The Design and Implementation of Gnu Compiler Collection

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Part 1

Outline

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- Open Source Vs. Free Software
- An Introduction to Compilation
- An overview of Gnu Compiler Collection
- Our work in GCC
- Conclusions

Part 2

Open Source Vs. Free Software

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- The open source initiative: (http://www.opensource.org/)
  Emphasis on development methodology
- The Free Software Foundation: (http://www.fsf.org/)
  Emphasis on freedom of the user
- In some cases, open source software has restricted user freedom

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- In some cases, open source software has restricted user freedom
  - May cooperate with restrictive systems
  - eg. DRM (Digital Rights Management)

Open Source and Free Software Development Model

- The Cathedral and the Bazaar

  Eric S Raymond, 1997.
- Cathedral: Total Centralized Control

  Design, implement, test, release
- Bazaar: Total Decentralization

  Release early, release often, let users fix bugs

The Bazaar Approach

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  Code errors, logical errors, and architectural errors.

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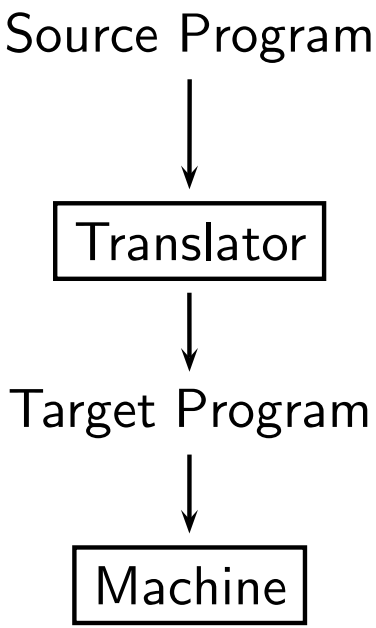
  Code errors, logical errors, and architectural errors.

A combination of the two seems more sensible

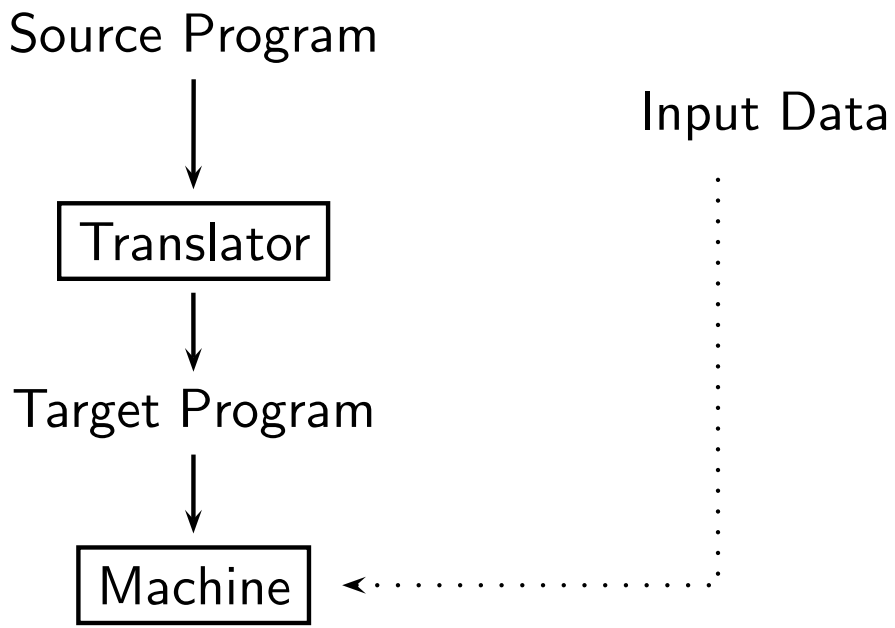
Part 3

Introduction to Compilation

Implementation Mechanisms



Implementation Mechanisms



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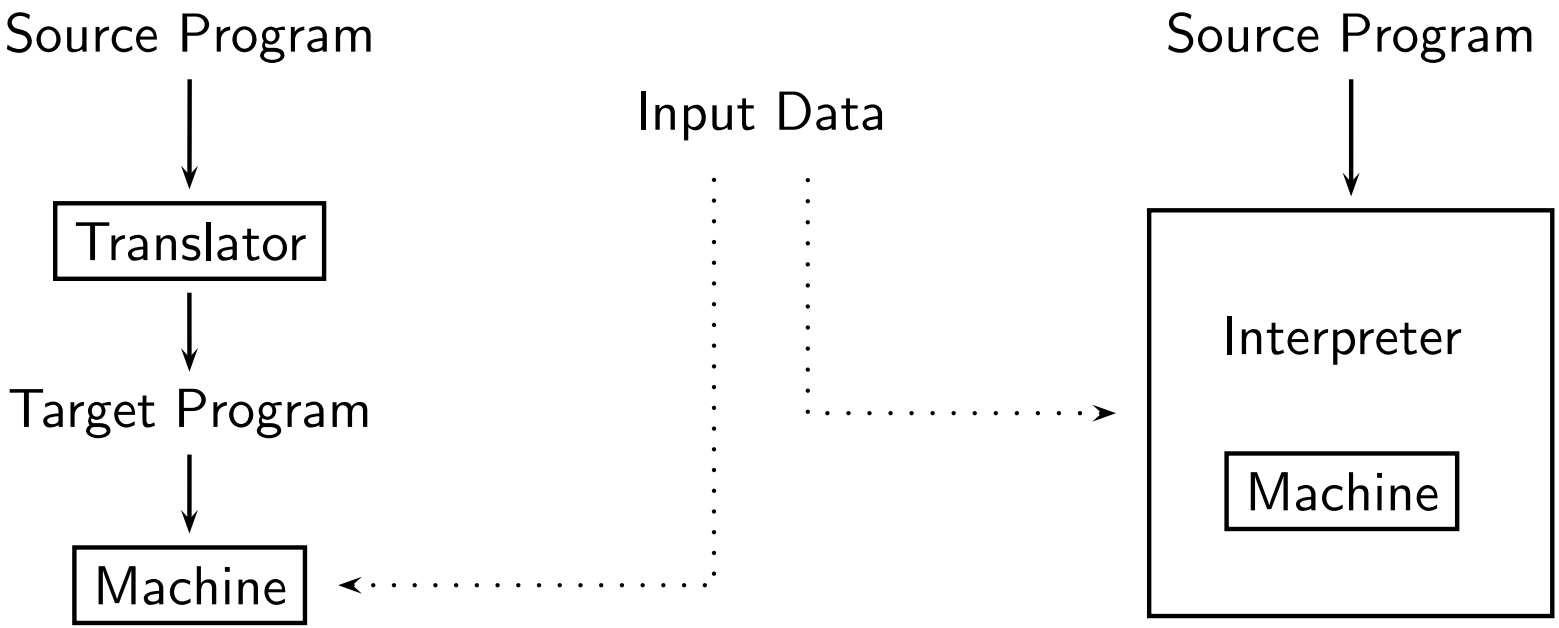
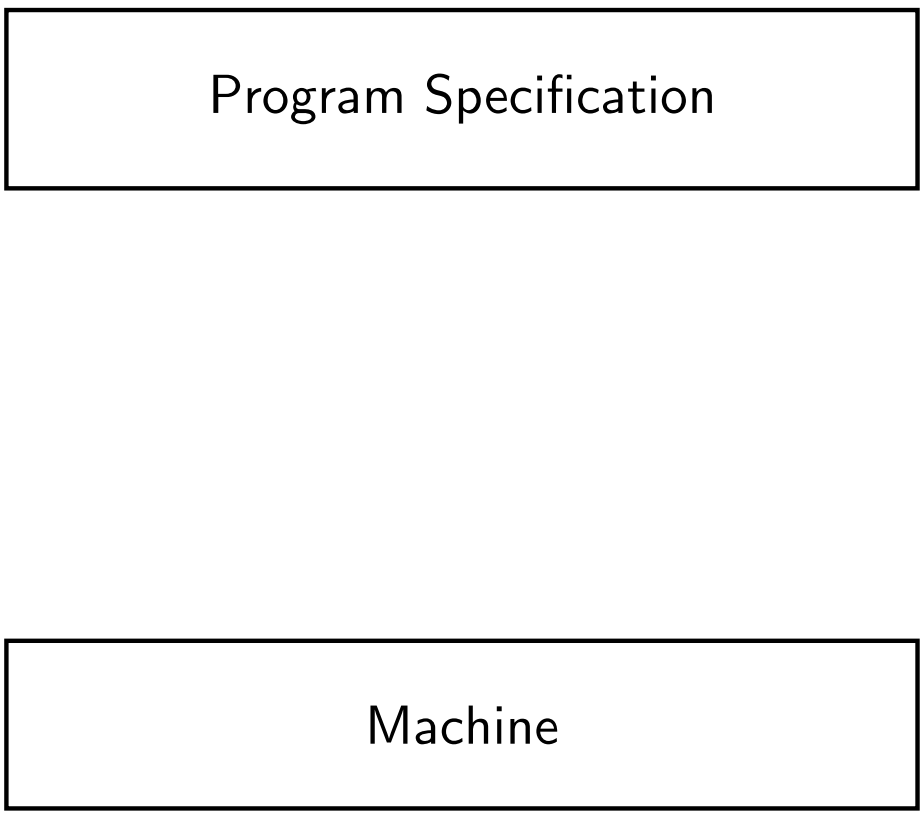


Implementation Mechanisms as "Bridges"

- "Gap" between the "levels" of program specification and execution



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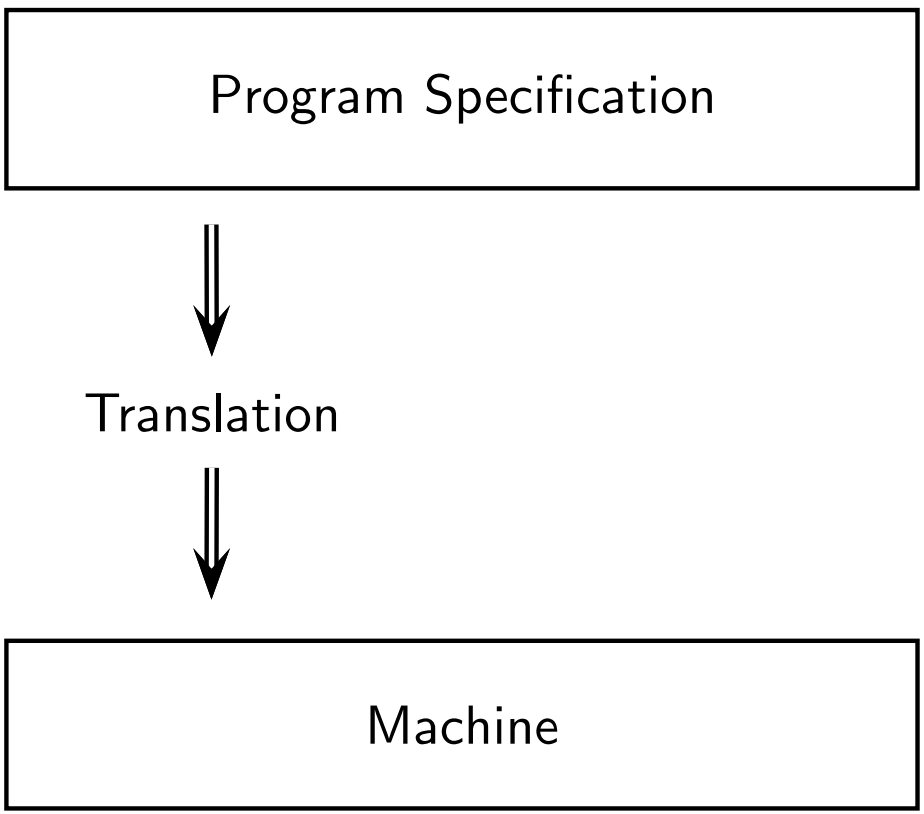

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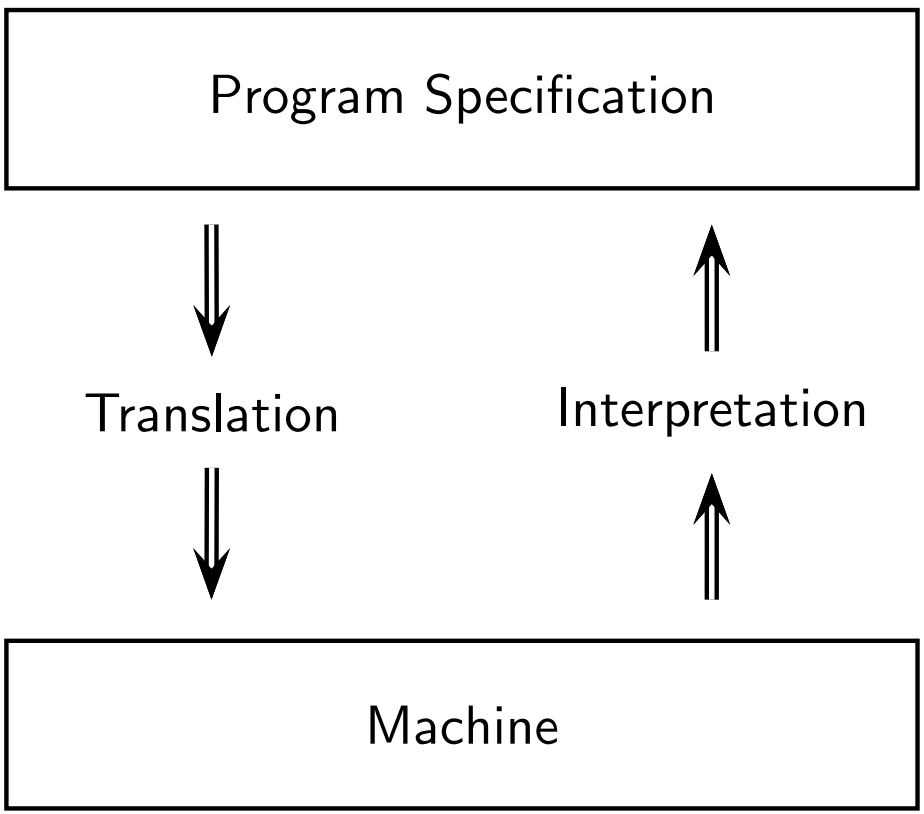

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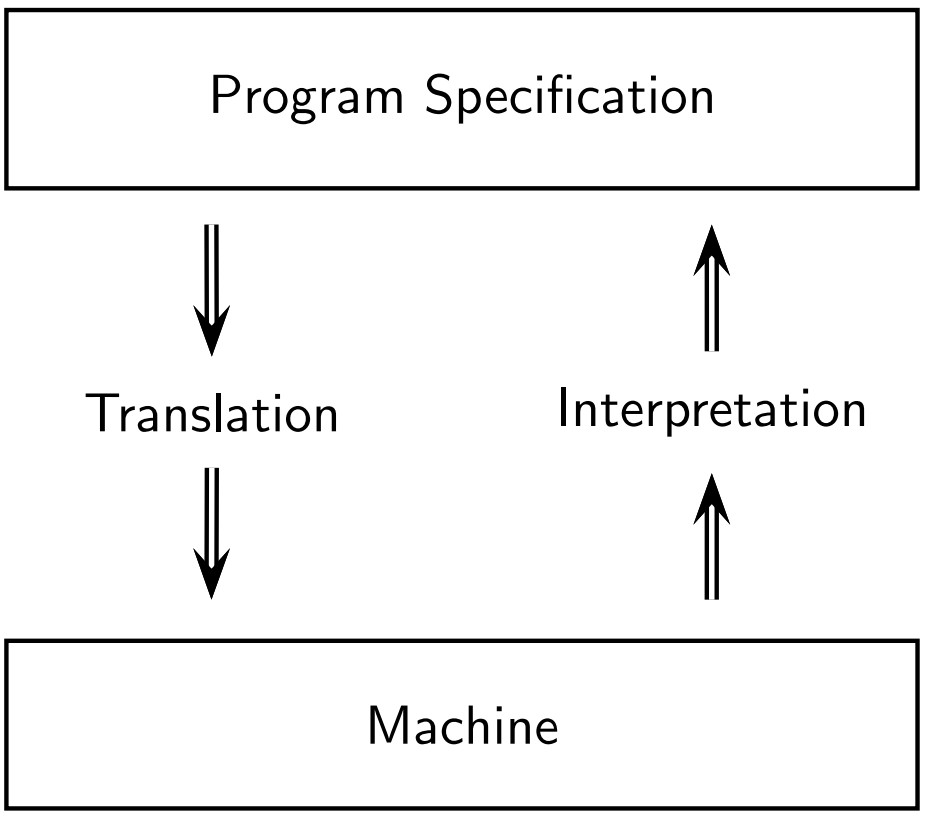


State : Variables
Operations: Expressions, Control Flow

State : Memory, Registers
Operations: Machine Instructions

High and Low Level Abstractions

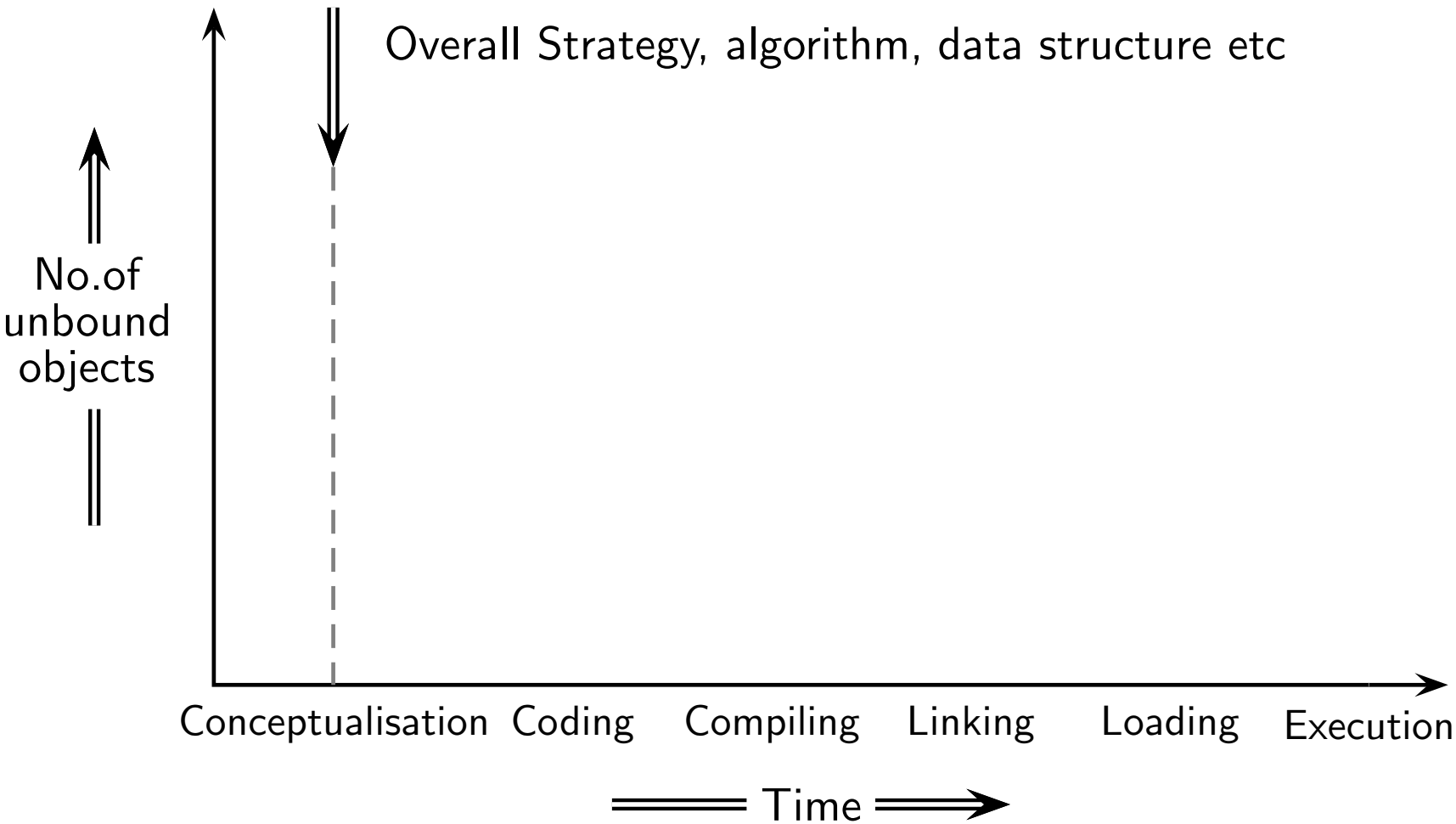
- A source statement

```
a = b < 10 ? b : c;
```

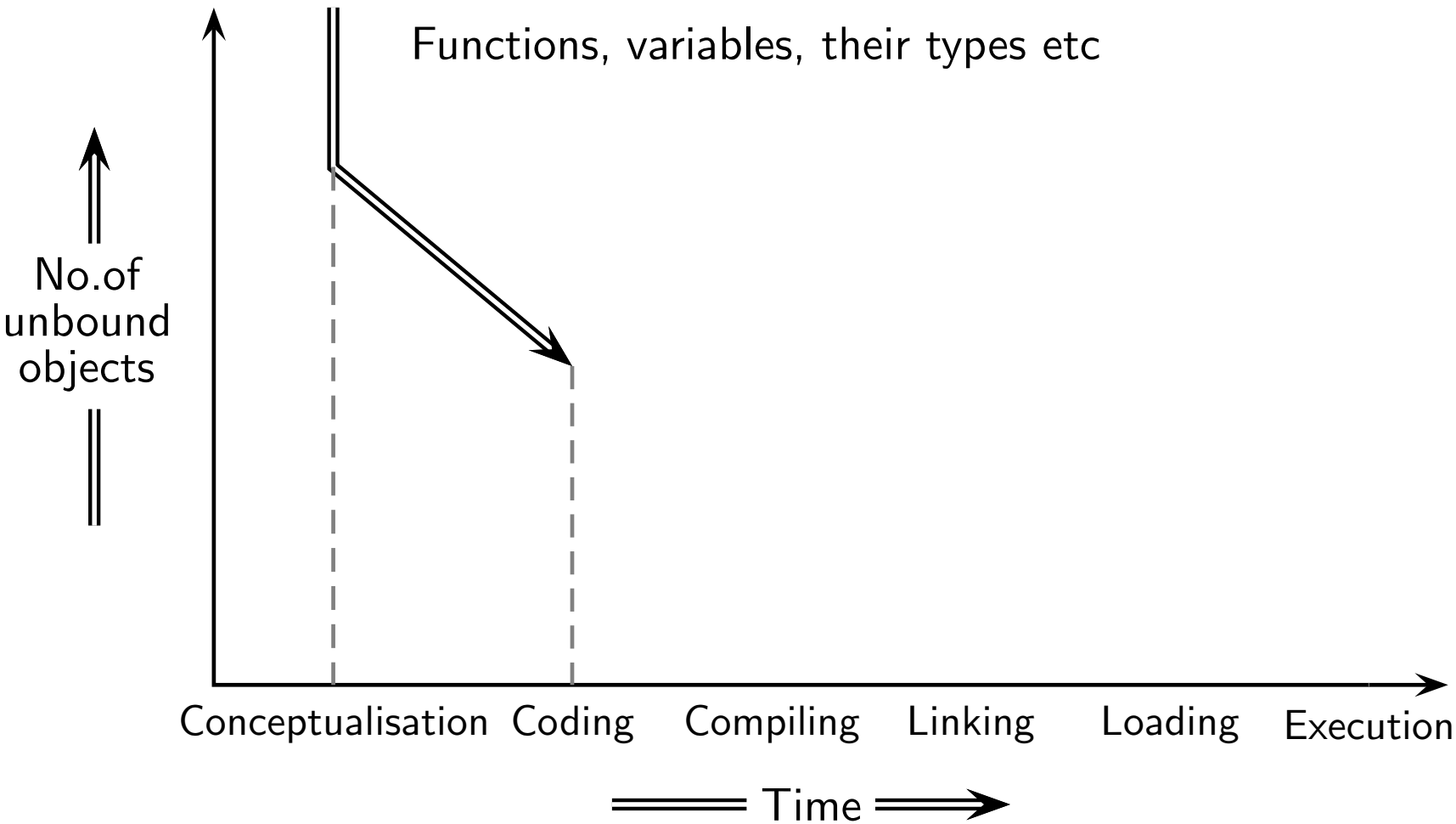
- Spim assembly equivalent

```
        lw   $t0, 4($fp)    #       $t0 <- b
        slti $t0, $t0, 10   #       $t0 <- $t0 < b
        not  $t0, $t0       #       $t0 <- ! $t0
        bgtz $t0, L0:       #       if $t0 >=  0 goto L0:
        lw   $t0, 4($fp)    #       $t0 <- b
        b    L1:            #       goto L1:
L0:     lw   $t0, 8($fp)    # L0:   $t0 <- c
L1:     sw   0($fp), $t0    # L1:   a <- $t0
```


Binding


Overall Strategy, algorithm, data structure etc
No.of unbound objects
Conceptualisation
Coding
Compiling
Linking
Loading
Execution
Time

Binding


Functions, variables, their types etc
No.of unbound objects
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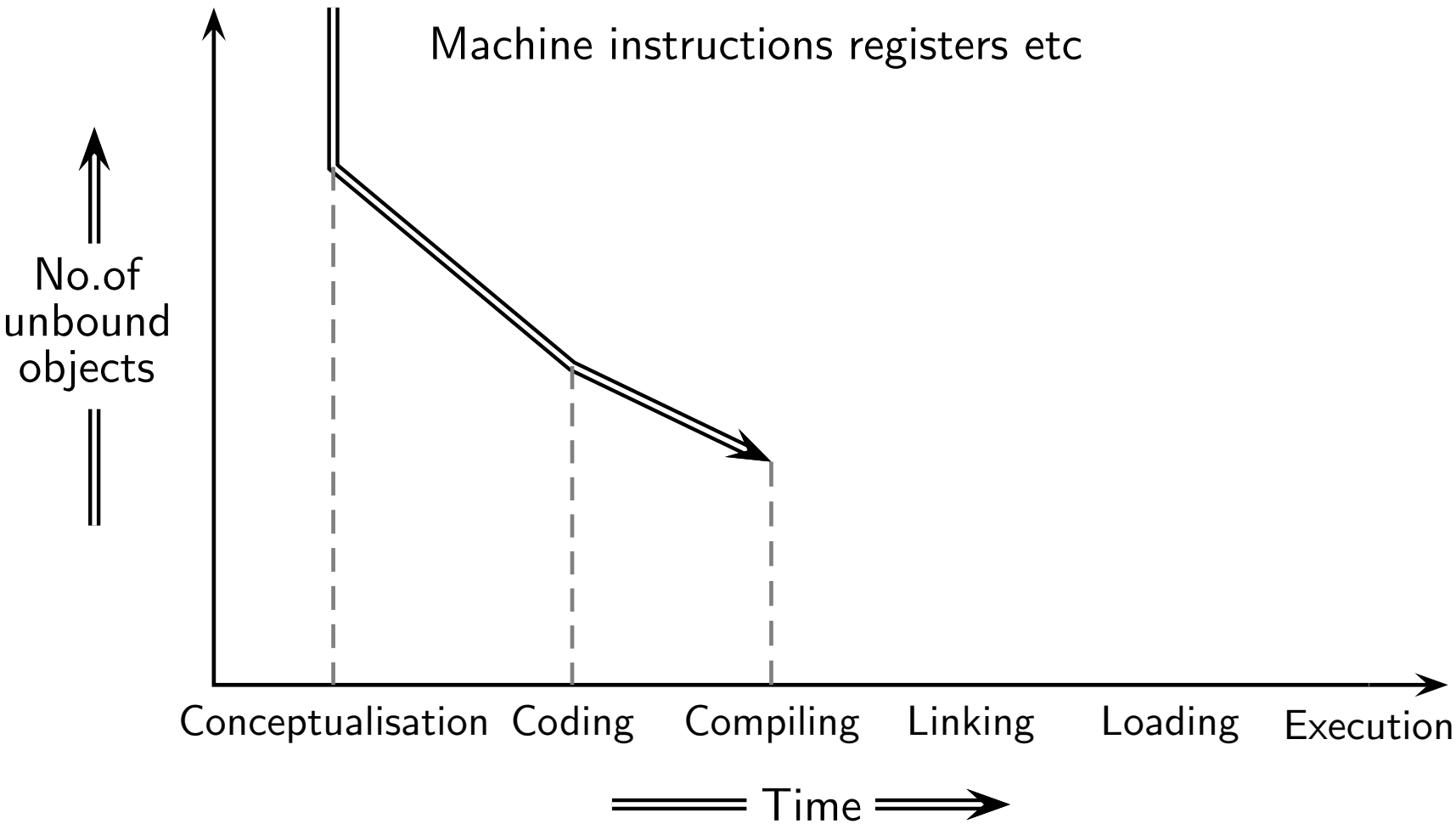
Machine instructions registers etc
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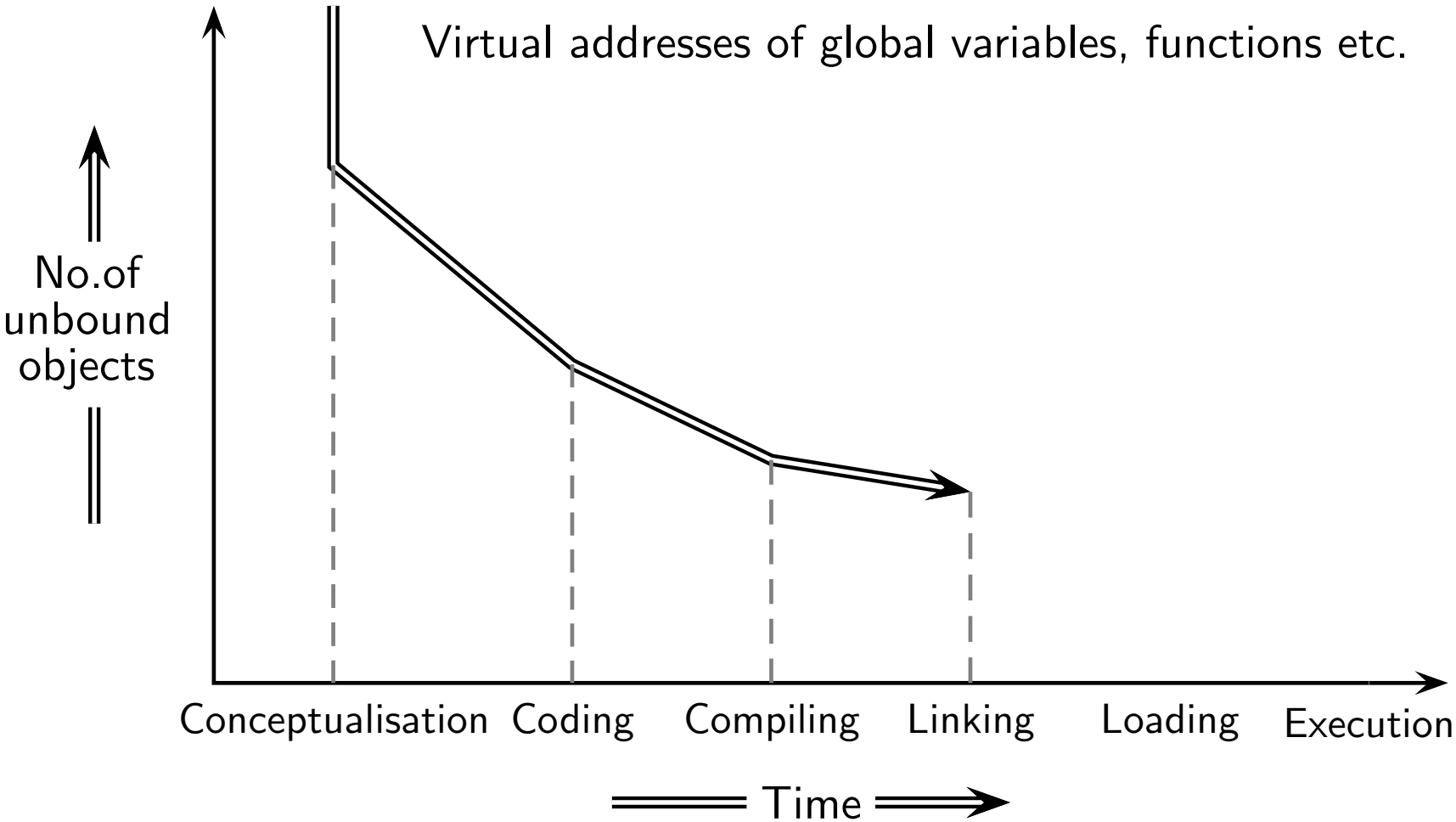
Virtual addresses of global variables, functions etc.
No.of unbound objects
Conceptualisation
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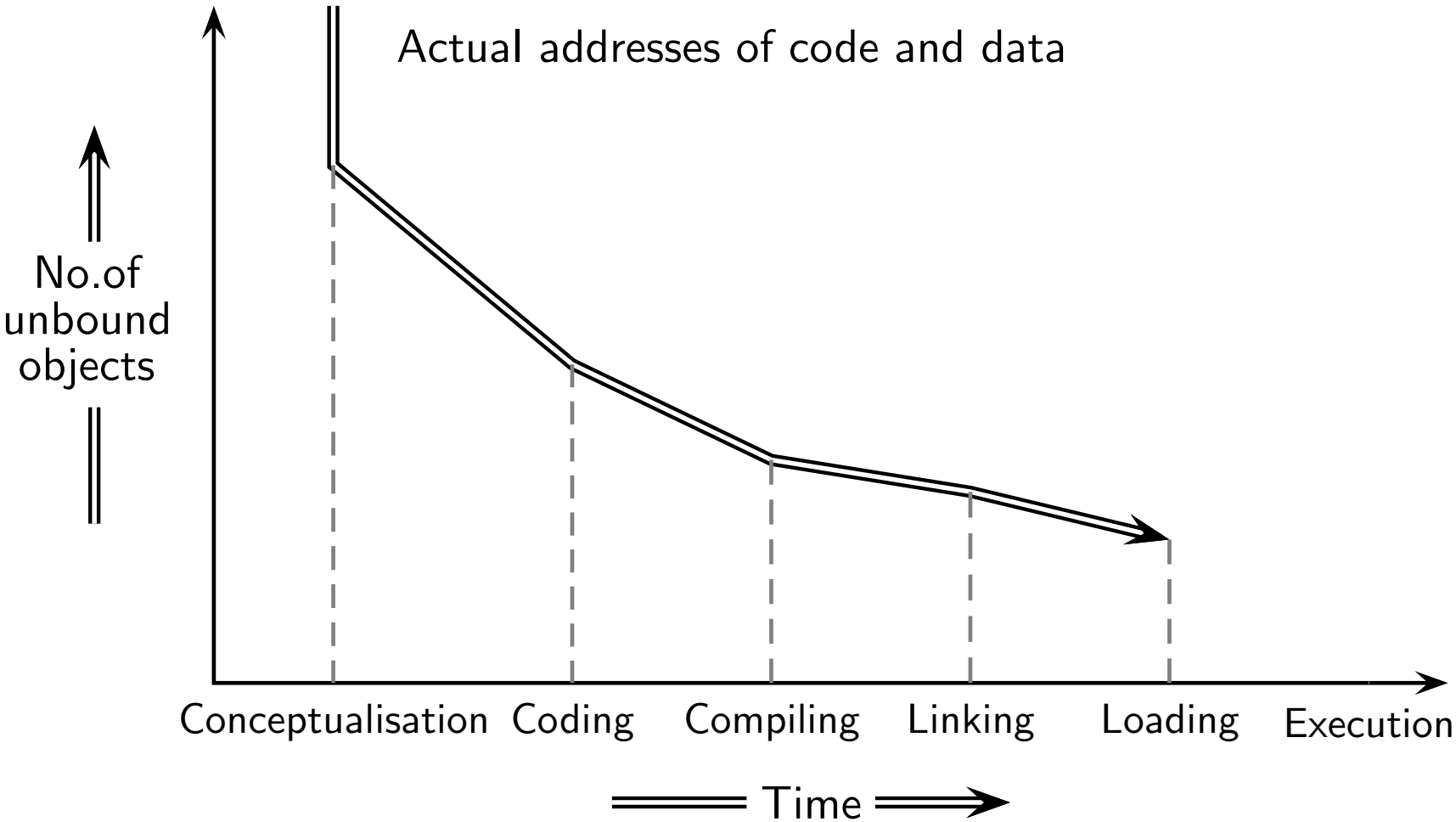
Actual addresses of code and data
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Conceptualisation
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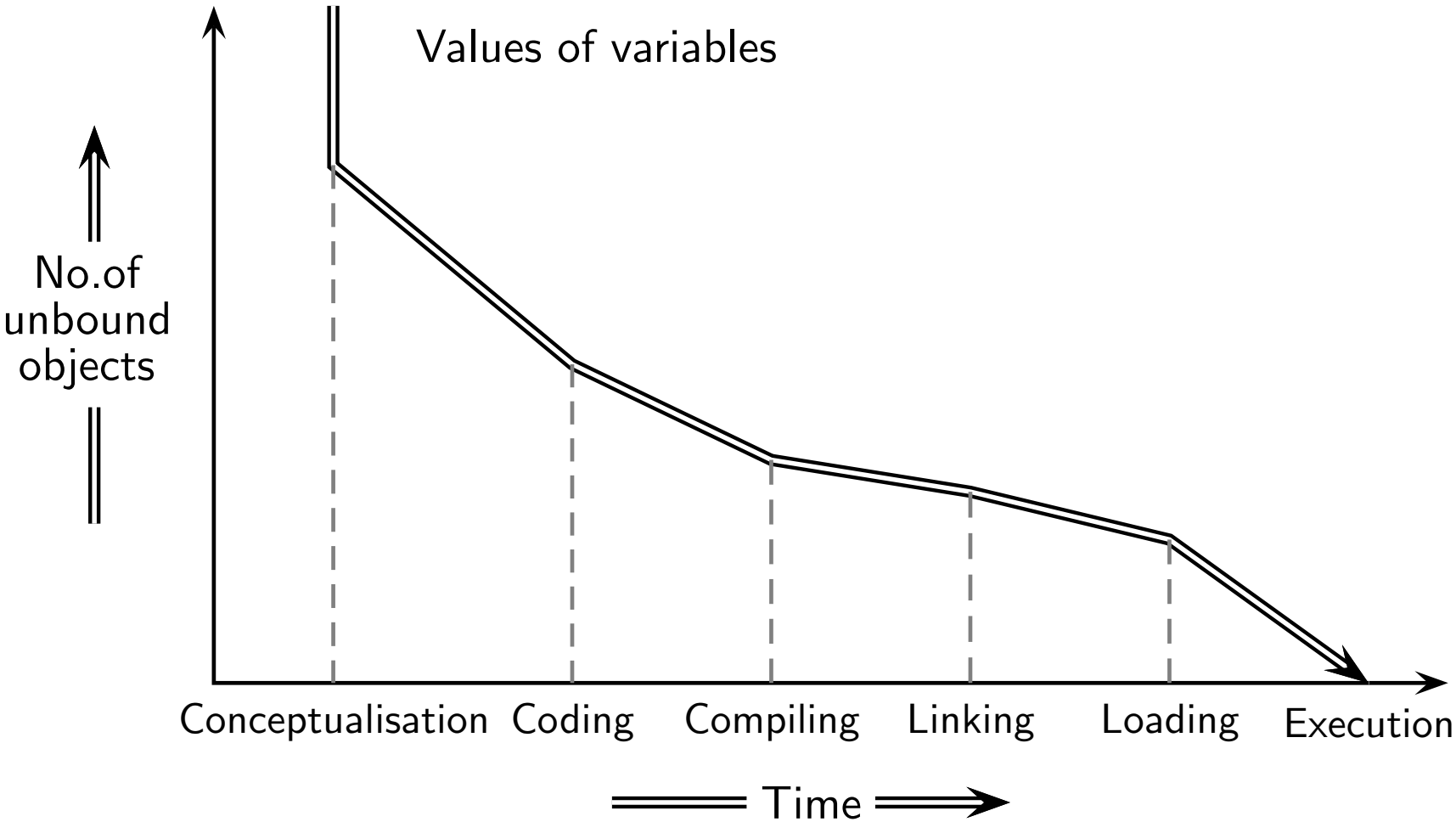
Values of variables
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Implementation Mechanisms

- Translation = Analysis + Synthesis

  Interpretation = Analysis + Execution

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- Translation Instructions $\Longrightarrow$ Equivalent Instructions

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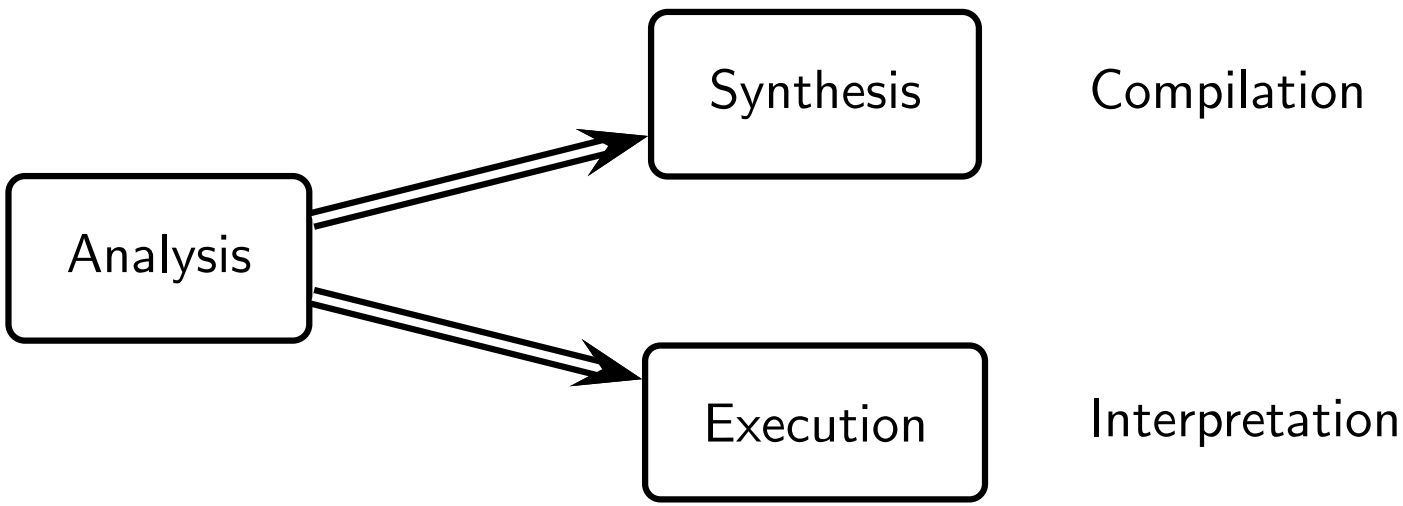
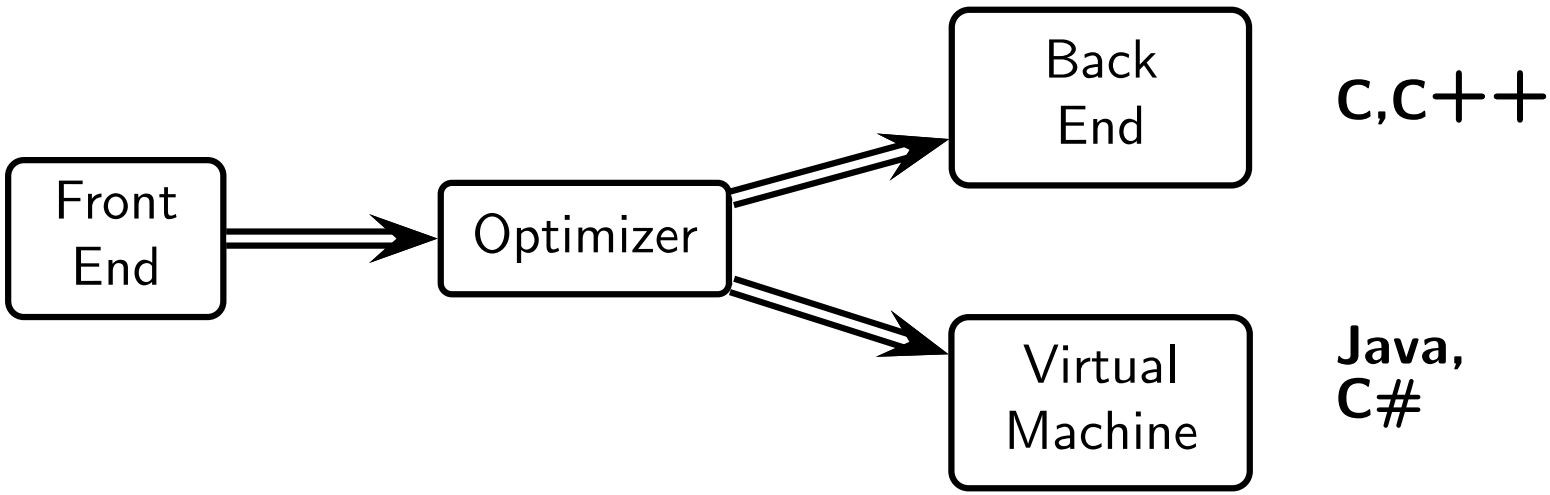
- Translation Instructions $\Longrightarrow$ Equivalent Instructions

  Interpretation Instructions $\Longrightarrow$ Actions Implied by Instructions

Language Implementation Models



Language Processor Models



Translation Sequence in Our Example: Parsing

```
a=b<10?b:c;
```

Input

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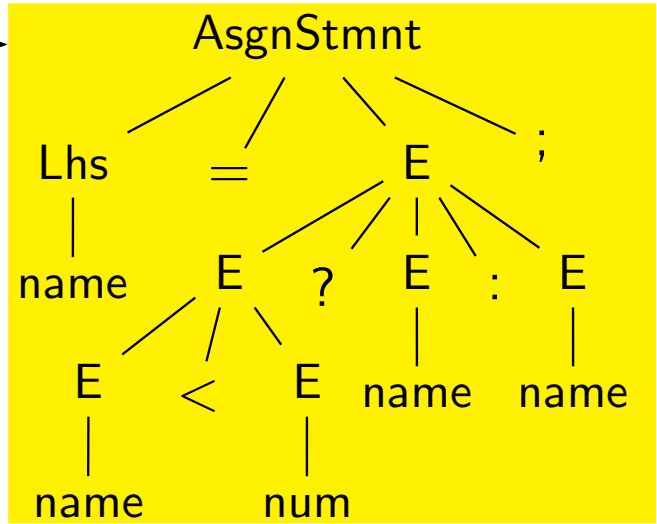

Parse Tree

Issues:

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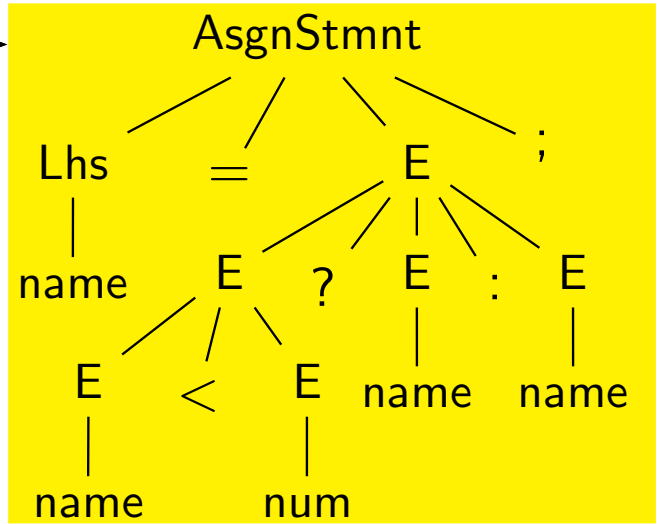

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Issues:

- Grammar rules, terminals, non-terminals

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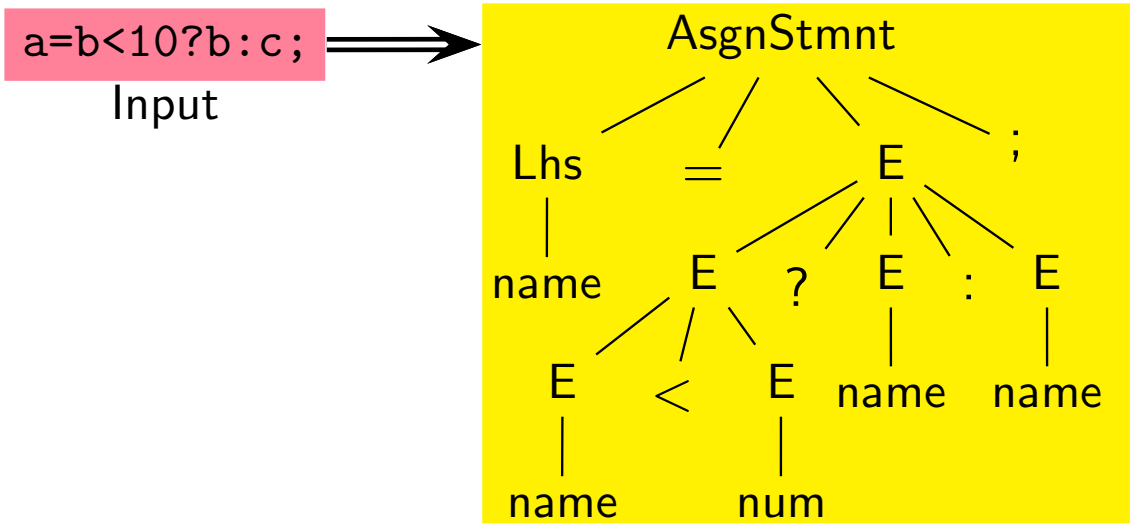

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- Grammar rules, terminals, non-terminals
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  eg. is it `(a = b<10?)` followed by `(b:c)`?

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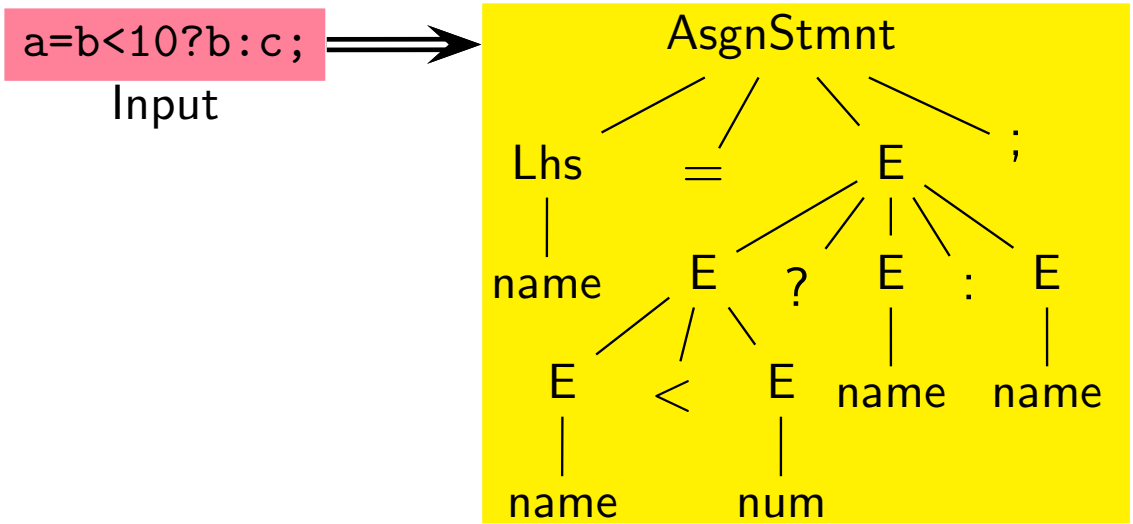

Parse Tree

Issues:

- Grammar rules, terminals, non-terminals
- Order of application of grammar rules

  eg. is it `(a = b<10?)` followed by `(b:c)`?
- Values of terminal symbols

  eg. string "10" vs. integer number 10.

Translation Sequence in Our Example: Semantic Analysis

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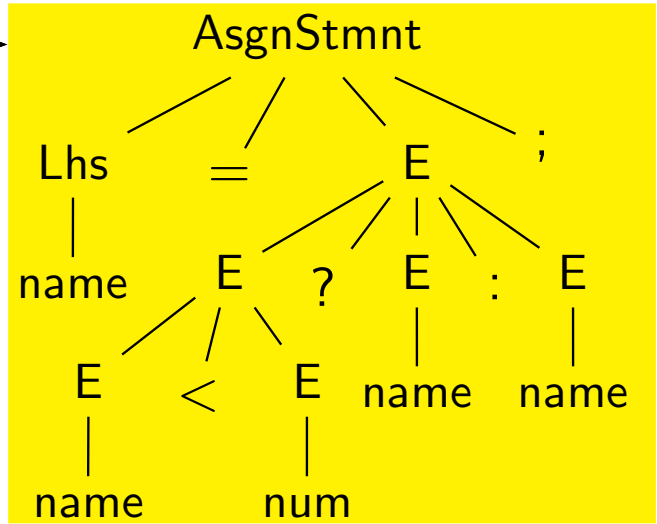
a=b<10?b:c;
```

Input



Parse Tree

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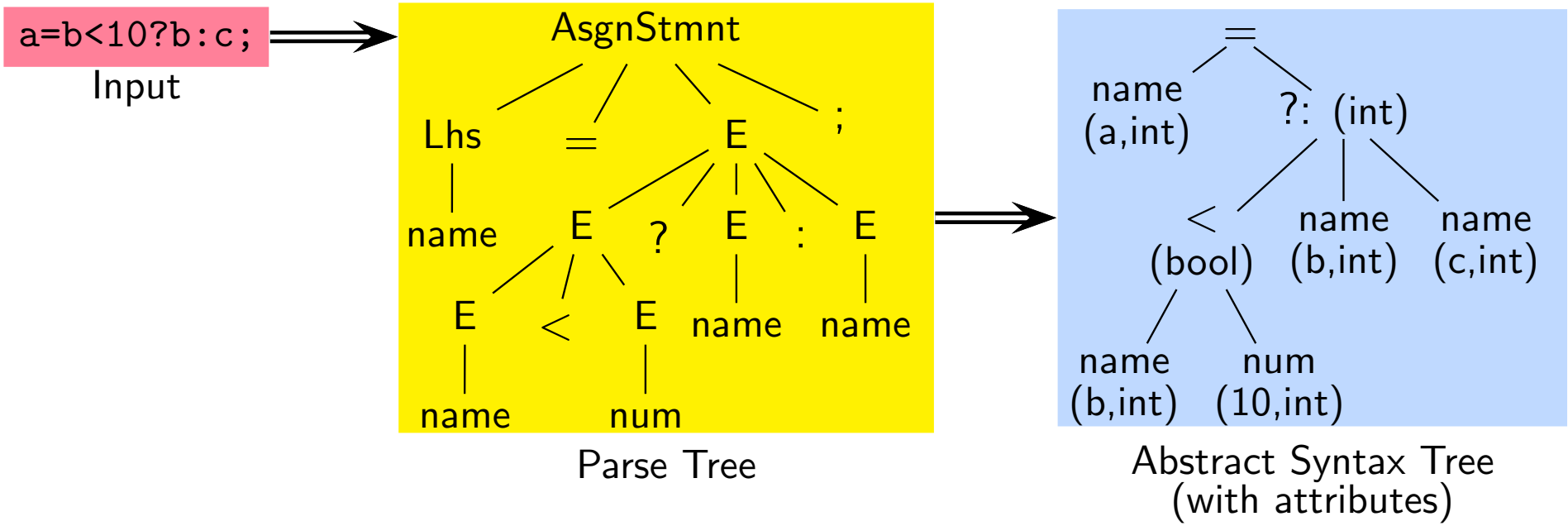

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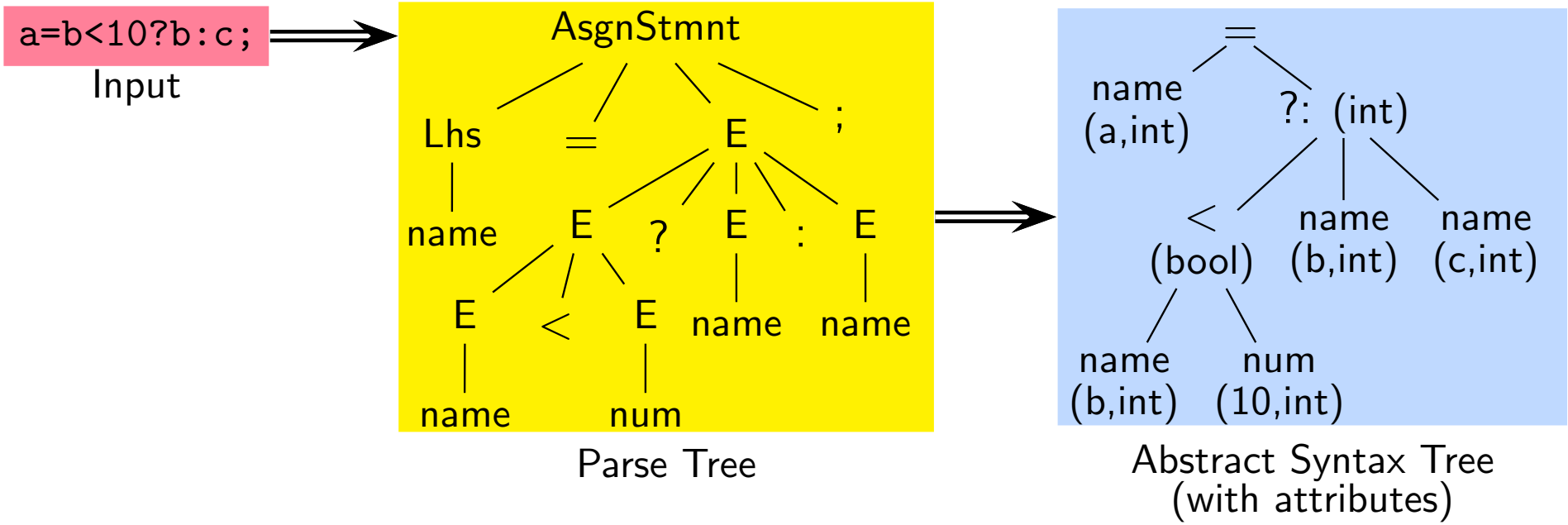

Issues:

- Symbol tables

  Have variables been declared? What are their types? What is their scope?

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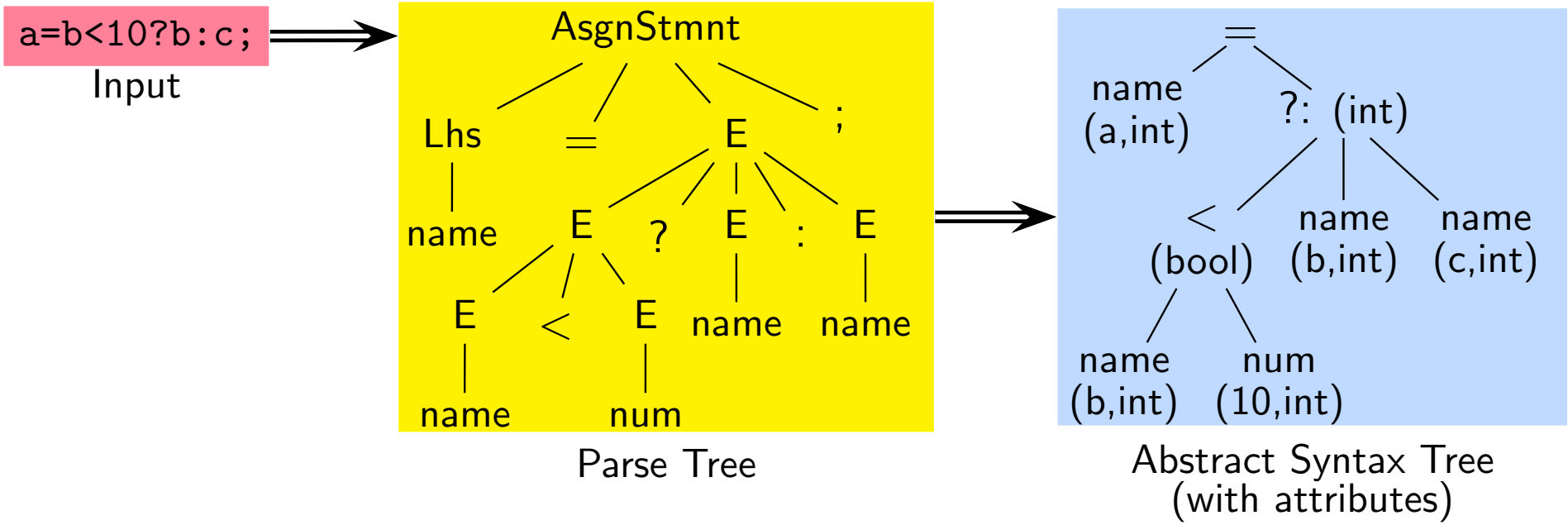

Issues:

- Symbol tables

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- Type consistency of operators and operands

  The result of computing b<10? is bool and not int

Translation Sequence in Our Example: IR Generation

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a=b<10?b:c;
```

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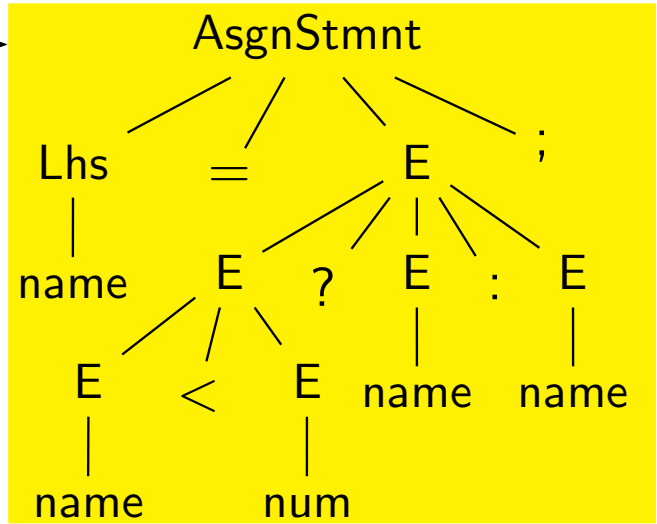
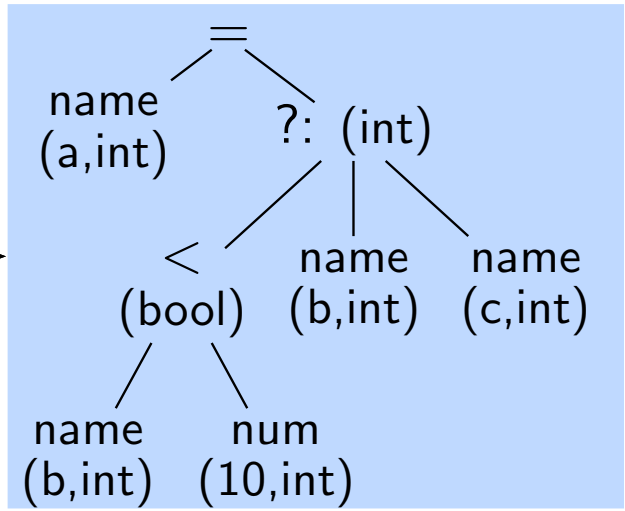


Parse Tree



Abstract Syntax Tree
(with attributes)

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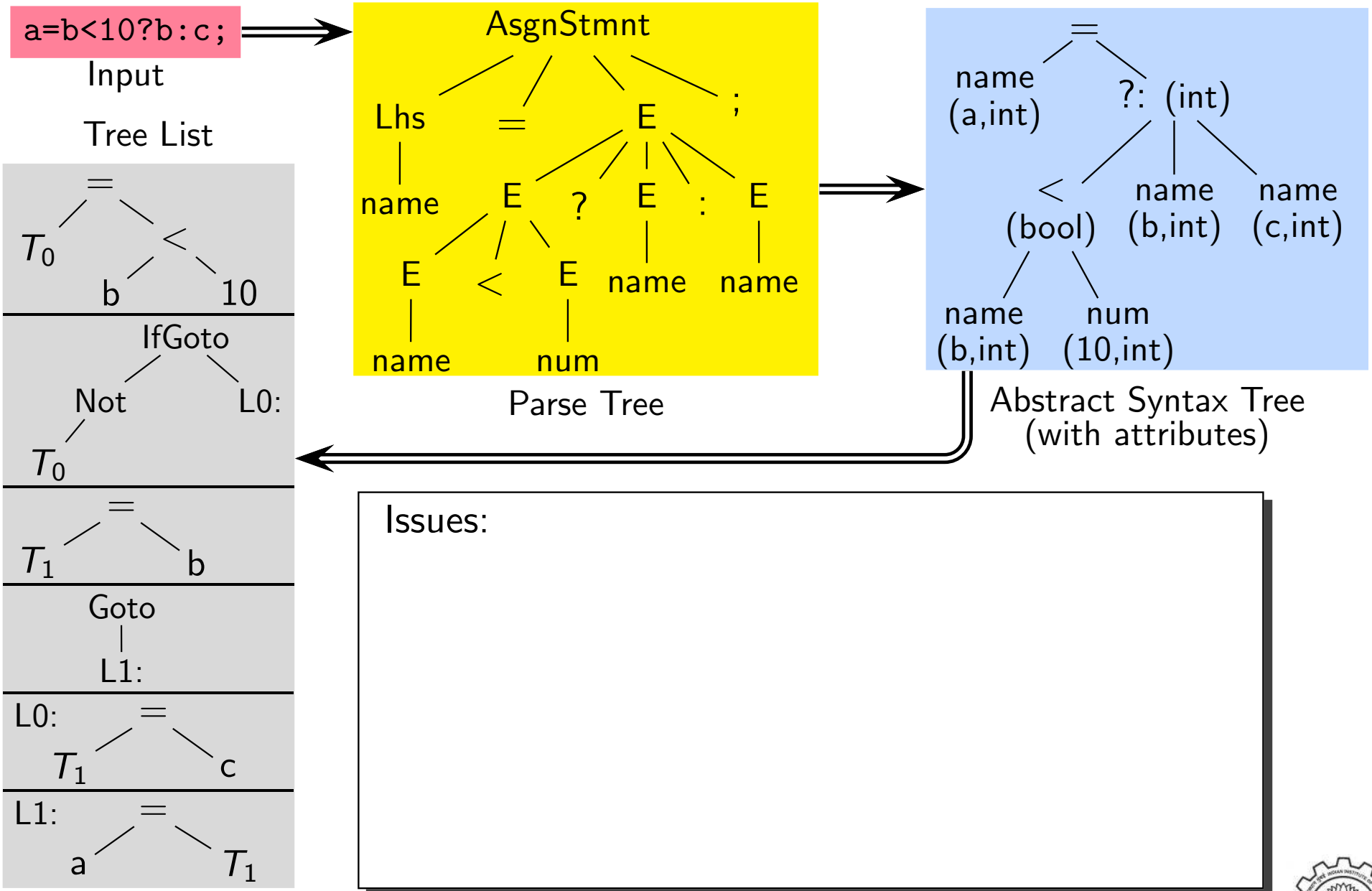

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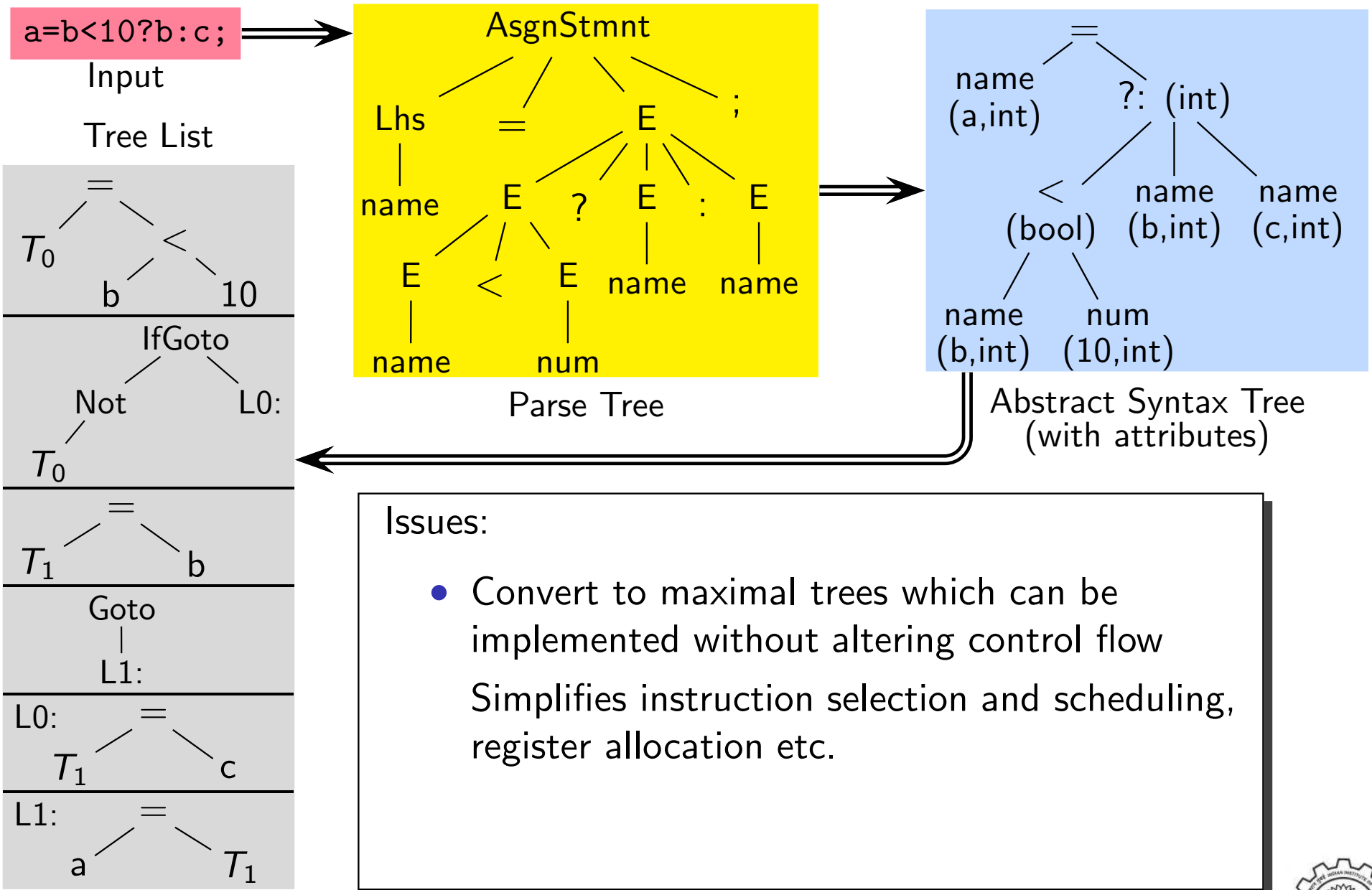

Issues:

- Convert to maximal trees which can be implemented without altering control flow

  Simplifies instruction selection and scheduling, register allocation etc.

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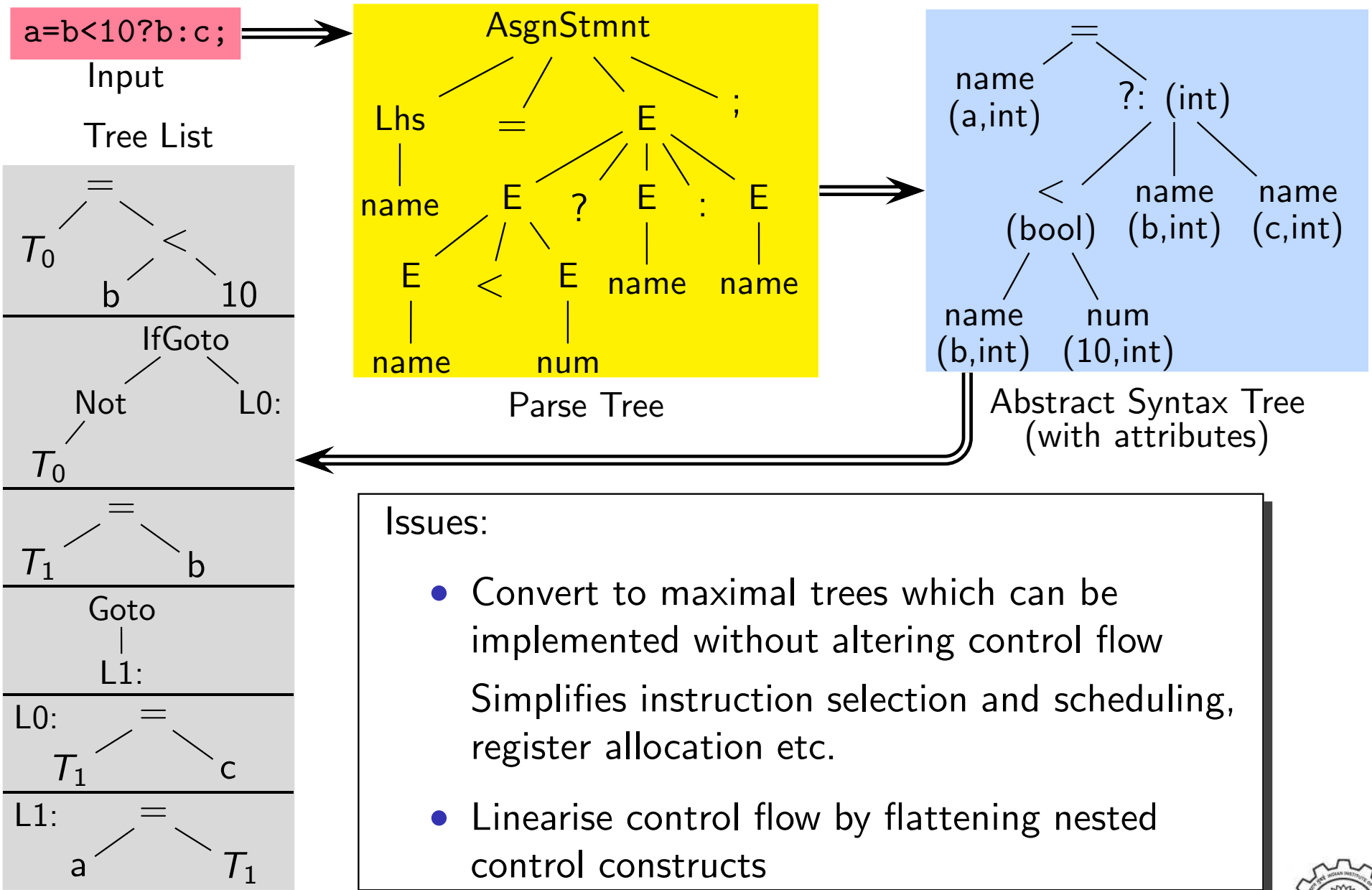

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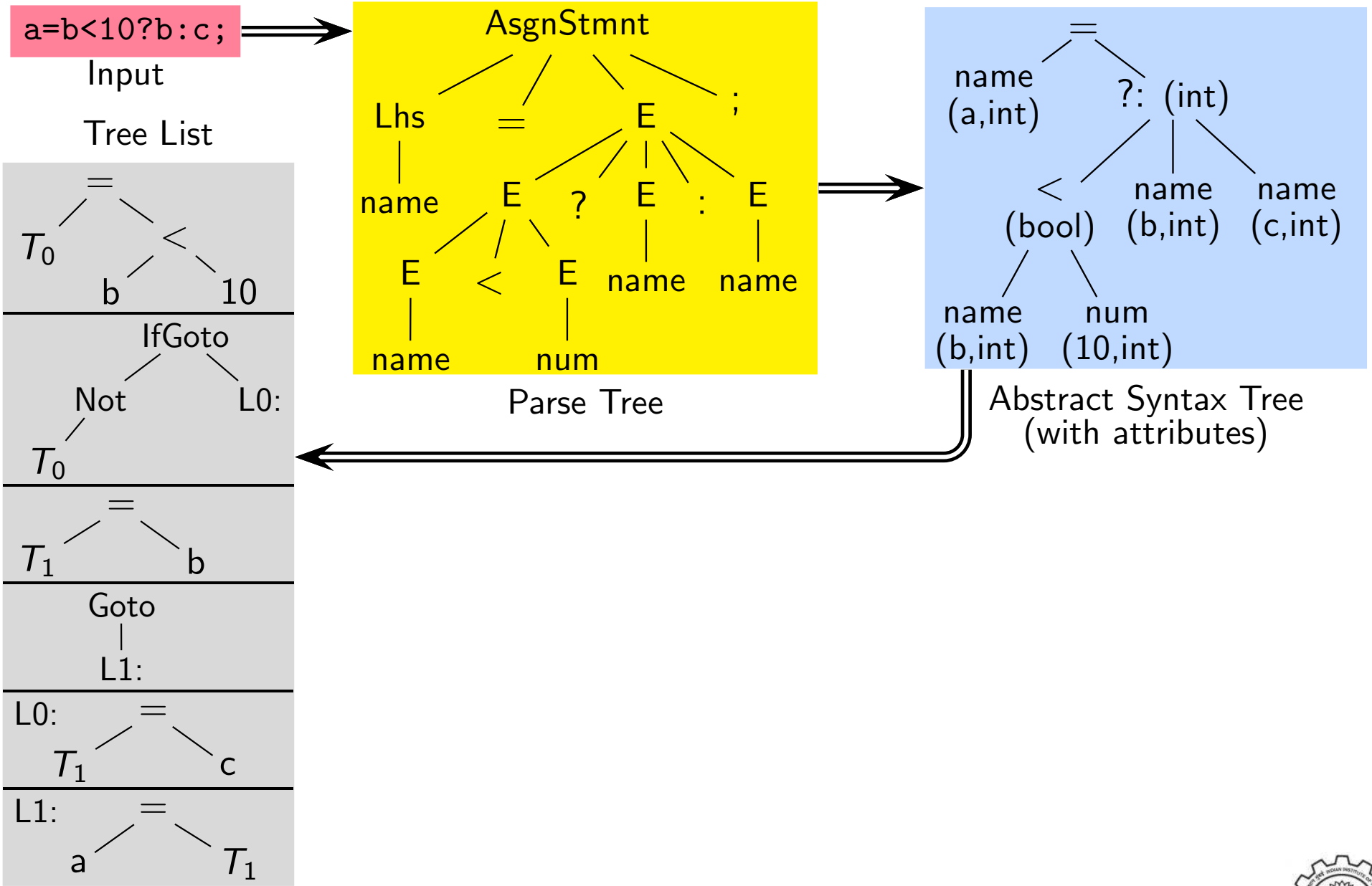
- Linearise control flow by flattening nested control constructs

Translation Sequence in Our Example: Instruction Selection



Translation Sequence in Our Example: Instruction Selection

`a=b<10?b:c;`

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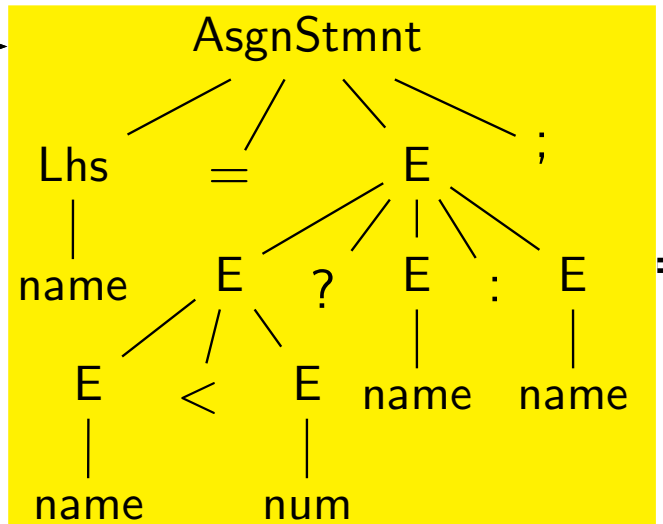

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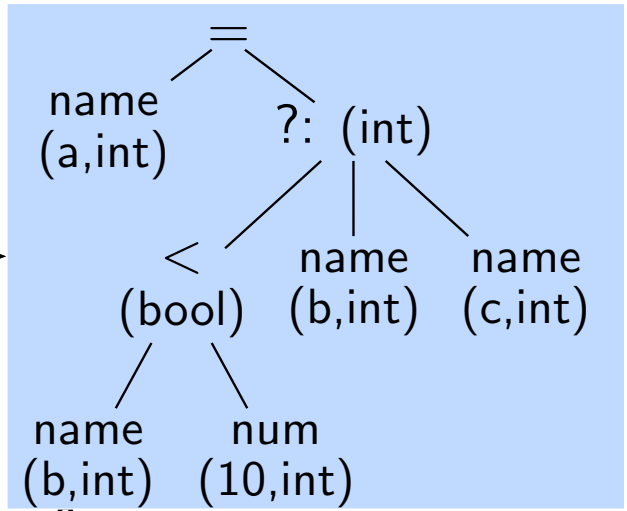
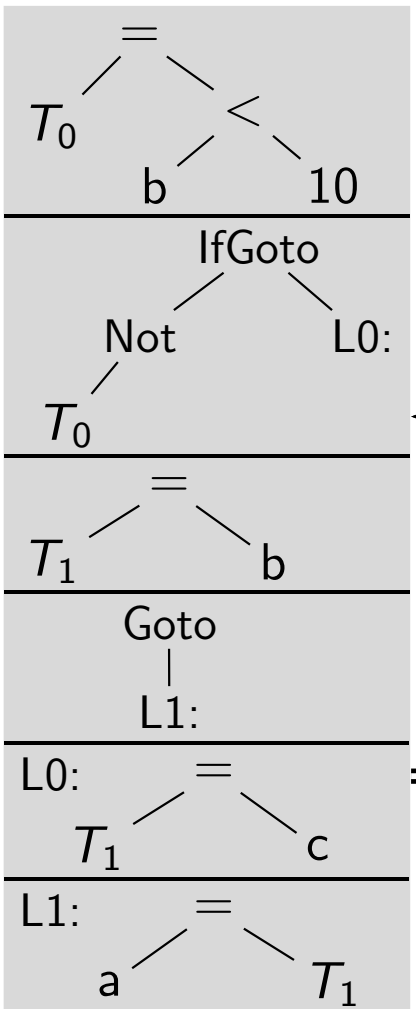


Abstract Syntax Tree
(with attributes)

Tree List



Instruction List

$T_0 \leftarrow$ b
$T_0 \leftarrow T_0 <$ b
$T_0 \leftarrow !\ T_0$
if $T_0 \geq 0$ goto L0:
$T_1 \leftarrow$ b
goto L1:
L0: $T_1 \leftarrow$ c
L1: a $\leftarrow T_1$

Issues:

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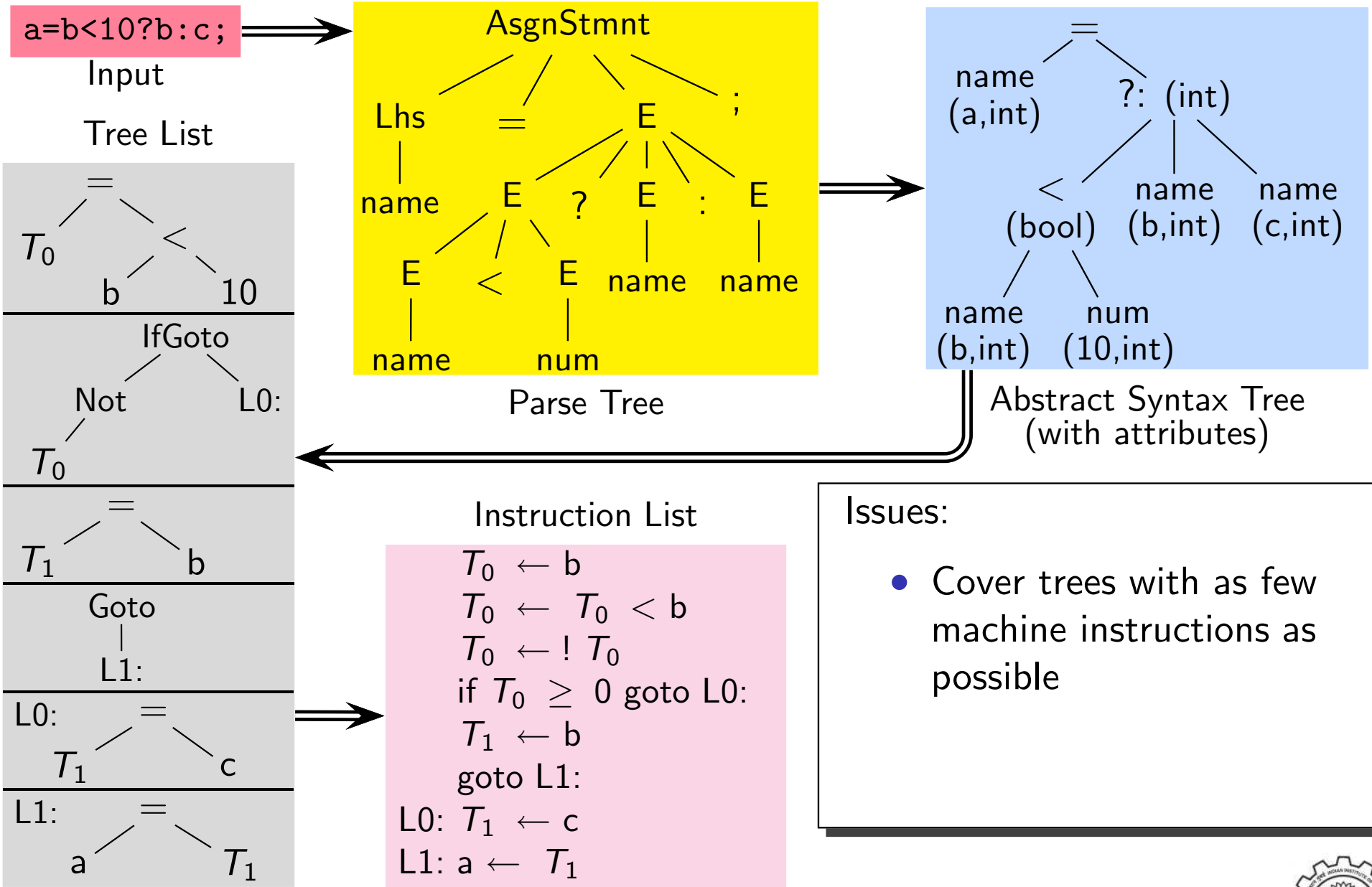

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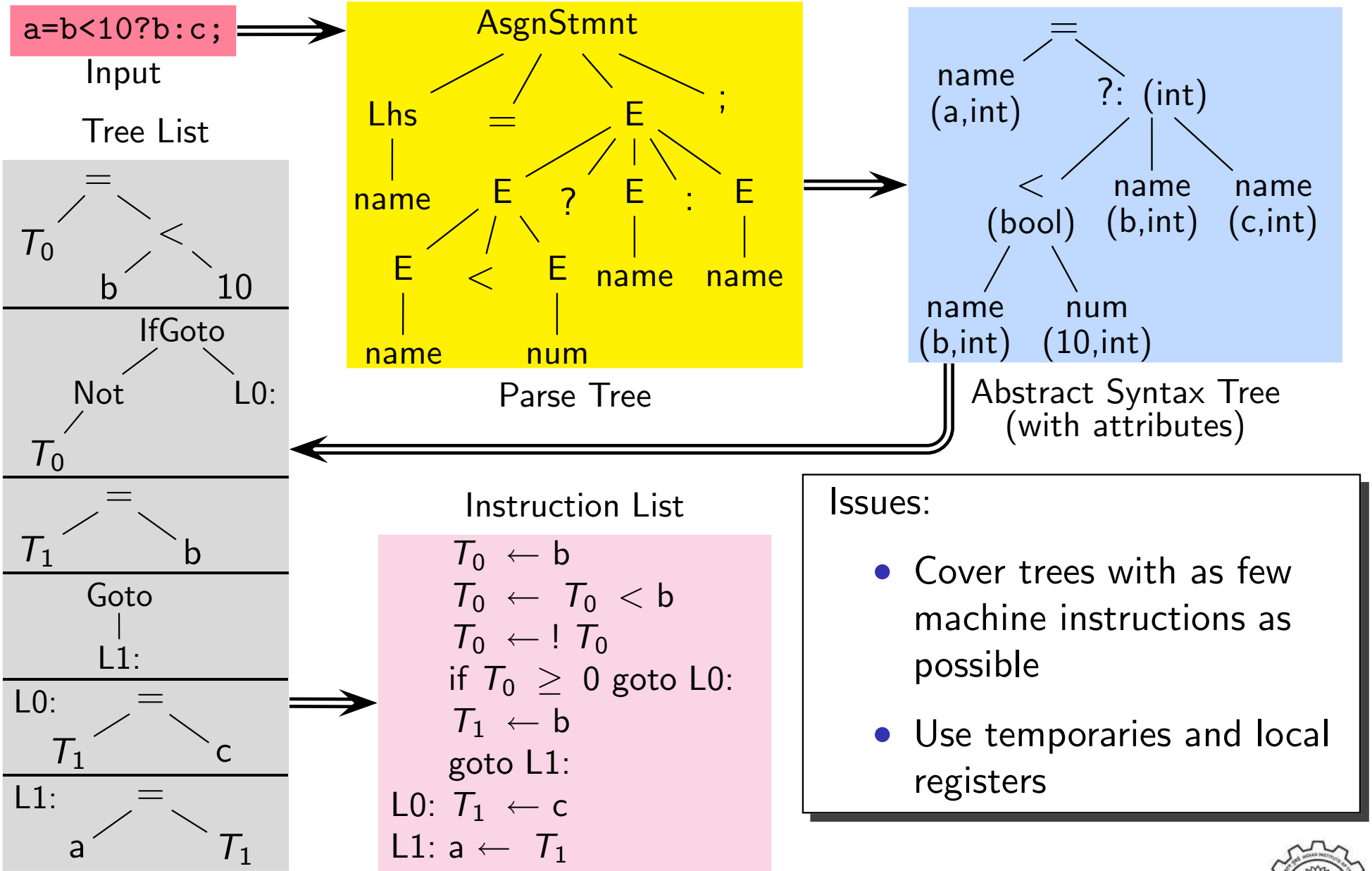
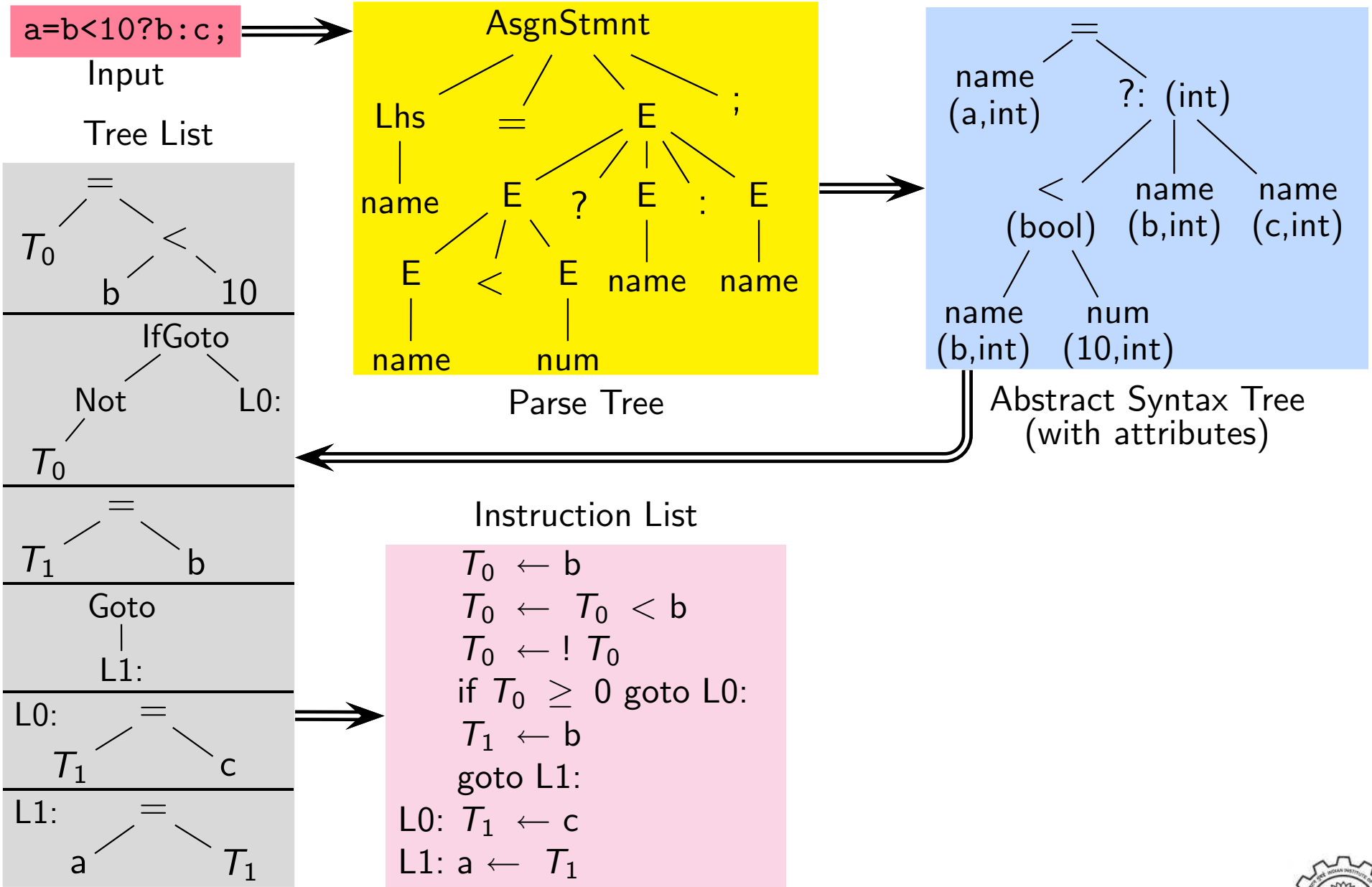


Translation Sequence in Our Example: Emitting Instructions



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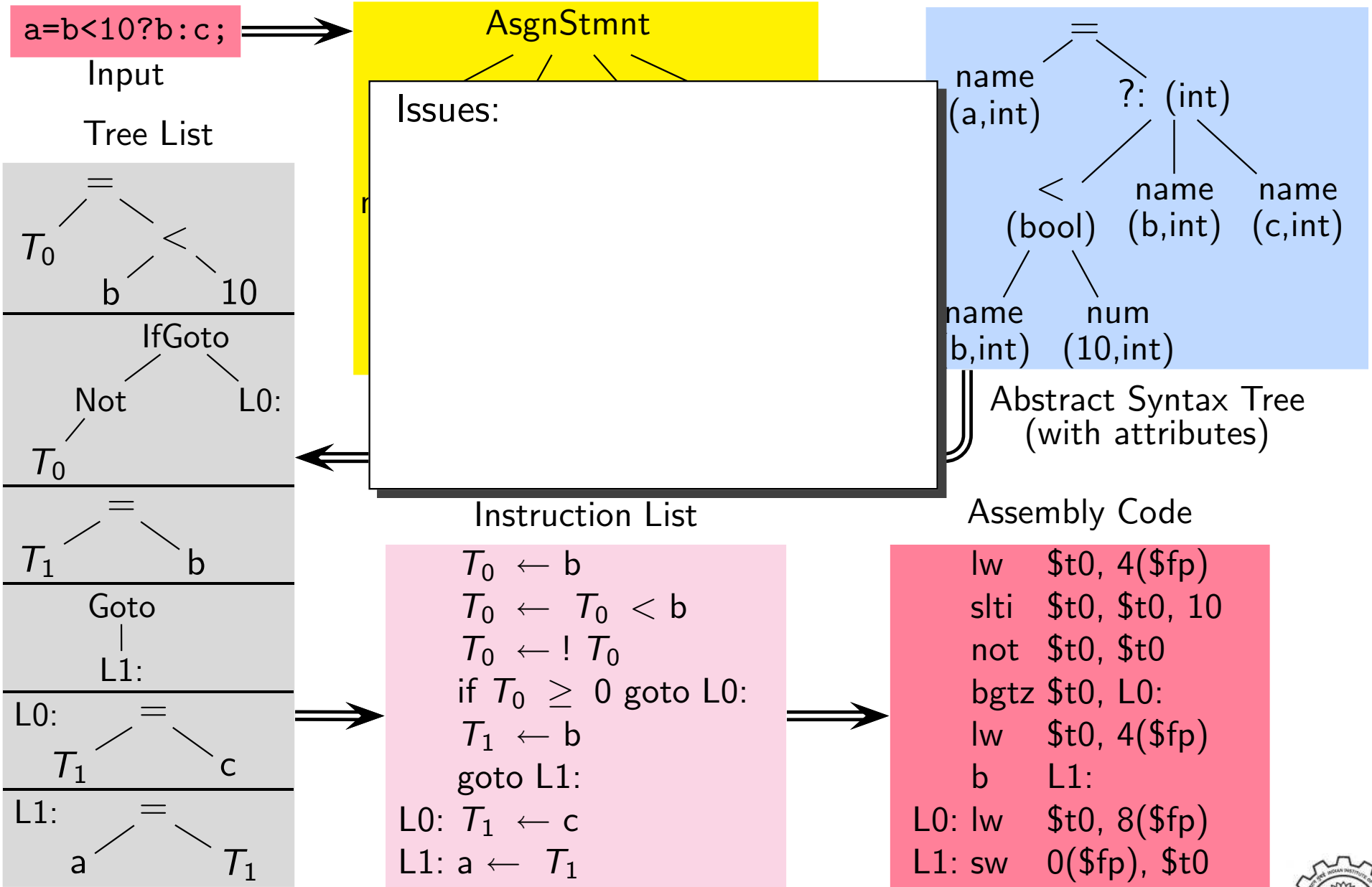

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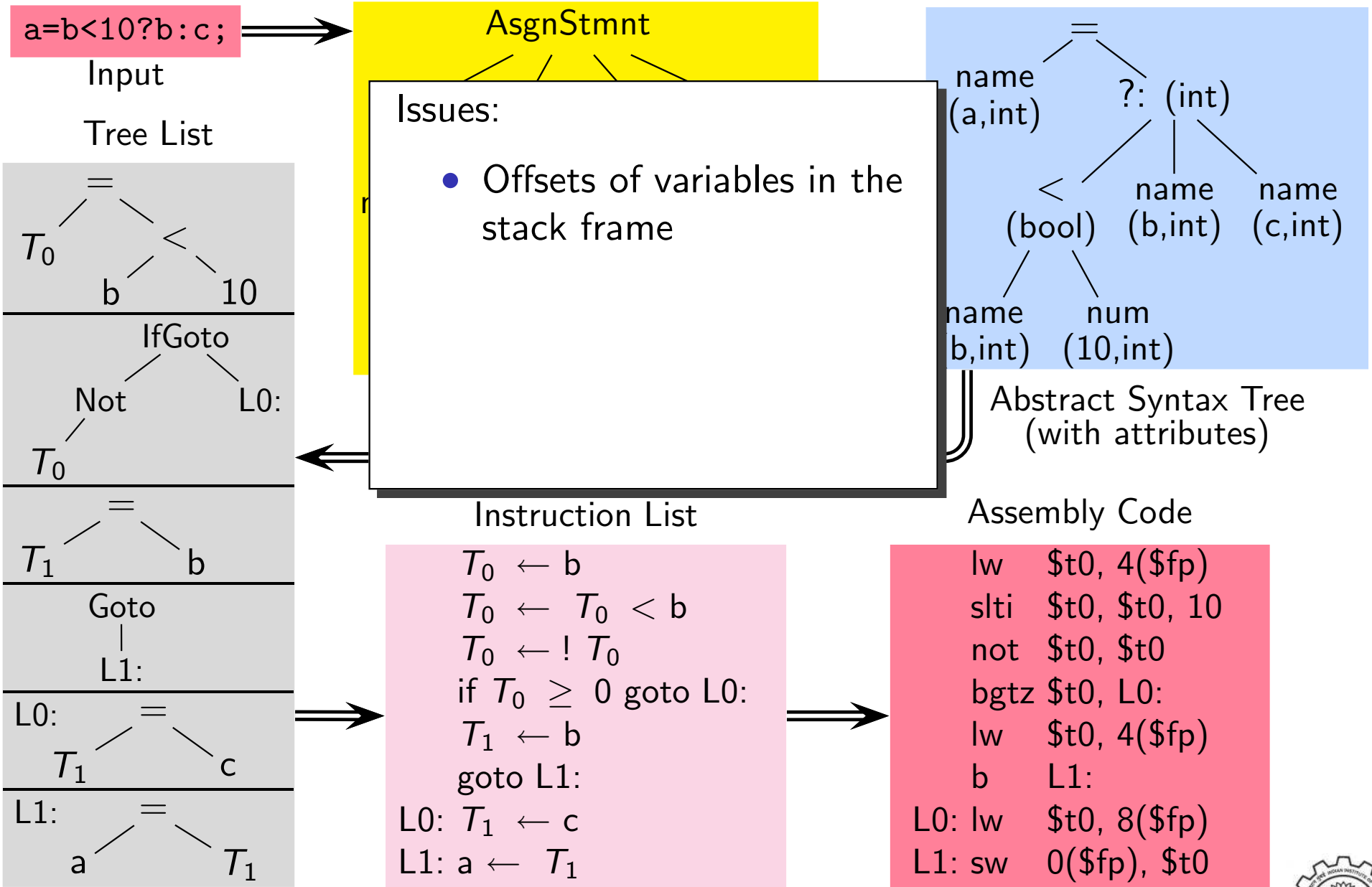

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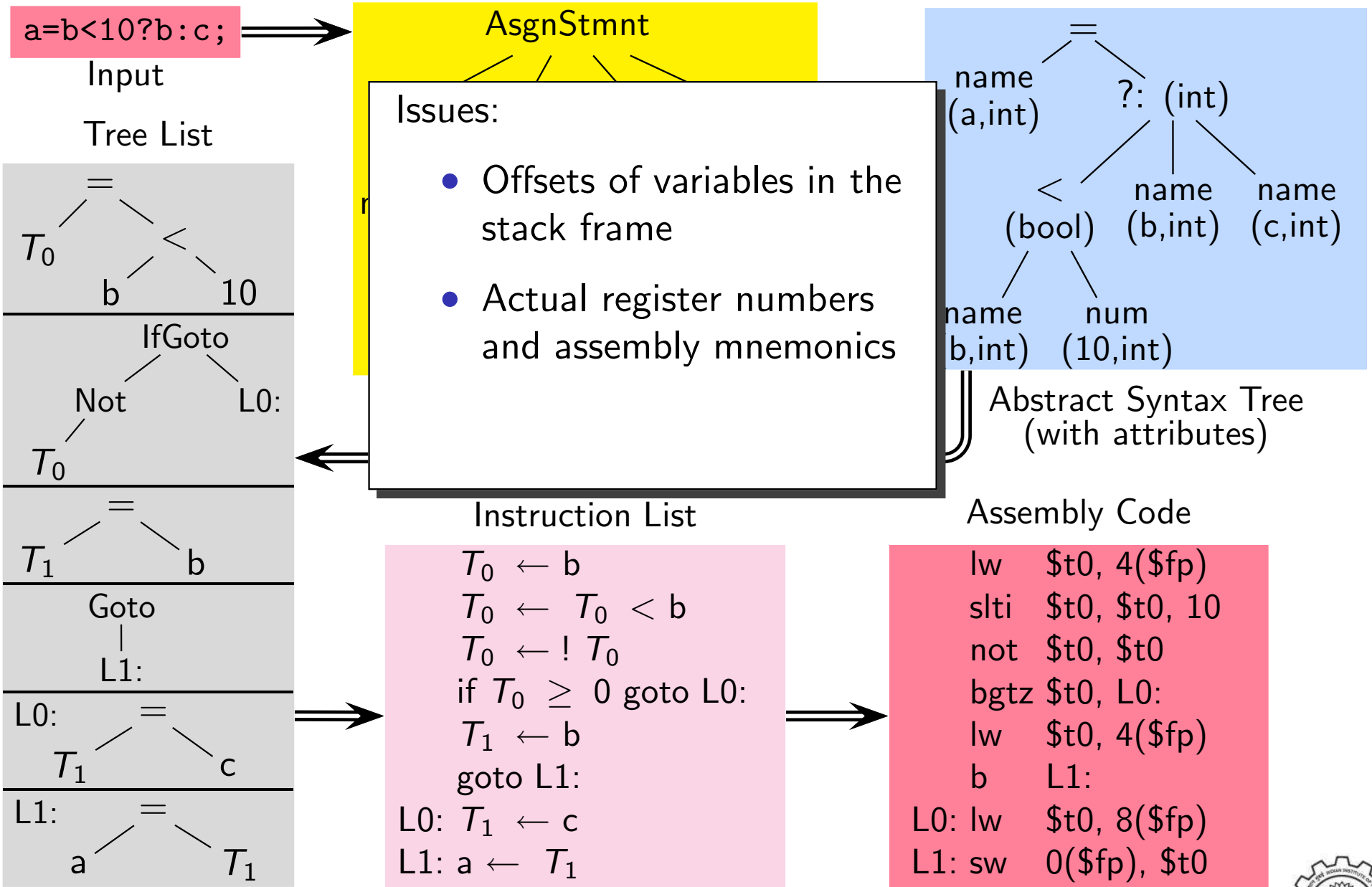

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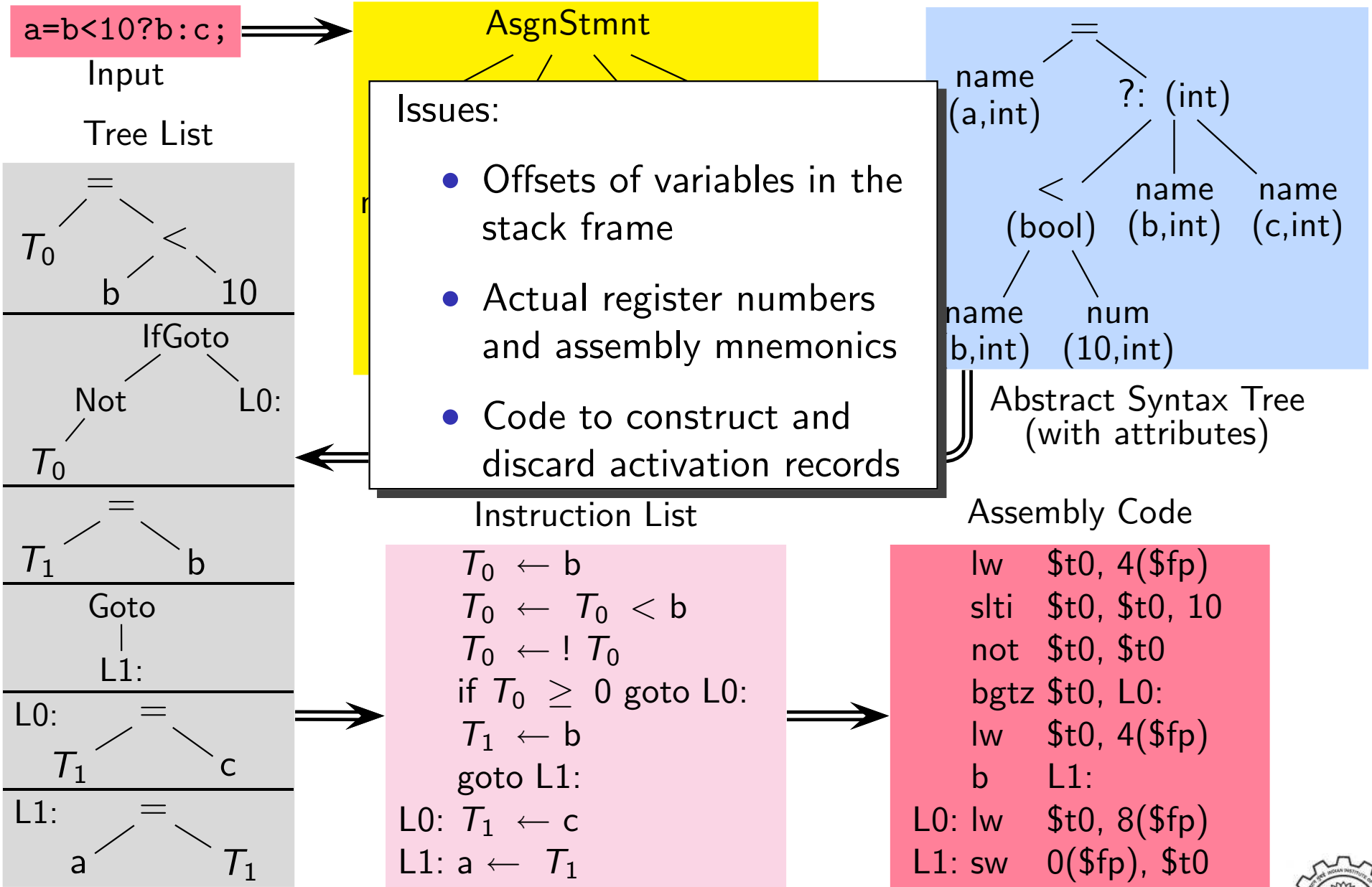

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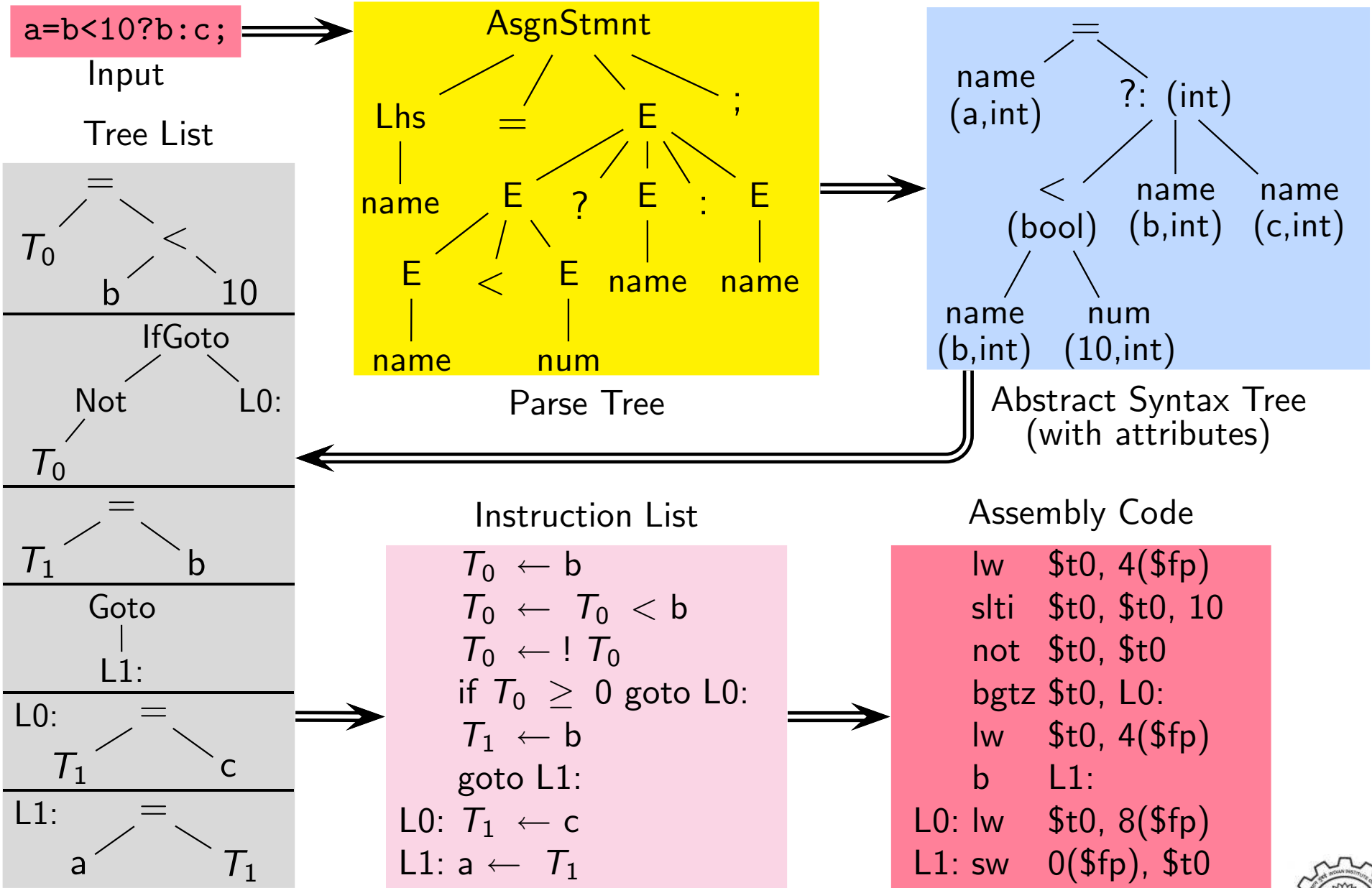
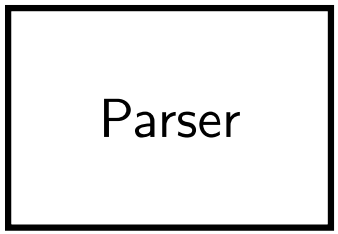


Typical Front Ends



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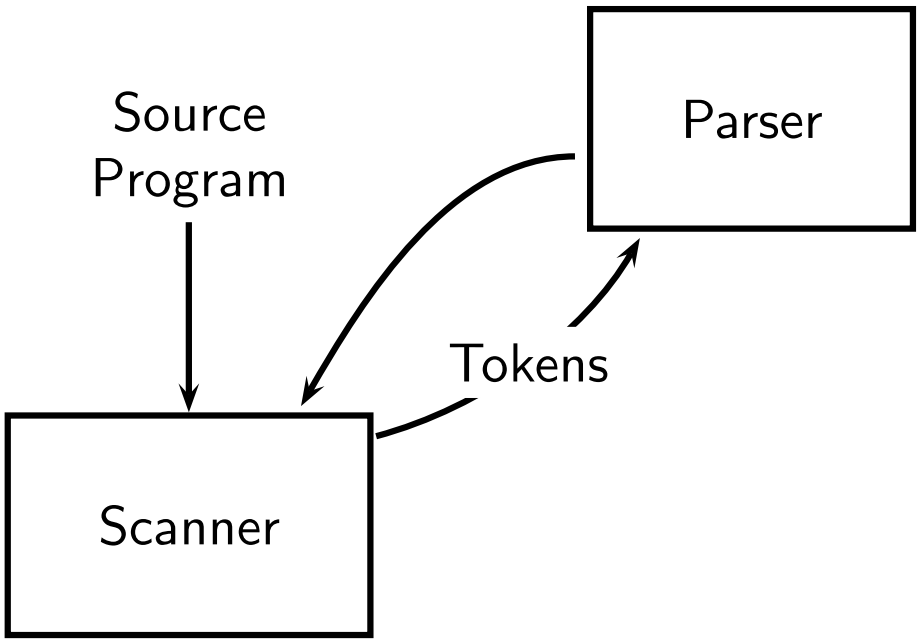

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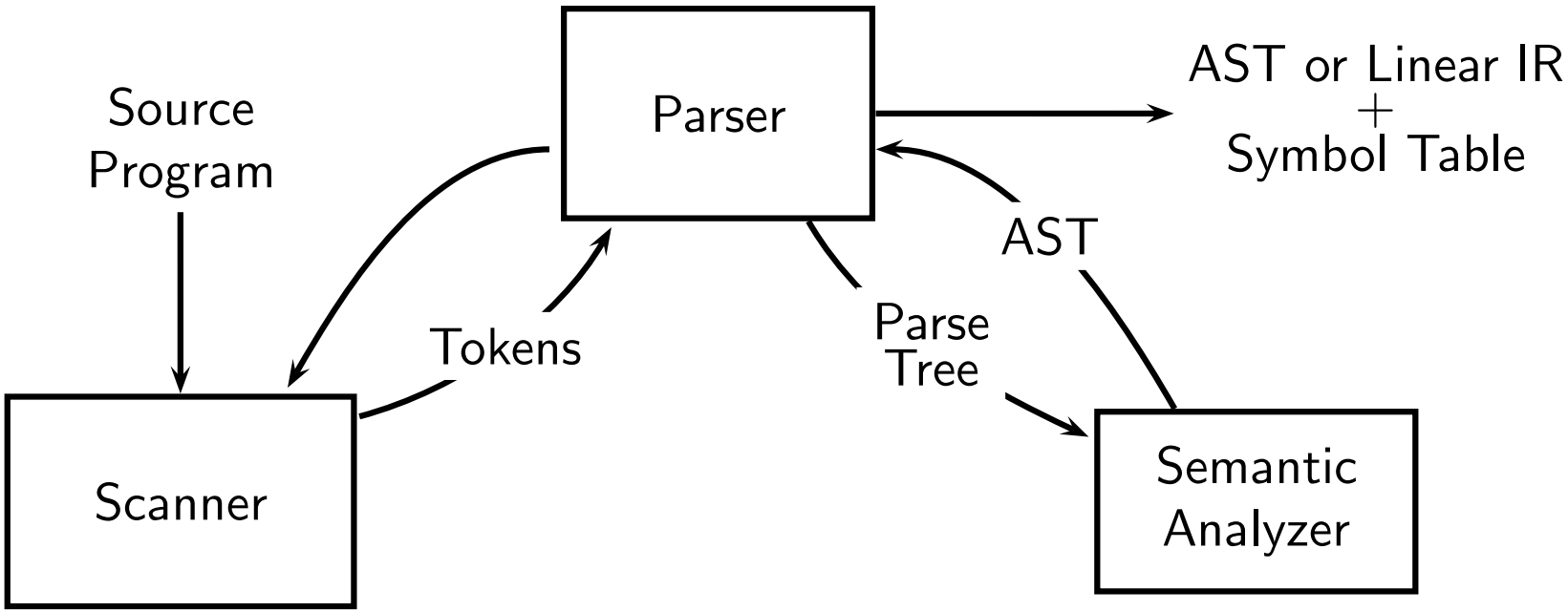
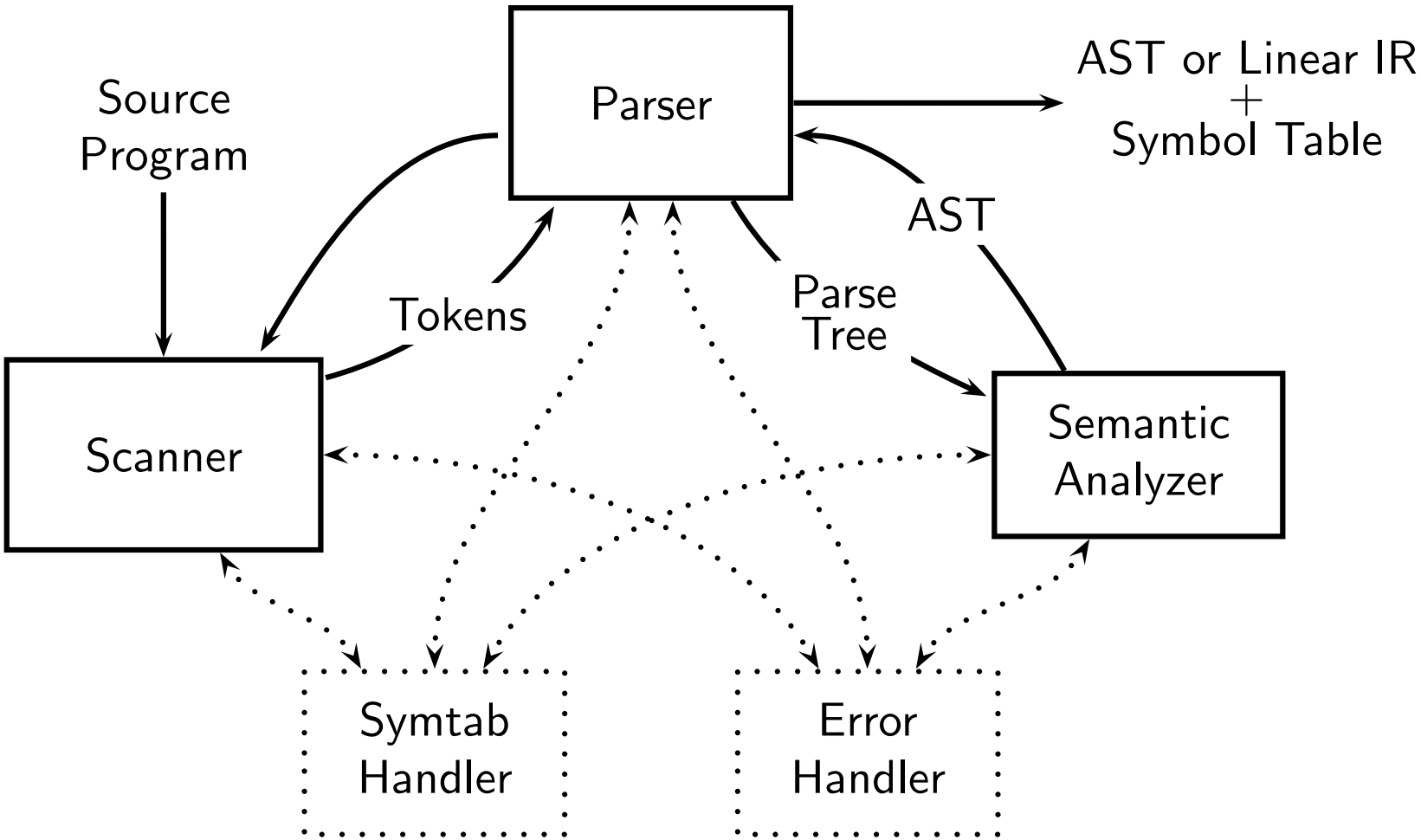
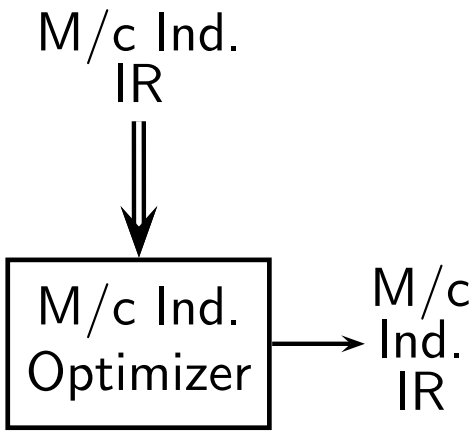


Typical Front Ends

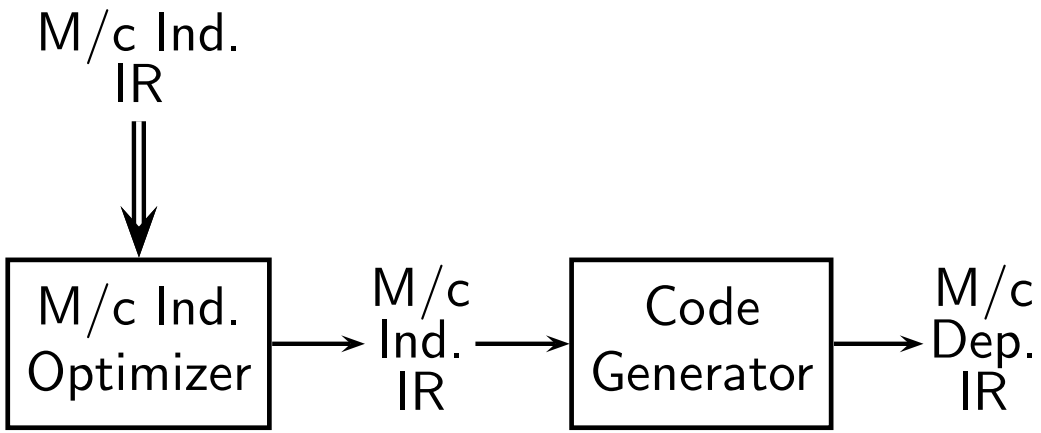


Typical Back Ends



- Compile time evaluations
- Eliminating redundant computations

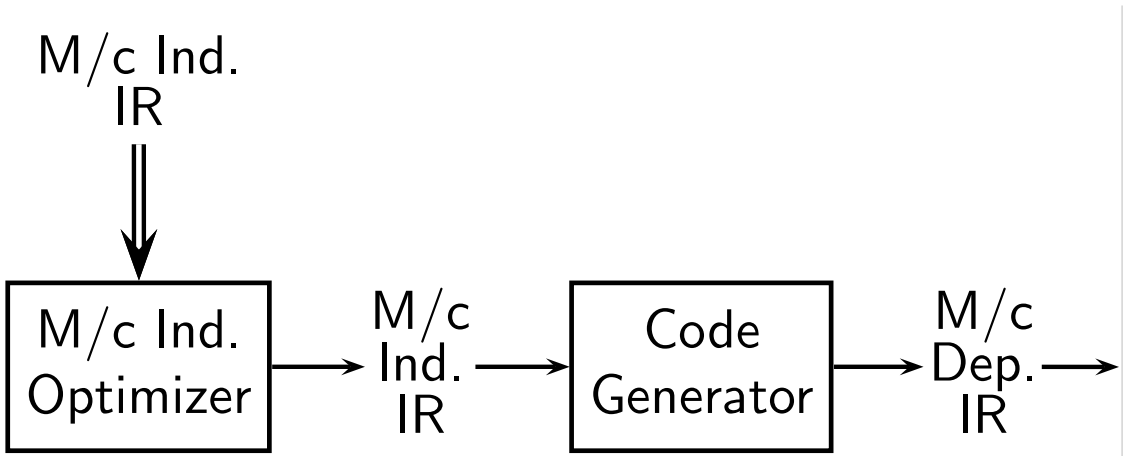
Typical Back Ends



- Compile time evaluations
- Eliminating redundant computations

- Instruction Selection
- Local Reg Allocation
- Choice of Order of Evaluation

Typical Back Ends



- Compile time evaluations
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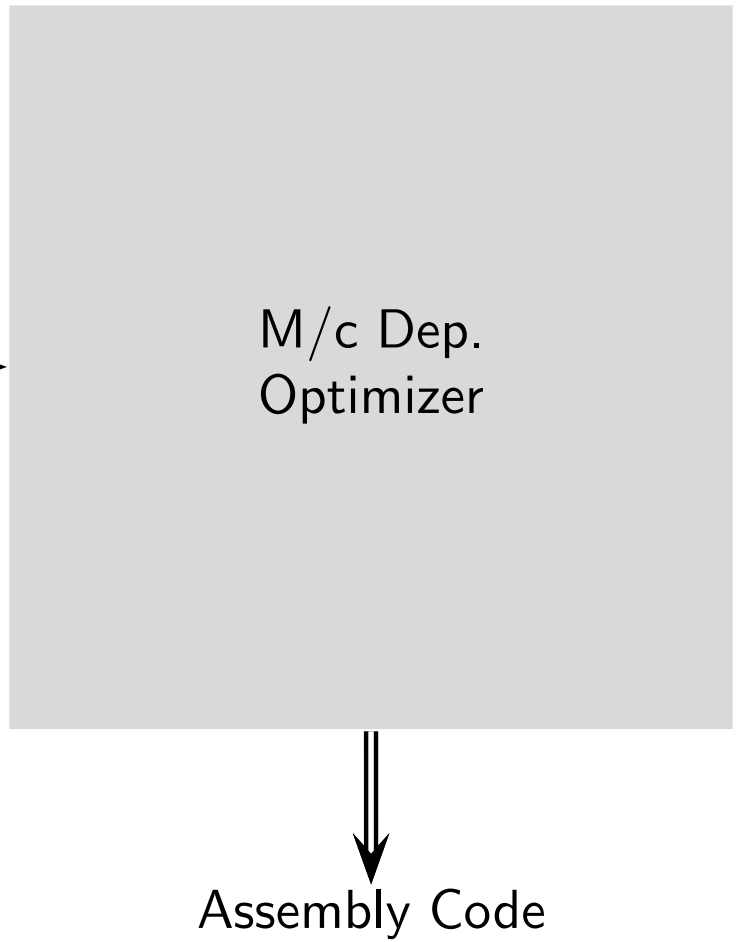
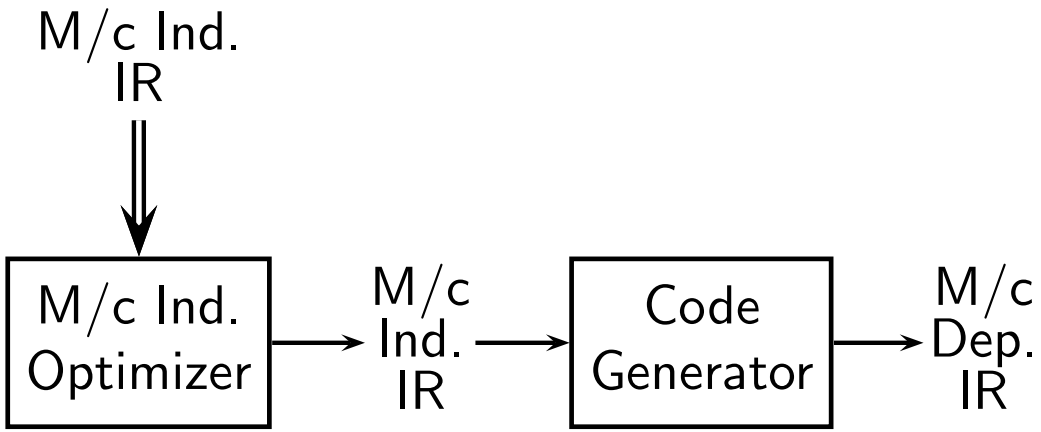


Typical Back Ends



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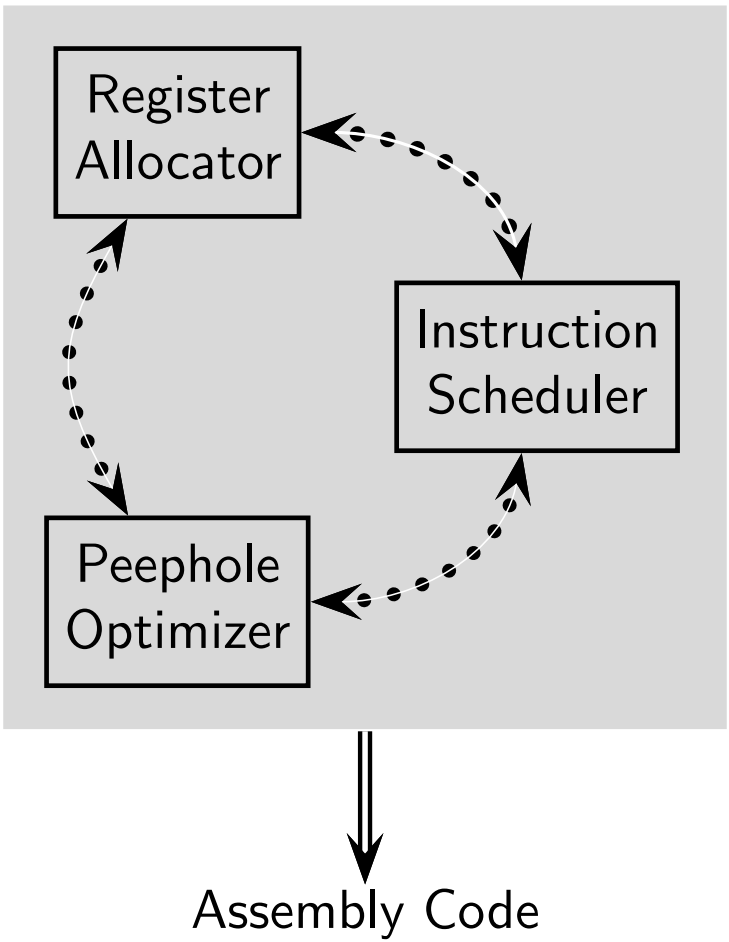
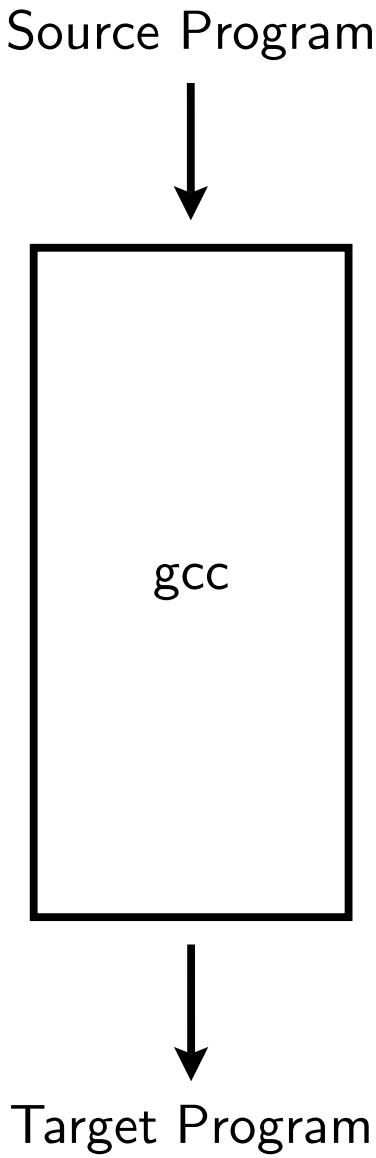


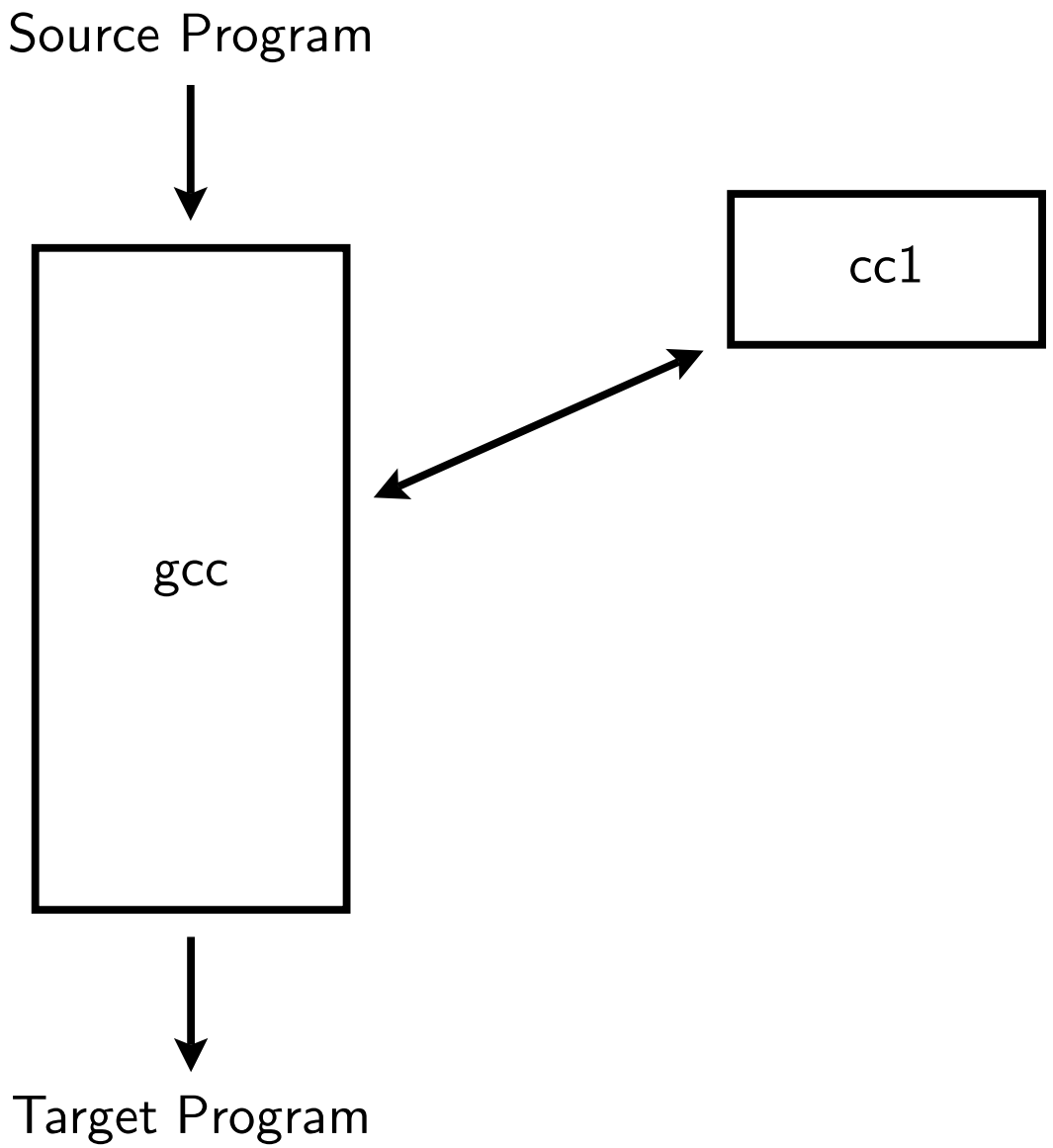
Part 4

Introduction to GCC

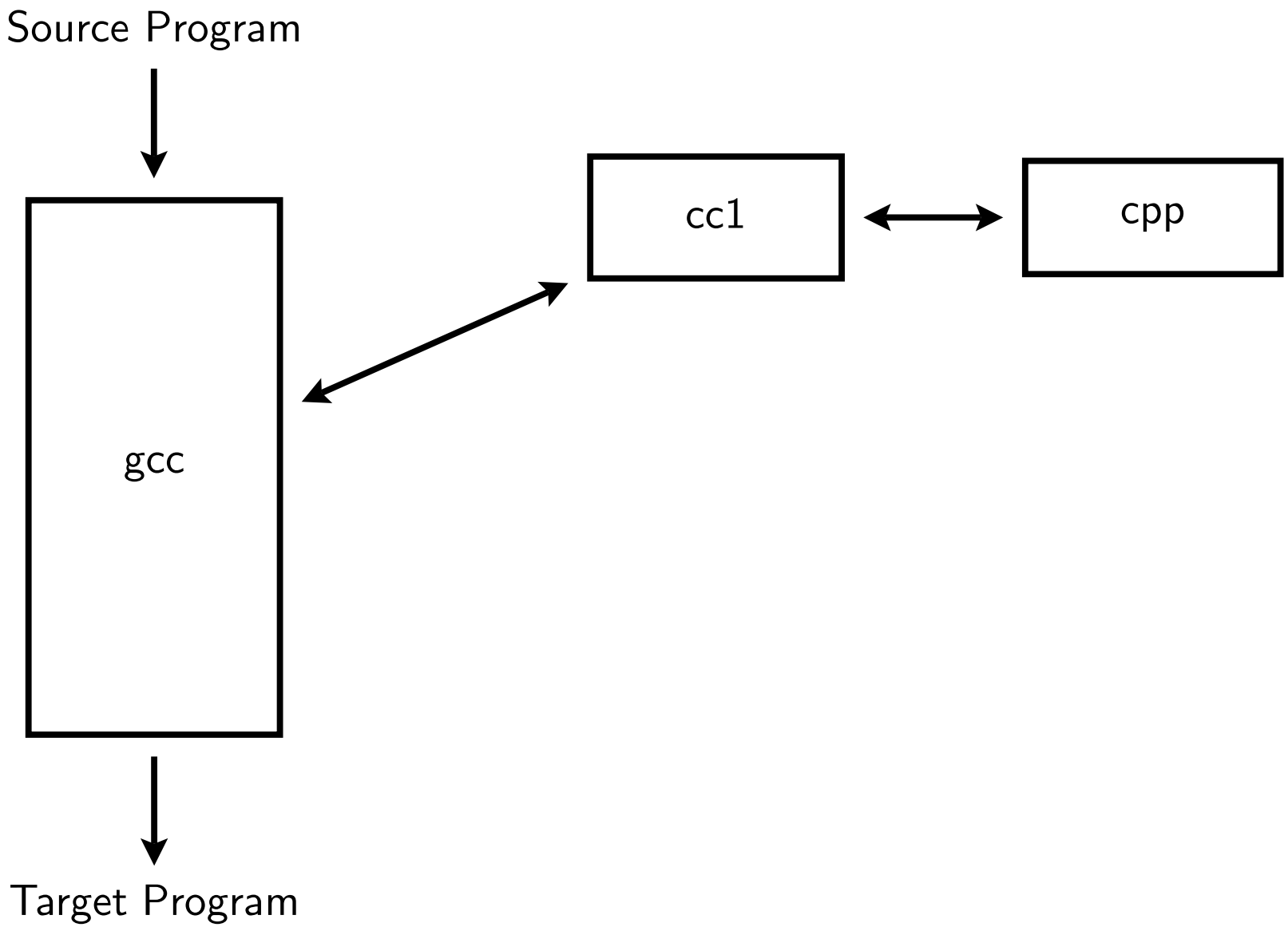
The GNU Tool Chain



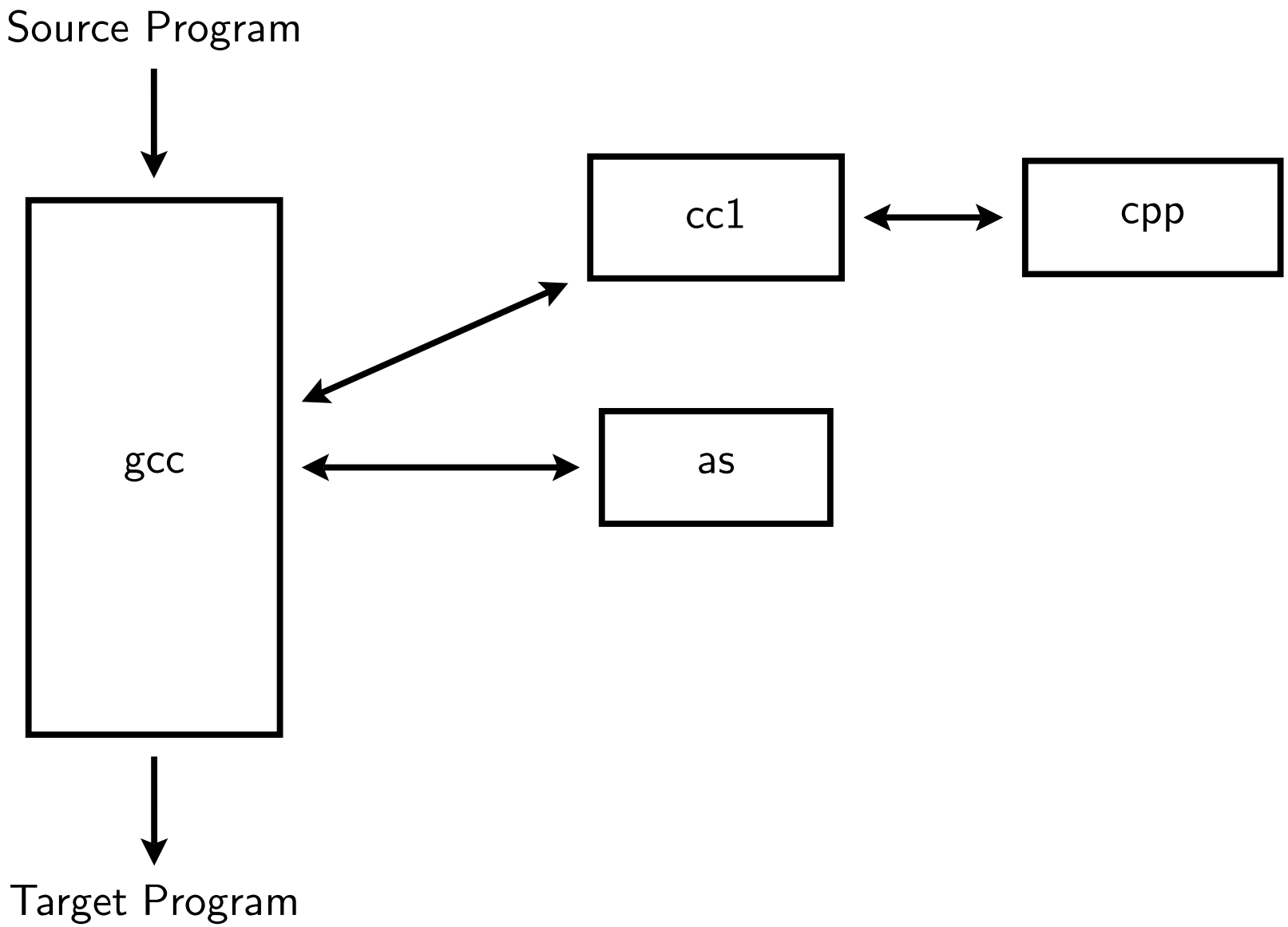
The GNU Tool Chain



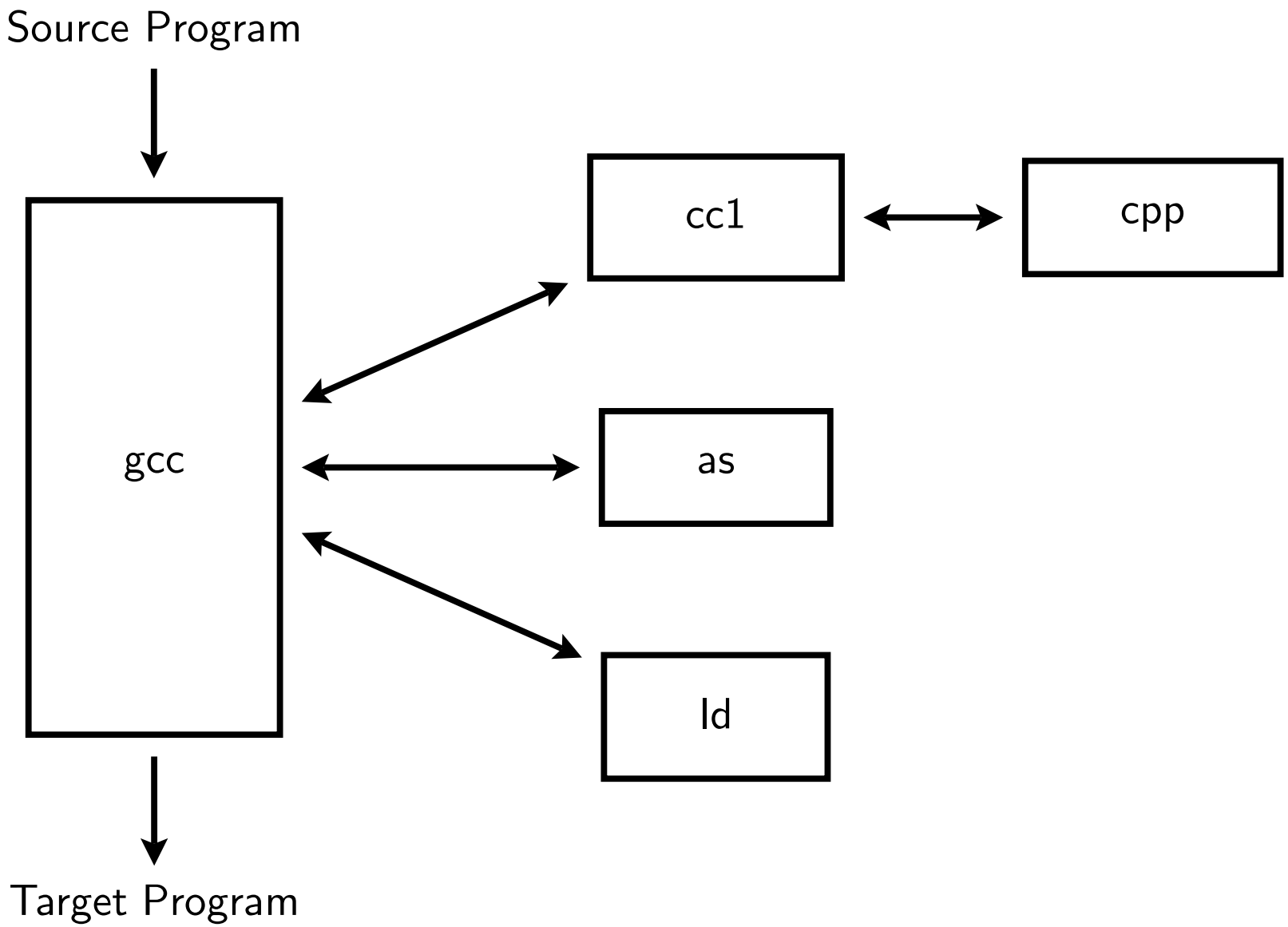
The GNU Tool Chain



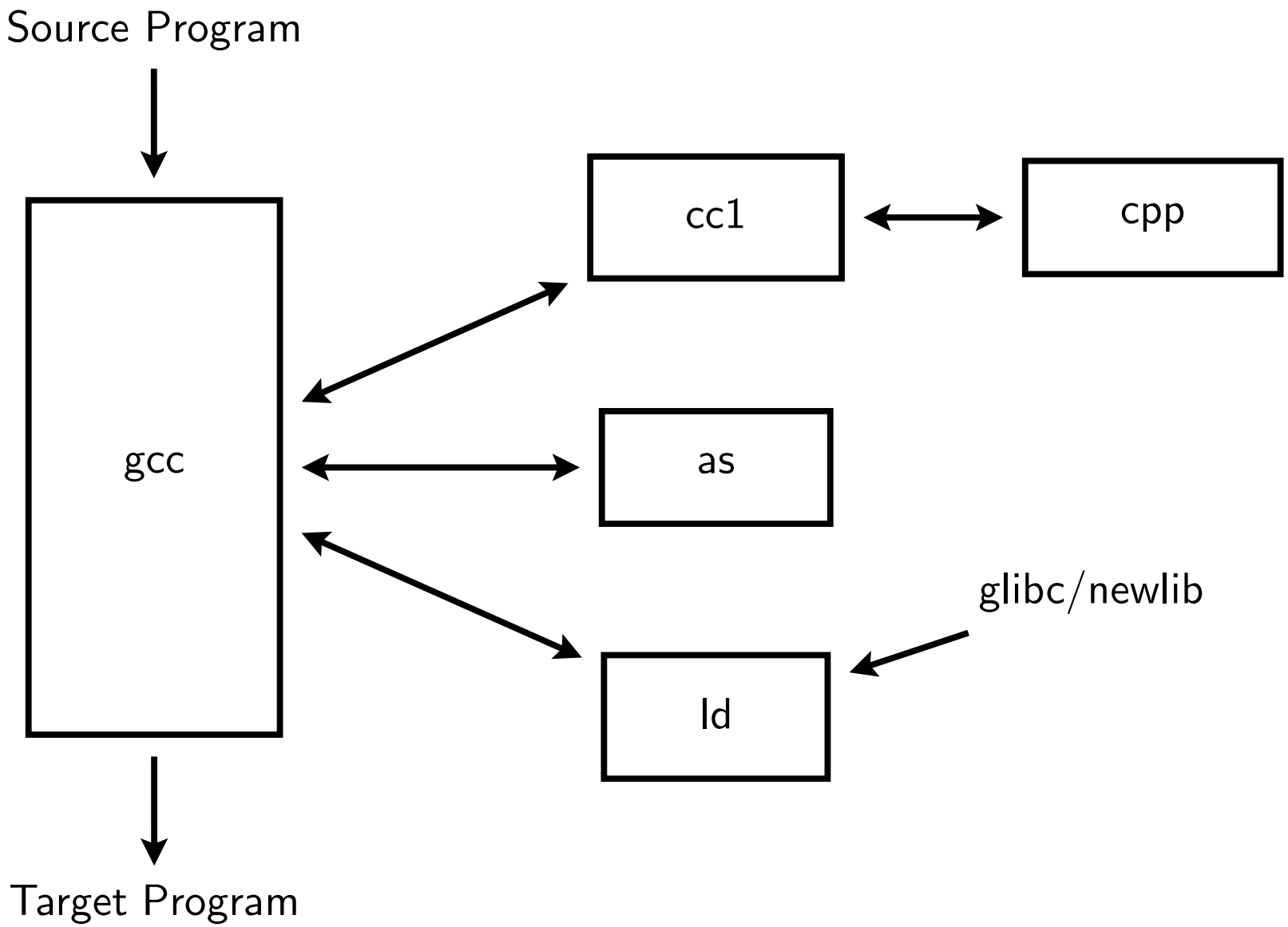
The GNU Tool Chain



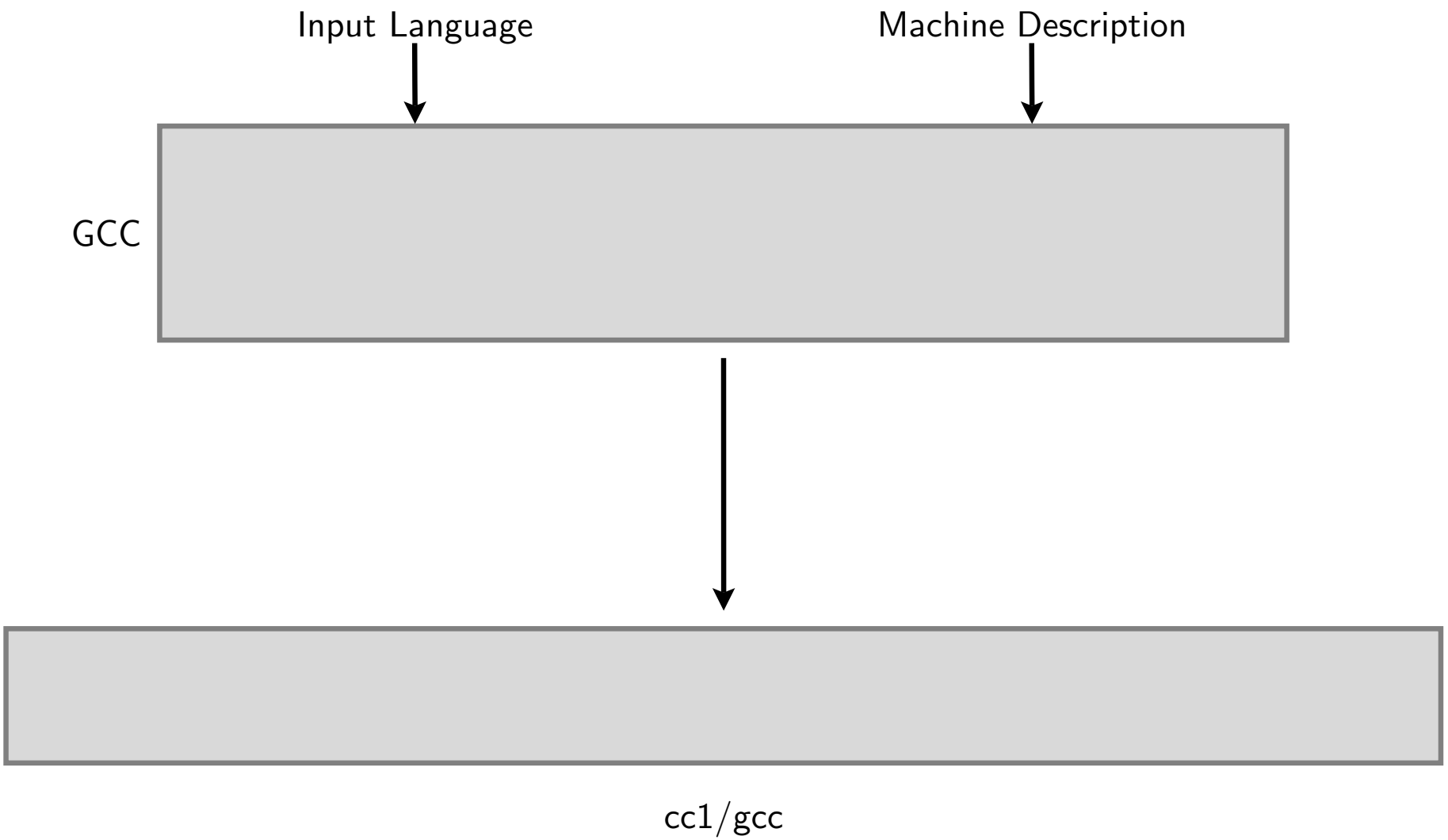
The GNU Tool Chain



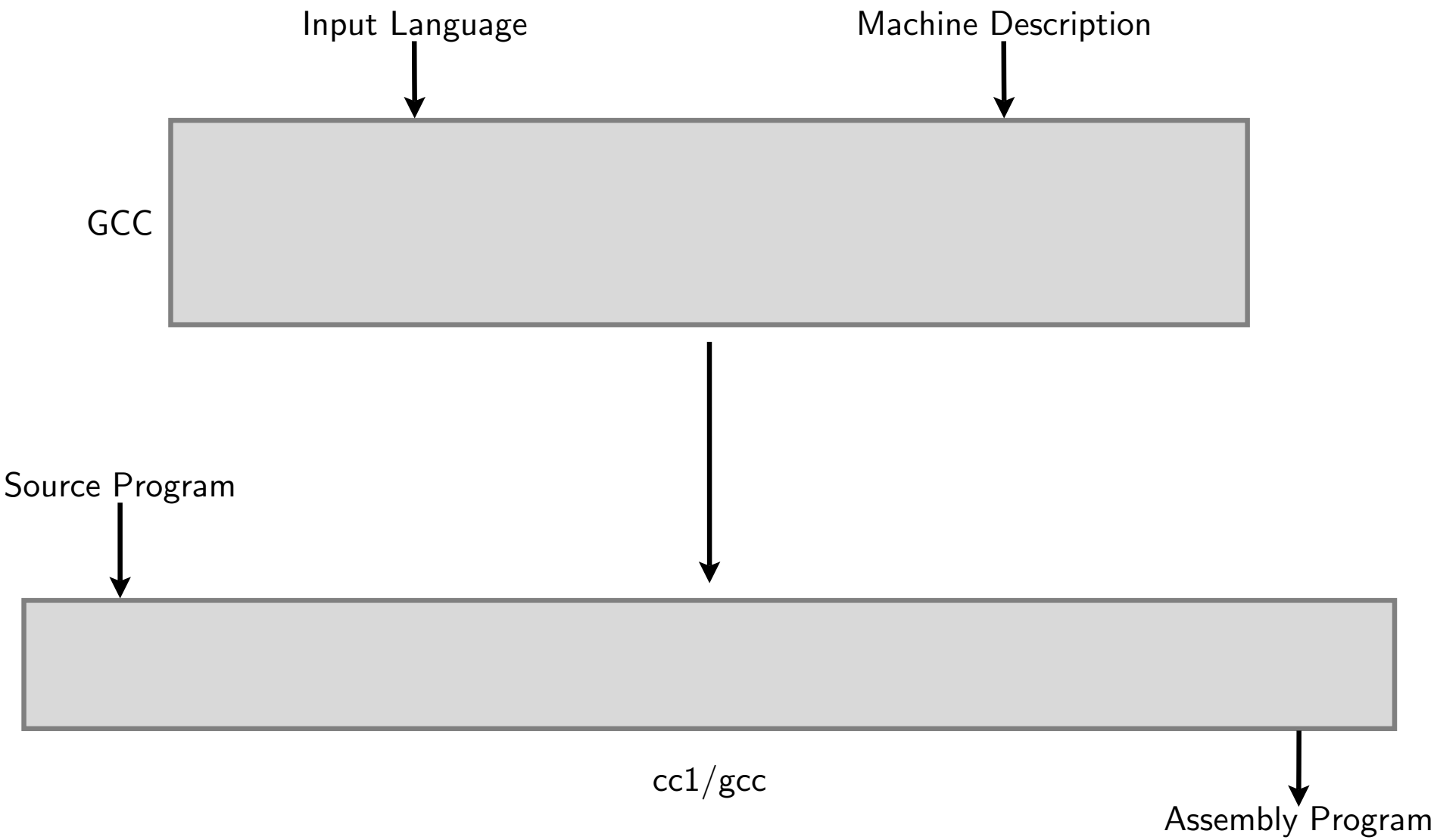
The GNU Tool Chain



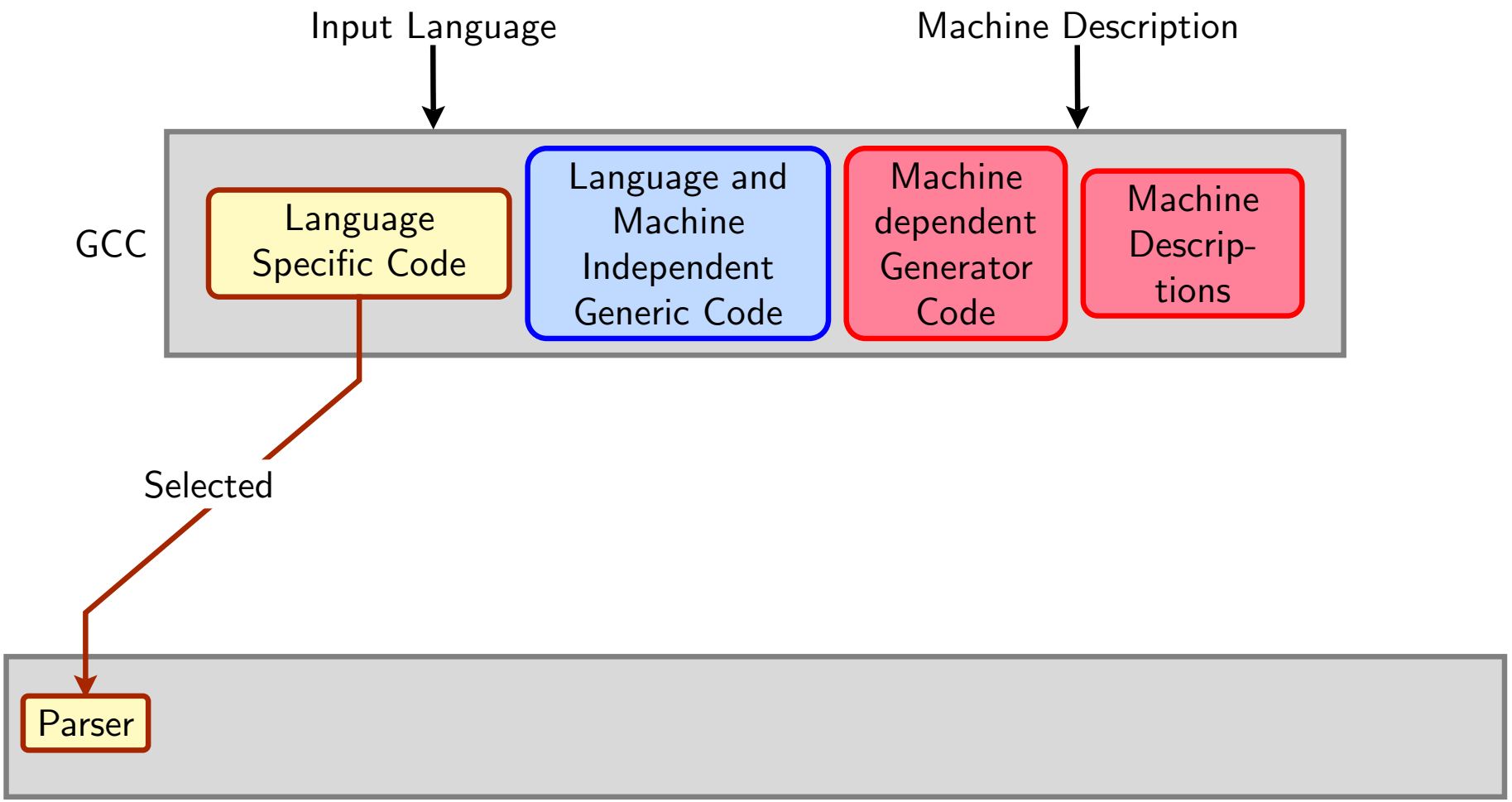
The GCC Framework



The GCC Framework

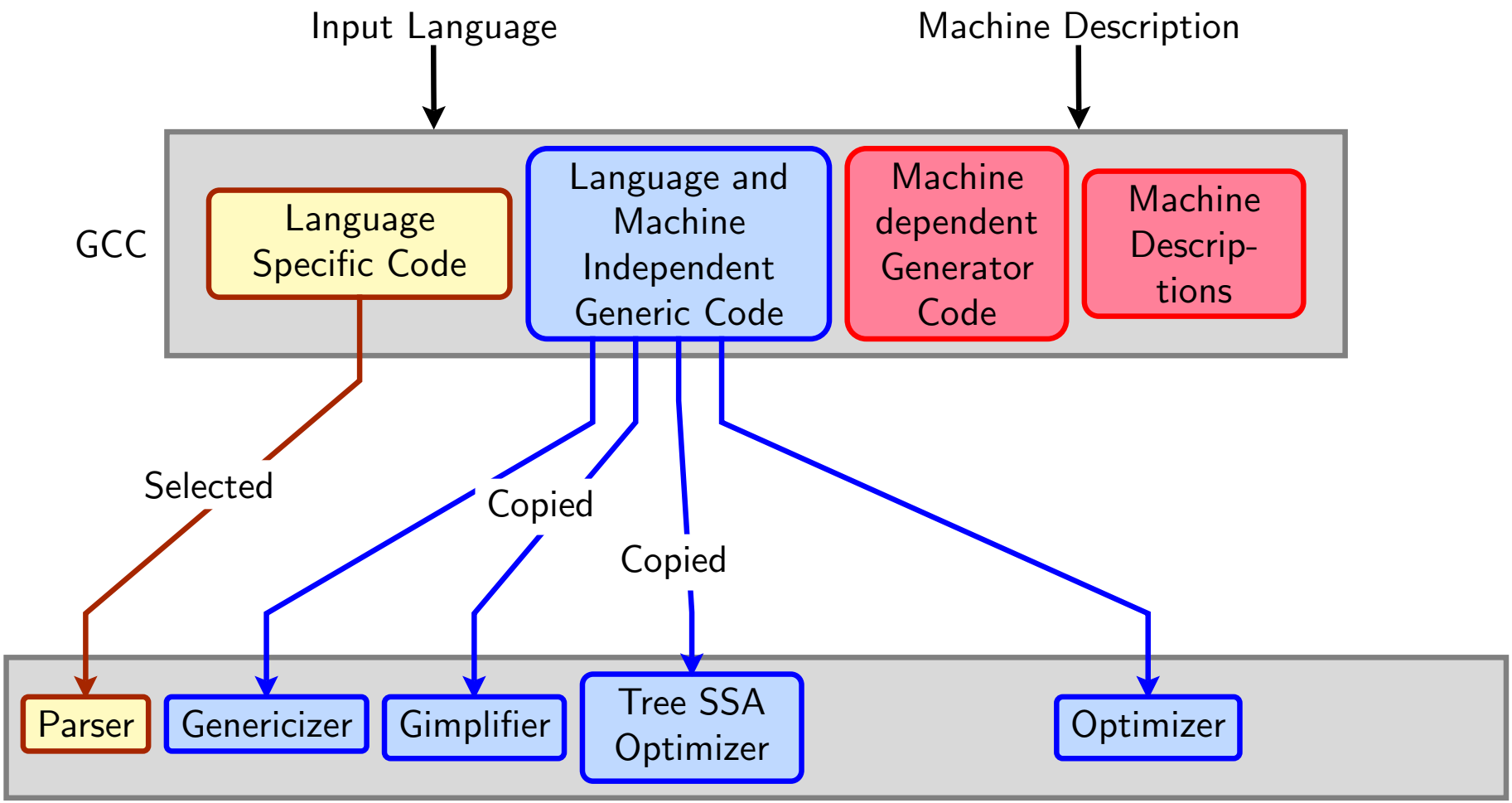


The GCC Framework



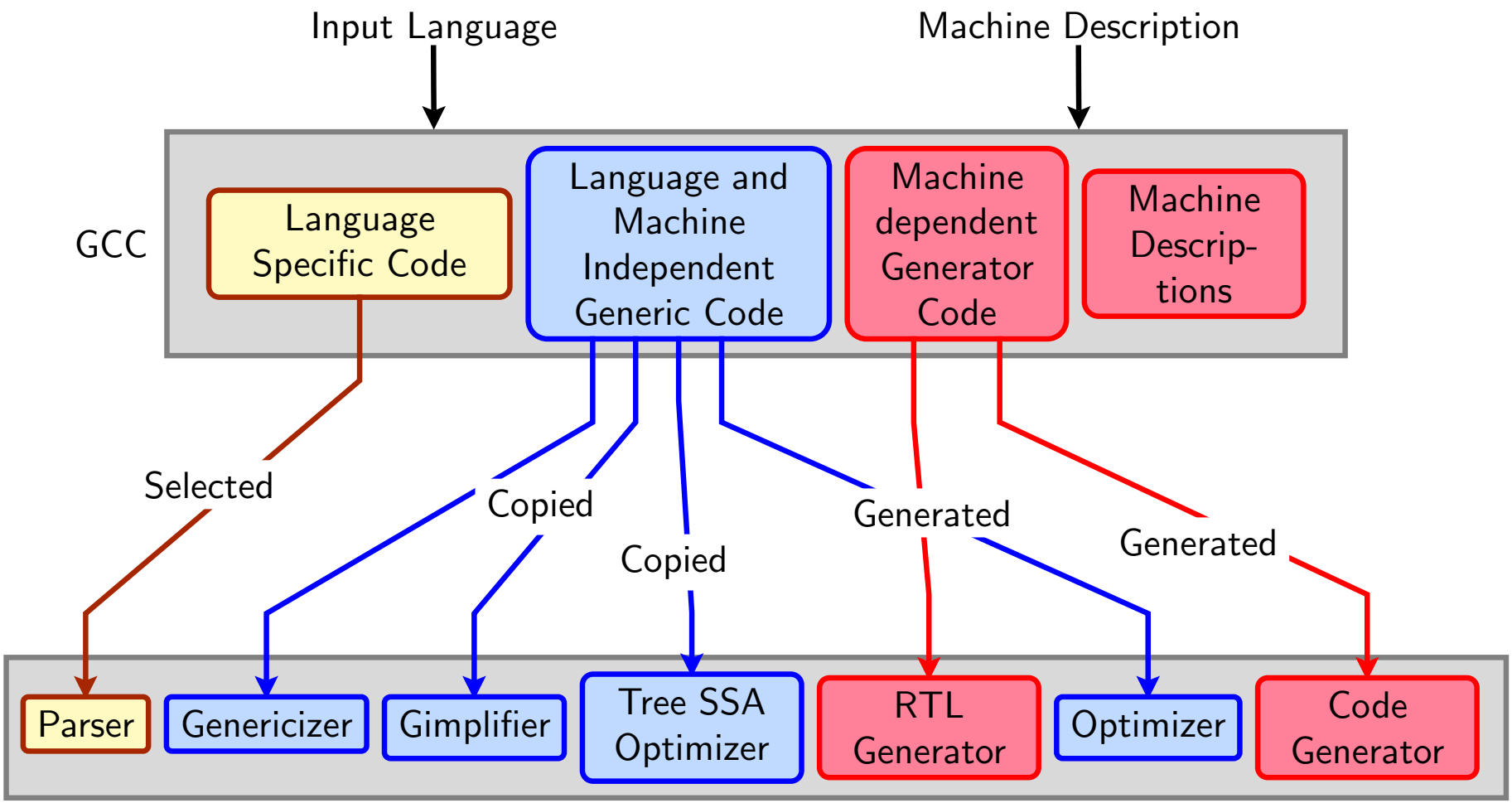
cc1/gcc

The GCC Framework



cc1/gcc

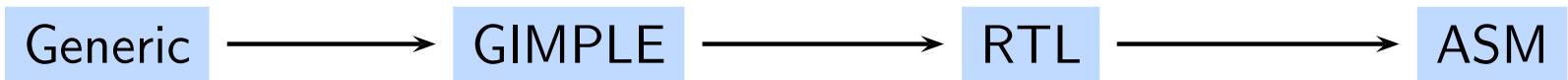
The GCC Framework



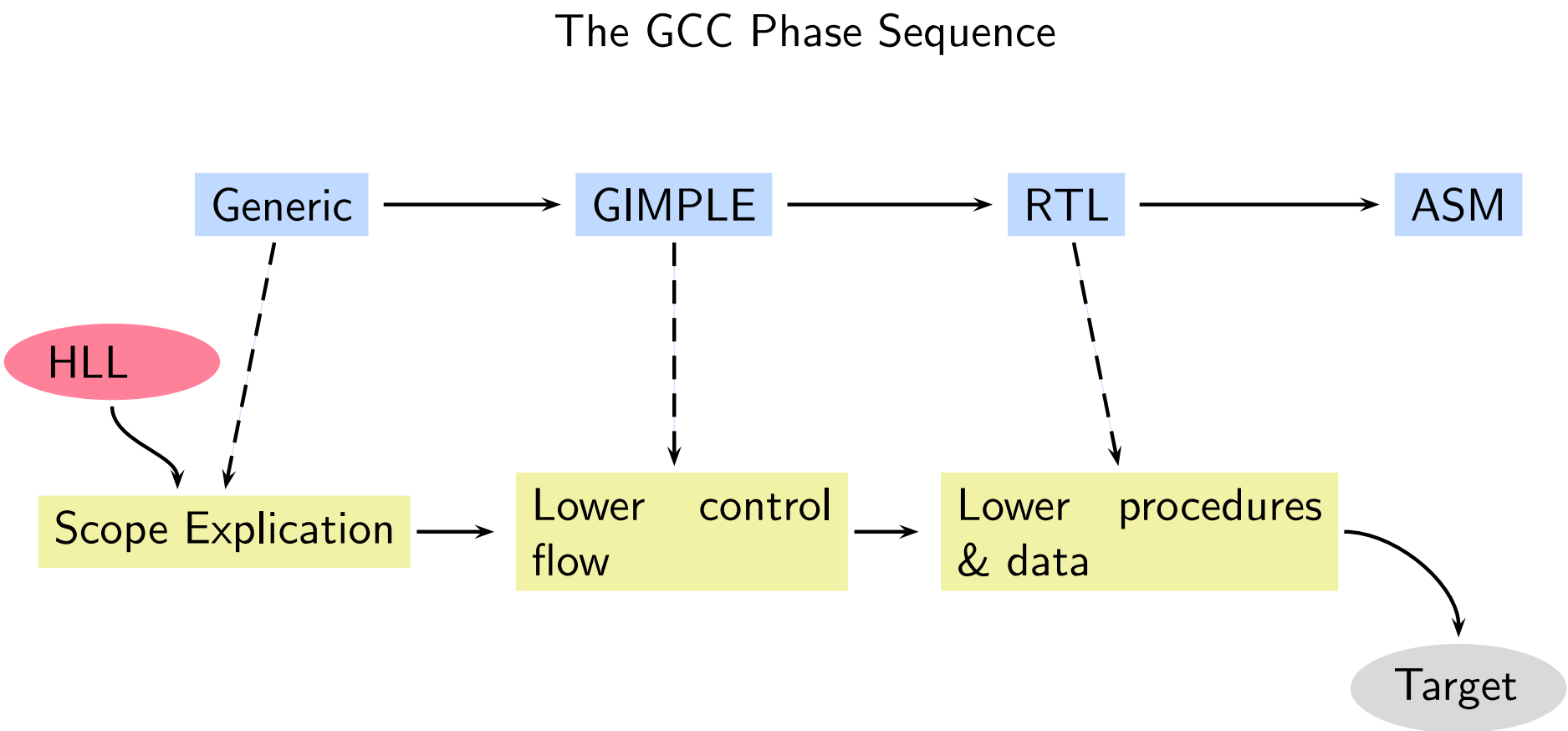
cc1/gcc

The `cc1` Phase Sequence as IR Chain

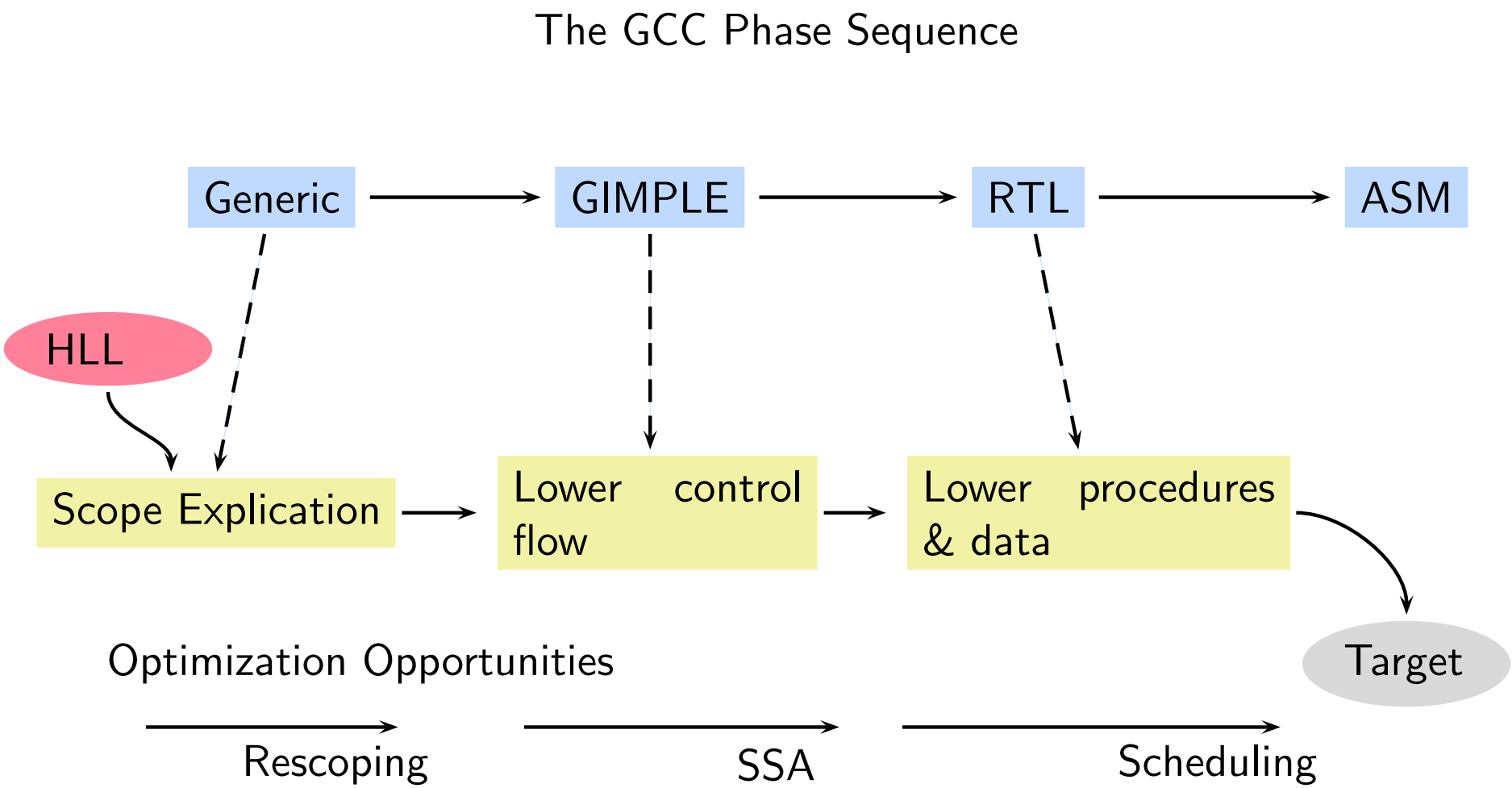
The GCC Phase Sequence



The `cc1` Phase Sequence as IR Chain



The `cc1` Phase Sequence as IR Chain



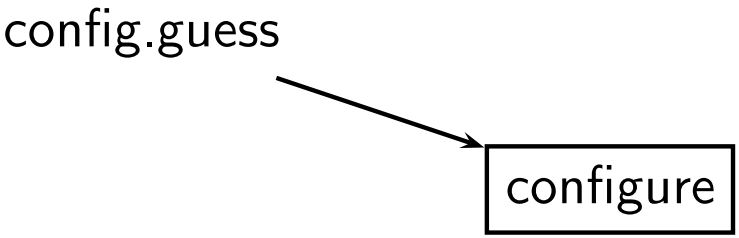
Part 5

Configuration and Building

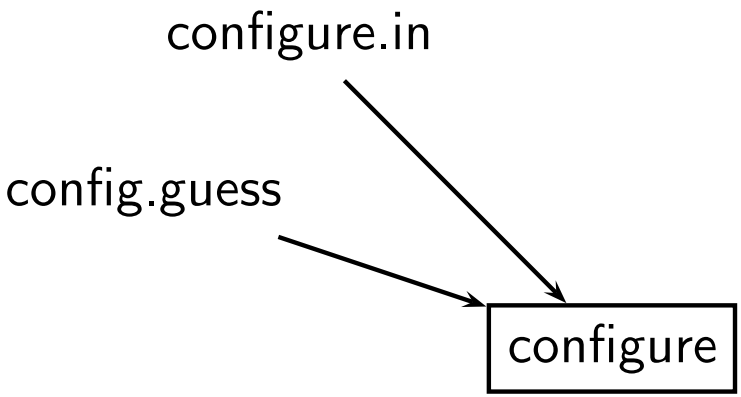
Configuring GCC

configure

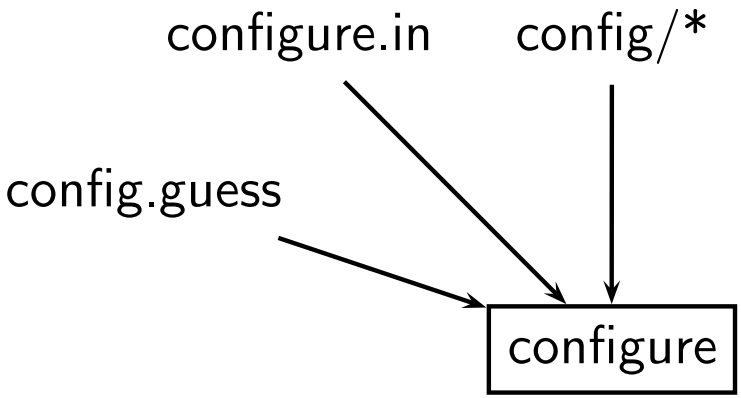
Configuring GCC



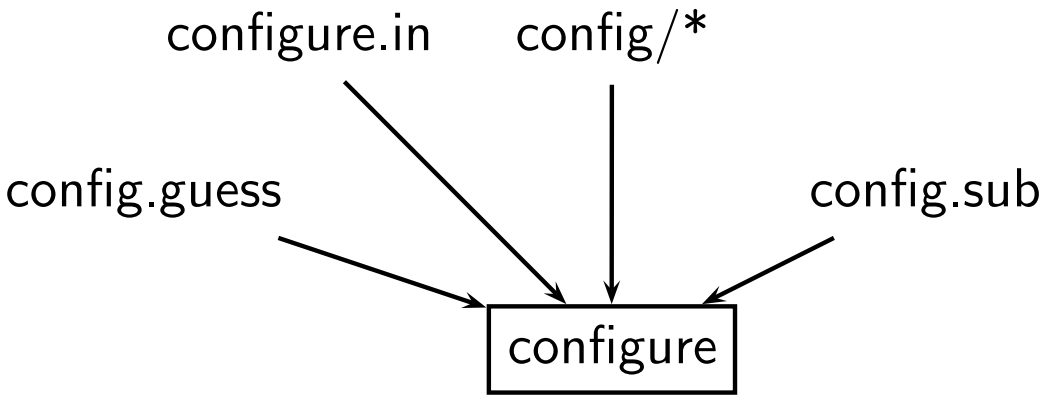
Configuring GCC



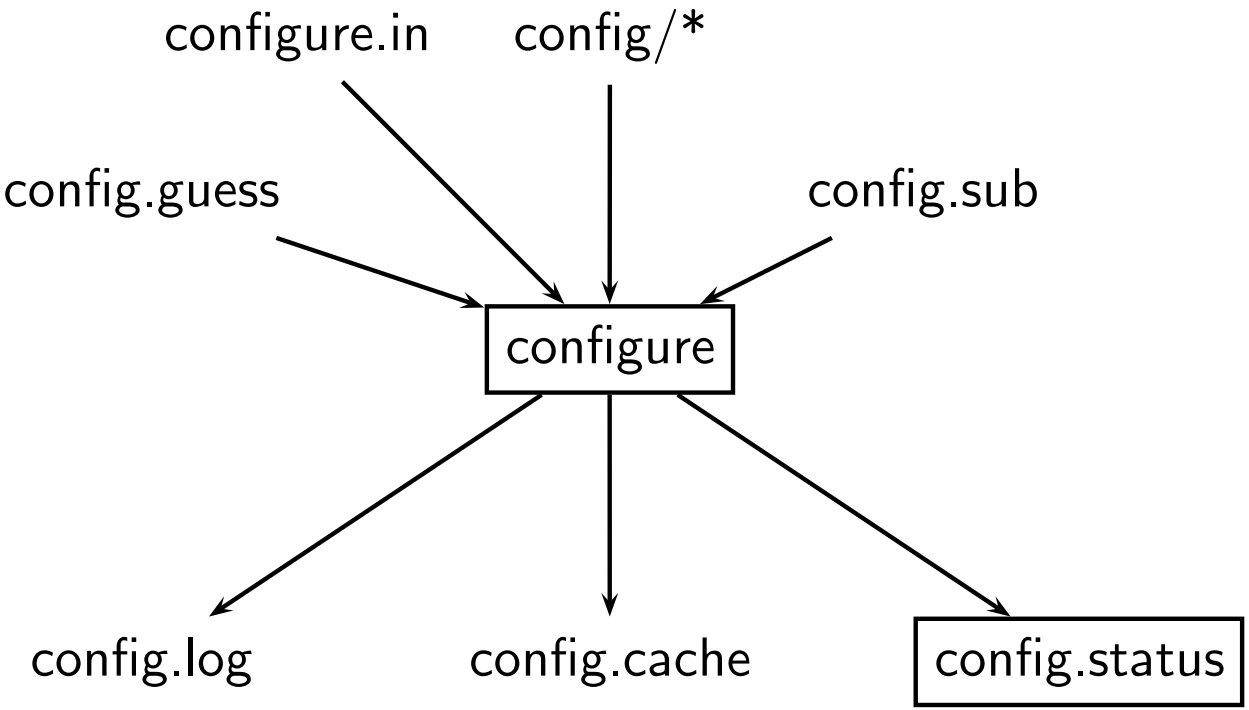
Configuring GCC



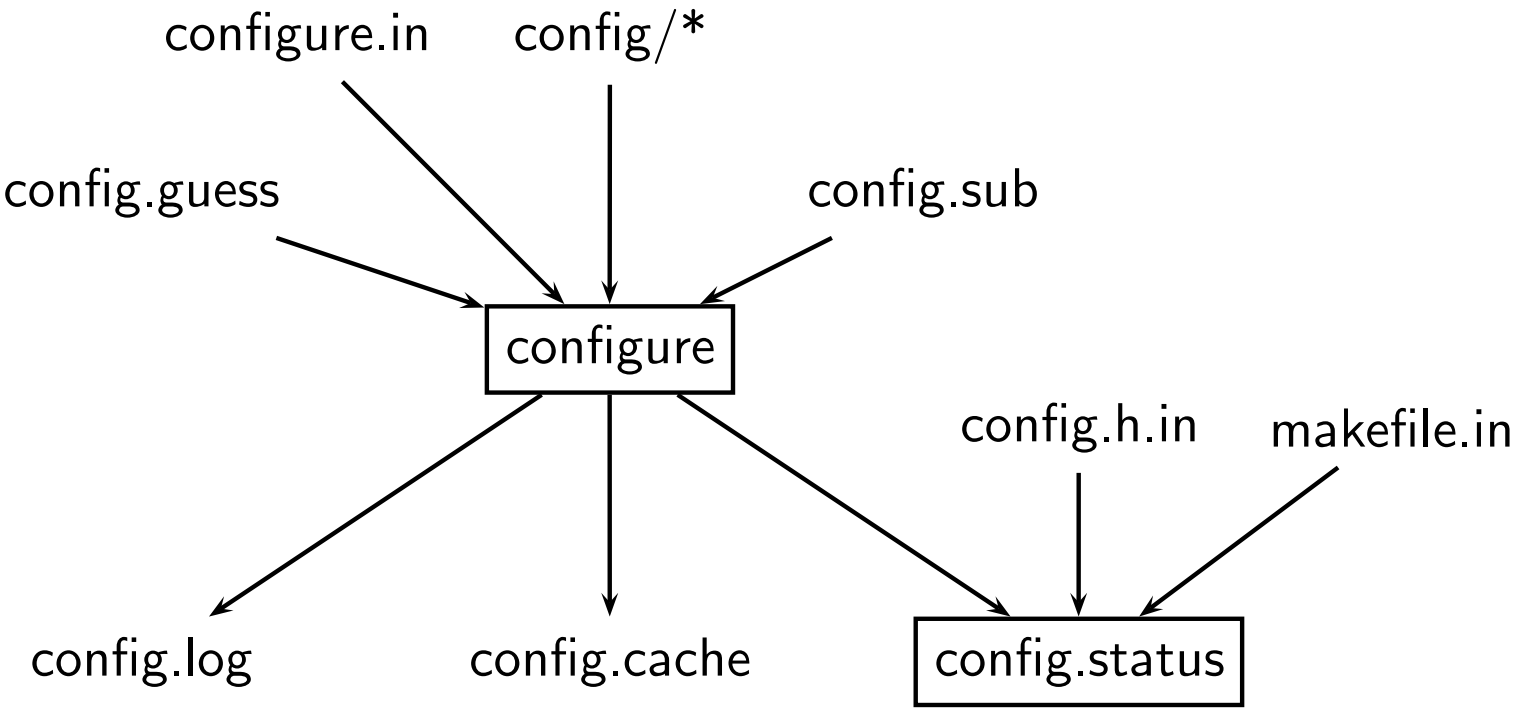
Configuring GCC



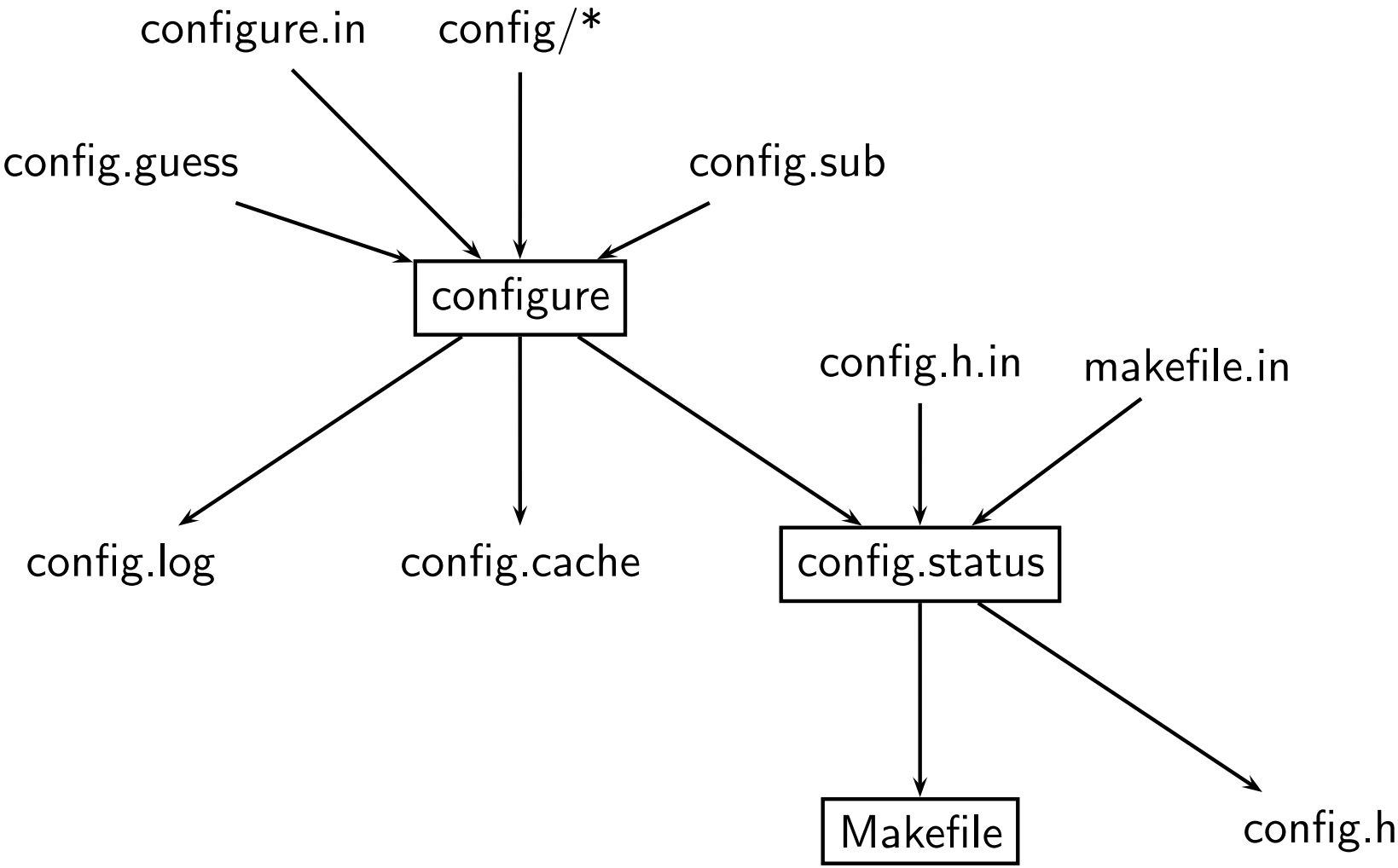
Configuring GCC



Configuring GCC



Configuring GCC



Part 6

About The Course