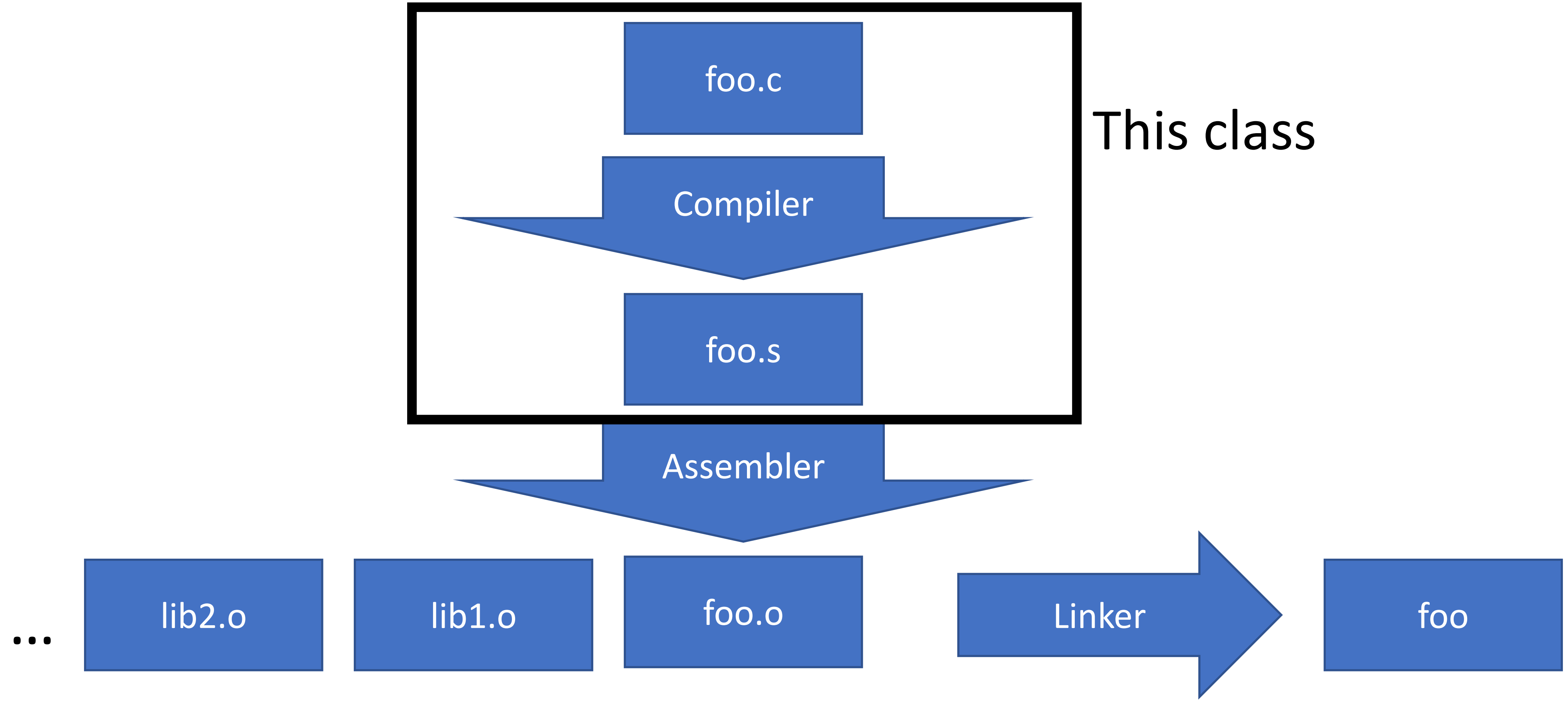
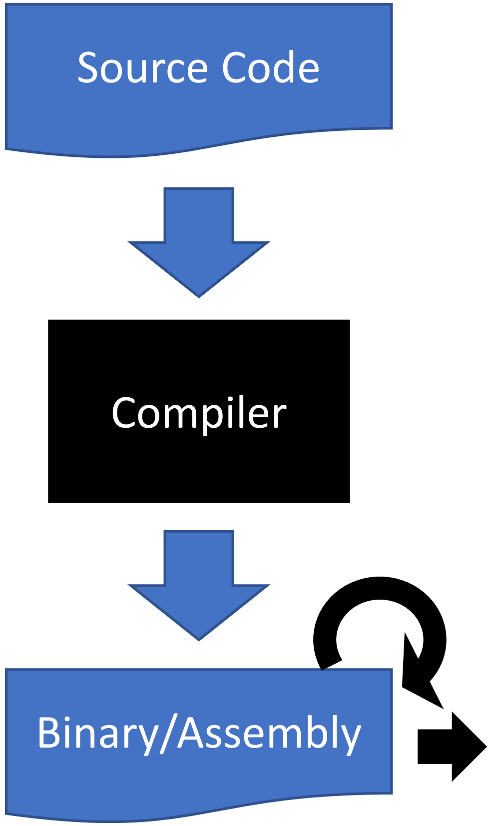
CS443: Compiler Construction

Lecture 0

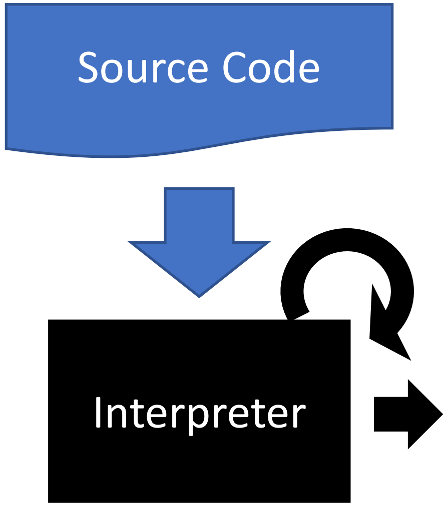
What happens when you call gcc?



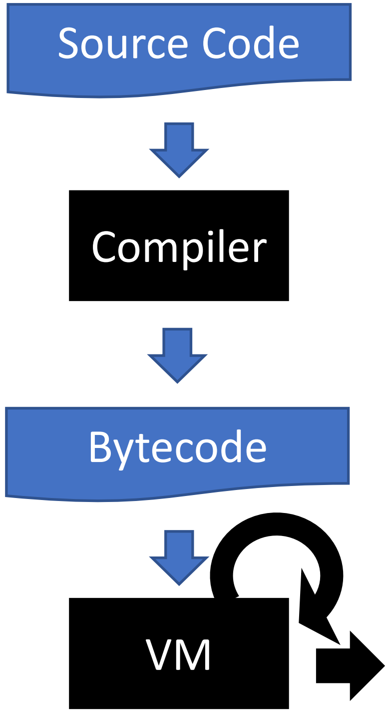
There are different ways of translating a programming language



Ex.: C, C++

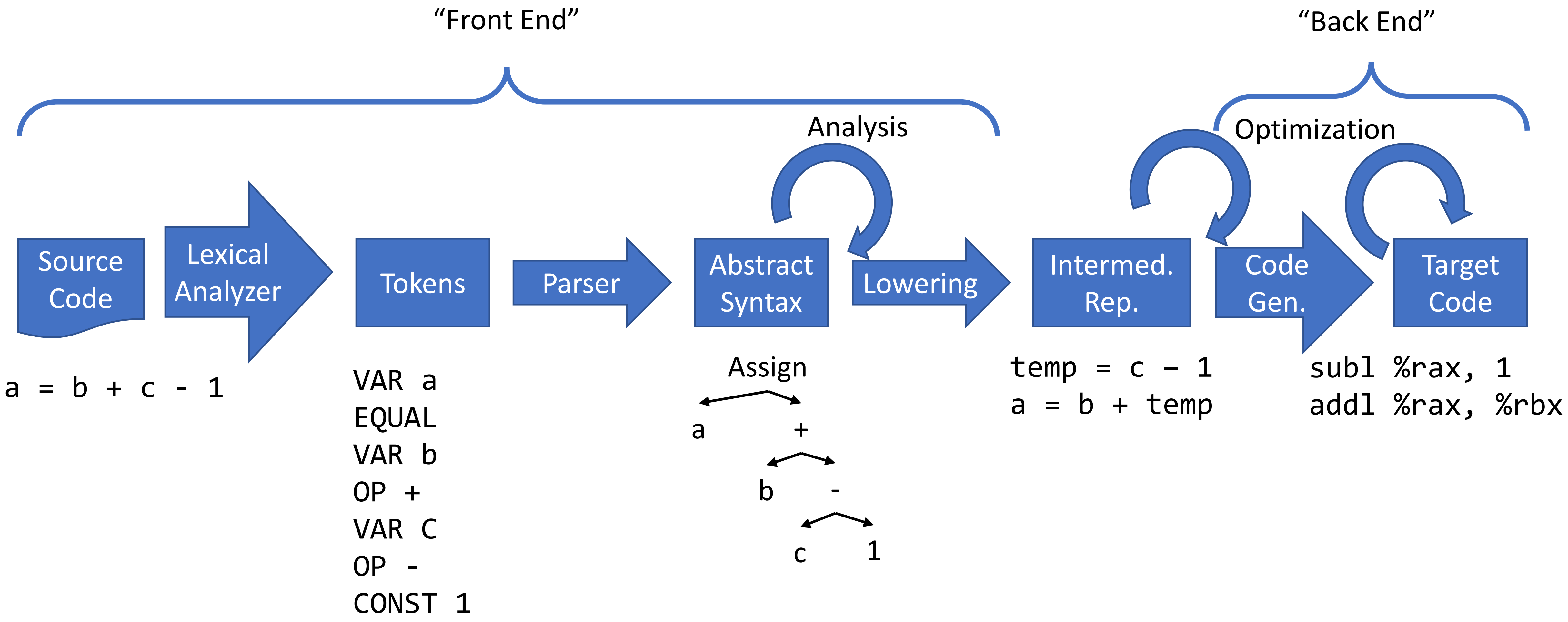


Ex.: Python

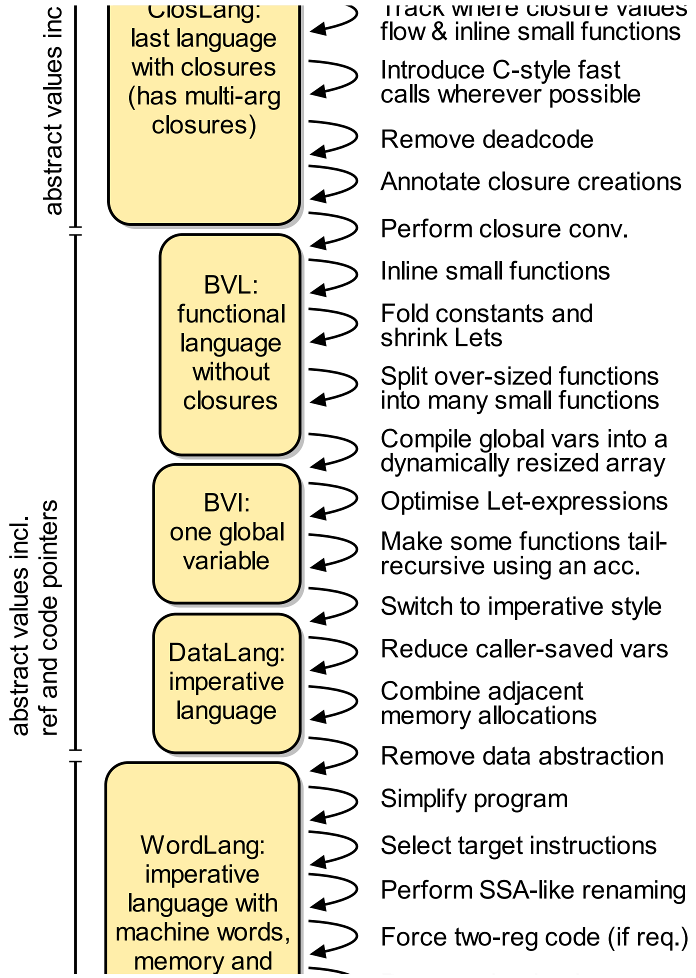


Ex.: Java

Compilers translate code in phases

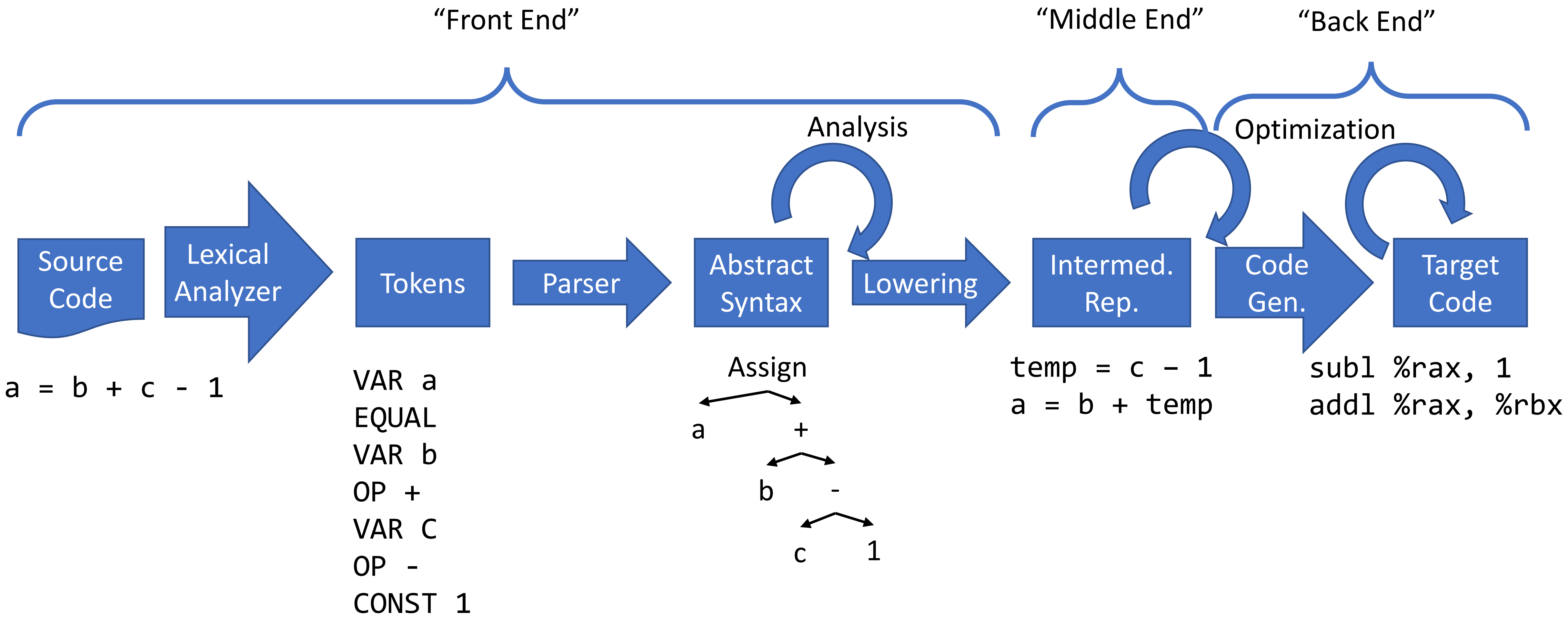


May have many more phases, several intermediate representations

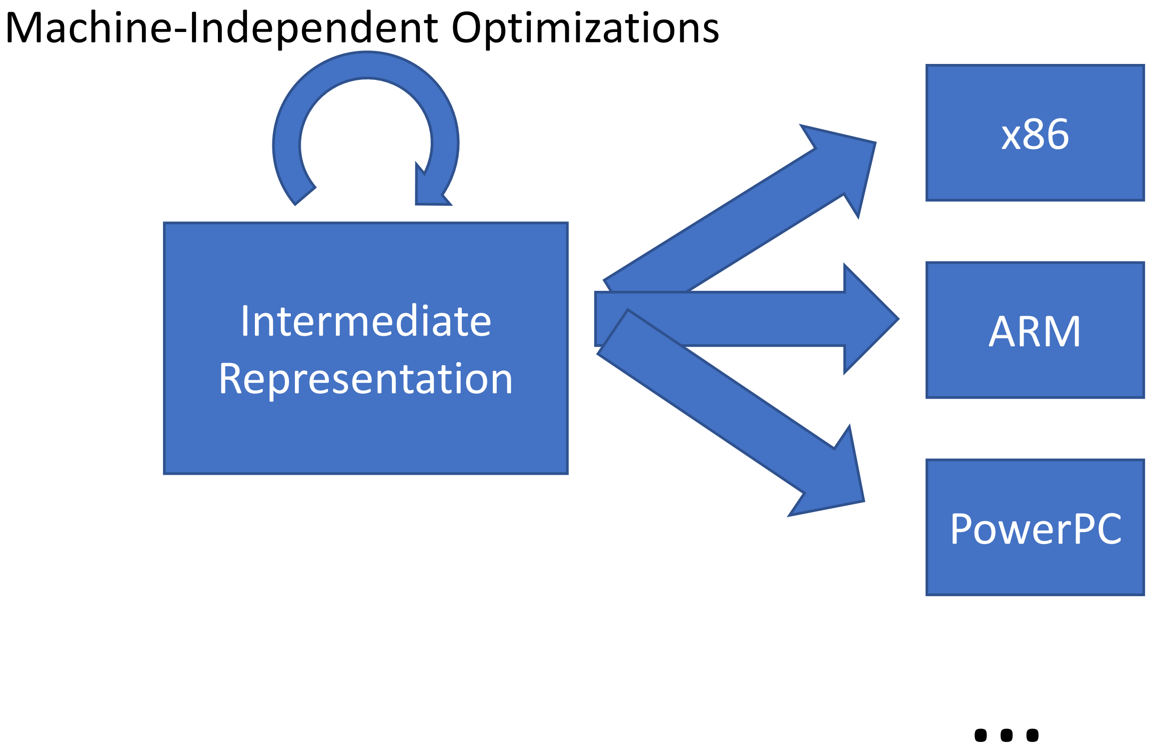


CAKEML
A Verified Implementation of ML

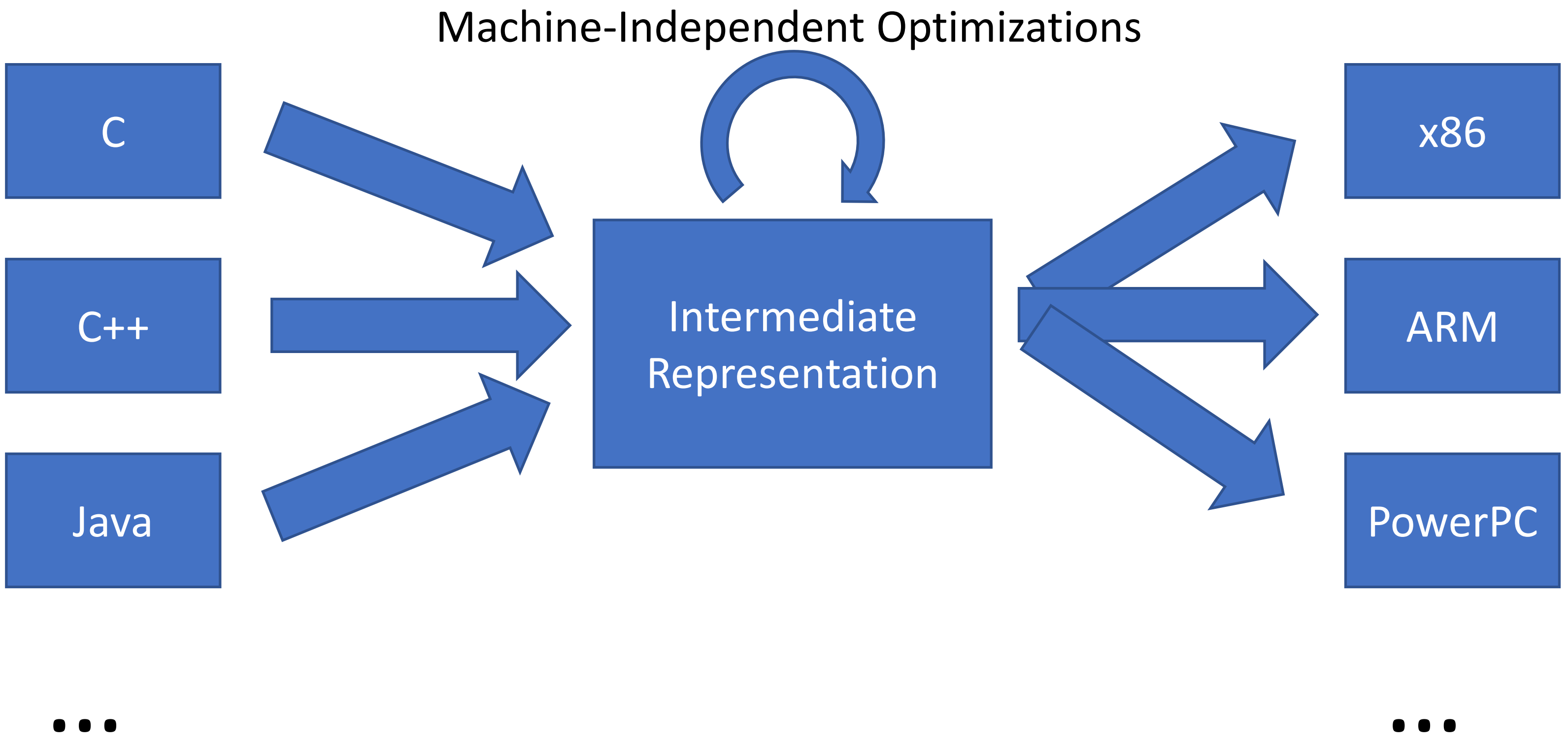
Front End is language specific
Back End is machine specific



Can (and usually do) swap out back ends to target different machines



Compiler collections also swap out front ends for different languages



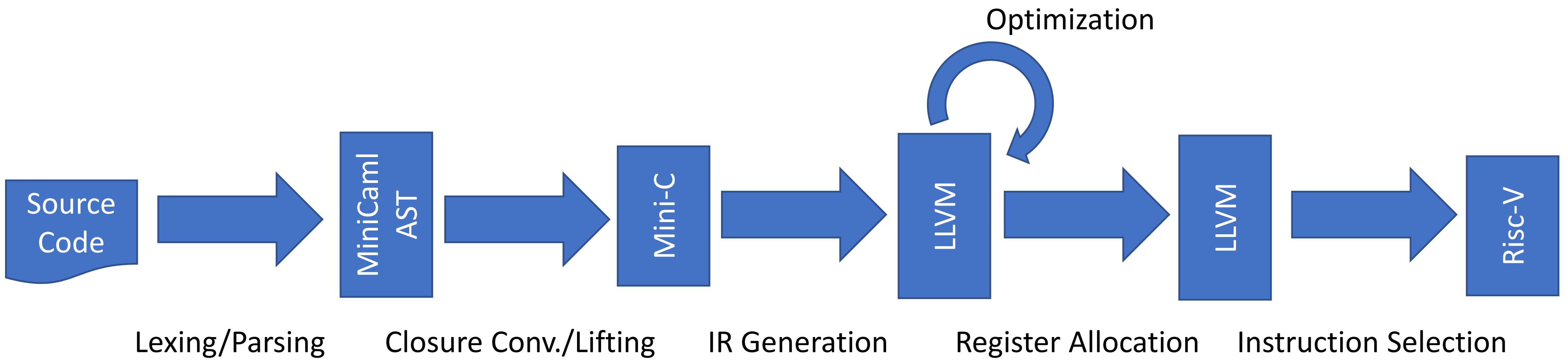
A Small ML Compiler

Higher-order
Typed
Structured Data
Nested Expressions
Unlimited Variables

First-order
Typed
Structured Data
Nested Expressions
Unlimited Variables

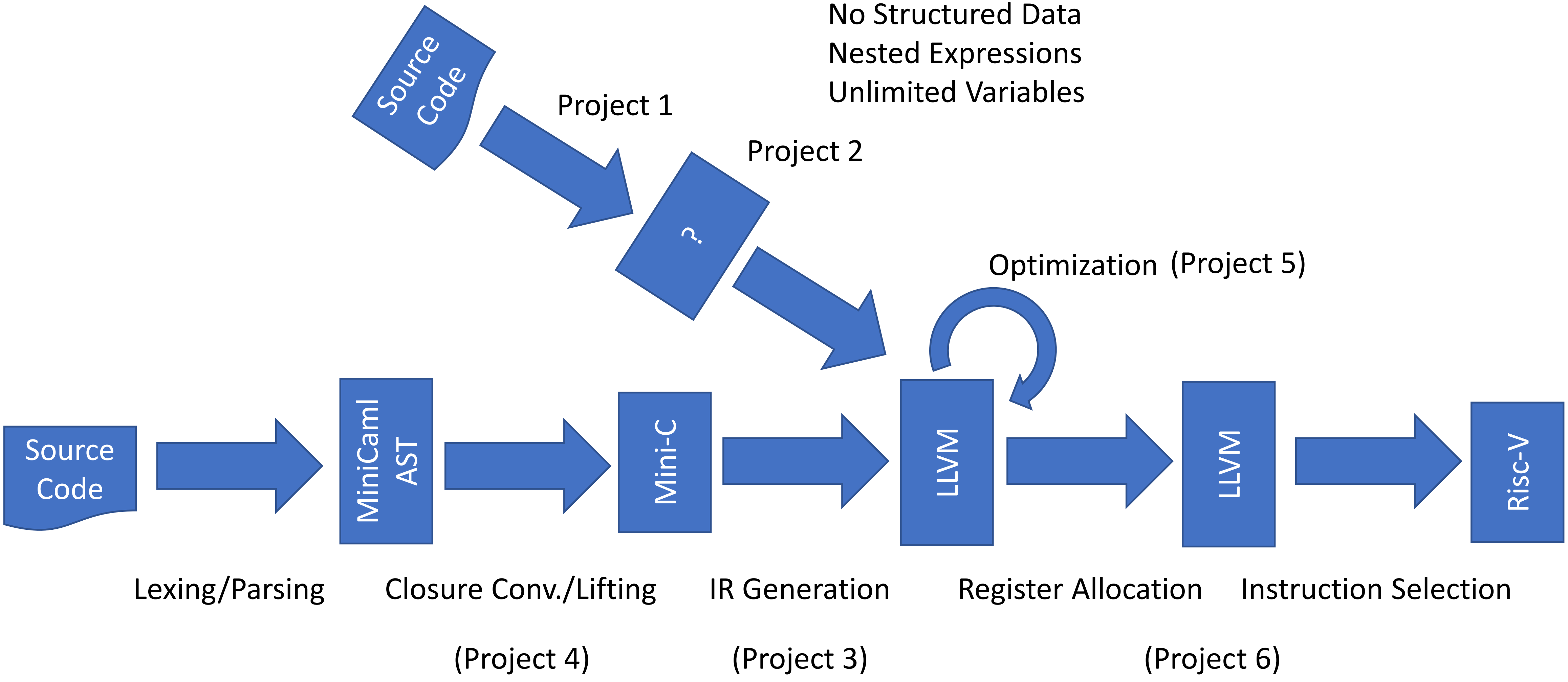
First-order
Typed
Structured Data
Flat Expressions
Unlimited Variables

First-order
Untyped
No Structured Data
Flat Expressions
32 Hardware Registers



Course Projects

First-order
Typed
No Structured Data
Nested Expressions
Unlimited Variables



Projects

- 7 projects, 2-3 weeks each (Except Project 0, Due 8/30)
- Mostly (entirely?) programming – graded with automated tests
- Work individually or in pairs
- Handed out + submitted on Blackboard

Late Days:

- 6 per student, extend deadline 24 hours
- No more than 2 per assignment
- If a pair, must both use a late day

Background

- Prerequisite: CS440 (Programming Languages and Translators)
  - Lexing and Parsing (Will review)
  - Abstract syntax, working with ASTs (will review very briefly today)
  - Type checking/inference
  - Statically-typed functional programming
    - Specifically, OCaml. If you know Haskell or Racket, can learn it quickly.
    - Haskell w/o monads
    - Racket w/ way fewer parens
  - If you're not familiar with the above, I suggest brushing up in the next couple weeks.

Websites to know

- Course website: http://cs.iit.edu/~smuller/cs443/
  - Full syllabus/policies/schedule/lecture notes. Go there.
- Blackboard
- Discord

Exams

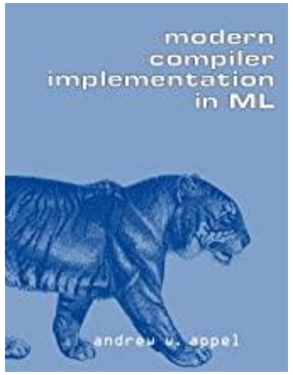
- Midterm (Oct. 25)
- Final Exam (during finals week, schedule posted by Registrar)

- Open book, open notes

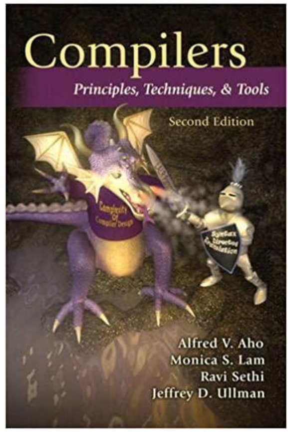
Grading

- 50% Projects
- 20% Midterm
- 30% Final

Textbooks



- **Appel. *Modern Compiler Implementation in ML***
  (Highly recommended)
  (Also have C, Java versions)



If you already have it:

- "Purple Dragon Book": Aho et al. *Compilers: Principles, Techniques and Tools (2nd ed.)*

Academic Honesty

- Submitted solutions must be your own work (and your partner)
- Can discuss course concepts with other students, but don’t share/look at code.
- If using online resources/code:
  - Don’t search for code that substantially solves the assigned problem. Be reasonable.
  - If using small snippets of code, *cite them* (e.g., URL in a comment)

OK, back to programming languages

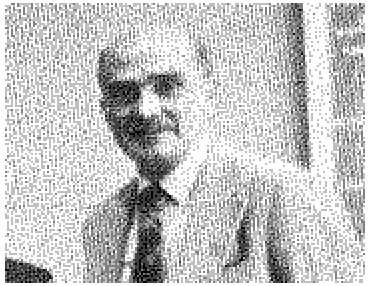
First-order
Typed
No Structured Data
Nested Expressions
Unlimited Variables
Simple
Easy to compile

} **IITRAN**

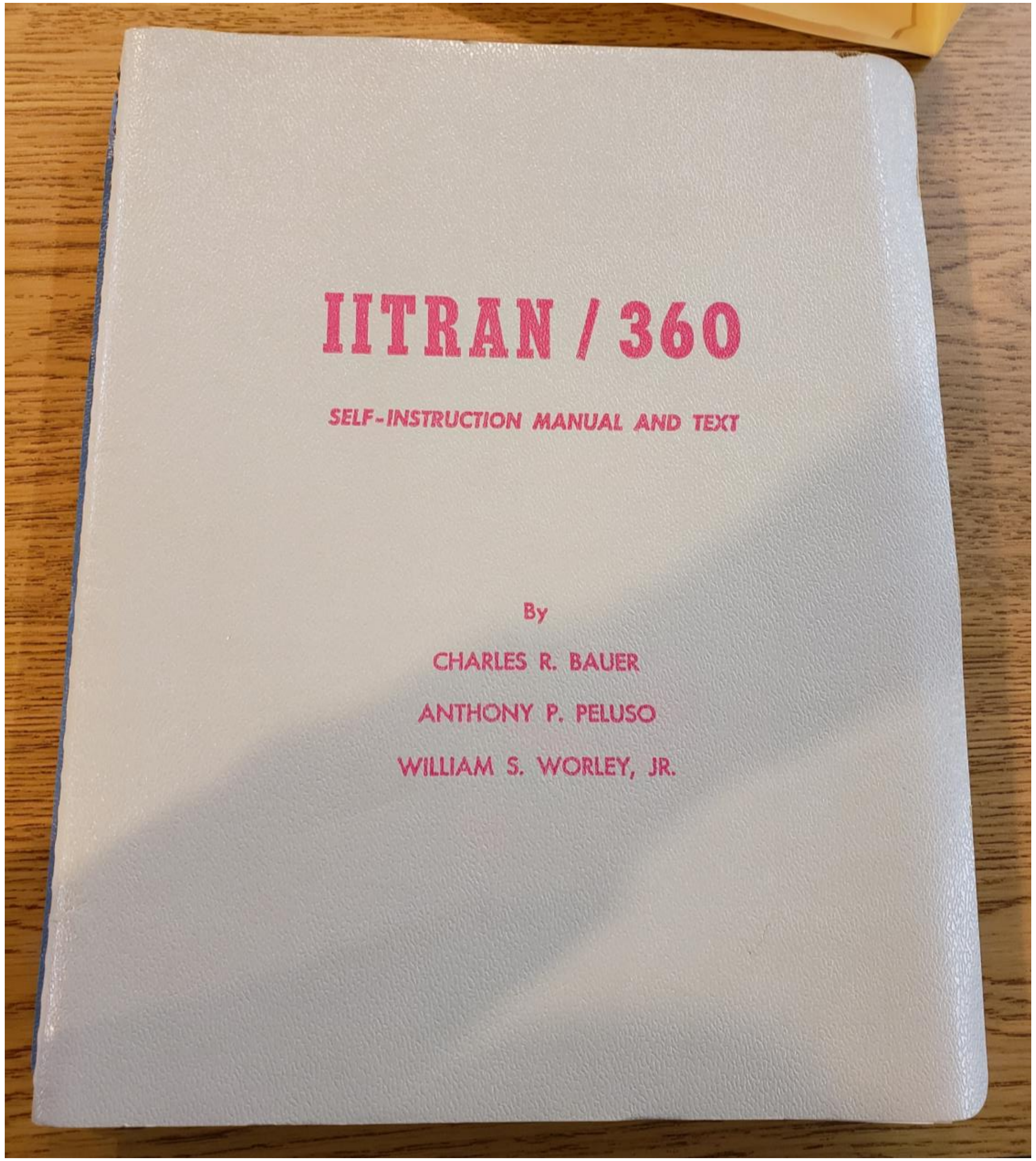
IITRAN/7040 – 1964
IITRAN/360 - 1966

IITRAN

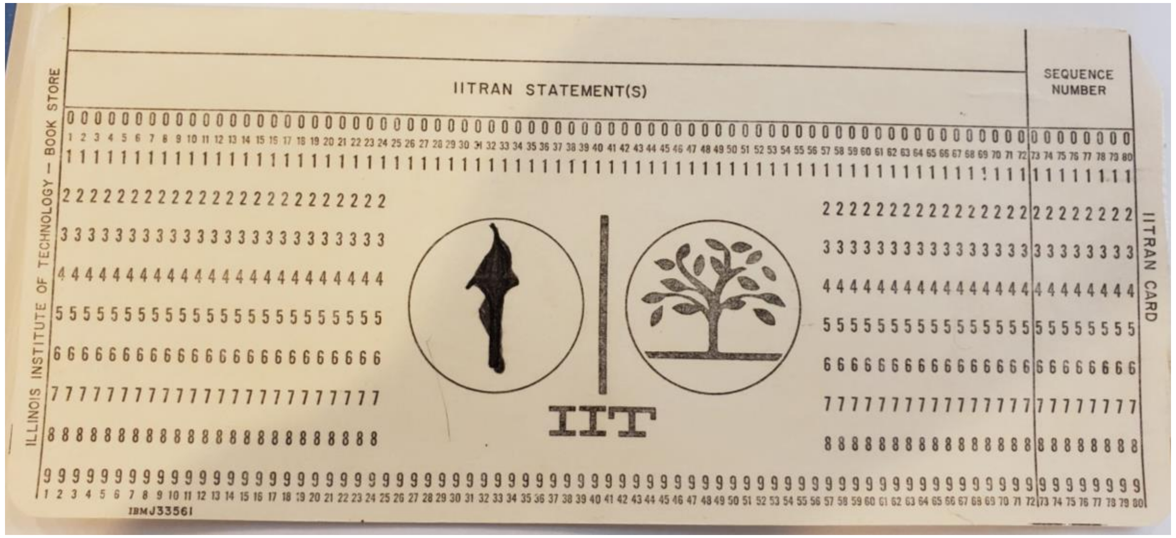
Robert Dewar

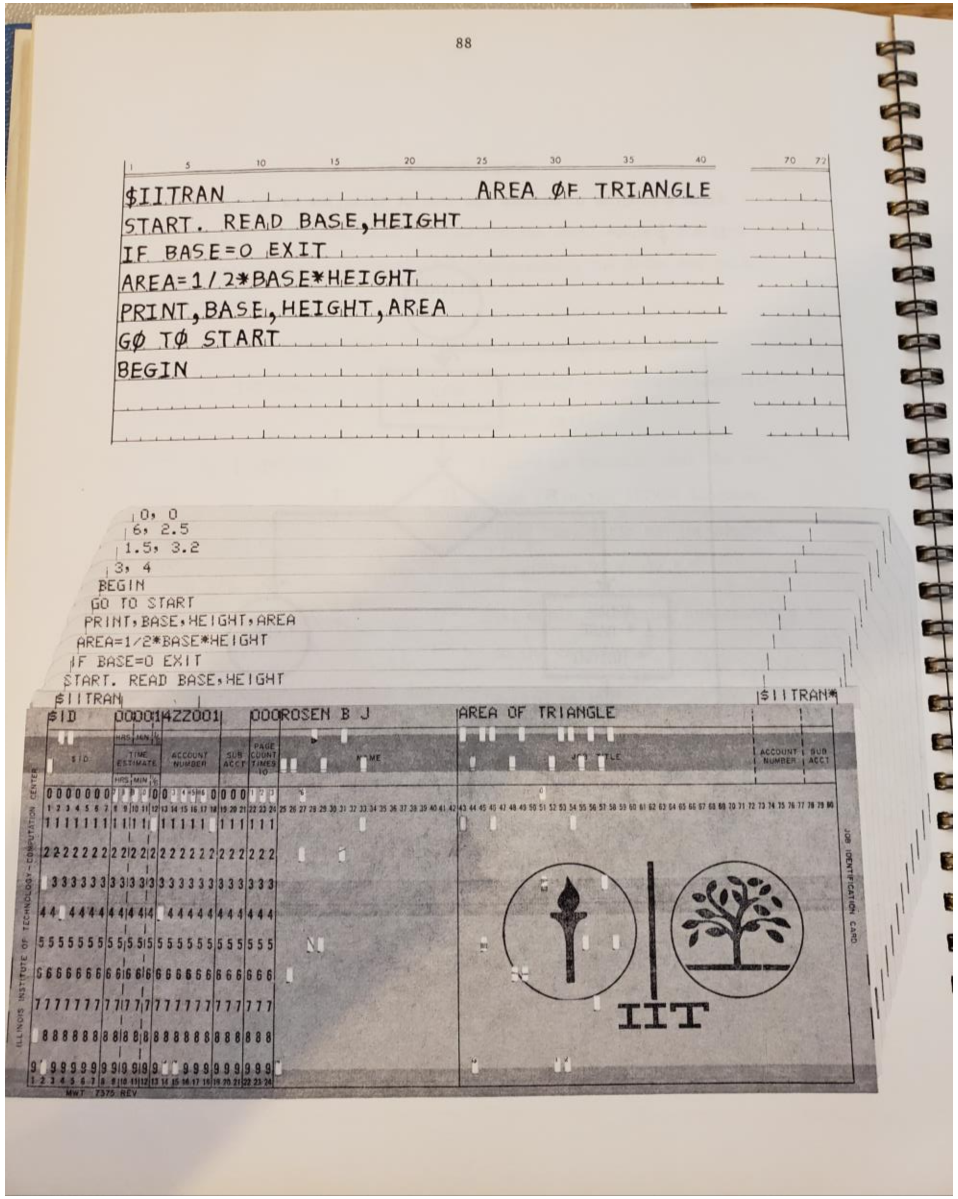


Charles Bauer



IITRAN/360


IITRAN STATEMENT(S)
SEQUENCE NUMBER
ILLINOIS INSTITUTE OF TECHNOLOGY — BOOK STORE
IITRAN CARD
IIT
IBMJ33561


88
$IITRAN AREA ØF TRIANGLE
START. READ BASE,HEIGHT
IF BASE=0 EXIT
AREA=1/2*BASE*HEIGHT
PRINT,BASE,HEIGHT,AREA
GØ TØ START
BEGIN
0, 0
6, 2.5
1.5, 3.2
3, 4
BEGIN
GO TO START
PRINT,BASE,HEIGHT,AREA
AREA=1/2*BASE*HEIGHT
IF BASE=0 EXIT
START. READ BASE,HEIGHT
$IITRAN
$IITRAN*
$ID 00001 4ZZ001 000 ROSEN B J AREA OF TRIANGLE
IIT

Abstract Syntax

- BNF (Backus-Naur Form)

type ::= INTEGER | CHARACTER | LOGICAL

Type casts

bop ::= + | - | * | / | <-   *uop* ::= ~ | NOT | INT | CH | LG

exp ::= x | *num* | *char* | *exp bop exp* | *uop exp*

stmt ::= STOP | IF *exp* THEN *stmt* (ELSE *stmt*) | WHILE *exp stmt*

| DO *stmtlist* | *type varlist*

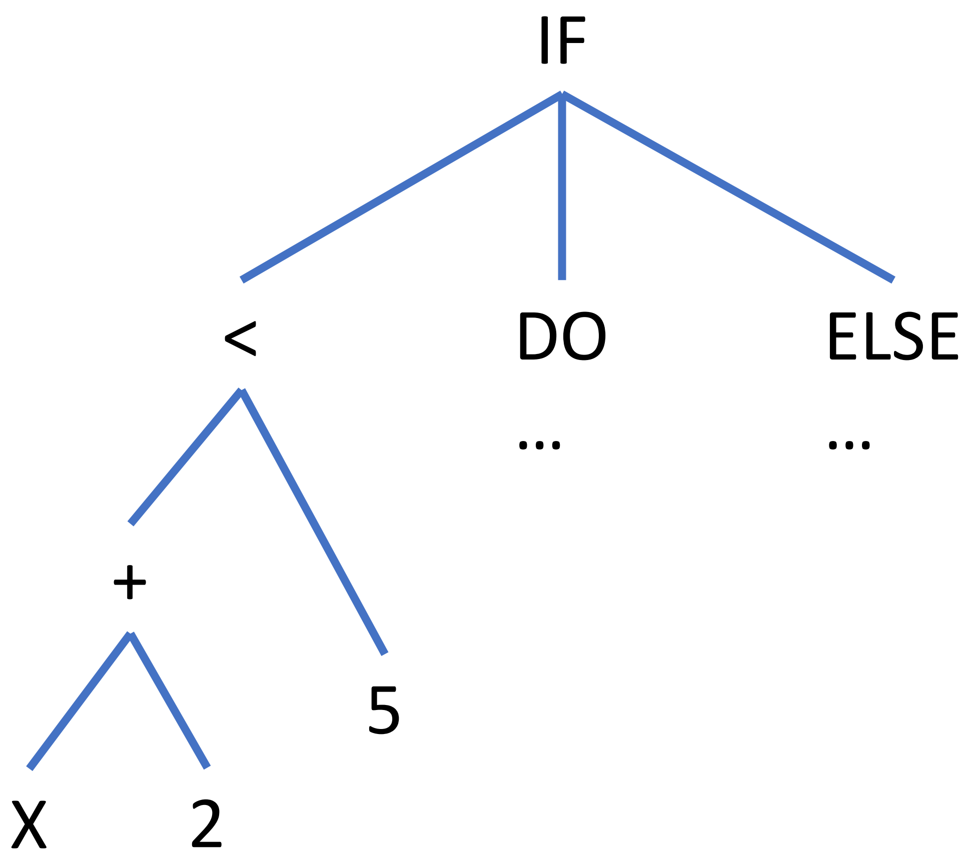
Not actually BNF, but you know what we mean

varlist ::= x | x *varlist*

stmtlist ::= *stmt* | *stmt stmtlist*

Abstract Syntax Trees (ASTs)

IF X + 2 < 5 DO … ELSE …



AST definition in OCaml

```
type var = string
type typ = TLogical | TCharacter | TInteger
type bop = BAdd | BSub | BMul | BDiv | BAnd | BOr  | BGt (* > *)
         | BGe (* >= *) | BLt (* < *) | BLe (* <= *) | BNe (* # *) | BEq (* = *)
type unop = UNeg | Unot (* type conversions *) | UChar | ULog | UReal | Uint
type const = CChar of char | CInt of int | CLog of bool
type exp = EConst of const | EVar of var | EBinop of bop * exp * exp
         | EAssign of exp * exp | EUnop of unop * exp
type stmt = SDecl of typ * spec list | SDo of stmt list
          | SExp of exp
          | SIf of exp * stmt * (* ELSE *) stmt option
          | SWhile of exp * stmt | SStop
```

Pattern matching on an AST in OCaml

```
let print_const c =
match c with
| CChar c -> Printf.printf “%c\n” c
| CInt n -> Printf.printf “%d\n” n
| CLog true -> Printf.printf “true\n”
| CLog false -> Printf.printf “false\n”
```

Example: type checking

```
let rec typecheck_exp (ctx: ctx) (e: exp) : typ =
match e with
| EConst c -> typecheck_const c
| EVar v -> lookup ctx v
| EBinop (b, e1, e2) ->
  let (e1t, e2t) = (typecheck_exp ctx e1, typecheck_exp ctx e2) in
  let (etype, rtype) =
    match b with | BAdd | BSub | BMul | BDiv -> (TInteger, TInteger)
                 | BGt | BGe | BLt | BLe | BNe | BEq -> (TInteger, TLogical)
                 | BAnd | BOr -> (TLogical, TLogical) )
   in
   (if e1t <> e2t then raise (TypeError (e1t, e2t))
    else if e1t = etype then ()
    else raise (TypeError (etype, e1t)));
    rtype
…
```

Abstract Syntax is not Concrete Syntax

IF X + 2 < 5 DO … ELSE …