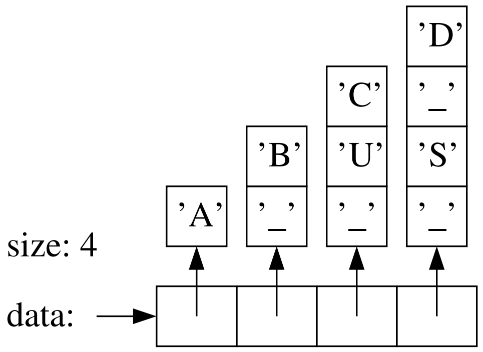
CSCI-1200 Data Structures
Test 2 — Practice Problem Solutions

1 Dynamically Allocated & Templated Stairs [/ 28]

In this problem you will write a simple class to build a staircase-shaped storage shelf. Here's an example usage of the class, which constructs the diagram on the right.

```
Stairs<char> s(4,'_');
s.set(0,0,'A');
s.set(1,1,'B');
s.set(2,2,'C');
s.set(3,3,'D');
s.set(2,1,'U');
s.set(3,1,'S');
```



1.1 Stairs Class Declaration [/ 14]

First, fill in the blanks in the class declaration:

Solution:

```
template <class T>  class Stairs {

  public:
    // constructor

    Stairs(int s, const T& val);

    // destructor

    ~Stairs();

    // prototypes of 2 other important functions related to the constructor & destructor

    Stairs(const Stairs& s);
    Stairs& operator=(const Stairs& s);

    // modifier

    void set(int i, int j,  const T&  val) { data[i][j] = val; }

    /* NOTE: other Stair functions omitted */
  private:
    // representation

    int size;
    T** data;

};
```

1.2 `Stairs` Constructor [/ 9]

Now write the constructor, as it would appear outside of the class declaration (because the implementation is > 1 line of code).

Solution:
```
template <class T> Stairs<T>::Stairs(int s, const T& val) {
  size = s;
  data = new T*[s];
  for (int i = 0; i < s; i++) {
    data[i] = new T[i+1];
    for (int j = 0; j <= i; j++) {
      data[i][j] = val;
    }
  }
}
```

1.3 `Stairs` Destructor [/ 5]

Now write the destructor, as it would appear outside of the class declaration (because the implementation is > 1 line of code).

Solution:
```
template <class T> Stairs<T>::~Stairs() {
  for (int i = 0; i < size; i++) {
    delete [] data[i];
  }
  delete [] data;
}
```

2 Comparing Linked List Pointers w/ Recursion [/ 32]

Ben Bitdiddle is working on a software project for essay writing using a doubly-linked chain of nodes. His initial `Node` class is on the right.

```
class Node {
public:
  std::string word;
  Node* next;
  Node* prev;
};
```

One of the features of his software allows a user to compare the location of two words within the document and say which word appears first. Ben plans to implement this using two helper functions: `search` and `compare`.

2.1 Searching for a Word [/ 7]

First, let's write the `search` function, which takes in two arguments: a pointer to the first `Node` in the document (word chain) and the specific `word` we're looking to find. The function returns a pointer to the first `Node` containing that `word`. Use *recursion* to implement this function.

Solution:
```
Node* search(Node* head, const std::string& word) {
  if (head == NULL) return NULL;
  if (head->word == word) {
    return head;
  }
  return search (head->next,word);
}
```

If the `Node` chain contains n elements, what is the running time of the `search` function?

Solution: O(n)

2.2 Comparing Positions within the Node Chain [/ 8]

Next, let's implement the `compare` function. This function takes in two `Node` pointers and returns true if the first argument appears closer to the front of the list than the second argument. For example, let's say a chain of word `Node`s named `sentence` contains:

```
  the quick brown fox jumps over the lazy dog
```

Here's an example using the `search` and `compare` functions:

```
Node* over  = search(sentence,"over");
Node* quick = search(sentence,"quick");
Node* lazy  = search(sentence,"lazy");

assert (compare(quick,over) == true);
assert (compare(over,quick) == false);
assert (compare(quick,lazy) == true);
assert (compare(lazy,over)  == false);
```

Again using *recursion*, implement the `compare` function.

Solution:

```
bool compare(Node *a, Node *b) {
  if (a == NULL) return false;
  if (b == NULL) return false;
  if (a == b) return false;
  if (a->next == b) return true;
  return compare(a->next,b);
}
```

If the `Node` chain contains n elements, what is the running time of the `compare` function?

Solution: O(n)

Improving Word Position Comparison Performance

```
class Node {
public:
  std::string word;
  Node* next;
  Node* prev;
  float distance;
};
```

Alyssa P. Hacker stops by to help, and suggests that Ben switch to a different data structure if he is frequently comparing word positions within a long essay.

But Ben's a stubborn guy. Instead of switching to a different data structure, he has a plan to augment his list structure to improve the running time of `compare`. Ben explains that the new `distance` member variable in each node will indicate how far away the node is from the front of the list.

Here's Ben's new compare function:

```
bool compare_fast(Node *a, Node *b) {
  return a->distance < b->distance;
}
```

Ben reassures Alyssa that he'll add some error checking to this code.
SIDE NOTE: Hopefully your implementation of the original compare function has some error checking!

But Alyssa is more concerned about how this addition to the data structure will impact performance when the essay or sentence is edited. She says he can't afford to change the `distance` in all or many `Node`s in the data structure any time a small edit is made to the document.

Ben explains that the `push_back` function will assign the distance of the new `Node` to be the distance of the last `Node` in the chain plus 10.0. And similarly, `push_front` will assign the new `Node` to be the distance from the first `Node` minus 10.0. *BTW, negative distance values are ok.* Finally, Ben says the `insert_between` function (on the next page) can similarly be implemented without editing the distance value in any existing `Node`!

2.3 Implementing `insert_between` and Maintaining Fast Comparisons [/ 17]

Continuing with the previous example, here's a quick demonstration of how this function works:

```
bool success = insert_between(sentence,"the","lazy","VERY");
assert (success);
Node* VERY = search(sentence,"VERY");
assert (compare(VERY,lazy)       == true);
assert (compare(quick,VERY)      == true);
assert (compare_fast(VERY,lazy)  == true);
assert (compare_fast(quick,VERY) == true);
success = insert_between(sentence,"quick","fox","RED");
assert (!success);
```

And here's the contents of the `sentence` variable after the above fragment of code:

```
  the quick brown fox jumps over the VERY lazy dog
```

Implement `insert_between`. And yes, use *recursion.*

Solution:

```
bool insert_between(Node *head, const std::string& before, const std::string& after, const std::string& word) {
  if (head == NULL) return false;
  if (head->next == NULL) return false;
  if (head->word == before && head->next->word == after) {
    Node* tmp = new Node;
    tmp->word = word;
    tmp->prev = head;
    tmp->next = head->next;
    tmp->next->prev = tmp;
    tmp->prev->next = tmp;
    tmp->distance = (tmp->next->distance + tmp->prev->distance) / 2.0;
    return true;
  } else {
    return insert_between(head->next,before,after,word);
  }
}
```

3 Erase Middles [/ 20]

Write a function named `erase_middles` that takes in 2 arguments: an STL list named `data` and a `value`. The function should remove all instances of `value` from `data`, except the first and the last instances. The function returns the number of removed elements. For example, if `data` initially contains:

```
   5  2  5  2  3  4  3  2  5  2  3  2  3  4  2  5
```

A call to `erase_middles(data,5)` will return 2 and now `data` contains:

```
   5  2  2  3  4  3  2  2  3  2  3  4  2  5
```

And then a call to `erase_middles(data,2)` will return 4 and `data` contains:

```
   5  2  3  4  3  3  3  4  2  5
```

Solution:

```
template <class T>
int erase_middles(std::list<T>& data, const T& val) {
  bool found_first = false;
  typename std::list<T>::iterator prev = data.end();
  typename std::list<T>::iterator itr = data.begin();
  int count = 0;
  while (itr != data.end()) {
    if (*itr == val) {
      if (prev != data.end()) {
        data.erase(prev);
        count++;
      }
      if (found_first == false) {
        found_first = true;
      } else {
        prev = itr;
      }
    }
    itr++;
  }
  return count;
}
```

4 Debugging Skillz [/ 17]

For each program bug description below, write the letter of the most appropriate debugging skill to use to solve the problem. Each letter should be used at most once.

A) get a backtrace	E) examine different frames of the stack
B) add a breakpoint	F) reboot your computer
C) use step or next	G) use Dr Memory or Valgrind to locate the leak
D) add a watchpoint	H) examine variable values in gdb or lldb

Solution: E A complex recursive function seems to be entering an infinite loop, despite what I think are perfect base cases.

Solution: G The program always gets the right answer, but when I test it with a complex input dataset that takes a long time to process, my whole computer slows down.

Solution: A I'm unsure where the program is crashing.

Solution: H I've got some tricky math formulas and I suspect I've got an order-of-operations error or a divide-by-zero error.

Solution: D I'm implementing software for a bank, and the value of a customer's bank account is changing in the middle of the month. Interest is only supposed to be added at the end of the month.

Select one of the letters you did not use above, and write a concise and well-written 3-4 sentence description of a specific situation where this debugging skill would be useful.

Solution: B) Once you've found the general area of the problem, it can be helpful to add a breakpoint shortly before the crash, so you can examine the situation more closely. C) Once you've decided the state of the program is reasonable, you can advance the program one line at a time using `next` or `step` into a helper function that may be causing problems. Rebooting your computer is unlikely to fix a bug in your own code.

5 Flipping & Sorting Words [/ 18]

Finish the implementation of the function `FlipWords` that takes in an *alphabetically sorted* STL `list` of STL `strings` named `words` and modifies the list. The function should remove all palindromes (words that are the same forwards & backwards). The function should insert the flipped (reversed) version of all other words into the list, *in sorted order*. For example this input list:

```
bard civic diva flow pots racecar stop warts
```

Should be changed to contain:

```
avid bard diva drab flow pots stop straw warts wolf
```

You may not use STL `sort`. You may assume the input list does not contain any duplicates. And after calling the `FlipWords` function the list should not contain any duplicates.

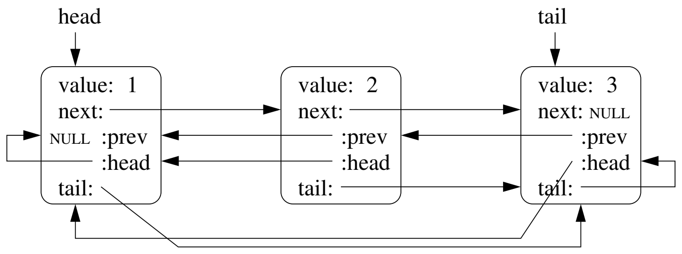
Solution:

```
std::string reverse(std::string &word) {
  std::string answer(word.size(),' ');
  for (int i = 0; i < word.size(); i++) { answer[i] = word[word.size()-1-i]; }
  return answer;
}
void FlipWords(std::list<std::string> &words) {
  std::list<std::string>::iterator current = words.begin();
  while (current!= words.end()) {
    std::string flip = reverse(*current);
    if (flip == *current) {
      current = words.erase(current);
    } else {
      std::list<std::string>::iterator tmp = words.begin();
      while (tmp != words.end() && flip > *tmp) {
        tmp++;
      }
      if (tmp == words.end() || flip != *tmp) {
        words.insert(tmp,flip);
      }
      current++;
    }
  }
}
```

6 "Smart" List Nodes [/ 18]

Ben Bitdiddle thinks he has stumbled on a brilliant idea to make each `Node` of a doubly linked list "smart" and store global information about the list. Each `Node` will have a pointer to the `head` and `tail` `Node`s of the overall list.

```
class Node {
public:
  Node* head;
  Node* tail;
  Node* next;
  Node* prev;
  int value;
};
```



Help him by finishing the implementation of `PushFront` to add a new element to the list. *Note: You should not change the* `value` *inside of any existing* `Node`*s.*

Solution:

```
void PushFront(Node* &head, Node* &tail, int v) {
  Node* tmp = new Node;
  tmp->value = v;
  if (head == NULL) {
    assert (tail == NULL);
    tmp->next = tmp->prev = NULL;
    tmp->head = tmp->tail = tmp;
    head = tail = tmp;
  } else {
    tmp->prev = NULL;
    tmp->next = head;
    tmp->tail = tail;
    head->prev = tmp;
    head = tmp;
    while (tmp != NULL) {
      tmp->head = head;
      tmp = tmp->next;
    }
  }
}
```

7 Dynamically Allocated Student Schedules [/ 30]

Alyssa P. Hacker has joined the Rensselaer Center for Open Source Software and is working on a program to help students manage their schedules over their time at RPI. She will use a two dimensional array to store courses taken each term. The declaration for two key classes is shown on the right:

Alyssa's program assumes that all undergraduate RPI degree programs require students to take 32 4-credit courses. She also assumes that each specific student takes the same number of courses per term throughout their time at RPI.

Your task is to implement the critical functions for this class with dynamically allocated memory, as they would appear in the `Student.cpp` file. Make sure to use the private helper functions as appropriate so your code is concise.

A few examples of usage are shown below.

```
class Course {
public:
  Course(const std::string &p="XXXX", int n=1000)
    : prefix(p), num(n) {}
  /* member functions omitted */
private:
  std::string prefix;
  int num;
};
class Student {
public:
  Student();
  Student(int courses_per_term_);
  Student(const Student& s);
  const Student& operator=(const Student& s);
  ~Student();
  int numTerms() const { return num_terms; }
  const Course& getCourse(int t, int c) const
      { return data[t][c]; }
  /* additional member functions omitted */
private:
  void initialize();
  void copy(const Student& s);
  void destroy();
  int num_terms;
  int courses_per_term;
  Course** data;
};
```

```
// a typical student takes 4 courses per term for 8 terms
Student regular;          assert (regular.numTerms() == 8);
// if a student takes 5 courses per term, they can finish in 3.5 years
Student overachiever(5);  assert (overachiever.numTerms() == 7);
// students who take 3 courses per term will require 5.5 years
Student supersenior(3);   assert (supersenior.numTerms() == 11);
/* details of how courses are scheduled omitted */
```

Solution:

```
Student::Student() {
  num_terms = 8;
  courses_per_term = 4;
  initialize();
}
```

```
Student::Student(int courses_per_term_) {
  courses_per_term = courses_per_term_;
  num_terms = ceil(32 / float(courses_per_term));
  initialize();
}
Student::Student(const Student& s) {
  copy(s);
}

const Student& Student::operator=(const Student& s) {
  if (this != &s) {
    destroy();
    copy(s);
  }
  return *this;
}

Student::~Student() {
  destroy();
}
void Student::initialize() {
  data = new Course* [num_terms];
  for (int i = 0; i < num_terms; i++) {
    data[i] = new Course[courses_per_term];
  }
}

void Student::copy(const Student& s) {
  courses_per_term = s.courses_per_term;
  num_terms = s.num_terms;
  initialize();
  for (int i = 0; i < num_terms; i++) {
    for (int j = 0; j < courses_per_term; j++) {
      data[i][j] = s.data[i][j];
    }
  }
}

void Student::destroy() {
  for (int i = 0; i < num_terms; i++) {
    delete [] data[i];
  }
  delete [] data;
}
```

8 Reverse Iterators [/ 10]

Complete the function below named `reverse` that takes in an STL `list` as its only argument and returns an STL `vector` that contains the same list except in reverse order. You should use a *reverse iterator* and you may not use `push_back`.

Solution:

```
template <class T>
std::vector<T> reverse(const std::list<T> &my_list) {
  std::vector<T> answer (my_list.size());
  int i = 0;
  typename std::list<T>::const_reverse_iterator itr = my_list.rbegin();
  while (itr != my_list.rend()) {
    answer[i] = *itr;
    i++;
    itr++;
  }
  return answer;
}
```

9 Order Notation [/ 5]

Rank these 6 order notation formula from fastest(1) to slowest(6).

Solution: 1 $O(8 \cdot s \cdot w \cdot h)$

Solution: 5 $O(w \cdot h \cdot 8^s)$

Solution: 4 $O((s \cdot w \cdot h)^8)$

Solution: 2 or 3 $O((s + w \cdot h)^8)$

Solution: 6 $O((8 \cdot w \cdot h)^s)$

Solution: 2 or 3 $O(w \cdot h \cdot s^8)$

NOTE: The ordering of the '2' vs. '3' depends on the relative size of the variables h, w, and s.
If $w = h = s$ **:** $(w + w \cdot w)^8 = w^{16} > w \cdot w \cdot w^8 = w^{10}$.
If $w = h$ & $s = w^2$ **:** $(w^2 + w \cdot w)^8 = w^{16} < w \cdot w \cdot (w^2)^8 = w^{18}$.

10 Mystery Recursion [/9]

For each function or pair of functions below, choose the letter that best describes the program purpose or behavior.

A) infinite loop	E) function is not recursive	I) reverse the digits
B) factorial	F) sum of the digits	J) multiplication
C) integer power	G) syntax error	K) greatest common divisor
D) the answer is 42	H) modulo 2	L) other

Solution: K

```
int mysteryONE(int x, int y) {
  if(y == 0)
    return x;
  else
    return mysteryONE(y, x % y);
}
```

Solution: F

```
int mysteryTWO(int x) {
  if (x == 0)
    return 0;
  else
    return mysteryTWO(x/10)
           + x%10;
}
```

Solution: H

```
int mysteryTHREEa(int x);

int mysteryTHREEb(int x) {
  if (x == 0)
    return 1;
  else
    return mysteryTHREEa(x-1);
}

int mysteryTHREEa(int x) {
  if (x == 0)
    return 0;
  else
    return mysteryTHREEb(x-1);
}
```

Solution: J

```
int mysteryFOUR(int x, int y) {
  if (x == 0)
    return 0;
  else
    return y +
      mysteryFOUR(x-1,y);
}
```

Solution: I

```
int mysteryFIVEa(int x, int y) {
  if (x == 0)
    return y;
  else
    return mysteryFIVEa
       (x/10, y*10 + x%10);
}

int mysteryFIVEb(int x) {
  return mysteryFIVEa(x,0);
}
```

Solution: B

```
int mysterySIX(int x) {
  if (x == 0)
    return 1;
  else
    return x *
        mysterySIX(x-1);
}
```

11 Collecting Words [/ 18]

Write a function named `Collect` that takes in two *alphabetically sorted* STL `list`s of STL `string`s named `threes` and `candidates`. The function searches through the second list and removes all three letter words and places them in the first list in alphabetical order. For example, given these lists as input:

```
threes:      cup dog fox map
candidates:  ant banana egg goat horse ice jar key lion net
```

After the call to `Collect(threes, candidates)` the lists will contain:

```
threes:      ant cup dog egg fox ice jar key map net
candidates:  banana goat horse lion
```

If there are n and m words in the input lists, the order notation of your solution should be $O(n + m)$.

Solution:

```
void collect(std::list<std::string> &threes, std::list<std::string> &candidates) {
  // start an iterator at the front of each list
  std::list<std::string>::iterator itr = threes.begin();
  std::list<std::string>::iterator itr2 = candidates.begin();
  // loop over all of candidate words
  while (itr2 != candidates.end()) {
    // if the candidate is length 3
    if ((*itr2).size() == 3) {
      // find the right spot for this word
      while (itr != threes.end() && *itr < *itr2) {
        itr++;
      }
      // modify the two lists
      threes.insert(itr,*itr2);
      itr2 = candidates.erase(itr2);
    } else {
      // only advance the pointer if the length is != 3
      itr2++;
    }
  }
}
```

12 Constantly Referencing `DSStudent` [/ 12]

The expected output of the program below is:

```
chris is a sophomore, his/her favorite color is blue, and he/she has used 1 late day(s).
```

However, there are a number of small but problematic errors in the `DSStudent` class code. Hint: This problem's title is relevant! Only one completely new line may be added (line 6), and the 7 other lines require one or more small changes. These lines are tagged with an asterisk, `*`. Your task is to rewrite each incorrect or missing line in the appropriately numbered box. *Please write the entire new line in the box.*

```
  1 class DSStudent {
  2  public:
* 3   DSStudent(std::string n, int y)
  4     : name(n) {
* 5     int entryYear = y;
* 6
  7   }
* 8   std::string& getName() const {
  9     return name;
 10   }
*11   const std::string& getYear() {
 12     if (entryYear == 2014) {
 13       return "freshman"; }
 14     } else if (entryYear == 2013) {
```

```
 15       return "sophomore";
 16     } else if (entryYear == 2012) {
 17       return "junior";
 18     } else {
 19       return "senior";
 20     }
 21   }
*22   void incrLateDaysUsed() const {
 23     days++;
 24   }
*25   int& getLateDaysUsed() const {
 26     return days;
 27   }
*28   std::string FavoriteColor() {
 29     return color;
 30   }
 31  private:
 32   std::string name;
 33   std::string color;
 34   int entryYear;
 35   int days;
 36 };
 37
 38 int main() {
 39   DSStudent s("chris",2013);
 40   s.FavoriteColor() = "blue";
 41   s.incrLateDaysUsed();
 42   std::cout << s.getName()
 43             << " is a " << s.getYear()
 44             << ", his/her favorite color is " << s.FavoriteColor()
 45             << ", and he/she has used " << s.getLateDaysUsed()
 46             << " late day(s)." << std::endl;
 47 }
```

3 **Solution:** `DSStudent(const std::string &n, int y)`

5 **Solution:** `entryYear = y;`

6 **Solution:** `days = 0;`

8 **Solution:** `const std::string& getName() const {`

11 **Solution:** `std::string getYear() const {`

22 **Solution:** `void incrLateDaysUsed() {`

25 **Solution:** `int getLateDaysUsed() const {`

28 **Solution:** `std::string& FavoriteColor() {`

13 Efficient Occurrences [/ 22]

Write a *recursive* function named `Occurrences` that takes in a *sorted* STL `vector` of STL `string`s named `data`, and an STL `string` named `element`. The function returns an integer, the number of times that `element` appears in `data`. Your function should have order notation $O(log\ n)$, where n is the size of `data`.

Solution:

```
// the recursive helper function
int occurrences(const std::vector<std::string> &data, const std::string &element,
                int s1, int s2, int e1, int e2) {
  // s1 & s2 are the current range for the start / first occurence
  // e1 & e2 are the current range for the end / last occurence (+1)
  assert (s1 <= s2 && e1 <= e2);
  if (s1 < s2) {
    // first use binary search to find the first occurrence of element
    int mid = (s1 + s2) / 2;
    if (data[mid] >= element)
      return occurrences(data,element,s1,mid,e1,e2);
    return occurrences(data,element,mid+1,s2,e1,e2);
  } else if (e1 < e2) {
    // then use binary search to find the last occurrence of element (+1)
    int mid = (e1 + e2) / 2;
    if (data[mid] > element)
      return occurrences(data,element,s1,s2,e1,mid);
    return occurrences(data,element,s1,s2,mid+1,e2);
  } else {
    // the simply subtract these indices
    assert (s1 == s2 && e1 == e2 && e1 >= s1);
    return e1 - s1;
  }
}

// "driver" function
int occurrences(const std::vector<std::string> &data, const std::string &element) {
  // use binary seach twice to find the first & last occurrence of element
  return occurrences(data,element,0,data.size(),0,data.size());
}
```

14 Short Answer [/ 8]

14.1 What's Wrong? [/ 4]

Write 1-2 complete and concise sentences describing the problem with this code fragment:

```
std::vector<std::string> people;
people.push_back("sally");
people.push_back("brian");
people.push_back("monica");
people.push_back("fred");
std::vector<std::string>::iterator mom = people.begin() + 2;
std::vector<std::string>::iterator dad = people.begin() + 1;
people.push_back("paula");
std::cout << "My parents are " << *mom << " and " << *dad << std::endl;
```

Solution: Any iterators attached to an STL vector should be assumed to be invalid after a call to push_back (or erase or resize) because the internal dynamically allocated array may have been relocated in memory (or the data shifted). Dereferencing the pre-push_back iterators to print the data is dangerous since that memory may have been deleted/freed.

14.2 Fear of Recursion [/ 4]

Rewrite this function without recursion:

```
class Node {
public:
  std::string value;
  Node* next;
};
```

```
void printer (Node* n) {
  if (n->next == NULL) {
    std::cout << n->value;
  } else {
    std::cout << "(" << n->value << "+";
    printer (n->next);
    std::cout << ")";
  }
}
```

Solution:

```
void printer (Node* n) {
  int count = 0;
  while (n != NULL) {
    if (n->next != NULL) {
      std::cout << "(" << n->value << "+";
      count++;
    } else {
      std::cout << n->value;
    }
    n = n->next;
  }
  std::cout << std::string(count,')');
}
```

15 Converting Between `Vec` and `dslist` [/ 26]

Ben Bitdiddle is working on a project that stores data with two different data structures: our `Vec` and `dslist` classes. Occasionally he needs to convert data from one format to the other format. Alyssa P. Hacker suggests that he write a copy-constructor-like function for each class that takes in a single argument, the original format of the data. For example, here's how to convert data in `Vec` format to `dslist` format:

```
  // create a Vec object with 4 numbers
  Vec<int> v;  v.push_back(1);  v.push_back(2);  v.push_back(3);  v.push_back(4);
  // create a dslist object that initially stores the same data as the Vec object
  dslist<int> my_lst(v);
```

Here are the relevant portions of the two class declarations (and the `Node` helper class):

```
template <class T> class Vec {
public:
  // conversion constructor
  Vec(const dslist<T>& lst);
  /* other functions omitted */
  // representation
  T* m_data;
  unsigned int m_size;
  unsigned int m_alloc;
};
```

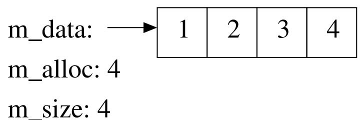
```
template <class T> class Node {
public:
  Node(const T& v):
    value_(v),next_(NULL),prev_(NULL){}
  T value_;
  Node<T>* next_;
  Node<T>* prev_;
};

template <class T> class dslist {
public:
  // conversion constructor
  dslist(const Vec<T>& vec);
  /* other functions omitted */
  // representation
  Node<T>* head_;
  Node<T>* tail_;
  unsigned int size_;
};
```

Ben asks about access to the private member variables of one class from a member function of the other. Alyssa says he can write the functions assuming he has full access to the private member variables. (She promises to teach him how to use the `friend` keyword to make that work after Test 2.)

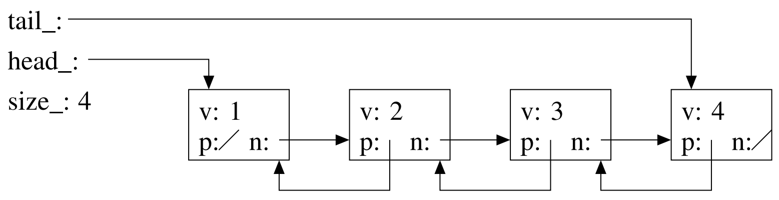
15.1 Diagrams [/ 8]

First, draw the detailed internal memory representations for a `Vec` object and a `dslist` object, each storing the numbers: `1 2 3 4`.

Solution:



Solution:



15.2 Implementing the Conversion Constructors [/ 18]

Now write the two conversion constructors. You may not use `push_back`, `push_front`, `insert` or iterators in your answer. Instead, demonstrate that you know how to construct and manipulate the low level memory representation.

Solution:

```
template <class T> Vec<T>::Vec(const dslist<T>& lst) {
  m_alloc = m_size = lst.size();
  if (m_alloc > 0)
    m_data = new T[m_alloc];
  else
    m_data = NULL;
  int i = 0;
  Node<T> *tmp = lst.head_;
  while (tmp != NULL) {
    m_data[i] = tmp->value_;
    tmp = tmp->next_;
    i++;
  }
}


template <class T> dslist<T>::dslist(const Vec<T>& v) {
  head_ = tail_ = NULL;
  size_ = v.size();
  Node<T> *tmp = NULL;
  for (int i = 0; i < size_; ++i) {
    tail_ = new Node<T>(v.m_data[i]);
    if (tmp != NULL) {
      tail_->prev_ = tmp;
      tmp->next_ = tail_;
    }
    if (i == 0) head_ = tail_;
    tmp = tail_;
  }
}
```