# Integrating C with Other Languages

C Programming and Software Tools

N.C. State Department of Computer Science

Computer Science
NC STATE UNIVERSITY

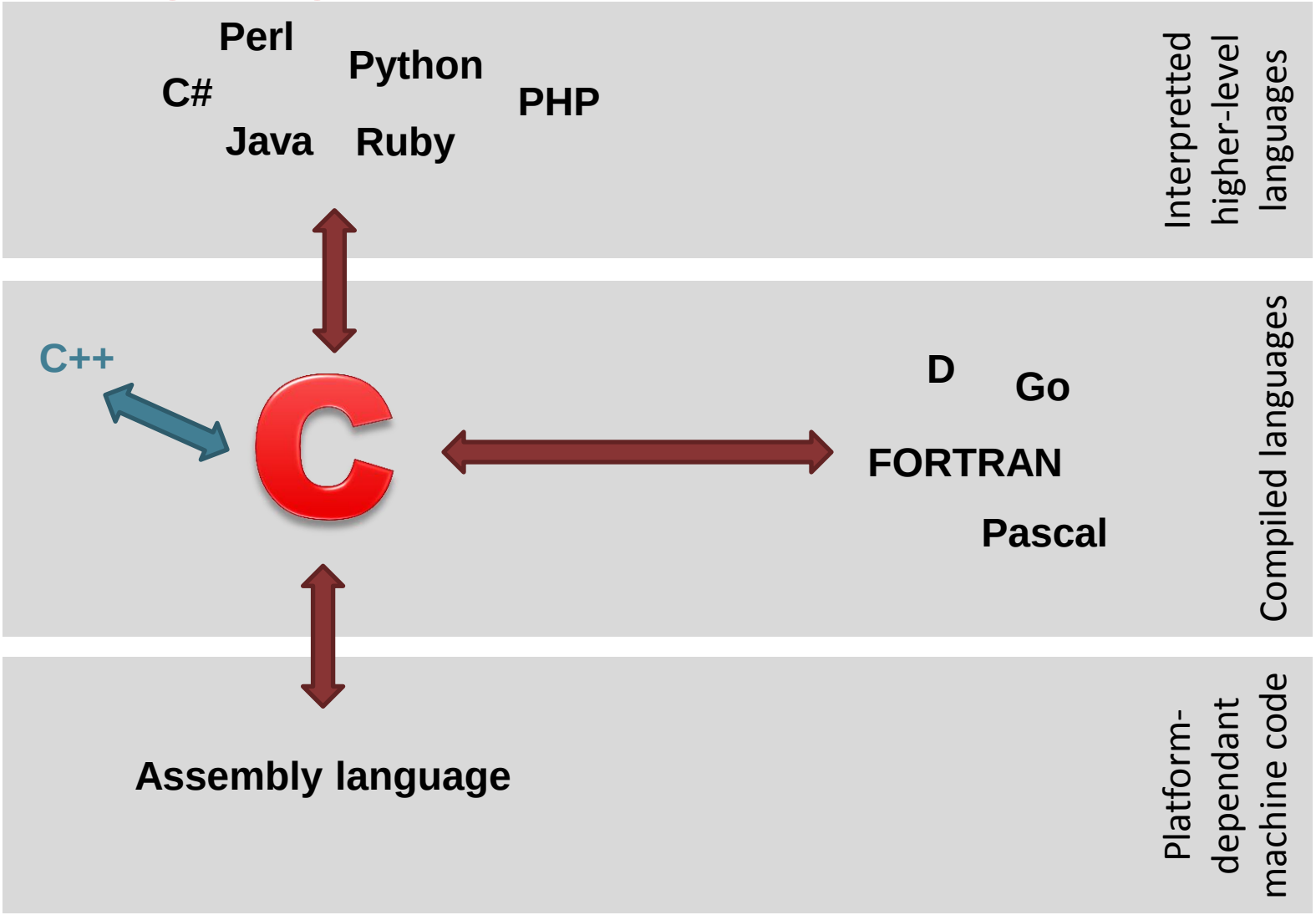
# Why integrate

- I want performance from C
- I want ease of use from higher level languages
- I want low-level control with assembly language

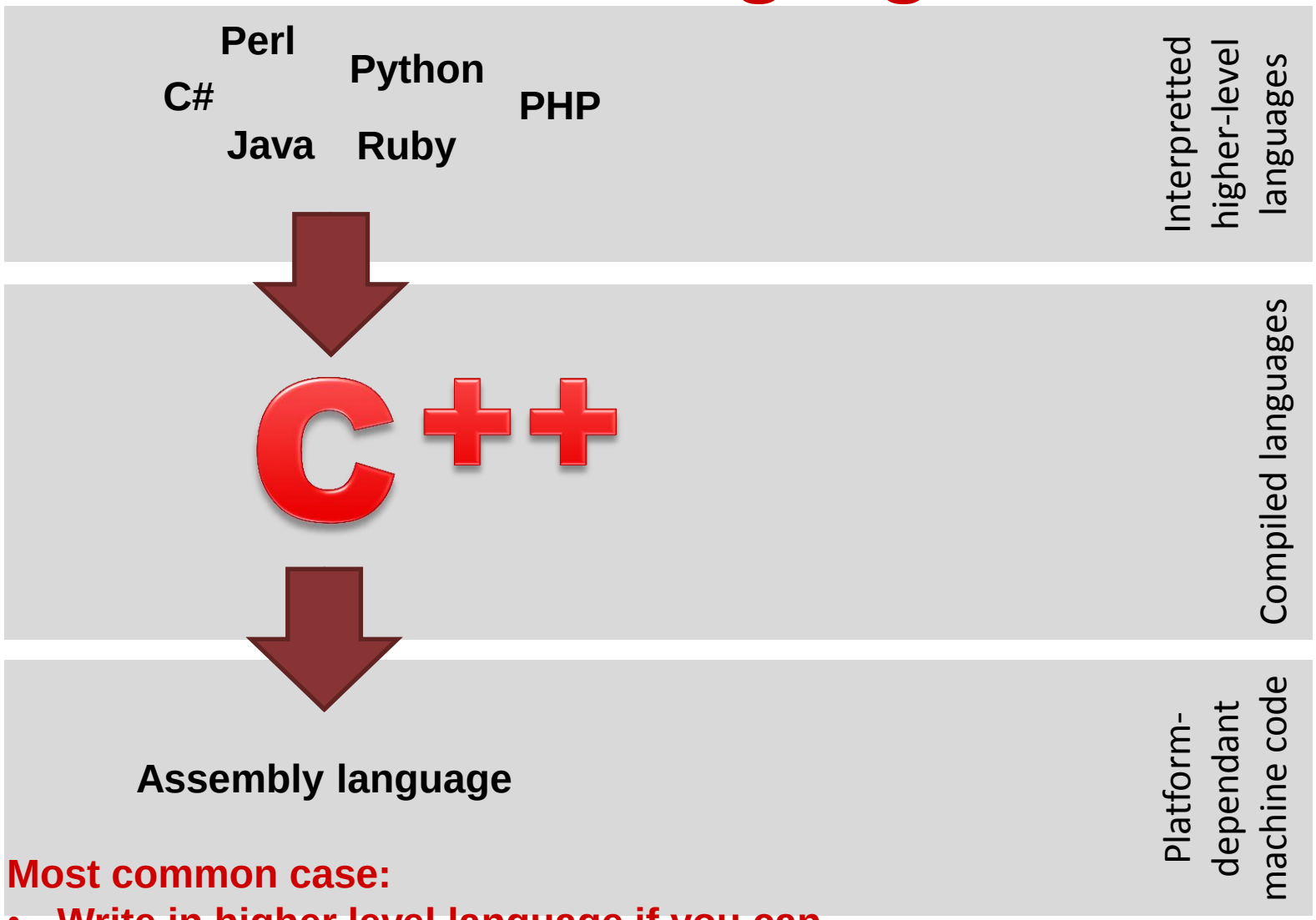
- Sometimes, I want all of these at once!

- Also, sometimes the library I need is only written for one language.

# Language interactions



# Most common language interactions



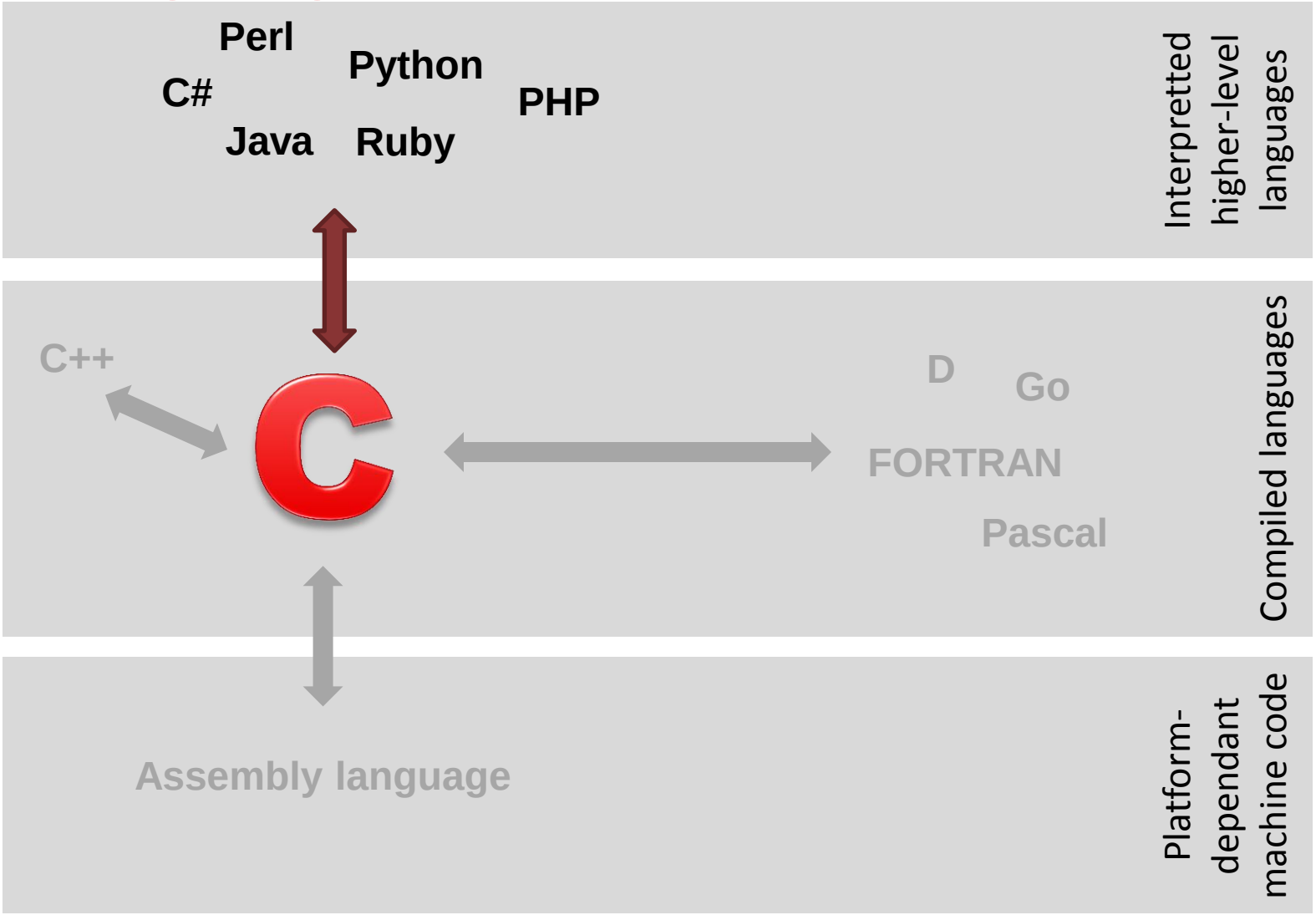

**Most common case:**

- **Write in higher level language if you can**
- **Call assembly language if you need to**
- **Promote your program to C++ if you need to talk to C++ or do OOP**

# Attributes of language interaction

- What **direction**?
  - C calling other, or other calling C?
- What **mechanism**?
  - Direct call
  - Shim layer
    - Automatically generated or manually written?
  - Inlining foreign code
  - Other/weird (shared memory, common caller, etc.)
- Handling **language feature mismatches**?
  - E.g., garbage collection?

# Language interactions



# Examples: Higher level languages

- Calling C from other languages:
  - **Direct**: Python's built-in ctypes module can be used to create variables in C data types and to make calls to C shared libraries
  - **Shim (manually developed)**: Homework 6 includes a Python class that uses ctypes to wrap up calls to your libCTurtle.
  - **Shim (auto-generated)**: The Perl tool h2xs generates stubs which call C library code based on a header file.
  - **Inline**: The Perl Inline::C module is used to write C code directly mixed in with Perl code.

```
#!/usr/bin/python
from ctypes import *
libc = cdll.LoadLibrary("libc.so.6")
libc.printf(
   "Hello world with C's printf!\n");
```

```
#!/usr/bin/perl
use Inline C;
hello_inline();

__END__
__C__
#include <stdio.h>

void hello_inline( ) {
    printf("Hello World inline!\n");
}
```

# Examples: Higher level languages

- Calling other languages from C:
  - **Direct**: Java JNI allows you to run a JVM from C directly and run code on it.
  - **Shim (manually developed)**: You can write a C module using Java JNI.
  - **Shim (auto-generated)**: Java has a javah tool to create C header files from Java classes.
  - **Inline**: Python supports embedding in C via multiple interfaces, such as the Very High Level (VHL) interface.

Adapted from:
https://docs.python.org/2/extending/embedding.html

```
#include <Python.h>

int
main(int argc, char *argv[])
{
  Py_SetProgramName(argv[0]);
  Py_Initialize();
  PyRun_SimpleString("from time import time,ctime\n"
                     "print 'Today is',ctime(time())\n");
  Py_Finalize();
  return 0;
}
```

# Garbage collection

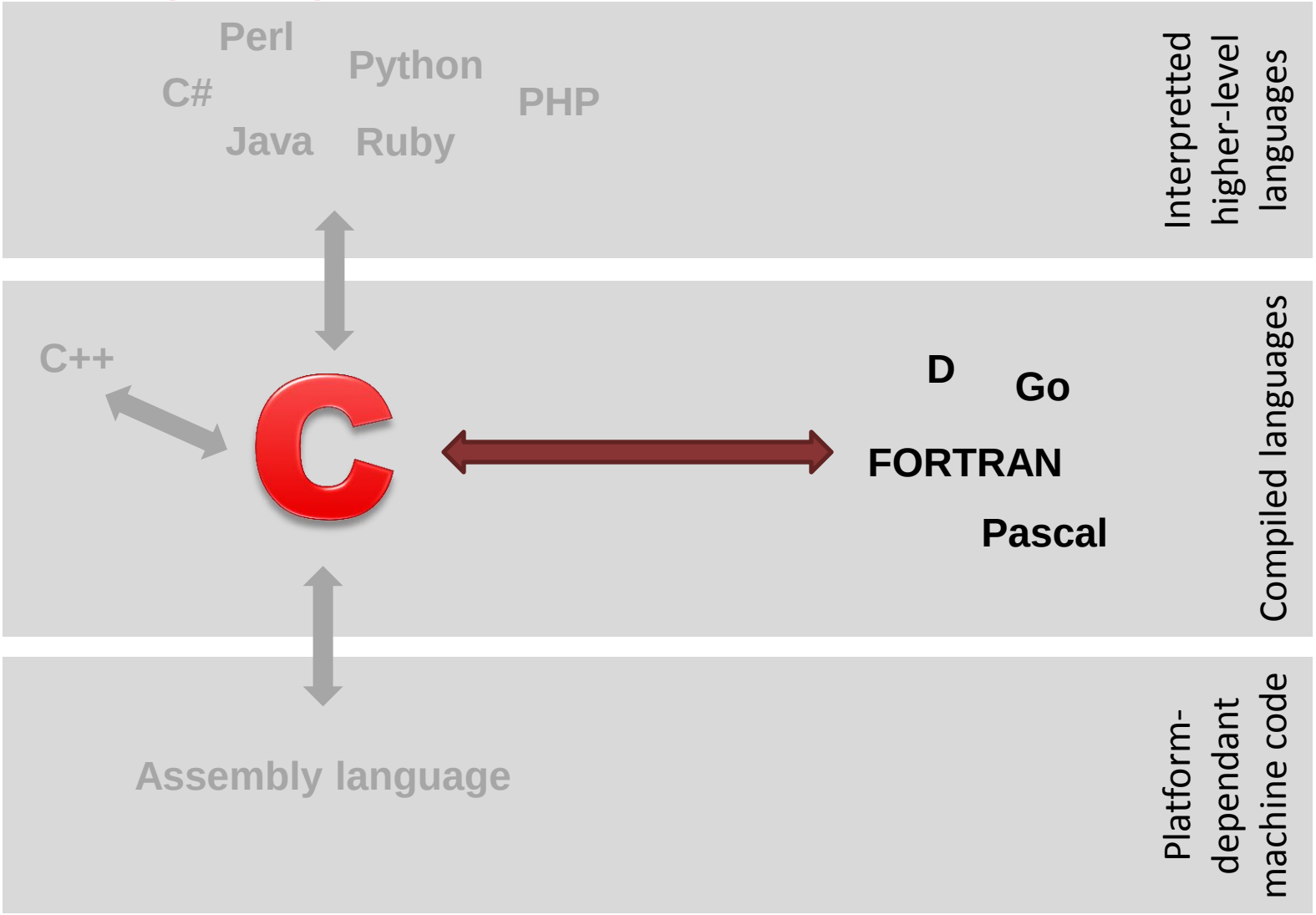
- When C is called from a garbage collected language, you hook the garbage collection notice to clean up C-based objects.
- This is done in the Homework 6 destructor:

```
class CTurtle(object):
    c = ctypes.cdll.LoadLibrary("libCTurtle.so")
    c.get_last_error.restype = ctypes.c_char_p

    @classmethod
    def new(self,w,h):
        r = CTurtle()
        r.img = self.c.create_image(w,h)
        return r

    def __del__(self):
        self.c.destroy_image(self.img)
```

# Language interactions



# Examples: Other compiled languages

- **Direct**: You can link C and FORTRAN object files together
- **Inline**: n/a

my_sub.h

```
void my_sub(int, double *);
```

main.c

```
#include "my_sub.h"

int main(){
  double b;
  int a=3;
  my_sub(a,&b);
  ...
}
```

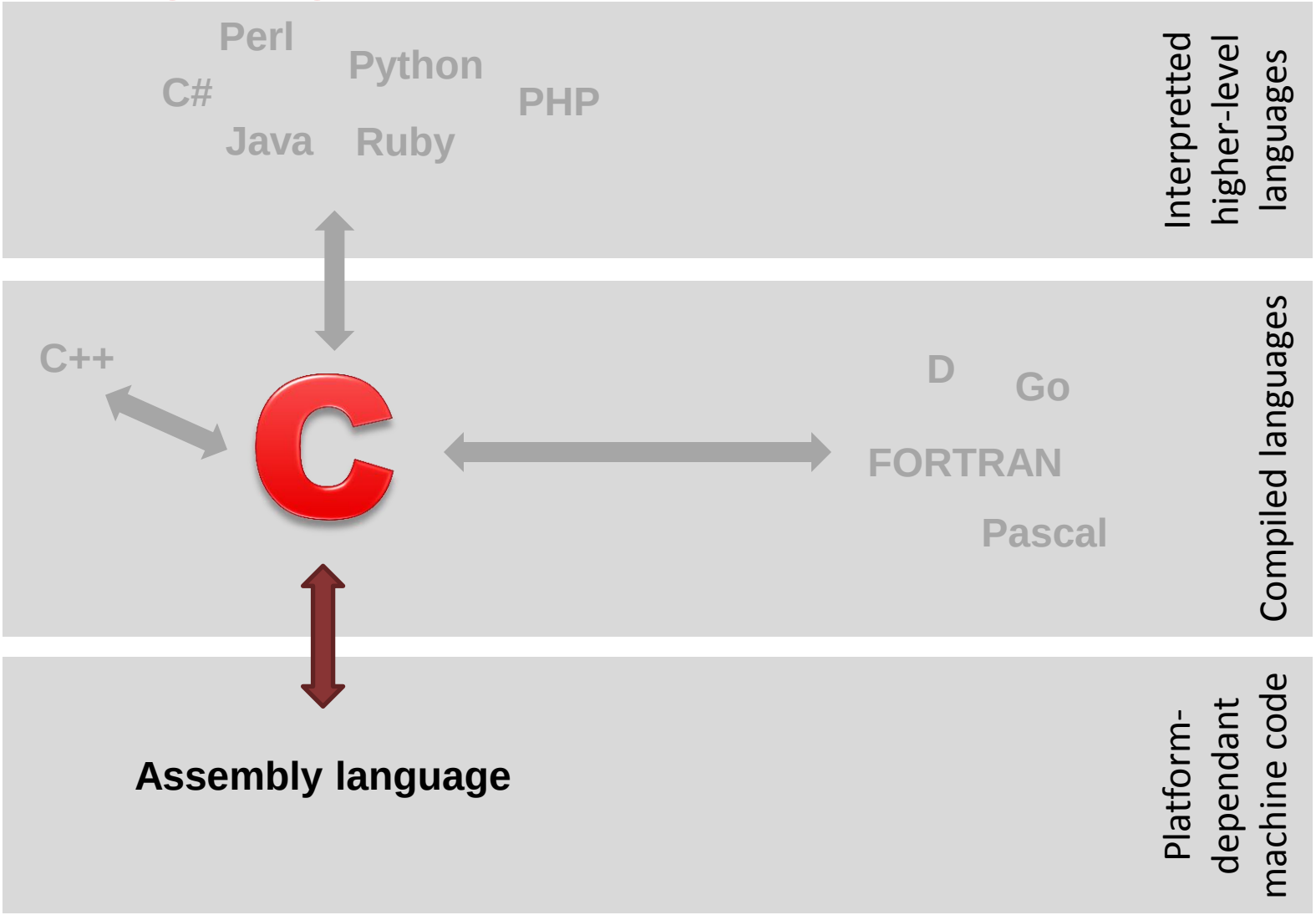
my_sub.f

```
MODULE my_fortran
  USE iso_c_binding
  IMPLICIT NONE
  CONTAINS
  SUBROUTINE my_subroutine(a,b) BIND(C,name="my_sub")
    INTEGER(c_int),INTENT(in),VALUE :: a
    REAL(C_DOUBLE),INTENT(out) :: b
    ...
  END SUBROUTINE
END MODULE
```

```
$ g77 -c -o my_sub.o my_sub.f
$ gcc -c -o main.o main.c
$ gcc -o myapp main.o mylib.o
```

Adapted from:
http://stackoverflow.com/questions/7743801/mixed-programming-fortran-and-c

# Language interactions



# Interacting with assembly language

- Calling assembly from C:
  - **Direct**: Can call assembly routines in C directly (just compile them together)
  - **Shim**: You can wrap 'em if you want.
  - **Inline**: C lets you put assembly right in your code (see next slide).
- Calling C from assembly:
  - **Direct**: Just need to put the arguments on the stack properly and do a call instruction
  - **Shim**: n/a
  - **Inline**: n/a

# Inline assembly language

- Literally gets dumped in with the compiler-generated assembly instructors
- Useful for small tricks and recipes

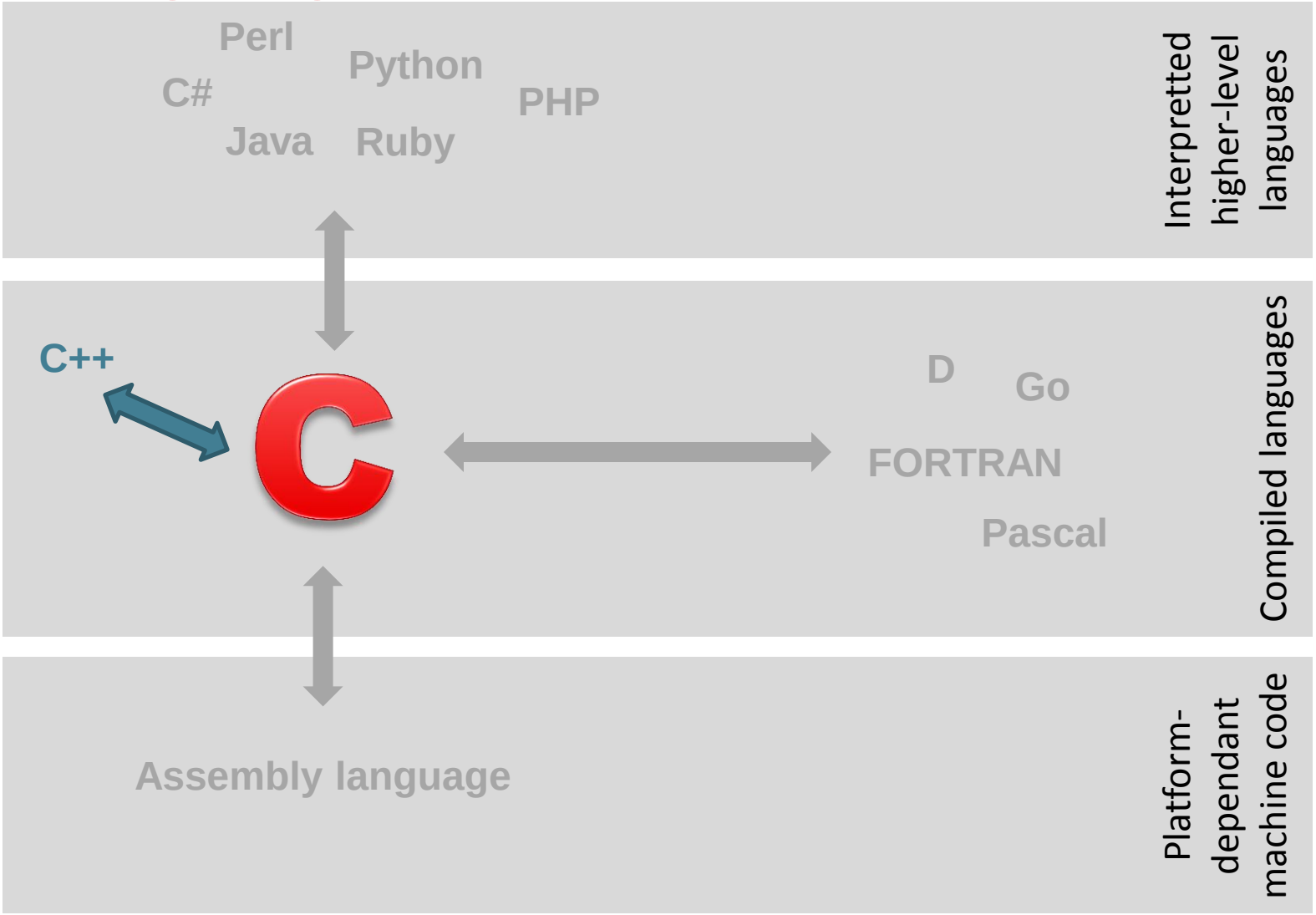
**What does this do?**

```
$ gcc a.c && ./a.out
Testing!
```

```
#include <string.h>

int main() {
    char* msg = "Testing!\n";
    asm (
        "movq %1, %%rdx\n" // set param 3 (length) to length of msg
        "movq %0, %%rcx\n" // set param 2 (buffer) to address of msg
        "movq $1, %%rbx\n" // set param 1 (file descriptor) to stdout (1)
        "movq $4, %%rax\n" // set syscall number 4 (write)
        "int $0x80\n" // ask kernel to do it
    : // no outputs
    : "r"(msg), "r"(strlen(msg)) // inputs assigned to %0, %1, etc.
    : "%rax","%rbx","%rcx","%rdx" // tell compiler which registers we trashed
    );
}
```

# Language interactions



# Interacting between C and C++

- Letting C call C++
  - C++ is a thin layer of simple tricks on top of C which create OO-friendly syntax
  - To get C to call C++, you just need to cut through the tricks with `extern "C" {…}`, which just says "disable C++ trickery for this part".
  - See next slide
- Letting C++ call C
  - Just do it. No steps necessary.

Adapted from:
http://stackoverflow.com/questions/7281441/elegantly-call-c-from-c

# C/C++ example

Duck.h

```
#ifdef __cplusplus
extern "C" {
#endif

struct Duck;

struct Duck* new_Duck(int feet);
void delete_Duck(struct Duck* d);
void Duck_quack(struct Duck* d, float volume);

#ifdef __cplusplus
}
#endif
```

Duck.cpp

```
extern "C" {
#include "Duck.h"
}

class Duck {
public:
    Duck(int feet) : { … }
    ~Duck() { … }

    void quack(float volume) { … }
};

struct Duck* new_Duck(int feet) { return new Duck(feet); }
void delete_Duck(struct Duck* d) { delete d; }
void Duck_quack(struct Duck* d, float volume) { d->quack(volume); }
```

# Any Questions?