

Sequence Types

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Lecture Topics

- String Characters and Indexes
- String Testing Functions
- String Slicing
- List Basics
 - Retrieving and Changing Elements
 - Iterating Over a List
 - Adding Elements to Lists
 - Deleting Elements from Lists
- List Slicing
- Copying Lists
- Testing the Equality of Lists
- Two Dimensional Lists

Colors/Fonts

• Variable Names	—	Brown
• Standard data types	—	Fuchsia
• Literals	—	Blue
• Keywords	—	Orange
• Operators/Punctuation	—	Black
• Function Names	—	Purple
• Comments	—	Gray
• Module Names	—	Pink

Source Code	— Consolas
Output	— Courier New

String Character Indexes

- Strings are a sequence type and are comprised of characters.
 - Characters can be letters, numbers, symbols and whitespace.
- Every character in a string has an index.

`example = "Example String"`

E	x	a	m	p	l	e		S	t	r	i	n	g
0	1	2	3	4	5	6	7	8	9	10	11	12	13

String Characters

- Characters in a string can be accessed using subscript notation.

```
example = "Example String"  
first_character = example[0]  
print(first_character)  
print(example[8])
```

E

S

String Character Indexes

- Strings are immutable.
 - Characters in a string cannot be changed.

```
example = "Example String"  
example[13] = "G"  
print(example)
```

```
Traceback (most recent call last):  
  File "C:\testing\examples.py", line 8, in <module>  
    example[13] = "G"  
TypeError: 'str' object does not support item assignment  
>>>
```

String Character Indexes

- Attempting to access an index that does not exist will raise in an `IndexError` exception.

```
example = "Example String"  
character = example[20]  
print(character)
```

```
Traceback (most recent call last):  
  File "C:\testing\examples.py", line 8, in <module>  
    character = example[20]  
IndexError: string index out of range  
>>>
```

String Length

- A string's length is the total number of characters it contains.
 - Use Python's built-in len function to return the length of a string.

```
example = "Example String"  
length = len(example)  
print(length)
```

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Iterating Over String Characters

- A for loop can iterate over a string's characters.
 - To loop through all or part of a string's characters:

```
example = "Example"  
for index in range(0, len(example)) :  
    print(example[index])
```

- To loop through all of a string's characters:

```
example = "Example"  
for character in example :  
    print(character)
```

E
x
a
m
p
l
e

Testing if a String is Alphabetic

- The string's `isalpha` function determines if a string contains only letters.

- Returns a Boolean

```
example1 = "Example"  
example2 = "Example123"
```

```
if example1.isalpha() :  
    print("example1 contains only letters")
```

```
if example2.isalpha() :  
    print("example2 contains only letters")
```

```
example1 contains only letters
```

Testing if a String is Numeric

- The string's `isdigit` function determines if a string contains only numbers.
 - Returns a Boolean

```
example1 = "Example"  
example2 = "Example123"
```

```
if example1.isdigit() :  
    print("example1 contains only numbers")
```

```
if example2.isdigit() :  
    print("example2 contains only numbers")
```

Testing if a String is Alphanumeric

- The string's `isalnum` function determines if a string contains only letters and/or numbers.

- Returns a Boolean

```
example1 = "Example"
```

```
example2 = "Example123"
```

```
if example1.isalnum() :  
    print("example1 contains only letters and/or numbers")
```

```
if example2.isalnum() :  
    print("example2 contains only letters and/or numbers")
```

```
example1 contains only letters and/or numbers
```

```
example2 contains only letters and/or numbers
```

Testing if a String Contains Only Whitespace

- The string's isspace function determines if a string contains only spaces.
 - Returns a Boolean

```
example1 = "Example"
```

```
example2 = "    "
```

```
if example1.isspace() :
```

```
    print("example1 contains only spaces.")
```

```
if example2.isspace() :
```

```
    print("example2 contains only spaces.")
```

```
example2 contains only spaces.
```

Testing if a String is Uppercase

- The string's `isupper` function determines if a string contains only uppercase letters.

- Returns a Boolean

```
example1 = "Example123"
```

```
example2 = "EXAMPLE123"
```

```
if example1.isupper() :  
    print("example1 contains only uppercase letters.")
```

```
if example2.isupper() :  
    print("example2 contains only uppercase letters.")
```

```
example2 contains only uppercase letters.
```

Testing if a String is Lowercase

- The string's `islower` function determines if a string contains only lowercase letters.

- Returns a Boolean

```
example1 = "Example123"
```

```
example2 = "example123"
```

```
if example1.islower() :  
    print("example1 contains only lowercase letters.")
```

```
if example2.islower() :  
    print("example2 contains only lowercase letters.")
```

```
example2 contains only lowercase letters.
```

Testing if a *Character* is Alphabetic

```
example = "ABC 123 ! xyz"
```

```
if example[2].isalpha() :  
    print("Character at index 2 is a letter.")
```

```
if example[5].isalpha() :  
    print("Character at index 5 is a letter.")
```

```
if example[7].isalpha() :  
    print("Character at index 7 is a letter.")
```

```
if example[8].isalpha() :  
    print("Character at index 8 is a letter.")
```

```
if example[10].isalpha() :  
    print("Character at index 10 is a letter.")
```


Testing if a *Character* is Numeric

```
example = "ABC 123 ! xyz"

if example[2].isdigit() :
    print("Character at index 2 is a number.")

if example[5].isdigit() :
    print("Character at index 5 is a number.")

if example[7].isdigit() :
    print("Character at index 7 is a number.")

if example[8].isdigit() :
    print("Character at index 8 is a number.")

if example[10].isdigit() :
    print("Character at index 10 is a number.")
```

Testing if a *Character* is Alphanumeric

```
example = "ABC 123 ! xyz"
```

```
if example[2].isalnum() :  
    print("Character at index 2 is a letter/number.")
```

```
if example[5].isalnum() :  
    print("Character at index 5 is a letter/number.")
```

```
if example[7].isalnum() :  
    print("Character at index 7 is a letter/number.")
```

```
if example[8].isalnum() :  
    print("Character at index 8 is a letter/number.")
```

```
if example[10].isalnum() :  
    print("Character at index 10 is a letter/number.")
```

Testing if a *Character* is Whitespace

```
example = "ABC 123 ! xyz"
```

```
if example[2].isspace() :  
    print("Character at index 2 is a space.")
```

```
if example[5].isspace() :  
    print("Character at index 5 is a space.")
```

```
if example[7].isspace() :  
    print("Character at index 7 is a space.")
```

```
if example[8].isspace() :  
    print("Character at index 8 is a space.")
```

```
if example[10].isspace() :  
    print("Character at index 10 is a space.")
```

Testing if a *Character* is an Uppercase Letter

```
example = "ABC 123 ! xyz"
```

```
if example[2].isupper() :  
    print("Character at index 2 is an uppercase letter.")
```

```
if example[5].isupper() :  
    print("Character at index 5 is an uppercase letter.")
```

```
if example[7].isupper() :  
    print("Character at index 7 is an uppercase letter.")
```

```
if example[8].isupper() :  
    print("Character at index 8 is an uppercase letter.")
```

```
if example[10].isupper() :  
    print("Character at index 10 is an uppercase letter.")
```

Testing if a *Character* is a Lowercase Letter

```
example = "ABC 123 ! xyz"
```

```
if example[2].islower() :  
    print("Character at index 2 is a lowercase letter.")
```

```
if example[5].islower() :  
    print("Character at index 5 is a lowercase letter.")
```

```
if example[7].islower() :  
    print("Character at index 7 is a lowercase letter.")
```

```
if example[8].islower() :  
    print("Character at index 8 is a lowercase letter.")
```

```
if example[10].islower() :  
    print("Character at index 10 is a lowercase letter.")
```

Replacing parts of a String

- The string's replace function replaces part of a string with new data.
- Two arguments (both strings)- first is the string to find, second is what to replace it with. *CASE SENSITIVE*

```
orig_string = "Today is Monday."  
new_string = orig_string.replace("Monday", "Tuesday")  
print(new_string)
```

Today is Tuesday.

Note the value of orig_string **does not change**.

The replace method returns a new string with the every sequence of the first argument replaced with the second argument.

Replacing parts of a String

- The string's replace function replaces all matches.

```
orig_string = "Today is Monday."  
new_string = orig_string.replace("day", "night")  
print(new_string)
```

Tonight is Monnight.

String Slicing

- String slicing selects a range of characters from a string.
 - String slices are commonly referred to as *substrings*.
- The general syntax for slicing a string is:

string[startIndex:endIndex]

- This will return a string containing all characters between those indexes.
 - The start index is inclusive.
 - The end index is exclusive.

String Slicing

```
college = "Community College of Philadelphia"  
slice = college[10:17]  
print(slice)
```

College

String Slicing

- Specifying only start index will return a slice beginning with the start index's character through the end of the string.

```
college = "Community College of Philadelphia"  
slice = college[10:]  
print(slice)
```

```
College of Philadelphia
```

String Slicing

- Specifying only an ending index will return a slice beginning with the start of the string up to, but not including, the ending index.

```
college = "Community College of Philadelphia"  
slice = college[:17]  
print(slice)
```

```
Community College
```

String Slicing

- String slicing is safe from IndexError exceptions.
- If the starting index is greater than the ending index, an empty list will be returned.

```
college = "Community College of Philadelphia"  
slice = college[13:7]  
print(slice)
```

```
[]
```

String Slicing

- If the ending index is beyond the length of the string, Python will use the length as the ending index.

```
college = "Community College of Philadelphia"  
slice = college[21:100]  
print(slice)
```

Philadelphia

String Slicing

- If the starting index is negative, Python will use 0 as the starting index.

```
college = "Community College of Philadelphia"  
slice = college[-5:9]  
print(slice)
```

Community

- This is not the case if there is no ending index or the ending index is negative.

String Slicing

- When only a negative starting index is specified, the slice will begin relative to the end of the string.

```
college = "Community College of Philadelphia"  
slice = college[-12:]  
print(slice)
```

```
Philadelphia
```

String Slicing

- When both starting and ending indexes are negative, the slice will begin and end relative to the end of the string.

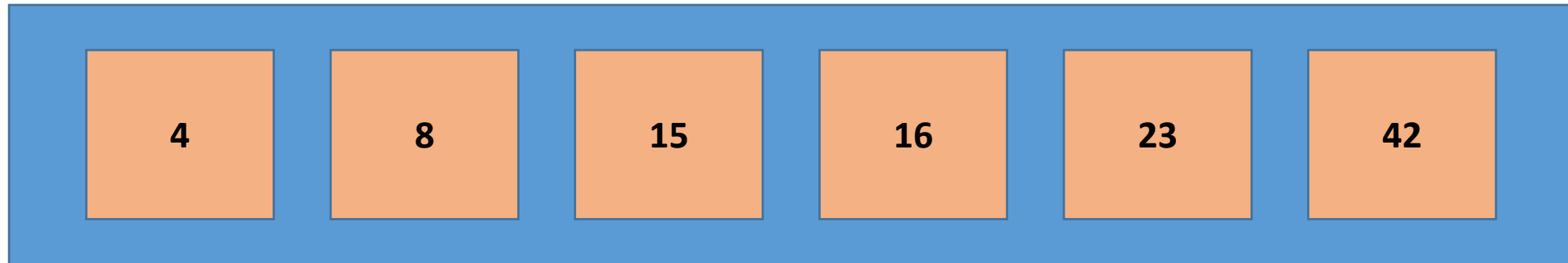
```
college = "Community College of Philadelphia"  
slice = college[-17:-24]  
print(slice)
```

College

- If a negative starting index is greater (closer to zero) than the negative ending index, an empty string will be returned.

What is a list?

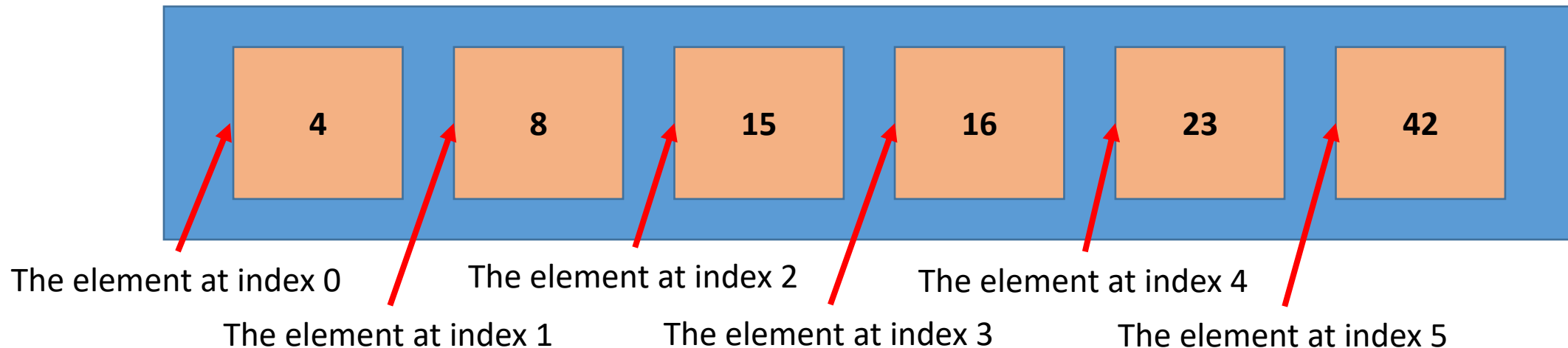
- An ***list*** is a sequence object that has multiple values.
 - Another way to look at it is a variable that has multiple values.



A list of ints

List Terminology

- An ***index*** (or ***subscript***) is the number representing the position of a list element.
 - First index is always zero.
 - The index is always an int.
- An ***element*** is the data or object referenced by an index.



Creating a List

- The elements are comma separated, enclosed in square brackets.

```
numbers = [4, 8, 15, 16, 23, 42]  
values = [35.6, 32.76, 51.4]  
pets = ["dog", "cat", "bird", "fish"]
```

- The data types of a list may vary.

```
mixed_values = [35.6, 15, "cat"]
```

- An empty list:

```
example = []
```

Printing a List

- When passed to the print function, the entire list is printed.
 - Includes commas and brackets.
 - Useful for testing/debugging.

```
numbers = [4, 8, 15, 16, 23, 42]  
print(numbers)
```

```
[4, 8, 15, 16, 23, 42]
```

Getting the Length of a List

- A list's *length* is the total number of elements contained within it.
 - Python's built-in len function returns the length of a sequence data type.

```
pets = ["dog", "cat", "bird", "fish"]  
length = len(pets)  
print(length)
```

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Retrieving an Element from a List

- Elements of a list are referenced using *subscript notation*.
 - Specify the index of the list's element.

```
numbers = [4, 8, 15, 16, 23, 42]  
test_value1 = numbers[0]  
print(test_value1)
```

```
test_value2 = numbers[4]  
print(test_value2)
```

```
print(numbers[2])
```

4
23
15

Changing an Element from a List

- Lists are *mutable*, meaning the elements can be changed.
 - Specify the index of the list's element and assign to it a new value.

```
values = [35.6, 32.76, 51.4]
print(values[1])
values[1] = 27.21
print(values[1])
```

32.76

27.21

Relative Indexes

- Negative indexes retrieve elements relative to the end of the list.

```
numbers = [4, 8, 15, 16, 23, 42]
print(numbers[-1])
numbers[-4] = 100
print(numbers[-4])
print(numbers[2])
```

Length - 1 = 6 - 1 = 5

Length - 4 = 6 - 4 = 2

42

100

100

IndexError Exception

- An IndexError exception will be raised if you try to access an index that does not exist.

```
numbers = [4, 8, 15, 16, 23, 42]  
print(numbers[10])
```

```
Traceback (most recent call last):  
  File "C:\testing\examples.py", line 8, in <module>  
    print(numbers[10])  
IndexError: list index out of range  
>>>
```

Iterating Over a List

- For loops can iterate over the values of a list.

```
numbers = [4, 8, 15, 16, 23, 42]
```

```
for number in numbers :  
    print(number)
```

```
print()
```

```
pets = ["dog", "cat", "bird", "fish"]
```

```
for animal in pets :  
    print(animal)
```

```
4  
8  
15  
16  
23  
42
```

```
dog  
cat  
bird  
fish
```

Iterating Over a List

- For loops (using the range function) can iterate over the entire list or a segment of the list.

```
numbers = [4, 8, 15, 16, 23, 42]
```

```
for i in range(0, 3) :  
    print(numbers[i])
```

```
print()
```

```
pets = ["dog", "cat", "bird", "fish"]
```

```
for i in range(1, len(pets)) :  
    print(pets[i])
```

4
8
15

cat
bird
fish

Determining if an Element Exists in a List

- An if statement can be used to find if an element/value is present in a list.
 - Utilizes the **in** keyword.
 - Does not tell us where (what index) the element was found.

```
numbers = [4, 8, 15, 16, 23, 42]
value = 7
if value in numbers :
    print("Value exists in list")
else :
    print("Value does not exist in list")
```

Value does not exist in list

Index Function

- A list's index function returns the index of an element/value.
 - Returns the index of the first matching element/value.
 - Case sensitive.

```
numbers = [4, 8, 8, 15, 16, 23, 42]  
found_index = numbers.index(8)  
print(found_index)
```

1

Index Function

- If the list's index function does not find a matching element/value a ValueError exception will be raised.

```
pets = ["dog", "cat", "bird"]  
found_index = pets.index("fish")  
print(found_index)
```

```
Traceback (most recent call last):  
  File "C:\testing\examples.py", line 9, in <module>  
    foundIndex = pets.index("fish")  
ValueError: 'fish' is not in list  
>>>
```

Adding to Lists

- Values can be added/concatenated to a list using the addition operator ONLY if the values are in list form.

```
numbers = [4, 8, 15, 16, 23, 42]  
numbers = numbers + 100  
print(numbers)
```

Error



```
numbers = [4, 8, 15, 16, 23, 42]  
numbers = numbers + [100]  
print(numbers)
```

```
[4, 8, 15, 16, 23, 42, 100]
```

Adding to Lists

- Two lists are merged/concatenated together when combined using the addition operator.

```
numbers = [4, 8, 15, 16, 23, 42]  
numbers = numbers + [100, 101, 102]  
print(numbers)
```

```
[4, 8, 15, 16, 23, 42, 100, 101, 102]
```


Adding to Lists

- Another way to add values to a list is with the addition combined assignment operator.

```
numbers = [4, 8, 15, 16, 23, 42]  
numbers += [100, 101, 102]  
print(numbers)
```

```
[4, 8, 15, 16, 23, 42, 100, 101, 102]
```

Append Function

- A list's append function can add a single element to the end of a list.

```
numbers = [4, 8, 15, 16, 23, 42]  
numbers.append(100)  
print(numbers)
```

```
[4, 8, 15, 16, 23, 42, 100]
```

Append Function vs Addition Operator

- A list's append function can only add a single element to the end of a list.
 - Does not have to be in list form.

```
numbers = [4, 8, 15, 16, 23, 42]
numbers.append(100)
print(numbers)
```

- Concatenating data to the end of a list using the addition/combined assignment operator can be used to add one or multiple elements.
 - Must be in list form.

```
numbers = [4, 8, 15, 16, 23, 42]
numbers = numbers + [100]
print(numbers)
```

```
numbers = [4, 8, 15, 16, 23, 42]
numbers += [100, 101, 102]
print(numbers)
```

Deleting Elements from Lists

- To remove an element by index, use the **del** (delete) keyword to remove it.
 - Any subsequent elements will be shifted over.

```
numbers = [4, 8, 15, 16, 23, 42]
```

```
del numbers[3]
```

```
print(numbers)
```

```
[4, 8, 15, 23, 42]
```

Deleting Elements from Lists

- To remove an element by value, the list's remove function will delete the element.
 - Only removes the first match.
 - Case-sensitive.

```
pets = ["dog", "cat", "bird", "cat", "fish"]  
pets.remove("cat")  
print(pets)
```

```
["dog", "bird", "cat", "fish"]
```

Deleting Elements from Lists

- If the element is not found, a ValueError exception will be raised.

```
pets = ["dog", "cat", "bird", "cat", "fish"]  
pets.remove("CAT")  
print(pets)
```

```
Traceback (most recent call last):  
  File "C:\testing\examples.py", line 9, in <module>  
    pets.remove("CAT")  
ValueError: list.remove(x): x not in list  
>>>
```

Remove Function vs del Keyword

- The value to delete must be known in order to use the list's remove function.
 - May raise a ValueError exception.
- When deleting using the del keyword, only the index must be known.
 - May raise an IndexError exception if the index does not exist.

Insert Function

- A list's insert function places a value at a specified index.
 - The existing elements are shifted over to make room.
 - First argument is the index.
 - If the specified index is beyond the length of the list, the value will be inserted at the end of the list.
 - Second argument is the value to insert.

```
numbers = [10, 20, 40, 50]  
numbers.insert(2, 30)  
print(numbers)
```

```
[10, 20, 30, 40, 50]
```


Sort Function

- A list's sort function rearranges a list so the values are in ascending order.

```
numbers = [30, 40, 20, 10]
numbers.sort()
print(numbers)
[10, 20, 30, 40]
```

- Strings are sorted in ascending, lexicographical order

```
pets = ["dog", "cat", "bird", "Cat", "fish"]
pets.sort()
print(pets)
['Cat', 'bird', 'cat', 'dog', 'fish']
```

Reverse Function

- A list's reverse function rearranges a list so the values are in reverse order.

```
numbers = [20, 40, 10, 30]  
numbers.reverse()  
print(numbers)
```

```
[30, 10, 40, 20]
```

Reverse Function

- We can use the sort and reverse functions together to sort a list in descending order.

```
numbers = [20, 40, 10, 30]
```

```
numbers.sort()
```

```
print(numbers)
```

```
[10, 20, 30, 40]
```

```
numbers.reverse()
```

```
print(numbers)
```

```
[40, 30, 20, 10]
```

List Slicing

- *Slicing* selects a range of elements from a sequence type.
- The general syntax for slicing a list is:

List[startIndex:endIndex]

- This will return a list containing the values between those indexes.
 - The start index is inclusive.
 - The end index is exclusive.

List Slicing

```
numbers = [4, 8, 15, 16, 23, 42]  
slice = numbers[1:4]  
print(slice)
```

```
[8, 15, 16]
```

```
pets = ["dog", "cat", "bird", "fish"]  
slice = pets[0:2]  
print(slice)
```

```
['dog', 'cat']
```

List Slicing

- Specifying only start index will return a slice beginning with the start index's element through the end of the list.

```
numbers = [4, 8, 15, 16, 23, 42]
slice = numbers[2:]
print(slice)
```

```
[15, 16, 23, 42]
```

```
pets = ["dog", "cat", "bird", "fish"]
slice = pets[1:]
print(slice)
```

```
['cat', 'bird', 'fish']
```

List Slicing

- Specifying only an ending index will return a slice beginning with the start of the list up to, but not including, the ending index.

```
numbers = [4, 8, 15, 16, 23, 42]  
slice = numbers[:3]  
print(slice)
```

```
[4, 8, 15]
```

```
pets = ["dog", "cat", "bird", "fish"]  
slice = pets[:2]  
print(slice)
```

```
['dog', 'cat']
```

List Slicing

- Slicing is safe from IndexError exceptions.
- If the starting index is greater than the ending index, an empty list will be returned.

```
numbers = [4, 8, 15, 16, 23, 42]
slice = numbers[3:1]
print(slice)

[]
```


List Slicing

- If the ending index is beyond the length of the list, Python will use the length as the ending index.

```
numbers = [4, 8, 15, 16, 23, 42]  
slice = numbers[2:100]  
print(slice)
```

```
[15, 16, 23, 42]
```

List Slicing

- If the starting index is negative, Python will use 0 as the starting index.

```
pets = ["dog", "cat", "bird", "fish"]  
slice = pets[-5:2]  
print(slice)  
['dog', 'cat']
```

- This is not the case if there is no ending index or the ending index is negative.

List Slicing

- When only a negative starting index is specified, the slice will begin relative to the end of the list.

```
pets = ["dog", "cat", "bird", "fish"]  
slice = pets[-3:]  
print(slice)  
['cat', 'bird', 'fish']
```

List Slicing

- When both starting and ending indexes are negative, the slice will begin and end relative to the end of the list.

```
pets = ["dog", "cat", "bird", "fish"]  
slice = pets[-3:-2]  
print(slice)  
['cat']
```

List Slicing

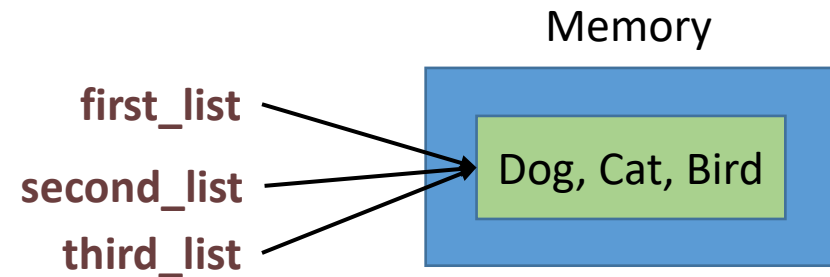
- If a negative starting index is greater (closer to zero) than the negative ending index, an empty list will be returned.

```
pets = ["dog", "cat", "bird", "fish"]  
slice = pets[-2:-3]  
print(slice)  
[]
```

Copying Lists

- Copying a list like the example below creates a ***shallow copy***.
 - Shallow copies are multiple variables referencing the same data.

```
first_list = ["Dog", "Cat", "Bird"]  
second_list = first_list  
third_list = first_list
```



Shallow Copies

- Since the variables reference the same list, changing one appears to change any others.

```
first_list = ["Dog", "Cat", "Bird"]  
second_list = first_list  
print(first_list[0])
```

Dog


```
second_list[0] = "Fish"  
print(first_list[0])
```

Fish

Copying Arrays

- To create a second, separate list with the same contents you need to perform a ***deep copy***.
 - A deep copy copies the contents of one list into a second list.

```
original = [3, 5, 7, 9]  
copy = []
```



Empty List

```
for element in original :  
    copy.append(element)
```


Deep Copies

- Since the variables reference different lists, changing one does not alter the original.

```
original = [3, 5, 7, 9]  
copy = []
```

```
for element in original :  
    copy.append(element)
```

```
print(original[0])
```

3

```
copy[0] = 99
```

```
print(original[0])
```

3

Deep Copies

- An alternative, simpler way to deep copy a list.
 - Concatenate the original list with an empty list.

```
original = [3, 5, 7, 9]  
copy = [] + original
```

```
for element in copy :  
    print(element)
```

3
5
7
9

Testing Equality of Lists

- The equality operator (==) compares lists to determine if they are equal.

```
first_list = ["Dog", "Cat", "Bird"]  
second_list = ["Dog", "Cat", "Bird"]
```

```
if first_list == second_list :  
    print("The lists are equal")  
else :  
    print("The lists are not equal")
```

```
The lists are equal
```

Testing Equality of Lists

- Order of the elements matter when determining equality.

```
first_list = ["Dog", "Cat", "Bird"]  
second_list = ["Cat", "Bird", "Dog"]
```

```
if first_list == second_list :  
    print("The lists are equal")  
else :  
    print("The lists are not equal")
```

```
The lists are not equal
```

Testing Equality of Lists

- Elements must be exact matches.
 - Not the case for numeric types. 10 and 10.0 would be a match.

```
first_list = ["Dog", "Cat", "Bird"]  
second_list = ["DOG", "CAT", "BIRD"]
```

```
if first_list == second_list :  
    print("The lists are equal")  
else :  
    print("The lists are not equal")
```

```
The lists are not equal
```

Testing Equality of Lists

- Must be the same length.

```
first_list = ["Dog", "Cat", "Bird"]  
second_list = ["Dog", "Cat"]
```

```
if first_list == second_list :  
    print("The lists are equal")  
else :  
    print("The lists are not equal")
```

The lists are not equal

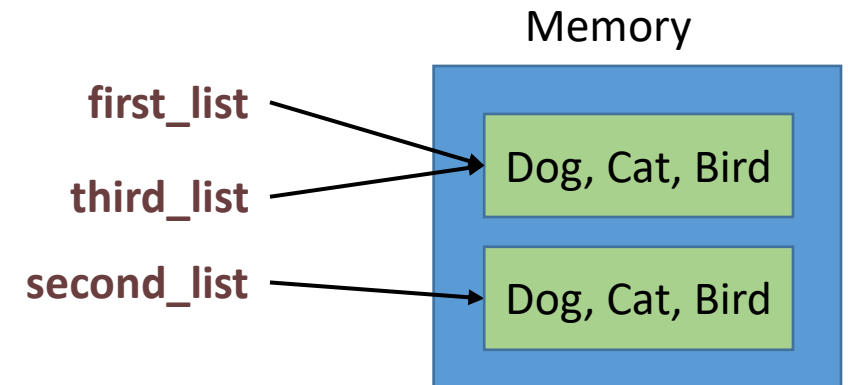
Testing Equality of Arrays

- The **is** keyword tests if two variables reference the same object.
 - In other words, the **is** keyword will determine if two list variables are shallow copies.

```
first_list = ["Dog", "Cat", "Bird"]  
second_list = ["Dog", "Cat", "Bird"]  
third_list = first_list #Shallow Copy
```

```
if first_list is third_list :  
    print("These lists are shallow copies")
```

```
if first_list is second_list :  
    print("These lists are shallow copies")
```



Multidimensional Lists

- When an list contains lists, it is called ***multidimensional***.

- A one dimensional list:

```
my_1d_list = [2, 4, 6]
```

- A two dimensional list:

```
my_2d_list = [[8, 3, 7], [1, 9, 9], [5, 6, 9]]
```


Multidimensional Lists

- It's often better to write two dimensional lists like this:

```
my_2d_list = [[8, 3, 7],  
               [1, 9, 9],  
               [5, 6, 9]]
```

- This way, it's easier to see each row (first dimension) and column (second dimension).

Multidimensional Lists

- Elements in a two dimensional list are referenced by row and column.
 - Row and column numbers start at zero.

```
my_2d_list = [[8, 3, 7],  
              [1, 9, 9],  
              [5, 6, 9]]
```

```
my_2d_list[1][2] = 2 #Assignment  
print(my_2d_list[0][1]) #Retrieval
```

3

Multidimensional Lists

```
my_2d_list = [[2, 4, 6],  
               [1, 3, 5],  
               [3, 6, 9],  
               [1, 2, 3]]
```

What element is at `my_2d_list[0][2]`?

What element is at `my_2d_list[3][1]`?

What element is at `my_2d_list[1][0]`?

Multidimensional Lists

- Rows in a multidimensional array do not have to be the same length.
 - This is called a ***Ragged List***.

```
my_2d_list = [[2, 4, 6],  
              [1, 3],  
              [9],  
              [1, 2, 3, 4]]
```

- Be careful with ragged lists as not all rows have the same number of columns.

`my_2d_list[2][1]` does not exist, even though every other row has a column 1.

Multidimensional Lists

- Two for loops are required to iterate through a two dimensional array.

```
my_2d_list = [[8, 3],  
              [1, 9]]
```

```
Rows { for row in range(0, len(my_2d_list)) :  
      for col in range(0, len(my_2d_list[row])) :  
      print(my_2d_list[row][col]) } Columns
```

Multidimensional Lists

- Iteration without using indexes.

```
my_2d_list = [[8, 3],  
              [1, 9]]
```

```
Rows { for row in my_2d_list :  
      for col in row :  
          print(col) } Columns
```

Multidimensional Lists

- There is no limit to the number of dimensions an list can have.
- A three dimensional list:

```
my_3d_list = [[[4,8],[15,16,23,42]],[[11,33],[22,44]]]
```

- In the case of a three dimensional array, the rows themselves have rows.

```
my_3d_list[2][2][3] = 100
```

Outer Row Inner Row Column

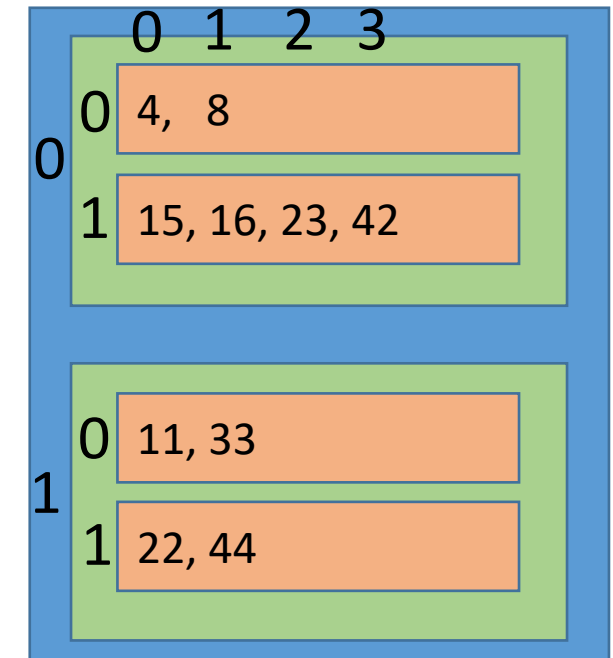
Multidimensional Lists

```
my_3d_list = [[0 1 2 3[4, 8],  
               [0 115, 16, 23, 42]],  
              [0 111, 33],  
              [22, 44]]]
```

Diagram illustrating the structure of `my_3d_list`. The list is a list of lists. The first dimension (outermost) has two elements, indexed 0 and 1. The second dimension (innermost) has four elements, indexed 0, 1, 2, and 3. The elements are: `my_3d_list[0][0] = 4`, `my_3d_list[0][1] = 8`, `my_3d_list[0][2] = 15`, `my_3d_list[0][3] = 16`, `my_3d_list[1][0] = 23`, `my_3d_list[1][1] = 42`, `my_3d_list[1][2] = 11`, `my_3d_list[1][3] = 33`, `my_3d_list[2][0] = 22`, `my_3d_list[2][1] = 44`.

What element is at `my_3d_list[0][1][2]`?

What element is at `my_3d_list[1][0][0]`?



Multidimensional Lists

- Three for loops are required to iterate through a three dimensional list.

```
my_3d_list = [[[4, 8],  
               [15,16,23,42]],  
               [[11,33],  
               [22,44]]]
```

```
for outer in range(0, len(my_3d_list)) :  
    for inner in range(0, len(my_3d_list[outer])) :  
        for col in range(0, len(my_3d_list[outer][inner])) :  
            print(my_3d_list[outer][inner][col])
```

Columns { Inner Rows { Outer Rows

Multidimensional Lists

- Iteration without using indexes.

```
my_3d_list = [[[4, 8],  
               [15,16,23,42]],  
              [[11,33],  
               [22,44]]]
```

```
for outer_row in my_3d_list :  
    for inner_row in outer_row :  
        for col in inner_row :  
            print(col)
```

Columns { Inner Rows { Outer Rows