

# CS61B Lecture #5: Simple Pointer Manipulation

**Recreation** Prove that for every acute angle  $\alpha > 0$ ,

$$\tan \alpha + \cot \alpha \geq 2$$

## Announcement

- **Today:** More pointer hacking.
- **Handing in labs and homework:** We'll be lenient about accepting late homework and labs for lab1, lab2, and hw0. Just get it done: part of the point is getting to understand the tools involved. We will *not* accept submissions by email.

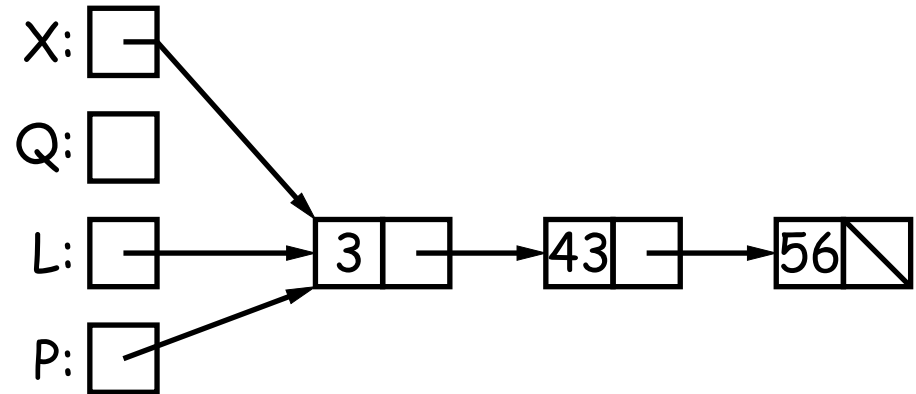
# Destructive Incrementing

*Destructive* solutions may modify objects in the original list to save time or space:

```
/** Destructively add N to L's items. */
static IntList dincrList(IntList P, int n) {
    if (P == null)
        return null;
    else {
        P.head += n;
        P.tail = dincrList(P.tail, n);
        return P;
    }
}
```

```
/** Destructively add N to L's items. */
static IntList dincrList(IntList L, int n)
{
    // 'for' can do more than count!
    for (IntList p = L; p != null; p = p.tail)
        p.head += n;
    return L;
}
```

```
X = IntList.list(3, 43, 56);
/* IntList.list from HW #1 */
Q = dincrList(X, 2);
```



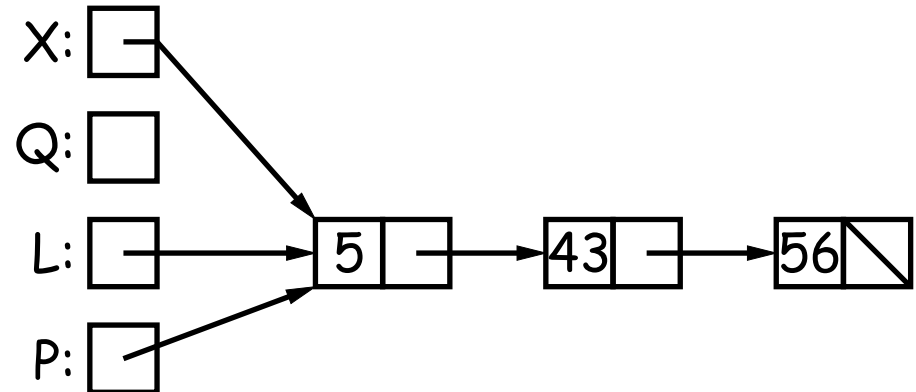
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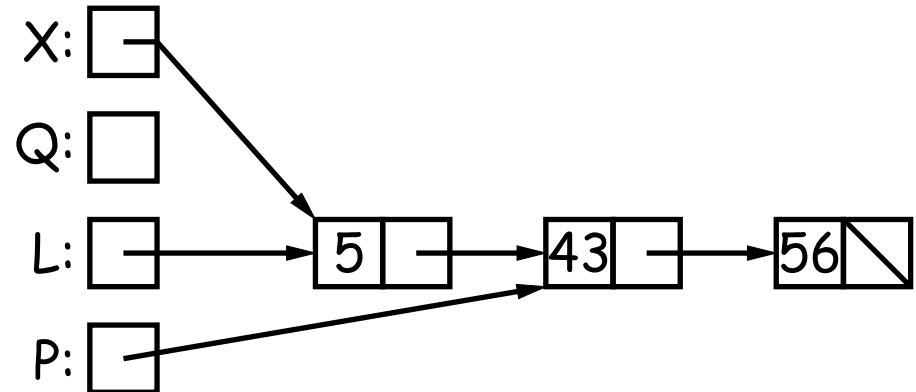
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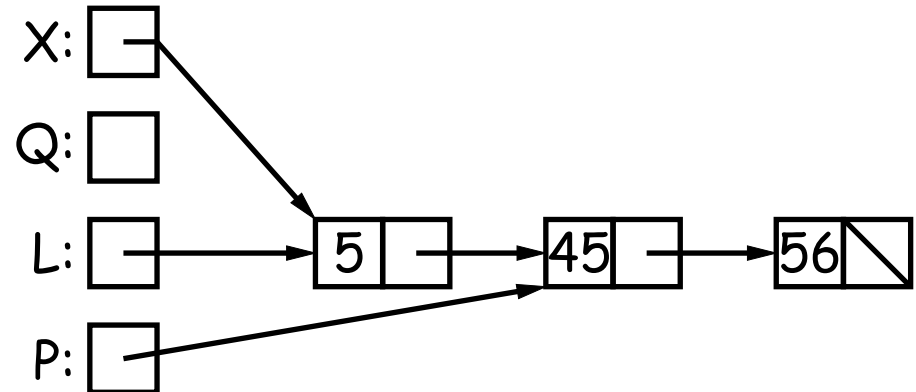
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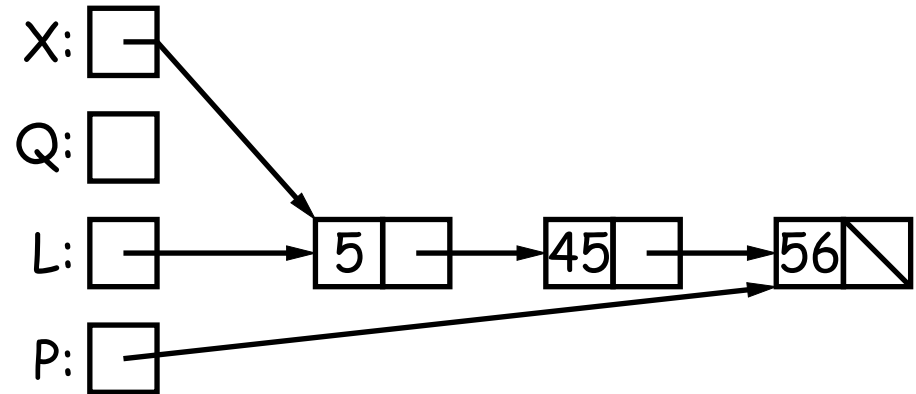
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/** Destructively add N to L's items. */
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        p.head += n;
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}
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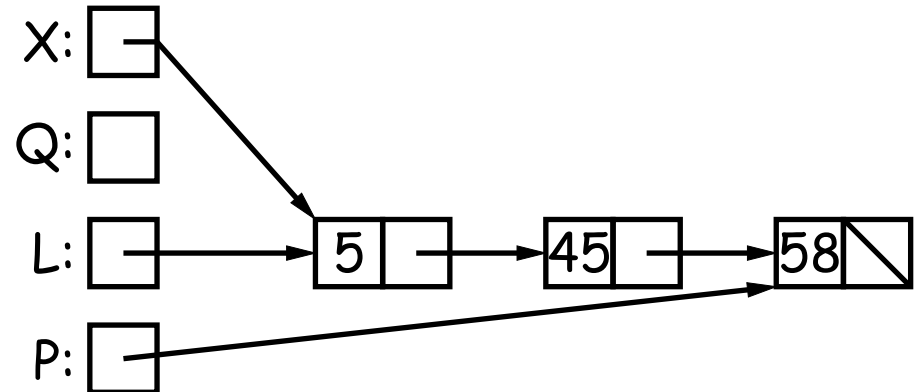
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/** Destructively add N to L's items. */
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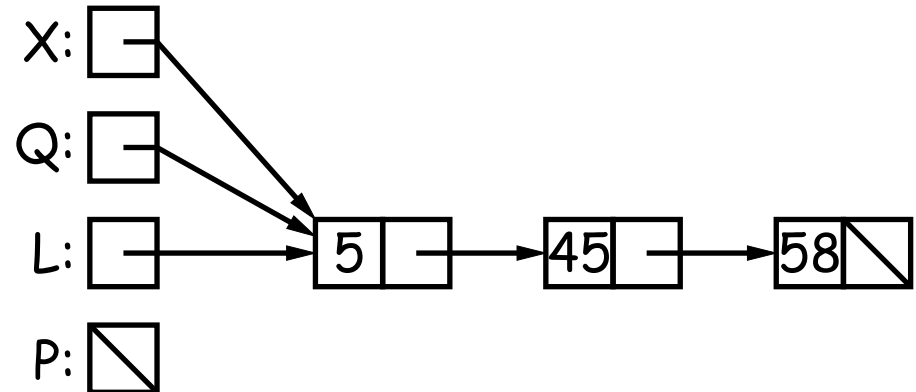
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/** Destructively add N to L's items. */
static IntList dincrList(IntList L, int n)
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    // 'for' can do more than count!
    for (IntList p = L; p != null; p = p.tail)
        p.head += n;
    return L;
}
```

```
X = IntList.list(3, 43, 56);
/* IntList.list from HW #1 */
Q = dincrList(X, 2);
```





## Another Example: Non-destructive List Deletion

If  $L$  is the list  $[2, 1, 2, 9, 2]$ , we want `removeAll(L, 2)` to be the new list  $[1, 9]$ .

```
/** The list resulting from removing all instances of X from L
 * non-destructively. */
static IntList removeAll(IntList L, int x) {
    if (L == null)
        return /*( null with all x's removed )*/;
    else if (L.head == x)
        return /*( L with all x's removed (L!=null, L.head==x) )*/;
    else
        return /*( L with all x's removed (L!=null, L.head!=x) )*/;
}
```

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    if (L == null)
        return null;
    else if (L.head == x)
        return removeAll(L.tail, x);
    else
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If  $L$  is the list  $[2, 1, 2, 9, 2]$ , we want `removeAll(L, 2)` to be the new list  $[1, 9]$ .

```
/** The list resulting from removing all instances of X from L
 * non-destructively. */
static IntList removeAll(IntList L, int x) {
    if (L == null)
        return null;
    else if (L.head == x)
        return removeAll(L.tail, x);
    else
        return new IntList(L.head, removeAll(L.tail, x));
}
```

# Iterative Non-destructive List Deletion

Same as before, but use front-to-back iteration rather than recursion.

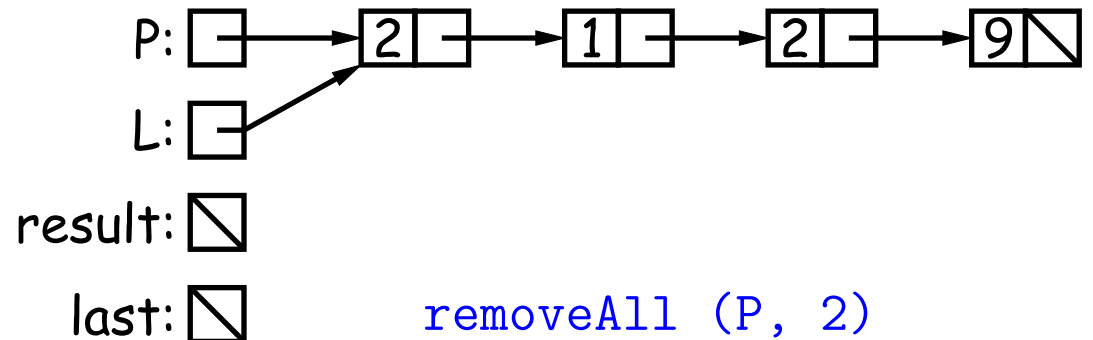
```
/** The list resulting from removing all instances
 * of X from L non-destructively. */
static IntList removeAll(IntList L, int x) {
    IntList result, last;
    result = last = null;
    for ( ; L != null; L = L.tail) {
        if (x == L.head)
            continue;
        else if (last == null)
            result = last = new IntList(L.head, null);
        else
            last = last.tail = new IntList(L.head, null);
    }
    return result;
}
```

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            last = last.tail = new IntList(L.head, null);
    }
    return result;
}
```

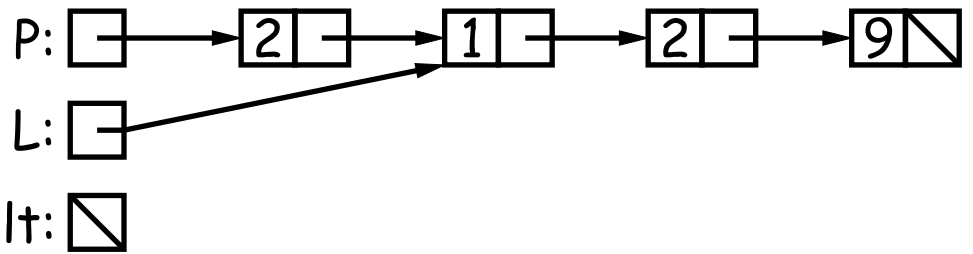


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            continue;
        else if (last == null)
            result = last = new IntList(L.head, null);
        else
            last = last.tail = new IntList(L.head, null);
    }
    return result;
}
```



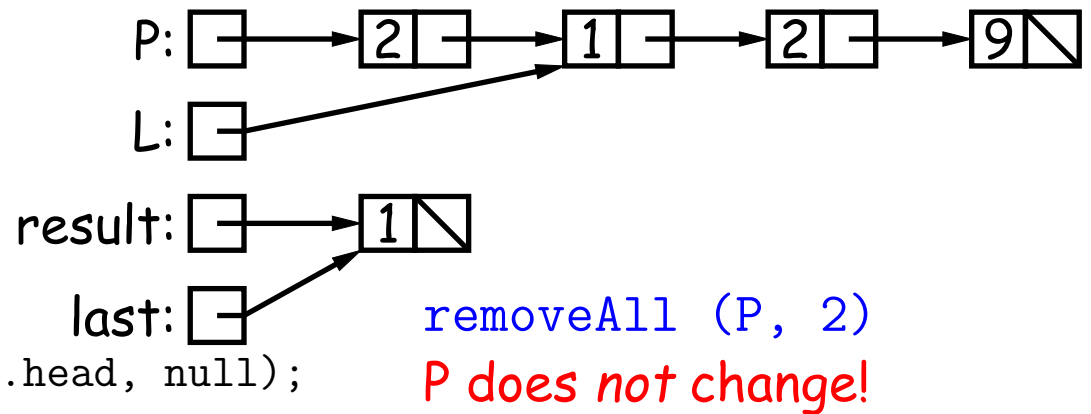
removeAll (P, 2)  
*P does not change!*

# Iterative Non-destructive List Deletion

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        if (x == L.head)  
            continue;  
        else if (last == null)  
            result = last = new IntList(L.head, null);  
        else  
            last = last.tail = new IntList(L.head, null);  
    }  
    return result;  
}
```





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/** The list resulting from removing all instances  
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```
static IntList removeAll(IntList L, int x) {
```

```
    IntList result, last;
```

```
    result = last = null;
```

```
    for ( ; L != null; L = L.tail) {
```

```
        if (x == L.head)
```

```
            continue;
```

```
        else if (last == null)
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```
            result = last = new IntList(L.head, null);
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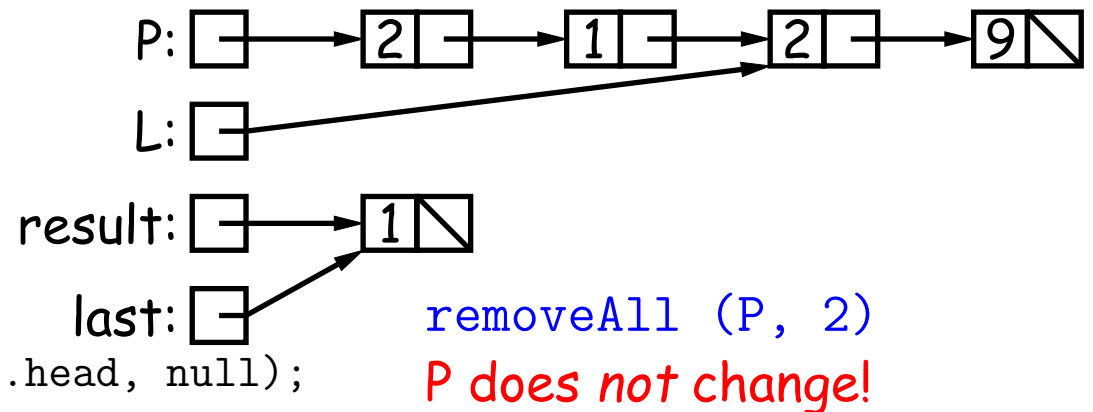
```
        else
```

```
            last = last.tail = new IntList(L.head, null);
```

```
    }
```

```
    return result;
```

```
}
```

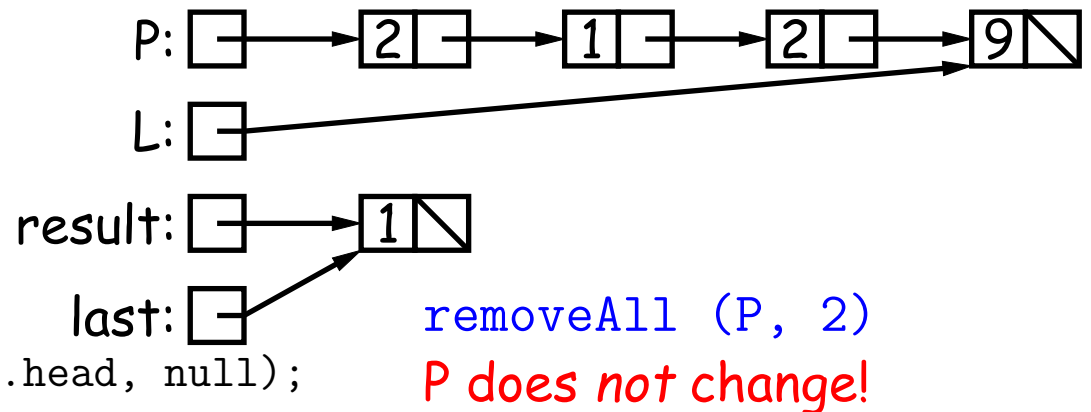


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            continue;
        else if (last == null)
            result = last = new IntList(L.head, null);
        else
            last = last.tail = new IntList(L.head, null);
    }
    return result;
}
```

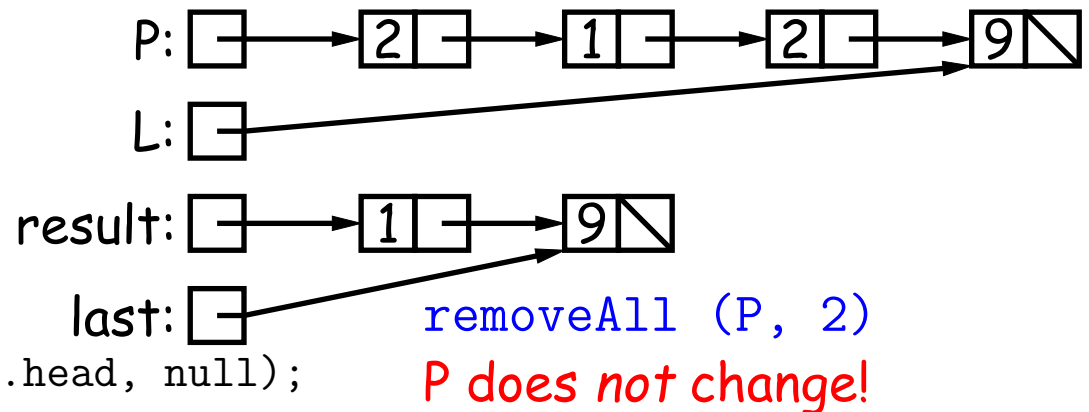


# Iterative Non-destructive List Deletion

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```
/** The list resulting from removing all instances
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```
    for ( ; L != null; L = L.tail) {
```

```
        if (x == L.head)
```

```
            continue;
```

```
        else if (last == null)
```

```
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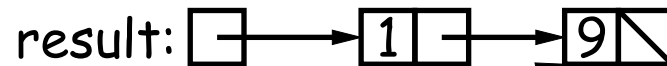
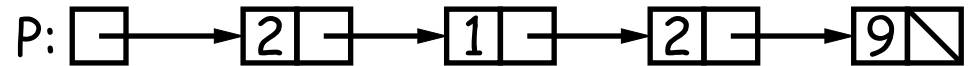
```
        else
```

```
            last = last.tail = new IntList(L.head, null);
```

```
    }
```

```
    return result;
```

```
}
```



*P does not change!*

# Destructive Deletion

→ : Original

..... : after Q = dremoveAll (Q,1)



```
/** The list resulting from removing all instances of X from L.
```

```
 * The original list may be destroyed. */
```

```
static IntList dremoveAll(IntList L, int x) {
```

```
    if (L == null)
```

```
        return /*( null with all x's removed )*/;
```

```
    else if (L.head == x)
```

```
        return /*( L with all x's removed (L != null) )*/;
```

```
    else {
```

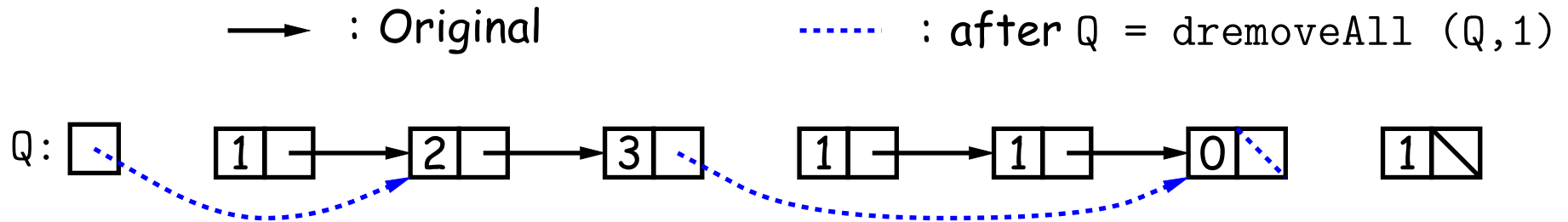
```
        /*{ Remove all x's from L's tail. }*/;
```

```
        return L;
```

```
    }
```

```
}
```

# Destructive Deletion



/\*\* The list resulting from removing all instances of X from L.

\* The original list may be destroyed. \*/

```

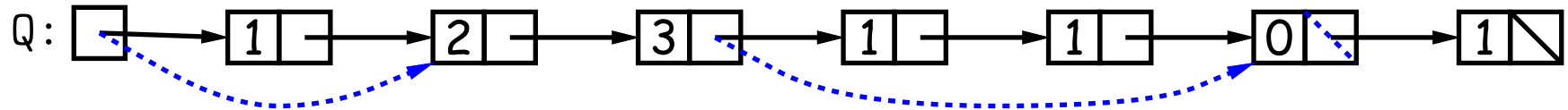
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    if (L == null)
        return /*( null with all x's removed )*/;
    else if (L.head == x)
        return /*( L with all x's removed (L != null) )*/;
    else {
        /*{ Remove all x's from L's tail. }*/;
        return L;
    }
}

```

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..... : after Q = dremoveAll (Q,1)



```
/** The list resulting from removing all instances of X from L.
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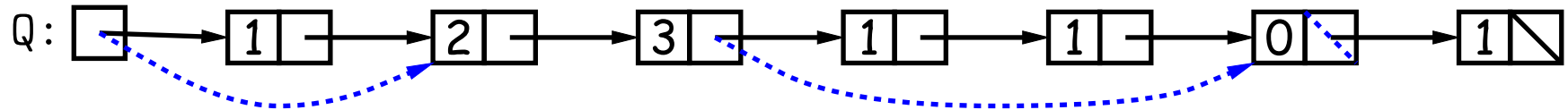
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 * The original list may be destroyed. */
```

```
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        return /*( L with all x's removed (L != null) )*/;  
    else {  
        /*{ Remove all x's from L's tail. }*/;  
        return L;  
    }  
}
```

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..... : after Q = dremoveAll (Q,1)



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```

```
    else {
```

```
        /*{ Remove all x's from L's tail. }*/;
```

```
        return L;
```

```
    }
```

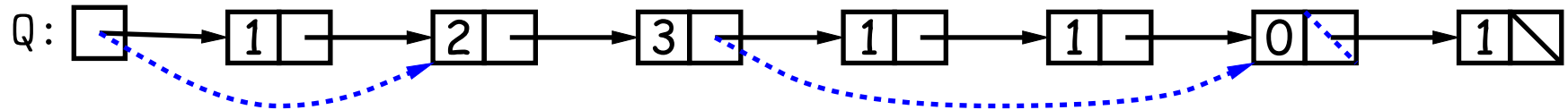
```
}
```



# Destructive Deletion

→ : Original

..... : after Q = dremoveAll (Q,1)



```
/** The list resulting from removing all instances of X from L.
```

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```

```
    if (L == null)
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```
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    else if (L.head == x)
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        /*{ Remove all x's from L's tail. }*/;
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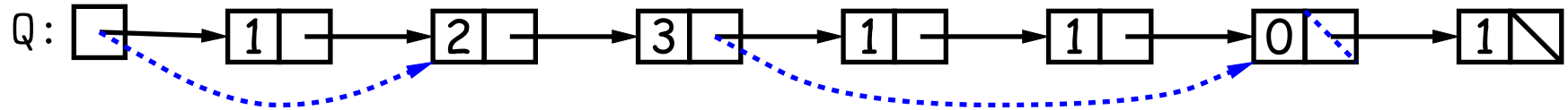
```
    }
```

```
}
```

# Destructive Deletion

→ : Original

..... : after Q = dremoveAll (Q,1)



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```

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```

```
    if (L == null)
```

```
        return
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```
    else if (L.head == x)
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```
        return dremoveAll(L.tail, x);
```

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        /*{ Remove all x's from L's tail. }*/;
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        return L;
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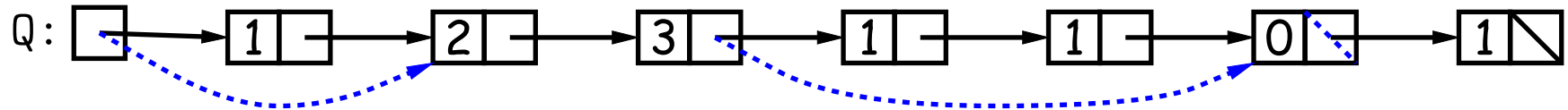
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    }
```

```
}
```

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```

```
 * The original list may be destroyed. */
```

```
static IntList dremoveAll(IntList L, int x) {
    if (L == null)
        return
    else if (L.head == x)
        return dremoveAll(L.tail, x);
    else {
        L.tail = dremoveAll(L.tail, x);
        return L;
    }
}
```

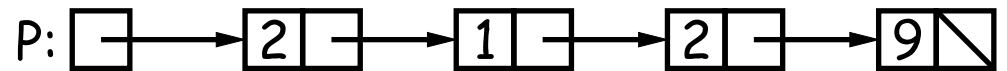
# Iterative Destructive Deletion

```
/** The list resulting from removing all X's from L
 * destructively. */
static IntList dremoveAll(IntList L, int x) {
    IntList result, last;
    result = last = null;
    while (L != null) {
        IntList next = L.tail;
        if (x != L.head) {
            if (last == null)
                result = last = L;
            else
                last = last.tail = L;
            L.tail = null;
        }
        L = next;
    }
    return result;
}
```

# Iterative Destructive Deletion

```
/** The list resulting from removing all X's from L
 * destructively. */
```

```
static IntList dremoveAll(IntList L, int x) {
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            if (last == null)
                result = last = L;
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                last = last.tail = L;
            L.tail = null;
        }
        L = next;
    }
    return result;
}
```



result:

last:

L:

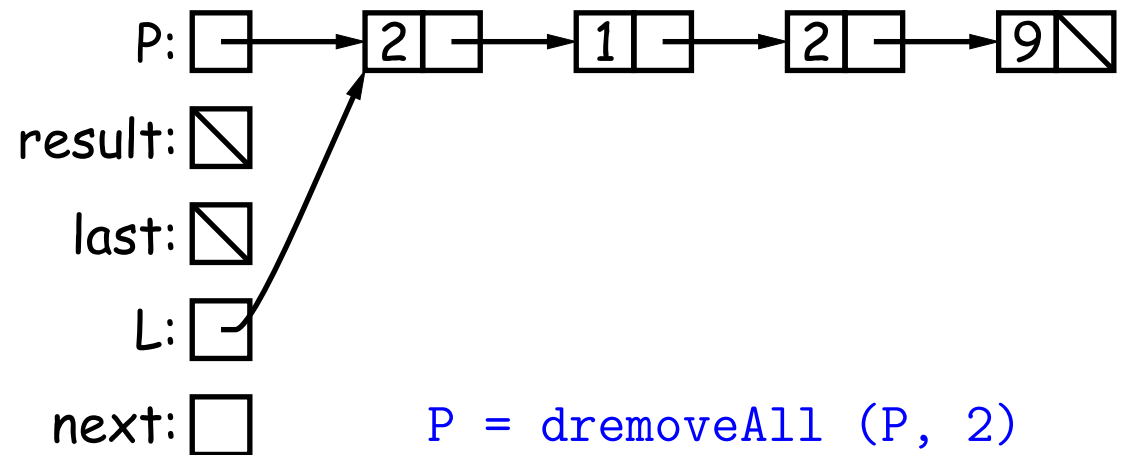
next:

P = dremoveAll (P, 2)

# Iterative Destructive Deletion

```
/** The list resulting from removing all X's from L
 * destructively. */
```

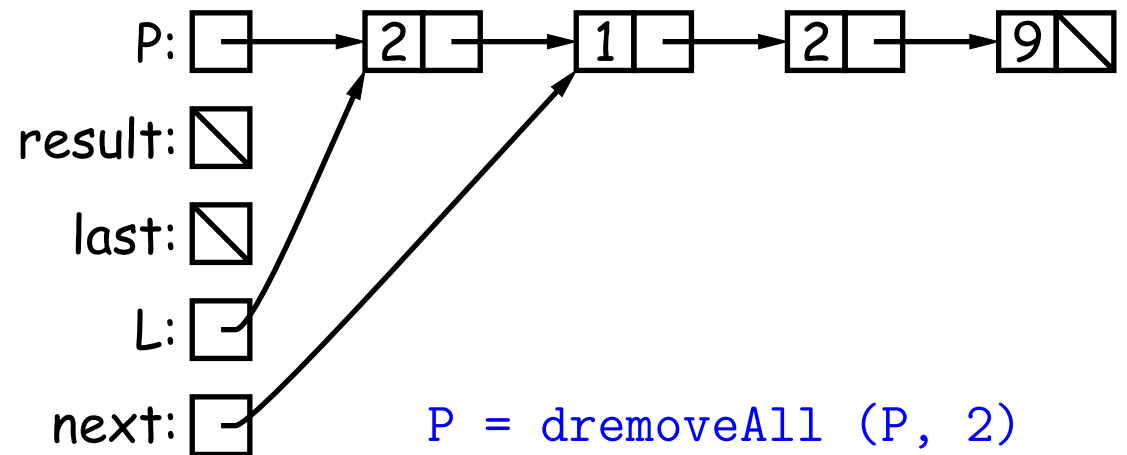
```
static IntList dremoveAll(IntList L, int x) {
    IntList result, last;
    result = last = null;
    while (L != null) {
        IntList next = L.tail;
        if (x != L.head) {
            if (last == null)
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            else
                last = last.tail = L;
            L.tail = null;
        }
        L = next;
    }
    return result;
}
```



# Iterative Destructive Deletion

```
/** The list resulting from removing all X's from L
 * destructively. */
```

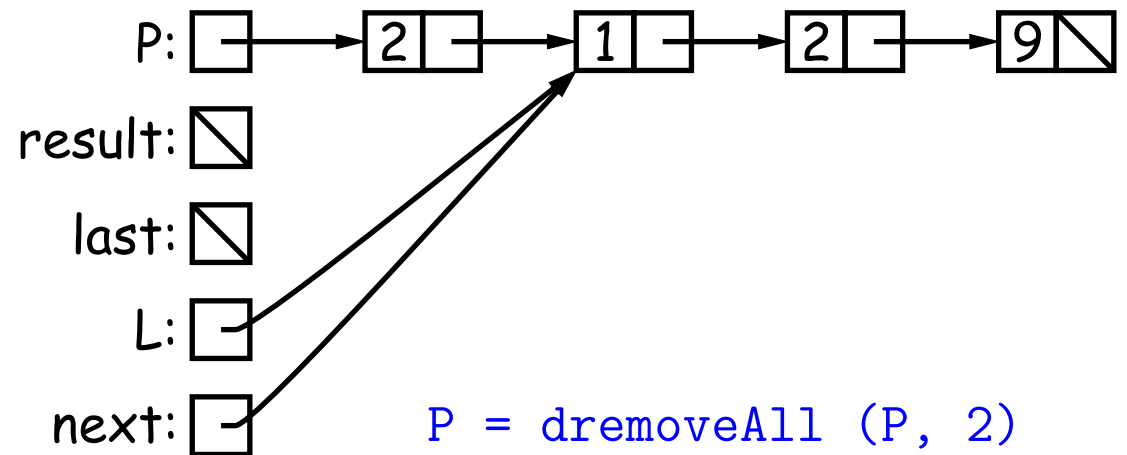
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    }
    L = next;
  }
  return result;
}
```

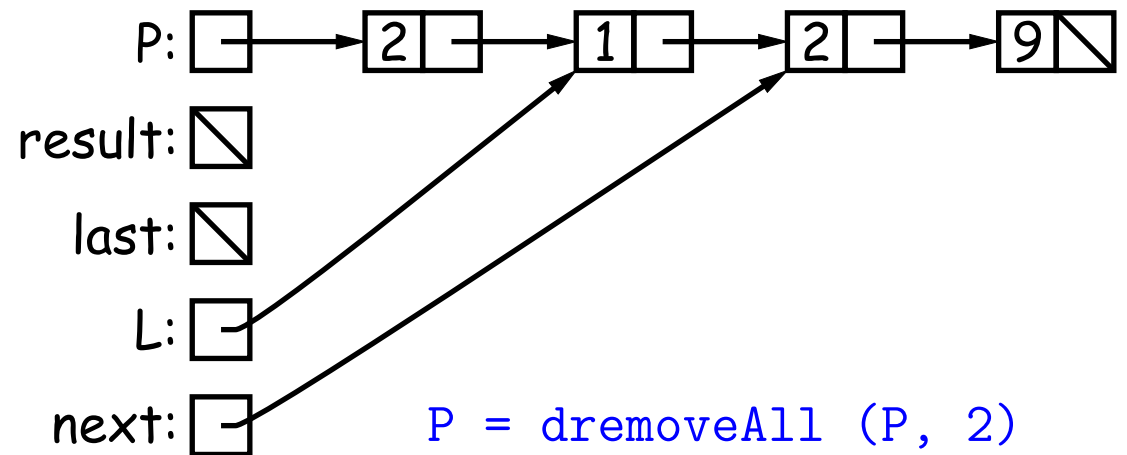




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```

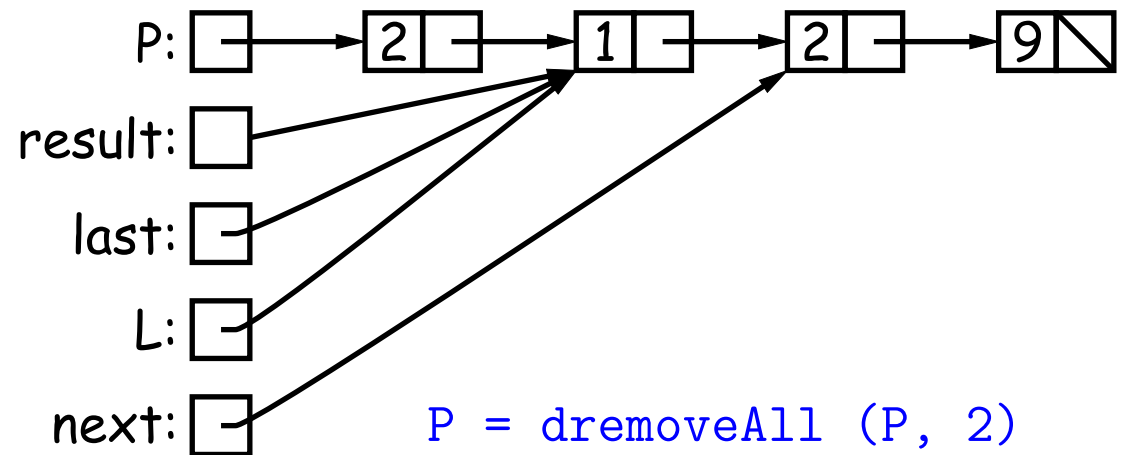
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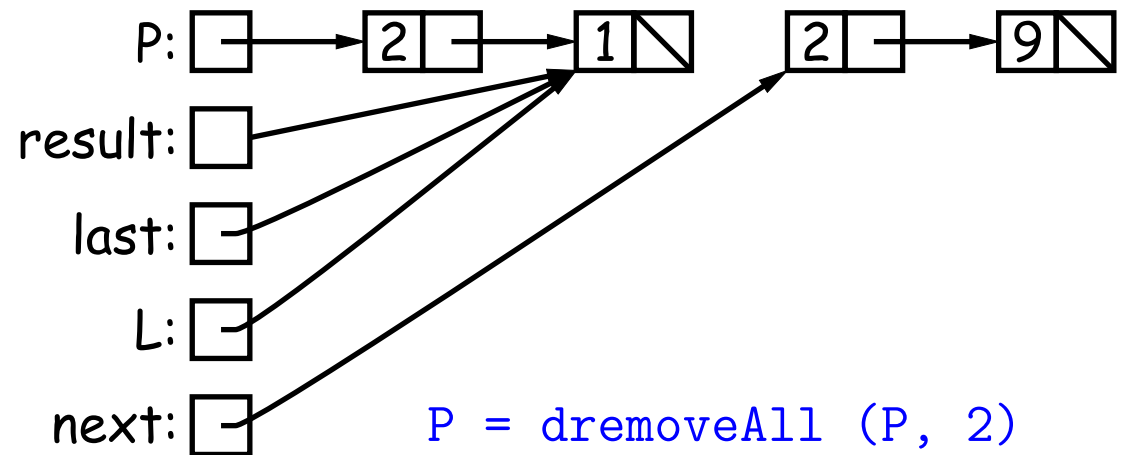
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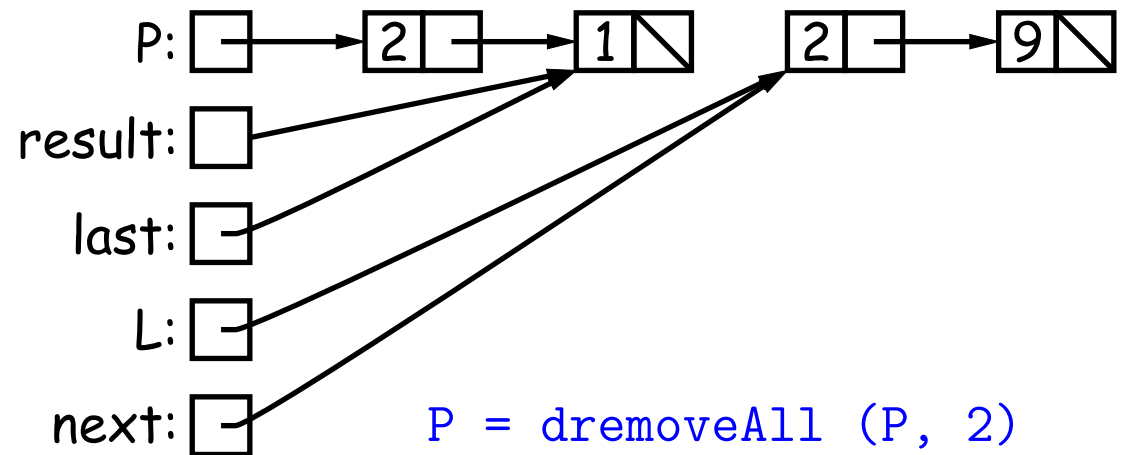
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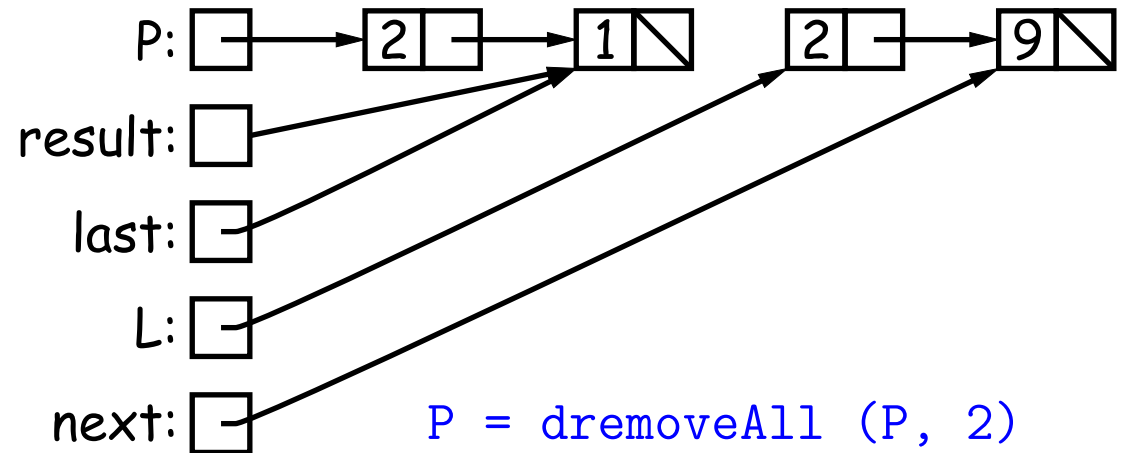
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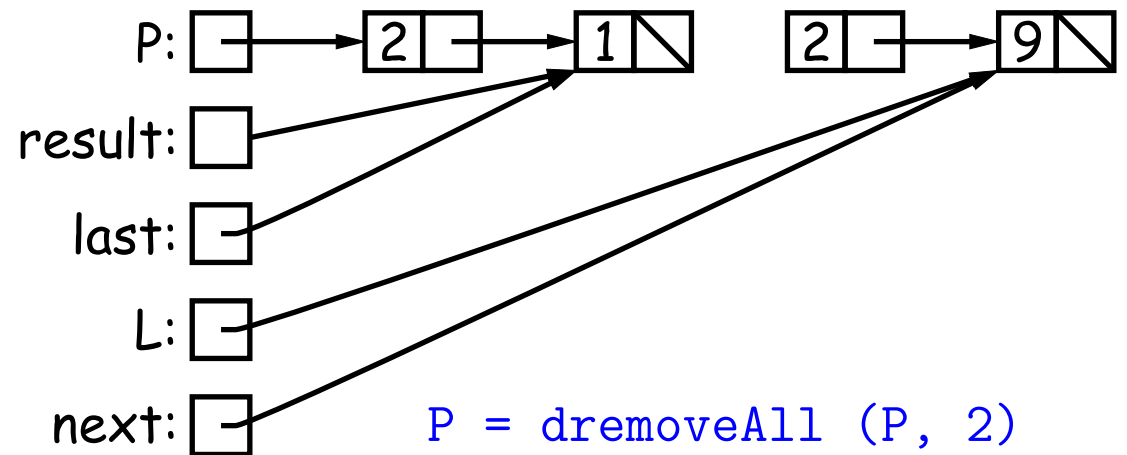
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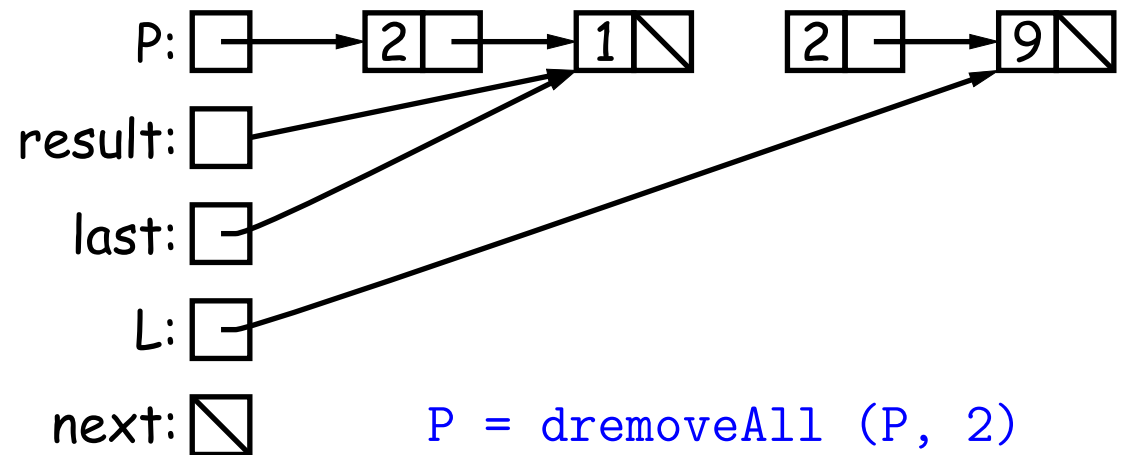
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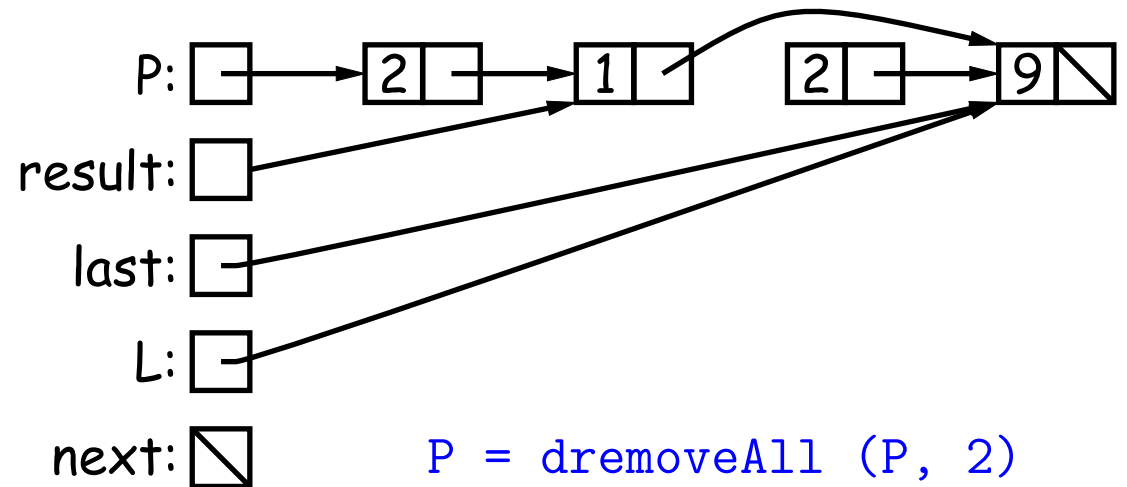
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    L = next;
  }
  return result;
}
```

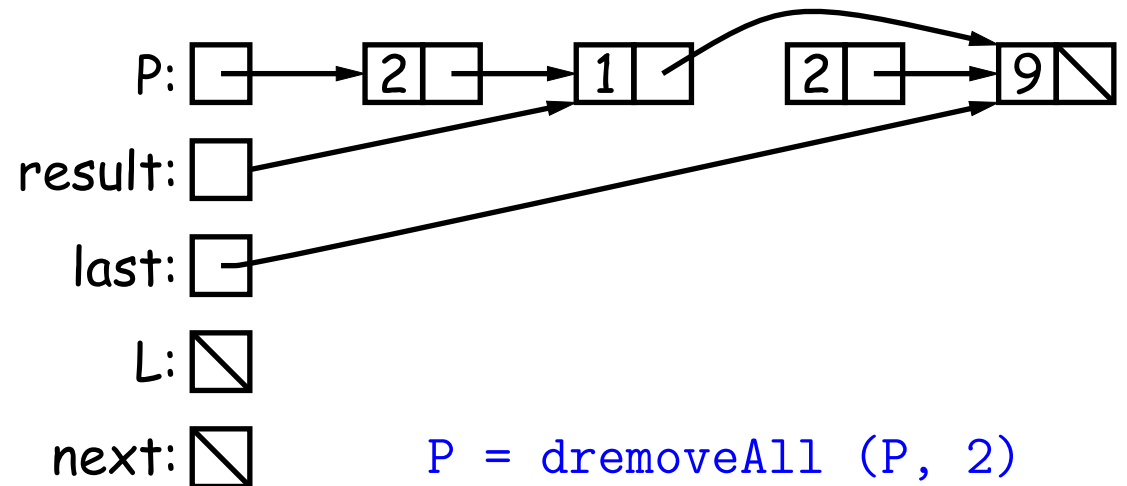




# Iterative Destructive Deletion

```
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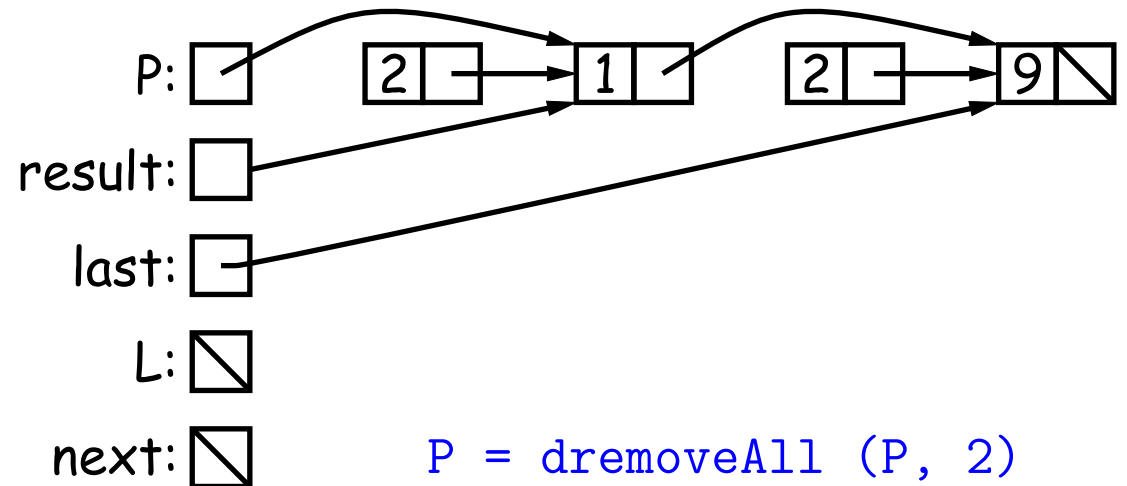
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    L = next;
  }
  return result;
}
```



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        }
        L = next;
    }
    return result;
}
```



`P = dremoveAll (P, 2)`

## Aside: How to Write a Loop (in Theory)

- Try to give a description of how things look on *any arbitrary iteration* of the loop.
- This description is known as a *loop invariant*, because it is always true at the start of each iteration.
- The loop body then must
  - Start from any situation consistent with the invariant;
  - Make progress in such a way as to make the invariant true again.

```
while (condition) {  
    // Invariant true here  
    loop body  
    // Invariant again true here  
}  
// Invariant true and condition false.
```

- So if our loop gets the desired answer whenever *invariant* is true and *condition* if false, our job is done!

# Example: Loop Invariant for dremoveAll

```
/** The list resulting from removing all X's from L
 * destructively. */
```

```
static IntList dremoveAll(IntList L, int x) {
```

```
    IntList result, last;
```

```
    result = last = null;
```

```
    while ** (L != null) {
```

```
        IntList next = L.tail;
```

```
        if (x != L.head) {
```

```
            if (last == null)
```

```
                result = last = L;
```

```
            else
```

```
                last = last.tail = L;
```

```
            L.tail = null;
```

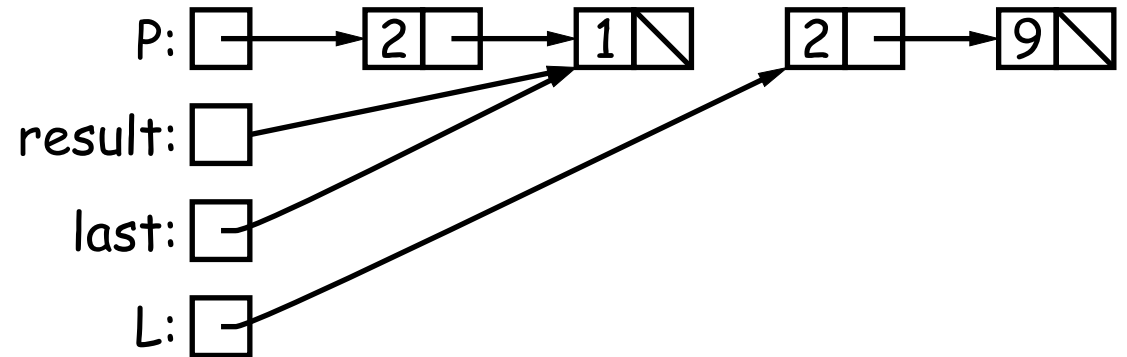
```
        }
```

```
        L = next;
```

```
    }
```

```
    return result;
```

```
}
```



P = dremoveAll (P, 2)

**\*\* Invariant:**

- result points to the list of items in the final result except for those from L onward.
- L points to an unchanged tail of the original list of items in L.
- last points to the last item in result or is null if result is null.