CS 32 Worksheet Week 5

LA FEEDBACK FORM -> www.tinyurl.com/LA-Feedback-W24
LA APPLICATIONS DUE 2/20 -> http://tinyurl.com/LAAppS24

Concepts: Inheritance, Polymorphism, Recursion

1. (5 mins) What does the following code output, and what changes do you have to make to it to have it output "`I'm Gene`"? HINT: You will need to use the virtual keyword!

Current Output:

```
I'm a living thing
```

```
#include <iostream>
using namespace std;

class LivingThing {
    public:
        void intro() { cout << "I'm a living thing" << endl; }
};

class Person : public LivingThing {
    public:
        void intro() { cout << "I'm a person" << endl; }
};

class UniversityAdministrator : public Person {
    public:
        void intro() { cout << "I'm a university administrator" << endl; }
};

class Chancellor : public UniversityAdministrator {
    public:
        void intro() { cout << "I'm Gene" << endl; }
};

int main() {
    LivingThing* thing = new Chancellor();
    thing->intro();
}
```

Solution:

```
// The idea is to include the virtual keyword in the intro() member
// function to bind it at runtime. This allows any class that inherits the
// base class to redefine intro()’s functionality using the same prototype.
// A.K.A. Polymorphism!
class LivingThing {
    public:
        virtual void intro() { cout << "I'm a living thing" << endl; }
};
```

2. (5 mins) What is the output of the following code?

```
#include <iostream>
using namespace std;

class Pet {
    public:
        Pet() { cout << "Pet" << endl; }
        ~Pet() { cout << "~Pet" << endl; }
};

// This is an unusual class that derives from Pet but also
// contains a Pet as a data member.
class Dog : public Pet {
    public:
        Dog() { cout << "Woof" << endl; }
        ~Dog() { cout << "Dog ran away!" << endl; }
    private:
        Pet buddy;
};

int main() {
    Pet* milo = new Dog;
    delete milo;
}
```

Solution/Output:

```
Pet
Pet
Woof
~Pet

Undefined behavior after this, because Pet's destructor is not
declared virtual.
```

3. (5 mins) Suppose the class declaration for Pet was changed as shown below. What is the output of the code in problem 2) with these new changes?

```
class Pet {
    public:
        Pet() { cout << "Pet" << endl; }
        virtual ~Pet() { cout << "~Pet" << endl; }
};
```

Solution/Output:

```
Pet
Pet
Woof
Dog ran away!
~Pet
~Pet
```

4. (5 mins) Would the following work in C++? Why or why not?

```
class B;
class A : public B { ... code for A ... };
class B : public A { ... code for B ... };
```

Solution:

This does not work in C++.

Conceptually, this code is saying "A is a proper subset of B, and B is a proper subset of A", which is nonsense.
Practically, every object of a derived class contains an instance of the base class. If the code above were legal, a B object would contain an A object that contains a B object that contains an A object, ad infinitum.

5. (10 mins) Given a singly-linked list class LL with a member variable *head* that points to the first *Node* struct in the list, write a function to recursively delete the whole list, void LL::deleteList(). Assume each Node object has a next pointer.

```
struct Node {
    int data;
    Node* next;
};

class LL {
    public: // other functions such as insert not shown
        void deleteList(); // implement this function
    private: // additional helper function allowed
        Node* m_head;
};
```

Solution:

```
// Recursive solution using a helper function
void LL::deleteListHelper(Node* p) {
  if (p == nullptr)
      return;

  deleteListHelper(p->next);
  delete p;
}

void LL::deleteList() {
  deleteListHelper(m_head);
  m_head = nullptr;
}

// Alternate solution
void LL:deleteList(){
    if (m_head == nullptr) {
         return;
     }
    Node* p = m_head->next;
    delete m_head;
    m_head = p;
    deleteList();
```

```
}
```

6. (15 mins) Implement the function `isPalindrome` recursively. The function should return whether the given string is a palindrome. A palindrome is described as a word, phrase or sequence of characters that reads the same forward and backwards.

```
bool isPalindrome(string foo);

isPalindrome("kayak"); // true
isPalindrome("stanley yelnats"); // true
isPalindrome("LAs rock"); // false (but the sentiment is true :))
```

Solution:

```
bool isPalindrome(string foo) {
    int len = foo.length();
    if (len <= 1)
        return true;
    if (foo[0] != foo[len-1])
        return false;
    return isPalindrome(foo.substr(1, len-2));
}
```

7. (15 mins) Write a recursive function `isPrime` to determine whether a given positive integer input is a prime number or not. You may add an auxiliary helper function if necessary.

Example:

```
isPrime(11) → true
isPrime(4) → false

bool isPrime(int num) {
      // Fill in code here
}
```

Solution:

```
// We notice that without a secondary parameter to keep count of
// where we are in our check, this problem is impossible
// recursively. Thus the solution can be done with either a
// default parameter or with an auxiliary helper function.
bool isPrime(int num) {
      return isPrimeHelper(num, 2); // start with testing
   // divisibility by 2
}
bool isPrimeHelper(int num, int i) {
      if (num <= 2)
            return num == 2; // 1 is not prime
      if (num % i == 0)  // not prime if divisible by i
            return false;
      if (i*i > num)  // is prime if exhausted all divisors
            return true;
      return isPrimeHelper(num, i + 1); // increment i and see if it is
divisible by it
}
```

8. (20 mins) Implement the following recursive function:

```
string longestCommonSubsequence(string s1, string s2);
```

The function should return the longest common subsequence of characters between the two strings `s1` and `s2`. Basically, it should return a maximum length string of characters that are common to both strings and are in the same order in both strings.

Example:

```
string res = longestCommonSubsequence("smallberg", "nachenberg");
//res should contain "aberg" as seen in the purple chars
res = longestCommonSubsequence("los angeles", "computers");
//res should contain the string "oes"
```

Solution:

```
string longestCommonSubsequence(string s1, string s2) {
      if (s1.empty()  ||  s2.empty()) // base case: either empty
          return "";
      // split the strings into head and tail for simplicity
      char s1_head = s1[0];
      string s1_tail = s1.substr(1);
      char s2_head = s2[0];
      string s2_tail = s2.substr(1);

      // if heads are equal, use the head and
      // recursively find rest of common subsequence
      if (s1_head == s2_head)
          return s1_head + longestCommonSubsequence(s1_tail, s2_tail);
      // heads different, so check for common subsequences not
      // including one of the heads
      string if_behead_s1 = longestCommonSubsequence(s1_tail, s2);
      string if_behead_s2 = longestCommonSubsequence(s1, s2_tail);

      // return the longer of the subsequences we found
      return if_behead_s1.length() >= if_behead_s2.length() ? if_behead_s1
: if_behead_s2;
}
```

Additional Practice Problems

1. Given the following class declarations, complete the implementation of each constructor so that the program compiles. Your implementations should correctly assign constructor arguments to class member variables.

HINT: You will need to use initializer lists!

```
class Animal {
    public:
        Animal(string name);
    private:
        string m_name;
};

class Cat : public Animal {
    public:
        Cat(string name, int amountOfYarn);
    private:
        int m_amountOfYarn;
};

class Himalayan : public Cat {
    public:
        Himalayan(string name, int amountOfYarn);
};

class Siamese: public Cat {
    public:
        Siamese(string name, int amountOfYarn, string toyName);
    private:
        string m_toyName;
};
```

Solution:

```
Animal::Animal(string name)
    : m_name(name) {}

Cat::Cat(string name, int amountOfYarn)
    : Animal(name), m_amountOfYarn(amountOfYarn) {}
```

```
Himalayan::Himalayan(string name, int amountOfYarn)
    : Cat(name, amountOfYarn) {}

Siamese::Siamese(string name, int amountOfYarn, string toyName)
    : Cat(name, amountOfYarn), m_toyName(toyName) {}
```

2. Examine the following code and determine its output.

```
#include <iostream>
#include <string>

using namespace std;

class A {
    public:
        A() : m_val(0) {
            cout << "What a wonderful world! " << m_val << endl;
        }

        virtual ~A() { cout << "Guess this is goodbye " << endl; }
        virtual void saySomething() = 0;
        virtual int giveMeSomething() = 0;

    private:
        int m_val;
};

class B : public A {
    public:
        B() : m_str("me"), m_val(1) {
            cout << m_str << " has just been birthed."  << endl;
        }
        B(string str, int val) : m_str(str), m_val(val) {
            cout << "More complex birth " << m_str << endl;
        }
        ~B() {
            cout << "Why do I have to leave this world!" << endl;
        }
        virtual void saySomething() {
            cout << "Coming in from " << m_str << " with "
            << giveMeSomething() << endl;
        }
        virtual int giveMeSomething() { return m_val*5; }
    private:
        int m_val;
        string m_str;
};
```

```
class C {
    public:
        C() : m_val(2) {
            m_b = new B("C", m_val);
            cout << "Hello World!!" << endl;
        }
        C(const B& b, int val) :  m_val(val) {
            m_b = new B(b);
            cout << m_b->giveMeSomething() << endl;
        }
        ~C() {
            m_b->saySomething();
            delete m_b;
            cout << "Goodbye world!" << endl;
        }
    private:
        B* m_b;
        int m_val;
};

int main() {
    B* b_arr = new B[3];
    for(int i = 0; i < 3; i++) {
        b_arr[i].saySomething();
    }
    B b("B", 5);
    A* a = &b;
    cout << a->giveMeSomething() << endl;
    C c;
    C c2(b, b.giveMeSomething());
    delete [] b_arr;
}
```

Solution/Output:

```
What a wonderful world! 0
me has just been birthed.
What a wonderful world! 0
me has just been birthed.
What a wonderful world! 0
me has just been birthed.
Coming in from me with 5
```

```
Coming in from me with 5
Coming in from me with 5
What a wonderful world! 0
More complex birth B
25
What a wonderful world! 0
More complex birth C
Hello World!!
25
Why do I have to leave this world!
Guess this is goodbye
Why do I have to leave this world!
Guess this is goodbye
Why do I have to leave this world!
Guess this is goodbye
Coming in from B with 25
Why do I have to leave this world!
Guess this is goodbye
Goodbye world!
Coming in from C with 10
Why do I have to leave this world!
Guess this is goodbye
Goodbye world!
Why do I have to leave this world!
Guess this is goodbye
```

3. What does the following code output and what does the function LA_power do?

```
#include <iostream>
using namespace std;

int LA_power(int a, int b) {
    if (b == 0)
        return 0;
    if (b % 2 == 0)
        return LA_power(a+a, b/2);

    return LA_power(a+a, b/2) + a;
}

int main() {
    cout << LA_power(3, 4) << endl;
}
```

Solution/Output:

It outputs 12. LA_power returns the result of multiplying its arguments.

4. Implement the recursive function `merge` that merges two sorted linked lists `l1` and `l2` into a single sorted linked list. The lists are singly linked; the last node in a list has a null next pointer. The function should return the head of the merged linked list. No new Nodes should be allocated while merging.

Example:

```
l1:   1 -> 4 -> 6 -> 8
l2:   3 -> 9 -> 10
After merge:   1 -> 3 -> 4 -> 6 -> 8 -> 9 -> 10
```

```
// Node definition for singly linked list
struct Node {
    int val;
    Node* next;
};

Node* merge(Node* l1, Node* l2);
```

Solution:

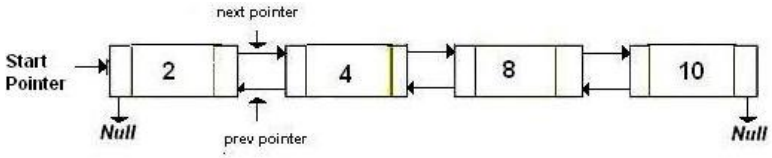
```
Node* merge(Node* l1, Node* l2) {
    // base cases: if a list is empty, return the other list
    if (l1 == nullptr)
        return l2;
    if (l2 == nullptr)
        return l1;

    // determine which head should be the head of the merged list
    // then set head->next to the head returned from recursive calls
    Node* head;
    if (l1->val < l2->val) {
        head = l1;
        head->next = merge(l1->next, l2);
    }
    else {
        head = l2;
        head->next = merge(l1, l2->next);
    }

    // return the head of the merged list
```

```
    return head;
}
```

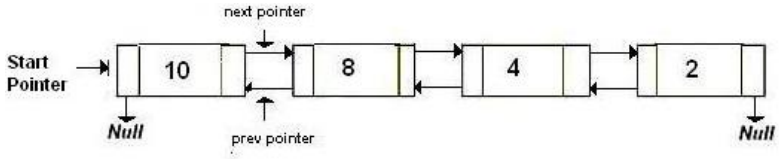
5. Implement `reverse`, a recursive function to reverse a doubly linked list. It returns a pointer to the new head of the list. The integer value in each node must not be changed (but of course the pointers can be).

Example:

Original:



After:




```
// Node definition for doubly linked list
struct Node {
    int val;
    Node* next;
    Node* prev;
};

Node* reverse(Node* head);
```

Solution:

```
Node* reverse(Node* head) {
    if (head == nullptr)
        return head;
    // Swap next and prev
    Node* temp = head->next;
    head->next = head->prev;
    head->prev = temp;
    // If previous is null then we are done
    if (head->prev == nullptr)
        return head;
    return reverse(head->prev);
}
```