CMSC201
Computer Science I for Majors

Lecture 12 –
Program Design and Modularity

Last Class We Covered

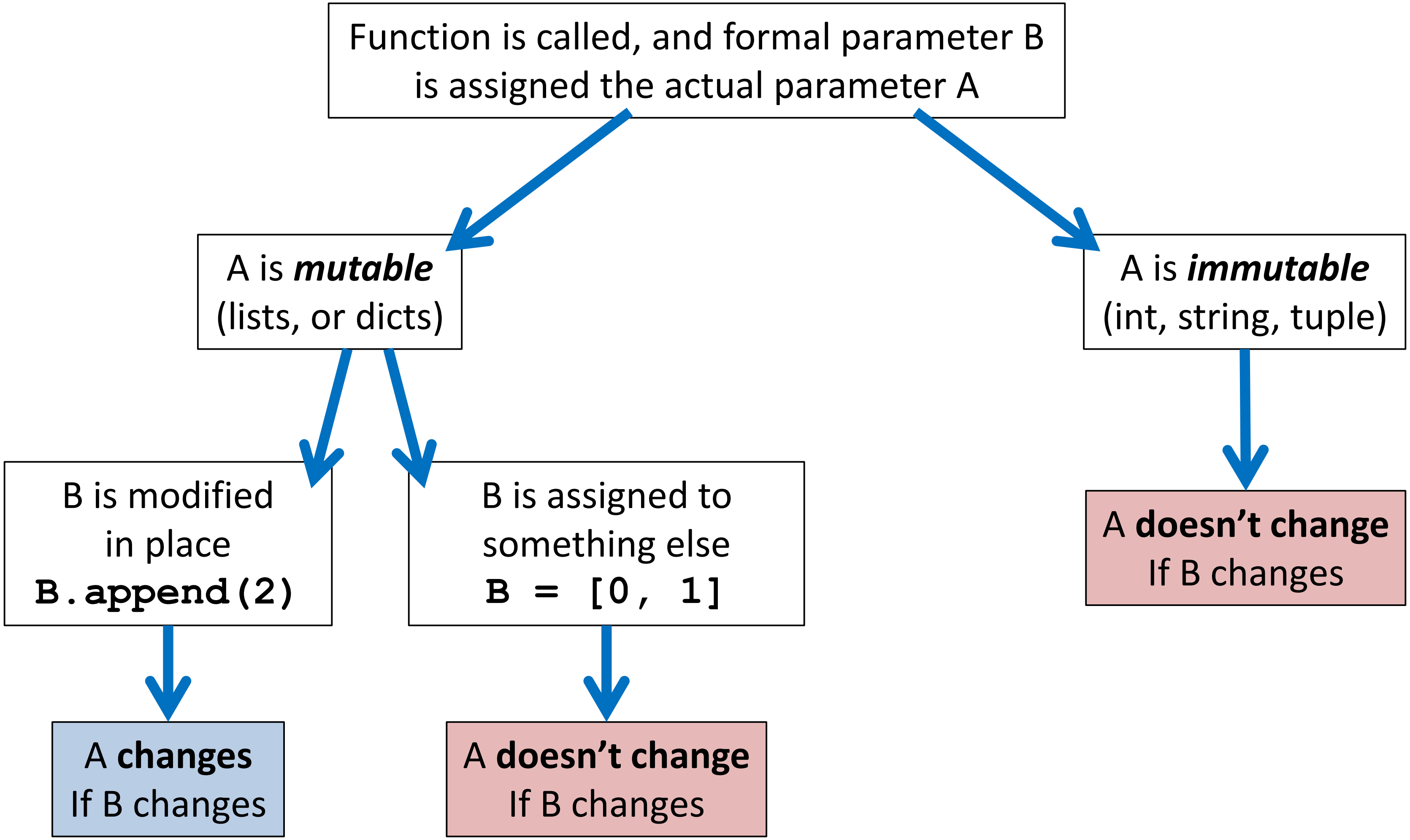
- Functions
  - Returning values
  - Matching parameters
  - Matching return assignments
- Mutability
  - Immutability
  - Effect on functions

Any Questions from Last Time?

Today's Objectives

- To understand shallow copy
- To practice program design
  - With the max of three example
- To better understand the purpose of modularity, functions, and incremental development
  - Through a design example

Review: Mutability in Functions



Function is called, and formal parameter B is assigned the actual parameter A

A is ***mutable*** (lists, or dicts)

A is ***immutable*** (int, string, tuple)

B is modified in place `B.append(2)`

B is assigned to something else `B = [0, 1]`

A **changes** If B changes

A **doesn't change** If B changes

A **doesn't change** If B changes

From http://stackoverflow.com/a/25670170

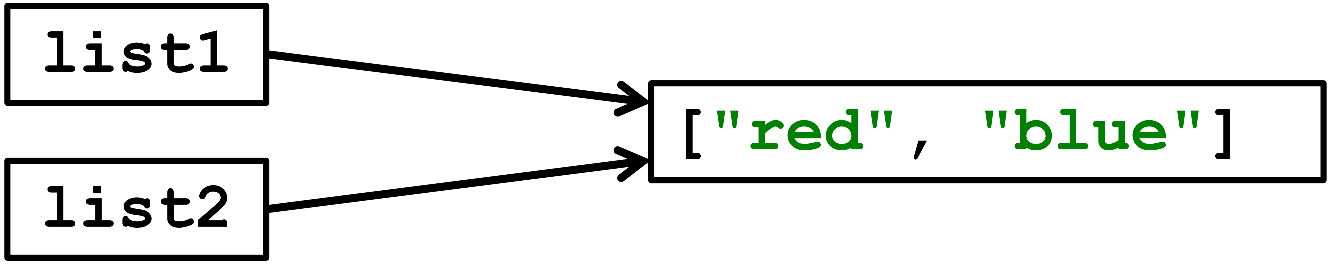
Shallow (and Deep) Copies

Copying Lists

- When you assign one list to another, it is by default a “shallow” copy of the list
- A ***shallow copy*** is when the new variable actually points to the old variable, rather than making an actual copy
- A ***deep copy*** is the opposite, creating an entirely new list for the new variable
  - This is what you probably want to be happening!

Shallow Copy

- When we make a shallow copy, we are essentially just giving the same list two different variable names
  - This only happens to ***mutable*** data types , like lists, and only if we alter them in-place



Shallow Copy Example

- A shallow copy and its effects on the original:

```
list1 = ["red", "blue"]     # original list
list2 = list1               # shallow copy made
list2.append("green")       # update shallow copy
list2[1] = "yellow"         # and again
print("list1 (end):   ", list1)
print("list2 (end):   ", list2)
```

```
list1 (start): ['red', 'blue']
list1 (end):   ['red', 'yellow', 'green']
list2 (end):   ['red', 'yellow', 'green']
```

Deep Copy

- There are two easy ways to do a deep copy:
  - Use slicing, and “slice” out the entire list
  - Cast the original as a list when assigning
- With these, Python returns an entirely new list that you can then assigned to the new variable
  - Now you have two separate lists!

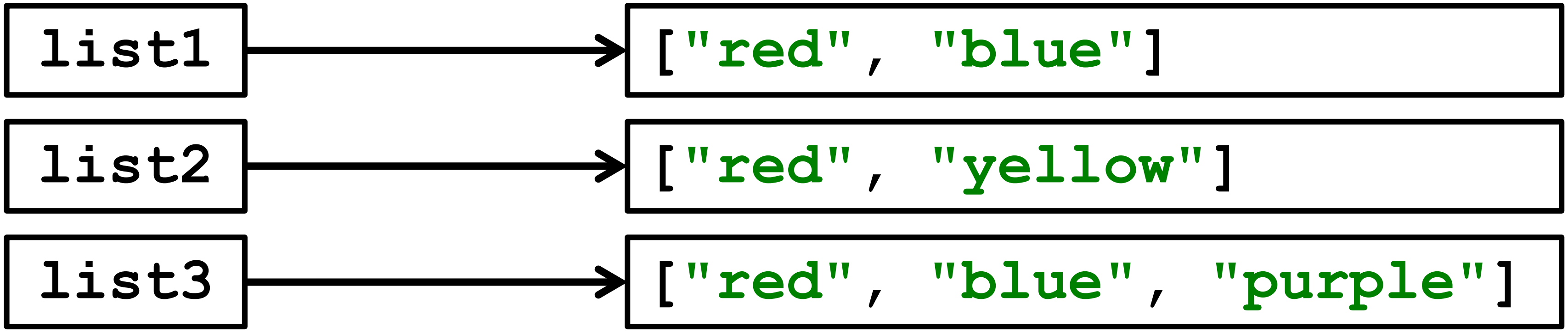
Deep Copy Example

```
list1 = ["red", "blue"]
list2 = list1[:]        # use slicing to copy
list2[1] = "yellow"
list3 = list(list1)     # use casting to copy
list3.append("purple")
print("original:     ", list1)
print("deep copy1:   ", list2)
print("deep copy2:   ", list3)
```

```
original:      ['red', 'blue']
deep copy1:    ['red', 'yellow']
deep copy2:    ['red', 'blue', 'purple']
```

Deep Copy

- Creates a copy of the entire list’s contents, not just of the list itself
- Each variable now has its own individual list



```
list1  -->  ["red", "blue"]
list2  -->  ["red", "yellow"]
list3  -->  ["red", "blue", "purple"]
```

Program Design Example

Study in Design: Max of Three

- You know about a lot of tools at this point in the semester, but knowing when and how to apply them may still be difficult sometimes

- Let’s create an algorithm to find the largest of three numbers
- Start off by writing the code to get the input from the user, and to print the final maximum

Max of Three: Code Framework

- Here’s the “easy” part of our code completed:

```
def main():
    x1 = int(input("Please enter a value: "))
    x2 = int(input("Please enter a value: "))
    x3 = int(input("Please enter a value: "))

    # we need to write the missing code that sets
    # "maximum" to the value of the largest number

    print("The largest value is ", maximum)

main()
```

Max of Three: Strategies

- Spend a few minutes thinking about the different ways you could compare these three numbers to find the maximum
- Don’t write code right away – brainstorm first!
- Your first idea might not be your best idea, so be prepared to be flexible

Strategy 1: Compare Each to All

- This looks like a three-way decision, where we need to execute one of the following:

```
maximum = x1
maximum = x2
maximum = x3
```

- What we need to do now is preface each one of these with the right condition

Strategy 1: Solution

- Here’s our completed code:

```
def main():
    # getting input goes here
    if x1 >= x2 and x1 >= x3:
        maximum = x1
    elif x2 >= x1 and x2 >= x3:
        maximum = x2
    else:
        maximum = x3

    print("The largest value is ", maximum)
main()
```

Strategy 1: Downsides

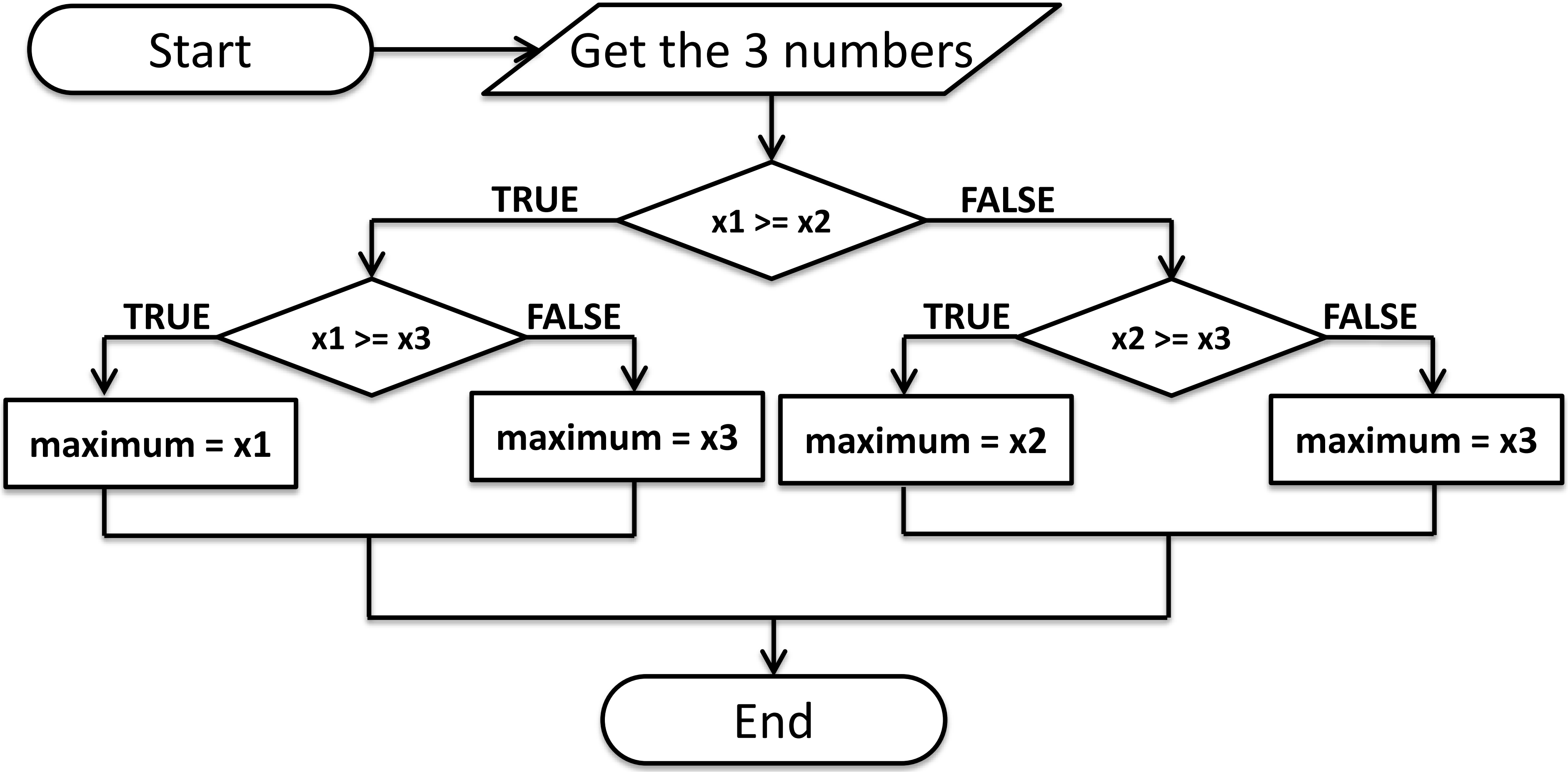
- What would happen if we were trying to find the max of five values?
  - We would need four Boolean expressions, each consisting of four conditions **`and`**'ed together
- What about twenty values?
  - We would need nineteen Boolean expressions, with nineteen conditions each
- There has to be a better way!

Strategy 2: Decision Tree

- We can avoid the redundant tests of the previous algorithm by using a ***decision tree***

- Suppose we start with checking if **`x1 >= x2`**
    - This knocks either **`x1`** or **`x2`** out of the running to be the maximum value
    - If the condition is **`True`**, then we move on to check whether **`x1`** or **`x3`** is larger

Strategy 2: Decision Tree Flowchart



Strategy 2: Decision Tree Code

- Here's the code for the previous flowchart

```
if x1 >= x2:
    if x1 >= x3:
        maximum = x1
    else:
        maximum = x3
else:
    if x2 >= x3:
        maximum = x2
    else:
        maximum = x3
```

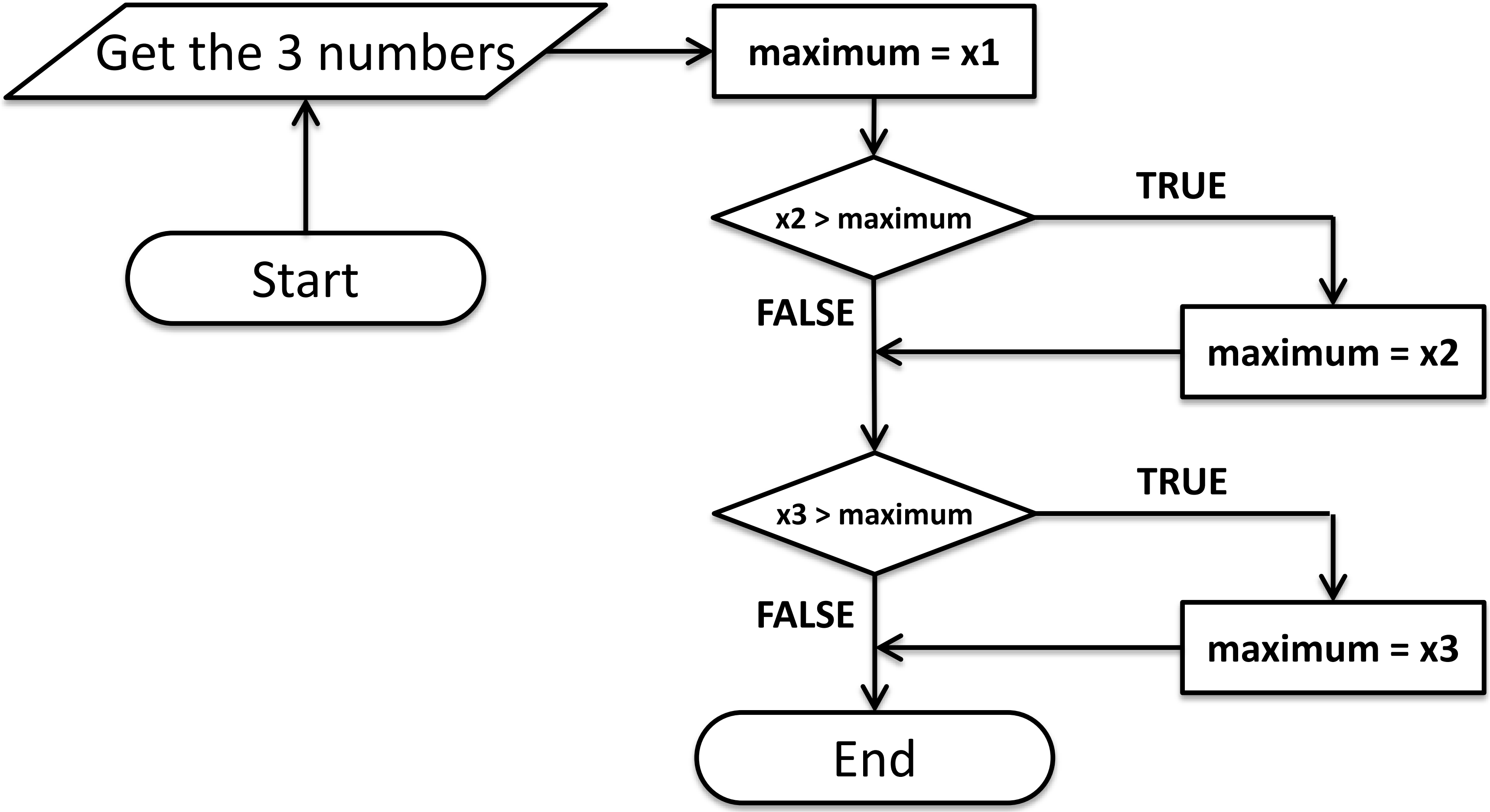
Strategy 2: (Dis)advantages

- This approach makes exactly two comparisons between the three variables
- However, this approach is more complicated than the first
  - To find the max of four values you'd need `if-else`s nested three levels deep with eight assignment statements
  - This isn't much better than the last method!

Strategy 3: Sequential Processing

- How would ***you*** solve the problem?
- Since you're not a computer, you could look at three numbers and know which is the largest
  - But what if there were one hundred numbers?
- One strategy is to scan the list for a big number
  - When one is found, mark it, and continue looking
  - If you find a larger value, mark it, erase the previous mark, and continue looking

Strategy 3: Sequential Processing



Strategy 3: Sequential Processing Code

- This idea can be easily done in Python code

```
maximum = x1
if x2 >= maximum:
    maximum = x2
if x3 >= maximum:
    maximum = x3
```

Why do we use two **`if`** statements?

What would happen if we used an **`if-elif`** statement?

Strategy 3: Sequential Processing

- This process is pretty repetitive
  - Which means we could use a loop!
- We would repeat the following steps:
  1. Prompt the user for a number
  2. Compare it to the current maximum
  3. If it is larger, update the max value
  - Repeat until the user is done entering numbers
- Or combine it with a list of given numbers

Strategy 4: Take Advantage of Python

- Python has a built-in function called **`max`**
  - It takes in numbers and returns the max value

```
def main():
    # getting input goes here
    maximum = max(x1, x2, x3)
    print("The largest value is ", maximum)
main()
```

  - This is why we called our variable "**`maximum`**" instead of **`max`** – because **`max`** is already defined!

Modularity

Modularity

- A program being ***modular*** means that it is:
- Made up of individual pieces (modules)
  - That can be changed or replaced
  - Without affecting the rest of the system

- So if we replace or change one function, the rest should still work, even after the change

Modularity

- With modularity, you can also reuse and repurpose your code

- What are some pieces of code you've had to write multiple times?
  - Getting input between some min and max
  - Using a sentinel loop to create a list
  - What else?

Functions and Program Structure

- So far, functions have been used as a mechanism for reducing code duplication
- Another reason to use functions is to make your programs more modular

- As the algorithms you design get increasingly complex, it gets more and more difficult to make sense out of the programs

Functions and Program Structure

- One option to handle this complexity is to break it down into smaller pieces

- Each piece makes sense on their own
- You can easily combine them together to form the complete program

Program Design Example

Vending Machine

- We want to write a program that simulates a vending machine

- How do we even start!?
- With questions:
  - What things do we want our program to be able to do?
  - What info does it need?
  - How will we store data?

Image from wikimedia.org

Announcements

- Homework 5 is/was due Wednesday
- Homework 6 does not come out this week
  - It will come out the night of October 20th
- The midterm exam is when?
  - During class on October 19th and 20th!
- Review packets will be available in class on October 17th and 18th