lst = ["ant", "bat", "cat", "dog"]
for i in range(len(lst))
    print(i, lst[i])
I is for ...

- **Identity**
  - Who are you? Computer Science Student

- **Invariant**
  - Reasoning formally and informally about loops

- **Internet**
  - Network of networks
  - Far more than that!
Lynn Conway

See Wikipedia and lynnconway.com

• Helped invent dynamic scheduling early '60s IBM
• Transgender, fired in ‘68
• IBM apologized in 2020 (52 years later)

• Joined Xerox Parc in 1979
• Revolutionized VLSI design with Carver Mead

• Joined U. Michigan 1985
• NAE '89, IEEE Pioneer ‘09
• Professor and Dean, retired '98

“If you want to change the future, start living as if you are already there.”
Announcements

• Assignment 2 Turtles due Thurs!
• Lab 5 Friday – Prelab coming out Wed or Thur
• Coming, APT-3 out Thursday
• Coming, APT-1 QUIZ (Feb 23-27)
  • Timed APTs, take when you want during these dates
  • Your own work!
• **DO NOT discuss Exam 1 until it is handed back**
  • Will be handed back on Gradescope
Plan for the Day

• Accumulator Pattern
• Range
• Loop Index
• Loop Tracing
• Files
The Accumulator Pattern

• Pattern you will see with a lot of loops
• Here is the pattern:
  • Initialize a variable
  • loop over a sequence (list or string)
    • Accumulate (add a little more to variable)
  • Do something with variable (result)
The Accumulator Pattern

• Pattern you will see with a lot of loops
• Here is the pattern:
  • Initialize a variable
  • loop over a sequence (list or string)
    • Accumulate (add a little more to variable)
  • Do something with variable (result)
Example of Accumulator Pattern

```python
def sumlist(lst):
    total = 0
    for num in lst:
        total += num
    return total
```
Example of Accumulator Pattern

```python
def sumlist(lst):
    total = 0
    for num in lst:
        total += num
    return total
```
Example of Accumulator Pattern

```python
def sumlist(lst):
    total = 0
    for num in lst:
        total += num
    return total
```

```python
lst = [3, 7, 8, 2, 6]
print(sumlist(lst))
```

Output:
Example of Accumulator Pattern

```python
def sumlist(lst):
    total = 0
    for num in lst:
        total += num
    return total

lista = [3, 7, 8, 2, 6]
print(sumlist(lista))
```

Output:

```
0
```
Example of Accumulator Pattern

```python
def sumlist(lst):
    total = 0
    for num in lst:
        total += num
    return total
```

```python
lsta = [3, 7, 8, 2, 6]
print(sumlist(lsta))
```

Output:

```
0
3
```

```python
Output: 26
```
Example of Accumulator Pattern

```python
def sumlist(lst):
    total = 0
    for num in lst:
        total += num
    return total

lsta = [3, 7, 8, 2, 6]
print(sumlist(lsta))
```

Output:

```
3
3
```

```
```
Example of Accumulator Pattern

```python
def sumlist(lst):
    total = 0
    for num in lst:
        total += num
    return total

lsta = [3, 7, 8, 2, 6]
p
```
Example of Accumulator Pattern

```python
def sumlist(lst):
    total = 0
    for num in lst:
        total += num
    return total

lst = [3, 7, 8, 2, 6]
print(sumlist(lst))
```

Output:

```
26
```
Example of Accumulator Pattern

```python
def sumlist(lst):
    total = 0
    for num in lst:
        total += num
    return total
```

```python
lst = [3, 7, 8, 2, 6]
print(sumlist(lst))
```

Output:

```
10
8
```

```
Output:
```

```
Output:
```
Example of Accumulator Pattern

def sumlist(lst):
    total = 0
    for num in lst:
        total += num
    return total

lsta = [3, 7, 8, 2, 6]
print(sumlist(lsta))

Output:
Example of Accumulator Pattern

```python
def sumlist(lst):
    total = 0
    for num in lst:
        total += num
    return total

lsta = [3, 7, 8, 2, 6]
print(sumlist(lsta))
```

Output:

```
26
```
Example of Accumulator Pattern

```python
def sumlist(lst):
    total = 0
    for num in lst:
        total += num
    return total
```

```python
lsta = [3, 7, 8, 2, 6]
print(sumlist(lsta))
```

Output: 20
Example of Accumulator Pattern

def sumlist(lst):
    total = 0
    for num in lst:
        total += num
    return total

lsta = [3, 7, 8, 2, 6]
print(sumlist(lsta))

Output:
Example of Accumulator Pattern

```python
def sumlist(lst):
    total = 0
    for num in lst:
        total += num
    return total

lsta = [3, 7, 8, 2, 6]
print(sumlist(lsta))
```

Output: 26
Example of Accumulator Pattern

```python
def sumlist(lst):
    total = 0
    for num in lst:
        total += num
    return total

lsta = [3, 7, 8, 2, 6]
print(sumlist(lsta))
```

Output:

 total 26
 num 6
Example of Accumulator Pattern

```python
def sumlist(lst):
    total = 0
    for num in lst:
        total += num
    return total

lst = [3, 7, 8, 2, 6]
print(sumlist(lst))
```

Output: 26

We implemented the sum function
Example 2: Accumulator Pattern

```python
def numLetters(word):
    total = 0
    for letter in word:
        total += 1
    return total
```
Example 2: Accumulator Pattern

```python
def numLetters(word):
    total = 0
    for letter in word:
        total += 1
    return total
```
Example 2: Accumulator Pattern

```python
def numLetters(word):
    total = 0
    for letter in word:
        total += 1
    return total

word = "card"
print(numLetters(word))
```

Output:
Example 2: Accumulator Pattern

```python
def numLetters(word):
    total = 0
    for letter in word:
        total += 1
    return total
```

```python
word = "card"
print(numLetters(word))
```

Output:

```
total  0
```

Output:
Example 2: Accumulator Pattern

```python
def numLetters(word):
    total = 0
    for letter in word:
        total += 1
    return total

word = "card"
print(numLetters(word))
```

Output:

```
total: 0
letter: 'c'
```
Example 2: Accumulator Pattern

```python
def numLetters(word):
    total = 0
    for letter in word:
        total += 1
    return total

word = "card"
print(numLetters(word))
```

Output:

```
total: 1
letter: 'c'
```

Output:
Example 2: Accumulator Pattern

```python
def numLetters(word):
    total = 0
    for letter in word:
        total += 1
    return total
```

```python
word = "card"
print(numLetters(word))
```

Output: 1

letter 'a'
Example 2: Accumulator Pattern

```python
def numLetters(word):
    total = 0
    for letter in word:
        total += 1
    return total

word = "card"
print(numLetters(word))
```

Output:

```
<table>
<thead>
<tr>
<th>total</th>
<th>letter</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>'a'</td>
</tr>
</tbody>
</table>
```

Output:
Example 2: Accumulator Pattern

def numLetters(word):
    total = 0
    for letter in word:
        total += 1
    return total

word = "card"
print(numLetters(word))

Output:

total = 2
letter = 'r'
Example 2: Accumulator Pattern

```python
def numLetters(word):
    total = 0
    for letter in word:
        total += 1
    return total

word = "card"
print(numLetters(word))
```

Output:

```
total  3
letter 'r'
```

word = "card"
print(numLetters(word))

Output:
Example 2: Accumulator Pattern

```python
def numLetters(word):
    total = 0
    for letter in word:
        total += 1
    return total

word = "card"
print(numLetters(word))
```

Output:

```
3
'd'
```
Example 2: Accumulator Pattern

```python
def numLetters(word):
    total = 0
    for letter in word:
        total += 1
    return total

word = "card"
print(numLetters(word))
```

Output:

```
4 'd'
```

Example 2: Accumulator Pattern

def numLetters(word):
    total = 0
    for letter in word:
        total += 1
    return total

word = "card"
print(numLetters(word))

Output:

total 4
letter 'd'
Example 2: Accumulator Pattern

```python
def numLetters(word):
    total = 0
    for letter in word:
        total += 1
    return total
```

word = "card"

```python
print(numLetters(word))
```

Output: 4

We implemented the len function.
REVIEW: Looping over Sequences

• Let’s explore this:
  • Given a sentence:
    • “Duke Computer Science is so much fun!”
  • How do we create this sentence?
    • “Dk Cmprt Scnc s s mch fn!”
  • Input is sentence. Output has vowels removed
Accumulator Pattern: NoVowels

• “For each character, if it’s not a vowel add it to the output string”

• Accumulator pattern: change a variable in a loop
  • Accumulate a value while iterating through loop

```python
def noVowels(phrase):
    ret = ""
    for ch in phrase:
        if not isVowel1(ch):
            ret = ret + ch
    return ret
```
Accumulator Pattern: NoVowels

- “For each character, if it’s not a vowel add it to the output string”
- Accumulator pattern: change a variable in a loop
  - Accumulate a value while iterating through loop

```python
def noVowels(phrase):
    ret = ""
    for ch in phrase:
        if not isVowel1(ch):
            ret = ret + ch
    return ret
```
range() Sequence

• Range generates a sequence of values
• `range(y)` – starts at 0 and goes up to but doesn't include y: 0 ... (y-1)
  • y is an integer
• `range(x, y): x ... (y-1)`
  • x and y are integers
• Sequence that provides access to int values
• "up to but not including" sounds familiar? Slicing!
Example

range(5)
list(range(5))
range(5)[0]
range(5)[4]
range(5)[5]
range(5,10)
list(range(5,10))
range(5,10)[3]
for x in range(3):
    print(x)
<table>
<thead>
<tr>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>range(5)</td>
</tr>
<tr>
<td>list(range(5))</td>
</tr>
<tr>
<td>range(5)[0]</td>
</tr>
<tr>
<td>range(5)[4]</td>
</tr>
<tr>
<td>range(5)[5]</td>
</tr>
<tr>
<td>range(5,10)</td>
</tr>
<tr>
<td>list(range(5,10))</td>
</tr>
<tr>
<td>range(5,10)[3]</td>
</tr>
<tr>
<td>for x in range(3):</td>
</tr>
<tr>
<td>print(x)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

- range(x) generates a sequence that can be used in a for loop.
- Not a list, but generates a sequence of numbers!
- Convert to a list.
Range Examples

• Access all the values in a list to print them
  • Use the "for each in sequence" pattern

```
lst = ["ant", "bat", "cat", "dog"]
for s in lst:
    print(s)
```
Range Examples

• Access all the values in a list to print them
  • Use the "for each in sequence" pattern

```python
lst = ['ant', 'bat', 'cat', 'dog']
for s in lst:
    print(s)
```

Output: ant
        bat
cat
dog
Range Examples

• Access all the values in a list to print them
  • Use an index to access i\textsuperscript{th} element

```python
lst = ["ant", "bat", "cat", "dog"]
for i in range(len(lst))
    print(i, lst[i])
```
Range Examples

• Access all the values in a list to print them
  • Use an index to access \(i^{th}\) element

```python
lst = ["ant", "bat", "cat", "dog"]
for i in range(len(lst))
    print(i, lst[i])
```

Output: 0 ant
        1 bat
        2 cat
        3 dog

range(0,3)
Think of as [0, 1, 2, 3]
But it is NOT a list
Repetition with Range

• Sometimes rather than looping over a sequence of values you want to repeat # times
  • Do this 4 times
  • Do that 250 times

• Can do this with the Python range function!
  • If don’t care about the value in the range (e.g. “Do this four times”), can do:
    ```python
    for _ in range(4):
        CODE
    ```
Code-Tracing a Loop

1. Find the changing variables/expressions
2. Create table, columns are variables/expressions
   1. First column is loop variable
   2. Add columns to help track everything else
3. Each row is an iteration of the loop
   1. Before execute code block, copy down each variable’s value
   2. Execute code block, update a value in the row as it changes
Code-Tracing a Loop

1. Find the changing variables/expressions
2. Create table, columns are variables/expressions
   1. First column is loop variable
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```python
def mystery(lst):
    idxMax = 0
    for i in range(len(lst)):
        if lst[idxMax] < lst[i]:
            idxMax = i
    return idxMax
```

What should be the table’s columns?
Code-Tracing a Loop

1. Find the changing variables
2. Create table, columns are the variables
   1. First column is loop variable
   2. Add columns to help track everything else

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def mystery(lst):
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```
Fill in table

1. Before execute code block, copy down each variable’s value

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```python
def mystery(lst):
    idxMax = 0
    for i in range(len(lst)):
        if lst[idxMax] < lst[i]:
            idxMax = i
    return idxMax

mystery([2, 12, 4, 15, 15])
```

<table>
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<tr>
<th>i</th>
<th>idxMax</th>
<th>lst[idxMax]</th>
<th>lst[i]</th>
<th>lst[idxMax] &lt; lst[i]</th>
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</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>lst[0] is 2</td>
<td>lst[0] is 2</td>
<td>False</td>
</tr>
</tbody>
</table>

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2. Execute code block, update a value in the row as it changes

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mystery([2, 12, 4, 15, 15])

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<tr>
<td>0</td>
<td>0</td>
<td>2</td>
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</tr>
<tr>
<td>1</td>
<td>0</td>
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<td>lst[1] is 12</td>
<td>True</td>
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<td>12</td>
<td>True</td>
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<td>2</td>
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return 3
What is always true about the loop?

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What is always true about the loop?

1. \texttt{lst[idxMax]} is always the largest value seen so far, up through value of \texttt{i}

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    idxMax = 0
    for i in range(len(lst)):
        if lst[idxMax] < lst[i]:
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    return idxMax
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What is always true about the loop?

1. \( \text{lst[idxMax]} \geq \text{lst[k]} \) for all \( k \leq i \)
2. \( i < \text{len(lst)} \)
3. \( \text{idxMax} < \text{len(lst)} \)

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WOTO-2 Loop Tracing

• Remember the steps
• (1) Find the changing variable/expressions,
• (2) Create the table with these as the column
• (3) Each row is an iteration of the loop
Examples of Processing Data

- Lecture 1: count letters in Bible

- Another example: Google Ngram viewer
  - Ngram informs how words evolve
  - Shows number of times phrases occur in books over the years
  - [https://books.google.com/ngrams](https://books.google.com/ngrams)

- Funny video on irregular words
  - [https://www.youtube.com/watch?v=tFW7orQsBuo](https://www.youtube.com/watch?v=tFW7orQsBuo)
Studying Language Evolution

• friend vs enemy
Processing Data

• How do we find the longest word in .. Any text?
• How do we find the word that occurs the most?
• How is this related to how Google Search works?

• Text files can be viewed as sequences
  • Sequences of lines
  • Each line is a string
  • Some clean-up because of ‘\n’
File Pattern: One line at a time

• Simplest and reasonably efficient Python pattern
  • Open, loop, close, return/process
  • LineCounter.py

• File as sequence
  • One line at-a-time

```python
def lineCount(fname):
    """
    return # lines in file `fname`
    """
    f = open(fname)
    lc = 0
    for line in f:
        lc = lc + 1
    f.close()
    return lc
```
File Pattern: One line at a time

- Simplest and reasonably efficient Python pattern
  - Open, loop, close, return/process
  - LineCounter.py

- File as sequence
  - One line at-a-time

- Asymmetry in Open vs Close steps

```python
def lineCount(fname):
    return len(open(fname))

f = open(fname)
lc = 0
for line in f:
    lc = lc + 1
f.close()
return lc
```
def lineCount(fname):
    """
    return # lines in file fname
    """
    f = open(fname)
    lc = 0
    for line in f:
        lc = lc + 1
    f.close()
    return lc
```python
def altCount(fname):
    """
    return # lines in file fname
    """

    f = open(fname)
    lc = len(f.readlines())
    f.close()

    return lc
```
if __name__ == "__main__":
    name = "data/poe.txt"
    pc = lineCount(name)
    print("# lines:", pc)
    pc2 = altCount(name)
    print("# lines:", pc2)
File Objects

• **A file is an object, like a string**
  • Functions applied to object: `len("word")`
  • To get file object use `open("data.txt")`
  • What is returned? Integer value, file object

• **Often methods (aka function) applied to object**
  • `f.readlines(), f.read(), f.close()`
  • Just like: `st.lower(), st.count("e")`
WOTO-3 Files