Compiler Construction: Introduction

The Evolution of the Compiler Architecture

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Compiler Architecture: Outline

- Compilation task.
  Compilation in a narrow & in a wide sense
- Advanced architecture, or How to turn compiler inside out?
- Program semantic representation
- Compiler integration into an IDE

Main Problems

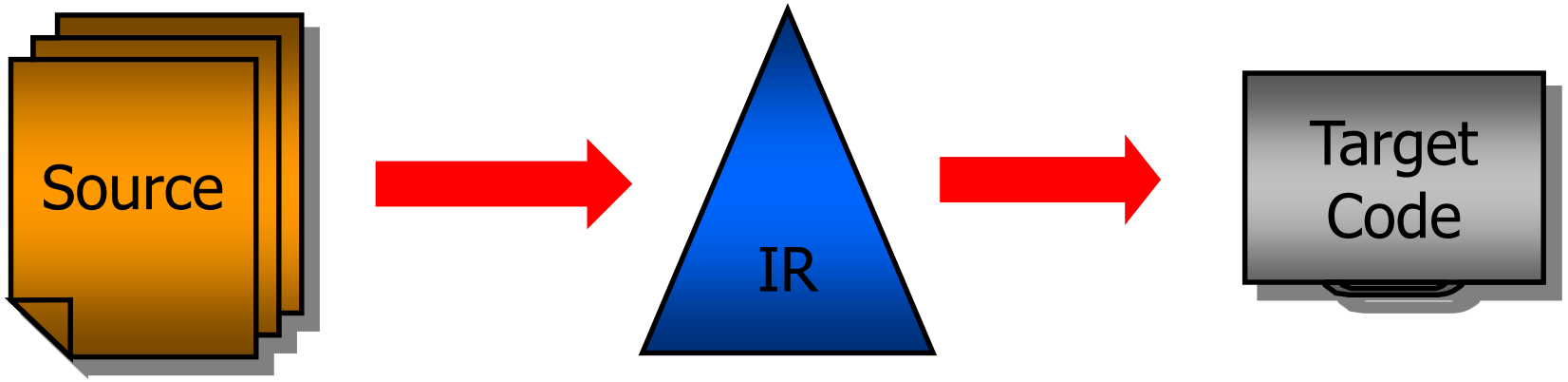
- Unsatisfactory language design ☹☹
- Efficient code generation
- Program analysis
  Program understanding
- Integration compilers into integrated development environments (IDEs)

Main Problems

- **Unsatisfactory language design ☹☹**
  Out of the scope of the talk…
- **Efficient code generation**
  Is solved by conventional compilers
- **Program analysis**
  Program understanding
- **Integration compilers into integrated development environments (IDEs)**

Compilation in a "narrow sense"

- Analysis of a program for producing semantically equivalent machine code for direct execution.



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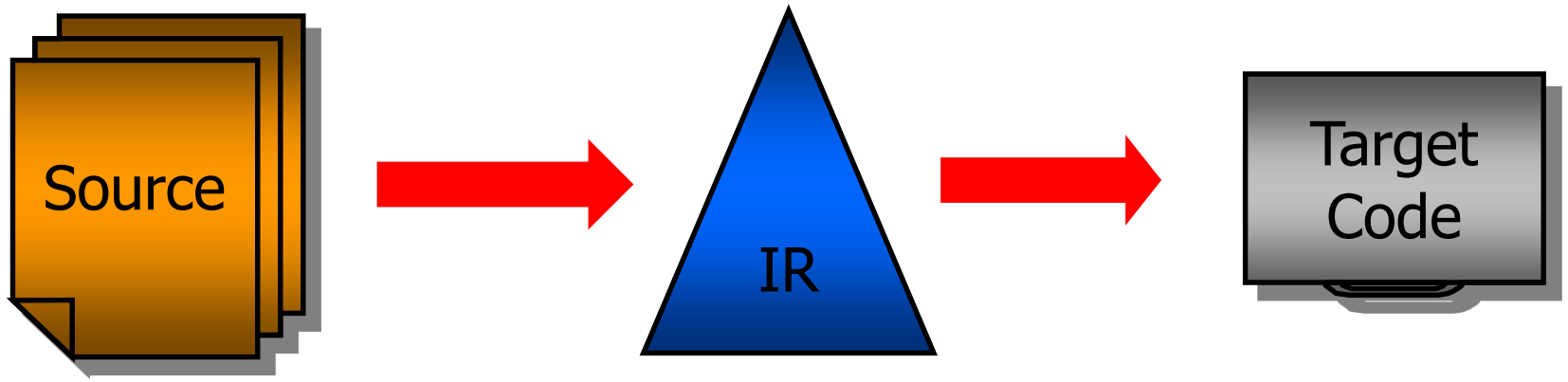
- Analysis of a program for producing semantically equivalent machine code for direct execution.



This is my key point

However, producing machine code is not the single compilation task – and often is **even not the most important one**!

Why compilation "in a narrow sense" is not enough?

There are many actual tasks ("challenges") **not related to producing executable code**:

- **Legacy code reengineering**; source-to-source translation; automatic program generation.
- Maintenance and improving existing programs; **refactoring**.
- **Program static analysis**: detailed diagnostics without executing code; eliminating vulnerabilities, potentially problematic code; "dead code" eliminating; source level optimizations.
- **«Understanding»** programs; visualization: creating UML diagrams (reverse engineering), XREF diagrams; metrics calculation.
- **Testing**; creating test coverages.
- Program **verification**: formal correctness proving; abstract interpretation; partial interpretation.
- …

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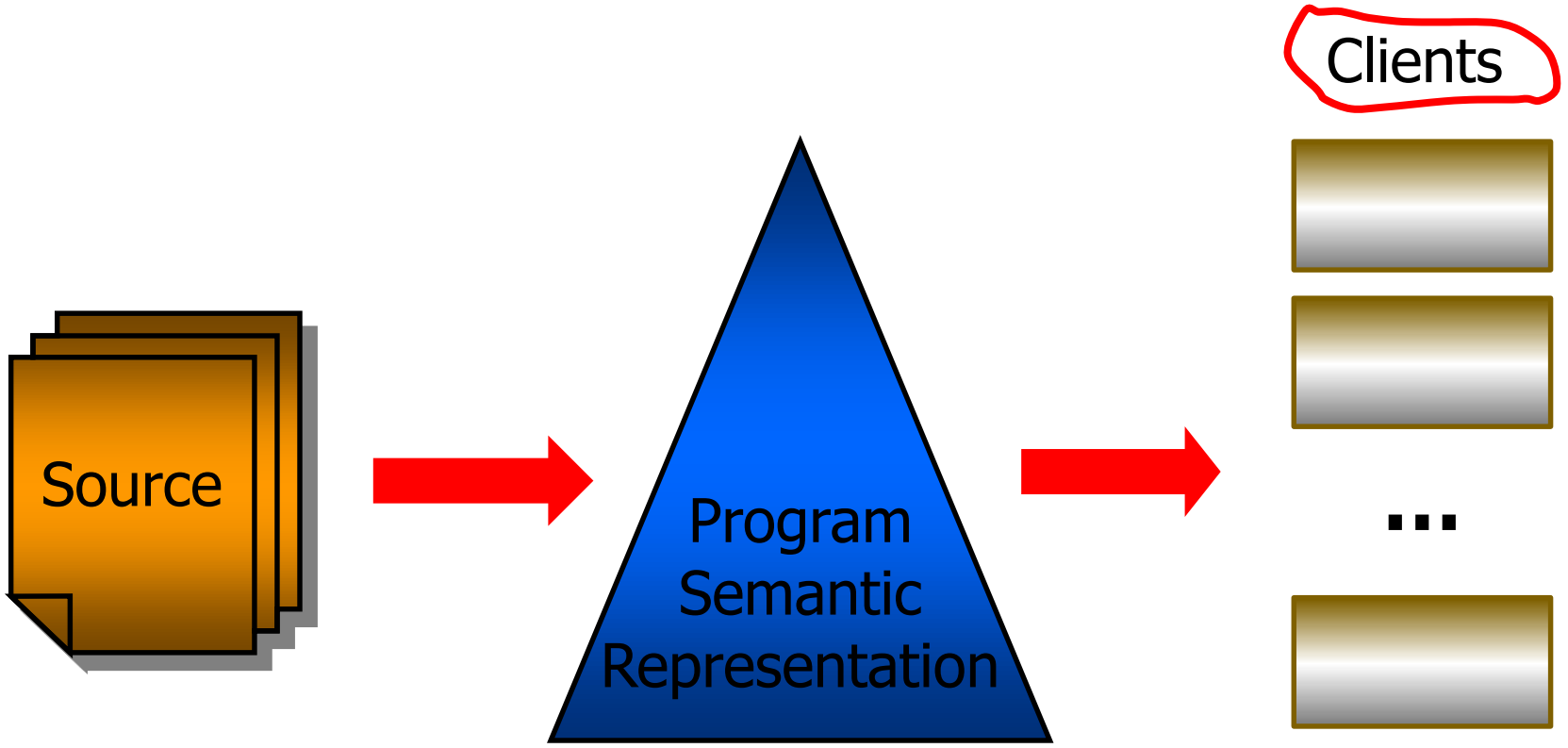
To solve these and similar tasks **we need full information about program semantics**.

Compilation in a "wide sense"

- Analysis of a program for getting full information about **all its features**.

This is my key point



- Static analyzers
- Visualizers
- Engineering tools (UML-based)
- Program verifiers/ proofers
- Code generators
- Interpreters (virtual machines)
- Etc.

How these problems are solved?

- By creating **specific software tools & systems**: from simple utilities like **lint** for C (or **lint++** for C++) to powerful systems like **Klocwork**, **Fortify**, or **Coverity**.

  Typically, they are either command-line utilities, or "hermetic" systems without possibilities for improving their functionality.

- By creating **open infrastructures** (APIs) providing access to programs' semantics.

Open Infrastructures: Related Projects

ASIS

Ada **S**emantic **I**nterface **S**pecification (for Ada95):
the ISO standard

SAGE - SAGE II - ROSE (for C/C++, HPF…)

An open compiler infrastructure for source-to-source transformations

Pivot (for C++)

B.Stroustrup & Dos Reis; "General infrastructure for transformation and static analysis of C++ programs"

CCI (for .NET)

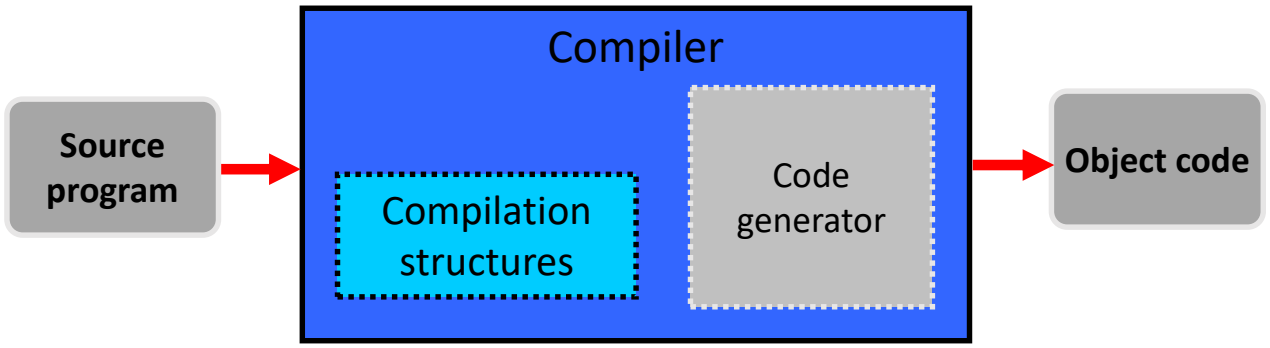
Program infrastructure for compiler construction for .NET

llvm/clang

C/C++ compiler & API for program analysis

Roslyn for .NET

The Evolution of Compiler Architecture
(on one slide)



Conventional monolithic compiler

The Evolution of Compiler Architecture
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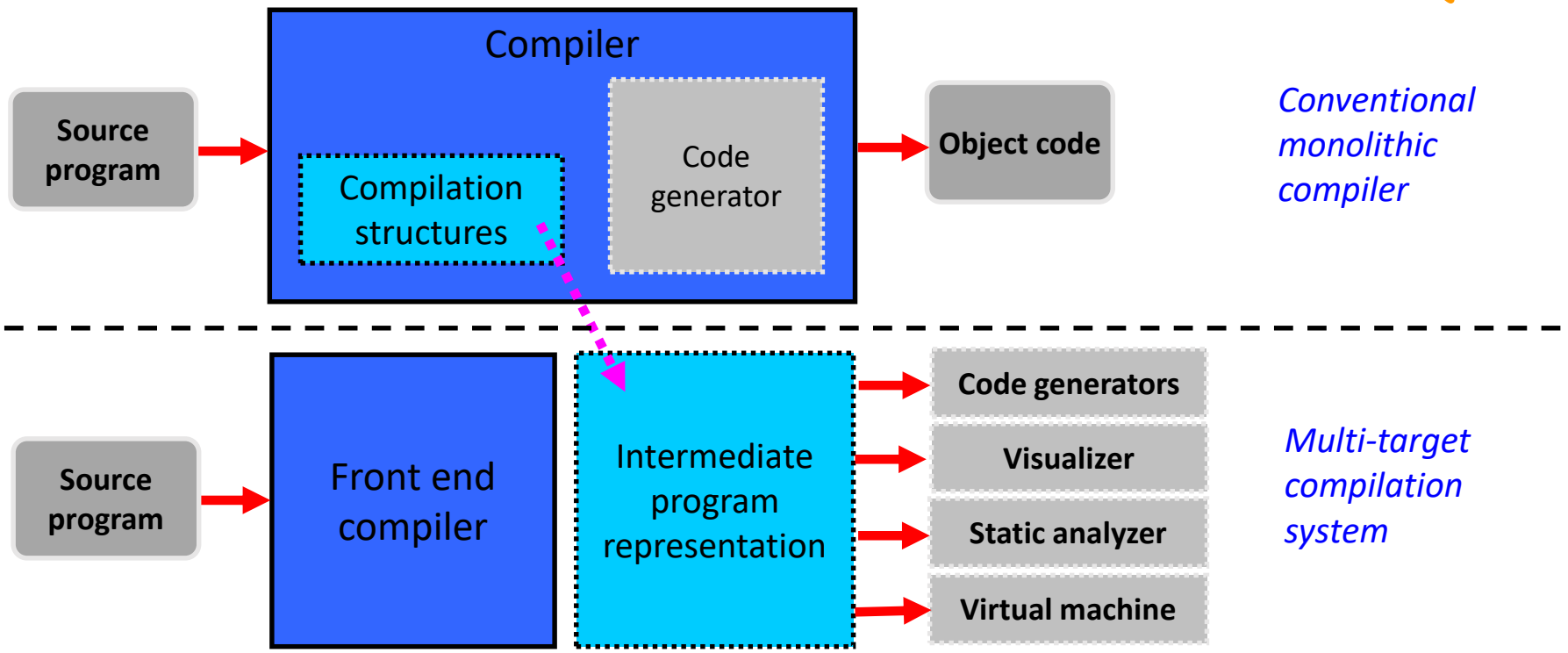

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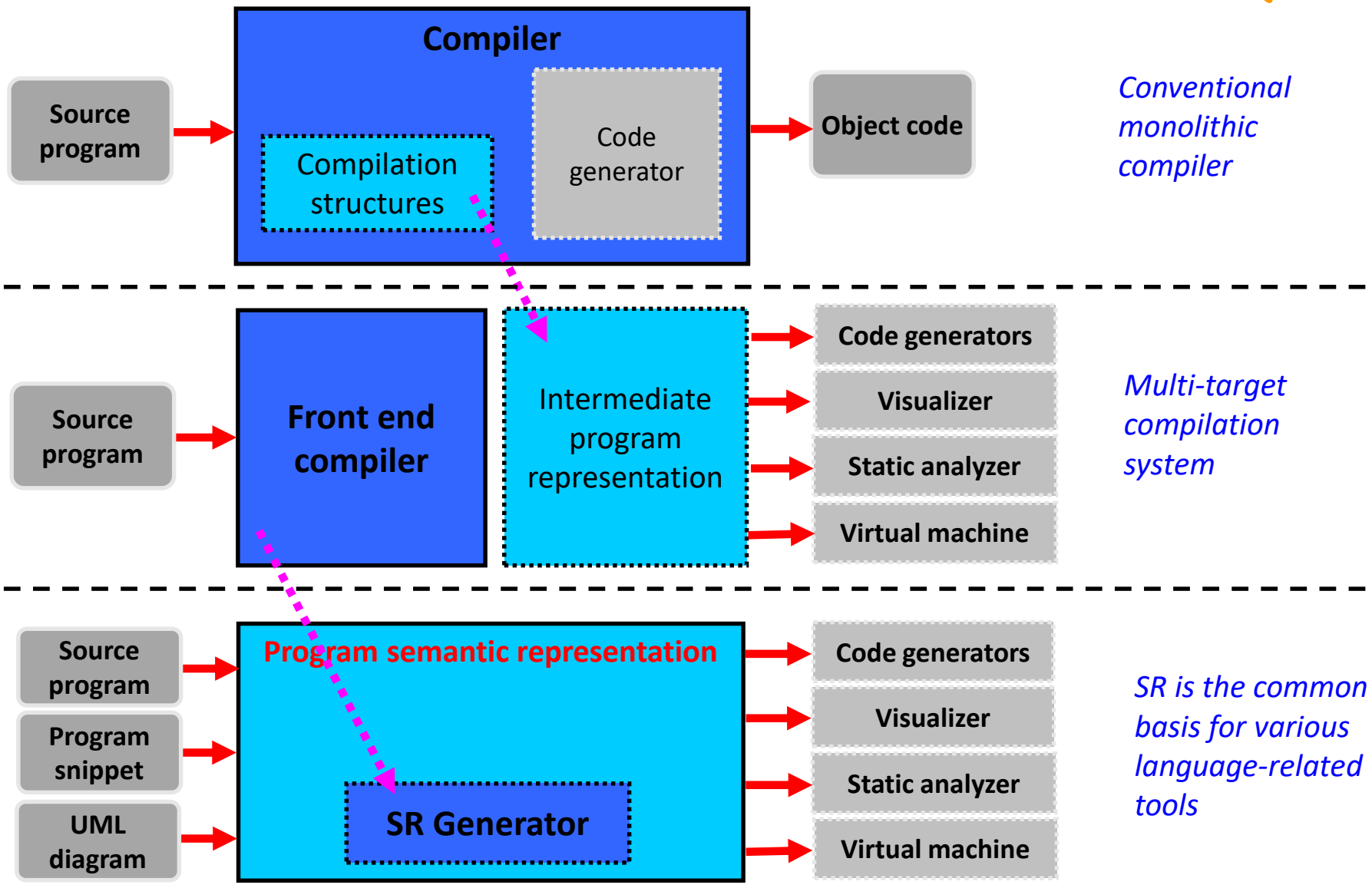
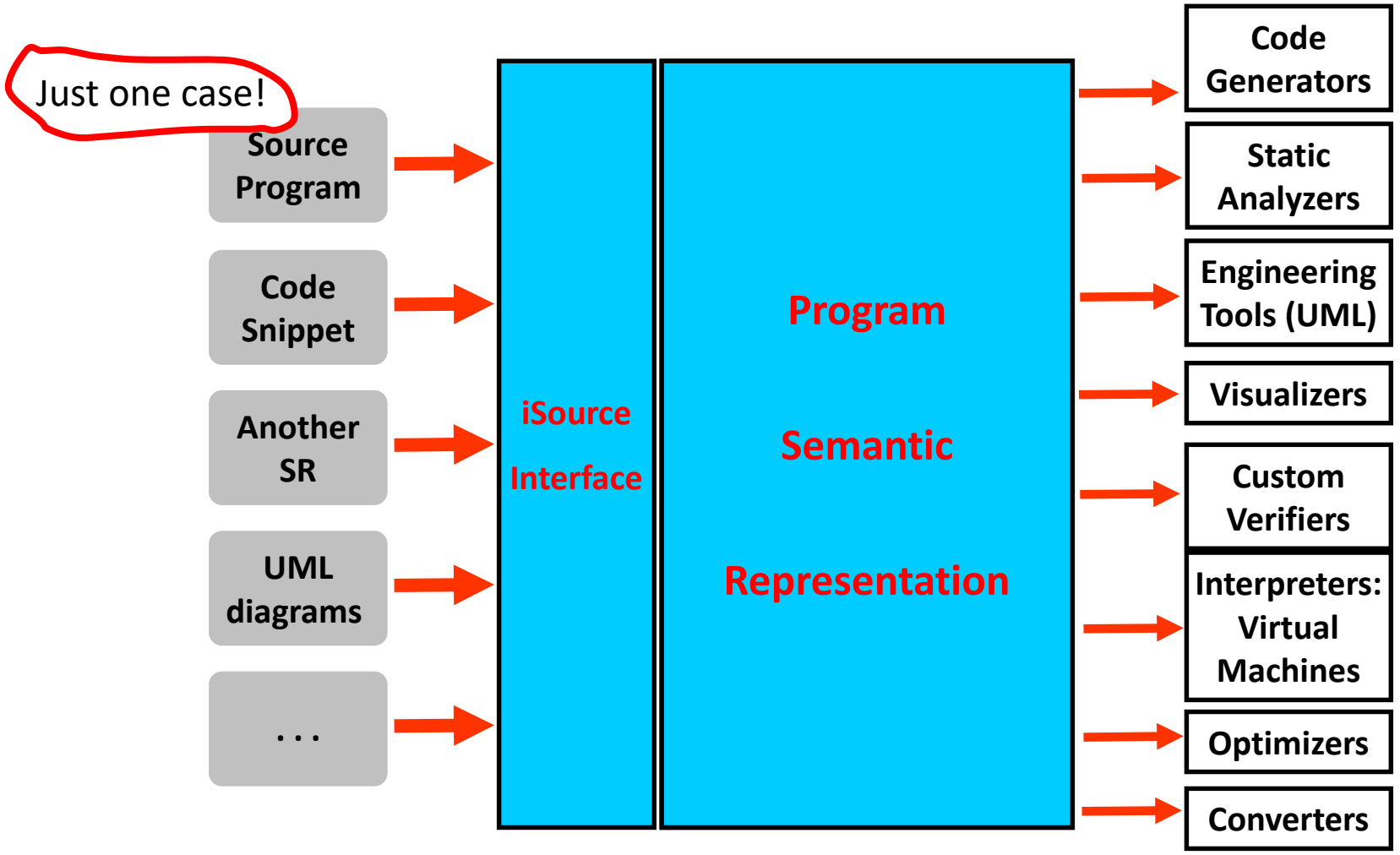
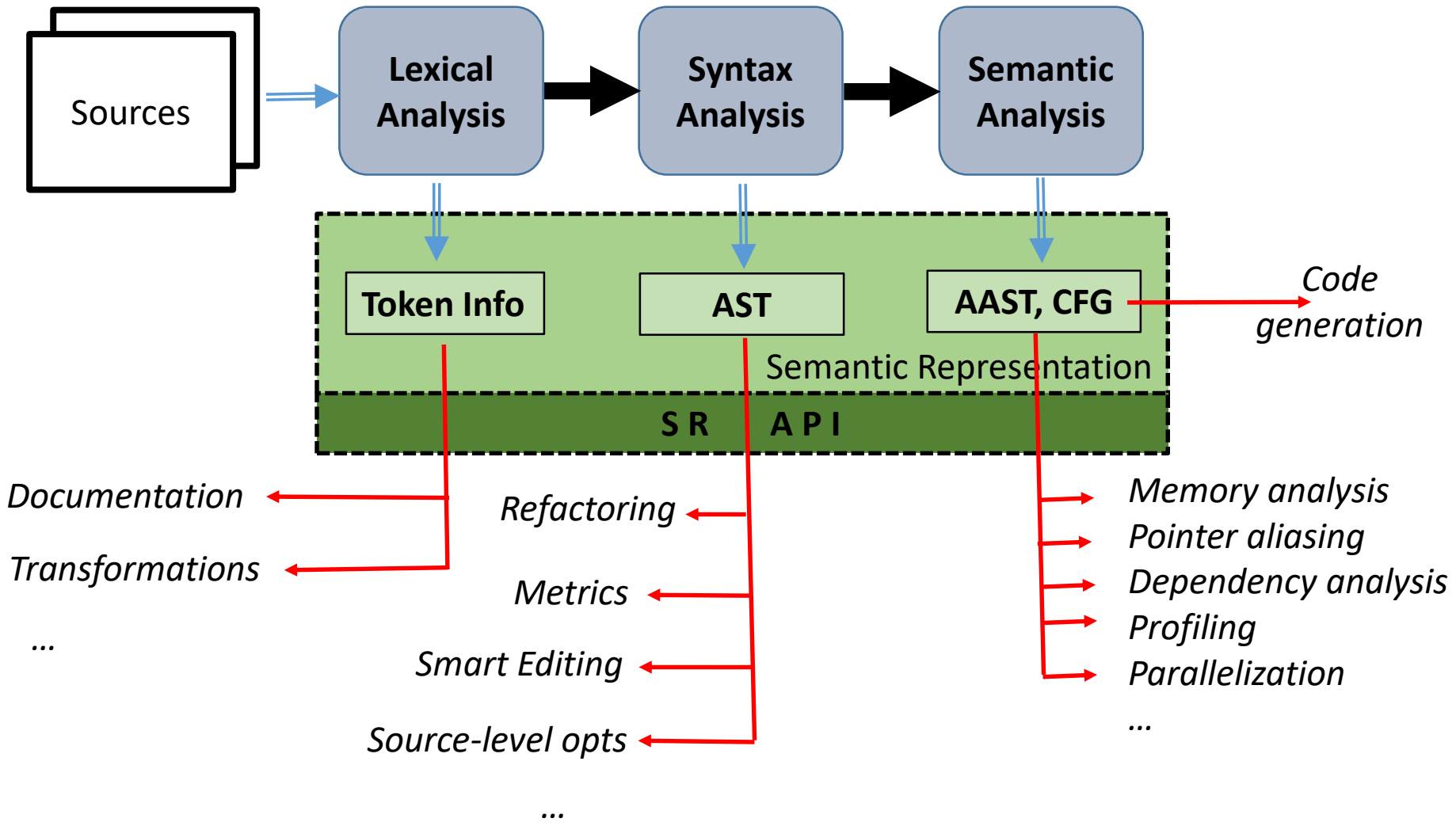


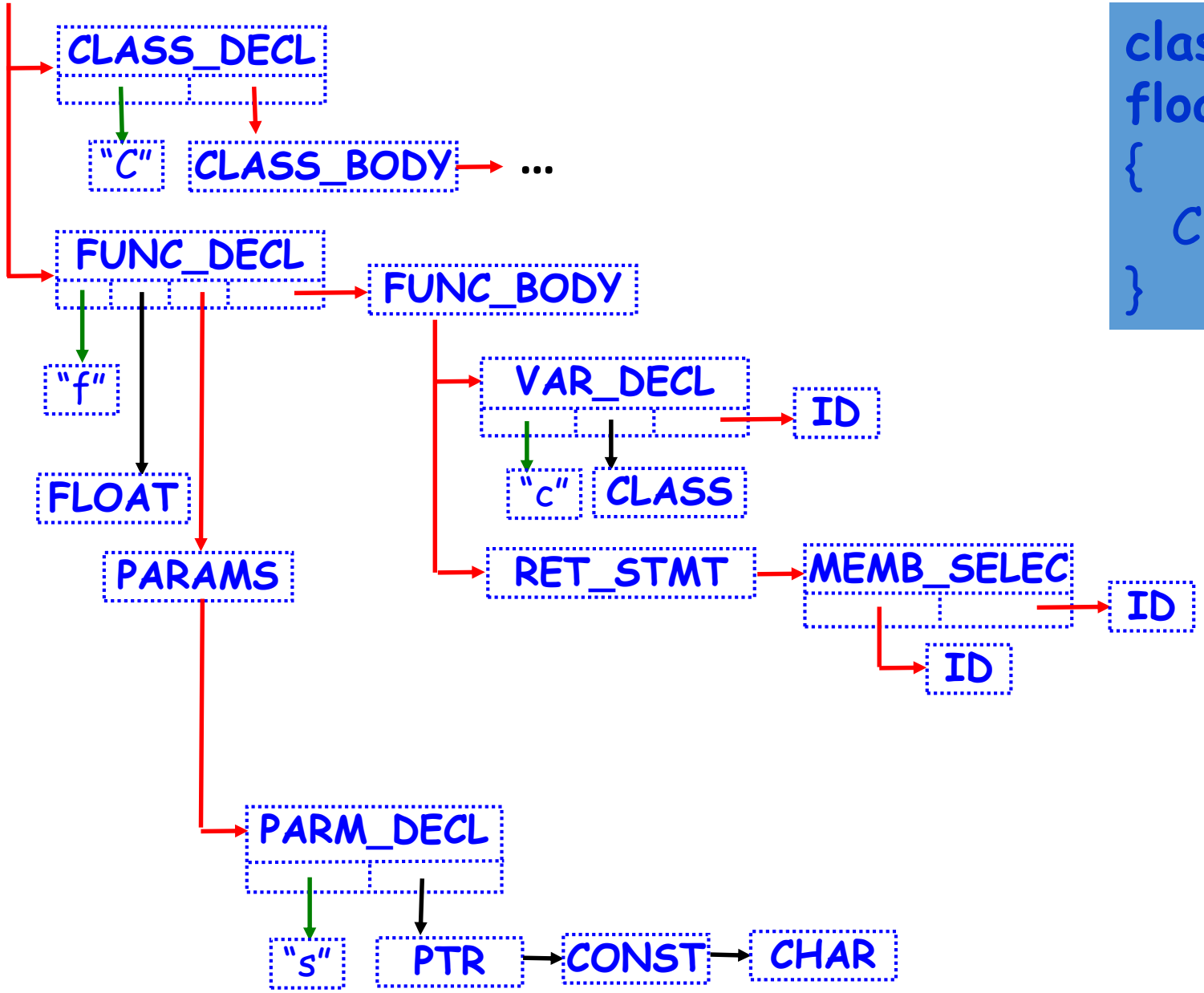
Compilation in a "wide sense": the conceptual view



Semantic Representation in More Details



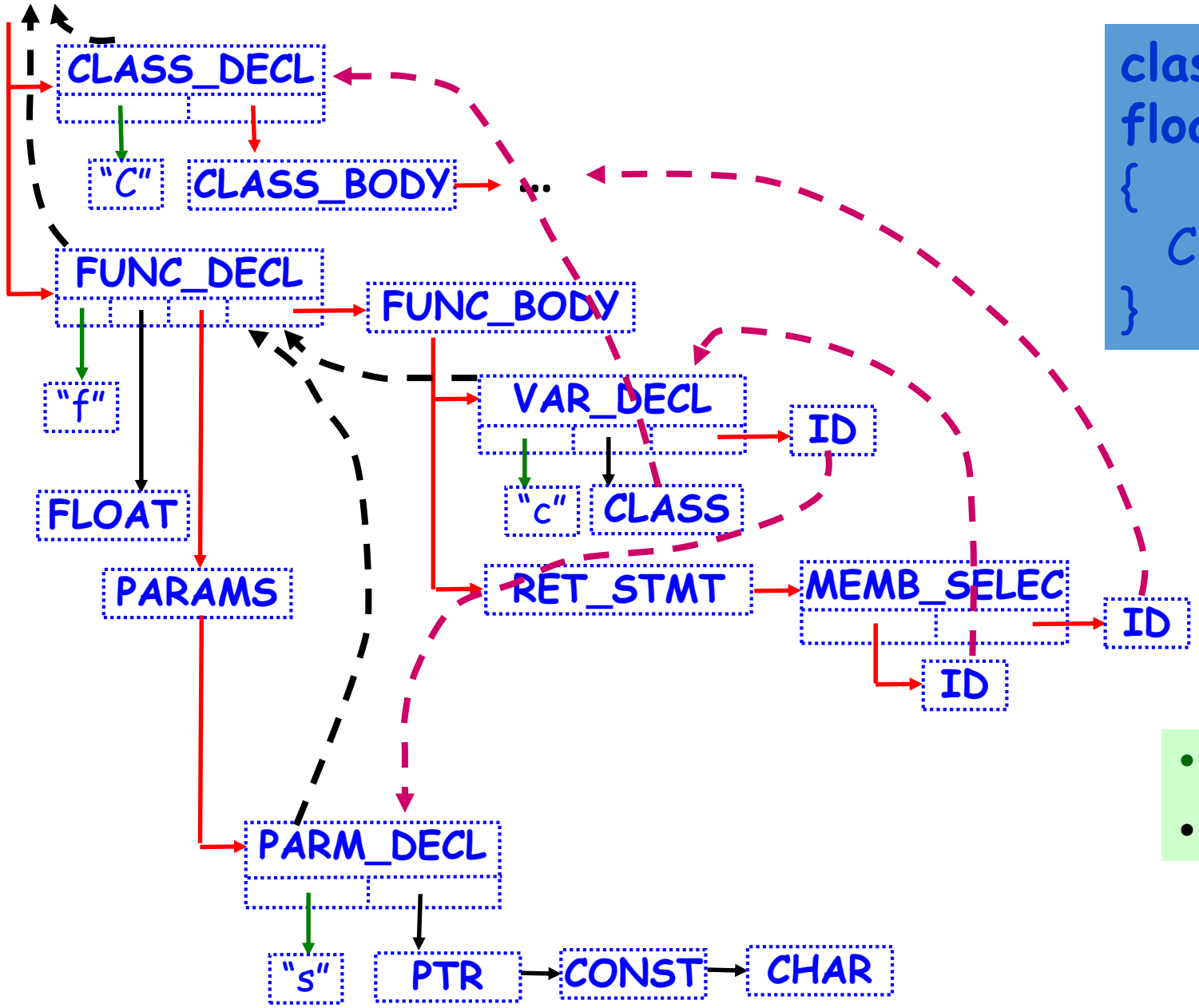
Annotated AST as the Basis of SR (1)




```
class C { ... };
float f(const char* s)
{
   C c(s); return c.m;
}
```

- Structural relations
- Type information
- Various attributes

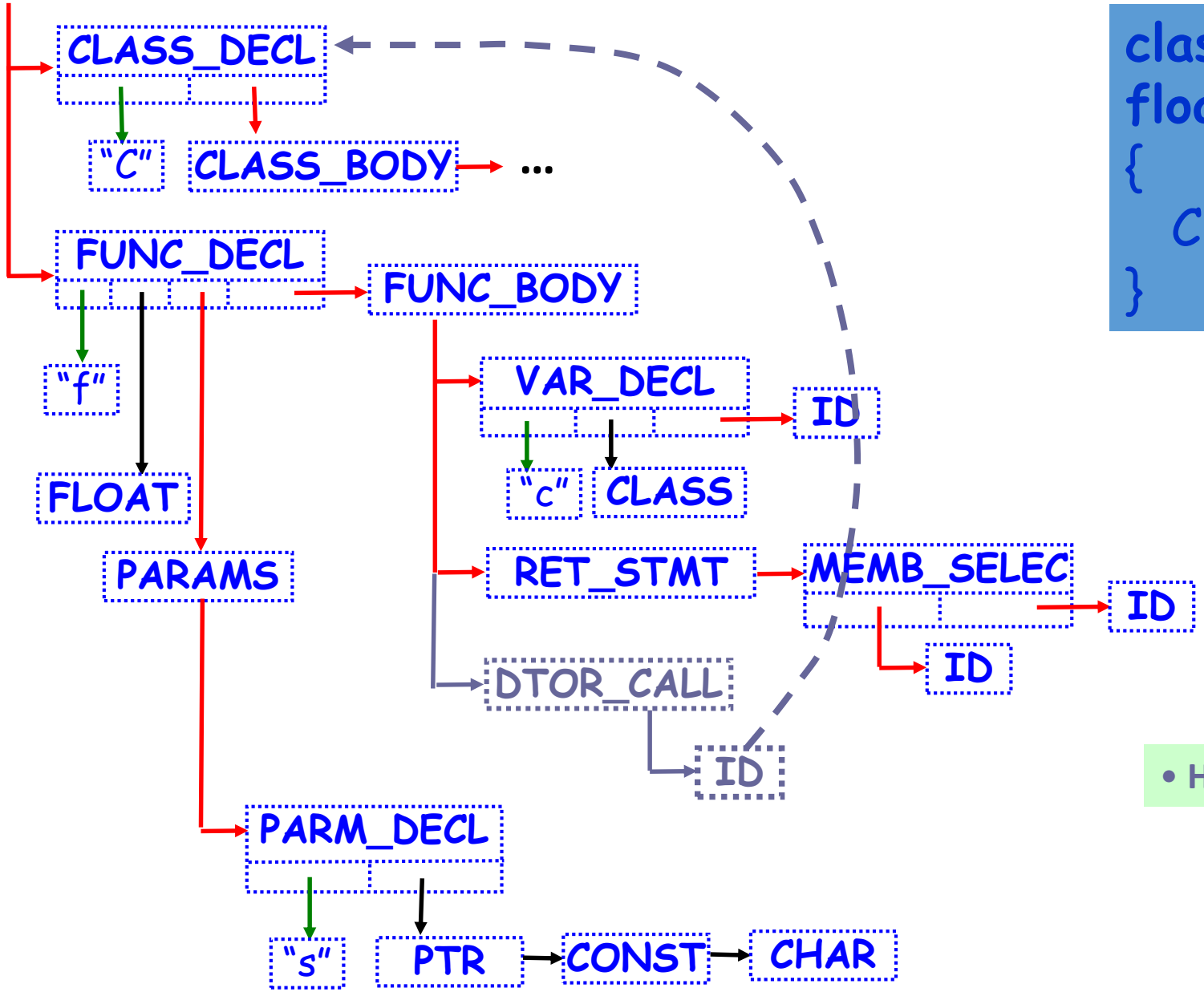
Annotated AST as the Basis of SR (2)




```
class C { ... };
float f(const char* s)
{
   C c(s); return c.m;
}
```

- Semantic relationships
- Scoping rules

Annotated AST as the Basis of SR (3)




```
class C { ... };
float f(const char* s)
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```
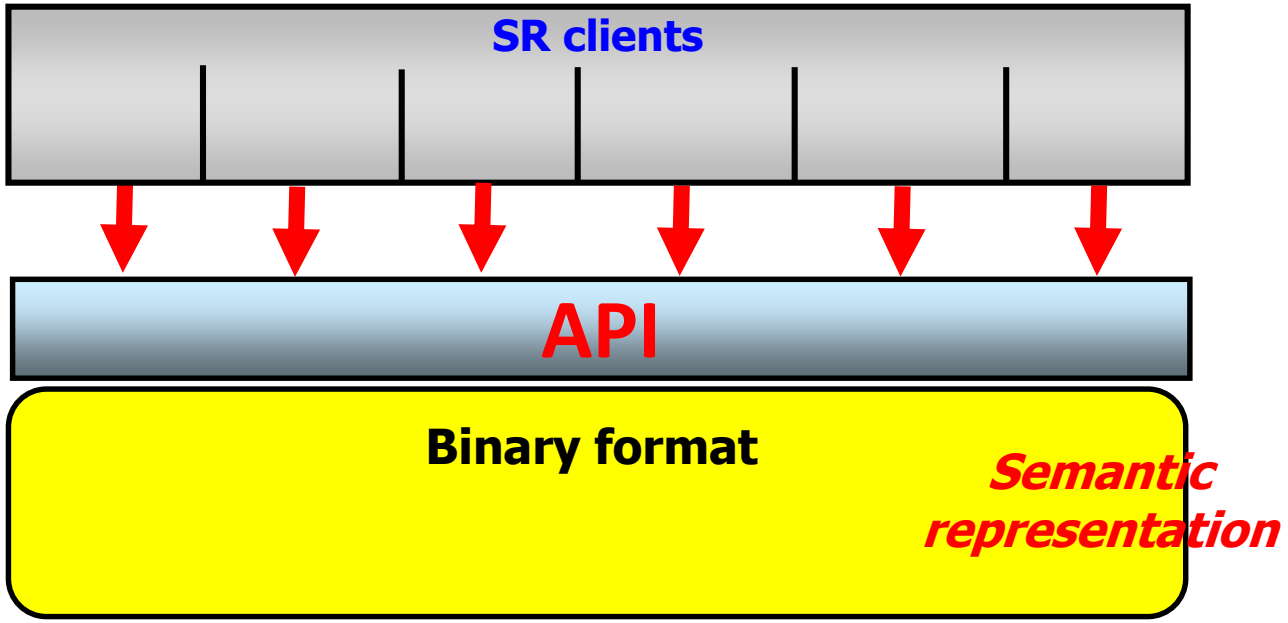
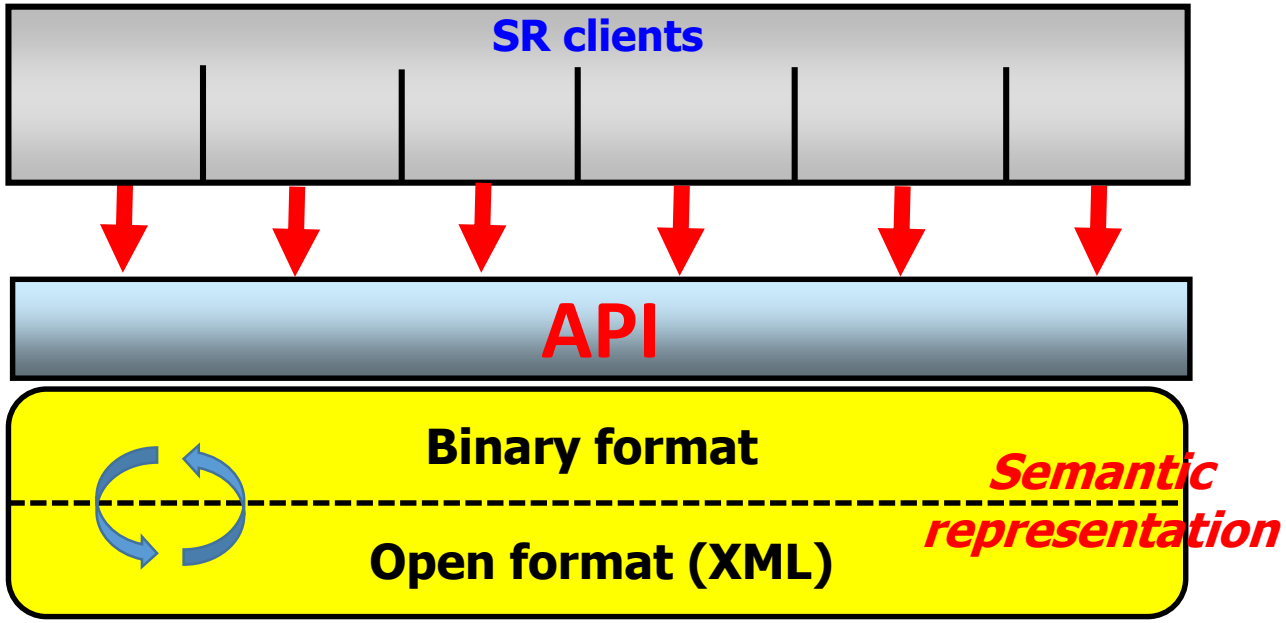

- Hidden semantics



Binary or open format? (or both?)



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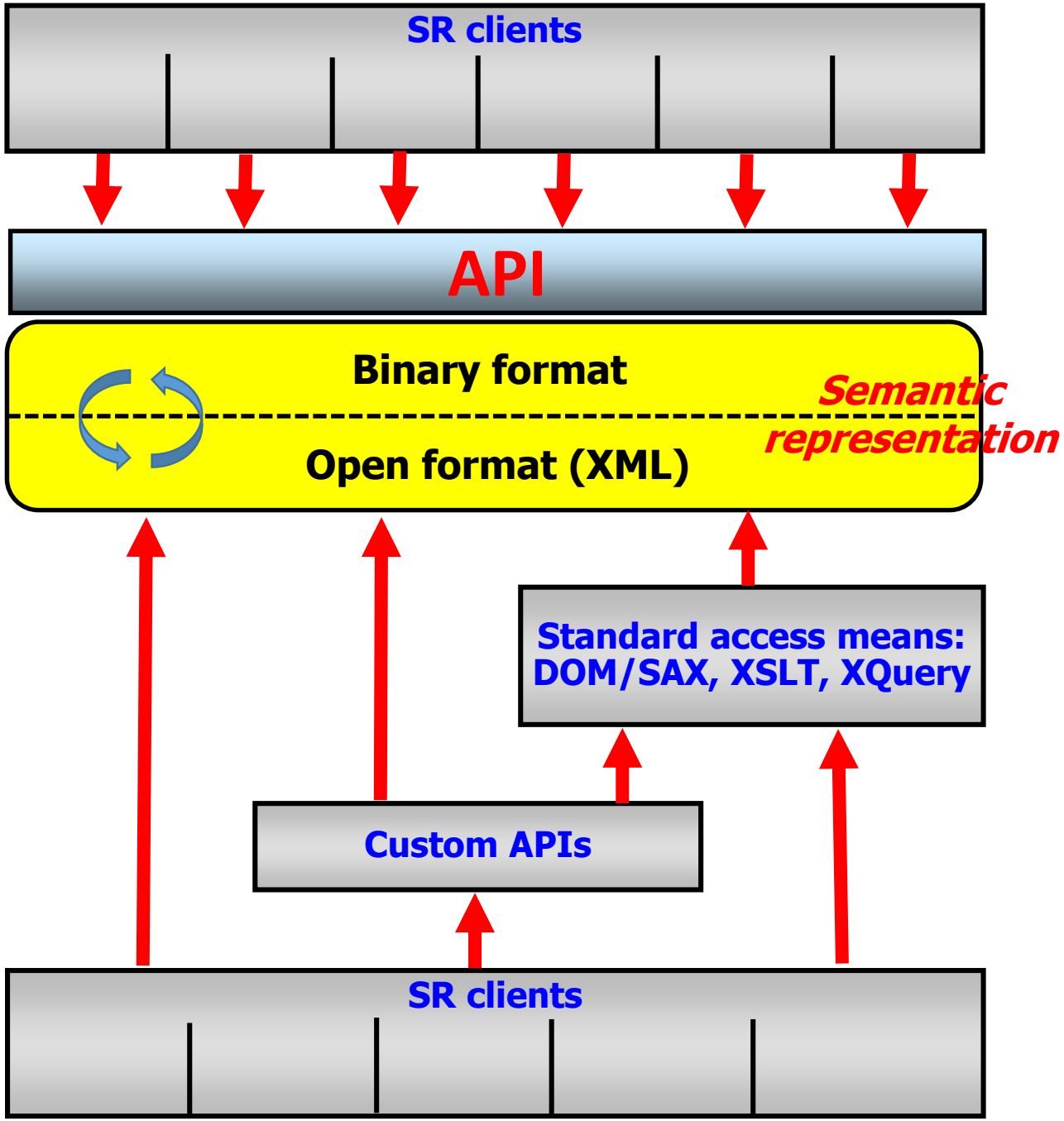

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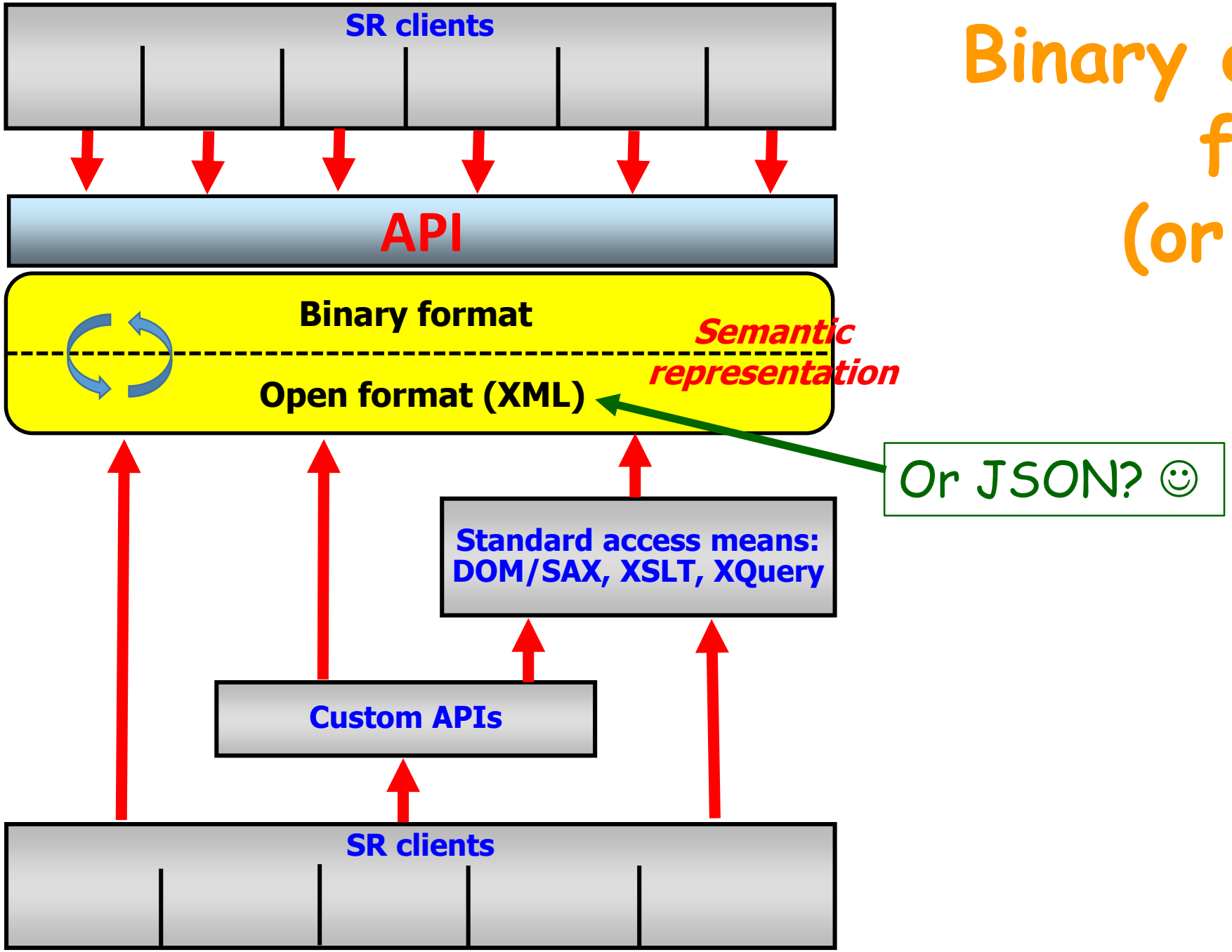

Why XML?

- Open format
- Extendable (XML is the *meta*language actually)
- Extremely simple representation model
- De facto standard
- Plenty of available XML-based technologies (XQuery, XSLT etc.) and tools for XML manupulating

Why XML?

Or JSON? ☺

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- Extendable (XML is the *meta*language actually)
- Extremely simple representation model
- De facto standard
- Plenty of available XML-based technologies (XQuery, XSLT etc.) and tools for XML manupulating

All this applies to JSON as well ☺

SR example in XML format

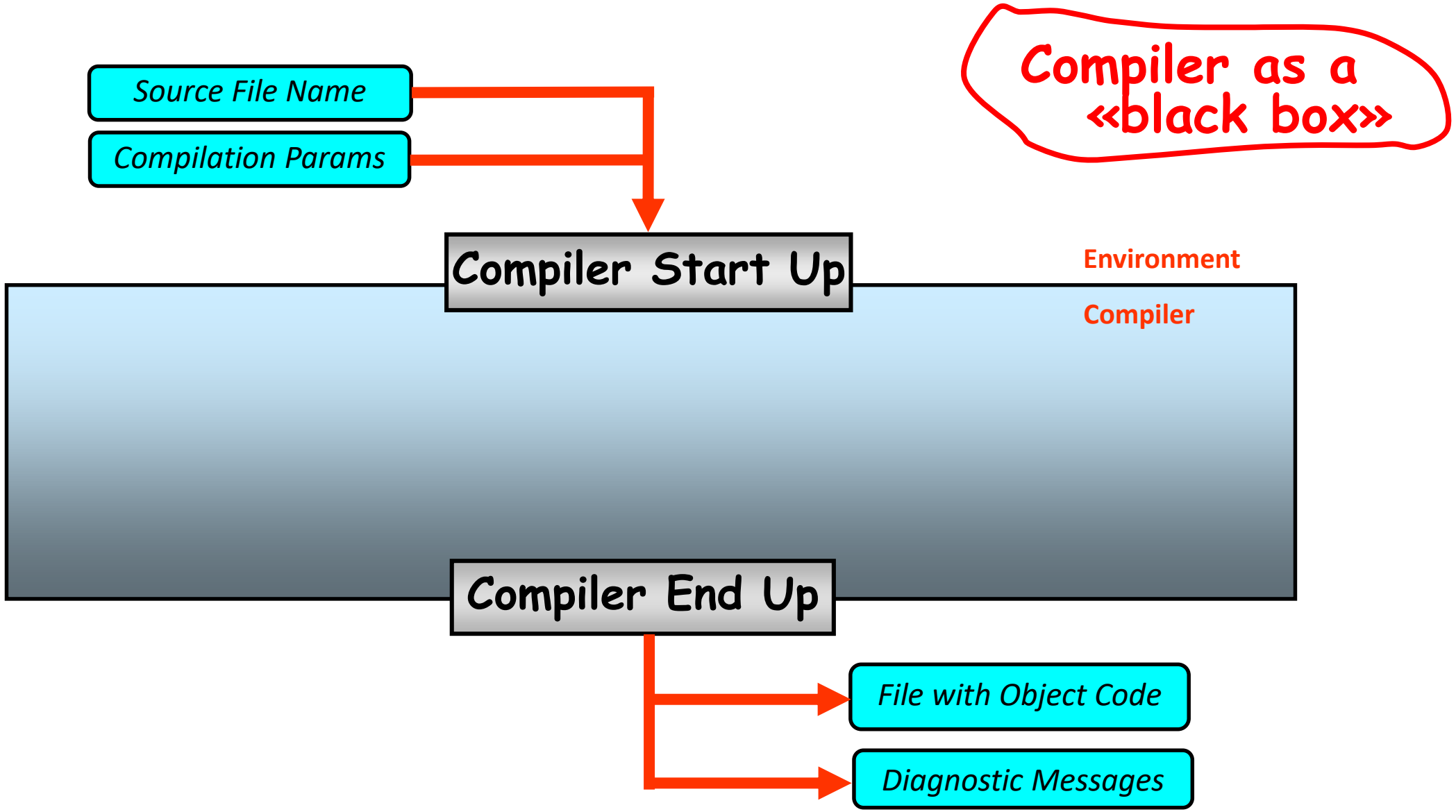
```
<while-statement ln="1" col="1">
    <condition>
        <expression ln="1" col="7"> ... </expression>
    <condition>
    <compound-statement>
        <assignment-expression ln="2" col="4">
            <name ln="2" col="4">x</name>
            <expression ln="2" col="9"> ... </expression>
        </assignment>
        <call ln="3" col="4">
            <name ln="3" col="4">P</name>
            <argument-list>
                <expression ln="3" col="5"> ... </expression>
            </argument-list>
        </call>
    </compound-statement>
</while-statement>
```

```
while ... {
    x = ...;
    P(...);
}
```

simplified

Compilers in IDEs
&
Compiler Architecture

Compilation: Conventional Approach



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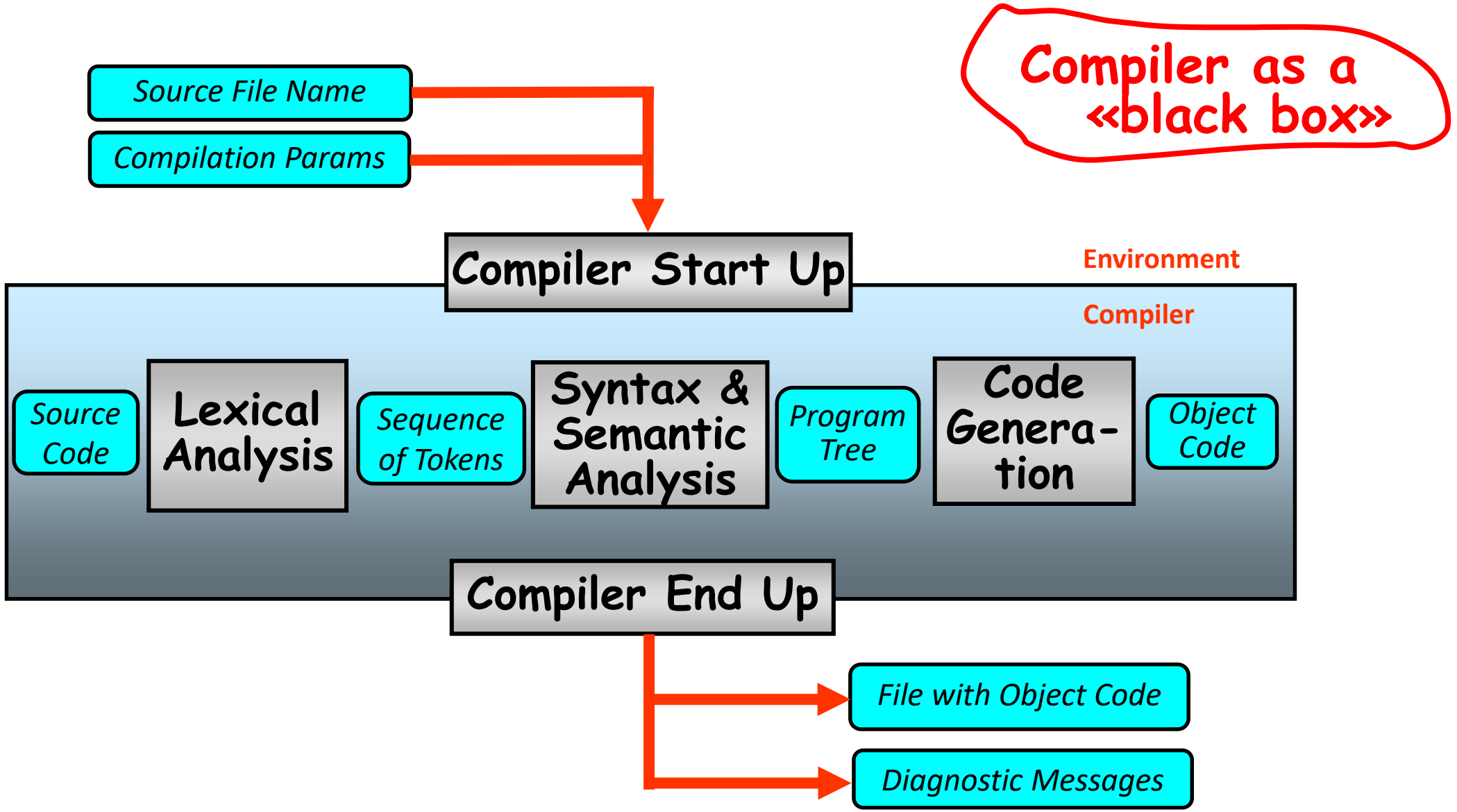

Compiler Integration (1)

How the editor knows that these are types?

```
        while ( true )
        {
            token = s.expect(TokenCode.Identifier);
            var id = IDENTIFIER.create(token);
            result.add(id);
            id.parent = result;

            token = s.get();
            if ( token.code == TokenCode.Comma ) { s.forget(); continue; }
            break;
        }
        token = s.expect(TokenCode.RightBracket);
        result.setSpan(begin,token.span);

        return result;
    }

    #endregion
```

Example: integration the C# compiler into Visual Studio

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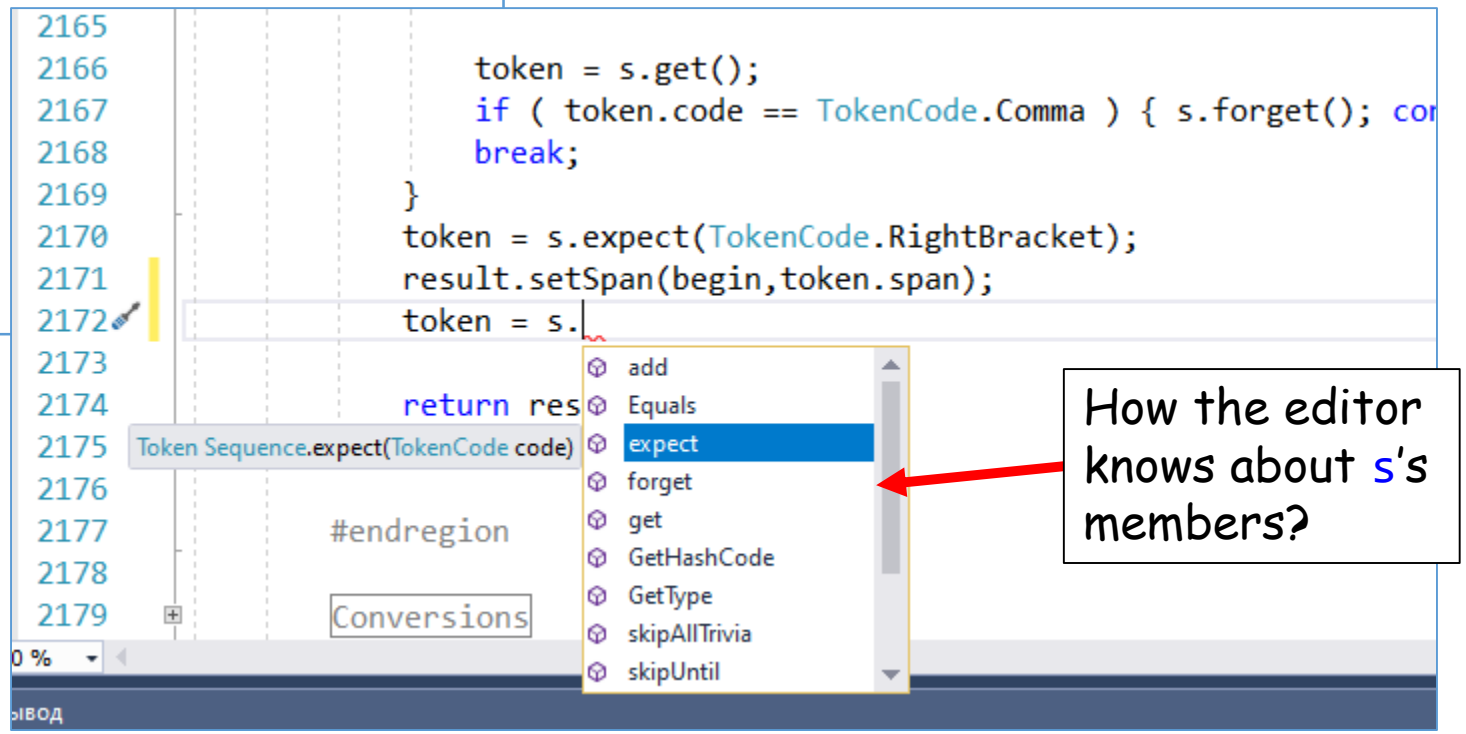

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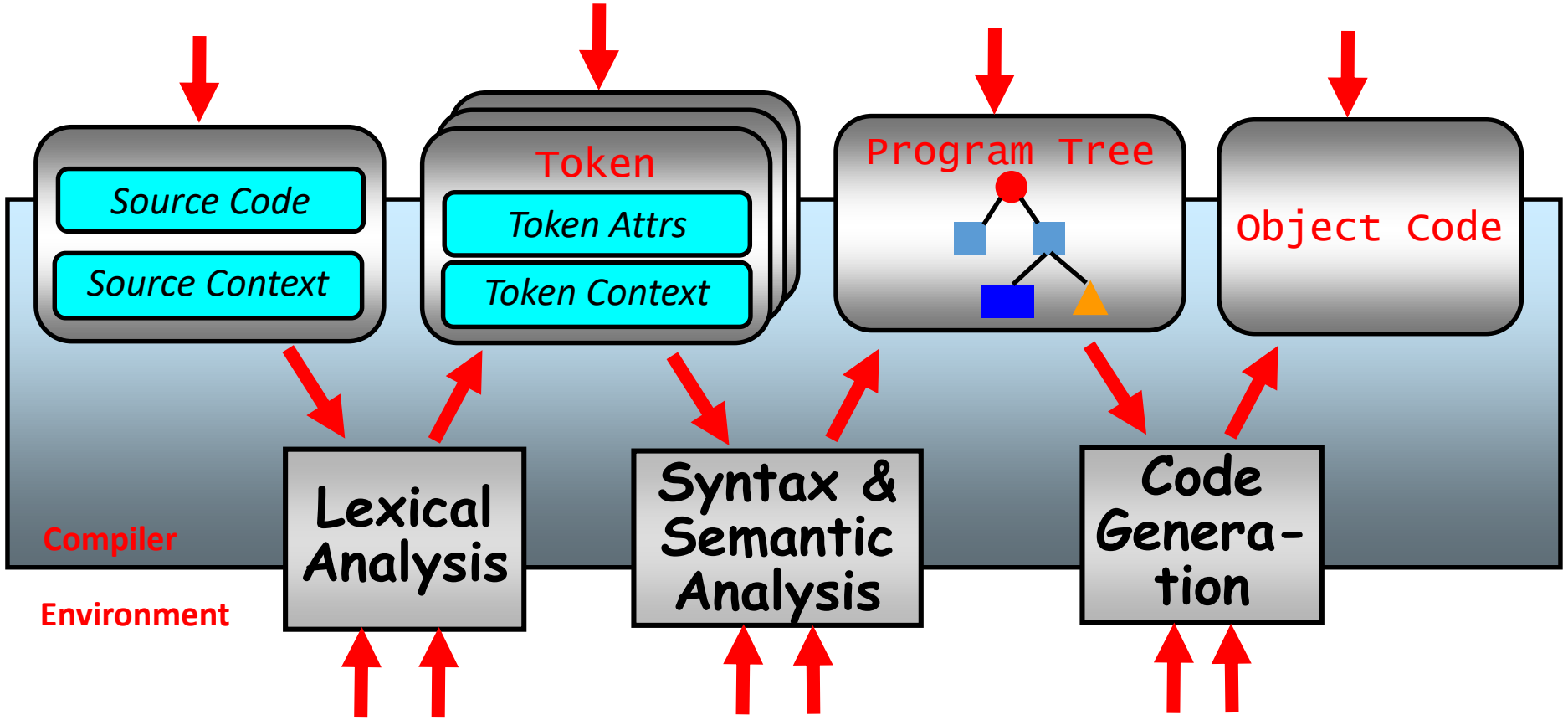

Compiler as a collection of resources

Compiler Integration (3)