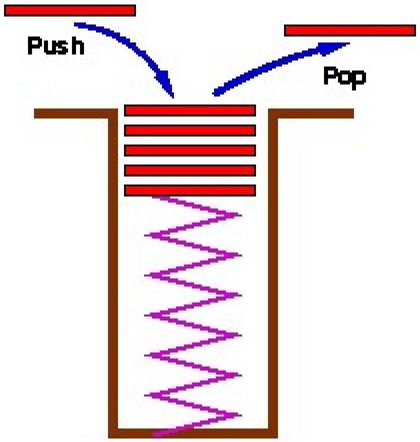
Stacks, Lists

Stacks

- Stacks are a special form of collection with LIFO semantics
- Two methods
  - `int push( Stack s, void *item );`
    - add item to the top of the stack
  - `void *pop( Stack s );`
    - remove an item from the top of the stack
- Like a plate stacker
  - Other methods

```
int IsEmpty( Stack s );
/* Return TRUE if empty */
void *Top( Stack s );
/* Return the item at the top,
    without deleting it */
```



Stacks - Relevance

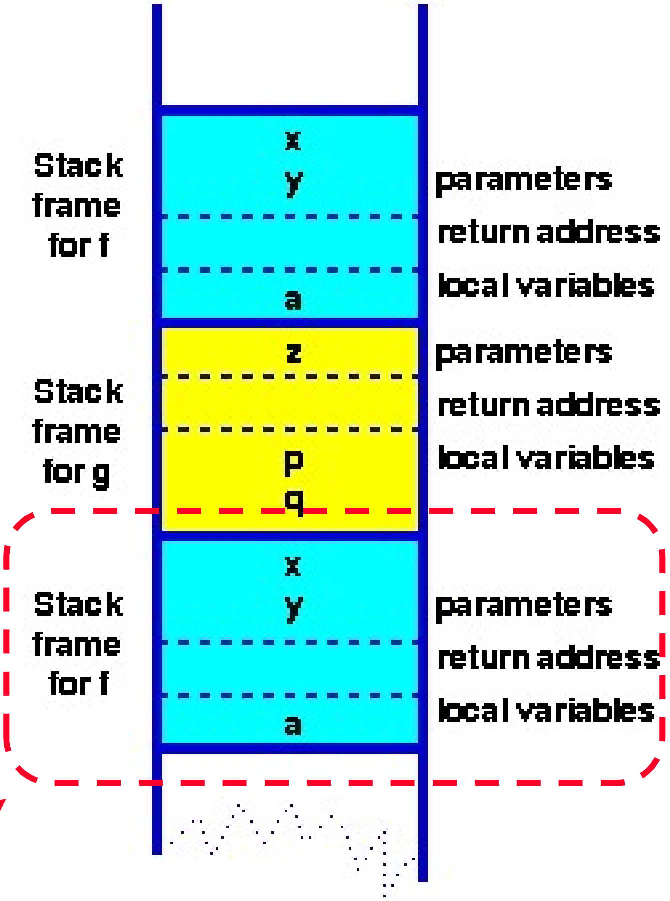
- Stacks appear in computer programs
  - Key to call / return in functions & procedures
  - Stack frame allows recursive calls
  - Call: push stack frame
  - Return: pop stack frame
- Stack frame
  - Function arguments
  - Return address
  - Local variables

Stack Frames - Functions in HLL

- **Program**

```
function f( int x, int y) {
   int a;
   if ( term_cond ) return …;
   a = ….;
   return g( a );
   }

function g( int z ) {
   int p, q;
   p = …. ; q = …. ;
   return f(p,q);
   }
```



Context for execution of `f`

Recursion

- **Very useful technique**
  - **Definition of mathematical functions**
  - **Definition of data structures**
    - **Recursive structures are naturally processed by recursive functions!**

Recursion

- ***Very useful technique***
    - **Definition of mathematical functions**
    - **Definition of data structures**
        - **Recursive structures are naturally processed by recursive functions!**
- **Recursively defined functions**
    - **Factorial**
    - **Fibonacci**
    - **Games**
        - **Towers of Hanoi**
        - **Chess**

Recursion - Example

- Fibonacci Numbers

Pseudo-code

```
fib( n ) = if ( n = 0 ) then 1
           else if ( n = 1 ) then 1
           else fib(n-1) + fib(n-2)
```

C

```
int fib( n ) {
     if ( n < 2 ) return 1;
     else return fib(n-1) + fib(n-2);
     }
```

Simple, elegant solution!

Recursion - *Example*

- Fibonacci Numbers

C

```
int fib( n ) {
     if (             urn 1;
                 urn fib(n-1) + fib(n-2);
     }
```

But, in the Fibonacci case, a run-time disaster!!!!

However, many recursive functions,
eg **binary search, are simple, elegant** ***and efficient!***

Array Limitations

- **Arrays**
  - **Simple,**
  - **Fast**

  but

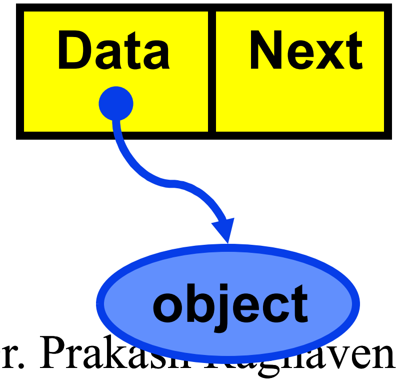
  - **Must specify size at construction time**
  - **Murphy's law**
    - **Construct an array with space for n**
      - **n = twice your estimate of largest collection**
    - **Tomorrow you'll need $n+1$**
  - **More flexible system?**

Linked Lists

- **Flexible space use**
  - **Dynamically allocate space for each element as needed**
  - **Include a pointer to the next item**

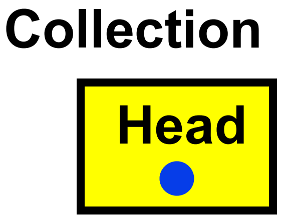
 Linked list

  - **Each node of the list contains**
    - **the data item** **(an object pointer in our ADT)**
    - **a pointer to the next node**



Linked Lists

- Collection structure has a pointer to the list head
  - Initially NULL

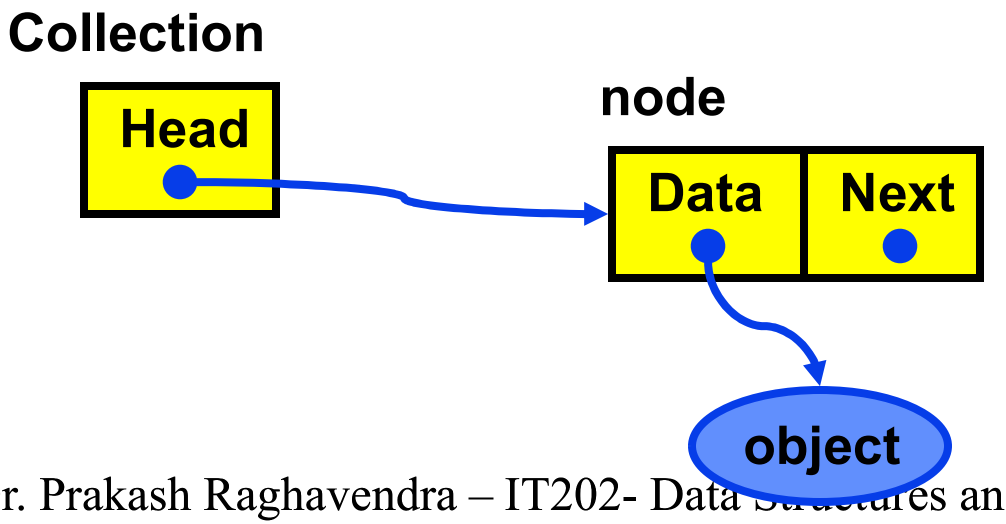


Collection

Head

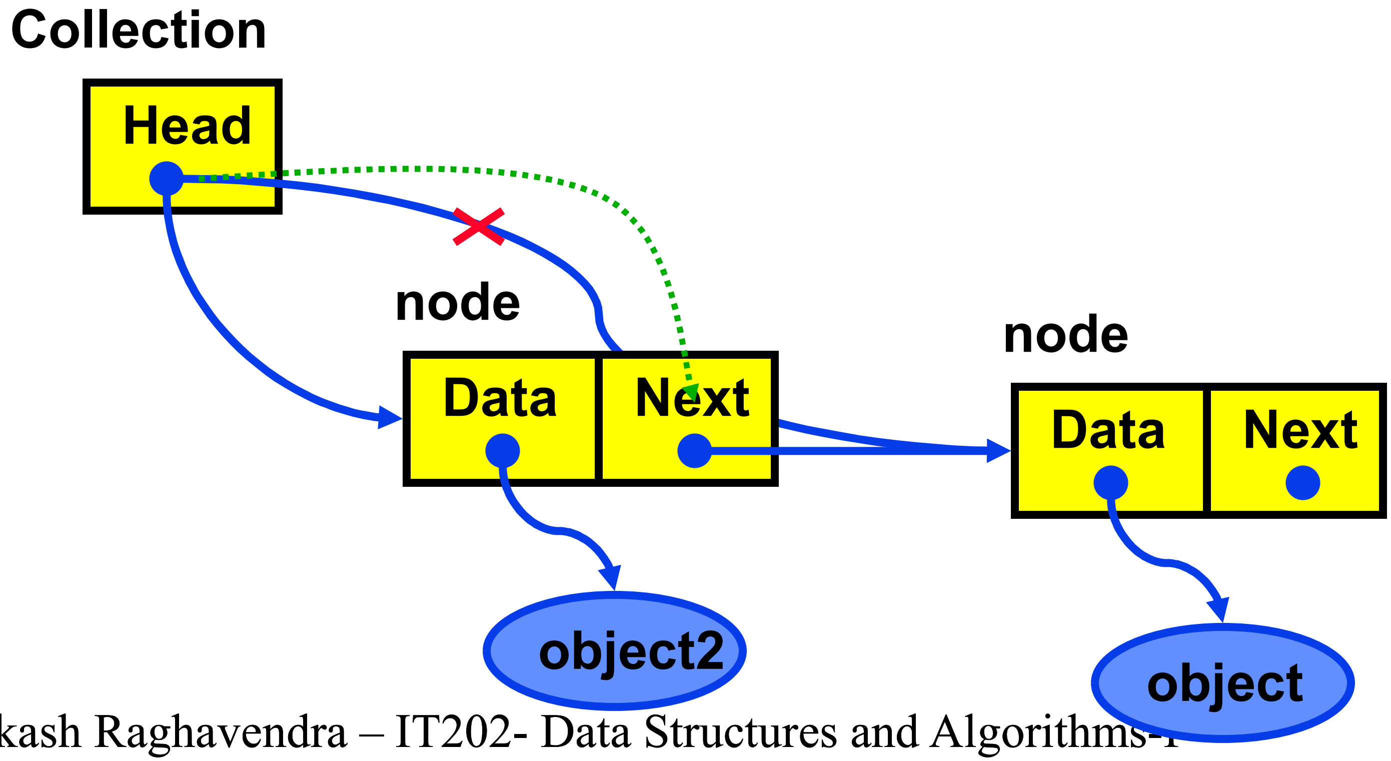
Linked Lists

- Collection structure has a pointer to the list head
  - Initially NULL
- Add first item
  - Allocate space for node
  - Set its data pointer to object
  - Set Next to NULL
  - Set Head to point to new node



Linked Lists

- **Add second item**
  - **Allocate space for node**
  - **Set its data pointer to object**
  - **Set Next to current Head**
  - **Set Head to point to new node**



Linked Lists - `Add` *implementation*

- **Implementation**

```
struct t_node {
    void *item;
    struct t_node *next;
    } node;
typedef struct t_node *Node;
struct collection {
    Node head;
    ……
    };
int AddToCollection( Collection c, void *item ) {
    Node new = malloc( sizeof( struct t_node ) );
    new->item = item;
    new->next = c->head;
    c->head = new;
    return TRUE;
    }
```

Linked Lists - `Add` *implementation*

- Implementation

```
struct t_node {
    void *item;
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    return TRUE;
    }
```
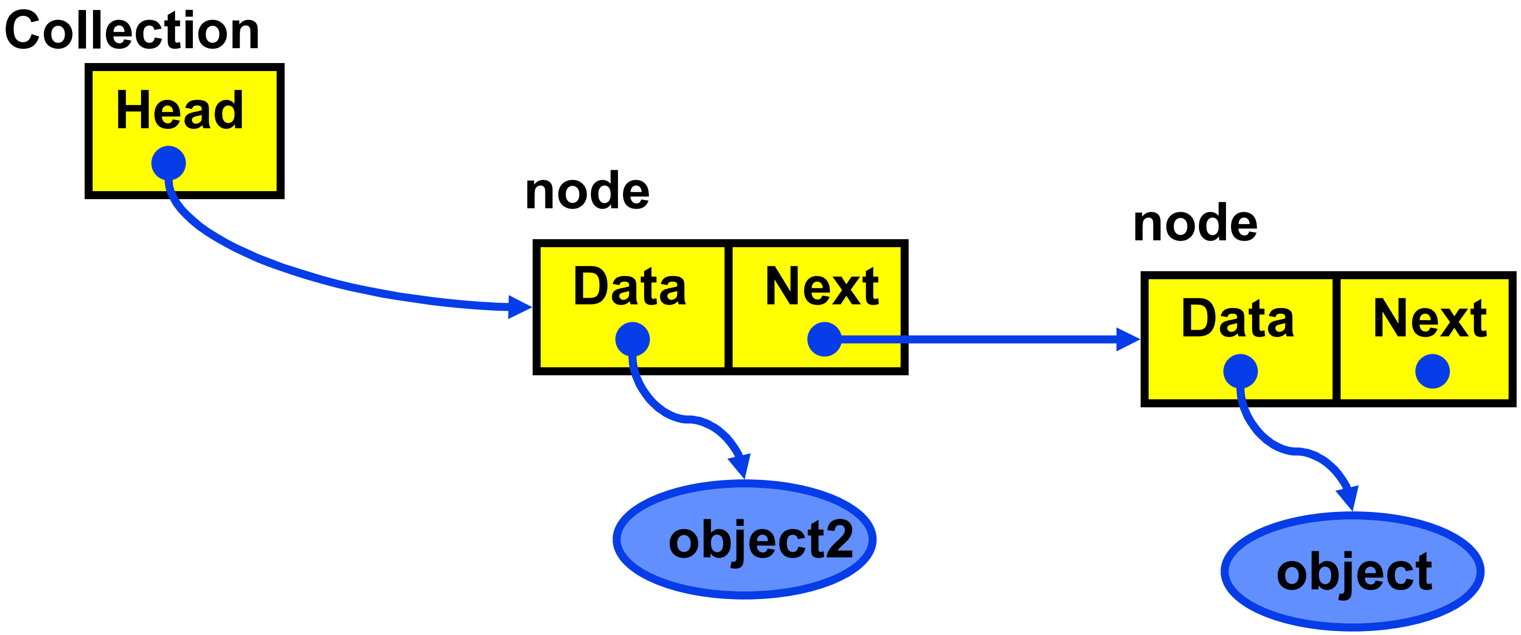

Recursive type definition - C allows it!

Error checking, asserts omitted for clarity!

Linked Lists

- Add time
    - Constant - independent of n
- Search time
    - Worst case - n



Linked Lists - `Find` *implementation*

- **Implementation**

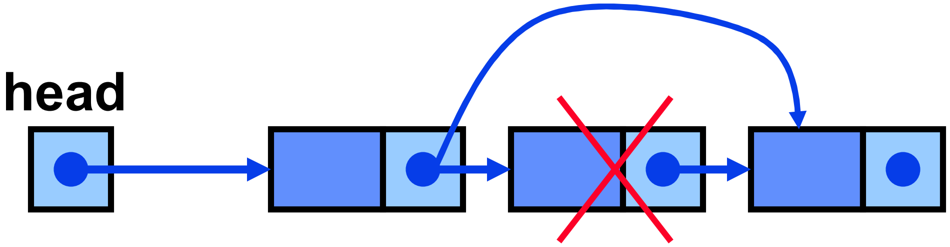
```
void *FindinCollection( Collection c, void *key ) {
    Node n = c->head;
    while ( n != NULL ) {
      if ( KeyCmp( ItemKey( n->item ), key ) == 0 ) {
            return n->item;
      n = n->next;
      }
    return NULL;
    }
```

- ***A recursive implementation is also possible!***

Linked Lists - Delete *implementation*

- **Implementation**

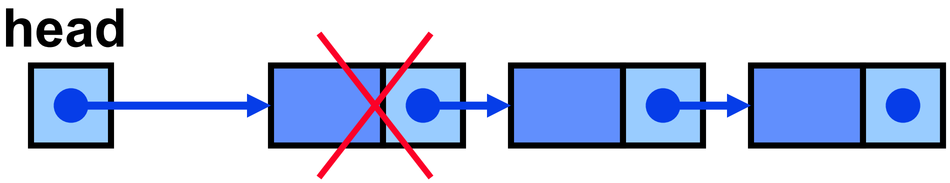
```
void *DeleteFromCollection( Collection c, void *key ) {
    Node n, prev;
    n = prev = c->head;
    while ( n != NULL ) {
      if ( KeyCmp( ItemKey( n->item ), key ) == 0 ) {
            prev->next = n->next;
            return n;
            }
      prev = n;
      n = n->next;
      }
    return NULL;
    }
```



Linked Lists - `Delete` *implementation*

- **Implementation**

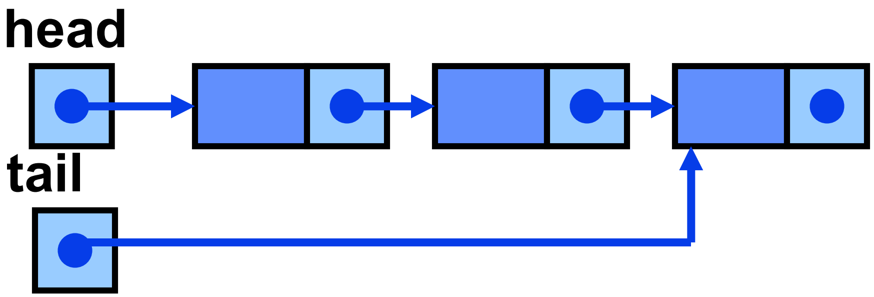
```
void *DeleteFromCollection( Collection c, void *key ) {
    Node n, prev;
    n = prev = c->head;
    while ( n != NULL ) {
      if ( KeyCmp( ItemKey( n->item ), key ) == 0 ) {
            prev->next = n->next;
            return n;
            }
      prev = n;
      n = n->next;
      }
    return NULL;
    }
```



Minor addition needed to allow for deleting this one! An exercise!

Linked Lists - LIFO and FIFO

- Simplest implementation
  - Add to head
  - Last-In-First-Out (LIFO) semantics
- Modifications
  - First-In-First-Out (FIFO)
  - Keep a tail pointer



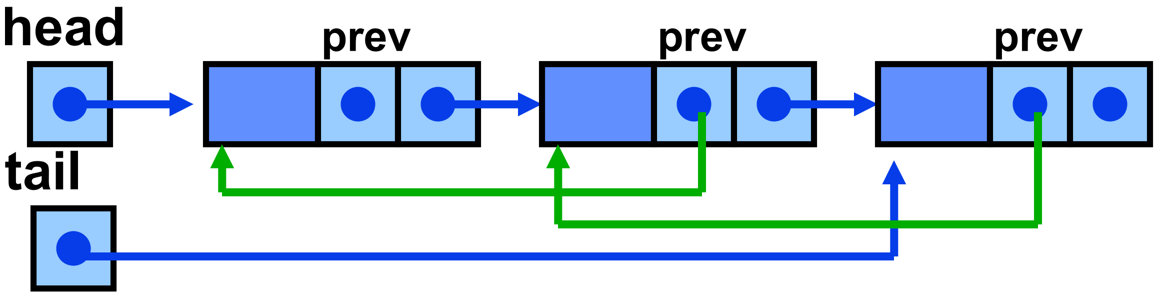
```
struct t_node {
     void *item;
     struct t_node *next;
     } node;
typedef struct t_node *Node;
struct collection {
     Node head, tail;
     };
```

`tail` is set in the `AddToCollection` method if `head == NULL`

Linked Lists - Doubly linked

- Doubly linked lists
  - Can be scanned in both directions

```
struct t_node {
    void *item;
    struct t_node *prev,
                  *next;
    } node;

typedef struct t_node *Node;
struct collection {
    Node head, tail;
    };
```


head
tail
prev
prev
prev