Data Structures and Algorithms (2)

Instructor: Ming Zhang

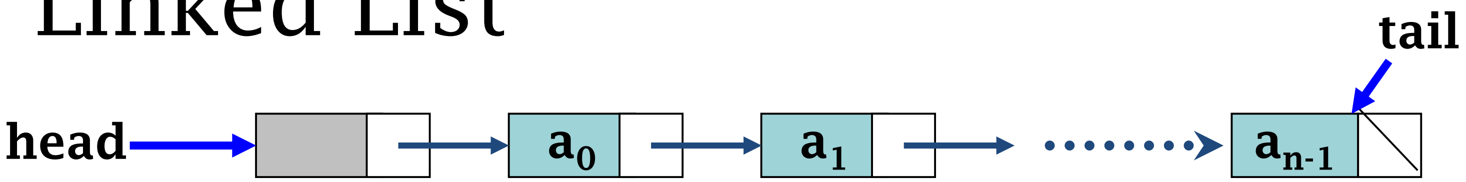
Textbook Authors: Ming Zhang, Tengjiao Wang and Haiyan Zhao

Higher Education Press, 2008.6 (the "Eleventh Five-Year" national planning textbook)

https://courses.edx.org/courses/PekingX/04830050x/2T2014/

Chapter II Linear List

- 2.1 Linear List
- 2.2 Sequential List
- 2.3 Linked List



- 2.4 Comparison between sequential list and linked list

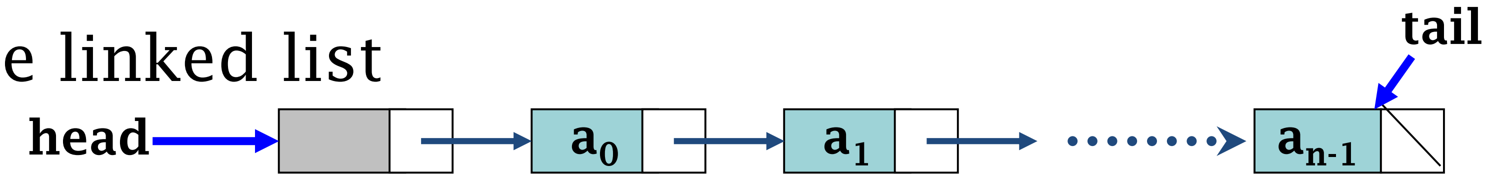
Linked List

- Link its storage nodes through pointers .
- Storage nodes are consisted of two parts
  - Data field + pointer field (successor address)

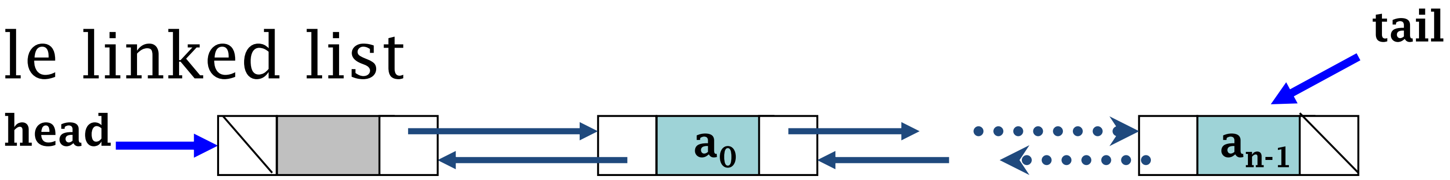
data	next

2.3 Linked List

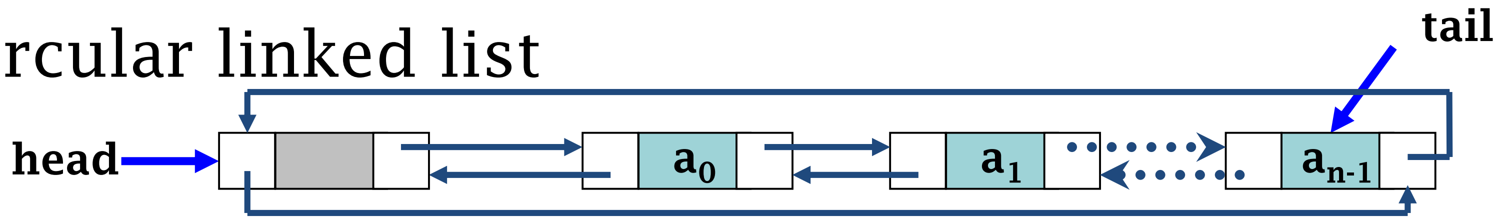
- **Classification (according to linked ways and the number of points)**
  - Single linked list



  - Double linked list



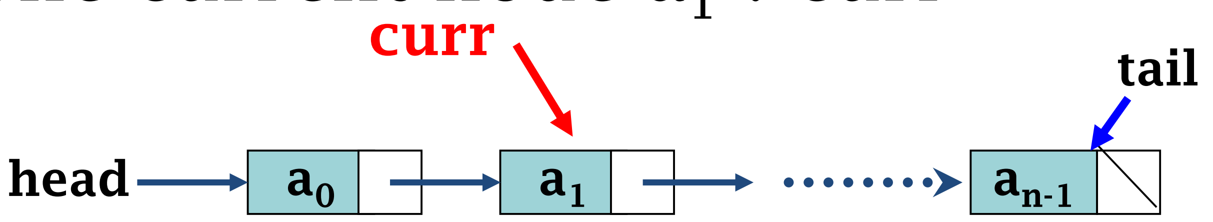
  - Circular linked list



Single linked list

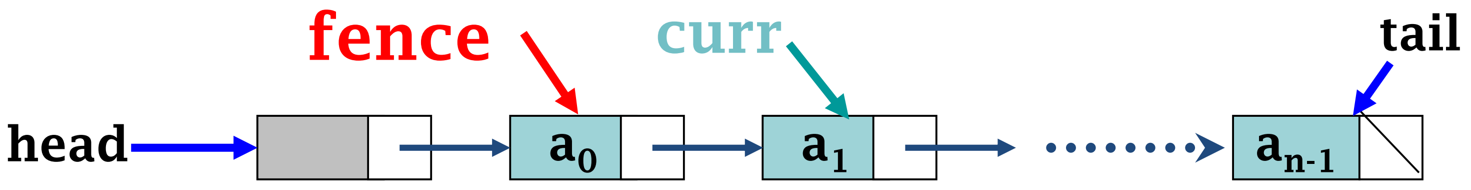
- Simple single linked list
  - The whole single linked list : head
  - The first node : head
  - The judge of empty list :

    head == NULL
  - The current node a_1 : curr



Single linked list

- Single linked list with head node
  - The whole single linked list ： head
  - The first node ： head->next , head ≠ NULL
  - The judge of empty list :
    - head->next == NULL
  - The current node a_1 : fence->next (curr implied)



Node type of the single linked list

```
template <class T> class Link {
    public:
    T   data;                // to protect content of the node elements
    Link<T> * next;          // the pointer which points to successor point

    Link(const T info, const Link<T>* nextValue =NULL)  {
        data = info;
        next = nextValue;
    }
    Link(const Link<T>* nextValue)  {
        next = nextValue;
    }
};
```

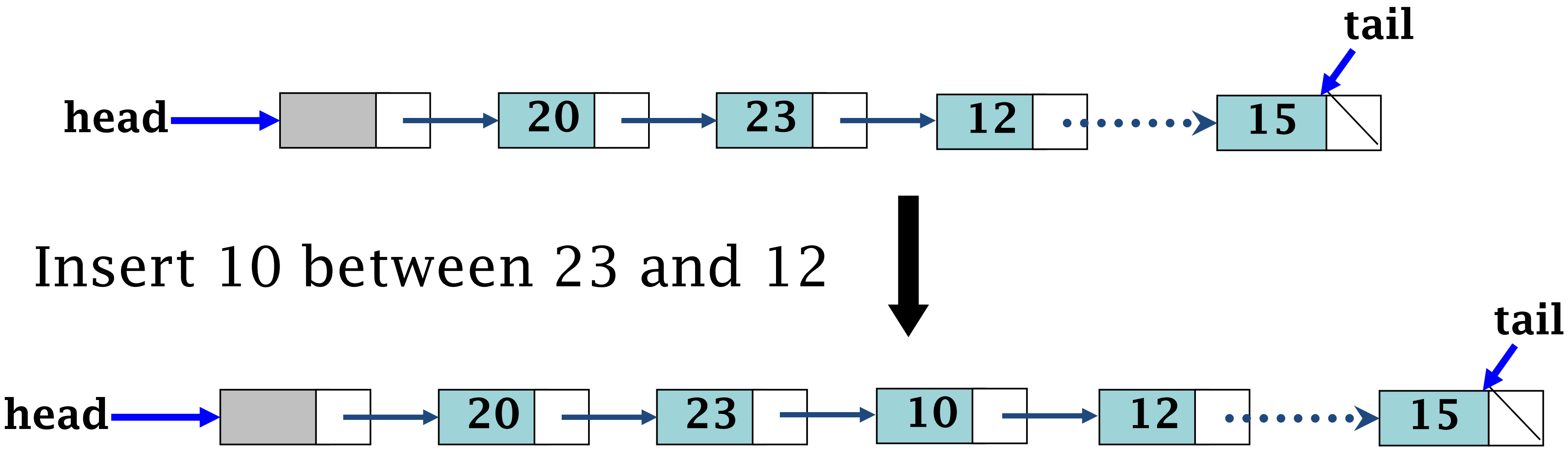
Class definition of single list

```
template <class T> class lnkList : public List<T>  {
    private:
    Link<T>  * head, *tail;                  // head and tail pointer of the single list
    Link<T>  *setPos(const int p);           // the pointer of the pth element
     public:
    lnkList(int s);                          // constructed function
    ~lnkList();                              // destructor
    bool isEmpty();                          // judge whether the link is empty
    void clear();             // clear the link's storage and it becomes an empty list
    int length();             // returns the current length of the sequential list
    bool append(cosnt T value);              // add an element value at the end ,
                                             // the length of the list added by 1
    bool insert(cosnt int p, cosnt T value); // insert an element at p
    bool delete(cosnt int p);                // delete the element at p ,
                                             // the length of the list decreased by 1
    bool getValue(cosnt int p, T& value);    // get the value of the element at p
    bool getPos(int &p, const T value);      // seek for element with value T
}
```

Seek the ith node in the single linked list

```
// the return value of the function is the found node pointer
template <class T>          // the element type of the linked list is P
Link<T> * lnkList <T>:: setPos(int i) {
    int count = 0;
     if (i == -1)                 // if i was -1, then locate it to the head
        return head;
    // circular location, if I was 0 then locate to the first node
    Link<T> *p = head->next;
    while (p != NULL && count < i) {
        p = p-> next;
        count++;
     };
     // points to the ith node , i=0,1,... , when the number of
     // the nodes of the list is less than i then return NULL
    return p;
}
```

Insert operation of single linked list



- Create a new node
- New node points to the right node
- The left node points to new node

Insert algorithm of single linked list

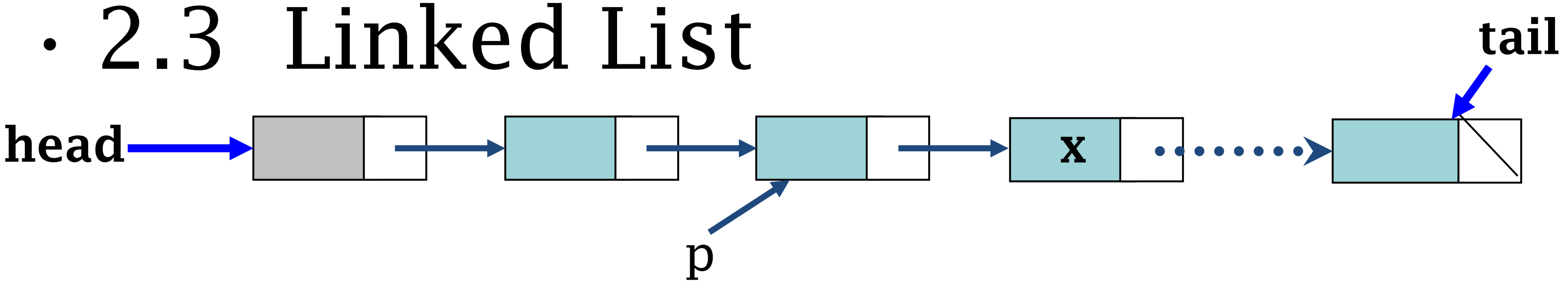
```
// insert a new node as the ith node
template <class T>
// element type of the linked list is T
bool lnkList<T> :: insert(const int i, const T value) {
    Link<T> *p, *q;
    if ((p = setPos(i -1)) == NULL) {    // p is the previous node of the ith node
        cout << " illegal insert position"<< endl;
        return false;
    }
    q = new Link<T>(value, p->next);
    p->next = q;
    if (p == tail)                       // insert position is at the tail and
                                         // the node inserted becomes the new tail
        tail = q;
    return true;
}
```

Delete operation of single linked list

- Delete the node x from linked list
  - 1. Assign p to point to the previous node of element x
  - 2. delete the node with element x
  - 3. release the space that x occupied

Example of delete operation of single linked list

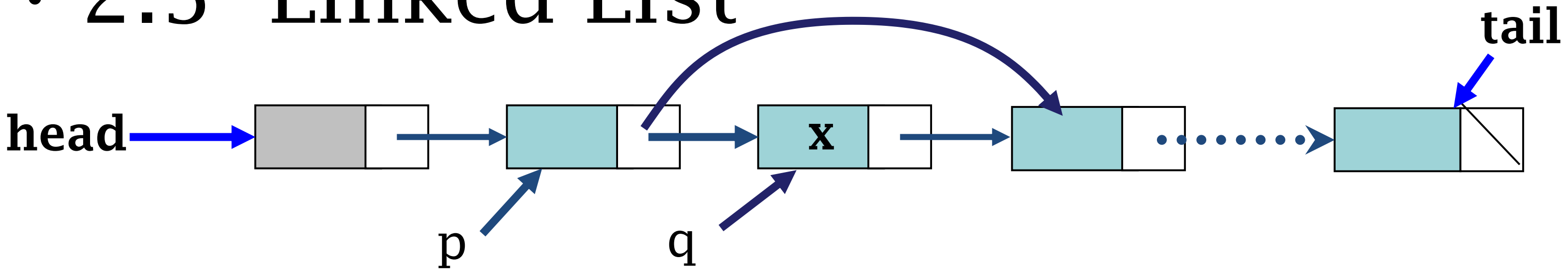
- 2.3 Linked List




```
p = head;
while (p->next!=NULL && p->next->info!= x)
        p = p->next;
```

Delete the node with value X

- 2.3 Linked List




```
q = p->next;
p->next = q->next;
free(q);
```

Delete algorithm of single linked list

```
template <class T>                    // Element type of the linked list is T
bool lnkList<T>:: delete((const int i) {
    Link<T> *p, *q;
    // node to delete doesn't exist, when the given i is bigger than
    // the number of the current elements in the list
    if ((p = setPos(i-1)) == NULL || p == tail) {
        cout << " illegal delete position " << endl;
        return false;
    }
    q = p->next;                      // q is the real node to delete
    if (q == tail) {                  // if the node to delte is the tail,
                                      // then change the tail pointer
        tail = p;       p->next = NULL:
    }
    else                              //delete node q and change linked pointer
        p->next = q->next;
    delete q;
    return true;
}
```

Operation analysis of single linked list

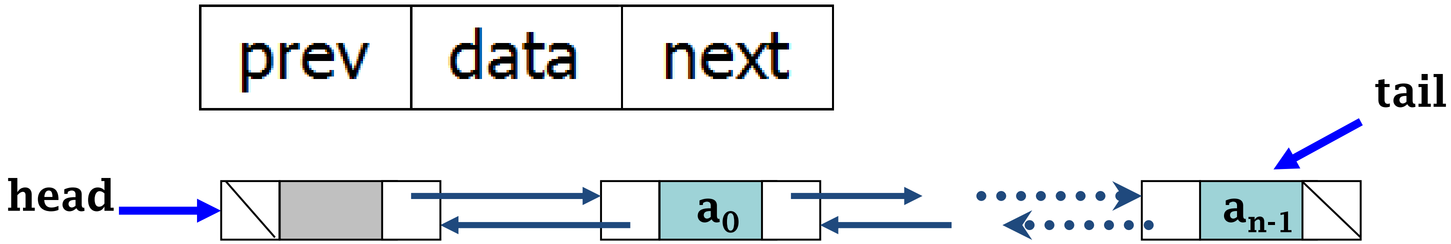
- To operate on a node you must find it first, which means to get a pointer address
- To find any node in single linked list you must begin from the first node

```
p = head;
while (not reaching) p = p->next;
```

- The time complexity $O(n)$
  - locating : $O(n)$
  - insert : $O(n) + O(1)$
  - delete : $O(n) + O(1)$

Double linked list

- To make up the disadvantages of single linked list, double linked list appears.
  - The next field of single linked list only points to the previous node , it can not be used to find the successive node. The same for “single prev”.
  - So, we add a pointer that points to the precursor node of it in the double linked list.

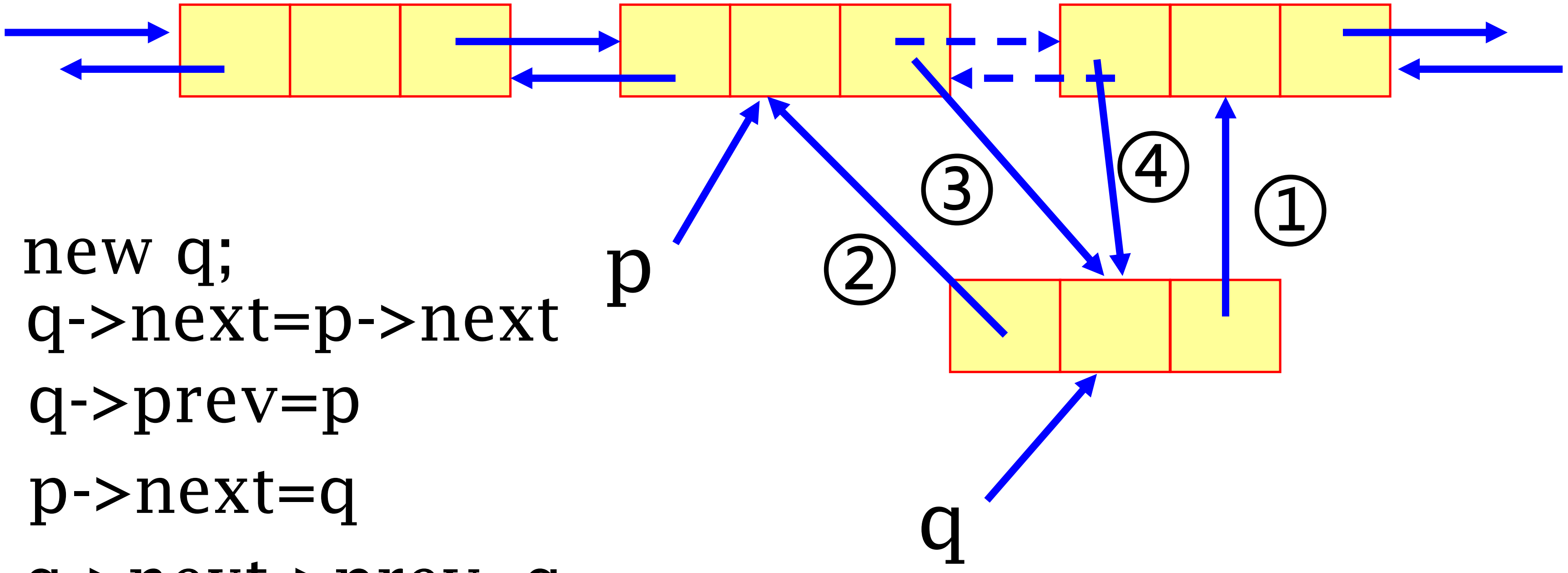


Double linked list and type of its node

```
template <class T> class Link {
    public:
    T  data;                        // used to store content of node elements
    Link<T> * next;                 // the pointer points to successor node
    Link<T> *prev;                  // the pointer points to precursor node
    Link(const T info, Link<T>* preValue = NULL, Link<T>* nextValue = NULL)
{
        // constructor with given value and precursor and successor pointers
        data = info;
        next = nextValue;
        prev = preValue;
    }
    Link(Link<T>* preValue = NULL, Link<T>* nextValue = NULL)  {
        // constructor with given value and precursor and successor pointers
        next = nextValue;
        prev = preValue;
    }
}
```

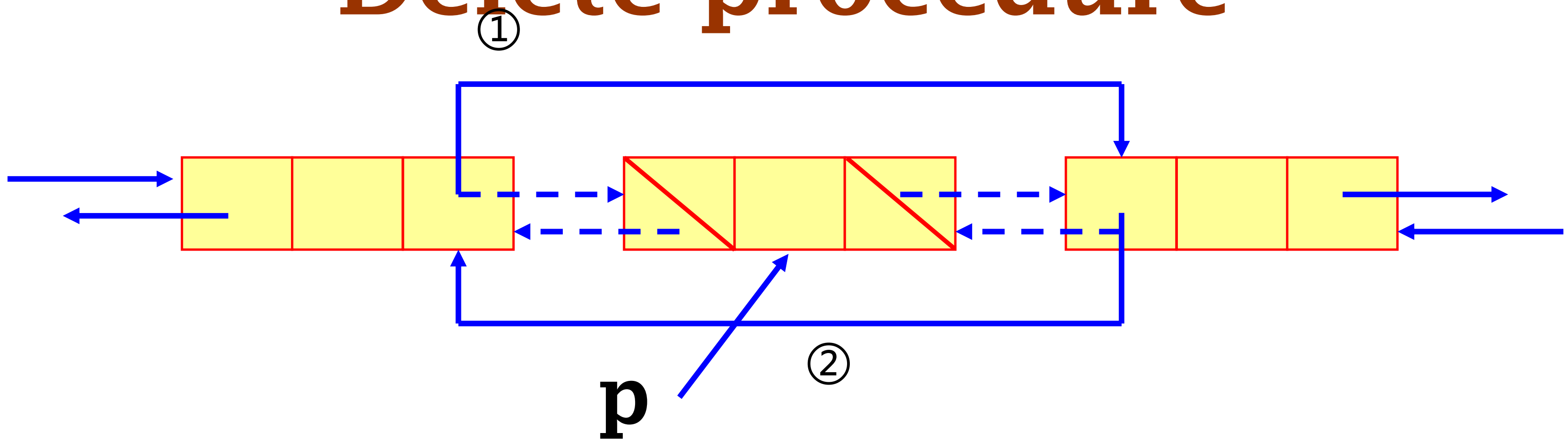
Insert procedure of double linked list (Be careful with the order)

Insert a new node after the node pointed by p



new q;
q->next=p->next
q->prev=p
p->next=q
q->next->prev=q

Delete procedure



Delete the node pointed by p

p->prev->next=p->next

p->next->prev=p->prev

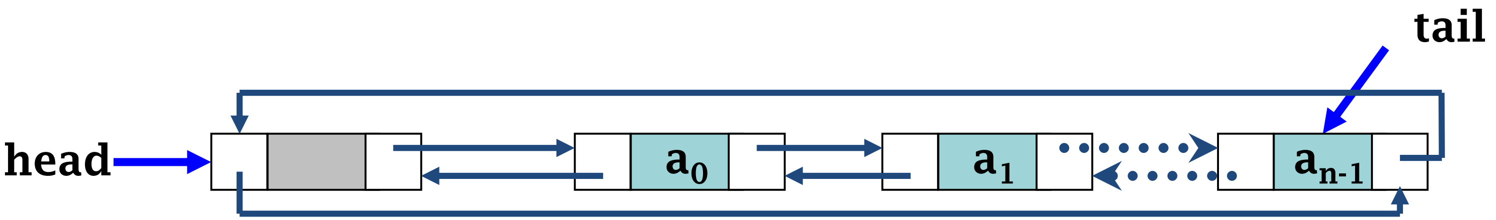
p->next=NULL

p->prev=NULL

- If you delete p immediately
  - Do not need to assign the null value

Circularly linked list

- Link the head and tail of single linked list and double linked list, and we created circular lists
- Do not increase other cost, but benefit lots of operations
  - From any node of circular list you can access all the other nodes



Boundary conditions of linked list

- Treatment of some special points
  - Treatment with the head node
  - Pointer field of the tail node of a non-circular list should be kept as NULL
  - Tail of a circular list points to its head pointer
- Treatment with linked list
  - Special treatment with empty linked list
  - When insert or delete nodes, be careful with the linking process of the related pointers
  - The correctness of points moving
    - insert
    - search or iteration

Thinking

- Think about the single linked list with head or not.
- The problems you should consider when deal with linked list.

Data Structures and Algorithms

Thanks

the National Elaborate Course (Only available for IPs in China)
http://www.jpk.pku.edu.cn/pkujpk/course/sjjg/

Ming Zhang, Tengjiao Wang and Haiyan Zhao

Higher Education Press, 2008.6 (awarded as the "Eleventh Five-Year" national planning textbook)