CONTROL AND ENVIRONMENTS 1

COMPUTER SCIENCE 61A

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1 Control

Control structures direct the flow of logic in a program. For example, conditionals (`if-elif-else`) allow a program to skip sections of code, while iteration (`while`), allows a program to repeat a section.

1.1 If statements

Conditional statements let programs execute different lines of code depending on certain conditions. Let's review the `if- elif-else` syntax:

```
if <conditional expression>:
    <suite of statements>
elif <conditional expression>:
    <suite of statements>
else:
    <suite of statements>
```

Recall the following points:

- The `else` and `elif` clauses are optional, and you can have any number of `elif` clauses.
- A **conditional expression** is a expression that evaluates to either a true value (`True`, a non-zero integer, etc.) or a false value (`False`, `0`, `None`, `""`, `[]`, etc.).
- Only the **suite** that is indented under the first `if/elif` with a **conditional expression** evaluating to a true value will be executed.

- If none of the **conditional expressions** evaluate to a true value, then the `else` suite is executed. There can only be one `else` clause in a conditional statement!

1.2 Boolean Operators

Python also includes the **boolean operators** `and`, `or`, and `not`. These operators are used to combine and manipulate boolean values.

- `not` returns the opposite truth value of the following expression.
- `and` stops evaluating any more expressions (short-circuits) once it reaches the first false value and returns it. If all values evaluate to a true value, the last value is returned.
- `or` short-circuits at the first true value and returns it. If all values evaluate to a false value, the last value is returned.

```
>>> not None
True
>>> not True
False
>>> -1 and 0 and 1
0
>>> False or 9999 or 1/0
9999
```

1.3 Questions

1. Alfonso will only wear a jacket outside if it is below 60 degrees or it is raining. Fill in the function `wears_jacket` which takes in the current temperature and a Boolean value telling if it is raining and returns `True` if Alfonso will wear a jacket and `False` otherwise.

   This should only take one line of code!

```
def wears_jacket(temp, raining):
    """
    >>> rain = False
    >>> wears_jacket(90, rain)
    False
    >>> wears_jacket(40, rain)
    True
    >>> wears_jacket(100, True)
    True
    """
```

Solution:

```
    return temp < 60 or raining
```

2. To handle discussion section overflow, TAs may direct students to a more empty section that is happening at the same time. Write the function `handle_overflow`, which takes in the number of students at two sections and prints out what to do if either section exceeds 30 students. **Note:** Don't worry about printing "spot" for singular values and "spots" for multiple values.

```
def handle_overflow(s1, s2):
    """
    >>> handle_overflow(27, 15)
    No overflow.
    >>> handle_overflow(35, 29)
    1 spot left in Section 2.
    >>> handle_overflow(20, 32)
    10 spots left in Section 1.
    >>> handle_overflow(35, 30)
    No space left in either section.
    """
```

Solution:

```
    if s1 <= 30 and s2 <= 30:
        print("No overflow.")
    elif s2 > 30 and s1 < 30:
        print(str(30 - s1) + "spots left in Section 1.")
    elif s1 > 30 and s2 < 30:
        print(str(30 - s2) + "spots left in Section 2.")
    else:
        print("No space left in either section.")
```

1.4 While loops

Iteration lets a program repeat statements multiple times. A common iterative block of code is the **`while` loop**:

```
while <conditional clause>:
    <body of statements>
```

As long as `<conditional clause>` evaluates to a true value, `<body of statements>` will continue to be executed. The conditional clause gets evaluated each time the body finishes executing.

1.5 Questions

1. What is the result of evaluating the following code?

```
def square(x):
    return x * x

def so_slow(num):
    x = num
    while x > 0:
        x = x + 1
    return x / 0

square(so_slow(5))
```

> **Solution:** Infinite loop because `x` will always be greater than 0; the `num / 0` is never executed.

2. Fill in the `is_prime` function, which returns `True` if `n` is a prime number and `False` otherwise. After you have a working solution, think about potential ways to make your solution more *efficient*.

   Hint: use the `%` operator: `x % y` returns the remainder of `x` when divided by `y`.

```
def is_prime(n):
```

> **Solution:**
>
> ```
>     if n == 1:
>         return False
>     k = 2
>     while k < n:
>         if n % k == 0:
>             return False
>         k += 1
>     return True
> ```
>
> Alternatively, the while loop's conditional expression could ensure that `k` is less than the square root of `n`.

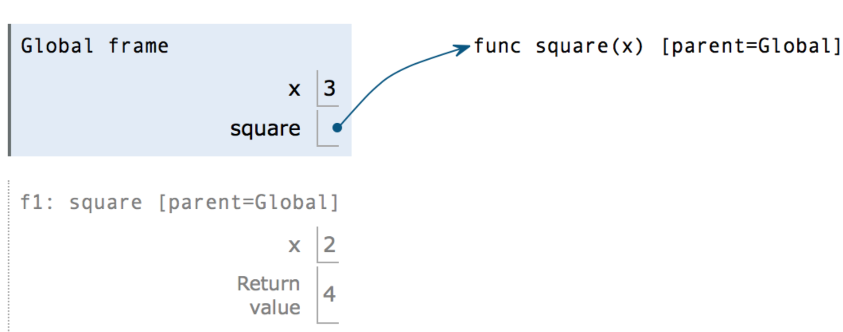
2 Environment Diagrams

An **environment diagram** keeps track of all the variables that have been defined and the values they are bound to.

```
x = 3

def square(x):
    return x ** 2

square(2)
```



When you execute *assignment statements* in an environment diagram (like `x = 3`), you need to record the variable name and the value:

1. Evaluate the expression on the right side of the = sign
2. Write the variable name and the expression's value in the current frame.

When you execute *`def` statements*, you need to record the function name and bind the function object to the name.

1. Write the function name (e.g., `square`) in the frame and point it to a function object (e.g., `func square(x) [parent=Global]`). The `[parent=Global]` denotes the frame in which the function was *defined*.

When you execute a *call expression* (like `square(2)`), you need to create a new frame to keep track of local variables.

1. Draw a new frame. [a] Label it with
   - a unique index (`f1`, `f2`, `f3` and so on)
   - the **intrinsic name** of the function (`square`), which is the name of the function object itself. For example, if the function object is `func square(x) [parent=Global]`, the intrinsic name is `square`.
   - the parent frame (`[parent=Global]`)
2. Bind the formal parameters to the arguments passed in (e.g. bind `x` to 3).
3. Evaluate the body of the function.

If a function does not have a return value, it implicitly returns `None`. Thus, the "Return value" box should contain `None`.

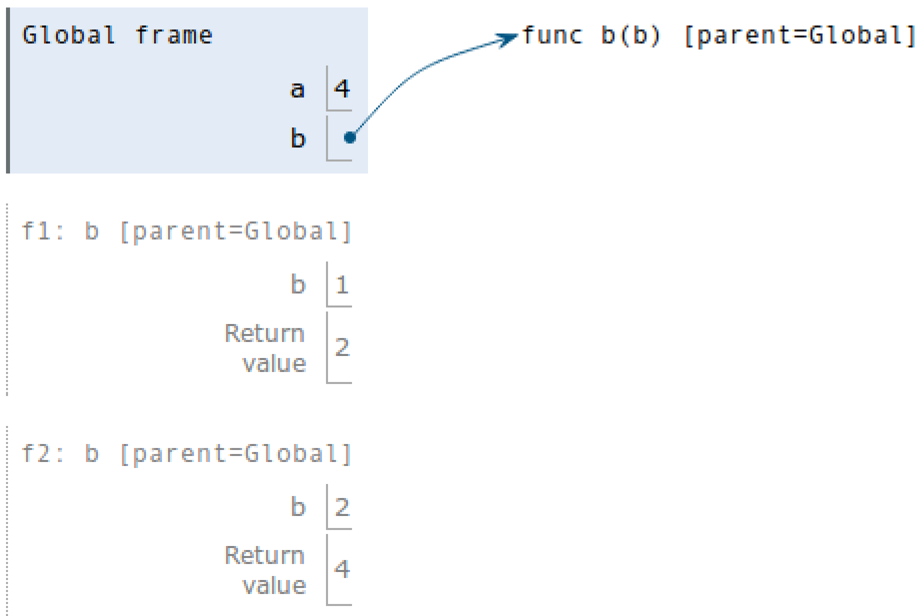
[a] Since we do not know how built-in functions like `add(...)` or `min(...)` are implemented, we do *not* draw a new frame when we call built-in functions.

2.1 Environment Diagram Questions

1. Draw the environment diagram that results from running the following code.

```
a = 1
def b(b):
    return a + b
a = b(a)
a = b(a)
```

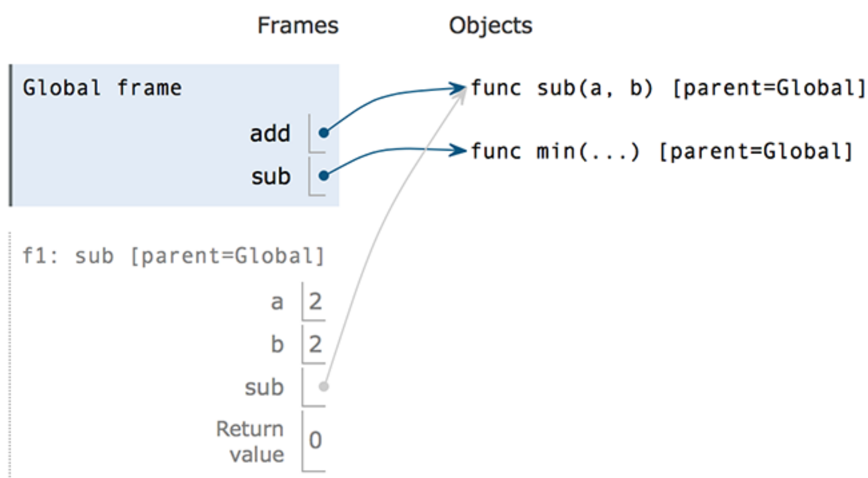
Solution:



2. Draw the environment diagram so we can visualize exactly how Python evaluates the code. What is the output of running this code in the interpreter?

```
>>> from operator import add
>>> def sub(a, b):
...     sub = add
...     return a - b
>>> add = sub
>>> sub = min
>>> print(add(2, sub(2, 3)))
```

Solution:



Output:

0

3 Higher Order Functions

A **higher order function** (HOF) is a function that manipulates other functions by taking in functions as arguments, returning a function, or both.

3.1 Functions as Arguments

One way a higher order function can manipulate other functions is by taking functions as input (an argument). Consider this higher order function called `negate`.

```
def negate(f, x):
    return -f(x)
```

`negate` takes in a function `f` and a number `x`. It doesn't care what exactly `f` does, as long as `f` is a function, takes in a number and returns a number. Its job is simple: call `f` on `x` and return the negation of that value.

3.2 Questions

1. Implement a function `keep_ints`, which takes in a function `cond` and a number `n`, and only prints a number from `1` to `n` if calling `cond` on that number returns `True`:

```
def keep_ints(cond, n):
    """Print out all integers 1..i..n where cond(i) is true

    >>> def is_even(x):
    ...     # Even numbers have remainder 0 when divided by 2.
    ...     return x % 2 == 0
    >>> keep_ints(is_even, 5)
    2
    4
    """
```

Solution:

```
    i = 1
    while i <= n:
        if cond(i):
            print(i)
        i += 1
```

3.3 Functions as Return Values

Often, we will need to write a function that returns another function. One way to do this is to define a function inside of a function:

```
def outer(x):
    def inner(y):
        ...
    return inner
```

The return value of `outer` is the function `inner`. This is a case of a function returning a function. In this example, `inner` is defined inside of `outer`. Although this is a common pattern, we can also define `inner` outside of `outer` and still use the same `return` statement. However, note that in this second example (unlike the first example), `inner` doesn't have access to variables defined within the `outer` function, like `x`.

```
def inner(y):
    ...
def outer(x):
    return inner
```

3.4 Questions

1. Use this definition of `outer` to fill in what Python would display when the following lines are evaluated.

```
def outer(n):
    def inner(m):
        return n - m
    return inner
>>> outer(61)
```

Solution:
`<function outer.inner ...>`

```
>>> f = outer(10)
>>> f(4)
```

Solution:
`6`

```
>>> outer(5)(4)
```

Solution:

```
1
```

2. Implement a function `keep_ints` like before, but now it takes in a number `n` and returns a function that has one parameter `cond`. The returned function prints out all numbers from 1..i..n where calling `cond(i)` returns True.

```
def keep_ints(n):
    """Returns a function which takes one parameter cond and
    prints out all integers 1..i..n where calling cond(i)
    returns True.

    >>> def is_even(x):
    ...     # Even numbers have remainder 0 when divided by 2.
    ...     return x % 2 == 0
    >>> keep_ints(5)(is_even)
    2
    4
    """
```

Solution:

```
    def do_keep(cond):
        i = 1
        while i <= n:
            if cond(i):
                print(i)
            i += 1
    return do_keep
```