# CSE 101:
# Introduction to Computational Thinking

# Unit 7:
# Random Numbers; Object-oriented Programming

# Games of Chance

- Many games involve chance of some kind:
  - Card games with drawing cards from a shuffled deck
  - Rolling dice to determine how many places we move a piece on a game board
  - Spinning a wheel to randomly determine an outcome
- We expect these outcomes to be **random** or unbiased – in other words, *unpredictable*
- Computers can be programmed to generate *apparently* "random" sequences of numbers and other quantities for such games and other applications

# Games of Chance

- In this unit we will explore algorithms for generating values that are apparently random and unpredictable
- We say "apparently" because we need to use mathematical formulas to generate sequences of numbers that at the very least appear to be random
- Since we will use an algorithm to generate "random" values, then we really can't say the sequence of values is truly random
- We say instead that a computer generates **pseudorandom** numbers

# Pseudorandom Numbers

- Randomness is a difficult property to quantify
  - Is the list **`[3, 7, 1, 4]`** more or less random than **`[4, 1, 7, 3]`**?
- The algorithm that generates pseudorandom numbers is called a **pseudorandom number generator**, or PRNG
- The goal is for the algorithm to generate numbers without any kind of apparent predictability
- Python has built-in the capability to generate random values through its **`random`** module
- To generate a random integer in the range $1 - 10$:

```
import random
num = random.randint(1, 10) # 10, not 11!
```

# Modular Arithmetic

- The **mod** operator, denoted `%` in Python, will be a key part of generating pseudorandom numbers
- Suppose we wanted to generate a seemingly random sequence of numbers, all in the range 0 through 11
- Let's start with the number 0 and store it in a new list named **`t`**:

```
t = [0]
```

- One basic formula for generating numbers involves (1) adding a value to the previously-generated number and then (2) performing a modulo operation

# Modular Arithmetic

- For our particular example, we could use 7 as our added value and then mod by 12
- Conveniently, the Python language lets us write **`t[-1]`** to mean "retrieve the last element of list **`t`**"
- We can write **`t[-2]`** to get the second-to-last element, **`t[-3]`** to get the third-to-last element, and so on
- So in general we can write **`t.append((t[-1]+7)%12)`** to generate and store the "next" pseudorandom number
- If we put this code inside of a loop we can generate a series of random values and store in them in the list

# Modular Arithmetic

```
t = [0]
for i in range(15):
    t.append((t[-1] + 7) % 12)
```

- The above code will generate the list:

`[0,7,2,9,4,11,6,1,8,3,10,5,0,7,2,9]`

- How "random" are these numbers?
  - They look pretty random, but we notice that eventually they start to repeat
- Can we improve things?
  - Part of the issue is the divisor of 12, but the formula itself is a little too simplistic

# Modular Arithmetic

- A more general formula for generating pseudorandom numbers is $x_{i+1} = (a \cdot x_i + c) \bmod m$
  - $x_{i+1}$ is the "next" random number
  - $x_i$ is the most recently generated random number
  - $i$ is the position of the number in the list
  - $a$, $c$ and $m$ are constants called the *multiplier*, *increment* and *modulus*, respectively
- If the values $a$, $c$ and $m$ are chosen carefully, then every value from 0 through $m - 1$ will appear in the list exactly once before the sequence repeats
- The number of items in the repetitive part of the list is called the **period** of the list

# Modular Arithmetic

- We want the period to be as long as possible to make the numbers as unpredictable as possible
- We will implement the above formula, but first we need to explore some new programming concepts

# Numbers on Demand

- One possibility for working with random numbers is to generate as many as we need and store them in a list
  - Often, however, in real applications we don't know exactly how many random numbers we will ultimately need
  - Also, in practice we might not want to generate a very long list of random numbers and store them
- Typically, we need only one or just a few random numbers at a time, so generating thousands or even millions of them at once is a waste of time and memory
- Rather than building such a list, we can instead generate the numbers one at a time, *on demand*

# Numbers on Demand

- We will define a function `rand()` and a **global variable** `x` to store the most recently generated random number
  - A global variable is a variable defined outside functions and is available for use by any function in a .py file
- The value of a global variable is preserved between function calls, unlike local variables, which disappear when a function returns
- If we want a function to change the value of a global variable, we need to indicate this by using the `global` keyword in the function
- If we are only reading the global variable, we do not need to use the `global` keyword

# The `rand()` Function (v1)

- Let's consider a function for generating random numbers that uses the formula we saw earlier:

```
x = 0  # global variable
def rand(a, c, m):
    global x
    x = (a * x + c) % m
    return x
```

- Call the function several times with $a = 1, c = 7, m = 12$:

```
rand(1,7,12)  # returns 7 and updates x to 7
rand(1,7,12)  # returns 2 and updates x to 2
rand(1,7,12)  # returns 9 and updates x to 9
```

- Let's see why **x** is updated in this way

# The `rand()` Function (v1)

- The key line of code is **`x = (a * x + c) % m`**
- Initially, **`x = 0`**

1. **`rand(1,7,12)`**: **`x = (1 * 0 + 7) % 12 = 7`**
   - So, **`x`** becomes **`7`**
2. **`rand(1,7,12)`**: **`x = (1 * 7 + 7) % 12 = 2`**
   - So, **`x`** becomes **`2`**
3. **`rand(1,7,12)`**: **`x = (1 * 2 + 7) % 12 = 9`**
   - So, **`x`** becomes **`9`**

- The only reason this series of computations works correctly is because the value of **`x`** is preserved between function calls

# Modules and Encapsulation

- Suppose we wanted to use our new **`rand()`** function in several files. We have two options:
  - Copy and paste the function to each file (bad idea), or
  - Place the file in a .py by itself (or with other functions) to create a **module** that can be imported using an **`import`** statement (the right way)
- We should place our function in a module, along with the global variable **`x`**
- This global variable will be “hidden” inside the module so that there is no danger of a “name clash”, meaning that other modules could have their own global variables named **`x`** if they want to

# Modules and Encapsulation

- This idea of gathering functions and their related data values (variables) into a single package is called **encapsulation**
- It's an extension of the concept called **abstraction** we studied earlier in the course
- We know that the **`math`** module has some useful functions and constants, like **`sqrt()`** and **`pi`**
- A module like **`math`** is an example of a **namespace**, a collections of names that could be names of functions, objects or anything else in Python that has a name
  - A module/namespace is one way of implementing the concept of encapsulation in Python

# Modules and Encapsulation

- To create a new module, all we need to do is save the functions and variables of the module in a file ending in .py
  - For example, if we were to save the **`rand()`** function in the file **`prng.py`**, we could then import the **`rand()`** function in a new Python program by typing **`import prng`** at the top of the new program
- Below is a revised version of our **`rand()`** function that encapsulates the function in a module and stores the values of *x*, *a*, *c* and *m* as global variables
- This means the user no longer needs to pass *a*, *c* or *m* as arguments anymore
- We will also add a new function **`reset()`** to reset the PRNG to its starting state

# The `rand()` Function (v2)

```
x = 0
a = 81
c = 337
m = 1000
```

```
def rand():
    global x
    x = (a * x + c) % m
    return x
```

```
def reset(mult, inc, mod):
    global x, a, c, m
    x = 0
    a = mult
    c = inc
    m = mod
```

# The `rand()` Function (v2)

```
x = 0
a = 81
c = 337
m = 1000
```

- Examples:

1. `rand(): (81 * 0   + 337) % 1000 = 337`
2. `rand(): (81 * 337 + 337) % 1000 = 634`
3. `rand(): (81 * 634 + 337) % 1000 = 691`

# The `rand()` Function (v2)

- We can change the values of *a*, *c* and *m* by calling the **`reset()`** function. Example: **`reset(19, 4, 999)`**. **`reset()`** also sets **`x = 0`**.
- Now we will generate a different sequence of random numbers:

1. **`rand()`**: **`(19 * 0  + 4) % 999 = 4`**
2. **`rand()`**: **`(19 * 4 + 4) % 999 = 80`**
3. **`rand()`**: **`(19 * 80 + 4) % 999 = 525`**

# Games with Random Numbers

- Suppose we wanted to simulate the rolling of a six-sided die in a board game
- We would want to generate integers in the range 1 through 6, inclusive
- Our function **`rand()`** generates values outside this range, however
- We can solve this problem using an expression like **`rand() % 6 + 1`**
- The expression **`rand() % 6`** gives us a value in the range 0 through 5, which we can then "shift up" by adding 1

# Games with Random Numbers

- If we always initialize $x$, $a$, $c$ and $m$ to the same values, then every program that uses the **`rand()`** function will get the same exactly sequence of pseudorandom values
- Instead, we could allow someone using our code to set the starting value of $x$, which we call the **seed** of the pseudorandom number generator
- Another option is we can have the computer pick the seed by using the system clock
- The time module has a function called **`time()`** which returns the number of seconds since January 1, 1970
- Fractions of a second are also included in the returned value

# Games with Random Numbers

- Our revised module shown on the right uses **`time.time()`** to pick a random seed

```
import time
a = 81
c = 337
m = 1000
x = int(time.time()) % m

def rand():
    global x
    x = (a * x + c) % m
    return x
```

- See unit07/random_numbers.py

# Random Numbers in a Range

- In general, how can we generate random integers from an arbitrary range?
- The formula is surprisingly simple:

```
rand() % (high - low + 1) + low
```

- For example, suppose we wanted to generate a value in the range −5 through 10, inclusive
- The formula indicates we should use this code:

```
rand() % (10 - (-5) + 1) + (-5)
```

- Simplifying gives us: `rand() % 16 – 5`
- See unit07/random_numbers.py

# List Comprehensions

- Python features a very compact syntax for generating a list called a **list comprehension**
  - We write a pair of square brackets and inside the brackets put an expression that describes each list item
- For example to make a list of numbers from 1 to 10 write
  **`[i for i in range(1,11)]`**
- To make a list of the first 10 perfect squares we could write
  **`[i**2 for i in range(1,11)]`**
- In general, we write an expression that describes each new item in the new list and a loop that describes a set of existing values to work from
- A list of 10 random numbers:
  **`[rand() for i in range(10)]`**

# List Comprehensions

- Suppose we wanted to take a list of words and capitalize them all:

```
names = ['bob', 'DANE', 'mikey', 'ToMmY']
names = [s.capitalize() for s in names]
```

- **`names`** would become **`['Bob', 'Dane', 'Mikey', 'Tommy']`**
- Or perhaps we wanted to extra the first initial of each person and capitalize it:

```
initials = [s[0].upper() for s in names]
```

- **`initials`** would be **`['B', 'D', 'M', 'T']`**

# Random Shuffles

- Suppose we needed the ability to randomly *permute* (shuffle) a list of items, such as a deck of 52 playing cards
- Let's explore how we might write a function that does exactly this
- First, in Card.py we define a **class** called **`Card`**
- A **class** defines a new type of object in an object-oriented programming language like Python
- We use a special method called the **constructor** to create (construct) new objects of the class

```
from Card import Card
card = Card()
```

# The `Card` Class

- A **`Card`** object has a separate rank and suit, which we can query using the **`rank()`** and **`suit()`** methods, respectively
- The 2 through Ace are ranked 0 through 12
- The suits are mapped to integers as follows:
  - Clubs: 0
  - Diamonds: 1
  - Hearts: 2
  - Spades: 3
- For example, for a **`Card`** object representing the 9 of Spades, **`rank()`** would return 7 and **`suit()`** would return 3

# The `Card` Class

- The ranks and suits are numbered so that we can uniquely identify each card of a standard 52-card deck
  - When calling the constructor to create a **`Card`** object, we provide a number in the range 0 through 51 to identify which card we want
- Examples:
  - **`Card(0)`** and **`Card(1)`** are the 2 and 3 of Clubs, respectively
  - **`Card(50)`** and **`Card(51)`** are the King and Ace of Spaces, respectively
- **`print(Card(51))`** would output **A♠** (yes, including that Spades symbol!)

# The `Card` Class

- We can use a list comprehension to generate all 52 cards and store them in a list:

```
deck = [Card(i) for i in range(0,52)]
```

- With slicing we can take a look at just the first 5 by appending **`[:5]`** to the name of the variable
  - This notation means “slice out all the elements of the list up to (but not including) the element at index 5”

```
print(deck[:5])
```

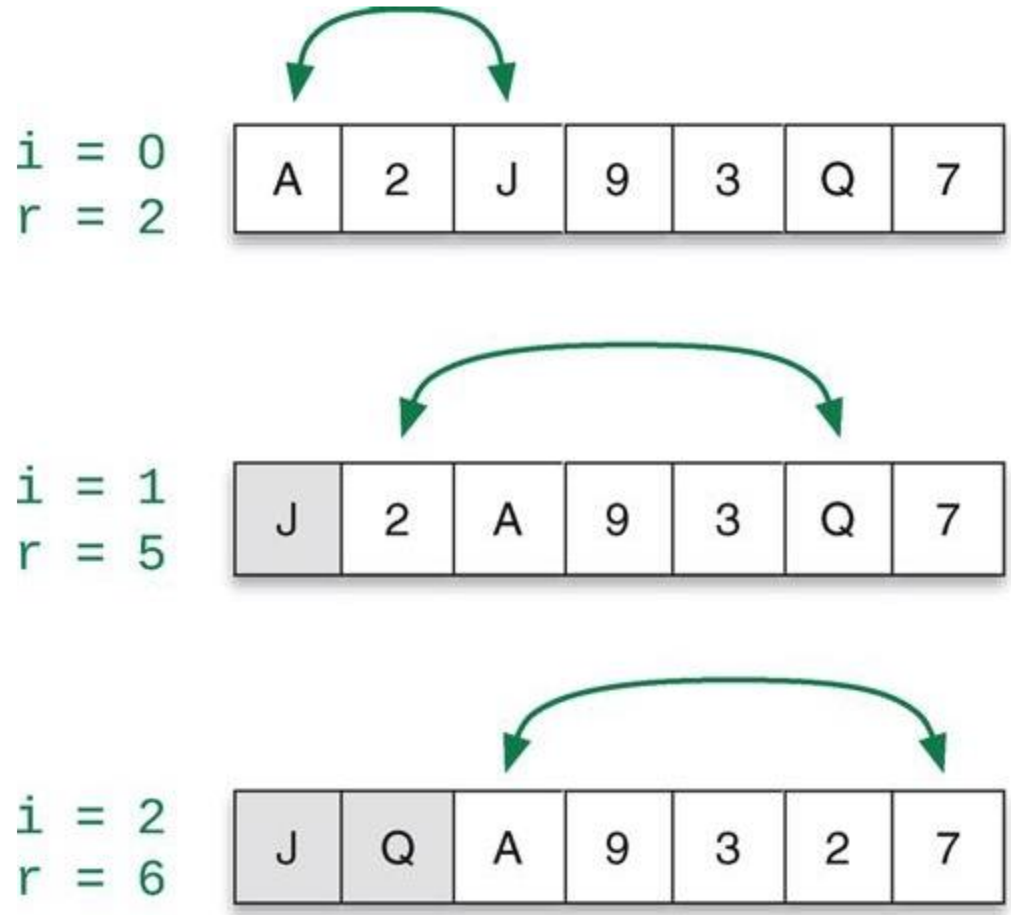
- Output: **`[2♣, 3♣, 4♣, 5♣, 6♣]`**

# Shuffling `Card` Objects

- The order of the cards generated by the list comprehension (i.e., sequential order) is only one particular ordering or **permutation** of the cards
- We want to define a function that will let us permute a list to generate a more random ordering of the items in the list
- A simple algorithm for permuting the items in a list is to iterate over the list and exchange each element with a random element to its right
- This is most easily seen by example, as on the next slide

# Shuffling `Card` Objects

- Iterate over the entire array **`deck`** (with **`i`** as the loop variable and index), swapping a random item to the right of **`i`** with **`deck[i]`**



# Shuffling `Card` Objects

- This shuffling algorithm is very easy to implement with the help of a function that will choose a random item to the right of **`deck[i]`**
- The function **`randint(low, high)`** from the **`random`** module generates a random integer in the range **`low`** through **`high`** (inclusive of both **`low`** and **`high`**)
- The **`permute`** function will shuffle any list of items:

```
import random
def permute(a):
    for i in range(0, len(a)-1):
        r = random.randint(i, len(a)-1)
        a[i], a[r] = a[r], a[i] # swap items
```

# Shuffling `Card` Objects

```
import random
def permute(a):
    for i in range(0, len(a)-1):
        r = random.randint(i, len(a)-1)
        a[i], a[r] = a[r], a[i] # swap items
```

- **`r = random.randint(i, len(a)-1)`** picks the random index, **`r`**, that is to the right of **`i`** (or might choose **`i`** itself, meaning that **`a[i]`** doesn't move)
- **`a[i], a[r] = a[r], a[i]`** swaps **`a[i]`** with the randomly chosen item to its right
- We would call this function with **`permute(deck)`** to shuffle our list of **`Card`** objects

# Defining New Objects

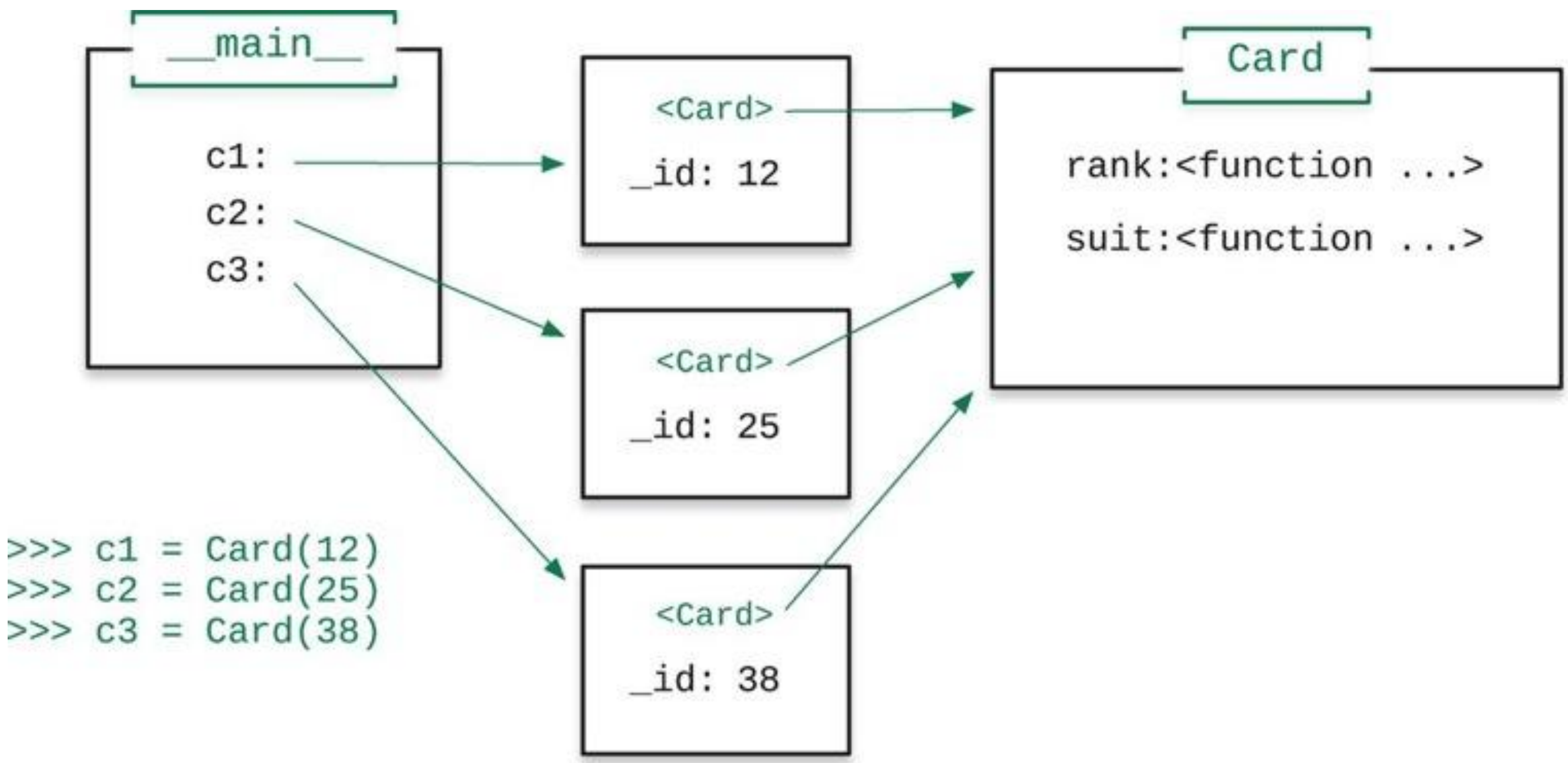
- The **`Card`** class we have been working with defines a new kind of object we can use in programs
- In object-oriented programming, a class determines the data and operations associated with an object
- For example, for a playing card object we need some way to store the rank and suit of a card; these are its data attributes
- Operations for a playing card might include code that lets us print a playing card on the screen or retrieve the card's rank and suit

# Defining New Objects

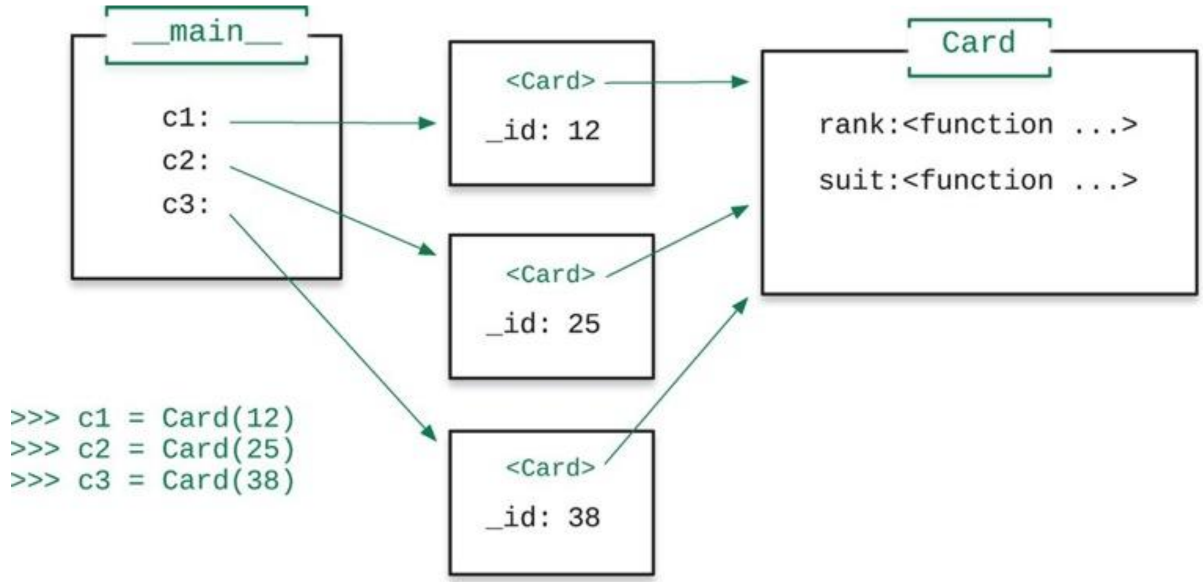
- The data values associated with a particular object are called **instance variables**
- We say that an object is an **instance** of a class
  - For example, each of the 52 `Card` objects is an independent instance of the `Card` class
  - As such, each `Card` object has its own copies of the instance variable that store the object's rank and suit
- The operations associated with an object are called **methods**
- So, a class defines the data properties and methods that an object of the class has

# Defining New Objects

- Let's see an example where we create three distinct **`Card`** objects in a program:

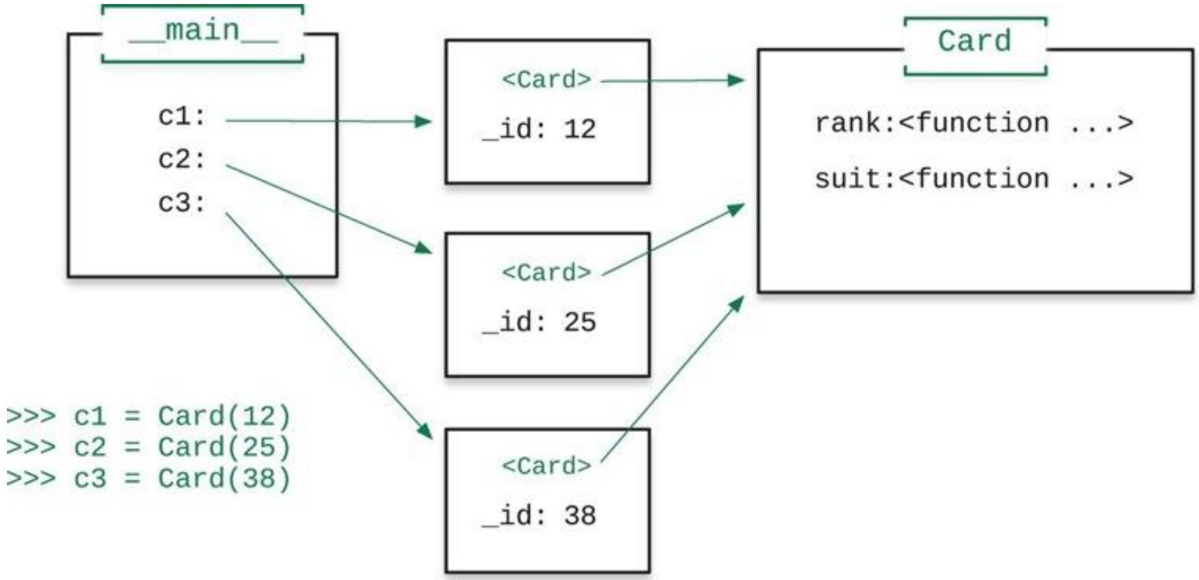


# Defining New Objects




- Three **`Card`** objects were constructed. They are referenced using the variables **`c1`**, **`c2`** and **`c3`**, as shown on the left
- The objects as they might exist in the memory of the computer are shown in the middle of the diagram
- Rather than store the rank and suit separately, they are combined into a single integer called **`_id`**

# Defining New Objects




- Prepending an underscore to a variable indicates that **`_id`** is an instance variable; this is a naming convention, not a strict rule
- To retrieve the rank or suit, we need to call the methods **`rank()`** or **`suit()`**, as depicted on the right

# Defining New Objects

- To define a new class we usually include the following aspects:
  - One or more instance variables
  - One or more methods that perform some operation or execute some algorithm
  - A **`__init__`** method, which initializes (gives starting values to) the instance variables
  - A **`__repr__`** method, which defines a string *representation* of an object that is suitable for printing on the screen
- Let's step through building the **`Card`** class from the ground up

# Building the `Card` Class

- The code we build up in piecemeal fashion will all eventually be saved in a file named Card.py
- We begin by writing a class statement:

```
class Card:
```

- Next we write the **`__init__`** method. The **`self`** keyword refers to the object itself.

```
def __init__(self, n):
    self._id = n
```

- The **`__init__`** method is called the class's **constructor** because it is used to construct new objects

# Building the `Card` Class

- Now we can write the **`rank()`** and **`suit()`** methods
- They translate the **`_id`** number into the rank and suit of a card

```
def suit(self):
    return self._id // 13
def rank(self):
    return self._id % 13
```

- This encoding ensures that all 13 cards of a single suit are placed together in consecutive order
- Now let's write a simple **`__repr__`** method

```
def __repr__(self):
    return 'Card #' + str(self._id)
```

# Building the `Card` Class

- The **`Card`** class so far:

```
class Card:
    def __init__(self, n):
        self._id = n

    def suit(self):
        return self._id // 13

    def rank(self):
        return self._id % 13

    def __repr__(self):
        return 'Card #' + str(self._id)
```

# Building the `Card` Class

- Suppose we created card #43: **`c1 = Card(43)`**
- If we go ahead and print out **`c1`**, we will get output like this: **`Card #43`**
- That's not very informative, so we'll have to fix it later
- We can write a function **`new_deck()`** that creates a list of 52 playing-card objects. This function is not part of the **`Card`** class itself.

```
def new_deck():
    return [Card(i) for i in range(52)]
```

- An example call to this function:

```
deck = new_deck()
```

# Building the `Card` Class

- Another improvement we can make is to add special methods that allow us to compare **`Card`** objects
- If we want to be able to sort **`Card`** objects, we must provide the **`__lt__()`** method, which tells us if one object is "less than" another:

```
def __lt__(self, other):
    return self._id < other._id
```

- **`__eq__()`** defines what it means for two **`Card`** objects to be "equal to" each other:

```
def __eq__(self, other):
    return self._id == other._id
```

# Building the `Card` Class

- For example, consider the following objects:

  **`c1 = Card(1)`**

  **`c2 = Card(4)`**

- The expression **`c1 < c2`** would be **`True`**, but **`c1 == c2`** would be **`False`**
- Now that we can compare **`Card`** objects, we can sort them using the **`sorted`** function
  - **`sorted`** makes a copy of a list and then sorts the copy:

    **`cards_sorted = sorted(cards)`**

# Building the `Card` Class

- The **`Card`** class defines an **application program interface** or API: a set of related methods that other programmers can use to build other software
- Also, we are applying the concept of encapsulation by gathering all the code that defines a **`Card`** object in one place
- On that topic, it can be useful to define **class variables**, values that pertain to a particular class but are not instance variables
- For our **`Card`** class it would be useful if we could print symbols representing the suits and ranks: ♣ ♦ ♥ ♠
- In Python we have access to many thousands of symbols.
- We can access them by giving the correct numeric codes.

# Building the `Card` Class

- **`suit_sym = {0: '\u2663', 1: '\u2666', 2: '\u2665', 3: '\u2660'}`**
- If we were to print **`suit_sym`**, we would get this output:
  **`{0: '♣', 1: '♦', 2: '♥', 3: '♠'}`**
- The codes for various symbols can be found on the Internet by searching for "Unicode characters"
- Likewise, we can define a dictionary for all the ranks:
- **`rank_sym = {0: '2', 1: '3', 2: '4', 3: '5', 4: '6', 5: '7', 6: '8', 7: '9', 8: '10', 9: 'J', 10: 'Q', 11: 'K', 12: 'A'}`**
- Our goal now is to be able to print a **`Card`** object in a form like "2♣". Let's see how to do that.

# Building the `Card` Class

- We will change our definition of the **`__repr__`** method to this:

```
def __repr(self):
    return Card.rank_sym[self.rank()] +
           Card.suit_sym[self.suit()]
```

- Now, when we print a **`Card`** object, we will get output like 2♣, A♦, 8♠, J♠, etc.

# Exceptions and Exception-handling

- What if another programmer using our class inadvertently gives a value outside the range 0 through 51 for **`n`** when constructing a **`Card`** object?
  - The **`__init__`** method will accept the value, but it really shouldn't
- We can solve this problem by adding **exception handling** to our code
  - An **exception** is an unexpected event or error that has been detected
  - We say that the program has **raised** an exception
  - Let's have the **`__init__`** method raise an exception if an invalid value is given for **`n`**

# Exceptions and Exception-handling

```
def __init__(self, n):
    if n in range(0, 52):
        self._id = n
    else:
        raise Exception('Card number must be
                         in the range 0-51.')
```

- The new version of `__init__` verifies that the argument `n` is valid
- If not, it raises the exception and includes a diagnostic message of sorts

# Exceptions and Exception-handling

- Consider a function now that a programmer might use to make new cards that catches any exception that might be thrown by the **`__init__`** method:

```
def make_card(n):
    try:
        return Card(n)
    except Exception as e:
        print('Invalid card: ' + str(e))
        return None
```

- If we call **`make_card(55)`**, we get this output:

```
Invalid card: Card number must be in the
range 0-51.
```

# Exceptions and Exception-handling

- This concludes our development of the **`Card`** class
- See unit07/Card.py for the completed **`Card`** class and unit07/playing_cards.py for some tests

# Example: Acronym Generator (v1)

- Let’s explore a function that will create an acronym from the first letter of each “long” word in a list
- Define a “long” word to be any word with more than two letters
- After studying this first version, we will look at a second version that affords a little extra flexibility in creating acronyms

# Example: acronym1.py

```
def acronym(phrase):
    result = ''
    words = phrase.split()
    for w in words:
        if len(w) >= 3: # keep only long words
            result += w.upper()[0]
    return result
```

# Trace: `acronym()` (version 1)

- Let's trace the execution of this function for one example:

**`acronym('United States of America')`**

```
def acronym(phrase):
    result = ''
    words = phrase.split()
    for w in words:
        if len(w) > 3:
            result += w.upper()[0]
    return result
```

| **Variable** | **Value** |
|---|---|
| `phrase` | `'United States of America'` |

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    return result
```

| **Variable** | **Value** |
|---|---|
| `phrase` | `'United States of America'` |
| `result` | `''` |

# Trace: `acronym()` (version 1)

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    return result
```

| Variable | Value |
|---|---|
| `phrase` | `'United States of America'` |
| `result` | `''` |
| `words` | `['United', 'States', 'of', 'America']` |

# Trace: `acronym()` (version 1)

- Let's trace the execution of this function for one example:

**`acronym('United States of America')`**

```
def acronym(phrase):
    result = ''
    words = phrase.split()
    for w in words:
        if len(w) > 3:
            result += w.upper()[0]
    return result
```

| **Variable** | **Value** |
| --- | --- |
| `phrase` | `'United States of America'` |
| `result` | `''` |
| `words` | `['United', 'States', 'of', 'America']` |
| `w` | `'United'` |

# Trace: `acronym()` (version 1)

- Let's trace the execution of this function for one example:

  **`acronym('United States of America')`**

```
def acronym(phrase):
    result = ''
    words = phrase.split()
    for w in words:
        if len(w) > 3: True
            result += w.upper()[0]
    return result
```

| Variable | Value |
|---|---|
| `phrase` | `'United States of America'` |
| `result` | `''` |
| `words` | `['United', 'States', 'of', 'America']` |
| `w` | `'United'` |

# Trace: `acronym()` (version 1)

- Let's trace the execution of this function for one example:

**`acronym('United States of America')`**

```
def acronym(phrase):
    result = ''
    words = phrase.split()
    for w in words:
        if len(w) > 3:
            result += w.upper()[0]
    return result
```

| Variable | Value |
|---|---|
| `phrase` | `'United States of America'` |
| `result` | `'U'` |
| `words` | `['United', 'States', 'of', 'America']` |
| `w` | `'United'` |

# Trace: `acronym()` (version 1)

- Let's trace the execution of this function for one example:

**`acronym('United States of America')`**

```
def acronym(phrase):
    result = ''
    words = phrase.split()
    for w in words:
        if len(w) > 3:
            result += w.upper()[0]
    return result
```

| Variable | Value |
|---|---|
| `phrase` | `'United States of America'` |
| `result` | `'U'` |
| `words` | `['United', 'States', 'of', 'America']` |
| `w` | `'States'` |

# Trace: `acronym()` (version 1)

- Let's trace the execution of this function for one example:

**`acronym('United States of America')`**

```
def acronym(phrase):
    result = ''
    words = phrase.split()
    for w in words:
        if len(w) > 3: True
            result += w.upper()[0]
    return result
```

| Variable | Value |
|---|---|
| `phrase` | `'United States of America'` |
| `result` | `'U'` |
| `words` | `['United', 'States', 'of', 'America']` |
| `w` | `'States'` |

# Trace: `acronym()` (version 1)

- Let's trace the execution of this function for one example:

**`acronym('United States of America')`**

```
def acronym(phrase):
    result = ''
    words = phrase.split()
    for w in words:
        if len(w) > 3:
            result += w.upper()[0]
    return result
```

| Variable | Value |
|---|---|
| phrase | 'United States of America' |
| result | 'US' |
| words | ['United', 'States', 'of', 'America'] |
| w | 'States' |

# Trace: `acronym()` (version 1)

- Let's trace the execution of this function for one example:

**`acronym('United States of America')`**

```
def acronym(phrase):
    result = ''
    words = phrase.split()
    for w in words:
        if len(w) > 3:
            result += w.upper()[0]
    return result
```

| Variable | Value |
|---|---|
| `phrase` | `'United States of America'` |
| `result` | `'US'` |
| `words` | `['United', 'States', 'of', 'America']` |
| `w` | `'of'` |

# Trace: `acronym()` (version 1)

- Let's trace the execution of this function for one example:

**`acronym('United States of America')`**

```
def acronym(phrase):
    result = ''
    words = phrase.split()
    for w in words:
        if len(w) > 3: False
            result += w.upper()[0]
    return result
```

| Variable | Value |
|---|---|
| `phrase` | `'United States of America'` |
| `result` | `'US'` |
| `words` | `['United', 'States', 'of', 'America']` |
| `w` | `'of'` |

# Trace: `acronym()` (version 1)

- Let's trace the execution of this function for one example:

**`acronym('United States of America')`**

```
def acronym(phrase):
    result = ''
    words = phrase.split()
    for w in words:
        if len(w) > 3:
            result += w.upper()[0]
    return result
```

| Variable | Value |
| --- | --- |
| `phrase` | `'United States of America'` |
| `result` | `'US'` |
| `words` | `['United', 'States', 'of', 'America']` |
| `w` | `'America'` |

# Trace: `acronym()` (version 1)

- Let's trace the execution of this function for one example:

**`acronym('United States of America')`**

```
def acronym(phrase):
    result = ''
    words = phrase.split()
    for w in words:
        if len(w) > 3: True
            result += w.upper()[0]
    return result
```

| Variable | Value |
|---|---|
| `phrase` | `'United States of America'` |
| `result` | `'US'` |
| `words` | `['United', 'States', 'of', 'America']` |
| `w` | `'America'` |

# Trace: `acronym()` (version 1)

- Let's trace the execution of this function for one example:

  **`acronym('United States of America')`**

```
def acronym(phrase):
    result = ''
    words = phrase.split()
    for w in words:
        if len(w) > 3:
            result += w.upper()[0]
    return result
```

| Variable | Value |
|---|---|
| `phrase` | `'United States of America'` |
| `result` | `'USA'` |
| `words` | `['United', 'States', 'of', 'America']` |
| `w` | `'America'` |

# Trace: `acronym()` (version 1)

- Let's trace the execution of this function for one example:

**`acronym('United States of America')`**

```
def acronym(phrase):
    result = ''
    words = phrase.split()
    for w in words:
        if len(w) > 3:
            result += w.upper()[0]
    return result
```

| Variable | Value |
|---|---|
| `phrase` | `'United States of America'` |
| `result` | `'USA'` |
| `words` | `['United', 'States', 'of', 'America']` |
| `w` | `'America'` |

# Example: Acronym Generator (v2)

- Python allows function arguments to have **default values**
  - If the function is called without the argument, the argument gets its default value
  - Otherwise, the argument's value is given in the normal way
- We have seen a few examples of functions that have optional arguments
- A good example is the **`round()`** function, which takes two arguments: the value to round and an optional argument that indicates how many digits after the decimal point we want
  - If the second argument is not provided, the number of digits defaults to 0

# Example: Acronym Generator (v2)

- The second version of **`acronym`** takes an optional argument, **`include_shorts`**, that tells the function to include the first letter of all words (including short words), but short words will not be capitalized if they are included
- The first version of **`acronym`** simply discarded all short words

# Example: acronym2.py

```
def acronym(phrase, include_shorts=False):
    result = ''
    words = phrase.split()
    for w in words:
        if len(w) > 3:
            result += w.upper()[0]
        elif include_shorts:
            result += w.lower()[0]
    return result
```

- By default, the optional argument is **`False`**, causing short words to be excluded
- When the optional argument is **`True`** and **`w`** is a short word, the first letter of the word in lowercase is concatenated to **`result`**

# Example: `acronym()` (v2)

- Examples:
- **`acronym('United States of America')`** still returns **`'USA'`**
- **`acronym('United States of America', True)`** returns **`'USoA'`**

# Optional Arguments

- As another example, suppose we want to make a revised version of the **`bmi()`** function from earlier in the course:

```
def bmi(weight, height):
    return (weight * 703) / (height ** 2)
```

- This version of **`bmi()`** assumes weight is given in pounds and height in total inches
- Suppose instead we want to give the programmer the option to use metric or standard (English) units
- We can add a third, optional argument, **`units`**, that defaults to metric if the programmer doesn't give a third argument
- Let's see the function on the next slide

# Example: bmi_v4.py

```
def bmi(height, weight, units = 'metric'):
    if units == 'metric':
        return weight / height**2
    elif units == 'standard':
        return (weight * 703) / (height ** 2)
    else:
        return None
```

- Examples: Return Value:
- **`bmi(100, 150, ‘standard’)`** **`10.545`**
- **`bmi(100, 150)`** **`0.015`**
- **`bmi(100, 150, ‘metric’):`** **`0.015`**
- **`bmi(100, 150, ‘unknown’)`** **`None`**