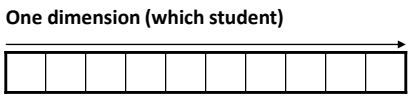
Composite Types, Lists Part 2

- When to use multi-dimensional lists
- Creating 2D lists
- How to access a 2D list and its parts
- Basic 2D list operations: display, accessing parts, copying the list
- Using named constants to stay within list bounds
- Dynamically creating 2D lists with the append function

When To Use Lists Of Different Dimensions

- It's determined by the data – the number of categories of information determines the number of dimensions to use.
- Examples:
- (1D list)
  - –Tracking grades for a class (previous example)
  - –Each cell contains the grade for a student i.e., `grades[i]`
  - –There is one dimension that specifies which student's grades are being accessed



- (2D list)
  - –Expanded grades program (table: grades for multiple lectures)
  - –Again there is *one dimension* that specifies which student's grades are being accessed
  - –The *other dimension* can be used to specify the lecture section

When To Use Lists Of Different Dimensions (2)

- (2D list continued)

Student

Lecture section

	First student	Second student	Third student	…
L01				
L02				
L03				
L04				
L05				
:				
L0N				

When To Use Lists Of Different Dimensions (3)

- (2D list continued)
- Notice that each row is merely a 1D list
- (A 2D list is a list containing rows of 1D lists)

Important:

- List elements are specified in the order of `[row] [column]`
- Specifying only a single set of brackets specifies the row

Columns (e.g. grades)

	[0]	[1]	[2]	[3]
[0] L01				
[1] L02				
[2] L03				
[3] L04				
[4] L05				
[5] L06				
[6] L07				

Rows (e.g. lecture section)

Creating And Initializing A Multi-Dimensional List In Python (Fixed Size During Creation)

General structure

```
<list_name> = [ [<value 1>,  <value 2>, ... <value n>],
                [<value 1>,  <value 2>, ... <value n>],
                     : :        :
                     : :        :
                [<value 1>,  <value 2>, ... <value n>] ]
```

Rows

Columns

Creating And Initializing A Multi-Dimensional List In Python (2): Fixed Size During Creation

Name of the example program: `1display2DList.py`

Learning: creating, displaying a fixed size 2D list

```
table = [ [0, 0, 0],
          [1, 1, 1],
          [2, 2, 2],
          [3, 3, 3]]

for r in range (0, 4, 1):
   print (table[r])  #Each call to print displays a 1D list
```

```
c=0  c=1  c=2
r = 0 [0, 0, 0]
r = 1 [1, 1, 1]
r = 2 [2, 2, 2]
r = 3 [3, 3, 3]
```

```
for r in range (0,4,1):
   for c in range (0,3,1):
       print(table[r][c], end="")
   print()
                #Displays a list element

print(table[2][0]) #Displays 2 not 0
```

```
0 1 2 (col)
r = 0 000
r = 1 111
r = 2 222
r = 3 333

2
```

2D Lists: Levels Of Access

```
table = [ [0, 0, 0],
          [1, 1, 1],
          [2, 2, 2],
          [3, 3, 3]]
print(table)  #Entire list
print(table[0]) #First row
print(table[3][1]) #4th row, 2nd column
print(table[0][0][0]) #What does this do?
```

```
[[0, 0, 0], [1, 1, 1], [2, 2, 2], [3, 3, 3]]
[0, 0, 0]
3
TypeError: 'int' object is not subscriptable
```

```
table = [ [["a","b"], 0, 0],
          [1, 1, 1],
          [2, 2, 2],
          [3, 3, 3]]

print(table[0][0][0]) #Now what does this do?
```

James Tam

Creating 2D Lists Via The Repetition Operator

Name of the example program: 2creatingListViaRepetition.py

Learning:

- Creating a variable sized 2D list using the repetition operator and the append method.
- The 2D list is created by creating a 1D list and **appending the 1D list to the end of the 2D list**.

```
MAX_COLUMNS = 5
MAX_ROWS = 3
ELEMENT = "*"
aList = []
r = 0
while (r < MAX_ROWS):
   tempList = [ELEMENT] * MAX_COLUMNS
   aList.append(tempList)
   r = r + 1
```

James Tam

How To Avoid Overflowing 2D Lists

- Employ named constants
- Recall that the previous example declared 2 named constants.

```
MAX_COLUMNS = 5
MAX_ROWS = 3
```

- Control access to list elements using these constants.

```
r = 0
while (r < MAX_ROWS):
    c = 0
    while (c < MAX_COLUMNS):
        print(aList[r][c], end = "")
        c = c + 1
    print()
    r = r + 1
```

James Tam

Copying Lists

- Important: A variable that appears to be a list is really a reference to a list.
  - Recall: the reference and the list are two separate memory locations!

```
matrix = [ [0, 0, 0],
           [1, 1, 1],
           [2, 2, 2],
           [3, 3, 3]]
```

  - Wrong way to 'copy' a 2D list

`aList1 = aList2` (Why is this wrong? Hint: recall what is stored in `aList1` and `aList1`)

James Tam

Copying Lists: Example

- **Name of the example program:** `3copyingListsBothWays.py`
- This is the **wrong way**.

```
aGrid1 = create()
aGrid2 = aGrid1
aGrid1[3][3] = "!"
print("First list")
display(aGrid1)
print("Second list")
display(aGrid2)
```

```
# FYI:
def create():
    aGrid = [["*","*","*","*"],
             ["*","*","*","*"],
             ["*","*","*","*"],
             ["*","*","*","*"]]
    return(aGrid)
```

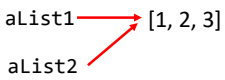
James Tam

New Terminology

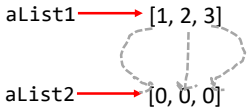
- **Shallow copy**: copies what's stored in the reference (location of a list).

Code

```
aList1 = [1,2,3]
aList2 =aList1
```



- **Deep copy**: copies the data from one list to another.
  - Create a new list e.g. aList2 = [0]*3
  - Copy each piece of data (list elements) from one list to another e.g. `aList2[0] = aList1[0]`



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Copying Lists: Example (2)

- This is the **right way**.

```
aGrid1 = create()
aGrid2 = create()
copy(aGrid1,aGrid2)
```

```
def copy(destination,source):
    for r in range (0,SIZE,1):
        for c in range (0,SIZE,1):
            destination[r][c] = source[r][c]
```

```
copy(aGrid1,aGrid2)
aGrid1[0][0] = "?" #These statements prove there's two lists
aGrid1[3][3] = "?"
print("First list")
display(aGrid1)
print("Second list")
display(aGrid2)
```

James Tam

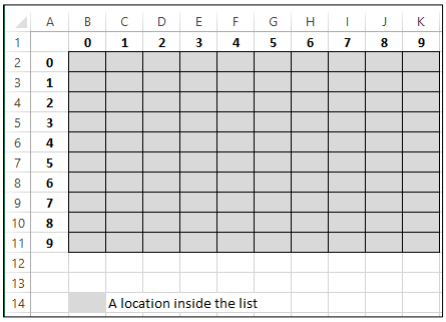
Copying Lists: Write The Code Yourself

- For this class you should not use some else's pre-created list copy method (e.g. those defined when you "`import copy`")
- Not all programming languages have this capability (you will need to know how to do it yourself).
- Writing the code yourself will provide you with extra practice and help you become more familiar with list (in other languages 'array') operations.

James Tam

Boundary Checking Lists

- Checking if a particular location (row, column) for a 2D list is inside the bounds of the list is a common program task.



- Rather than repeating the check it may be more efficient to write one Boolean function to implement this task.

James Tam

Boundary Checking Lists (2)

- **Name of the example**: 4boundary_checking

```
SIZE = 4
FIELD = " "
FOREST = "^"
WATER = "W"
BURNT = "F"
ERROR = "!"

def display(world):
    r = -1
    c = -1
    for r in range (0,SIZE,1):
        for c in range (0,SIZE,1):
            print(world[r][c], end="")
        print()
    print()
```

James Tam

Boundary Checking Lists (3)

```
def editLocation(row,column,world):
   world[row][column] = "!"

def generateElement(randomNumber):
    element = ERROR
    if ((randomNumber >= 1) and (randomNumber <= 50)):
        element = FIELD
    elif ((randomNumber >= 51) and (randomNumber <= 80)):
        element = FOREST
    elif ((randomNumber >= 81) and (randomNumber <= 100)):
        element = WATER
    else:
        element = ERROR
    return(element)
```

James Tam

Boundary Checking Lists (4)

```
def getLocation():
    outOfBounds = True
    row = -1
    column = -1
    while (outOfBounds == True):
       print("Enter location of square to change to a !")
       row = int(input("Enter a row (0-4): "))
       column = int(input("Enter a column (0-4): "))
       outside = isOut(row,column)
       if (outside == True):
          print("Row=%d, Col=%d" %(row,column), end = " ")
          print("is outside range of 0-" + str(SIZE) + "." )
       else:
          outOfBounds = False
    return(row,column)
```

James Tam

Boundary Checking Lists (5)

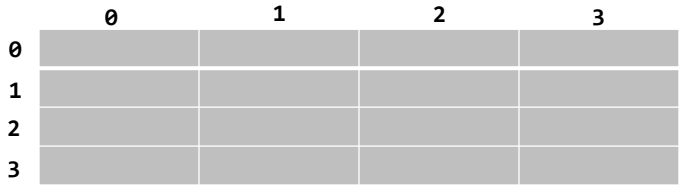
```
def initialize():
    world = []
    r = -1
    c = -1
    randomNumber = -1
    newElement = ERROR
    for r in range (0,SIZE,1):
        randomNumber = random.randrange(1,101)
        element = generateElement(randomNumber)
        tempRow = [element] * SIZE
        world.append(tempRow)  # Add in new empty row
        print(tempRow)
    return(world)
```

James Tam

Boundary Checking Lists (6)

```
def isOut(row,column):
    outside = False
    if ((row < 0) or \
        (row >= SIZE) or \
        (column < 0) or \
        (column >= SIZE)):
        outside = True
    return(outside)
```

SIZE = 4



James Tam

Boundary Checking Lists (7)

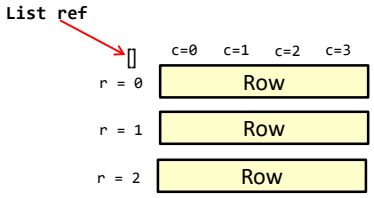
```
def start():
    stillRunning = True
    answer = ""
    row = -1
    column = -1
    world = initialize()
    while(stillRunning): #while(stillRunning == True):
        display(world)
        row,column = getLocation()
        editLocation(row,column,world)
        answer = input("Hit enter to continue,'q' to quit: ")
        if ((answer == "q") or (answer == "Q")):
            stillRunning = False

start()
```

James Tam

Creating And Initializing A Multi-Dimensional List In Python: Dynamic Creation

General structure (Using loops):

- Create a variable that refers to an empty list
- Create list:
  - One loop (outer loop) traverses the rows.
  - Each iteration of the outer loop creates a new 1D list (empty at start)
  - Then the inner loop traverses the columns of the newly created 1D list creating and initializing each element in a fashion similar to how a single 1D list was created and initialized (add to end)
- Repeat the process for each row in the list



Etc.

```
aGrid = []
for r in range (0, 3, 1):
    aGrid.append ([])
    for c in range (0, 3, 1):
        aValue = <Some source>
        aGrid[r].append(aValue)
```

Repeating Just The Steps In The Code Creating The List

1. Create a variable that refers to an empty list

```
aGrid = []
```

2. Successively create rows in the list

```
for r in range (0,noRows,1):
    aGrid.append ([])
```

3. Each row is a 1D list, add elements to the end of the 1D list (empty list needed in #2 so that the append method can be called to add elements to the end).

```
for c in range (0,noColumns,1):
   aGrid[r].append("*")
```

– The [r] part of specifies which row the loop will add elements on the end.
`aGrid[r].append("*")`

Recall 'append' is unique to a list. Append won't work if for something other than a list but for a list an empty row can have new elements appended.

```
num = 123
num.append(4)
```

James Tam

Example 2D List Program: A Variable Sized 2D List (Dynamic)

•**Name of the example program:** `5variableSize2DList.py`

```
aGrid = []
noRows = int(input("Number rows: "))
noColumns = int(input("Number columns: "))
#Create list
for r in range (0,noRows,1):
    aGrid.append ([]) #Create empty row, add to list
    for c in range (0,noColumns,1):
        aGrid[r].append("*") #Add elements to the end of new row

#Display list
for r in range (0,noRows,1):
   for c in range (0,noColumns,1):
      print(aGrid[r][c], end="")
   print()
```

2D Lists: Using Append

Final JT hint: Make sure you apply the right operation on the right type of variable.

```
table = [ [0, 0, 0],
          [1, 1, 1],
          [2, 2, 2],
          [3, 3, 3]]

table.append([2,1,7]) #Where was the append occurring?
print(table)

table[3].append(3) #Where was the append occurring?
print(table)

#What element is the append applied to?
table[2][1].append(888)

Hint: add the following before the last instruction
print(table[2][1])
```

James Tam

Extra Practice

List operations:

- For a numerical list: implement some common mathematical functions (e.g., average, min, max, mode – last one is challenging).
- For any type of list: implement common list operations (e.g., displaying all elements one at a time, inserting elements at the end of the list, insert elements in order, searching for elements, removing an element, finding the smallest and largest element).
  - In order to develop your programming skills you should write the code yourself rather than using predefined python methods such as append, `min`, `max` etc.

After This Sub-Section You Should Now Know

- When to use lists of different dimensions
- Basic operations on a 2D list
- How to create a 2D list: fixed size and a variable sized list by using the repetition operator.
- How to access a 2D list: the whole list, rows in the list and individual elements.
- How to properly copy the contents of a 2D list into another 2D list as well as a common mistake when copying lists.
- The use of a named constant to ensure that list boundaries are adhered to.
- The ability to dynamically creating 2D lists using the append function for both the rows and columns.