Coral

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* please note that this presentation theme is also called Coral

The Coral Team*

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Snakes are nice

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Loves Coral Snakes

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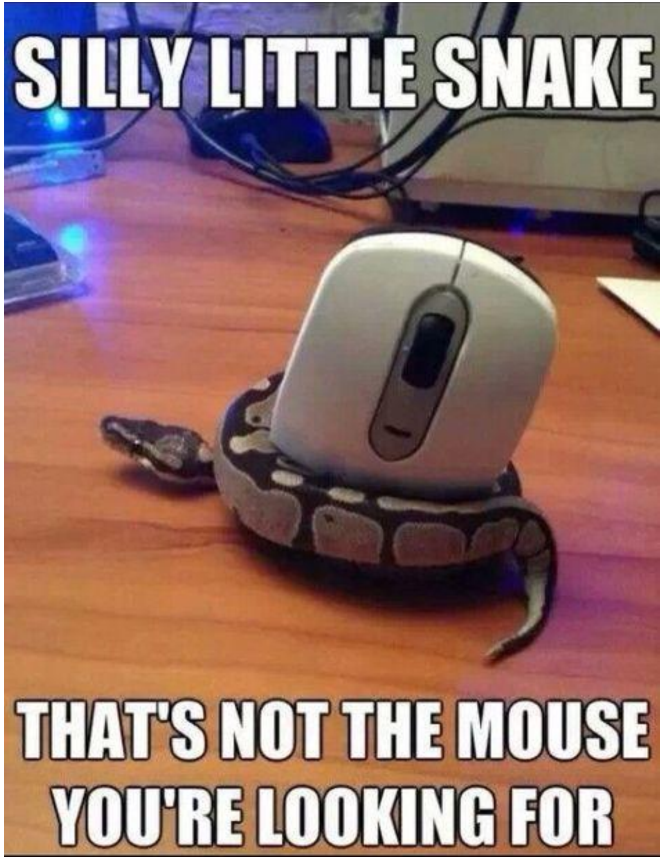
Our Inspiration

- Coral to Python as TypeScript to Javascript
- **Type Safety:** optional static typing enforced at compile and runtime.
- **Optimization:** use type-inference to generate code as fast as C.



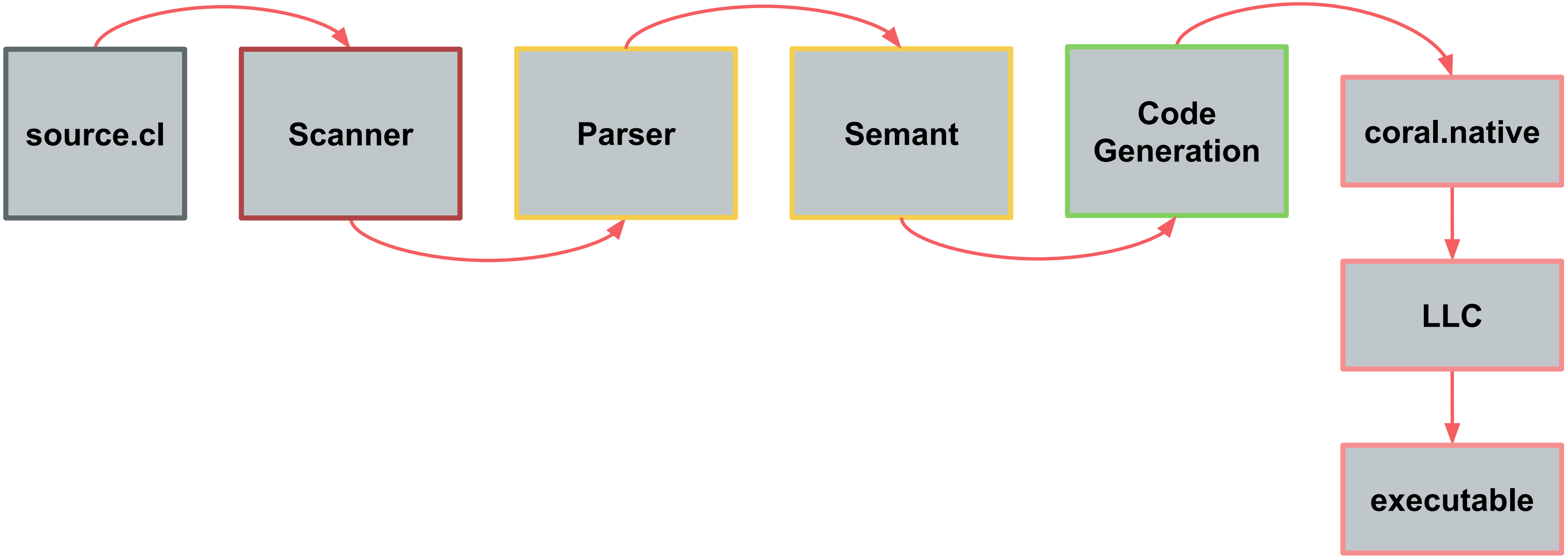
Source: Pintrest

What is CORAL

- Dynamically typed programming language
- Cross compatible with Python
- Optional static typing enforced by the compiler and runtime environment
- Type inference and optimization based on static typing
- Types: int, char, float, boolean, strings, lists
- First class functions
- No classes (no time)
- Compile and runtime exceptions

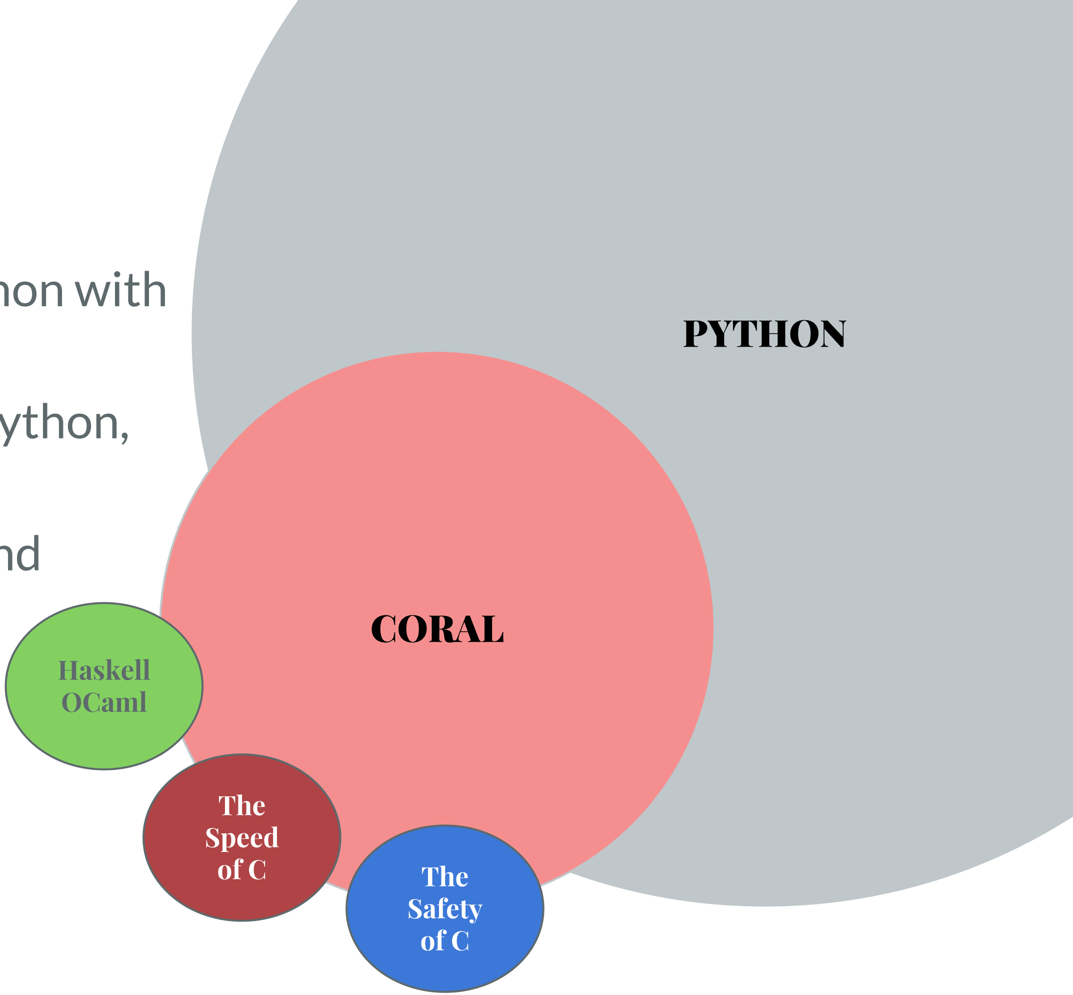
Implementation

Architectural Design



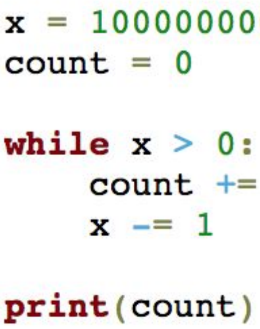
Coral v Python

- Coral is a smaller version of Python with extended support for typing.
- Coral uses the **same syntax** as Python, allowing for cross compatibility
- The difference between Coral and Python is our **optimization and safety**



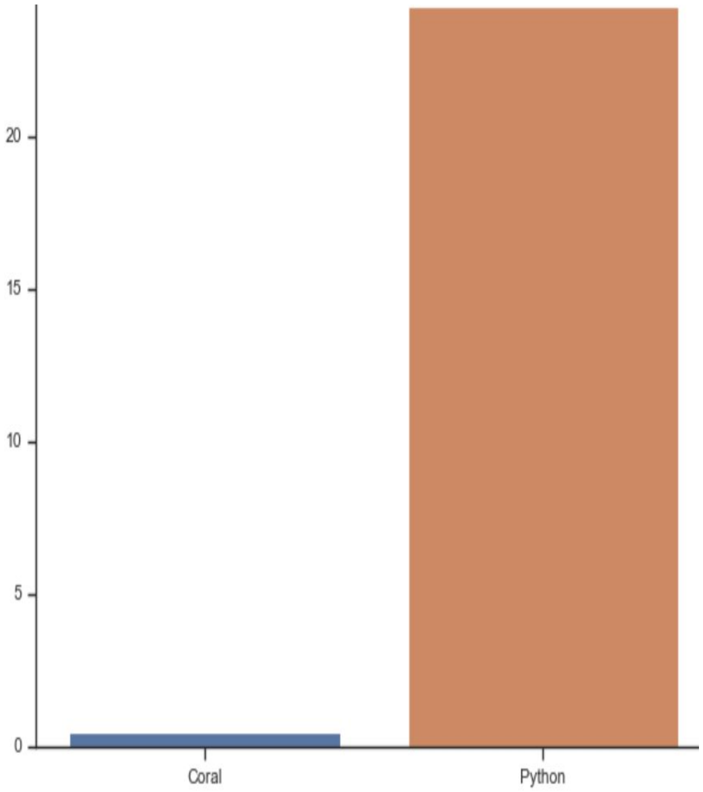
Comparison to Python

Wall-time on simple programs allows comparison between Coral and Python. For a program like this:



```
x = 100000000
count = 0

while x > 0:
    count += 1
    x -= 1

print(count)
```

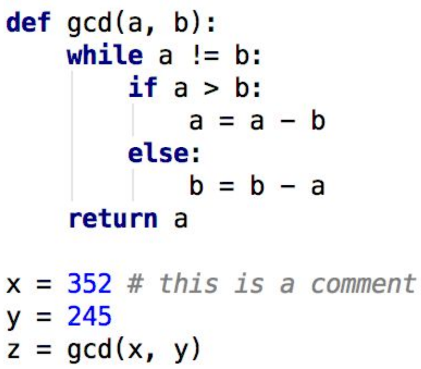
performance is about 40 times faster (.4 seconds to 23.4 seconds wall time).



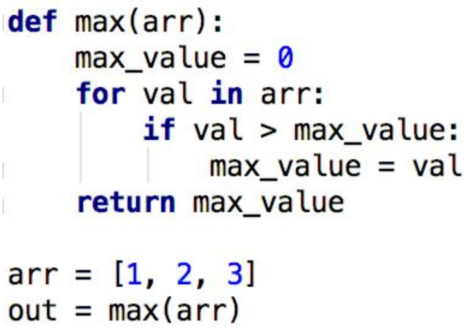
Key Features

Syntax & Grammar

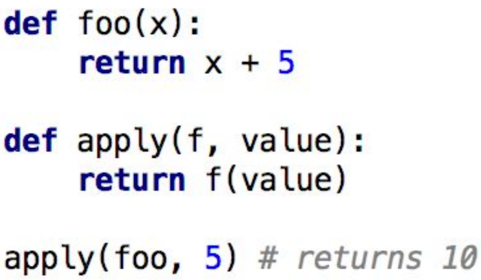
- Coral strictly follows the current Python 3.7 syntax, and **any valid Coral program can also be run and compiled by an up-to-date Python 3.7 interpreter.**
- Coral supports **for loops, while loops, for loops, if and else statements, first-class functions**, all in a strictly Pythonic syntax.
- Some valid programs include:



```
def gcd(a, b):
    while a != b:
        if a > b:
            a = a - b
        else:
            b = b - a
    return a

x = 352 # this is a comment
y = 245
z = gcd(x, y)
```



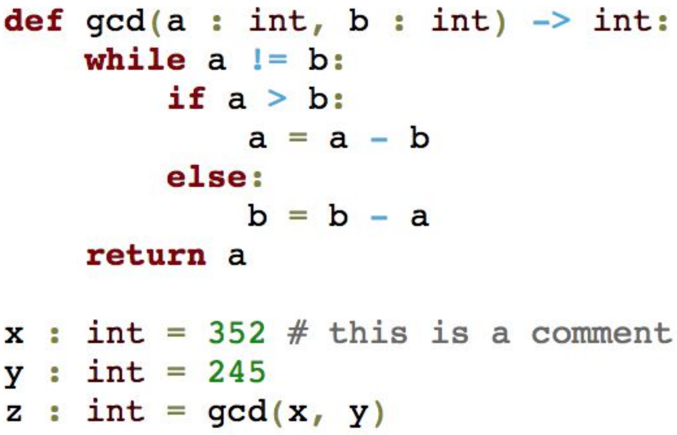
```
def max(arr):
    max_value = 0
    for val in arr:
        if val > max_value:
            max_value = val
    return max_value

arr = [1, 2, 3]
out = max(arr)
```



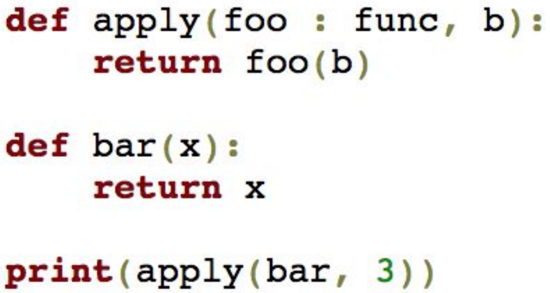
```
def foo(x):
    return x + 5

def apply(f, value):
    return f(value)

apply(foo, 5) # returns 10
```

Type Annotation

- Coral supports **optional type annotations** as supported by Python 3.7, which can be attached to variable assignments and function declarations.
- While these labels are only cosmetic in Python, they are **fully enforced in Coral**, either at compile time (if possible) or at runtime. A program will generally not compile (or in rare cases will terminate at runtime) if these type annotations are violated.



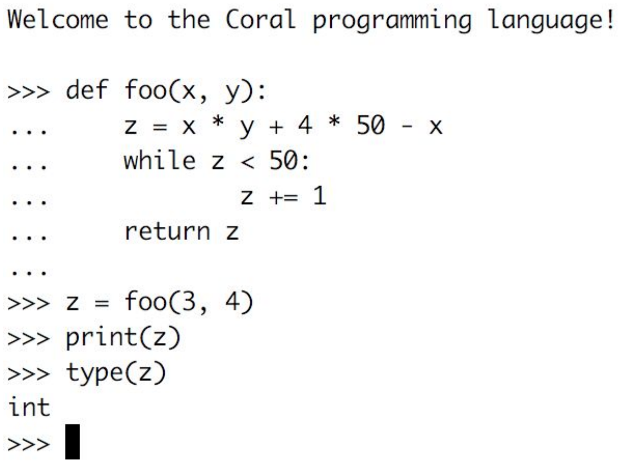
```
def gcd(a : int, b : int) -> int:
    while a != b:
        if a > b:
            a = a - b
        else:
            b = b - a
    return a

x : int = 352 # this is a comment
y : int = 245
z : int = gcd(x, y)
```



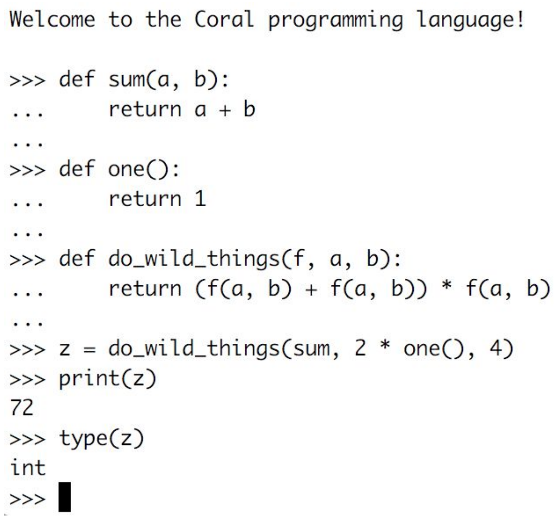
```
def apply(foo : func, b):
    return foo(b)

def bar(x):
    return x

print(apply(bar, 3))
```

Type Inference

- Coral supports gradual/partial type-inference built on top of the optional typing system. This is a sort of **bottom-up type inference** based on identifying literals and propagating these types up through the tree.
- Even programs with no annotations can be **fully type-inferred**. The type inference system does its best to infer whatever is possible.



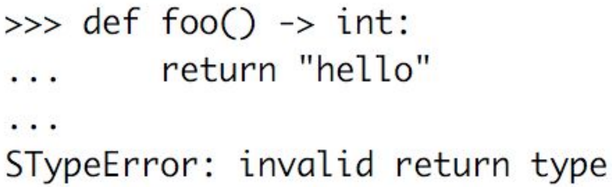
```
Welcome to the Coral programming language!

>>> def foo(x, y):
...     z = x * y + 4 * 50 - x
...     while z < 50:
...             z += 1
...     return z
...
>>> z = foo(3, 4)
>>> print(z)
>>> type(z)
int
>>> █
```



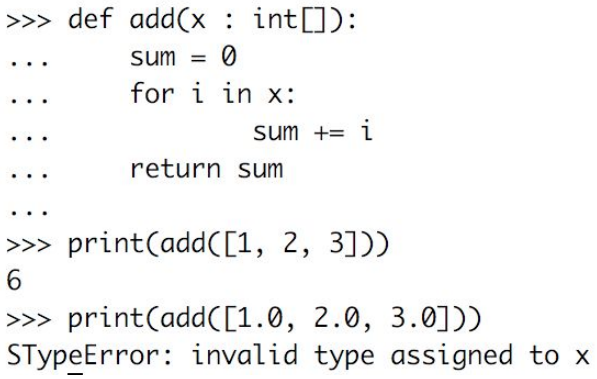
```
Welcome to the Coral programming language!

>>> def sum(a, b):
...     return a + b
...
>>> def one():
...     return 1
...
>>> def do_wild_things(f, a, b):
...     return (f(a, b) + f(a, b)) * f(a, b)
...
>>> z = do_wild_things(sum, 2 * one(), 4)
>>> print(z)
72
>>> type(z)
int
>>> █
```

Compile Time Exceptions

- Uses type inference to determine types of functions and variables **at compile time** which allows both **optimization and the enforcement of type annotations**. Coral cannot be fully type inferred while retaining all the type flexibility of Python, but many common errors can be captured by the Coral compiler.
- At compile time, Coral checks for:
  - **Invalid assignments** (to explicitly typed variables): global and local, formal args, function returns
  - **Invalid argument and return types** (for functions and operators)
- For example:



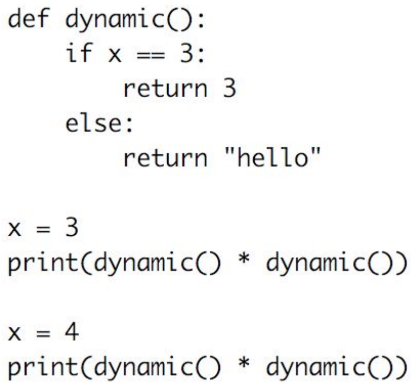
```
>>> def foo() -> int:
...     return "hello"
...
STypeError: invalid return type
```



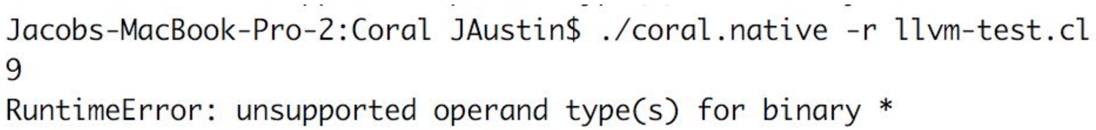
```
>>> def add(x : int[]):
...     sum = 0
...     for i in x:
...             sum += i
...     return sum
...
>>> print(add([1, 2, 3]))
6
>>> print(add([1.0, 2.0, 3.0]))
STypeError: invalid type assigned to x
```

Runtime Exceptions

- **Only has runtime checks when type isn't inferrable.** Prevents violations of type annotations.
- Coral checks for:
  - **Invalid assignments** (to explicitly typed variables): global and local, formal args, function returns
  - **Invalid argument types** (for operators)
  - **Initialization**: can't use null objects
  - **List bounds**



```
def dynamic():
    if x == 3:
        return 3
    else:
        return "hello"

x = 3
print(dynamic() * dynamic())

x = 4
print(dynamic() * dynamic())
```



```
Jacobs-MacBook-Pro-2:Coral JAustin$ ./coral.native -r llvm-test.cl
9
RuntimeError: unsupported operand type(s) for binary *
```

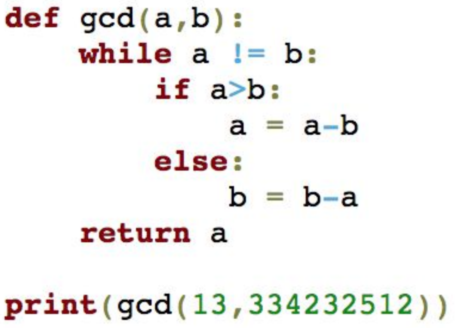
Optimization

- Optimization is done in cases where there are **immutable Objects** and all of the Objects have **known types** through the type inference system
- In programs which can be optimized, the code generation is similar to **MicroC** and therefore programs can run “as fast as C”. This optimization is integrated into the compilation, and can be performed only where possible, while seamlessly transitioning back to a dynamic Python-style runtime model.

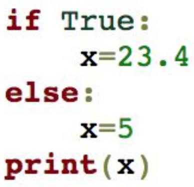
Statistics for optimized code:

- For fully optimized code, LLVM loc count drops by at least 1000 lines, **reducing binary sizes by tens of kilobytes**.
- Runtime **performance increases by as much as 100x** for code like gcd or code involving frequent heap allocations in Python (like counting while loops).

Optimization Examples

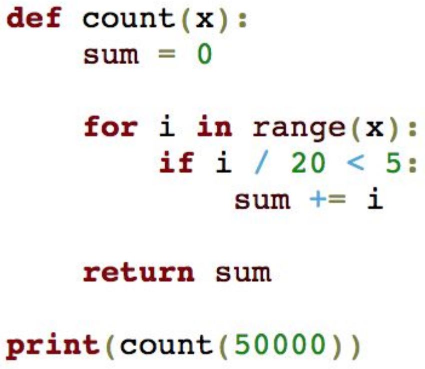


```python
def gcd(a,b):
    while a != b:
        if a>b:
            a = a-b
        else:
            b = b-a
    return a

print(gcd(13,334232512))
```



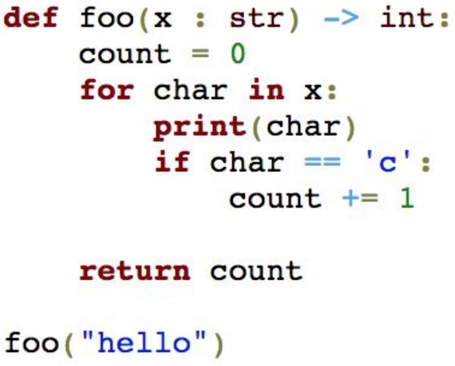
```python
if True:
    x=23.4
else:
    x=5
print(x)
```

GCD function with dynamic objects created. Runtime is 10 seconds for Python and .2 seconds for Coral. No explicit type annotations.



```python
def count(x):
    sum = 0

    for i in range(x):
        if i / 20 < 5:
            sum += i

    return sum

print(count(50000))
```

For-loop based function traditionally expensive in Python. Does not terminate in reasonable time in Python. Runs in .75 seconds in Coral



```python
def foo(x : str) -> int:
    count = 0
    for char in x:
        print(char)
        if char == 'c':
            count += 1

    return count

foo("hello")
```

For-loop iteration over chars. Partial type inference for sub-operations even though full code cannot be optimized because of lists.

Testing

Test Suite

- Sample program output compared to *.out file.
- Checks the following file types: **stest-***, **sfail-* and test-***, **fail-*** for semant tests and llvm/runtime tests respectively.
- Done by each member as feature implemented. Generally one new test for each new feature or commit.
- Over 100 tests in the final repository.

DEMO TIME

Thank you
&
Happy Holidays

Source: Pintrest