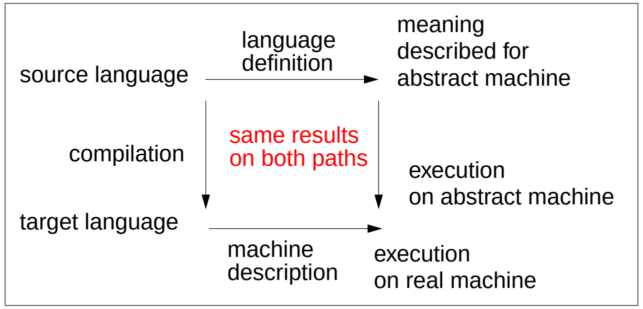
1. Language properties - compiler tasks
Meaning preserving transformation

A **compiler** transforms **any correct sentence** of its **source language** into a sentence of its **target language** such that its **meaning is unchanged**.


source language
language definition
meaning described for abstract machine
compilation
same results on both paths
execution on abstract machine
target language
machine description
execution on real machine

A **meaning** is defined only for **all correct** programs => compiler task: error handling

Static language properties are analyzed at **compile time,** e. g. definitions of Variables, types of expressions; => determine the transformation, if the program **compilable**

Dynamic properties of the program are determined and checked at **runtime,** e. g. indexing of arrays => determine the effect, if the program **executable** (However, just-in-time compilation for Java: bytecode is compiled at runtime.)

Levels of language properties - compiler tasks

- **a. Notation of tokens** — **lexical analysis**
  keywords, identifiers, literals
  formal definition: **regular expressions**
- **b. Syntactic structure** — **syntactic analysis**
  formal definition: **context-free grammar**
- **c. Static semantics** — **semantic analysis, transformation**
  binding names to program objects, typing rules
  usually defined by informal texts,
  formal definition: **attribute grammar**
- **d. Dynamic semantics** — **transformation, code generation**
  semantics, effect of the execution of constructs
  usually defined by informal texts
  in terms of an abstract machine**,**
  formal definition: **denotational semantics**

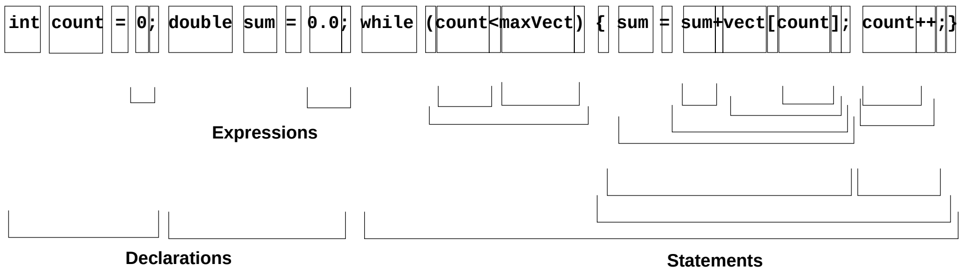
Definition of target language (target machine) — **transformation, code generation assembly**

Example: Tokens and structure

Character sequence

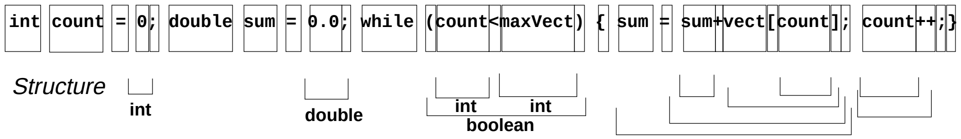
```
int count = 0; double sum = 0.0; while (count<maxVect) { sum = sum+vect[count]; count++;}
```

Tokens



Structure

Example: Names, types, generated code



k1: (count, local variable, int)
k2: (sum, local variable, double)
k3: (maxVect, member variable, int)
k4: (vect, member variable, double array)
. . .

Static properties: names and types

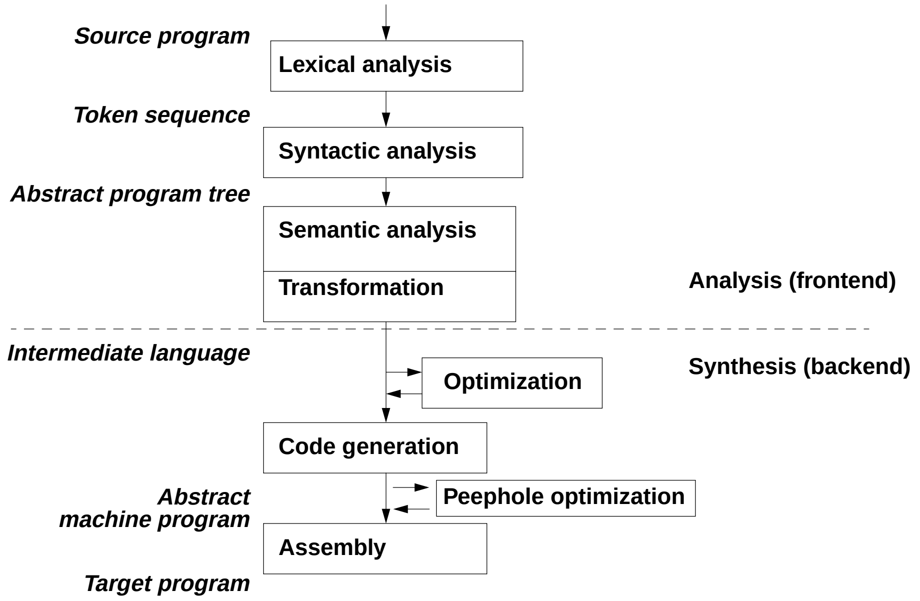
generated Bytecode

```
0 iconst_0                  12 faload
1 istore_1                  13 f2d
2 dconst_0                  14 dadd
3 dstore_2                  15 dstore_2
4 goto 19                   16 iinc 1 1
7 dload_2                   19 iload_1
8 getstatic #5 <vect[]>     20 getstatic #4 <maxVect>
11 iload_1                  23 if_icmplt 7
```

Compiler tasks

Structuring	Lexical analysis	Scanning Conversion
	Syntactic analysis	Parsing Tree construction
Translation	Semantic analysis	Name analysis Type analysis
	Transformation	Data mapping Action mapping
Encoding	Code generation	Execution-order Register allocation Instruction selection
	Assembly	Instruction encoding Internal Addressing External Addressing

Compiler structure and interfaces



Software qualities of the compiler

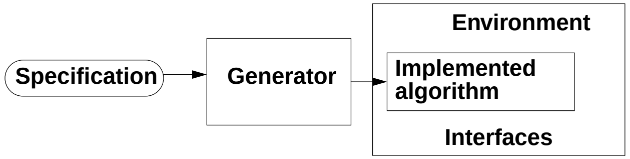
- **Correctness** Compiler translates correct programs correctly; rejects wrong programs and gives error messages
- **Efficiency** Storage and time used by the compiler
- **Code efficiency** Storage and time used by the generated code; compiler task: optimization
- **User support** Compiler task: Error handling (recognition, message, recovery)
- **Robustness** Compiler gives a reasonable reaction on every input; does not break on any program

Strategies for compiler construction

- **Obey exactly to the language definition**
- **Use generating tools**
- **Use standard components**
- **Apply standard methods**
- **Validate the compiler against a test suite**
- **Verify components of the compiler**

Generate from specifications

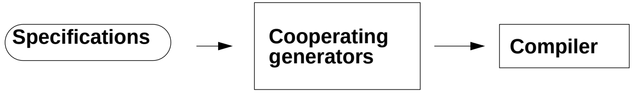
Pattern:



Typical compiler tasks solved by generators:

Regular expressions	**Scanner generator**	Finite automaton
Context-free grammar	**Parser generator**	Stack automaton
Attribute grammar	**Attribute evaluator generator**	Tree walking algorithm
Code patterns	**Code selection generator**	Pattern matching

integrated system Eli:



Compiler Frameworks (Selection)

Amsterdam Compiler Kit: (Uni Amsterdam)
The Amsterdam Compiler Kit is fast, lightweight and retargetable compiler suite and toolchain written by Andrew Tanenbaum and Ceriel Jacobs.
Intermediate language EM, set of frontends and backends

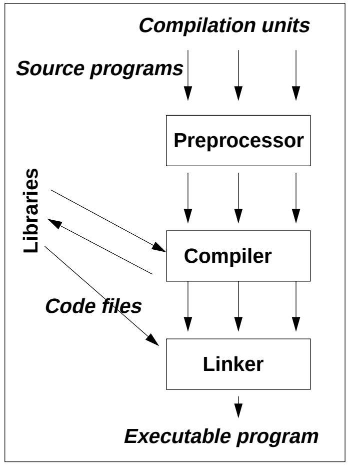
ANTLR: (Terence Parr, Uni San Francisco)
ANother Tool for Language Recognition, (formerly PCCTS) is a language tool that provides a framework for constructing recognizers, compilers, and translators from grammatical descriptions containing Java, C#, C++, or Python actions

CoCo: (Uni Linz)
Coco/R is a compiler generator, which takes an attributed grammar of a source language and generates a scanner and a parser for this language. The scanner works as a deterministic finite automaton. The parser uses recursive descent.

Eli: (Unis Boulder, Paderborn, Sydney)
Combines a variety of standard tools that implement powerful compiler construction strategies into a domain-specific programming environment called Eli. Using this environment, one can automatically generate complete language implementations from application-oriented specifications.

SUIF: (Uni Stanford)
The SUIF 2 compiler infrastructure project is co-funded by DARPA and NSF.
It is a free infrastructure designed to support collaborative research in optimizing and parallelizing compilers.

Environment of compilers



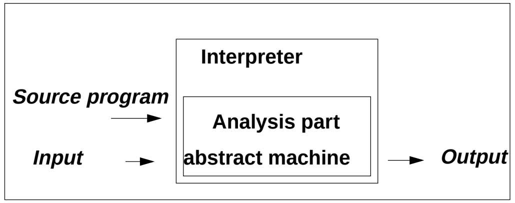
Preprocessor cpp substitutes text macros in source programs, e.g.

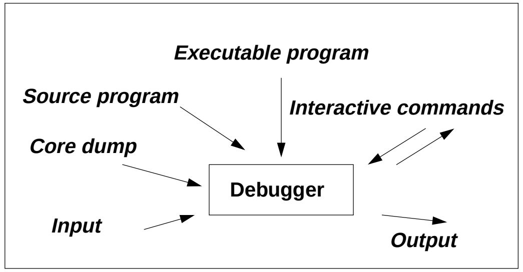
```
#include <stdio.h>
#include "module.h"

#define SIZE 32
#define SEL(ptr,fld) ((ptr)->fld)
```

Separate compilation of compilation units

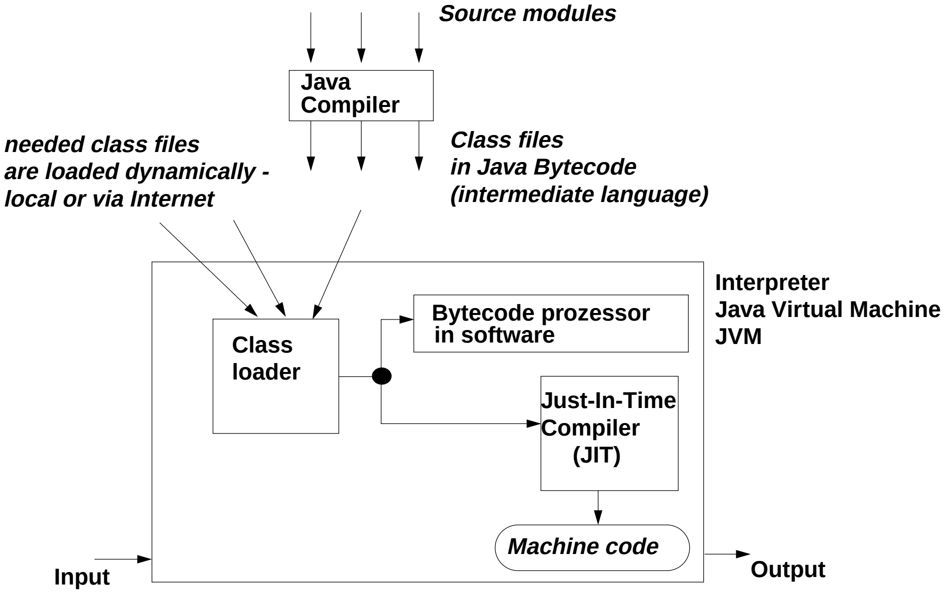
- with interface specification, consistency checks, and language specific linker: Modula, Ada, Java
- without ...; checks deferred to system linker: C, C++

Interpreter and Debugger





Compilation and interpretation of Java programs


Source modules
Java Compiler
Class files in Java Bytecode (intermediate language)
needed class files are loaded dynamically - local or via Internet
Interpreter Java Virtual Machine JVM
Class loader
Bytecode prozessor in software
Just-In-Time Compiler (JIT)
Machine code
Input
Output