Intermediate Programming

Day 18

Outline

- Exercise 17
- Linked lists
- Review questions

Exercise 17

Implement **length**.

list.h

```
…
unsigned int length( const Node *head );
…
```

list.c

```
…
unsigned int length( const Node *head )
{
        unsigned int len = 0;
        while( head ) len++ , head = head->next;
        return len;
}
…
```

list.c

```
…
unsigned int length( const Node *head )
{
        unsigned int len = 0;
        for( ; head ; head=head->next , len++ ) ;
        return len;
}
…
```

Exercise 17

Implement **length**.

list.h

```
...
unsigned int length( const Node *head );
...
```

list.c

```
...
unsigned int length( const Node *head )
{
        if( head ) return 1 + length( head->next );
        else return 0;
}
...
```

Recursion:

- For recursion we need to be able to describe the solution to the bigger problem in terms of a solution to the smaller problem.
- In this case the smaller problem is getting the length of the sub-linked-list "rooted" at **node->next**.
- If we can get the length of the sub-linked-list starting at **node->next**, then the length of the entire linked-list is just one more than that.

Exercise 17

Implement **add_after**.

list.h

```
...
add_after( Node *n , char c );
...
```

list.c

```
...
int add_after( Node *n , char c )
{
	Node *_n = create_node(c);
	if( !_n ) return 1;
	_n->next = n->next;
	n->next = _n;
	return 0;
}
...
```

Exercise 17

Implement **reverse_print**.

list.h

```
…
add_after( Node *n , char c );
…
```

list.c

```
…
void reverse_print( const Node *node )
{
        if( node->next ) reverse_print( node->next );
        printf( "%c " , node->data );
}
…
```

Recursion:

- For recursion we need to be able to describe the solution to the bigger problem in terms of a solution to the smaller problem.
- In this case the smaller problem is printing the sub-linked-list "rooted" at **node->next**.
- If we can print the linked-list starting at **node->next** in reverse order, then to print the entire linked-list we only need to print value in **node->data**.

Outline

- Exercise 17
- Linked lists
- Review questions

Linked lists

We've seen some linked-list operations

- Create a node
- Add a node after a node
- Get the length of the list
- Print out the contents

We need some more:

- Add to the front of the list
- Remove an element from the list
- Deallocate memory associated to the list
- Make a copy of the list

charList.h

```
#ifndef charList_included
#define charList_included
typedef struct _Node
{
    struct _Node *next;
    char value;
} Node;

Node *create_node( char c );
int add_after( Node *n , char c );
int length( const Node *head );
void print( const Node *head );
...
#endif // charList_included
```

Linked lists

- Insertion
  - Create the linked-list element
  - Update the pointers

charList.c

```
#include "charList.h"
…
int add_front( Node **head , char c )
{
      Node *n = create_node( c );
      if( !n ) return 1;
      n->next = *head;
      *head = n;
      return 0;
}
```

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Node *create_node( char c );
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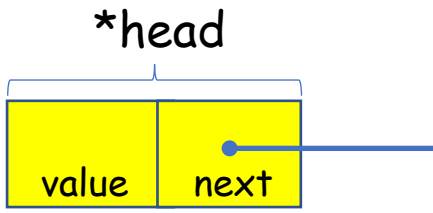

Linked lists

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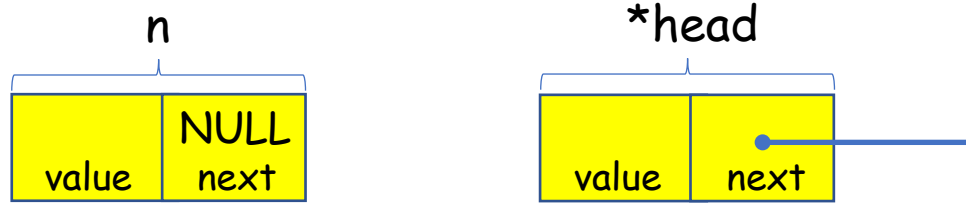

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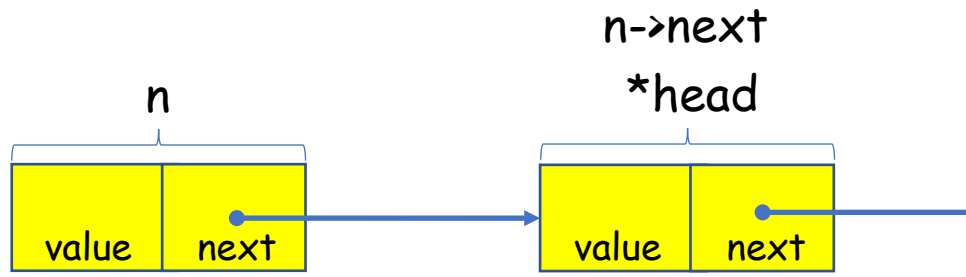

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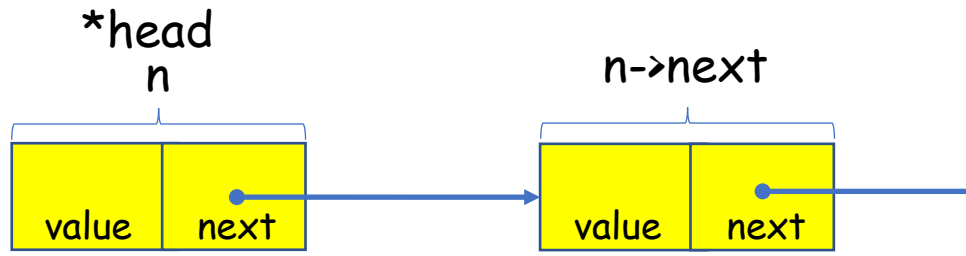

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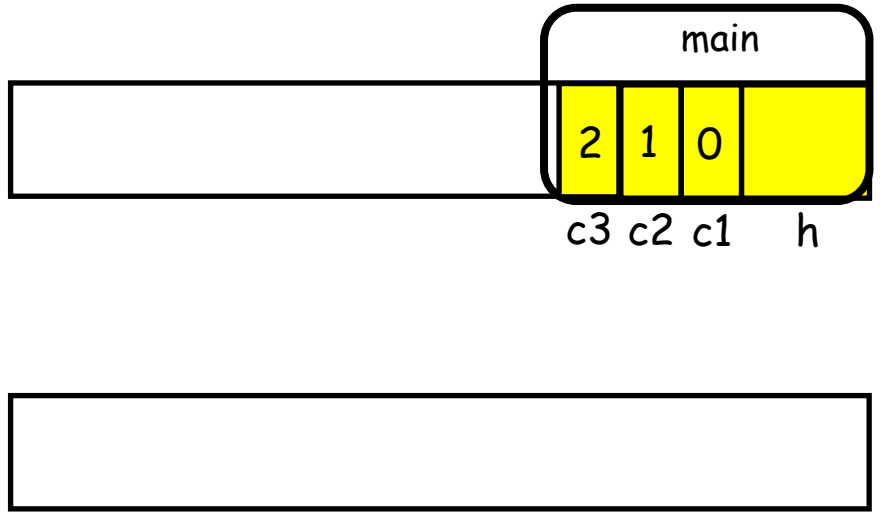
main.c

```
#include "charList.h"

void main( void )
{
      char c1=0 , c2=1 , c3=2;
      Node *h = create_node( c1 );
      add_after( h , c2 );
      add_front( &h , c3 );
      return 0;
}
```



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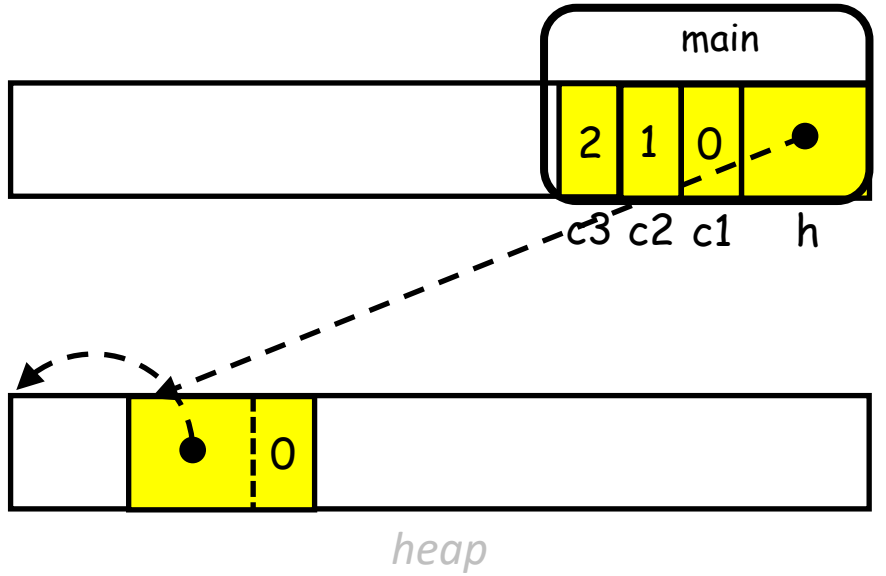

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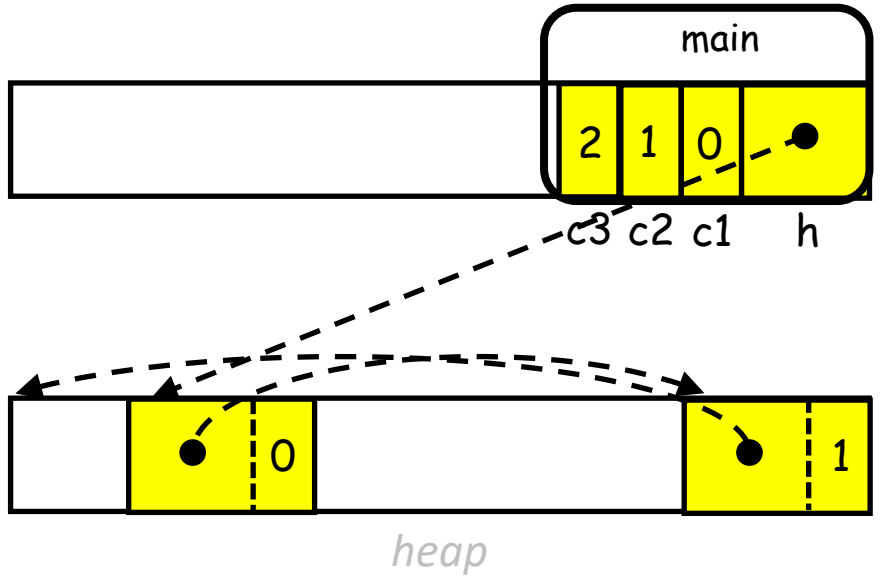

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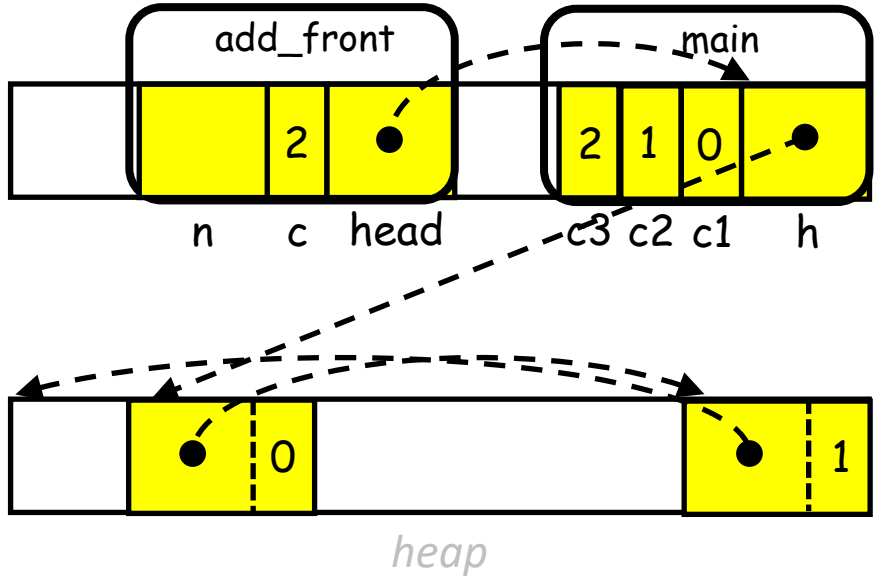

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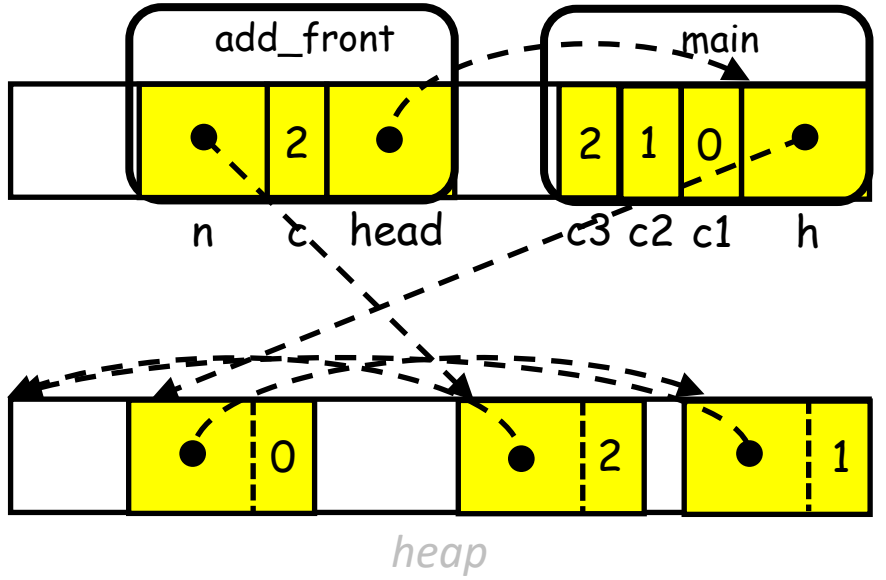

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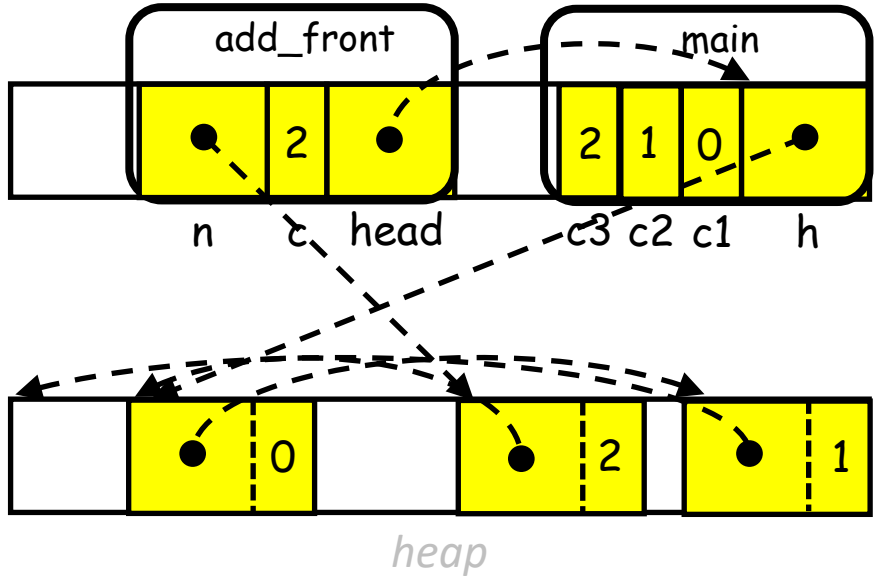

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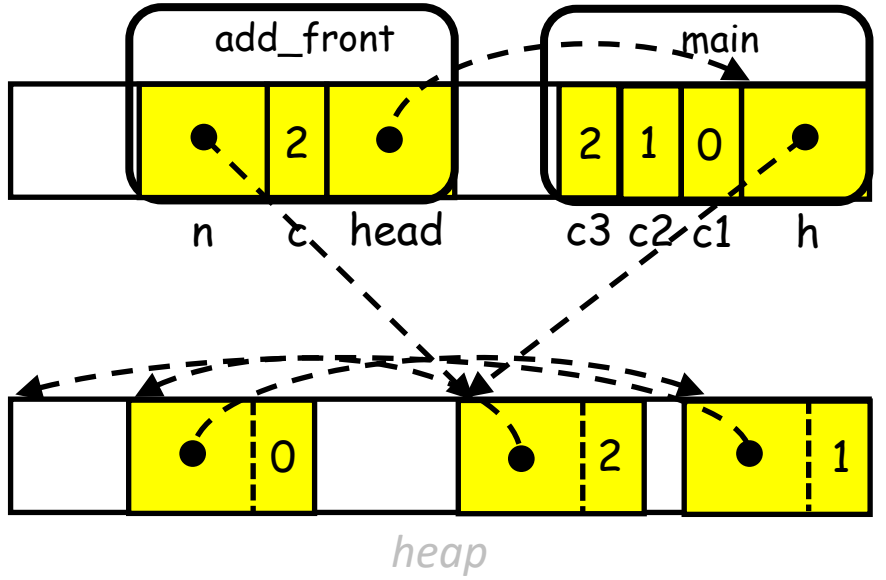

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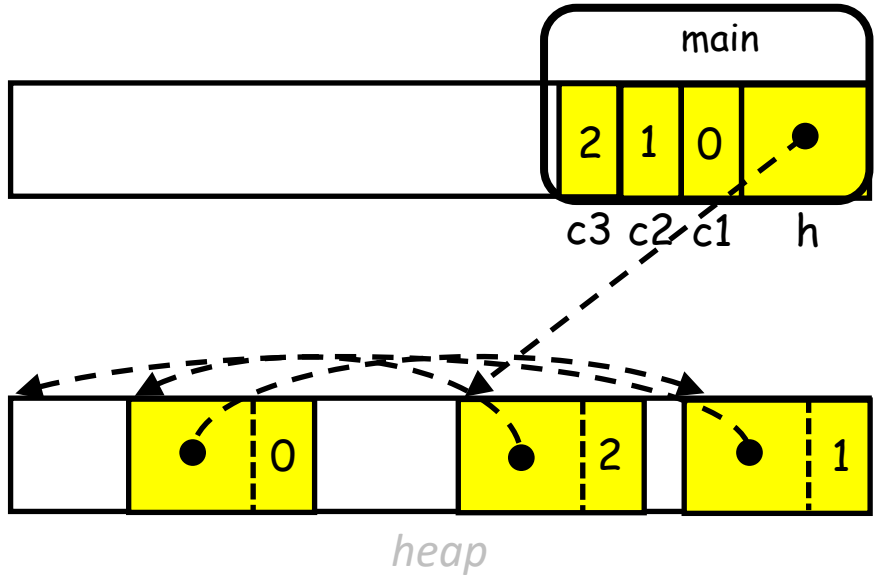

Linked lists

- Deletion
  - Update the pointers
  - Delete the linked-list element

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int add_front( Node **h , char c );
void remove_after( Node *n );
int length( const Node *head );
void print( const Node *head );
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#endif // charList_included
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charList.c

```
#include "charList.h"
...
void remove_after( Node *n )
{
    Node *nNext = n->next;
    if( !nNext ) return;
    n->next = n->next->next;
    free( nNext );
}
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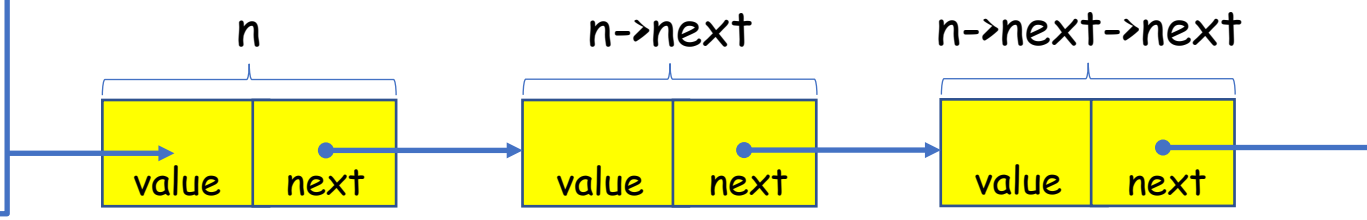

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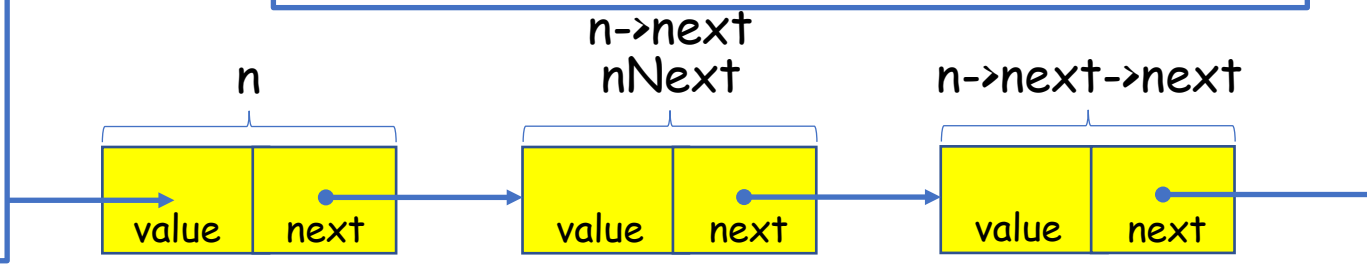

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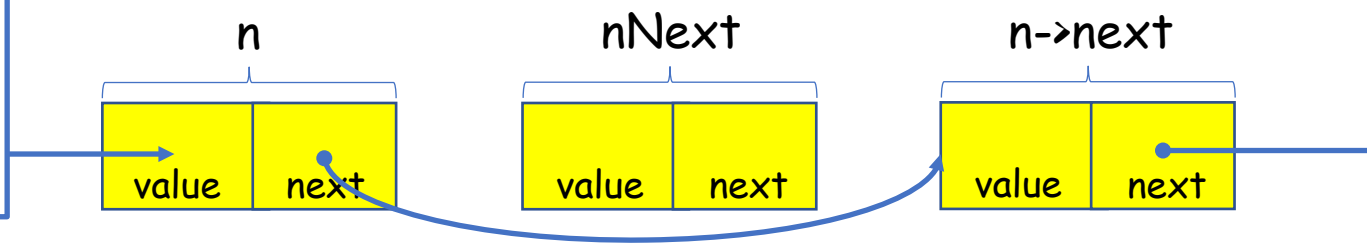

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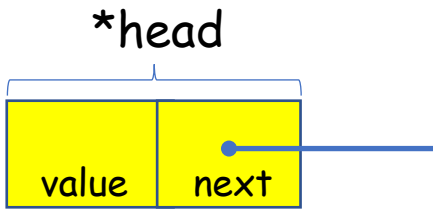

Linked lists

- Copying
  - Create a new node with the head's **value**
  - Make it's **next** a deep copy of the remainder of the list

charList.c

```
#include "charList.h"
…
Node *copy( const Node *head )
{
    if( !head ) return NULL;
    Node *_head = create_node( head->value );
    _head->next = copy( head->next );
    return _head;
}
```

charList.h

```
#ifndef charList_included
#define charList_included
typedef struct _Node
{
    struct _Node *next;
    char value;
} Node;

Node *create_node( char c );
int add_after( Node *n , char c );
int add_front( Node **h , char c );
void remove_after( Node *n );
void remove_front( Node **n );
int length( const Node *head );
void print( const Node *head );
Node *copy( const Node *head );
#endif // charList_included
```

Linked lists

Example (sorting chars)

- Read in chars from the stdin and insert them into a linked list, sorted from smallest to largest
  - Read the chars in
    - If the linked list is empty, create a head containing the char
    - Otherwise, if the char is smaller than everything in the linked list, add it at the head
    - Otherwise, add it after the largest element smaller than the char
  - Print out the (sorted) chars
  - Free up the memory

charList.h

```
#ifndef charList_included
#define charList_included
typedef struct _Node
{
    struct _Node *next;
    char value;
} Node;

Node *create_node( char c );
int add_after( Node *n , char c );
int add_front( Node **h , char c );
void remove_after( Node *n );
void remove_front( Node **n );
int length( const Node *head );
void print( const Node *head );
Node *copy( const Node *head );
#endif // charList_included
```

main.c

```
#include <stdio.h>
#include <stdlib.h>
#include <ctype.h>
#include "charList.h"
int main( void )
{
	Node *head = NULL , *n;
	char c;
	while( fscanf( stdin , " %c" , &c )==1 )
	{
		if( !head ) head  = create_node( c );
		else if( c<head->value ) add_front( &head , c );
		else
		{
			for( n=head ; n->next!=NULL && c>=n->next->value ; n=n->next ) ;
			add_after( n , c );
		}
	}
	for( n=head ; n!=NULL ; n=n->next ) printf( "%c" , n->value );
	printf( "\n" );
	while( head ) remove_front( &head );
	return 0;
}
```

charList.h

```
#ifndef charList_included
#define charList_included
typedef struct _Node
{
	struct _Node *next;
	char value;
} Node;
...
#endif // charList_included
```

```
>> ./a.out
misha
ahims
>>
```

main.c

```
#include <stdio.h>
#include <stdlib.h>
#include <ctype.h>
#include "charList.h"
int main( void )
{
    Node *head = NULL , *n;
    char c;
    while( fscanf( stdin , " %c" , &c )==1 )
    {
        if( !head ) head  = create_node( c );
        else if( c<head->value ) add_front( &head , c );
        else
        {
            for( n=head ; n->next!=NULL && c>=n->next->value ; n=n->next ) ;
            add_after( n , c );
        }
    }
    for( n=head ; n!=NULL ; n=n->next ) printf( "%c" , n->value );
    printf( "\n" );
    while( head ) remove_front( &head );
    return 0;
}
```

charList.h

```
#ifndef charList_included
#define charList_included
typedef struct _Node
{
    struct _Node *next;
    char value;
} Node;
...
#endif // charList_included
```

```
>> ./a.out
```

head

main.c

```
#include <stdio.h>
#include <stdlib.h>
#include <ctype.h>
#include "charList.h"
int main( void )
{
	Node *head = NULL , *n;
	char c;
	while( fscanf( stdin , " %c" , &c )==1 )
	{
		if( !head ) head  = create_node( c );
		else if( c<head->value ) add_front( &head , c );
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		}
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charList.h

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} Node;
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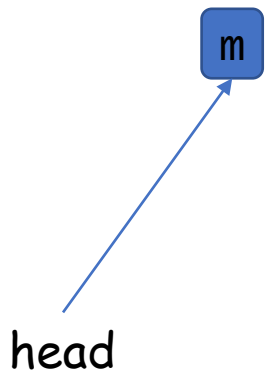
```

```
>> ./a.out
m
```



main.c

```
#include <stdio.h>
#include <stdlib.h>
#include <ctype.h>
#include "charList.h"
int main( void )
{
    Node *head = NULL , *n;
    char c;
    while( fscanf( stdin , " %c" , &c )==1 )
    {
        if( !head ) head  = create_node( c );
        else if( c<head->value ) add_front( &head , c );
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        {
            for( n=head ; n->next!=NULL && c>=n->next->value ; n=n->next ) ;
            add_after( n , c );
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charList.h

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#define charList_included
typedef struct _Node
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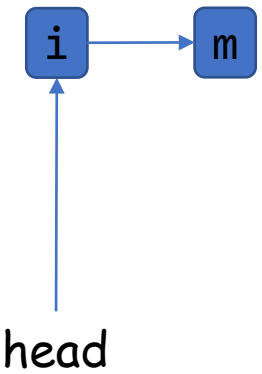
} Node;
...
#endif // charList_included
```

```
>> ./a.out
mi
```



main.c

```
#include <stdio.h>
#include <stdlib.h>
#include <ctype.h>
#include "charList.h"
int main( void )
{
    Node *head = NULL , *n;
    char c;
    while( fscanf( stdin , " %c" , &c )==1 )
    {
        if( !head ) head  = create_node( c );
        else if( c<head->value ) add_front( &head , c );
        else
        {
            for( n=head ; n->next!=NULL && c>=n->next->value ; n=n->next ) ;
            add_after( n , c );
        }
    }
    for( n=head ; n!=NULL ; n=n->next ) printf( "%c" , n->value );
    printf( "\n" );
    while( head ) remove_front( &head );
    return 0;
}
```

charList.h

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#ifndef charList_included
#define charList_included
typedef struct _Node
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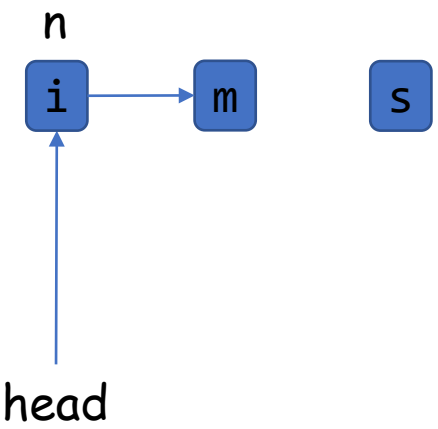
    struct _Node *next;
    char value;
} Node;
...
#endif // charList_included
```

```
>> ./a.out
mis
```



main.c

```
#include <stdio.h>
#include <stdlib.h>
#include <ctype.h>
#include "charList.h"
int main( void )
{
    Node *head = NULL , *n;
    char c;
    while( fscanf( stdin , " %c" , &c )==1 )
    {
        if( !head ) head  = create_node( c );
        else if( c<head->value ) add_front( &head , c );
        else
        {
            for( n=head ; n->next!=NULL && c>=n->next->value ; n=n->next ) ;
            add_after( n , c );
        }
    }
    for( n=head ; n!=NULL ; n=n->next ) printf( "%c" , n->value );
    printf( "\n" );
    while( head ) remove_front( &head );
    return 0;
}
```

charList.h

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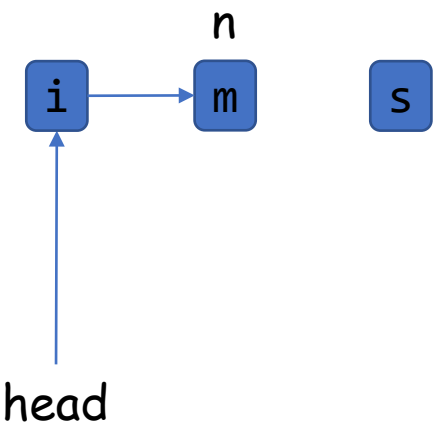
#define charList_included
typedef struct _Node
{
    struct _Node *next;
    char value;
} Node;
...
#endif // charList_included
```

```
>> ./a.out
mis
```



main.c

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#include <stdlib.h>
#include <ctype.h>
#include "charList.h"
int main( void )
{
	Node *head = NULL , *n;
	char c;
	while( fscanf( stdin , " %c" , &c )==1 )
	{
		if( !head ) head  = create_node( c );
		else if( c<head->value ) add_front( &head , c );
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		{
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			add_after( n , c );
		}
	}
	for( n=head ; n!=NULL ; n=n->next ) printf( "%c" , n->value );
	printf( "\n" );
	while( head ) remove_front( &head );
	return 0;
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```

charList.h

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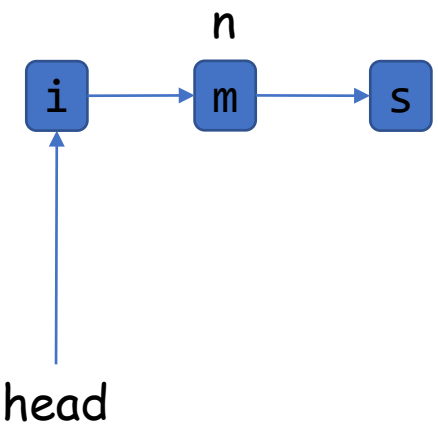
#define charList_included
typedef struct _Node
{
	struct _Node *next;
	char value;
} Node;
...
#endif // charList_included
```

```
>> ./a.out
mis
```



main.c

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#include <stdlib.h>
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int main( void )
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	Node *head = NULL , *n;
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} Node;
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```

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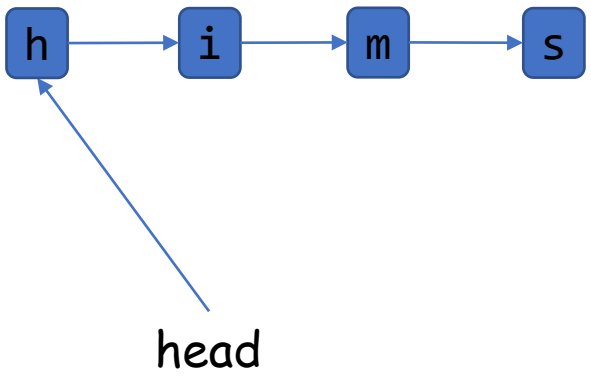
>> ./a.out
mish
```



main.c

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int main( void )
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	Node *head = NULL , *n;
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} Node;
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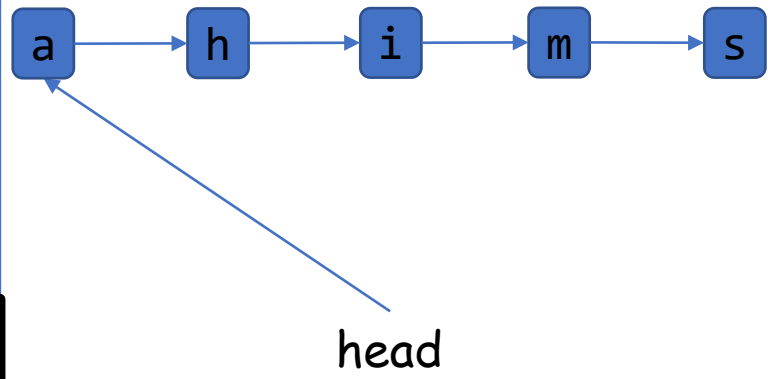
```

```
>> ./a.out
misha
```



main.c

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#include <ctype.h>
#include "charList.h"
int main( void )
{
	Node *head = NULL , *n;
	char c;
	while( fscanf( stdin , " %c" , &c )==1 )
	{
		if( !head ) head  = create_node( c );
		else if( c<head->value ) add_front( &head , c );
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```

charList.h

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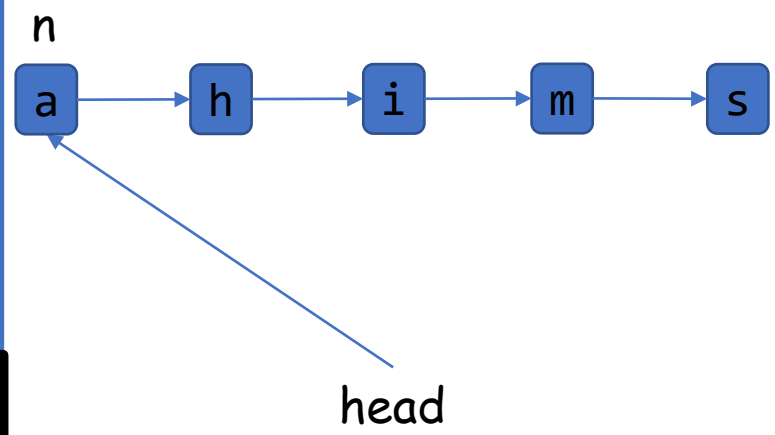
	char value;
} Node;
...
#endif // charList_included
```

```
>> ./a.out
misha
a
```



main.c

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#include <stdio.h>
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#include <ctype.h>
#include "charList.h"
int main( void )
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	Node *head = NULL , *n;
	char c;
	while( fscanf( stdin , " %c" , &c )==1 )
	{
		if( !head ) head  = create_node( c );
		else if( c<head->value ) add_front( &head , c );
		else
		{
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```

charList.h

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} Node;
...
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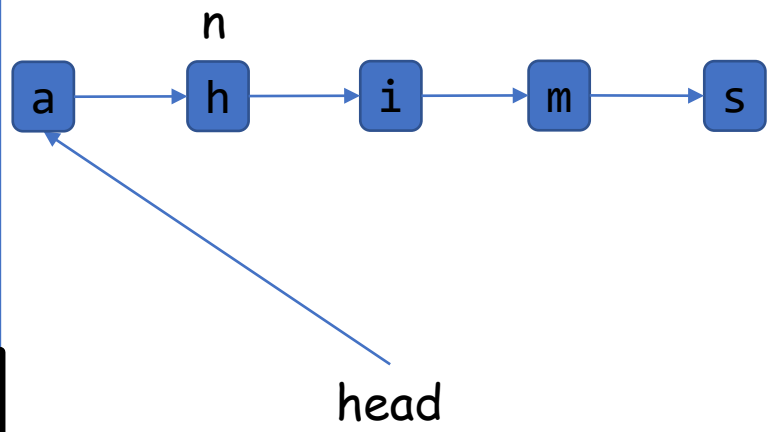
```

```
>> ./a.out
misha
ah
```



main.c

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#include <stdlib.h>
#include <ctype.h>
#include "charList.h"
int main( void )
{
	Node *head = NULL , *n;
	char c;
	while( fscanf( stdin , " %c" , &c )==1 )
	{
		if( !head ) head  = create_node( c );
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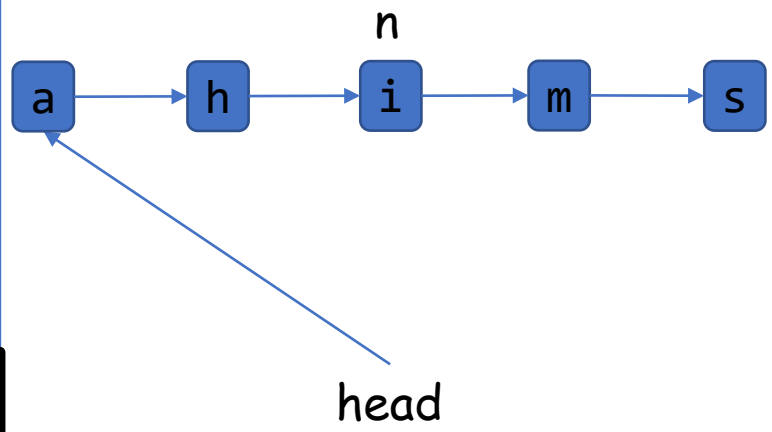
```

```
>> ./a.out
misha
ahi
```



main.c

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		}
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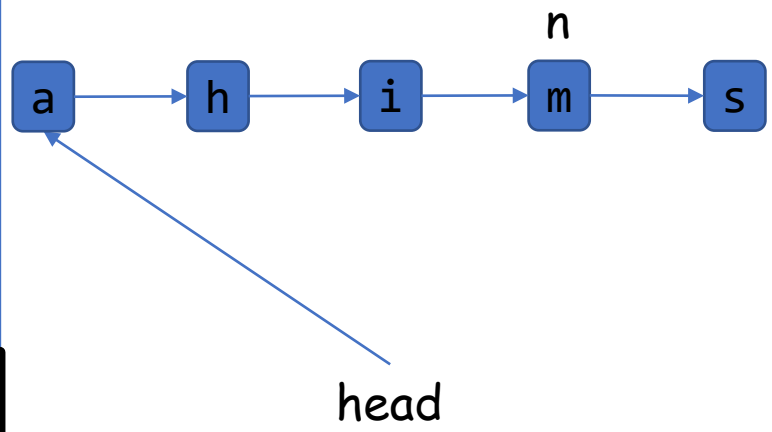
```

```
>> ./a.out
misha
ahim
```



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			add_after( n , c );
		}
	}
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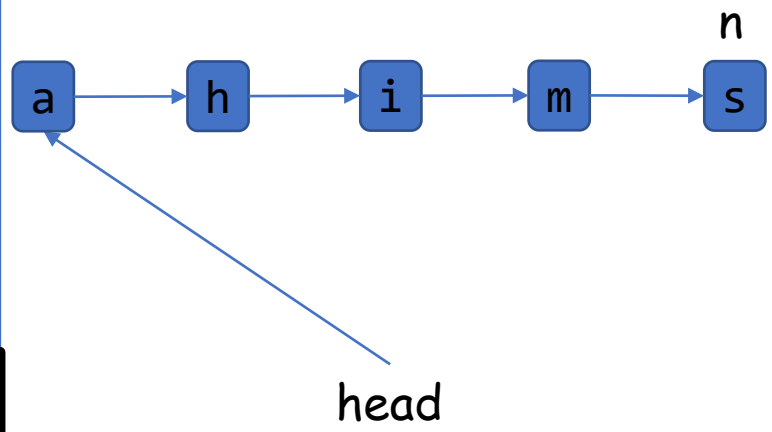
```
>> ./a.out
misha
ahims
```



main.c

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#include <ctype.h>
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	Node *head = NULL , *n;
	char c;
	while( fscanf( stdin , " %c" , &c )==1 )
	{
		if( !head ) head  = create_node( c );
		else if( c<head->value ) add_front( &head , c );
		else
		{
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			add_after( n , c );
		}
	}
	for( n=head ; n!=NULL ; n=n->next ) printf( "%c" , n->value );
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```
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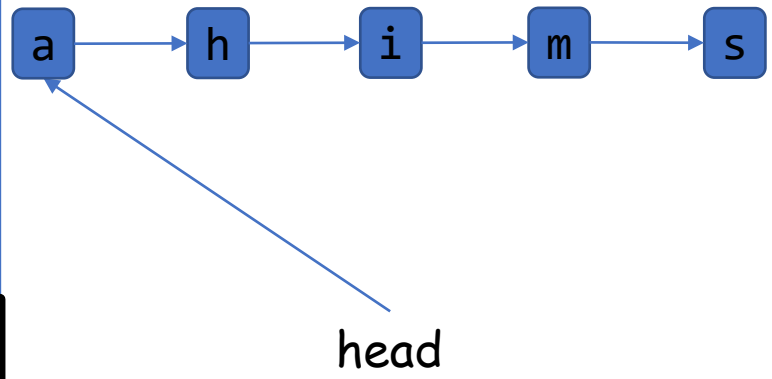
misha
ahims
```



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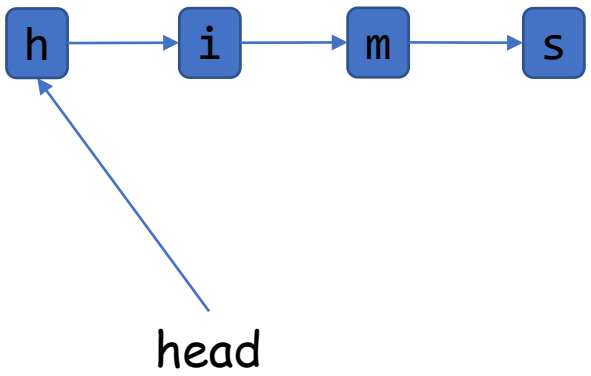
	Node *head = NULL , *n;
	char c;
	while( fscanf( stdin , " %c" , &c )==1 )
	{
		if( !head ) head  = create_node( c );
		else if( c<head->value ) add_front( &head , c );
		else
		{
			for( n=head ; n->next!=NULL && c>=n->next->value ; n=n->next ) ;
			add_after( n , c );
		}
	}
	for( n=head ; n!=NULL ; n=n->next ) printf( "%c" , n->value );
	printf( "\n" );
	while( head ) remove_front( &head );
	return 0;
}
```

charList.h

```
#ifndef charList_included
#define charList_included
typedef struct _Node
{
	struct _Node *next;
	char value;
} Node;
...
#endif // charList_included
```

```
>> ./a.out
misha
ahims
```



main.c

```
#include <stdio.h>
#include <stdlib.h>
#include <ctype.h>
#include "charList.h"
int main( void )
{
	Node *head = NULL , *n;
	char c;
	while( fscanf( stdin , " %c" , &c )==1 )
	{
		if( !head ) head  = create_node( c );
		else if( c<head->value ) add_front( &head , c );
		else
		{
			for( n=head ; n->next!=NULL && c>=n->next->value ; n=n->next ) ;
			add_after( n , c );
		}
	}
	for( n=head ; n!=NULL ; n=n->next ) printf( "%c" , n->value );
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	while( head ) remove_front( &head );
	return 0;
}
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charList.h

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misha
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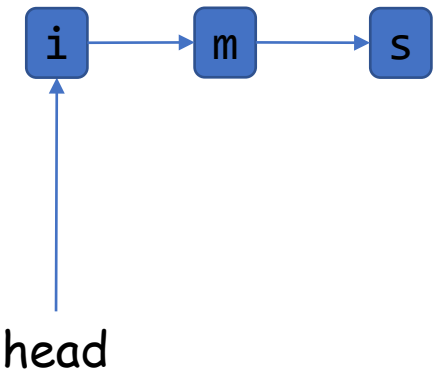
```



main.c

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	Node *head = NULL , *n;
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		}
	}
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	while( head ) remove_front( &head );
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}
```

charList.h

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	char value;
} Node;
...
#endif // charList_included
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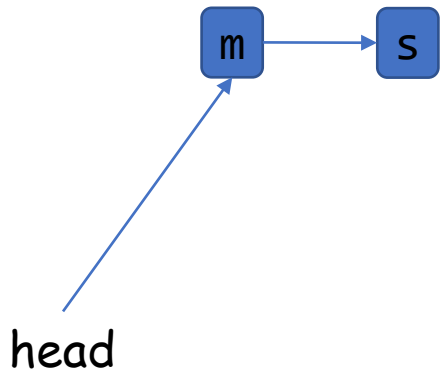
```
>> ./a.out
misha
ahims
```



main.c

```
#include <stdio.h>
#include <stdlib.h>
#include <ctype.h>
#include "charList.h"
int main( void )
{
	Node *head = NULL , *n;
	char c;
	while( fscanf( stdin , " %c" , &c )==1 )
	{
		if( !head ) head  = create_node( c );
		else if( c<head->value ) add_front( &head , c );
		else
		{
			for( n=head ; n->next!=NULL && c>=n->next->value ; n=n->next ) ;
			add_after( n , c );
		}
	}
	for( n=head ; n!=NULL ; n=n->next ) printf( "%c" , n->value );
	printf( "\n" );
	while( head ) remove_front( &head );
	return 0;
}
```

charList.h

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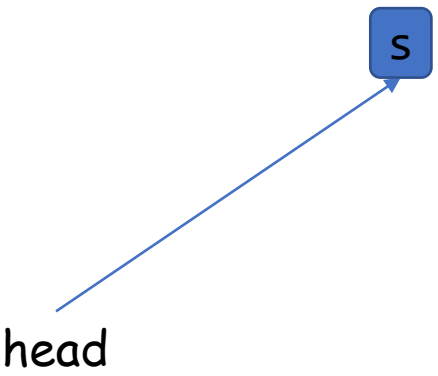
#ifndef charList_included
#define charList_included
typedef struct _Node
{
	struct _Node *next;
	char value;
} Node;
...
#endif // charList_included
```

```
>> ./a.out
misha
ahims
```



main.c

```
#include <stdio.h>
#include <stdlib.h>
#include <ctype.h>
#include "charList.h"
int main( void )
{
    Node *head = NULL , *n;
    char c;
    while( fscanf( stdin , " %c" , &c )==1 )
    {
        if( !head ) head  = create_node( c );
        else if( c<head->value ) add_front( &head , c );
        else
        {
            for( n=head ; n->next!=NULL && c>=n->next->value ; n=n->next ) ;
            add_after( n , c );
        }
    }
    for( n=head ; n!=NULL ; n=n->next ) printf( "%c" , n->value );
    printf( "\n" );
    while( head ) remove_front( &head );
    return 0;
}
```

charList.h

```
#ifndef charList_included
#define charList_included
typedef struct _Node
{
    struct _Node *next;
    char value;
} Node;
...
#endif // charList_included
```

```
>> ./a.out
misha
ahims
>>
```

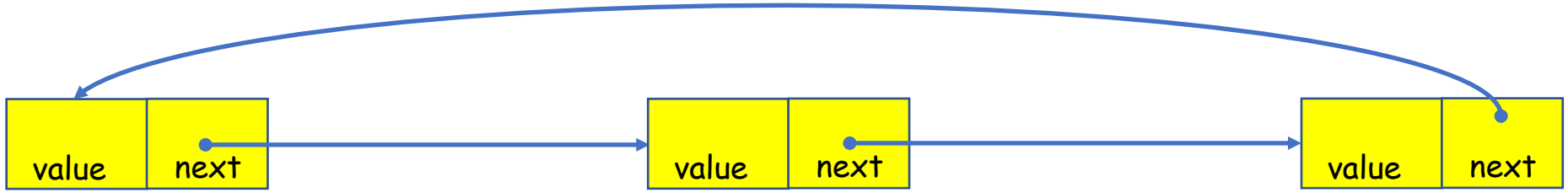
head

Linked lists

- Variants
  - Circular lists
    - ✓ No need for a "head" node
    - ✗ Iterating is trickier

charList.h

```
#ifndef charList_included
#define charList_included
typedef struct _Node
{
    struct _Node *next;
    char value;
} Node;
...
#endif // charList_included
```

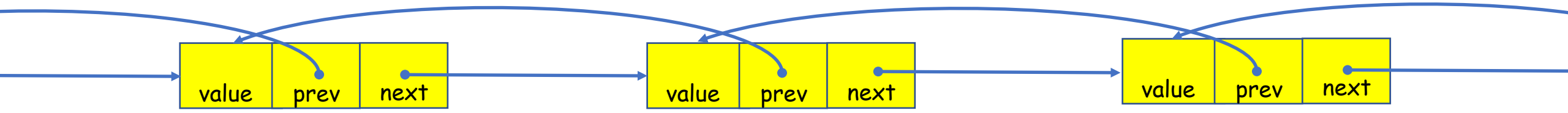


Linked lists

- Variants
  - Doubly linked lists
    - ✓ Can traverse in either direction
    - ✗ More pointers to track for insertions and deletions
    - ✗ The linked list can be inconsistent

charList.h

```
#ifndef charList_included
#define charList_included
typedef struct _Node
{
    struct _Node *next;
    struct _Node *prev;
    char value;
} Node;
...
#endif // charList_included
```



Outline

- Exercise 17
- Linked lists
- Review questions

Review questions

1.How do you implement add_front of a linked list?

```
int add_front( Node **head , char c )
{
    Node *n = create_node( c );
    if( !n ) return 1;
    n->next = *head;
    *head = n;
    return 0;
}
```

Review questions

2. How do you modify a linked list to a doubly linked list?

```
typedef struct _Node
{
    struct _Node *next;
    struct _Node *prev;
    char value;
} Node;
```

Review questions

3. How do you make a copy of a linked list?

We need a “deep copy”. We traverse the list and create new node from the old one. We need to pay attention to how to setup the next pointer for the new list. It should point to the newly created node.

Review questions

4. Why does `add_after` take a `Node*` as input, but `add_front` takes a `Node**`?

Because we need to change who the head is.

Review questions

5. What cases should be handled when implementing `remove_front`?

Check if the list is empty (the head is NULL).

Exercise 18

- Website -> Course Materials -> Exercise 18