EMC++ Chapter 4

Smart Pointers

C++11 / C++14 smart pointer types

auto_ptr

unique_ptr

shared_ptr

weak_ptr

C++11 / C++14 smart pointer types

auto_ptr

C++98. Deprecated in C++11. Removed in C++17.

unique_ptr

C++11 replacement for auto_ptr. C++14 adds make_unique.

shared_ptr

C++11. Reference-counting.

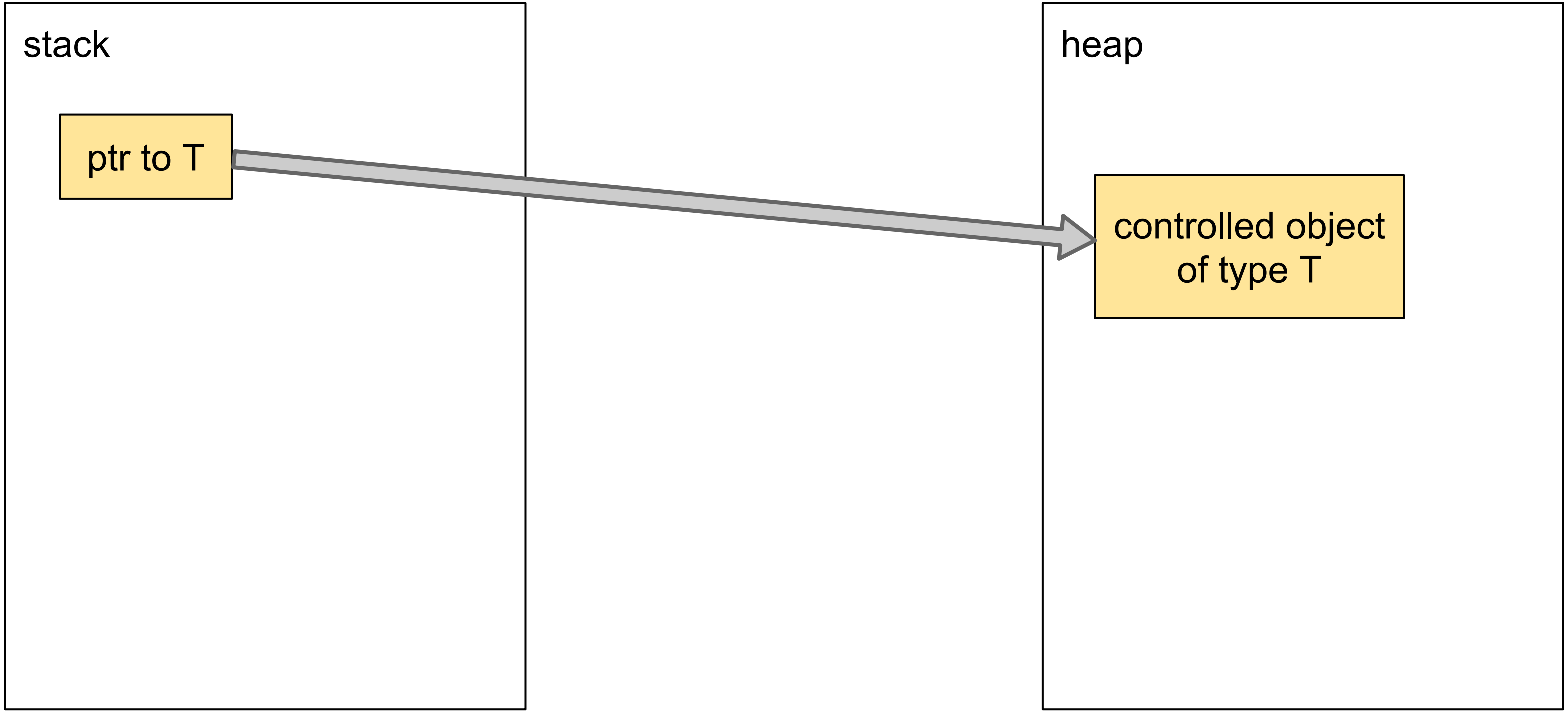
weak_ptr

C++11. "Weak" references.

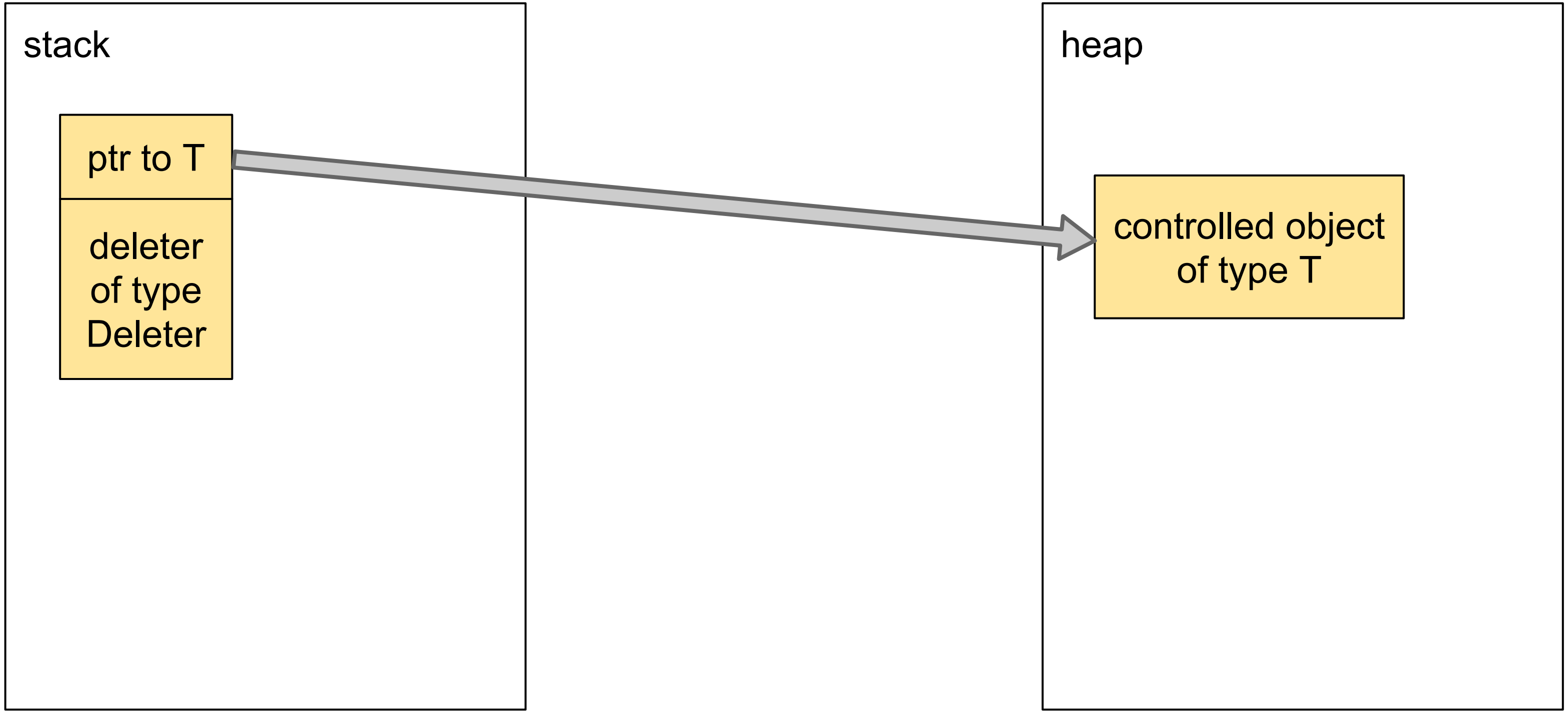
EMC++ Item 18

Use `std::unique_ptr` for exclusive-ownership resource management.

std::unique_ptr<T>



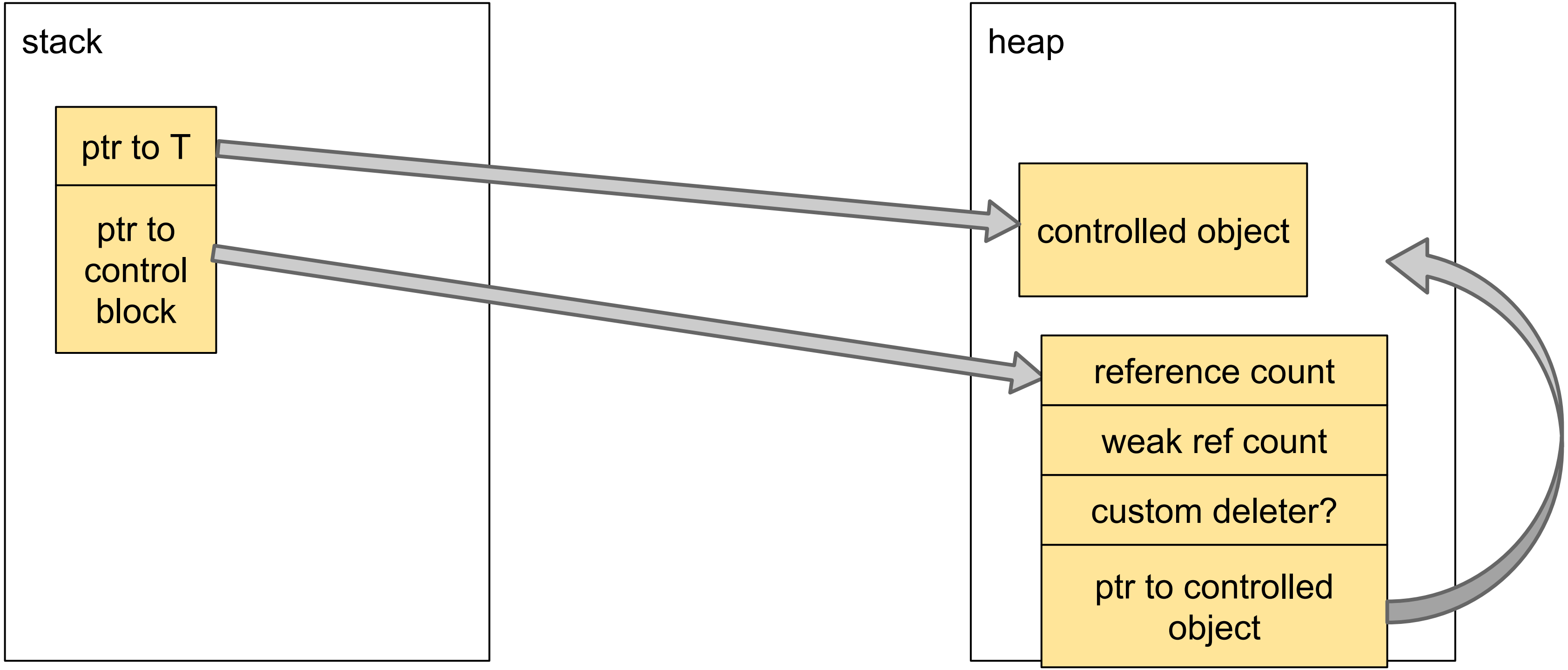
std::unique_ptr<T, Deleter>



EMC++ Item 19

Use `std::shared_ptr` for
shared-ownership
resource management.

std::shared_ptr<T>



stack

ptr to T

ptr to control block

heap

controlled object

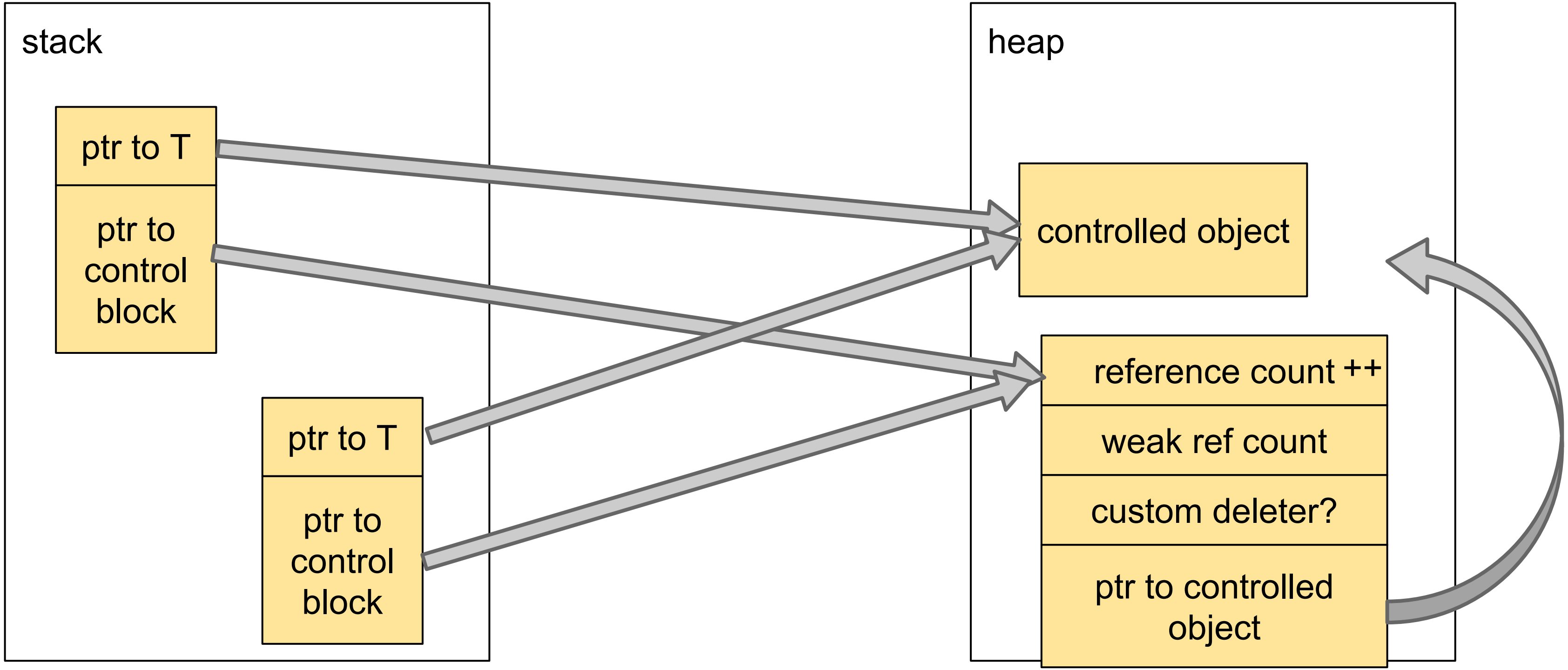
reference count

weak ref count

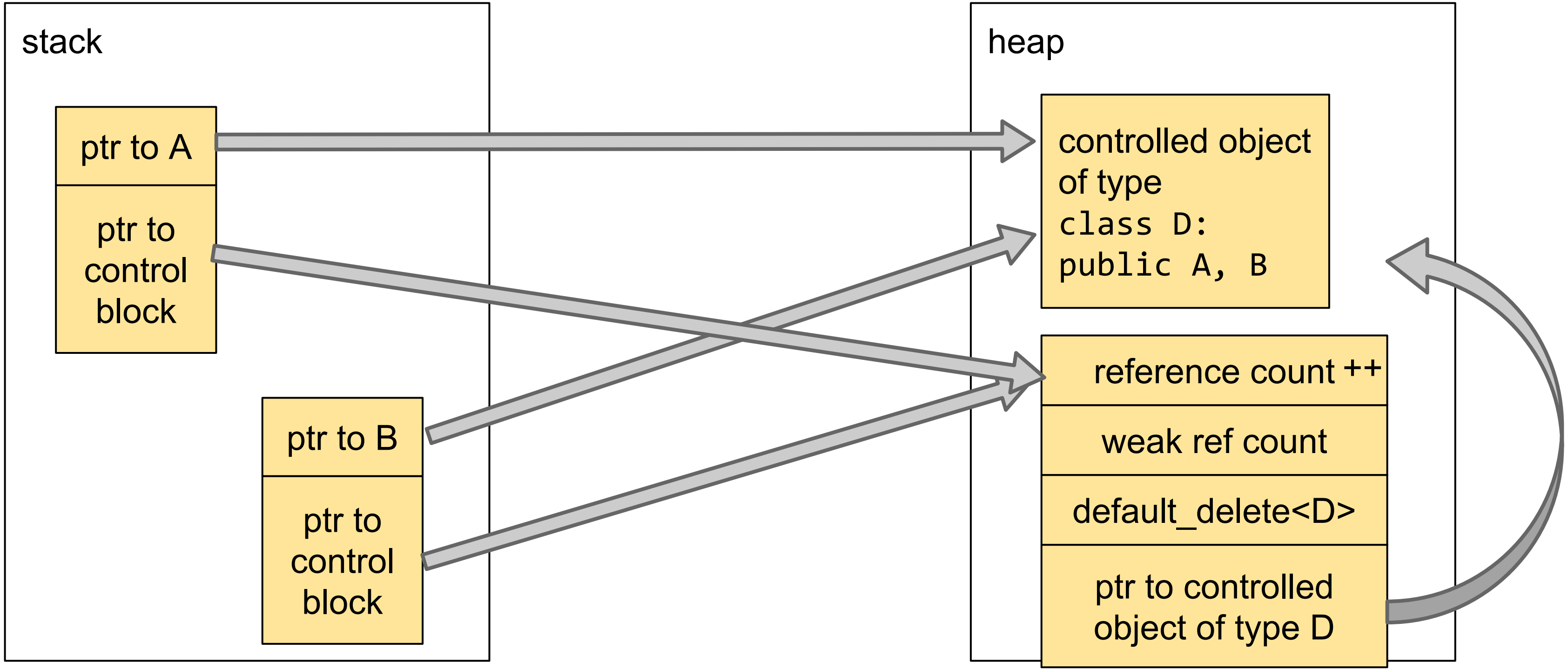
custom deleter?

ptr to controlled object

Copying a std::shared_ptr



std::shared_ptr to base class



“Shares ownership with”

```
#include <memory>
#include <vector>

using Vec = std::vector<int>;

std::shared_ptr<int> foo() {
  auto elts = { 0,1,2,3,4 };
  std::shared_ptr<Vec> pvec = std::make_shared<Vec>(elts);
  return std::shared_ptr<int>(pvec, &(*pvec)[2]);
}

int main() {
  std::shared_ptr<int> ptr = foo();
  for (auto i = -2; i < 3; ++i) {
    printf("%d\n", ptr.get()[i]);
  }
}
```

“Shares ownership with”

```
#include <memory>
#include <vector>

using Vec = std::vector<int>;

std::shared_ptr<int> foo() {
  auto elts = { 0,1,2,3,4 };
  std::shared_ptr<Vec> pvec = std::make_shared<Vec>(elts);
  return std::shared_ptr<int>(pvec, &(*pvec)[2]);
}

int main() {
  std::shared_ptr<int> ptr = foo();
  for (auto i = -2; i < 3; ++i) {
    printf("%d\n", ptr.get()[i]);
  }
}
```

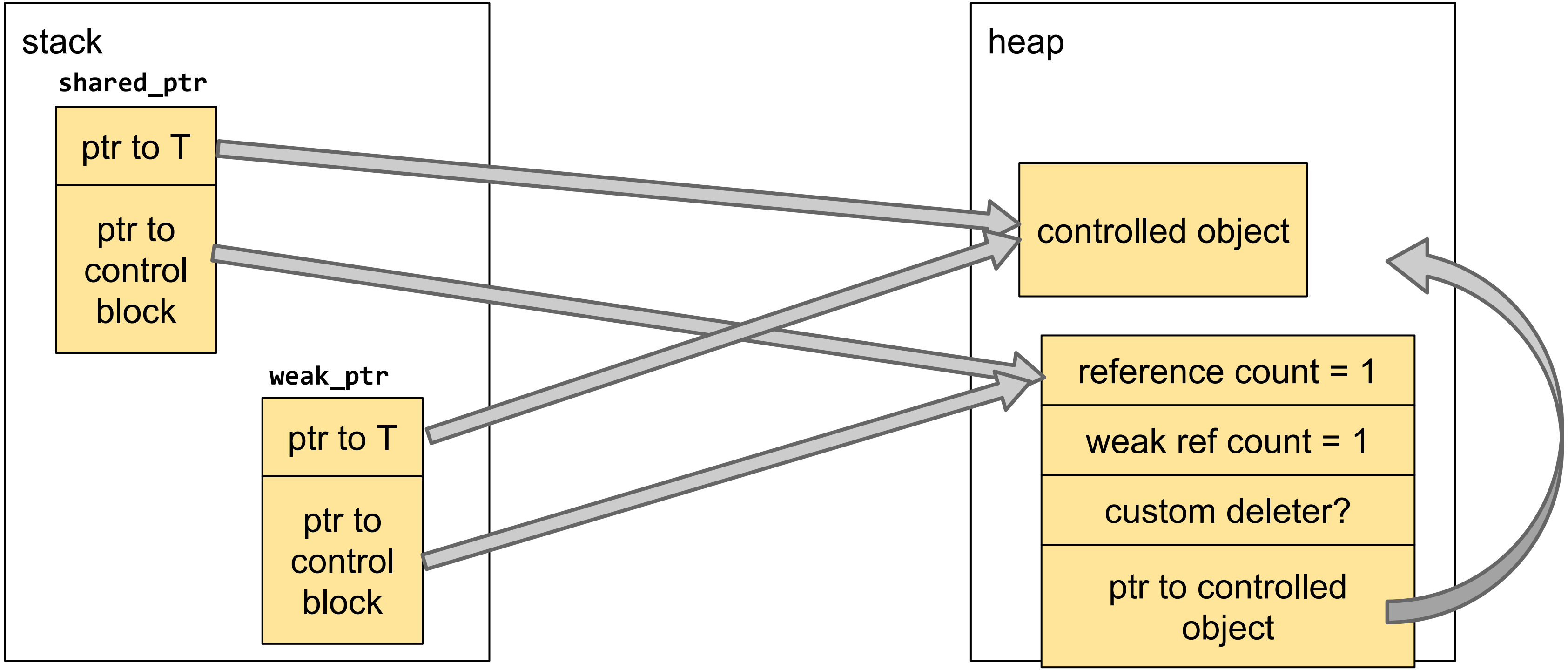
Share ownership with pvec

but point to &(*pvec)[2]

EMC++ Item 20

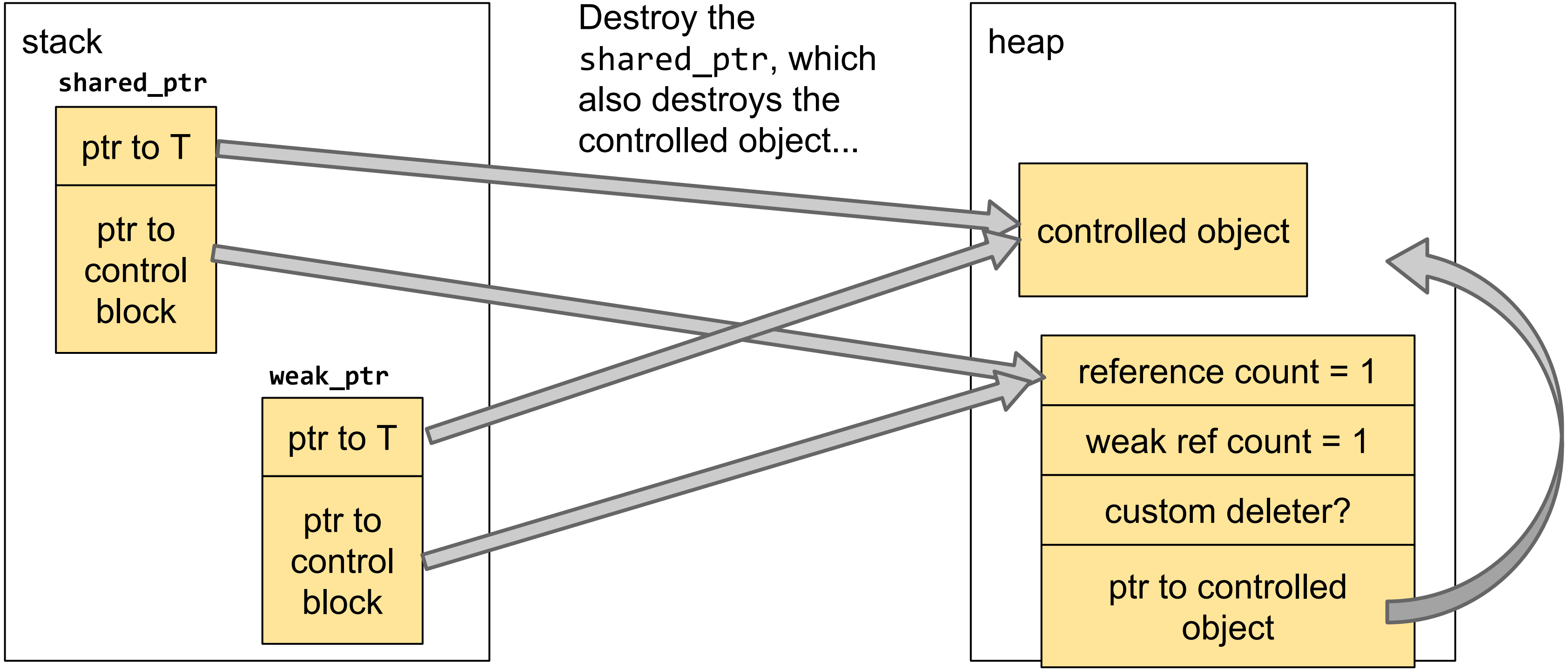
Use **`std::weak_ptr`** for
`shared_ptr`-like pointers
that can dangle.

std::weak_ptr



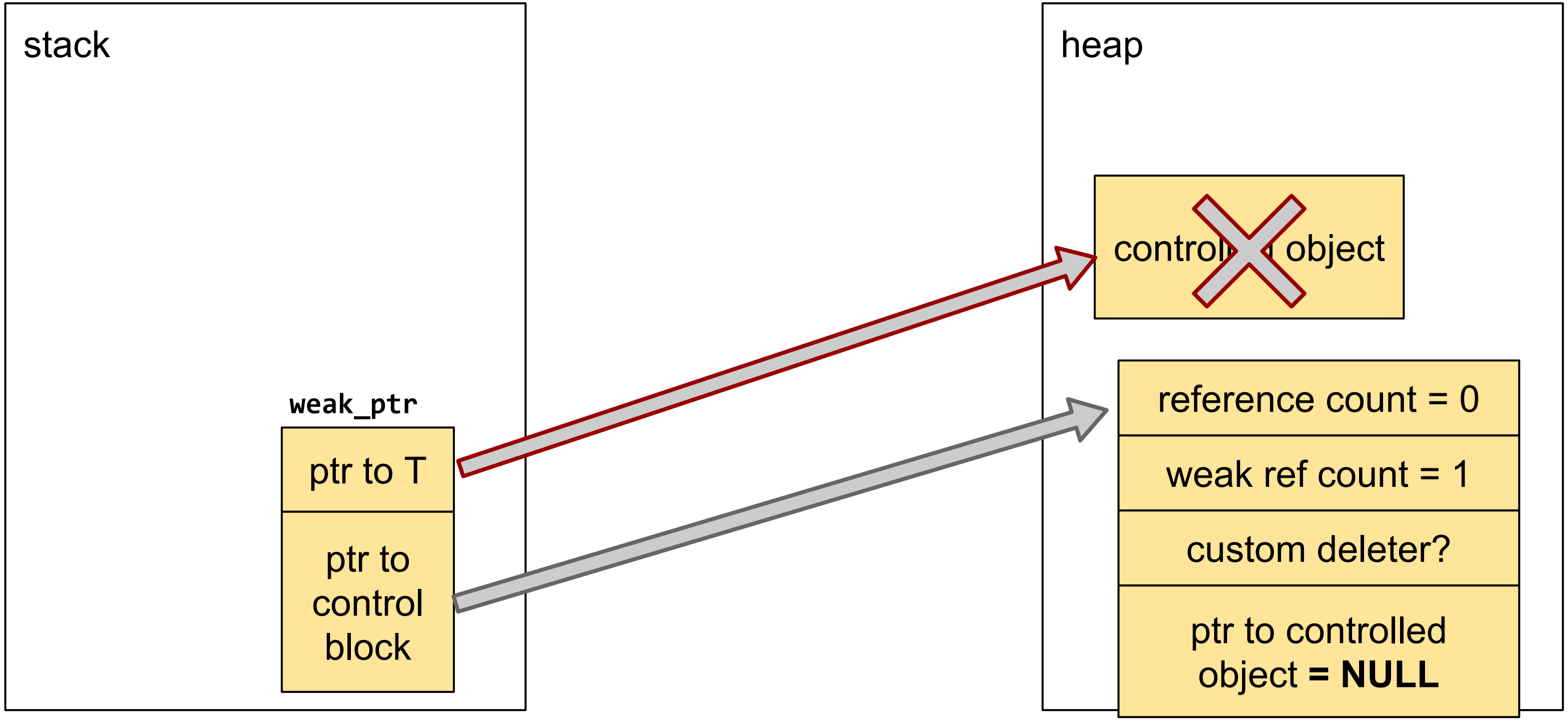
stack
shared_ptr
ptr to T
ptr to control block
weak_ptr
ptr to T
ptr to control block
heap
controlled object
reference count = 1
weak ref count = 1
custom deleter?
ptr to controlled object

std::weak_ptr



Destroy the `shared_ptr`, which also destroys the controlled object...

std::weak_ptr



stack

weak_ptr

ptr to T

ptr to control block

heap

controlled object

reference count = 0

weak ref count = 1

custom deleter?

ptr to controlled object **= NULL**

You can’t dereference a weak_ptr

You can only convert it to a shared_ptr.

```
void recommended(std::weak_ptr<T> wptr) {
  std::shared_ptr<T> sptr = wptr.lock();
  if (sptr) {
    use(sptr);
  }
}

void not_recommended(std::weak_ptr<T> wptr) {
  try {
    std::shared_ptr<T> sptr { wptr };  // call the explicit constructor
    use(sptr);
  } catch (std::bad_weak_ptr) {}
}
```

EMC++ Item 21

Prefer **`std::make_unique`**
and **`std::make_shared`**
to direct use of **`new`**.

EMC++ Item 21

`std::make_shared` is an optimization

`std::make_unique` is not

But! Both are useful for exception-safety

```
if (func(unique_ptr<T1>(new T1), unique_ptr<T2>(new T2))) {
  // “new T2” is unsequenced with respect to both
  // “new T1” and “unique_ptr<T1>(...)”
}
```

http://channel9.msdn.com/Events/GoingNative/2013/Don-t-Help-the-Compiler

EMC++ Item 22

When using the Pimpl idiom,
define special member functions
in the implementation file.

EMC++ Item 22: The Pimpl idiom

```
<<<Widget.h>>>



class Widget {
public:
  Widget();
  ~Widget();
private:
  struct Impl;
  Impl *pImpl;
};
```

```
<<<Widget.cpp>>>

struct Widget::Impl {
  ...
};

Widget::Widget()
  : pImpl(new Impl) {}

Widget::~Widget() {
  delete pImpl;
}
```

EMC++ Item 22: The Pimpl idiom

```
<<<Widget.h>>>

#include <memory>

class Widget {
public:
  Widget();
  ~Widget();
private:
  struct Impl;
  unique_ptr<Impl> pImpl;
};
```

```
<<<Widget.cpp>>>

struct Widget::Impl {
  ...
};

Widget::Widget()
  : pImpl(make_unique<Impl>())
{}

Widget::~Widget() {}
```

EMC++ Item 22: Why not...?

```
<<<Widget.h>>>

#include <memory>

class Widget {
public:
  Widget();
  ~Widget() = default;
private:
  struct Impl;
  unique_ptr<Impl> pImpl;
};
```

```
<<<Widget.cpp>>>

struct Widget::Impl {
  ...
};

Widget::Widget()
  : pImpl(make_unique<Impl>())
{}
```

EMC++ Item 22: Why not...? (gcc)

```
In file included from /usr/include/c++/4.7/memory:86:0,
                 from Widget.h:1,
                 from test.cc:1:
/usr/include/c++/4.7/bits/unique_ptr.h: In instantiation of ‘void std::default_delete<_Tp>::operator()(_Tp*) const [with _Tp = Widget::Impl]’:
/usr/include/c++/4.7/bits/unique_ptr.h:173:4:   required from ‘std::unique_ptr<_Tp, _Dp>::~unique_ptr() [with _Tp = Widget::Impl; _Dp =
std::default_delete<Widget::Impl>]’
Widget.h:6:3:   required from here
/usr/include/c++/4.7/bits/unique_ptr.h:63:14: error: invalid application of ‘sizeof’ to incomplete type ‘Widget::Impl’
```

EMC++ Item 22: Why not...? (clang)

```
/Applications/Xcode.app/Contents/Developer/Toolchains/XcodeDefault.xctoolchain/usr/bin/../include/c++/v1/memory:2424:27: error: invalid
      application of 'sizeof' to an incomplete type 'Widget::Impl'
            static_assert(sizeof(_Tp) > 0, "default_delete can not delete incomplete type");
                          ^~~~~~~~~~~
/Applications/Xcode.app/Contents/Developer/Toolchains/XcodeDefault.xctoolchain/usr/bin/../include/c++/v1/memory:2625:13: note: in instantiation
      of member function 'std::__1::default_delete<Widget::Impl>::operator()' requested here
            __ptr_.second()(__tmp);
            ^
/Applications/Xcode.app/Contents/Developer/Toolchains/XcodeDefault.xctoolchain/usr/bin/../include/c++/v1/memory:2593:46: note: in instantiation
      of member function 'std::__1::unique_ptr<Widget::Impl, std::__1::default_delete<Widget::Impl> >::reset' requested here
    _LIBCPP_INLINE_VISIBILITY ~unique_ptr() {reset();}
                                             ^
./Widget.h:6:3: note: in instantiation of member function 'std::__1::unique_ptr<Widget::Impl, std::__1::default_delete<Widget::Impl>
      >::~unique_ptr' requested here
  ~Widget() = default;
  ^
./Widget.h:8:10: note: forward declaration of 'Widget::Impl'
  struct Impl;
         ^
1 error generated.
```

~Widget doesn’t know how to delete *pImpl

```
<<<Widget.h>>>

#include <memory>

class Widget {
public:
  Widget();
  ~Widget() = default;
private:
  struct Impl;
  unique_ptr<Impl> pImpl;
};
```

```
<<<Widget.cpp>>>

struct Widget::Impl {
  ...
};

Widget::Widget()
  : pImpl(make_unique<Impl>())
{}
```

Sidebar: The Rule of Five

```
#include <memory>

struct Puzzle {
  struct Impl;
  std::unique_ptr<Impl> pImpl;
  Puzzle();
};


Puzzle foo() {
  return Puzzle();
}
```

```
/Applications/Xcode.app/Contents/Developer/Toolchains/XcodeDefault.xctoolchain
/usr/bin/../include/c++/v1/memory:2424:27: error: invalid
      application of 'sizeof' to an incomplete type 'Puzzle::Impl'
            static_assert(sizeof(_Tp) > 0, "default_delete can not delete
incomplete type");
                          ^~~~~~~~~~~
/Applications/Xcode.app/Contents/Developer/Toolchains/XcodeDefault.xctoolchain
/usr/bin/../include/c++/v1/memory:2625:13: note: in instantiation
      of member function 'std::__1::default_delete<Puzzle::Impl>::operator()'
requested here
            __ptr_.second()(__tmp);
            ^
/Applications/Xcode.app/Contents/Developer/Toolchains/XcodeDefault.xctoolchain
/usr/bin/../include/c++/v1/memory:2593:46: note: in instantiation
      of member function 'std::__1::unique_ptr<Puzzle::Impl,
std::__1::default_delete<Puzzle::Impl> >::reset' requested here
    _LIBCPP_INLINE_VISIBILITY ~unique_ptr() {reset();}
                                             ^
test.cc:3:8: note: in instantiation of member function
'std::__1::unique_ptr<Puzzle::Impl, std::__1::default_delete<Puzzle::Impl>
      >::~unique_ptr' requested here
struct Puzzle {
       ^
test.cc:4:10: note: forward declaration of 'Puzzle::Impl'
  struct Impl;
         ^
1 error generated.
```

Sidebar: The Rule of Five

```
#include <memory>

struct Puzzle {
  struct Impl;
  std::unique_ptr<Impl> pImpl;
  Puzzle();
  ~Puzzle();  // right?
};

Puzzle foo() {
  return Puzzle();
}
```

```
test.cc:11:10: error: call to implicitly-deleted copy
constructor of 'Puzzle'
  return Puzzle();
         ^~~~~~~~
test.cc:5:25: note: copy constructor of 'Puzzle' is
implicitly deleted because field 'pImpl' has a deleted
copy constructor
  std::unique_ptr<Impl> pImpl;
                        ^
/Applications/Xcode.app/Contents/Developer/Toolchains/X
codeDefault.xctoolchain/usr/bin/../include/c++/v1/memor
y:2510:31: note: copy constructor
      is implicitly deleted because
'unique_ptr<Puzzle::Impl,
std::__1::default_delete<Puzzle::Impl> >' has a
user-declared move constructor
    _LIBCPP_INLINE_VISIBILITY unique_ptr(unique_ptr&&
__u) _NOEXCEPT
                              ^
1 error generated.
```

Sidebar: The Rule of Five

12.8 [class.copy] 7

> If the class definition does not explicitly declare a copy constructor, one is declared *implicitly*. If the class definition declares a move constructor or move assignment operator, the implicitly declared copy constructor is defined as deleted; otherwise, it is defined as defaulted. The latter case is deprecated if the class has a user-declared copy assignment operator or a user-declared destructor.

Thus `class Puzzle`'s copy constructor is implicitly declared as defaulted; but since member `m` is uncopyable, the defaulted copy constructor is defined as deleted. **(12.8 [class.copy] 11)**

Sidebar: The Rule of Five

12.8 [class.copy] 9

> If the definition of a class `X` does not explicitly declare a move constructor, one will be implicitly declared as defaulted if and only if
>
> — `X` does not have a user-declared copy constructor,
> — `X` does not have a user-declared copy assignment operator,
> — `X` does not have a user-declared move assignment operator, and
> — `X` does not have a user-declared destructor.

`class Puzzle` has a user-declared destructor,
so no move constructor is implicitly declared.

Sidebar: The Rule of Five

12.8 [class.copy] 9

> [*Note:* When the move constructor is not implicitly declared or explicitly supplied, expressions that otherwise would have invoked the move constructor may instead invoke a copy constructor. — *end note*]

Yup.

Sidebar: The Rule of Five

```
struct Widget {
  Widget(Widget&&);                        // move construction
  Widget(const Widget&);                   // copy construction
  Widget& operator=(Widget&&);             // move assignment
  Widget& operator=(const Widget&);        // copy assignment
  ~Widget();                               // destructor
};
```

- If you declare any one of these, you ***should*** declare them all.
- Any of these may be declared `=default` or `=delete`

Sidebar: The Rule of Five

```
struct Widget {
  Widget(Widget&&);                     // move construction
  Widget(const Widget&);                // copy construction
  Widget& operator=(Widget&&);          // move assignment
  Widget& operator=(const Widget&);     // copy assignment
  ~Widget();                            // destructor
};
```

– If you declare any one of these, you ***should*** declare them all.

– Any of these may be declared `=default` or `=delete`, but...

– watch out for cases in which `=default` is not equivalent to `{}`

8.4.2 [dcl.fct.def.default] 4: A function is *user-provided* if it is user-declared and not explicitly defaulted or deleted on its first declaration.
8.5 [dcl.init] 7: If a program calls for the default initialization of an object of a const-qualified type T, T shall be a class type with a user-provided default constructor.