

# Smart Pointers

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# Recursive data structures

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

This does not work: would take infinite memory.

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

*PointToNode* 'points' to the first node of the tail.

# 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.

# Simple example

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; };  
};
```

# Creating a shared pointer

Allocation and pointer in one:

```
shared_ptr<Obj> X =  
    make_shared<Obj>( /* constructor args */ );  
    // or:  
auto X = make_shared<Obj>( /* args */ );
```

**Code:**

```
HasX xobj(5);  
cout << xobj.get() << endl;  
xobj.set(6);  
cout << xobj.get() << endl;  
  
auto xptr = make_shared<HasX>(5);  
cout << xptr->get() << endl;  
xptr->set(6);  
cout << xptr->get() << endl;
```

**Output**

**[pointer] pointx:**

5  
6  
5  
6

# Headers for smart pointers

Using shared pointers requires at the top of your file:

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

# What's the point of 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() << endl;  
yptr->set(6);  
cout << xptr->get() << endl;
```

**Output**

**[pointer] twopoint:**

5  
6

# Automatic memory management



# 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'.

Java/Python have 'garbage collection': runtime impact

C++ has the best solution: smart pointers.

# Reference counting illustrated

We need a class with constructor and destructor tracing:

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

# Pointer overwrite

Let's create a pointer and overwrite it:

**Code:**

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

**Output**

**[pointer] ptr1:**

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

# Pointer copy

## Code:

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

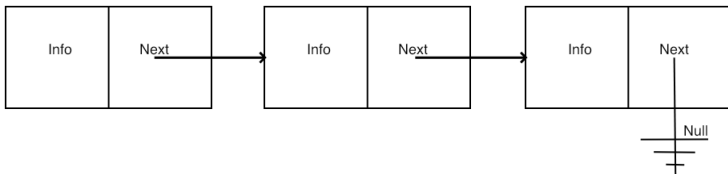
## Output

[pointer] ptr2:

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

## Example: linked lists

# Linked list



# 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; };
};
```

# 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() << endl;
first->print();
```

Output

[tree] simple:

List <<23,45>> has length 2



# 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 1

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();
```

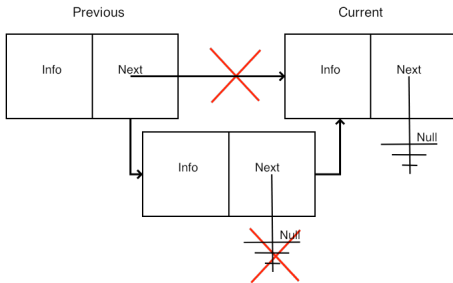
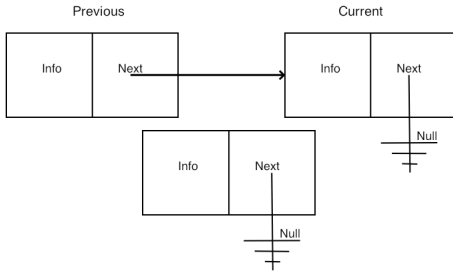
**Output**

**[tree] append:**

Append 23 & 45 gives <<23,45>>

Append 32 gives <<23,45,32>>

# Insertion



## Exercise 2

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.