# *CS201 - PL'S*

# Subroutines

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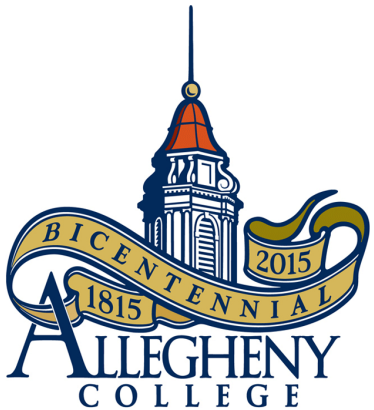
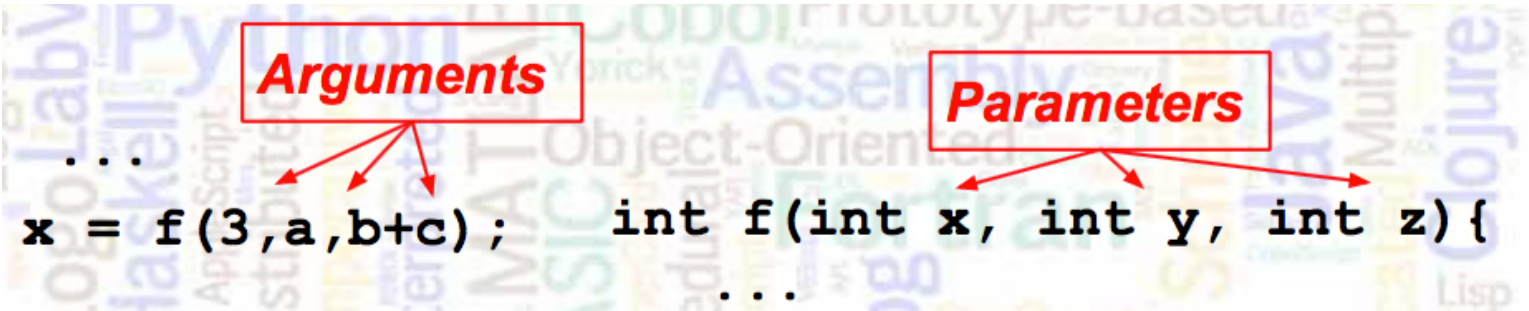


# Arguments, Parameters




Arguments are also called “actual parameters” (as opposed to “formal parameters” in the function definition)

# Examples of Function Calls (Python)

```
    def f(a,b,c):
...   return 100*a+10*b+c
```

# Examples of Function Calls (Python)

```
    def f(a=1,b=1,c=1):
...   return 100*a+10*b+c
```

- Default Parameter Values
- Named Arguments

# Examples of Function Calls (Haskell)

```
Prelude> let f a b c = 100 * a + 10 * b + c
Prelude> f 10 20 30
1230
Prelude> let g = f 1
Prelude> g 20 30
330
Prelude> let h = g 1
Prelude> h 30
140
```

g is a function obtained by giving parameter "a" the value "1" in function f. This is called "currying".

More currying; h x is equivalent to g 1 x, which is equivalent to f 1 1 x

# Parameter Evaluation

## "Applicative Order" evaluation:

arguments evaluated before the function call. "Eager" evaluation.

```
int slow(int n){
.../* count to n^2 */
   return count;
}
int f(int a, int b){
    return a+1;
}
```

```
int main(){
   int x;
   x = f(10,slow(1000000));
   printf("%d\n",x);
}
```

```
time ./a.out
a = 11
real   0m20.131s
user   0m20.126s
sys    0m0.000s
```

# Parameter Evaluation

## "Normal Order" evaluation:

arguments are not evaluated until they are needed (possibly never)

File **lazy.hs**:

```
slow 0 = 0
slow n = 1+slow (n-1)

f a b = a + 1
```

In ghci, try:

```
Prelude> :l lazy
[1 of 1] Compiling Main  ...
Ok, modules loaded: Main.
*Main> f 10 (slow 10000000)
11
*Main> f (slow 10000000) 10
10000001
```

# Parameter Evaluation

## "Lazy" evaluation:

- arguments are evaluated at most once (possibly never).
- Even though we used a Haskell example to illustrate "normal order", it is more accurate to call Haskell's evaluation order "lazy."
- In normal order, a parameter could be evaluated more than once (i.e., evaluated each time it appears in the function).

# Closures

- In languages that support “first-class functions,” a function may be a return value from another function; a function may be assigned to a variable.
- This raises some issues regarding scope.

# Closures

JavaScript example: http://goo.gl/kzUCes

```
function f(name) {
    var x = "hi there";
    function g() {
        return x+" "+name;
    }
    return g;
}
var k = f("bob");
```

Function **f** returns the function **g**. Therefore, variable k is assigned a *function*.
Once **f** is done, how will **k** (i.e., **g**) know the values of **x** and **name**?

# Closures

## One solution (NOT the one used by JavaScript!):

use the most recently-declared values of variables “name” and “x”.
– This is called “*shallow binding*.” Common in dynamically-scoped languages.

## Another solution (used by JavaScript and most other statically-scoped languages):

bind the variables that are in the environment where the function is defined.
– This is an illustration of “deep binding” and the combination of the function and its defining environment is called a closure.

# Closures: Another example (C#)

```
static void Main(string[] args) {
     Func <int,int> g = returnFunc(7);
     Console.WriteLine(g(9));
}
static Func<int,int> returnFunc(int x) {
     Func <int,int> g =
          delegate(int z) { int y = 10; return x+y+
     return g;
}
```

See `Closurer.cs` in the repo.

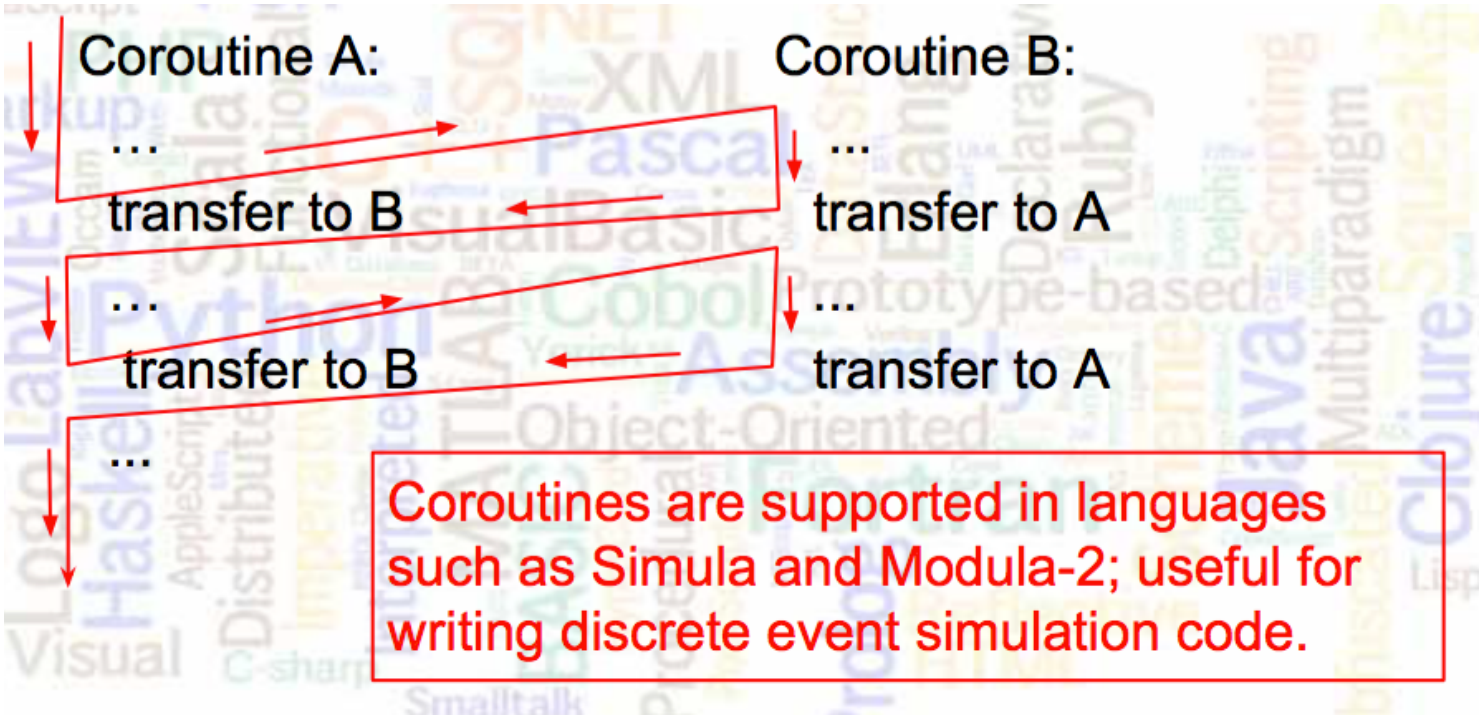
# Exceptions

See `Exc.java` in the repo.

# Coroutines

- A **coroutine** is a function that can be suspended and resumed.
- Several coroutines can be active at once, transferring control back and forth between them.

# Coroutines


Coroutine A:
...
transfer to B
...
transfer to B
...
Coroutine B:
...
transfer to A
...
transfer to A
Coroutines are supported in languages such as Simula and Modula-2; useful for writing discrete event simulation code.

# Generators in Python

Many other languages have features that allow the implementation of coroutines (even if they are not ”built in” to the language).
— Python has generator functions:

```
>>> def gen99():
...     for i in range(100):
...         yield i # NOTE: not "return i"
>>> a = gen99() # call the function just once
>>> next(a)
0
>>> next(a)
1
```

# Generators in Python

```
>>> next(a)
    2
    >>> for i in range(10):
    ...     print next(a),
    ...
    3 4 5 6 7 8 9 10 11 12
    >>> for i in range(10):
    ...     print next(a),
    ...
    13 14 15 16 17 18 19 20 21 22
```

# Generators in Python

- Several generators can be active at the same time; see sample program `gen.py` in the shared repository.
- This isn't precisely a coroutine example (we don't have "call" and "response" directly transferring back and forth).
- See `https://docs.python.org/3/library/asyncio-task.html` ("Tasks and coroutines", Python 3.5 documentation) intersection.

# Functions: Summary

We have considered the following topics:

- Parameter passing (e.g., pass by value, pass by reference)
- Special syntax (default values, named parameters)
- Parameter evaluation (applicative, normal, lazy)
- Closures
- Exceptions
- Coroutines

# Functions: Summary

We didn't cover:

- Generics (you have seen a lot of this in CMPSC 101)
- Events (we may revisit this topic in Chapter 13 if schedule permits).

# Reading Assignment

**PLP** Chapter 08 [8.1 - 8.3; 8.5 - 8.6]

# Questions

Do you have any questions from this class discussion?