Intermediate Programming

Day 16

Outline

- Exercise 15
- Linked lists
- Review questions

Exercise 15

Determine the endianness of the hardware, using the fact that:

950238851 = 0x38A37E83

Definition:

A big-endian system stores the most significant byte of a word at the smallest memory address

⇒ Little endian

```
>> gcc endian.c ... -g
>> gdb ./a.out
...
(gdb) b main
...
(gdb) r
...
(gdb) n
...
(gdb) n
...
21          printf("%u\n", *p);
(gdb) print/x ((unsigned char *)p)[0]
$1 = 0x83
(gdb) print/x ((unsigned char *)p)[1]
$2 = 0x7e
(gdb) print/x ((unsigned char *)p)[2]
$3 = 0xa3
(gdb) print/x ((unsigned char *)p)[3]
$4 = 0x38

>>
```

Exercise 15

Implement **magnitude** without using signed integers.

interp.c

```
…
unsigned int magnitude( unsigned int value )
{
        if( value & (1<<31) ) return ~value+1;  // Two's complement
        else return value;
}
…
```

Exercise 15

Implement **set_seed**.

random.c

```
...
void set_seed( int seed )
{
        srand( seed );
}
...
```

Exercise 15

Implement **gen_uniform**.

random.c

```
...
void set_seed( int seed )
{
        srand( seed );
}

int gen_uniform( int max_num )
{
        return rand() % max_num;
}
...
```

Exercise 15

Generate 500 uniformly distributed random numbers and increment the associated elements of the **hist** array.

random.c

```
…
int main( void )
{
        …
        for( unsigned int i=0 ; i<500 ; i++ ) hist[ gen_uniform(max_range) ]++;
        …
}
…
```

Exercise 15

Implement **normal_rand**.

random.c

```
...
void set_seed( int seed )
{
	srand( seed );
}

int gen_uniform( int max_num )
{
	return rand() % max_num;
}

int normal_rand( int max_num )
{
	const unsigned int N = 20;
	int sum = 0;
	for( unsigned int n=0 ; n<N ; n++ ) sum += gen_uniform( max_num );
	return sum / N;
}
```

Exercise 15

Generate 500 normally distributed random numbers and increment the associated elements of the **hist** array.

random.c

```
…
int main( void )
{
        …
        for( unsigned int i=0 ; i<500 ; i++ ) hist[ normal_rand(max_range) ]++;
        …
}
…
```

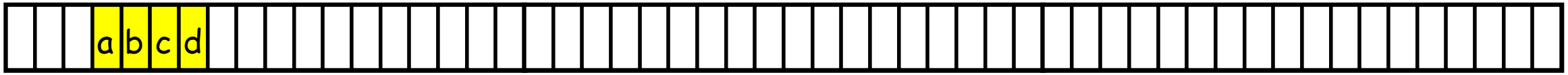
Outline

- Exercise 15
- Linked lists
- Review questions

Linked lists

- Arrays:
  - ✓Contiguous memory
    ⇒ Fast (constant time) look-up
  - ✗ Do not support dynamic insertion/deletion

```
…
char ar[] = { 'a' , 'b' , 'c' , 'd' };
…
```

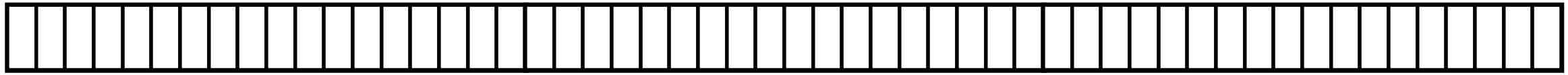


address space

Linked lists

- Arrays:
  - ✓ Contiguous memory
    ⇒ Fast (constant time) look-up
  - ✗ Do not support dynamic insertion/deletion
- Linked lists:
  - ✓ Support dynamic insertion/deletion
  - ✗ Discontiguous memory
    ⇒ Slow (linear time) look-up
  - ✗ Explicit pointer storage

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



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  - ✗Discontiguous memory
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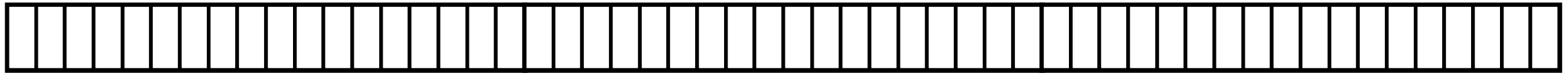
  - ✗Explicit pointer storage

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

Note that the **struct** cannot be unnamed since we need to access it within the **struct**, before the **typedef** is complete.



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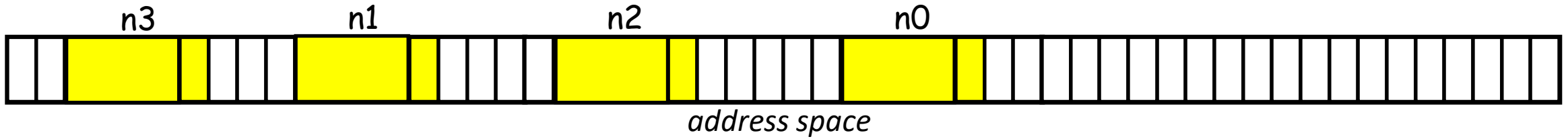
```
…
typedef struct _Node
{
      struct _Node *next;
      char value;
} Node;

Node *n0 = malloc( sizeof( Node ) );
Node *n1 = malloc( sizeof( Node ) );
Node *n2 = malloc( sizeof( Node ) );
Node *n3 = malloc( sizeof( Node ) );

…
```



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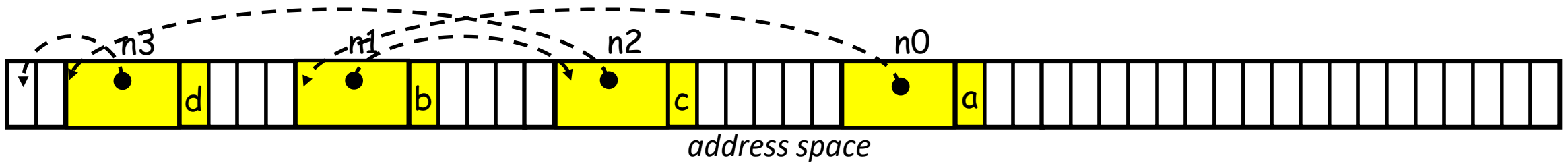
  - ✗ Explicit pointer storage

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

Node *n0 = malloc( sizeof( Node ) );
Node *n1 = malloc( sizeof( Node ) );
Node *n2 = malloc( sizeof( Node ) );
Node *n3 = malloc( sizeof( Node ) );

n0->value = 'a' ; n0->next = n1;
n1->value = 'b' ; n1->next = n2;
n2->value = 'c' ; n2->next = n3;
n3->value = 'd' ; n3->next = NULL;
…
```



Linked lists

- Basic operations:
  - Create a node
  - Add a node
  - …
- Terminology:
  - The first element of a linked list is the "head"

charList.h

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

…
```

Linked lists

- Create a node
  - Allocate the linked-list element
  - Set its members

charList.h

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

Node *create_node( char c );
…
```

charList.c

```
#include "charList.h"
#include <stdlib.h>

Node *create_node( char c )
{
    Node *n = malloc( sizeof( Node ) );
    if( !n ) return NULL;
    n->next = NULL ; n->value = c;
    return n;
}
```

Linked lists

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    return n;
}
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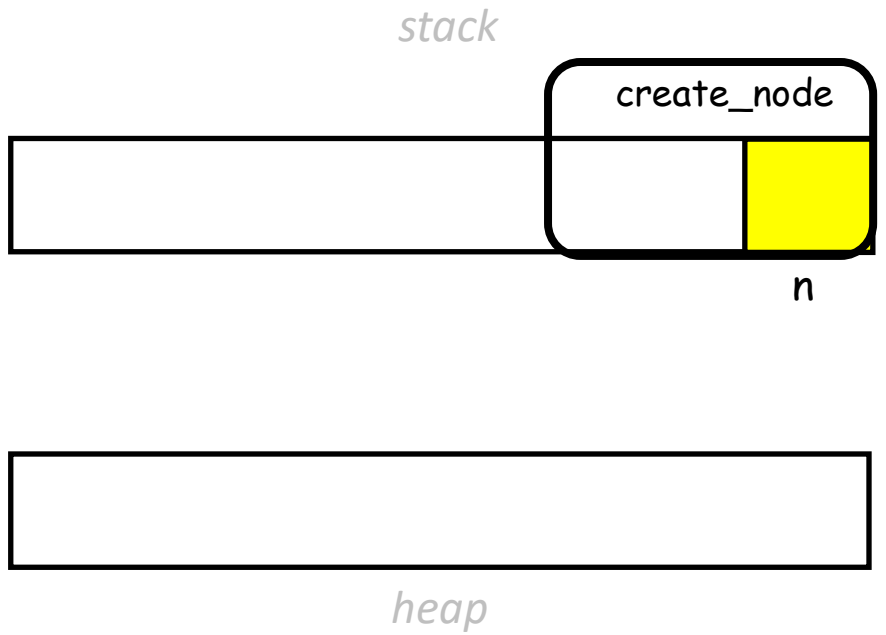

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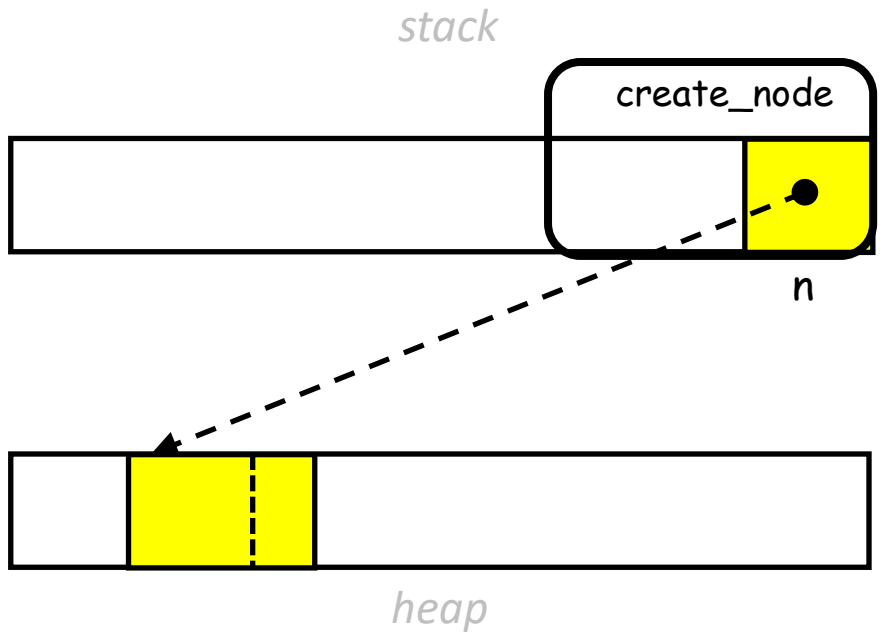
}
```



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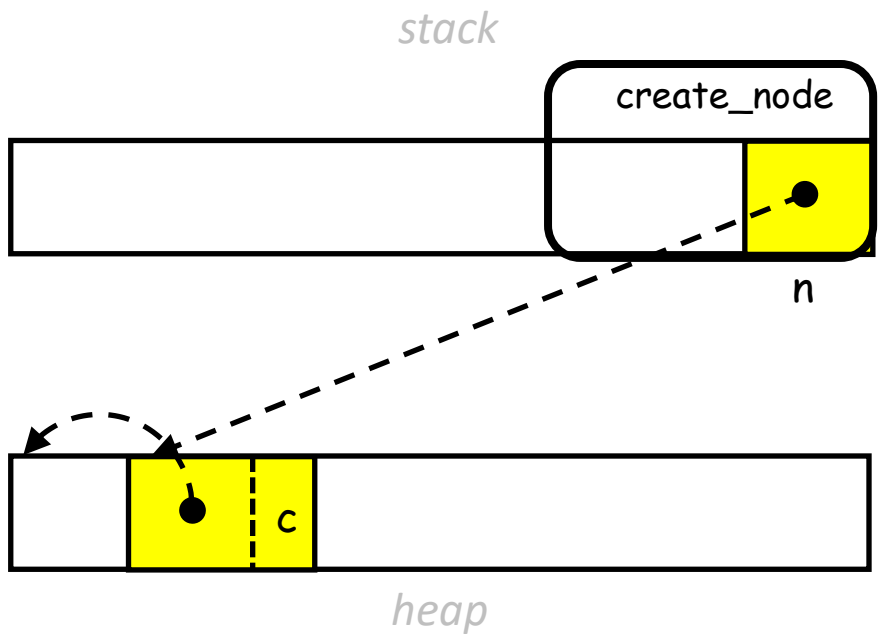

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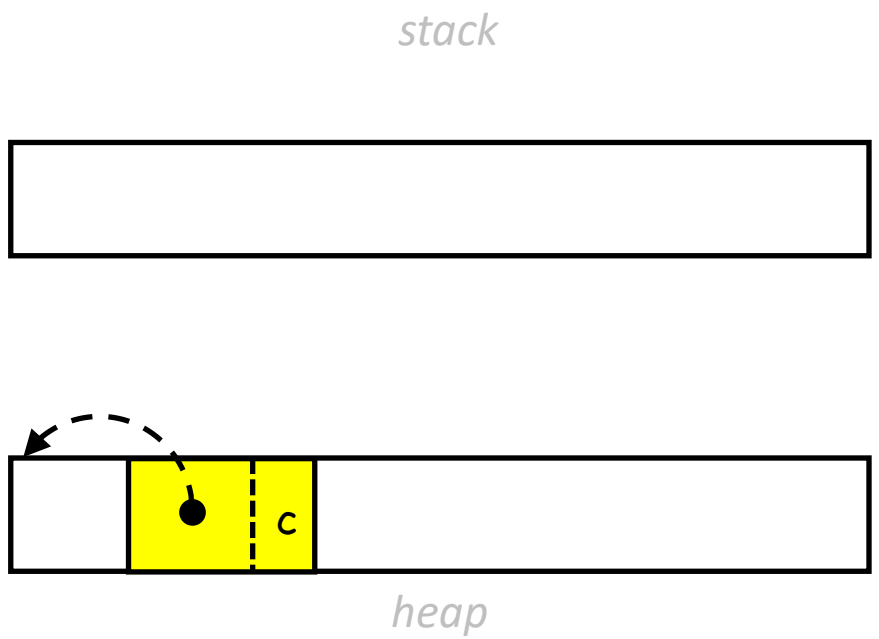

Linked lists

- Add a node
  - Create the node
  - Update the pointers

charList.h

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

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

charList.c

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

Linked lists

- Add a node
  - **Create the node**
  - Update the pointers

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    struct _Node *next;
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} Node;

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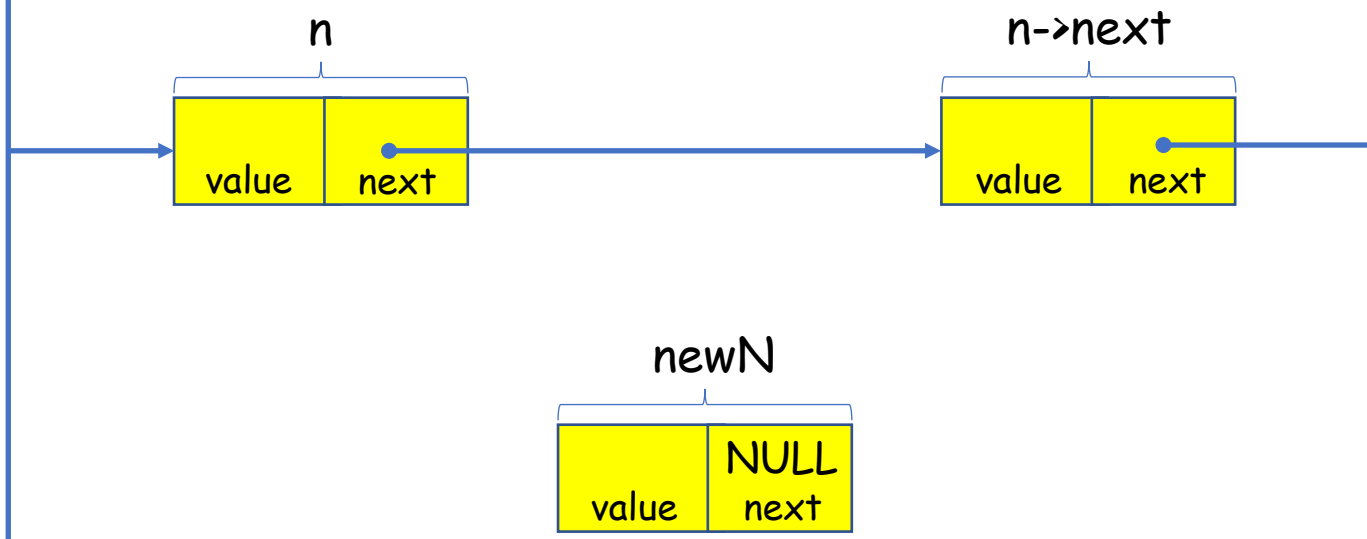

Linked lists

- Add a node
  - Create the node
  - **Update the pointers**

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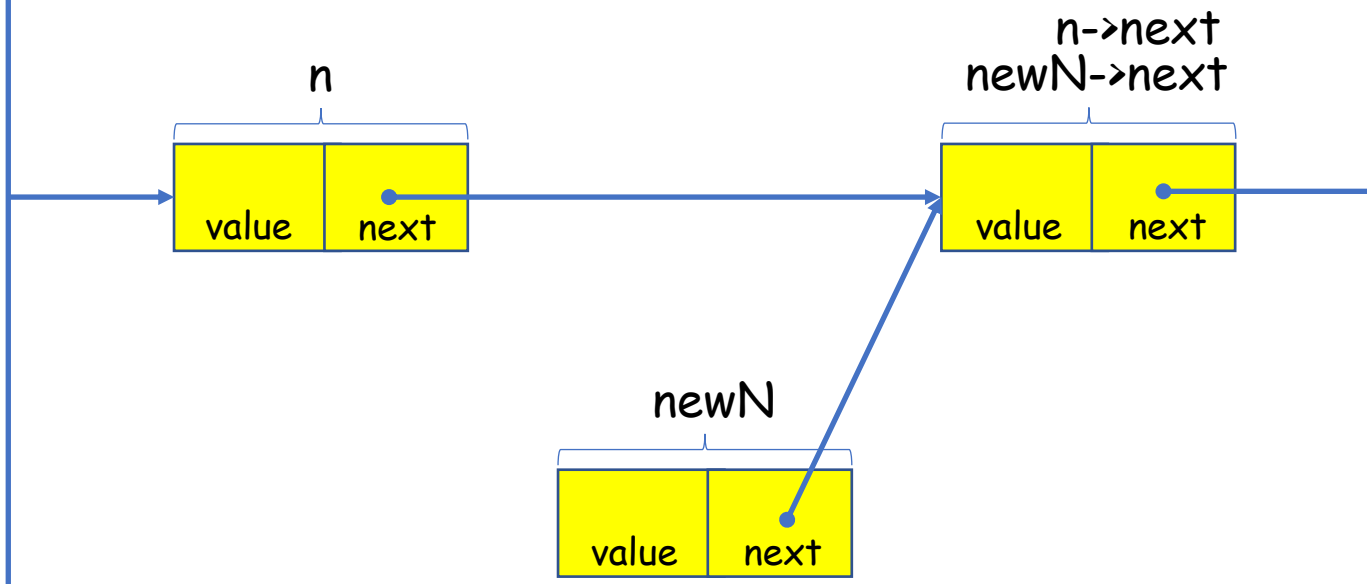

Linked lists

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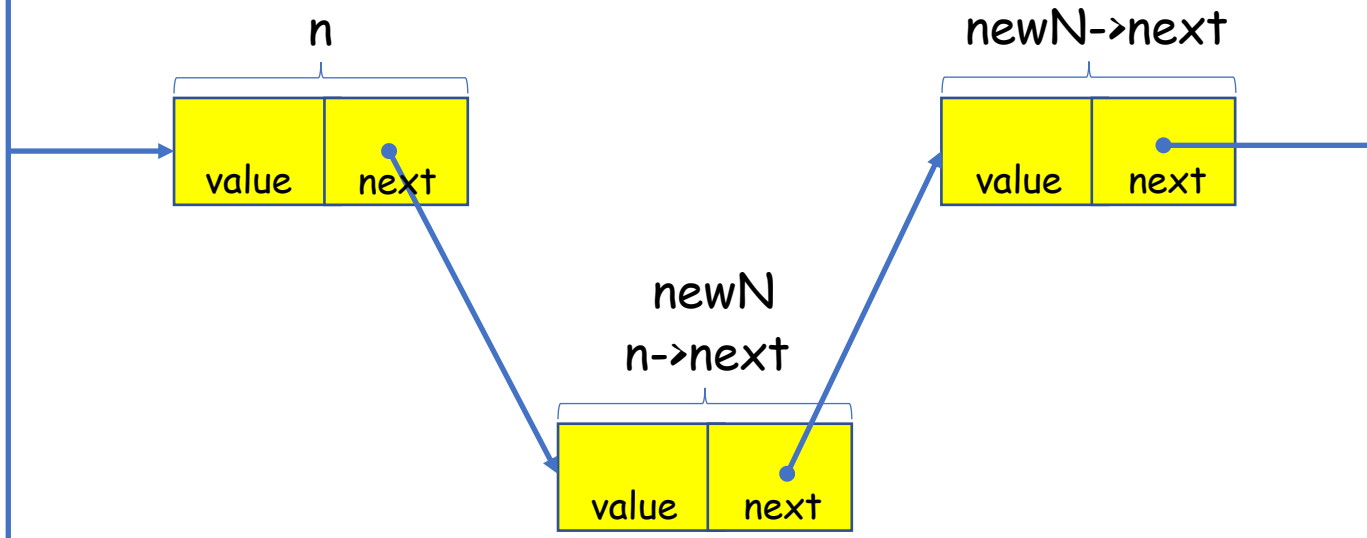

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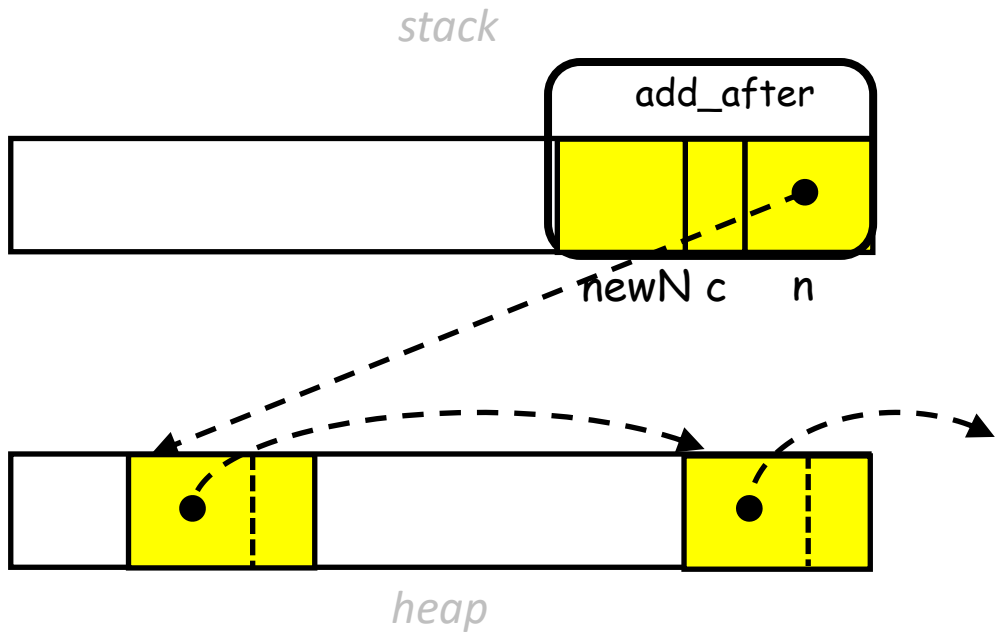

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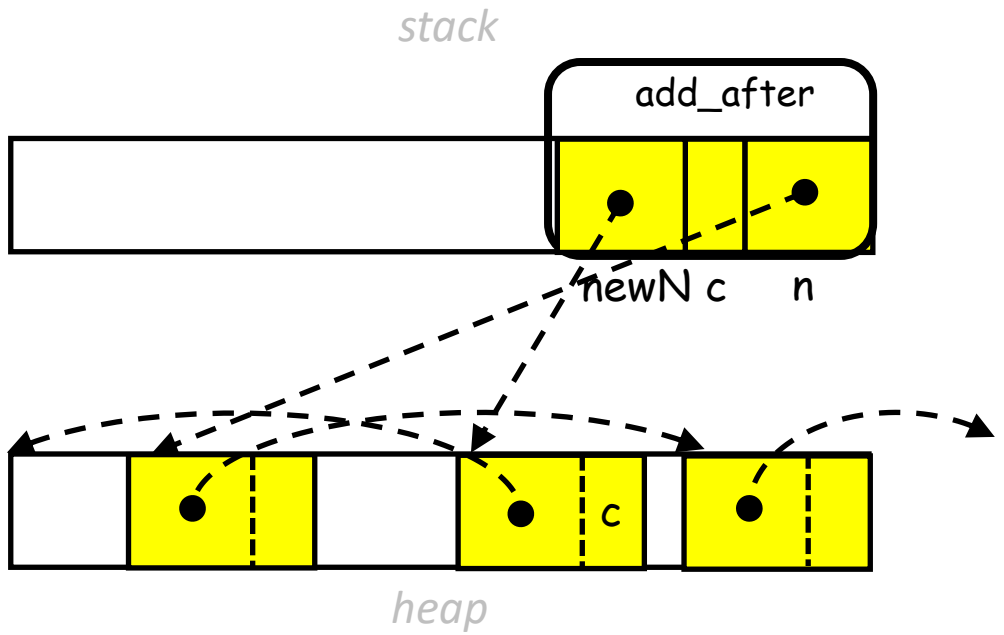

Linked lists

- Add a node
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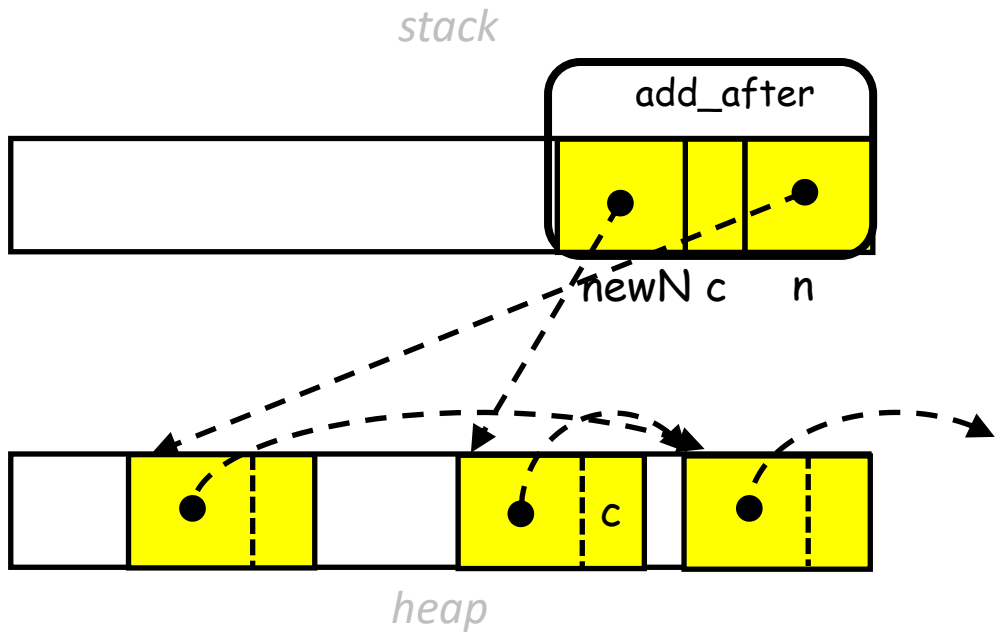

Linked lists

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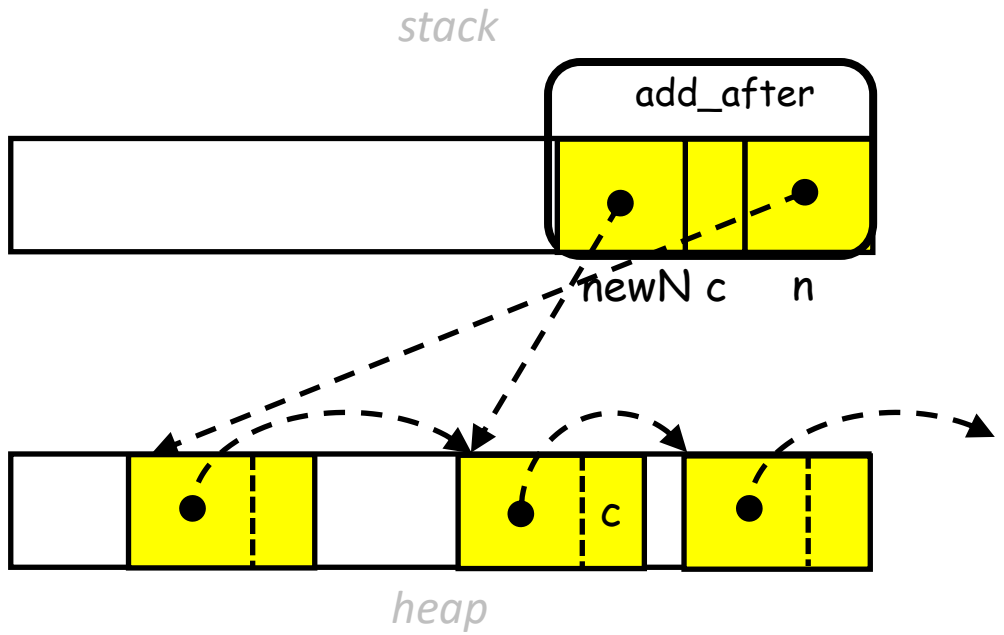
    newN->next = n->next;
    n->next = newN;
    return 0;
}
```



Linked lists

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    Node *newN = create_node( c );
    if( !newN ) return 1;
    newN->next = n->next;
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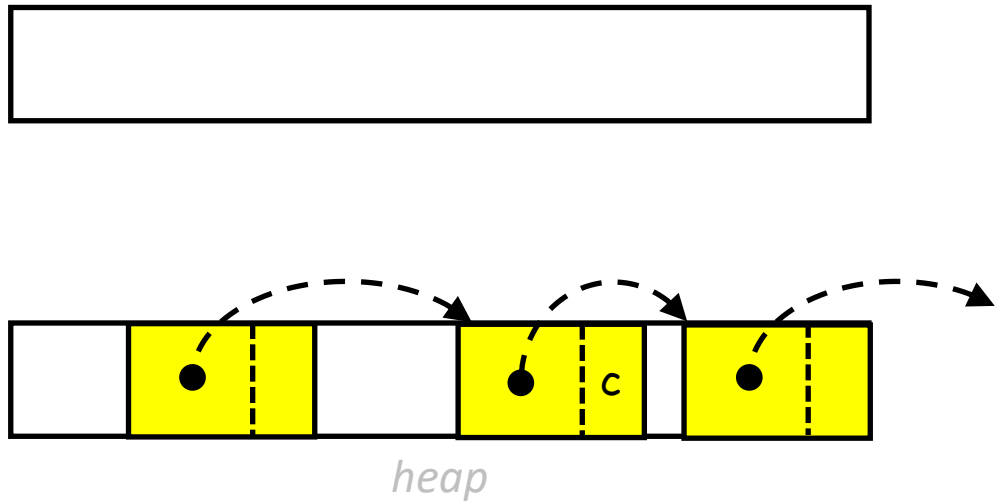
    return 0;
}
```

stack



Linked lists

- Getting the length
  - Increment a counter
  - Advance to the next node (if it isn't NULL)

charList.h

```
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 );
```

charList.c

```
#include "charList.h"
#include <stdlib.h>
...
int length( const Node *head )
{
    int len=0;
    while( head ){ len++ ; head = head->next; }
    return len;
}
```

Linked lists

- Printing
  - Print out the value in the current node
  - Advance to the next node
    (if it isn't NULL)

charList.h

```
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 );
```

charListIO.h

```
#include "charList.h"
void print( const Node *head );
```

charListIO.c

```
#include "charList.h"
#include <stdio.h>

void print( const Node *head )
{
    for( const Node *n=head ; n!=NULL ; n=n->next )
        printf( " %c" , n->value );
    printf( "\n" );
}
```

main.c

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

charList.h

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typedef struct _Node
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    char value;
} Node;

Node *create_node( char c );
int add_after( Node *n , char c );
int length( const Node *head );
```

charListIO.h

```
#include "charList.h"
void print( const Node *head );
```

```
>> gcc -std=c99 -Wall -Wextra -g main.c charList.c charListIO.c
In file included from charListIO.h:1:0,
                 from main.c:5:
charList.h:3:16: error: redefinition of struct _Node
 typedef struct _Node
                ^~~~~

...
>>
```

main.c

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

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Node *create_node( char c );
int add_after( Node *n , char c );
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```

charListIO.h

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void print( const Node* head );
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```

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	while( fscanf( stdin , " %c" , &c )==1 )
	{
		if( !head ) head  = create_node( c );
		else
		{
			n = head;
			while( n->next ) n = n->next;
			add_after( n , c );
		}
	}
	print( head );
	return 0;
}
```

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 );
#endif // charList_included
```

charListIO.h

```
#ifndef charListIO_included
#define charListIO_included
#include "charList.h"
void print( const Node *head );
#endif // charListIO_included
```

main.c

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

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 );
#endif // charList_included
```

charListIO.h

```
#ifndef charListIO_included
#define charListIO_included
*head );
included
```

```
>> gcc -std=c99 -Wall -Wextra -g main.c charList.c charListIO.c
>> ./a.out
b c d ae
```

main.c

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

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 );
#endif // charList_included
```

charListIO.h

```
#ifndef charListIO_included
#define charListIO_included
*head );
included
```

```
>> gcc -std=c99 -Wall -Wextra -g main.c charList.c charListIO.c
>> ./a.out
b c d ae
 b c d a e
>>
```

main.c

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

Problems with the code:

- We allocate but don't deallocate
- The characters are stored in the order they were read, not in alphabetical order

charList.h

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

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

charListIO.h

```
#ifndef charListIO_included
#define charListIO_included
                                    *head );
                                    included
```

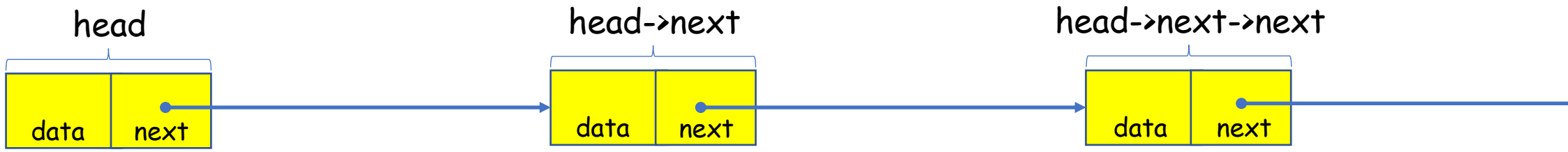
```
>> gcc -std=c99 -Wall -Wextra -g main.c charList.c charListIO.c
>> ./a.out
b c d ae
 b c d a e
>>
```

Outline

- Exercise 15
- Linked lists
- Review questions

Review questions

1. Describe the linked list structure by a diagram.



Review questions

2. Compare arrays and linked lists. Write down their pros and cons.

- Arrays:
  - ✓ Contiguous memory
    ⇒ Fast (constant time) look-up
  - ✗ Do not support dynamic insertion/deletion
- Linked lists:
  - ✓ Support dynamic insertion/deletion
  - ✗ Discontiguous memory
    ⇒ Slow (linear time) look-up
  - ✗ Explicit pointer storage

Review questions

3. What is a linked list's head?
   How is it different from a node? Explain.

The head is a pointer to the first node in the list.
It could be NULL (if the list is empty) and does not have anything point to it (so the rest of the list is accessible through it).

Review questions

4. How do you calculate length of a linked list?

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

Review questions

5. How do you implement `add_after` of a linked list?

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

Exercise 16

- Website -> Course Materials -> Exercise 16