

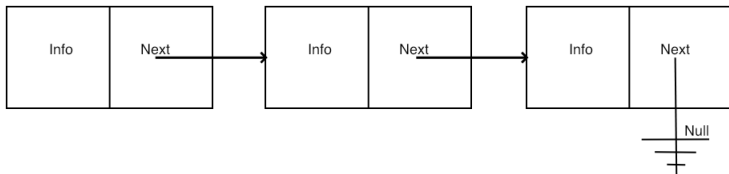
Smart Pointers

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1. Motivating application: linked list



- Used inside operating systems
- Model for complicated structures: trees, DAGs.

2. Recursive data structures

Naive code:

```
class Node {  
private:  
    int value;  
    Node tail;  
    /* ... */  
};
```

This does not work: would take infinite memory.

Indirect inclusion: only 'point' to the tail:

```
class Node {  
private:  
    int value;  
    PointToNode tail;  
    /* ... */  
};
```

3. Pointer types

- Smart pointers. You will see 'shared pointers'.
- There are 'unique pointers'. Those are tricky.
- Please don't use old-style C pointers, unless you become very advanced.

4. Example: step 1, we need a class

Simple class that stores one number:

```
class HasX {  
private:  
    double x;  
public:  
    HasX( double x) : x(x) {};  
    auto get() { return x; };  
    void set(double xx) { x = xx; };  
};
```

5. Example: step 2, creating the pointer

Allocation of object and pointer to it in one:

```
auto X = make_shared<HasX>( /* args */ );
```

```
// or explicitly:
```

```
shared_ptr<HasX> X =  
    make_shared<HasX>( /* constructor args */ );
```

6. Example: step 3: headers to include

Using smart pointers requires at the top of your file:

```
#include <memory>
using std::shared_ptr;
using std::make_shared;

using std::unique_ptr;
using std::make_unique;
```

(unique pointers will not be discussed further here)

7. Example: step 4: in use

Why do we use pointers?

Pointers make it possible for two variables to own the same object.

Code:

```
auto xptr = make_shared<HasX>(5);  
auto yptr = xptr;  
cout << xptr->get() << '\n';  
yptr->set(6);  
cout << xptr->get() << '\n';
```

Output

[pointer] twopoint:

5

6

What is the difference with

```
HasX five(5);
```

```
HasX v1 = five;
```

```
HasX v2 = five;
```

?

Exercise 1

Make a *DynRectangle* class, which is constructed from two shared-pointers-to-*Point* objects:

```
auto
    origin  = make_shared<Point>(0,0),
    fivetwo = make_shared<Point>(5,2);
DynRectangle lielow( origin,fivetwo );
```

Calculate the area, scale the top-right point, and recalculate the area:

Code:

```
cout << "Area: " << lielow.area() <<
    '\n';
/* ... */
// scale the 'fivetwo' point by two
cout << "Area: " << lielow.area() <<
    '\n';
```

Output

[pointer] dynrect:

Area: 10

Area: 40

You can base this off the file `dynrect.cxx` in the repository

Automatic memory management

8. Memory leaks

C has a 'memory leak' problem

```
// the variable 'array' doesn't exist
{
    // attach memory to 'array':
    double *array = new double[N];
    // do something with array
}
// the variable 'array' does not exist anymore
// but the memory is still reserved.
```

The application 'is leaking memory'.

(even worse if you do this in a loop!)

Java/Python have 'garbage collection': runtime impact

C++ has the best solution: smart pointers with reference counting.

9. Illustration

We need a class with constructor and destructor tracing:

```
class thing {  
public:  
    thing() { cout << ".. calling constructor\n"; }  
    ~thing() { cout << ".. calling destructor\n"; }  
};
```

10. Illustration 1: pointer overwrite

Let's create a pointer and overwrite it:

Code:

```
cout << "set pointer1"
      << '\n';
auto thing_ptr1 =
    make_shared<thing>();
cout << "overwrite pointer"
      << '\n';
thing_ptr1 = nullptr;
```

Output

[pointer] ptr1:

```
set pointer1
.. calling
    constructor
overwrite pointer
.. calling destructor
```

11. Illustration 2: pointer copy

Code:

```
cout << "set pointer2" << '\n';
auto thing_ptr2 =
    make_shared<thing>();
cout << "set pointer3 by copy"
    << '\n';
auto thing_ptr3 = thing_ptr2;
cout << "overwrite pointer2"
    << '\n';
thing_ptr2 = nullptr;
cout << "overwrite pointer3"
    << '\n';
thing_ptr3 = nullptr;
```

Output

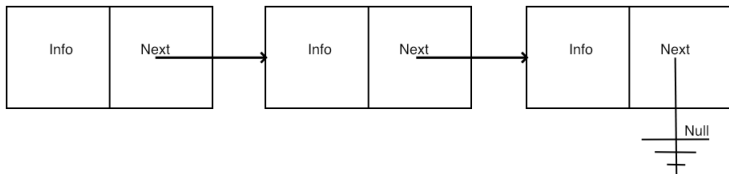
[pointer] ptr2:

```
set pointer2
.. calling
    constructor
set pointer3 by copy
overwrite pointer2
overwrite pointer3
.. calling destructor
```

- The object counts how many pointers there are:
- 'reference counting'
- A pointed-to object is deallocated if no one points to it.

Example: linked lists

12. Linked list



13. Linked lists

The prototypical example use of pointers is in linked lists. Consider a class *Node* with

- a data value to store, and
- a pointer to another *Node*, or `nullptr` if none.

Constructor sets the data value: Set next / test if there is a next:

```
class Node {
private:
    int datavalue{0};
    shared_ptr<Node>
        tail_ptr{nullptr};
public:
    Node() {}
    Node(int value)
        : datavalue(value) {};
    int value() { return
        datavalue; };

    bool has_next() {
        return tail_ptr!=nullptr; };
}
```

14. List usage

Example use:

Code:

```
auto
    first = make_shared<Node>(23),
    second = make_shared<Node>(45);
first->set_tail(second);
cout << "List length: "
    << first->list_length() << '\n';
first->print();
```

Output

[tree] simple:

*List <<23,45>> has
length 2*

15. Linked lists and recursion

Many operations on linked lists can be done recursively:

```
int Node::list_length() {  
    if (!has_next()) return 1;  
    else return 1+tail_ptr->list_length();  
};
```

Exercise 2

Write a method `set_tail` that sets the tail of a node.

```
Node one;  
one.set_tail( two ); // what is the type of 'two'?  
cout << one.list_length() << endl; // prints 2
```

Exercise 3

Write a recursive *append* method that appends a node to the end of a list:

Code:

```
auto
```

```
    first = make_shared<Node>(23),  
    second = make_shared<Node>(45),  
    third = make_shared<Node>(32);  
first->append(second);  
first->append(third);  
first->print();
```

Output

[tree] append:

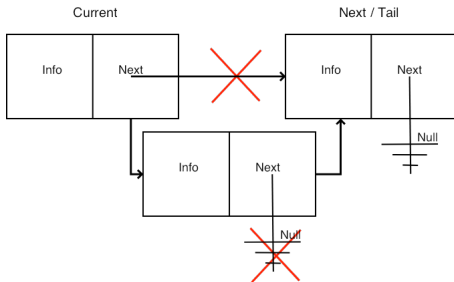
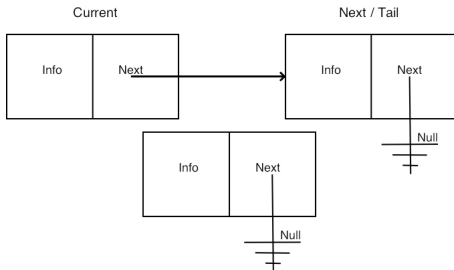
Append 23 & 45 gives

<<23,45>>

Append 32 gives

<<23,45,32>>

16. Insertion



Exercise 4

Write a recursive *insert* method that inserts a node in a list, such that the list stays sorted:

Code:

```
auto
    first = make_shared<Node>(23),
    second = make_shared<Node>(45),
    third = make_shared<Node>(32);
first->insert(second);
first->insert(third);
first->print();
```

Output

[tree] insert:

```
Insert 45 on 23
    gives <<23,45>>
Insert 32 gives
    <<23,32,45>>
```

Assume that the new node always comes somewhere after the head node.