Data Structures and Algorithms

Nested lists, comprehension and I/O

CS51 – Spring 2026

Nested lists

Unusual lists

- bizarre_list = [47, 'cs51', ['Feta','Cheddar', 'Edam', 'Gouda']]

- What would len(bizarre_list) return?
  - 3
- What would 'Feta' in bizarre_list return?
  - False
- What would ['Feta','Cheddar', 'Edam', 'Gouda'] in bizarre_list return?
  - True

bizarre_list →

element	47	'cs51'	['Feta','Cheddar', 'Edam', 'Gouda']
index	0	1	2

Nested lists

- Nested lists are lists of lists. *If* inner lists have the same length, you can think of them as matrices. For example,
- matrix = [[1, 2, 3], [4, 5, 6], [7, 8, 9], [10, 11, 12]] has 4 rows and 3 columns

matrix →

element	[1, 2, 3]	[4, 5, 6]	[7, 8, 9]	[10, 11, 12]
index	0	1	2	3

- If matrix[0] returns [
- matrix[1]
  - returns [4, 5, 6]
- matrix[2]
  - returns [7, 8, 9]
- matrix[3]
  - returns [10, 11, 12]

Nested lists

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- *If* inner lists have the same length, you can think of them as matrices. For example,
- matrix = [[1, 2, 3], [4, 5, 6], [7, 8, 9], [10, 11, 12]]

matrix →

element	[1, 2, 3]	[4, 5, 6]	[7, 8, 9]	[10, 11, 12]
index	0	1	2	3

- If matrix[0][0] returns 1 and matrix[1][1] returns 5, what do these return?
- matrix[2][1]
  - returns 8
- matrix[3][2]
  - returns 12
- matrix[3][3]
  - returns Error

Practice Time

- What would the following code print?

```
a_list = [[4, [True, False], 6, 8], [888, 999]]
if a_list[0][1][0]:
    print(a_list[1][0])
else:
    print(a_list[1][1])
```

Answer

- What would the following code print?

```
a_list = [[4, [True, False], 6, 8], [888, 999]]
if a_list[0][1][0]:
    print(a_list[1][0])
else:
    print(a_list[1][1])
```

- It would print 888

Practice Time

- Define a function nested_total that takes a list of lists of ints and returns the sum of all the values.
- For example:

```
lst = [[1, 2], [3], [4, 5, 6]]

sum = nested_total(lst)

print(sum)
```

- Would print 21

Answer

- Define a function nested_total that takes a list of lists of ints and returns the sum of all the values.

```
def nested_total(lst):
    sum = 0
    for i in range(len(lst)):
        for j in range(len(lst[i])):
            sum += lst[i][j]
    return sum
```

Practice Time

- Define a function nested_avg that takes a list of lists of ints and returns a list with each sublist averaged
- For example:

```
list = [[1, 2], [3], [4, 5, 6]]

lst_avg = nested_avg(lst)

print(lst_avg)
```

- Would print [1.5, 3.0, 5.0]

Answer

- Define a function nested_avg that takes a list of lists of ints and returns a list with each sublist averaged

```
def nested_avg(lst):
    lst_avg = []
    for i in range(len(lst)):
        length = len(lst[i])
        sum = 0
        for j in range(length):
            sum += lst[i][j]
        lst_avg.append(sum/length)
    return lst_avg
```

List comprehension

Appending elements to a list

```
courses = ['csci051', 'phys042', 'csci054', 'engl019']

cs_courses = []

for course in courses:

    if 'csci' in course:

        cs_courses.append(course)

print(cs_courses)
```

Would print ['csci051', 'csci054']

List comprehension

```
courses = ['csci051', 'phys042', 'csci054', 'engl019']

cs_courses = [course for course in courses if 'csci' in course]

print(cs_courses)
```

Would also print ['csci051', 'csci054']

List comprehension syntax

courses = ['csci051', 'phys042', 'csci054', 'engl019']

cs_courses = [course for course in courses if 'csci' in course]

print(cs_courses)

Would also print ['csci051', 'csci054']

In general, the syntax is:

- newlist = [*expression* for *item* in *iterable* if *condition* == True]
- iterable objects: string, list, tuple, range, etc
- Using list comprehension, create a new list of all courses that are not csci051.
- non_cs051 = [course for course in courses if course != 'csci051']

Practice Time

- Consider the following code. What will new_lst evaluate to?

```
new_lst = []

for x in range(10):

    if x % 2 == 0:

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

- Use list comprehension to shorten it

Answer

- Consider the following code. What will new_lst evaluate to?

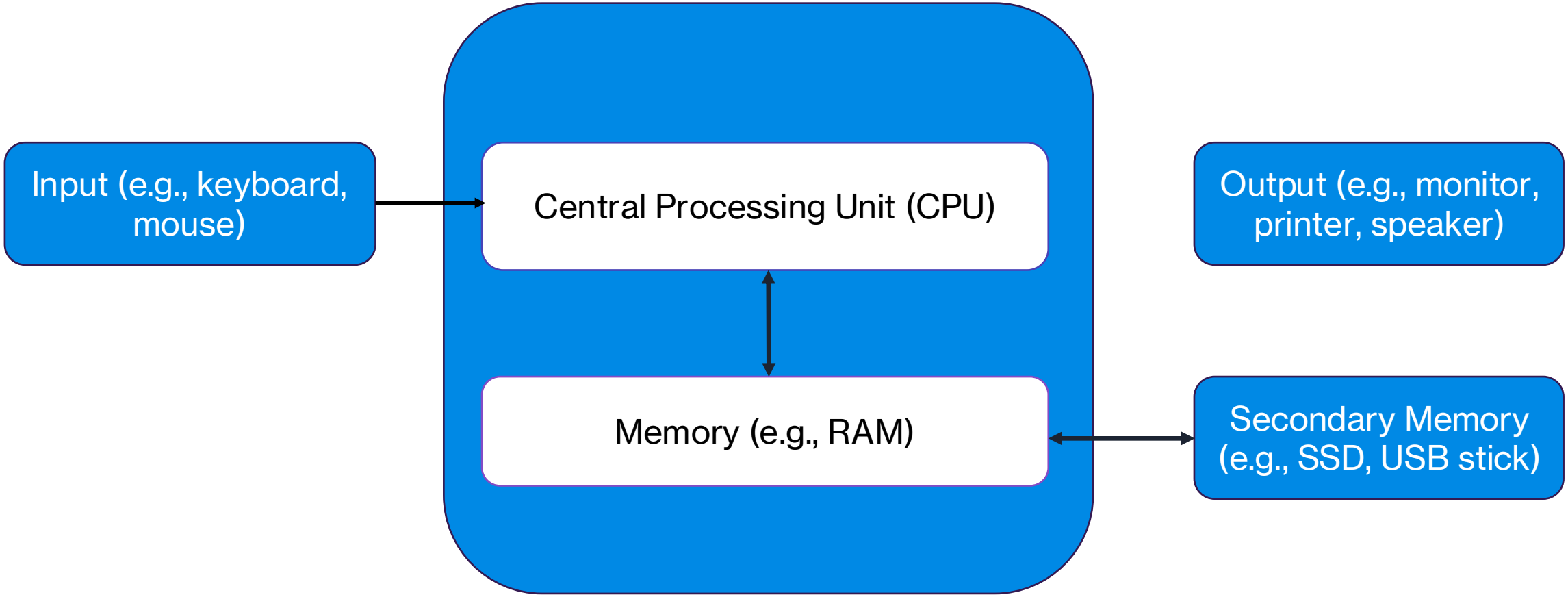
```
new_lst = []

for x in range(10):

    if x % 2 == 0:

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

- new_lst would be [0, 4, 16, 36, 64]
- Use list comprehension to shorten it
- [x**2 for x in range(10) if x % 2 == 0]

Files

Files

- Programs are stored in main memory, i.e. RAM.
- Files are data stored in secondary memory, such as the hard drive, USB sticks. etc.



Files

- Files store data in the form of bytes.
- Although we make a distinction between text and binary files, text files are binary files that follow a specific encoding, most likely UTF-8, to interpret the bytes as valid characters (letters, numbers, symbols, emojis).

File system

- A **filesystem** is the way that an operating system organizes and provides access to store files.
- Files have a **filename** that we can identify them by.
- Files also reveal information about their type or appropriate applications to read them through their **extension**. E.g., .pdf shows that this is a pdf file and can be read with pdf readers such as Adobe Reader.
- They also contain **metadata** about their size, when they were created, last accessed, who created them or last modified them, who can read them/change them etc.
- Files are organized in **folders** or **directories** which themselves can have nested folders.
- We specify where a file resides through its **path**. For example, in my laptop, this presentation is in the directory /Users/apaa2017/Documents/cs051/lectures

Reading text files line by line

- To read a file line by line, we use the following template:

```
reader = open('filename.txt', 'r')
for line in reader:
        # do something
reader.close()
```

- `reader` is a reference to a file object.
- `filename.txt` gets replaced with the actual name of the file we want to read.
- The parameter `r` stands for read. That means we want to open the file to read it.
- The for in loop allows us to go line by line in the file. We could have done for example `print(line)`
- Don't forget to close the once you open it.

Reading files as a list of strings

- Python also supports reading all lines of a file into a list of strings.
- Each string in the list represents a line from the file, and it includes the newline character ('\n') at the end of each line.
- reader = open('filename.txt', 'r')
  list_of_lines = reader.readlines()

Reading only a few lines of a file

- Python also supports reading one line at a time without using a for-each loop. For example, if you want to read the first 5 lines in a file you could do:

```
reader = open('filename.txt', 'r')

for i in range(10):

        reader.readline()

reader.close()
```

(Over) Writing to files

- To write in a file, we use the following template:

```
writer = open('filename.txt', 'w')

writer.write('First line\n')

writer.write('Second line\n')

writer.close()
```

- `writer` is a reference to a file object.
- `filename.txt` gets replaced with the actual name of the file we want to write in. If it already exists, it overwrites it. If the file does not exist, creates a new file for writing.
- The parameter `w` stands for write. That means we want to open the file to write in it.
- We use the `write` method to write in the file object.
- Don't forget to close a file once you open it.

(Appending when) Writing to files

- To write at the end of a file, we use the following template:

```
writer = open('filename.txt', 'a')

writer.write('Append to the end of the file\n')

writer.close()
```

- `writer` is a reference to a file object.
- `filename.txt` gets replaced with the actual name of the file we want to write in. If it already exists, the file pointer is at the end of the file. If the file does not exist, creates a new file for writing.
- The parameter `a` stands for append. That means we want to open the file to write at the end of it so that we don't lose existing content.
- We use the `write` method to write in the file object.
- Don't forget to close a file once you open it.

Practice Time

- Define a function `combine_files` that takes three parameters (`infile1`, `infile2`, `outfile`), all of which are strings and creates a new file named `outfile` whose contents are the contents of the file `infile1` followed by the contents of the file `infile2`.

Practice Time

```
def combine_files(infile1, infile2, outfile):
    f1 = open(infile1, 'r')
    f2 = open(infile2, 'r')
    out = open(outfile, 'w')
    for line in f1:
            out.write(line)
    for line in f2:
            out.write(line)
    f1.close()
    f2.close()
    out.close()
```

Practice Time

- Define a function `count_capital_letters` that takes on parameter `filename` and returns the number of capital letters in that file.
- You may use the `isupper` method to test if a character is uppercase.

Answer

- Define a function count_capital_letters that takes on parameter filename and returns the number of capital letters in that file.

```
def count_capital_letters(filename):
    count = 0
    opener = open(filename, 'r')
    for line in opener:
        for char in line:
            if char.isupper():
                count += 1
    opener.close()
    return count
```

Practice Time

- Define a function `unique_words` that takes on parameter `filename` and returns a list with all the words in the file. If a word exists multiple times, it should only include it once in the list. You can split words by whitespace and ignore capitalization (i.e. use the method `lower`)

Answer

```
def unique_words(filename):
    words = []
    reader = open(filename, 'r')
    for line in reader:
        for word in line.split():
            clean_word = word.strip().lower()
            if clean_word not in words:
                words.append(clean_word)
    reader.close()
    return words
```

Errors

Errors

- You already have experience with things going wrong when programming. Maybe:
  - you forgot to pass an argument
  - tried to print an int
  - tried to access a list item out of the valid range of indices
- When working with files, you may also face trouble:
  - try to read a file in the wrong directory
  - try to write in a file without having permission to do so

Exceptions

- Exceptions are errors that we know how to handle.
- The syntax is

```
try:
    # some potentially dangerous code
except:
    # handle the error
finally:
    # code you want to execute no matter what
```

Exceptions

- For example, when working with files

```
reader = open('filename.txt', 'r')
try:
    for line in reader:
            # do something
except:
    print('There was an error with the file when reading it line by line')
finally:
   reader.close()
```

Raising Exceptions

- You can use the raise keyword to throw your own exceptions. For example,
- raise Exception('CS51 Exception)
- raise ValueError('Invalid value')

Practice Time

- Define a function `pos_int_one_try` that asks the user to enter a positive integer. If the user enters a positive integer, the function returns that integer. If the user does not enter a positive integer, the function raises a `ValueError`.

- Hint: you can use the string method `isdigit()`

Answer

- Define a function pos_int_one_try that asks the user to enter a positive integer. If the user enters a positive integer, the function returns that integer. If the user does not enter a positive integer, the function raises a ValueError.

```
def return_pos_int_onetry():
    user_input = input('Enter a positive integer: ')
    if not user_input.isdigit() or int(user_input) < 0:
        raise ValueError(user_input + ' is not a positive integer.')
    return int(user_input)
```