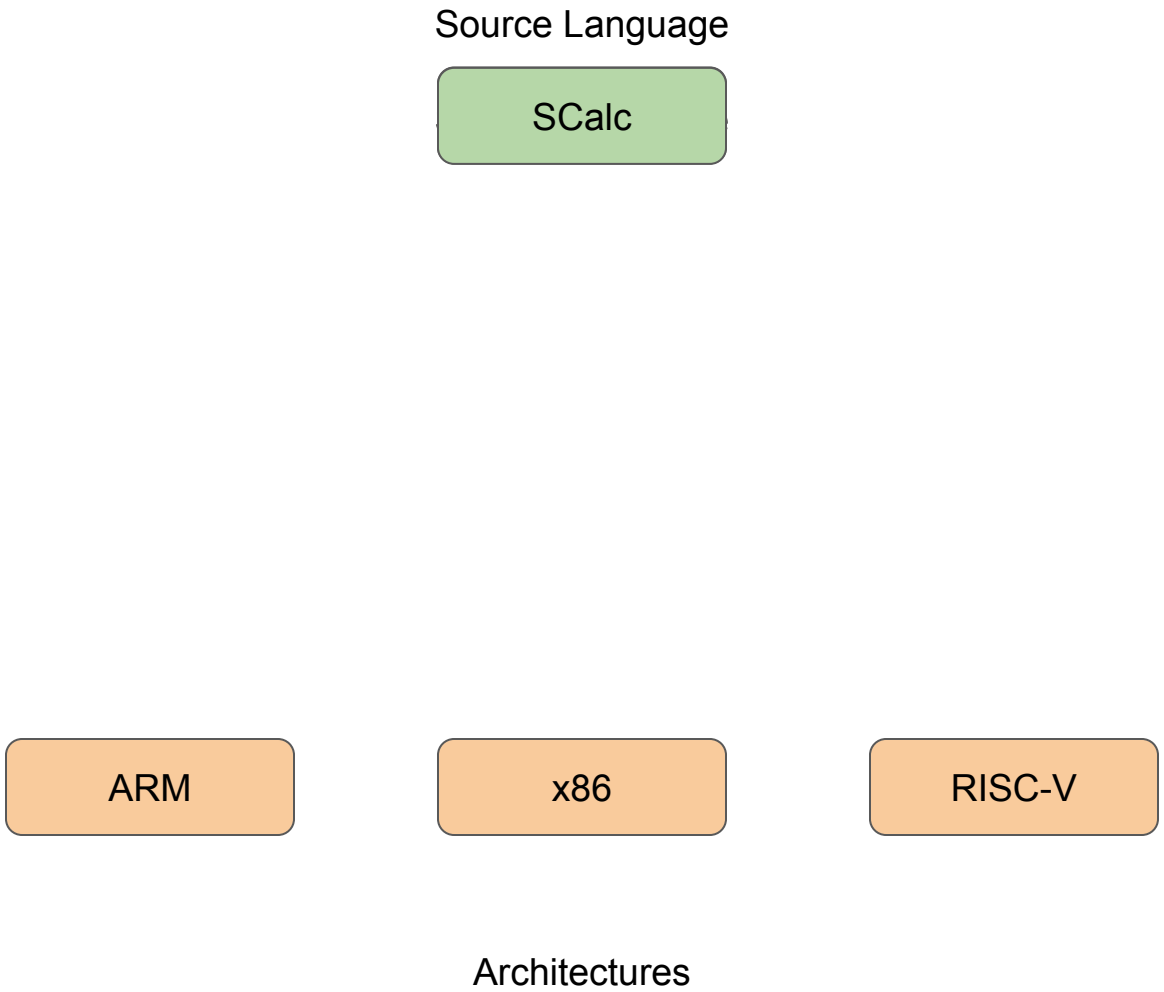
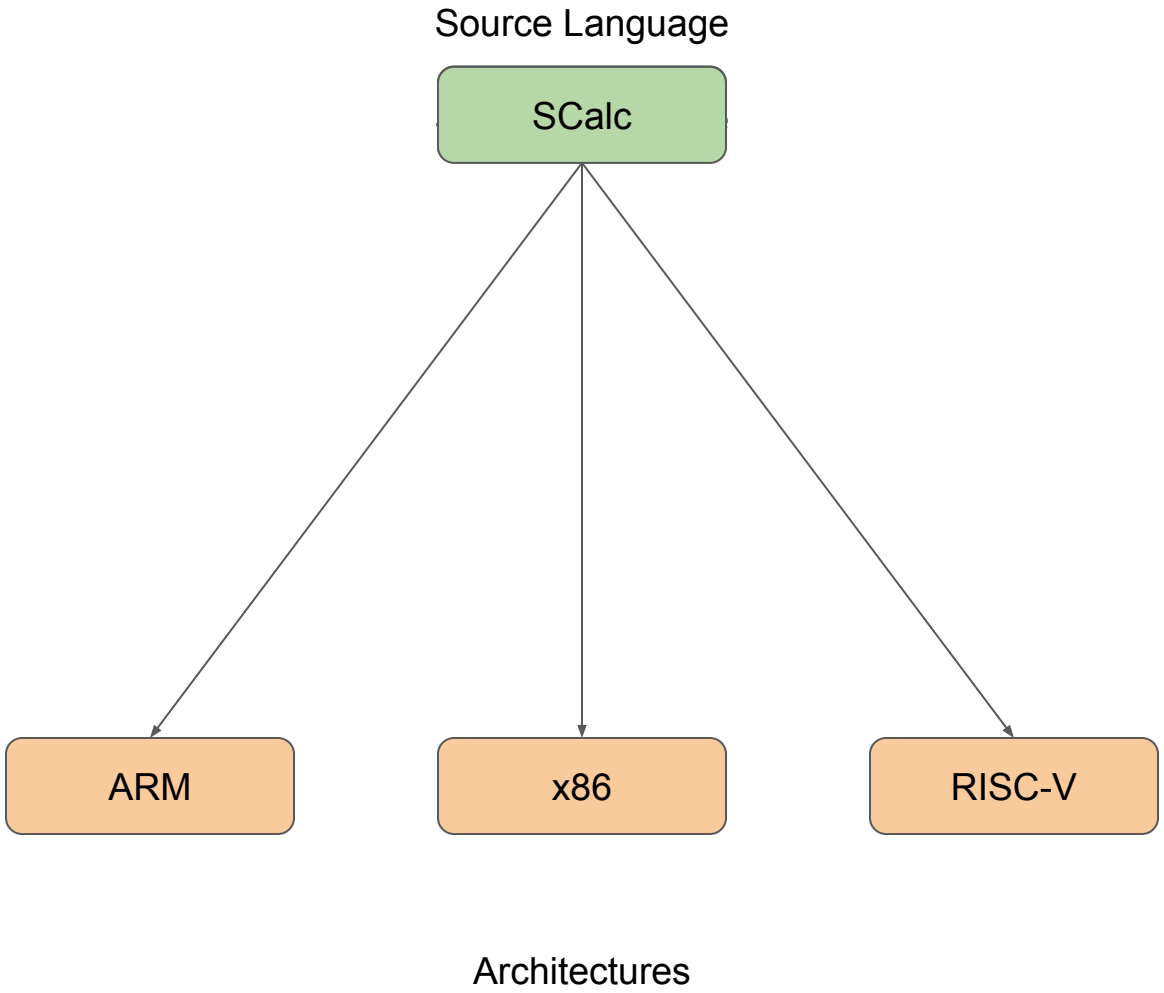
What is LLVM (and MLIR)?

Quinn Pham
Adapted from slides by Braedy Kuzma, Caio Salvador Rohwedder, and Nelson Amaral

Your Life Right Now

SCalc


Source Language
SCalc
ARM
x86
RISC-V
Architectures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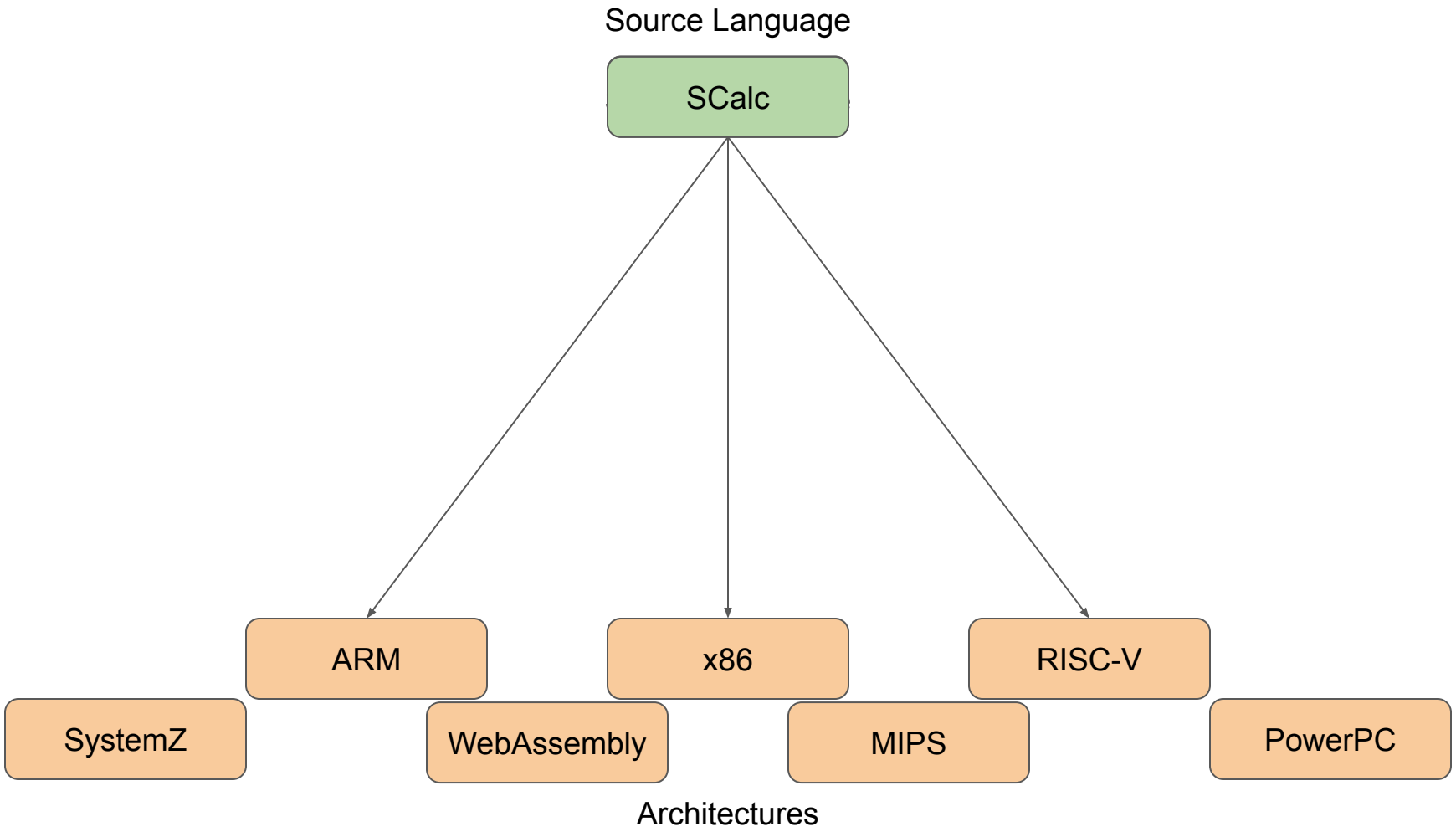
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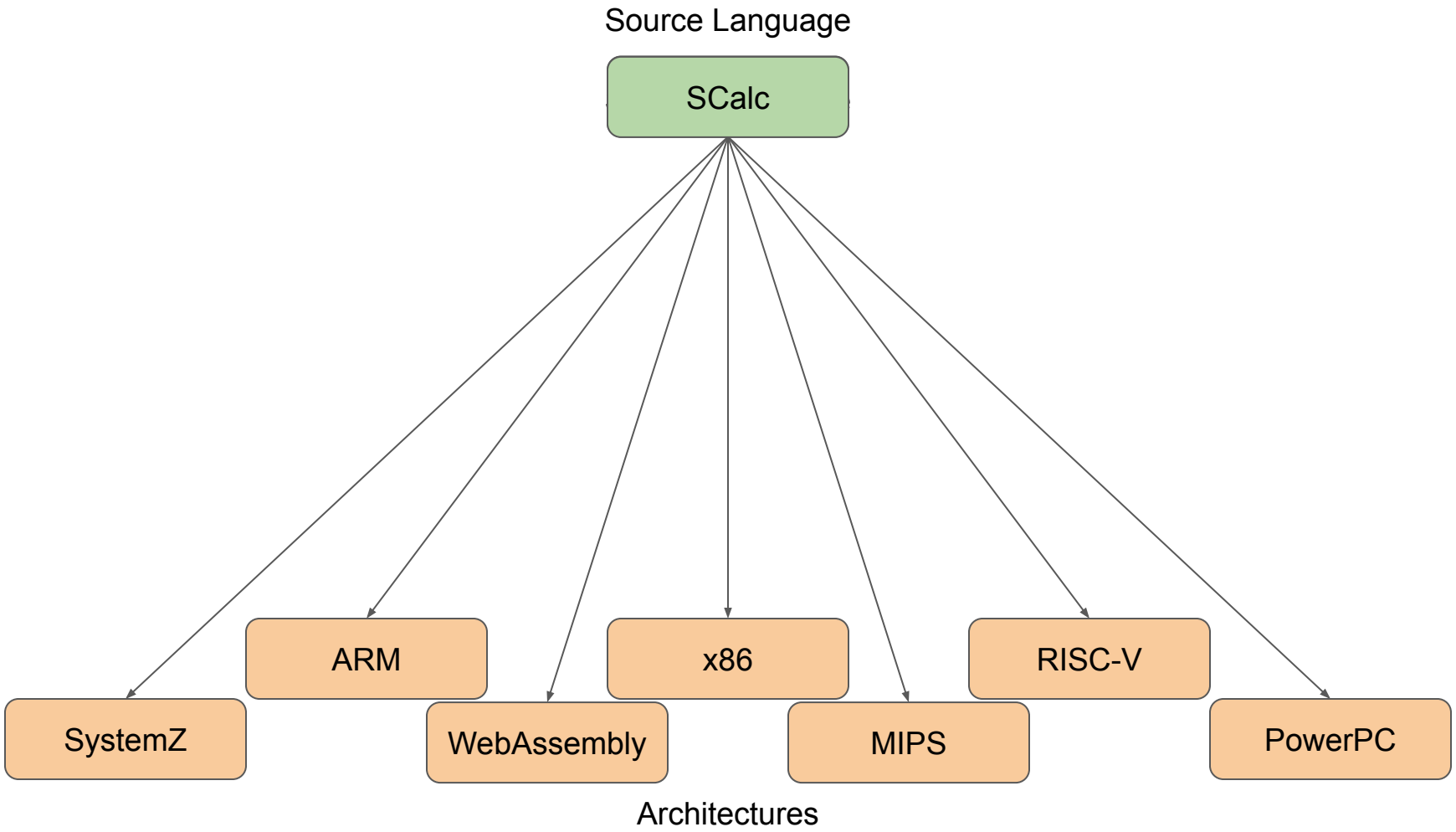
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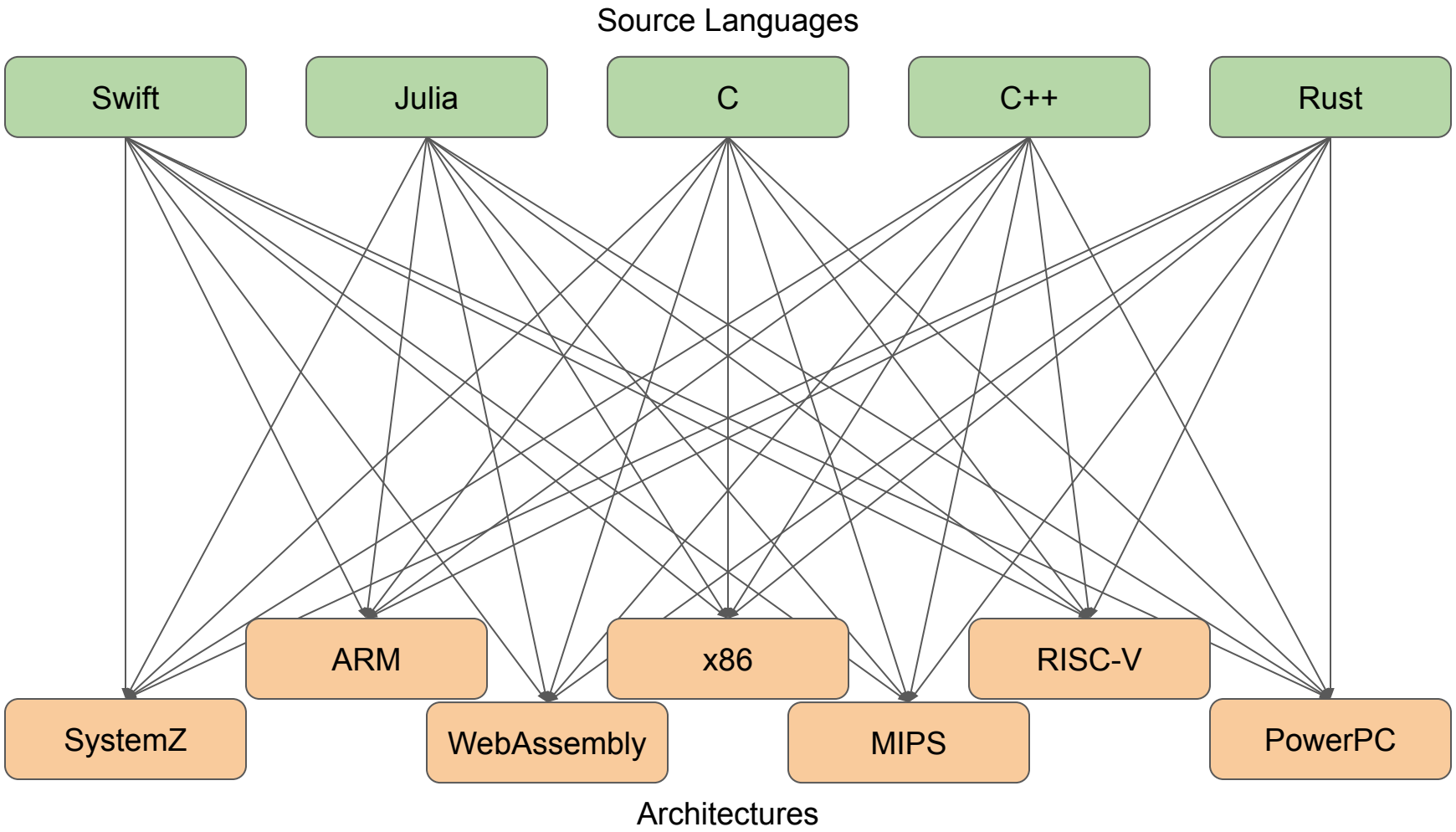
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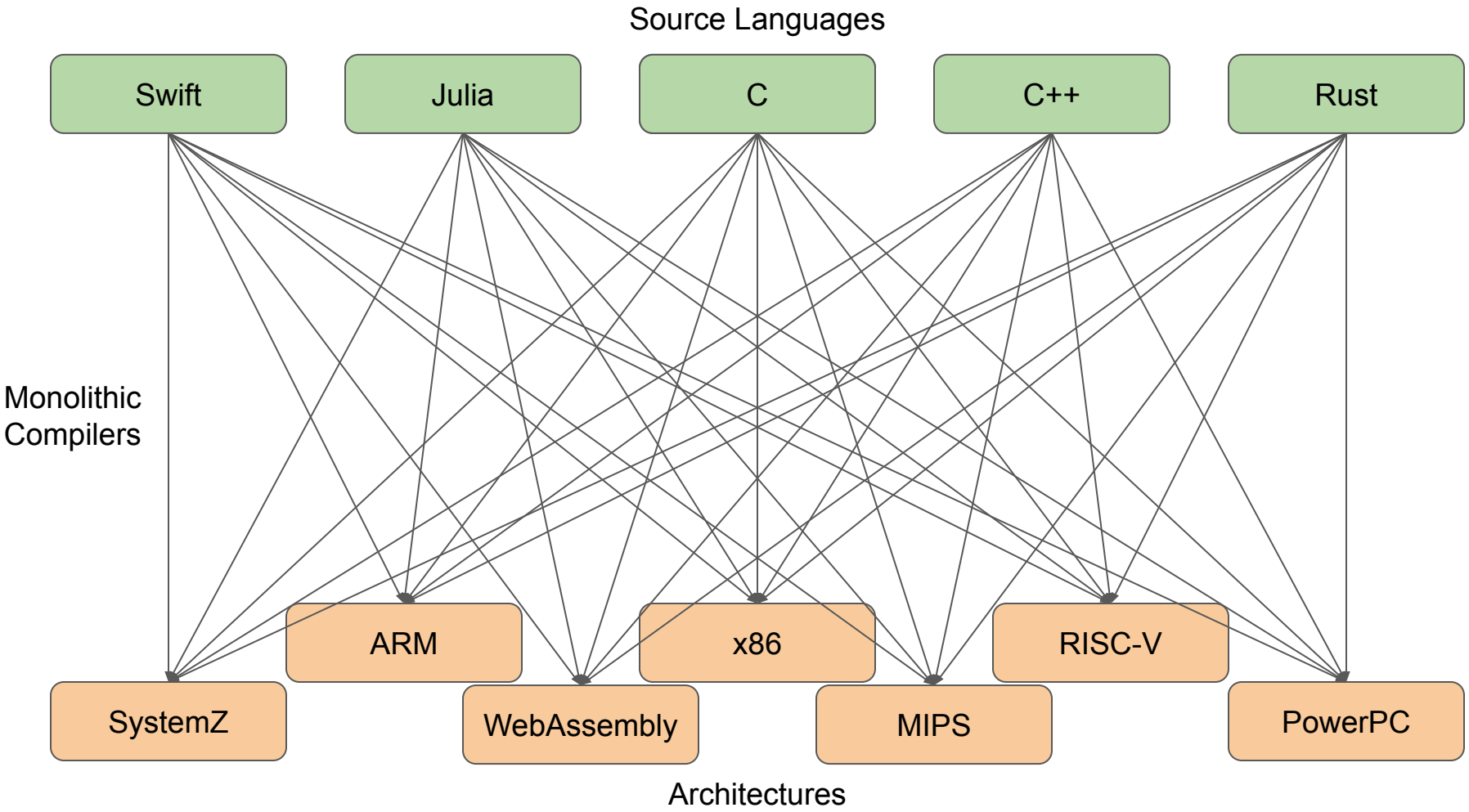
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Monolithic Compilers
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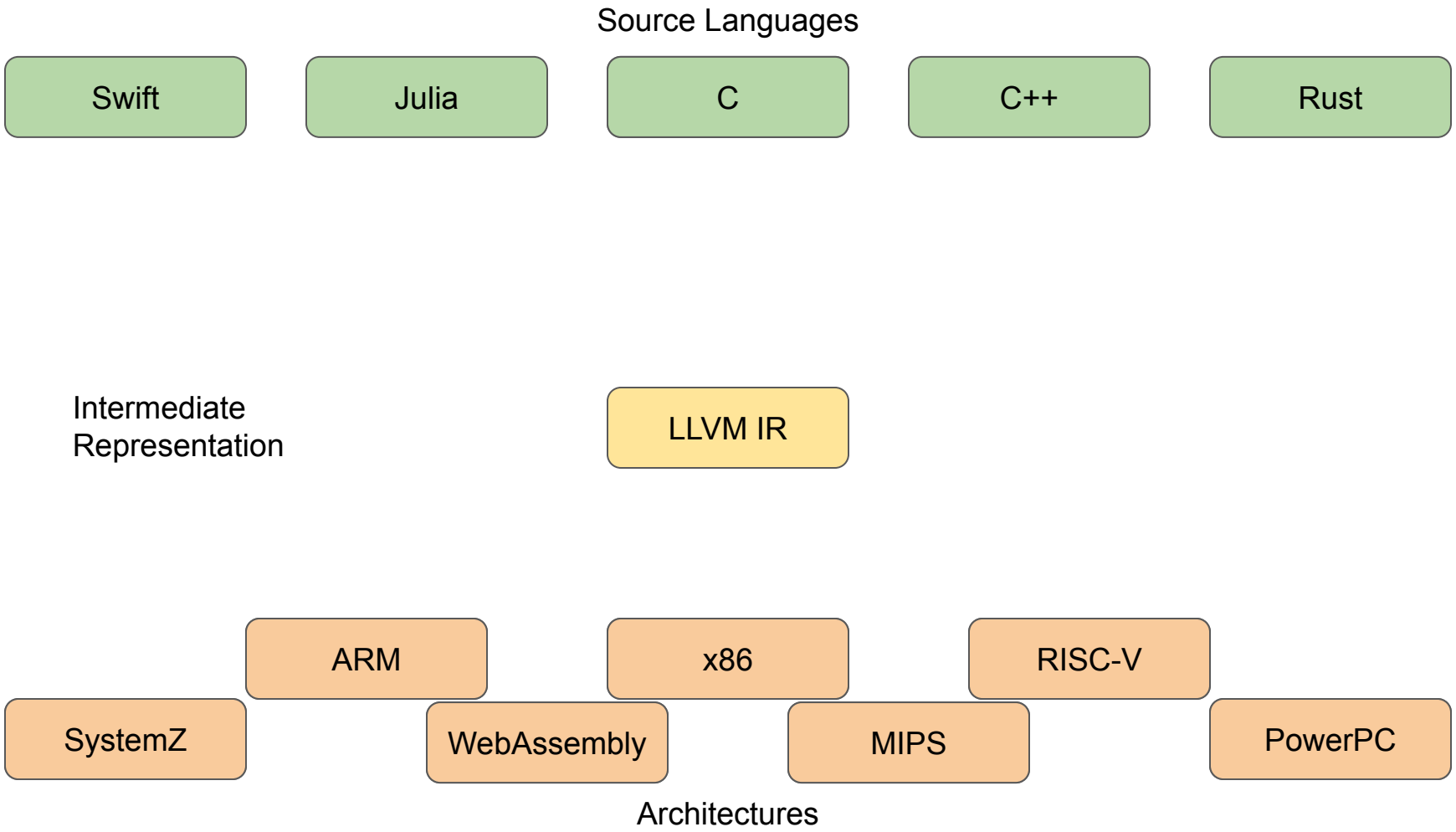
LLVM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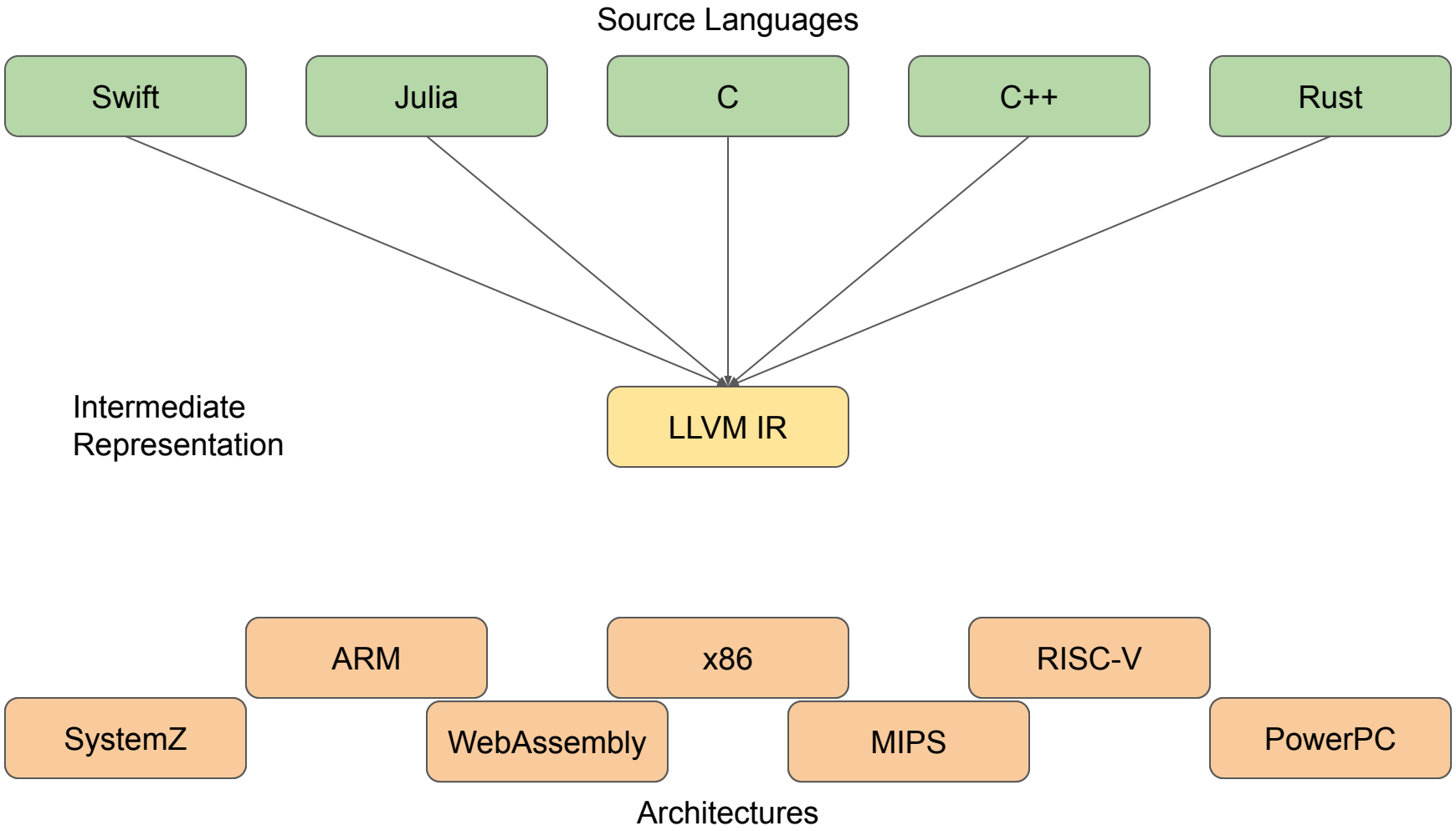
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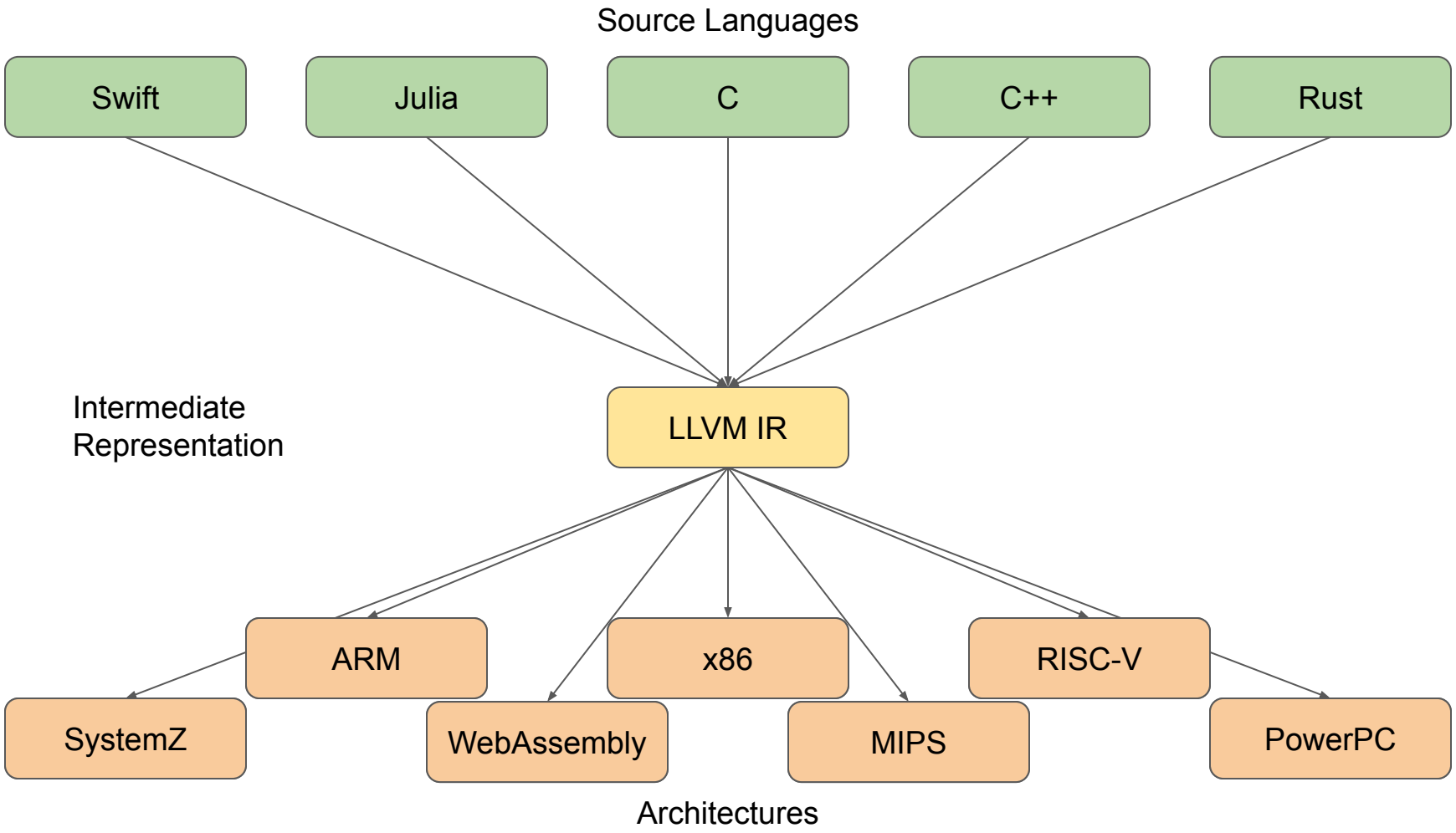
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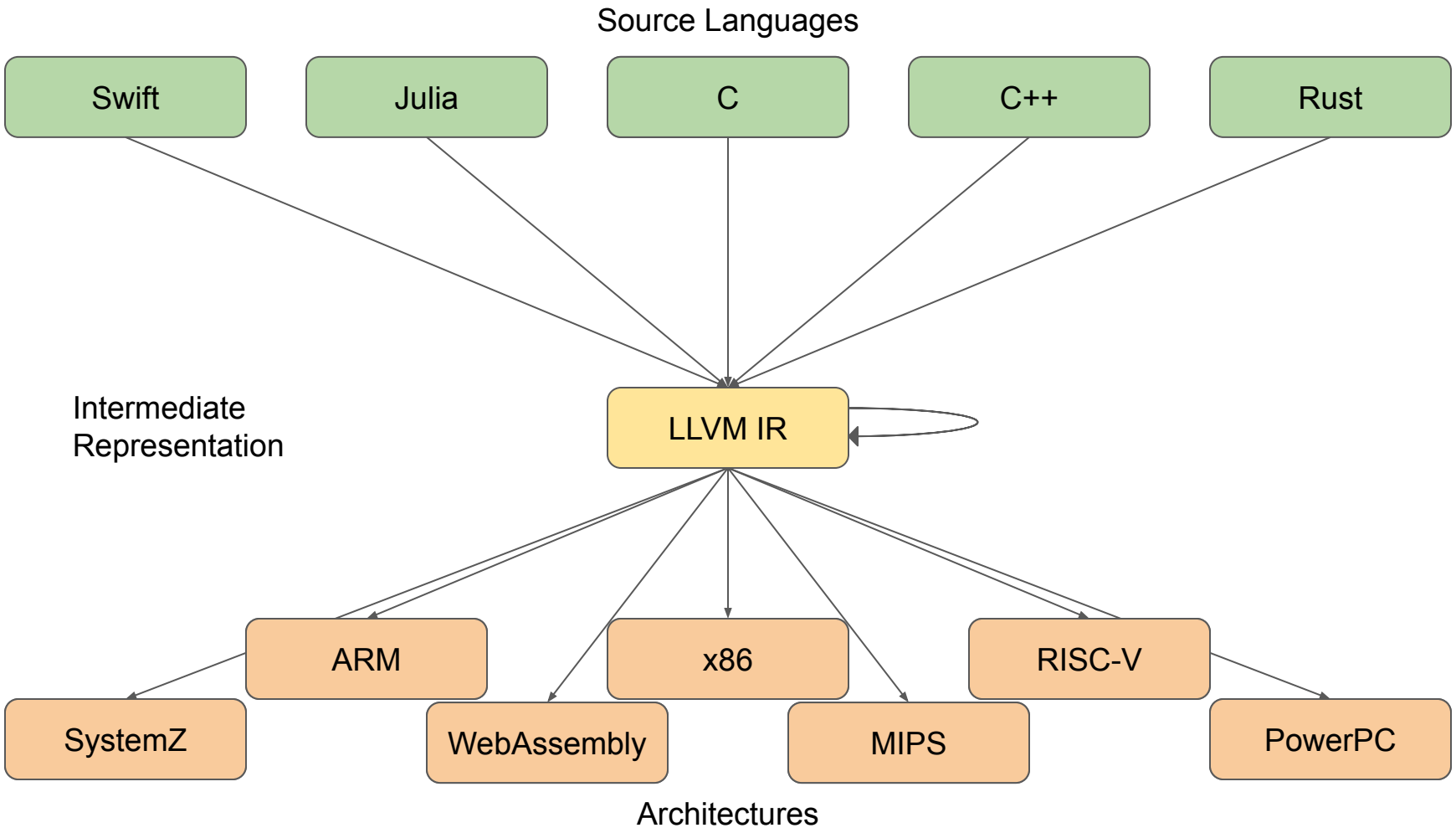
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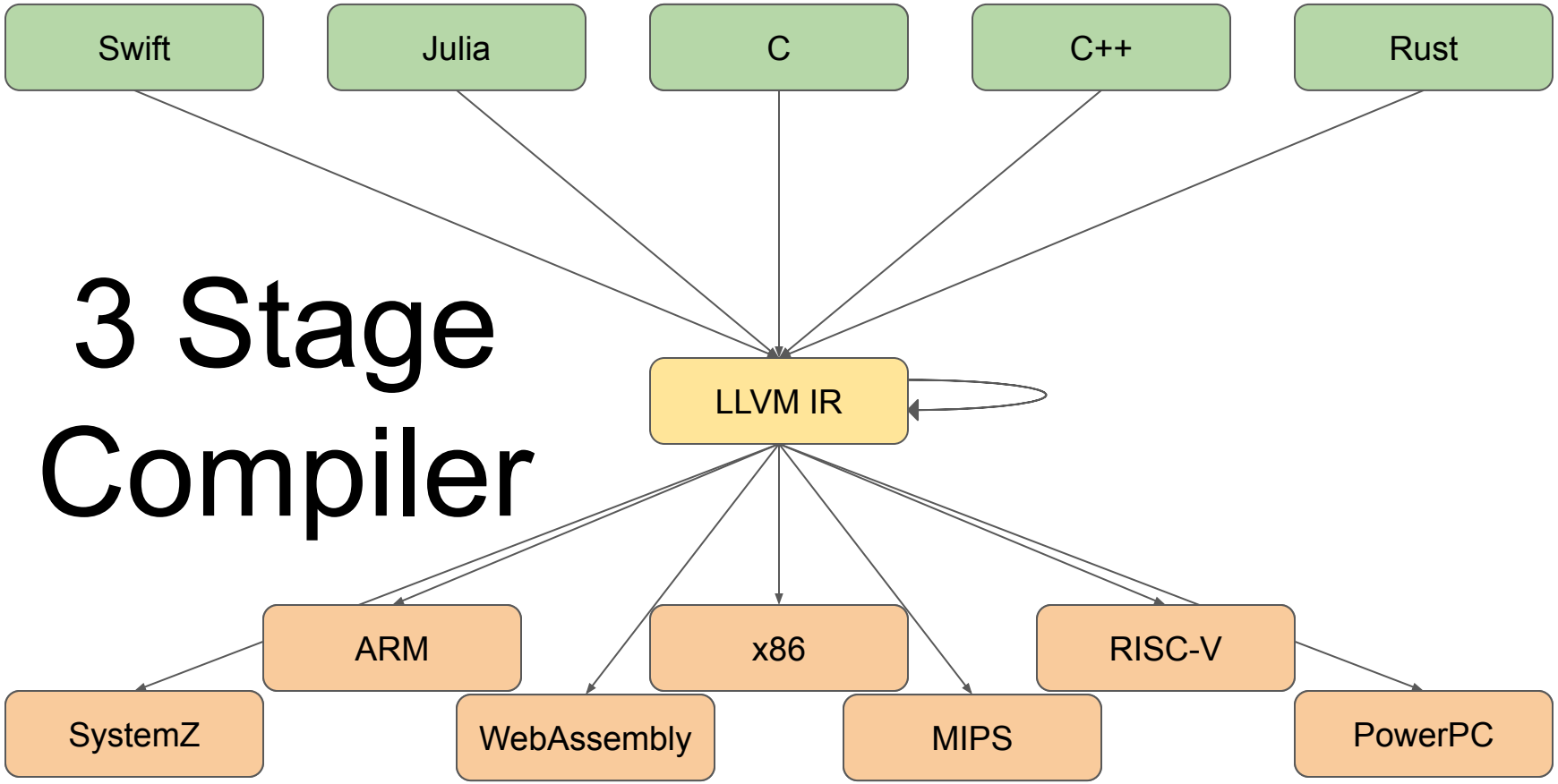
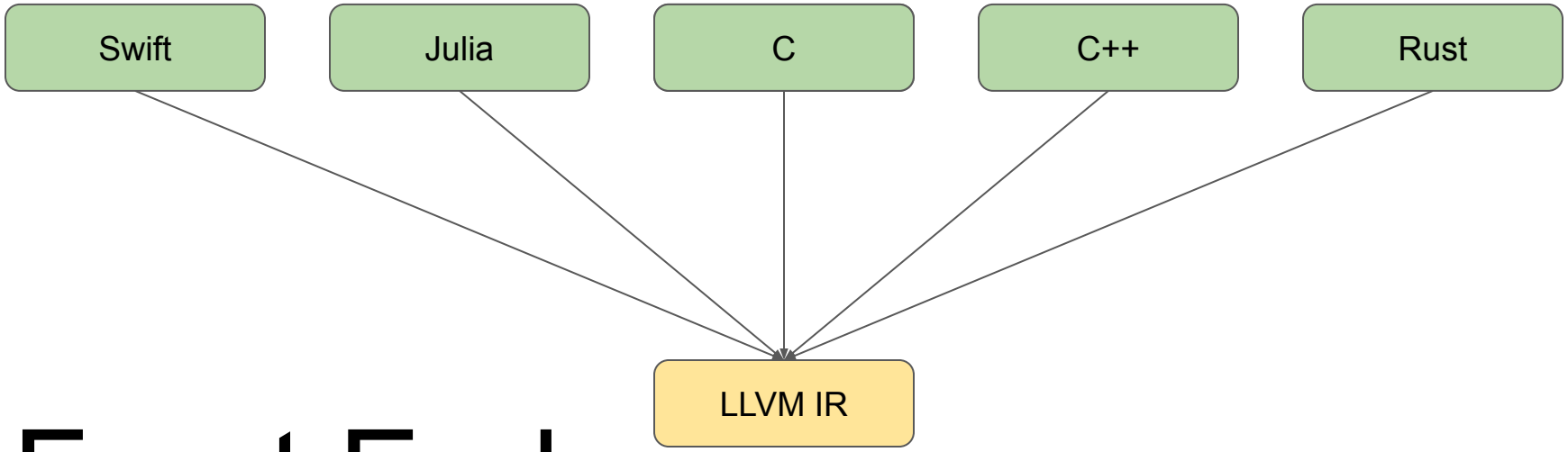
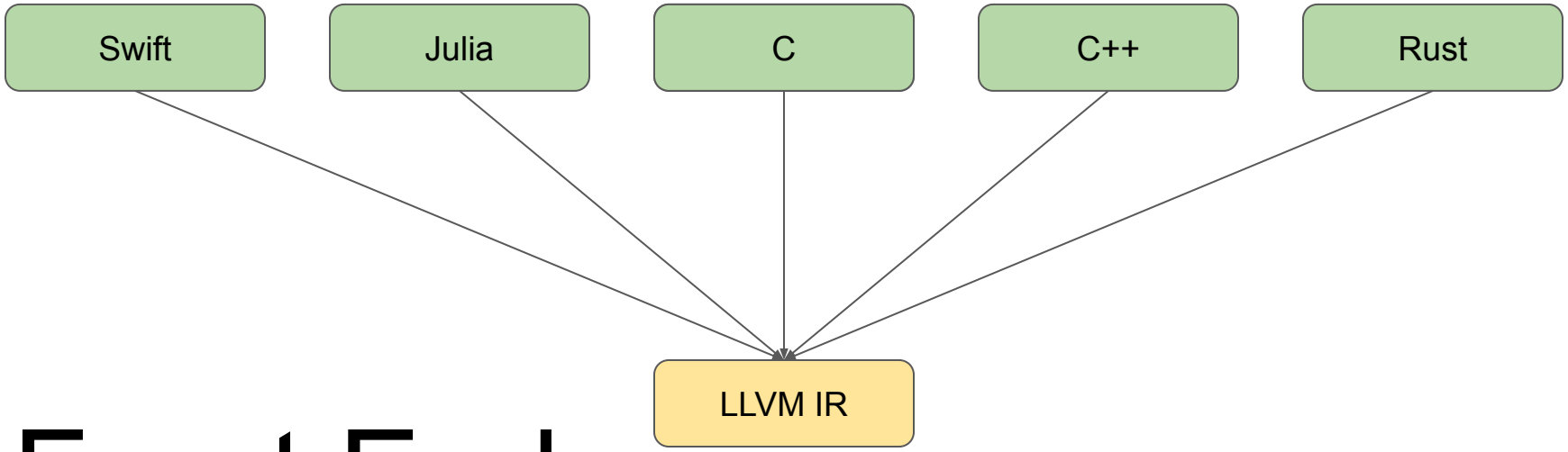
3 Stage Compiler





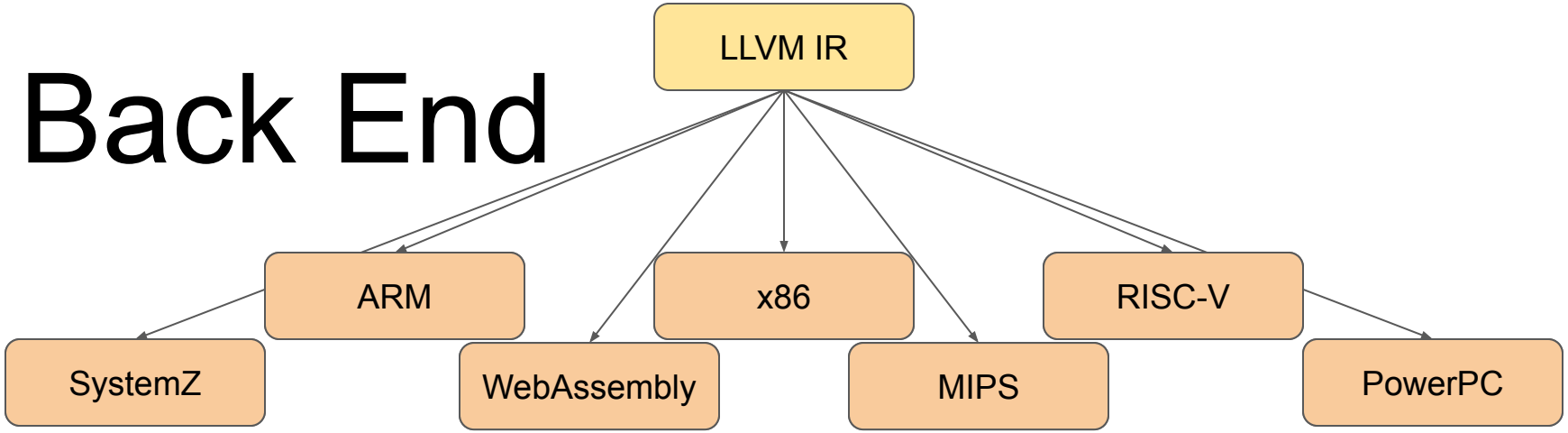
Front End



Front End

Analyzes the source code and builds the intermediate representation for the program.

Back End



Performs architecture specific optimizations and generates assembly code for the program.

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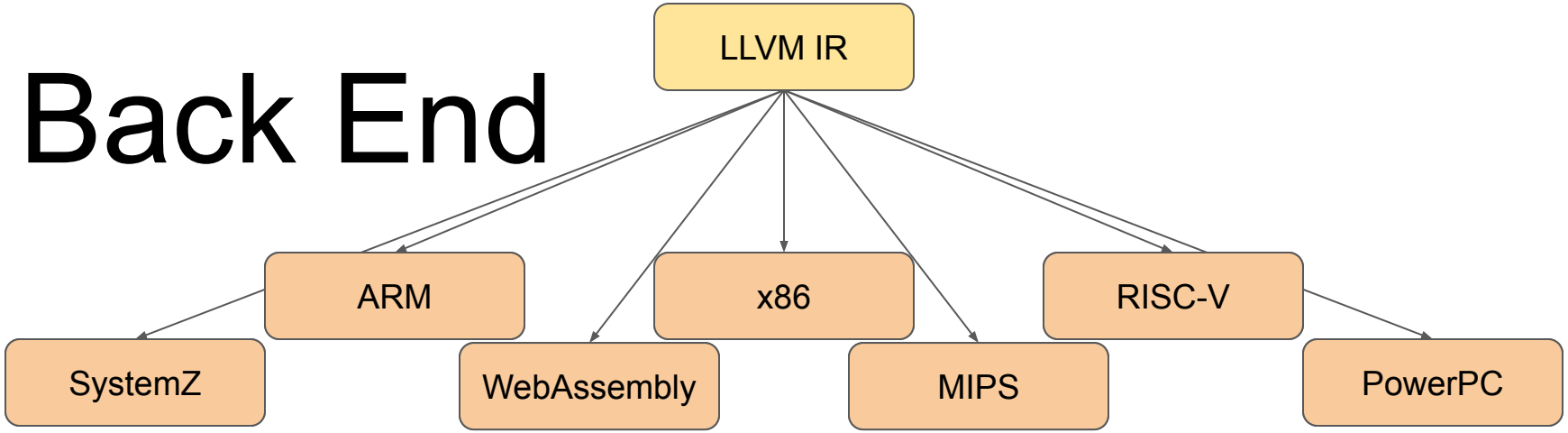

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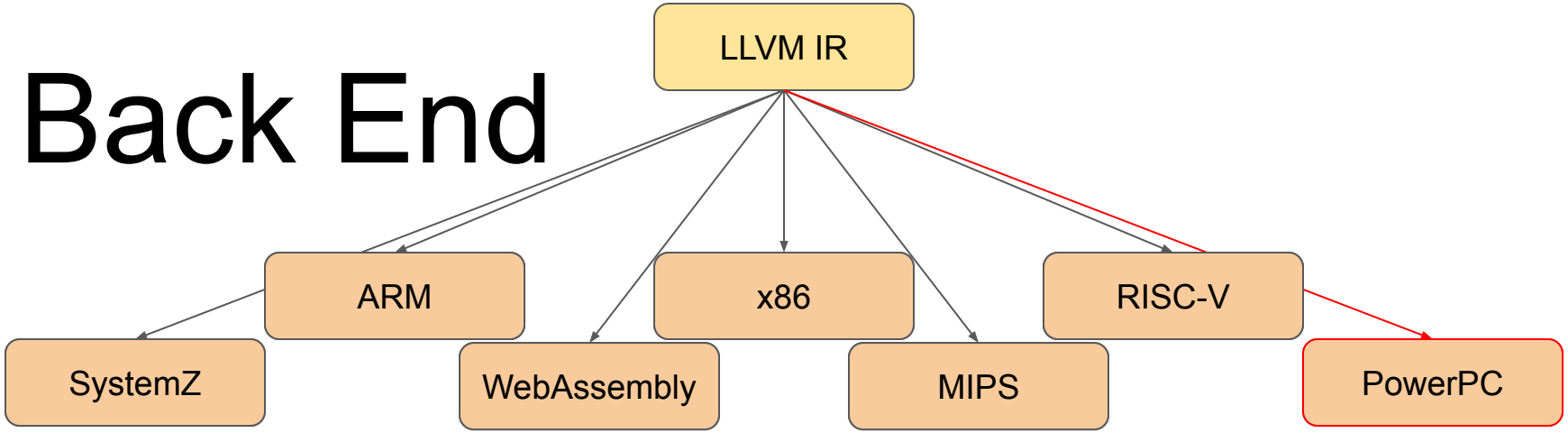
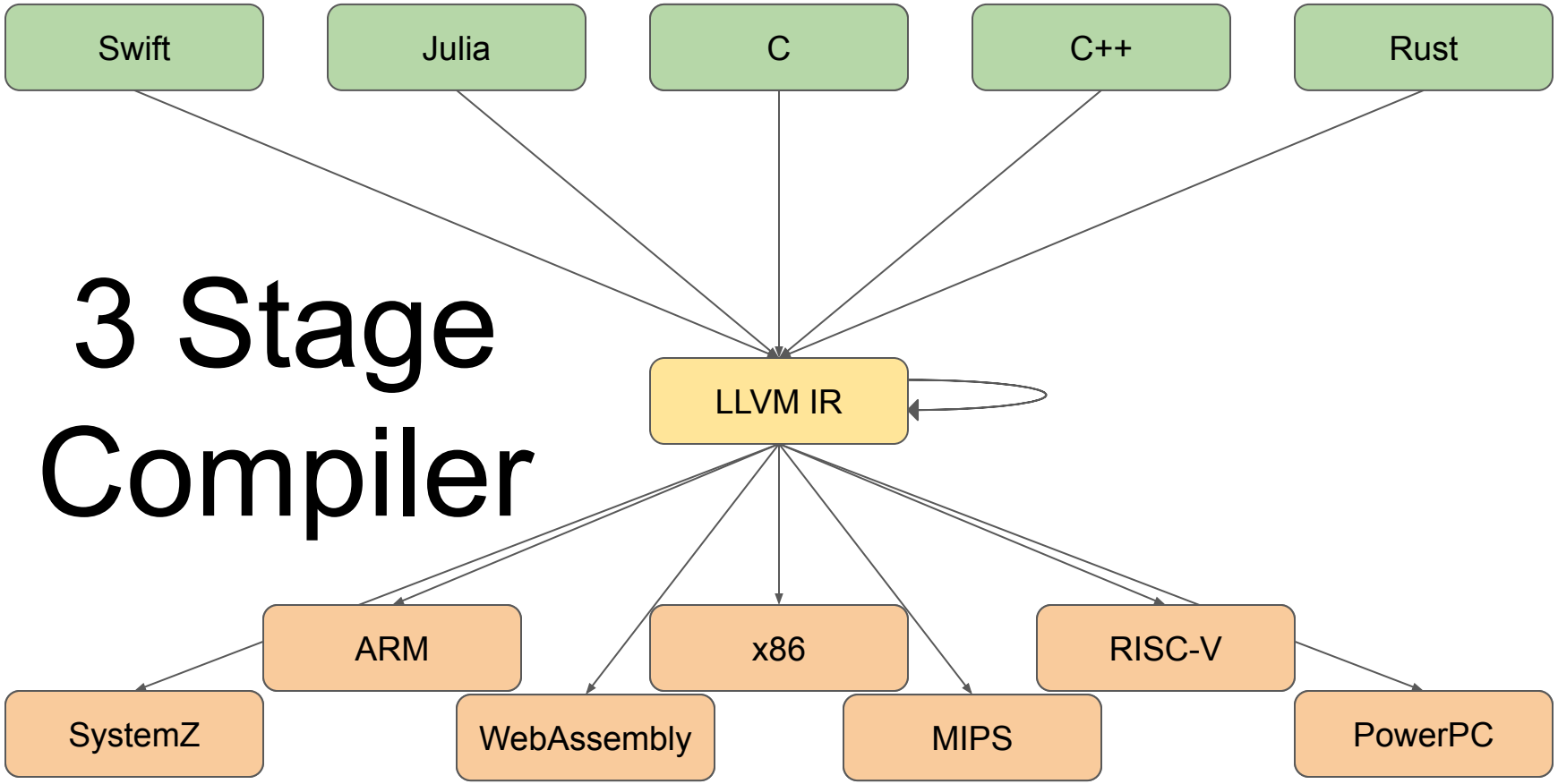


Middle End

Middle End

Performs analyses and transformations on the intermediate representation.

3 Stage Compiler



LLVM

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- Used to stand for Low Level Virtual Machine
  - No longer has meaning as an initialism

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- Open source

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About

The LLVM Project is a collection of modular and reusable compiler and toolchain technologies.

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+ 90 releases

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LLVM Language Reference Manual

https://llvm.org/docs/LangRef.html

LLVM Tools

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clang - C front end

.c -> .ll | .bc

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llc - compiler

.ll | .bc -> .o

What is LLVM (and MLIR)?

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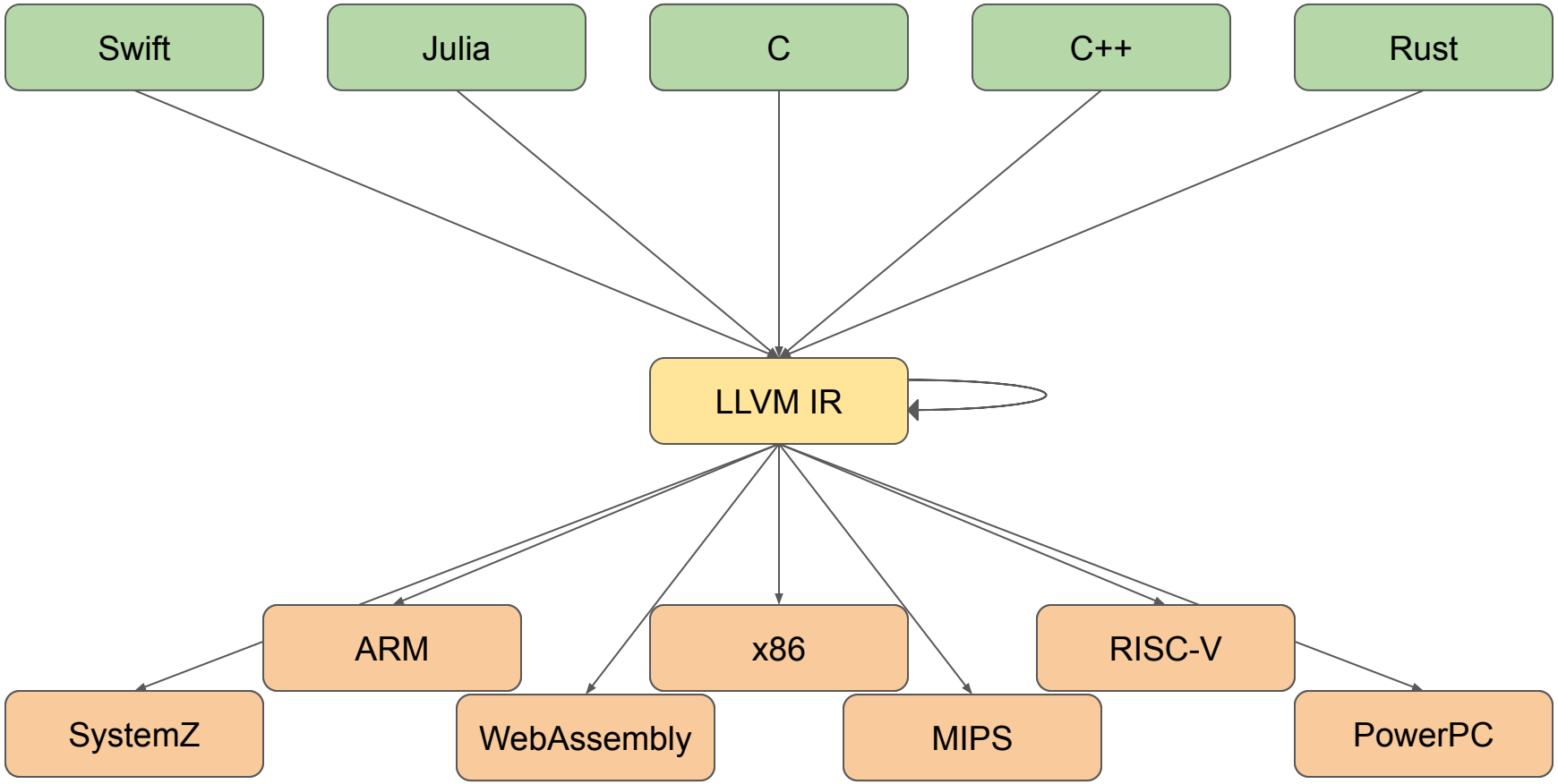
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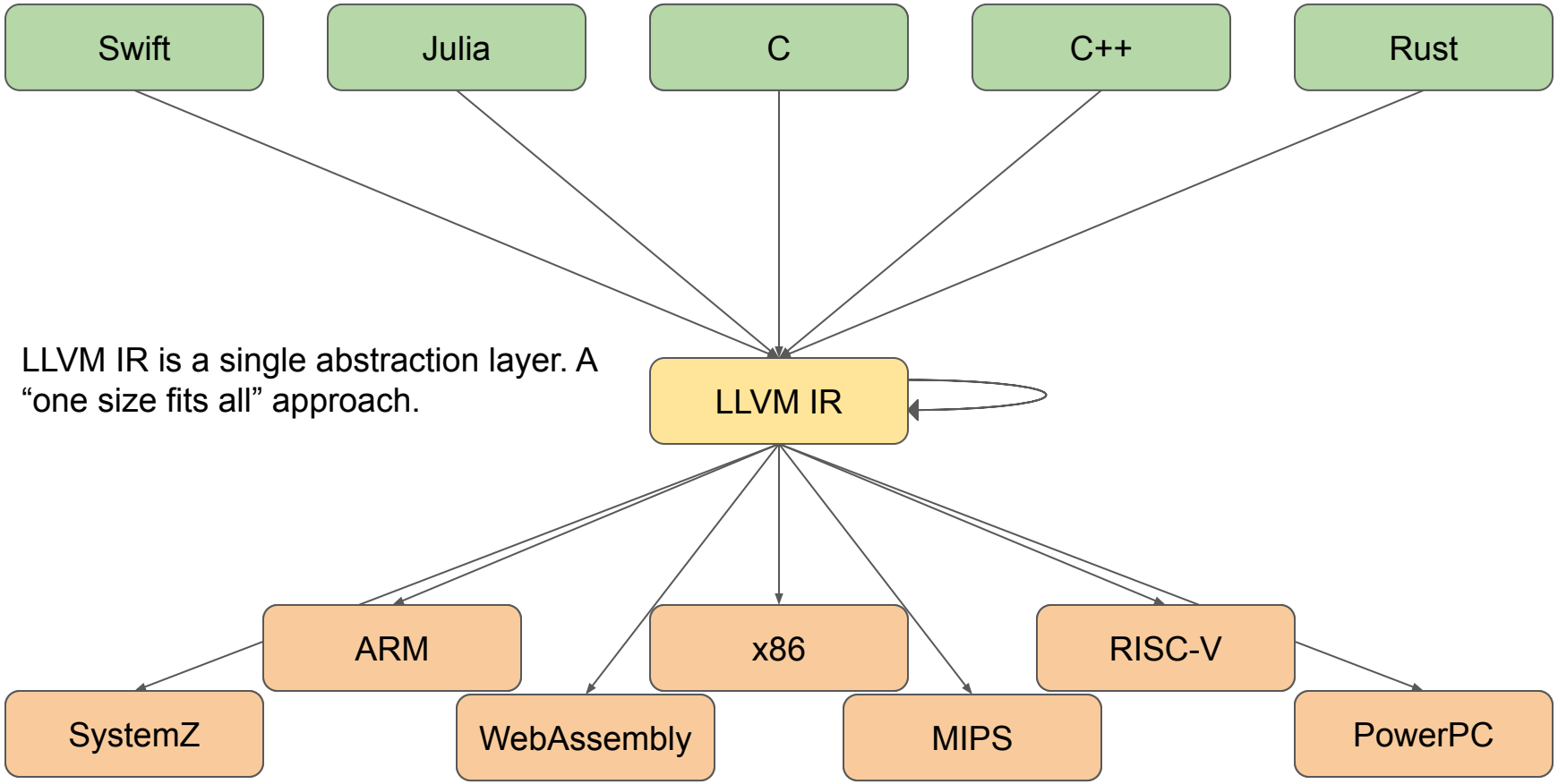
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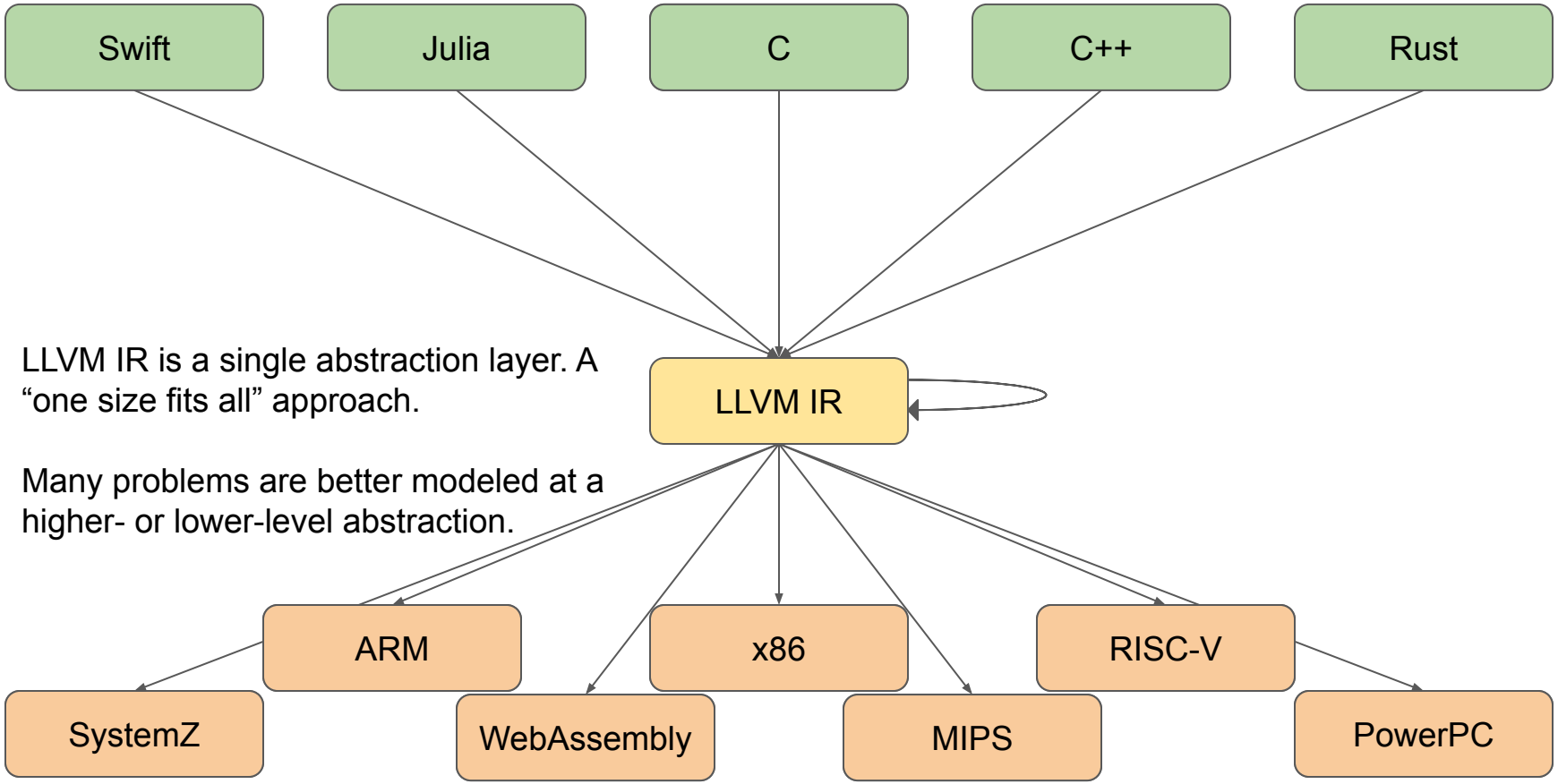
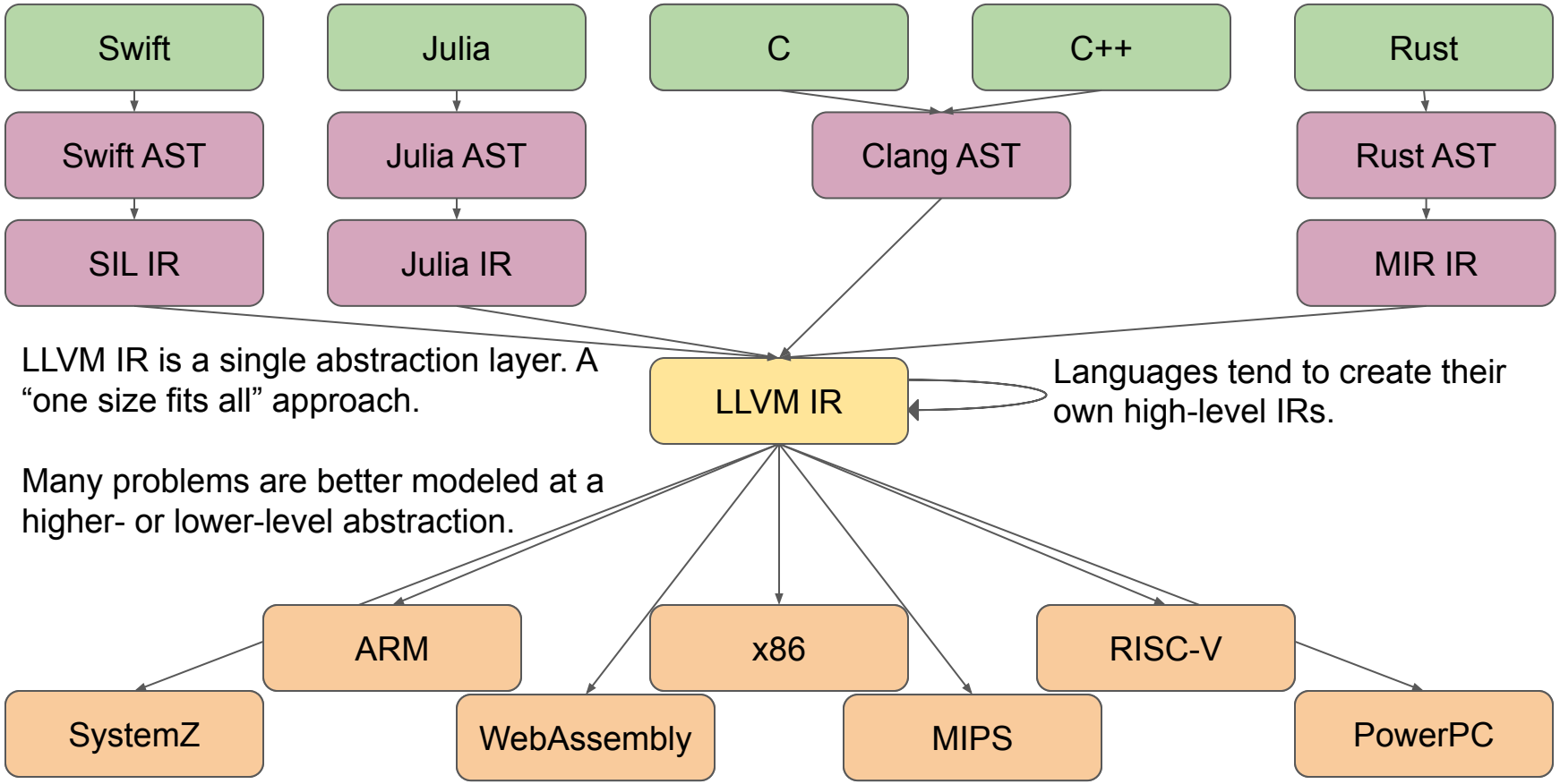


LLVM IR is a single abstraction layer. A “one size fits all” approach.

Many problems are better modeled at a higher- or lower-level abstraction.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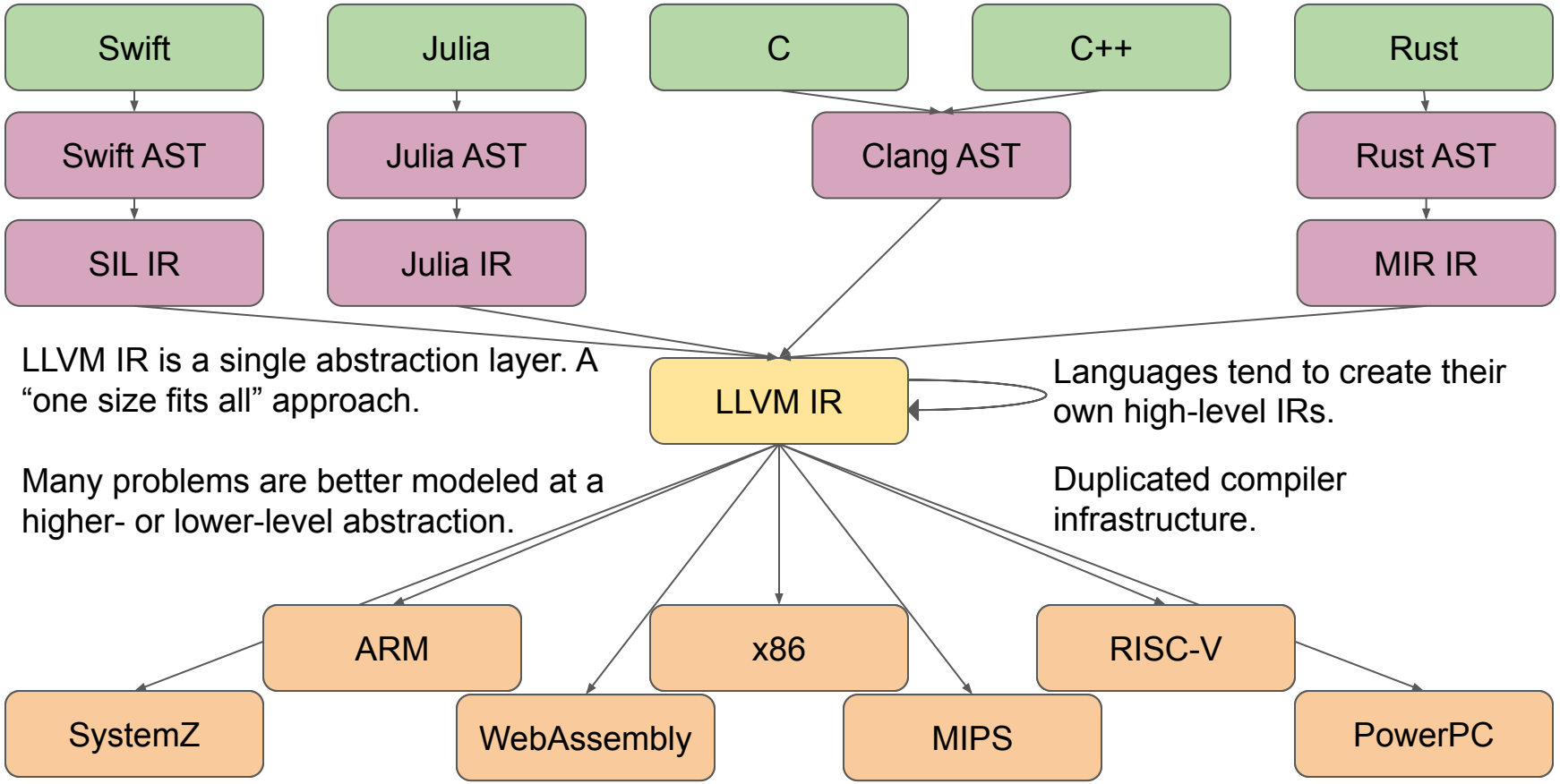
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MLIR

Multi-Level Intermediate Representation (MLIR)

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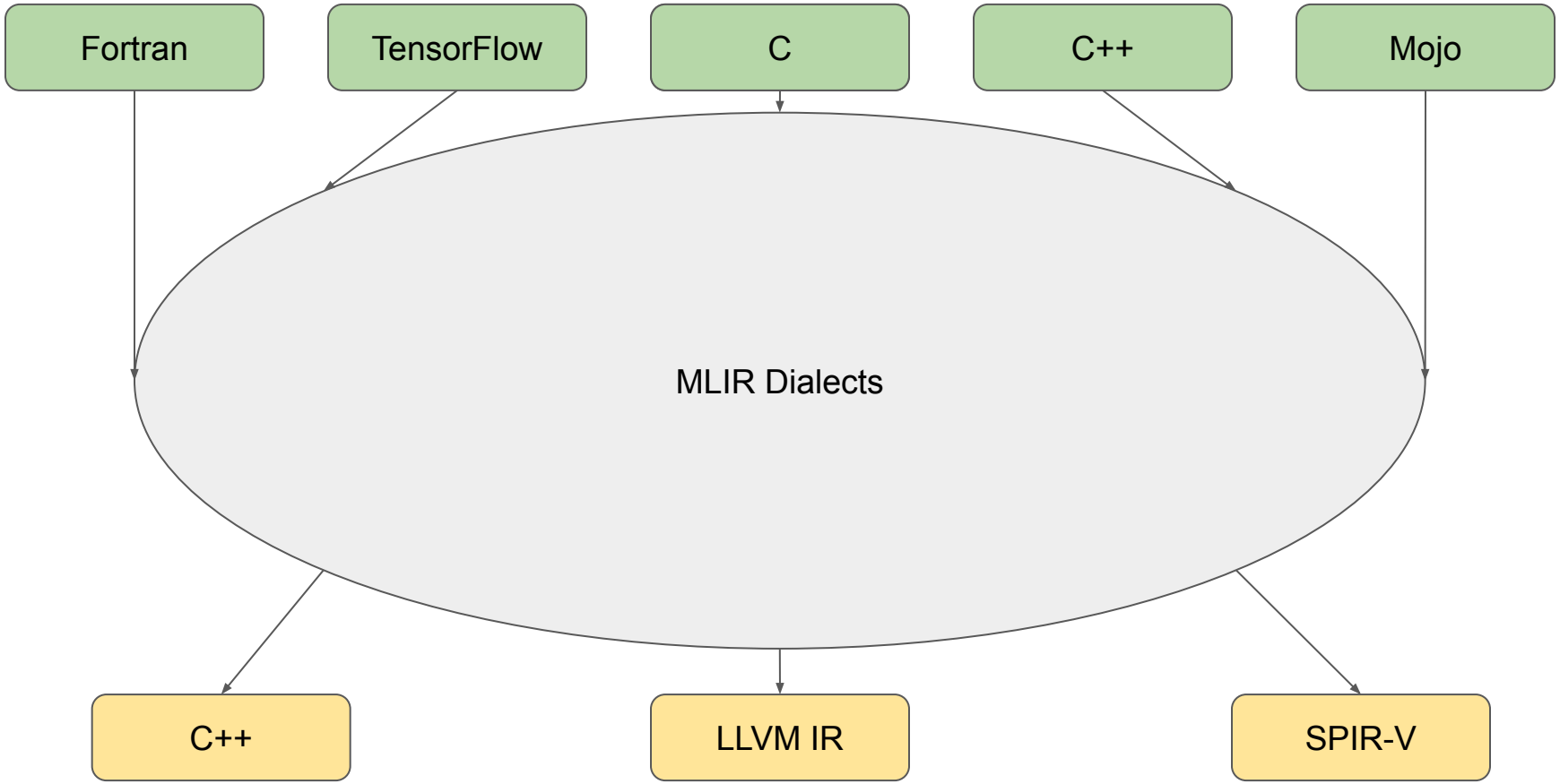
- Define passes to transform/analyze mlir and convert between dialects.
- Create pass pipelines.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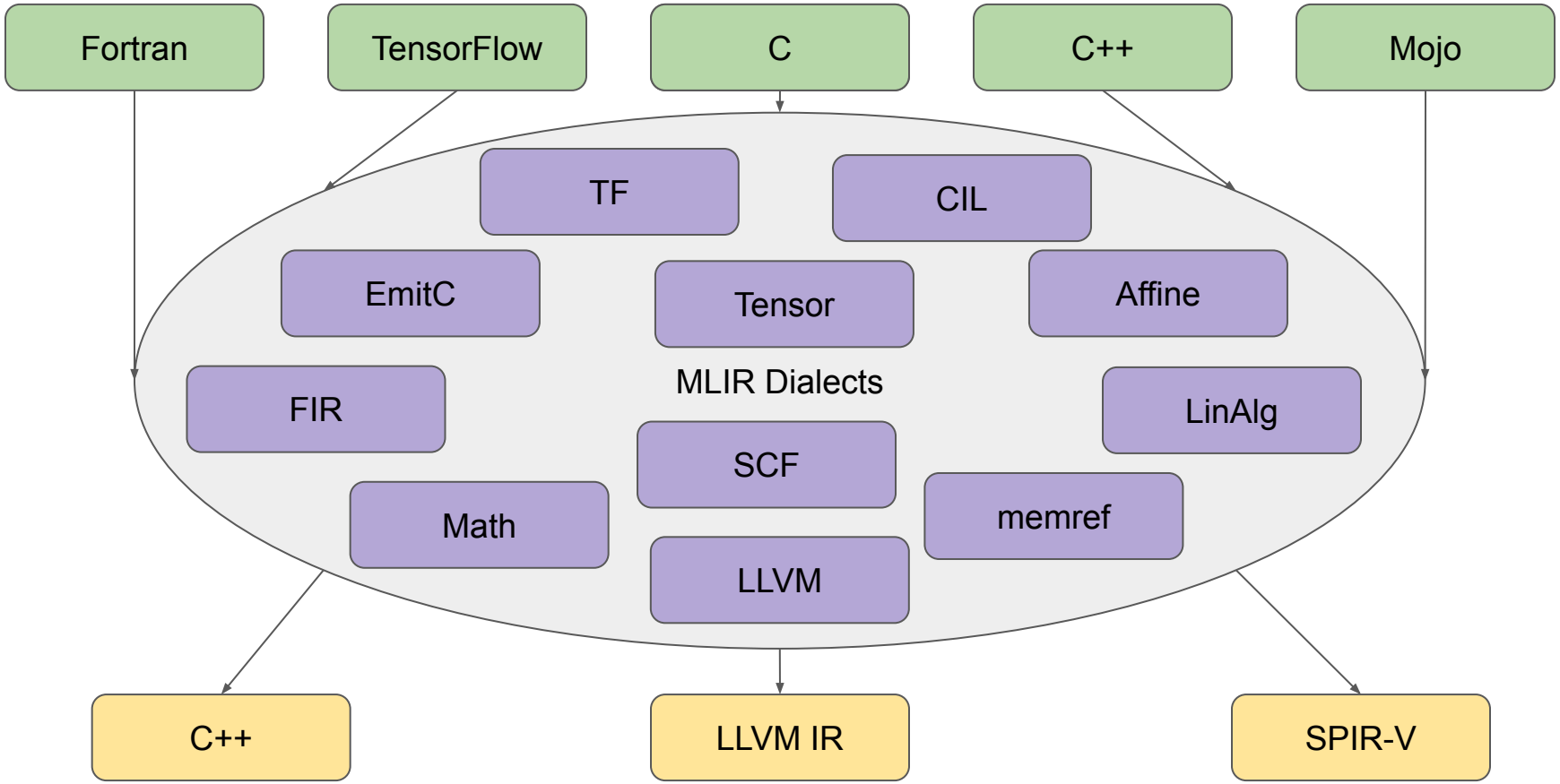
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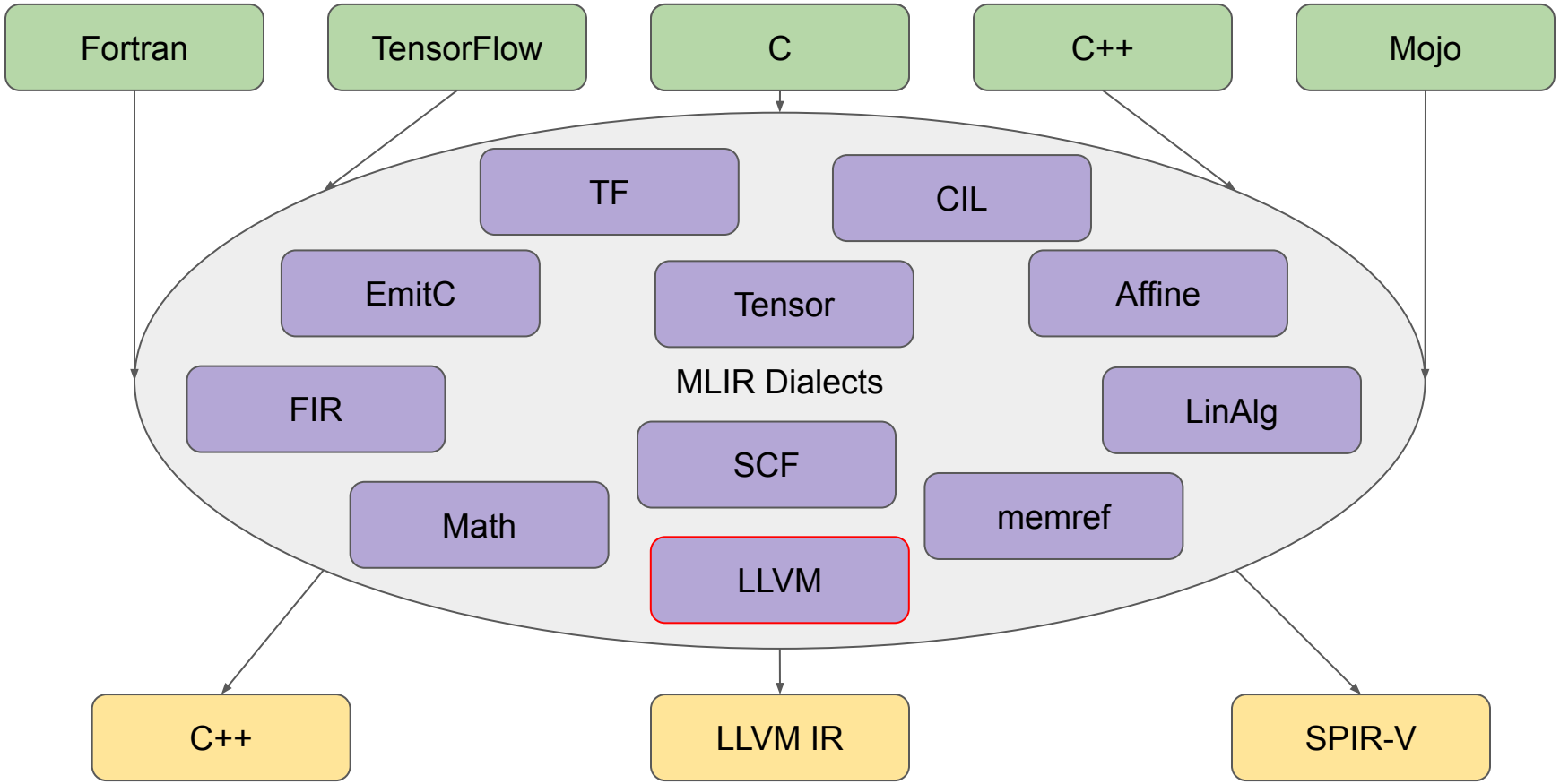
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What really goes on in MLIR…

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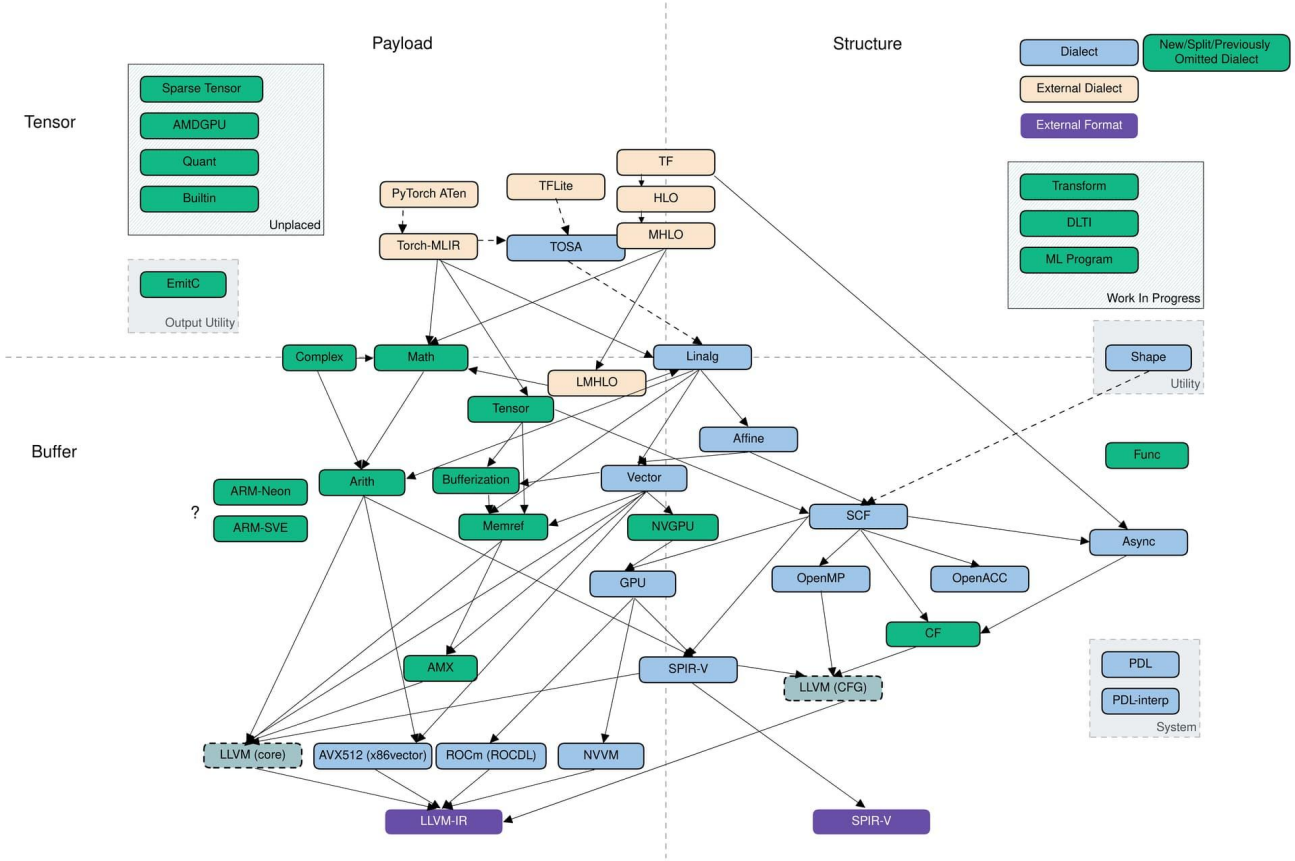

What you
need to do…

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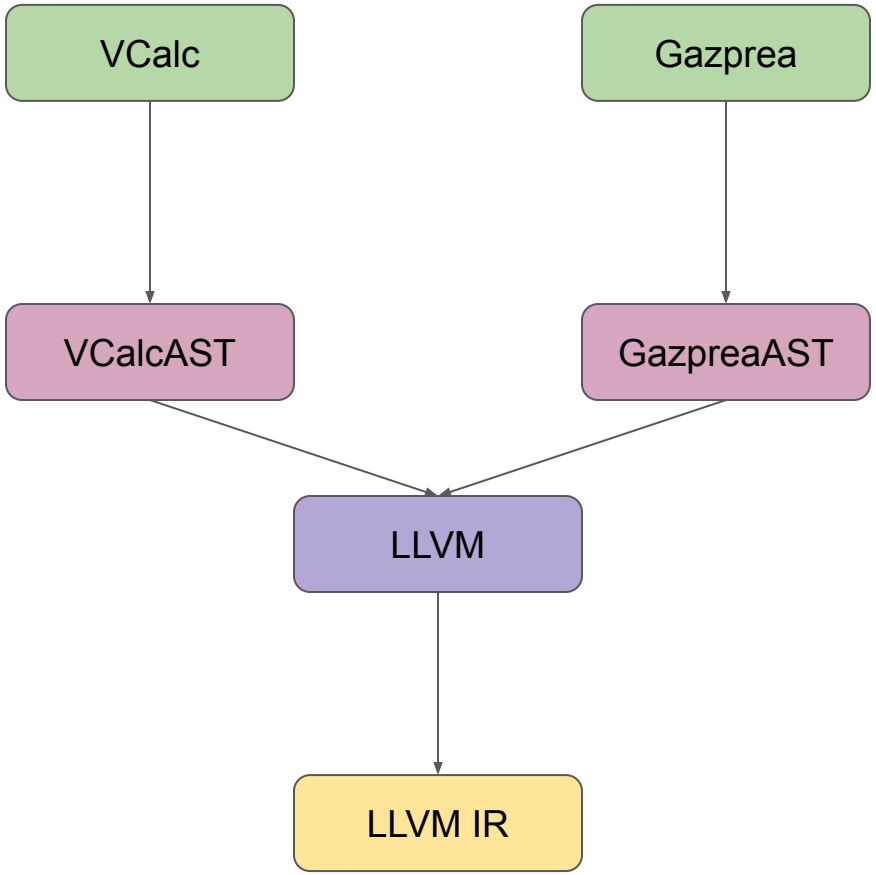

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mlir-opt - optimizer and lowerer

optimize mlir

lower mlir to lower level dialect

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optimize mlir

lower mlir to lower level dialect

mlir-translate - translation tool

mlir -> external representation

external representation -> mlir


Principles of Compiler Design
Alfred V. Aho
Jeffrey D. Ullman


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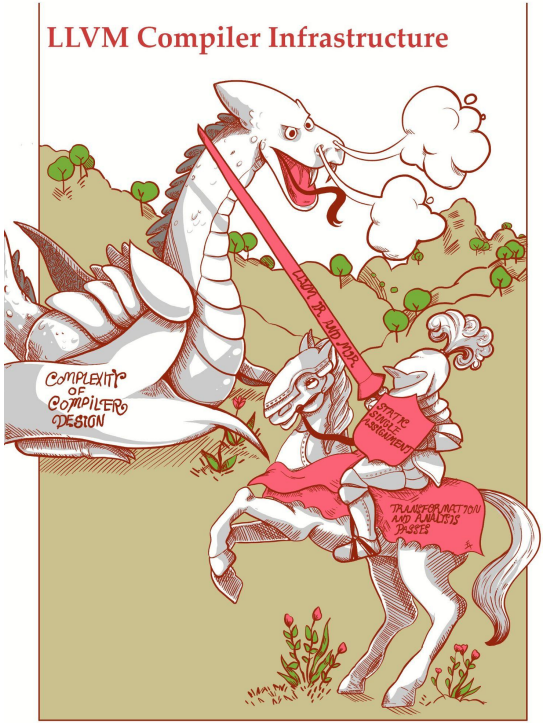
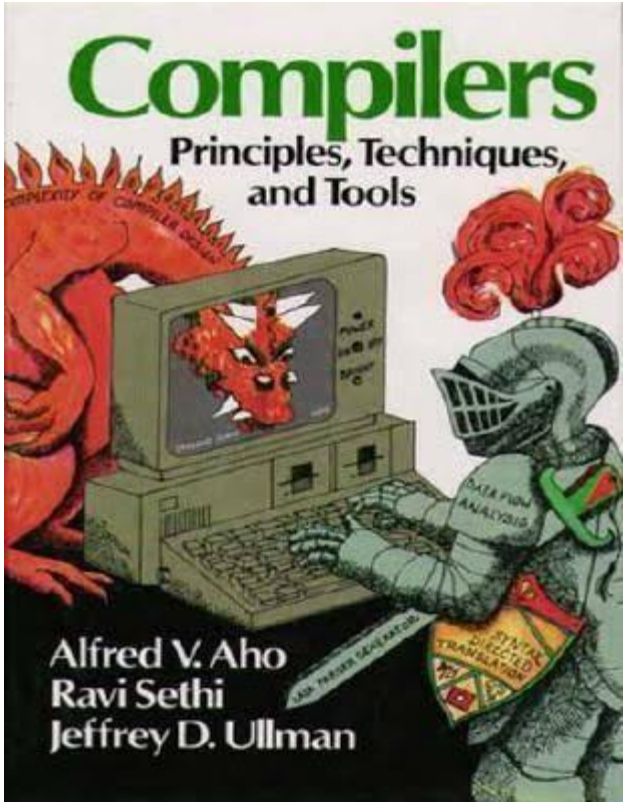

LLVM Compiler Infrastructure
COMPLEXITY OF COMPILER DESIGN
LLVM IR AND APIS
STATE MACHINE ASSIGNMENT
TRANSFORMATION AND ANALYSIS PASSES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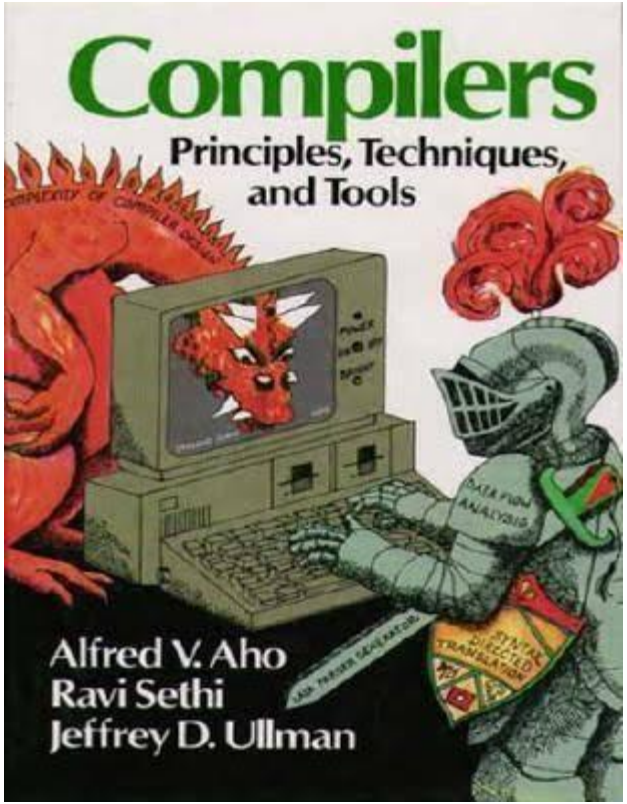
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LLVM
Compiler Infrastructure
COMPLEXITY OF COMPILER DESIGN
"NFC" COMMITS
ADDRESS SANITIZER
STATIC SINGLE ASSIGNMENT
JESSICA PAQUETTE 2018

Next Time

- LLVM IR & MLIR examples
- Working with LLVM & MLIR
- How to emit MLIR LLVM dialect in C++

https://llvm.org/docs/LangRef.html

```
int add(int left, int right) {
  return left + right;
}
```

```
define i32 @add(i32 %0, i32 %1) {
  %3 = alloca i32
  %4 = alloca i32
  store i32 %0, ptr %3
  store i32 %1, ptr %4
  %5 = load i32, ptr %3
  %6 = load i32, ptr %4
  %7 = add i32 %5, %6
  ret i32 %7
}
```

- Instruction Reference
  - Terminator Instructions
    - 'ret' Instruction
    - 'br' Instruction
    - 'switch' Instruction
    - 'indirectbr' Instruction
    - 'invoke' Instruction
    - 'callbr' Instruction
    - 'resume' Instruction
    - 'catchswitch' Instruction
    - 'catchret' Instruction
    - 'cleanupret' Instruction
    - 'unreachable' Instruction
  - Unary Operations
    - 'fneg' Instruction
  - Binary Operations
    - 'add' Instruction
    - 'fadd' Instruction
    - 'sub' Instruction
    - 'fsub' Instruction
    - 'mul' Instruction
    - 'fmul' Instruction
    - 'udiv' Instruction
    - 'sdiv' Instruction
    - 'fdiv' Instruction
    - 'urem' Instruction
    - 'srem' Instruction
    - 'frem' Instruction

```
int add(int left, int right) {
  return left + right;
}
define i32 @add(i32 %0, i32 %1) {
  %3 = alloca i32
  %4 = alloca i32
  store i32 %0, ptr %3
  store i32 %1, ptr %4
  %5 = load i32, ptr %3
  %6 = load i32, ptr %4
  %7 = add i32 %5, %6
  ret i32 %7
}
```