# Introduction to Computer Programming Lecture 3.2:

# **Data Structures**

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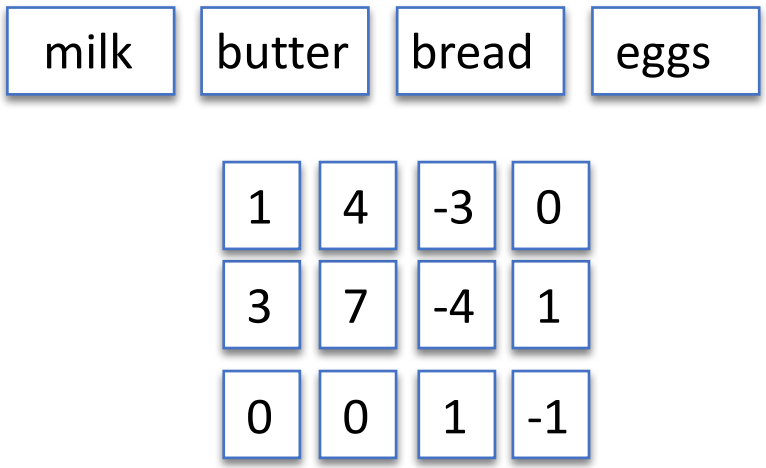
# Limitations of simple variables

```
ShoppingItem = "milk"

XCoordinate = 3.5

StudentNumber = 123456
```

**What if we need to deal with more complex data?**




# Learning Objectives

Data Structures

Lists

Tuples

Sets

Dictionary

Trees

Hash Tables

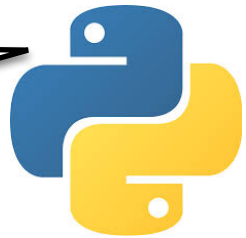
Queues

...

# Why use different data structures

Why would you need more than lists?

Different problems, need different solutions!



**Telephone Book**

**List 1**

| | |
|---|---|
| 1 | John Doe |
| 2 | Sarah Moor |
| 3 | Mary Salt |
| 4 | Kent Low |

**List 2**

| | |
|---|---|
| 1 | +555 7782 |
| 2 | +555 4039 |
| 3 | +555 9993 |
| 4 | +555 1234 |

**Dictionary**

| | |
|---|---|
| John Doe | +555 7782 |
| Sarah Moor | +555 4039 |
| Mary Salt | +555 9993 |
| Kent Low | +555 1234 |

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# Lists

Initialise with no elements

```
>>> ShoppingList = ["bread", "milk","eggs"]
>>> ShoppingList = []
>>> ShoppingList.append("bread")
>>> ShoppingList.append("eggs")
>>> ShoppingList.append("milk")
>>> ShoppingList
['bread', 'eggs', 'milk']
>>> ShoppingList[0]
'bread'
```

add to the end of the list

access individual items

```
>>> ShoppingList[0] = "rye bread"
>>> ShoppingList
['rye bread', 'eggs', 'milk']
```

edit (mutable), i.e. items can be changed

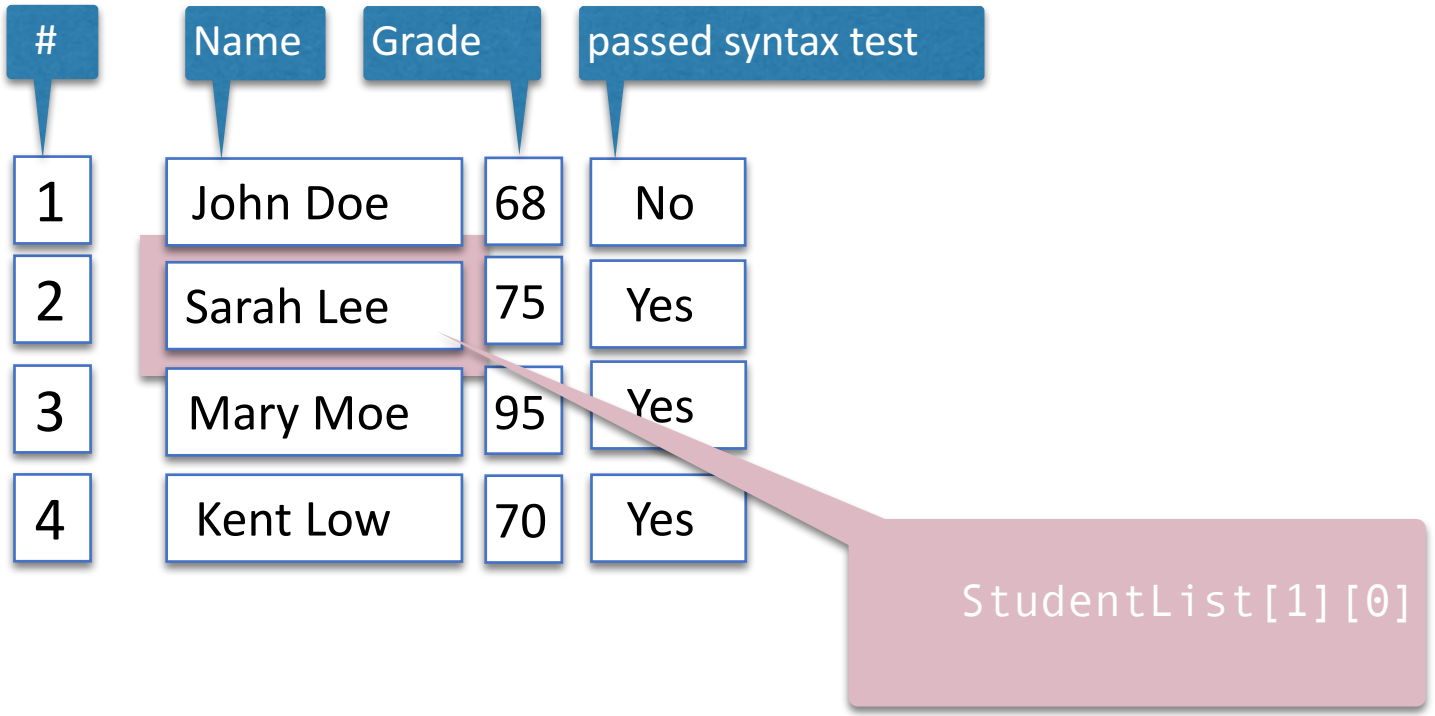
```
ShoppingList = ["butter","milk","bread"]
for item in ShoppingList:
    print(item)
```

you easily loop through a list (it's "iterable")

# Nested Lists

*List of lists* *List* *List*

```
StudentList =  [["John Doe",68,False],["Sarah Lee", 75, True],....]
```




```
StudentList.append(["Mary Moe",95,True])
```

# Nested Lists

```
>>> StudentList = [["John Doe", 68, False],["Sarah Lee", 75, True]]
>>> print(StudentList)
[['John Doe', 68, False], ['Sarah Lee', 75, True]]
```

```
>>> StudentList.append(["Kent Low", 70, True])
```

```
>>> print(StudentList[0][1])
68
```

"nested" index

```
for Entry in StudentList:
    for SubEntry in Entry:
        print(SubEntry)
```

nested loops

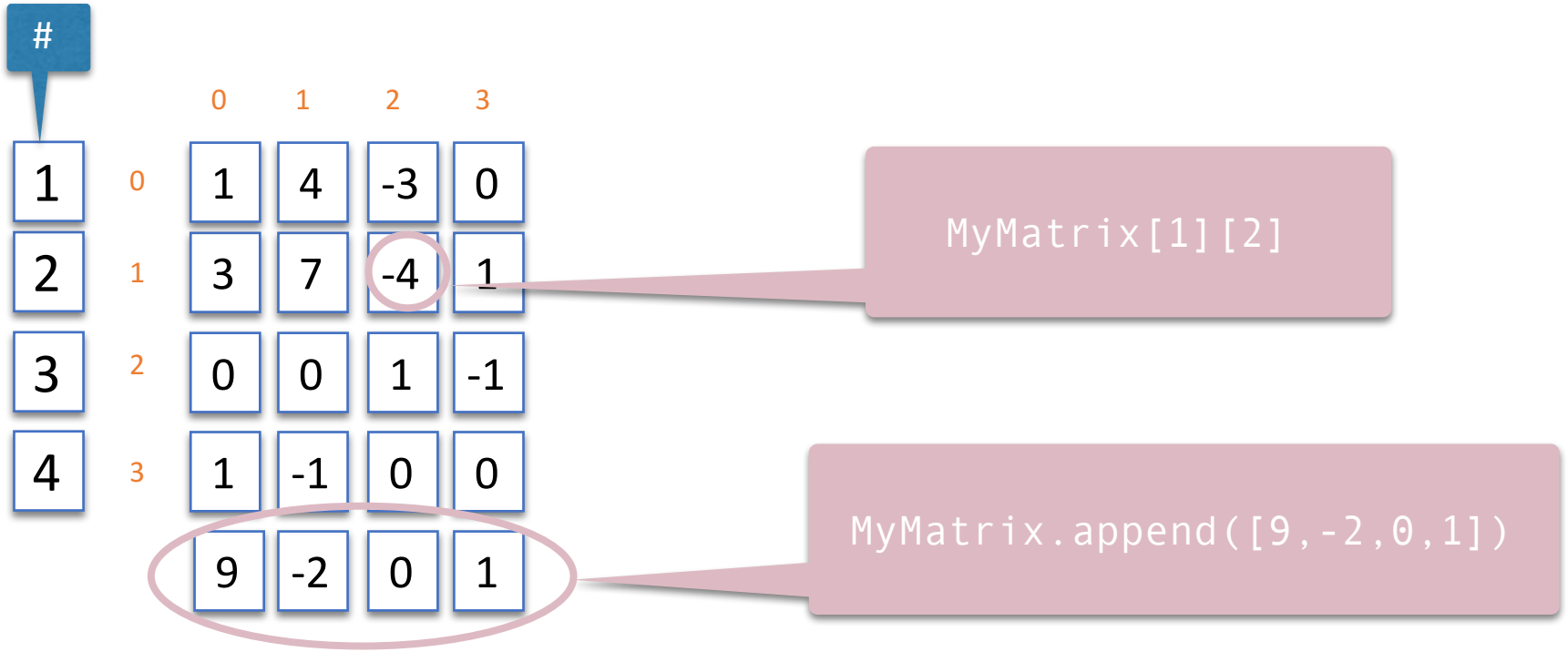
```
StudentList.append(45)
[['John Doe', 68, False], ['Sarah Lee', 75, True], 45]
```

Python lets you append anything.
You have to check as programmer!

# Nested Lists

## Application: Matrix

MyMatrix = [[1, 4, -3, 0], [3, 7, -4, 1], [0, 0, 1, -1], [1, -1, 0, 0]]



# Nested Lists

## Application: Matrix

```
MyMatrix = [[1, 4, -3, 0], [3, 7, -4, 1], [0, 0, 1, -1], [1, -1, 0, 0]]
```

```
>>> for Row in MyMatrix:
        print(Row)

[1, 4, -3, 0]
[3, 7, -4, 1]
[0, 0, 1, -1]
[1, -1, 0, 0]
```

```
>>> for Row in MyMatrix:
        for Item in Row:
            print(Item)

1
4
-3
0
3
7
-4
.
.
.
```

# List Comprehensions

Elegant way to create lists from sequences (rule-based).

1. **Make lists** where each element is the result of some operations applied to each member of the sequence.

2. **Create a subsequence** of those elements that satisfy a certain condition.

List comprehension is surrounded by brackets.

Instead of the list of data inside it, enter an expression followed by for loop and if-else clauses.

```
>>> # define a range
>>> xRange = [x for x in range(10)]
>>> print(xRange)
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]

print(type(xRange))
list
```

```
>>> # let the range start at 1
>>> xRange = [x+1 for x in range(10)]
>>> print(xRange)
[1, 2, 3, 4, 5, 6, 7, 8, 9, 10]
```

# List Comprehensions

```
#define a range
xRange = [x for x in range(10)]
print(xRange)

# to let range start at 1
xRange = [x+1 for x in range(10)]
print(xRange)

# to define a funcion
# e.g.: y = 3x^2+5
y = [3*x*x+5 for x in xRange]
print(y)

# nested lists are possible as well
xRangeSmall = [x+1 for x in range(5)]
newMatrix = [[x, x**2, x**3] for x in xRangeSmall]
print(newMatrix)
```

any offset is possible

```
# time vector with time step of 1 ms
t = [x/1000 for x in range(10)]
y = [x**2 for x in t]
```

time vector for plotting

# List Comprehensions

```
# to find subsets
# e.g., only even numbers
# module operation finds the remainder after division
# e.g. 9 mode 3 = 0 and 11 mod 3 = 3
# hence x mod 2 = 0 for even numbers
evenNr = [x for x in xRange if x % 2 == 0]
print(evenNr)
```

How would you get odd only numbers?

```
# works also for strings
# e.g., to make sure all characters are upper case
Names =["JAMEs", "claire", "ChLOe"]
upperCase = [x.upper() for x in Names]
print(upperCase)
```

Can also work as a filter

```
# filter out lower numbers
Numbers = [3, 0, 2, 10, 7]
LowerNumbers = [x for x in Numbers if x <= 5]
print(LowerNumbers)
```

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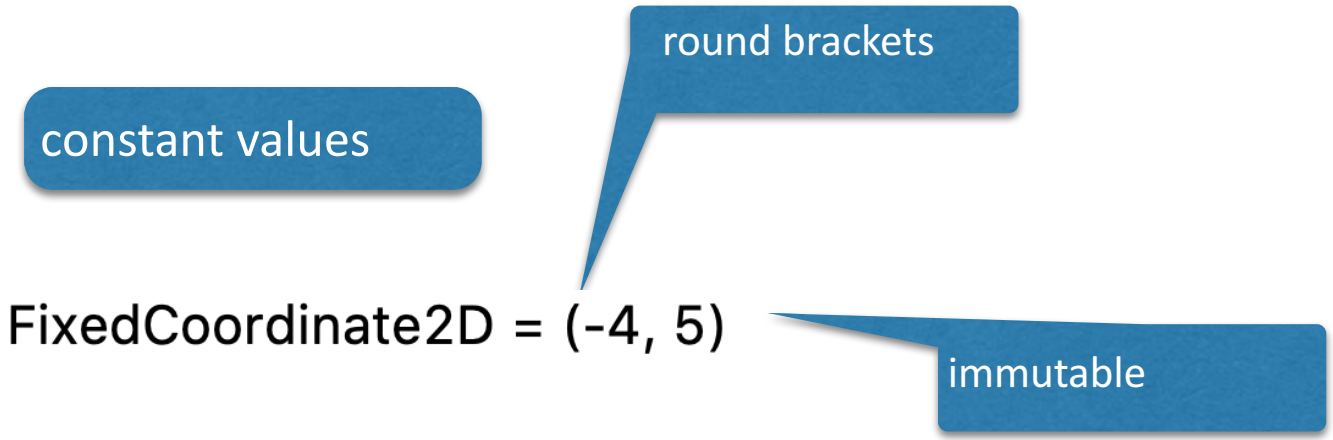
Dictionary

# Tuples

- Like lists, tuples are sequences of ’boxes’ that store data.
- Unlike lists, tuples are **immutable** (can **not** be changed)




**Note:** Tuples are lists with **functionality removed** — why do this?
It is an example of syntactic salt — “a feature designed to make it harder to write bad code”.

# Tuples

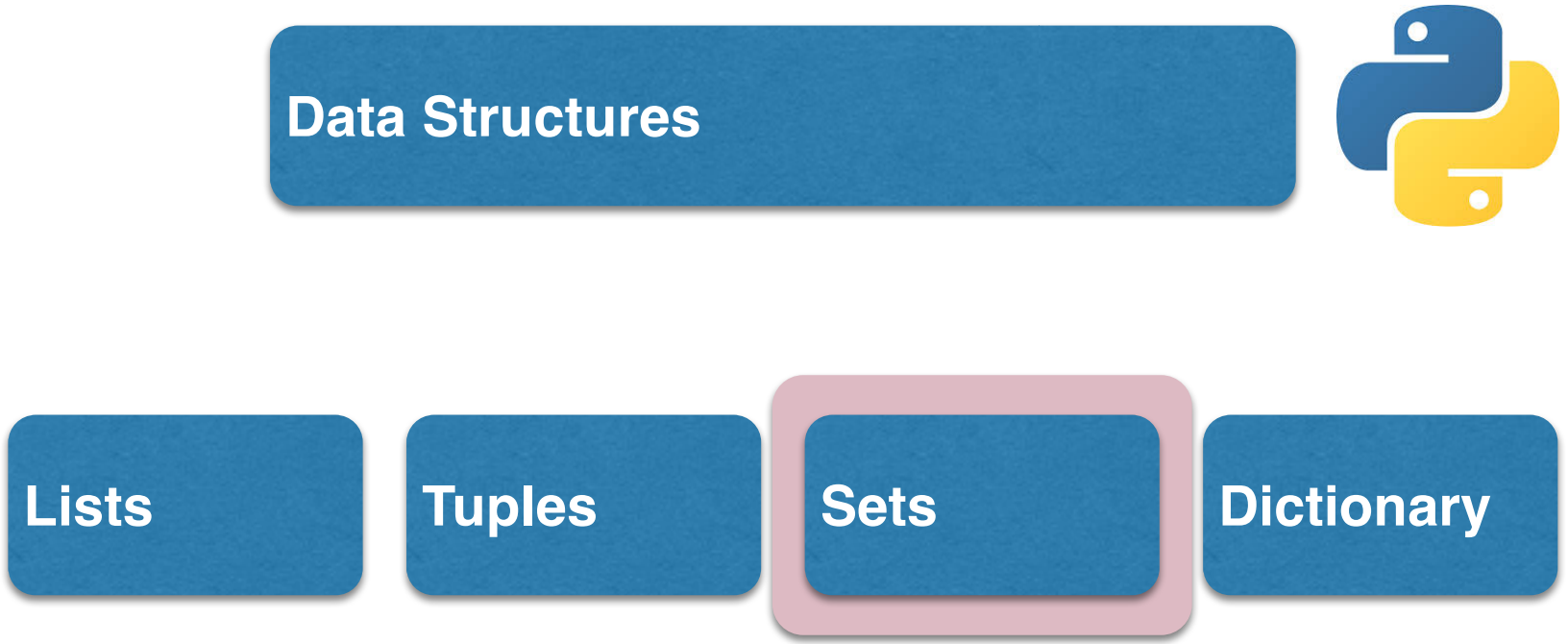
```
FixedCoordinates2D = (-4,5)
print(FixedCoordinates2D)

print(FixedCoordinates2D[1])

FixedCoordinates2D[0] = 3

NestedTuple = ( (4,"Hello"), (7, "OK"))
print(NestedTuple)

TupleOfCharacters = tuple("Hello")
```

access item with squared brackets

produces error immutable

casting works here as well

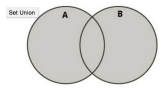
# Learning Objectives



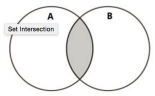
# Sets

- Sets are **unordered** collections with **no duplicate** elements.
- You can **test membership** of a set (“is element in set”)
- Supports **mathematical operations**

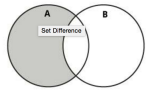
```
>>> FirstSet = {1, 2, 8, 6, 7}
>>> SecondSet = {5, 4, 6}
```



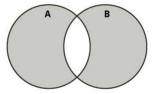
union (|) {1, 2, 8, 6, 7, 5, 4}



intersection (&) {6}



difference (-) {1, 2, 8, 7}



sym. diff (^) {1, 2, 8, 6, 7, 5, 4}

# Sets

order is irrelevant!

ignores double entries

```
>>> FirstSet = {1, 2, 3, 4, 4, 5}
>>> FirstSet
{1, 2, 3, 4, 5}
>>> SecondSet = {1, 2, 2, 7, 8}
>>> SecondSet
{8, 1, 2, 7}
>>> 3 in FirstSet
True
>>> 3 in SecondSet
False
>>> FirstSet - SecondSet
{3, 4, 5}
>>> FirstSet | SecondSet
{1, 2, 3, 4, 5, 7, 8}
>>> FirstSet & SecondSet
{1, 2}
>>> FirstSet ^ SecondSet
{3, 4, 5, 7, 8}
>>> FirstSet[2]
Traceback (most recent call last):
  File "<pyshell#62>", line 1, in <module>
    FirstSet[2]
TypeError: 'set' object does not support indexing
```

no order - no index

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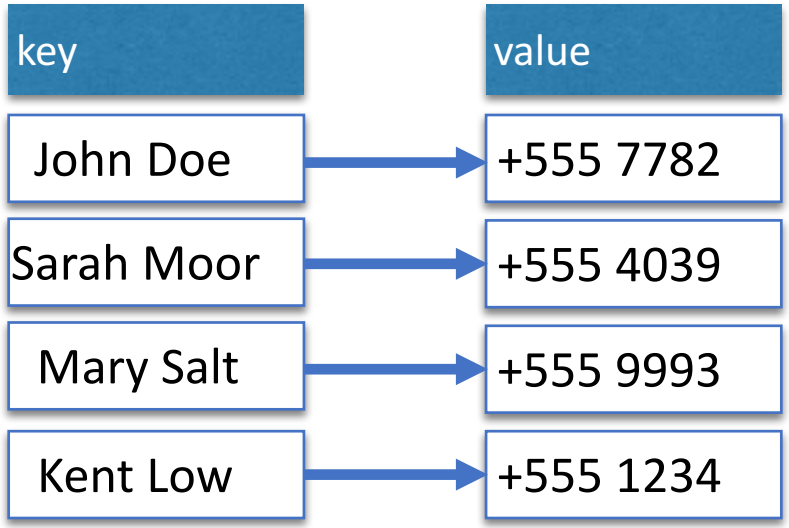
# Dictionary

Dictionaries are **unordered sets** of data that have a **key** and a **value** (an important idea in databases).




- Unlike sequences (lists, tuples), which are accessed by numerical indices (0,1,2,3...), dictionaries are **indexed by keys**.

- Keys must be **unique** and **immutable** (often numbers or strings).

# Dictionary

```
States = {
  "Oregon": "OR",
  "Florida": "FL",
  "California": "CA",
  "New York": "NY"
  }

# add a new entry
States["Michigan"] = "MI"
print(States)

# delete an entry
del States["New York"]
print(States)

# list the keys
print(States.keys())

# you can even sort them
print(sorted(States.keys()))

# check for entries
print("Florida" in States)
print("Texas" in States)

# loop through dictionary
for Name, Abbr in States.items():
  print(Name, Abbr)
```

True or False –
can be used for conditions

You get both key
and values