15-411 Compilers

Who are we?

- Andre Platzer
  - Out of town the first week
  - GHC 9103

- TAs
  - Alex Crichton, senior in CS and ECE
  - Ian Gillis, senior in CS

Logistics

- symbolaris.com/course/compiler12.html
  - symbolaris.com -> Teaching -> Compiler 12
- autolab.cs.cmu.edu/15411-f12
- Lectures
  - Tues/Thurs 1:30-2:50pm
  - GHC 4211
- Recitations - none!
- Office Hours
  - More coming soon...

Contact us

- 15411@symbolaris.com
  - Course staff
- Individually
  - Andre - aplatzer@cs.cmu.edu
  - Alex - acrichto@andrew.cmu.edu
  - Ian - igillis@andrew.cmu.edu
- Office Hours

Waitlisted?

- Long waitlist
  - Room may become available!
- Beware of partnering
  - If admitted but no singles left, you must solo
- Talk to me after lecture

Course Overview

- No exams
  - Not even a final!
- 5 homeworks
- 6 Labs
  - Required tests for each lab
- Paper at the end

Textbook(s)

- Modern Compiler Implementations in ML
  - Andrew W. Appel
  - Optional
- Compiler Construction
  - William M. Waite and Gerhard Goos
  - Optional
- Supplement lecture
  - Do not replace it

Homeworks

- One before each lab is due
  - About a week to work on each one
- Submitted through autolab individually
- Must be your own work
- 30% of the final grade (300 points total)
  - Each homework is 6% of your grade
- Due at the beginning of lecture
  - Can turn two homeworks in late
  - Only up to the next lecture
  - Excludes Thanksgiving

Labs - Overview

- Also submitted through autolab
- May be done in pairs (same pair for all labs)
  - Must be entirely team's work
  - Acknowledge outside sources in readme
- 70% of final grade (700 points total)
- 6 labs
  - First 5 are 100 points each
  - Last is 200

Labs - Overview

- Cumulatively build a compiler for C0
  - Expressions
  - Control flow
  - Functions
  - Structs and arrays
  - Memory safety and optimizations
  - Choose your own adventure
- Each lab is a subset of C0
  - Also superset of previous lab

Labs - Language

- Can write compiler in language of choice
- Starter code (initial parser/layout)
  - SML
  - Haskell
  - Scala
  - Java
- Grading process
  - make
  - ./bin/l{1,2,3,4,5,6}c

Labs - Layout

- Each lab has two parts
- Part 1: submit 10 tests
  - 20% of the lab grade
  - Based on number of tests submitted
  - Can be as creative as you like
- Part 2: submit a compiler
  - 80% of the lab grade
  - Based on number of tests passed
  - Tested against everyone's tests
    - And previous labs
    - And last years'
    - And the year before that

Labs - Tests

- Very good way to test compilers
  - Aren't comprehensive, however
  - Purpose is to find individual bugs
- You are graded on everyone's tests
- assert(1 + 1 == 2)

Labs - Submission

- SVN repositories set up
- Work is submitted through SVN into autolab
  - Only most recent submission is relevant
- We publish updates to tests and runtime
  - You just run 'svn update'
- Only one autolab submission is necessary per team for labs
  - We don't grade SVN, so submit updates to autolab!

Labs - Timing

- Two weeks for each lab
  - Tests due at end of first week (11:59)
  - Compiler due at end of second (11:59)
- No late days for tests
- 6 late days for compiler
  - At most two per lab

Labs - Partners

- Can do labs alone
- Can also do with a partner
  - Should remain the same for all labs
- Email 15411@symbolaris.com with partner
  - We will then assign you a team name

Labs - Partners

- If partnering, choose wisely
  - Must work as a team to be effective
  - Cannot let the other "do all the work"
- Trouble arises
  - Email 15411@symbolaris.com before too late
  - Day before lab is due is too late
  - Beginning of second lab is not too late

Labs - Warnings

- Labs are ***hard*** and take time
- Don't start the compiler only after submitting tests
- Errors in one lab carry over to the next
  - Each lab still runs previous tests
- Do not take labs lightly, plan accordingly
  - This class will consume much time
- 15-411 is by no means easy
  - Compilers take ***a lot*** of work

Labs - Suggestions

- Start early
  - Fixing tests takes a long time
- If submitted compiler has errors, fix quickly
  - Errors for lab 1 must be fixed for lab 2!
- Schedule with partner
  - Specifically set aside time for 15-411
- Talk to us!
  - Talk about design plans
  - Especially if soloing
  - Office hours or email
- Remember that this is exciting!

Labs - My suggestions

- Do not cram entire compiler into one week
- Compiler passes own tests when tests due
- Get to know the driver well
  - You will be running this many many times
  - Ask us if you want it do have feature X
- Write difficult tests
  - Forces you to think
- Submit early to autolab
  - Avoid the rush

Paper

- After 6th lab, a paper is required
- Technical paper demonstrating what you learned
  - What design decisions did you make?
  - What design decisions were good?
  - Which ones ended badly?
  - Were certain tests good or tricky?
- More details when time comes

Questions?

- Waitlist
- Course outline
- Homework
- Labs
  - Partners
- Paper

Writing a Compiler

Course Goals

- Understand how compilers work
  - General structure of compilers
  - Influence of target/source language on design
  - Restrictions of hardware
- Gain experience with a complex project
  - Both maintain it and work with others
- Develop in a modular fashion
  - Each lab builds on the next

What is a compiler?

- Translator from one language to another
  - Might have a few changes in the middle
- Adheres to 5 principles
  - Correctness
  - Efficiency
  - Interoperability
  - Usability
  - Retargetability

Compiler Principles - 1

- Correctness
  - How useful is an incorrect compiler?
  - What if it were extremely fast?
- How do you know?
  - Language specification
  - Formal proof
  - Tests, lots of tests

Compiler Principles - 1

- What to test for correctness?
  - 1 + 1 == 2
  - 1 + 1 != 1
  - *a == 3
  - *NULL is a segv
  - while (1) ; loops forever
- Language design
  - Can make correctness a lot easier
  - Or harder
  - C0 is much better specified than C

Compiler Principles - 2

- Efficiency
  - Generated code is fast
  - Compiling process is also fast
- Cannot forsake correctness
  - "But I got the wrong answer really fast!"

Compiler Principles - 3

- Interoperability
  - Most binaries are not static
  - Run with code from other compilers
- Interface, or an ABI
  - C0 uses the C ABI
  - x86 is different than x86-64
  - arm is very different

Compiler Principles - 4

- Usability
- Error messages
  - Error.
  - Error in file foo.c
  - Error at foo.c:3
  - Error at foo.c:3:5
  - Type Error at foo.c:3:5
  - Type Error at foo.c:3:5, did you mean ...?
- Not formally tested in this class
  - You're still writing code!

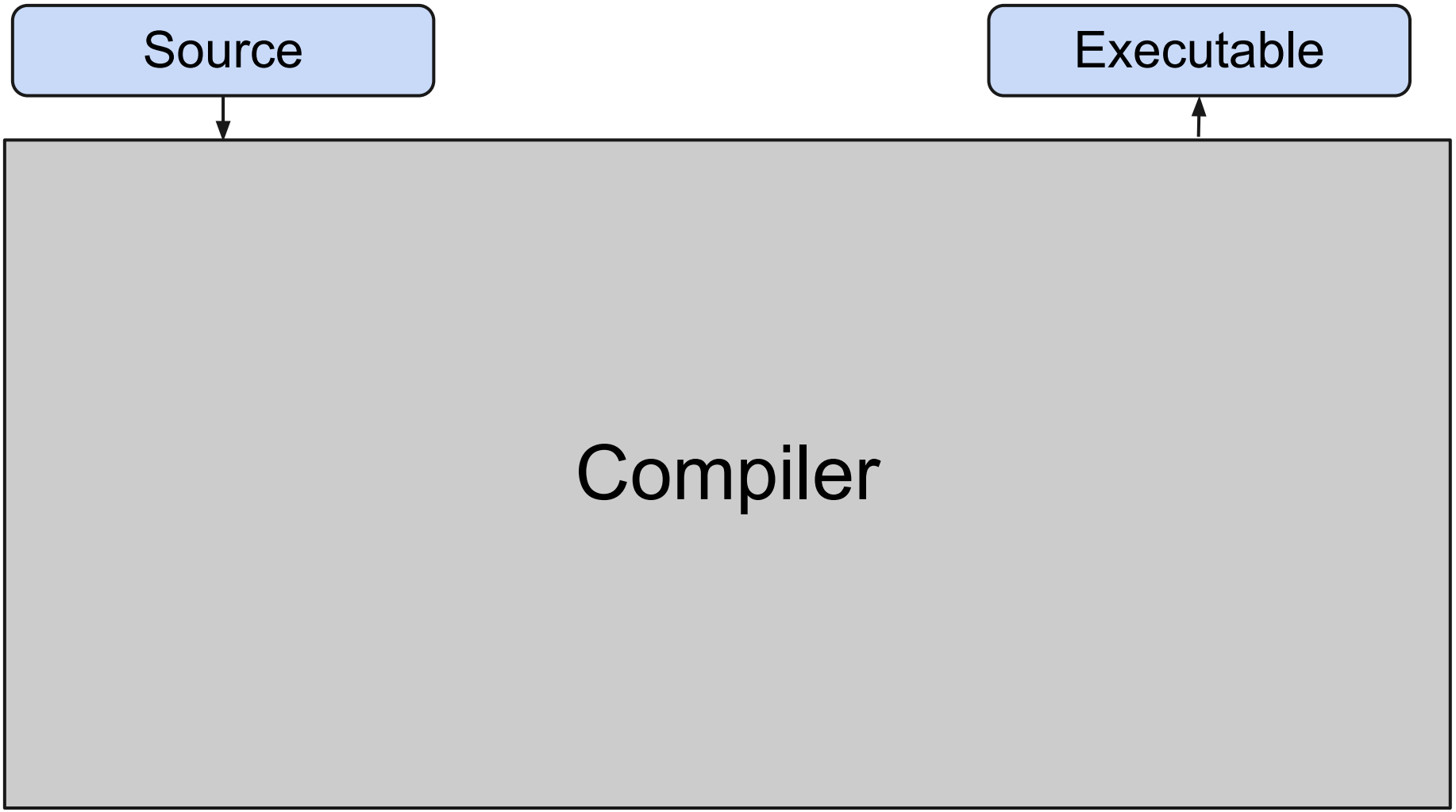
Compiler Principles - 5

- Retargetability
  - Multiple sources?
  - Multiple targets?
- We will not emphasize this
  - Does not mean you should disregard it

Designing a Compiler

- Correctness
- Efficiency
- Interoperability
- Usability
- Retargetability

Designing a Compiler



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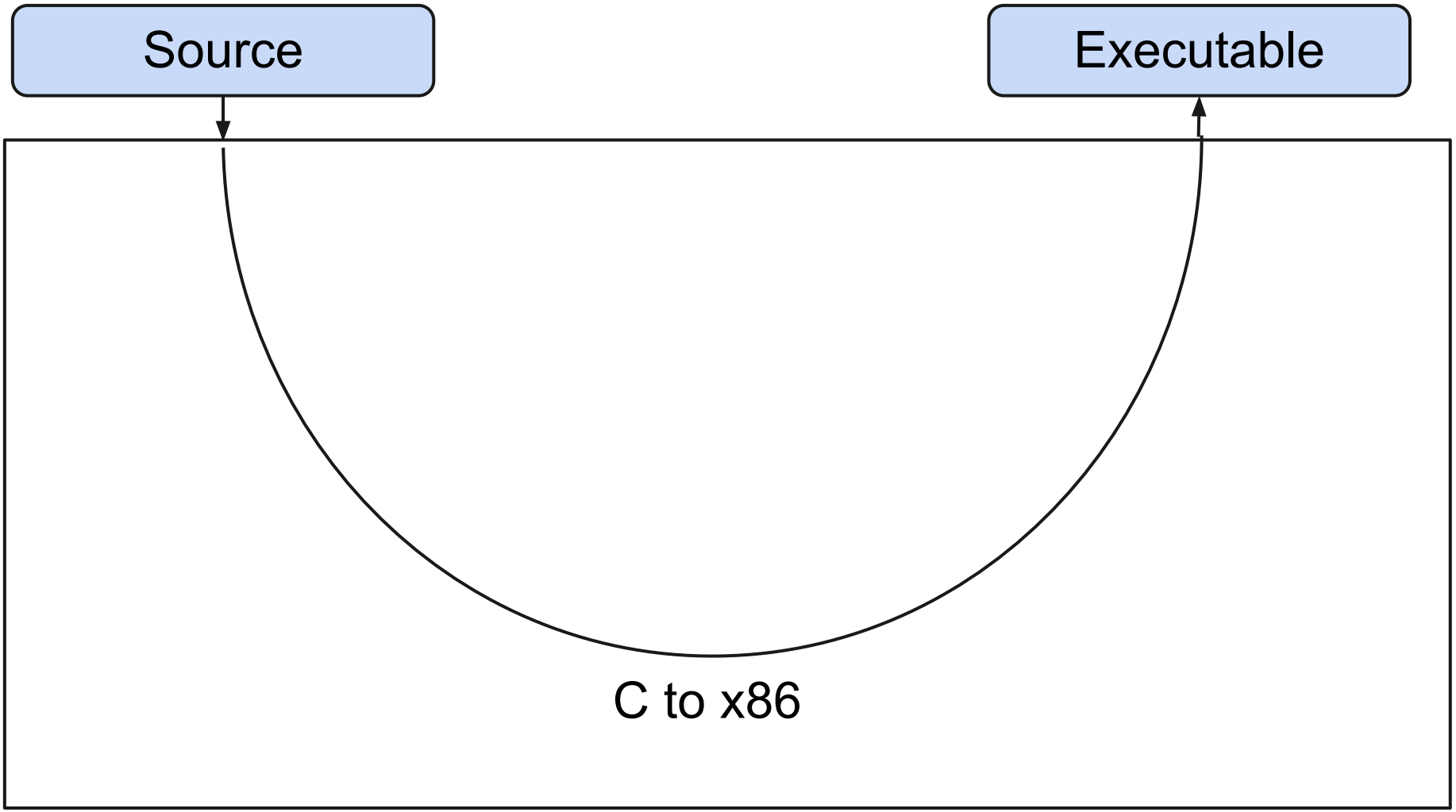

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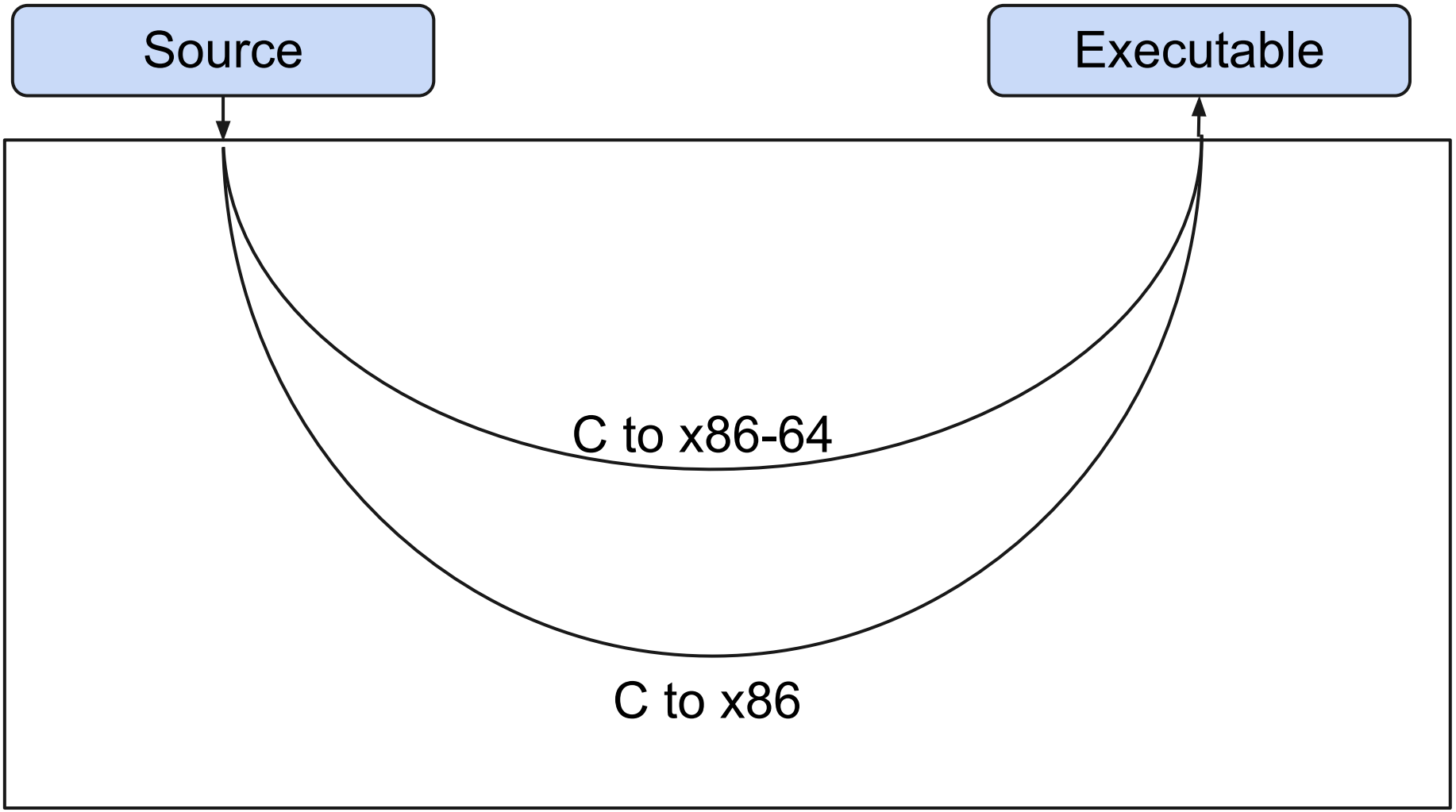

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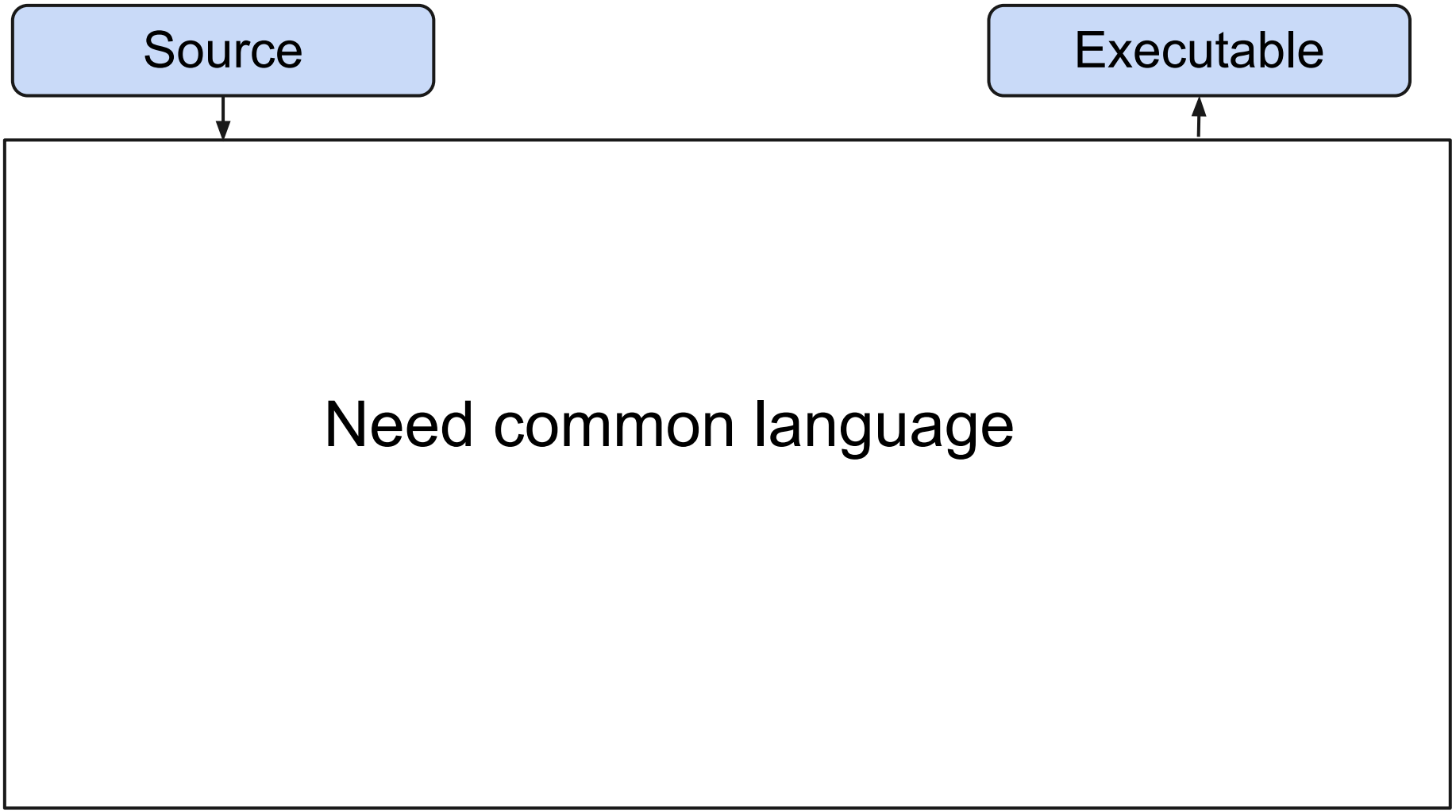

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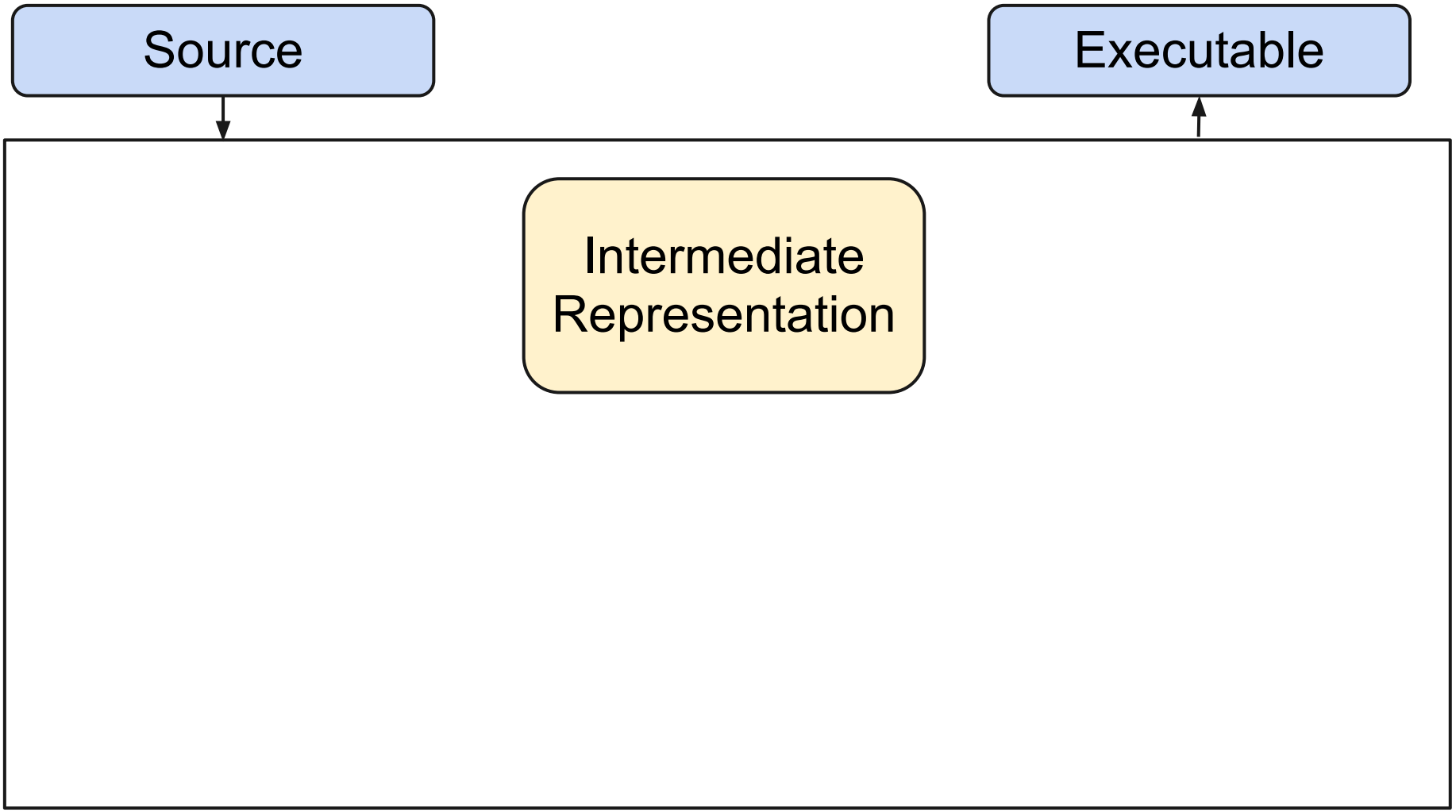

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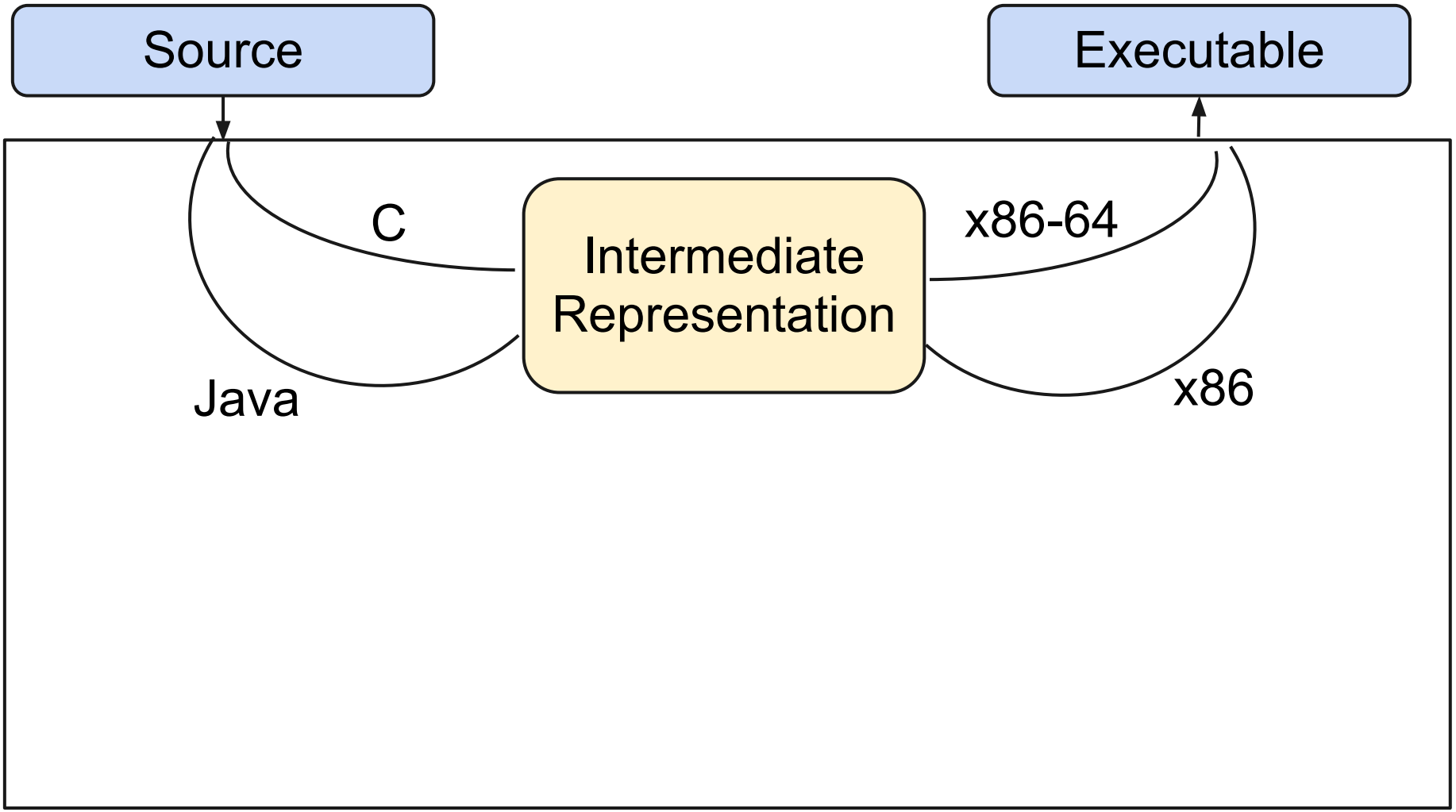

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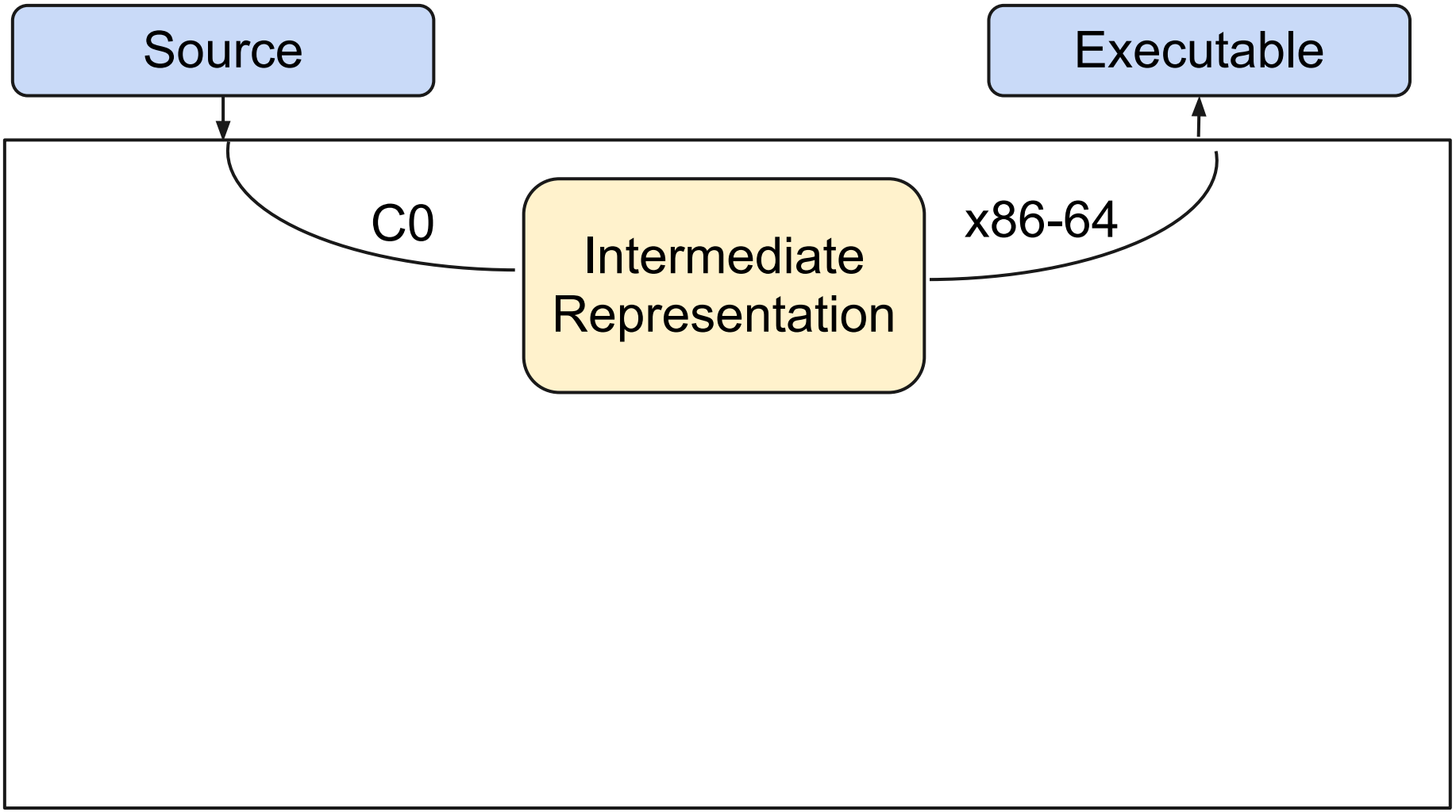

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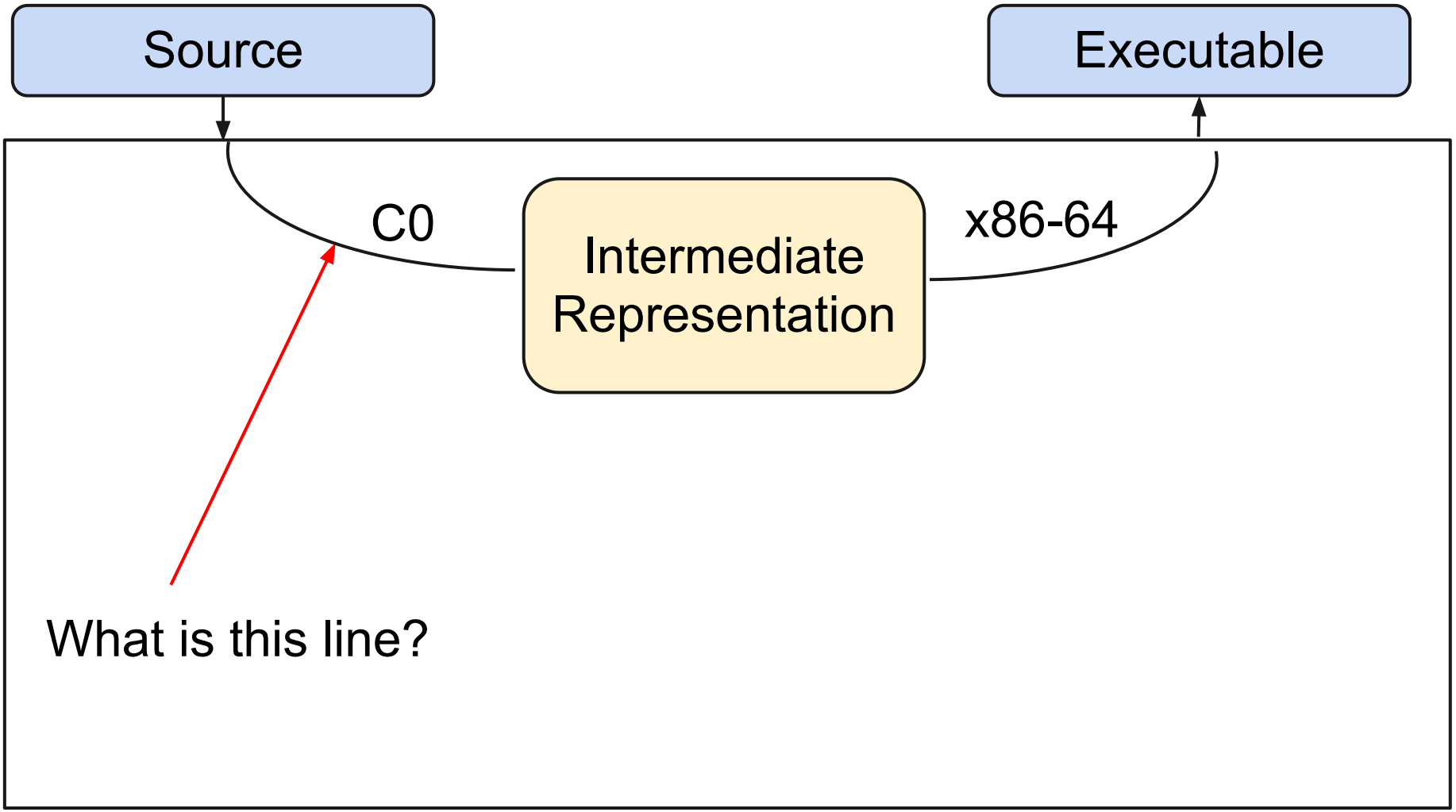

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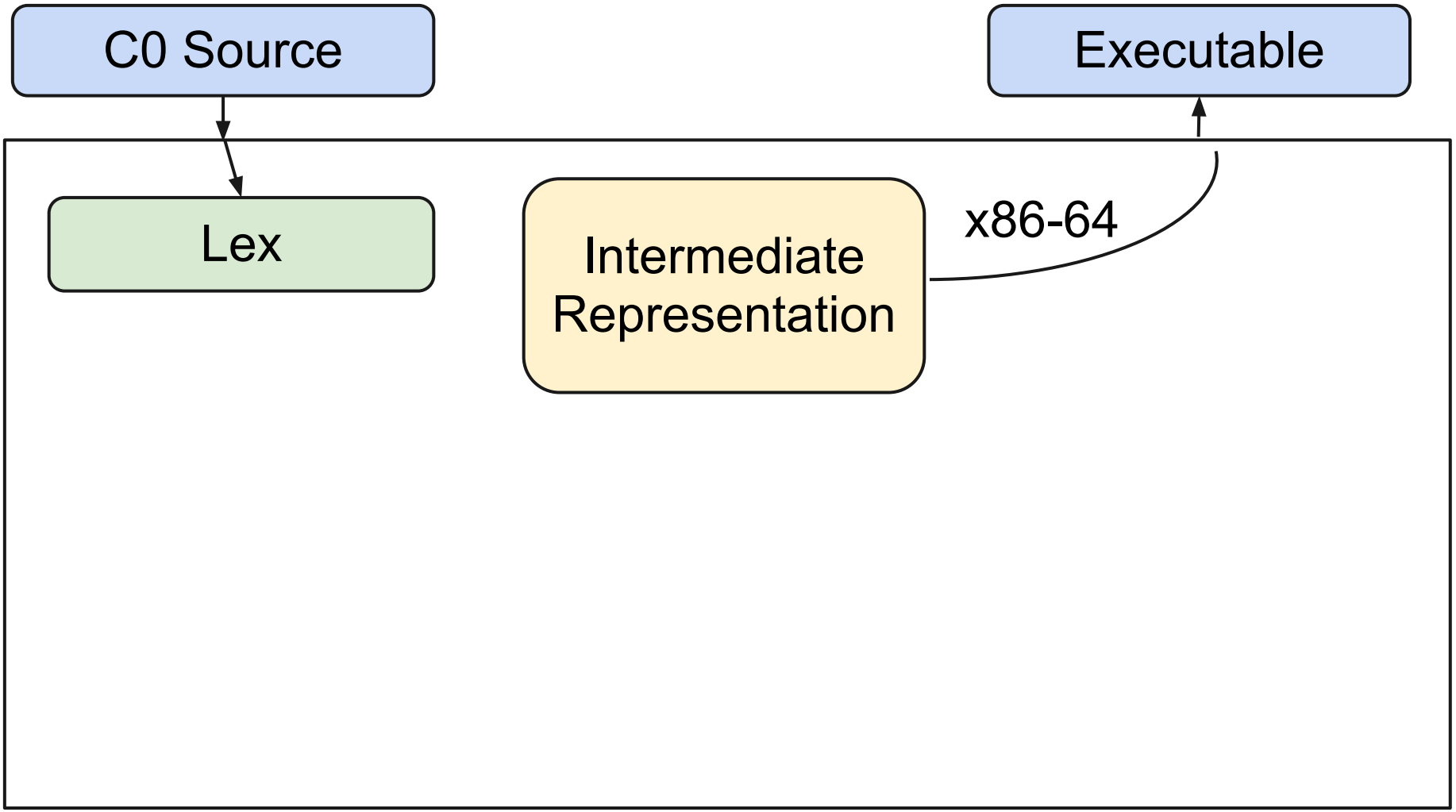

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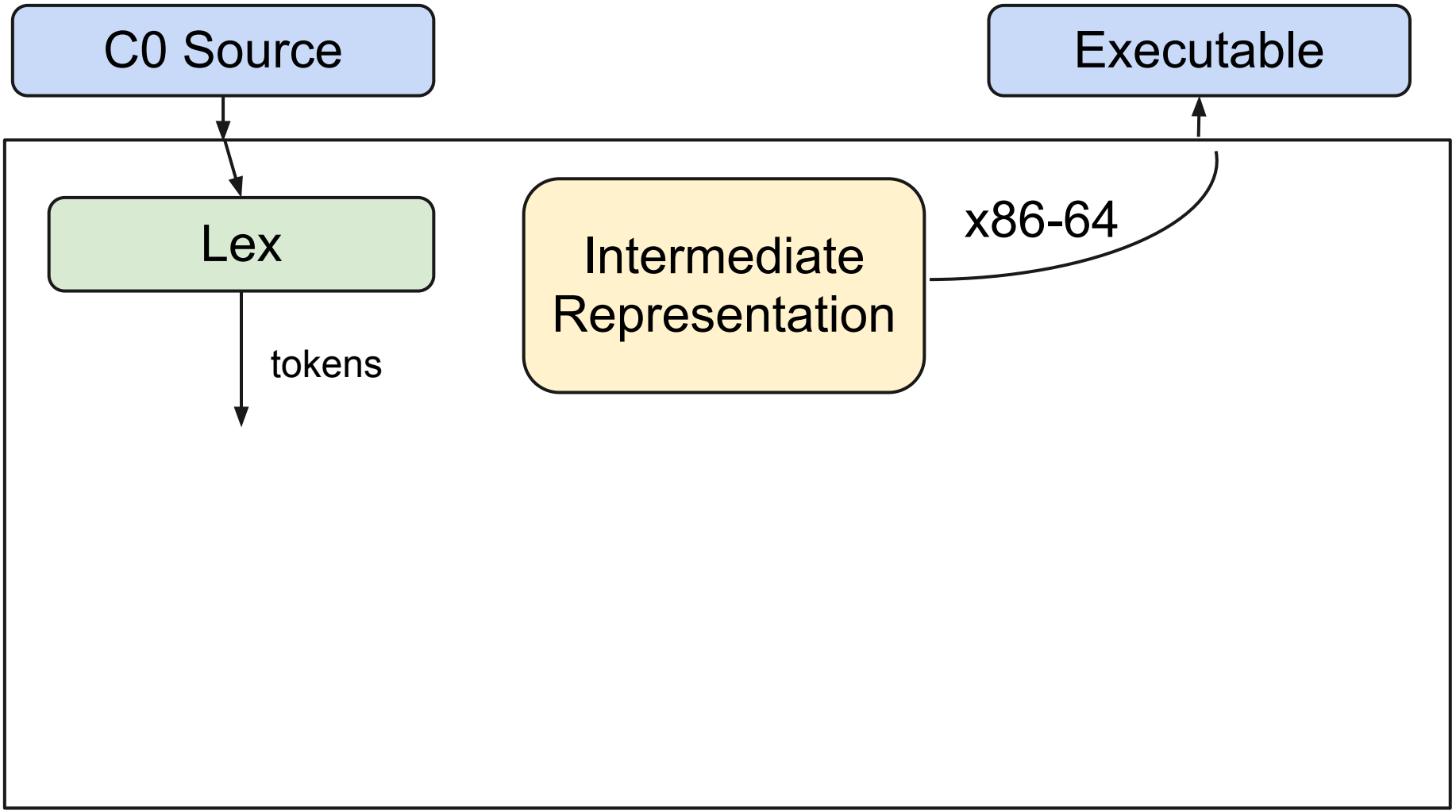

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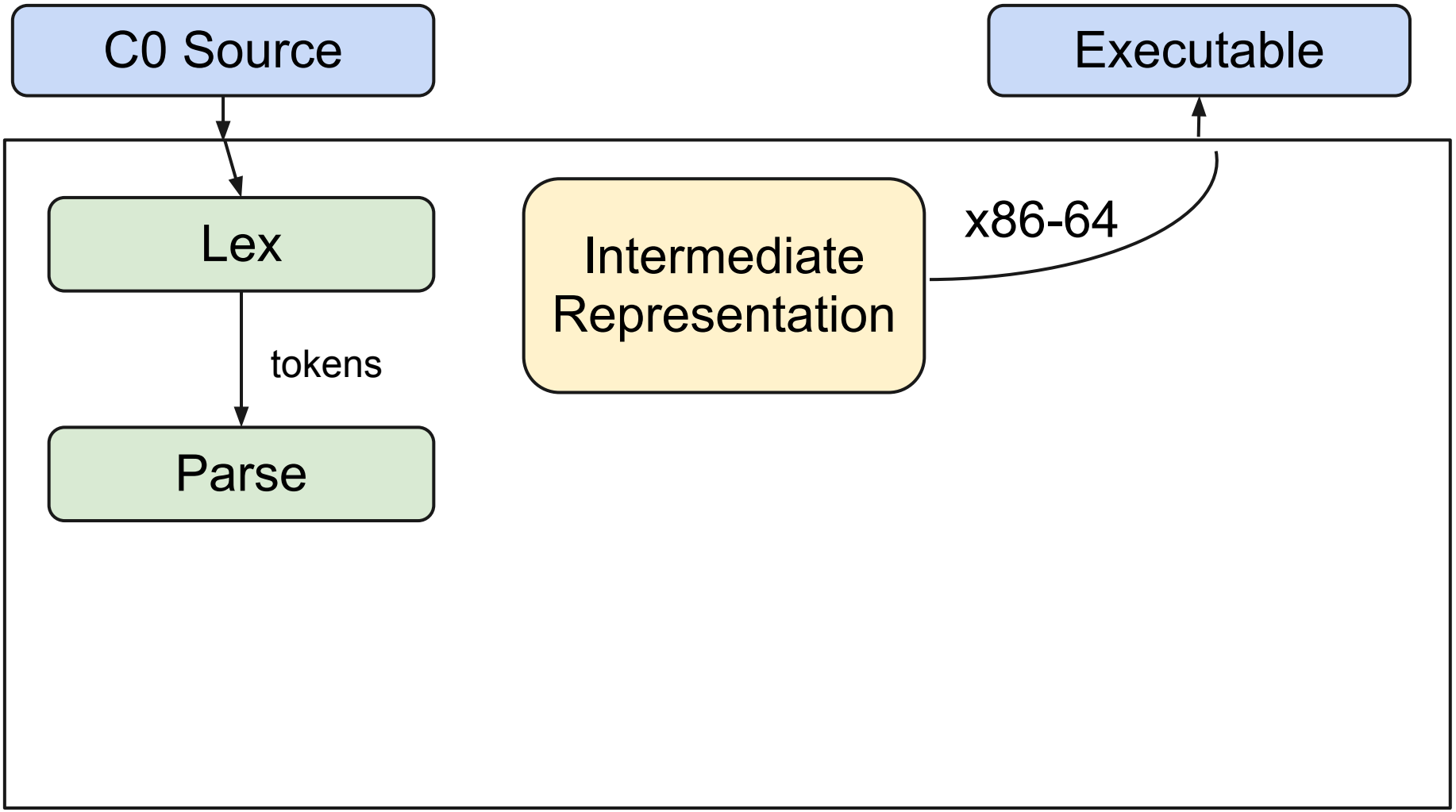

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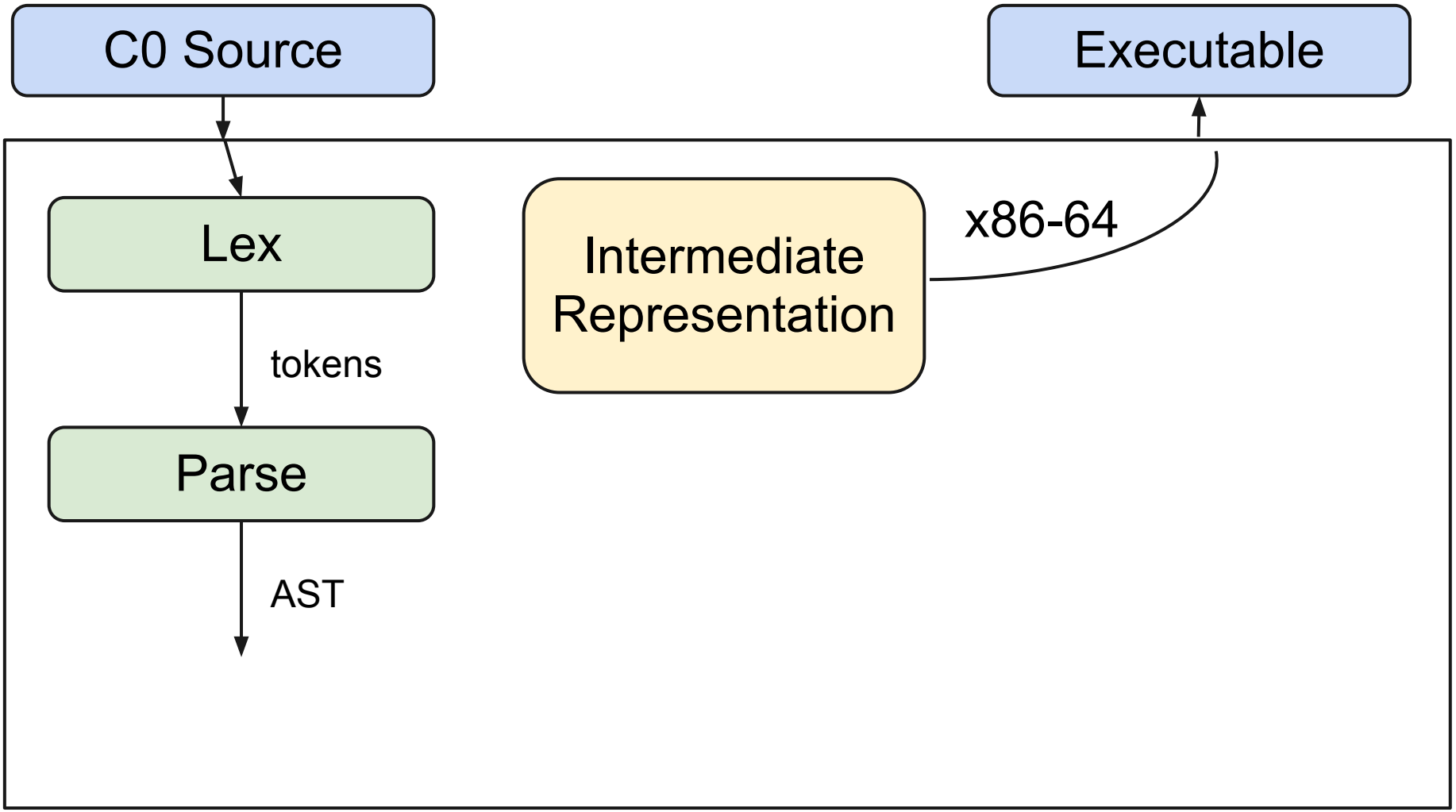

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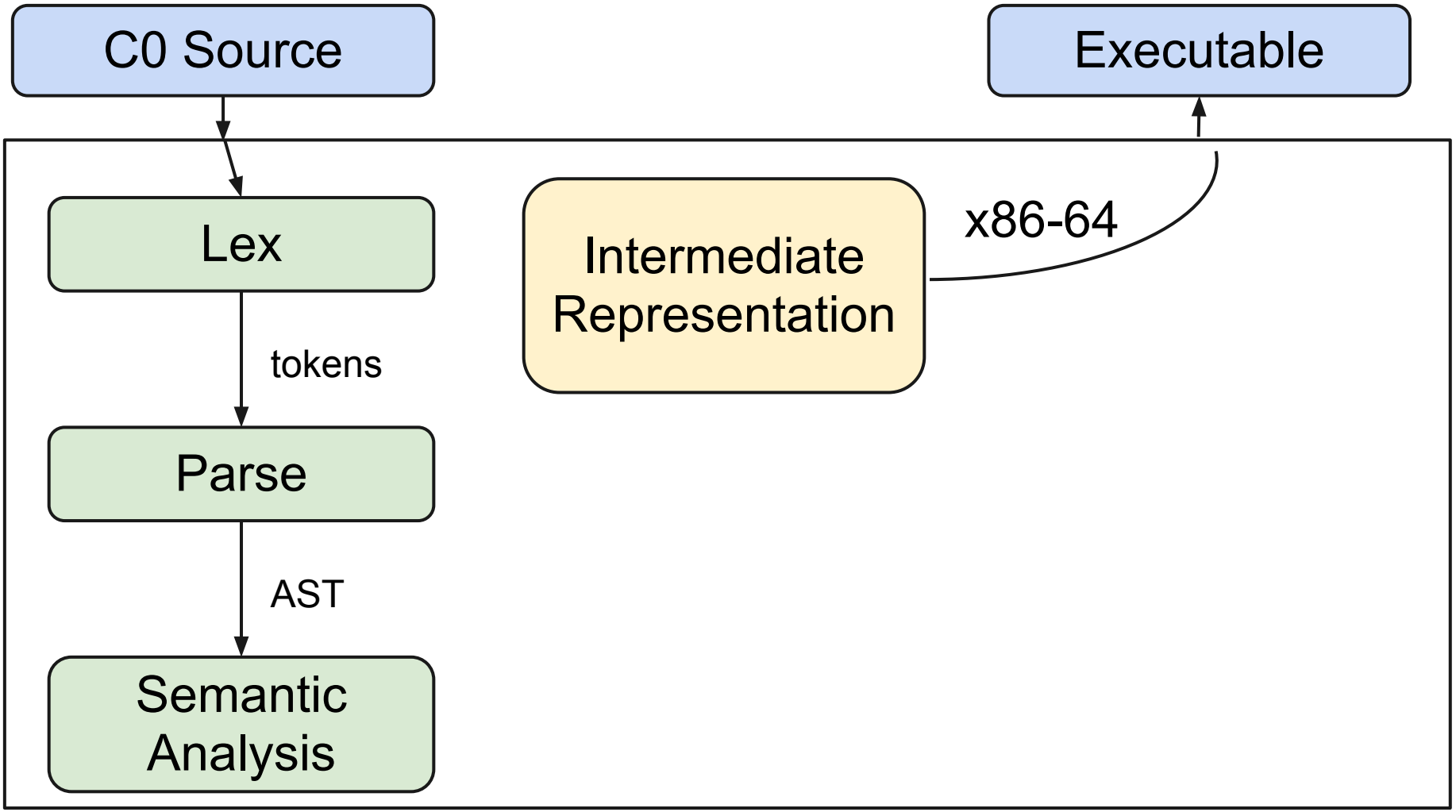

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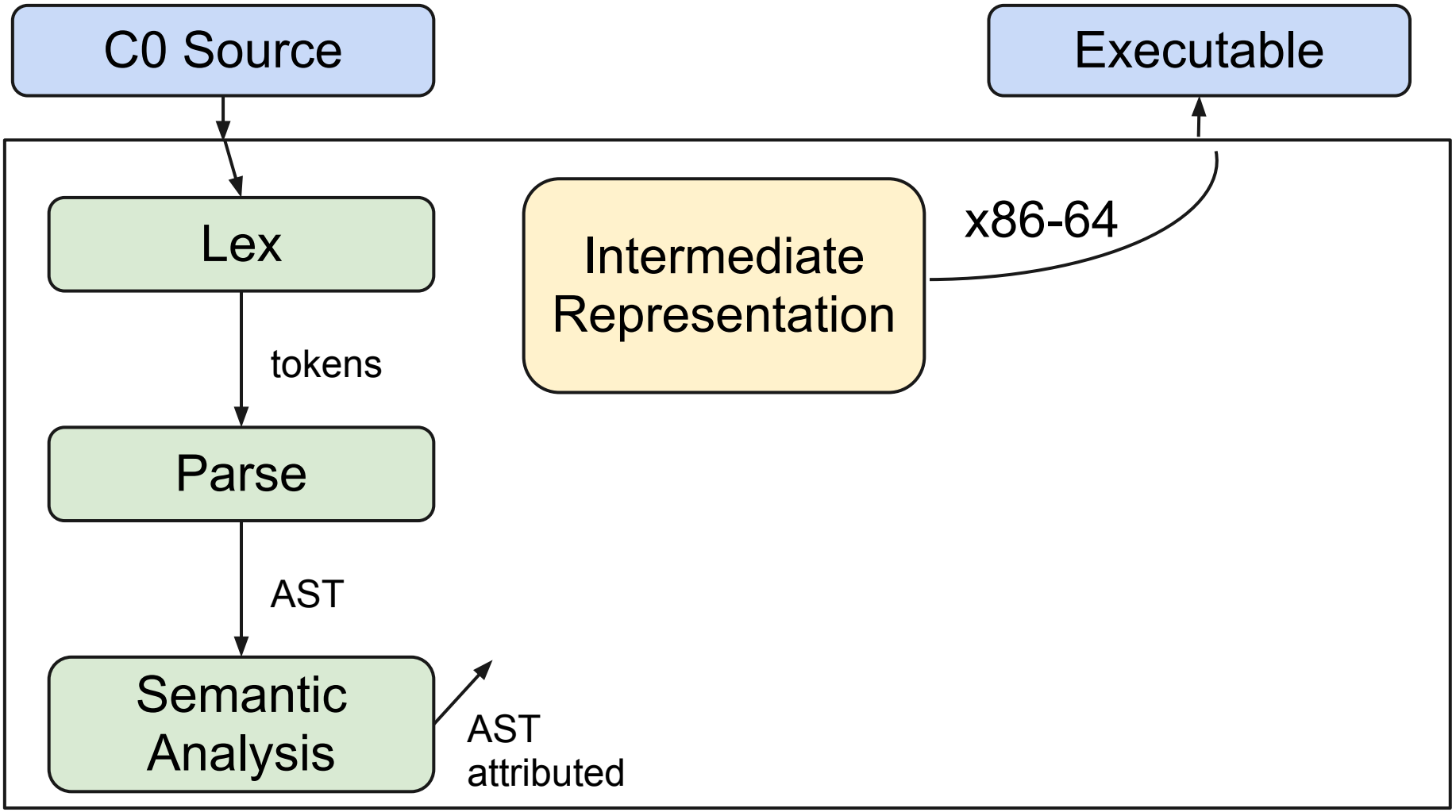

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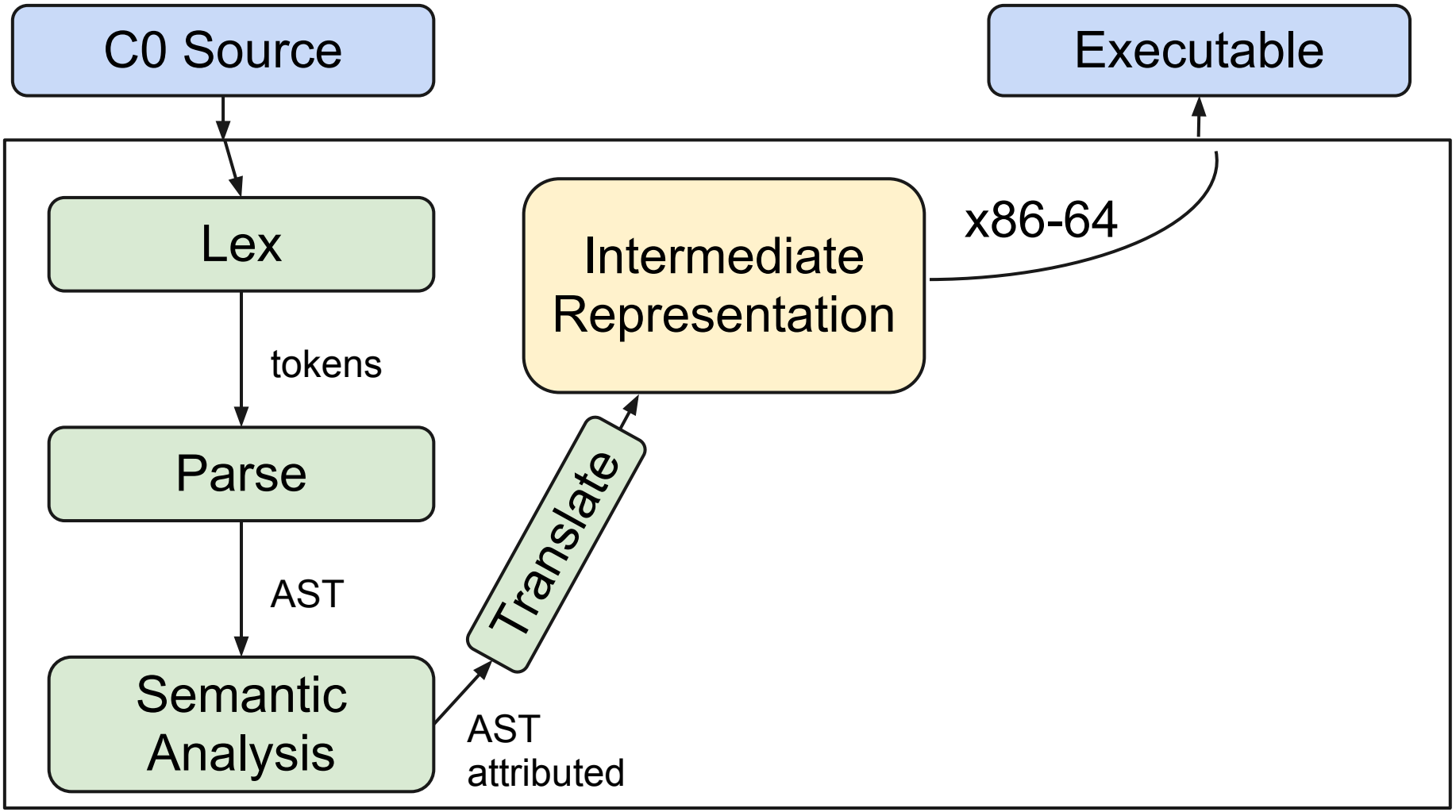

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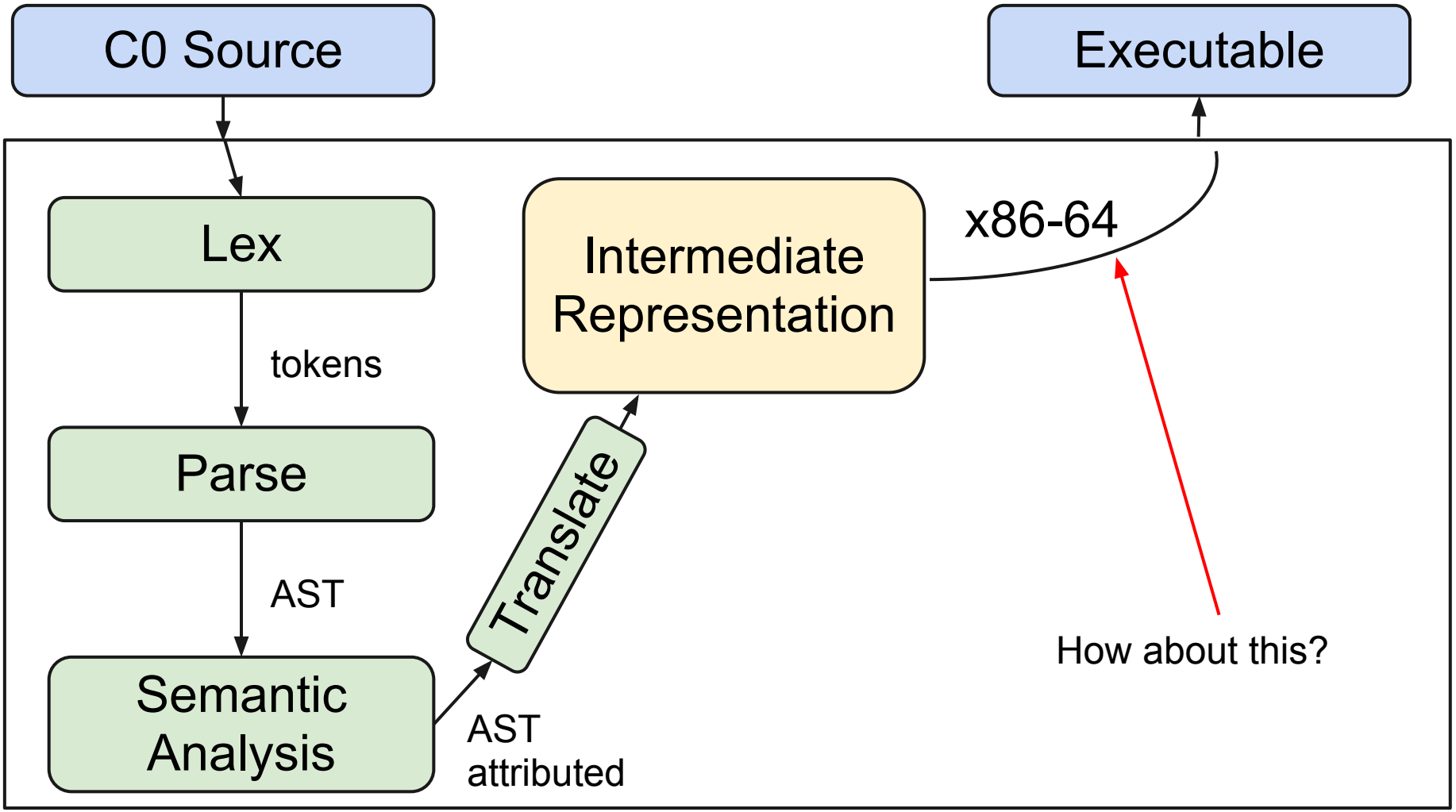

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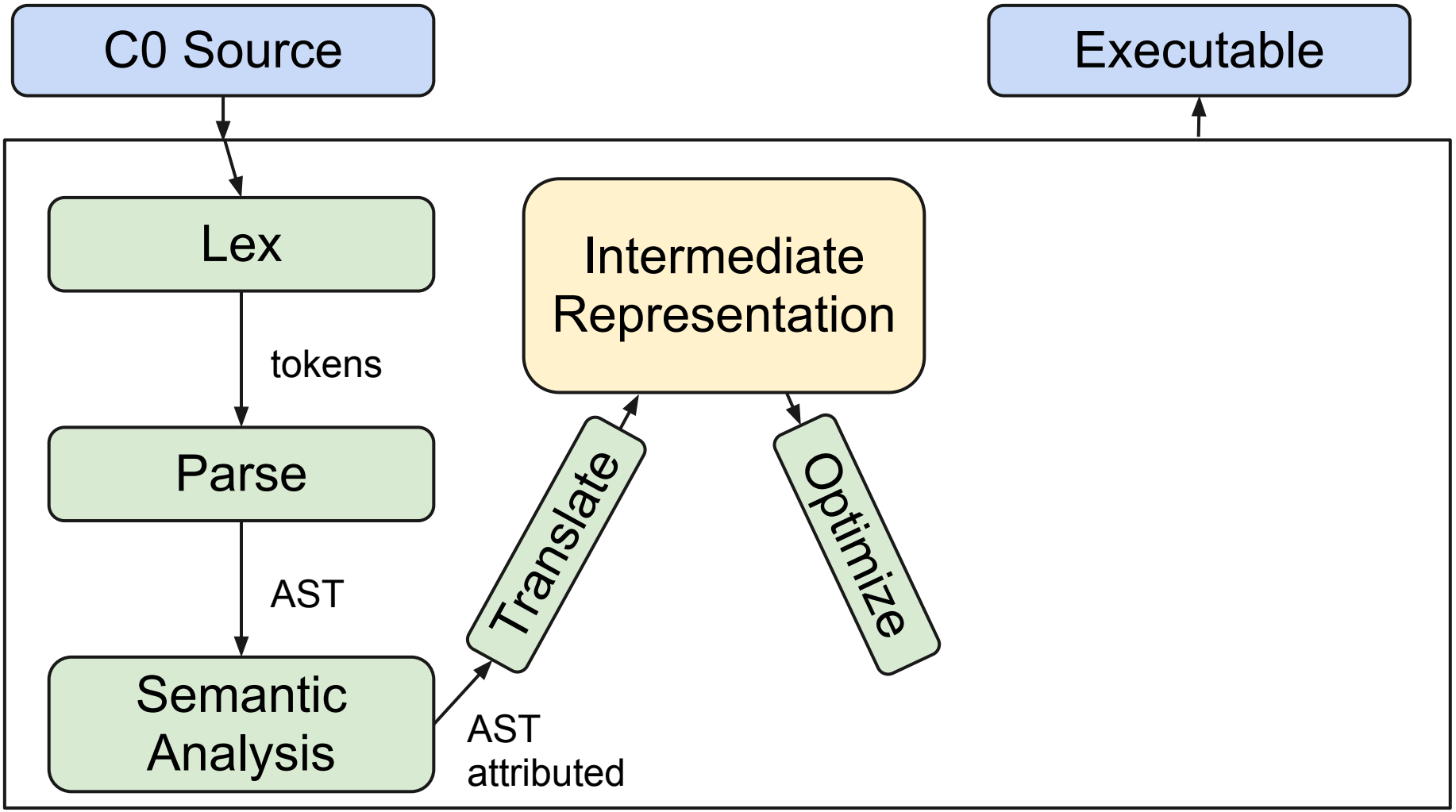

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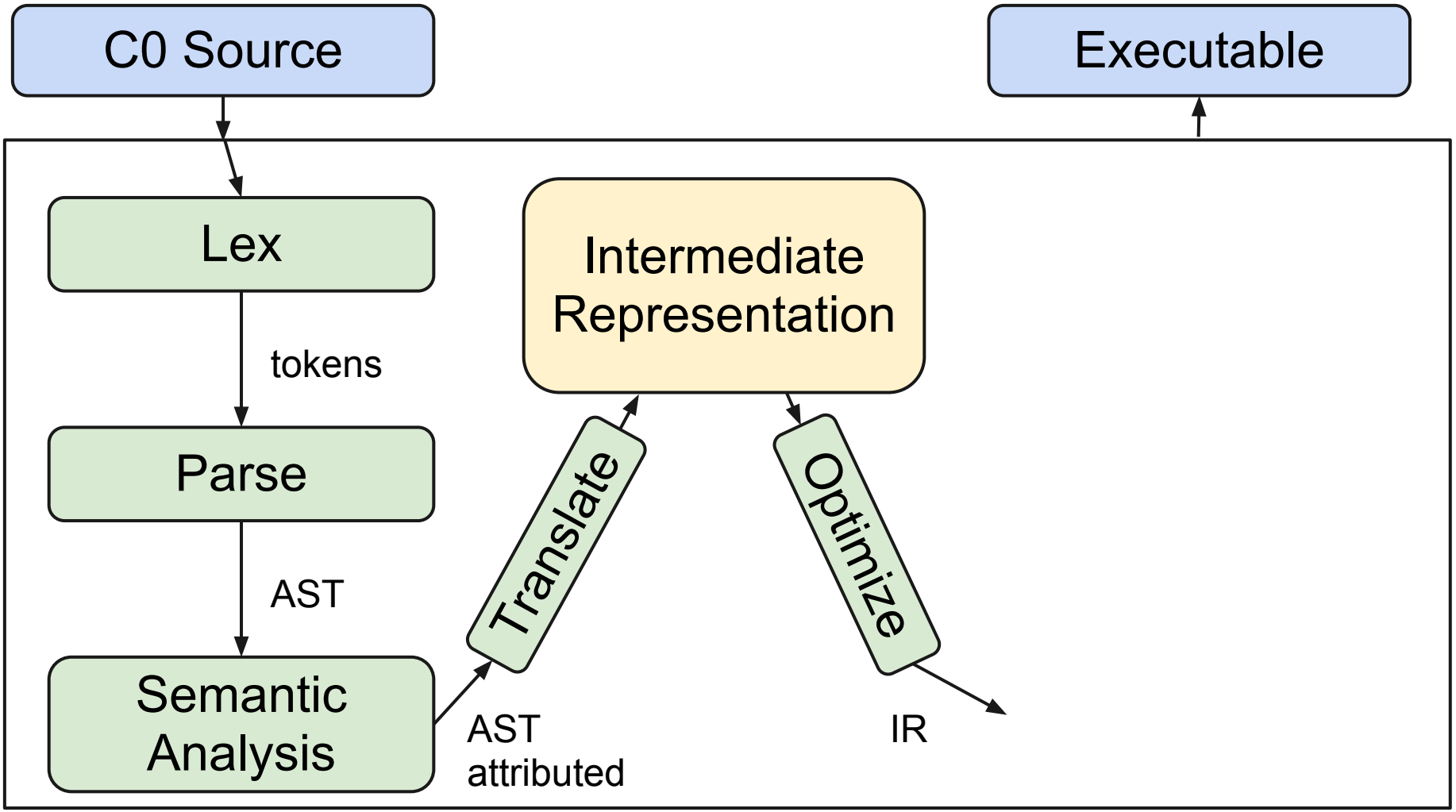

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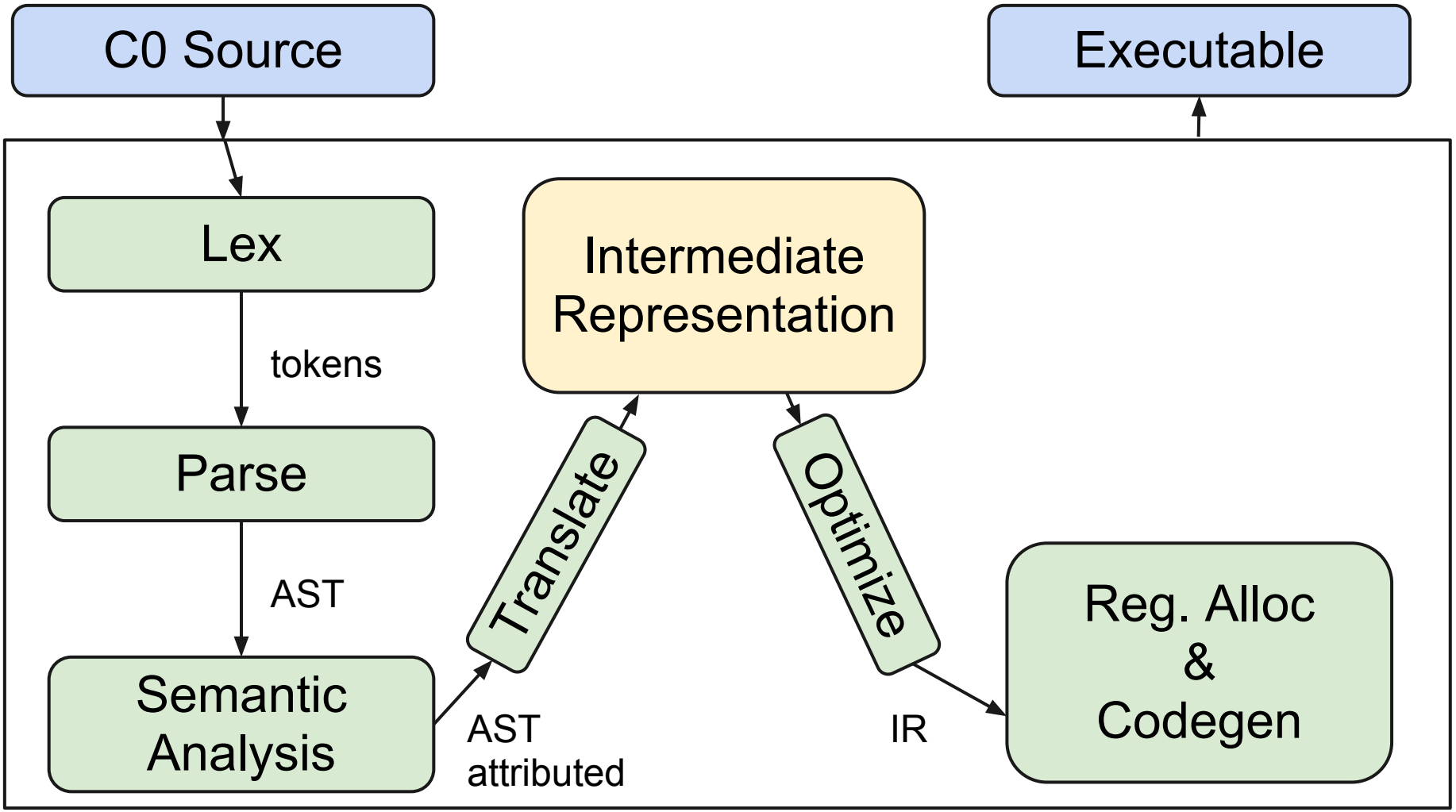

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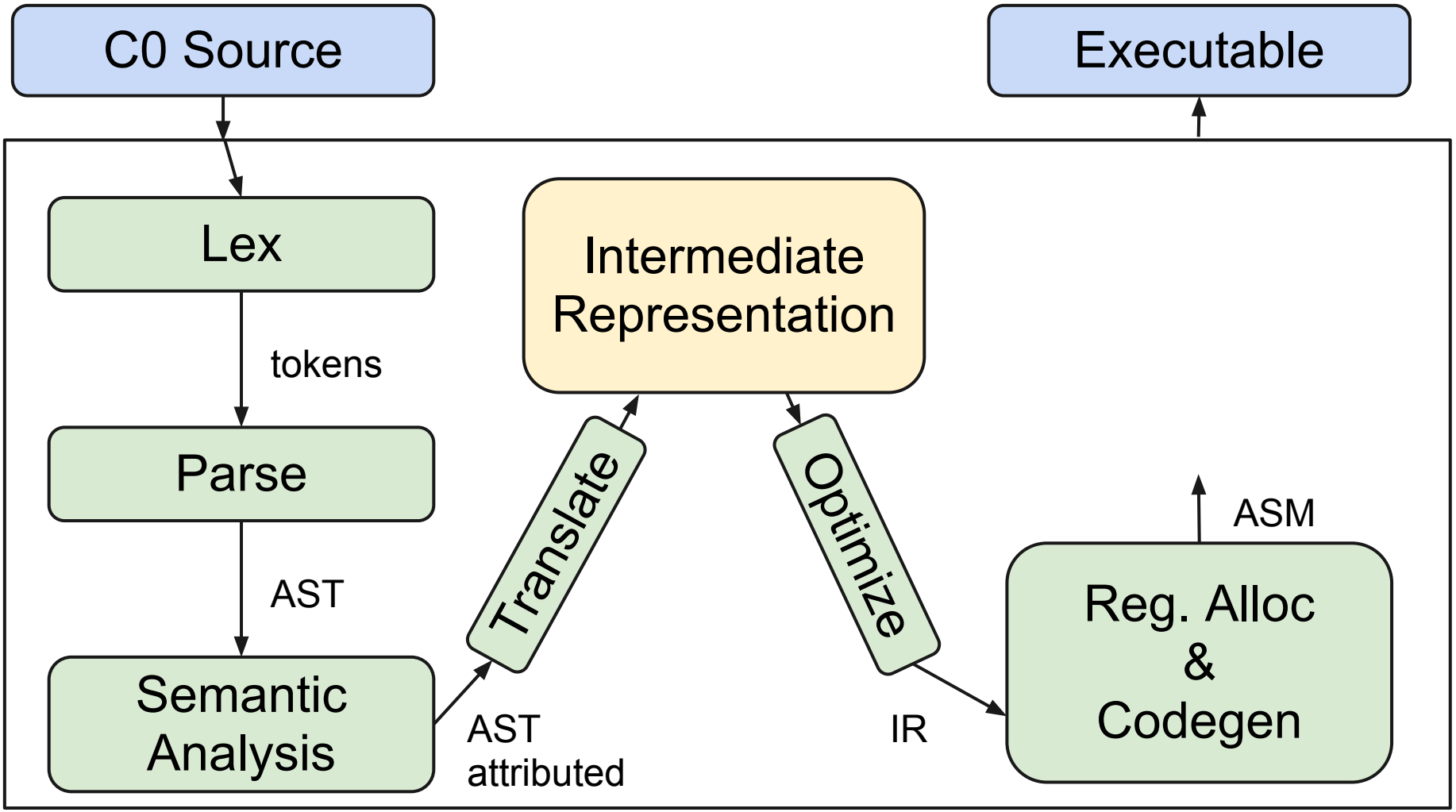

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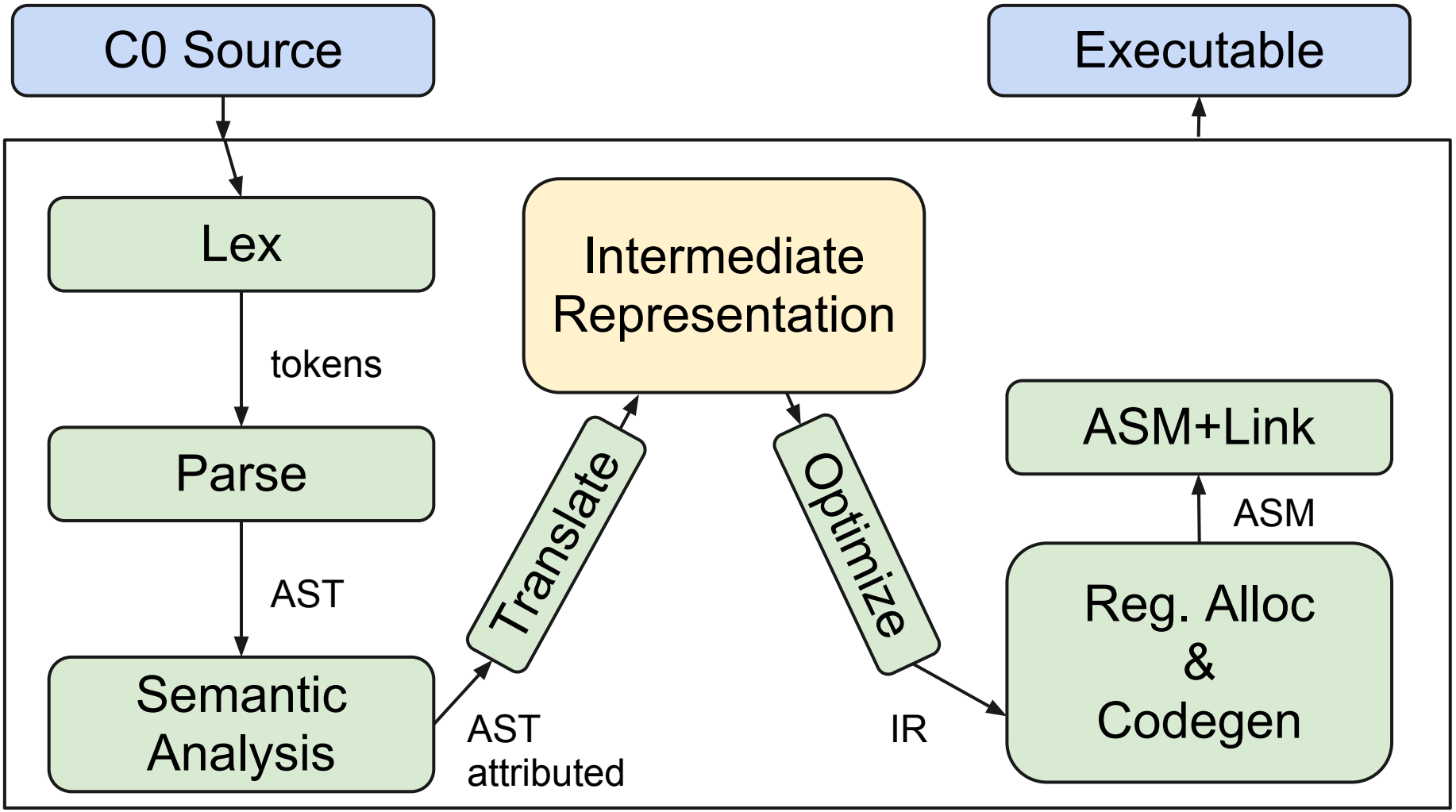
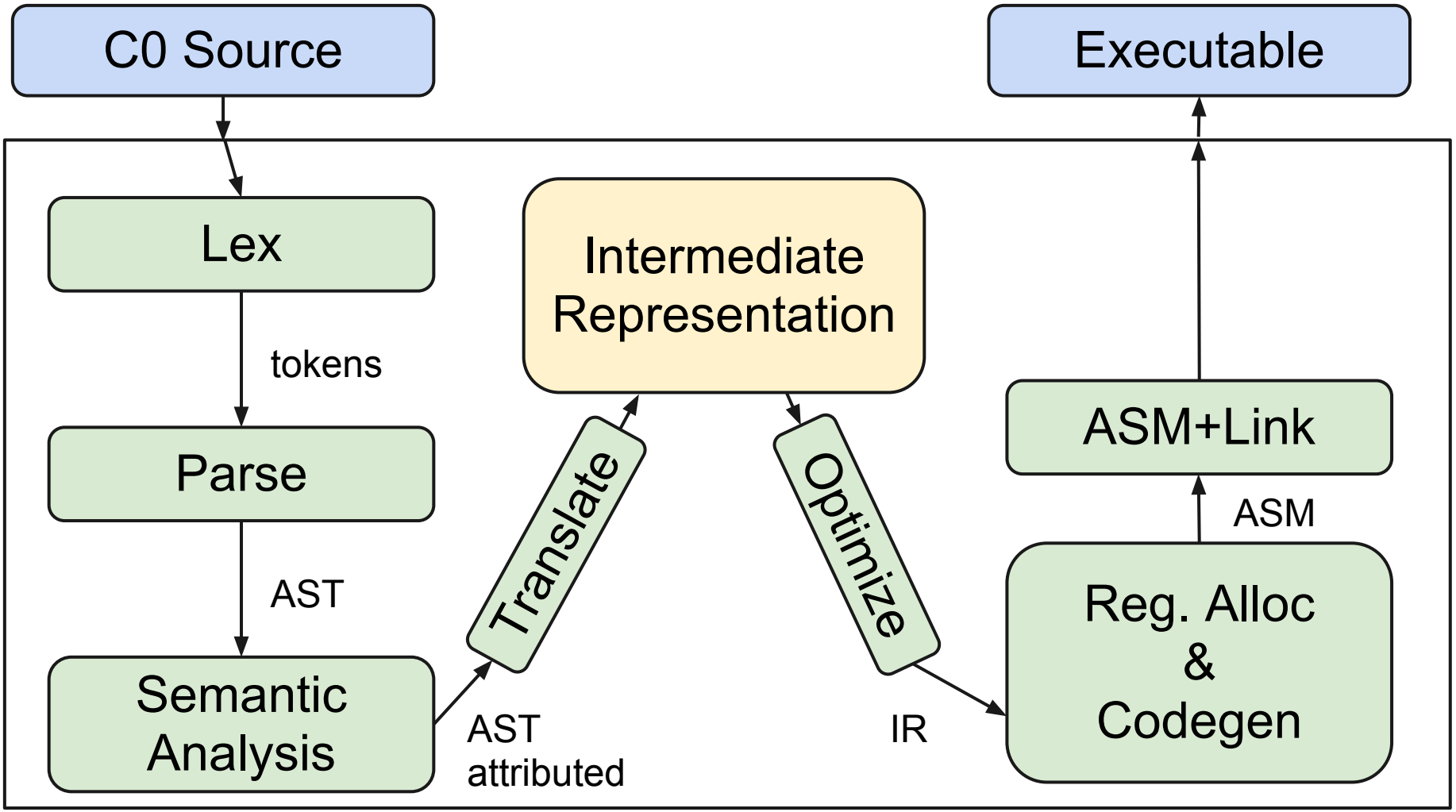


The Compiler 'W'



The Compiler 'W'

- Easy to re-target all source languages
  - Just add a new back end from the IR
- Easy to optimize all sources
  - Just add a pass to the IR
- Easy to add a new source language
  - Just add a new front end into the IR

The Compiler 'W'

- Variants
  - Split register allocation and code generation
  - Another optimize pass in codegen
  - Reorder passes in backend

What to compile?

- Simple
  - Goal is to learn how compilers work, not feature X
- Safe
  - Semantics should be well defined
  - Enables many optimizations

What to compile?

- What should happen here?

```
int foo(int a, int b, int *c) {
  if (a / b == 1 || *c == 3)
    return 3;
  return 4;
}
```

What to compile?

- C
  - Simple
  - Unsafe
- Java
  - Not simple
  - Safe(er)
- C0?

What to compile?

- C0 is a safe variant of C
  - Developed at CMU by Frank Pfenning and others
- All C0 programs are deterministic given same input
- Differences
  - No pointer arithmetic
  - No casting
  - No stack allocated structs
  - Hard(er) to shoot yourself in the foot
  - Can enable memory safety

What to target?

	ISA	Runnable?	Oddities?
x86	CISC	✓	✓
x86-64	CISC	✓	✓
arm, mips	RISC	simulators	✓

What to target?

- We have chosen x86-64
  - You generate assembly, gcc links it
- Lots of fun caveats to deal with still

Questions?

- Compiler Principles
- The compiler 'W'
  - Lexing/Parsing
  - Semantic analysis
  - IR/optimizations
  - Codegen/register allocation
- C0
  - Well-defined semantics
  - "safer C"

Remember...

- symbolaris.com
- Choose a partner
  - Email 15411@symbolaris.com
- Labs are cumulative
  - Don't fall behind
- Think about language you'll write in