Language Translators

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Columbia University

* Course website: https://verigu.github.io/4115Fall2022/

** These slides are borrowed from Prof. Edwards.

TA Mailing List

For any general questions related to assignments and projects, please send emails to the following TA mailing list using your **Columbia email address**:

Gu4115TA@lists.cs.columbia.edu

No exams are required to stay in the course.

What is a Translator?

A programming language is a notation that a person and a computer can both understand.

- It allows you to express what is the **task** to compute
- It allows a computer to **execute** the computation task

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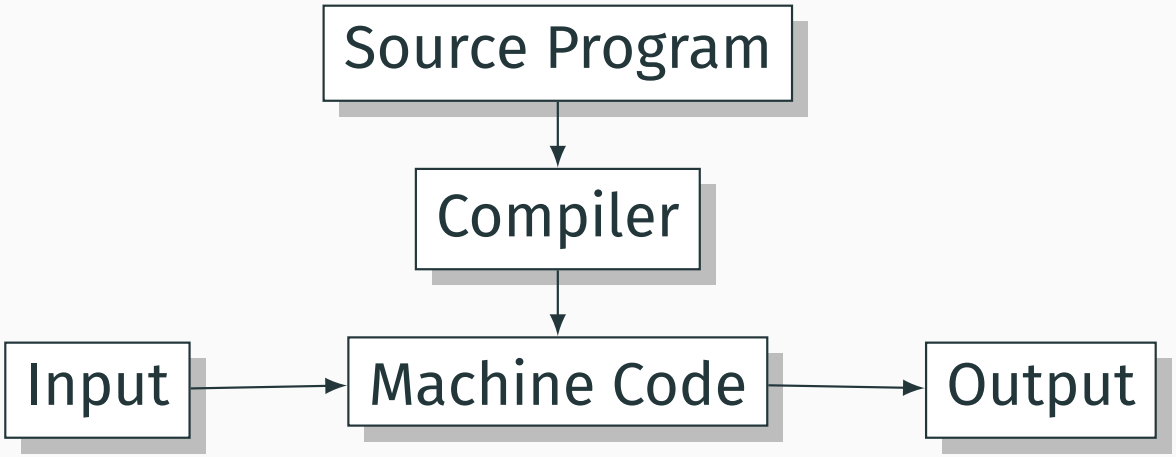
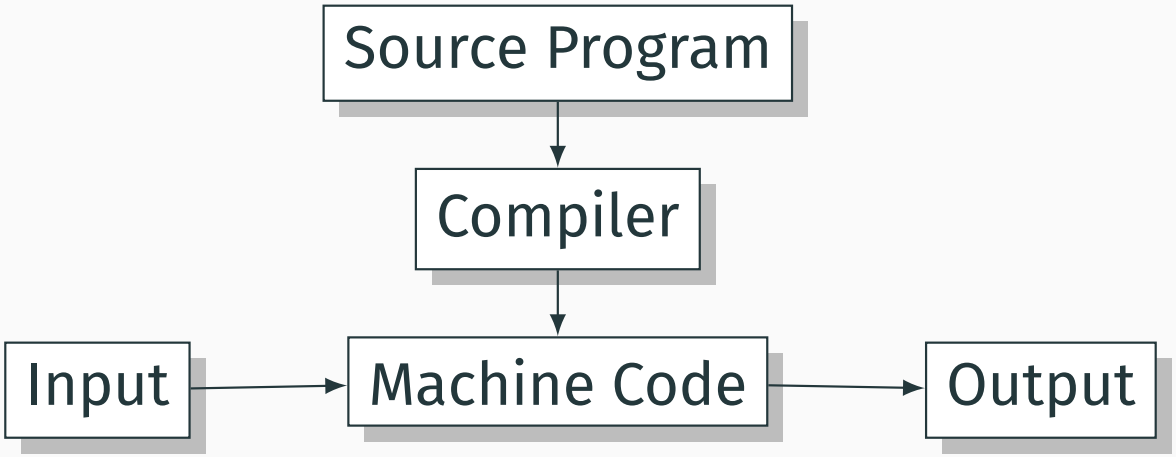
- It allows you to express what is the **task** to compute
- It allows a computer to **execute** the computation task

A translator translates what you express to what a computer can execute.

Compiler

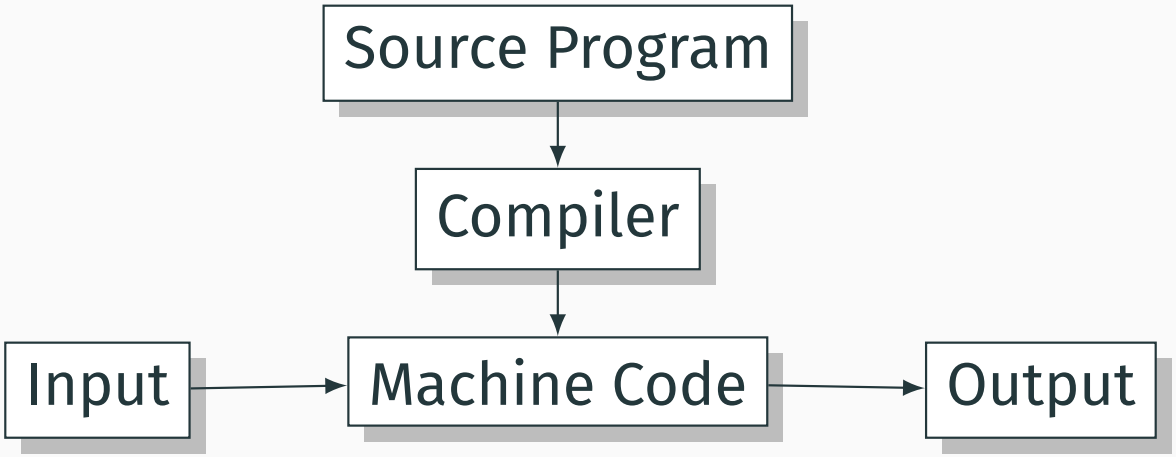


Compiler



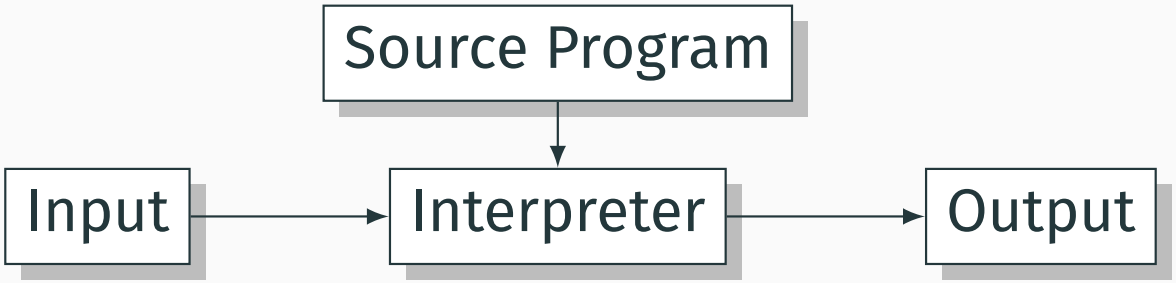
- **Pros**: translation is done once and for all; optimize code and map identifiers at compile time.

Compiler

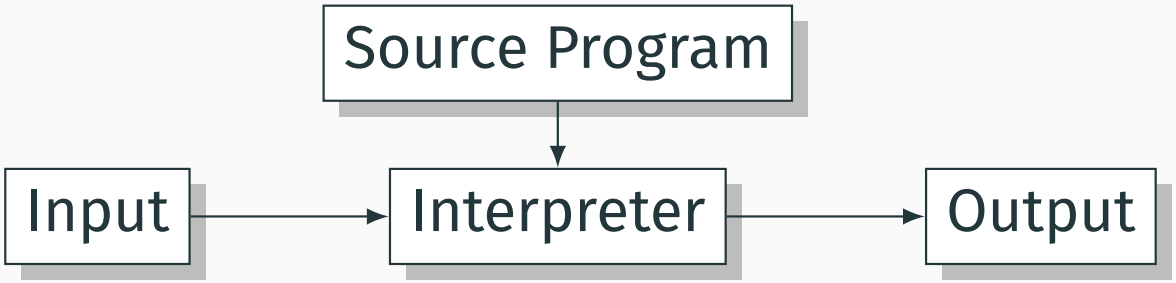


- **Pros**: translation is done once and for all; optimize code and map identifiers at compile time.
- **Cons**: long compilation time; hard to port.

Interpreter

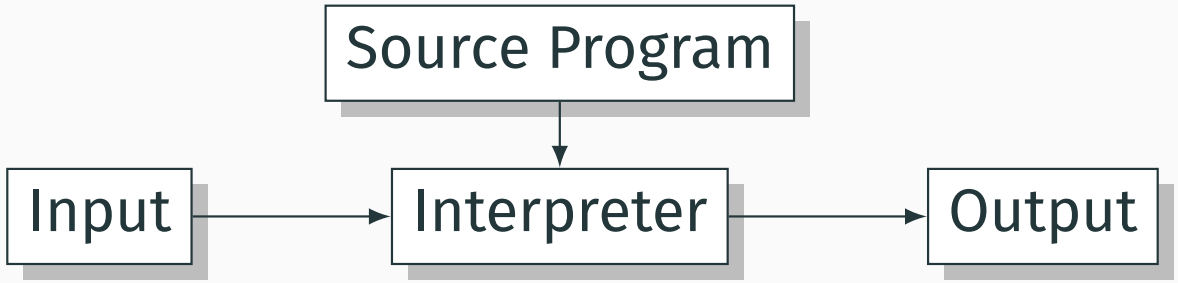


Interpreter



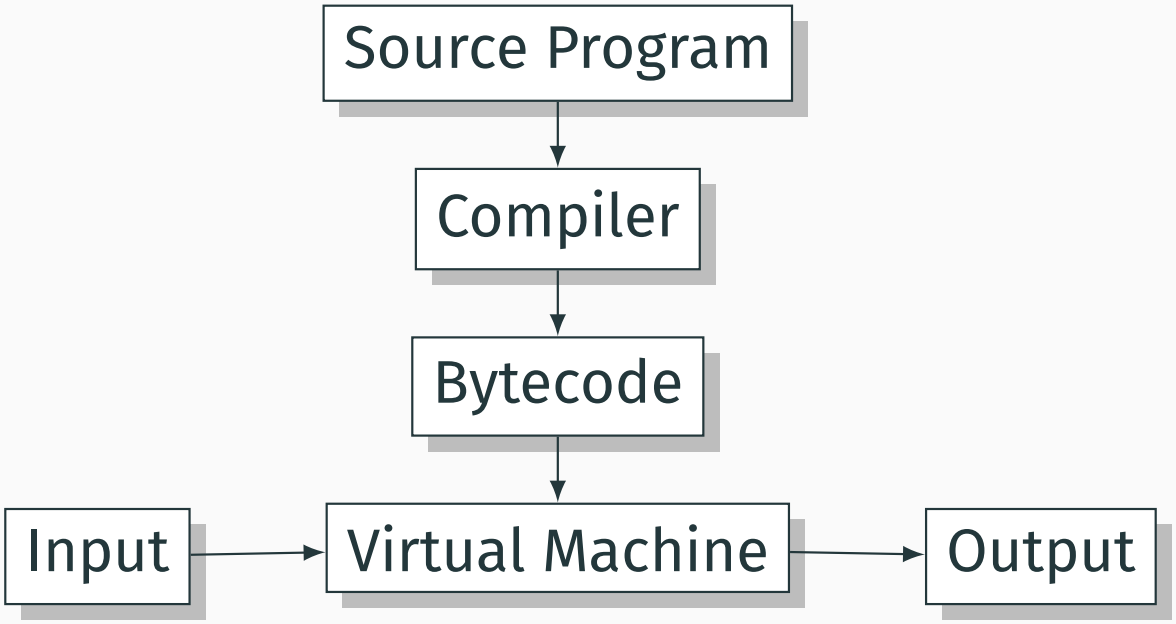
- **Pros**: source code distribution; short development cycle.

Interpreter

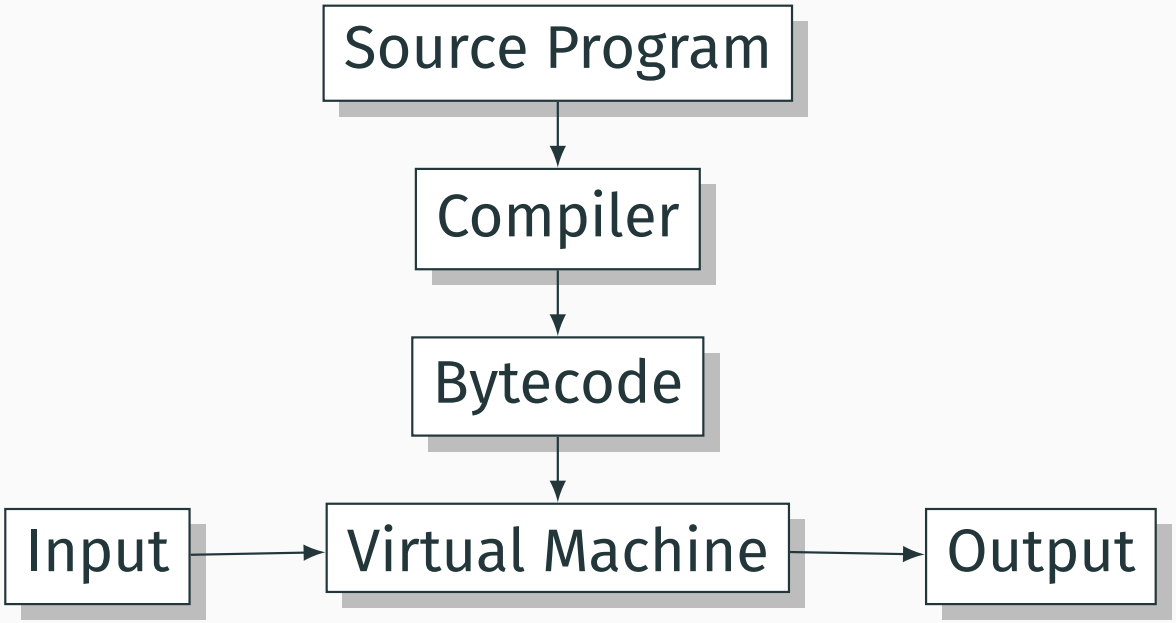


- **Pros**: source code distribution; short development cycle.
- **Cons**: translation is needed every time a statement is executed; lack optimization; map identifiers repeatedly.

Bytecode Interpreter

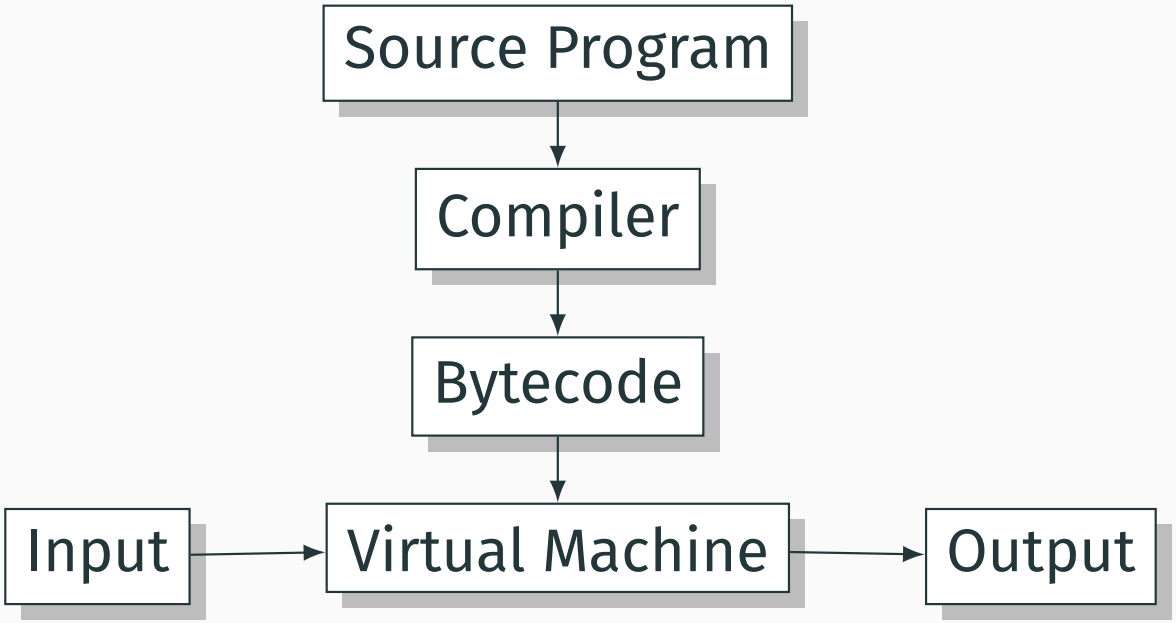


Bytecode Interpreter



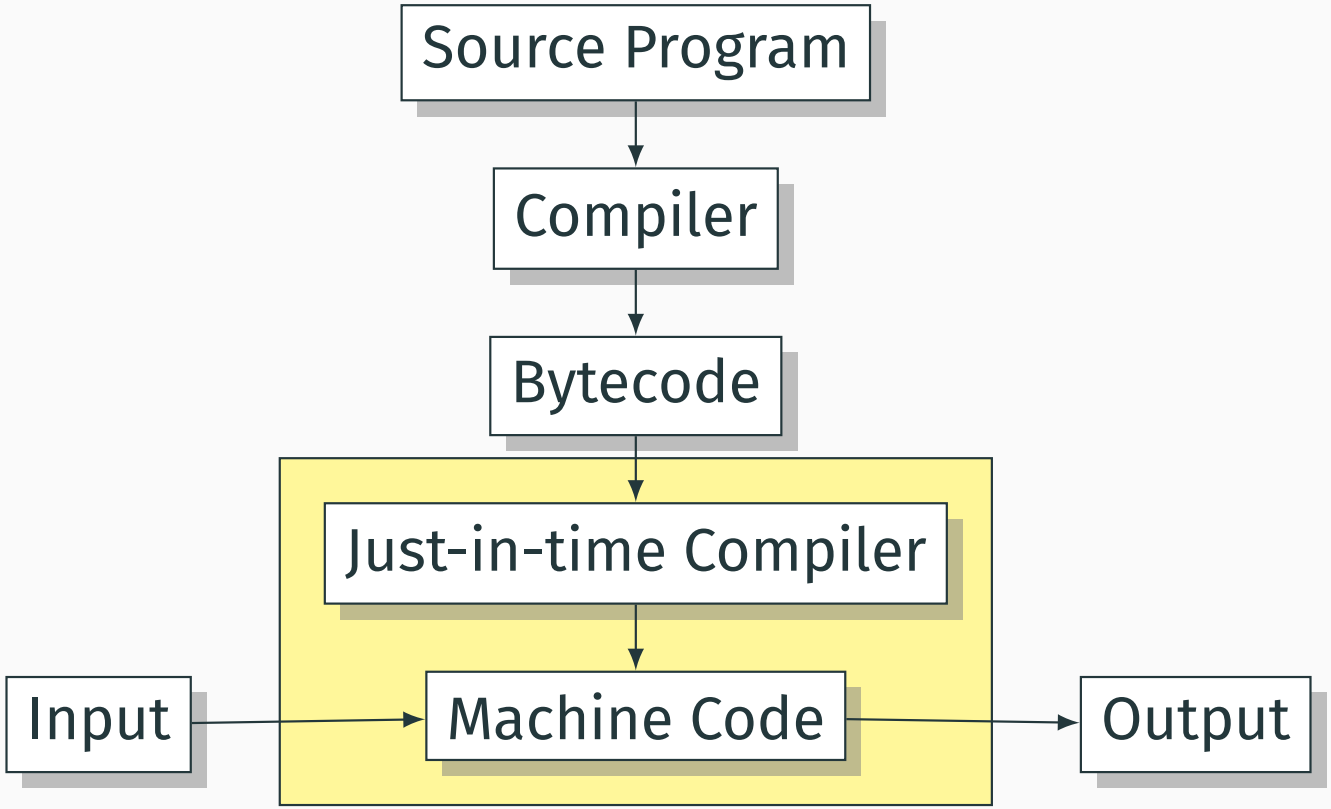
- **Pros**: bytecode is highly compressed and optimized; bytecode distribution.

Bytecode Interpreter



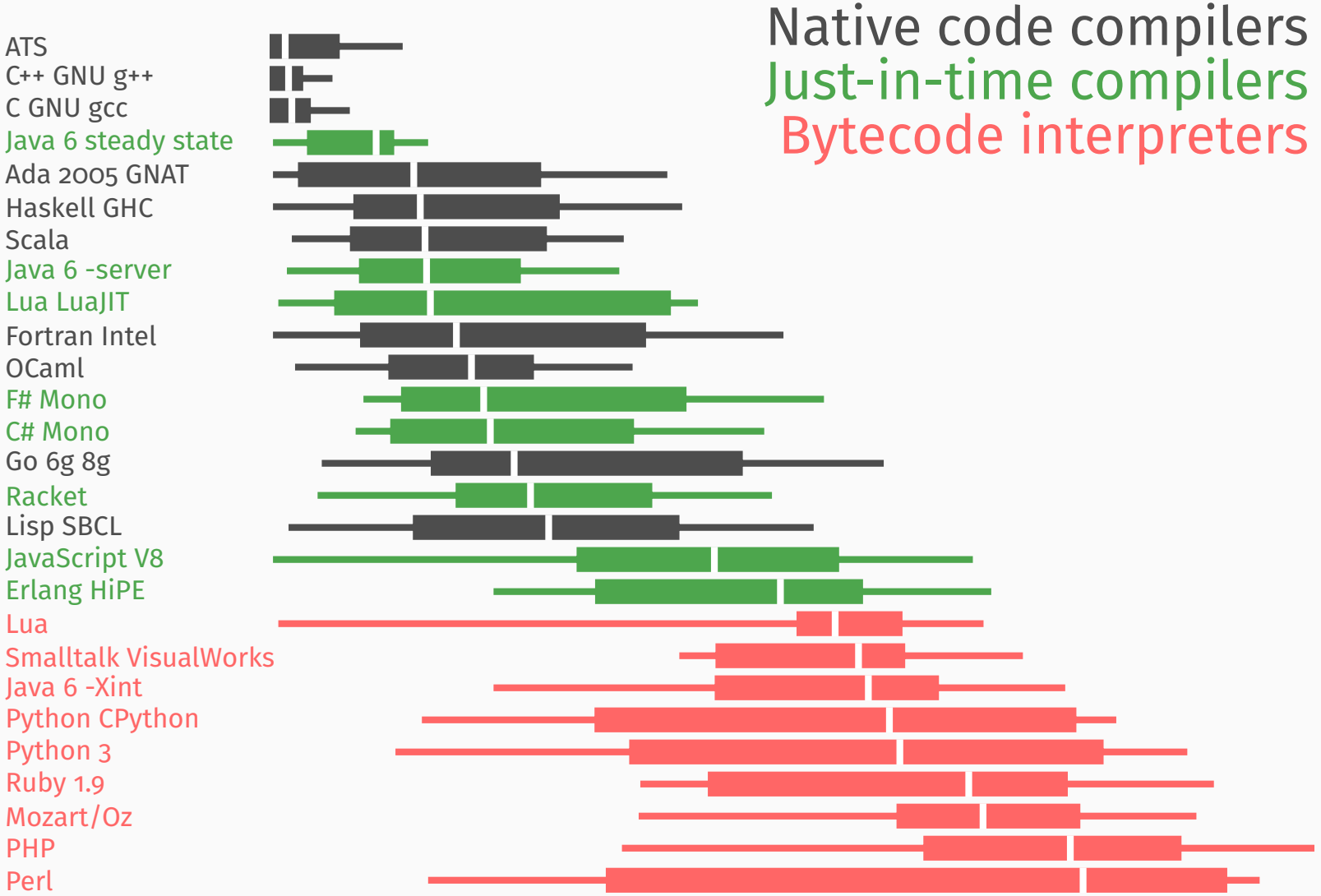
- **Pros**: bytecode is highly compressed and optimized; bytecode distribution.
- **Cons**: compilation overhead + interpreter overhead.

Just-In-Time Compiler



- **Pros**: compile and optimize many sections just before the execution (at runtime); bytecode distribution.
- **Cons**: compilation overhead + warm-up overhead.

Language Speeds Compared

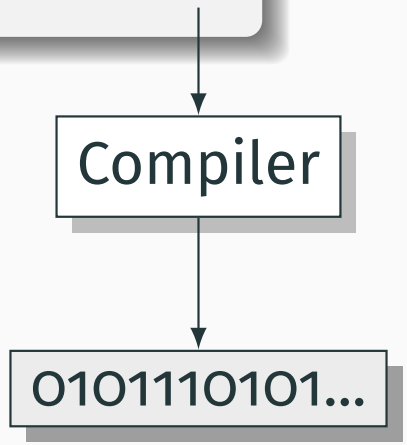


Source: http://shootout.alioth.debian.org/

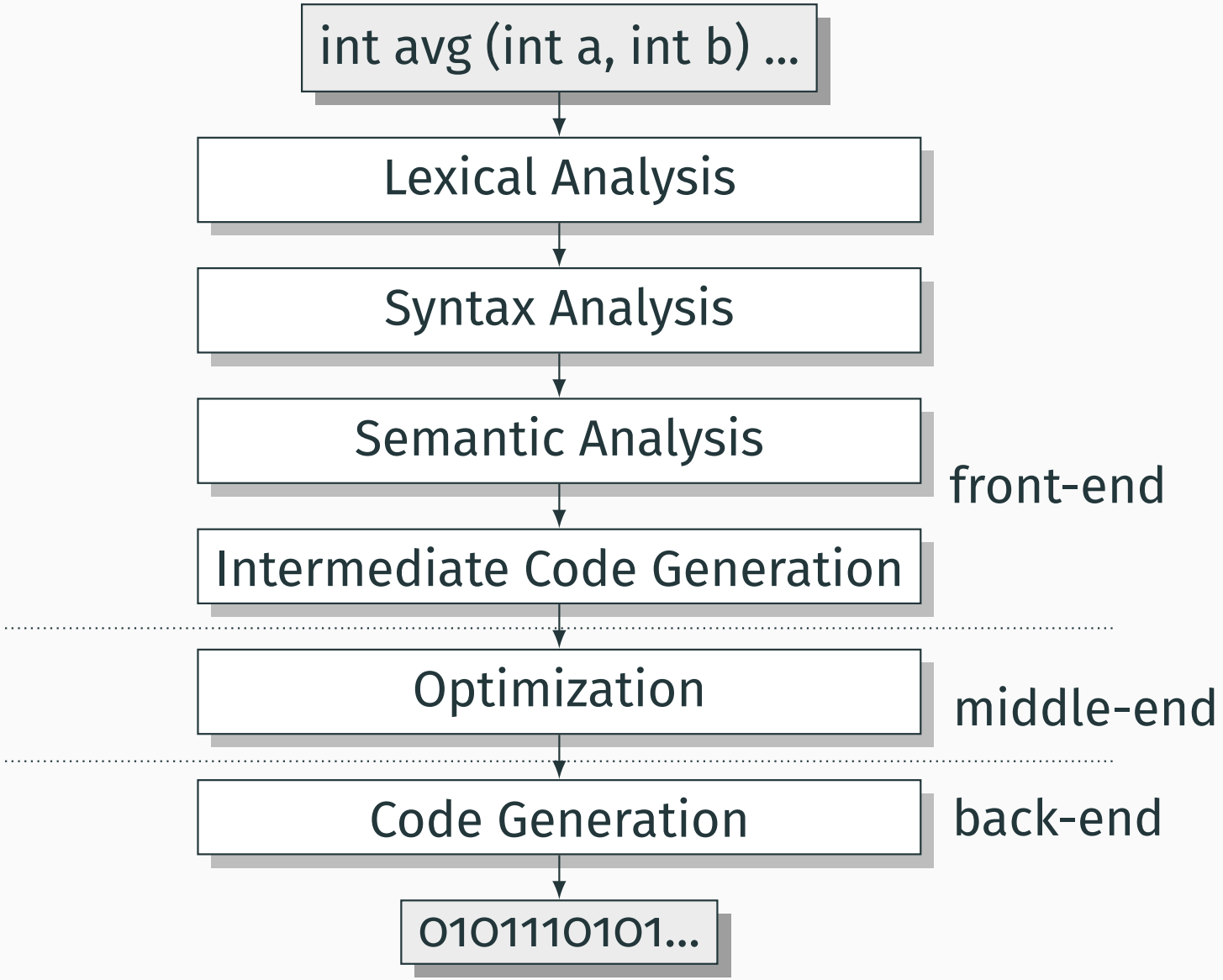
Compilation Phases

Compiling a Simple Program

```
int avg(int a, int b)
{
  return (a + b) / 2;
}
```



Compilation Phases



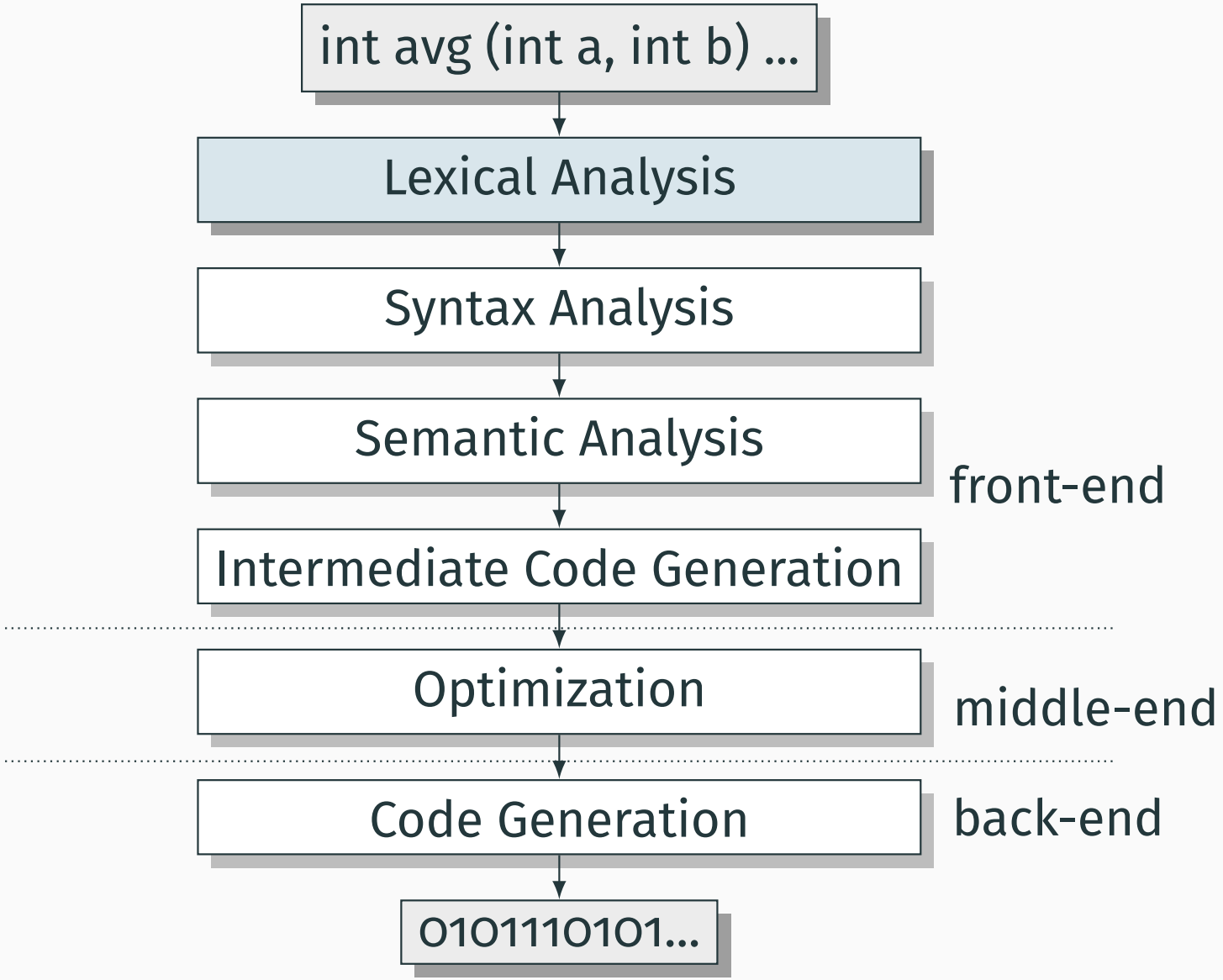
What the Compiler Sees

```
int avg(int a, int b)
{
  return (a + b) / 2;
}
```

i n t SP a v g (i n t SP a , SP i n t SP b) NL
{ NL
SP SP r e t u r n SP (a SP + SP b) SP / SP 2 ; NL
} NL

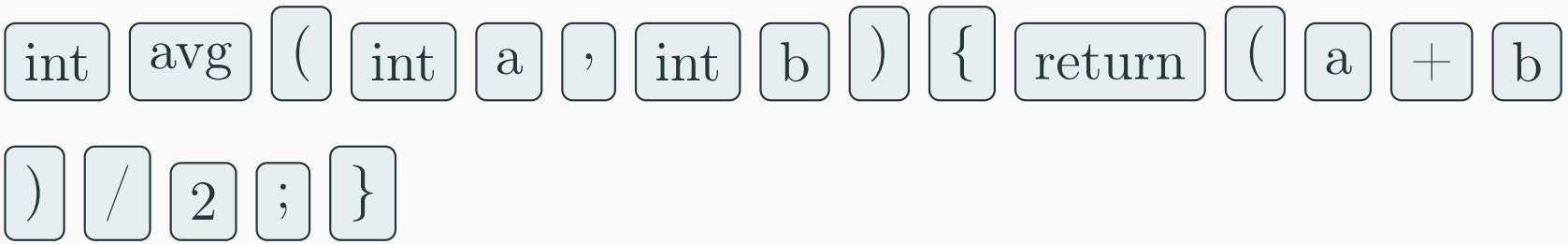
Just a sequence of characters

Lexical Analysis



Lexical Analysis Gives Tokens

```
int avg(int a, int b)
{
  return (a + b) / 2;
}
```



- A stream of **tokens**; whitespace, comments removed.

Lexical Analysis Gives Tokens

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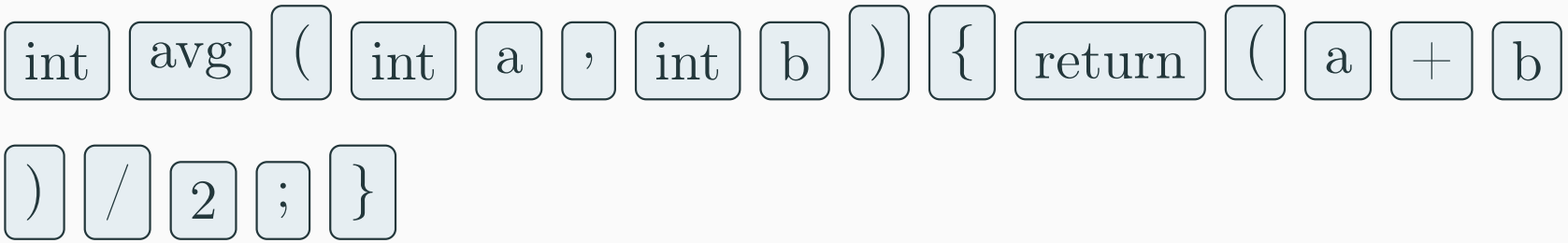
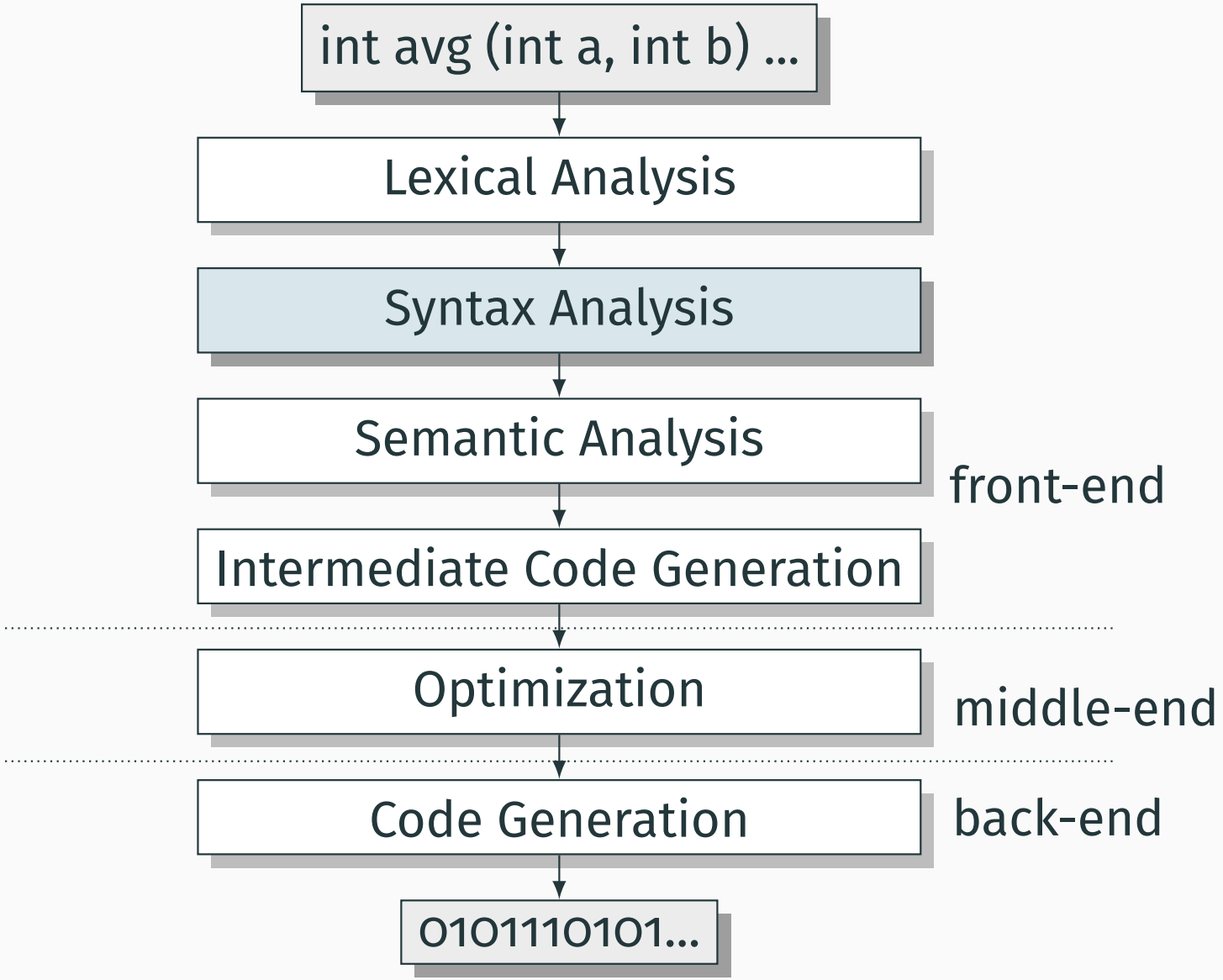
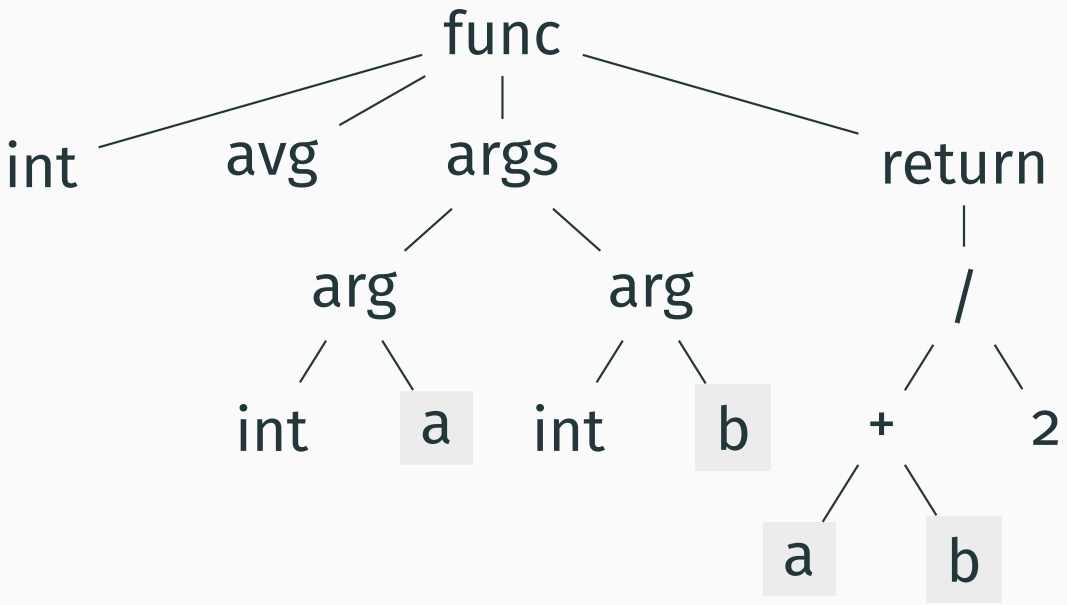


- A stream of **tokens**; whitespace, comments removed.
- Throw errors when failing to create tokens: malformed strings or numbers or invalid characters (such as non-ASCII characters in C).

Syntax Analysis



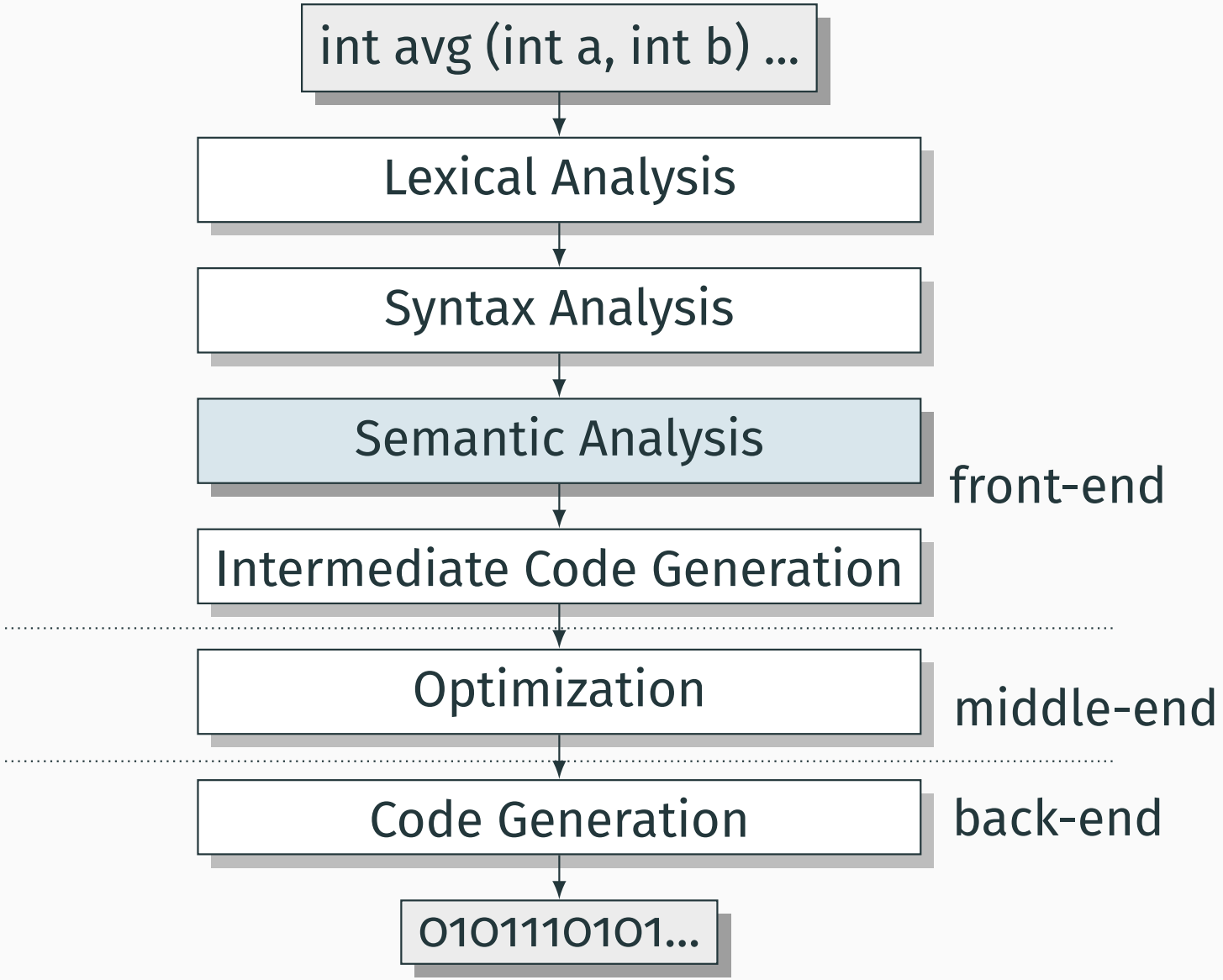
Syntax Analysis Gives an Abstract Syntax Tree



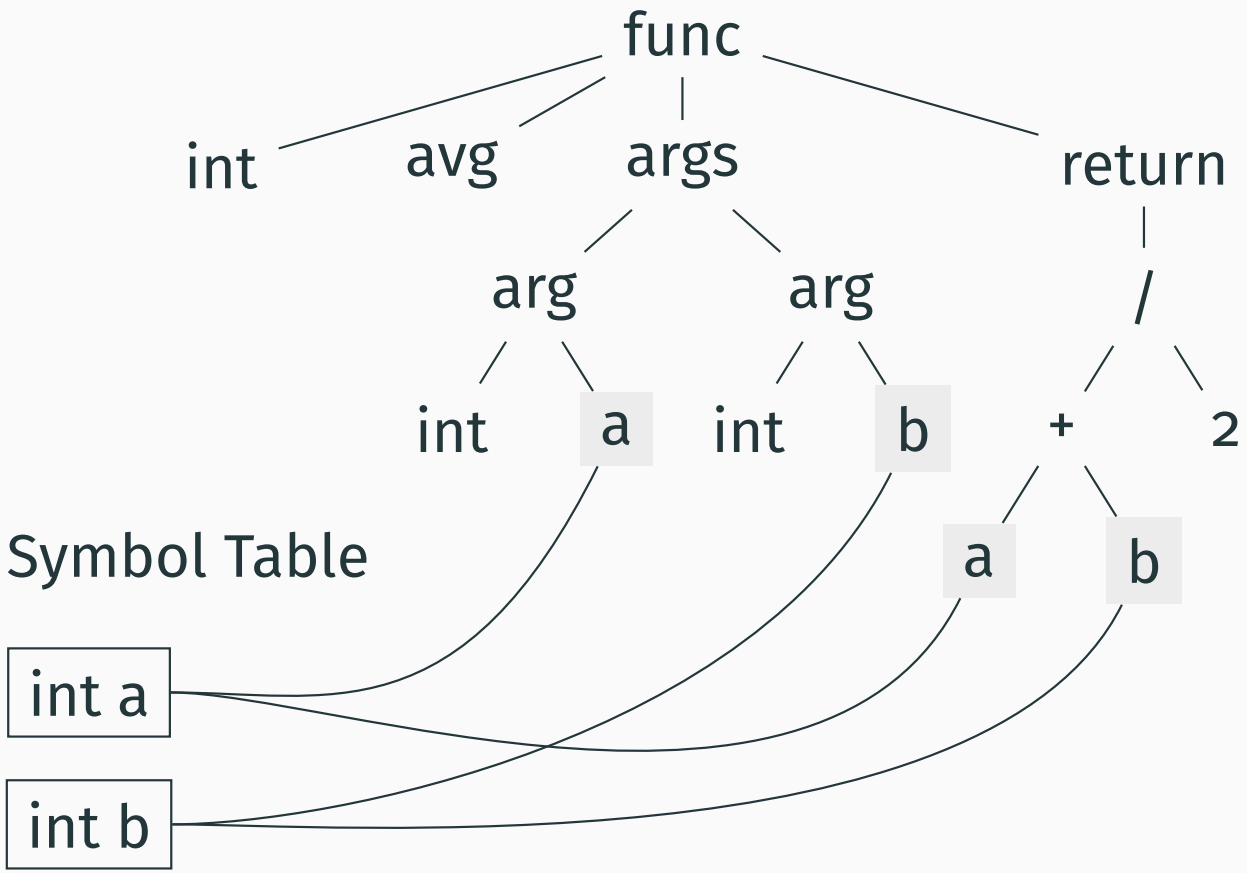

```
int avg(int a, int b)
{
  return (a + b) / 2;
}
```

- Syntax analysis will throw errors if “}” is missing. Lexical analysis will not.

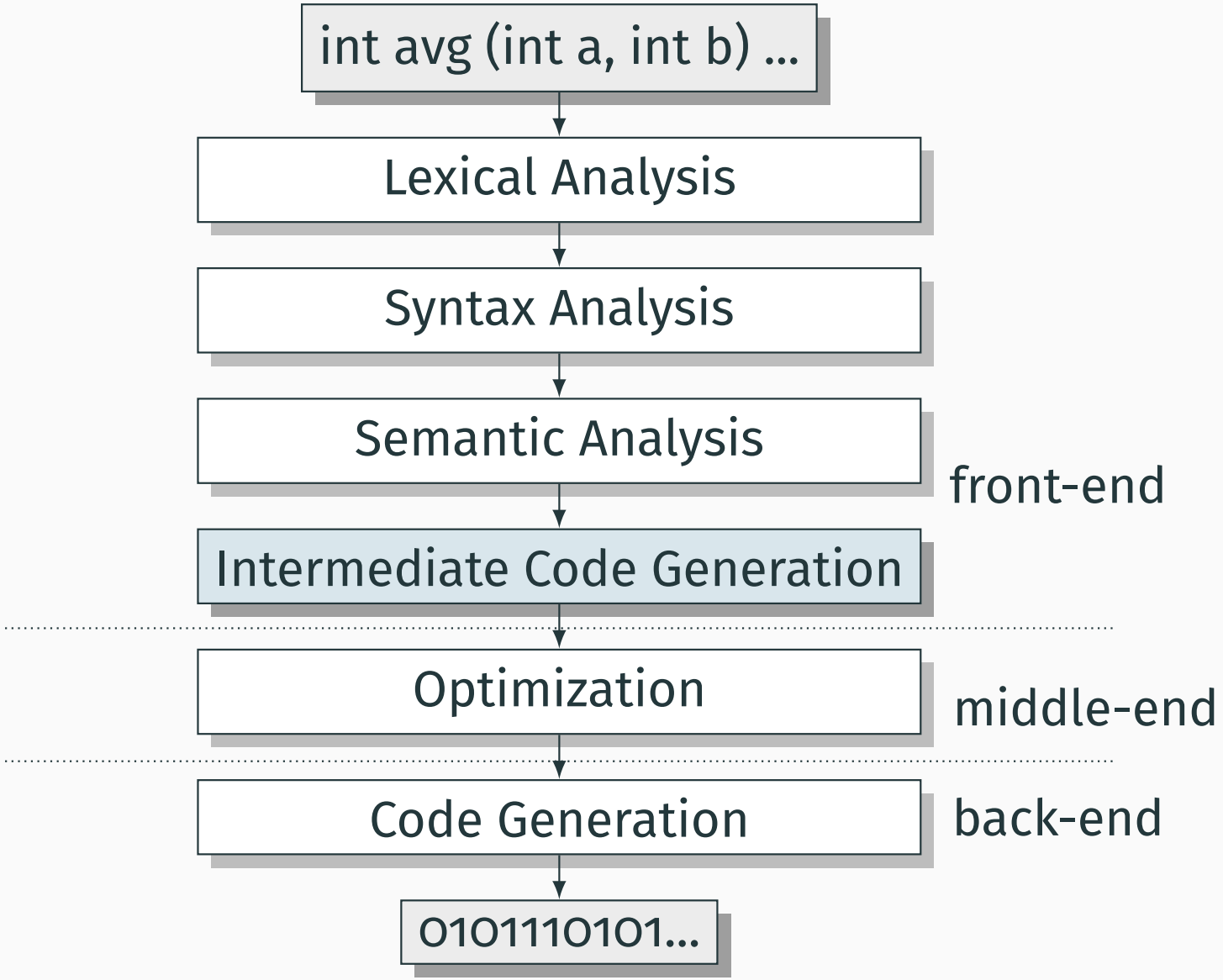
Semantic Analysis



Semantic Analysis: Resolve Symbols; Verify Types



Intermediate Code Generation



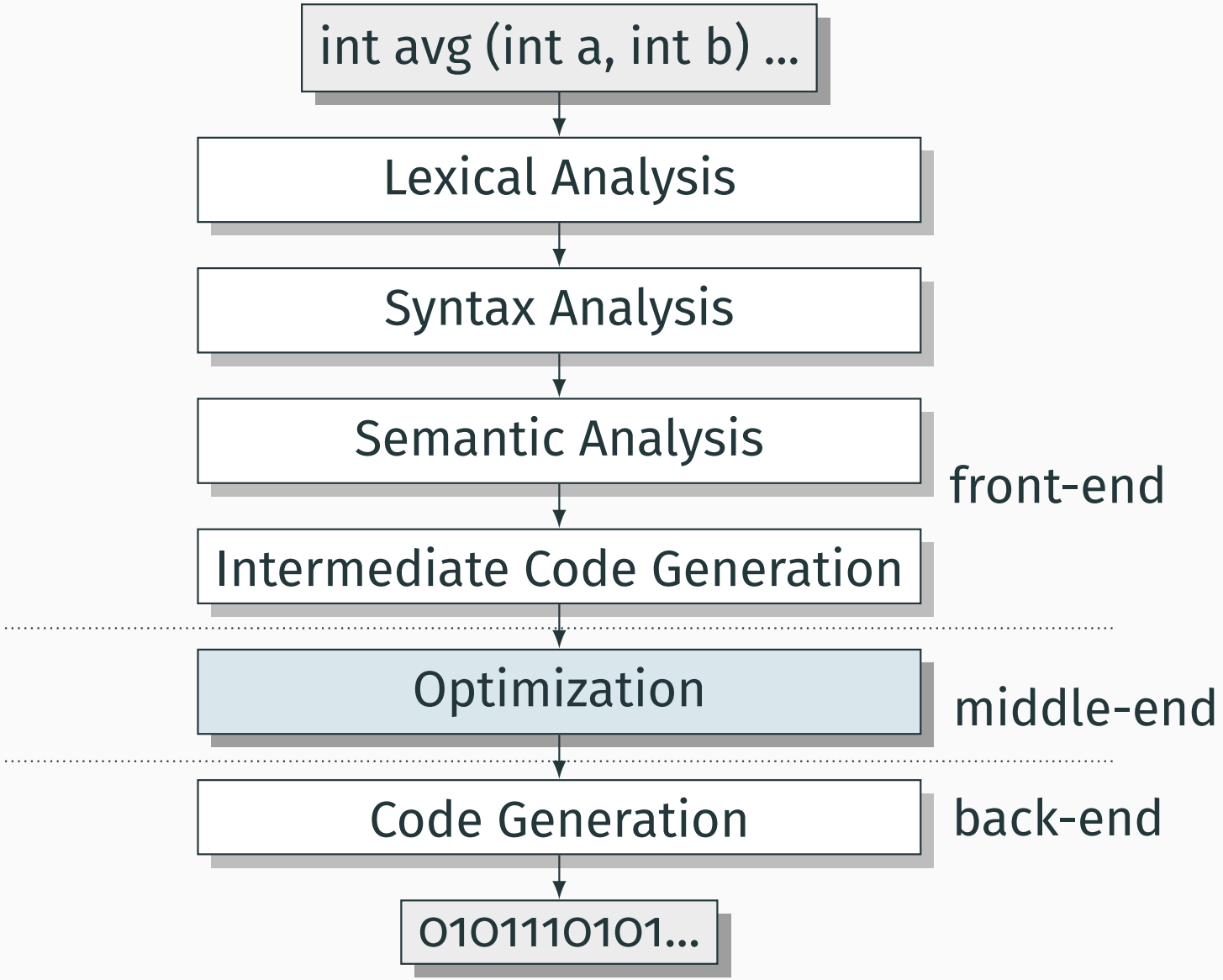
Translation into 3-Address Code

```
int avg(int a, int b)
{
  return (a + b) / 2;
}
```

Idealized assembly language w/ infinite registers

```
avg:
  t0 := a + b
  t1 := 2
  t2 := t0 / t1
  ret t2
```

Optimization



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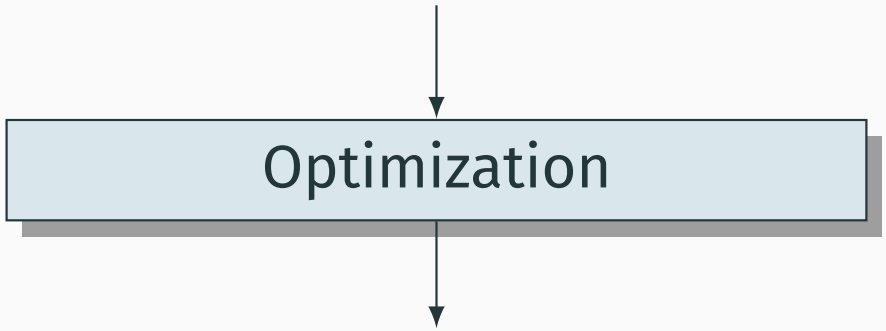


```
avg:
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```
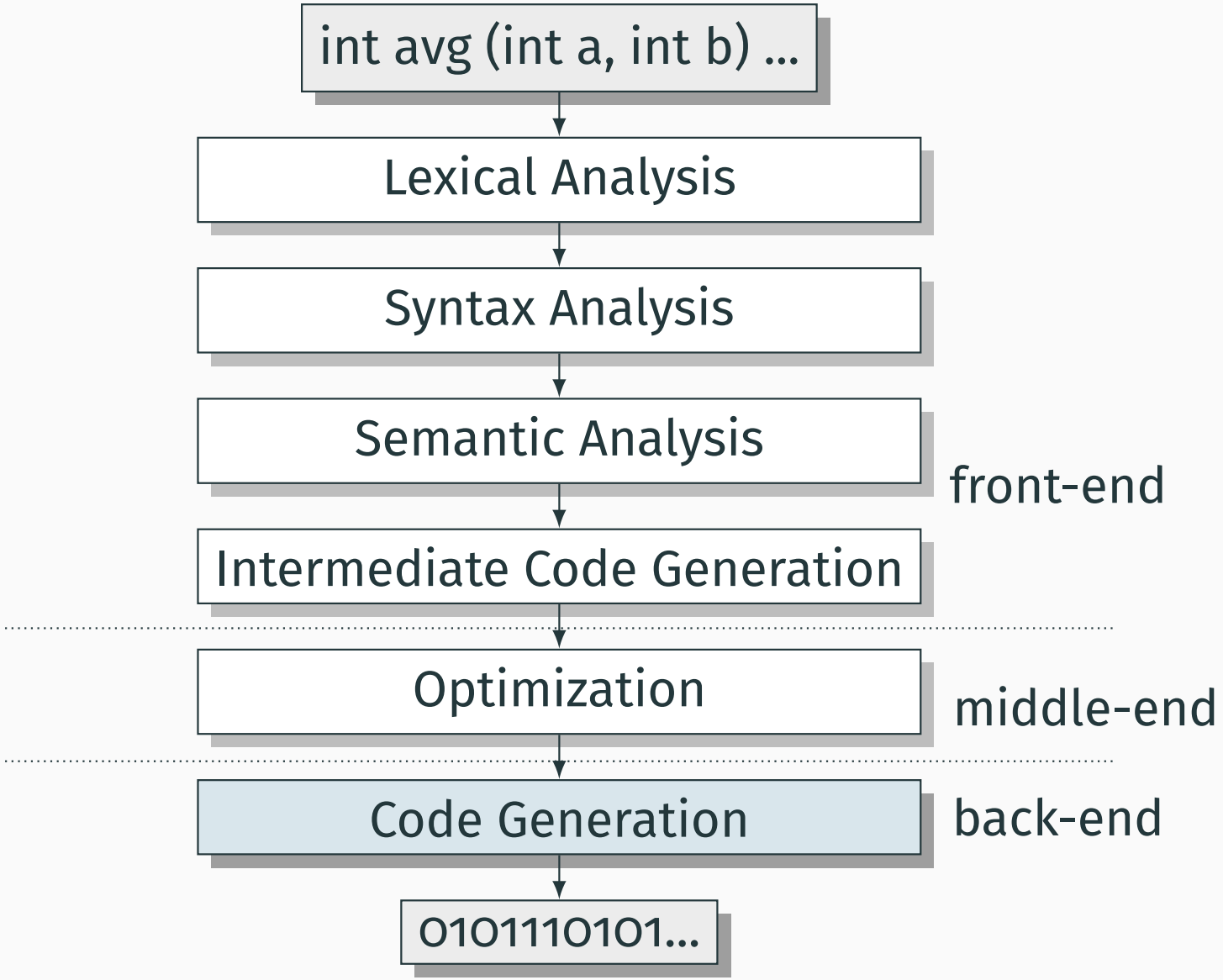
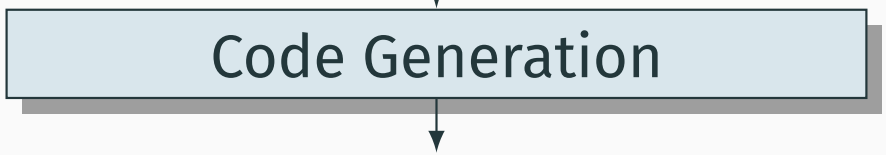

Code Generation



Generation of x86 Assembly

```
avg:
  t0 := a + b
  t2 := t0 / 2
  ret t2
```




```
avg:    pushl %ebp              # save BP
        movl  %esp,%ebp
        movl  8(%ebp),%eax      # load a from stack
        movl  12(%ebp),%edx     # load b from stack

        addl  %edx,%eax         # a += b
        shr   $1,%eax           # a /= 2
        ret
```