Combining Embedded & Interactive Python in The LLDB Debugger

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EuroPython 2011

Florence, Italy

Outline

- What is LLDB?
- Python in LLDB
- Particular Problems (& Solutions)
- Example Using Python to Debug Problem
- Questions

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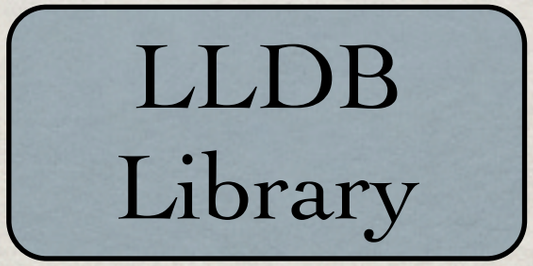
- LLDB = LLVM's Debugger
- LLDB: A debugger tool library
  - Provides debugger-related services

Some Uses Of the LLDB Library



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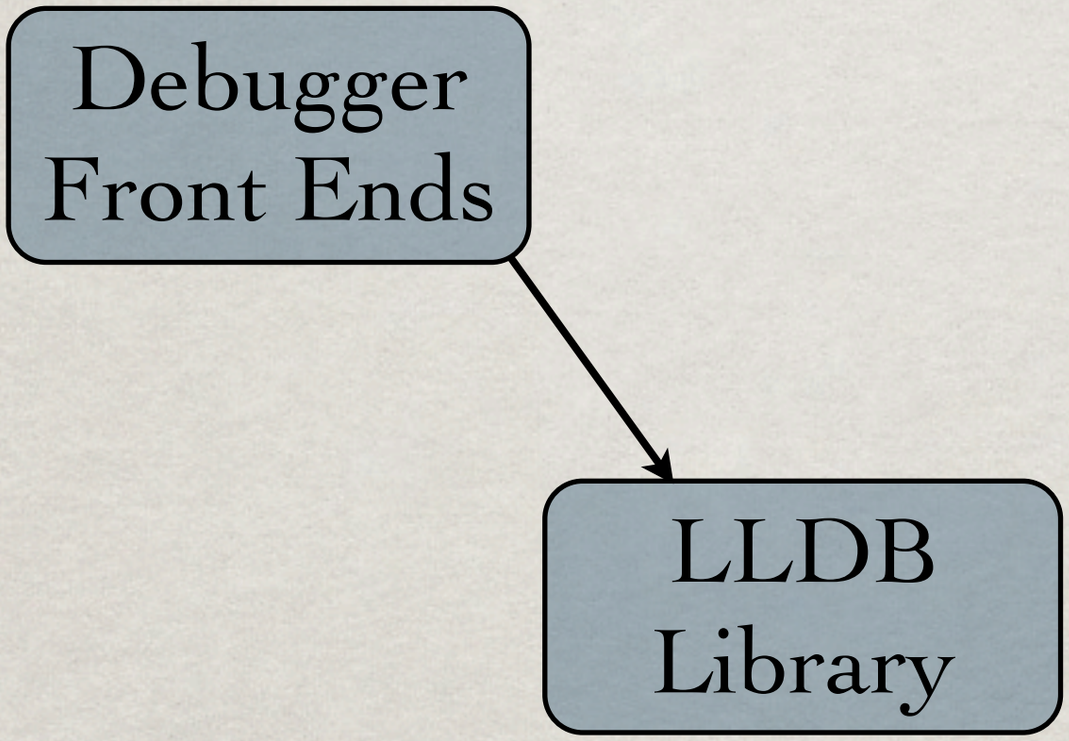

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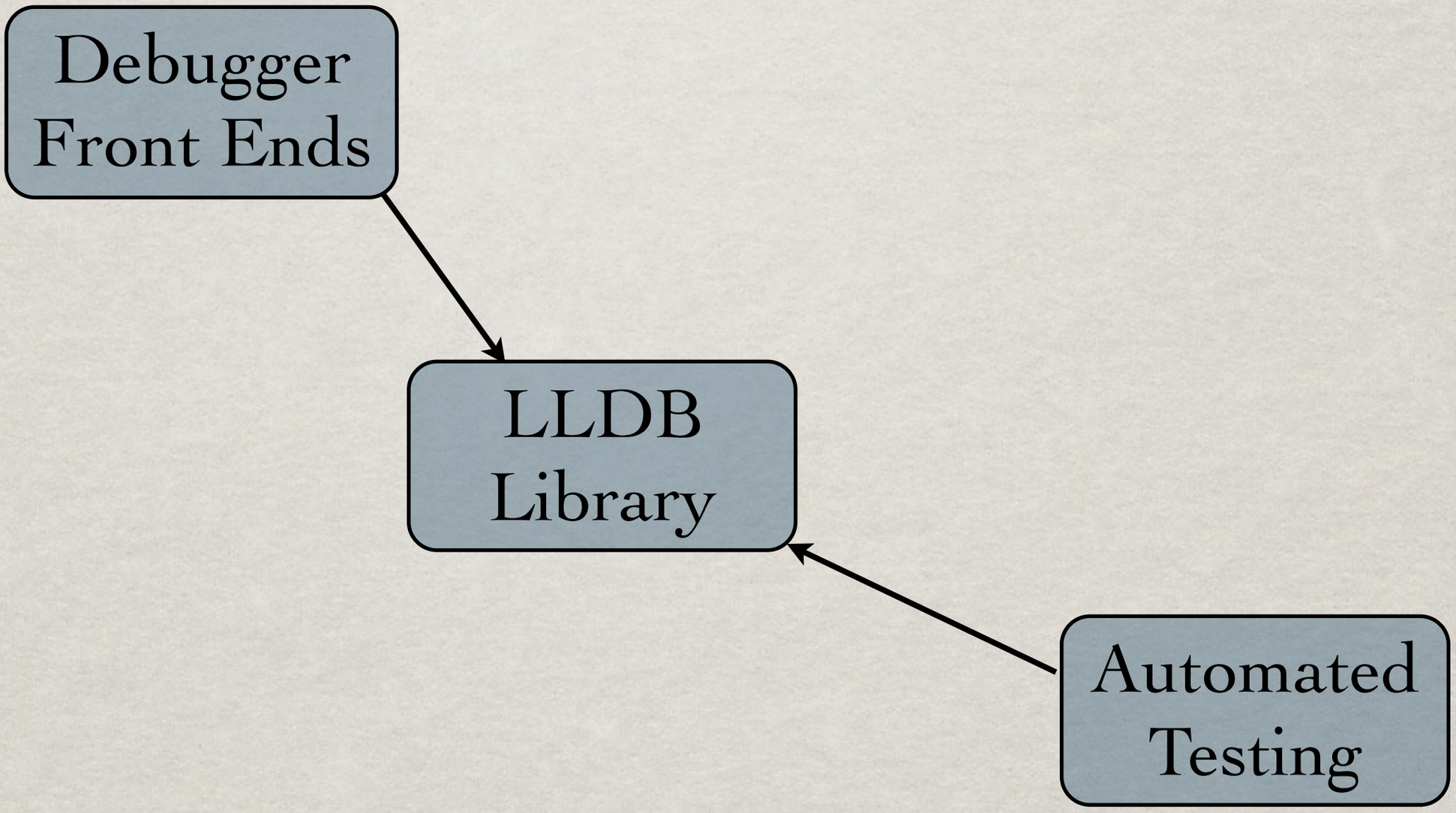

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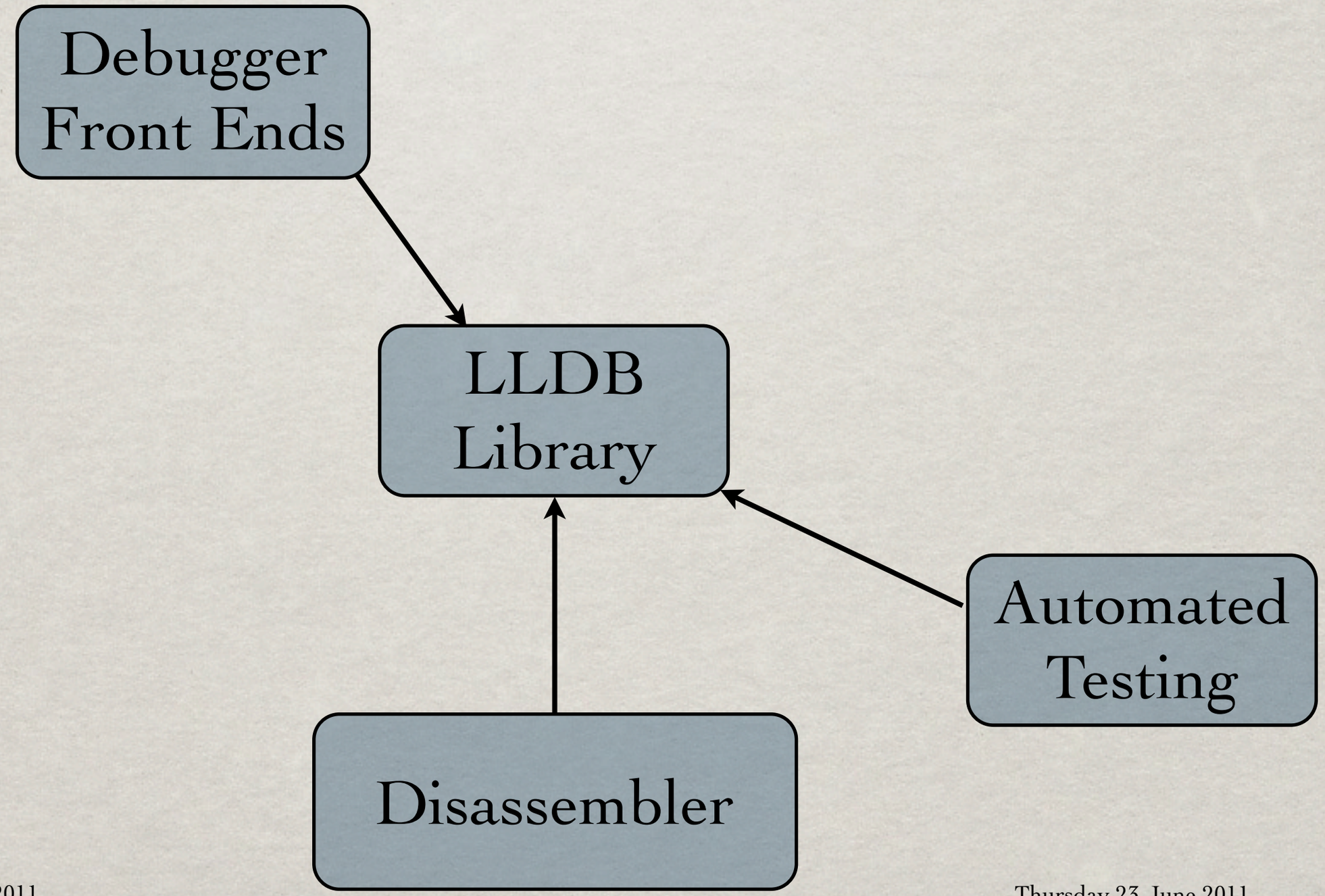

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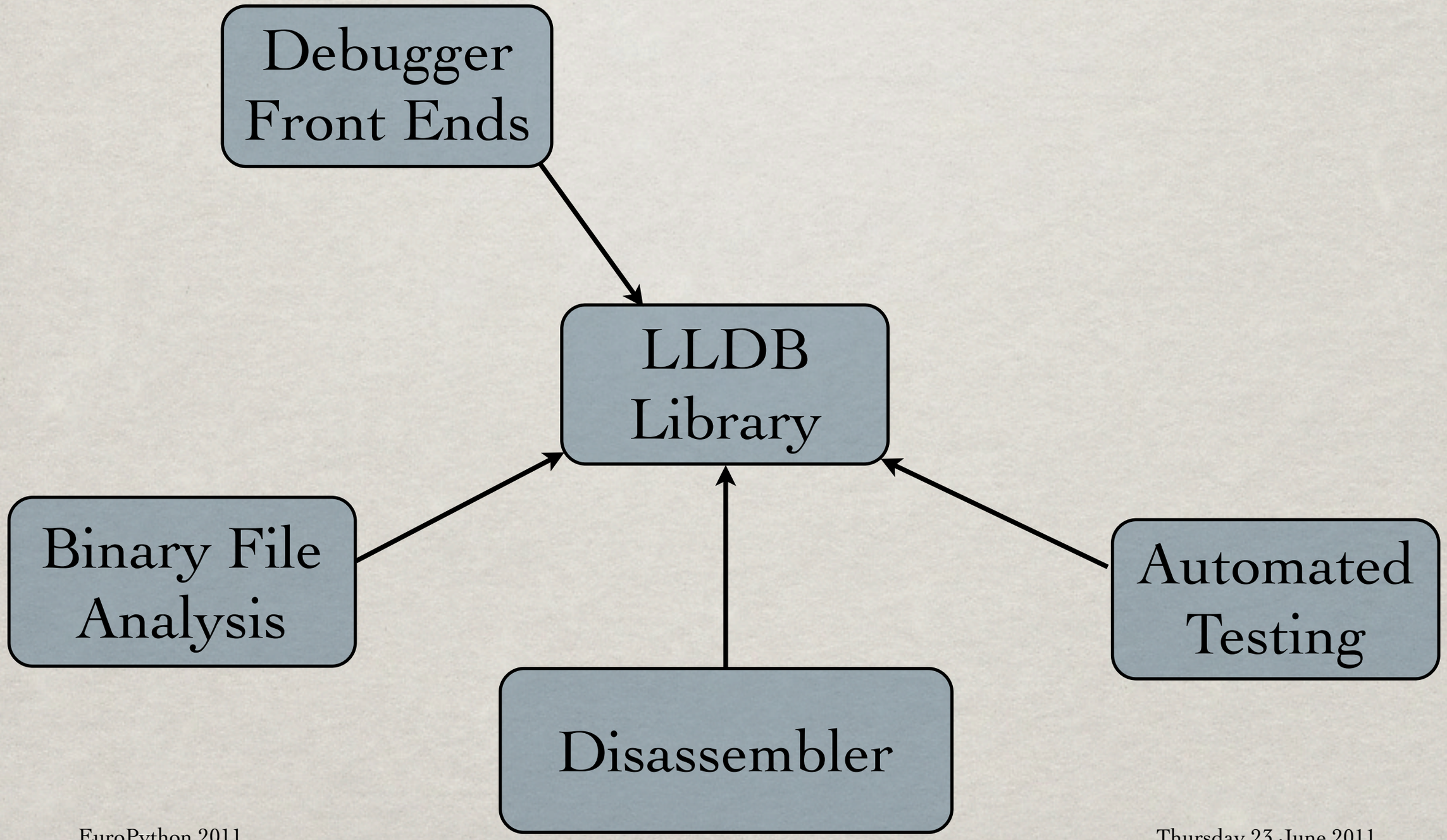

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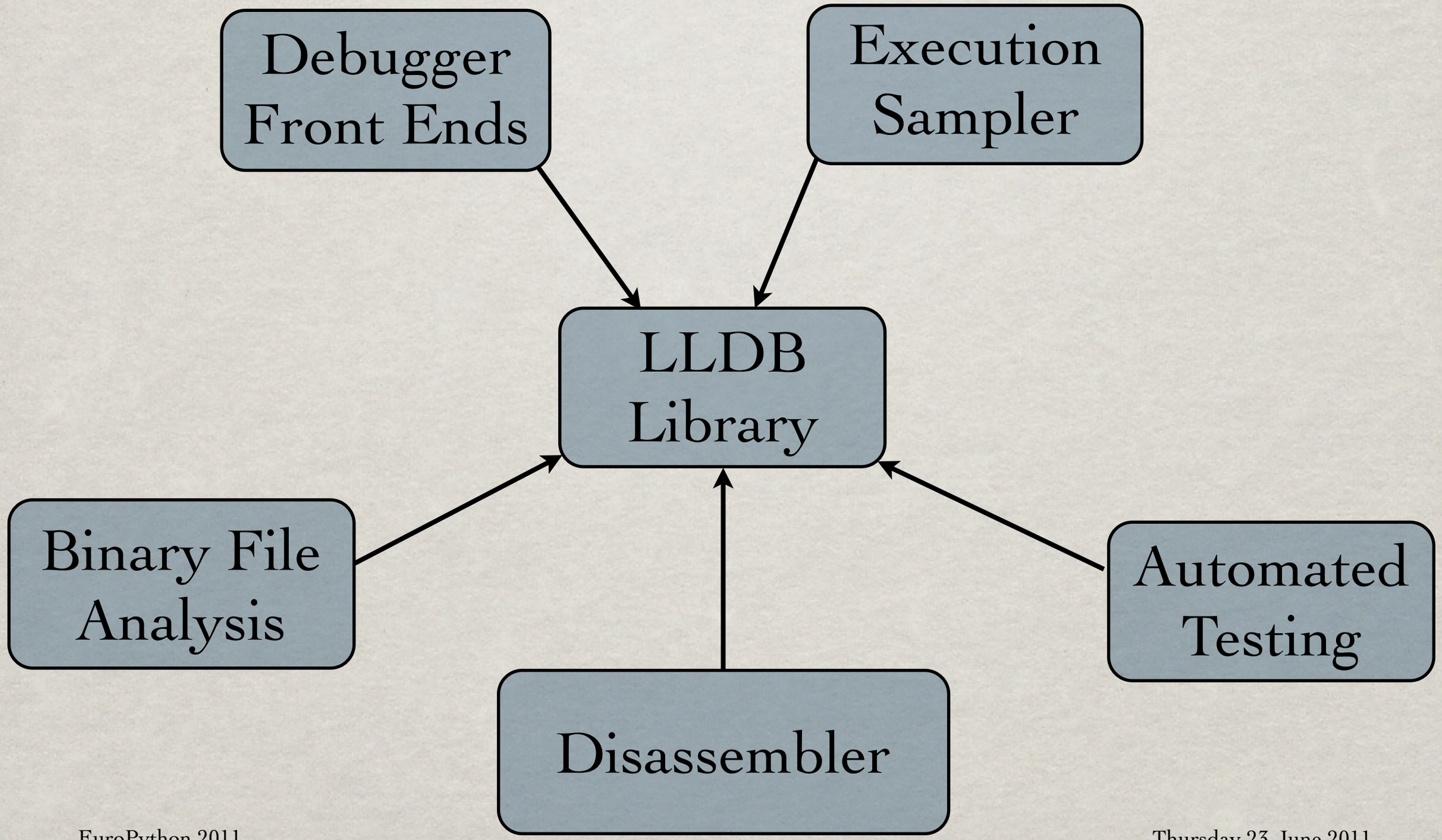

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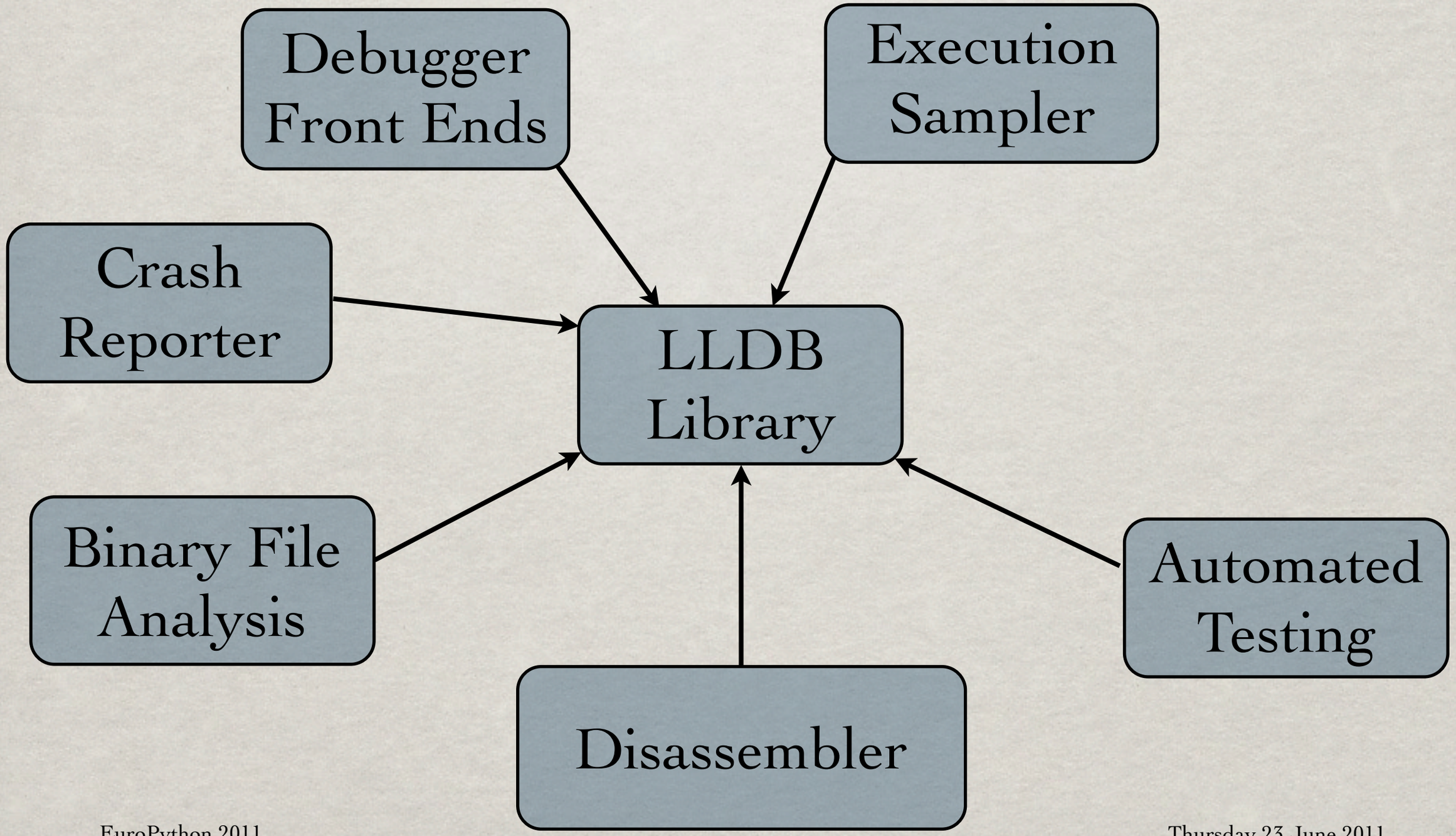

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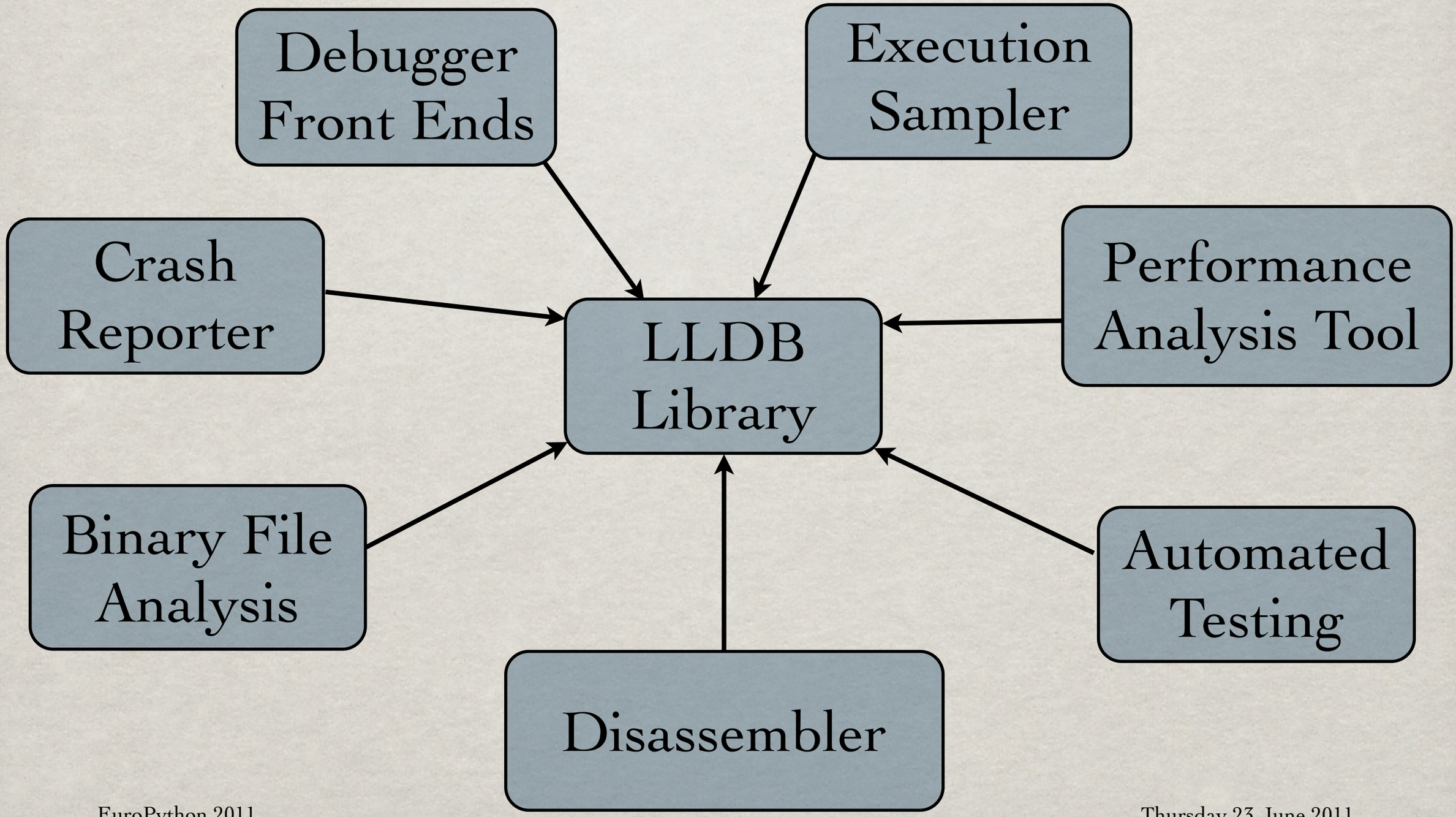

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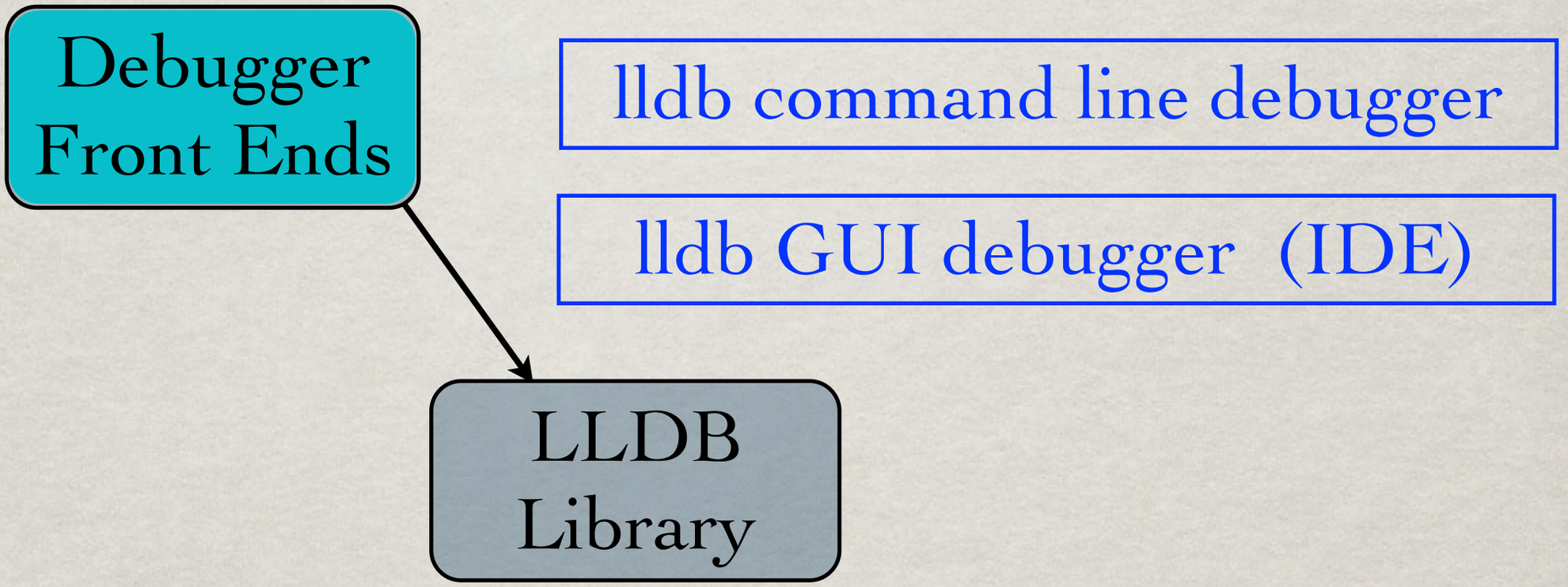

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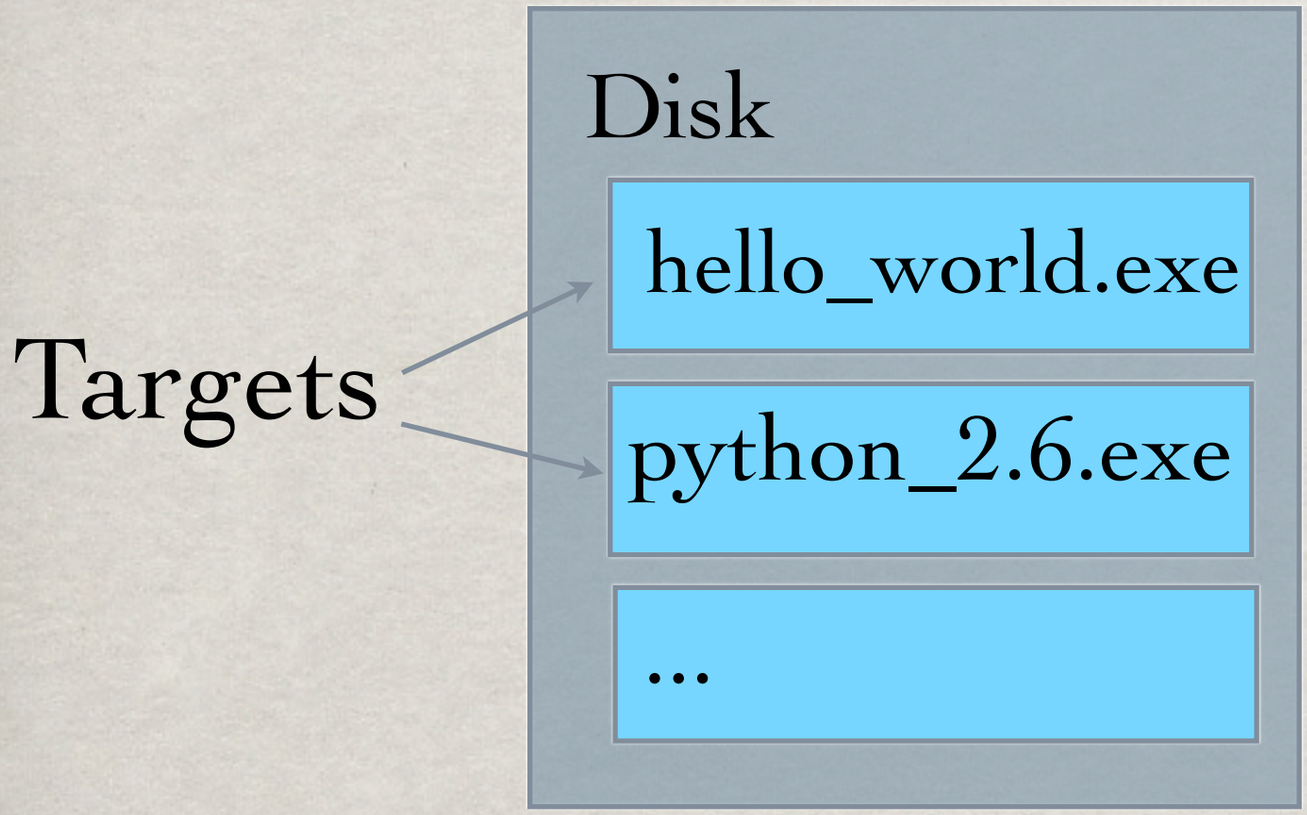

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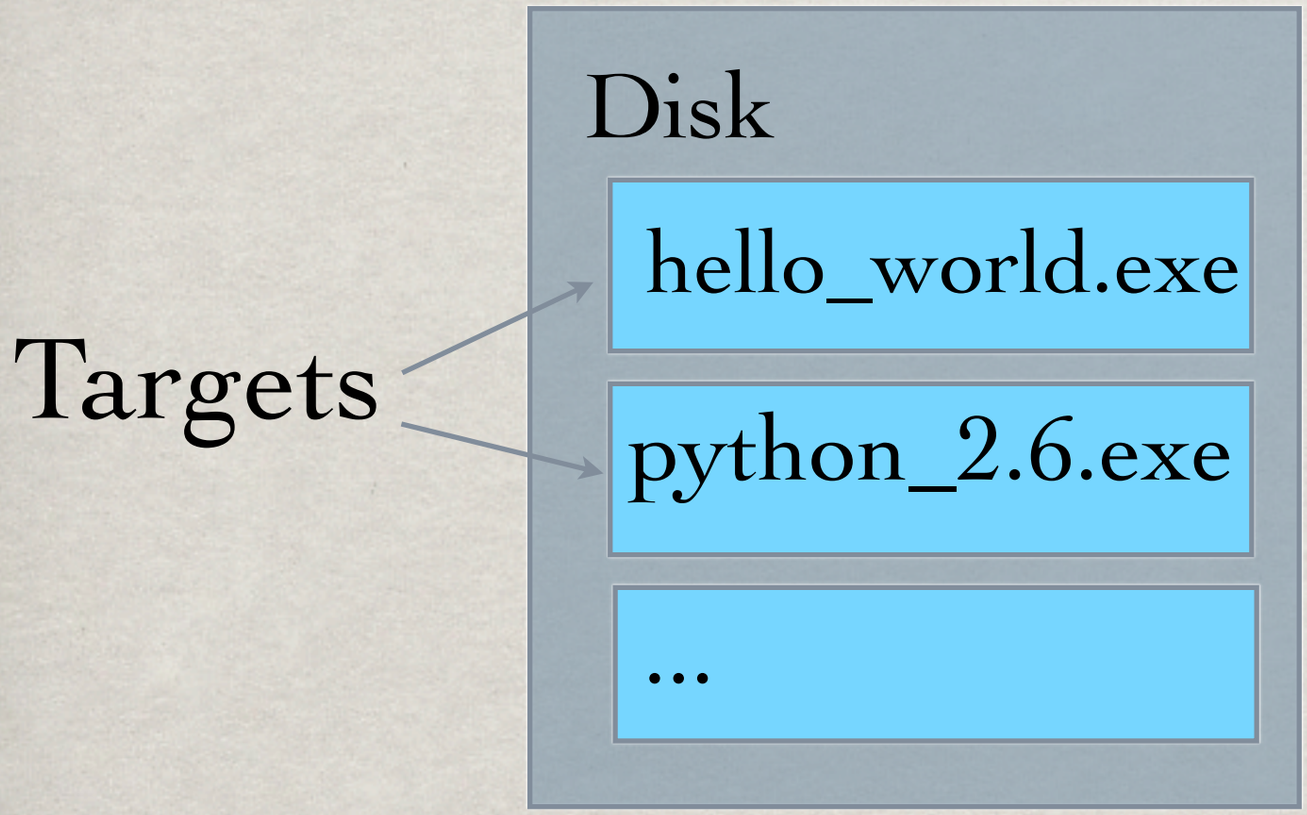

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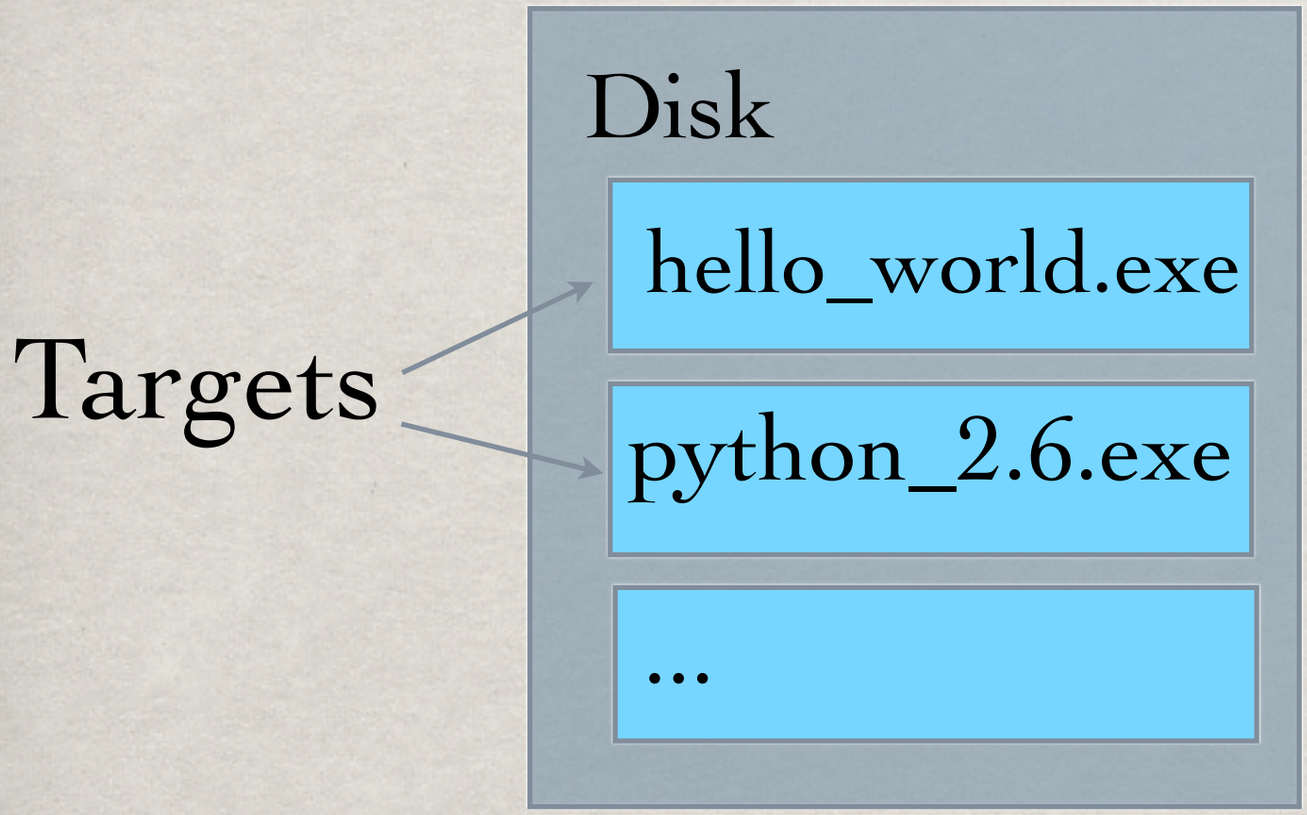

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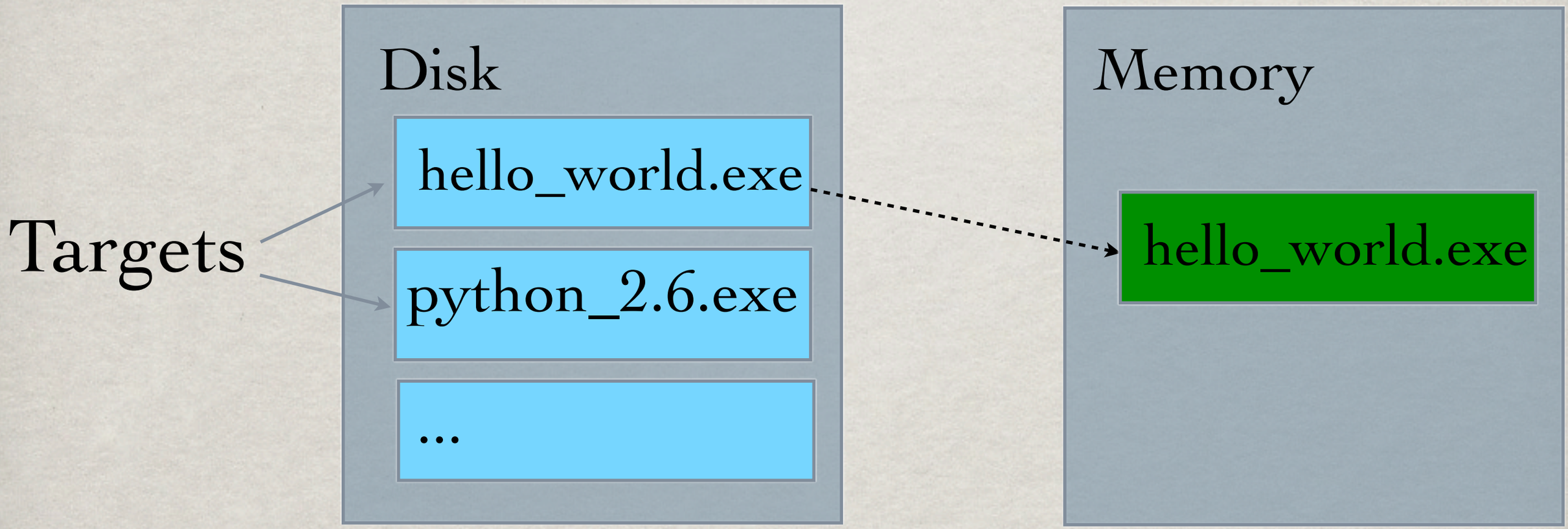

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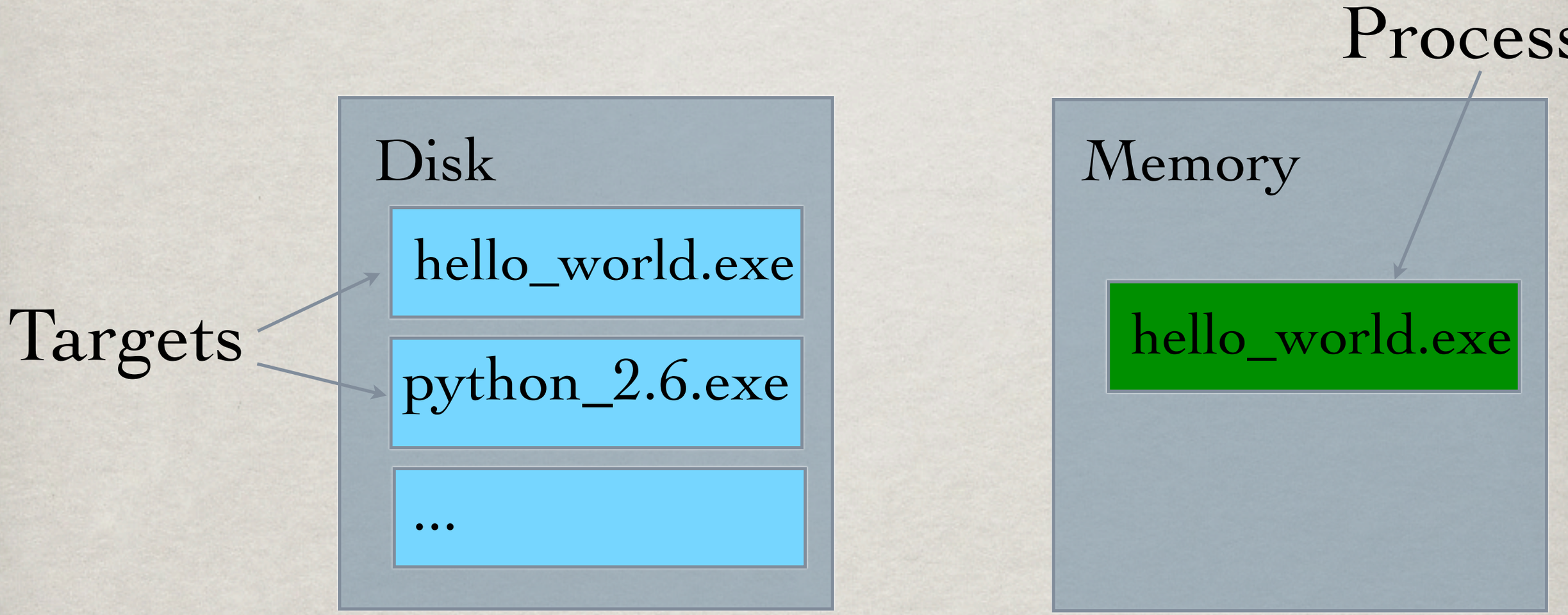

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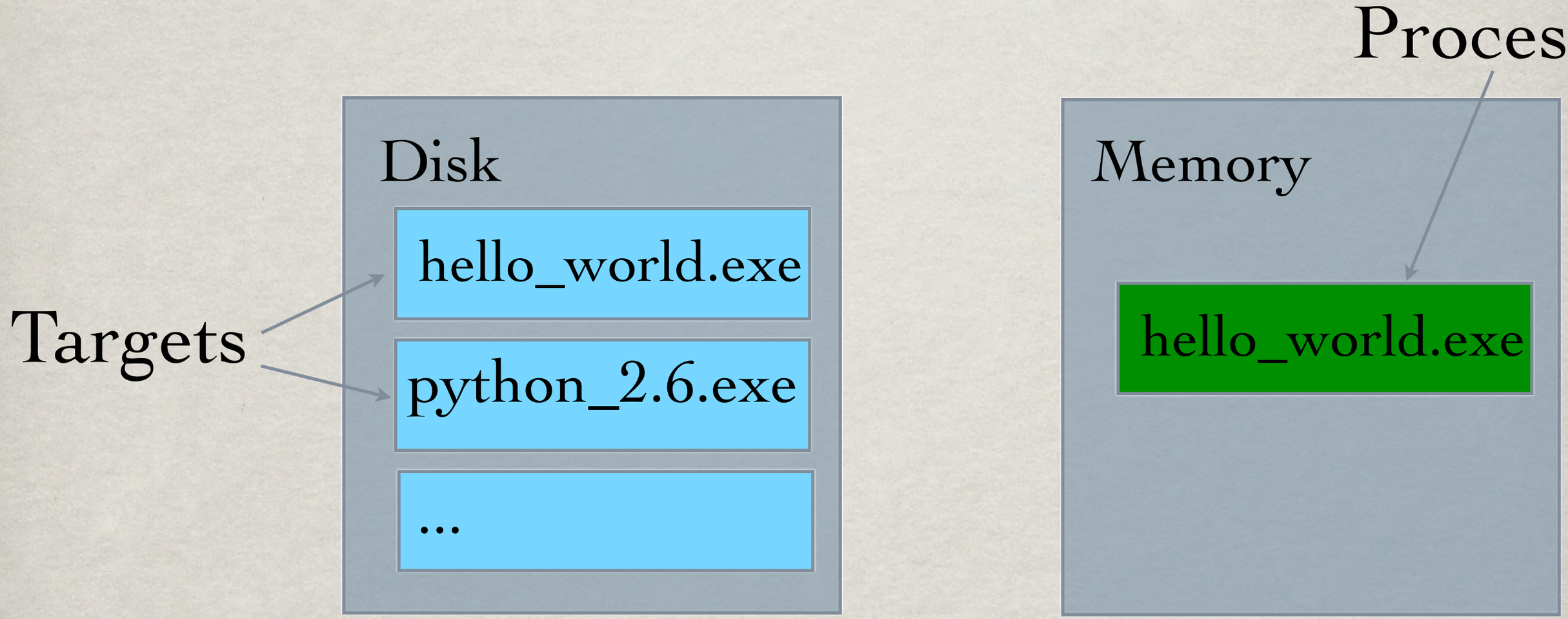


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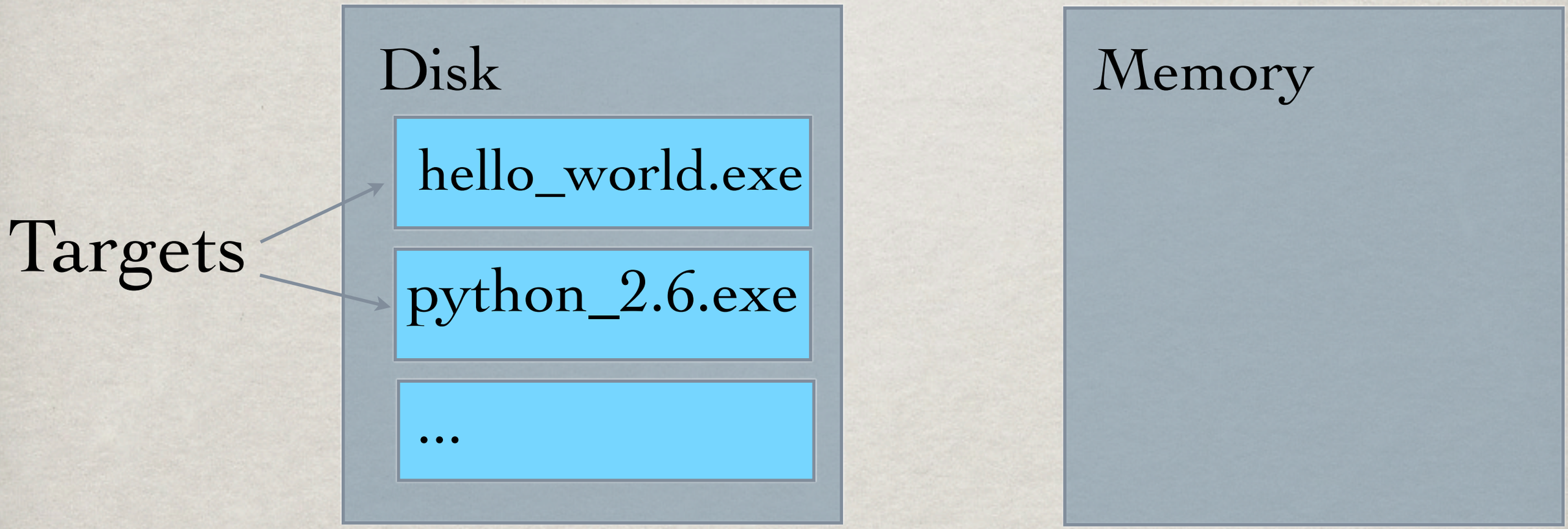


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  - only stop if particular condition is met
- Can have code attached to it
  - execute attached code when breakpoint is hit

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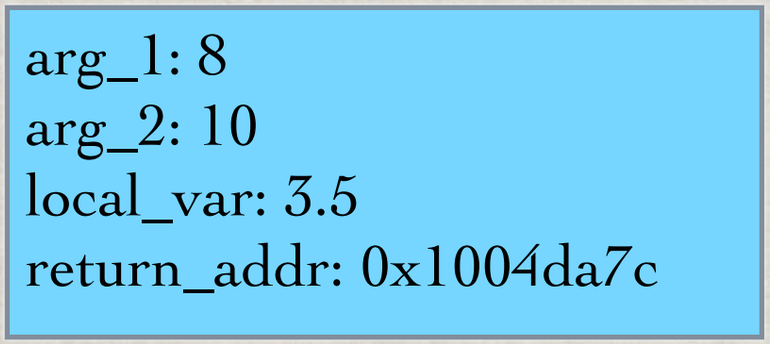

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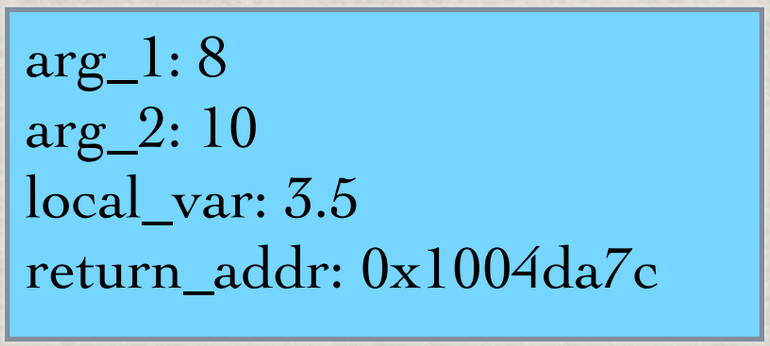

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arg_2: 10
local_var: 3.5
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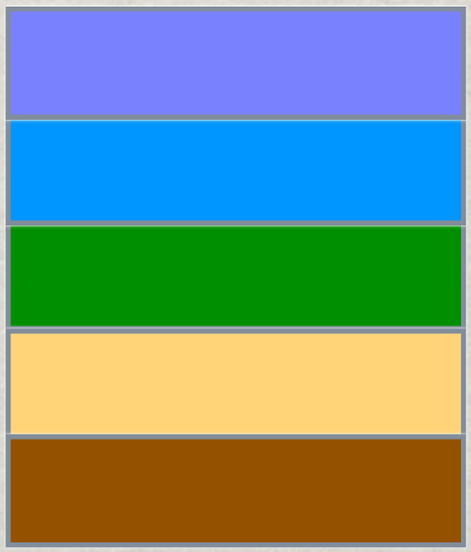

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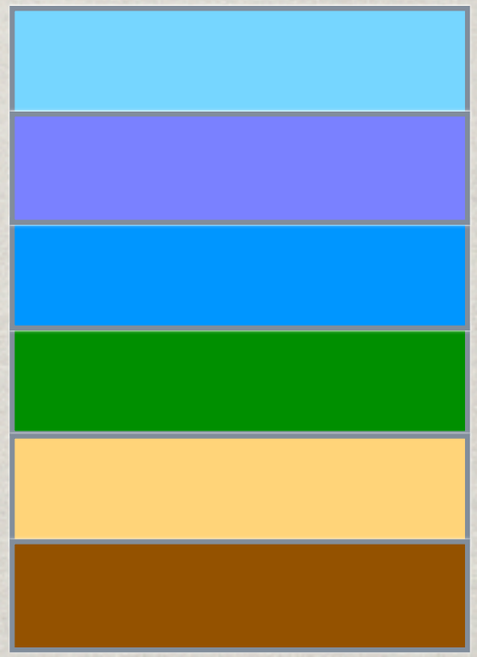

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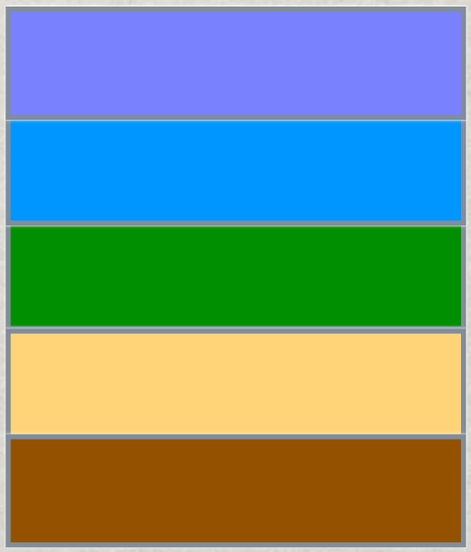


Call Stack

More About LLDB...

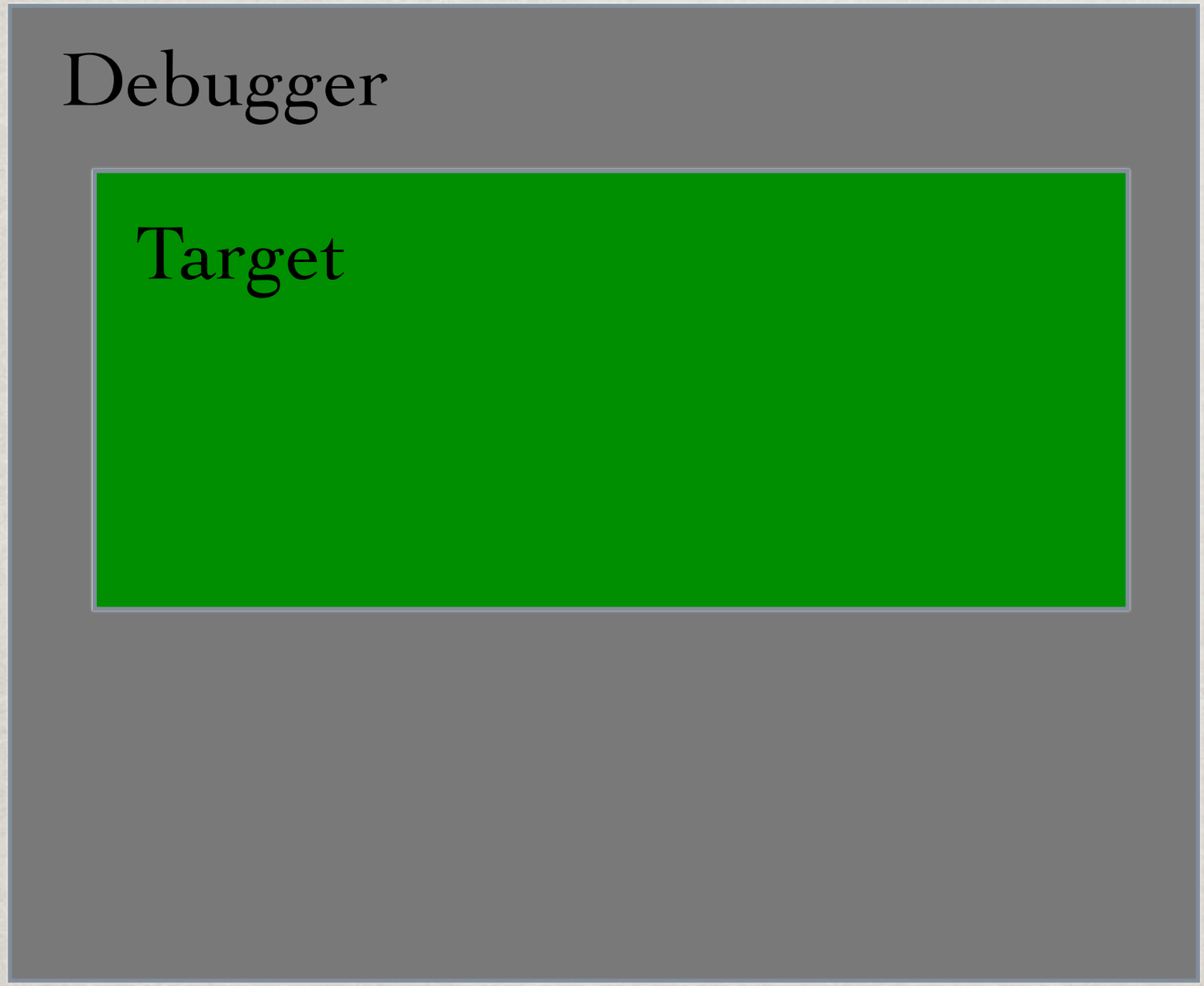
- Written in C++
- Multi-threaded
- Object-Oriented
  - Main pieces are objects
  - Objects are nested
- Currently in Beta release - still a few bumps!

Objects in LLDB

Objects in LLDB

Debugger

Objects in LLDB



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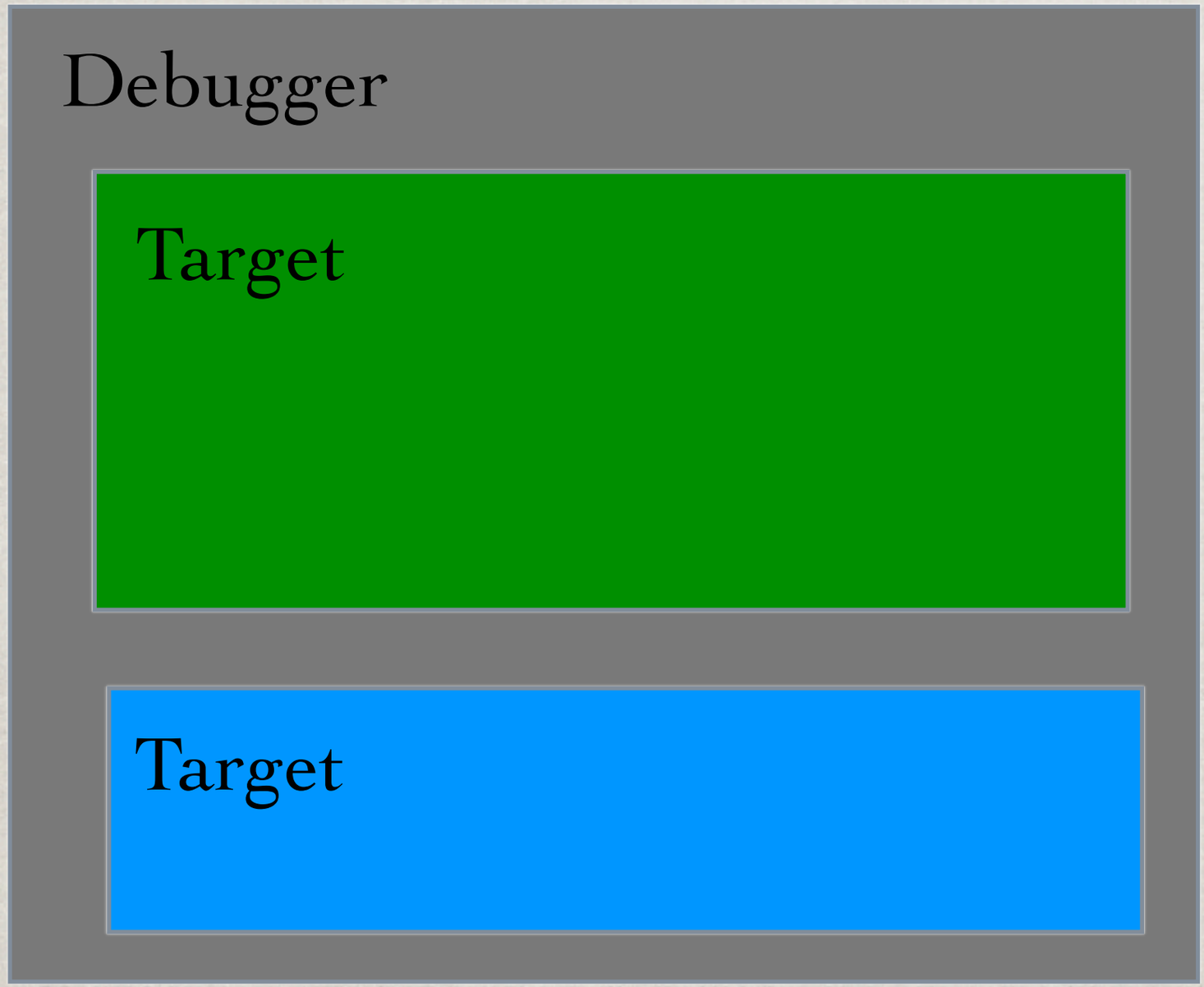

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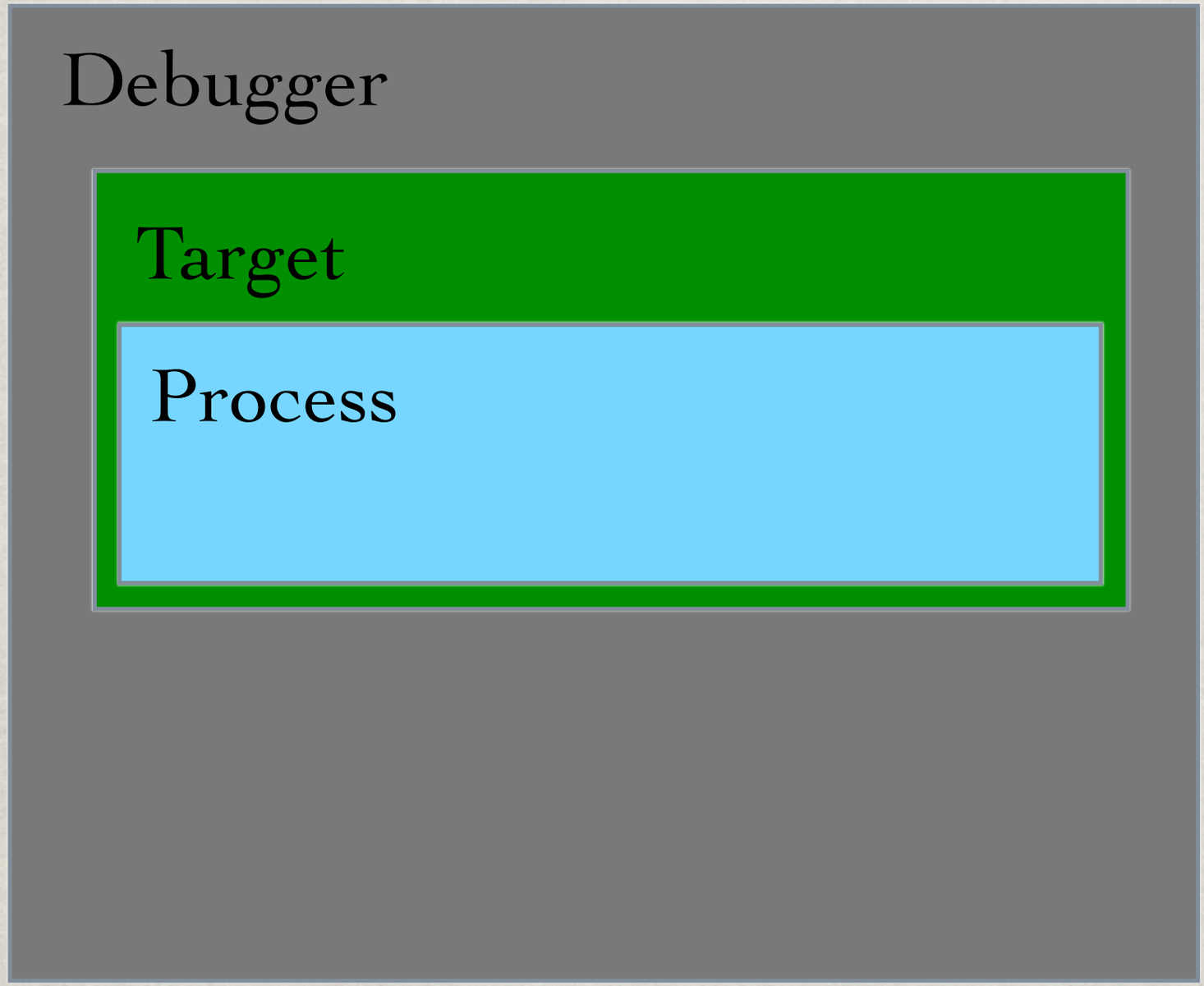

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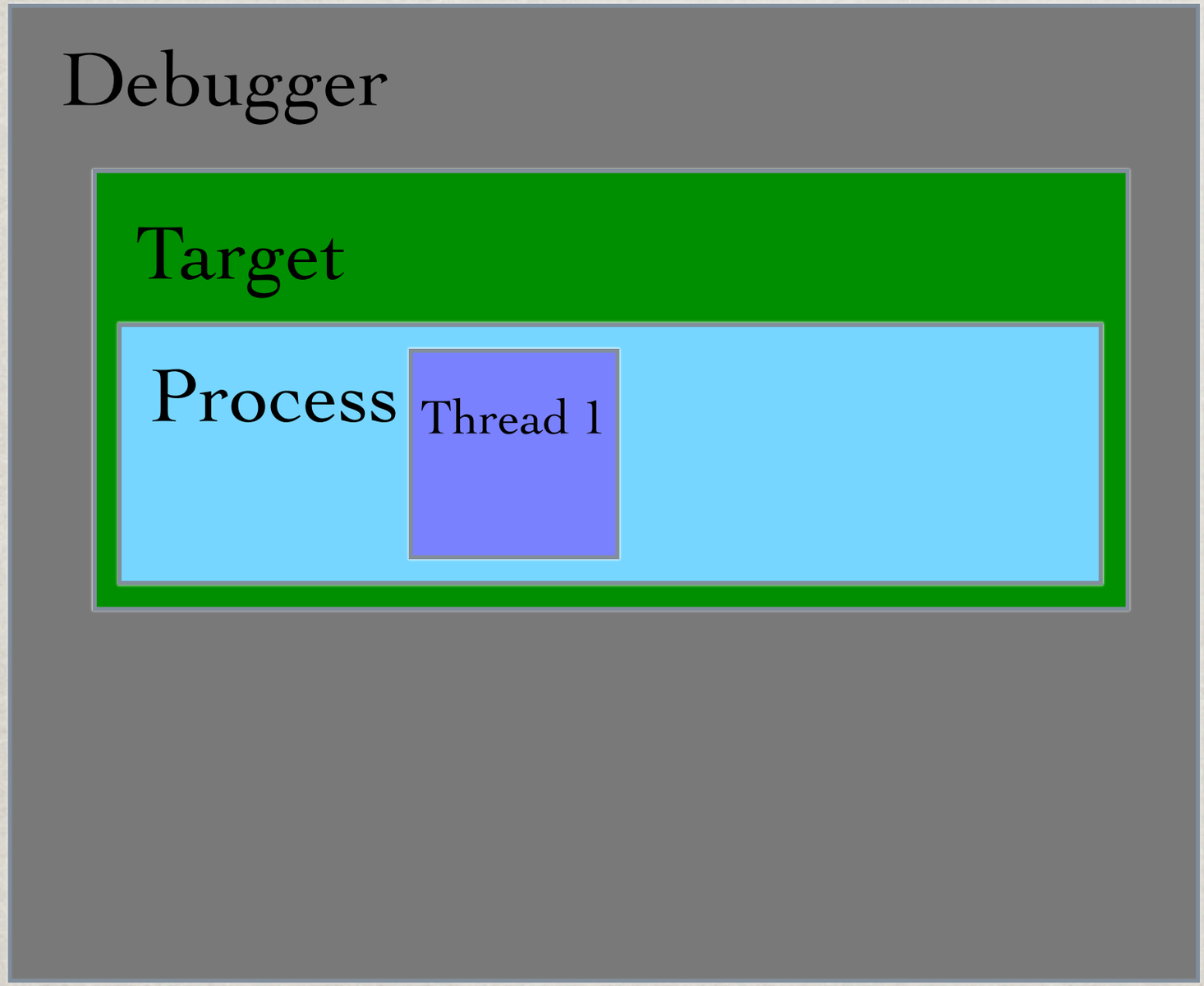

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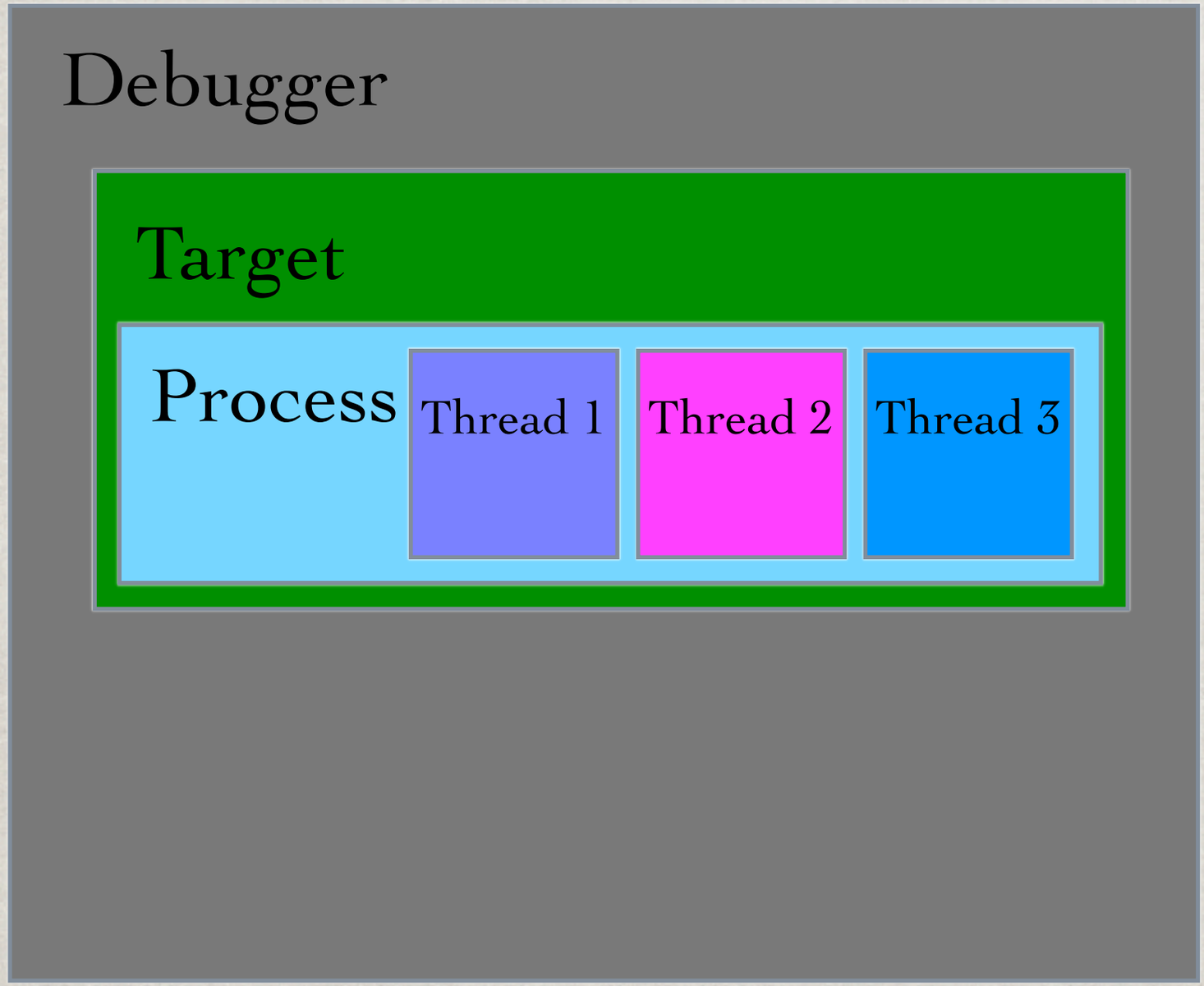

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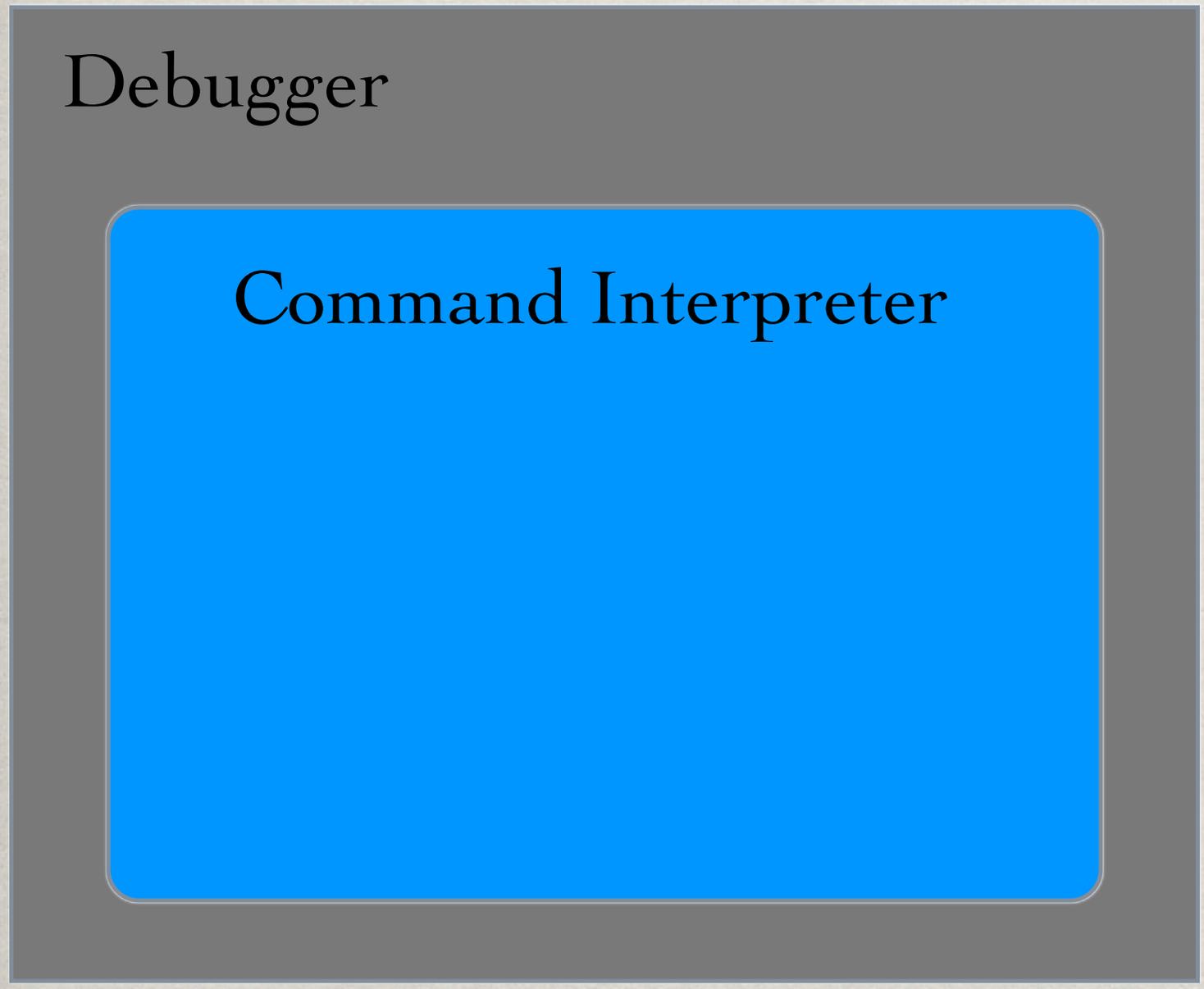

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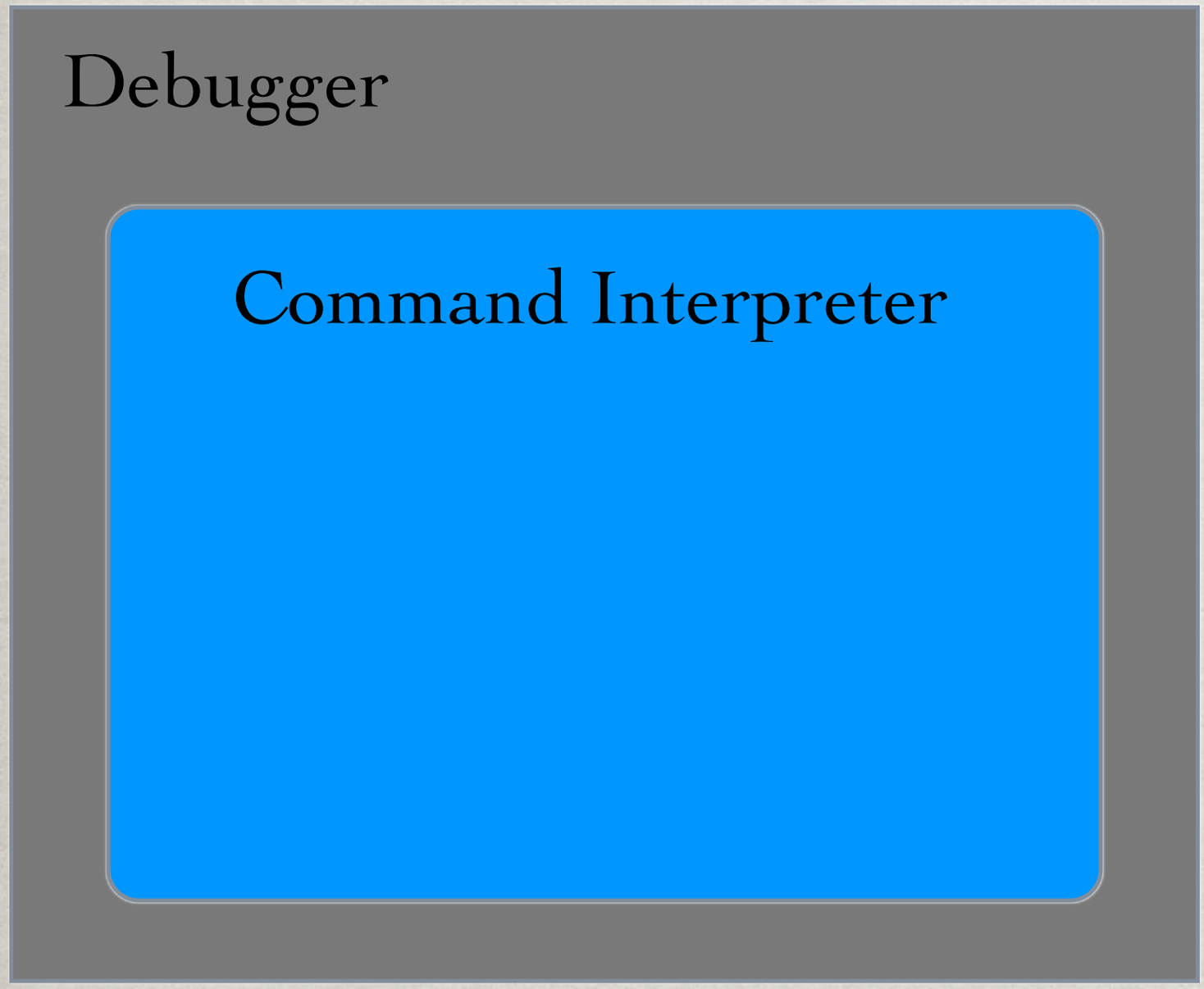


```
(lldb) file  hello-world
(lldb) break set -n main
(lldb) run
```

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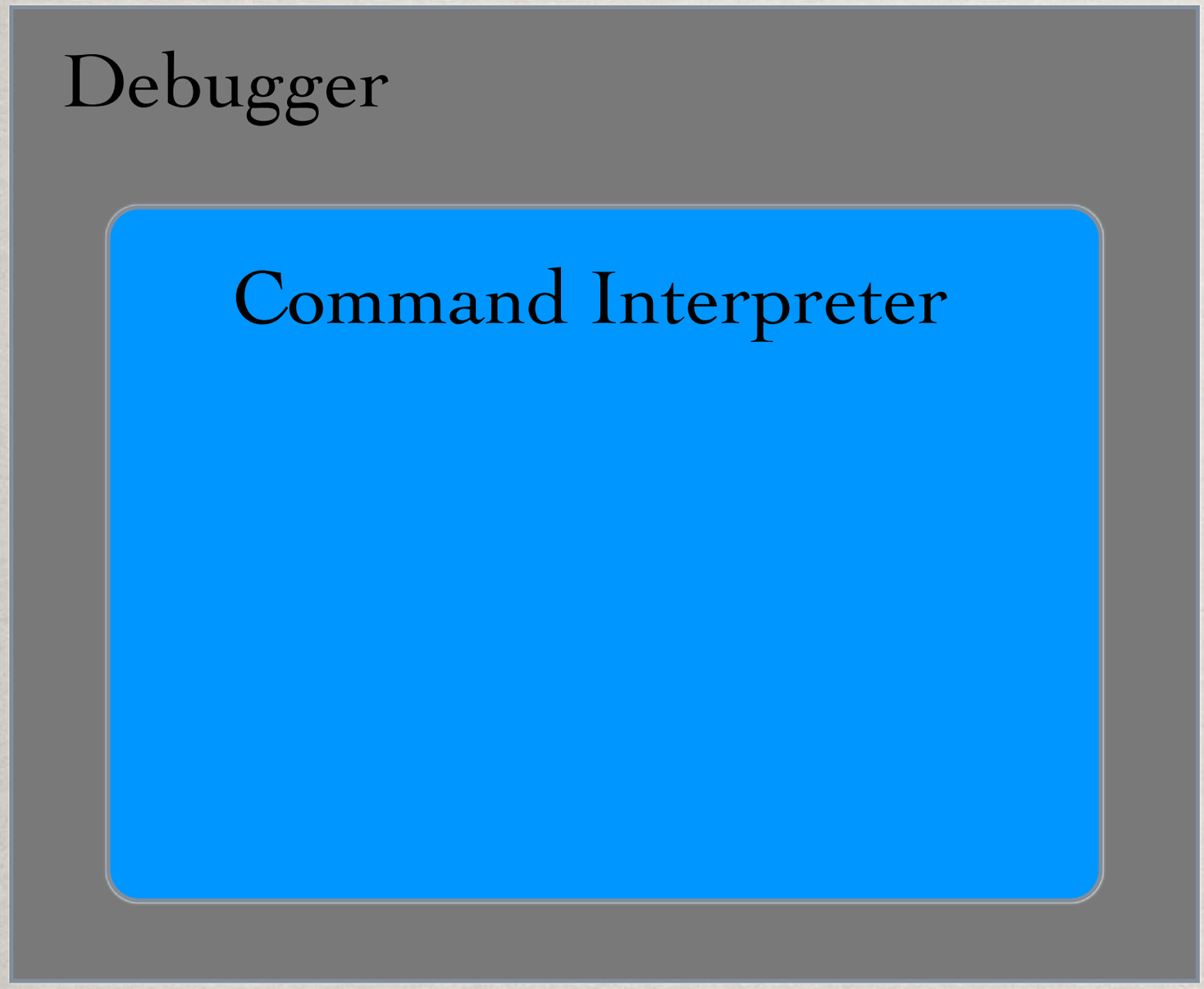

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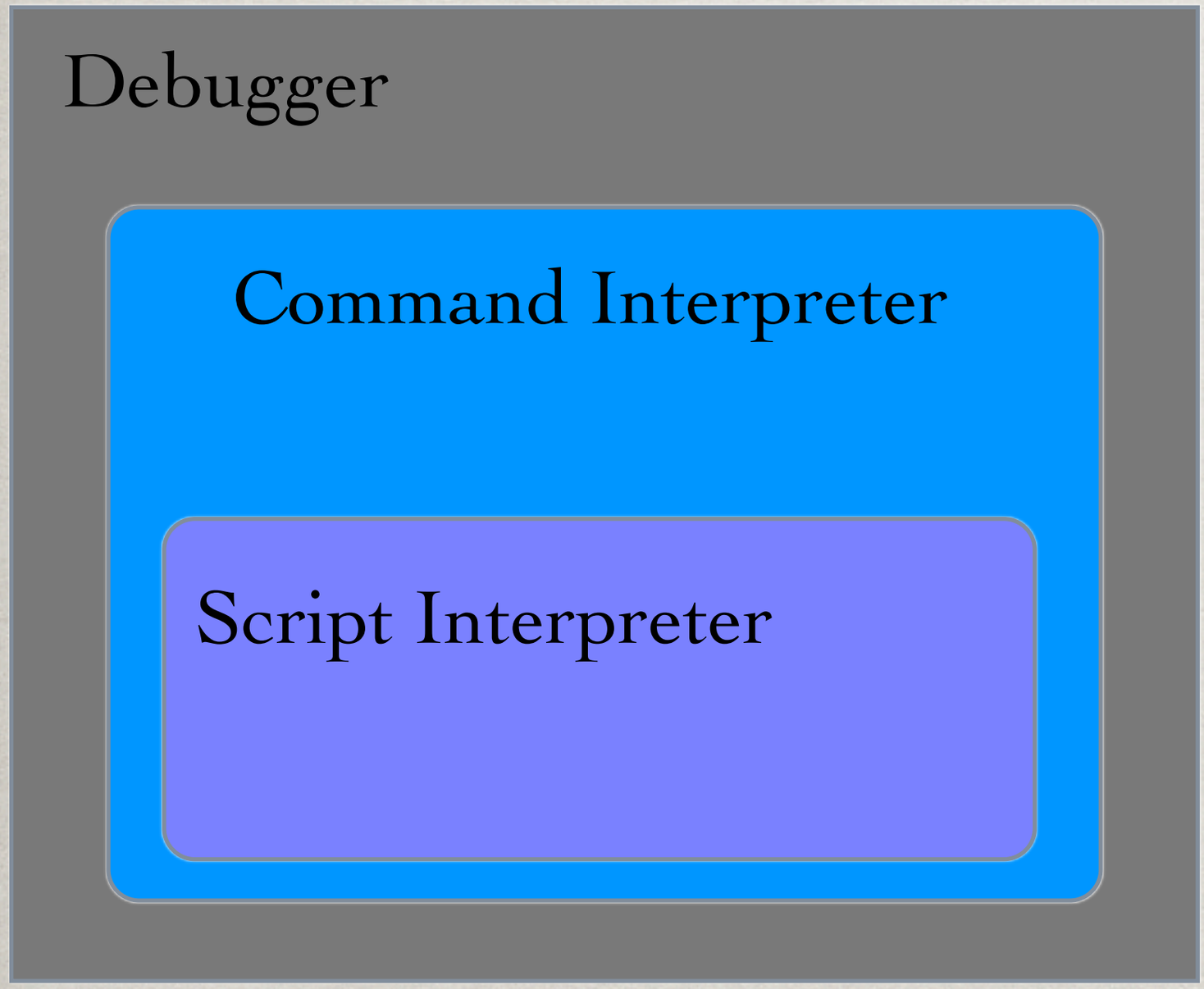

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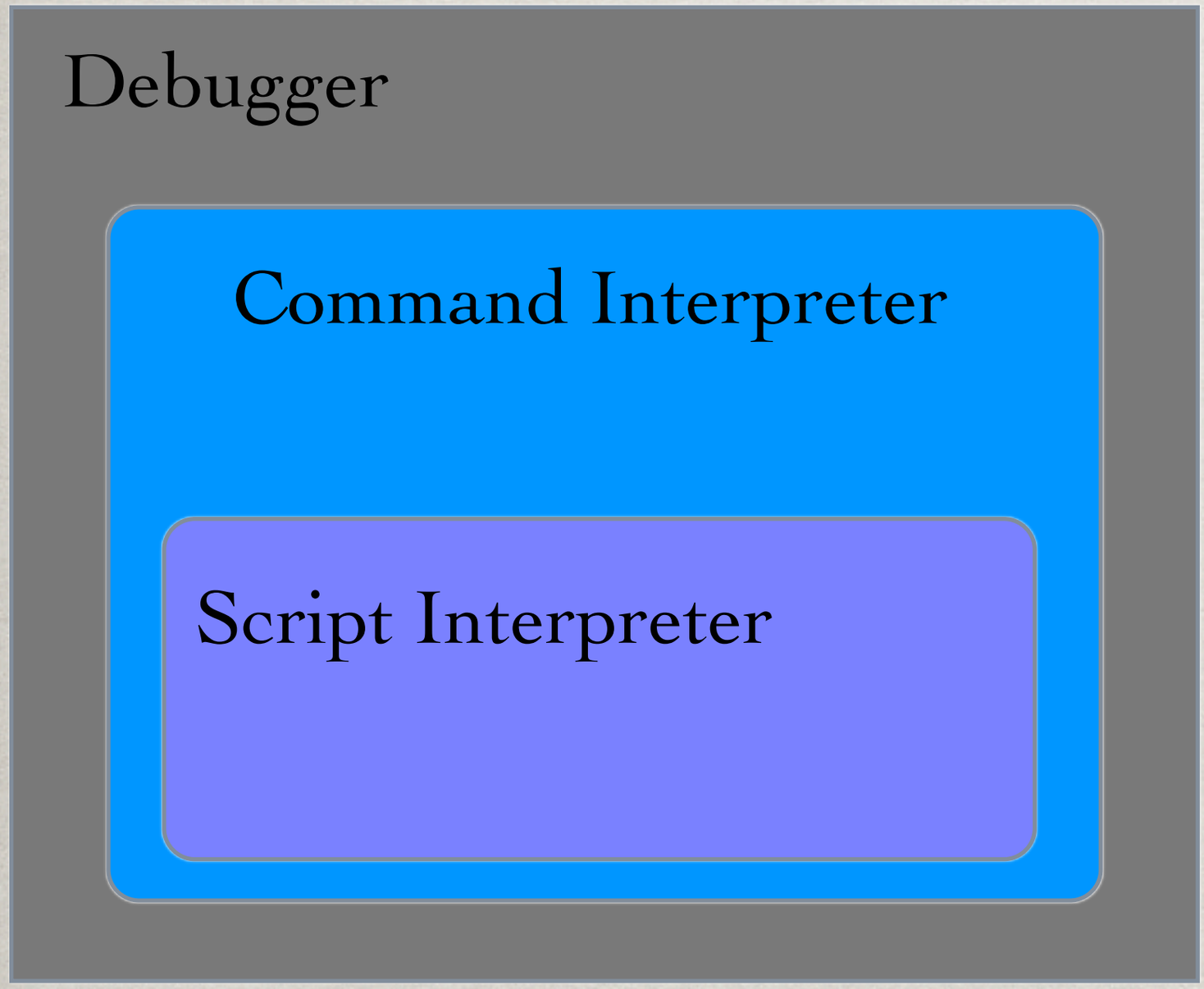


```
>>> import sys
>>> a = 9
>>>
```

Desired GUI Debugger Behavior

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- From single running GUI debugger process...

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- Launch multiple targets...

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- From single running GUI debugger process...
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  - ...each with a separate debugger session

GUI Debugger Python Requirements

- Multiple simultaneous debuggers
- Multiple Script Interpreters
- Ability to switch smoothly between them
- Complete isolation between sessions
- Thread safety
- No deadlocking

Debuggers in LLDB

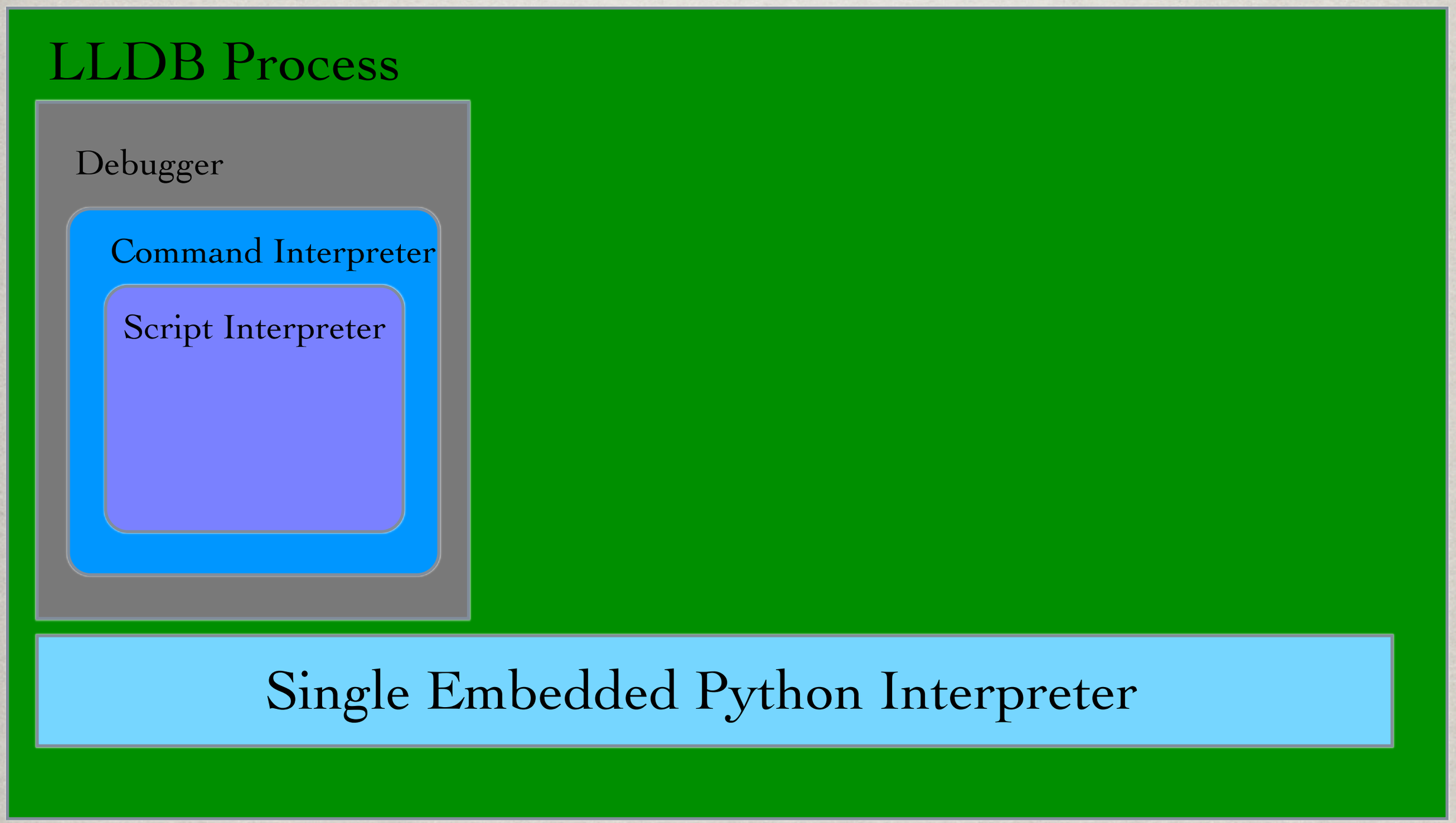
LLDB Process

Debuggers in LLDB

LLDB Process

Single Embedded Python Interpreter

Debuggers in LLDB



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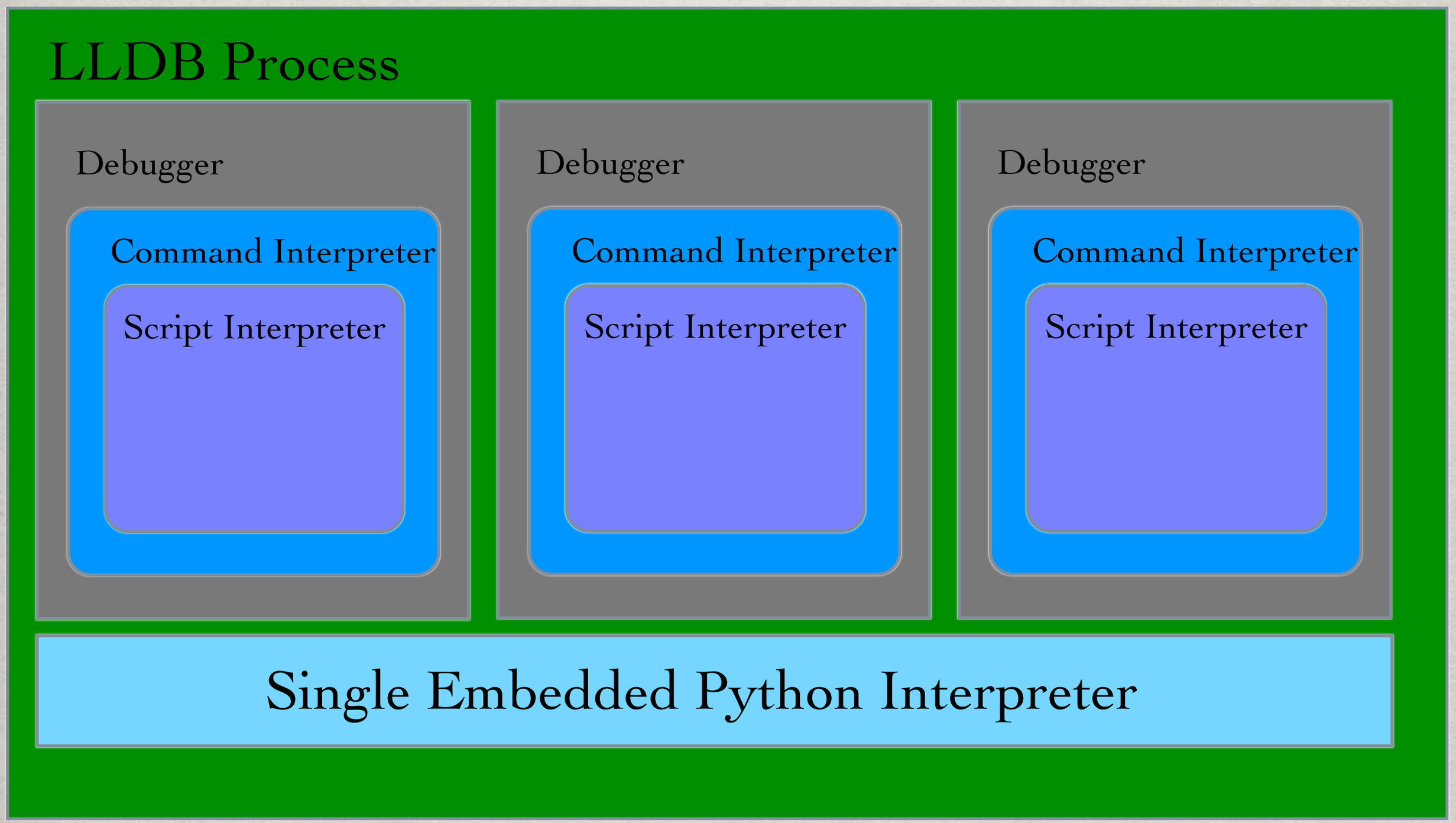

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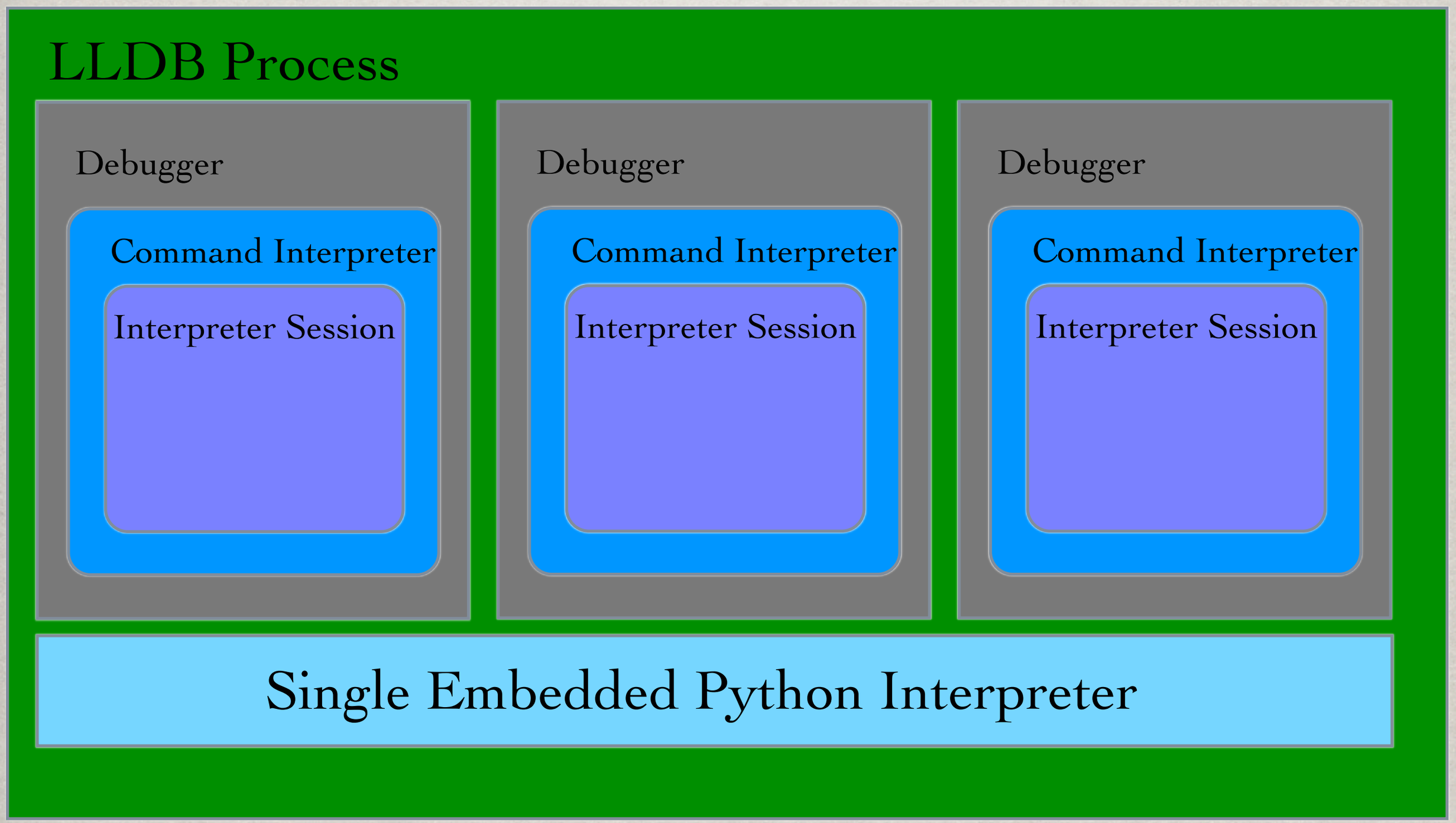

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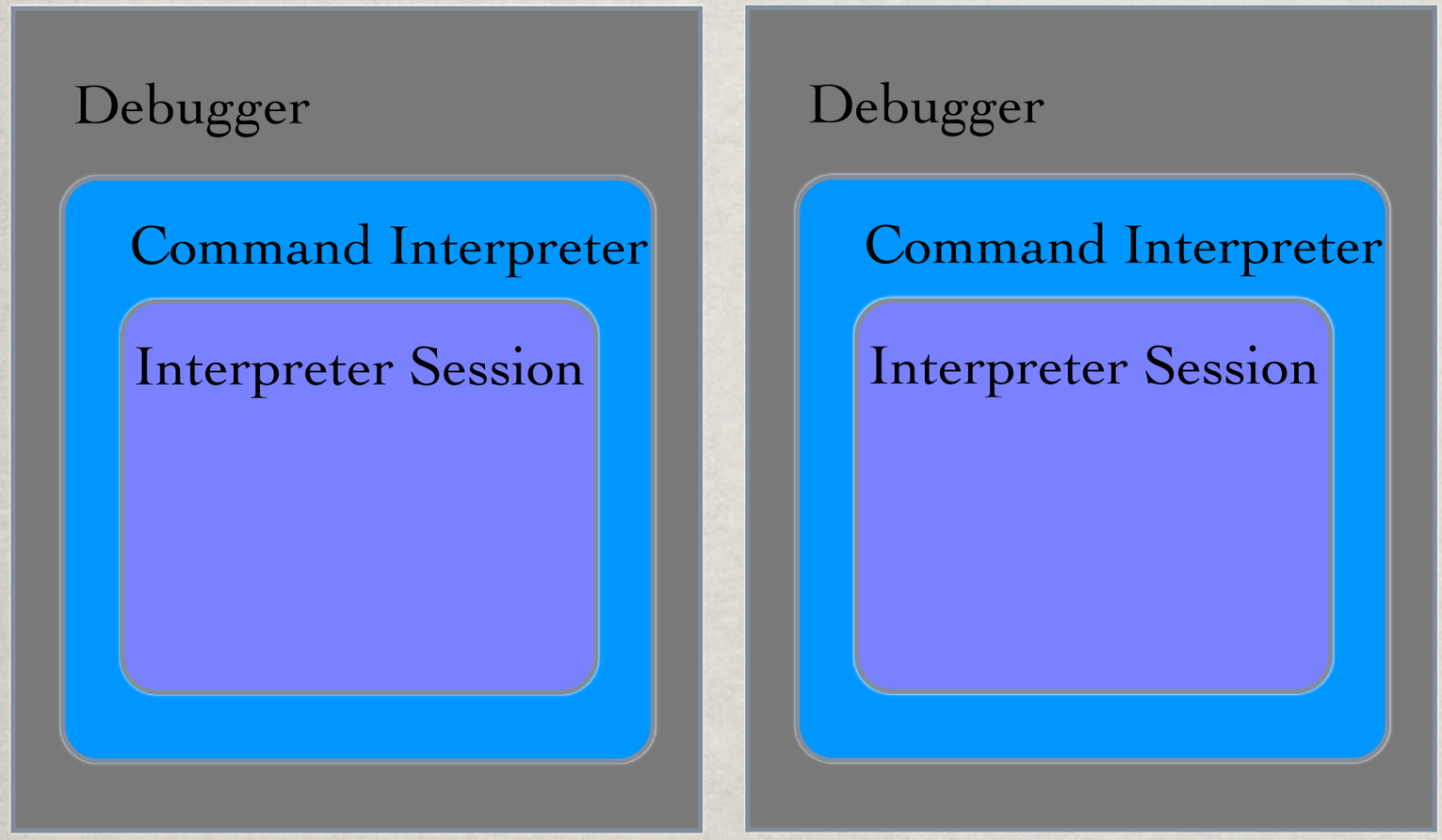

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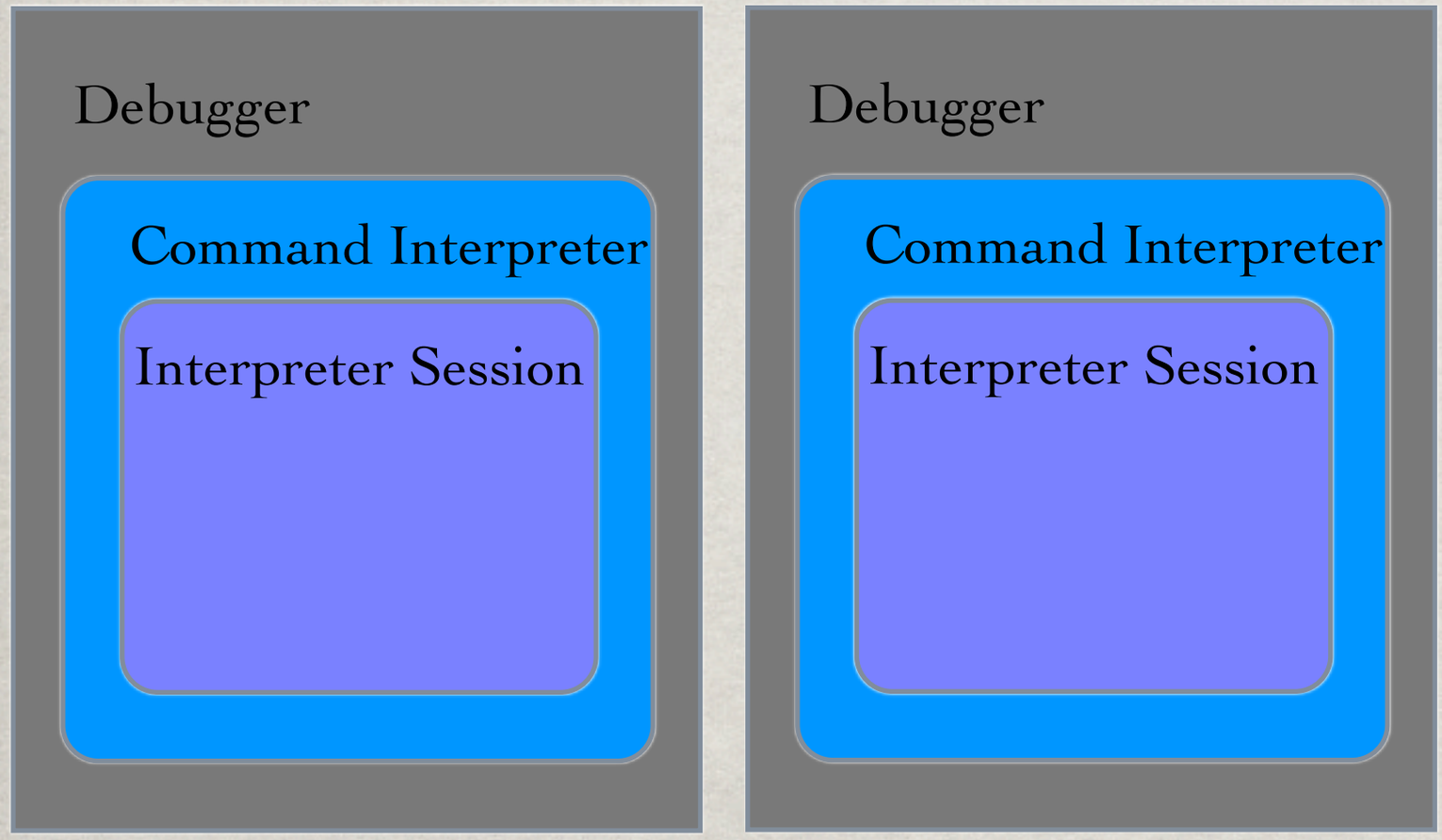

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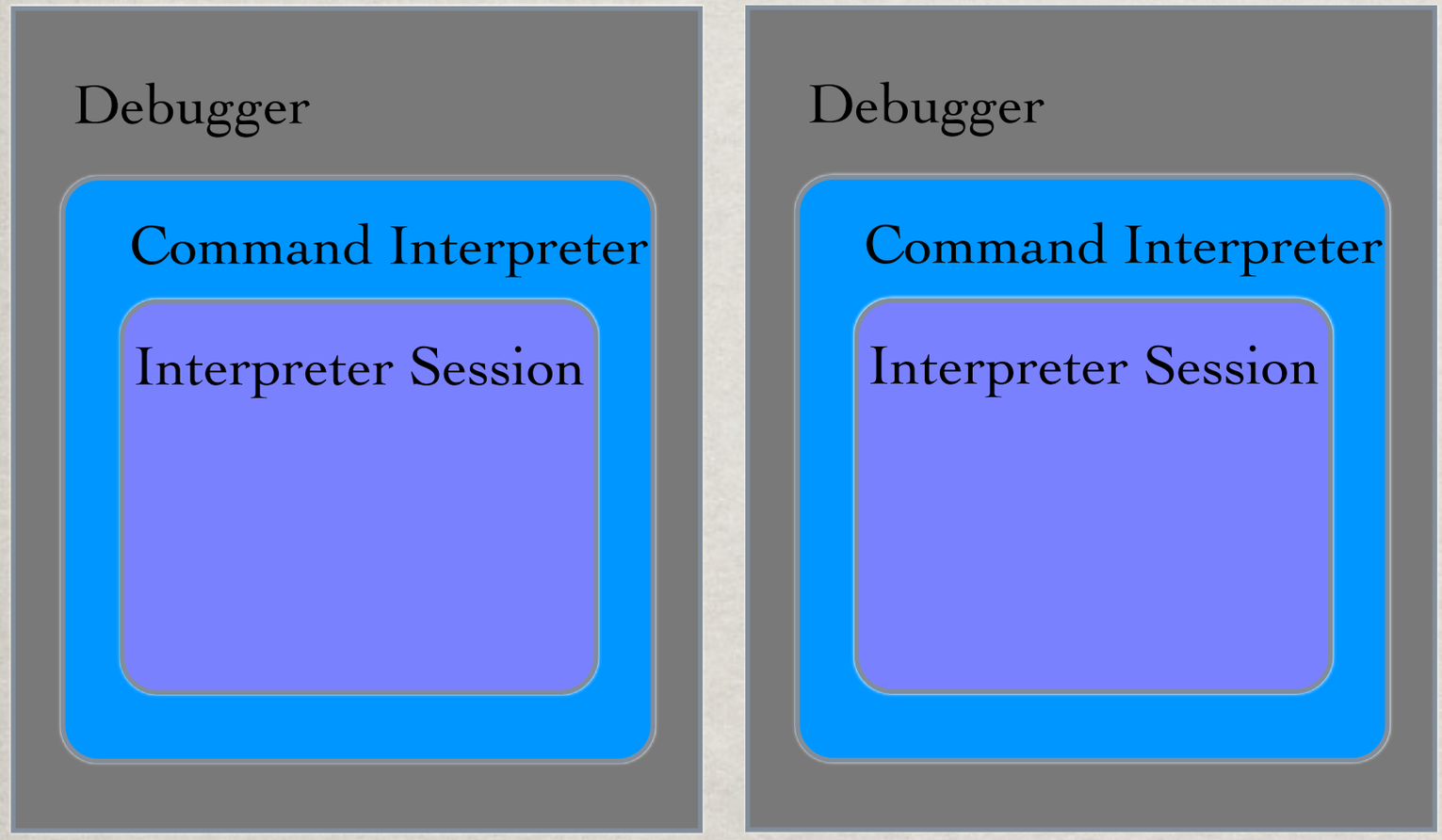


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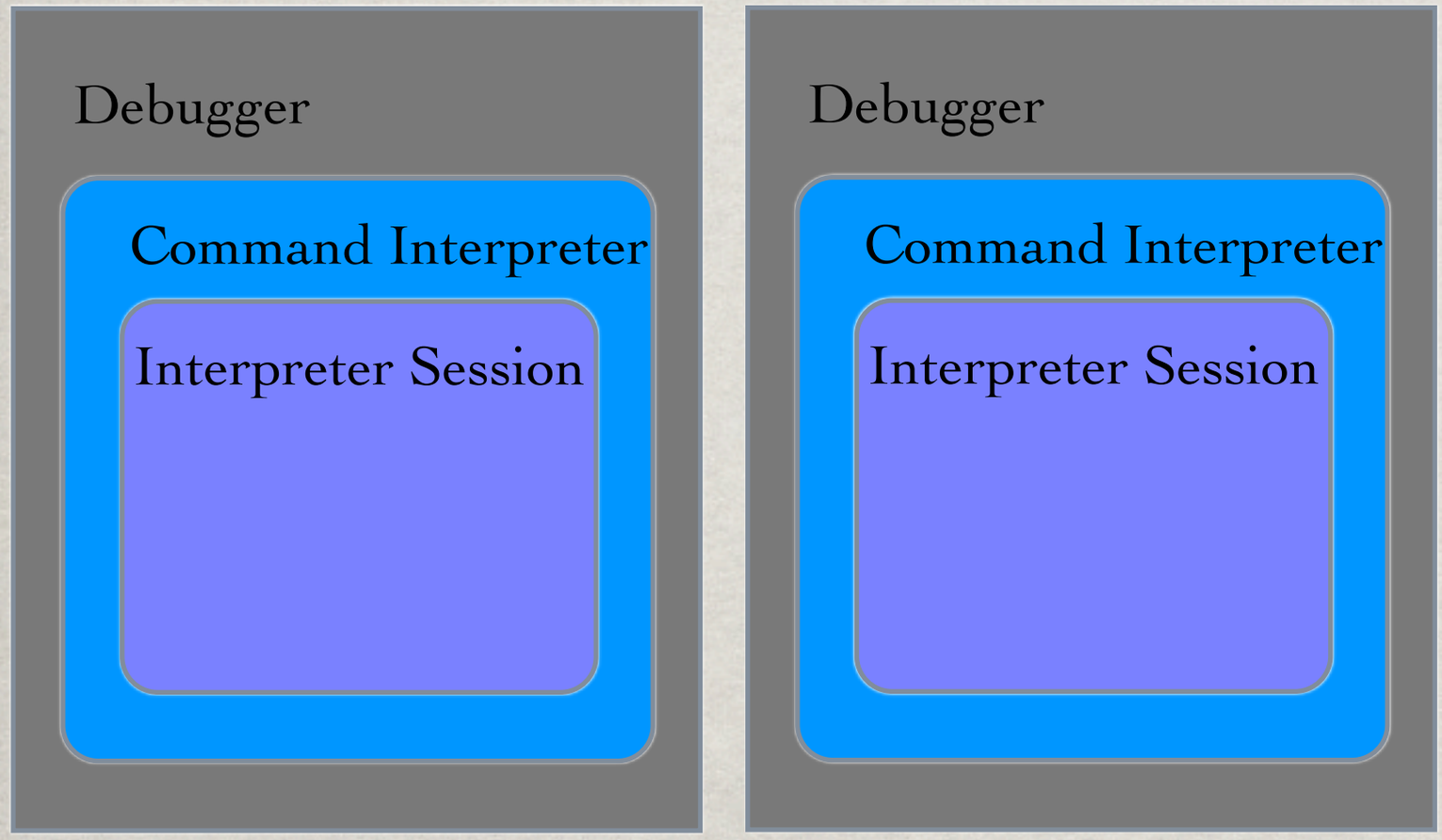

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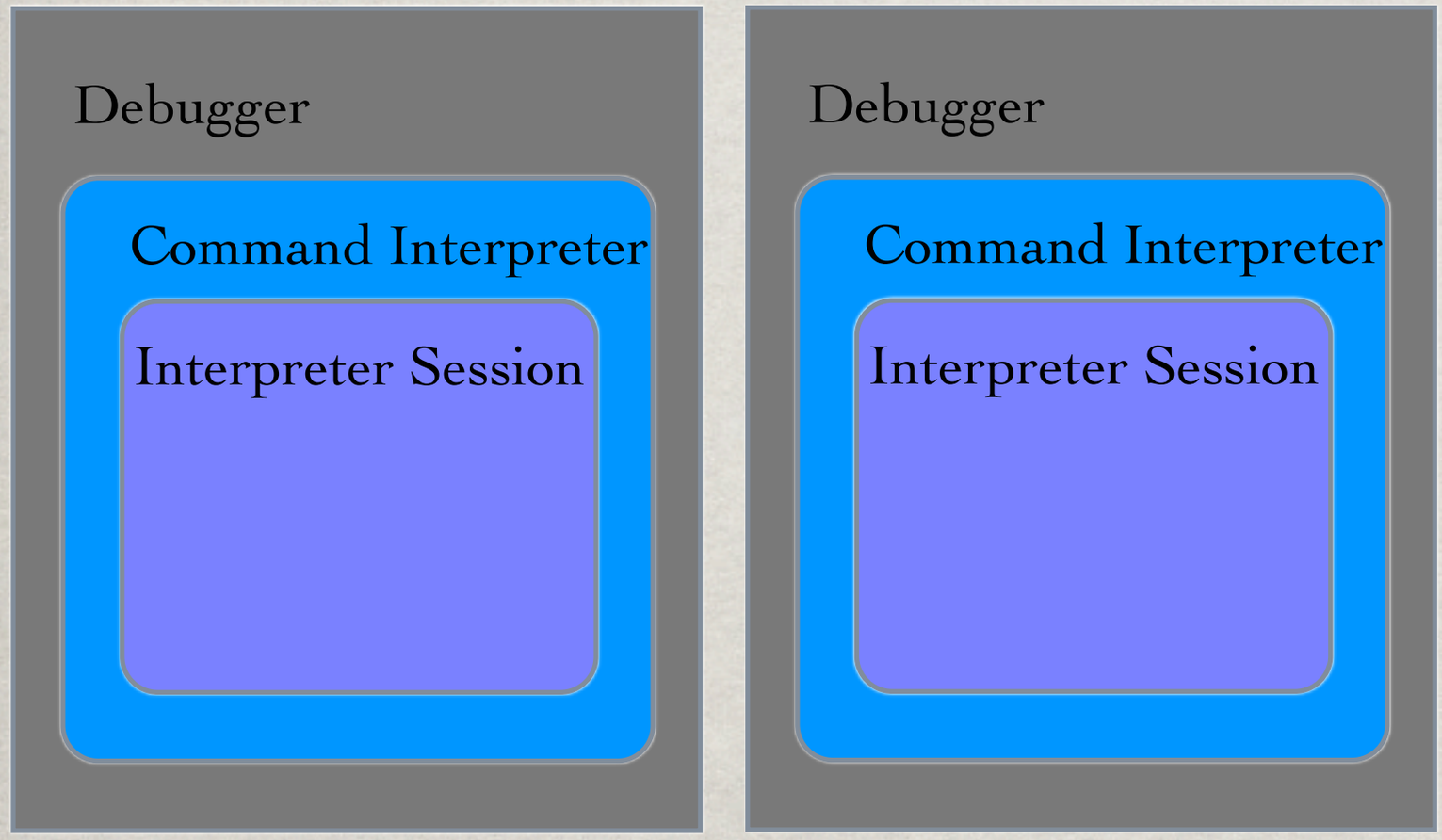


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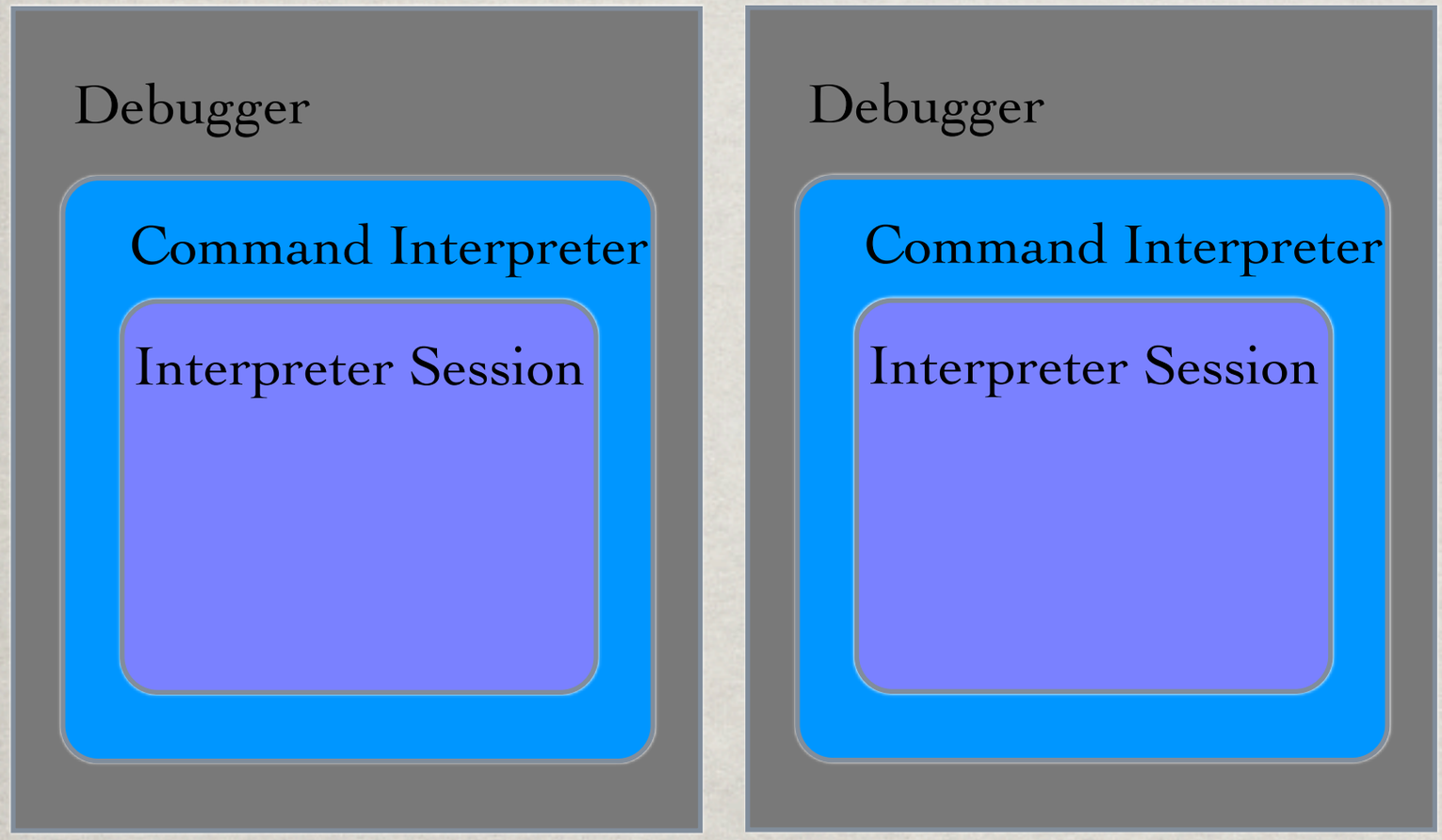

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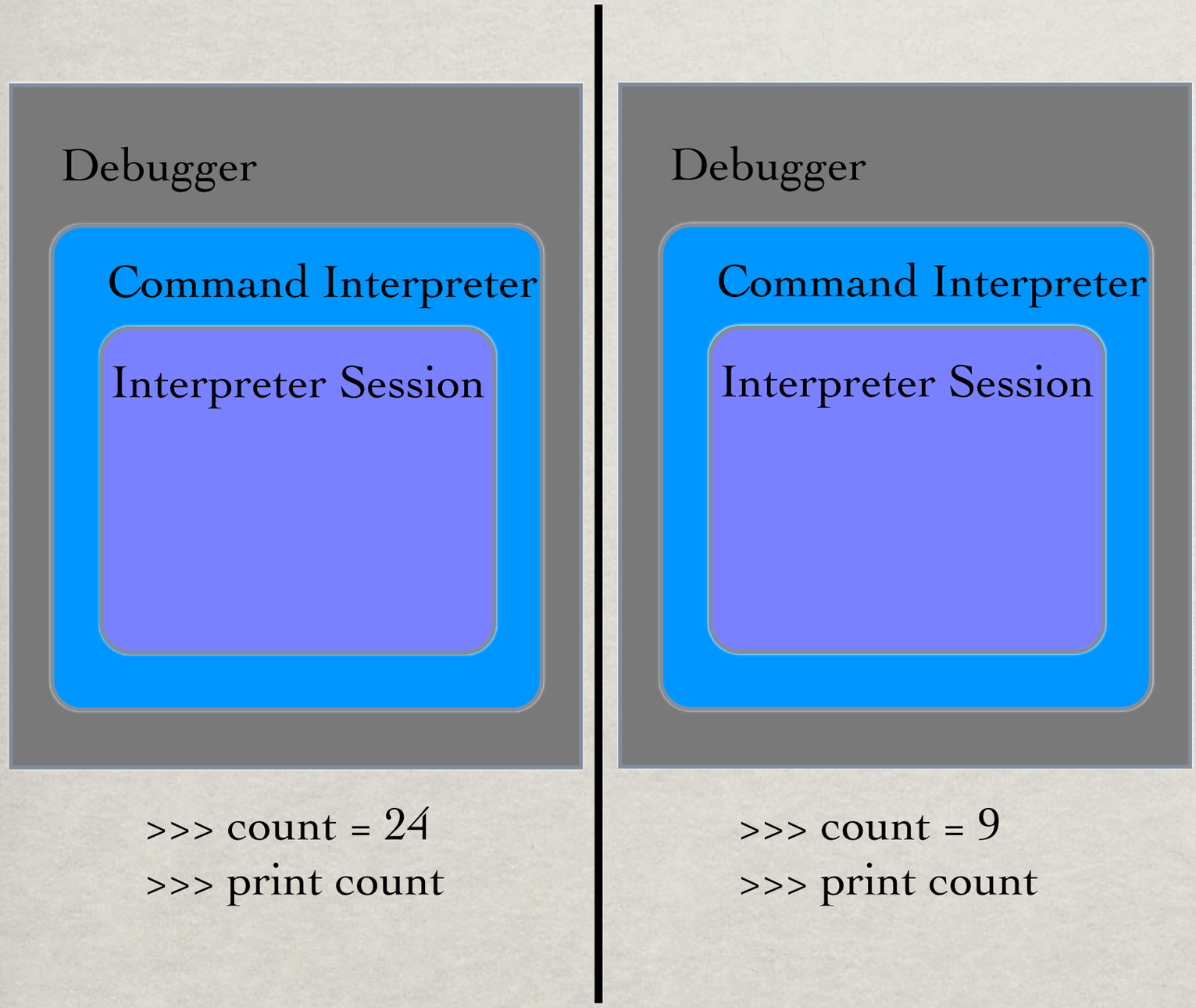

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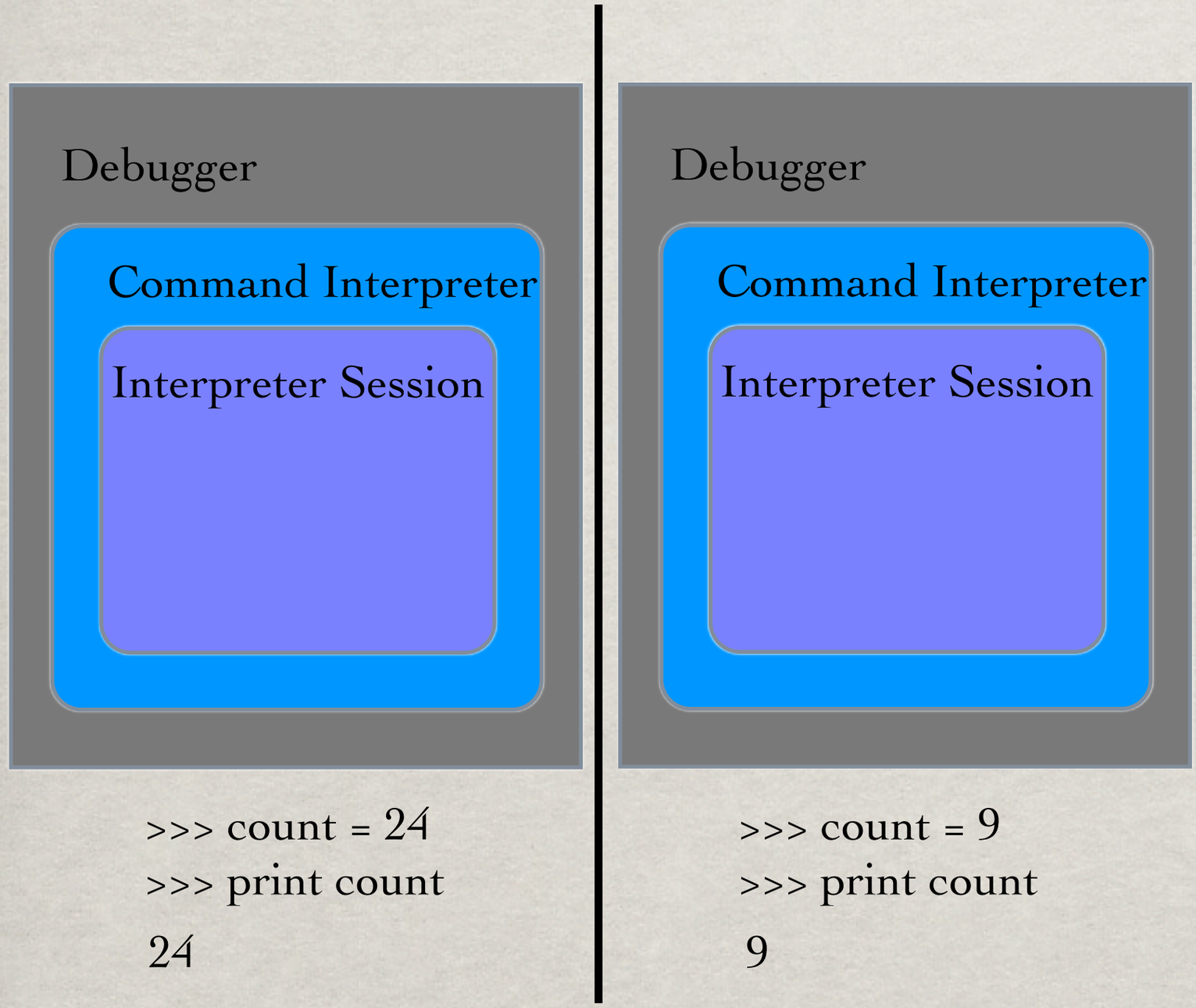


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Demo...

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... and whether same thread hit it last time!

Why Scripting In A Debugger?

- Set REALLY useful conditional breakpoints

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- Automatically record register values and program state
    - To a file...
    - Each time a program point is hit...
    - Across multiple RUNS of the program

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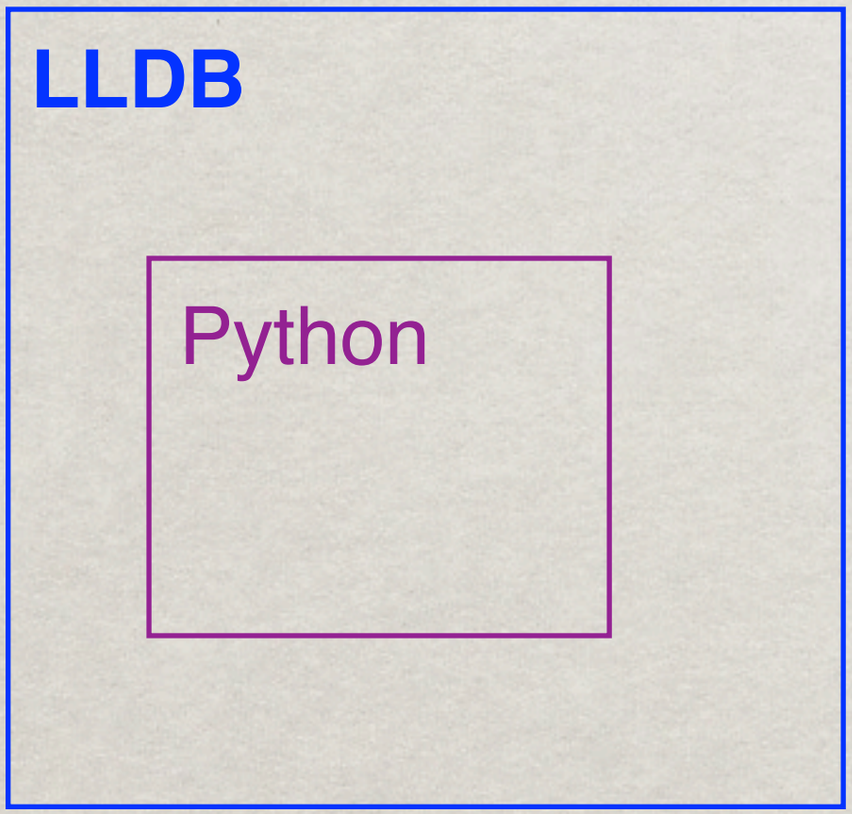
Why Scripting In A Debugger?

- Set REALLY useful conditional breakpoints
- Find specific data in large dynamic data structures
- Automatically record register values and program state
- Automated testing/QA

What Is Where?



Python is accessible from LLDB.

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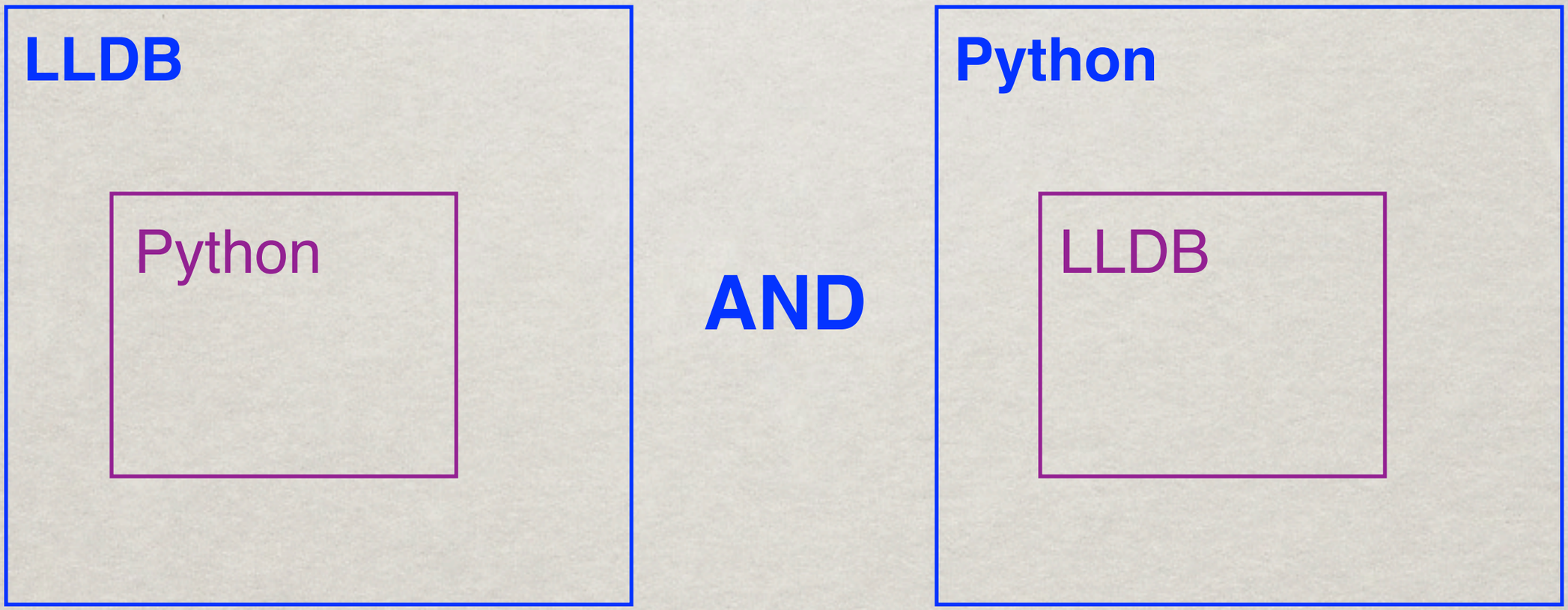

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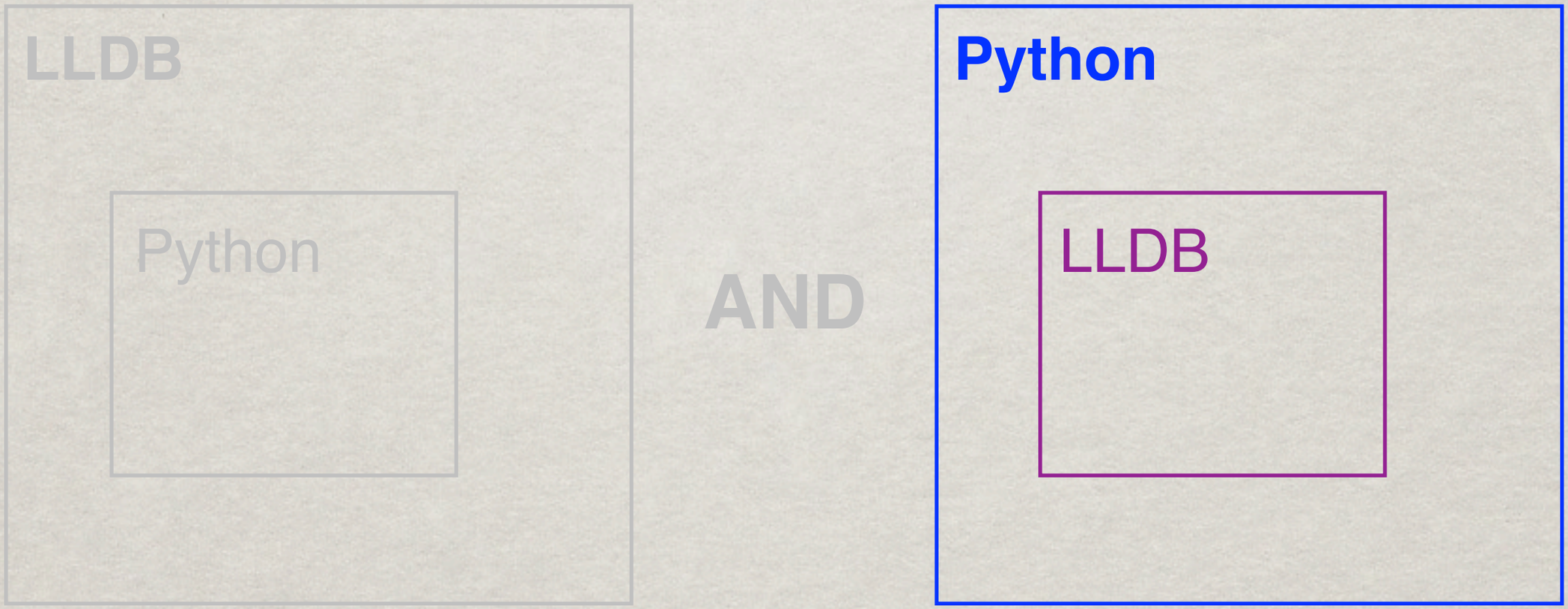

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LLDB Creates Python Module

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```
% python
Python 2.6.1 (r261:67515, Jun 24 2010, 21:47:49)
[GCC 4.2.1 (Apple Inc. build 5646)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
>>>
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>>> import lldb
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>>> import lldb
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Type "help", "copyright", "credits" or "license" for more information.
>>> import lldb
>>>  dbg = lldb.SBDebugger.Create()
>>>  target = dbg.CreateTarget (“/bin/ls”)
>>>
```

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>>> target = dbg.CreateTarget (“/bin/ls”)
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>>>
```

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>>> process = target.LaunchSimple (None, None, None)
```

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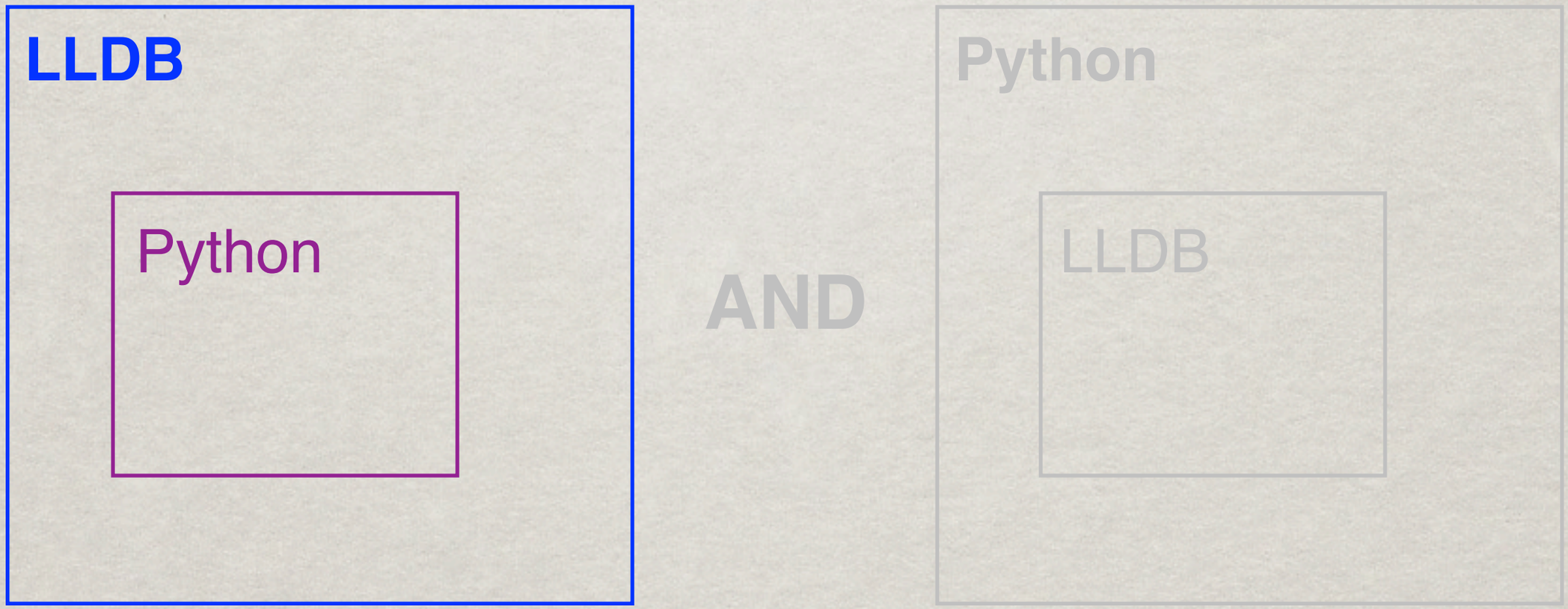
```

LLDB API functions

What Is Where?



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Python In LLDB

Python In LLDB

- LLDB contains full, complete Python Interpreter

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- Many ways to access Python in LLDB
  - one-line script command
  - interactive interpreter
  - breakpoint commands

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```
(lldb) script hex (123456)
'0x1e240'
(lldb)
```

Python In LLDB

- LLDB contains full, complete Python Interpreter
- Many ways to access Python in LLDB
  - one-line script command
  - interactive interpreter
  - breakpoint commands

```
(lldb) script
Python Interactive Interpreter. To exit type 'exit()', 'quit()'
or Ctrl-D.
>>>
```

Python In LLDB

- LLDB contains full, complete Python Interpreter
- Many ways to access Python in LLDB
  - one-line script command
  - interactive interpreter
  - breakpoint commands

```
(lldb) breakpoint command add -s python 1
Enter your Python commands. Type 'DONE' to end.
>
```

LLDB Extensions For Python

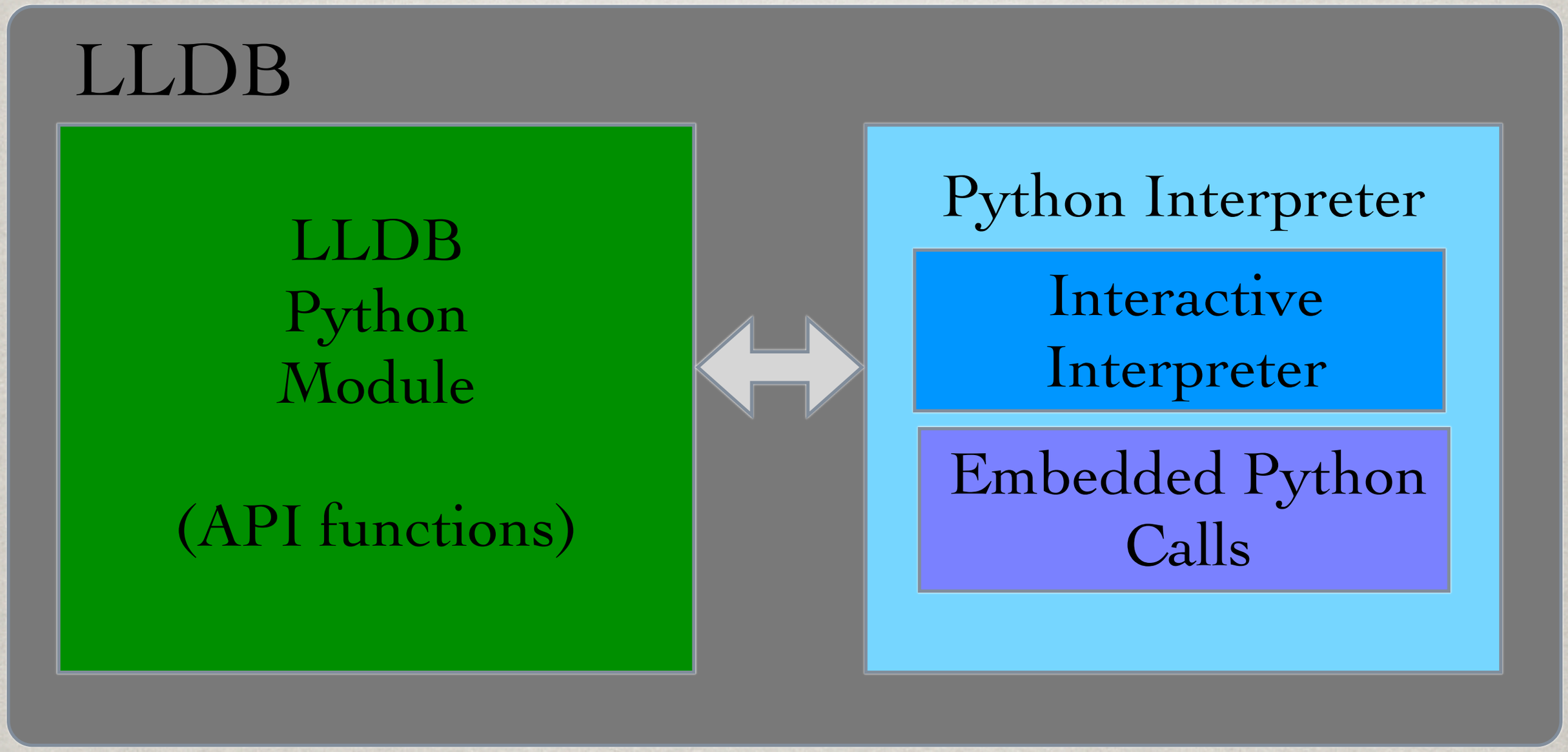
- API functions (automatically imported)
  - Create, access & manipulate debugger objects/state

- Pre-loaded LLDB objects into Python variables

```
lldb.target, lldb.process, lldb.thread, lldb.frame
```

- Single persistent Python dictionary for entire debugger session

Python In LLDB - More Detail



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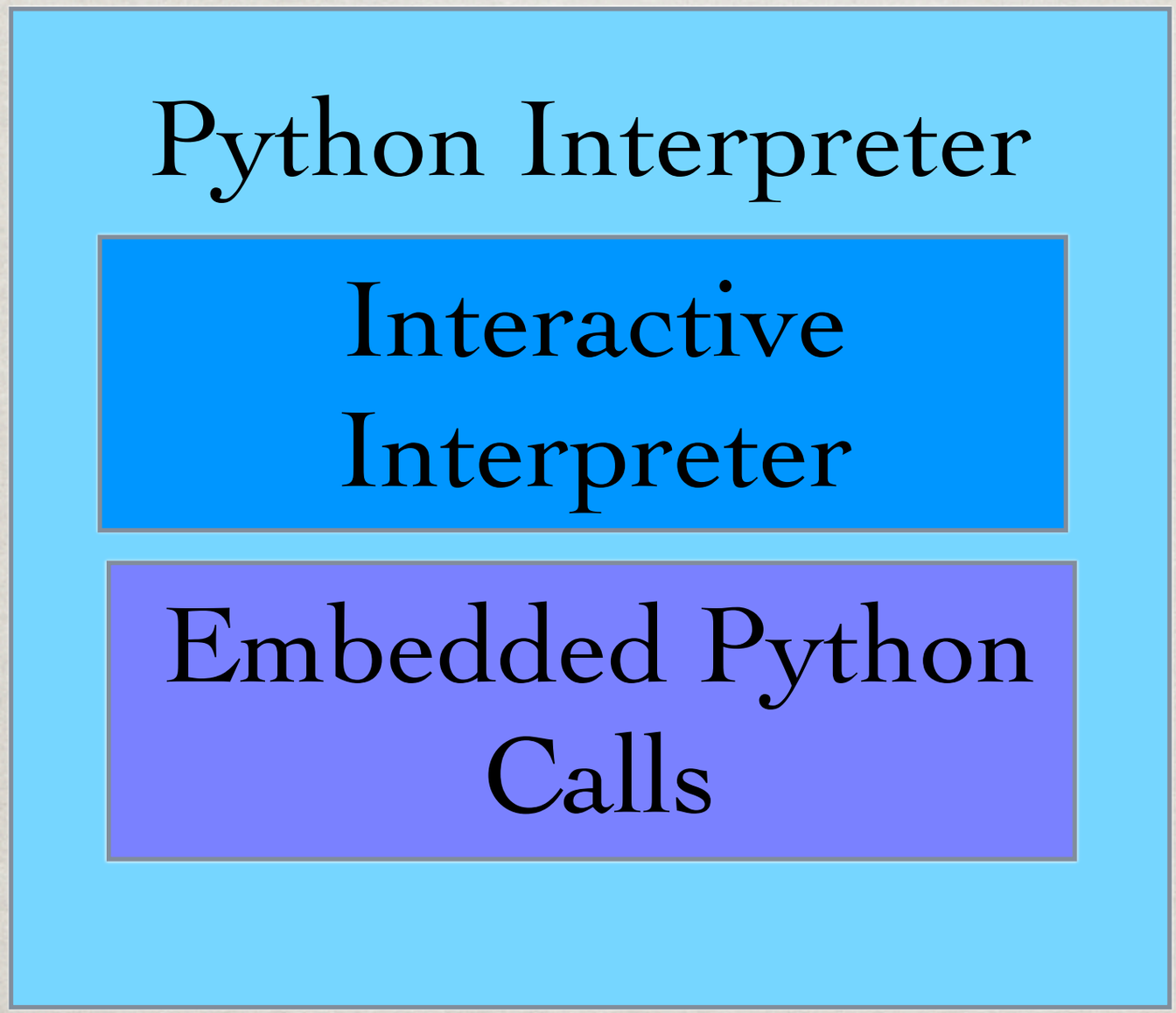

Implementing Interactive Python Interpreter

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- Wrote our own interactive interpreter module (in Python)
  - Inherited InteractiveConsole class ('code' module)
  - Takes dictionary as parameter
  - Executes all code in context of dictionary

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- Wrote our own interactive interpreter module (in Python)
  - Inherited InteractiveConsole class ('code' module)
  - Takes dictionary as parameter
  - Executes all code in context of dictionary
- Used Python C/API functions to:
  - Initialize Python interpreter
    - Initialize thread capabilities
    - Turn OFF Python's signal handlers
  - Import our interactive interpreter module

Implementing One-Line Script Commands

- Same mechanism as interactive interpreter...
- ...just call different method in our module

How The Dictionaries Work (1)

new Debugger();

Python Interpreter

Global Dictionary

run_one_line : <code>
run_python_interpreter : <code>

How The Dictionaries Work (1)

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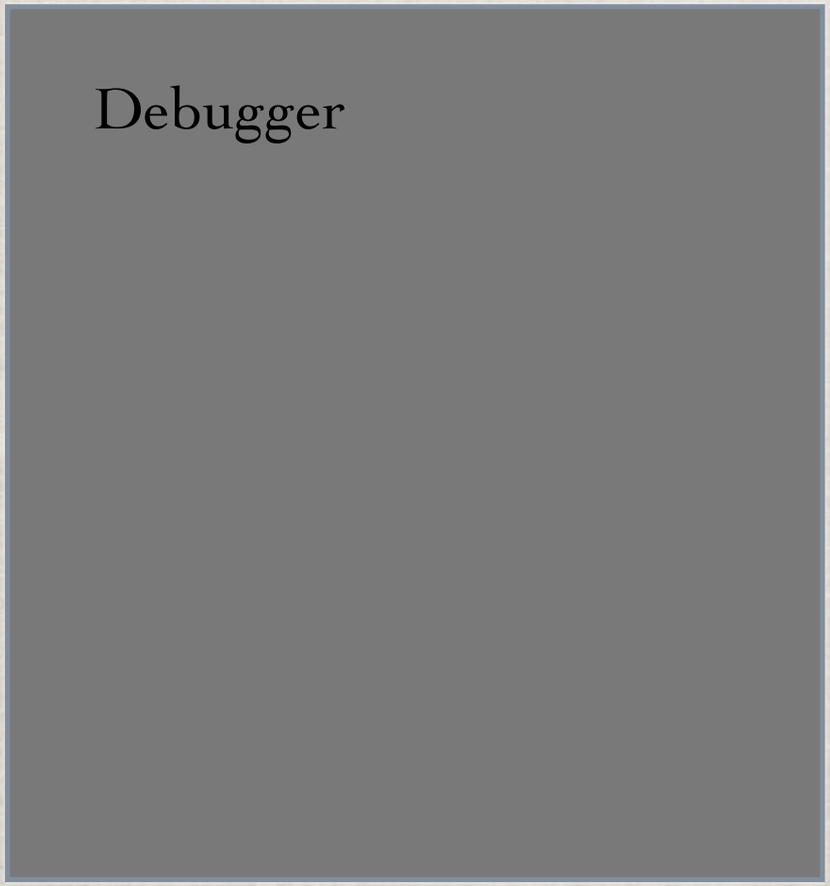

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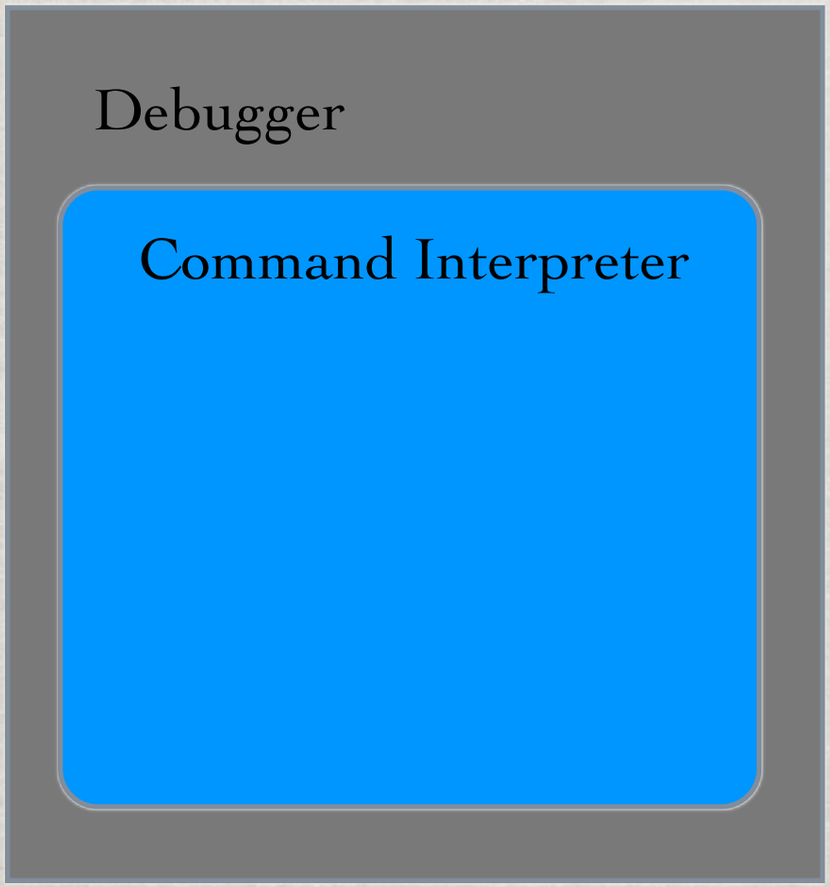

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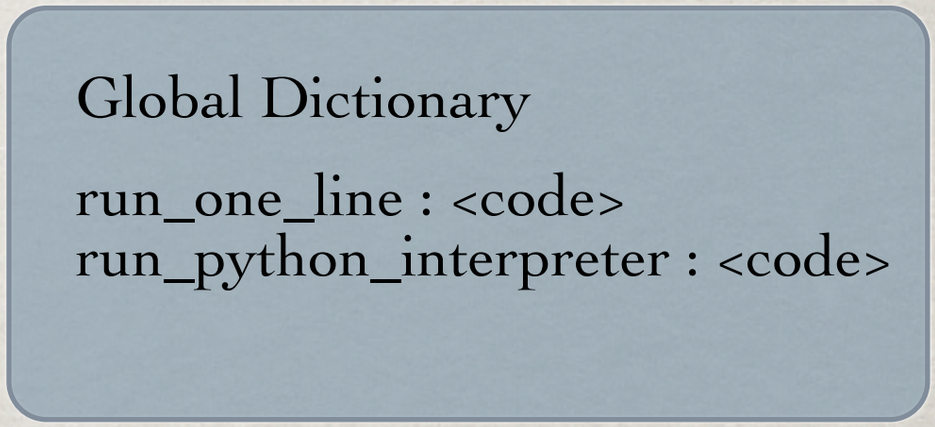

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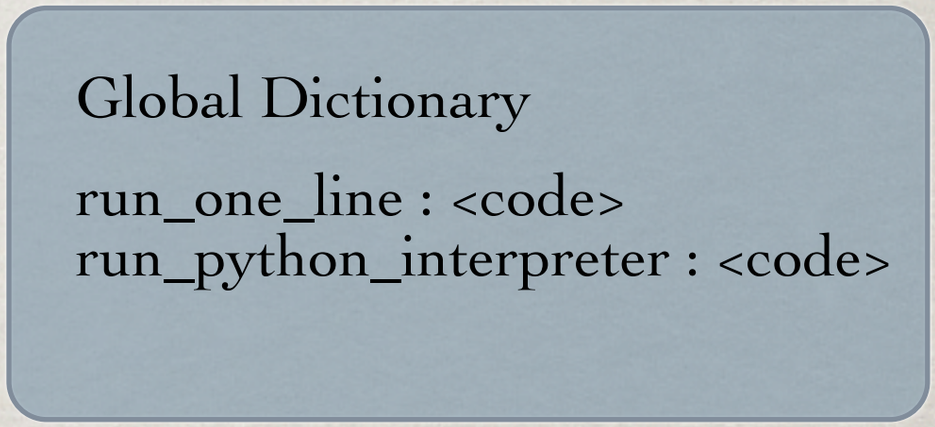

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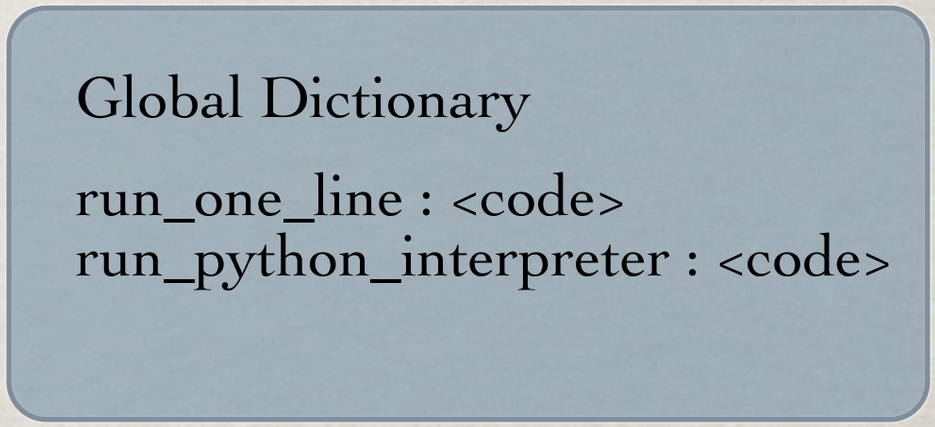

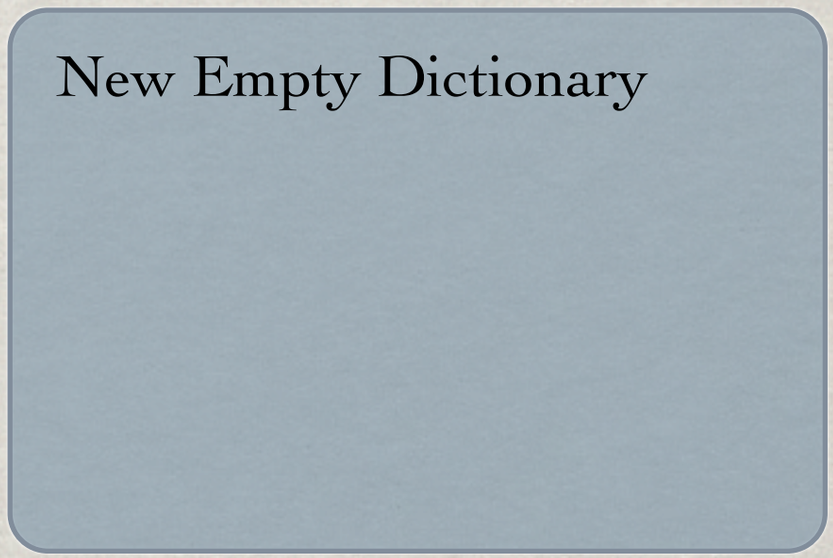

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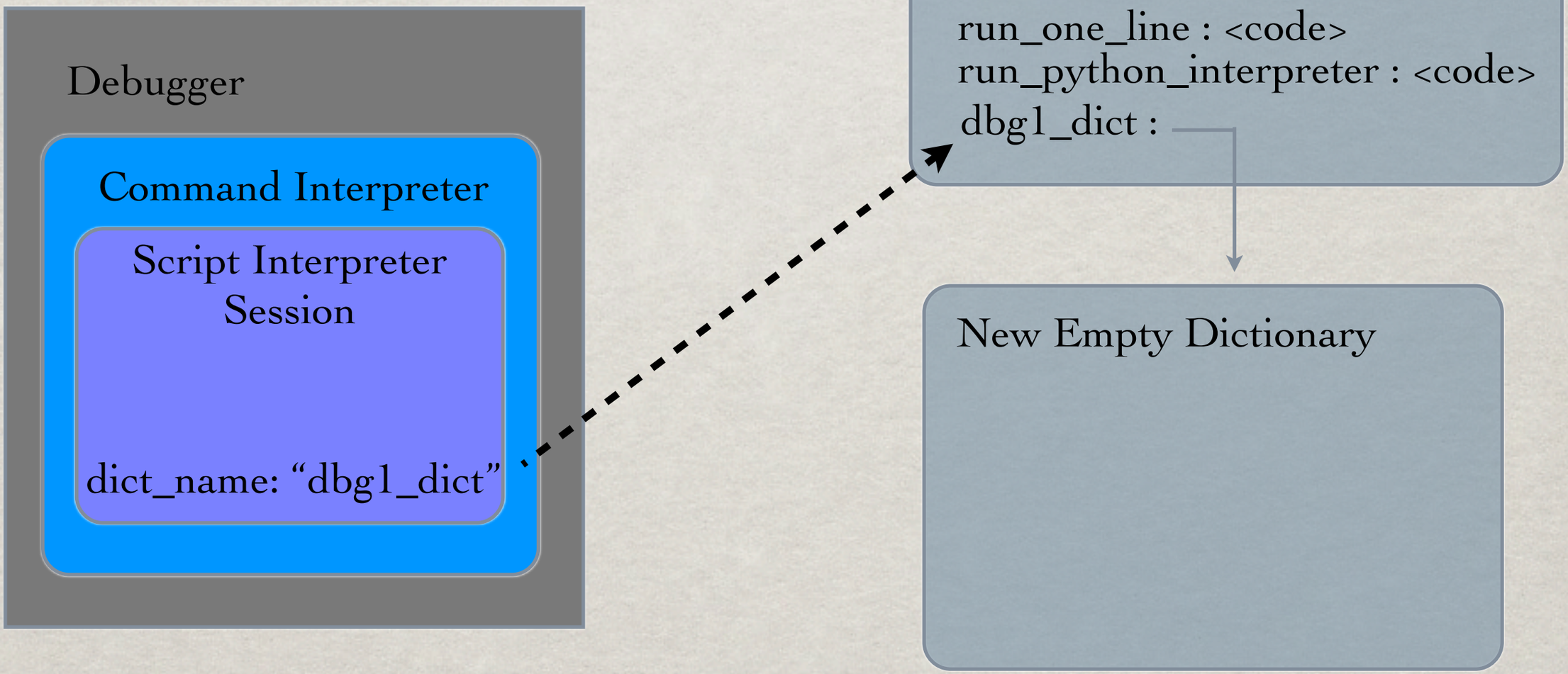
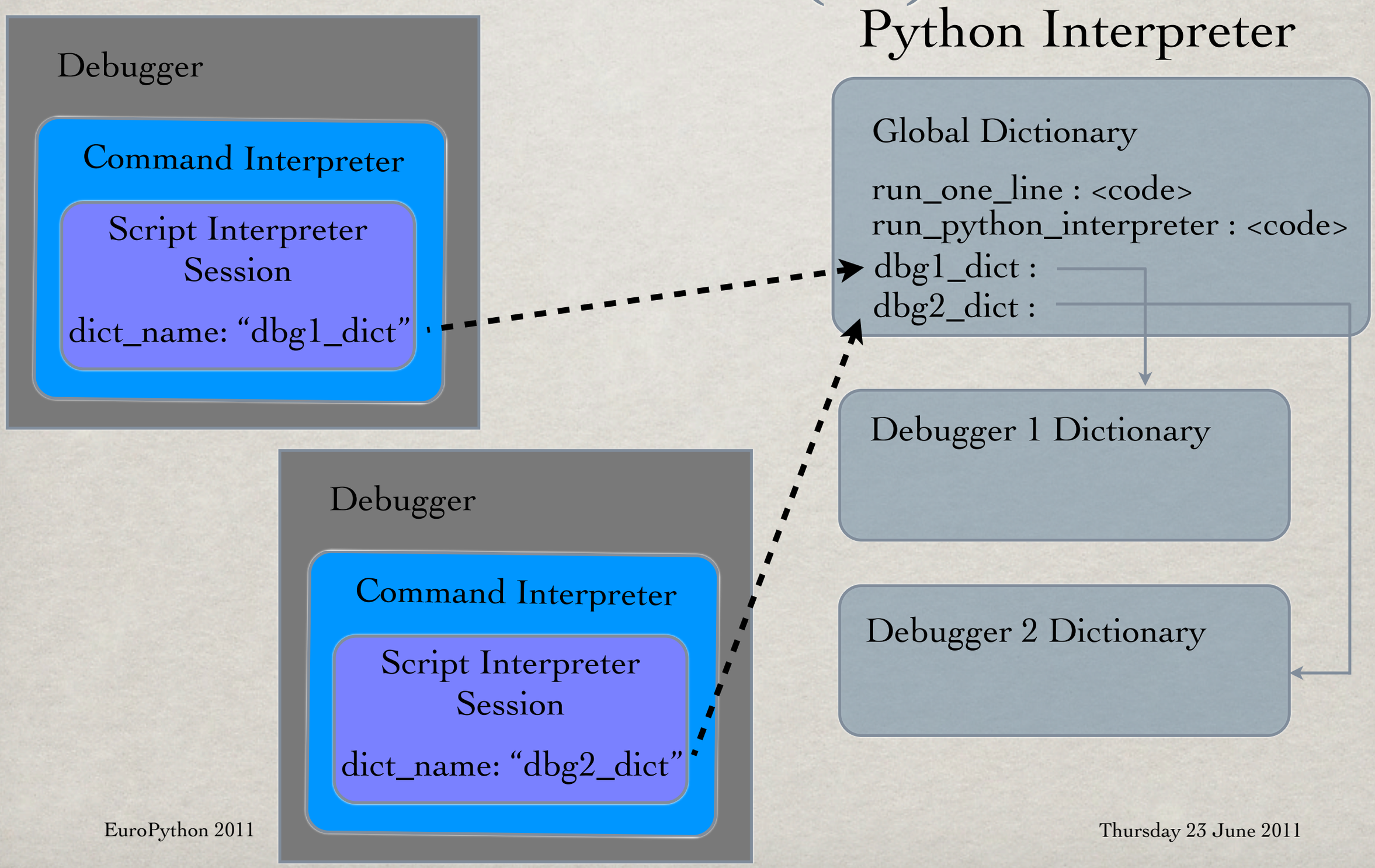
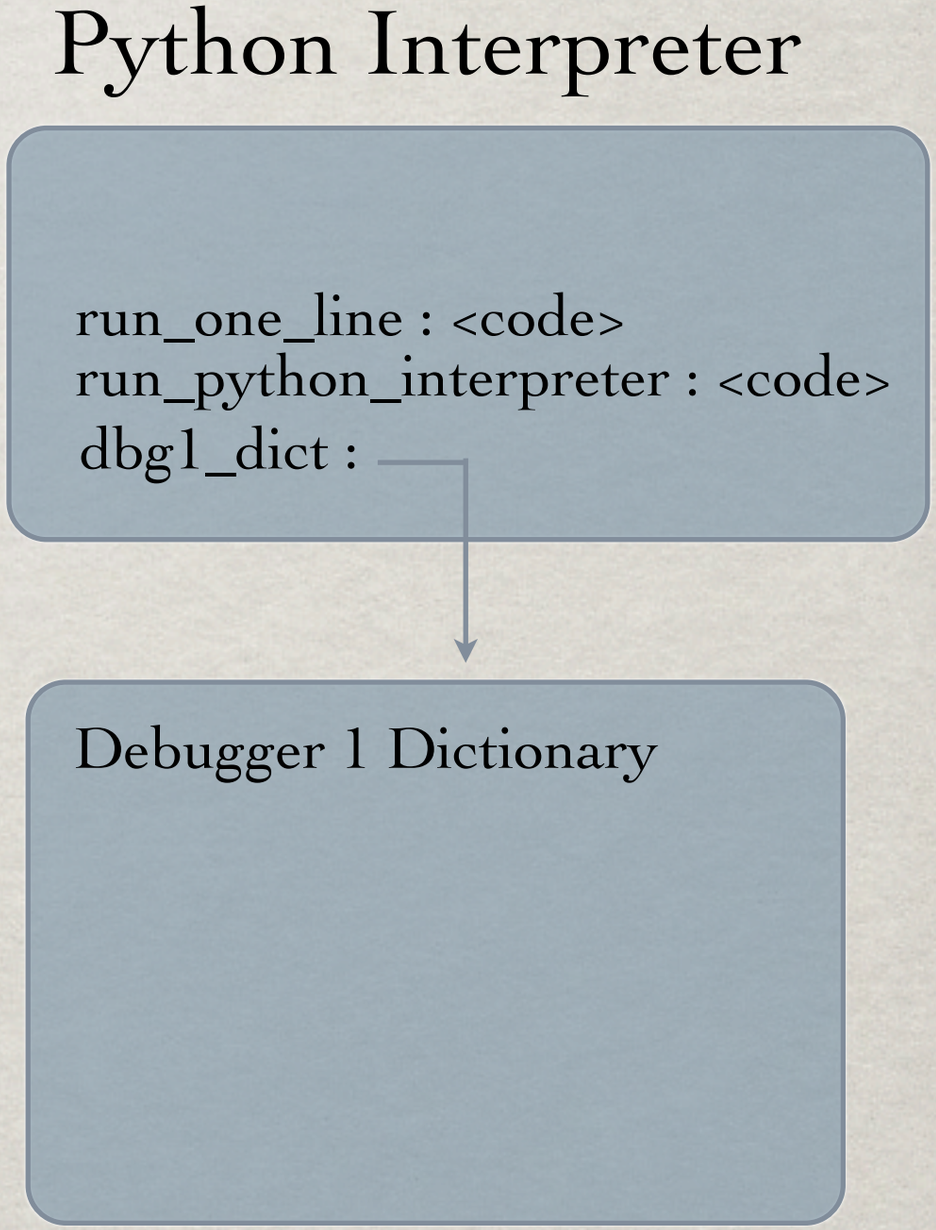


How The Dictionaries Work (2)



Invoking One-Line Script Commands

(lldb) script hex (3856)



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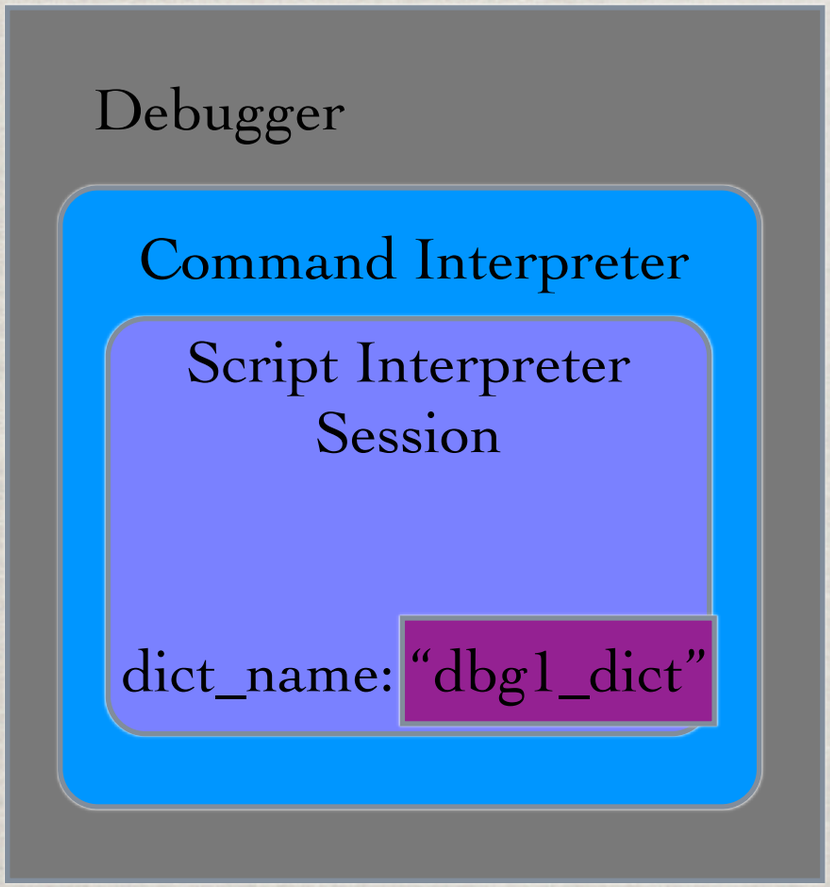

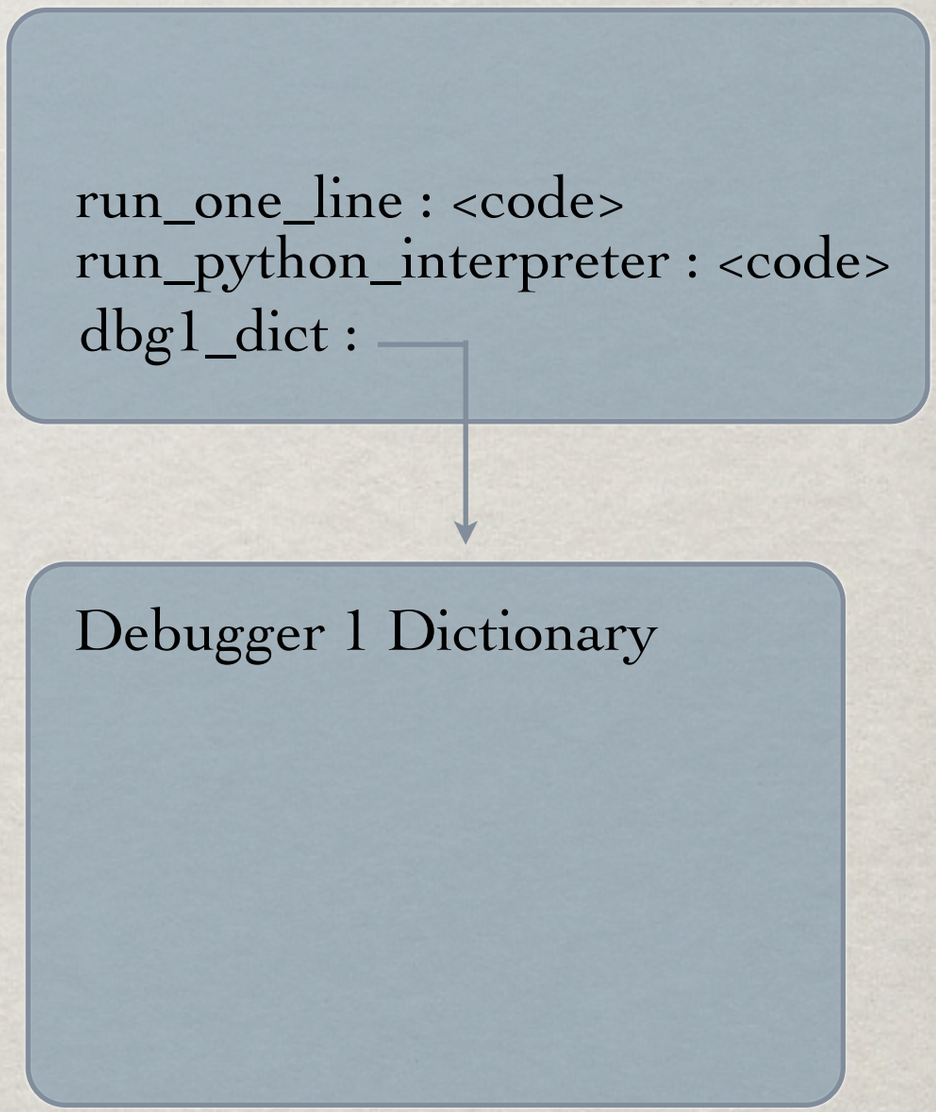

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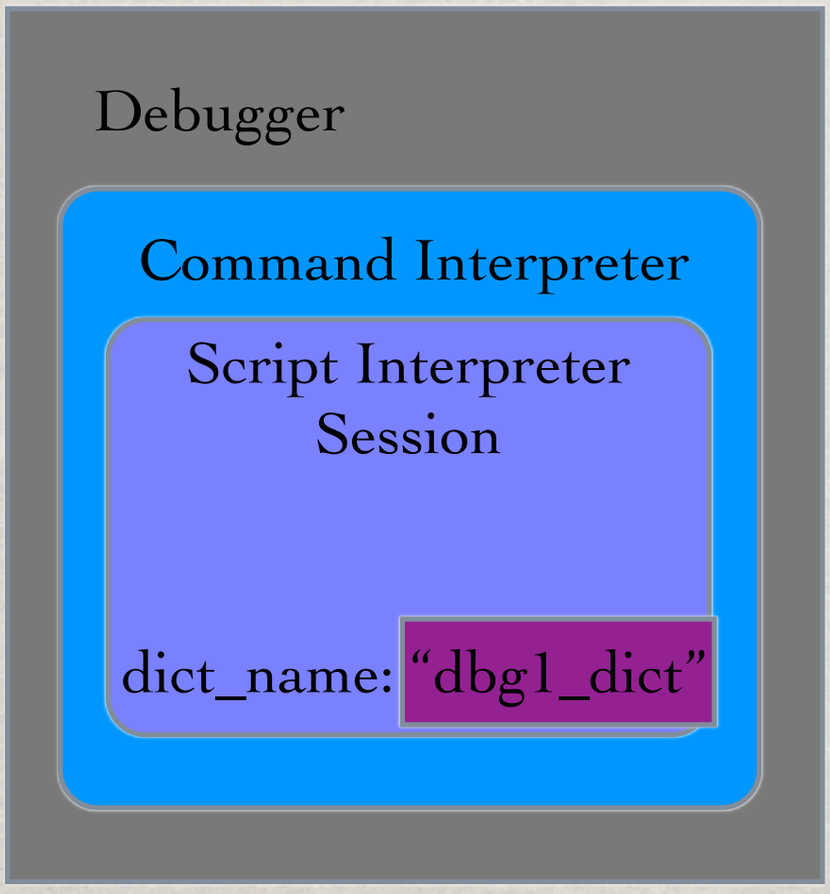

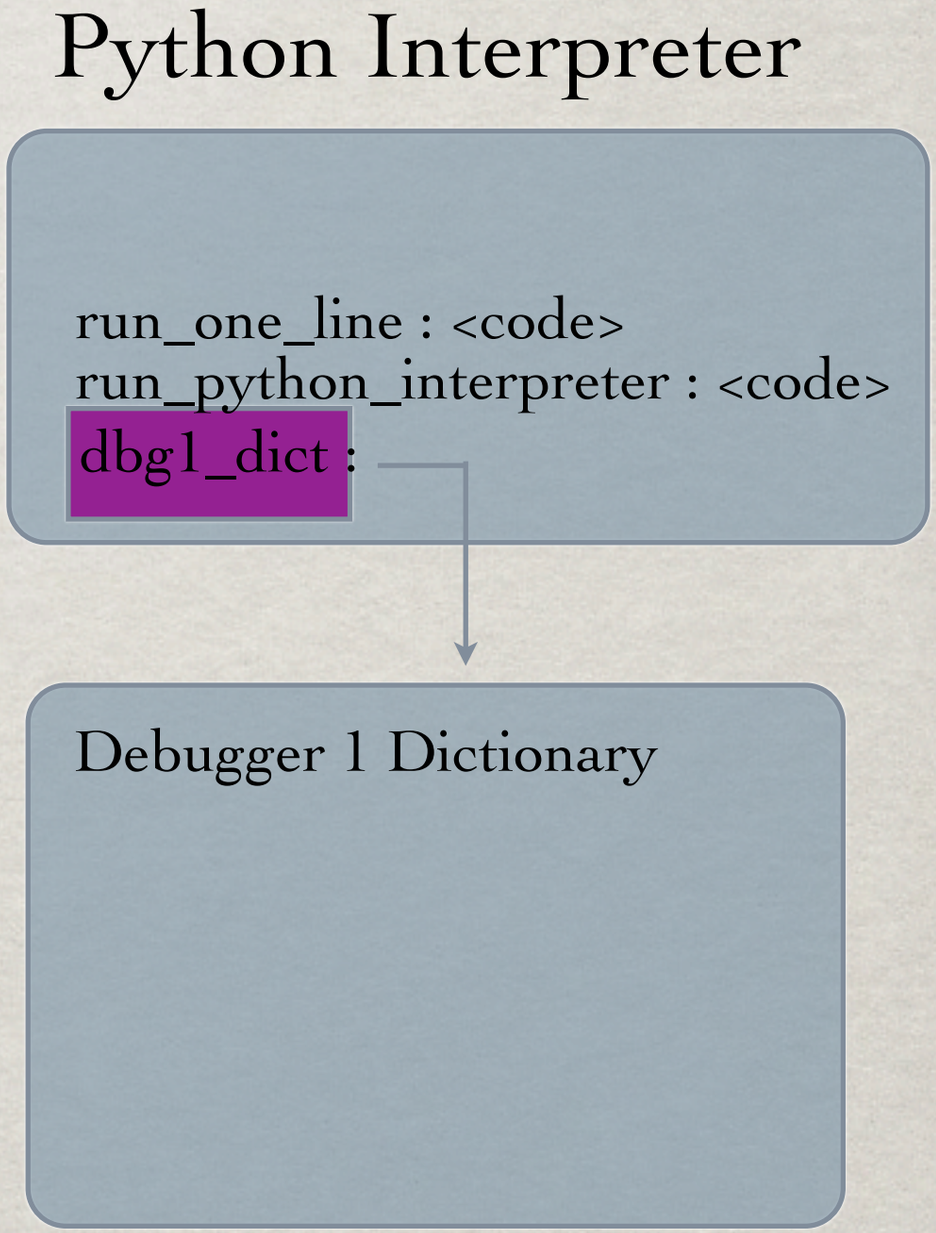

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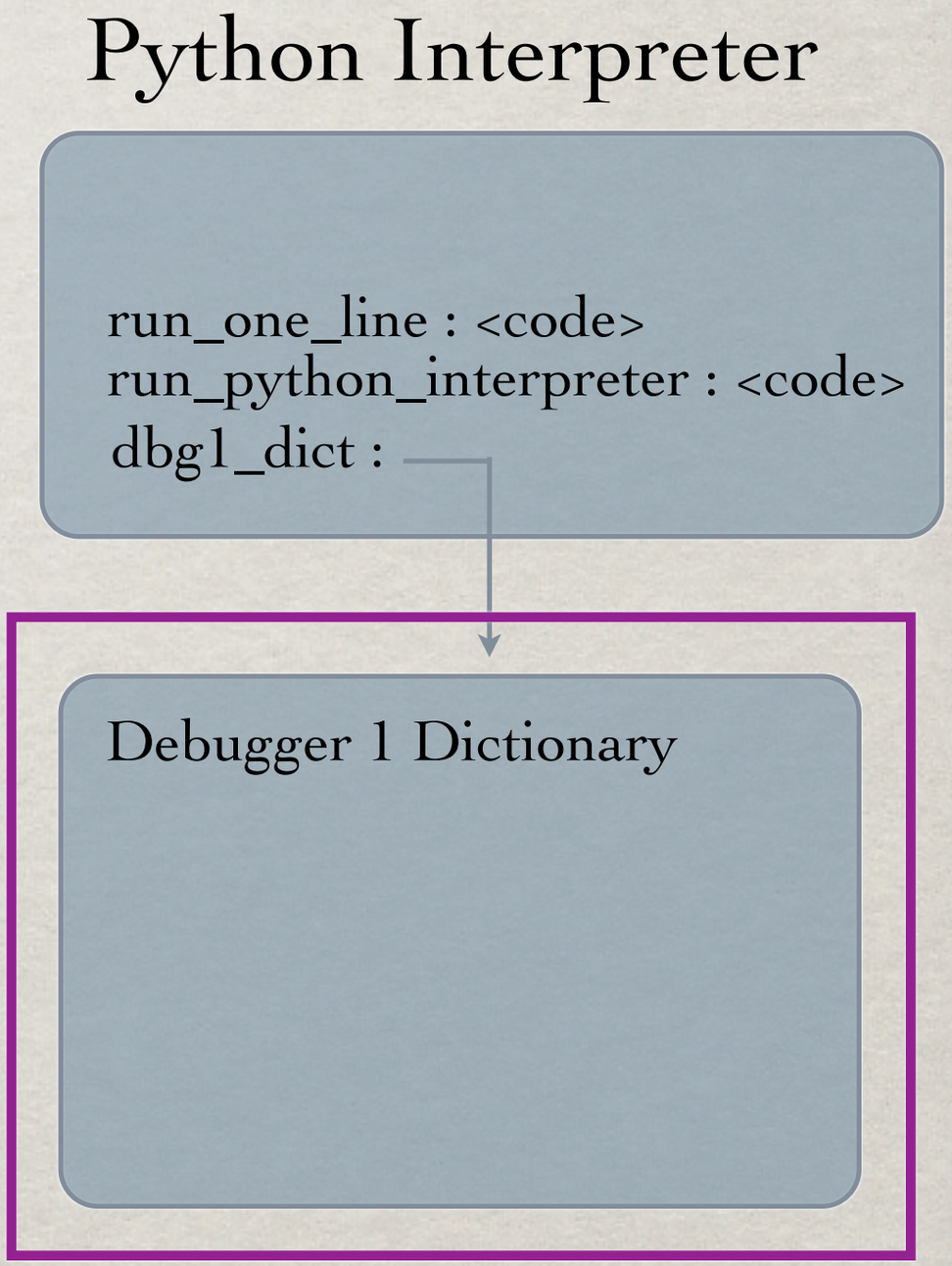

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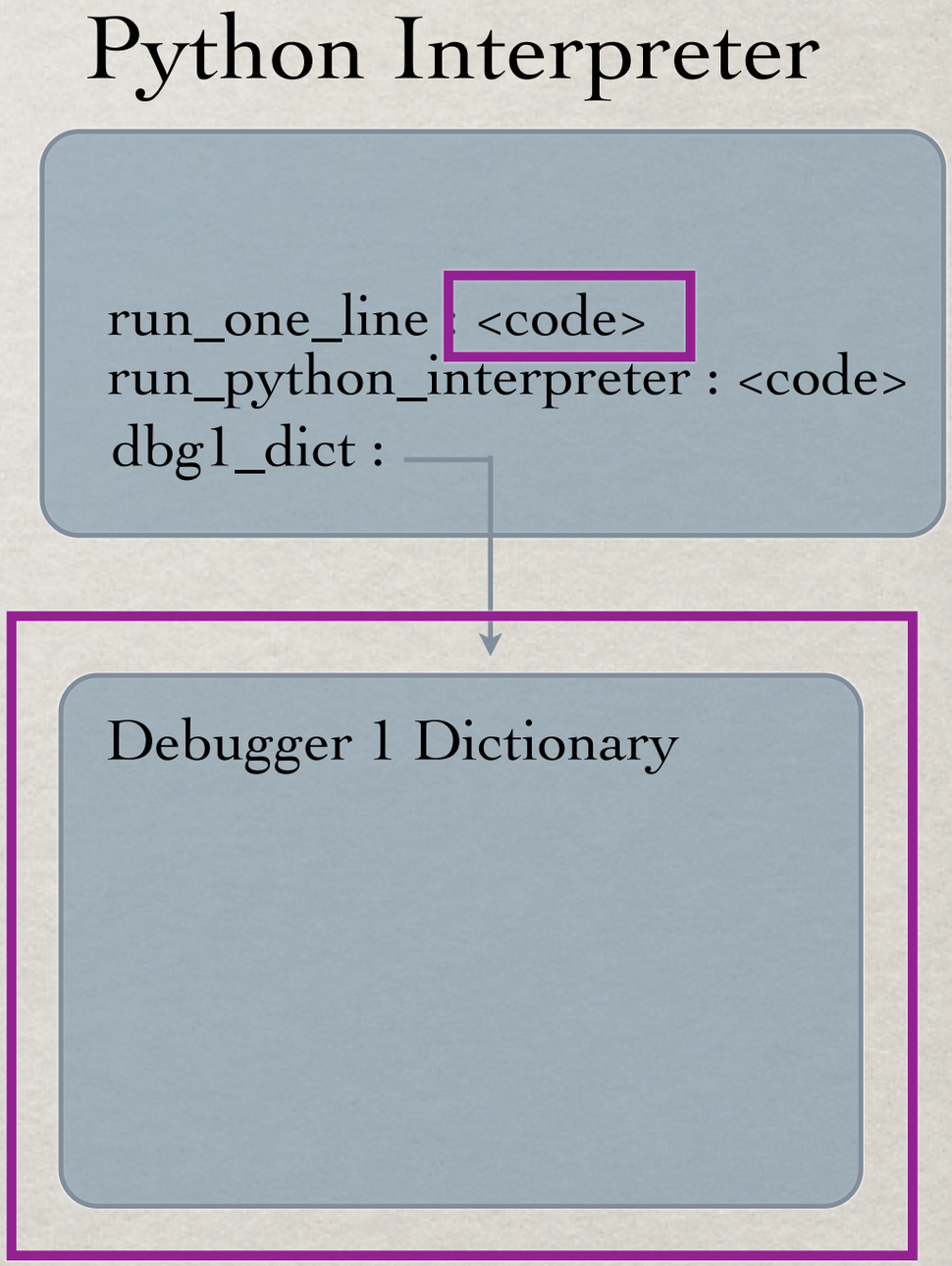

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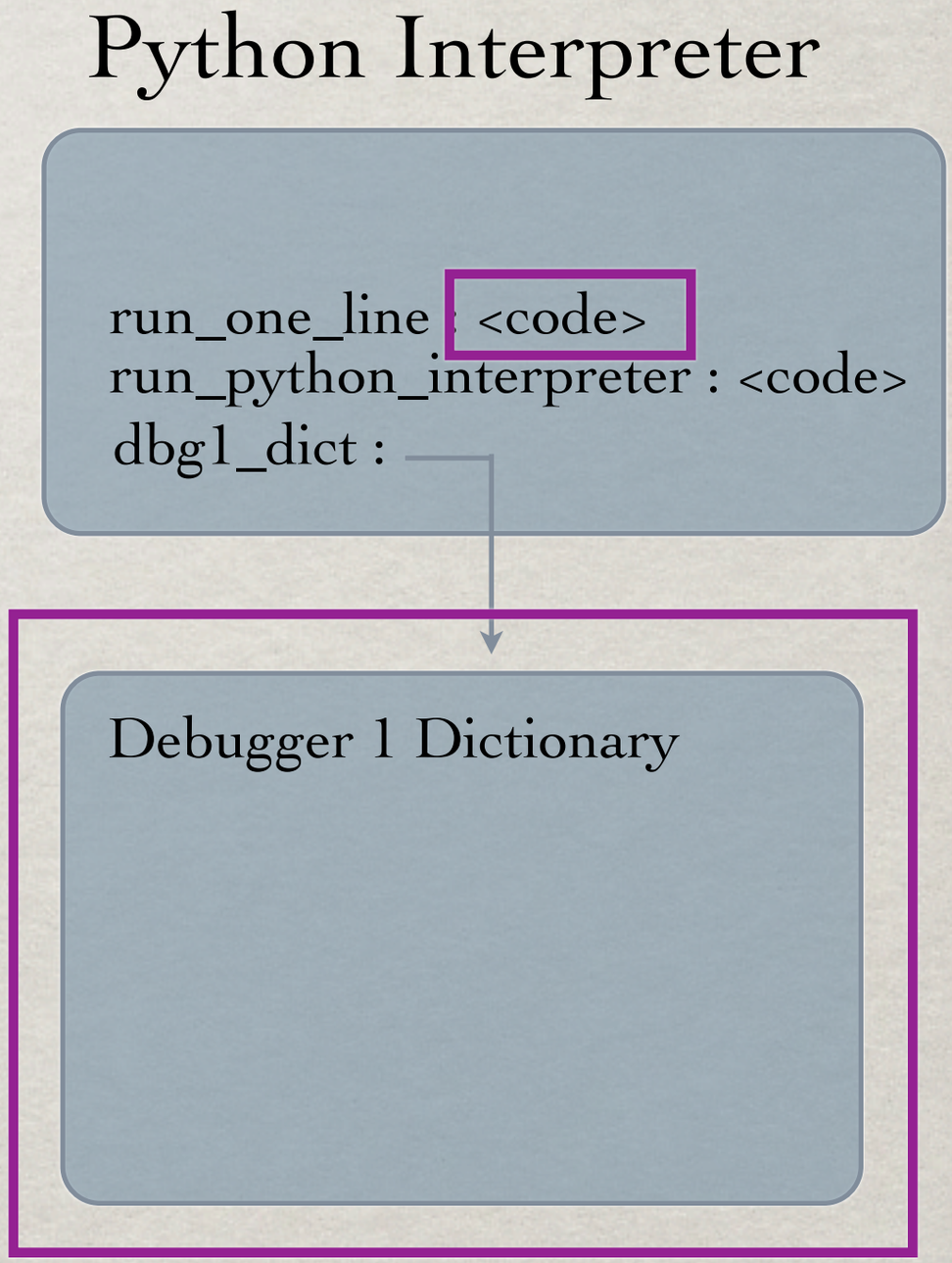

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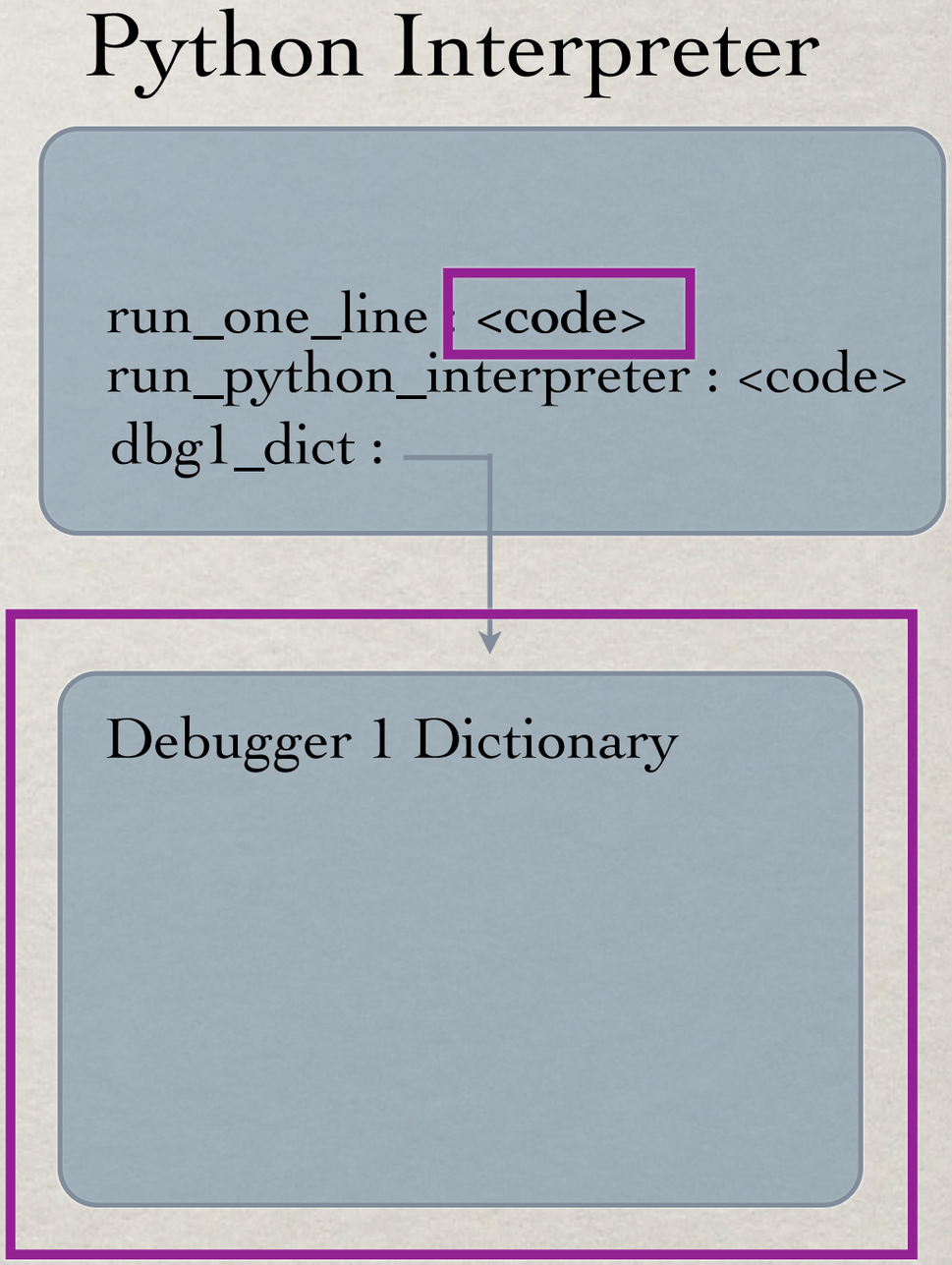

Invoking One-Line Script Commands

hex (3856)

<code>

Debugger 1 Dictionary

Invoking One-Line Script Commands

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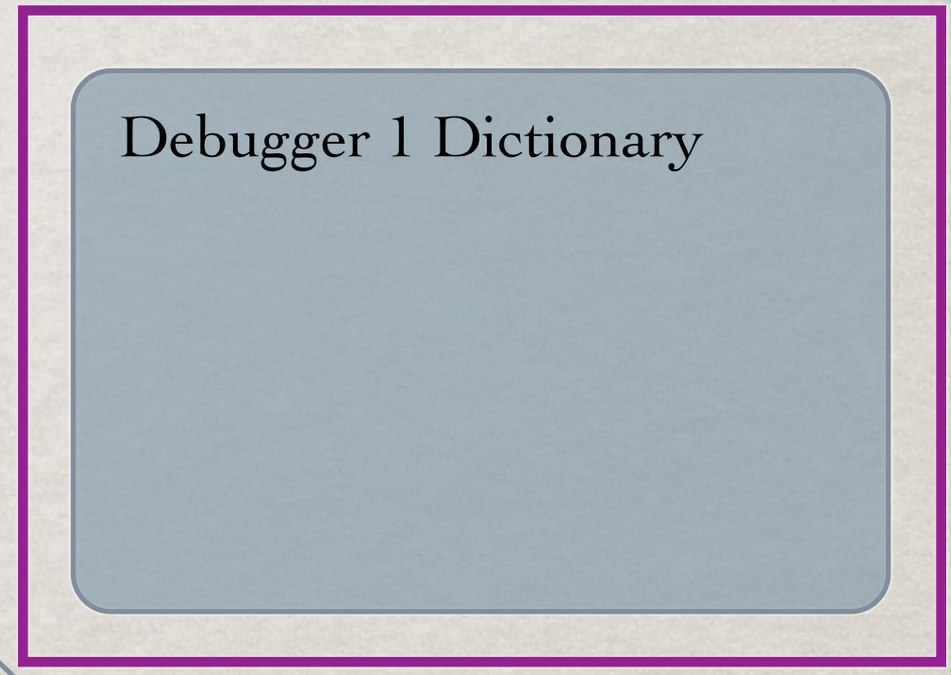
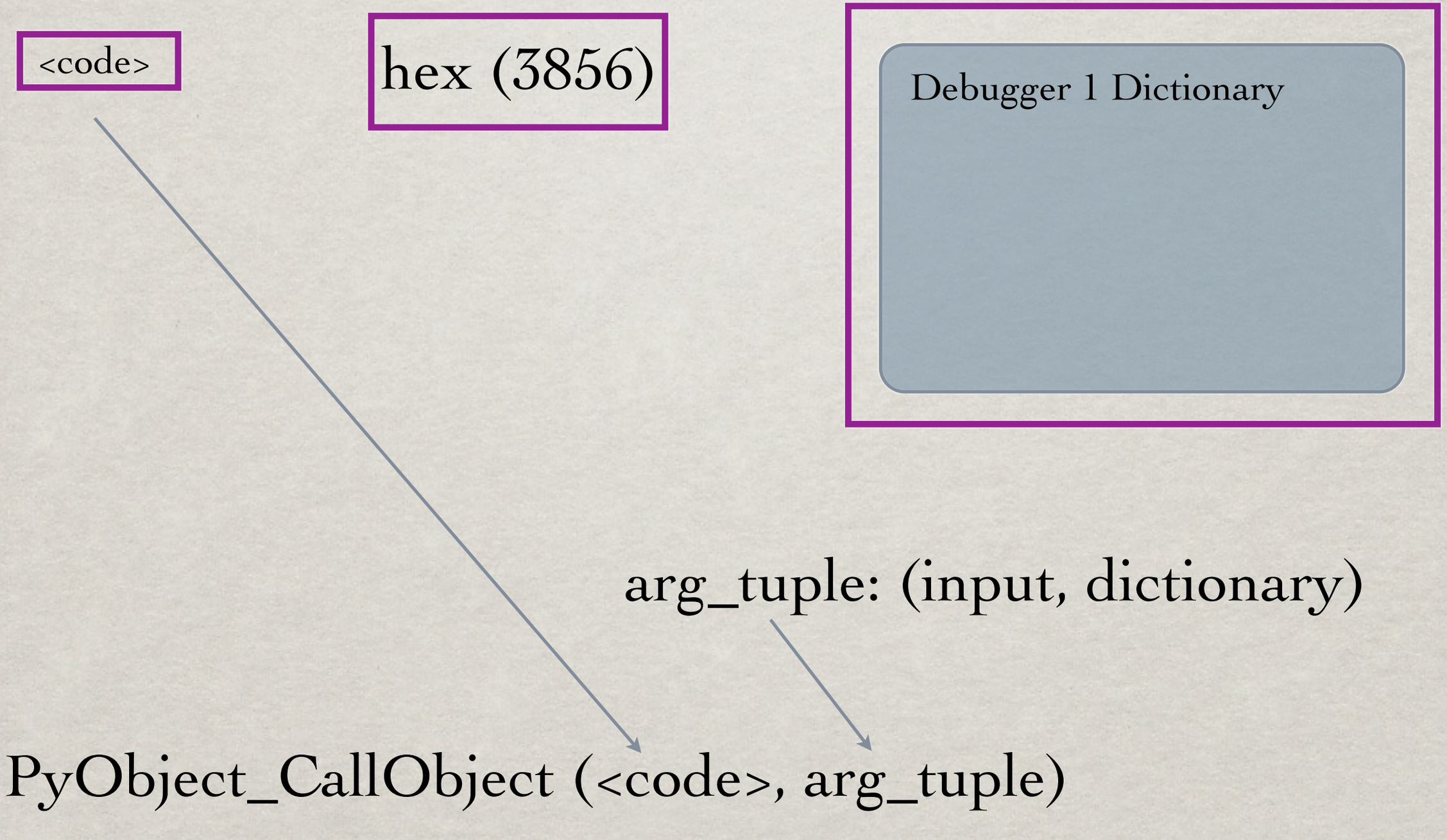


arg_tuple: (input, dictionary)

Invoking One-Line Script Commands



Invoking Interactive Script Interpreter

(lldb) script

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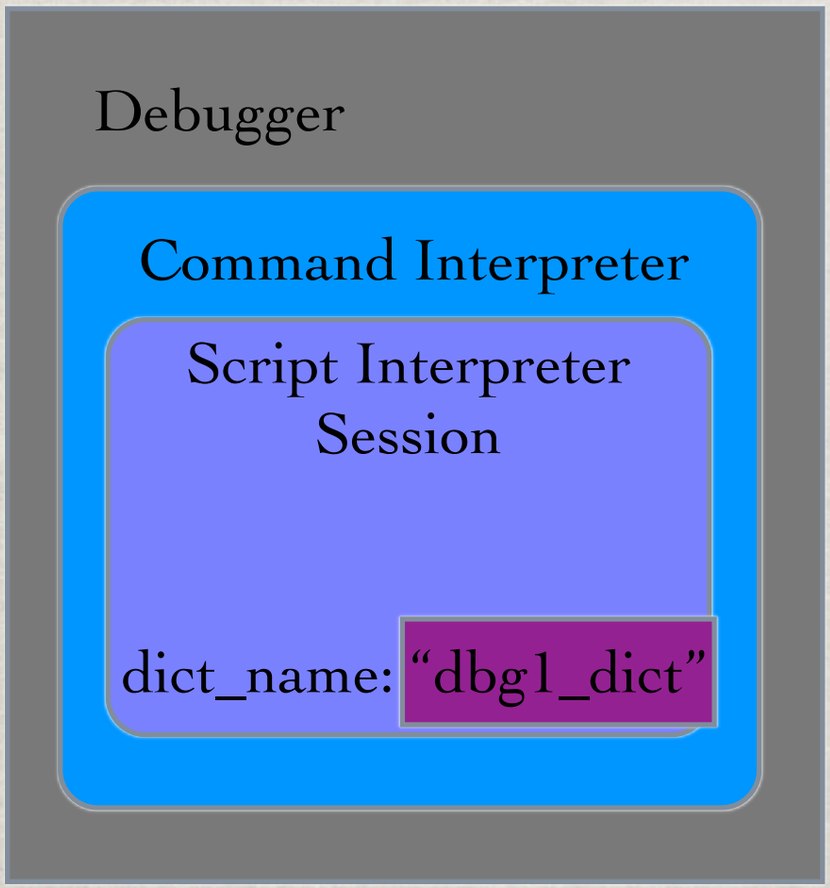

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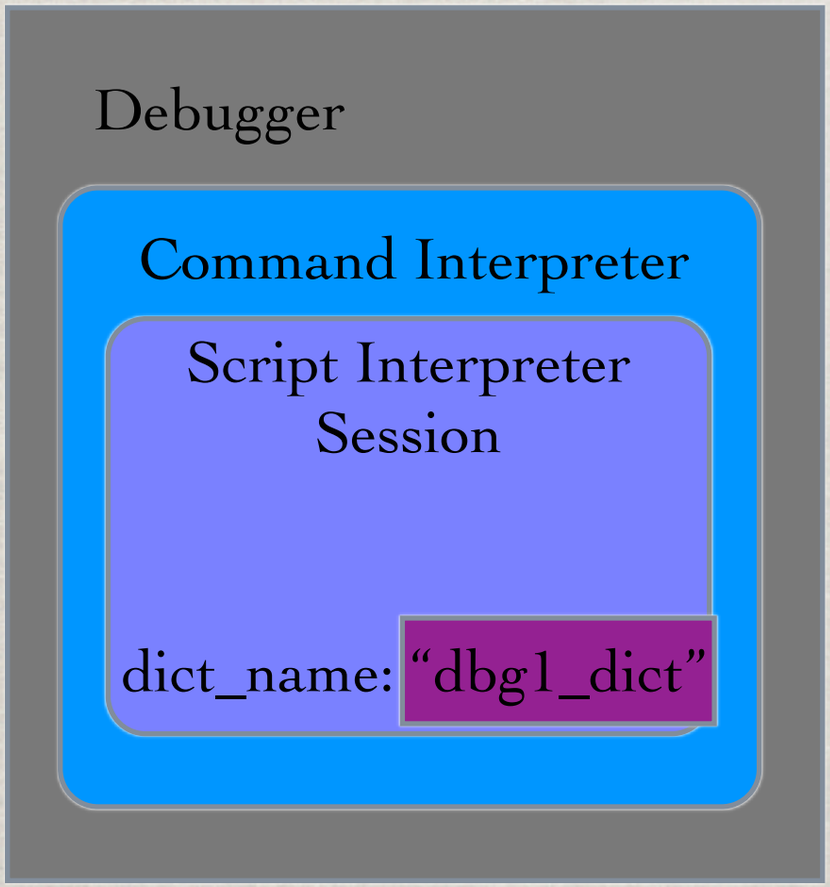


```
sprintf (buffer,
         “python_run_interpreter (‘%s’)”,
          dict_name);
```

Invoking Interactive Script Interpreter

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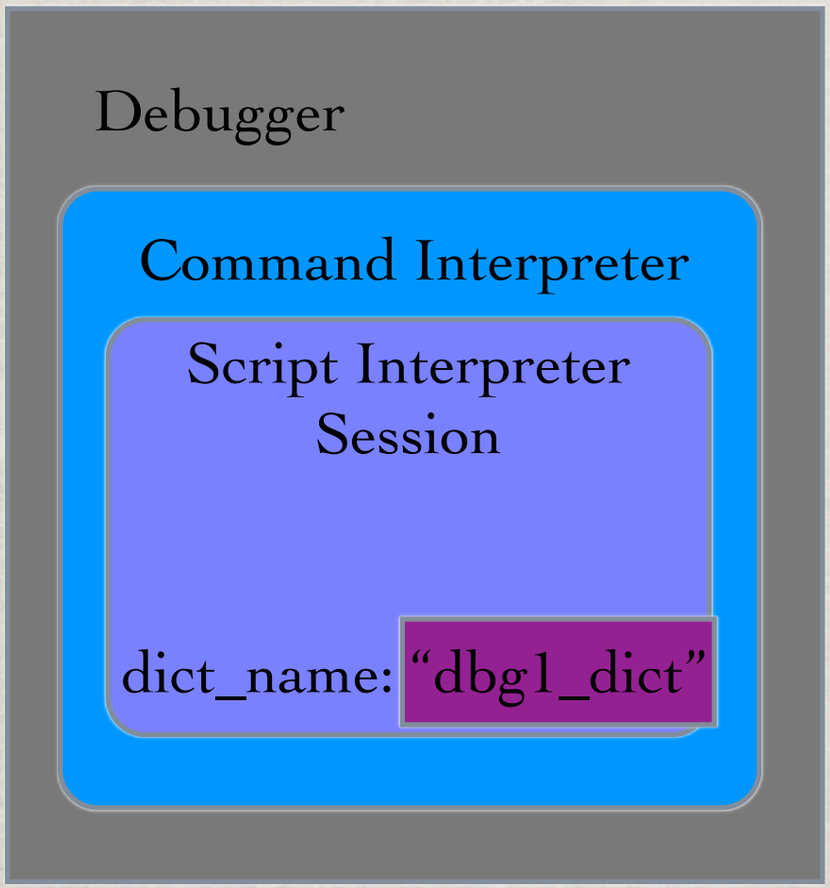


```
sprintf (buffer,
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         dict_name);
```

buffer = "python_run_interpreter ('dbg1_dict')"

Invoking Interactive Script Interpreter

(lldb) script


```
sprintf (buffer,
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Invoking Interactive Script Interpreter

(lldb) script


```
sprintf (buffer,
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```

PyRun_SimpleString (buffer);

Invoking Interactive Script Interpreter

(lldb) script


```
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```

Set sys.stdin & sys.stdout to appropriate values
Set termios appropriately

PyRun_SimpleString (buffer);

Invoking Interactive Script Interpreter

(lldb) script


```
sprintf (buffer,
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          dict_name);
```

Set sys.stdin & sys.stdout to appropriate values
Set termios appropriately

PyRun_SimpleString (buffer);

Restore sys.stdin & sys.stdout values
Restore termios

More About LLDB Breakpoint scripts...

(lldb) break command add -s python <bp_num>

More About LLDB Breakpoint scripts...

(lldb) break command add -s python <bp_num>
Enter your Python commands. Type 'DONE' to end.
>

More About LLDB Breakpoint scripts...

```
(lldb) break command add -s python <bp_num>
Enter your Python commands.  Type 'DONE' to end.
>   count = count + 1
>
```

More About LLDB Breakpoint scripts...

(lldb) break command add -s python <bp_num>
Enter your Python commands. Type 'DONE' to end.
> count = count + 1
> print "Hit this breakpoint " + repr (count) + " times!"
>

More About LLDB Breakpoint scripts...

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Enter your Python commands.  Type 'DONE' to end.
>   count = count + 1
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>   DONE
(lldb)
```

More About LLDB Breakpoint scripts...

```
count = count + 1
print “Hit this breakpoint ” + repr (count) + “ times!”
```

More About LLDB Breakpoint scripts...

```
def some_obscure_function_name (frame, bp_loc):
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        print “Hit this breakpoint ” + repr (count) + “ times!”
```

More About LLDB Breakpoint scripts...

```
def some_obscure_function_name (frame, bp_loc):
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```

LLDB Convenience Variables

More About LLDB Breakpoint scripts...

```
def some_obscure_function_name (frame, bp_loc):
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```

LLDB Convenience Variables

```
some_obscure_function_name (cur_frame, cur_bp_loc)
```

More About LLDB Breakpoint scripts...

```
def some_obscure_function_name (frame, bp_loc):
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More About LLDB Breakpoint scripts...

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def some_obscure_function_name (frame, bp_loc):
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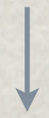
```

Breakpoint Script Commands - Create

(lldb) break command add -s python <bp_num>



Breakpoint Script Commands - Create

(lldb) break command add -s python <bp_num>

Collect script text from user

Breakpoint Script Commands - Create

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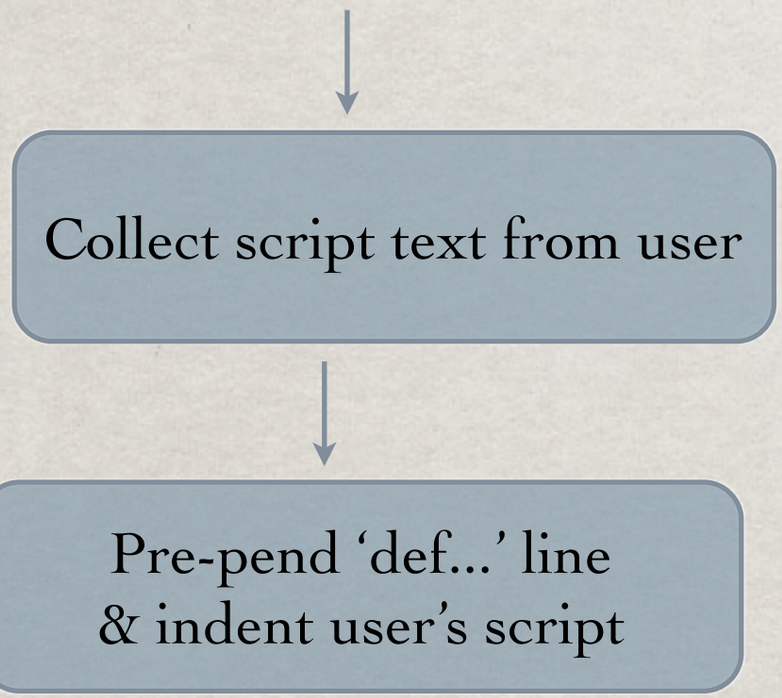

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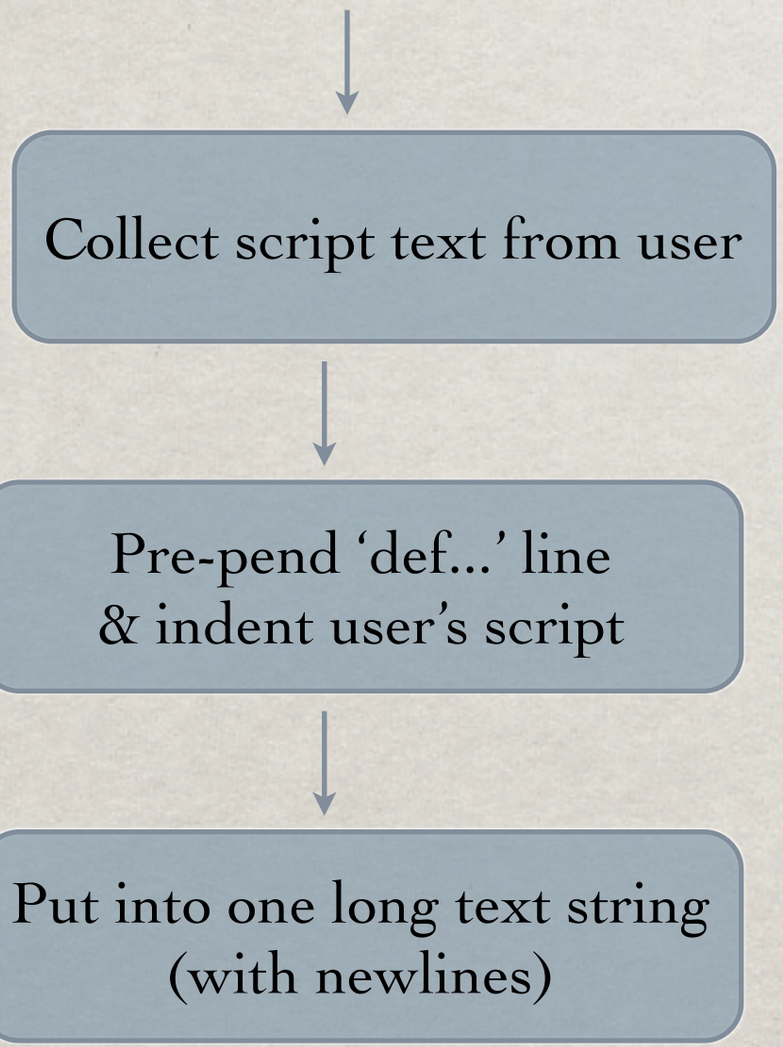

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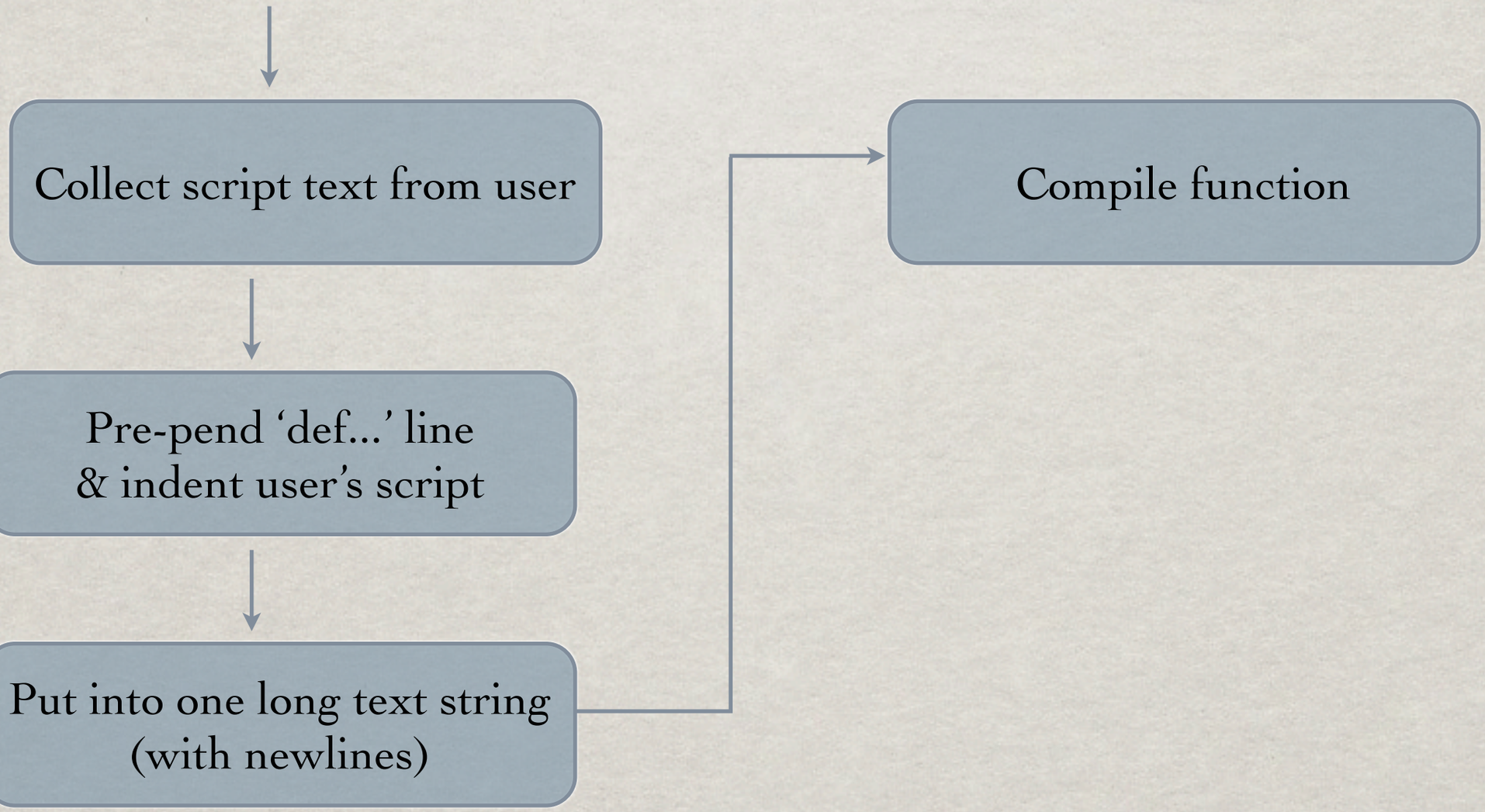

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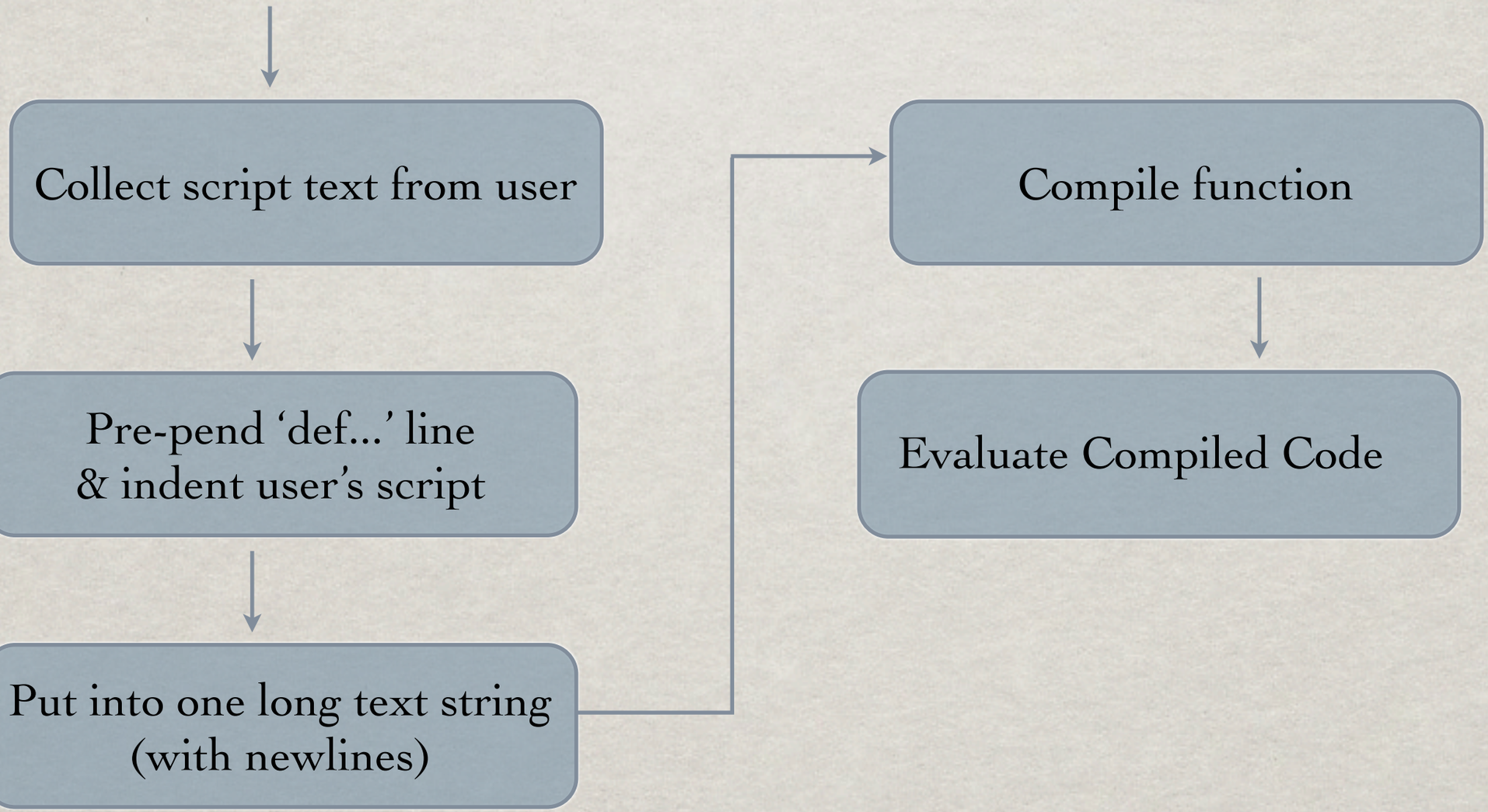

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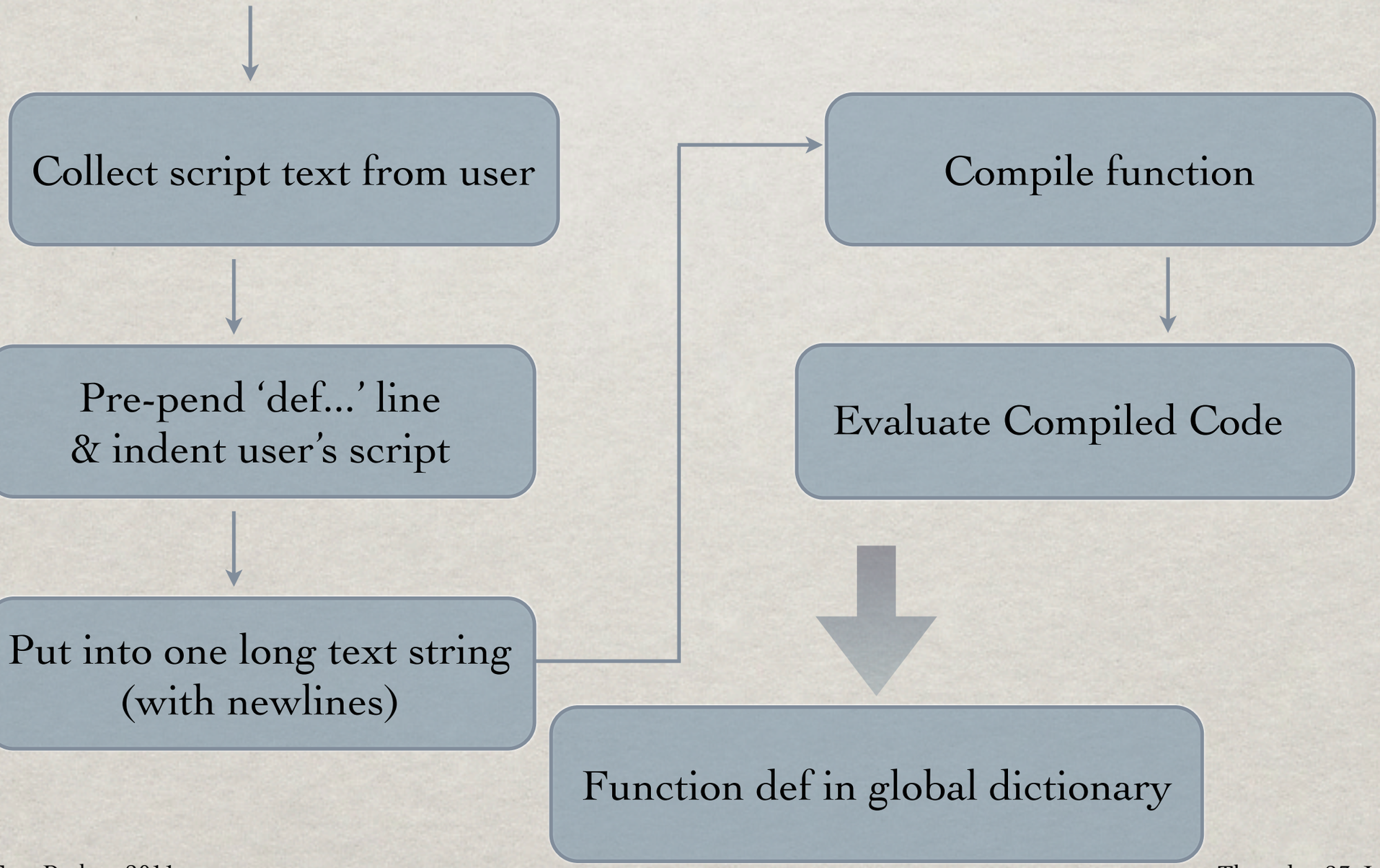

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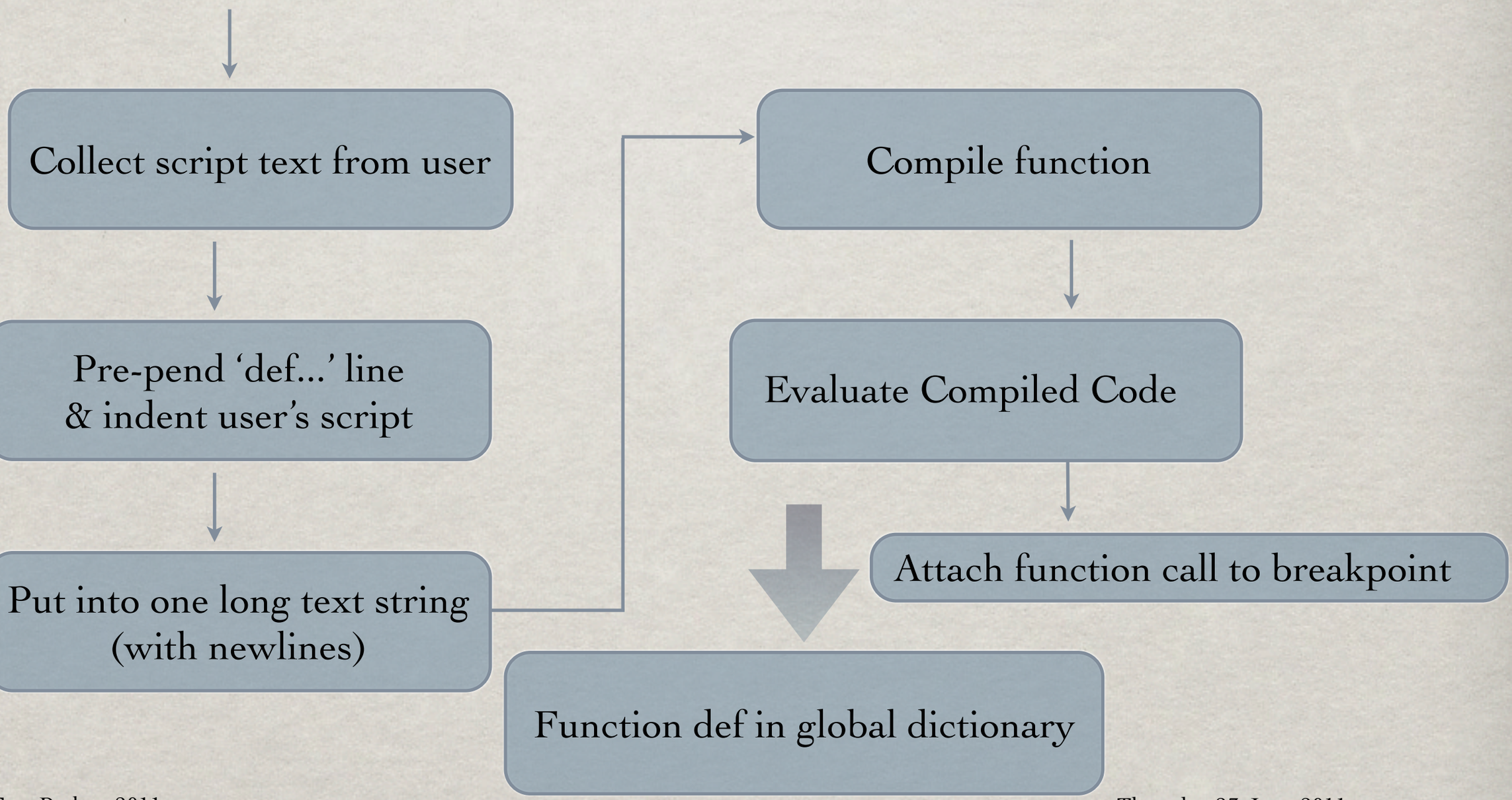

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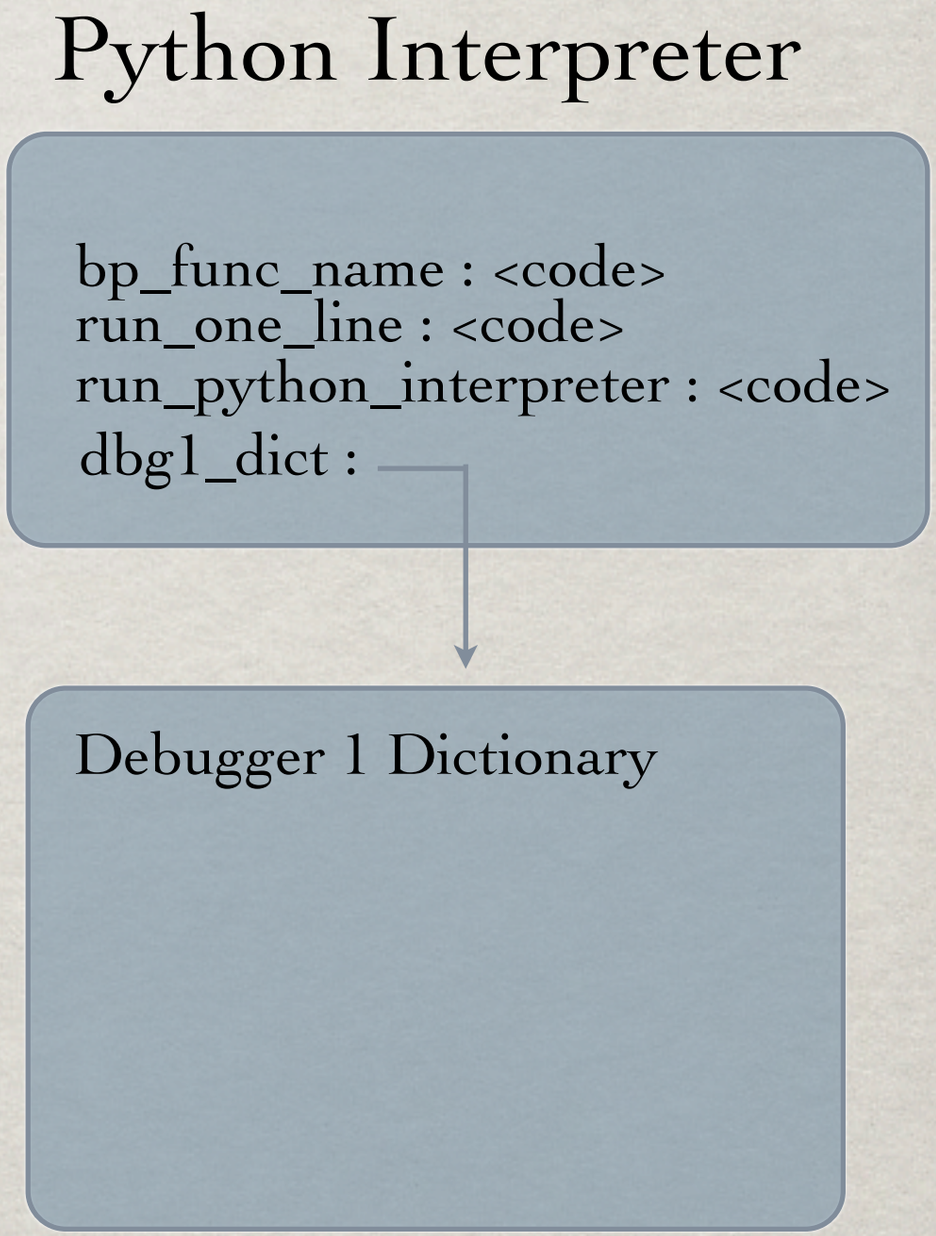

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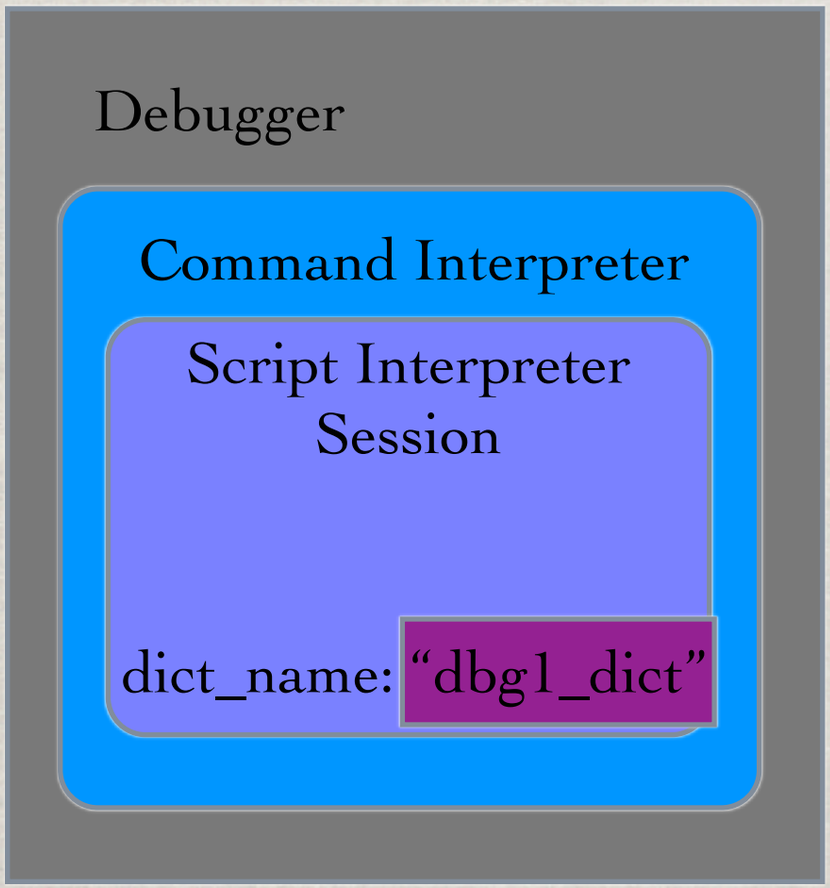

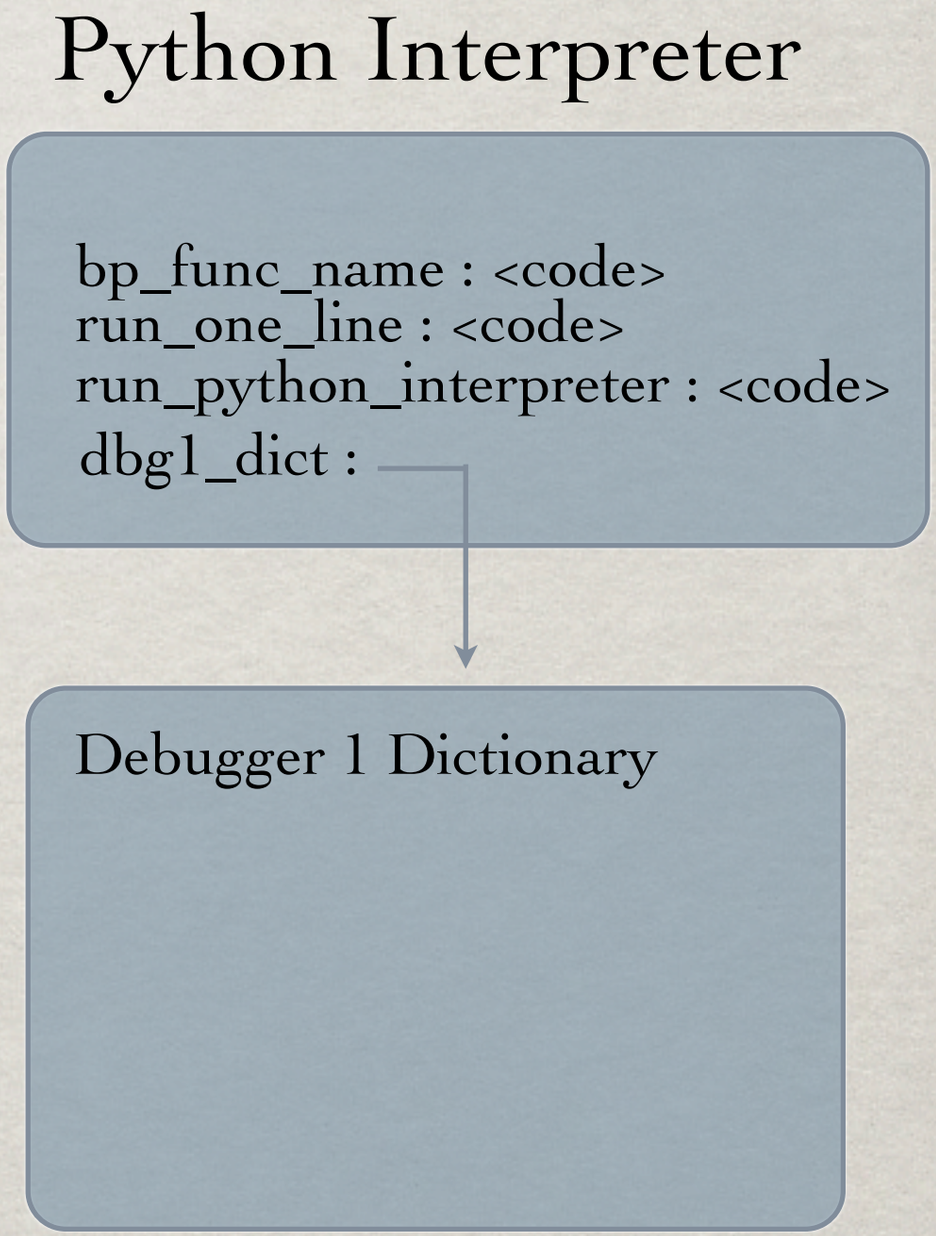

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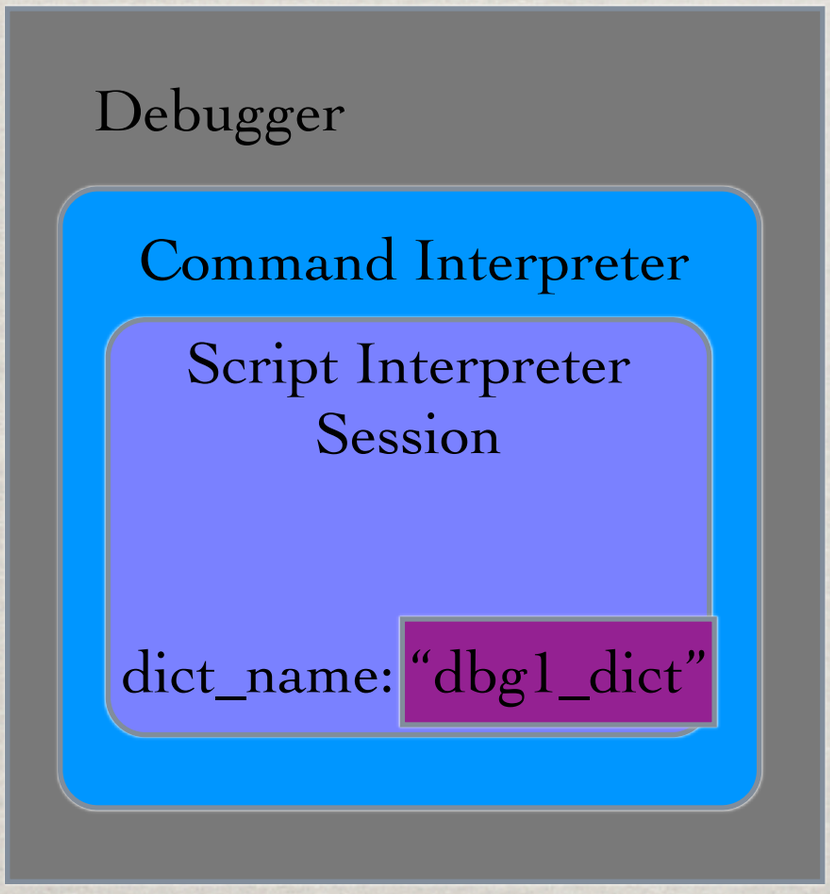

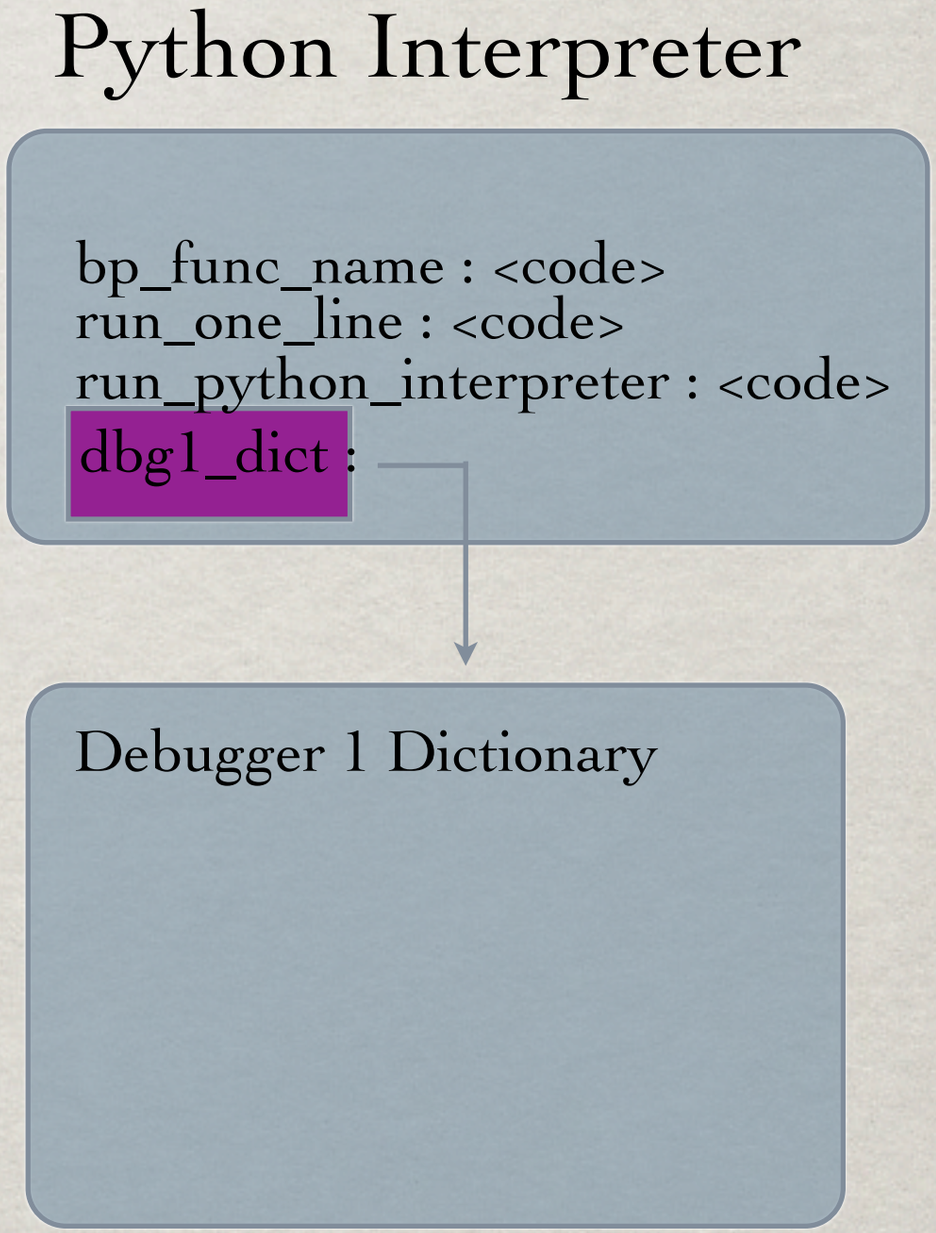

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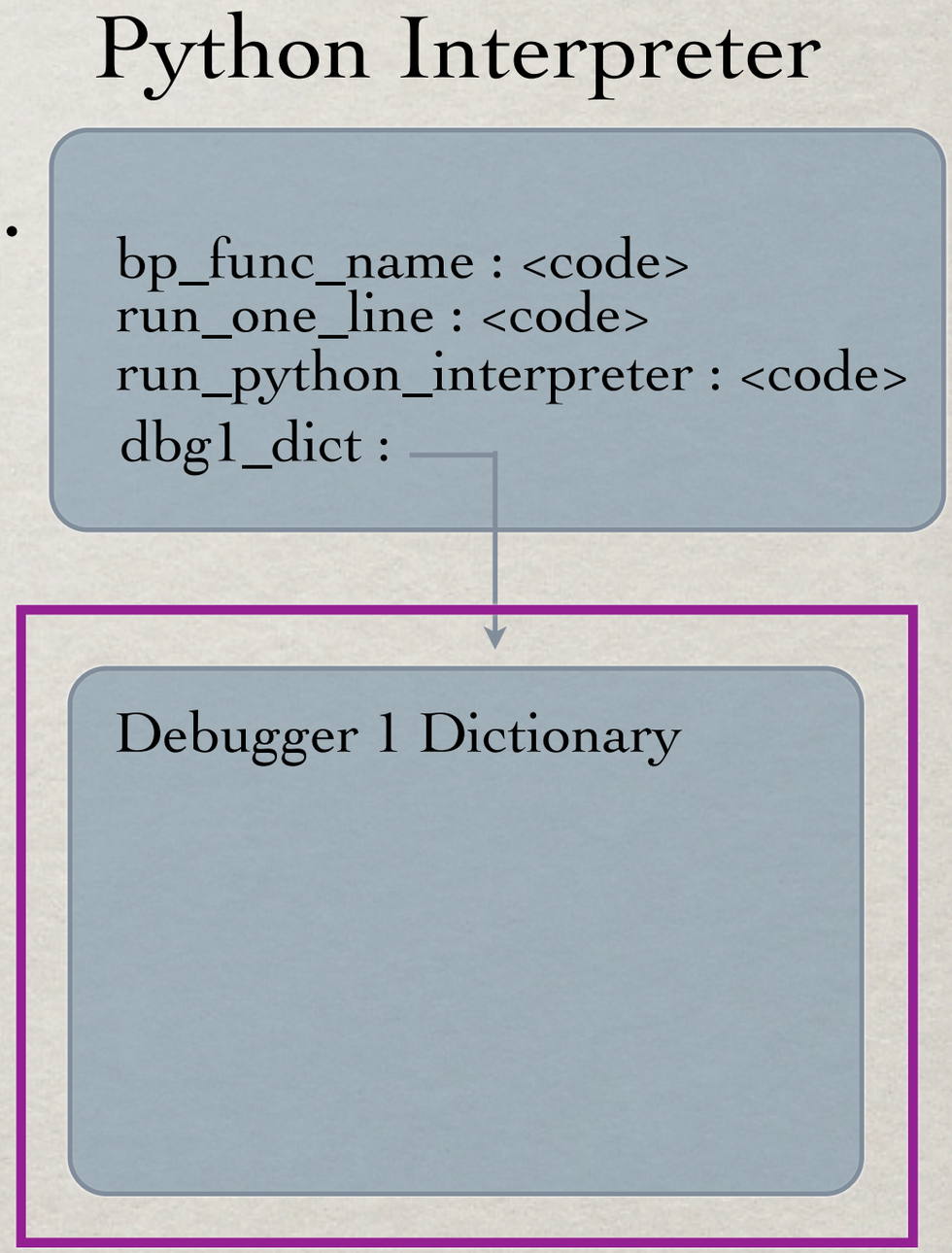

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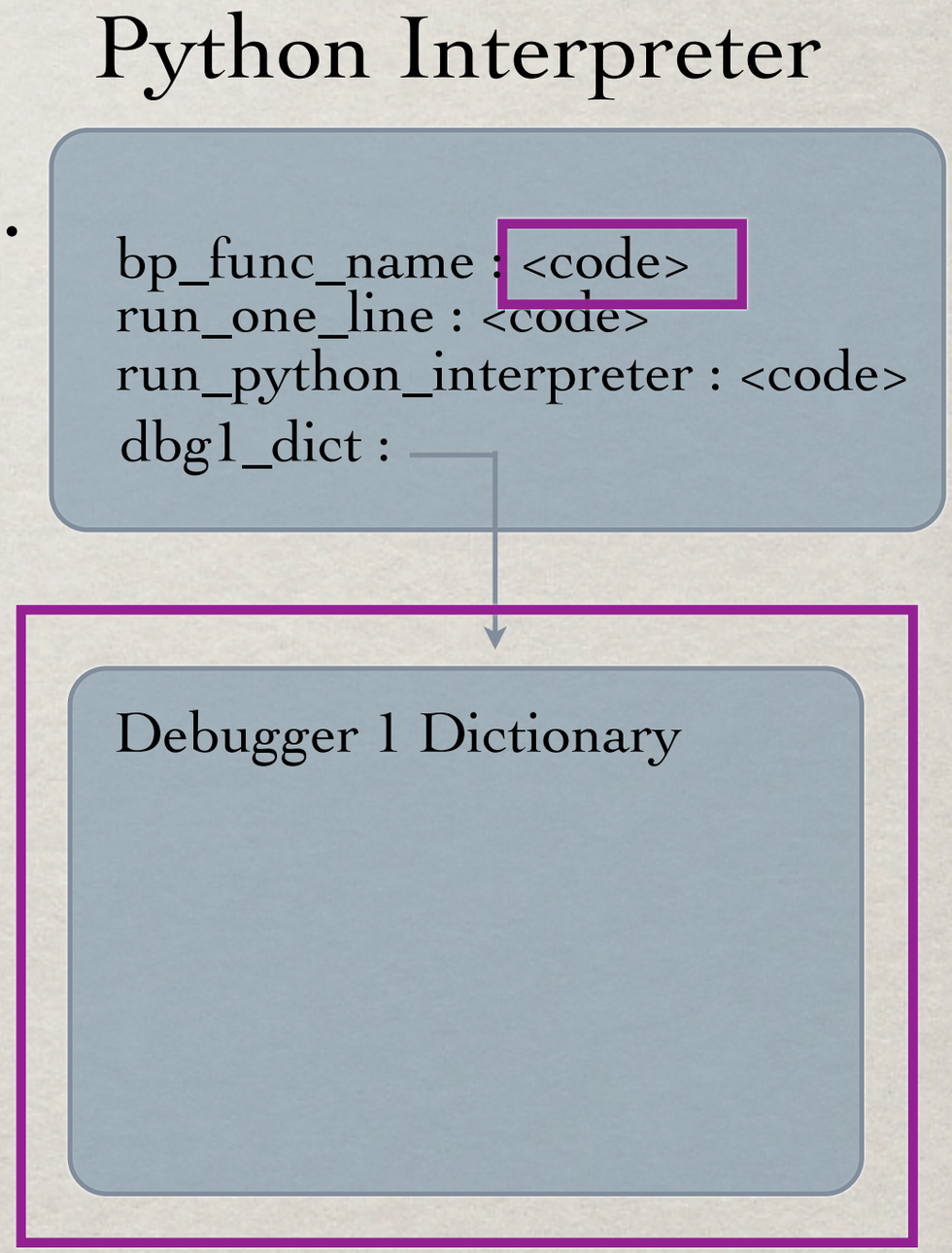

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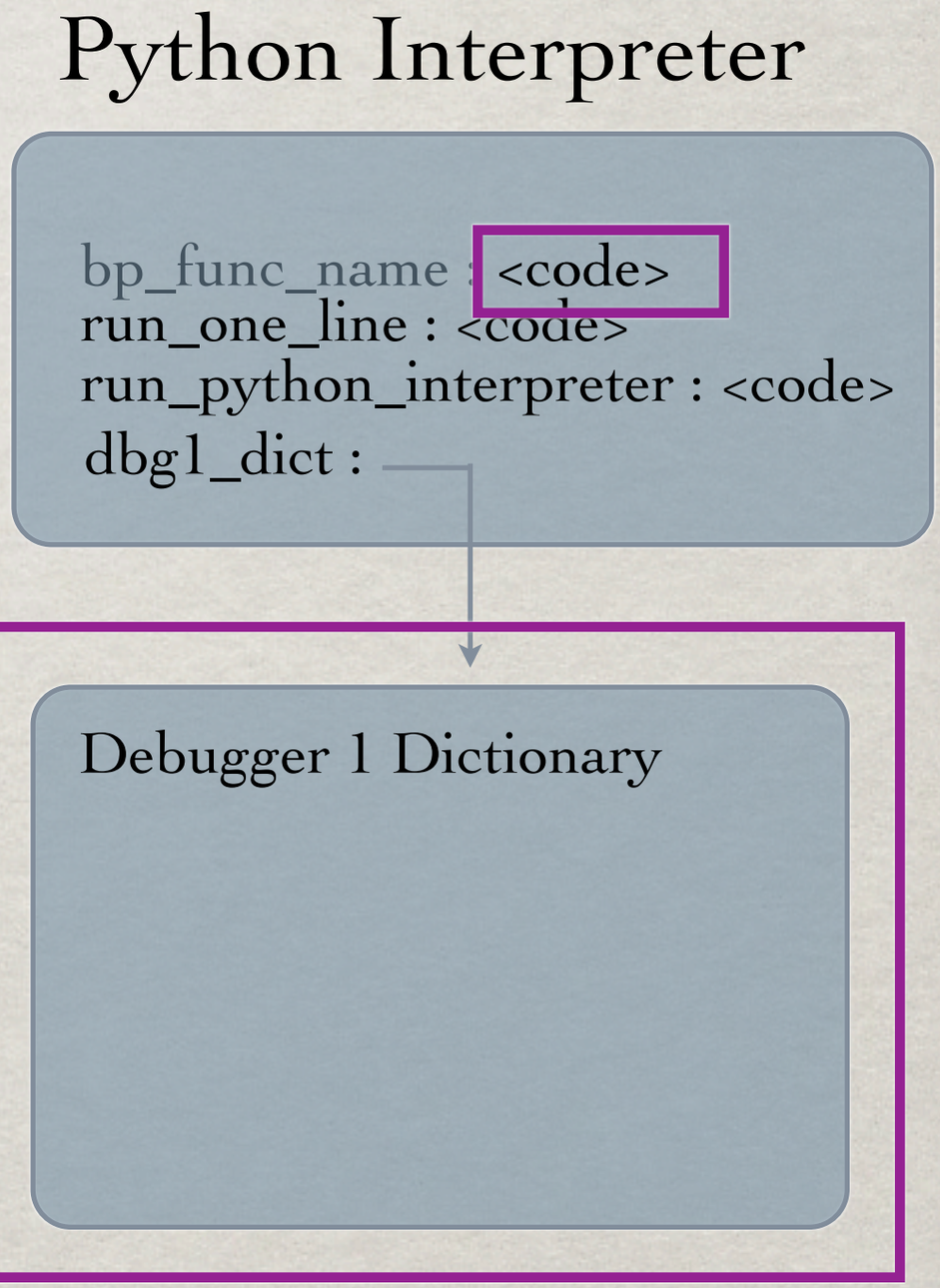


Breakpoint Script Commands - Call

(lldb) run
Process stopped. Hit breakpoint.

bp_func_name : <code>

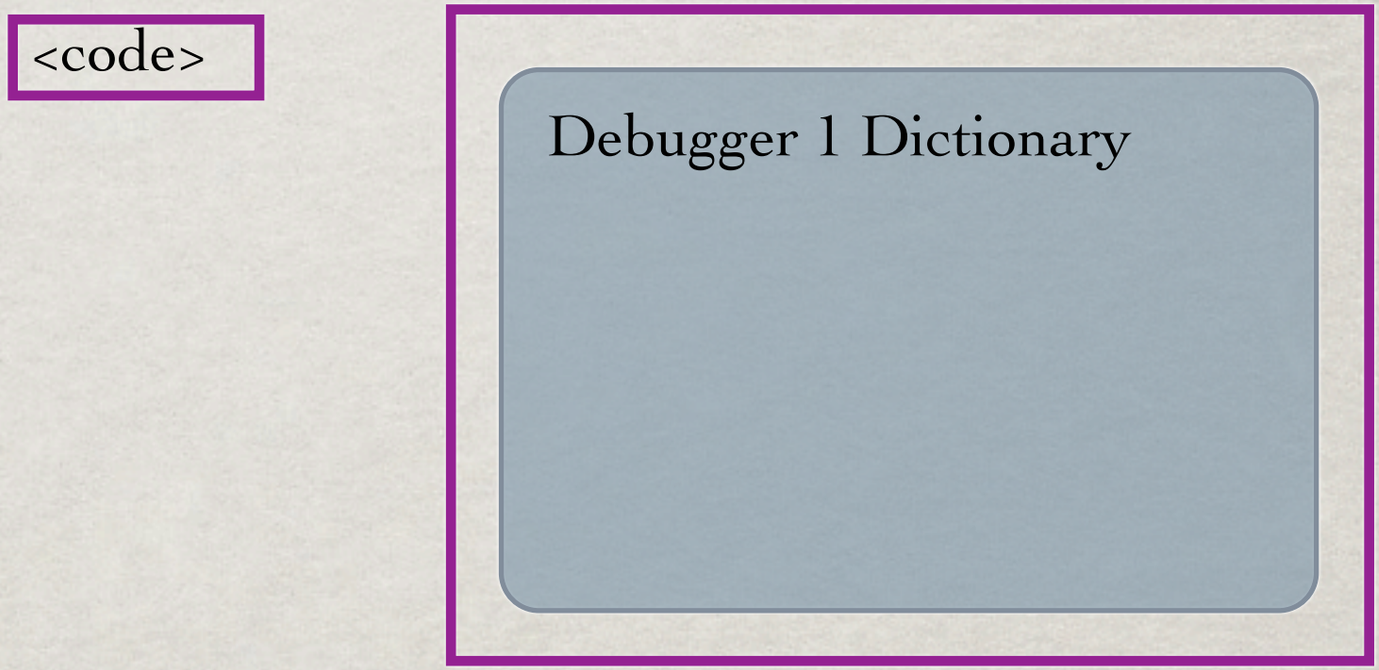
Debugger 1 Dictionary

Breakpoint Script Commands - Call

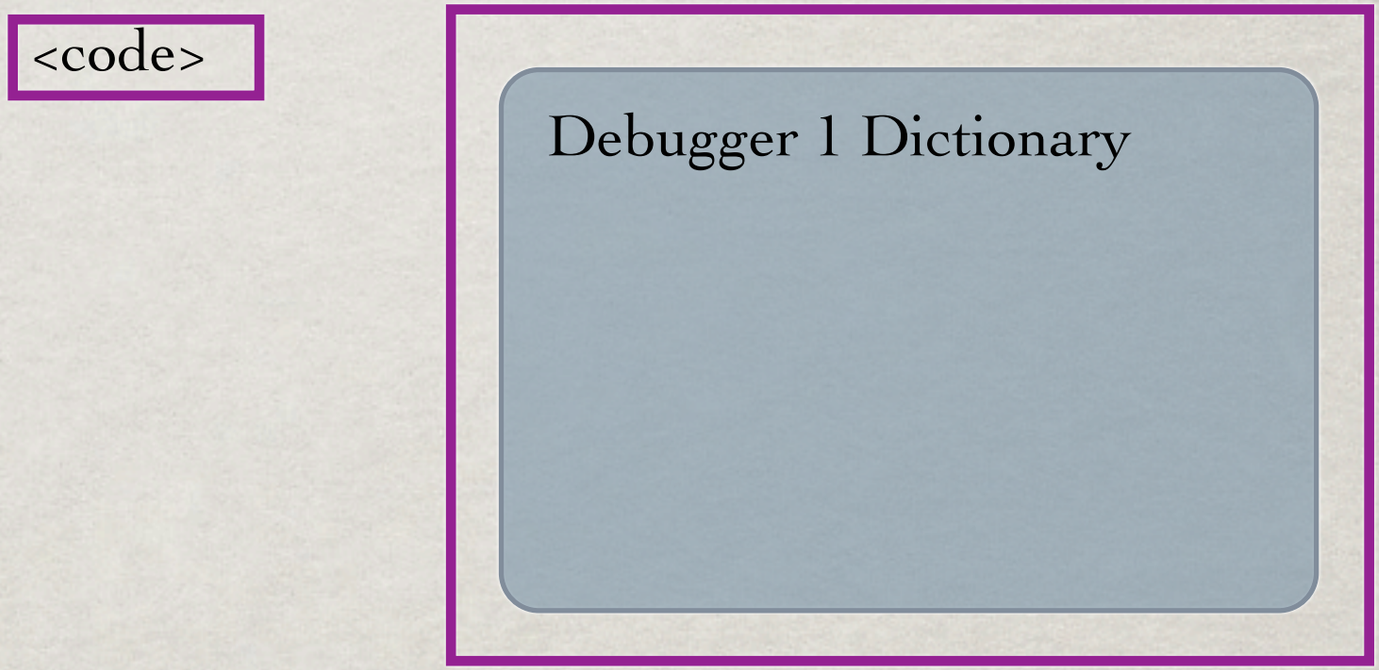
<code>

Debugger 1 Dictionary

Breakpoint Script Commands - Call



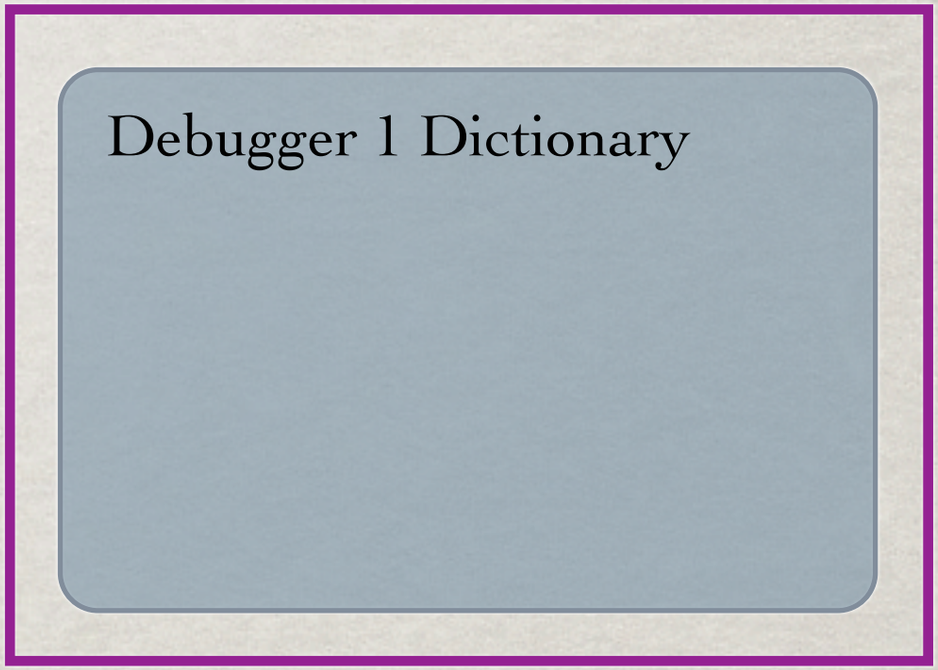
Breakpoint Script Commands - Call



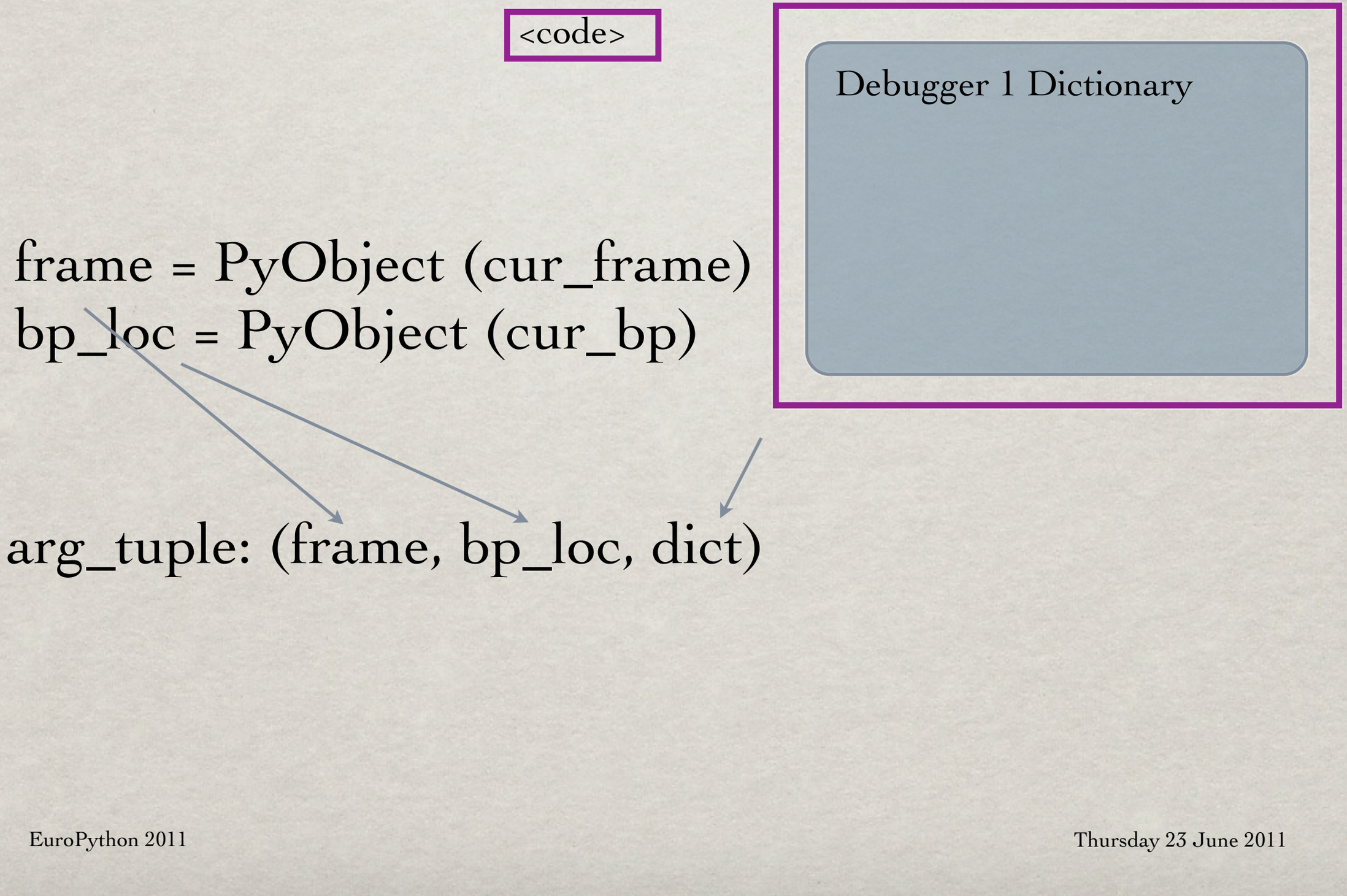
Breakpoint Script Commands - Call

<code>

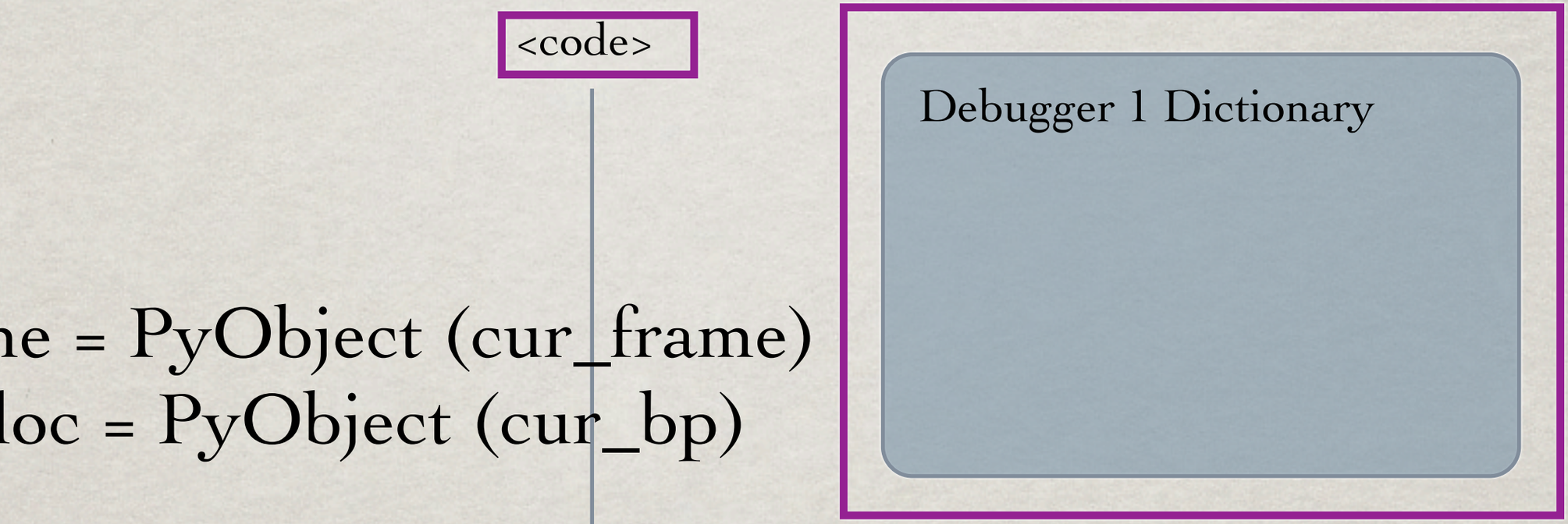
frame = PyObject (cur_frame)
bp_loc = PyObject (cur_bp)



Breakpoint Script Commands - Call



Breakpoint Script Commands - Call



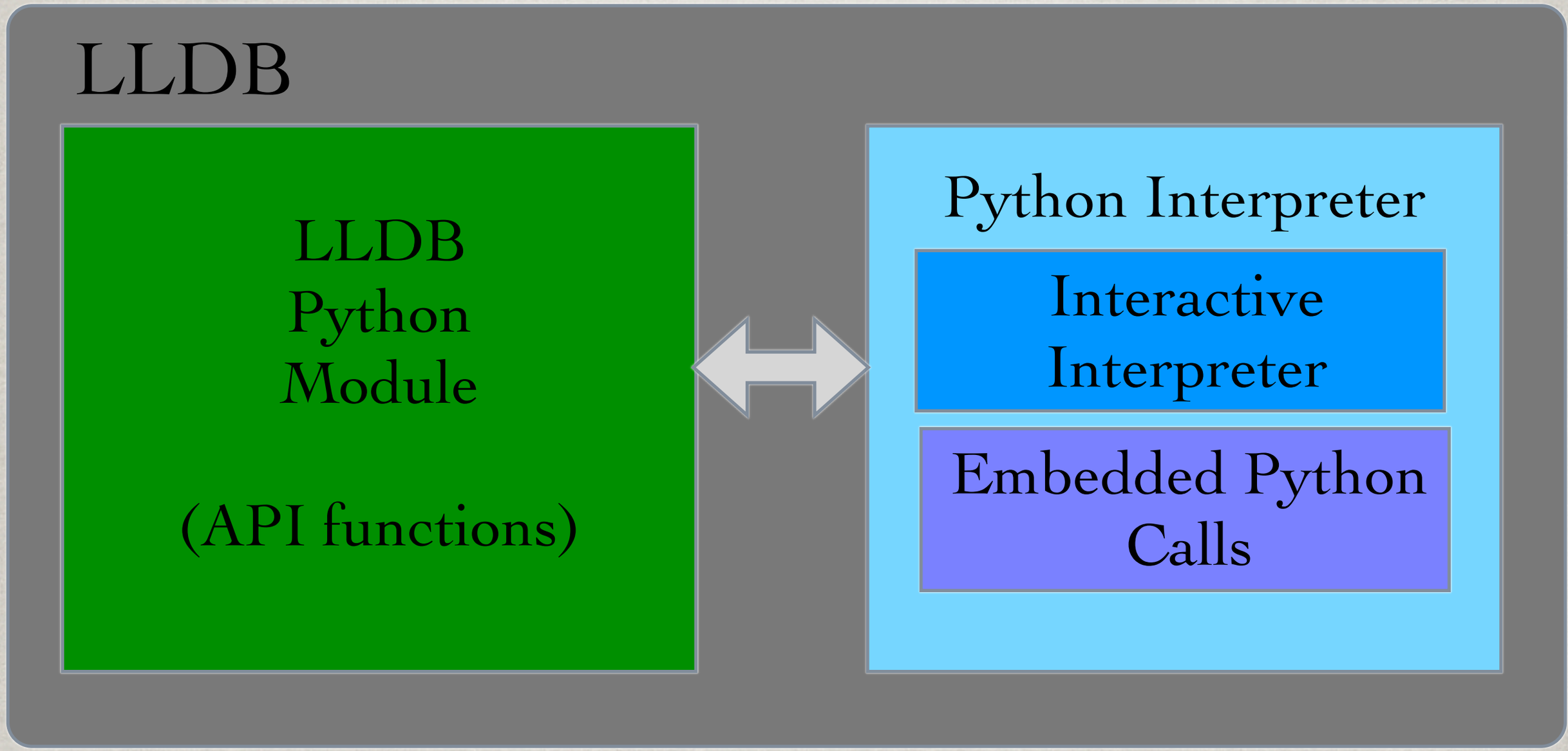
frame = PyObject (cur_frame)

bp_loc = PyObject (cur_bp)

arg_tuple: (frame, bp_loc, dict)

PyObject_CallObject (<code>, arg_tuple)

Python In LLDB - More Detail



Python In LLDB - More Detail

LLDB
Python
Module

(API functions)

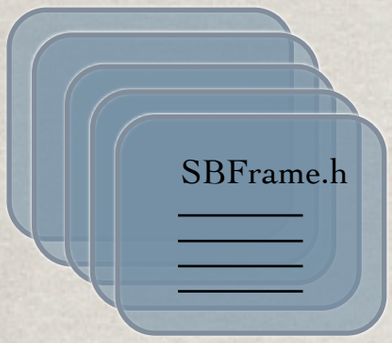
About SWIG...

- SWIG = "Simplified Wrapper and Interface Generator"

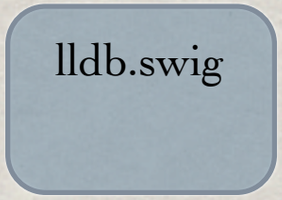
- Tool that parses C & C++ interfaces

- Generates "glue code" allowing Python to call the C/C++ code

Building The LLDB Python API Module

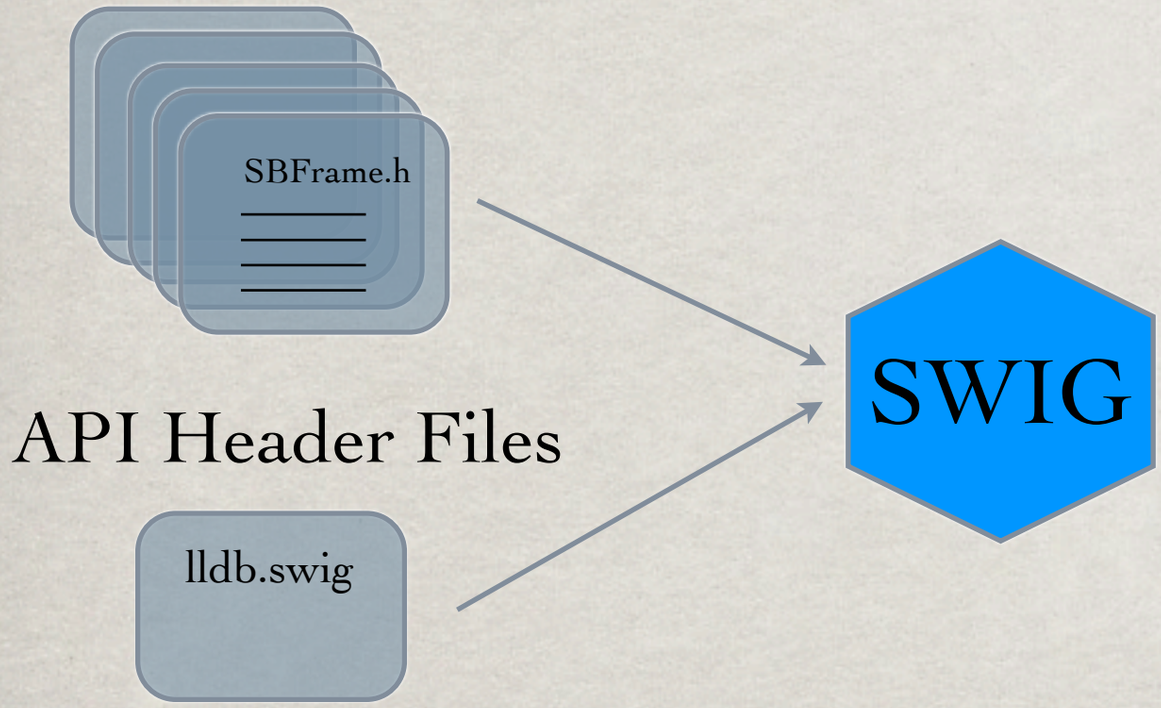


API Header Files



SWIG Input File

Building The LLDB Python API Module



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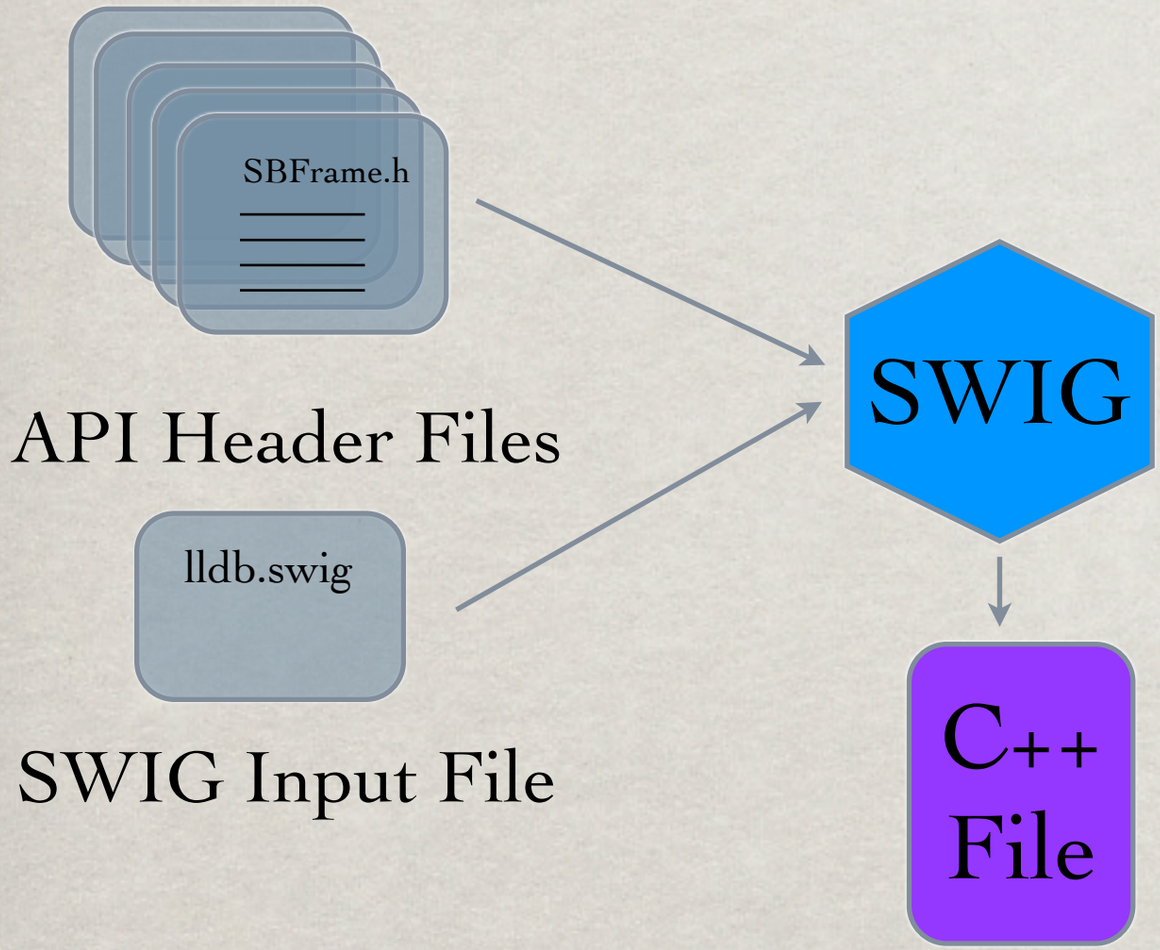

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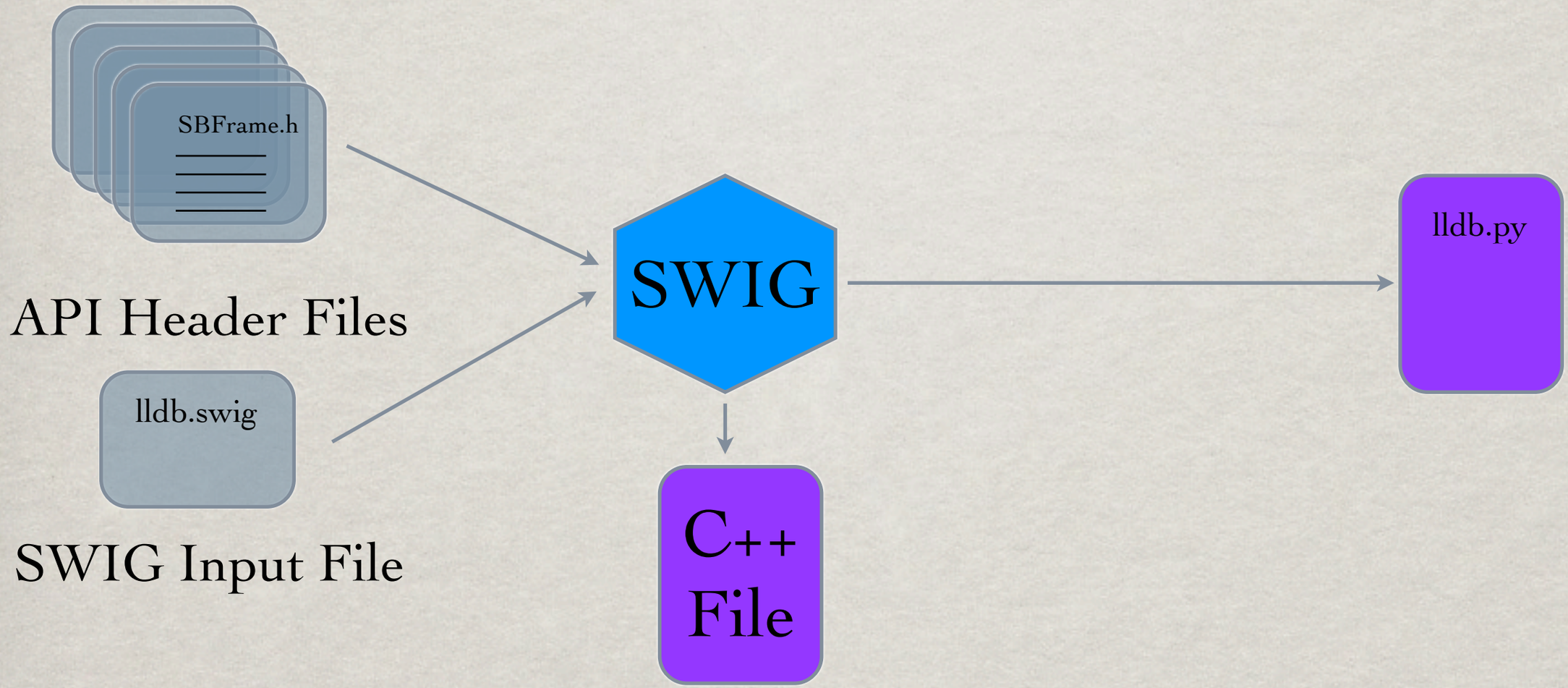

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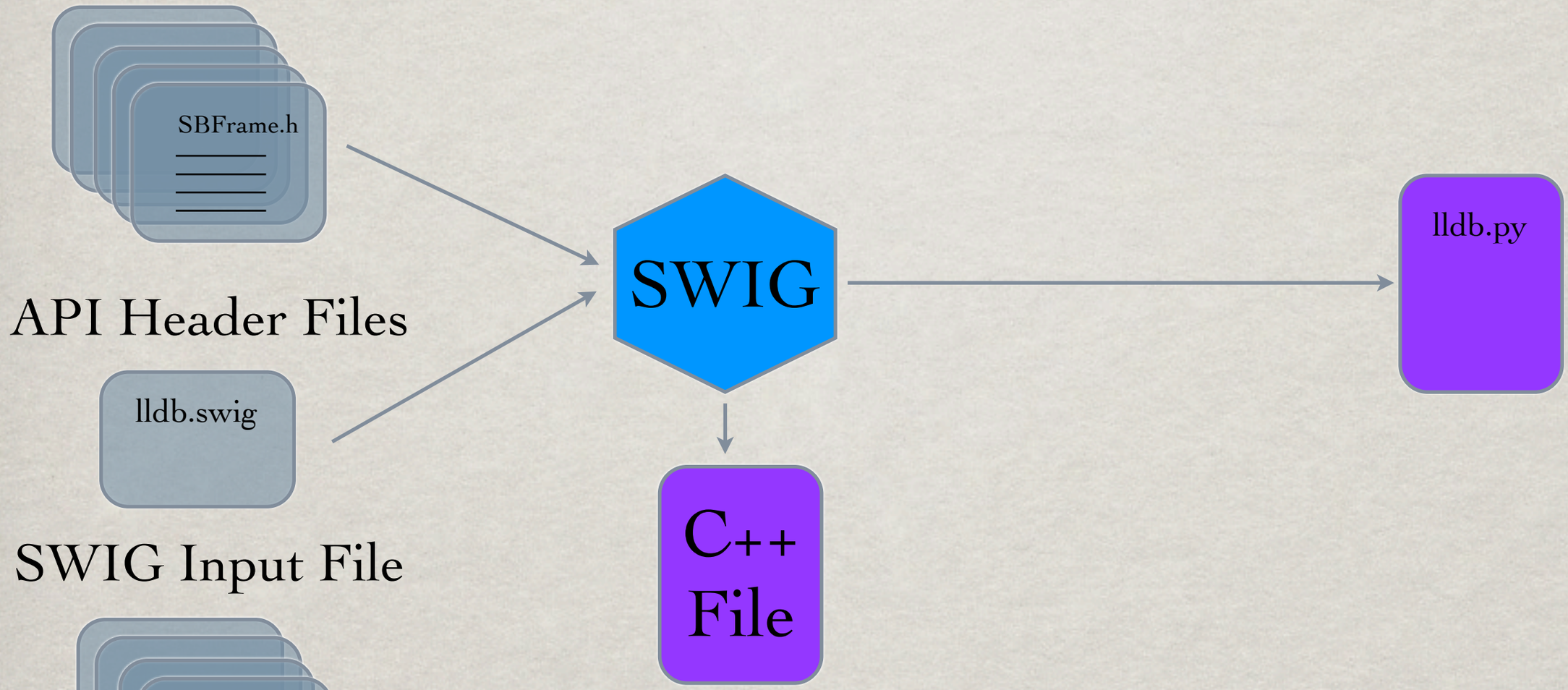

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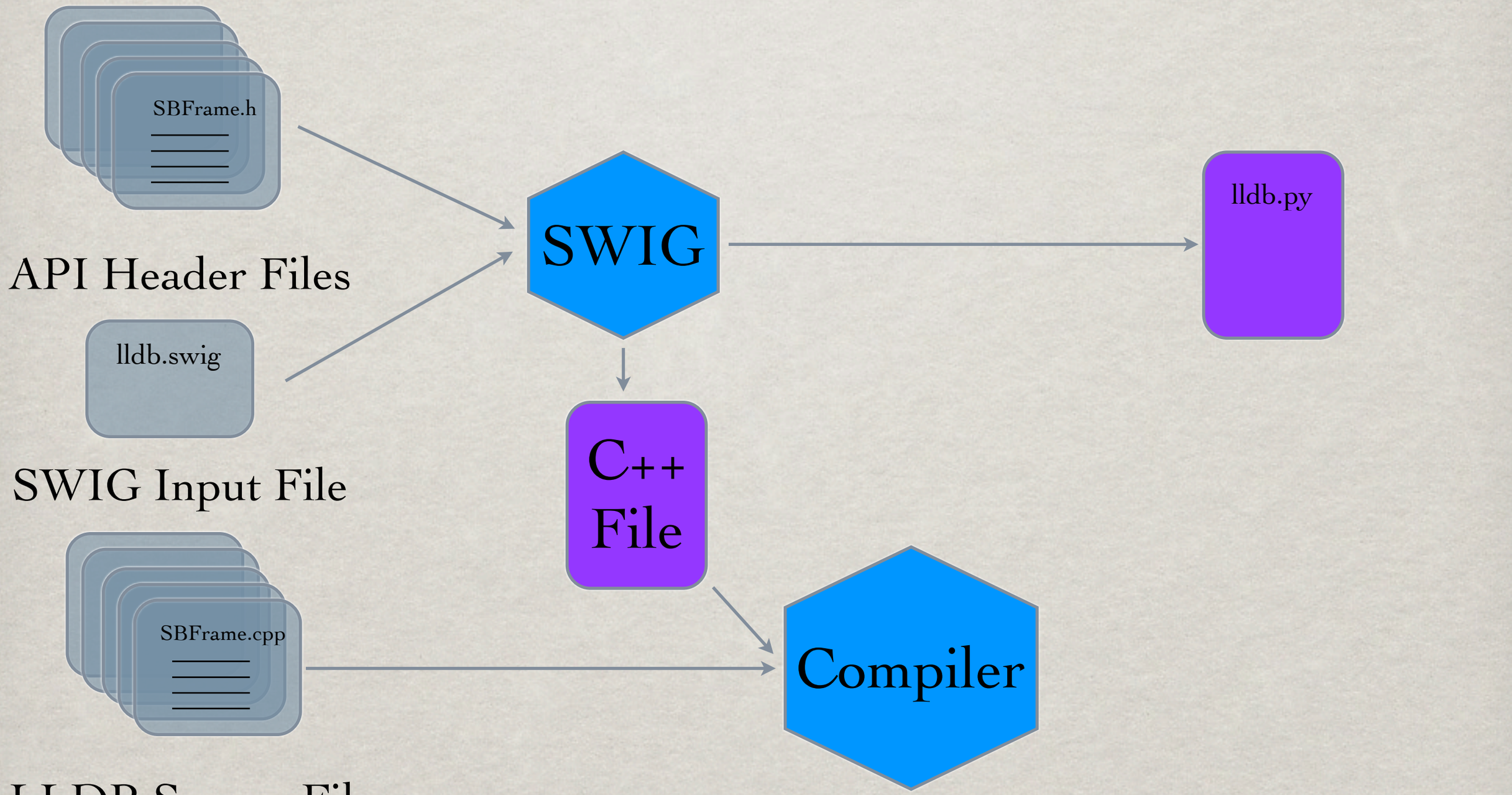

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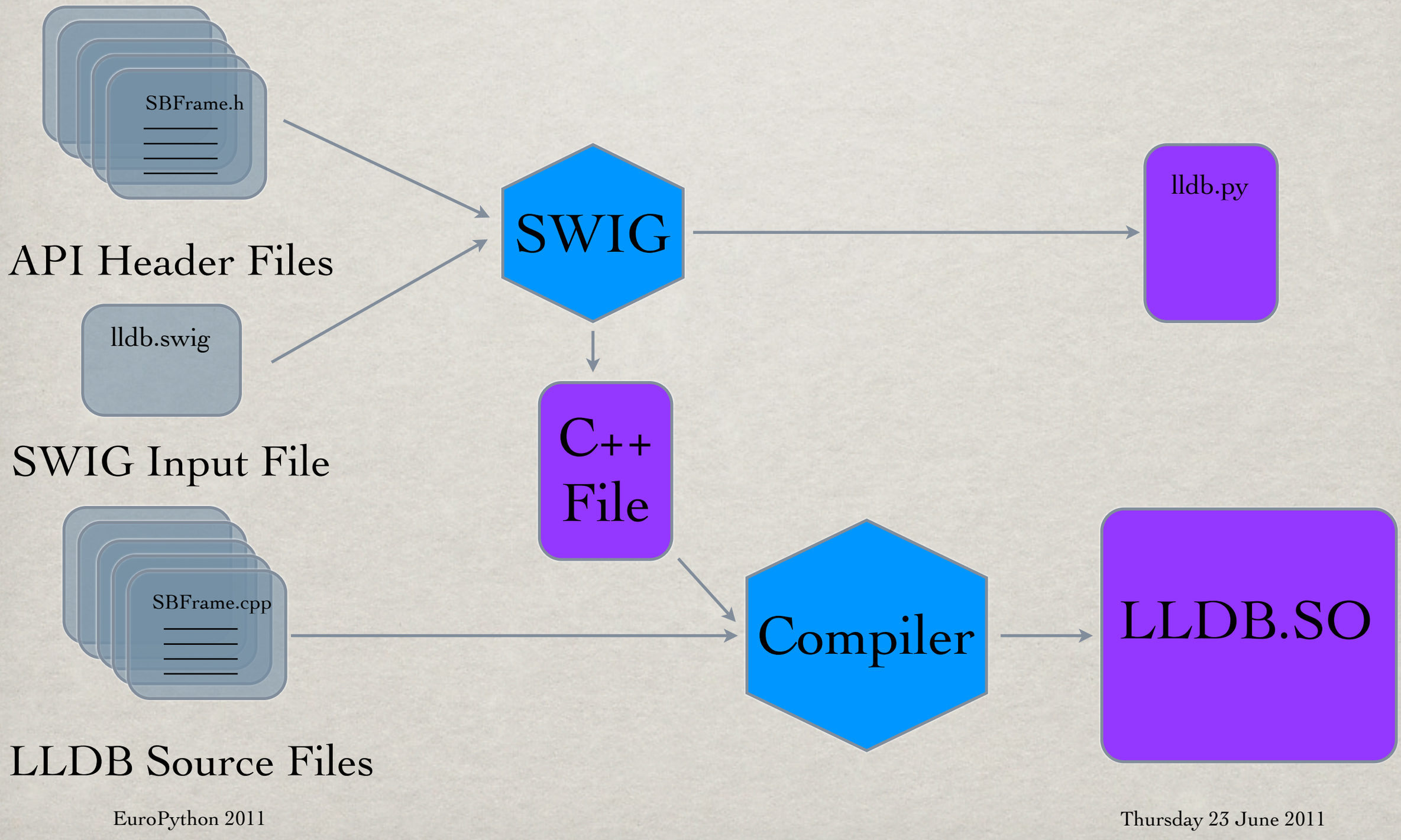

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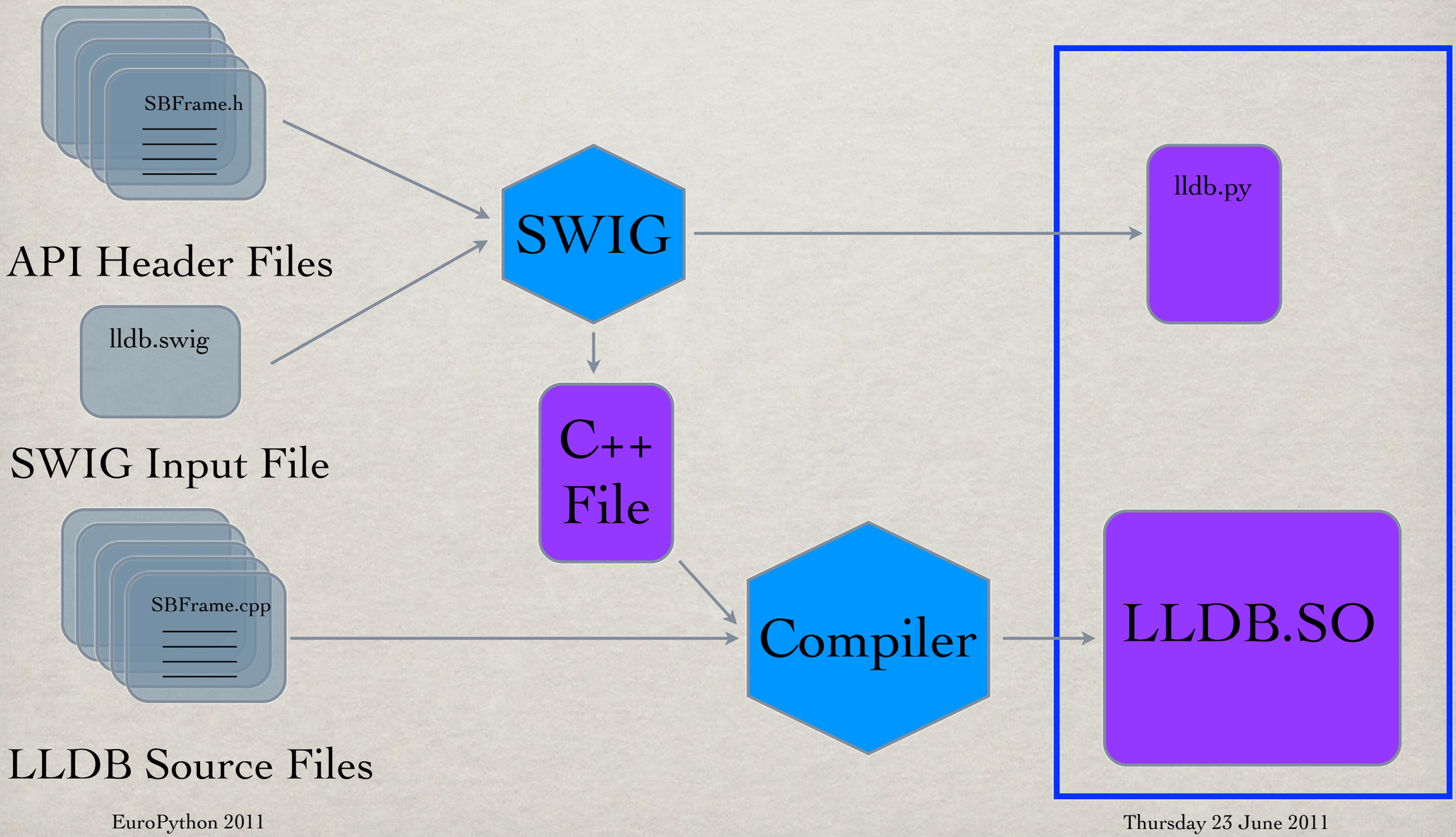

Outline

- What is LLDB?
- Python in LLDB
- Particular Problems (& Solutions)
- Example Using Python to Debug Problem
- Questions

Particular Problems & Solutions

- Passing Pointers & C++ Objects to Python
- Single Dictionary Across Debugger Session
- Multiple Debuggers/Single Interpreter

Particular Problems & Solutions

- Passing Pointers & C++ Objects to Python
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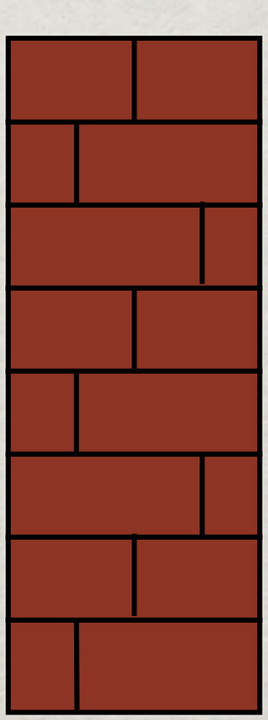
Passing Pointers & C++ Objects TO Python

- API functions operate on debugger objects
  - targets, processes, threads, frames, etc.
- LLDB stores them as objects or pointers
- Embedded Python only passes **scalar** data types back and forth (mostly)
- So...how to get LLDB objects "over" to Python?

How To Call GetNumThreads()?

(lldb) script
>>> ???

Interactive Python Interpreter



(Process *) cur_process

Process Object

Process methods:

GetNumThreads()	0x1001f25ac
...	...
...	...

lldb debugger (C++ code)

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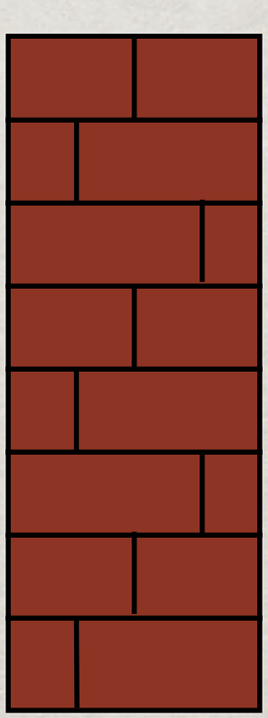

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NameError: name '...' is not defined

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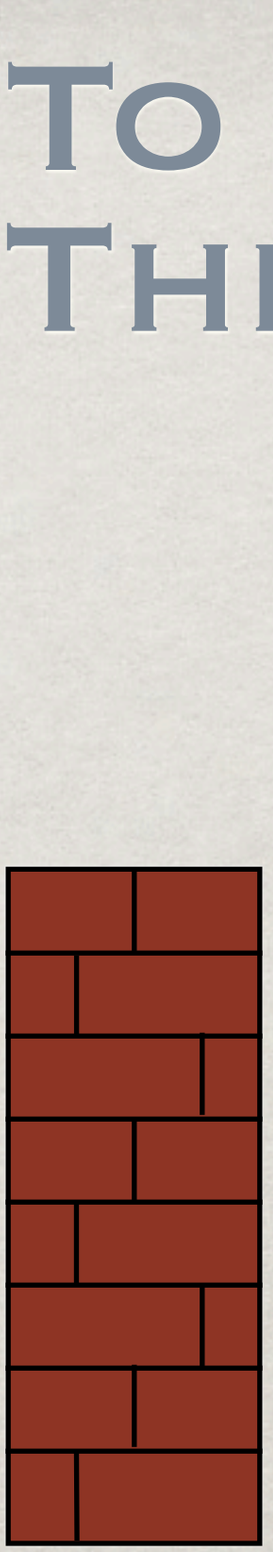

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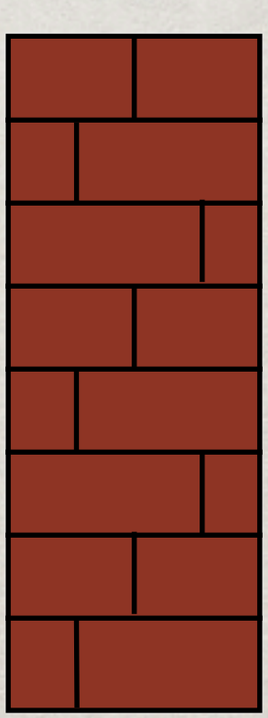

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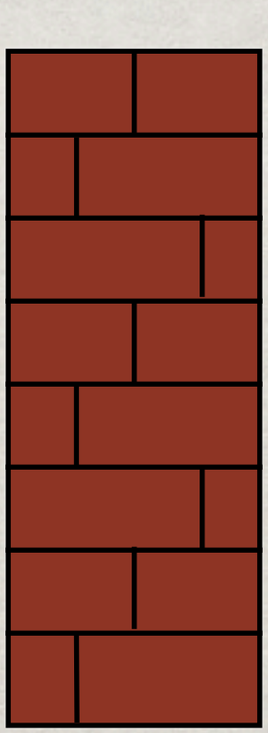

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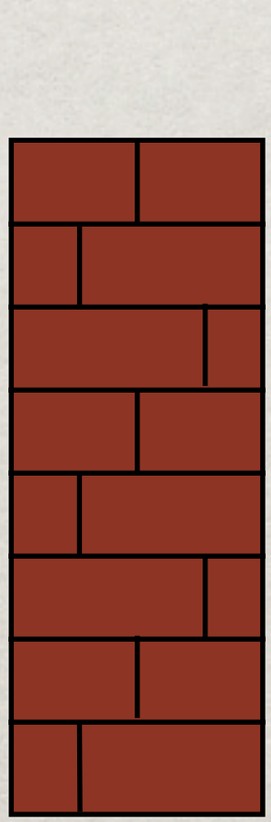

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(got nothing instead)

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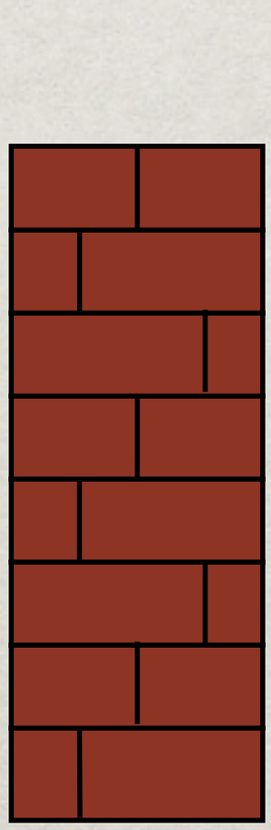

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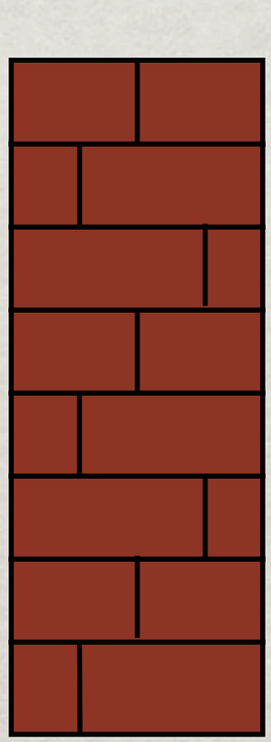

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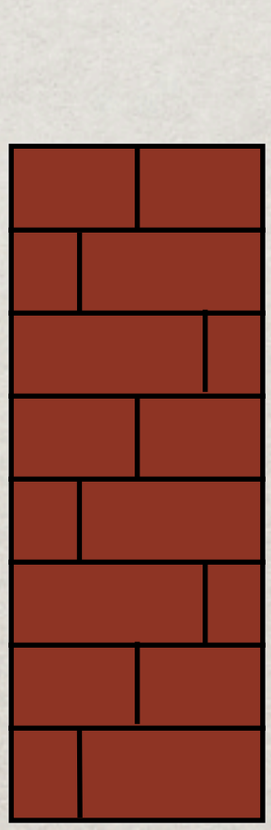

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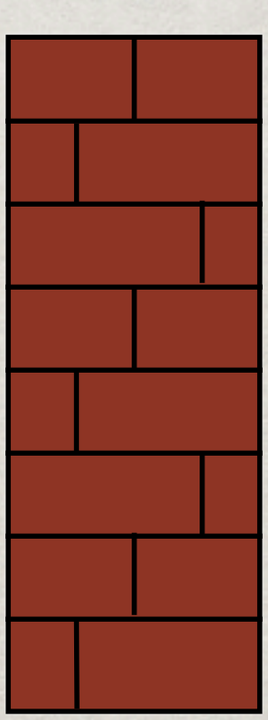
```
>>> process = ????
>>> process.GetNumThreads()
```

Interactive Python Interpreter



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GetNumThreads()	0x1001f25ac
...	...
...	...

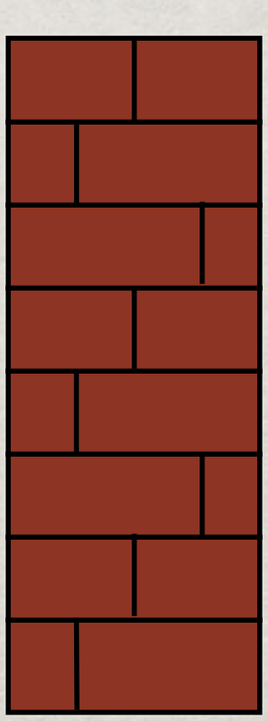
lldb debugger (C++ code)

How To Get Process Object Into Python Variable?

(lldb) script

```
>>> process = ????
>>> process.GetNumThreads()
```

Interactive Python Interpreter



(Process *) cur_process

Process Object

Process methods:

GetNumThreads()	0x1001f25ac
...	...
...	...

lldb debugger (C++ code)

Python-Provided conversions...

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    "anything" IFF... programmer writes conversion!

Solution (Part1): API Functions & Integers

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2. API functions exist to get one object from another

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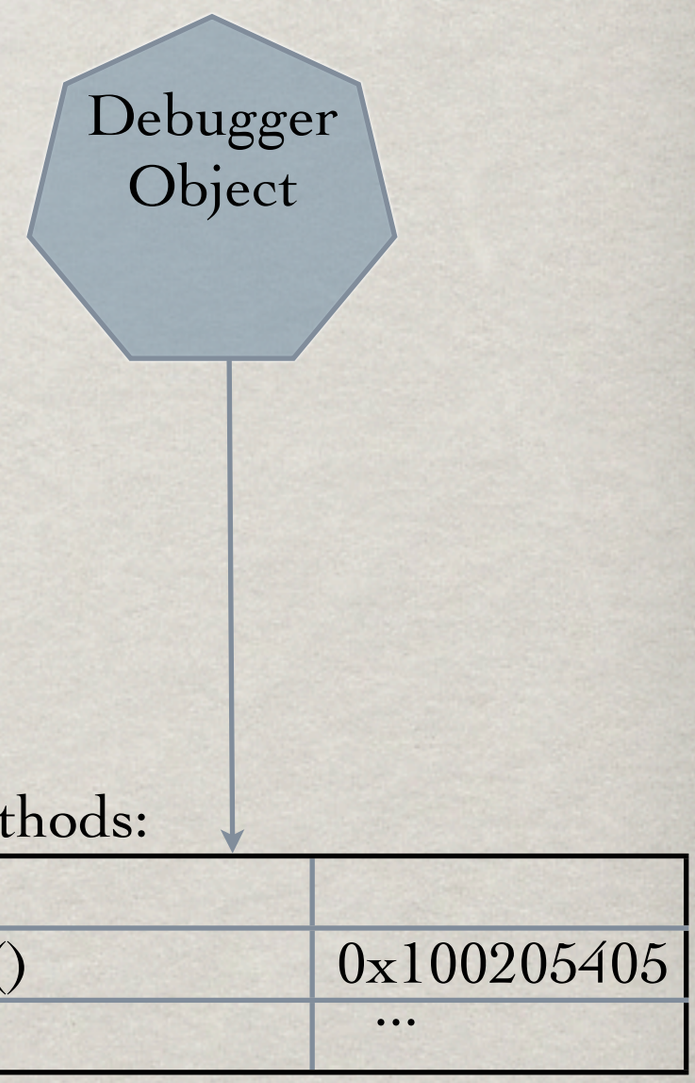
4. Use combination of API & integers

Getting a Single Object "across" - The Debugger



Getting a Single Object "across" - The Debugger

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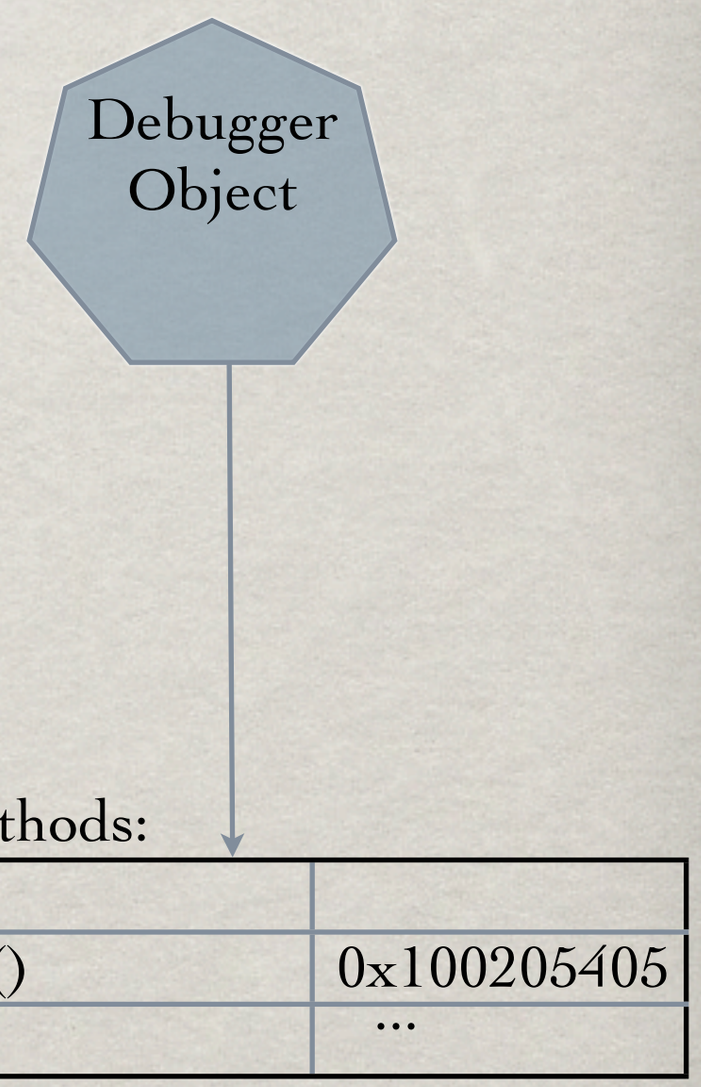

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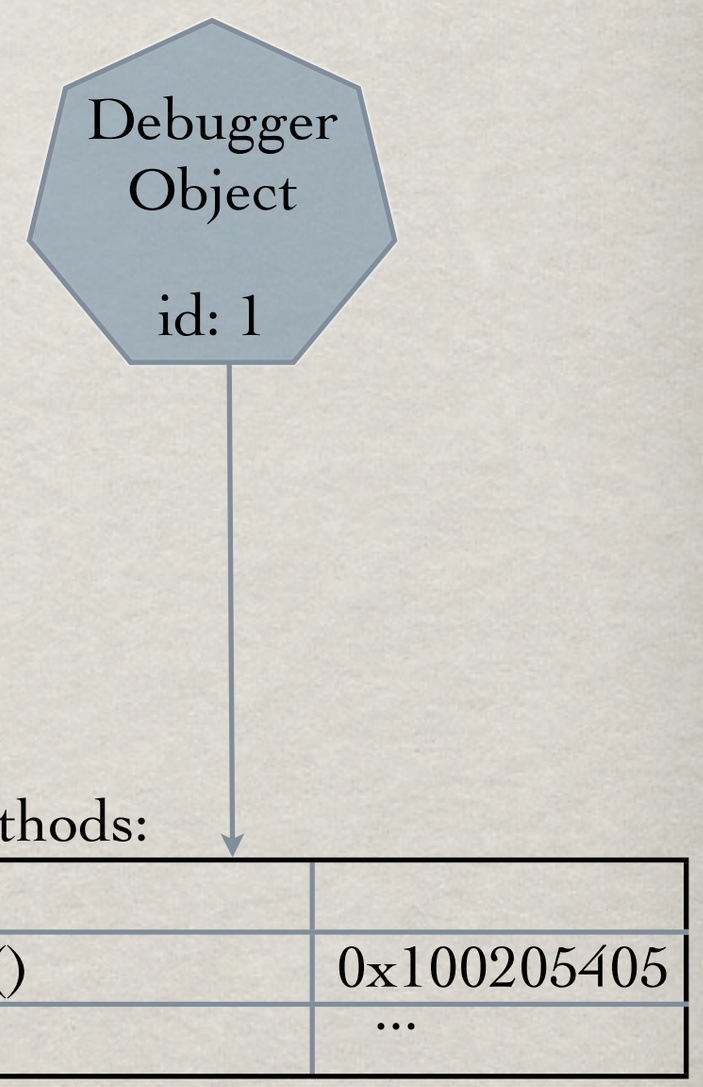

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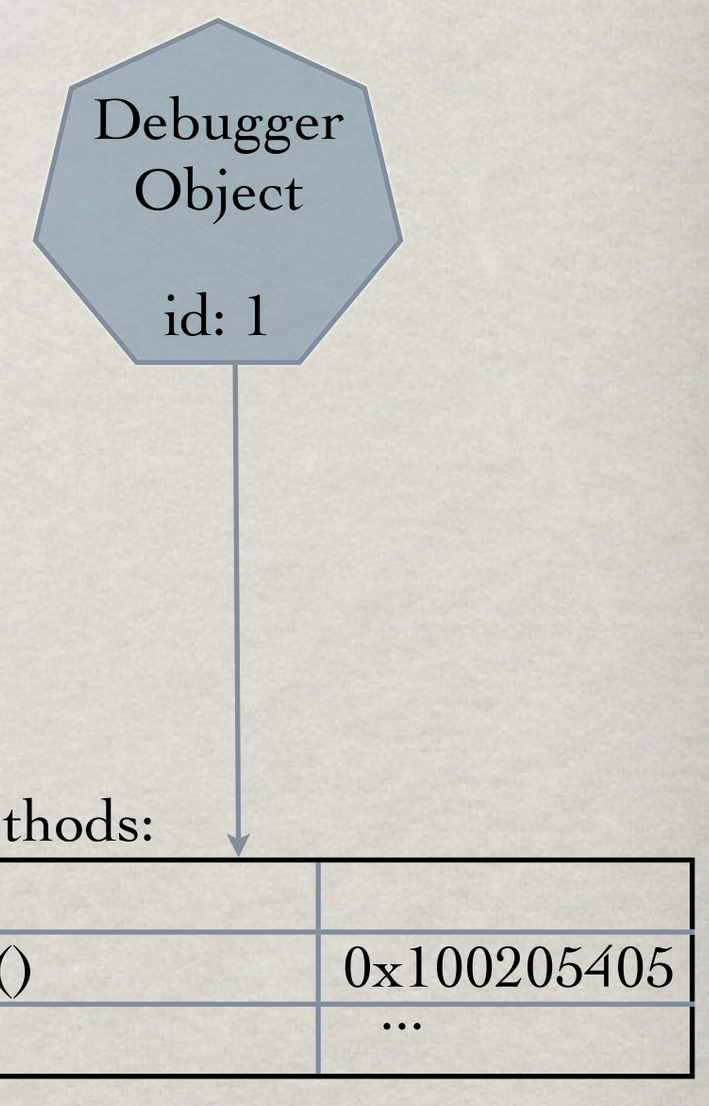

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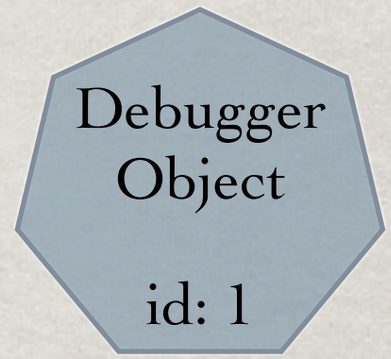


2. Pass the appropriate debugger id to Python

```
buffer = "lldb.debugger_unique_id = 1";
PyRun_SimpleString (buffer);
```

Debugger methods:

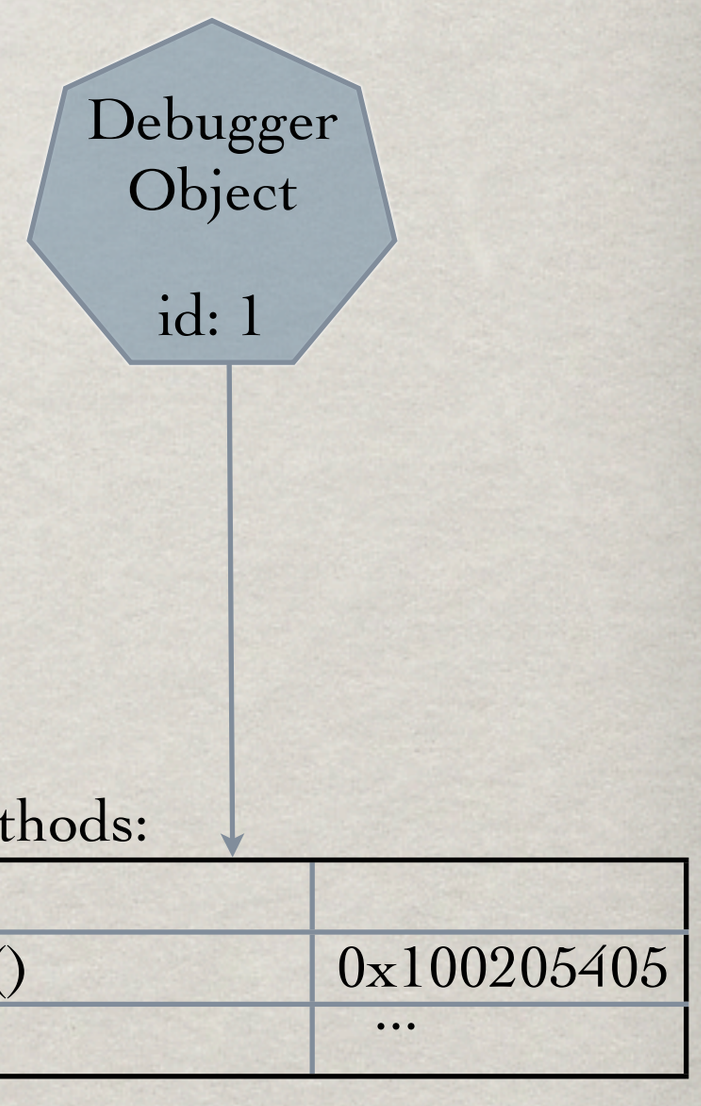
CreateTarget()	0x100205405
...	...

Getting a Single Object "across" - The Debugger

1. Attach unique integer to every debugger (id!)

2. Pass the appropriate debugger id to Python

3. Create STATIC API function to get the debugger from the id!



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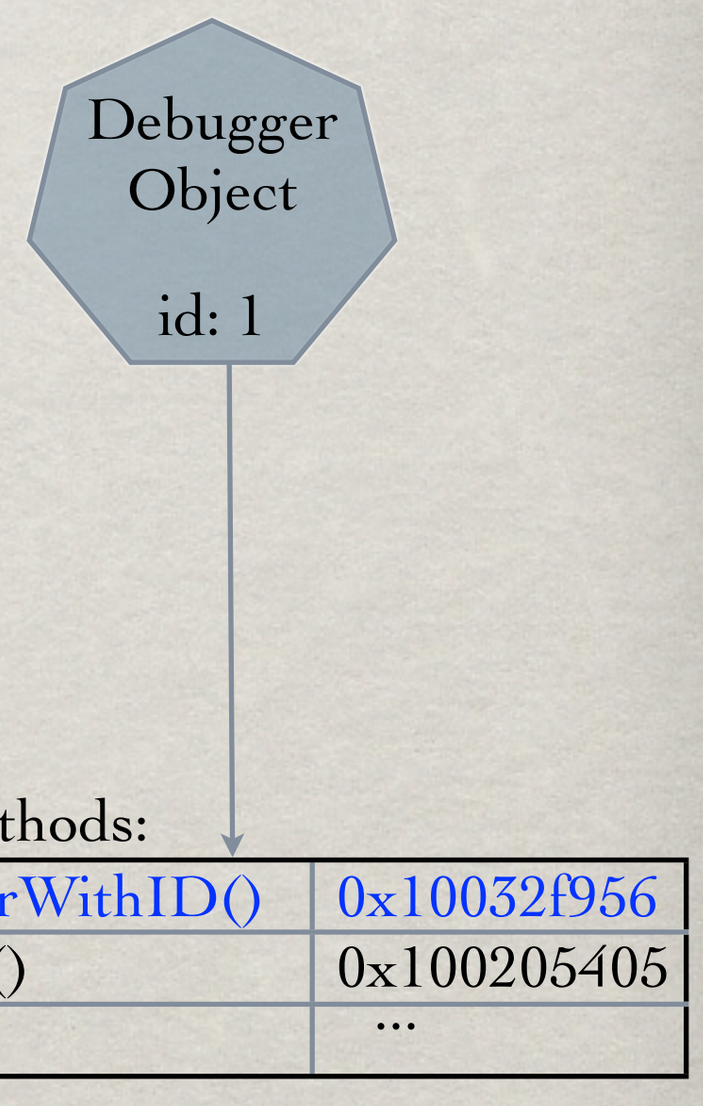

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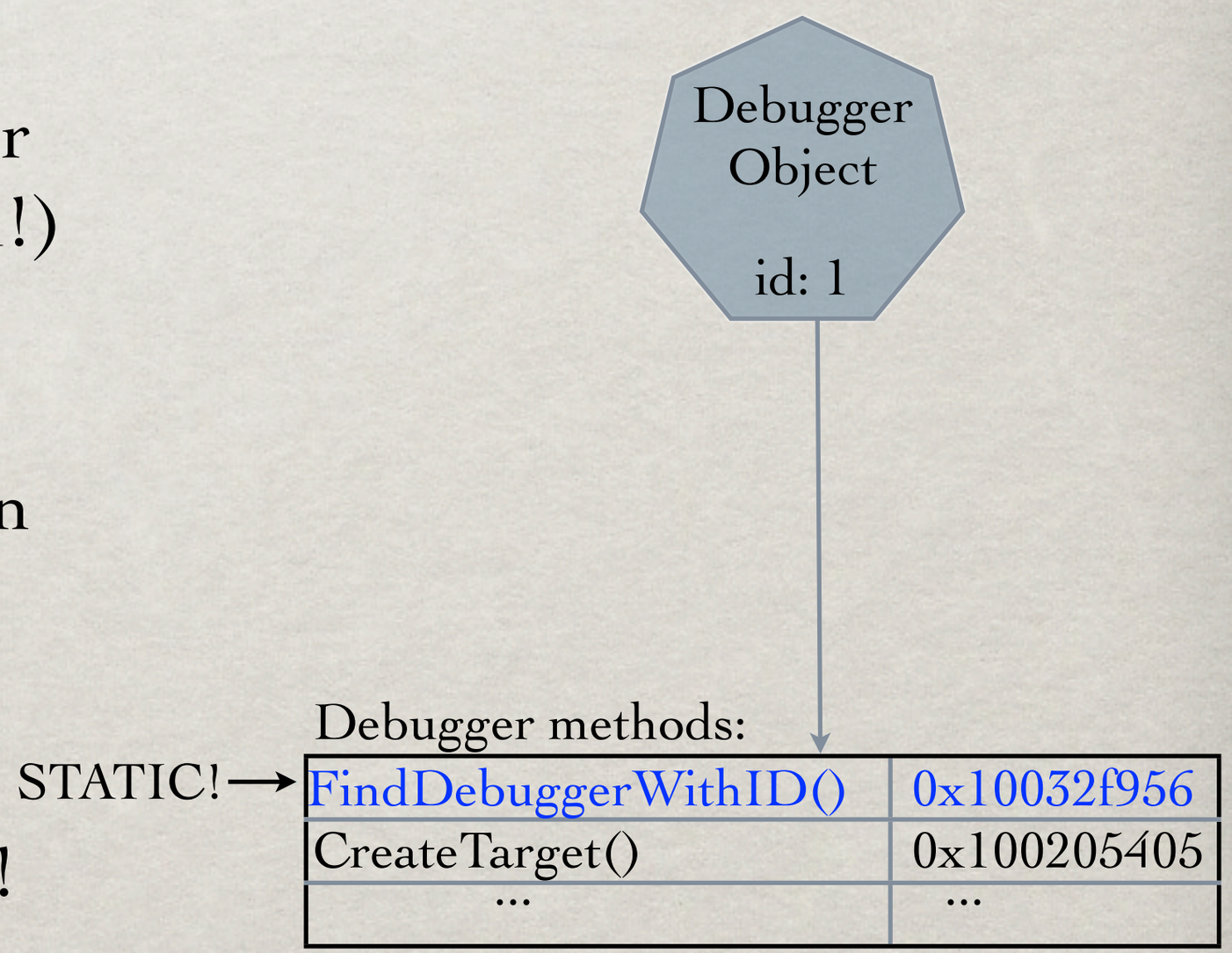
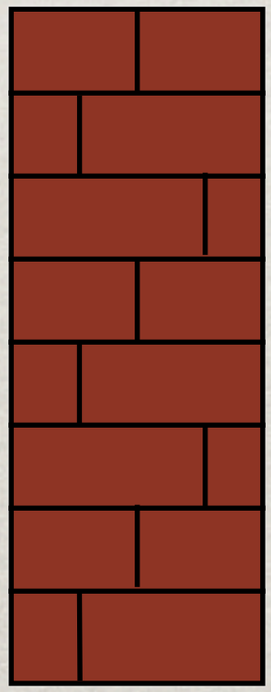


Putting It All Together...

(lldb) script



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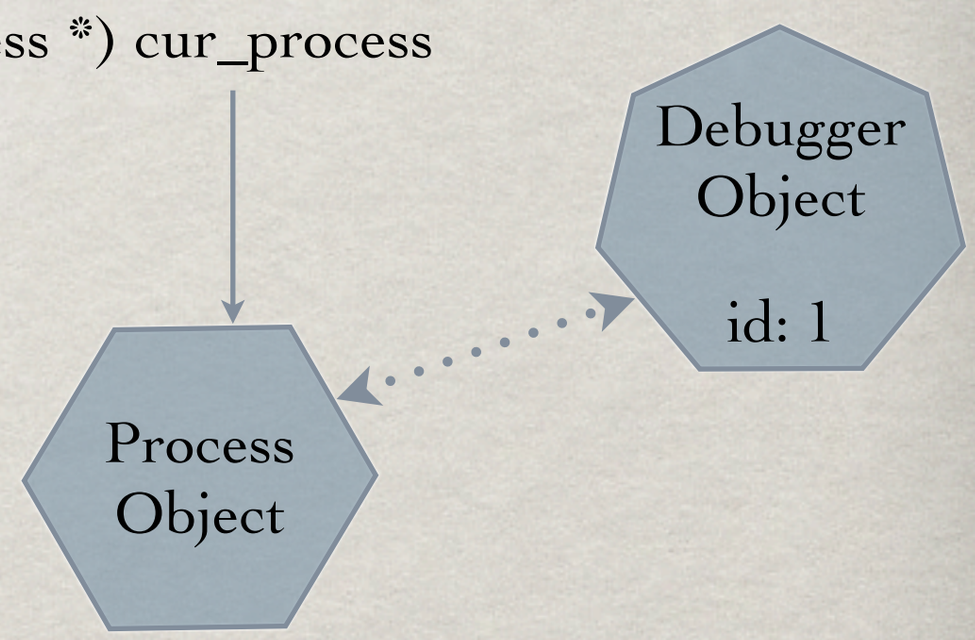

Interactive Python Interpreter

lldb debugger (C++ code)

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sprintf (tmp_str,"lldb.debugger_unique_id = %d", debugger.id);
PyRun_SimpleString (tmp_str);

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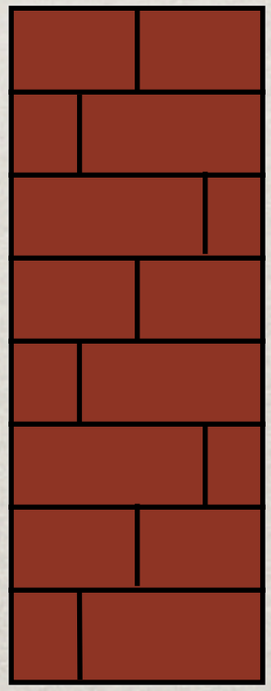

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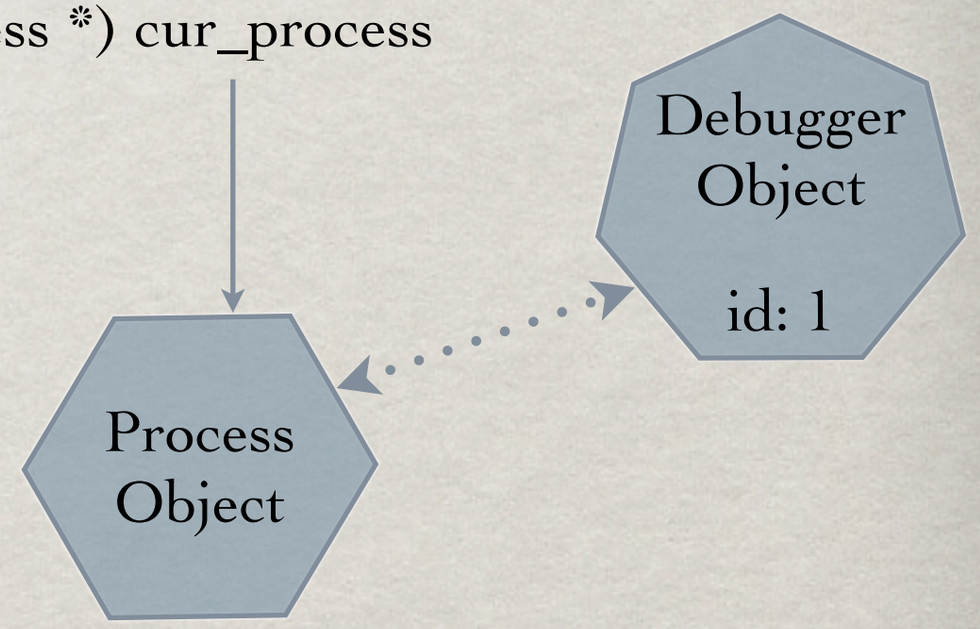

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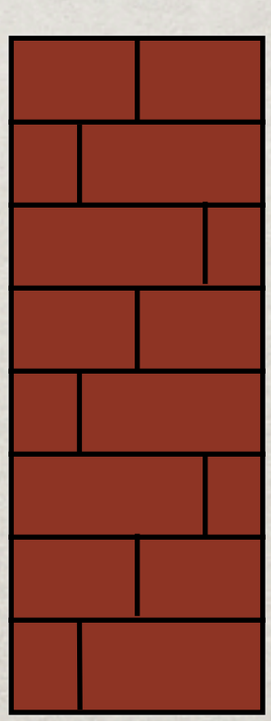

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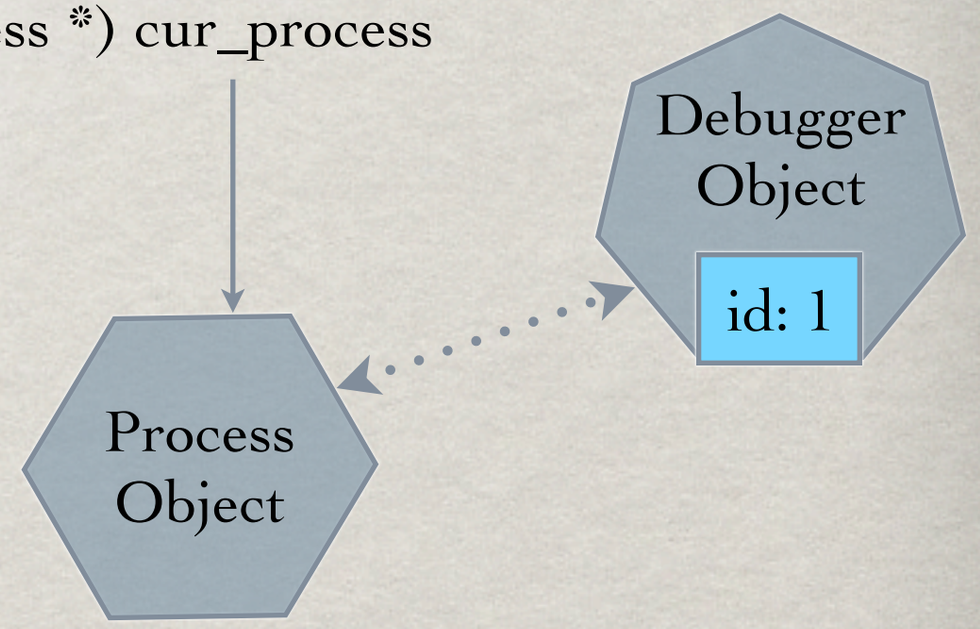

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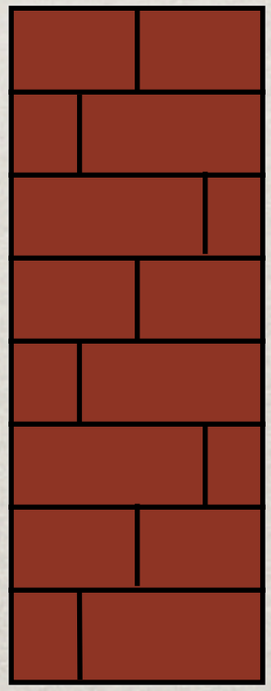

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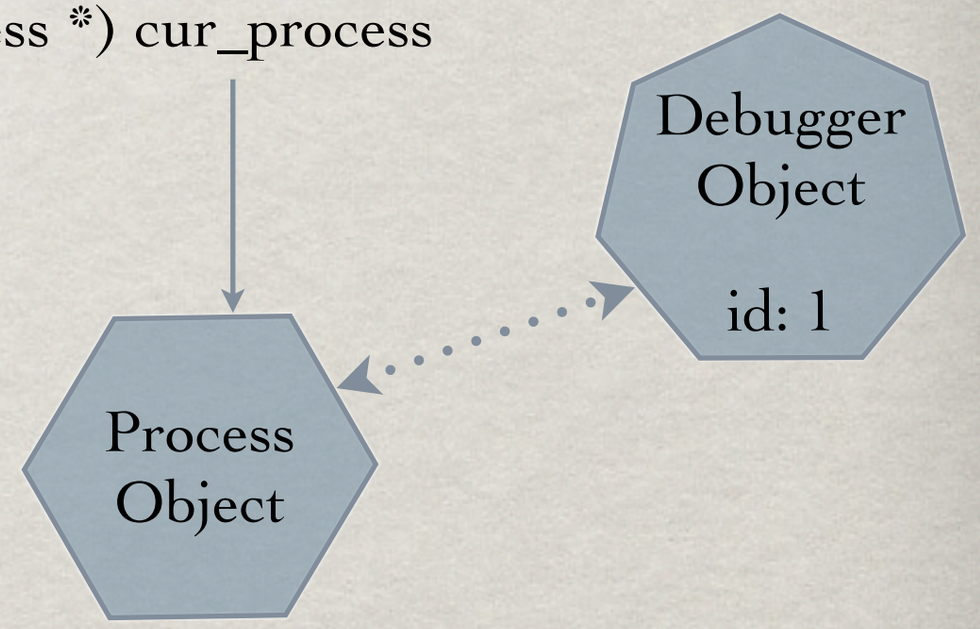

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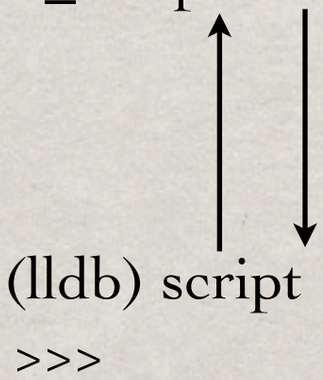

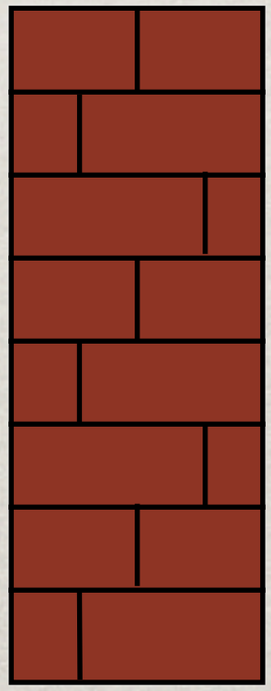

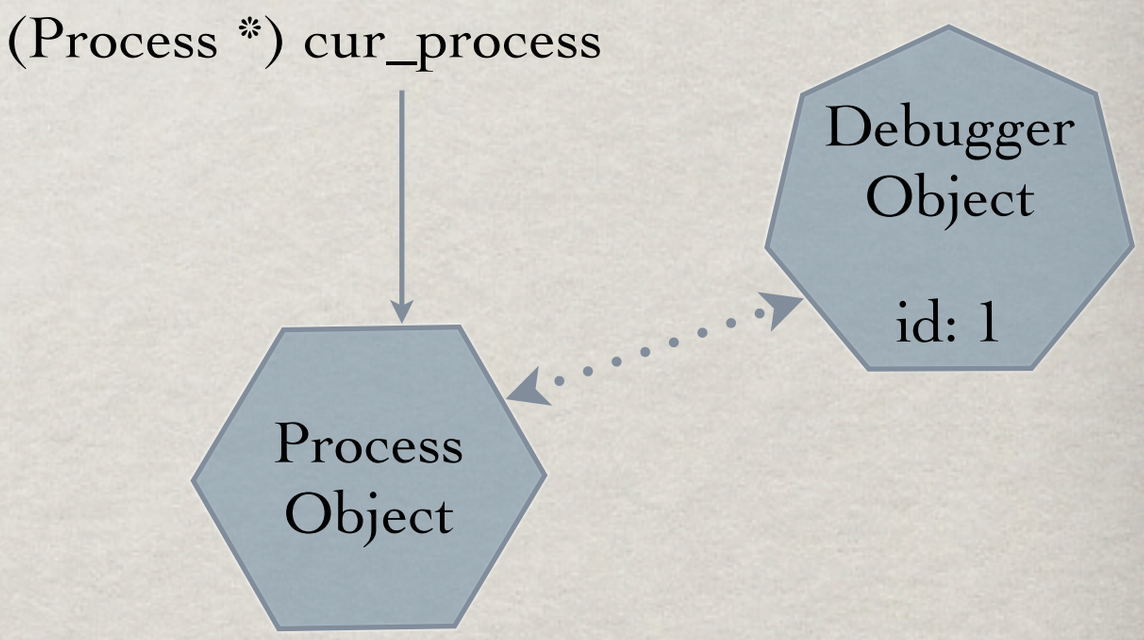

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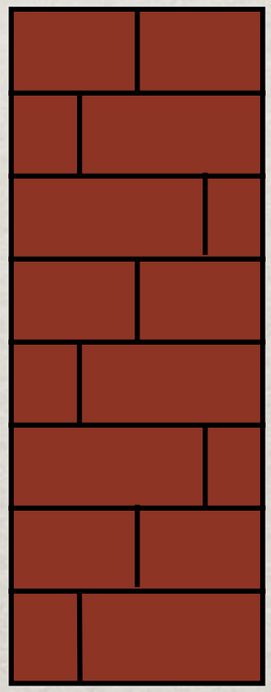
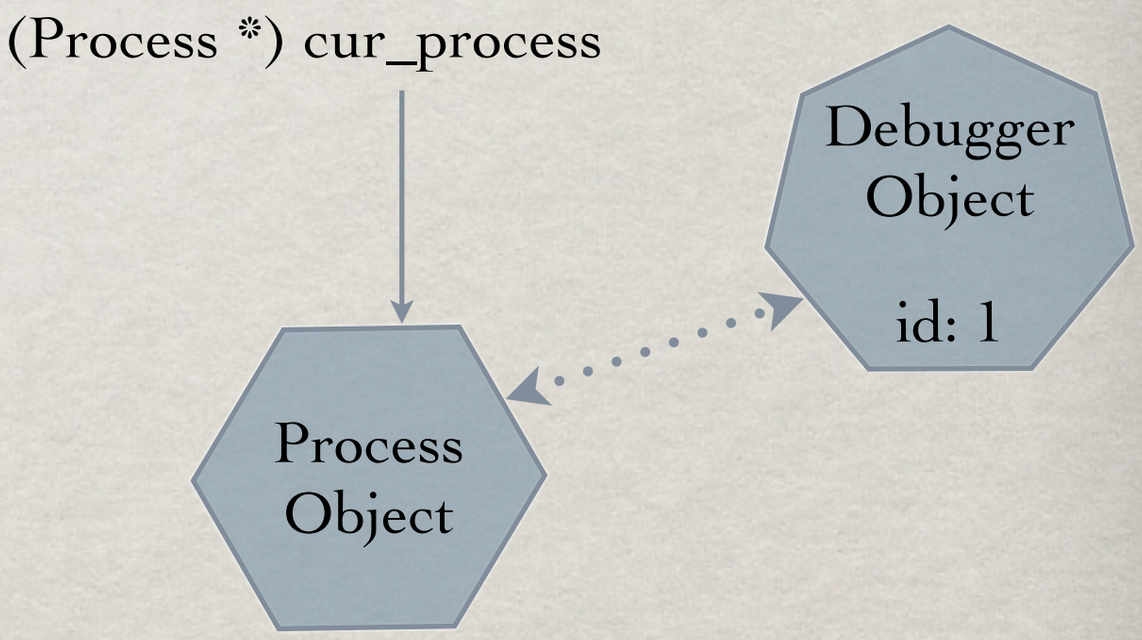
>>> id = lldb.debugger_unique_id
>>>
```



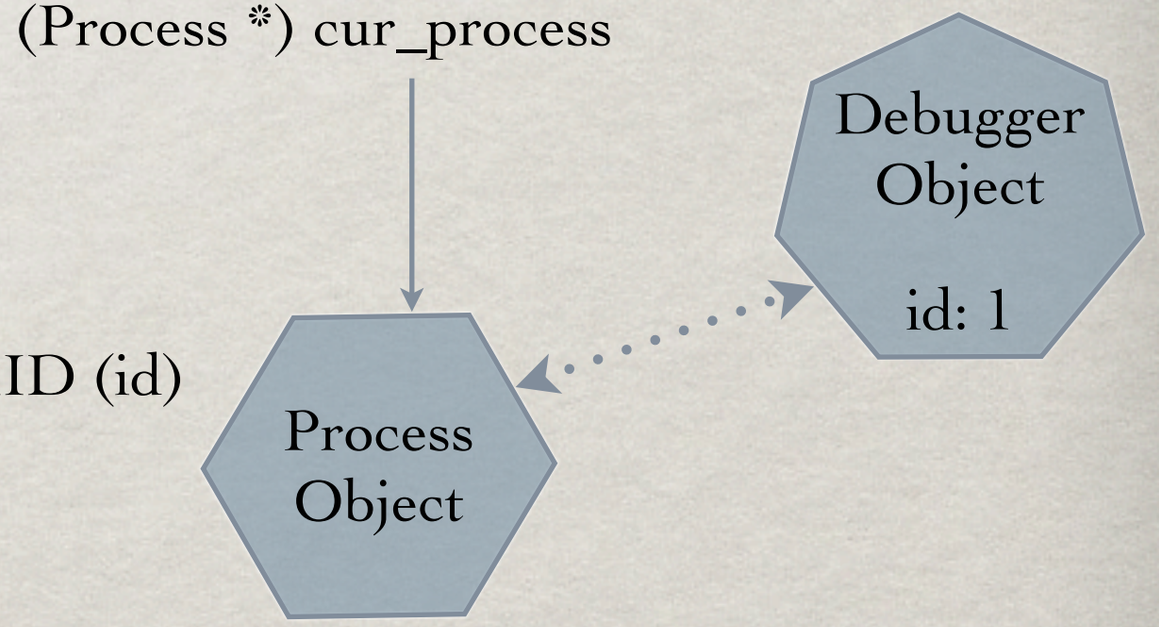


Interactive Python Interpreter

lldb debugger (C++ code)

Putting It All Together...

(lldb) script
>>> id = lldb.debugger_unique_id
>>> dbg = lldb.SBDebugger.FindDebuggerWithID (id)
>>>



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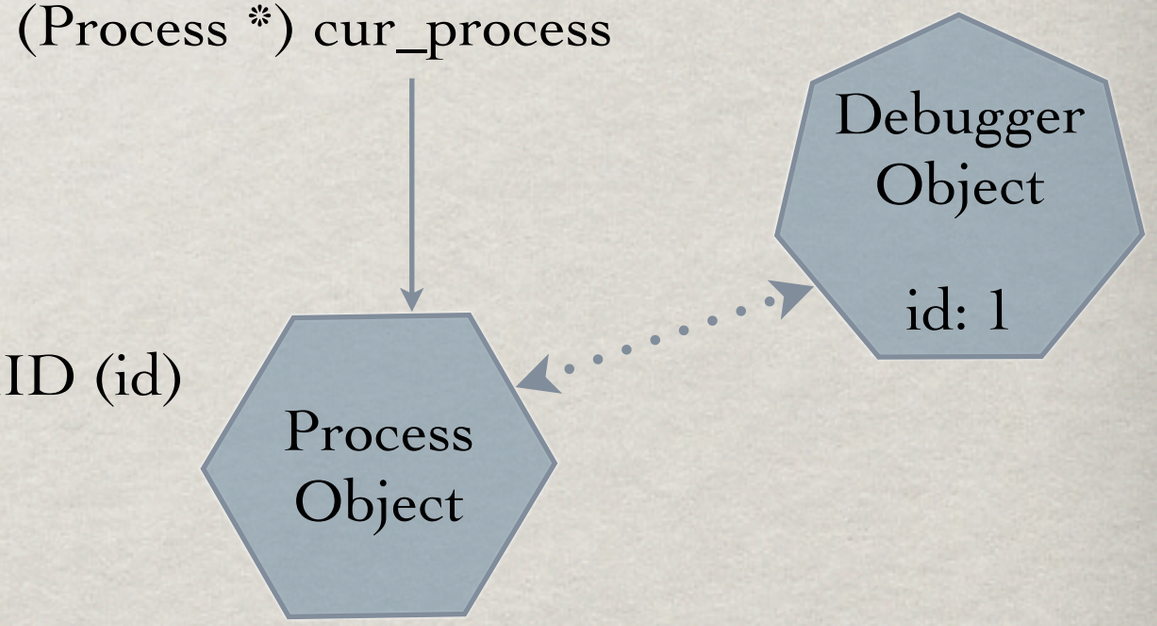
Putting It All Together...

(lldb) script
>>> id = lldb.debugger_unique_id
>>> dbg = lldb.SBDebugger.FindDebuggerWithID (id)
>>> target = dbg.GetSelectedTarget()
>>>



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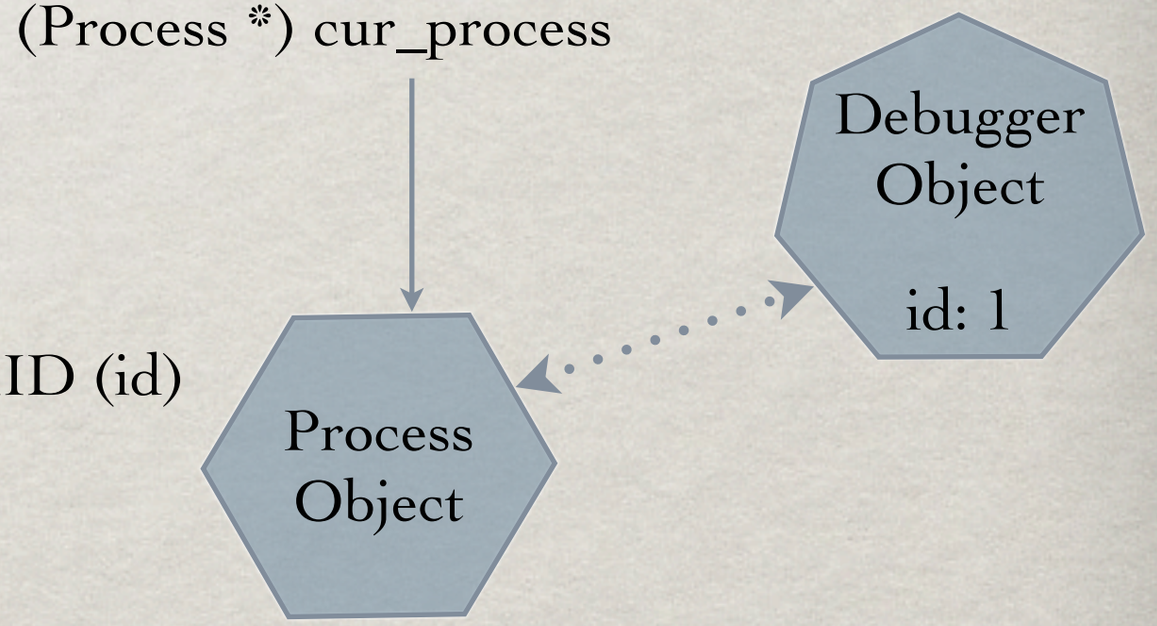
>>> target = dbg.GetSelectedTarget()
>>> process = target.GetProcess()
>>>
```



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>>>
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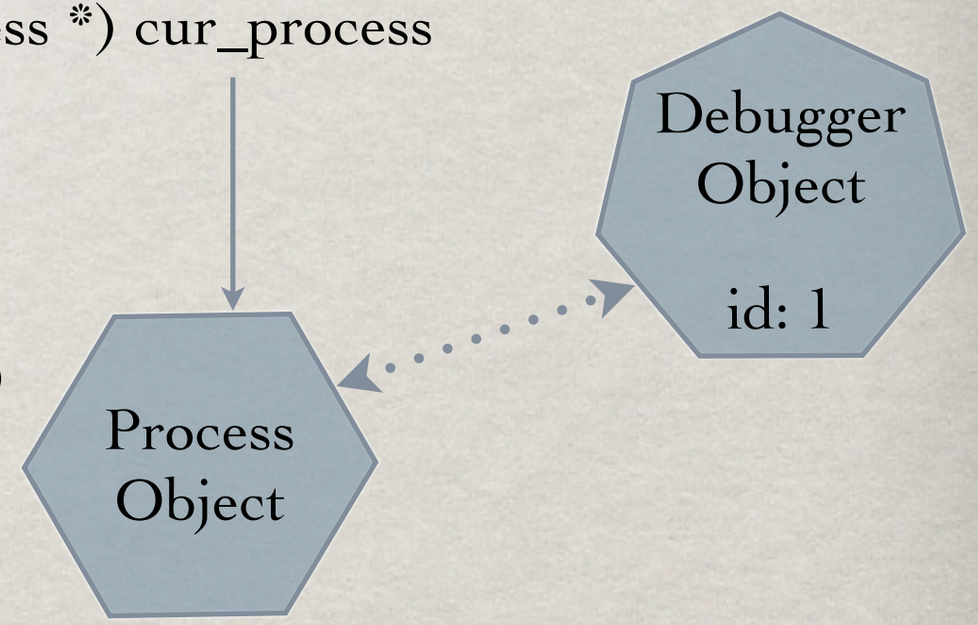

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lldb debugger (C++ code)

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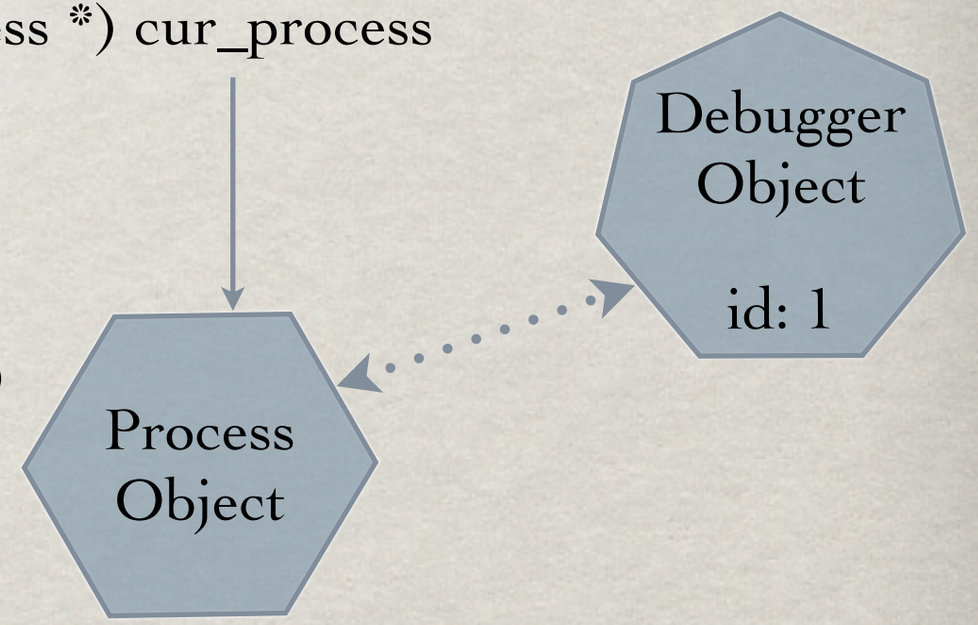
SUCCESS!



Interactive Python Interpreter

lldb debugger (C++ code)

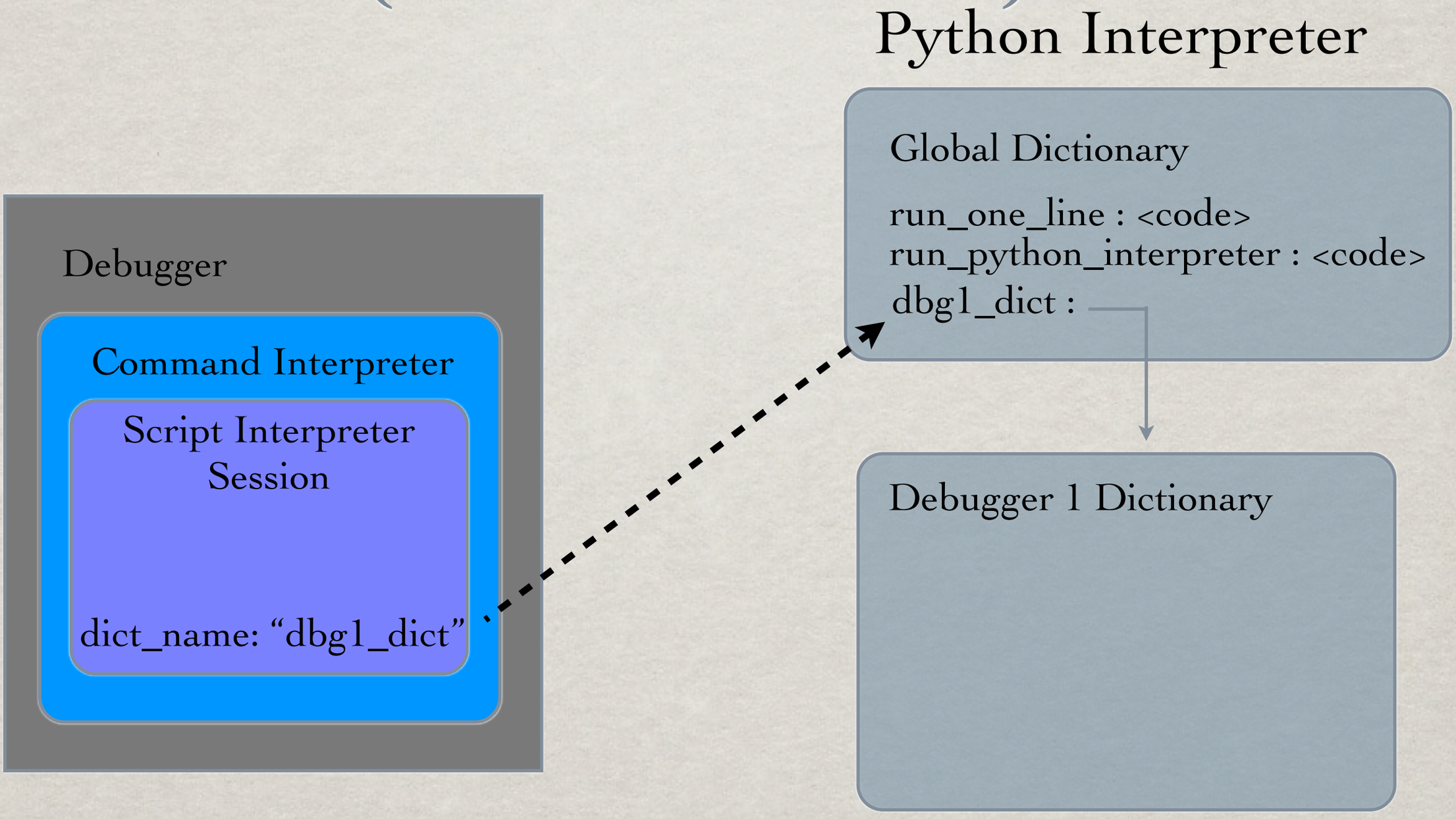
Particular Problems & Solutions

- Passing Pointers & C++ Objects to Python
- Single Dictionary Across Debugger Session
- Multiple Debuggers/Single Interpreter

Why a Debugger-Level Dictionary?

- Persistent, re-usable definitions
- Multiple debugger sessions
  - independent, non-interfering definitions

How It Works (Reminder)



Interactive Interpreter & One Line Commands

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Interactive Interpreter & One Line Commands

- All function & variables defs go into session dictionary
- All code is executed in context of session dictionary
- Dictionary persists (in globals()) => definitions persist

Breakpoint Commands: A Problem

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Breakpoint Commands: A Problem

- No encapsulating run environment => no way to run using session dictionary as global dict
- Breakpoint script function is called from global Python environment
- Solution: Modify the global environment (carefully!)

When Creating Command Script...

```
global count
count = count + 1
print “Hit this breakpoint “ + repr (count) + “ times!”
```

When Creating Command Script...

```
def some_obscure_function_name (frame, bp_loc       ):
    global count
    count = count + 1
    print “Hit this breakpoint “ + repr (count) + “ times!”
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When Creating Command Script...

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def some_obscure_function_name (frame, bp_loc, dict):
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Dictionary set-up magic

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Dictionary Set-Up Magic

Global Python Dictionary

Key_1: Value1
Key_2: Value2
Key_3: Value3
etc.

Debugger Session Dictionary

Key_A: Value1
Key_B: Value2
Key_C: Value3
etc.

Dictionary Set-Up Magic

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Dictionary Set-Up Magic

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Old_Keys:
New_Keys:

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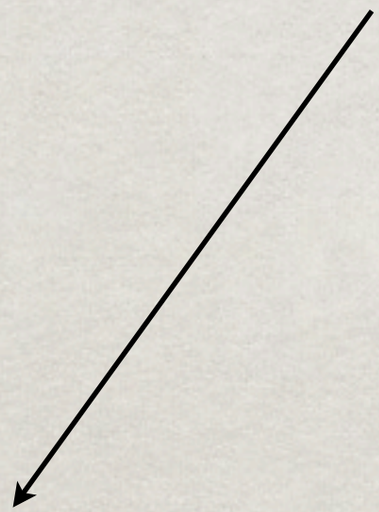

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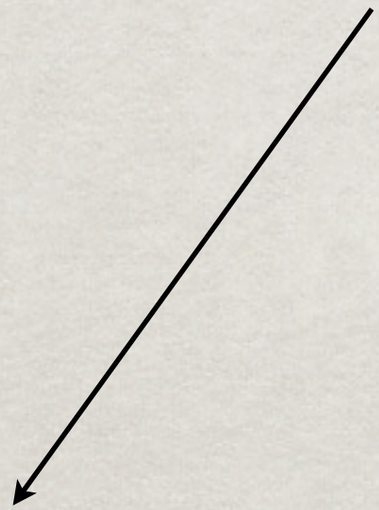

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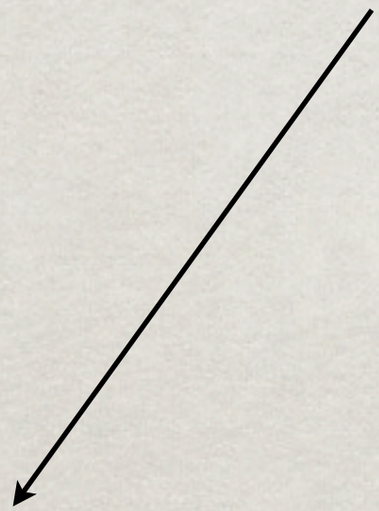

Breakpoint script executes in context of GLOBAL dictionary.

Dictionary Clean-Up Magic

Global Python Dictionary

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etc.

Old_Keys: ...
New_Keys: ...

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Particular Problems & Solutions

- Passing Pointers & C++ Objects to Python
- Single Dictionary Across Debugger Session
- Multiple Debuggers/Single Interpreter

Desired GUI Debugger Behavior

- From single running GUI debugger process...
- Launch multiple executables...
  - ...each in a separate window
  - ...each with a separate debugger session

GUI Debugger Python Requirements

- Multiple debugger sessions
  - Multiple Script Interpreters/Dictionaries
- Ability to switch smoothly between them
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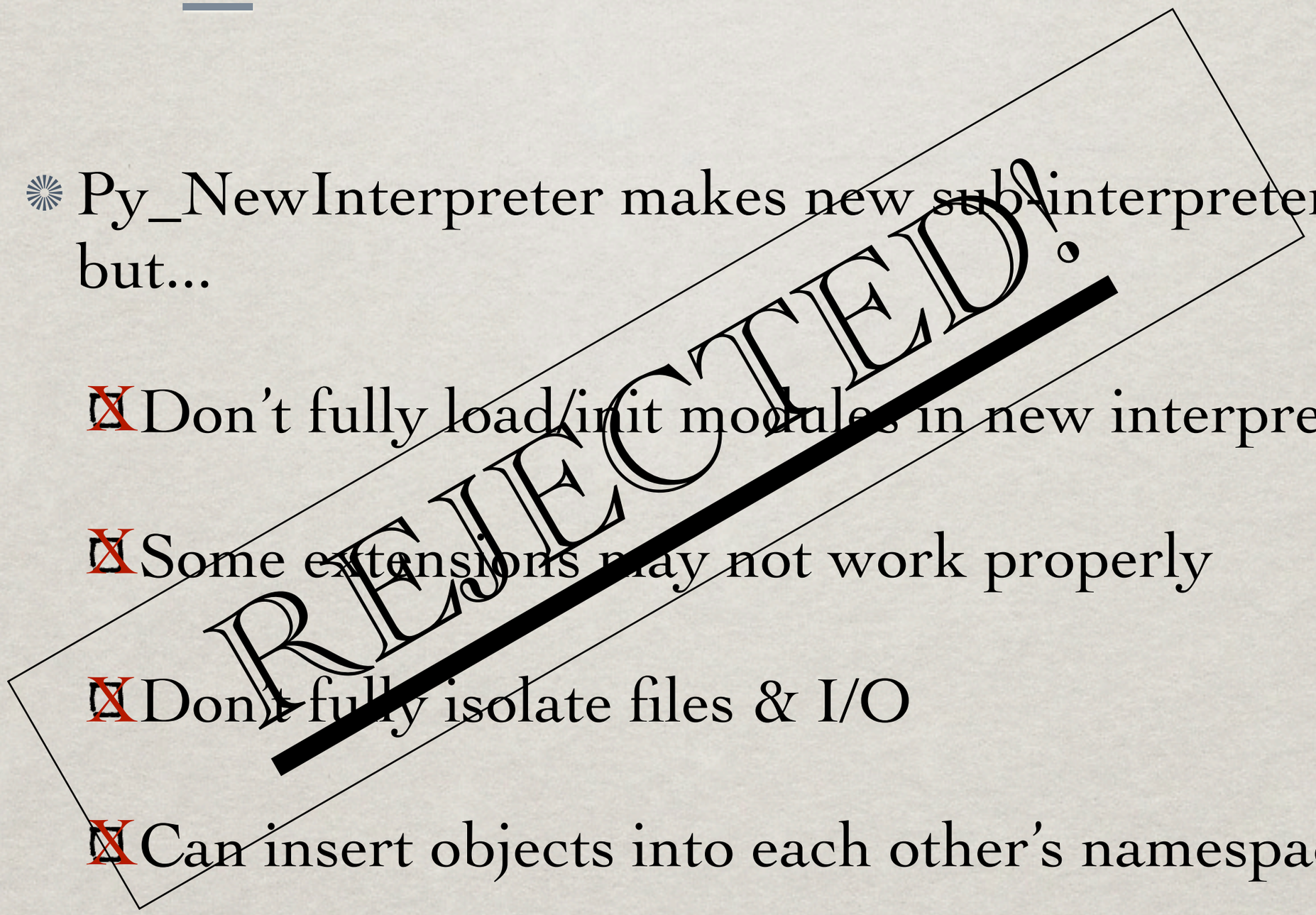

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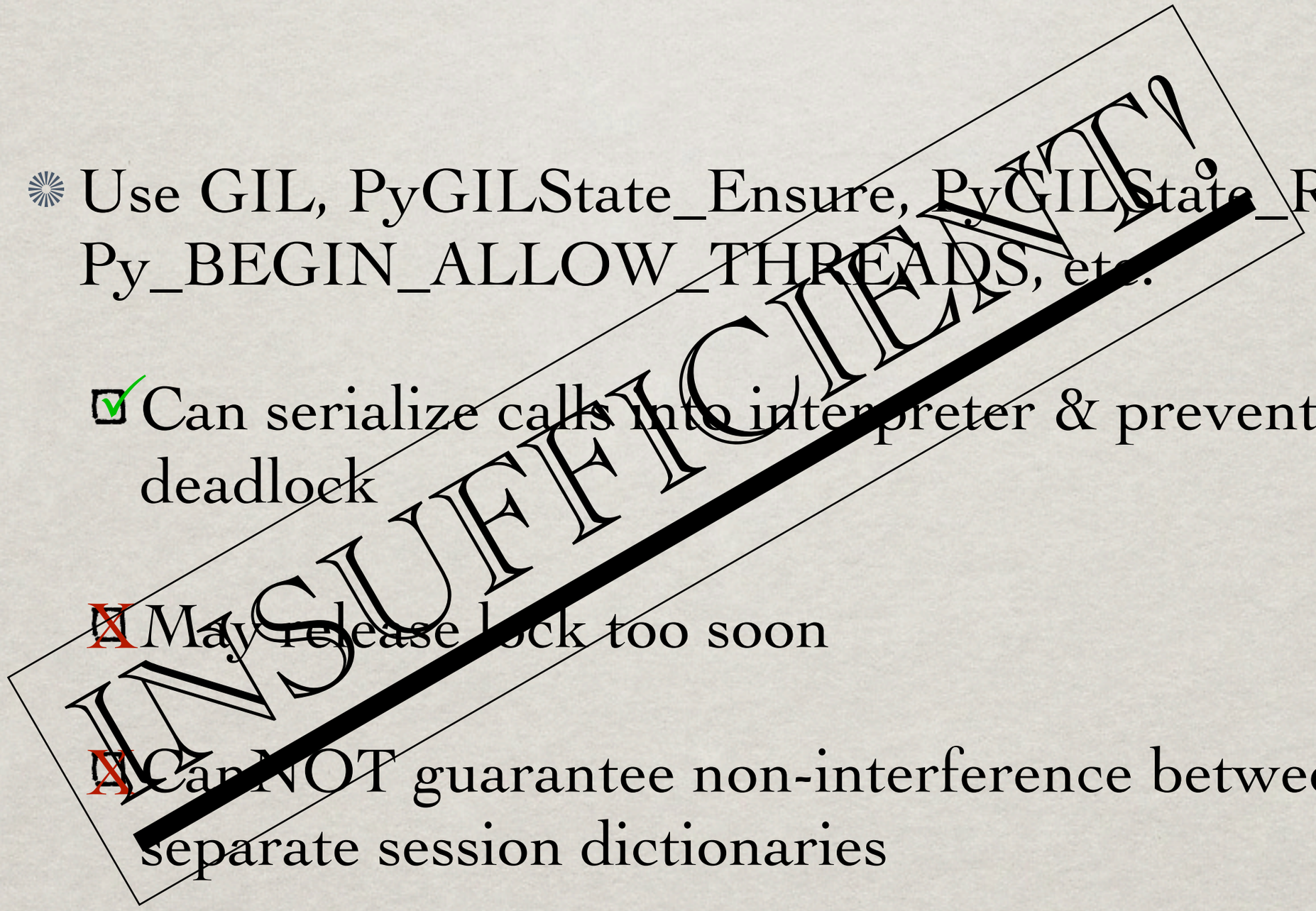

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Possible Approaches: Write our Own!

Python Script Interpreter

Global Mutex-Predicate

Session 1

Input PTY
Output PTY
Session Dictionary
IsActive

Session 2

Input PTY
Output PTY
Session Dictionary
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Session 3

Input PTY
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Possible Approaches: Write Our Own!

- Use a combination of pthread_mutex, pthread_cond_wait & our own Python lock:

Thread wants to access Python

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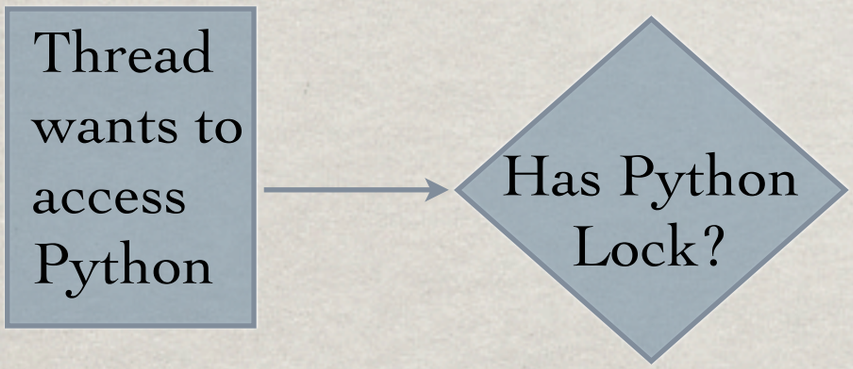

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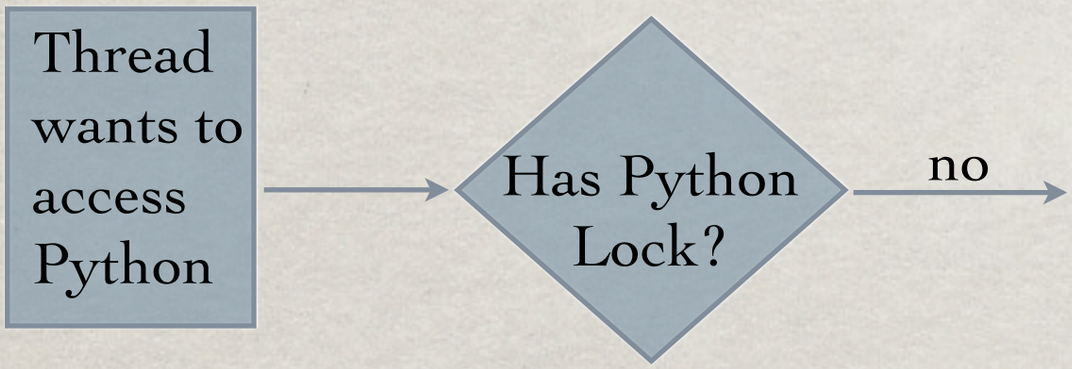

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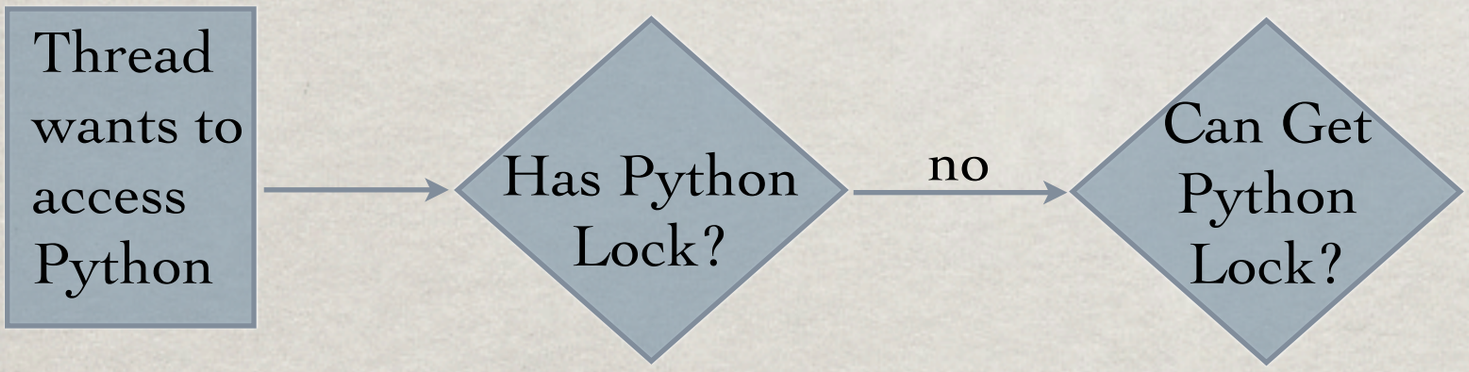

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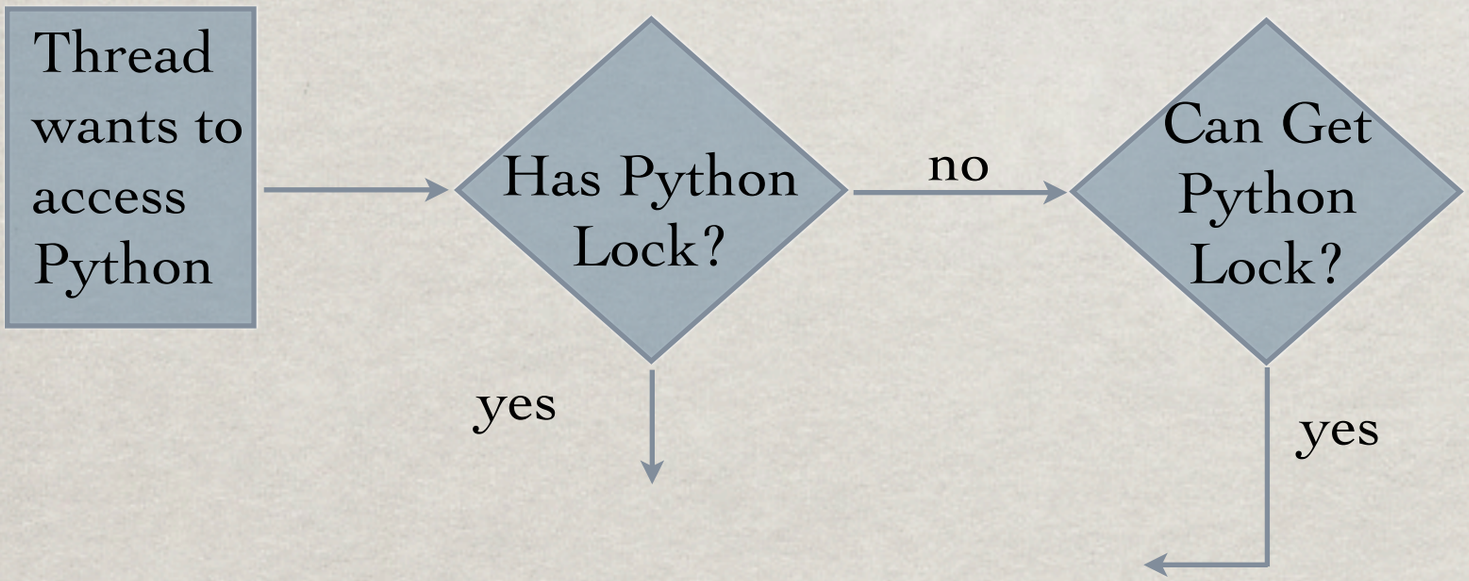

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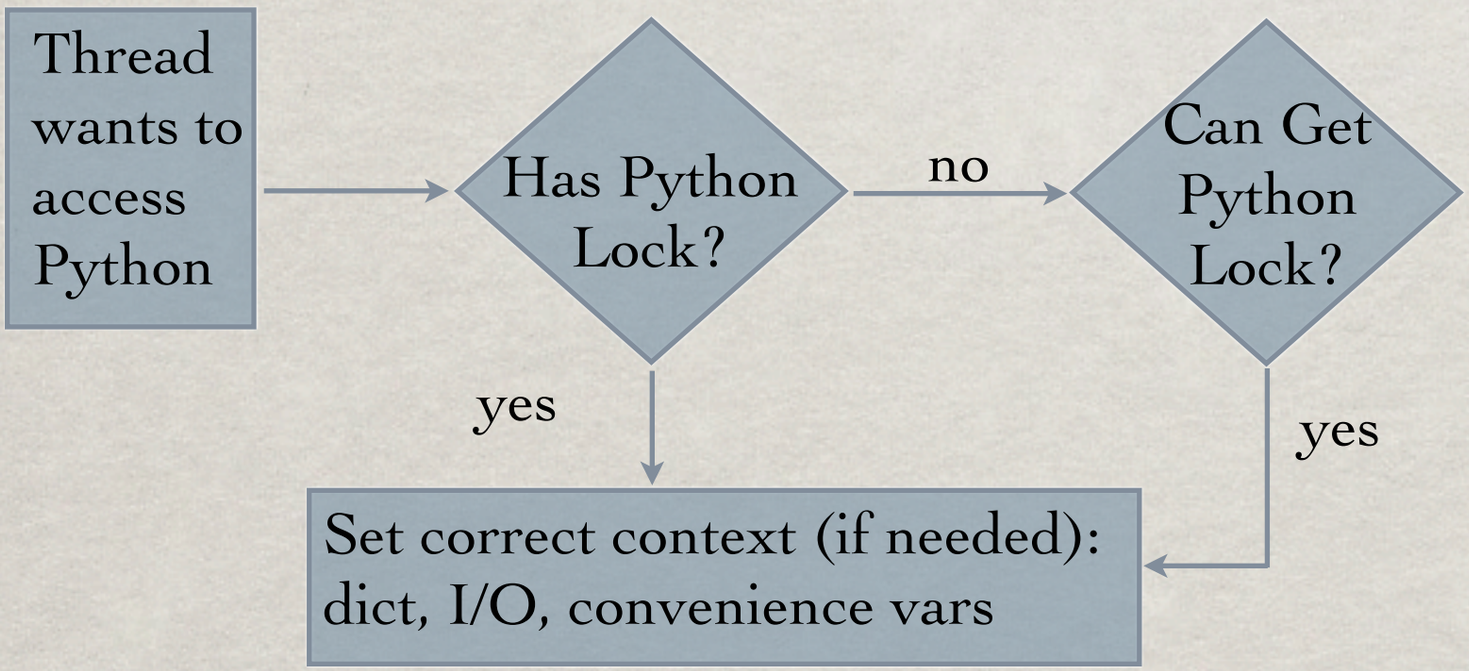

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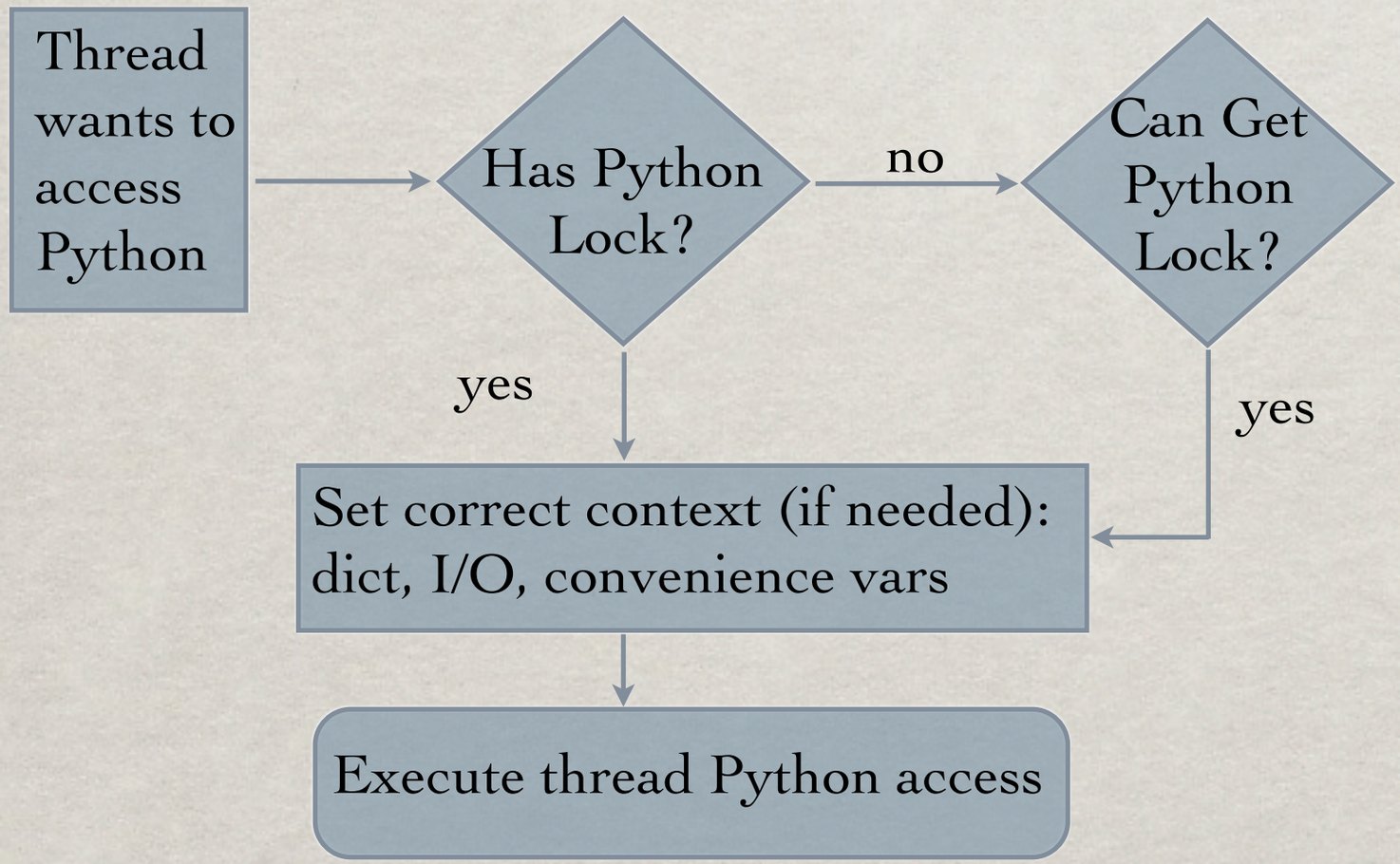

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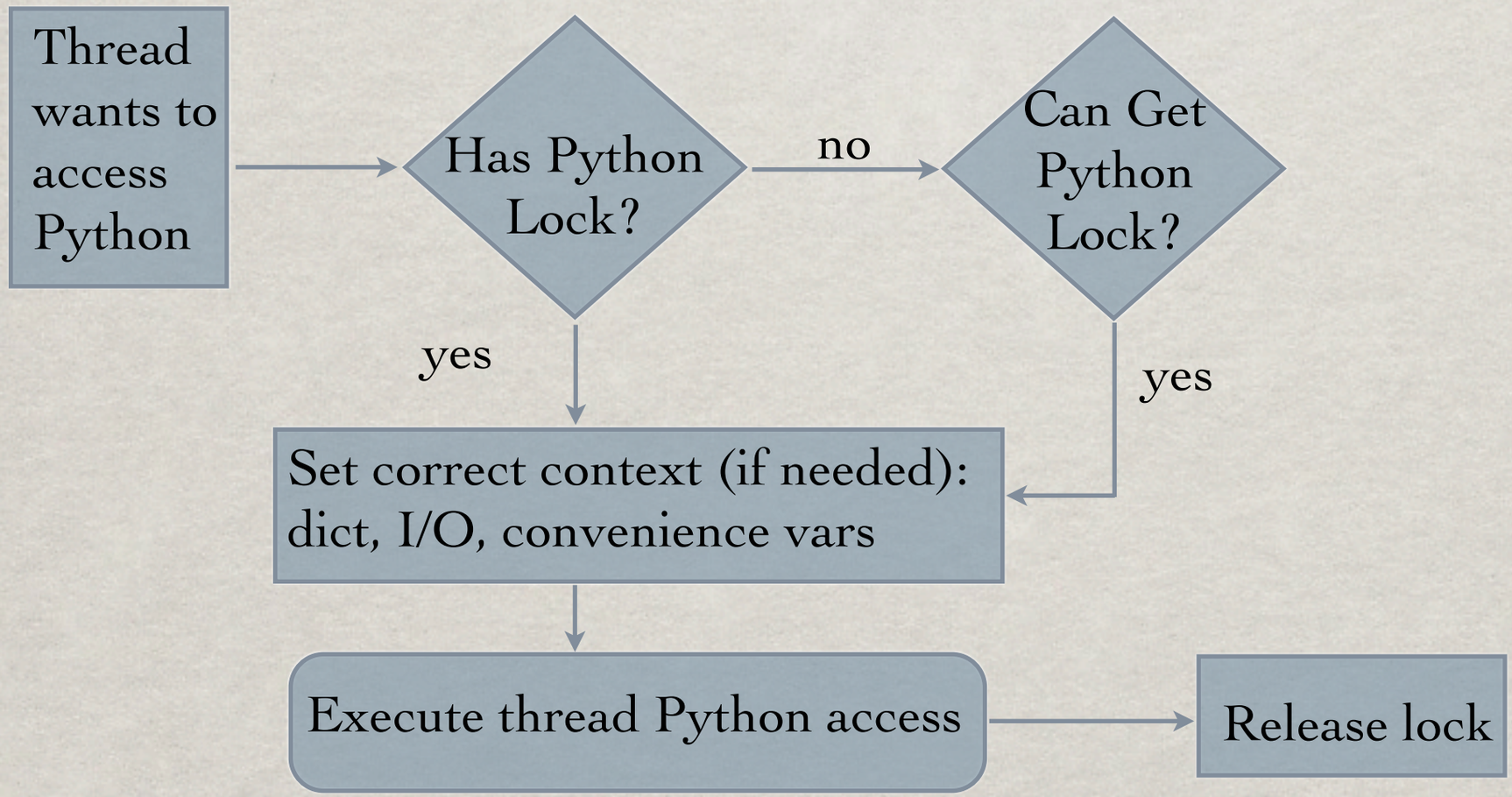

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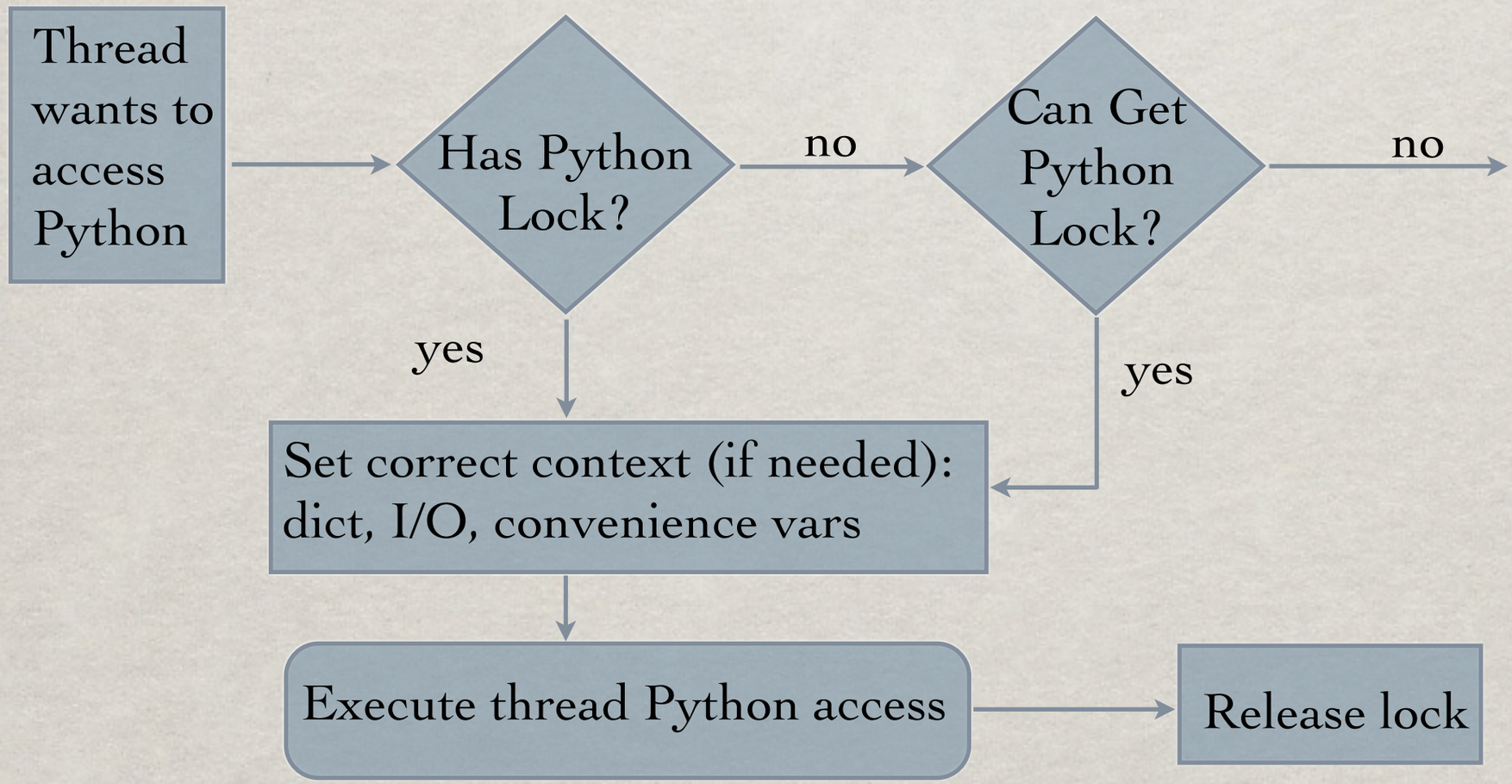

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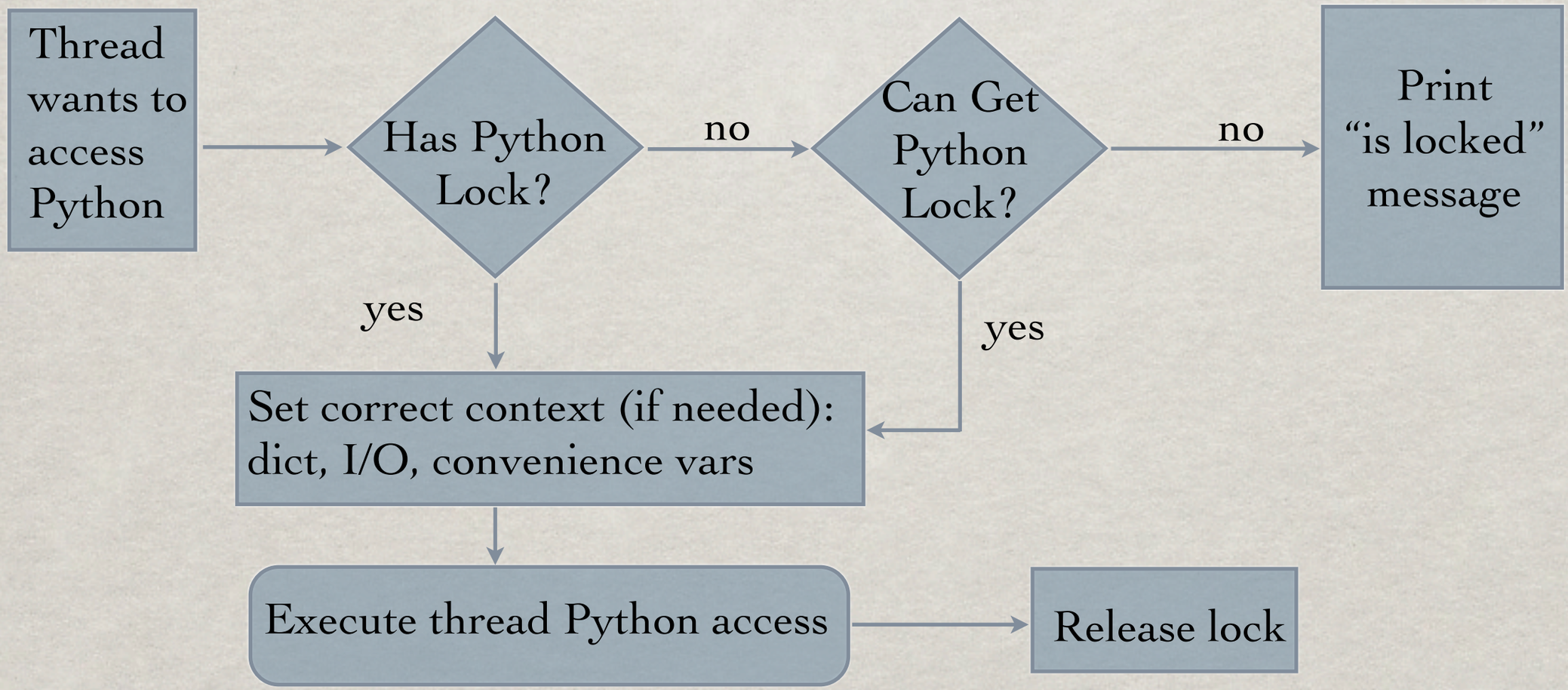

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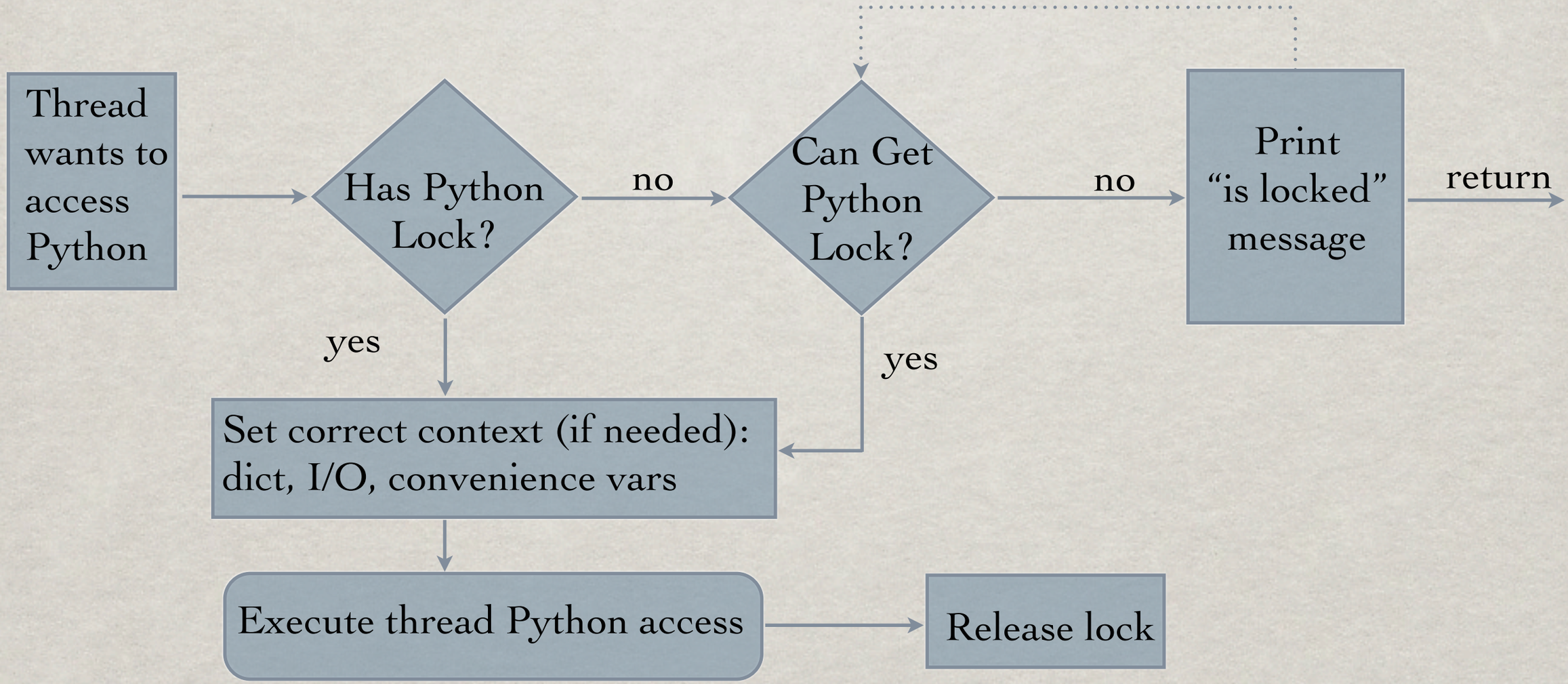

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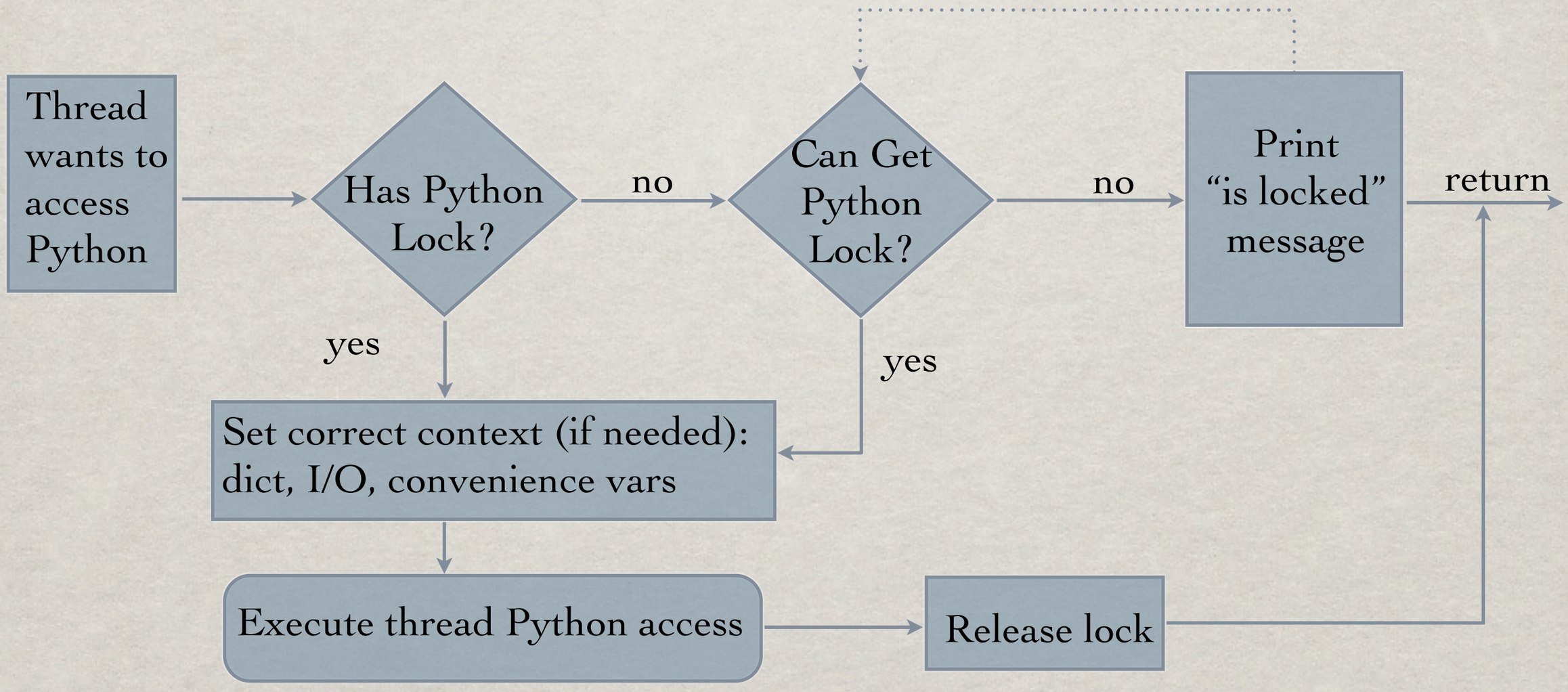
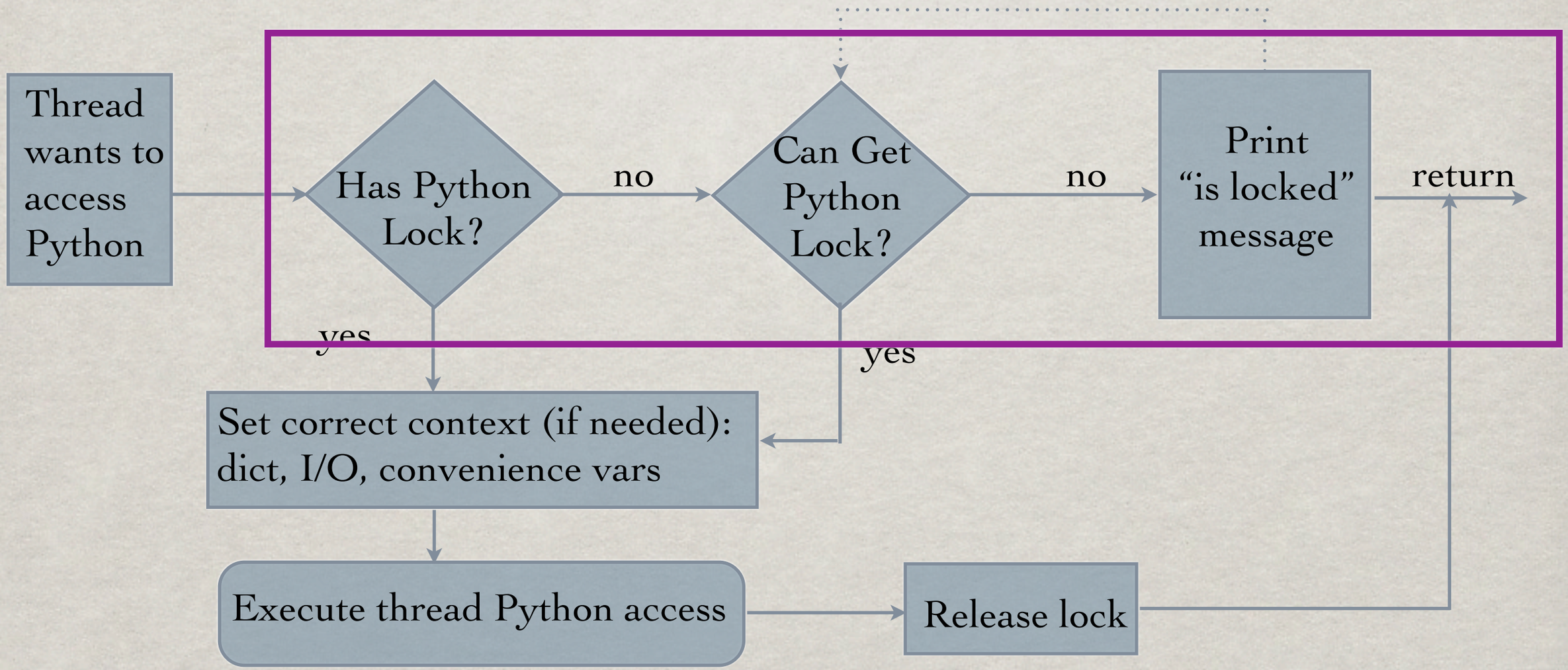


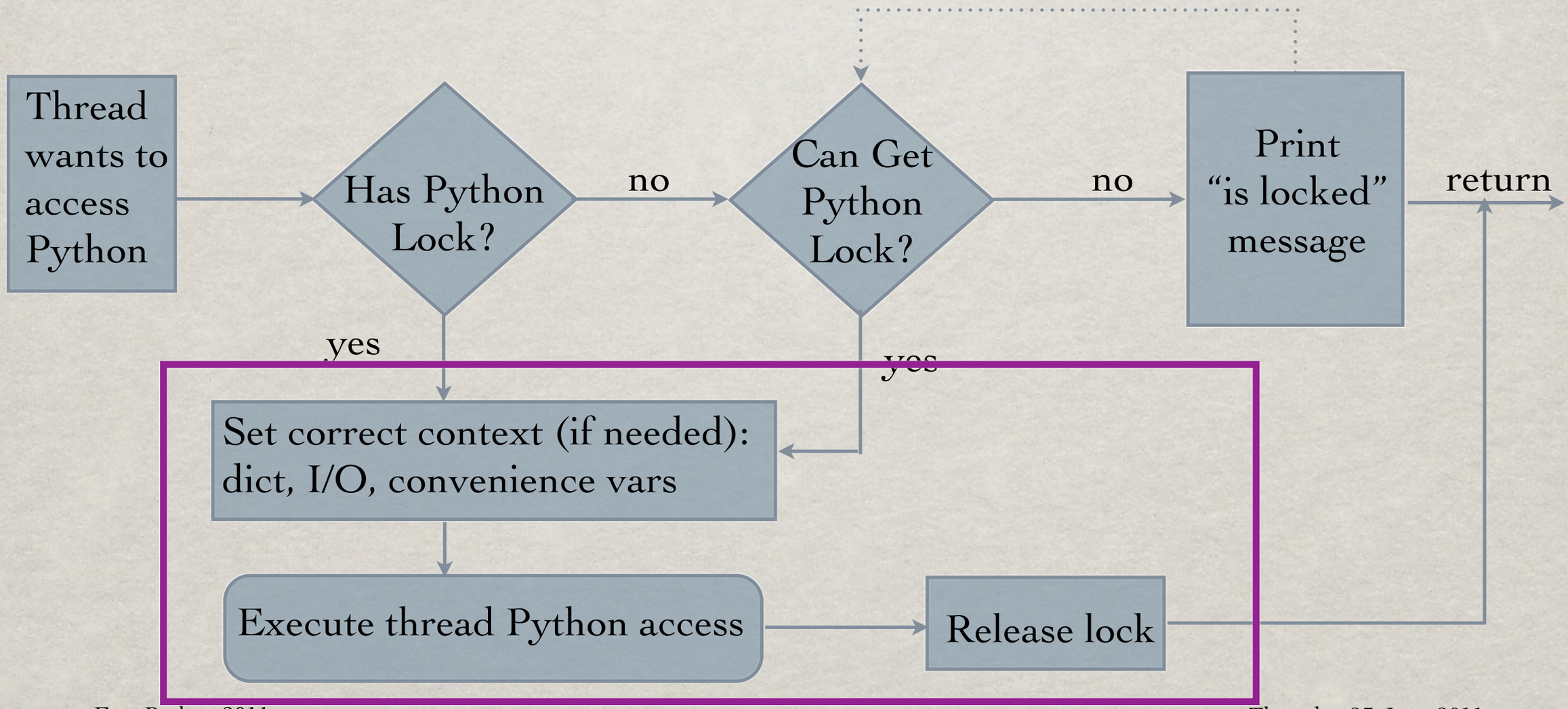
Possible Approaches: Write Our Own!

-Thread safety
-No deadlocking



Possible Approaches: Write Our Own!

-Correct dictionary
-No early release



GUI Debugger Python Requirements

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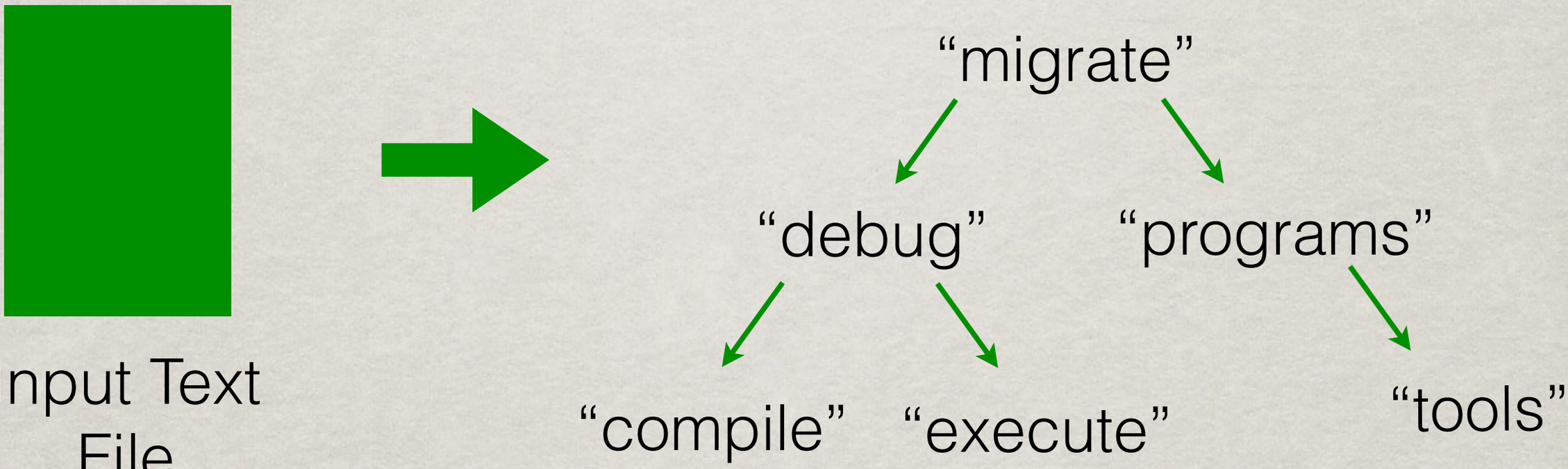
Outline

- What is LLDB?
- Python in LLDB
- Particular Problems (& Solutions)
- Example Using Python to Debug Problem
- Questions

Example: Simple Dictionary Program

Store and find words in Binary Search Tree



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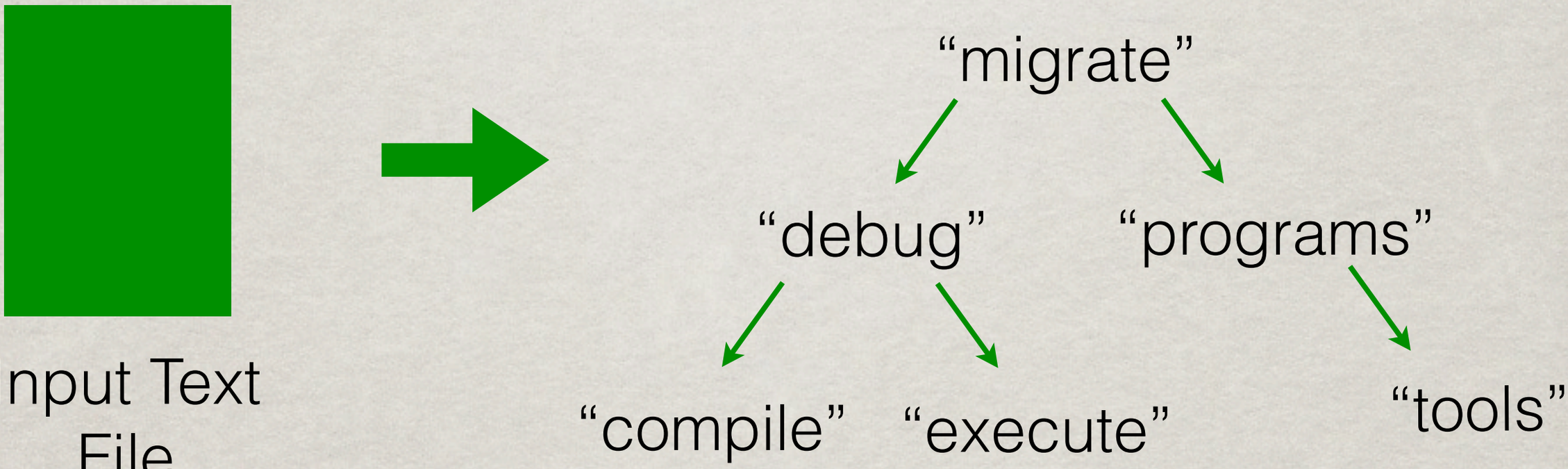

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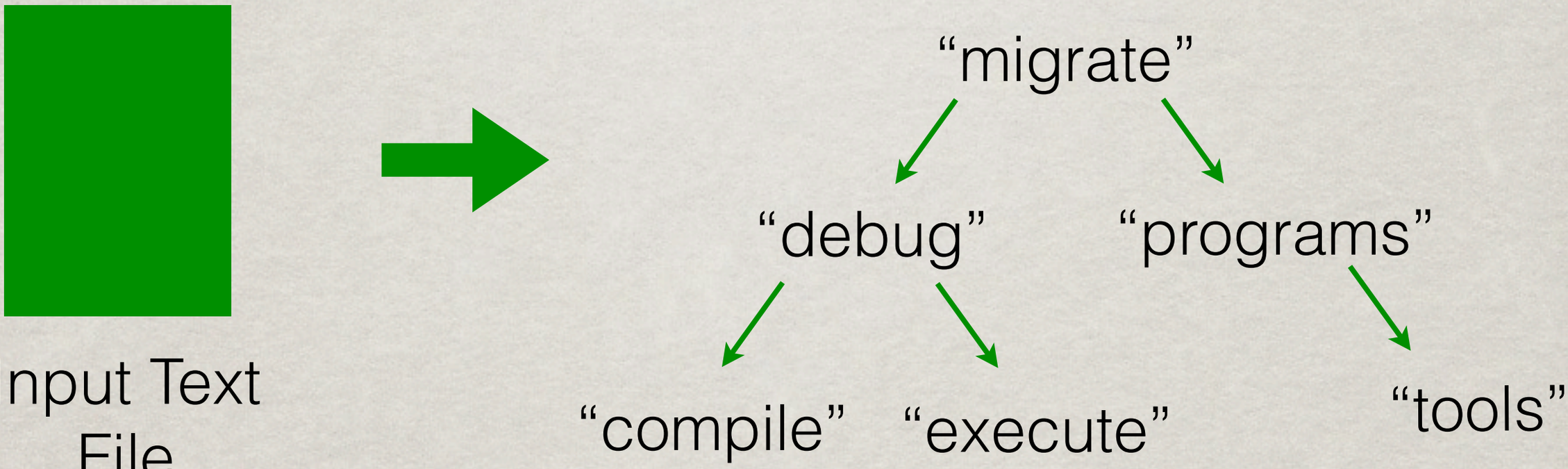

Find ("tools") => Yes
Find ("assemble") => No

Problem: Word Not Found in Dictionary

```
$  ./dictionary Romeo-and-Juliet.txt
Dictionary loaded.
Enter search word: love
Yes!
Enter search word: sun
Yes!
Enter search word: Romeo
No!
```

Problem: Word Not Found In Dictionary

- Possible causes for not finding word:
  - Word not inserted
  - Word inserted in unexpected location

- How to determine if word is in tree?
  - Traverse tree by hand?
    - Not practical: 100‘s or 1000’s of nodes!
  - Write a script!

The Plan

(Searching Tree Without Restarting Program)

- Write Depth-First Search (DFS) function in file (tree_utils.py)
- Attach to running program with LLDB
- Use interactive interpreter to call DFS on current tree
- DFS returns root-to-node path, if found

```
def DFS (root, word, cur_path):
    root_word_ptr = root.GetChildMemberWithName ("word");
    left_child_ptr = root.GetChildMemberWithName ("left");
    right_child_ptr = root.GetChildMemberWithName ("right");
    root_word = root_word_ptr.GetSummary()

    if root_word == word:
        return cur_path
    elif word < root_word:
        if left_child_ptr.GetValue() == None:
            return ""
        else:
            cur_path = cur_path + "L"
            return DFS (left_child_ptr, word, cur_path)
    else:
        if right_child_ptr.GetValue() == None:
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        else:
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LLDB Convenience Variable

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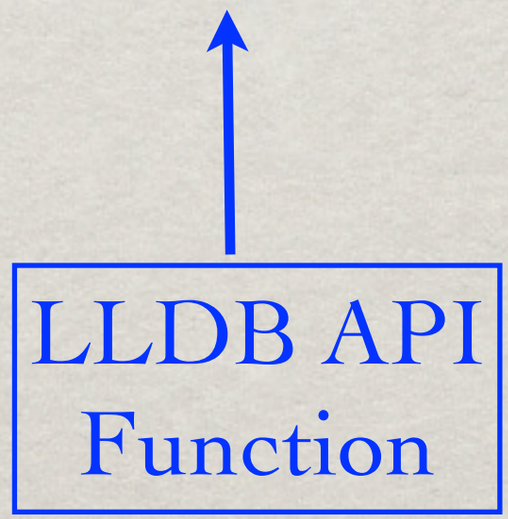

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Python Interactive Interpreter. To exit, type 'quit()', 'exit()'
or Ctrl-D.
>>> import tree_utils
>>> root = lldb.frame.FindVariable ("dictionary")
>>> cur_path = ""
>>>
```

Using The Interactive Interpreter

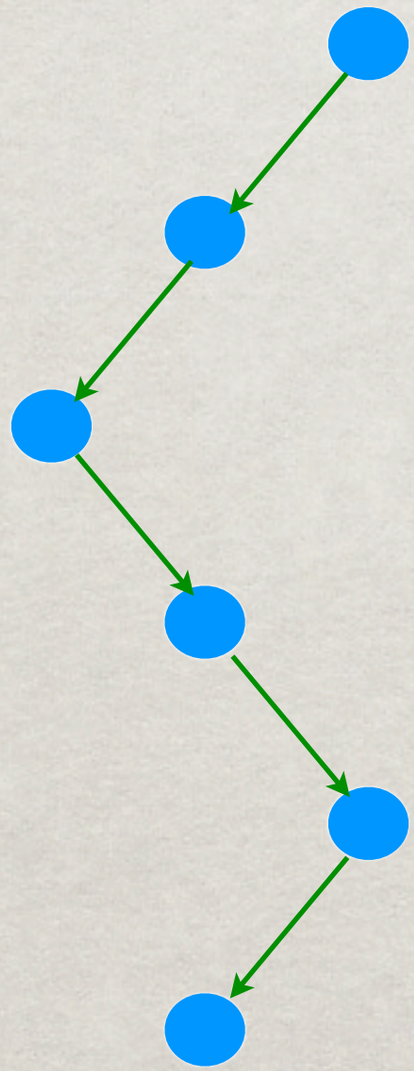
```
(lldb) process attach --name dictionary
Process 397 stopped
(lldb) script
Python Interactive Interpreter. To exit, type 'quit()', 'exit()'
or Ctrl-D.
>>> import tree_utils
>>> root = lldb.frame.FindVariable ("dictionary")
>>> cur_path = ""
>>> path = tree_utils.DFS (root, "Romeo", cur_path)
>>>
```

Using The Interactive Interpreter

```
(lldb) process attach --name dictionary
Process 397 stopped
(lldb) script
Python Interactive Interpreter. To exit, type 'quit()', 'exit()'
or Ctrl-D.
>>> import tree_utils
>>> root = lldb.frame.FindVariable ("dictionary")
>>> cur_path = ""
>>> path = tree_utils.DFS (root, "Romeo", cur_path)
>>> print path
LLRRL
>>> ^D
(lldb)
```

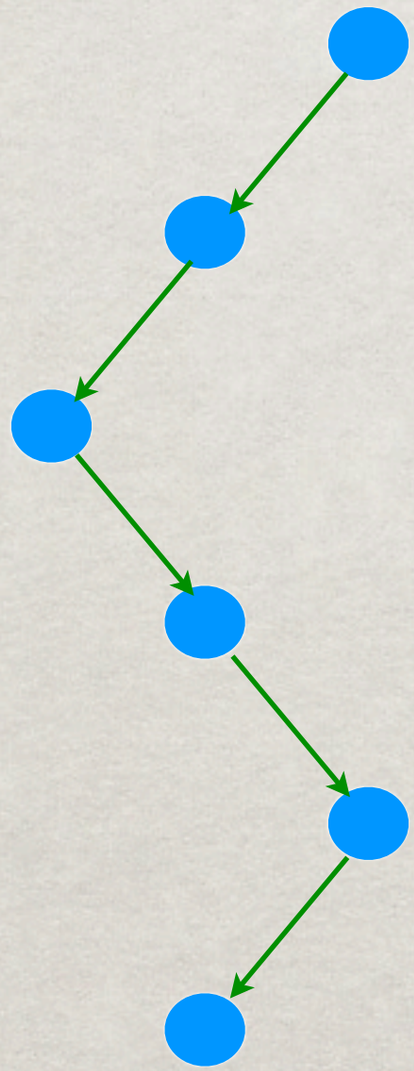
We're Halfway There!

Path: LLRRL



We're Halfway There!

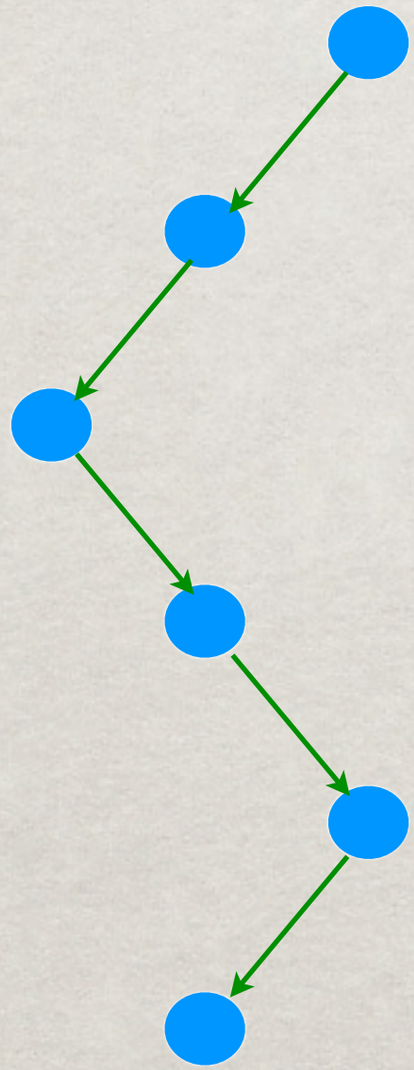
Path: LLRRL



- WE found it...why didn't the program?

We're Halfway There!

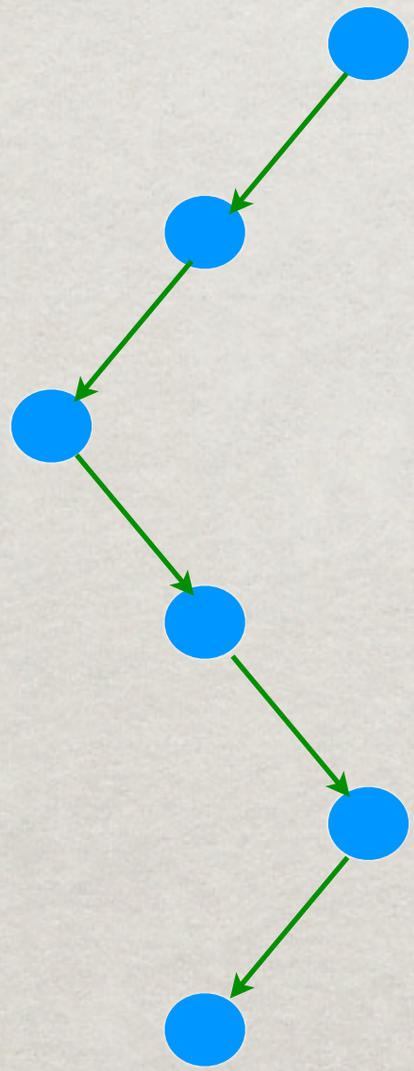
Path: LLRRL



- WE found it...why didn't the program?
- How to find the problem?

We're Halfway There!

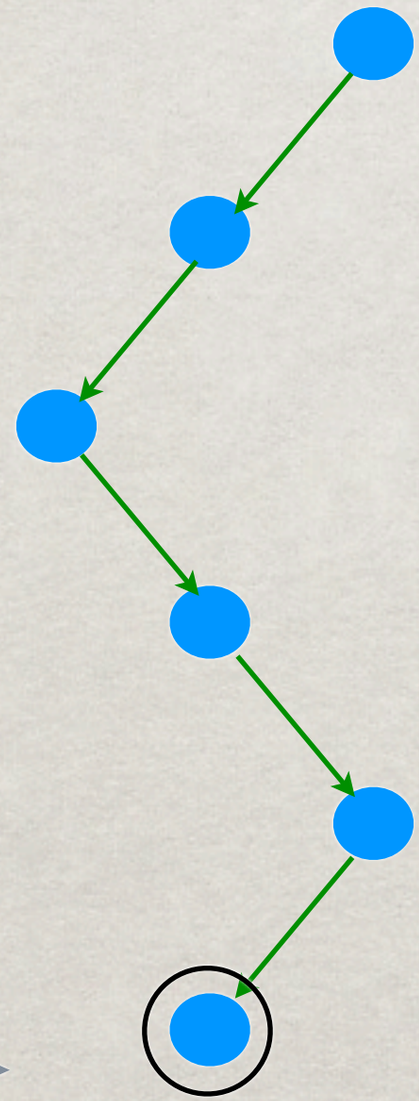
Path: LLRRL



- WE found it...why didn't the program?
- How to find the problem?
- Breakpoint command scripts!

We're Halfway There!

Path: LLRRL

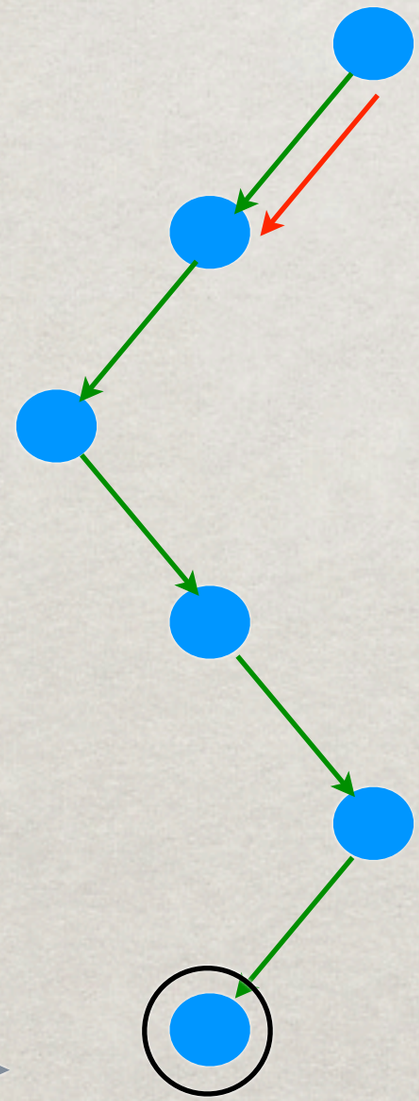


Our word

- WE found it...why didn't the program?
- How to find the problem?
- Breakpoint command scripts!

We're Halfway There!

Path: LLRRL

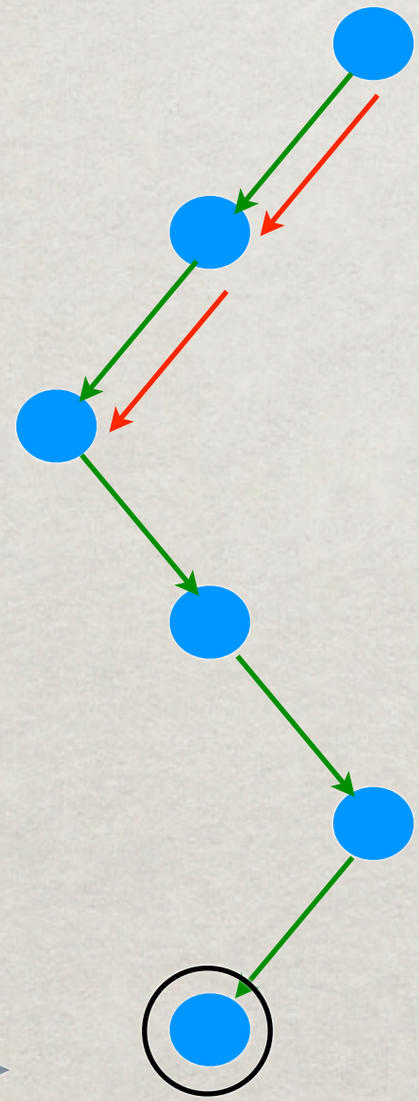


Our word

- WE found it...why didn't the program?
- How to find the problem?
- Breakpoint command scripts!

We're Halfway There!

Path: LLRRL



Our word

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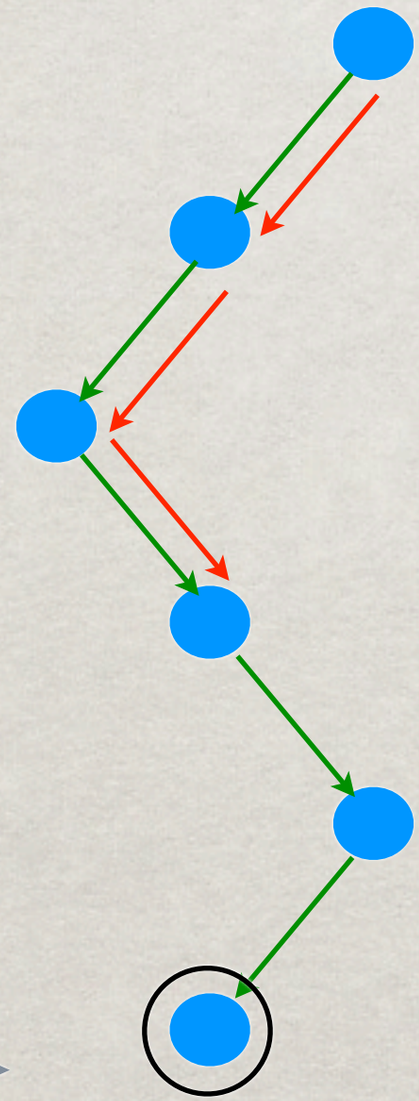
We're Halfway There!

Path: LLRRL



Our word

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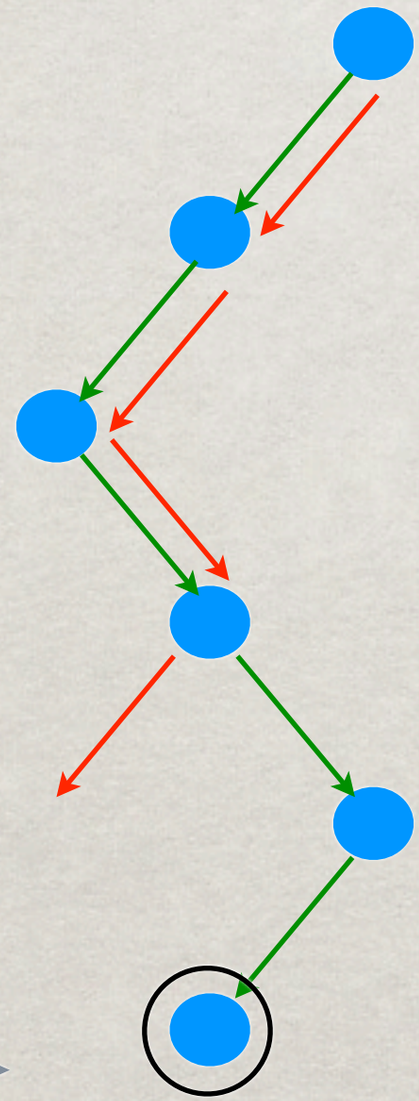
We're Halfway There!

Path: LLRRL



Our word

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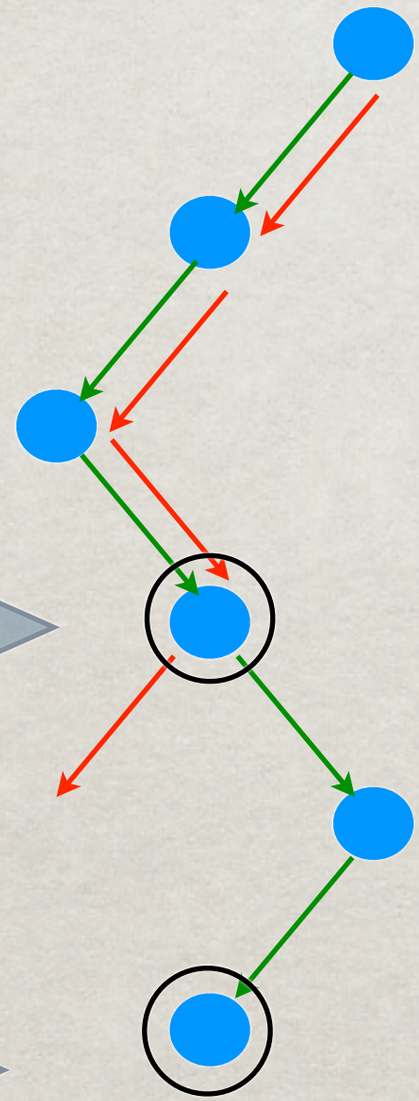
We're Halfway There!

Path: LLRRL



The problem

Our word

- WE found it...why didn't the program?
- How to find the problem?
- Breakpoint command scripts!

Python Breakpoint Command
(At Decision to Follow Right Child)

```
global path
if (path[0] == 'R'):
    path = path[1:]
    thread = frame.GetThread()
    process = thread.GetProcess()
    process.Continue()
else:
    print "Going right; should go left!"
```

Python Breakpoint Command
(At Decision to Follow Right Child)

```
def some_obscure_function_name (frame, bp_loc):
    global path
    if (path[0] == 'R'):
        path = path[1:]
        thread = frame.GetThread()
        process = thread.GetProcess()
        process.Continue()
    else:
        print "Going right; should go left!"
```

LLDB Convenience Variables

Python Breakpoint Command
(At Decision to Follow Right Child)

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global path
if (path[0] == 'R'):
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    thread = frame.GetThread()
    process = thread.GetProcess()
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Python Breakpoint Command
(At Decision to Follow Right Child)

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if (path[0] == 'R'):
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LLDB Convenience Variable

Python Breakpoint Command
(At Decision to Follow Right Child)

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if (path[0] == 'R'):
    path = path[1:]
    thread = frame.GetThread()
    process = thread.GetProcess()
    process.Continue()
else:
    print "Going right; should go left!"
```

LLDB API Functions

Results!

(lldb)

Results!

```
(lldb) breakpoint command add -s python 1
...
(lldb)
```

Results!

```
(lldb) breakpoint command add -s python 1
...
(lldb) breakpoint command add -s python 2
...
(lldb)
```

Results!

```
(lldb) breakpoint command add -s python 1
...
(lldb) breakpoint command add -s python 2
...
(lldb) continue

Going right; should go left!
Process 236 stopped
...
(lldb)
```

Results!

```
(lldb) breakpoint command add -s python 1
...
(lldb) breakpoint command add -s python 2
...
(lldb) continue

Going right; should go left!
Process 236 stopped
...
(lldb) expr root->word
(const char *) $0 = “dramatis”
(lldb)
```

Results!

```
(lldb) breakpoint command add -s python 1
...
(lldb) breakpoint command add -s python 2
...
(lldb) continue

Going right; should go left!
Process 236 stopped
...
(lldb) expr root->word
(const char *) $0 = “dramatis”
(lldb) expr search_word
(char *) $1 = “romeo”
(lldb)
```

Results!

(lldb) breakpoint command add -s python 1
...
(lldb) breakpoint command add -s python 2
...
(lldb) continue

Going right; should go left!
Process 236 stopped
...
(lldb) expr root->word
(const char *) $0 = “dramatis”
(lldb) expr search_word
(char *) $1 = “romeo”
(lldb) script print path
LLRRL
(lldb)

Results!

```
(lldb) breakpoint command add -s python 1
...
(lldb) breakpoint command add -s python 2
...
(lldb) continue

Going right; should go left!
Process 236 stopped
...
(lldb) expr root->word
(const char *) $0 = “dramatis”
(lldb) expr search_word
(char *) $1 = “romeo”
(lldb) script print path
LLRRL
(lldb) expr root->left->left->right->right->left->word
(const char *) $2 = “Romeo”
(lldb)
```

Results!

```
(lldb) breakpoint command add -s python 1
...
(lldb) breakpoint command add -s python 2
...
(lldb) continue

Going right; should go left!
Process 236 stopped
...
(lldb) expr root->word
(const char *) $0 = “dramatis”
(lldb) expr search_word
(char *) $1 = “romeo”
(lldb) script print path
LLRRL
(lldb) expr root->left->left->right->right->left->word
(const char *) $2 = “Romeo”
(lldb)
```

Case conversion problem!

Summary

- Embedding Python in a debugger gives users great power
- Passing pointers/objects can be done via API tweaks & integer passing
- Maintaining separate session dictionaries allowed persistence & multi-interpreter emulation

For Further Reference

- The LLDB website: http://lldb.llvm.org
  - Full project description
  - Download code (it's open source!)
  - Scripting example with explanations
    - http://lldb.llvm.org/scripting.html
  - Developer's Mailing List

Questions/Comments!

Caroline Tice
ctice42@gmail.com