List implementation in C++

- many times in Computer Science we need to maintain dynamically adjustable lists
- consider the following **C** function definitions
-

```
/*
 *  create an empty list.
 *     pre-condition:  none.
 *     post-condition: returns an empty list.
 */

list empty (void);
```

List specification

```
/*
 *  is_empty
 *     pre-condition:  an initialised list.
 *     post-condition: returns true if list is empty.
 */

bool is_empty (list l);
```

List specification

```
/*
 *  cons
 *     pre-condition:  an initialised list.
 *     post-condition: adds, i, to the end of list, l.
 */
list cons (list l, int i);
```

List specification

```
/*
 *  head
 *     pre-condition:  an initialised list containing 1 or more
 *                     elements.
 *     post-condition: returns the data associated with the first
 *                     element, the list is unaltered.
 */
int head (list l);
```

List specification

```
/*
 *  tail
 *     pre-condition:  an initialised list containing 1 or more
 *                     elements.
 *     post-condition: removes and deletes the first element of the list.
 *                     returns the remainder of the list.
 */
list tail (list l);
```

C++ definition of the list methods in a class

c++/lists/single-list/int/slist.h

```
#if !defined(SLISTH)
#  define SLISTH

/*
 *  single linked list implementation.
 */

class element
{
 public:
  element *next;
  int      data;
};
```

C++ definition of the list methods in a class

c++/lists/single-list/int/slist.h

```
class slist
{
  ...   //  missing code

 public:
  ...   // missing code

  slist empty (void);
  bool  is_empty (void);
  slist cons (int i);
  int   head (void);
  slist tail (void);
};
#endif
```

Comments on the class

- notice that because we are using a class we no longer need to pass the list as a parameter
  - it is implied by the object and reference as `this`

- notice that we specify which methods are visible for the user (via the keyword `public:`)

Example 1: how might this code be used?

c++/lists/single-list/int/test-slist.cc

```
/*
 *  test-slist.cc - test code for the slist.cc module.
 */

#include <slist.h>
#include <cassert>

main ()
{
  {
    slist l;   // created and automatically initialised
    assert (l.is_empty ());
    assert (l.empty ().is_empty ());   // recreated empty
  }
```

Example 2

- **c++/lists/single-list/int/test-slist.cc**

```
{
  slist l;
  assert (l.cons (12).head () == 12);
}
```

Example 3, 4

- c++/lists/single-list/int/test-slist.cc

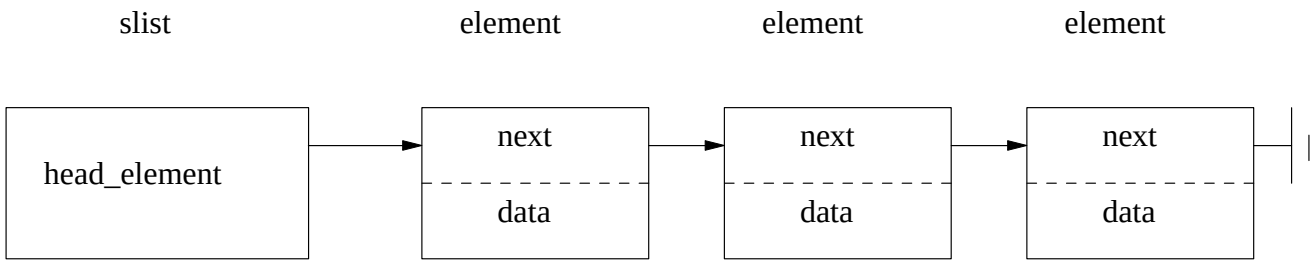
```
  {
    slist l;
    assert (l.cons (12).tail ().is_empty ());
  }
```

-

```
  {
    slist l;

    l = l.cons (12);
    l = l.tail ();
    assert (l.is_empty ());
  }
```

Diagram showing a possible implementation of the list



slist.h revisited

c++/lists/single-list/int/slist.h

```
#if !defined(SLISTH)
#  define SLISTH

/*
 *  single linked list implementation.
 */

class element
{
 public:
  element *next;
  int      data;
};
```

slist.h revisited

c++/lists/single-list/int/slist.h

```
class slist
{
 private:
  element *head_element;
  element *duplicate_elements (element *e);
  element *delete_elements (element *h);

 public:
  slist (void);
  ~slist (void);
  slist (const slist &from);
  slist& operator= (const slist &from);

  slist empty (void);
  bool  is_empty (void);
  slist cons (int i);
  int   head (void);
  slist tail (void);
};
#endif
```

slist.h revisited

- notice we introduce the `head_element` field as a private field
- we also have some private helper methods: `duplicate_elements` and `delete_elements`
- which duplicate and delete all elements

The C++ rule of three!

- most important!
- you must consider implementing : destructor, copy and assignment, methods for your class
- **c++/lists/single-list/int/slist.h**

```
 ~slist (void);                              // destructor
  slist (const slist &from);                 // copy
  slist& operator= (const slist &from);      // assignment
```

- the compiler will call these methods when evaluating expressions

The C++ rule of three!

```
static int a, b, c, t;
  ...
  t = c * (a+b)
  ...
```

- notice the compiler will need to compute `a+b` first and store this in a temporary before multiplying it by `c`

- in a similar way the C++ compiler will need to make temporary copies of the list when translating:

c++/lists/single-list/int/test-slist.cc

```
l.cons (12).tail ().is_empty ()
```

Output

- we can add an output method for this class overloading the traditional C++ shift operator <<

- **c++/lists/single-list/int/slist.h**

```
friend std::ostream& operator<< (std::ostream& os, const slist& l);
```

- check that this is inside `slist.h` and examine the implementation in `slist.cc`

slist::slist (void)

c++/lists/single-list/int/slist.cc

```
/*
 *  slist - constructor, builds an empty list.
 *          pre-condition:    none.
 *          post-condition:   list is created and is empty.
 */

slist::slist (void)
  : head_element(0)
{
}
```

Deconstructor (first of the three!)

- **c++/lists/single-list/int/slist.cc**

```
/*
 *  ~slist - deconstructor, releases the memory attached to the list.
 *           pre-condition:    none.
 *           post-condition:   list is empty.
 */

slist::~slist (void)
{
  head_element = delete_elements (head_element);
}
```

slist::delete_elements

c++/lists/single-list/int/slist.cc

```
/*
 *  delete_elements - delete all elements specified by, h.
 *                    pre-condition:  h points to a list of elements.
 *                    post-condition: zero is returned and all
 *                                    elements are deleted.
 */

element *slist::delete_elements (element *h)
{
  while (h != 0) {
    element *t = h;
    h = h->next;
    if (debugging)
      printf ("wanting to delete 0x%p\n", t);
    else
      delete t;
  }
  return 0;
}
```

Copy operator (second of the big three!)

- **c++/lists/single-list/int/slist.cc**

```
/*
 *  copy operator - redefine the copy operator.
 *                  pre-condition :  a list.
 *                  post-condition:  a copy of the list and its elements.
 */

slist::slist (const slist &from)
{
  head_element = duplicate_elements (from.head_element);
}
```

slist::duplicate_elements

c++/lists/single-list/int/slist.cc

```
/*
 *  duplicate_elements - return a copy of all elements found in, e.
 *                       pre-condition:  e points to a list of elements.
 *                       post-condition: a duplicate list is returned.
 */

element *slist::duplicate_elements (element *e)
{
  element *h = 0;
  element *l = 0;
  element *n;
```

slist::duplicate_elements

c++/lists/single-list/int/slist.cc

```
  while (e != 0)
    {
      n = new element;
      n->data = e->data;
      n->next = 0;
      if (h == 0)
        h = n;
      else
        l->next = n;
      l = n;
      e = e->next;
    }
  return h;
}
```

Assignment operator (3rd of the big three!)

c++/lists/single-list/int/slist.cc

```
/*
 *  operator=  - redefine the assignment operator.
 *               pre-condition :  a list.
 *               post-condition:  a copy of the list and its elements.
 *                                We delete 'this' lists elements.
 */

slist& slist::operator= (const slist &from)
{
  head_element = delete_elements (head_element);
  head_element = duplicate_elements (from.head_element);
}
```

slist::empty

c++/lists/single-list/int/slist.cc

```
/*
 *  empty - returns a new empty list.
 *          pre-condition:   none.
 *          post-condition:  a new empty list is returned.
 */

slist slist::empty (void)
{
  slist *l = new slist;
  return *l;
}
```

slist::is_empty

c++/lists/single-list/int/slist.cc

```
/*
 *  is_empty - returns true if list is empty.
 */

bool slist::is_empty (void)
{
  return head_element == 0;
}
```

slist::cons (int i)

c++/lists/single-list/int/slist.cc

```
/*
 *  cons - concatenate i to slist.
 *         pre-condition:   none.
 *         post-condition:  returns the list which has i at its head
 *                          and the remainer of contents as, slist.
 */

slist slist::cons (int i)
{
  element *e = new element;

  e->data = i;
  e->next = head_element;
  head_element = e;
  return *this;
}
```

slist:head

c++/lists/single-list/int/slist.cc

```
/*
 *  head - returns the data at the front of the list.
 *         pre-condition :  slist is not empty.
 *         post-condition:  data at the front of the list is returned.
 *                          slist is unchanged.
 */

int slist::head (void)
{
  assert (! is_empty());
  return head_element->data;
}
```

slist::tail

c++/lists/single-list/int/slist.cc

```
/*
 *  tail - opposite of cons.  Remove the head value and return
 *         the remainder of the list.
 *         pre-condition:   non empty list.
 *         post-condition:  return the list without the first element.
 */

slist slist::tail (void)
{
  element *e = head_element;

  assert (! is_empty());
  head_element = head_element->next;
  if (debugging)
    printf ("wanting to delete 0x%p\n", e);
  else
    delete e;
  return *this;
}
```

Tutorial Questions

- check out the example code

```
$ git clone https://github.com/gaiusm/examples
$ cd examples/c++/lists/single-list/int
$ make
```

- now single step the `a.out` executable using using `gdb`
  - satisfy your self that the big three are being invoked (copy, assignment and destructor methods)

Tutorial Questions

- implement the method
  - `int length (void);` and add this too the class `slist`
  - `length` returns the number of elements in `slist`
  - write some test code for `length`

- implement the method
  - `slist cons (slist l);`
  - this method must concatenate the contents of list, `l`, onto `this`
  - take case as `l` might be the same as `this`

- implement the method
  - `slist reverse (void);`

Tutorial Questions

- implement

- ```
/*
 * slice - return a slice of the list.
 *   pre-condition: an initialised non empty list.
 *   post-condition: the original list is unaltered.
 *   A new list is returned which is
 *   a copy of elements, l..r-1
 *   Negative values of l and r
 *   index from the right (aka Python).
 */

slist slist::slice (int l, int r);
```
```