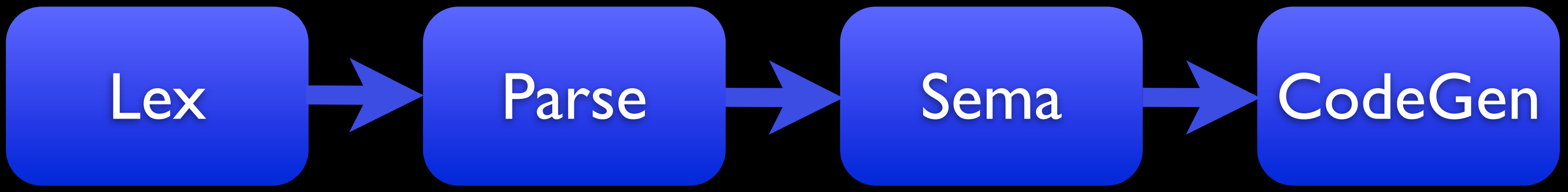
Extending Clang

Doug Gregor

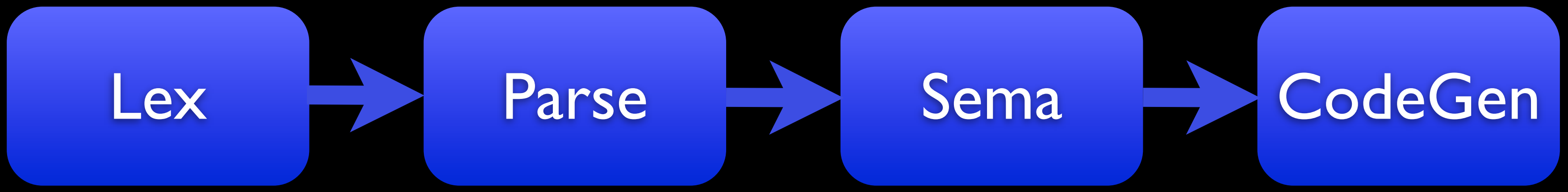
A Platform for Tools

- Library-based architecture
- Compatibility with various language standards
- Accurate representation of source code

Extension Points



Extension Points



- libclang
- Preprocessor callbacks, AST consumers
- Semantic analysis, static analyzer
- LLVM IR transformation and optimization
- Source-to-source translation

Source ⇔ AST Mapping

libclang: Clang C API

```
struct List {
  int Data;
  struct List *Next;
};
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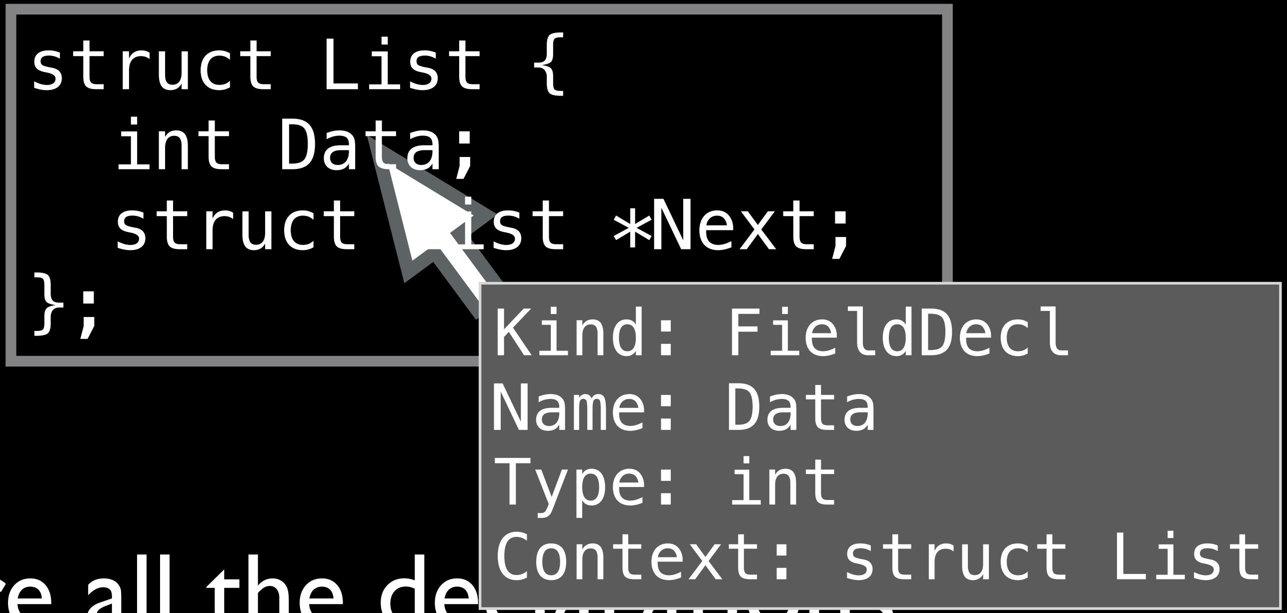
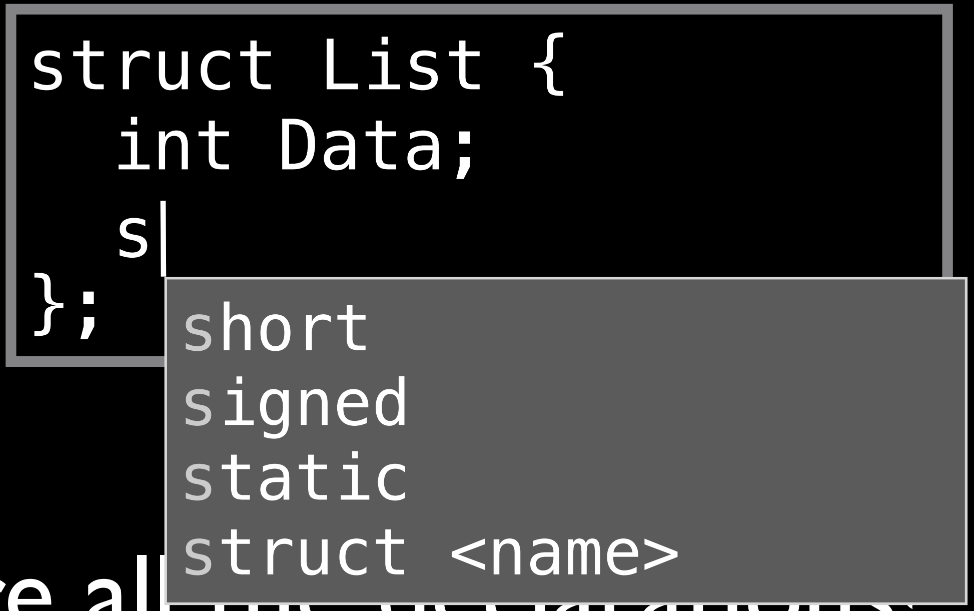


```
struct List {
  int Data;
  struct List *Next;
};
```

```
Kind: FieldDecl
Name: Data
Type: int
Context: struct List
```

- Where are all the declarations?
- Where are uses of List?
- What is under my cursor?

libclang: Clang C API



```
struct List {
  int Data;
  s|
};
```

```
short
signed
static
struct <name>
```

- Where are all the declarations?
- Where are uses of List?
- What is under my cursor?
- What code completions work here?

libclang: Clang C API

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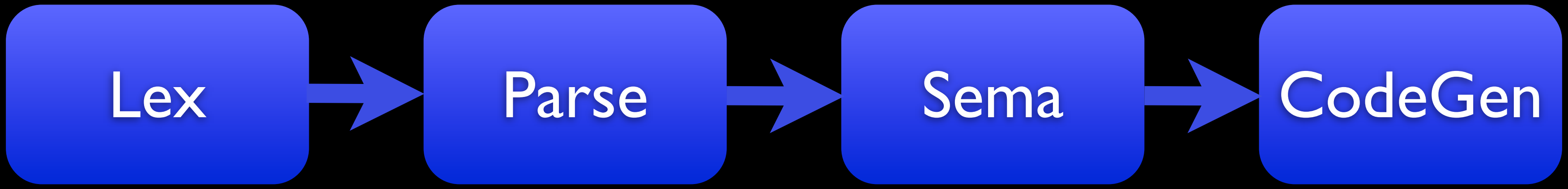
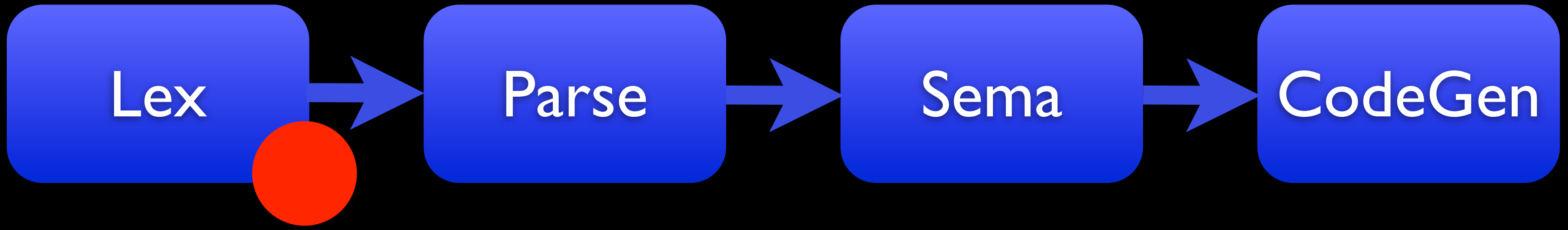
See 2010 talk "libclang: Thinking Beyond the Compiler"

Exploring a Program

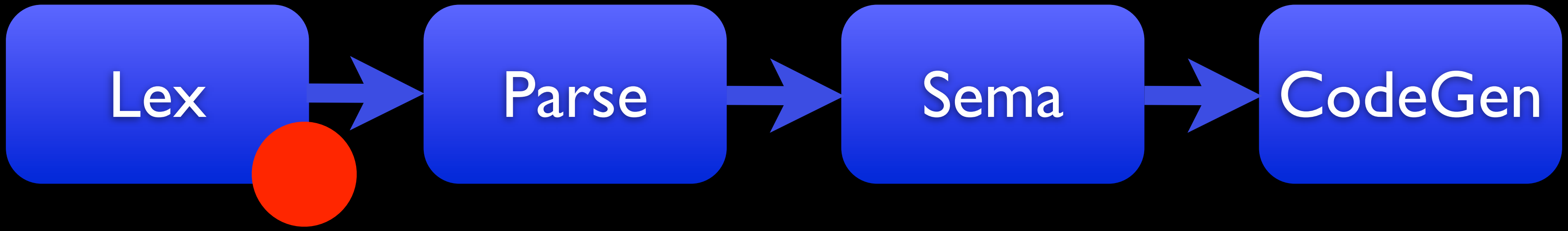
Preprocessor Callbacks



Preprocessor Callbacks



Preprocessor Callbacks

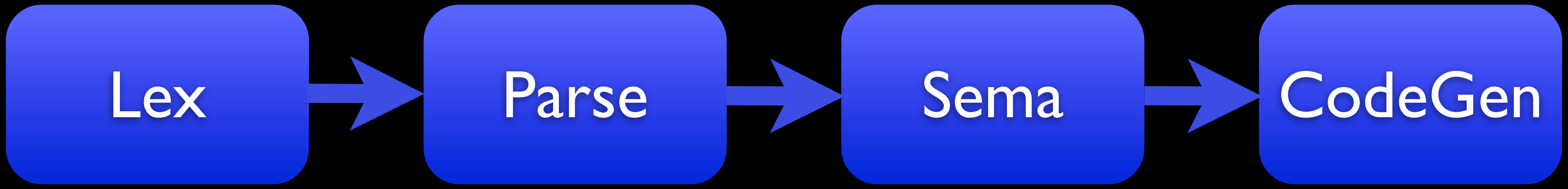


- Invoked for various preprocessor actions
  - Macro definition/expansion
  - Entering/leaving a file
  - Pragmas, ifdefs
- Customize by overriding callbacks

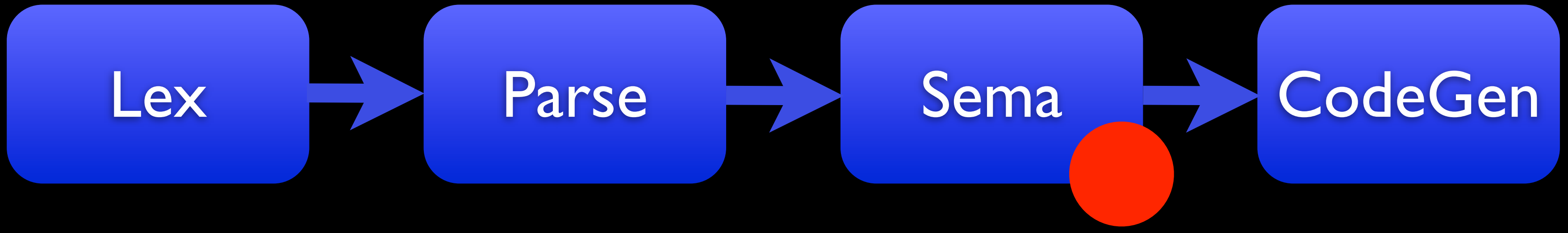
Header Dependencies

```
class FindDependencies : public PPCallbacks {
public:
  void FileChanged(SourceLocation Loc,
                   FileChangeReason Reason,
                   SrcMgr::CharacteristicKind,
                   FileID PrevFID) {
    if (Reason != EnterFile) return;
    if (const FileEntry *FE
          = SM.getFileEntryForID(
              SM.getFileID(Loc)))
      std::cout << “Depends on “
                << FE->getName() << “\n”;
  }
};
```

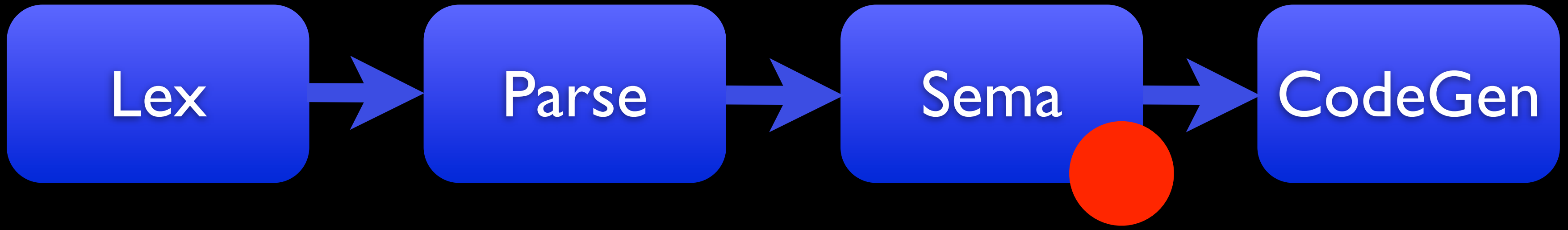
AST Consumers



AST Consumers



AST Consumers



```
class FindUnions : public ASTConsumer {
public:
  void HandleTagDeclDefinition(TagDecl *D) {
    if (D->isUnion()) {
      std::cout << “Union: “
                << D->getNameAsString()
                << “\n”;
    }
  }
};
```

RecursiveASTVisitor

- Recursively walk any part of the AST
    - Call `Visitor.Traverse<NodeType>(Node)`
- Customize by overriding visitation methods
- Used heavily within Clang itself

Finding Calls

Finding Calls

```
class FindCalls
  : public RecursiveASTVisitor<FindCalls> {











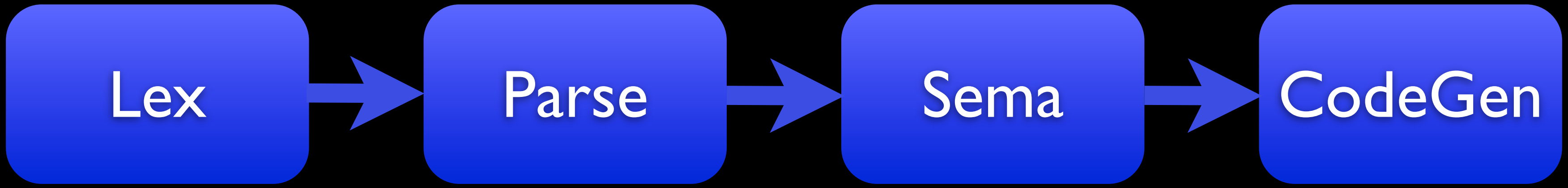
};
```

Finding Calls

```
class FindCalls
  : public RecursiveASTVisitor<FindCalls> {

public:
  bool VisitCallExpr(CallExpr *Call) {
    if (FunctionDecl *Callee
          = Call->getDirectCallee())
      std::cout << “Call to “
                << Callee->getNameAsString()
                << “\n”;
    return true;
  }
};
```

Warnings & Errors



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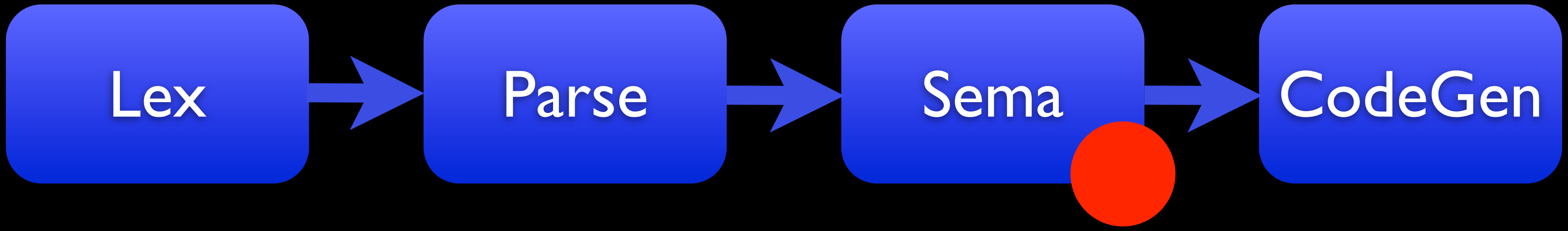

A Terrible Diagnostic

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```
typedef int N;
N::string str;
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```
t.cpp:2:1: error: expected a class or namespace
N::string str;
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// DiagnosticSemaKinds.td
def err_expected_class_or_namespace
  : Error<"expected a class or namespace">;
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```
// SemaCXXScopeSpec.cpp
Diag(IdentifierLoc,
     diag::err_expected_class_or_namespace);
```

Improving Diagnostics

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// DiagnosticSemaKinds.td
def err_not_class_or_namespace
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def err_not_class_or_namespace
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```
// SemaCXXScopeSpec.cpp
if (TypeDecl *TD
      = Found.getAsSingle<TypeDecl>())
  Diag(IdentifierLoc,
       diag::err_not_class_or_namespace)
    << Context.getTypeDeclType(TD);
```

Improving Diagnostics

```
typedef int N;
N::string str;
```

```
t.cpp:2:1: error: ‘N’ (aka ‘int’) is not a
   class or namespace
N::string str;
^
```

Improving Diagnostics

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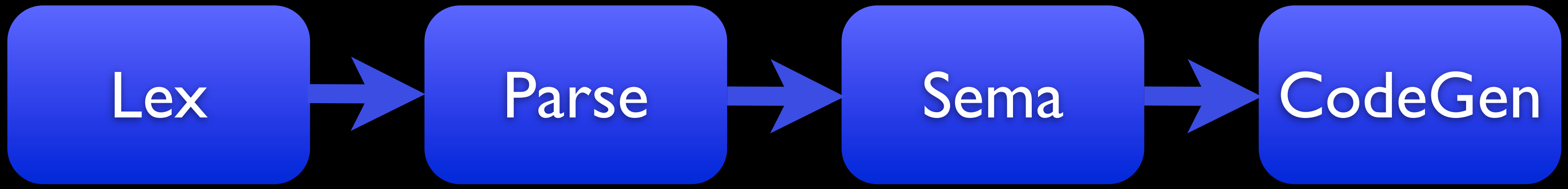
```
// SemaCXXScopeSpec.cpp
if (TypeDecl *TD
      = Found.getAsSingle<TypeDecl>()) {
  Diag(IdentifierLoc,
       diag::err_not_class_or_namespace)
    << Context.getTypeDeclType(TD);
  Diag(TD->getLocation(),
       diag::note_declared_at);
}
```

Improving Diagnostics

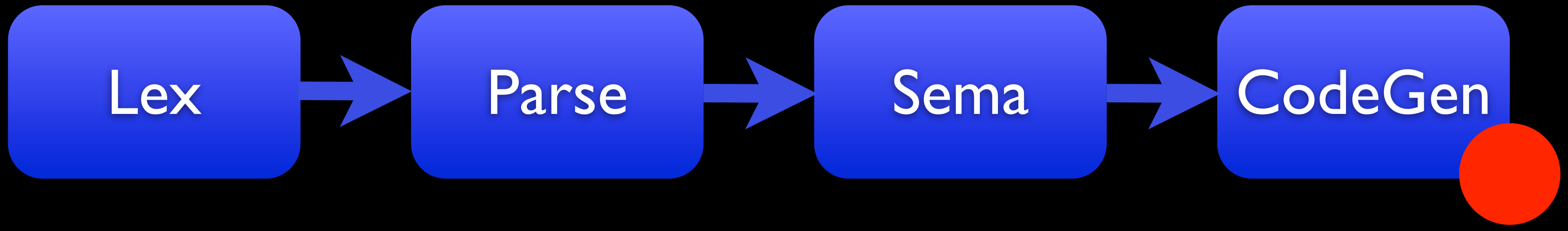
```
typedef int N;
N::string str;
```

```
t.cpp:2:1: error: ‘N’ (aka ‘int’) is not a
   class or namespace
N::string str;
^
t.cpp:1:13: note: declared here
typedef int N;
            ^
```

Attributes & LLVM IR



Attributes & LLVM IR



Feeding Information to IR

“If I could just tell the compiler that some declarations are <adjective>, my new optimization pass would be awesome!”

Feeding Information to IR

"If I could just tell the compiler that some declarations are <adjective>, my new optimization pass would be awesome!"

- Attributes make such experiments easy
  - Trivial to parse with few ambiguities
  - Easy to introduce into the AST

The annotate Attribute

- Clang supports the `annotate` attribute with arbitrary strings:

```
__attribute__((annotate(“singleton”)))
  Class *object;
```

- Annotations are mapped down to LLVM IR annotations

Adding Real Attributes

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```
// include/clang/Basic/Attr.td
def ReturnsTwice : InheritableAttr {
  let Spellings = ["returns_twice"];
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```
// lib/Sema/SemaDeclAttr.cpp
static void handleReturnsTwiceAttr(Sema &S, Decl *D,
                                   const AttributeList &Attr) {
  if (!isa<FunctionDecl>(D)) {
    // diagnose error
    return;
  }
  D->addAttr(::new (S.Context) ReturnsTwiceAttr(...));
}
```

Adding Real Attributes

```
// include/clang/Basic/Attr.td
def ReturnsTwice : InheritableAttr {
  let Spellings = ["returns_twice"];
}
```

```
// lib/Sema/SemaDeclAttr.cpp
static void handleReturnsTwiceAttr(Sema &S, Decl *D,
                                   const AttributeList &Attr) {
  if (!isa<FunctionDecl>(D)) {
    // diagnose error
    return;
  }
  D->addAttr(::new (S.Context) ReturnsTwiceAttr(...));
}
```

http://clang.llvm.org/docs/InternalsManual.html#AddingAttributes

Source-to-Source Translation

The `Rewriter` Class

- Rewriter class provides textual rewriting

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```
class Rewriter {
public:
  bool InsertText(SourceLocation Loc,
                  StringRef Text);

  bool RemoveText(SourceRange Range);
  bool ReplaceText(SourceRange Range,
                   StringRef Text);
};
```

Help Wanted

Plugins

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- Clang allows plugins during normal compilation:

```
clang -Xclang -load foo.so -Xclang -plugin
foo-plugin <command line arguments>
```

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  ```
  clang -Xclang -load foo.so -Xclang -plugin
  foo-plugin <command line arguments>
  ```

- Numerous problems with plug-in support:
  - ASTConsumers aren't chained in a natural way
  - Command-line option parsing is too hard
  - Building plugins is too hard
  - Documentation is absent

One-Off Tools

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    - CompilerInstance/CompilerInvocation/Action not simple enough
    - Missing a “quickstart” tutorial

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- Building one-off tools is possible (but hard):
  - CompilerInstance/CompilerInvocation/Action not simple enough
  - Missing a “quickstart” tutorial
- *Simple* source-to-source translation needed
  - Tie together traversal, rewriter, verification

Summary

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- Numerous extension points to Clang
  - Picking the best one is important

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- Numerous extension points to Clang
  - Picking the best one is important
- We need to make extension easier
  - Plugins need to be super-easy to write
  - “Your first extension” tutorials
  - Make source-to-source translation easy