CMPT 373
Software Development Methods

A Crash Course in (Some of) Modern C++

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With material from Bjarne Stroustrup & Herb Sutter

C++ *was* complicated/intimidating

- Pointers
  - Arithmetic & indexing
  - dangling
  - when to **`new`** and **`delete`**

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  - long names & scoping (iterators)
  - templates

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  - when to `new` and `delete`
- Nontrivial types
  - inheritance
  - long names & scoping (iterators)
  - templates
- Many proposed rules (of varying validity)
  - Rule of 3
  - Don't pass/return objects to/from functions by value
  - …

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- Now developed under a lightweight process with new revisions every ~3 years.

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  - types, bounds, lifetimes
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- Now de… …ions
  every ~…

To get you (re)acquainted,
we will explore *some* of modern C++ for now.

I will assume familiarity with older C++,
constructors, destructors, etc.

Managing Object Lifetimes

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Brace initialization was new in C++11

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Where does **`w`** live in memory?
Is that good/bad?

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Widget w{0, "fritter"};
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  - Automatic variables/management should be the default.

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Old:

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Widget* w = new Widget{0, "fritter"};
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Old:

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Widget* w = new Widget{0, "fritter"};
```

What problems does this create?

Managing Object Lifetimes

Suppose I have a **`Widget`** class constructed from an **`int`** and a string.

- How might I create one?

  ```
  Widget w{0, "fritter"};
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  - Automatic variables/management should be the default.
- What about creating one on the heap?

Old:
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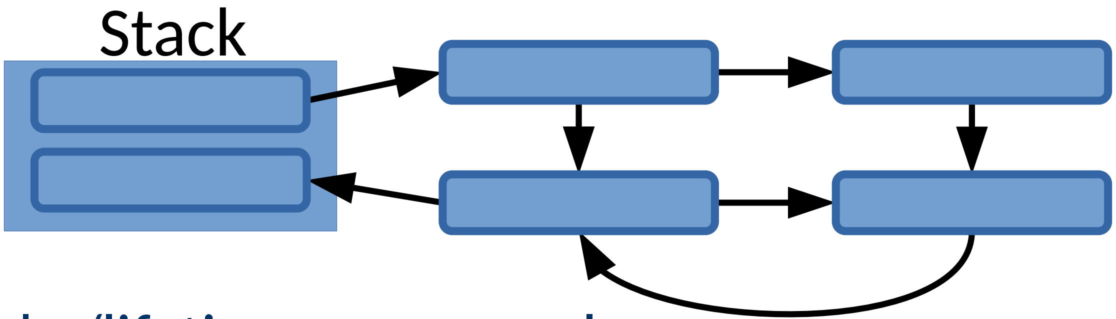
Widget* w = new Widget{0, "fritter"};
```

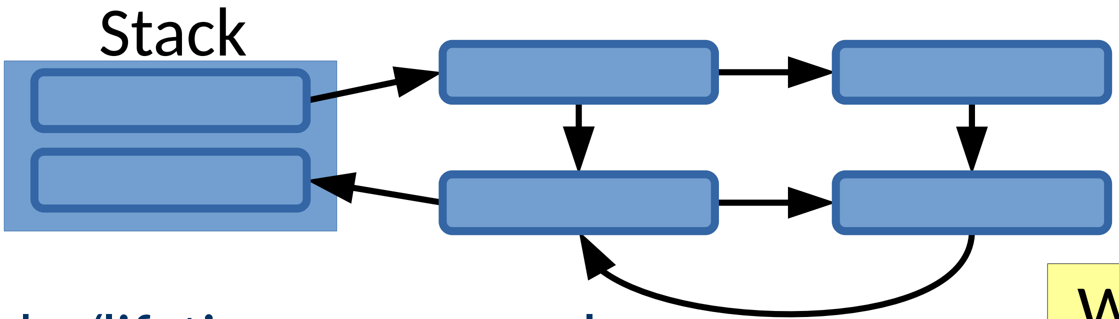
  - Need to delete everything.
  - Need to delete everything only once.
  - Complex object graphs make this harder

Managing Object Lifetimes



Object graphs/lifetimes are complex

Managing Object Lifetimes



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Which pointers can I `delete` & when?

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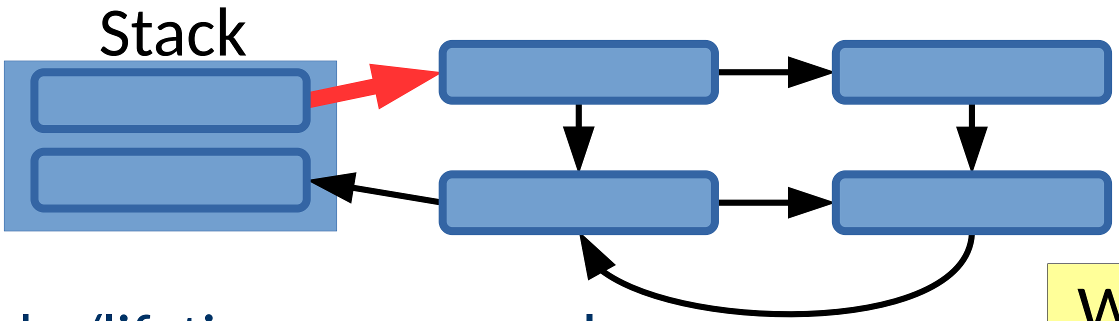

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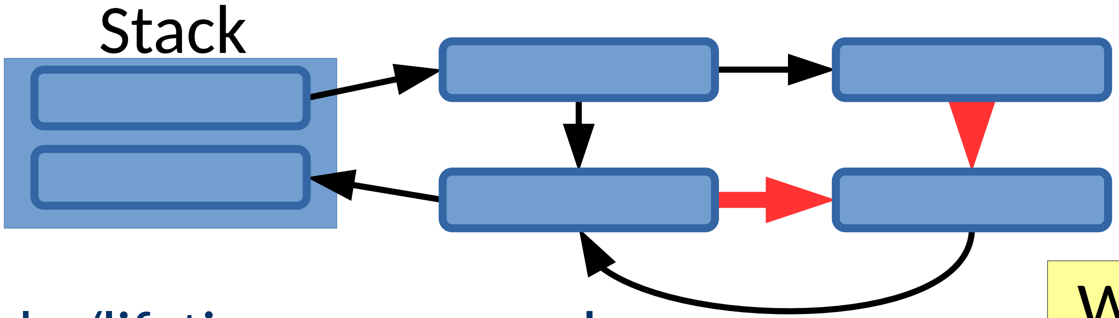

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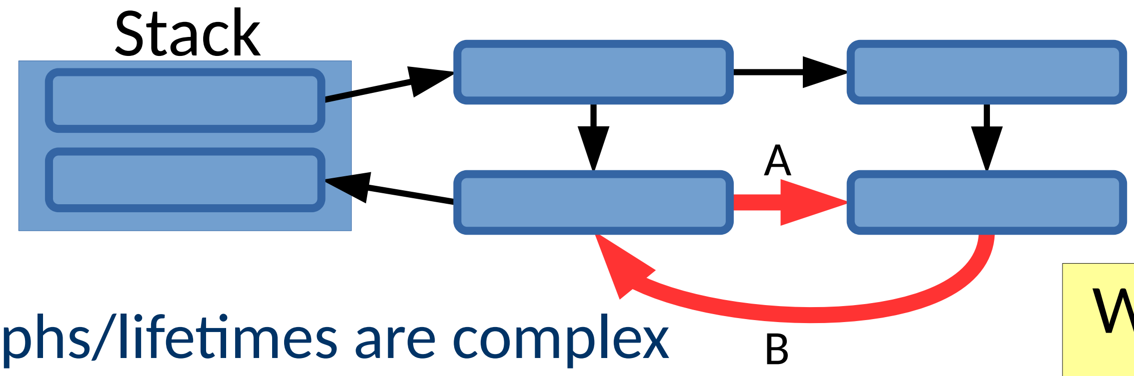

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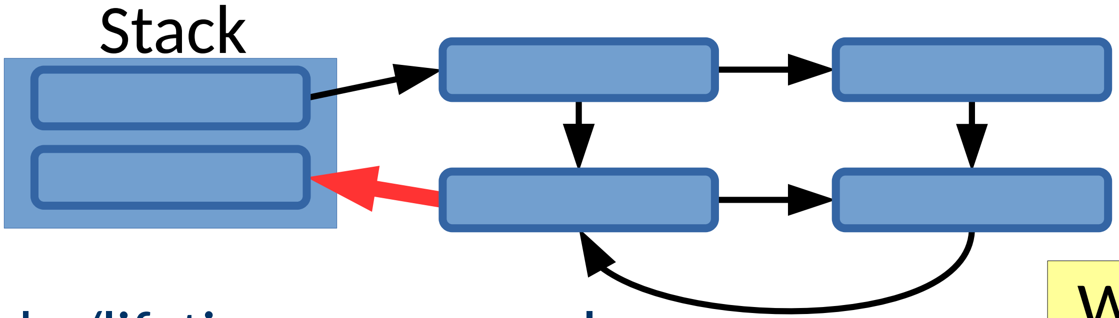

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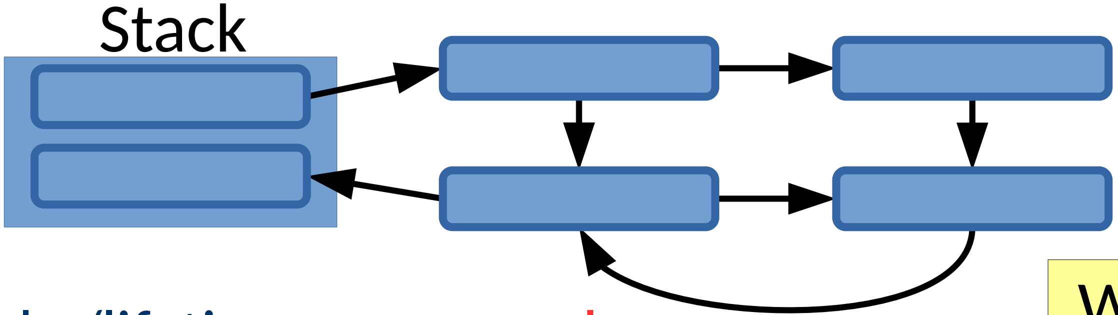

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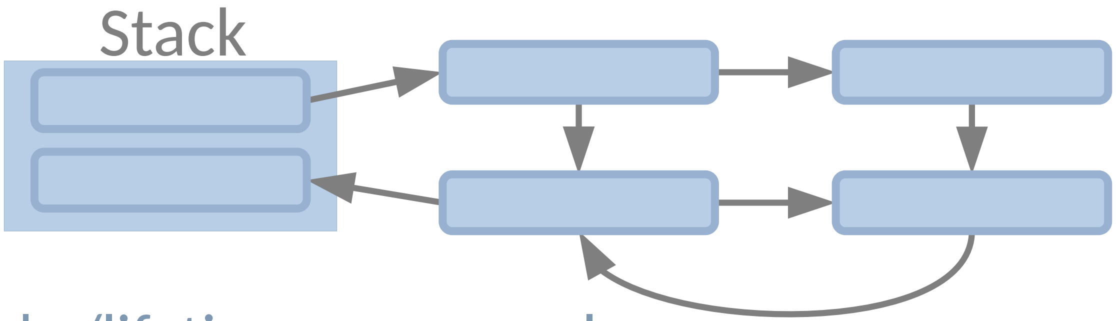
Managing Object Lifetimes (*Tangent*)



Object graphs/lifetimes are complex

When you ***use*** a data structure,
do you usually worry about these?

Managing Object Lifetimes (*Tangent*)

```
{
  std::vector<Widget> widgets
  widgets.emplace_back(3, “Fritter”);
  widgets.emplace_back(2, “Double chocolate”);
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Stack

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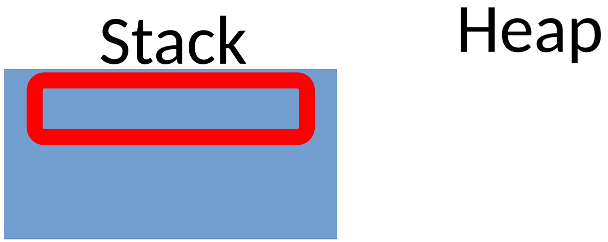

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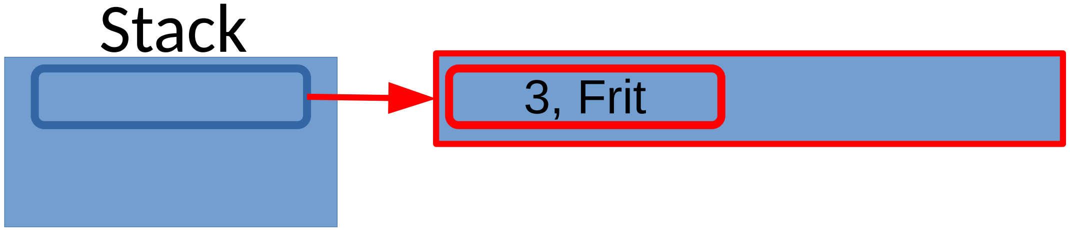

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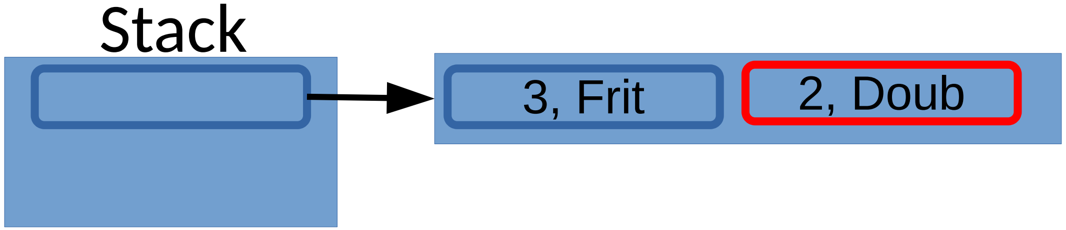

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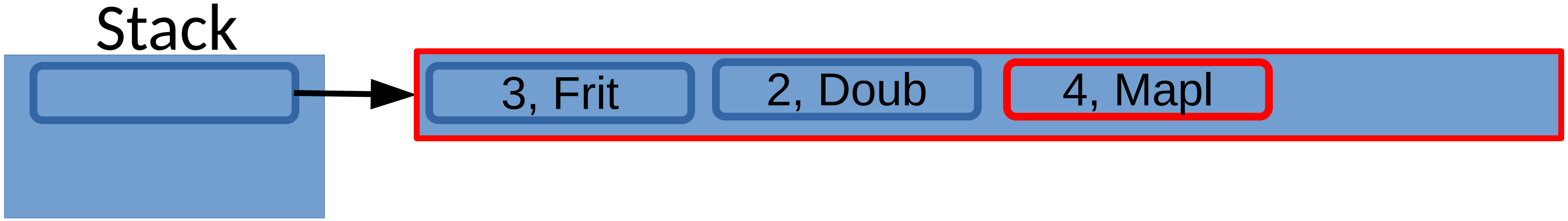

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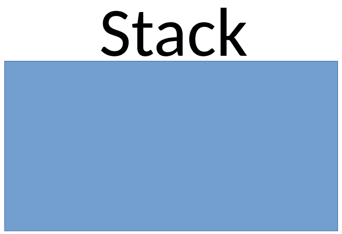
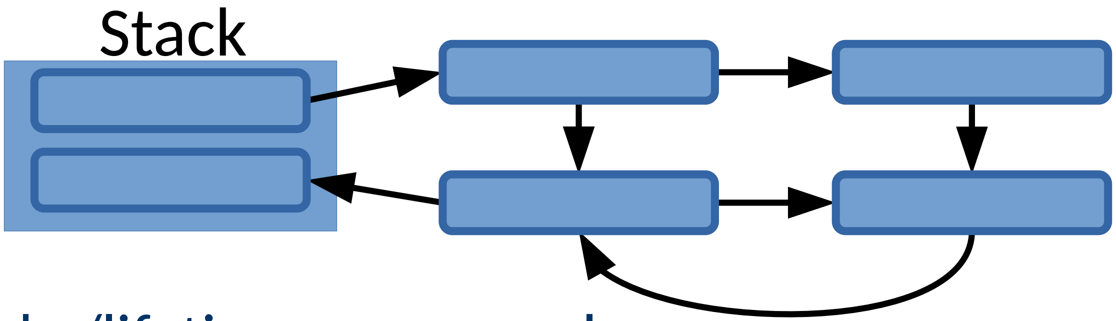


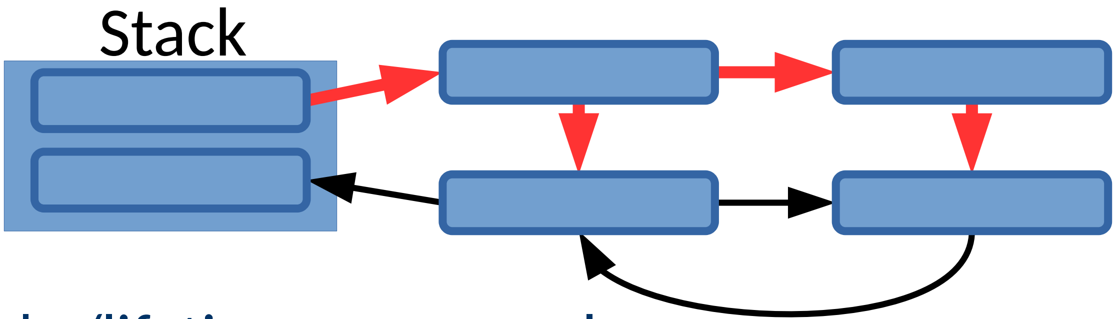
Managing Object Lifetimes (Revisiting)



Object graphs/lifetimes are complex

- Could this problem be solved using only **`std::vector`**?

Managing Object Lifetimes



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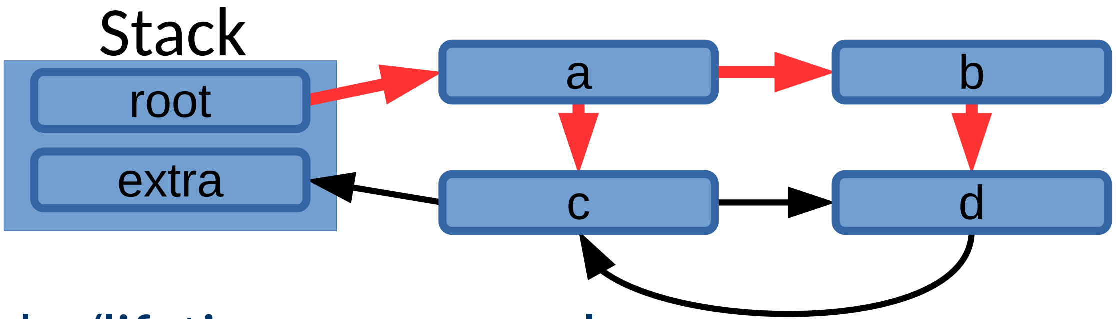
In a few different ways...

Managing Object Lifetimes



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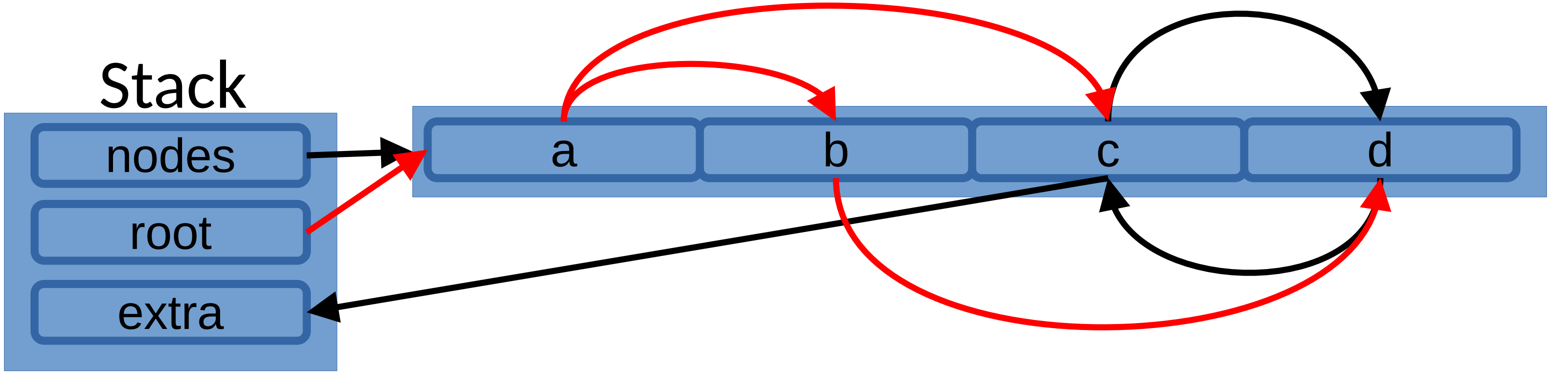

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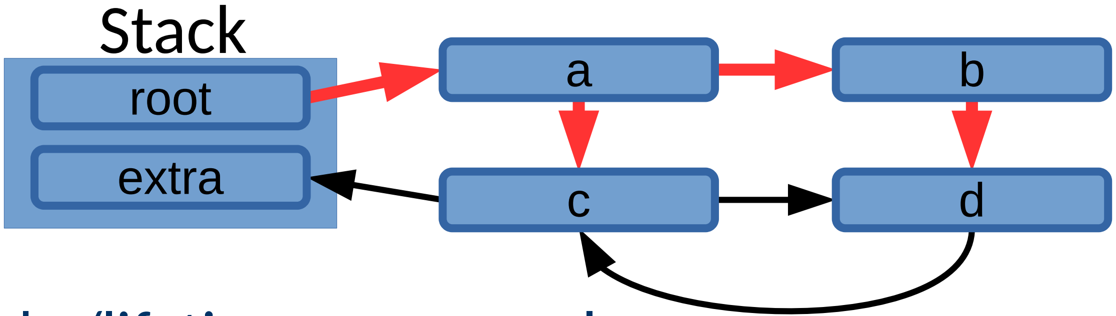

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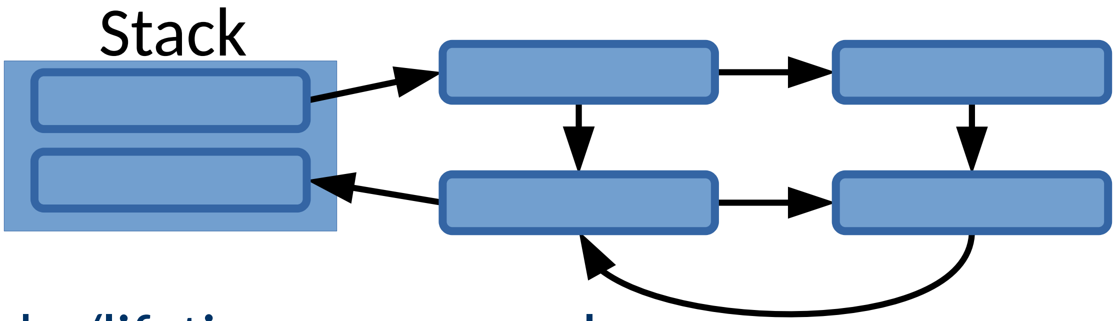
- Could this problem be solved using only **`std::vector`**?

Could instead have a, b, c, d be vectors of 1 element.

Managing Object Lifetimes



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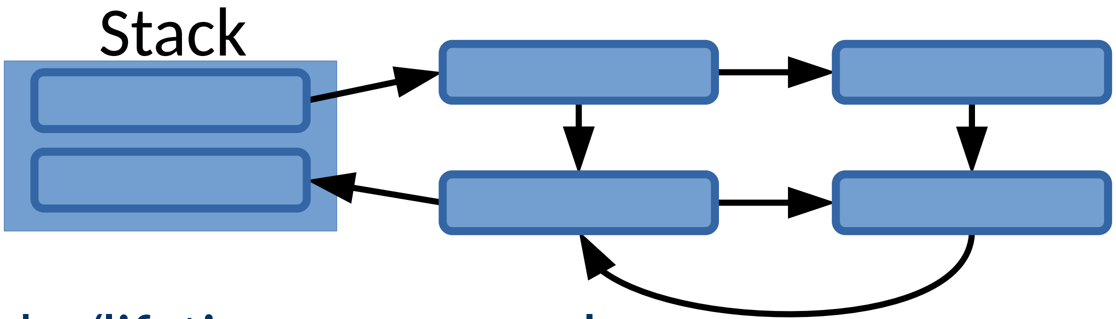

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  - Unclear?
  - Unnecessary overheads?
  - Mismatched lifetimes?

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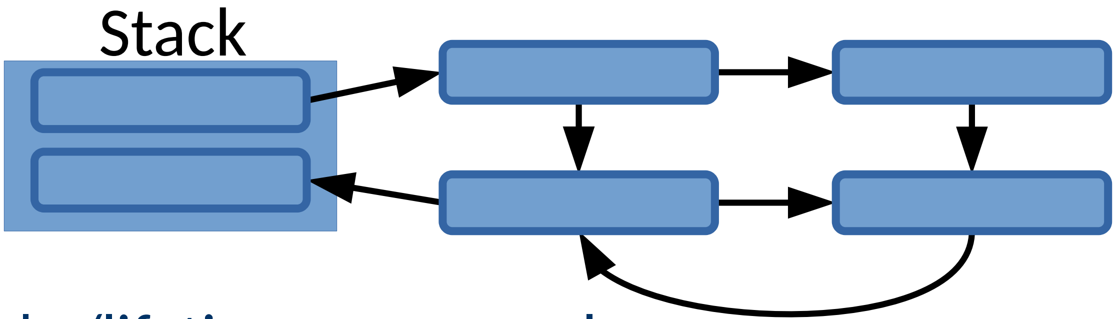

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What we want is a clear, intentional way to express *ownership*.

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You can think of this as a vector of 1 item

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auto w = std::make_shared<Widget>(0, "ponchik");
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What happens if you have a cycle?

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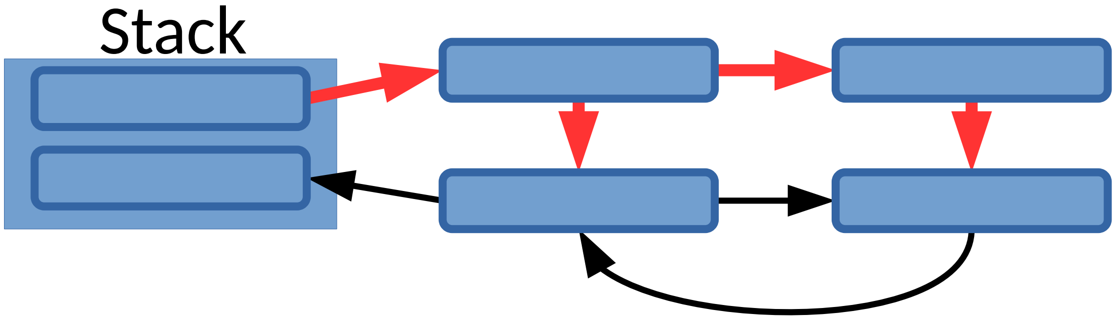
- Ownership *can* also be transferred

Managing Object Lifetimes

- A few rules:
  - Every object has (preferably) one owner



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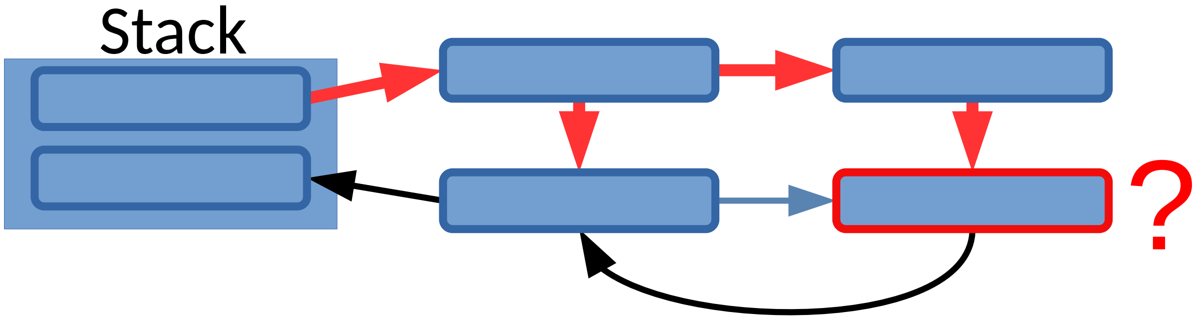

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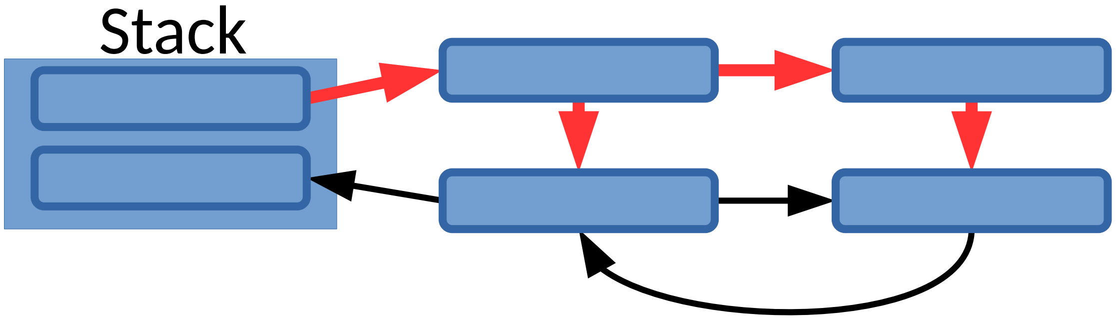

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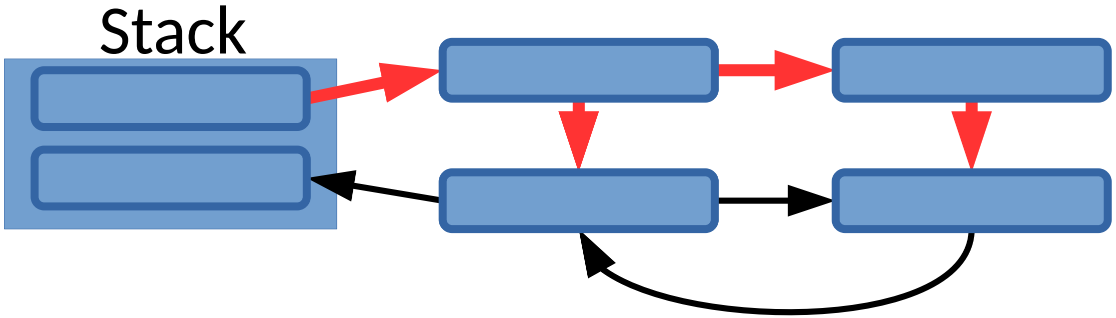

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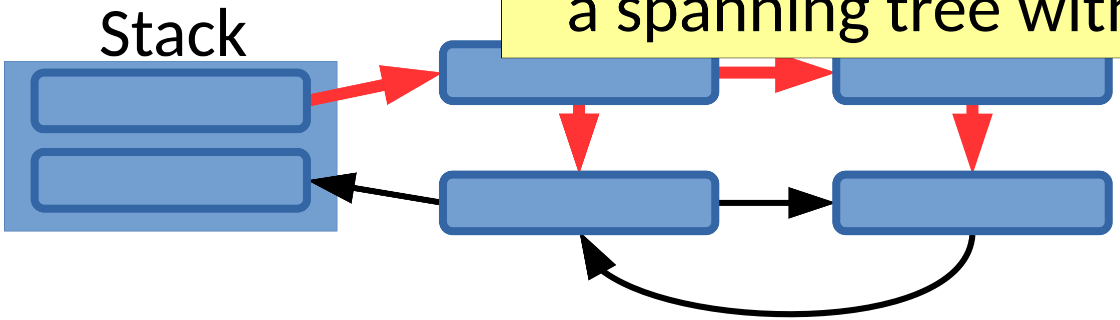
Note: Unique owning pointers form a spanning tree within the heap.



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foo(X)
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Using What You Know

```
void foo( [1] );

void bar() {
  auto [2] ique<Widget>(42, "churro");
  foo( [2] );
}
```

- What should go in 1 and 2 to pass **`w`** to **`foo`**?
  - (It may depend on what you want to do...)
  - Do you just want to give foo *access* to the Widget?
  - Do you want foo to *modify* the ownership?
  - Do you want to *transfer* ownership to foo?

Using What You Know

```
void foo(      1      );

void bar() {
  auto w = std::make_unique<Widget>(42, "churro");
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```

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Note: These are behaviors that would already happen.
Smart pointers make them *explicit* and *automatic*.

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  - Properly acquiring & releasing resources
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    - No leaks
  - What *other* resources do you manage?
    - Files
    - Locks
    - Database connections
    - Printers
    - ...

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- RAII
  - Bind the lifetime of the resource to object lifetime
  - Acquire the resource in the constructor

General Resource Management

- The problem is pervasive enough to have general solutions
  - Python: `with`
  - C#: `using`
  - Java: `try`-with-resources
  - C++: RAII (Resource Acquisition is Initialization)
- Goal: Simplify & control the lifetimes of resources
- RAII
  - Bind the lifetime of the resource to object lifetime
  - Acquire the resource in the constructor
  - Release the resource in the destructor

General Resource Management

- Memory

```
void memoryResource() {
  auto w = std::make_unique<Widget>(3, "bofrot");
  foo(*w);
}
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- Files

```
void fileResource() {
  auto out = std::ofstream{"output.txt"};
  out << "Boston cream\n";
}
```

General Resource Management

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void fileResource() {
  auto out = std::ofstream{"output.txt"};
  out << "
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out is automatically flushed & closed here.

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- Because they are scoped, they handle exceptions & multiple return statements!

General Resource Management

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  - It makes managing them automatic
  - It removes temporal coupling
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- How does RAII relate to managing complexity?
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  - In many cases, it is explicitly forbidden

Why?

General Resource Management

- How does RAII relate to managing complexity?
  - It makes resource designs explicit
  - It makes managing them automatic
  - It removes temporal coupling
  - It promotes composition & independence
- NOTE: What happens when you copy a resource object?
  - In many cases, it is explicitly forbidden
  - You can use **`std::move()`** to *transfer* resource ownership

Operating on Collections

- Iterating over collections can be painful

```
void oops() {
  std::vector numbers = {0, 1, 2, 3, 4};
  for (unsigned i = 0, e = 4; i <= 4; ++i) {
    std::cout << numbers[i] << "\n";
  }
}
```

Operating on Collections

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```

- Range based for loops are preferable

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void nice() {
  std::vector numbers = {0, 1, 2, 3, 4};
  for (auto number : numbers) {
    std::cout << number << "\n";
  }
}
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```

- Range based for loops are pref

The “collection” can be anything with **`begin()`** and **`end()`** methods.

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void nice() {
  std::vector numbers = {0, 1, 2, 3, 4};
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Operating on Collections

- Passing collections around can be error prone.

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void oops(const std::vector<int> numbers) {
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Operating on Collections

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void oops(const std::vector<int> numbers) {
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void better(const std::vector<int>& numbers) {
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Operating on Collections

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void better(const std::vector<int>& numbers) {
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}
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- Use std::span in C++20 for flexibility & correctness by design

```
void good(const std::span<int> numbers) {
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```

Guideline Support Library

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- **`std::string_view<T>`**
  - Avoid copying strings
  - Avoid conversions to and from C strings
    (a common mistake!)

Guideline Support Library

Some common classes for better code, specifically:

- `std::span<T>, gsl::span<T>`
  - Makes interfaces generic & safer

[demo]

- `std::string_view<T>`
  - Avoid copying strings
  - Avoid conversions to and from C strings
    (a common mistake!)
- Both of these abstractions are *non*-owning

λ (Lambdas)

- How should you check whether a list contains a number greater than 3?

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```
bool hasGreaterThan3 = false;
for (auto number : numbers) {
  if (number > 3) {
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  }
}
```

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bool hasGreaterThan3 =
  std::any_of(numbers.begin(), numbers.end(),
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In C++20:

```cpp
bool hasGreaterThan3 =
  std::ranges::any_of(numbers,
    [](auto number) { return number > 3; });
```

λ (Lambdas)

- Lambdas allow you to create small, self contained functions local to other code

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  ...
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You can capture arguments from the local scope.

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```

Additional arguments are passed in when invoked.

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- Lambdas allow you to use generic library functions in a clear, well localized fashion.

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auto found =
  std::ranges::find_if(numbers,
    [](auto number) { return number > 3; });
std::cout << *found << " is greater than 3.\n";
```

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See <algorithm>

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I will expect you to make use of built in algorithms and lambdas instead of raw loops from now on.

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Throw by value.

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} catch (const std::runtime_error& e) {
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```

Catch by reference.

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Error messages.

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- type safe enums
- delegating constructors
- **`using`** instead of **`typedef`**
- Destructuring: **`auto [x, y] = std::make_pair(3,4);`**
- …

More…

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And these are from almost a decade ago.