Lecture 01 - Introduction

THEORY OF COMPILATION

Eran Yahav

Who?

Eran Yahav
Taub 734
Tel: 8294318
yahave@cs.technion.ac.il
Monday 13:30-14:30
http://www.cs.tecnion.ac.il/~yahave

What?

- Understand
  - what is a compiler
  - how does it work
  - techniques that can be re-used in other settings

- What will help us
  - Text books
    - Modern compiler design
    - Compilers: principles, techniques and tools
  - 5 homework assignments
- Will also help
  - Taking a deep breath
  - Focusing on material and not on your grade

What is a Compiler?

- "A compiler is a computer program that transforms source code written in a programming language (source language) into another language (target language). The most common reason for wanting to transform source code is to create an executable program."

--*Wikipedia*

What is a Compiler?

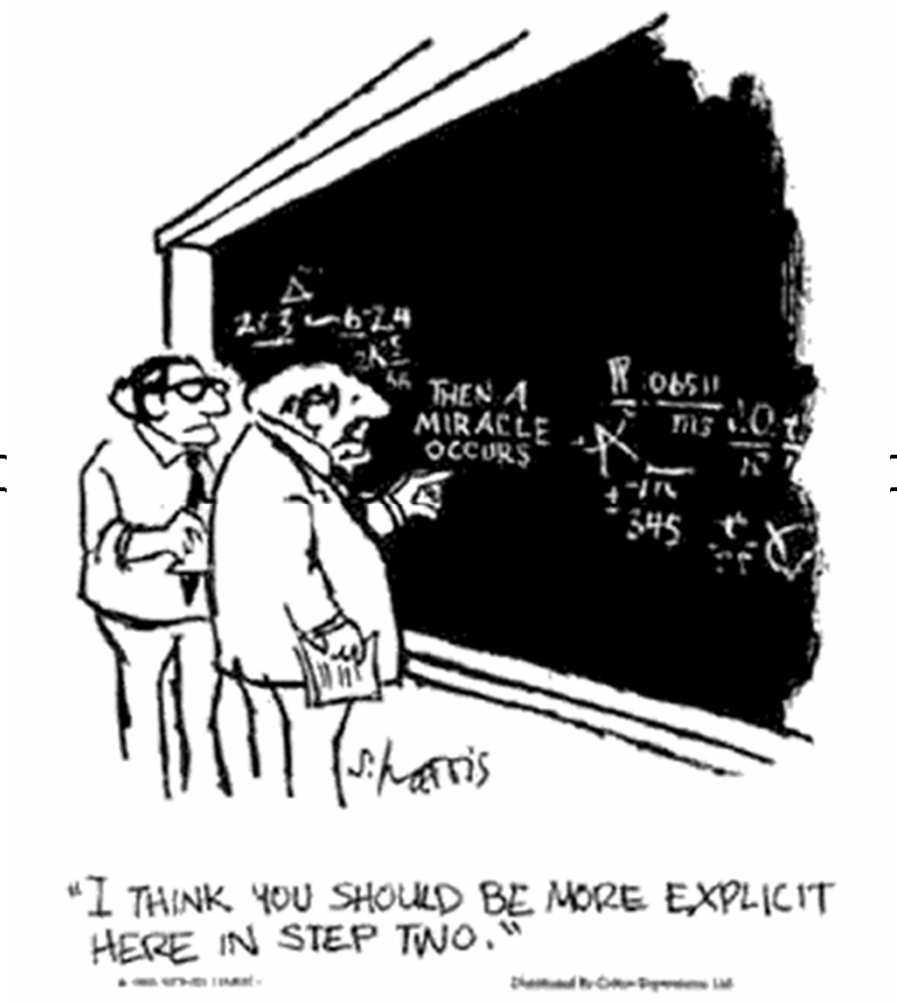
source language

C
C++
Pascal
Java
Postscript
TeX
Perl
JavaScript
Python
Ruby

Prolog

Lisp
Scheme
ML
OCaml

txt
Source text



Compiler

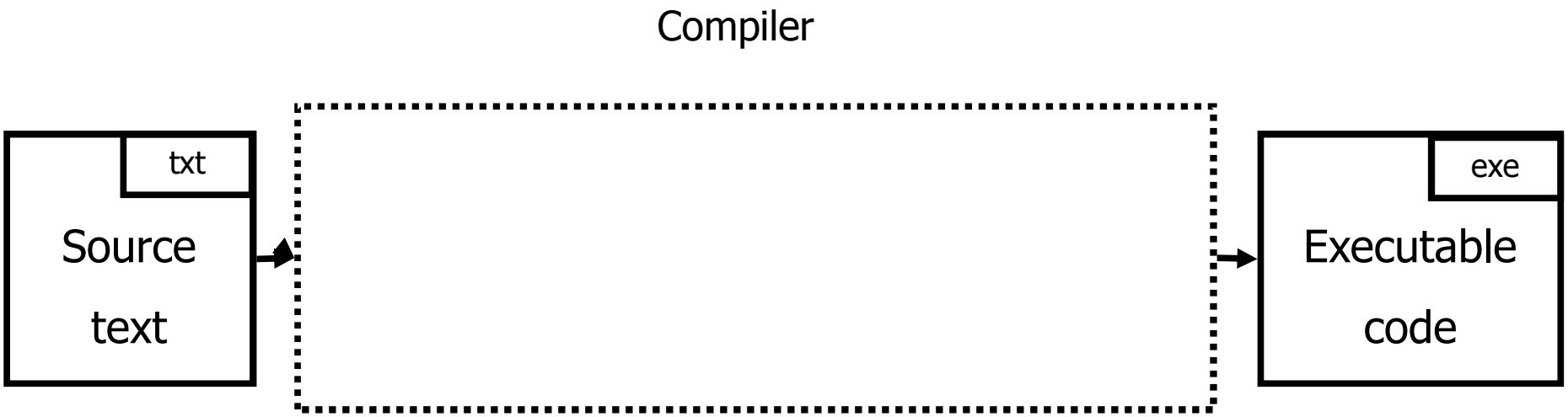
target language

IA32
IA64
SPARC

exe
C
C++
Pascal
Java
Executable code

Java Bytecode
...

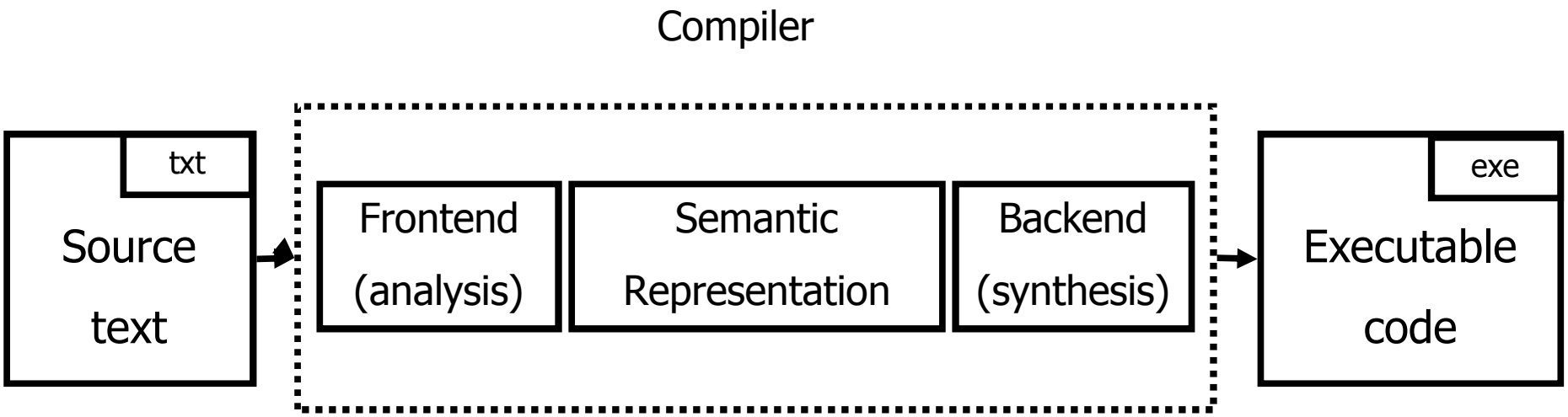
What is a Compiler?




```
int a, b;
a = 2;
b = a*2 + 1;
```

```
MOV R1,2
SAL R1
INC R1
MOV R2,R1
```

Anatomy of a Compiler

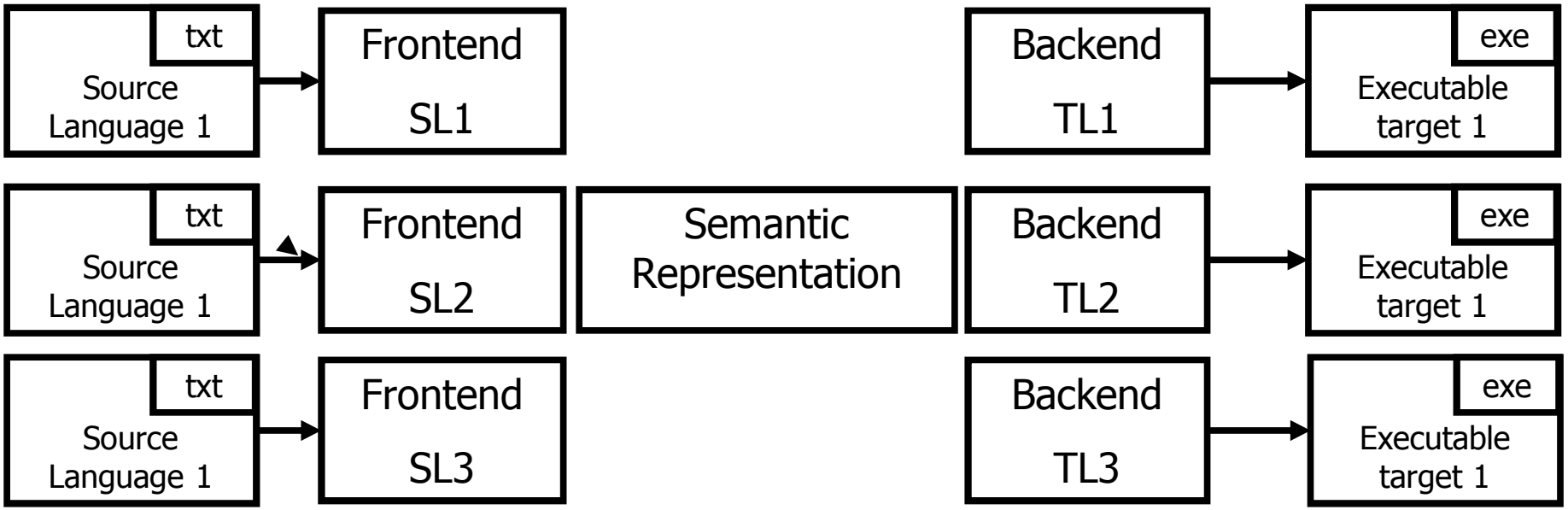



```
int a, b;
a = 2;
b = a*2 + 1;
```

```
MOV R1,2
SAL R1
INC R1
MOV R2,R1
```

Modularity

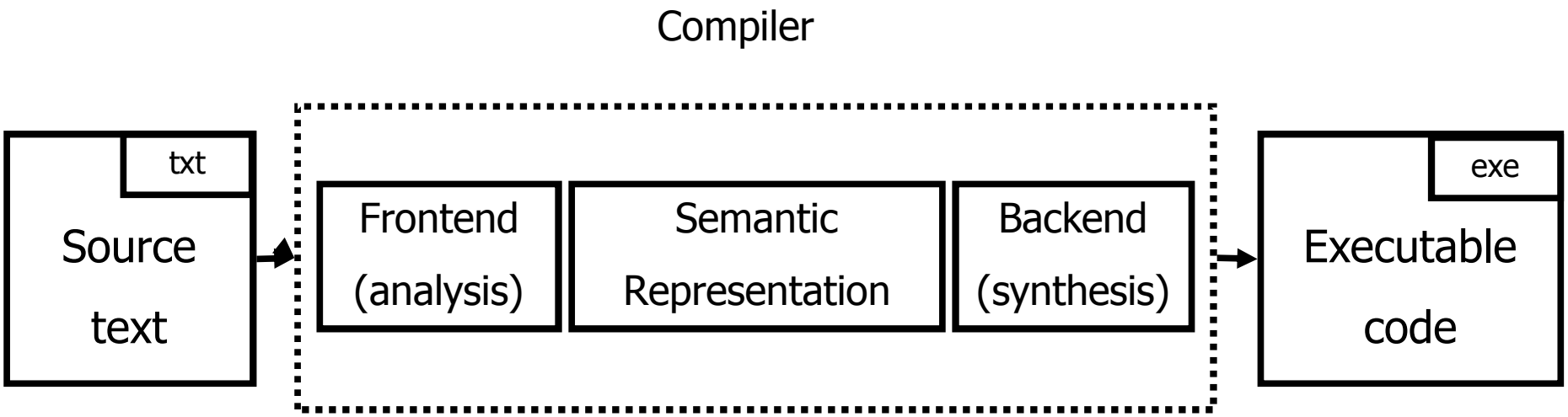
```
SET   R1,2
STORE #0,R1
SHIFT R1,1
STORE #1,R1
ADD   R1,1
STORE #2,R1
```



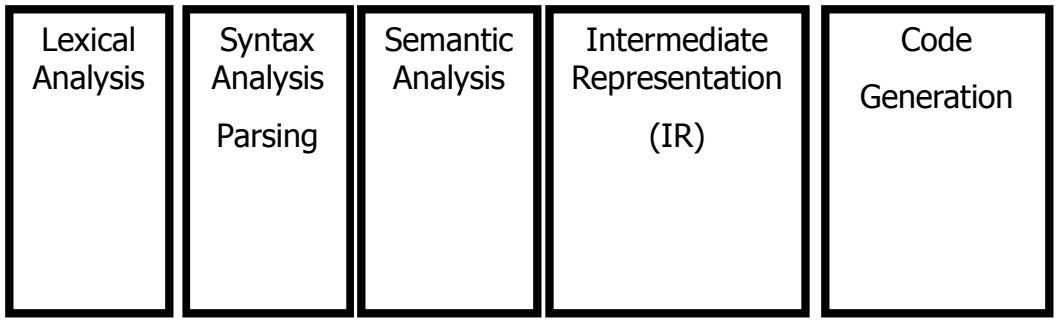

```
int a, b;
a = 2;
b = a*2 + 1;
```

```
MOV R1,2
SAL R1
INC R1
MOV R2,R1
```

Anatomy of a Compiler

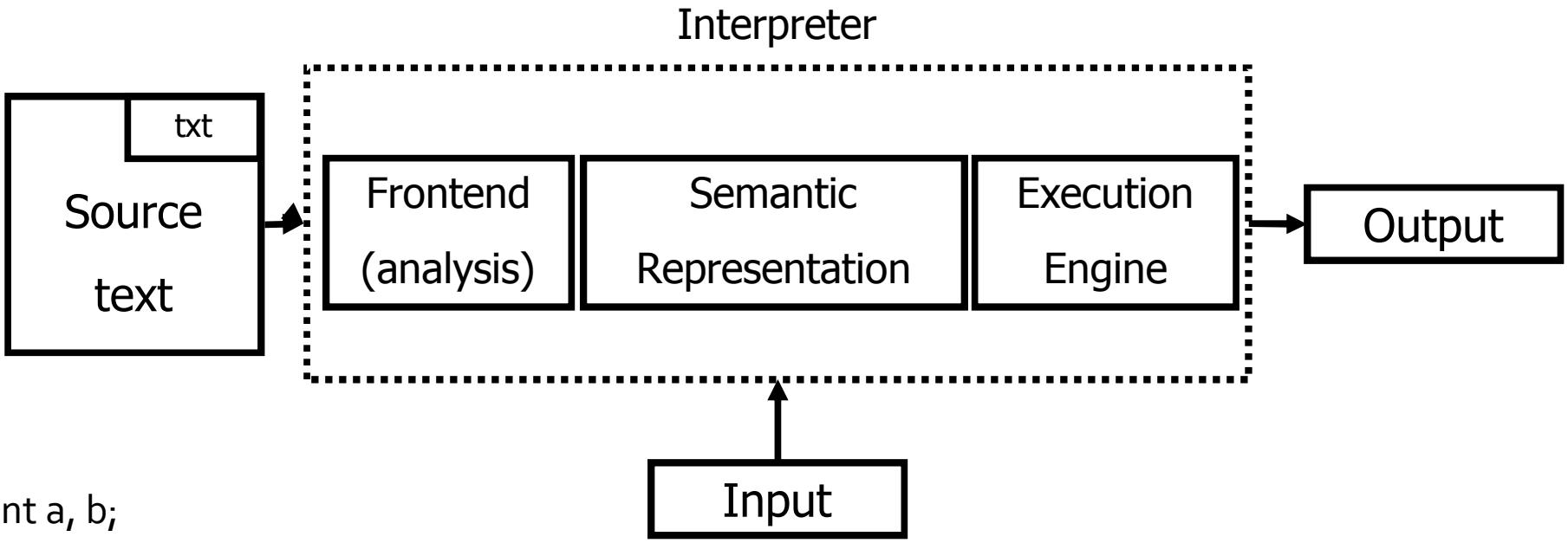



```
int a, b;
a = 2;
b = a*2 + 1;
```



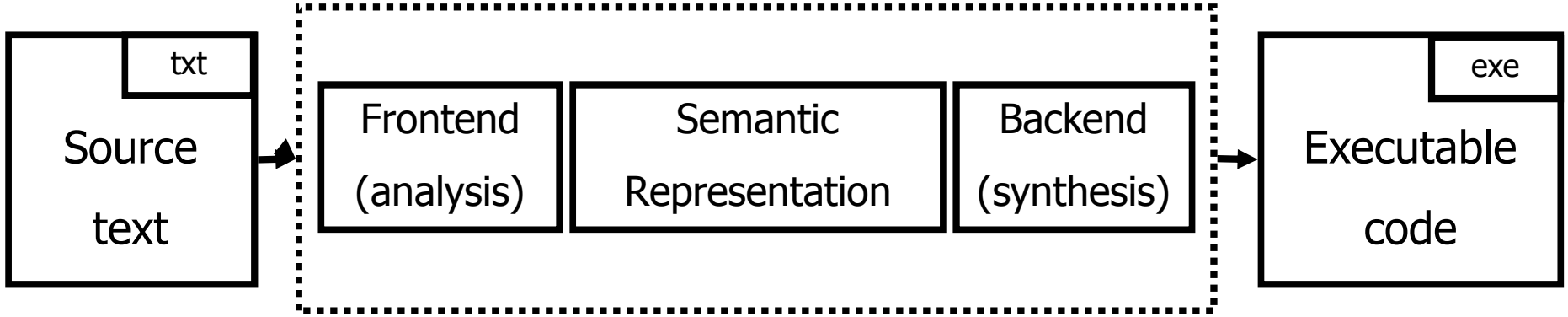

```
MOV R1,2
SAL R1
INC R1
MOV R2,R1
```

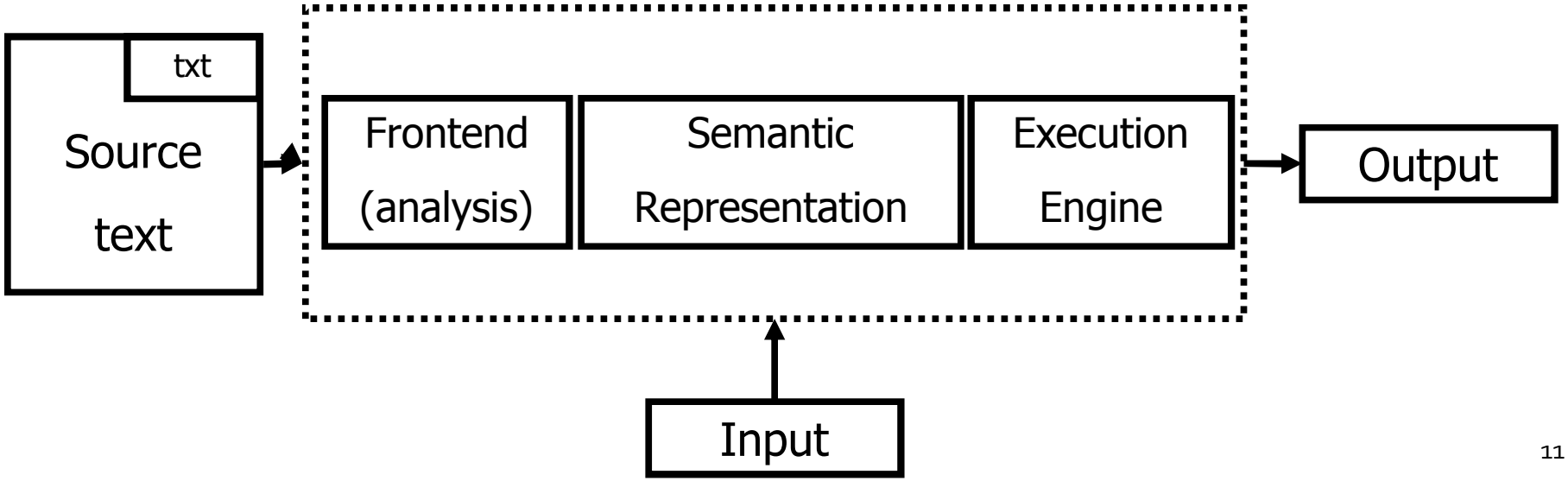
Interpreter



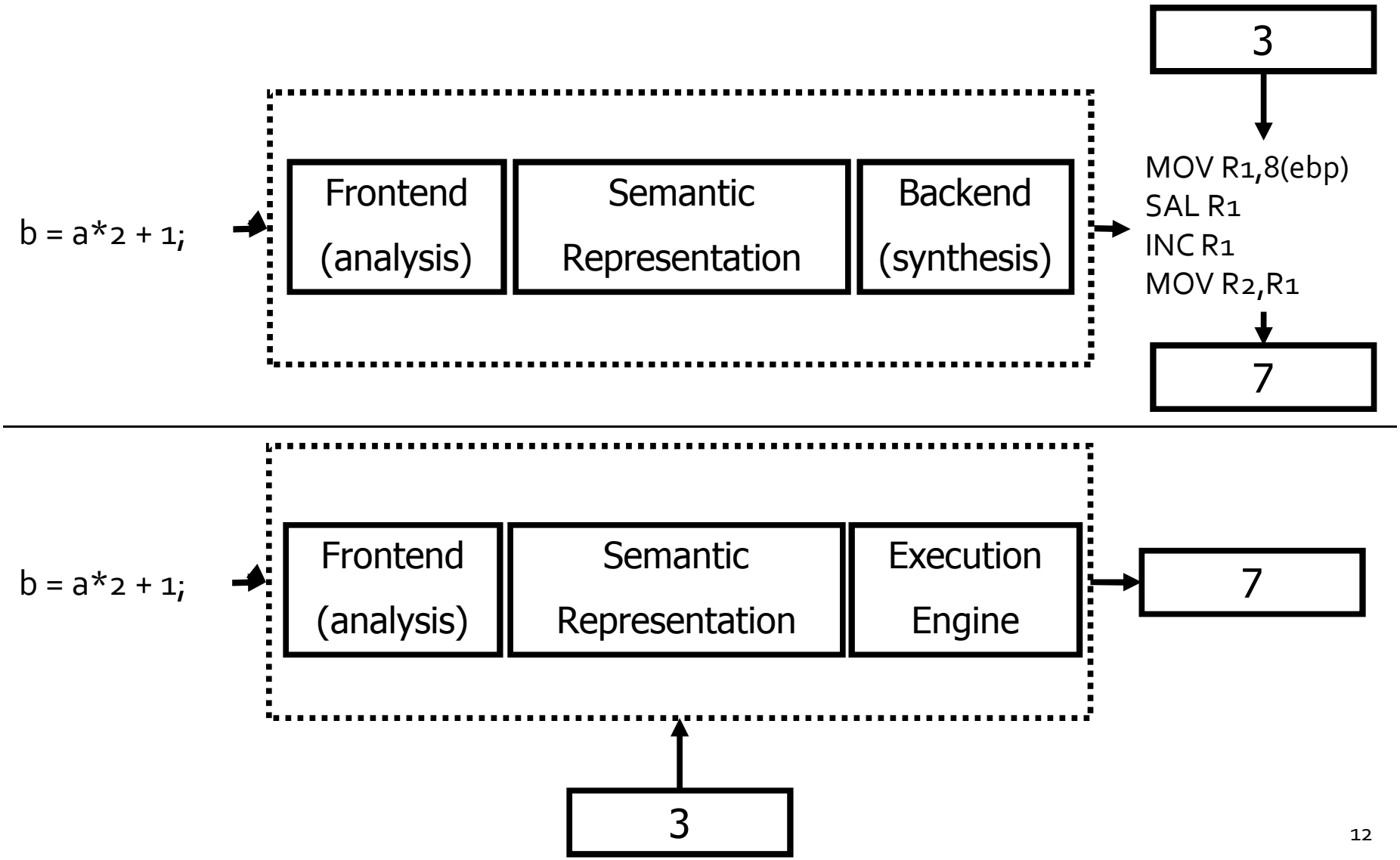

```
int a, b;
a = 2;
b = a*2 + 1;
```

Compiler vs. Interpreter

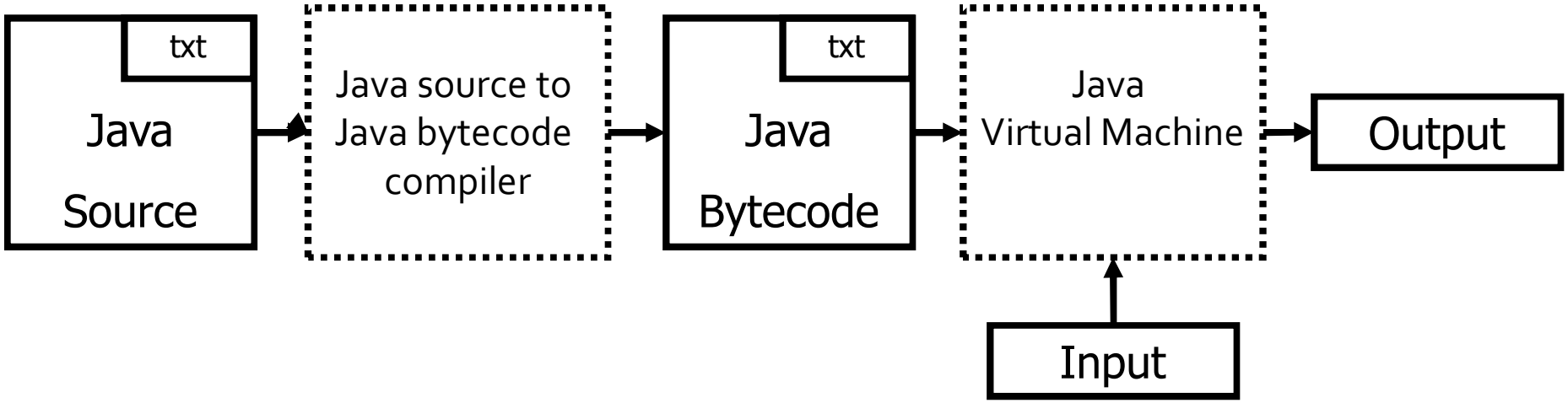




Compiler vs. Interpreter



Just-in-time Compiler (Java example)



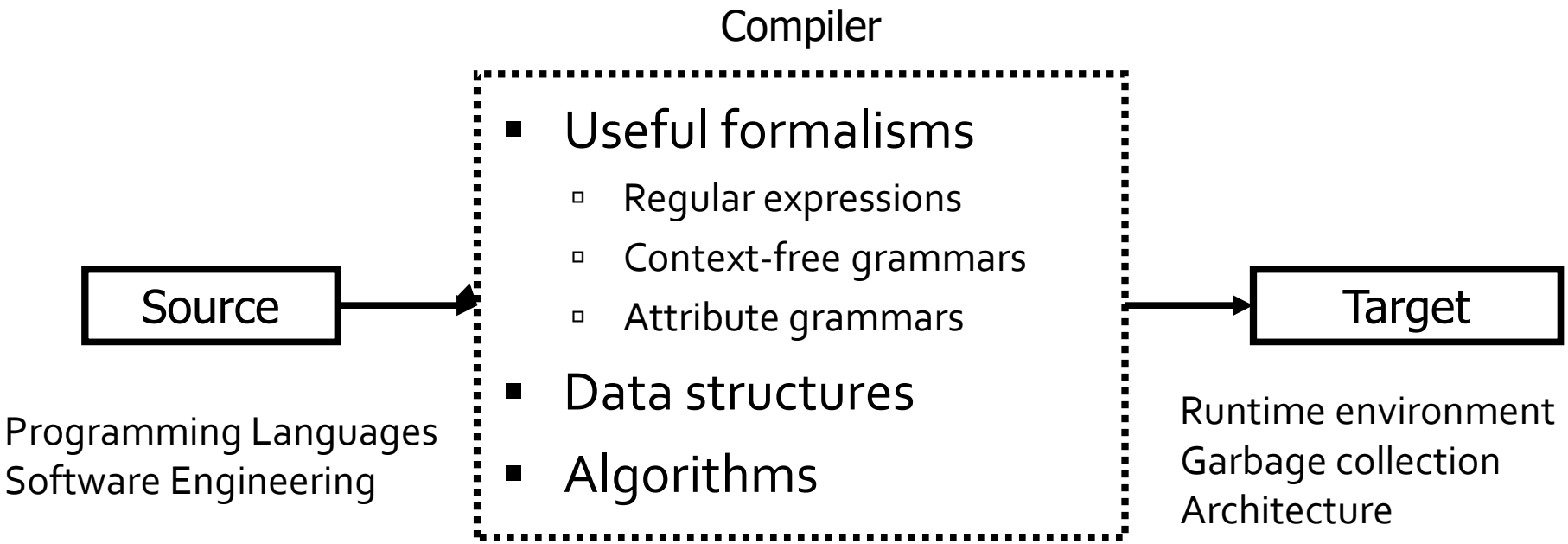
Just-in-time compilation: bytecode interpreter (in the JVM) compiles program fragments during interpretation to avoid expensive re-interpretation.

Why should you care?

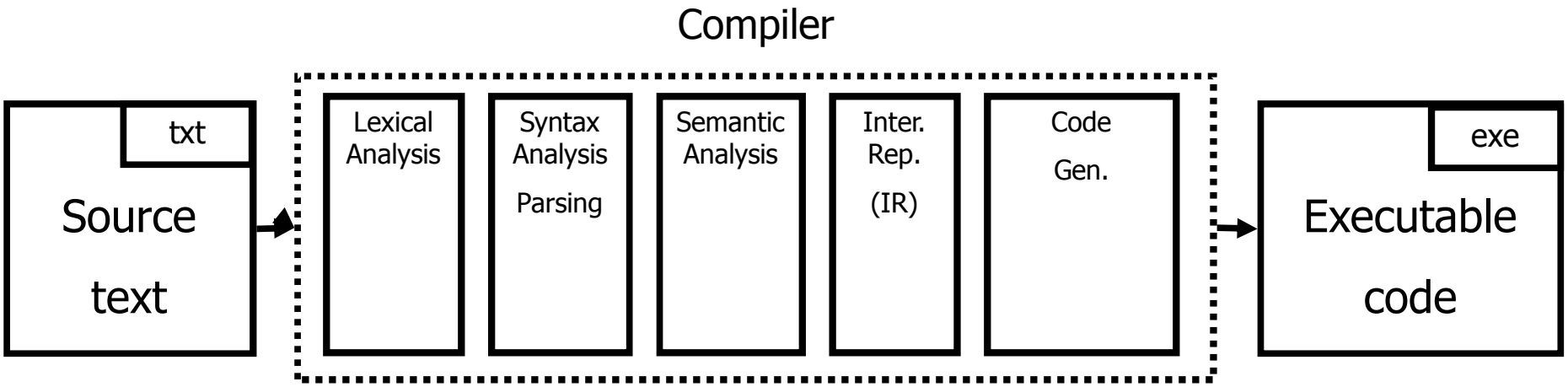
- Every person in this class will build a parser some day
  - Or wish he knew how to build one…
- Useful techniques and algorithms
  - Lexical analysis / parsing
  - Semantic representation
  - …
  - Register allocation

- Understand programming languages better
- Understand internals of compilers
- Understand (some) details of target architectures

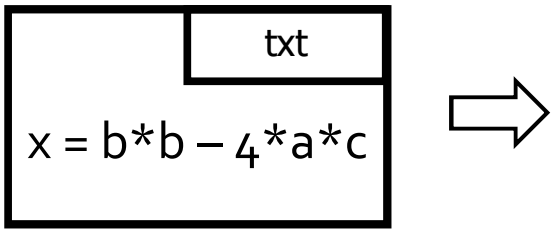
Why should you care?



Course Overview



Journey inside a compiler



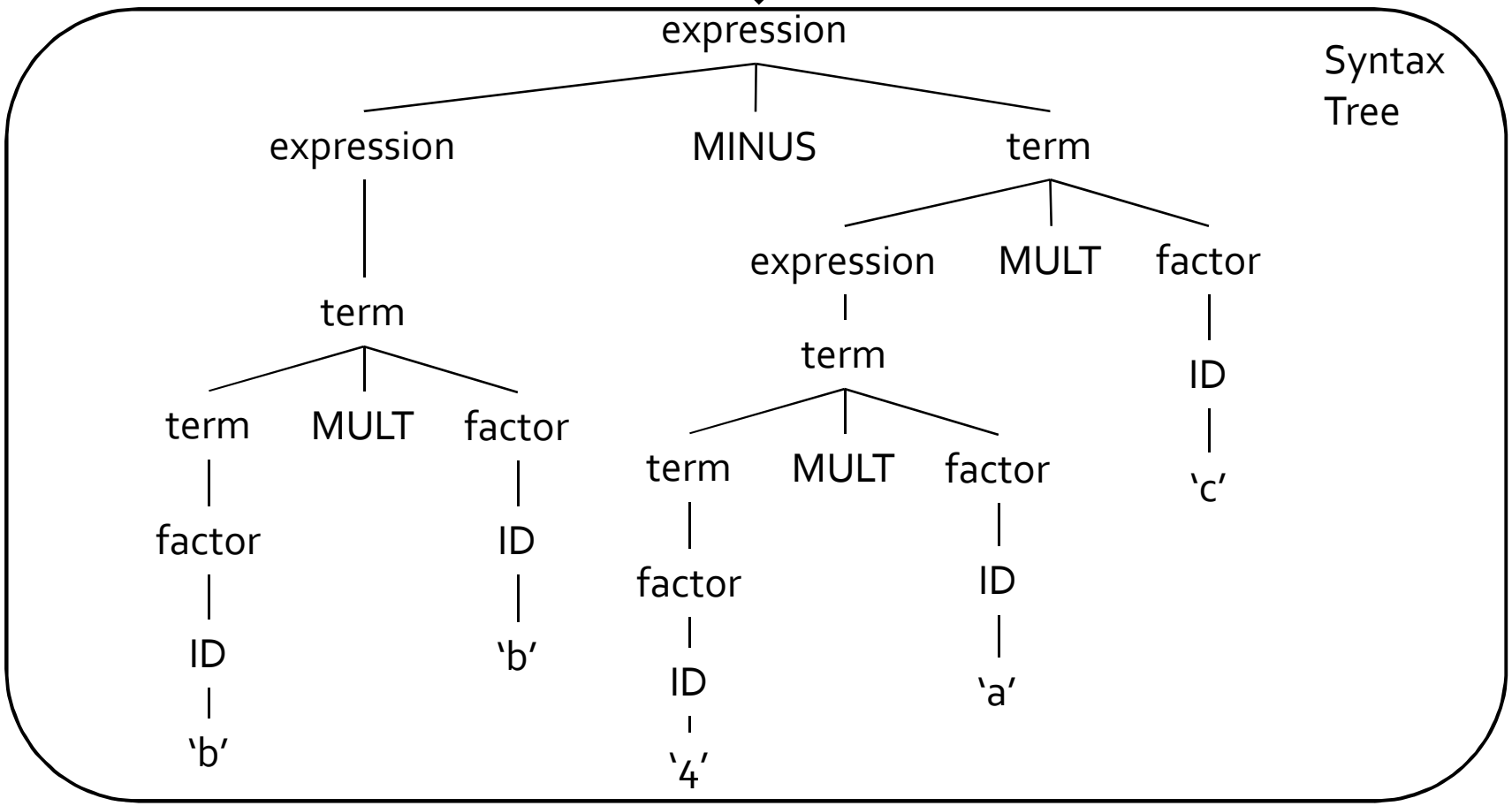
Token Stream

<ID,"x"> <EQ> <ID,"b"> <MULT> <ID,"b">
<MINUS> <INT,4> <MULT> <ID,"a"> <MULT> <ID,"c">

Lexical Analysis	Syntax Analysis	Sem. Analysis	Inter. Rep.	Code Gen.

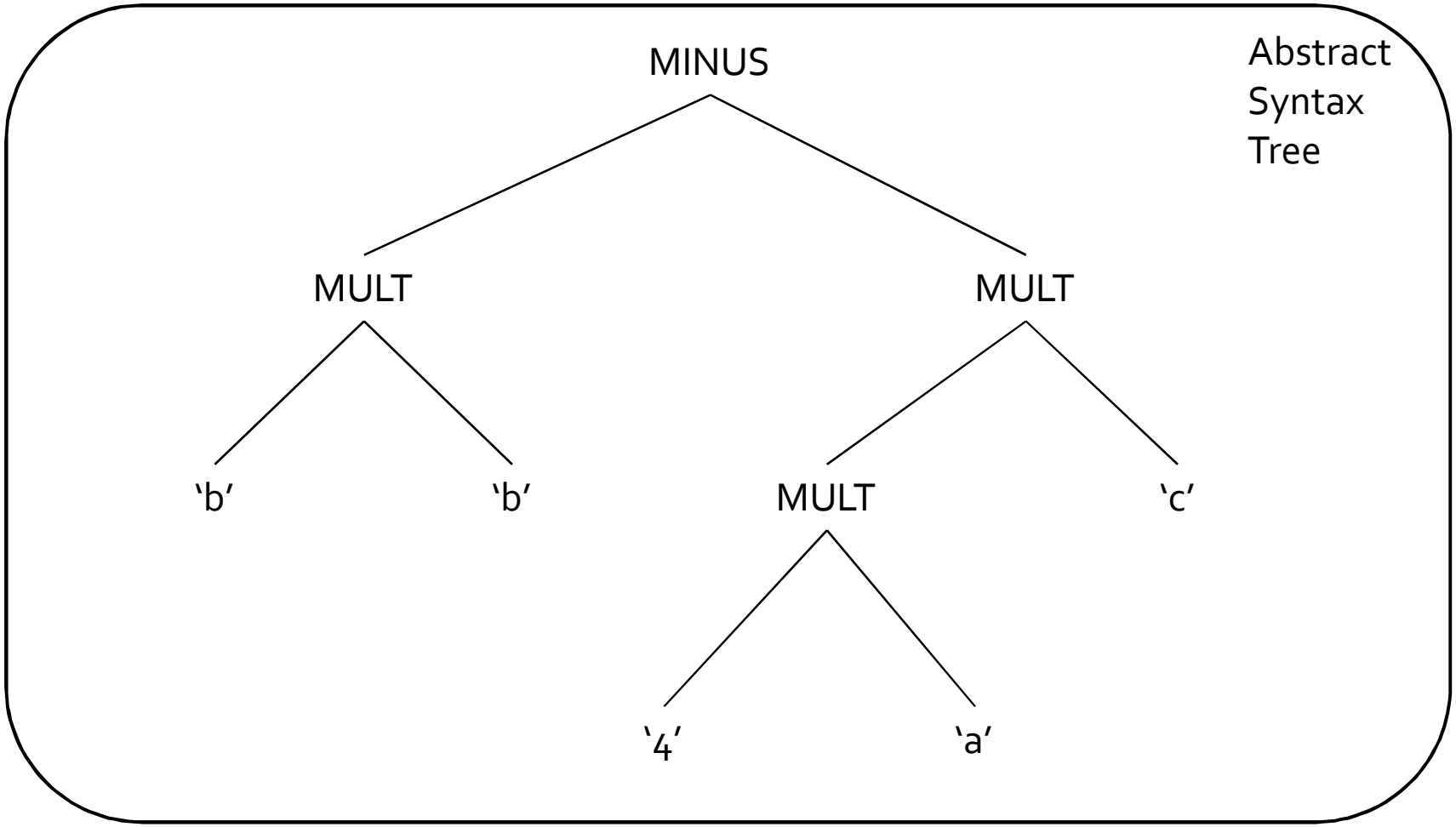
Journey inside a compiler

<ID,"x"> <EQ> <ID,"b"> <MULT> <ID,"b"> <MINUS> <INT,4> <MULT> <ID,"a"> <MULT> <ID,"c">

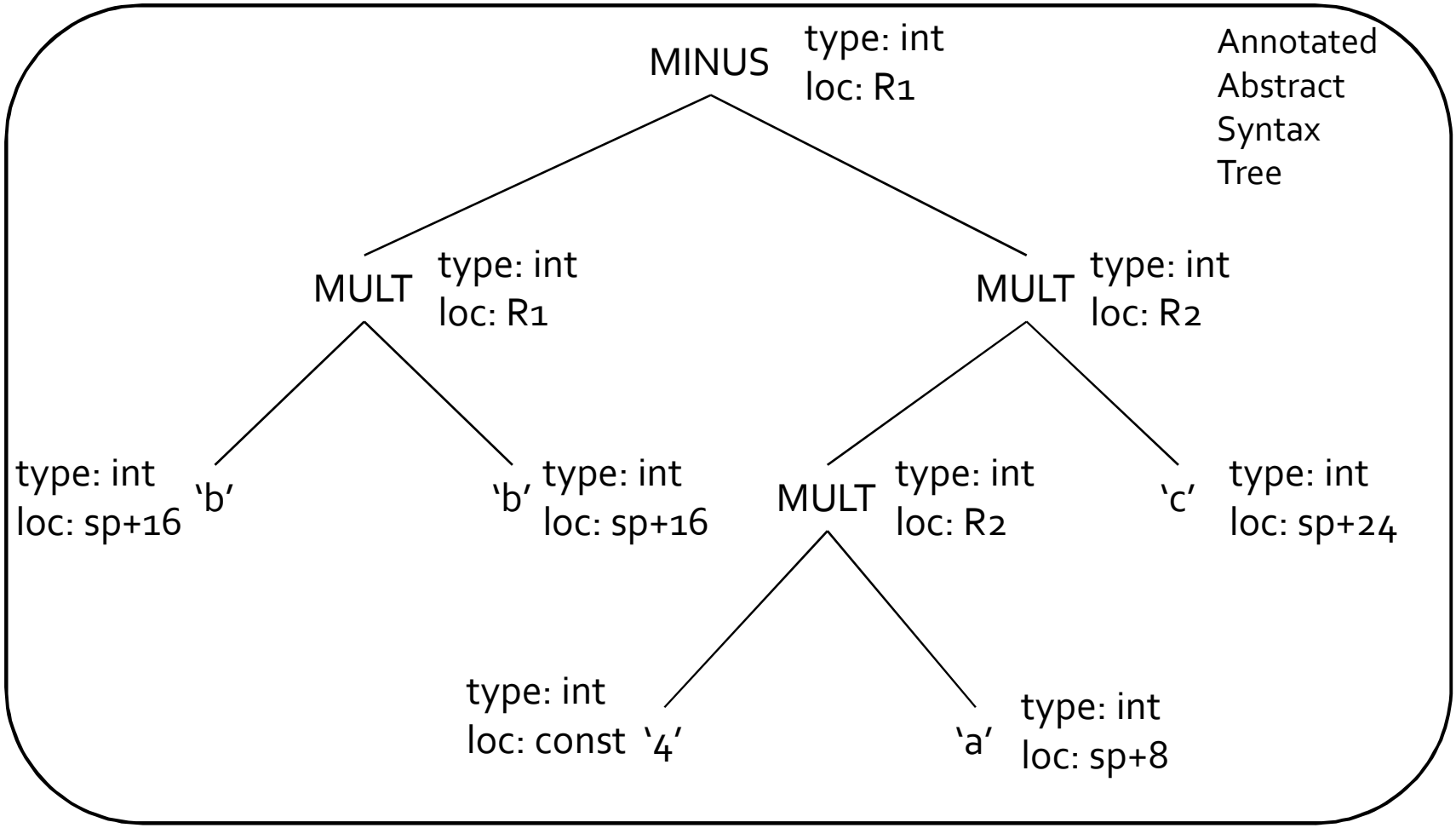


Lexical Analysis | Syntax Analysis | Sem. Analysis | Inter. Rep. | Code Gen.

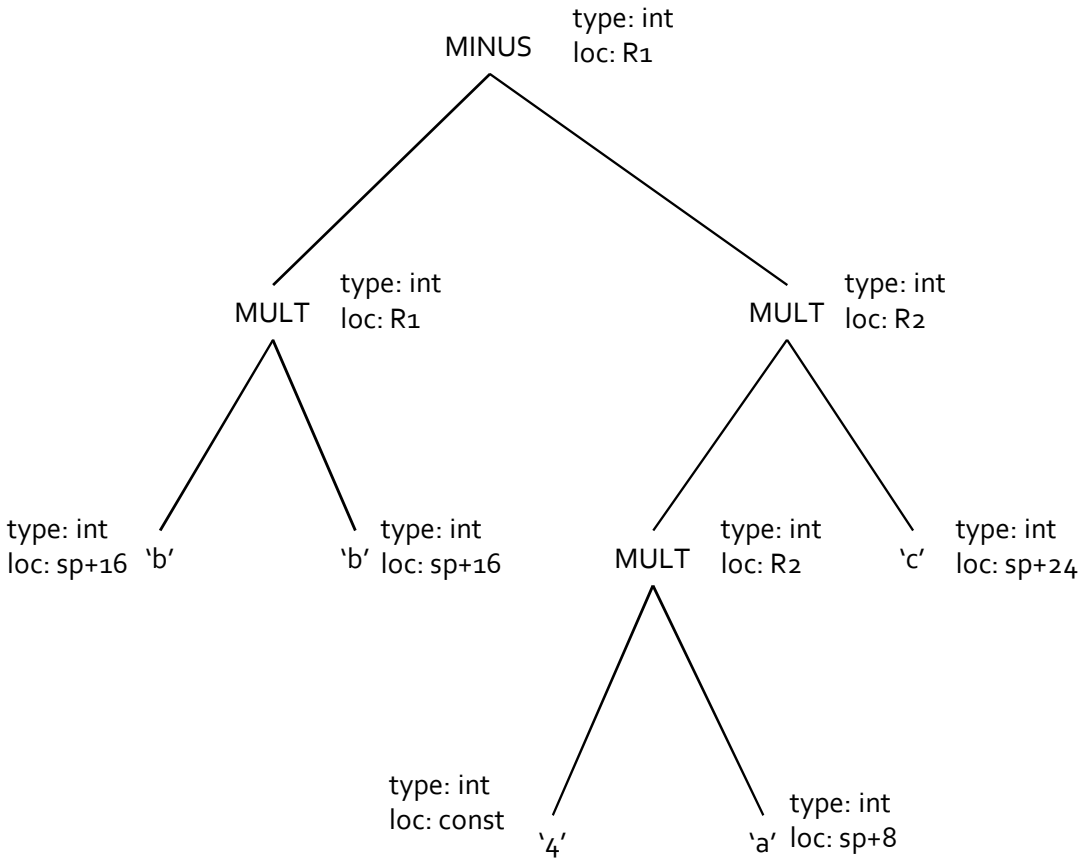
Journey inside a compiler



Journey inside a compiler



Journey inside a compiler

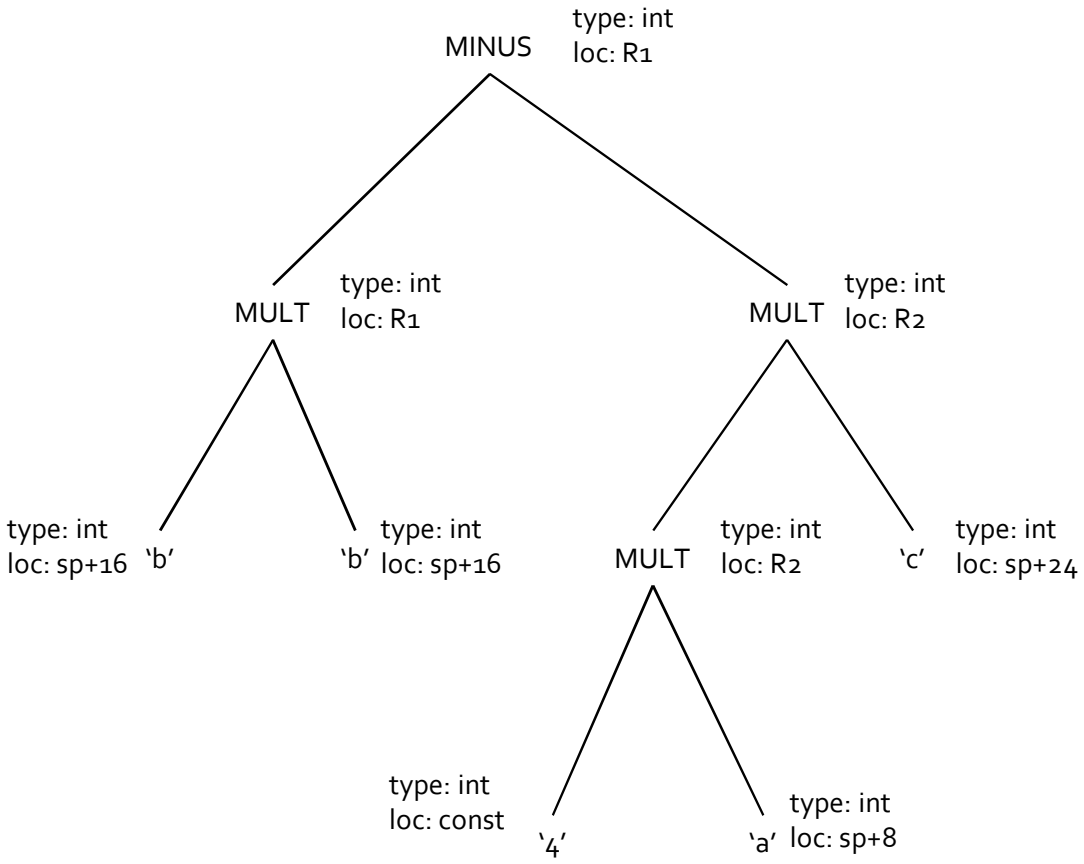


Intermediate Representation

R2 = 4*a
R1=b*b
R2= R2*c
R1=R1-R2

Lexical Analysis	Syntax Analysis	Sem. Analysis	Inter. Rep.	Code Gen.

Journey inside a compiler



Intermediate Representation

```
R2 = 4*a
R1=b*b
R2= R2*c
R1=R1-R2
```

Assembly Code

```
MOV R2,(sp+8)
SAL R2,2
MOV R1,(sp+16)
MUL R1,(sp+16)
MUL R2,(sp+24)
SUB R1,R2
```

Lexical Analysis	Syntax Analysis	Sem. Analysis	Inter. Rep.	Code Gen.

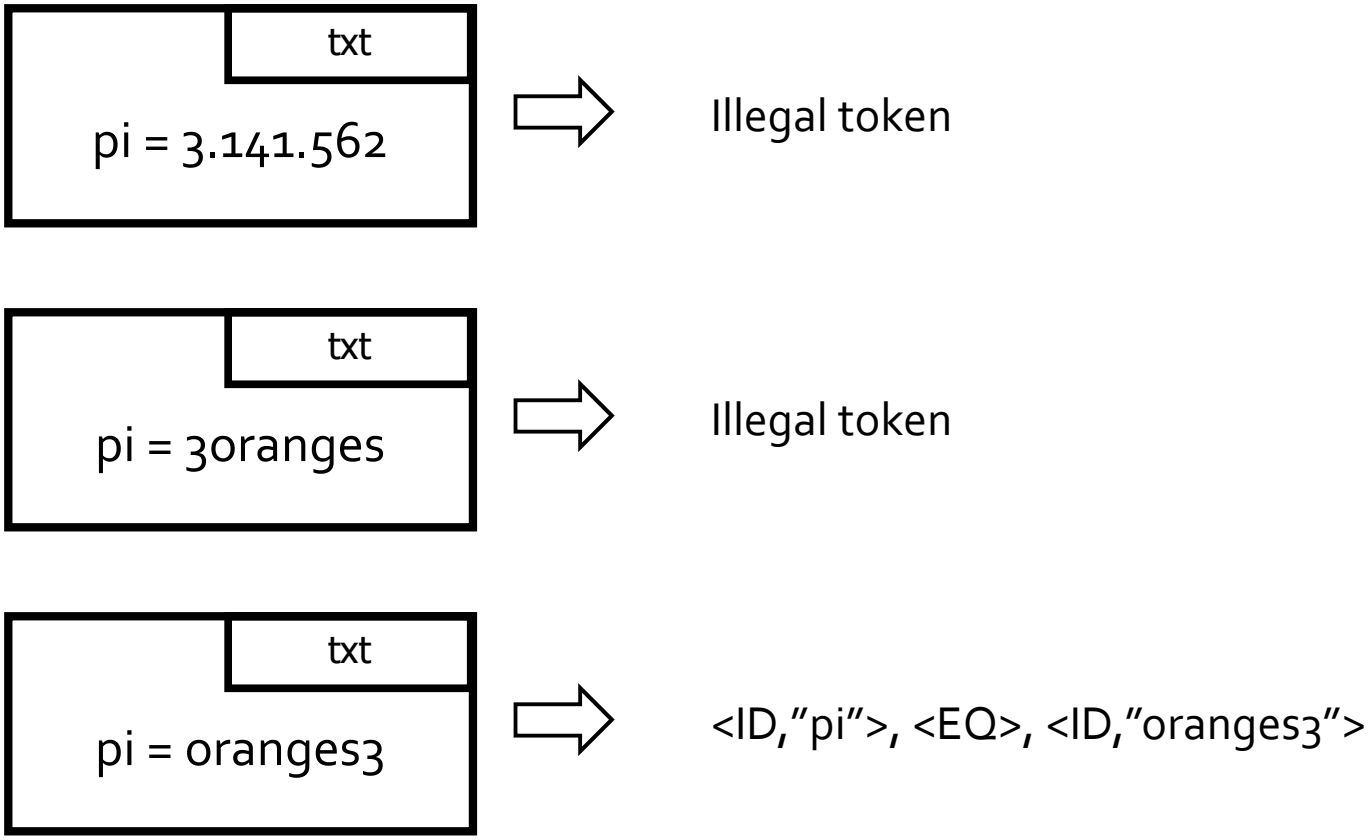
Error Checking

- In every stage…

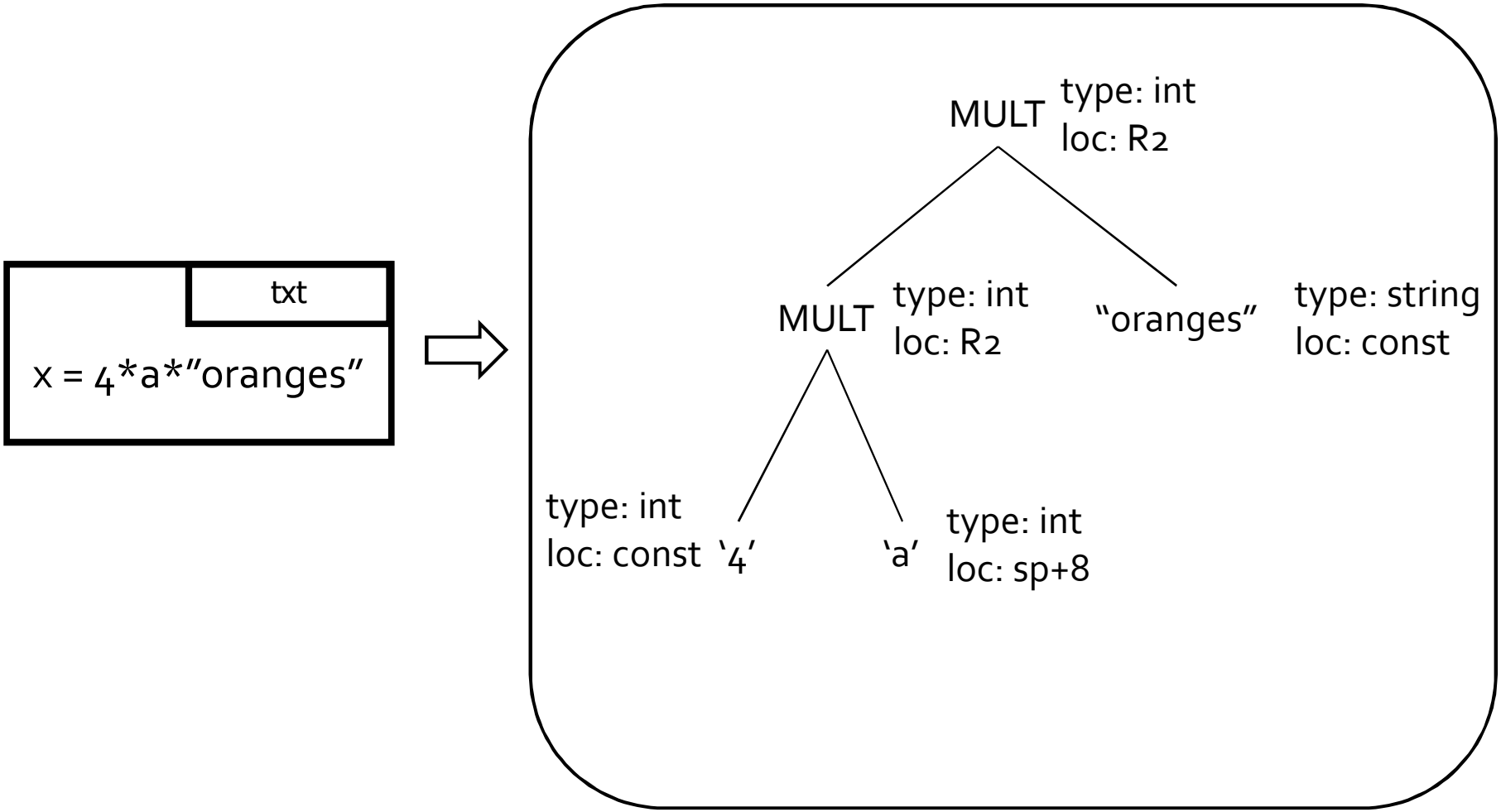
- Lexical analysis: illegal tokens
- Syntax analysis: illegal syntax
- Semantic analysis: incompatible types, undefined variables, …

- Every phase tries to recover and proceed with compilation (why?)
  - Divergence is a challenge

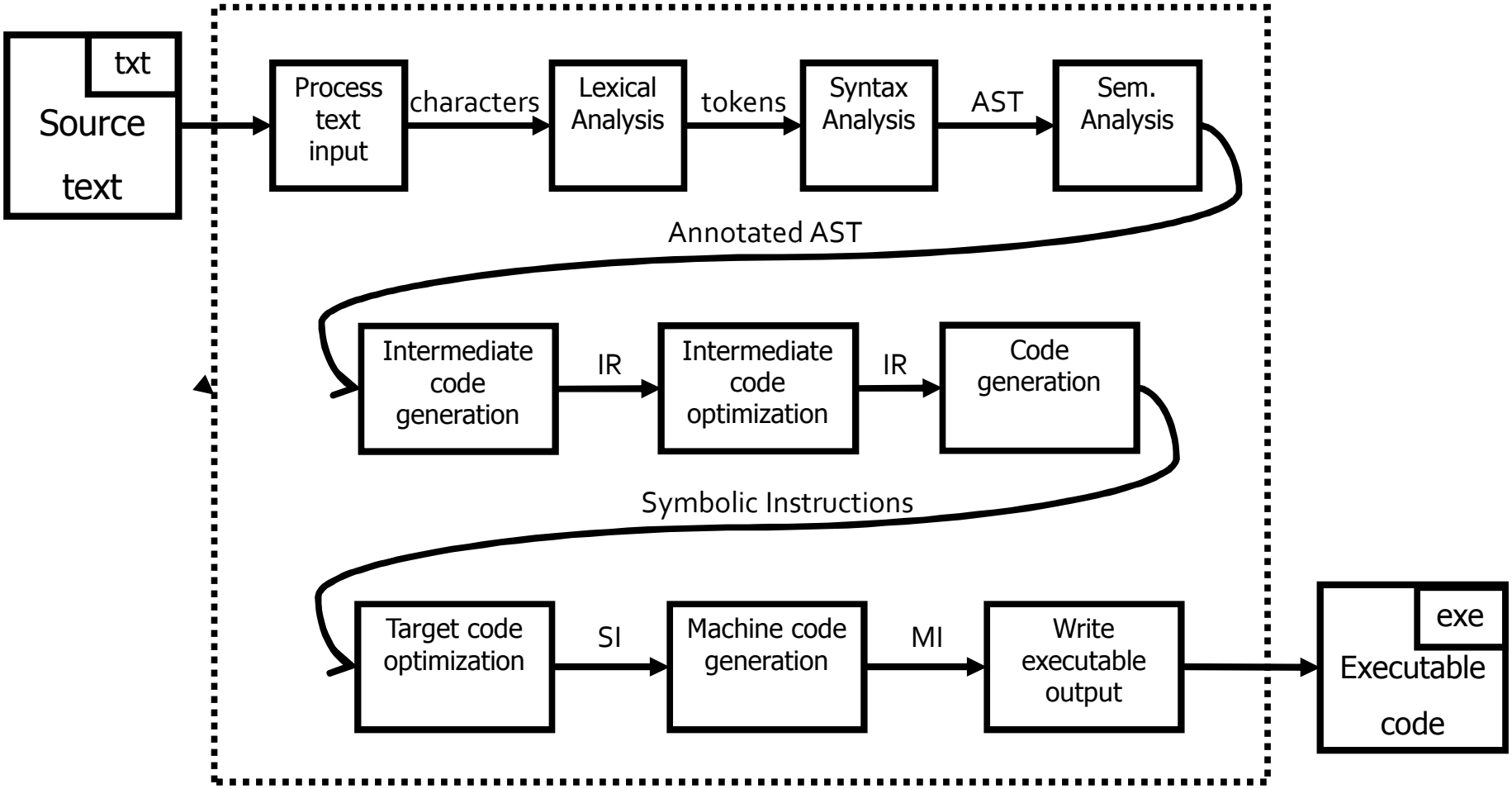
Errors in lexical analysis



Error detection: type checking



The Real Anatomy of a Compiler



Optimizations

- "Optimal code" is out of reach
  - many problems are undecidable or too expensive (NP-complete)
  - Use approximation and/or heuristics

- Loop optimizations: hoisting, unrolling, …
- Peephole optimizations
- Constant propagation
  - Leverage compile-time information to save work at runtime (pre-computation)
- Dead code elimination
  - space
- …

Machine code generation

- Register allocation
  - Optimal register assignment is NP-Complete
  - In practice, known heuristics perform well
- assign variables to memory locations
- Instruction selection
  - Convert IR to actual machine instructions

- Modern architectures
  - Multicores
  - Challenging memory hierarchies

Compiler Construction Toolset

- Lexical analysis generators
  - lex
- Parser generators
  - yacc
- Syntax-directed translators
- Dataflow analysis engines

Summary

- Compiler is a program that translates code from source language to target language
- Compilers play a critical role
  - Bridge from programming languages to the machine
  - Many useful techniques and algorithms
  - Many useful tools (e.g., lexer/parser generators)
- Compiler constructed from modular phases
  - Reusable
  - Different front/back ends

Coming up next

- Lexical analysis