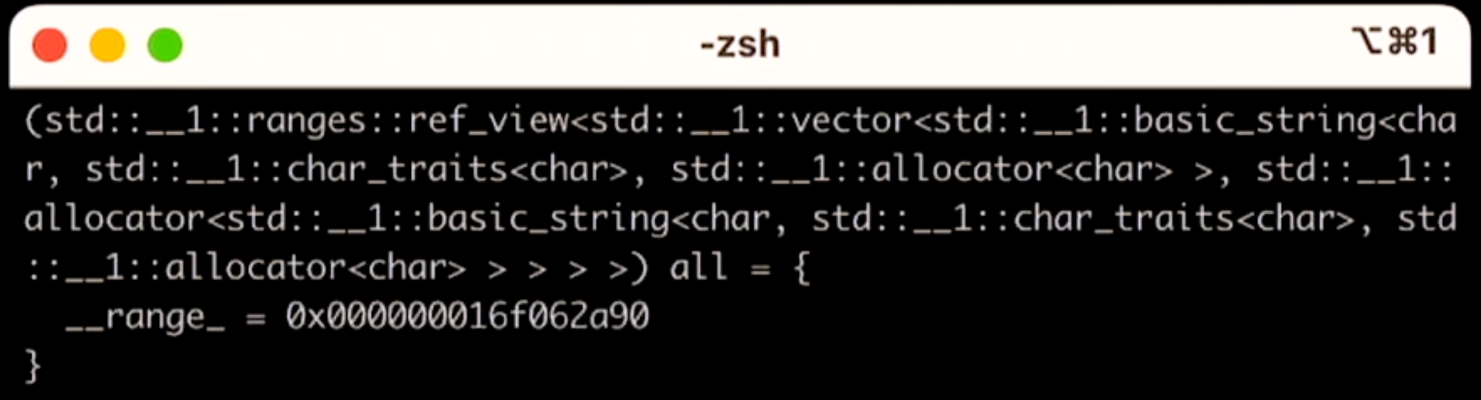
From std::ranges to simpler template names: A C++ debugging journey

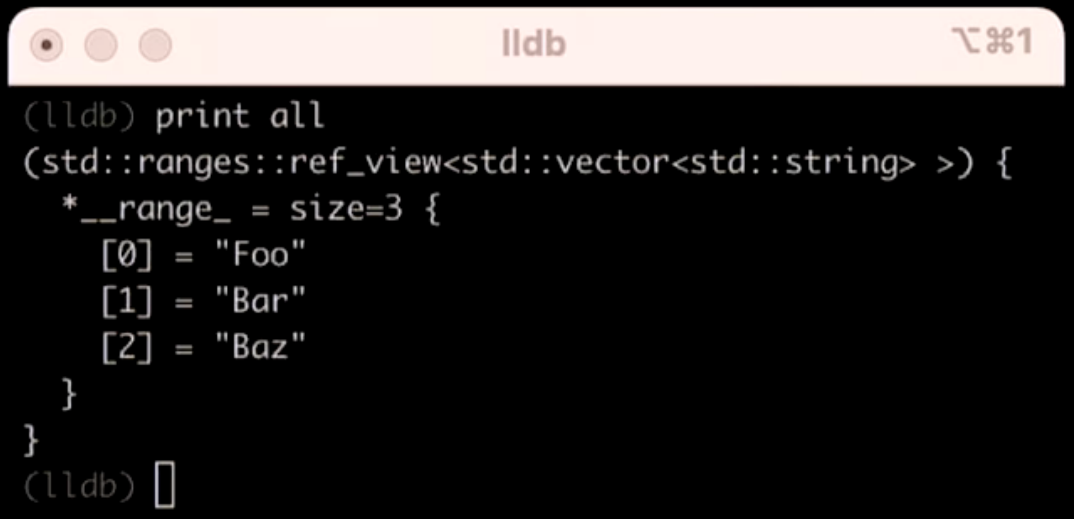
Michael Buch

EuroLLVM 2024 | Apple | 11th April 2024

LLDB Integration



```
(std::__1::ranges::ref_view<std::__1::vector<std::__1::basic_string<cha
r, std::__1::char_traits<char>, std::__1::allocator<char> >, std::__1::
allocator<std::__1::basic_string<char, std::__1::char_traits<char>, std
::__1::allocator<char> > > > >) all = {
  __range_ = 0x000000016f062a90
}
```



```
(lldb) print all
(std::ranges::ref_view<std::vector<std::string> >) {
  *__range_ = size=3 {
    [0] = "Foo"
    [1] = "Bar"
    [2] = "Baz"
  }
}
(lldb)
```

2023 LLVM DEVELOPERS' MEETING

Design and Implementation of C++20 Ranges in libc++

Konstantin Varlamov

https://youtu.be/g9p1oo8bDJA?t=1119

```cpp
std::map<int, std::vector<std::string>> map{
  {1, {“foo"}},
  {2, {"bar"}}};

auto elems = std::views::values(map);
```

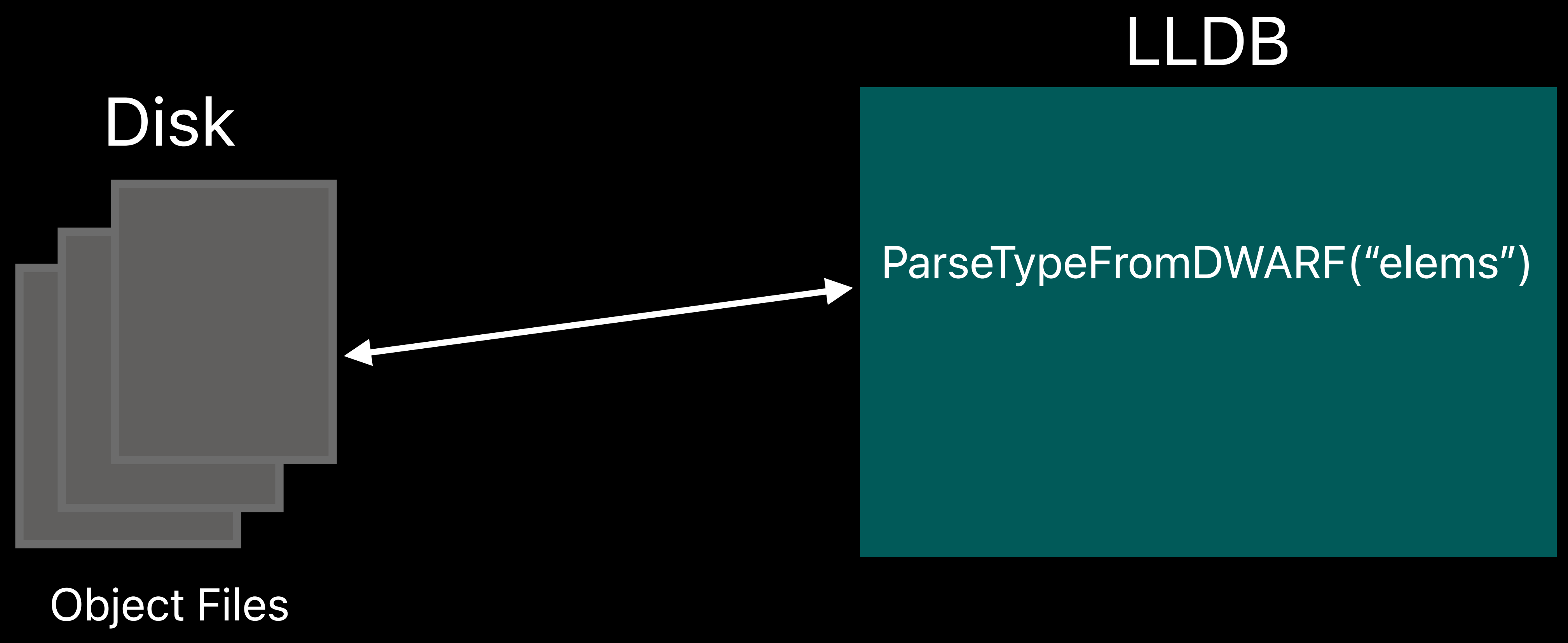
```
(lldb) p elems
```

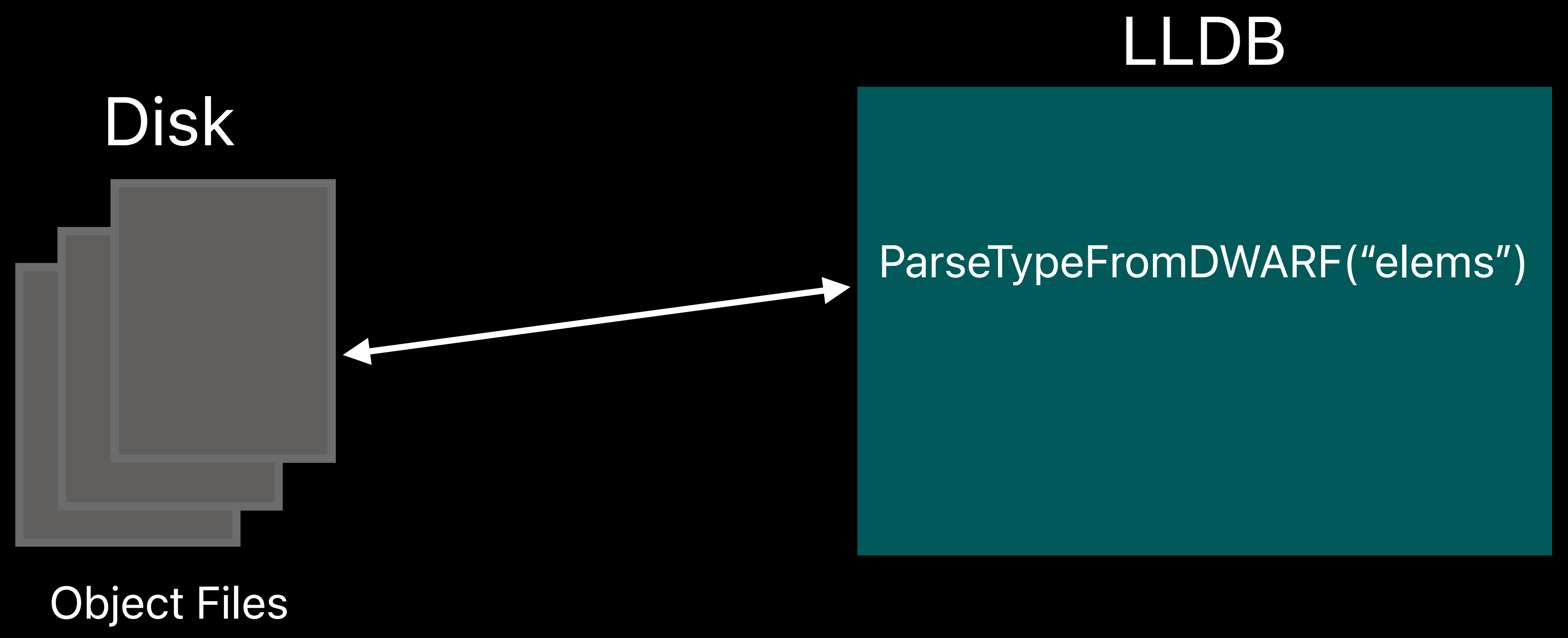
```
(lldb) p elems

(std::ranges::elements_view<std::ranges::ref_view<std::map<int,
std::vector<std::basic_string<char, std::char_traits<char>,
std::allocator<char> >, std::allocator<std::basic_string<char,
std::char_traits<char>, std::allocator<char> > > >, std::less<int>,
std::allocator<std::pair<const int, std::vector<std::basic_string<char,
std::char_traits<char>, std::allocator<char> >,
std::allocator<std::basic_string<char, std::char_traits<char>,
std::allocator<char> > > > > > > >, 1>) elems = {
  __base_ = {
    __range_ = 0x000000016fdfee18 size=2
  }
}
```

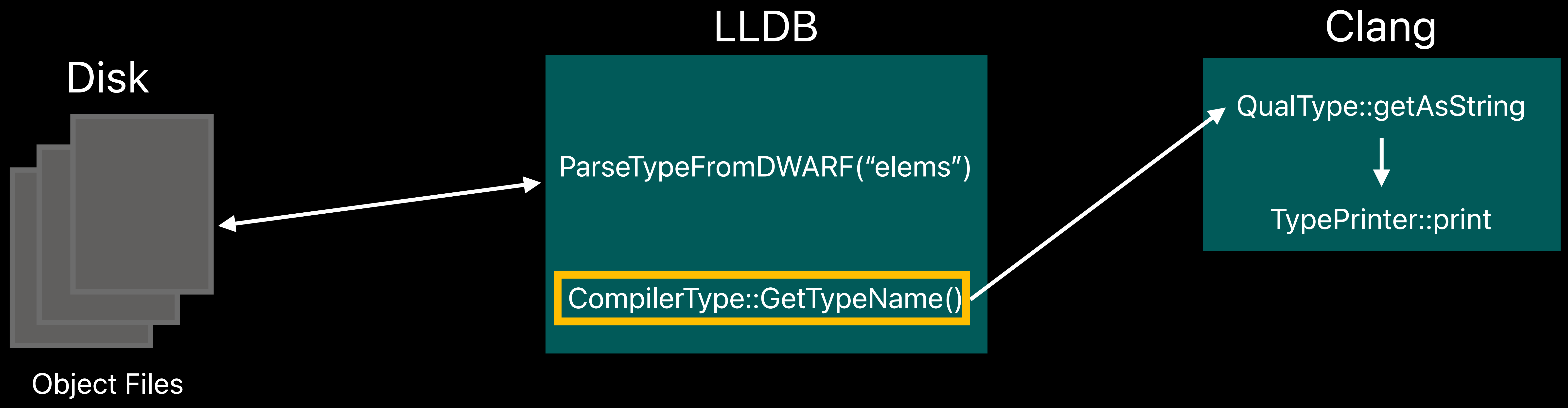
```
(lldb) p elems

(std::ranges::elements_view<std::ranges::ref_view<std::map<int,
std::vector<std::string> > >, 1>) elems = {
  __base_ = {
    *__range_ = size=2 {
      [0] = {
        first = 1
        second = size=1 {
          [0] = "foo"
        }
      }
      [1] = {
        first = 2
        second = size=1 {
          [0] = "bar"
        }
      }
    }
  }
}
```

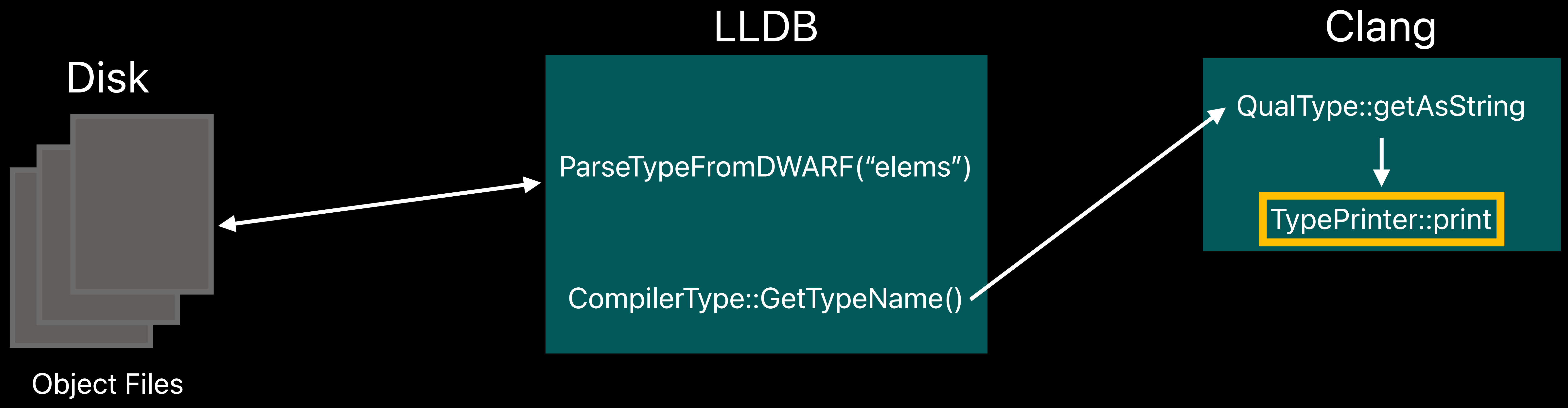

LLDB
Disk
ParseTypeFromDWARF("elems")
Object Files



```
ClassTemplateSpecializationDecl 0x14acc01d8 class map definition
|-TemplateArgument type 'int'
| `-BuiltinType 0x14ac64910 'int'
|-TemplateArgument type 'std::vector<std::string>'
| `-RecordType 0x14acbef10 'std::vector<std::string>'
|   `-ClassTemplateSpecialization 0x14acbee08 'vector'
|- …
```



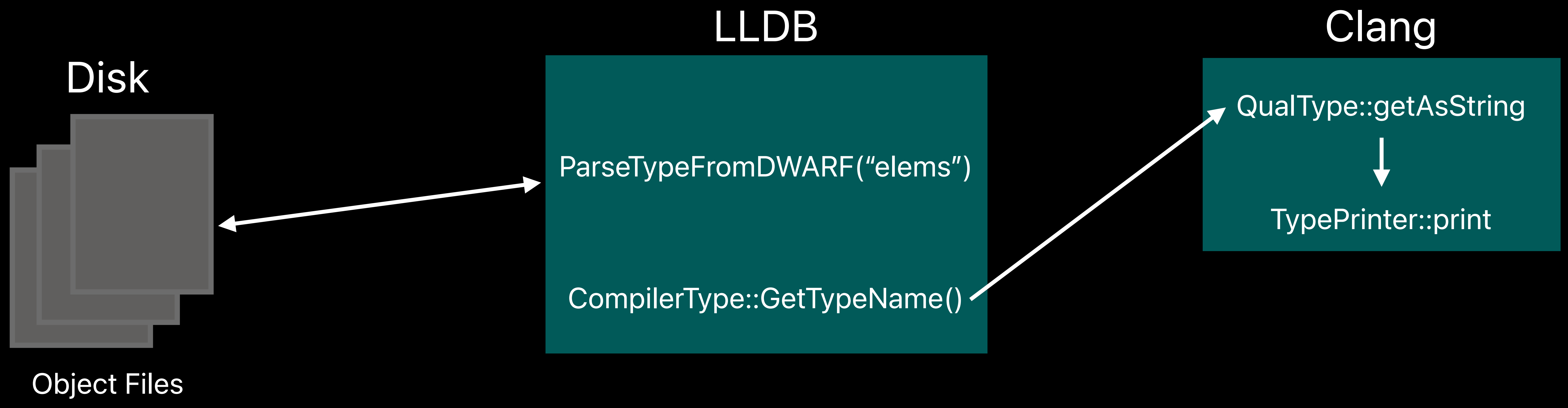
```
ClassTemplateSpecializationDecl 0x14acc01d8 class map definition
|-TemplateArgument type 'int'
| `-BuiltinType 0x14ac64910 'int'
|-TemplateArgument type 'std::vector<std::string>'
| `-RecordType 0x14acbef10 'std::vector<std::string>'
|   `-ClassTemplateSpecialization 0x14acbee08 'vector'
|- …
```



```
ClassTemplateSpecializationDecl 0x14acc01d8 class map definition
|-TemplateArgument type 'int'
| `-BuiltinType 0x14ac64910 'int'
|-TemplateArgument type 'std::vector<std::string>'
| `-RecordType 0x14acbef10 'std::vector<std::string>'
|   `-ClassTemplateSpecialization 0x14acbee08 'vector'
|- …
```

LLVM DEV MEETING
Raphael Isemann
Better C++ Debugging using Clang Modules in LLDB
LLVM.ORG
Expression Evaluation in LLDB

https://www.youtube.com/watch?v=vuNZLlHhy0k



```
ClassTemplateSpecializationDecl 0x14acc01d8 class map definition
|-TemplateArgument type 'int'
| `-BuiltinType 0x14ac64910 'int'
|-TemplateArgument type 'std::vector<std::string>'
| `-RecordType 0x14acbef10 'std::vector<std::string>'
|   `-ClassTemplateSpecialization 0x14acbee08 'vector'
|- …
```

```
(lldb) p elems

(std::ranges::elements_view<std::ranges::ref_view<std::map<int,
std::vector<std::basic_string<char, std::char_traits<char>,
std::allocator<char> >, std::allocator<std::basic_string<char,
std::char_traits<char>, std::allocator<char> > > >, std::less<int>,
std::allocator<std::pair<const int, std::vector<std::basic_string<char,
std::char_traits<char>, std::allocator<char> >,
std::allocator<std::basic_string<char, std::char_traits<char>,
std::allocator<char> > > > > > > >, 1>) elems = {
  __base_ = {
    __range_ = 0x000000016fdfee18 size=2
  }
}
```

```
(lldb) p elems

(std::ranges::elements_view<std::ranges::ref_view<std::map<int,
std::vector<std::basic_string<char, std::char_traits<char>,
std::allocator<char> >, std::allocator<std::basic_string<char,
std::char_traits<char>, std::allocator<char> > > >, std::less<int>,
std::allocator<std::pair<const int, std::vector<std::basic_string<char,
std::char_traits<char>, std::allocator<char> >,
std::allocator<std::basic_string<char, std::char_traits<char>,
std::allocator<char> > > > > > > >, 1>) elems = {
  __base_ = {
    __range_ = 0x000000016fdfee18 size=2
  }
}
```

```
$ clang++ -g main.cpp -fsyntax-only -Xclang -ast-dump
$ clang++ -g main.cpp -fsyntax-only -Xclang -ast-dump

ClassTemplateSpecializationDecl 0x1202f8250 class basic_string definition
|- …
|-TemplateArgument type 'char'
| `-BuiltinType 0x12804aeb0 'char'
|-TemplateArgument type 'std::char_traits<char>'
| `-RecordType 0x1202eb050 'std::char_traits<char>'
|   `-ClassTemplateSpecialization 0x11993ffc0 'char_traits'
|-TemplateArgument type 'std::allocator<char>'
| `-RecordType 0x1202f81a0 'std::allocator<char>'
|   `-ClassTemplateSpecialization 0x1202f80c0 'allocator'
|-OwnerAttr 0x119f424c0 <<invalid sloc>> Inherited Implicit
|-PreferredNameAttr 0x119ea2c98 string
```

```
$ clang++ -g main.cpp -fsyntax-only -Xclang -ast-dump

ClassTemplateSpecializationDecl 0x1202f8250 class basic_string definition
|- …
|-TemplateArgument type 'char'
| `-BuiltinType 0x12804aeb0 'char'
|-TemplateArgument type 'std::char_traits<char>'
| `-RecordType 0x1202eb050 'std::char_traits<char>'
|   `-ClassTemplateSpecialization 0x11993ffc0 'char_traits'
|-TemplateArgument type 'std::allocator<char>'
| `-RecordType 0x1202f81a0 'std::allocator<char>'
|   `-ClassTemplateSpecialization 0x1202f80c0 'allocator'
|-OwnerAttr 0x119f424c0 <<invalid sloc>> Inherited Implicit
|-PreferredNameAttr 0x119ea2c98 string
```

```
void TypePrinter::printRecordBefore(const RecordType *T, raw_ostream &OS) {
  // Print the preferred name if we have one for this type.
  if (Policy.UsePreferredNames) {
    for (const auto *PNA : T->getDecl()->specific_attrs<PreferredNameAttr>()) {
      if (!declaresSameEntity(PNA->getTypedefType()->getAsCXXRecordDecl(),
                              T->getDecl()))
        continue;
```

(from clang/lib/AST/TypePrinter.cpp)

```
void TypePrinter::printRecordBefore(const RecordType *T, raw_ostream &OS) {
  // Print the preferred name if we have one for this type.
  if (Policy.UsePreferredNames) {
    for (const auto *PNA : T->getDecl()->specific_attrs<PreferredNameAttr>()) {
      if (!declaresSameEntity(PNA->getTypedefType()->getAsCXXRecordDecl(),
                              T->getDecl()))
        continue;
```

(from clang/lib/AST/TypePrinter.cpp)

```
(lldb) target modules dump ast
```

```
(lldb) target modules dump ast

ClassTemplateSpecializationDecl 0x107a34dc8 class basic_string definition
|- …
|-TemplateArgument type 'char'
| `-BuiltinType 0x11c27cab0 'char'
|-TemplateArgument type 'std::char_traits<char>'
| `-RecordType 0x107a303c0 'std::char_traits<char>'
|   `-ClassTemplateSpecialization 0x107a46a50 'char_traits'
|-TemplateArgument type 'std::allocator<char>'
| `-RecordType 0x107a30850 'std::allocator<char>'
|   `-ClassTemplateSpecialization 0x107a35590 'allocator'
```

```
(lldb) target modules dump ast

ClassTemplateSpecializationDecl 0x107a34dc8 class basic_string definition
|- …
|-TemplateArgument type 'char'
| `-BuiltinType 0x11c27cab0 'char'
|-TemplateArgument type 'std::char_traits<char>'
| `-RecordType 0x107a303c0 'std::char_traits<char>'
|   `-ClassTemplateSpecialization 0x107a46a50 'char_traits'
|-TemplateArgument type 'std::allocator<char>'
| `-RecordType 0x107a30850 'std::allocator<char>'
|   `-ClassTemplateSpecialization 0x107a35590 'allocator'
```

PreferredNameAttr???

```
$ dwarfdump a.out.dSYM
$ dwarfdump a.out.dSYM

0x0123:  DW_TAG_class_type
           DW_AT_name  (“map<…>")
           DW_TAG_template_type_parameter
             DW_AT_type        (0x8332 "int")
             DW_AT_name        ("_Key")
           DW_TAG_template_type_parameter
             DW_AT_type        (0x0214 "std::__1::vector<std::__1::basic_string<…")
             DW_AT_name        (“_Tp")

0x0214:  DW_TAG_class_type
           DW_AT_name  (“std::vector<std::__1::basic_string<…”)
           DW_TAG_template_type_parameter
             DW_AT_type        (0x0dec "std::__1::basic_string<…")
             DW_AT_name        (“_Tp”)

0x0dec:  DW_TAG_class_type
           DW_AT_name  (“std::__1::basic_string<…”)
```

```
$ dwarfdump a.out.dSYM
                                          std::map
0x0123:  DW_TAG_class_type
           DW_AT_name  (“map<…>")
           DW_TAG_template_type_parameter
             DW_AT_type          (0x8332 "int")
             DW_AT_name          ("_Key")
           DW_TAG_template_type_parameter
             DW_AT_type          (0x0214 "std::__1::vector<std::__1::basic_string<…")
             DW_AT_name          (“_Tp")

0x0214:  DW_TAG_class_type                                             std::vector
           DW_AT_name  (“std::vector<std::__1::basic_string<…”)
           DW_TAG_template_type_parameter
             DW_AT_type          (0x0dec "std::__1::basic_string<…")
             DW_AT_name          (“_Tp”)

0x0dec:  DW_TAG_class_type
           DW_AT_name  (“std::__1::basic_string<…”)
                                                                       std::basic_string
```

```
$ dwarfdump a.out.dSYM

0x0123:  DW_TAG_class_type
           DW_AT_name  (“map<…>")
           DW_TAG_template_type_parameter
             DW_AT_type         (0x8332 "int")
             DW_AT_name         ("_Key")
           DW_TAG_template_type_parameter
             DW_AT_type         (0x0214 "std::__1::vector<std::__1::basic_string<…")
             DW_AT_name         (“_Tp")

0x0214:  DW_TAG_class_type
           DW_AT_name  (“std::vector<std::__1::basic_string<…”)
           DW_TAG_template_type_parameter
             DW_AT_type         (0x0dec "std::__1::basic_string<…")
             DW_AT_name         (“_Tp”)

0x0dec:  DW_TAG_class_type
           DW_AT_name  (“std::__1::basic_string<…”)
```

```
$ dwarfdump a.out.dSYM

0x0123:  DW_TAG_class_type
           DW_AT_name  (“map<…>")
           DW_TAG_template_type_parameter
             DW_AT_type         (0x8332 "int")
             DW_AT_name         ("_Key")
           DW_TAG_template_type_parameter
             DW_AT_type         (0x0214 "std::__1::vector<std::__1::basic_string<…")
             DW_AT_name         (“_Tp")

0x0214:  DW_TAG_class_type
           DW_AT_name  (“std::vector<std::__1::basic_string<…”)
           DW_TAG_template_type_parameter
             DW_AT_type         (0x0dec "std::__1::basic_string<…")
             DW_AT_name         (“_Tp”)

0x0dec:  DW_TAG_class_type
           DW_AT_name  (“std::__1::basic_string<…”)
```

```
$ dwarfdump a.out.dSYM

0x0123:  DW_TAG_class_type
           DW_AT_name  (“map<…>")
           DW_TAG_template_type_parameter
             DW_AT_type        (0x8332 "int")
             DW_AT_name        ("_Key")
           DW_TAG_template_type_parameter
             DW_AT_type        (0x0214 "std::__1::vector<std::__1::basic_string<…")
             DW_AT_name        (“_Tp")

0x0214:  DW_TAG_class_type
           DW_AT_name  (“std::vector<std::__1::basic_string<…”)
           DW_TAG_template_type_parameter
             DW_AT_type        (0x0dec "std::__1::basic_string<…")
             DW_AT_name        (“_Tp”)

0x0dec:  DW_TAG_class_type
           DW_AT_name  (“std::__1::basic_string<…”)
```

```
$ dwarfdump a.out.dSYM

0x0123:  DW_TAG_class_type
           DW_AT_name  (“map<…>")
           DW_TAG_template_type_parameter
             DW_AT_type        (0x8332 "int")
             DW_AT_name        ("_Key")
           DW_TAG_template_type_parameter
             DW_AT_type        (0x0214 "std::__1::vector<std::__1::basic_string<…")
             DW_AT_name        (“_Tp")

0x0214:  DW_TAG_class_type
           DW_AT_name  (“std::vector<std::__1::basic_string<…”)
           DW_TAG_template_type_parameter
             DW_AT_type        (0x0dec "std::__1::basic_string<…")
             DW_AT_name        (“_Tp”)

0x0dec:  DW_TAG_class_type
           DW_AT_name  (“std::__1::basic_string<…”)
```

```
$ dwarfdump a.out.dSYM

 0x0123:  DW_TAG_class_type
            DW_AT_name  (“map<…>")
            DW_TAG_template_type_parameter
              DW_AT_type        (0x8332 "int")
              DW_AT_name        ("_Key")
            DW_TAG_template_type_parameter
              DW_AT_type        (0x0214 "std::__1::vector<std::__1::basic_string<…")
              DW_AT_name        (“_Tp")

 0x0214:  DW_TAG_class_type
            DW_AT_name  (“std::vector<std::__1::basic_string<…”)
            DW_TAG_template_type_parameter
              DW_AT_type        (0x0b26 "string")
              DW_AT_name        (“_Tp”)

 0x0b26:  DW_TAG_typedef
              DW_AT_type        (0x0dec "std::__1::basic_string<…")
              DW_AT_name        (“string”)

 0x0dec:  DW_TAG_class_type
            DW_AT_name  (“std::__1::basic_string<…”)
```

```
(lldb) p elems

(std::ranges::elements_view<std::ranges::ref_view<std::map<int,
std::vector<std::basic_string<char, std::char_traits<char>,
std::allocator<char> >, std::allocator<std::basic_string<char,
std::char_traits<char>, std::allocator<char> > > >, std::less<int>,
std::allocator<std::pair<const int, std::vector<std::basic_string<char,
std::char_traits<char>, std::allocator<char> >,
std::allocator<std::basic_string<char, std::char_traits<char>,
std::allocator<char> > > > > > > >, 1>) elems = {
  __base_ = {
    __range_ = 0x000000016fdfee18 size=2
  }
}
```

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(lldb) p elems

(std::ranges::elements_view<std::ranges::ref_view<std::map<int,
std::vector<std::string, std::allocator<std::string> >, std::less<int>,
std::allocator<std::pair<const int, std::vector<std::string,
std::allocator<std::string> > > > > >, 1>) elems = {
  __base_ = {
    __range_ = 0x000000016fdfee18 size=2
  }
}
```

```
(lldb) p elems

(std::ranges::elements_view<std::ranges::ref_view<std::map<int,
std::vector<std::string, std::allocator<std::string> >, std::less<int>,
std::allocator<std::pair<const int, std::vector<std::string,
std::allocator<std::string> > > > > >, 1>) elems = {
  __base_ = {
    __range_ = 0x000000016fdfee18 size=2
  }
}
```

```
template <typename TA>
static void
printTo(raw_ostream &OS, ArrayRef<TA> Args, const PrintingPolicy &Policy,
        const TemplateParameterList *TPL, bool IsPack, unsigned ParmIndex) {
  if (TPL && Policy.SuppressDefaultTemplateArgs &&
    !Policy.PrintCanonicalTypes && !Args.empty() && !IsPack &&
    Args.size() <= TPL->size()) {
  ASTContext &Ctx = TPL->getParam(0)->getASTContext();
  llvm::SmallVector<TemplateArgument, 8> OrigArgs;
  for (const TA &A : Args)
    OrigArgs.push_back(getArgument(A));
  while (!Args.empty() &&
         isSubstitutedDefaultArgument(Ctx, getArgument(Args.back()),
                                      TPL->getParam(Args.size() - 1),
                                      OrigArgs, TPL->getDepth()))
    Args = Args.drop_back();
...
```

(from clang/lib/AST/TypePrinter.cpp)

```
template <typename TA>
static void
printTo(raw_ostream &OS, ArrayRef<TA> Args, const PrintingPolicy &Policy,
        const TemplateParameterList *TPL, bool IsPack, unsigned ParmIndex) {
  if (TPL && Policy.SuppressDefaultTemplateArgs &&
    !Policy.PrintCanonicalTypes && !Args.empty() && !IsPack &&
    Args.size() <= TPL->size()) {
  ASTContext &Ctx = TPL->getParam(0)->getASTContext();
  llvm::SmallVector<TemplateArgument, 8> OrigArgs;
  for (const TA &A : Args)
    OrigArgs.push_back(getArgument(A));
  while (!Args.empty() &&
         isSubstitutedDefaultArgument(Ctx, getArgument(Args.back()),
                                      TPL->getParam(Args.size() - 1),
                                      OrigArgs, TPL->getDepth()))
    Args = Args.drop_back();
...
```

(from clang/lib/AST/TypePrinter.cpp)

```
bool clang::isSubstitutedDefaultArgument(ASTContext &Ctx, TemplateArgument Arg,
                                          const NamedDecl *Param,
                                          ArrayRef<TemplateArgument> Args,
                                          unsigned Depth) {
  // An empty pack is equivalent to not providing a pack argument.
  if (Arg.getKind() == TemplateArgument::Pack && Arg.pack_size() == 0)
    return true;

  if (auto *TTPD = dyn_cast<TemplateTypeParmDecl>(Param)) {
    return TTPD->hasDefaultArgument() &&
           isSubstitutedTemplateArgument(Ctx, Arg, TTPD->getDefaultArgument(),
                                          Args, Depth);
```

(from clang/lib/AST/TypePrinter.cpp)

```
bool clang::isSubstitutedDefaultArgument(ASTContext &Ctx, TemplateArgument Arg,
                                         const NamedDecl *Param,
                                         ArrayRef<TemplateArgument> Args,
                                         unsigned Depth) {
  // An empty pack is equivalent to not providing a pack argument.
  if (Arg.getKind() == TemplateArgument::Pack && Arg.pack_size() == 0)
    return true;

  if (auto *TTPD = dyn_cast<TemplateTypeParmDecl>(Param)) {
    return TTPD->hasDefaultArgument() &&
           isSubstitutedTemplateArgument(Ctx, Arg, TTPD->getDefaultArgument(),
                                         Args, Depth);
```

(from clang/lib/AST/TypePrinter.cpp)

```
static TemplateParameterList *CreateTemplateParameterList(
    ASTContext &ast,
    const TypeSystemClang::TemplateParameterInfos &template_param_infos,
    llvm::SmallVector<NamedDecl *, 8> &template_param_decls) {
    ...

      auto *TTP = TemplateTypeParmDecl::Create(
          ast, decl_context, SourceLocation(), SourceLocation(), depth,
          num_template_params, identifier_info, is_typename,
          parameter_pack_true);

      template_param_decls.push_back(TTP);
    }
  }

  TemplateParameterList *template_param_list =
     TemplateParameterList::Create(
         ast, SourceLocation(), SourceLocation(), template_param_decls,
         SourceLocation(), requires_clause);
  ...
  return template_param_list;
```

(from lldb/source/Plugins/TypeSystem/Clang/TypeSystemClang.cpp)

```
static TemplateParameterList *CreateTemplateParameterList(
    ASTContext &ast,
    const TypeSystemClang::TemplateParameterInfos &template_param_infos,
    llvm::SmallVector<NamedDecl *, 8> &template_param_decls) {
    ...

      auto *TTP = TemplateTypeParmDecl::Create(
          ast, decl_context, SourceLocation(), SourceLocation(), depth,
          num_template_params, identifier_info, is_typename,
          parameter_pack_true);

      template_param_decls.push_back(TTP);
    }
  }

  TemplateParameterList *template_param_list =
     TemplateParameterList::Create(
         ast, SourceLocation(), SourceLocation(), template_param_decls,
         SourceLocation(), requires_clause);
  ...
  return template_param_list;
```

(from lldb/source/Plugins/TypeSystem/Clang/TypeSystemClang.cpp)

```
static TemplateParameterList *CreateTemplateParameterList(
    ASTContext &ast,
    const TypeSystemClang::TemplateParameterInfos &template_param_infos,
    llvm::SmallVector<NamedDecl *, 8> &template_param_decls) {
    ...

      auto *TTP = TemplateTypeParmDecl::Create(
          ast, decl_context, SourceLocation(), SourceLocation(), depth,
          num_template_params, identifier_info, is_typename,
          parameter_pack_true);
      TTP->setDefaultArgument(???);
      template_param_decls.push_back(TTP);
    }
  }

  TemplateParameterList *template_param_list =
     TemplateParameterList::Create(
         ast, SourceLocation(), SourceLocation(), template_param_decls,
         SourceLocation(), requires_clause);
  ...
  return template_param_list;
```

(from lldb/source/Plugins/TypeSystem/Clang/TypeSystemClang.cpp)

```
$ dwarfdump a.out.dSYM

DW_TAG_class_type
  DW_AT_name  ("map<int, std::__1::vector<std::__1::basic_string<char, std::__1::char_traits<char>,…")
  DW_TAG_template_type_parameter
    DW_AT_type        (0x8332 "int")
    DW_AT_name        ("_Key")
  DW_TAG_template_type_parameter
    DW_AT_type        (0x0214 "std::__1::vector<std::__1::basic_string<…")
    DW_AT_name        ("_Tp")
  DW_TAG_template_type_parameter
    DW_AT_type        (0x3e06 "std::__1::less<int>")
    DW_AT_name        ("_Compare")
  DW_TAG_template_type_parameter
    DW_AT_type        (0x3e5d "std::__1::allocator<std::__1::pair<const int, std::__1::vector<std::__1::basic_string<…")
    DW_AT_name        ("_Allocator")
```

```
$ dwarfdump a.out.dSYM

DW_TAG_class_type
  DW_AT_name  ("map<int, std::__1::vector<std::__1::basic_string<char, std::__1::char_traits<char>,…")
  DW_TAG_template_type_parameter
    DW_AT_type        (0x8332 "int")
    DW_AT_name        ("_Key")
  DW_TAG_template_type_parameter
    DW_AT_type        (0x0214 "std::__1::vector<std::__1::basic_string<…")
    DW_AT_name        ("_Tp")
  DW_TAG_template_type_parameter
    DW_AT_type        (0x3e06 "std::__1::less<int>")
    DW_AT_name        ("_Compare")
  DW_TAG_template_type_parameter
    DW_AT_type        (0x3e5d "std::__1::allocator<std::__1::pair<const int, std::__1::vector<std::__1::basic_string<…")
    DW_AT_name        ("_Allocator")
```

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  DW_AT_name  ("map<int, std::__1::vector<std::__1::basic_string<char, std::__1::char_traits<char>,…")
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    DW_AT_type        (0x0214 "std::__1::vector<std::__1::basic_string<…")
    DW_AT_name        ("_Tp")
  DW_TAG_template_type_parameter
    DW_AT_type        (0x3e06 "std::__1::less<int>")
    DW_AT_name        ("_Compare")
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    DW_AT_type        (0x3e5d "std::__1::allocator<std::__1::pair<const int, std::__1::vector<std::__1::basic_string<…")
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  DW_AT_name  ("map<int, std::__1::vector<std::__1::basic_string<char, std::__1::char_traits<char>,…")
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    DW_AT_type        (0x8332 "int")
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  DW_TAG_template_type_parameter
    DW_AT_type        (0x3e06 "std::__1::less<int>")
    DW_AT_name        ("_Compare")
  DW_TAG_template_type_parameter
    DW_AT_type        (0x3e5d "std::__1::allocator<std::__1::pair<const int, std::__1::vector<std::__1::basic_string<…")
    DW_AT_name        ("_Allocator")
```

```
template<typename _Key, typename _Tp,
         typename _Allocator = std::allocator<std::pair<_Key, _Tp>>>
class map;

Or

template<typename _Key, typename _Tp,
         typename _Allocator = std::allocator<std::pair<int, std::vector<…>>>>
class map;

?
```

| The entry may also have a DW_AT_default_value attribute, which is a flag indicating
| that the value corresponds to the default argument for the template parameter.

- DWARFv5 Section 2.23

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| that the value corresponds to the default argument for the template parameter.

- DWARFv5 Section 2.23

```
$ clang++ -gdwarf-5 map.cpp
$ dwarfdump a.out.dSYM
```

| The entry may also have a DW_AT_default_value attribute, which is a flag indicating
| that the value corresponds to the default argument for the template parameter.

- DWARFv5 Section 2.23

```
$ clang++ -gdwarf-5 map.cpp
$ dwarfdump a.out.dSYM
```

```
DW_TAG_class_type
  DW_AT_name  ("map<int, std::__1::vector<std::__1::basic_string<char, std::__1::char_traits<char>,…")
  DW_TAG_template_type_parameter
    DW_AT_type          (0x8332 "int")
    DW_AT_name          ("_Key")
  DW_TAG_template_type_parameter
    DW_AT_type          (0x0214 "std::__1::vector<std::__1::basic_string<…")
    DW_AT_name          ("_Tp")
  DW_TAG_template_type_parameter
    DW_AT_type          (0x3e06 "std::__1::less<int>")
    DW_AT_name          ("_Compare")
    DW_AT_default_value (true)
  DW_TAG_template_type_parameter
    DW_AT_type          (0x3e5d "std::__1::allocator<std::__1::pair<const int, std::__1::vector<std::__1::basic_string<…")
    DW_AT_name          ("_Allocator")
    DW_AT_default_value (true)
```

(Compile time)

Clang

```
clang::TemplateArgument {
  ...
  bool IsDefaulted : 1;
};
```

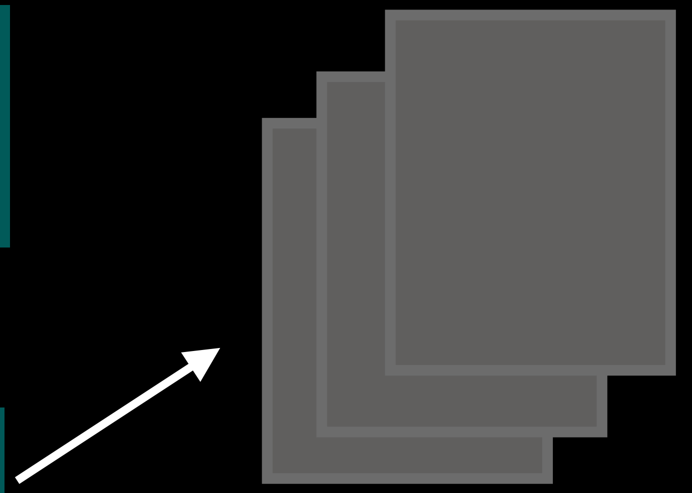
Sema

```
if(subst(Arg, Params[i]))
    Arg.SetIsDefaulted(true)
```

CGDebugInfo

```
if (Arg.GetIsDefaulted())
  addFlag(DW_AT_default_value)
```

Disk



Object Files

(Compile time)

Clang

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clang::TemplateArgument {
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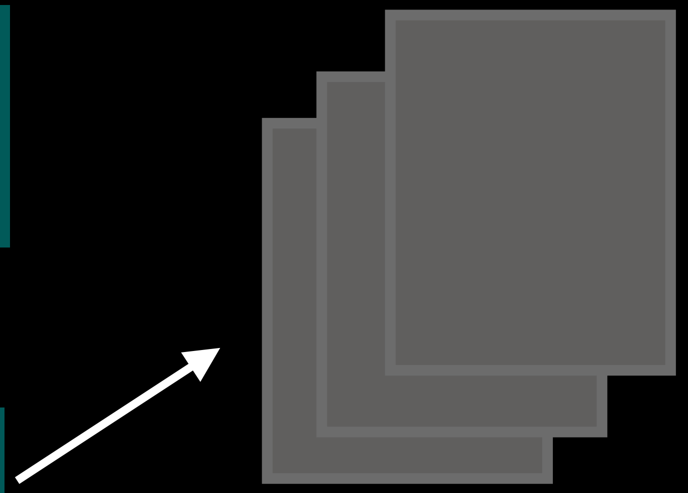

Object Files

(Compile time)

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```
clang::TemplateArgument {
  ...
  bool IsDefaulted : 1;
};
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Sema

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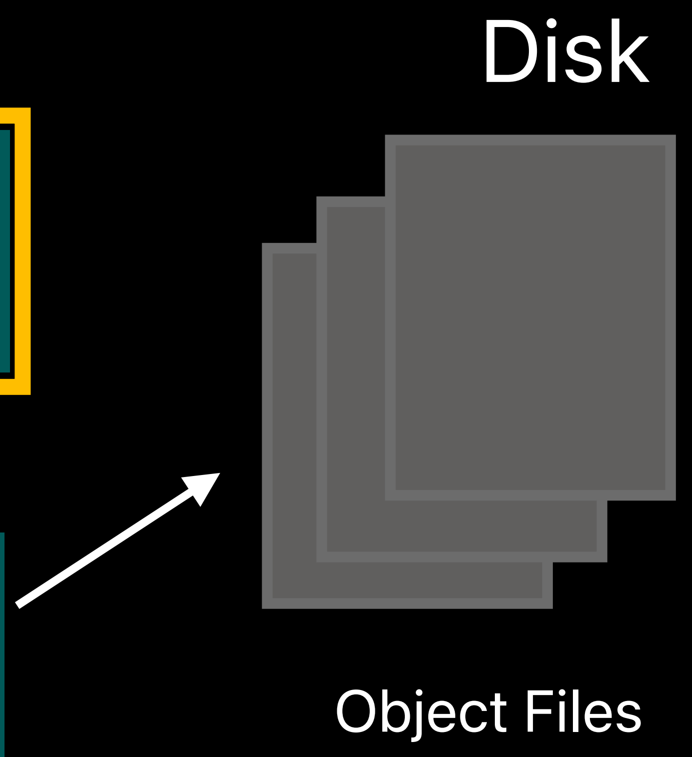

(Compile time)

Clang

```
clang::TemplateArgument {
  ...
  bool IsDefaulted : 1;
};
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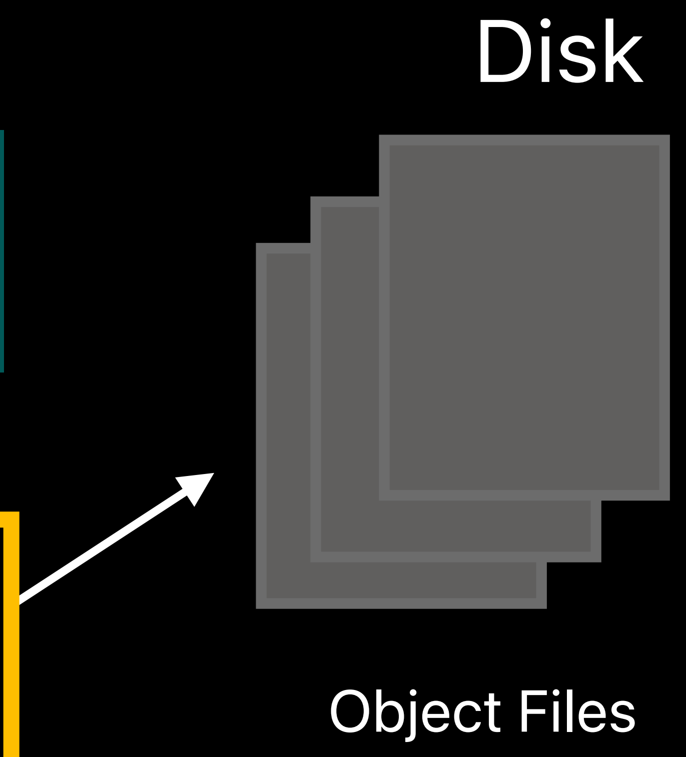

(Compile time)

(Debug time)

Clang

```
clang::TemplateArgument {
  ...
  bool IsDefaulted : 1;
};
```

Sema

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if(subst(Arg, Params[i]))
    Arg.SetIsDefaulted(true)
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CGDebugInfo

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if (Arg.GetIsDefaulted())
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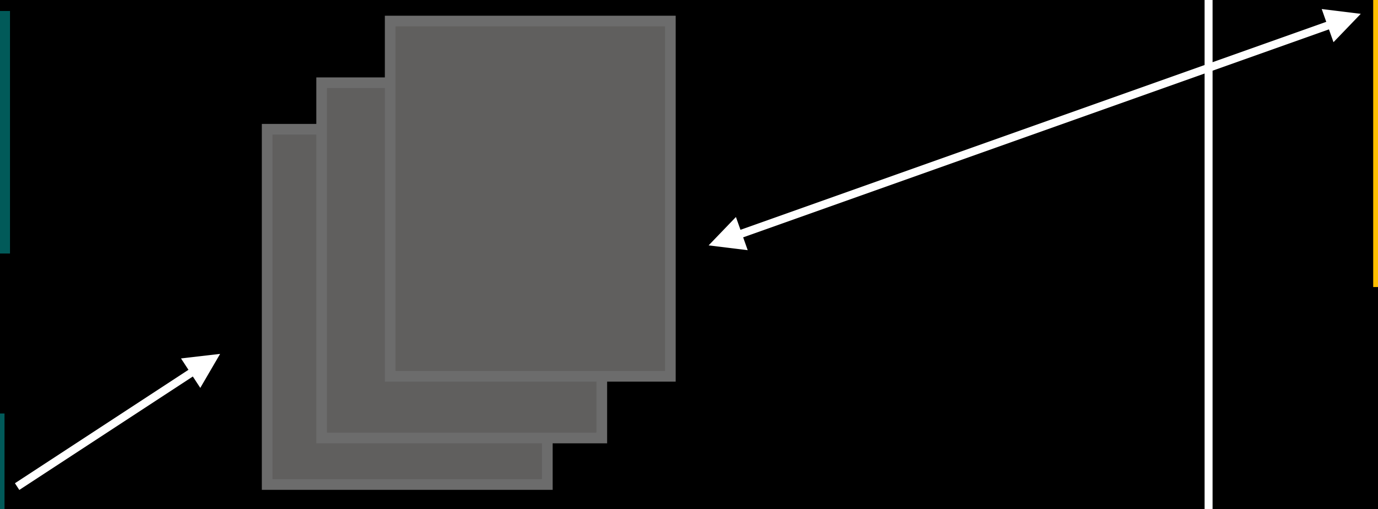
Disk

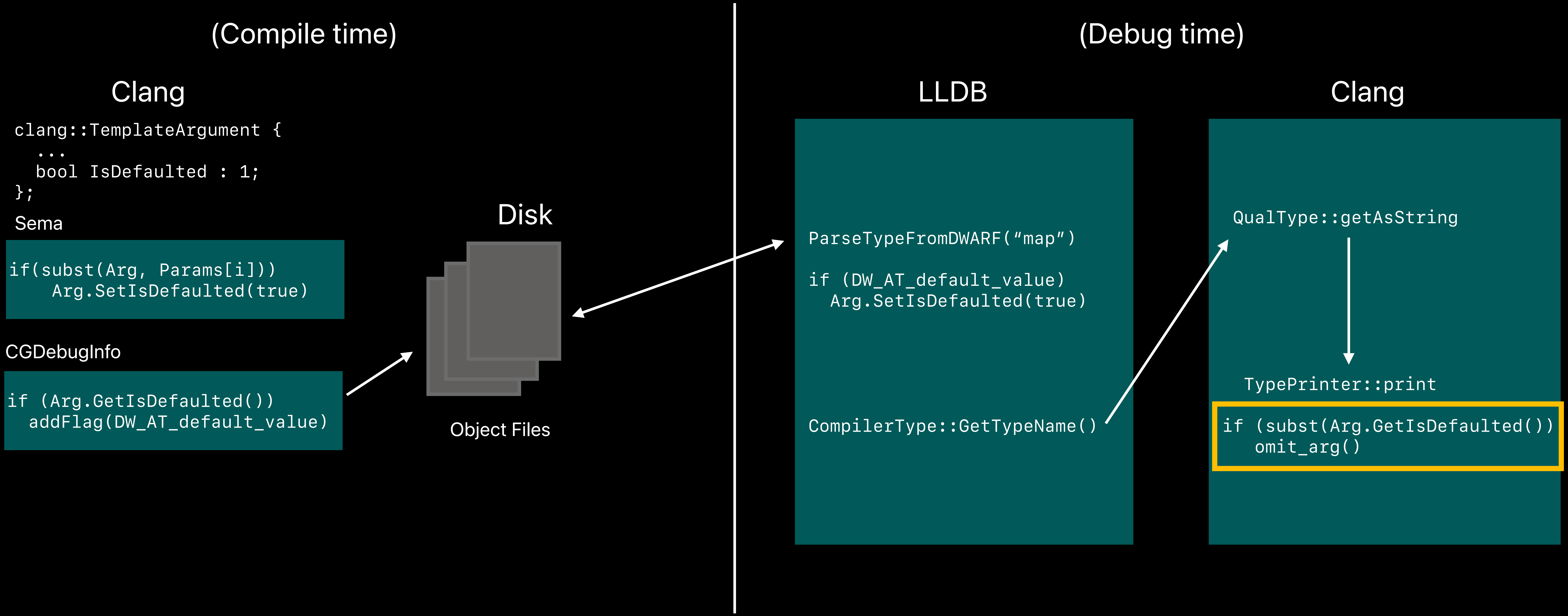


LLDB

```
ParseTypeFromDWARF("map")

if (DW_AT_default_value)
  Arg.SetIsDefaulted(true)
```

```
CompilerType::GetTypeName()
```



```
clang::TemplateArgument {
  ...
  bool IsDefaulted : 1;
};
```

Sema

```
if(subst(Arg, Params[i]))
    Arg.SetIsDefaulted(true)
```

CGDebugInfo

```
if (Arg.GetIsDefaulted())
  addFlag(DW_AT_default_value)
```

LLDB

```
ParseTypeFromDWARF("map")

if (DW_AT_default_value)
  Arg.SetIsDefaulted(true)


CompilerType::GetTypeName()
```

Clang

```
QualType::getAsString

TypePrinter::print

if (subst(Arg.GetIsDefaulted())
   omit_arg()
```

```
(lldb) p elems

(std::ranges::elements_view<std::ranges::ref_view<std::map<int,
std::vector<std::string, std::allocator<std::string> >, std::less<int>,
std::allocator<std::pair<const int, std::vector<std::string,
std::allocator<std::string> > > > > >, 1>) elems = {
  __base_ = {
    __range_ = 0x000000016fdfee18 size=2
  }
}
```

```
(lldb) p elems

(std::ranges::elements_view<std::ranges::ref_view<std::map<int,
std::vector<std::string> > >, 1>) elems = {
  __base_ = {
    __range_ = 0x000000016fdfee18 size=2
  }
}
```

```
(lldb) p elems

(std::ranges::elements_view<std::ranges::ref_view<std::map<int,
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    __range_ = 0x000000016fdfee18 size=2
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```
(lldb) p elems

(std::ranges::elements_view<std::ranges::ref_view<std::map<int,
std::vector<std::string> > >, 1>) elems = {
  __base_ = {
    __range_ = 0x000000016fdfee18 size=2
  }
}
```

```
namespace ranges {
template <range _Range>
  requires is_object_v<_Range>
class ref_view : public view_interface<ref_view<_Range>> {
  _Range* __range_;
```

(from libcxx/include/__ranges/ref_view.h)

```
(lldb) type synthetic list
…
^std::__[[:alnum:]]+::ranges::ref_view<.+>$:  libc++ std::ranges::ref_view synthetic children
…
```

```
lldb::ChildCacheState
lldb_private::formatters::LibcxxStdRangesRefViewSyntheticFrontEnd::Update() {
  ValueObjectSP range_ptr =
      GetChildMemberWithName(m_backend,{ConstString( "__range_")});
  if (!range_ptr)
    return lldb::ChildCacheState::eRefetch;

  lldb_private::Status error;
  m_range_sp = range_ptr->Dereference(error);
  …
}
```

(from lldb/source/Plugins/Language/CPlusPlus/LibCxxRangesRefView.cpp)

```
lldb::ChildCacheState
lldb_private::formatters::LibcxxStdRangesRefViewSyntheticFrontEnd::Update() {
  ValueObjectSP range_ptr =
      GetChildMemberWithName(m_backend,{ConstString( "__range_")});
  if (!range_ptr)
    return lldb::ChildCacheState::eRefetch;

  lldb_private::Status error;
  m_range_sp = range_ptr->Dereference(error);
  …
}
```

(from lldb/source/Plugins/Language/CPlusPlus/LibCxxRangesRefView.cpp)

```
lldb::ChildCacheState
lldb_private::formatters::LibcxxStdRangesRefViewSyntheticFrontEnd::Update() {
  ValueObjectSP range_ptr =
      GetChildMemberWithName(m_backend,{ConstString( "__range_")});
  if (!range_ptr)
    return lldb::ChildCacheState::eRefetch;

  lldb_private::Status error;
  m_range_sp = range_ptr->Dereference(error);
  …
}
```

(from lldb/source/Plugins/Language/CPlusPlus/LibCxxRangesRefView.cpp)

```
(lldb) p elems

(std::ranges::elements_view<std::ranges::ref_view<std::map<int,
std::vector<std::string> > >, 1>) elems = {
  __base_ = {
    __range_ = 0x000000016fdfee18 size=2
  }
}
```

```
(lldb) p elems

(std::ranges::elements_view<std::ranges::ref_view<std::map<int,
std::vector<std::string> > >, 1>) elems = {
  __base_ = {
    *__range_ = size=2 {
      [0] = {
        first = 1
        second = size=1 {
          [0] = "foo"
        }
      }
      [1] = {
        first = 2
        second = size=1 {
          [0] = "bar"
        }
      }
    }
  }
}
```

Conclusion

LLDB uses Clang for type introspection

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LLDB relies on DWARF for AST reconstruction

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Improving debugging experience is often a balance of where we want to shift complexity to (debugger vs. compiler)

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LLDB uses Clang for type introspection

LLDB relies on DWARF for AST reconstruction

Improving debugging experience is often a balance of where we want to shift complexity to (debugger vs. compiler)

Keep debugging and LLDB in mind when developing new language or standard library features