text[1:3]` is 0, 1, or 2 characters long

So `text[1:3]` is 0, 1, or 2 characters long

`' '`

`' '`

`'a'`

`' '`

`'ab'`

`'b'`

`'abc'`

`'bc'`

`'abcdef'`

`'bc'`

# Slicing always creates a new collection

Slicing always creates a new collection

Beware of aliasing

# Slicing always creates a new collection

## Beware of aliasing

```
>>> points = [[10, 10], [20, 20], [30, 30], [40, 40]]  
>>>
```

# Slicing always creates a new collection

## Beware of aliasing

```
>>> points = [[10, 10], [20, 20], [30, 30], [40, 40]]
>>> middle = points[1:-1]
>>>
```

# Slicing always creates a new collection

## Beware of aliasing

```
>>> points = [[10, 10], [20, 20], [30, 30], [40, 40]]
>>> middle = points[1:-1]
>>> middle[0][0] = 'whoops'
>>>
```

# Slicing always creates a new collection

## Beware of aliasing

```
>>> points = [[10, 10], [20, 20], [30, 30], [40, 40]]
>>> middle = points[1:-1]
>>> middle[0][0] = 'whoops'
>>> middle[1][0] = 'aliasing'
>>>
```



# Slicing always creates a new collection

## Beware of aliasing

```
>>> points = [[10, 10], [20, 20], [30, 30], [40, 40]]
>>> middle = points[1:-1]
>>> middle[0][0] = 'whoops'
>>> middle[1][0] = 'aliasing'
>>> print(middle)
[['whoops', 20], ['aliasing', 30]]
>>>
```

# Beware of aliasing

```
>>> points = [[10, 10], [20, 20], [30, 30], [40, 40]]
>>> middle = points[1:-1]
>>> middle[0][0] = 'whoops'
>>> middle[1][0] = 'aliasing'
>>> print(middle)
[['whoops', 20], ['aliasing', 30]]
>>> print(points)
[[10, 10], ['whoops', 20], ['aliasing', 30], [40, 40]]
>>>
```

# Python

List comprehensions - what are they? They are useful!

# List Comprehensions

Python supports a concept called "List Comprehensions".  
Imagine you want to create a list of square numbers from the list of numbers from 0 to 9. You would type:

```
>>> S = []
```

```
>>> for x in range(10):
```

```
...     S.append(x**2)
```

```
>>> print(S)
```

```
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]
```

# Saving on lines of code

*List Comprehensions* allow you to do it on **one line**:

```
>>> S = [x**2 for x in range(10)]  
>>> print(S)  
[0, 1, 4, 9, 16, 25, 36, 49, 64, 81]
```

These can be used to construct lists in a natural and easy way.

## It gets better - include conditions

Imagine our previous example - but you only want to include values in the list where the result is an even number:

```
>>> S = []  
>>> for x in range(10):  
...     res = x**2  
...     if res % 2 == 0:  
...         S.append(res)  
>>> print(S)  
  
[0, 4, 16, 36, 64]
```

Can be simplified to...

All one line

```
>>> S =
```

```
[x**2 for x in range(10) if x**2 % 2 == 0]
```

```
>>> print(S)
```

```
[0, 4, 16, 36, 64]
```

See more info at:

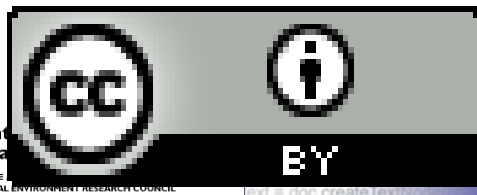
<https://www.python.org/dev/peps/pep-0202/#examples>



created by

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