

CS61B Lecture #5: Simple Pointer Manipulation

Announcement

- **Discussion Change:** This week (11 September), discussion section 114 (3-4PM) will move from 3 Evans to 6 Evans.
- **Today:** More pointer hacking.

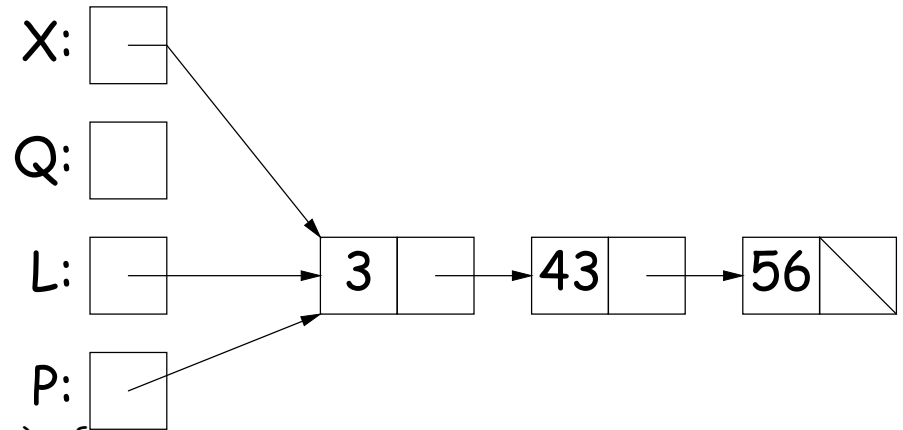
Destructive Incrementing

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

```
/** List of all items in P incremented by n. May destroy original. */
static IntList dincrList (IntList P, int n) {
    if (P == null)
        return null;
    else {
        P.head += n;
        P.tail = dincrList (P.tail, n);
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}
```

```
X = IntList.list (3, 43, 56);
/* IntList.list from HW #1 */
Q = dincrList (X, 2);
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/** List L destructively incremented
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static IntList dincrList (IntList L, int n) {
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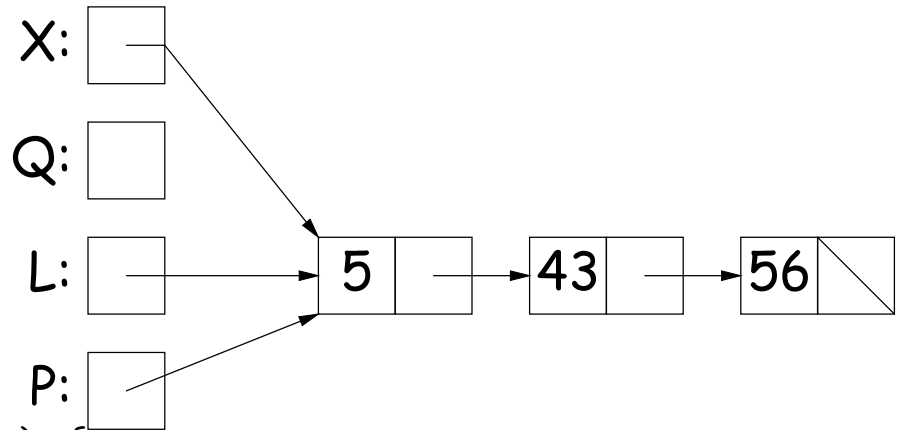
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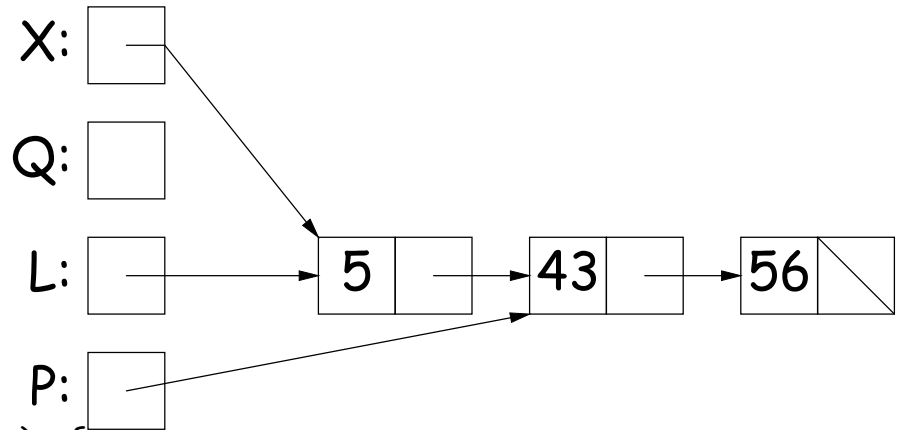
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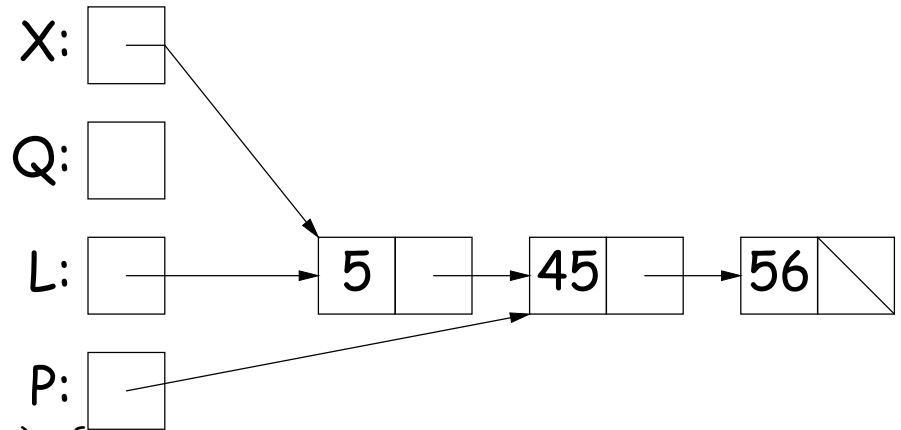
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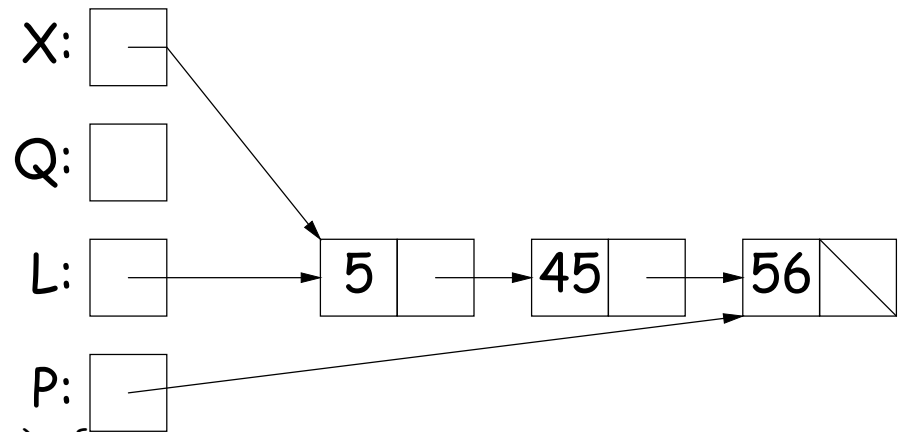
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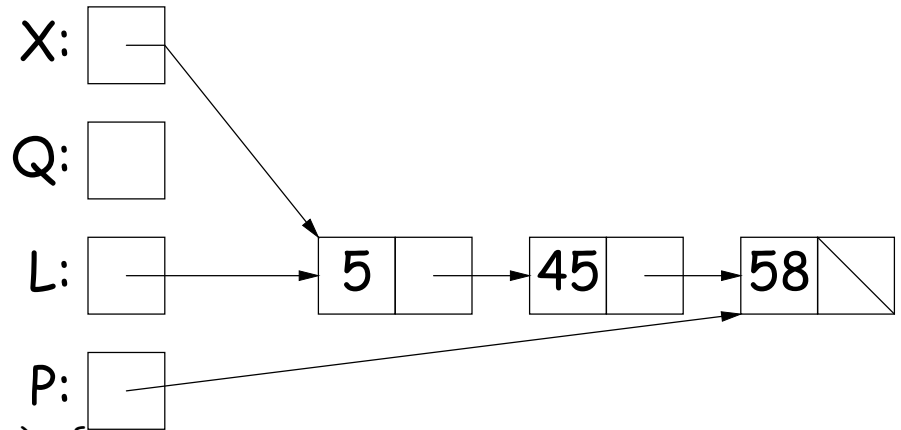
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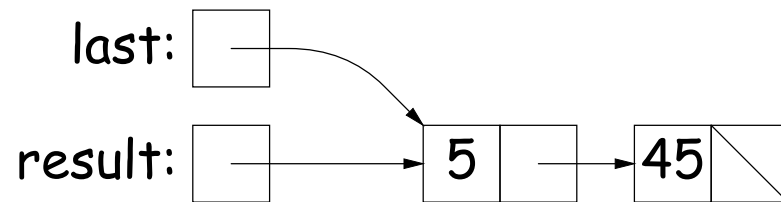
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Side Excursion: Another Way to View Pointers

- Some folks find the idea of "copying an arrow" somewhat odd.
- Alternative view: think of a pointer as a *label*, like a street address.
- Each object has a permanent label on it, like the address plaque on a house.
- Then a variable containing a pointer is like a scrap of paper with a street address written on it.
- One view:

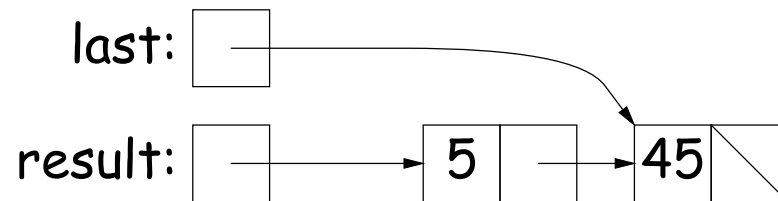


- Alternative view:

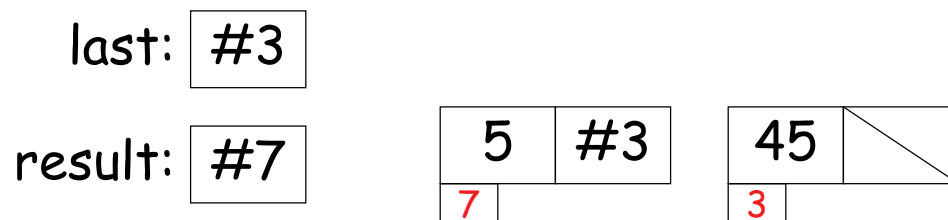


Another Way to View Pointers (II)

- Assigning a pointer to a variable looks just like assigning an integer to a variable.
- So, after executing "last = last.tail;" we have



- Alternative view:



- Under alternative view, you might be less inclined to think that assignment would change object #7 itself, rather than just "last".
- BEWARE! Internally, pointers really are just numbers, but Java treats them as more than that: they have *types*, and you can't just change integers into pointers.

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) )*/;
    else
        return /*( L with all x's removed (L != null, L.head!=x) )*/;
}
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    else if (L.head == x)
        return removeAll (L.tail, x);
    else
        return new IntList (L.head, removeAll (L.tail, x));
}
```

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 true from one iteration to the next.
- 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 (*invariant* and not *condition*) is enough to insure we've got the answer, we're done!

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) {
        /* L != null and  $\mathcal{I}$  is true. */
        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;
}
```

Here, \mathcal{I} is the *loop invariant*:

Result is all elements of L_0 not equal to x up to and not including L , and $last$ points to the last element of result, if any. We use L_0 here to mean "the original sequence of int values in L ."

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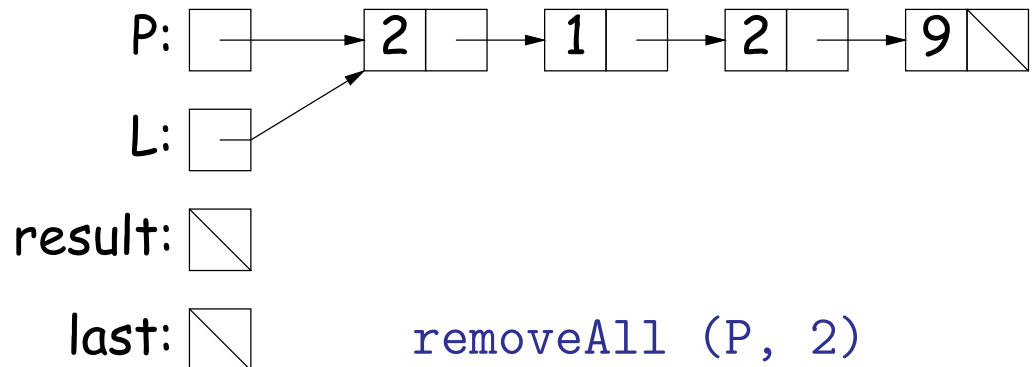
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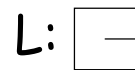
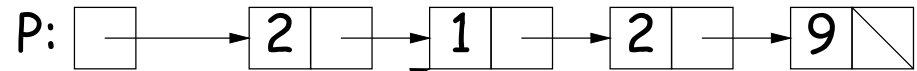
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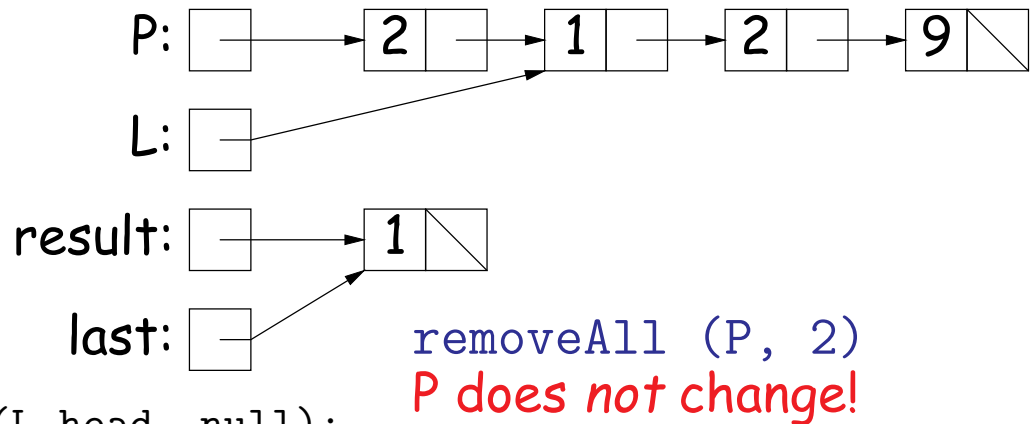
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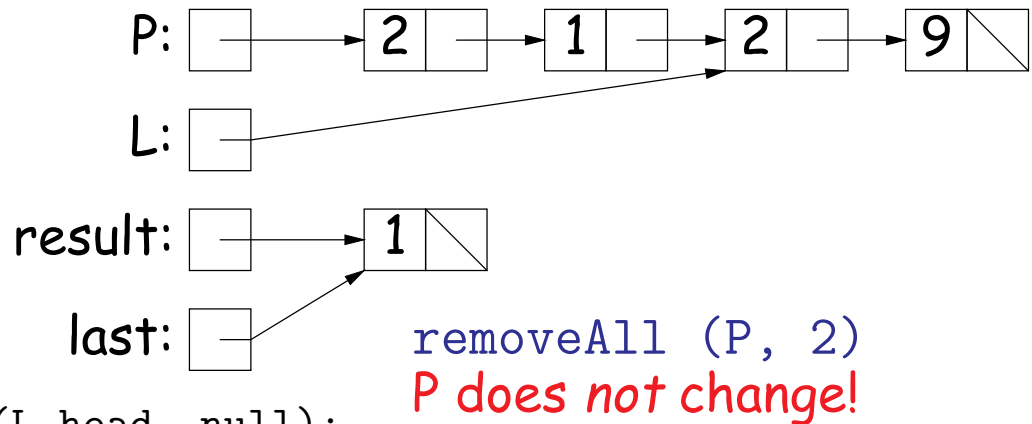
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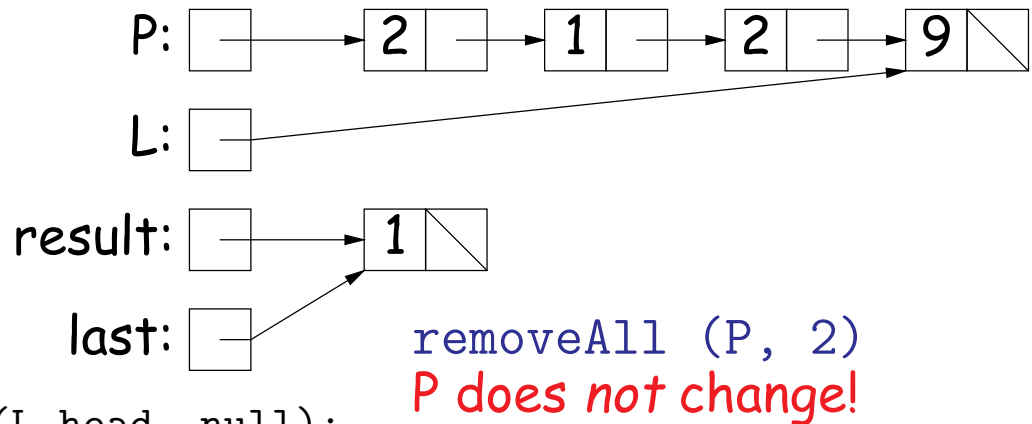
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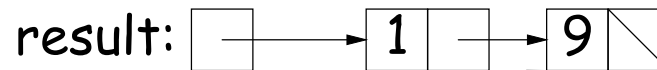
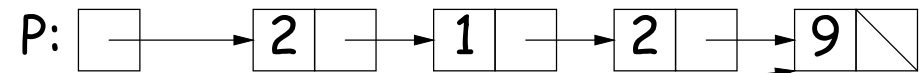
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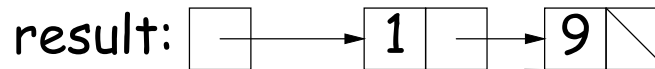
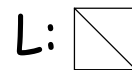
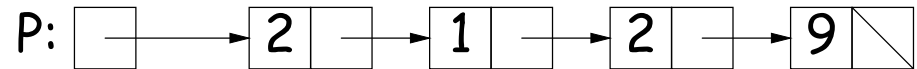
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P does not change!

Destructive Deletion

→ : Original

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



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

```
    else {
```

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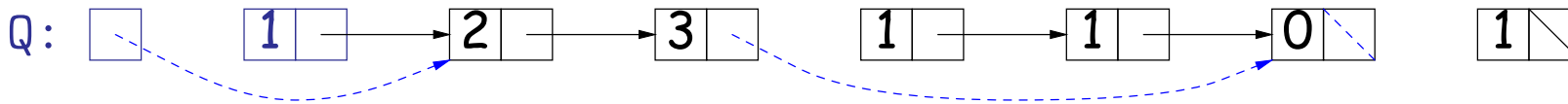
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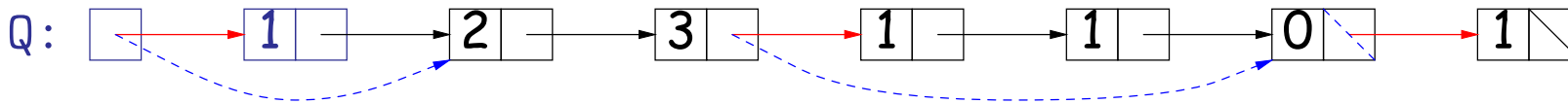
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        return L;
```

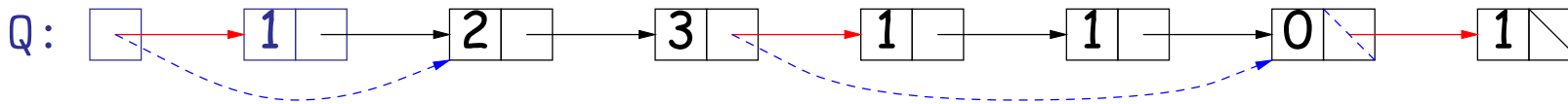
```
    }
```

```
}
```

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;
```

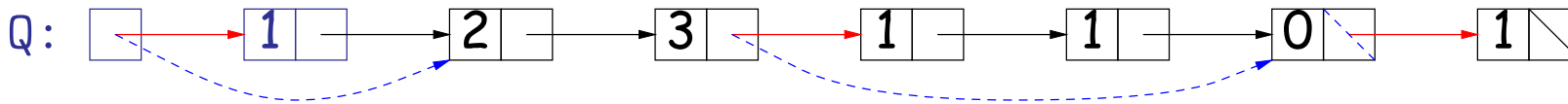
```
    }
```

```
}
```

Destructive Deletion

→ : Original

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



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

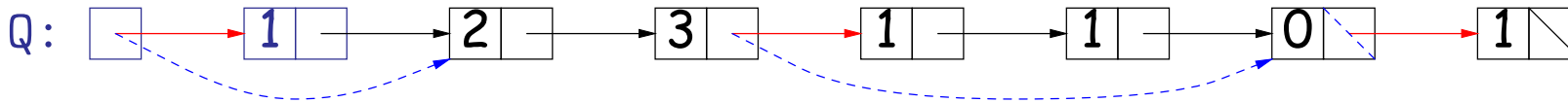
* The original list may be destroyed. */

```
static IntList dremoveAll (IntList L, int x) {
    if (L == null)
        return null;
    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

→ : 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;
```

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

```
        return dremoveAll (L.tail, x);
```

```
    else {
```

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

```
        return L;
```

```
    }
```

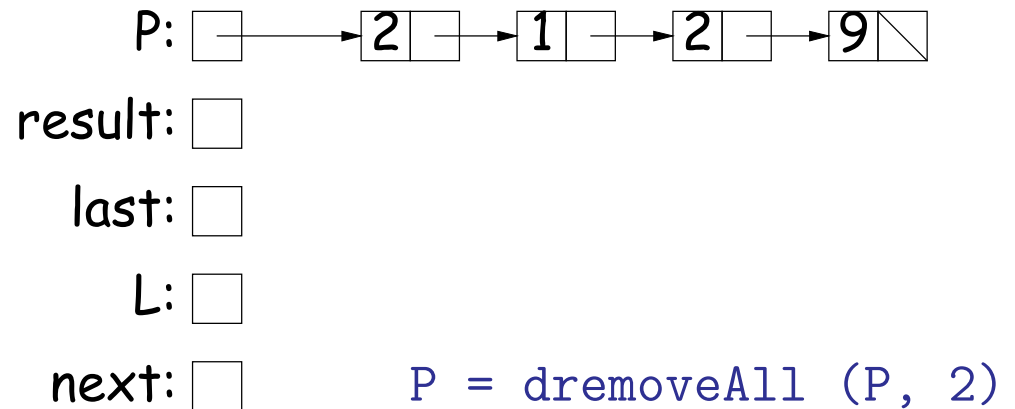
```
}
```


Iterative Destructive Deletion

```
/** The list resulting from removing all instances of X from L.
 * Original contents of L may be destroyed. */
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;
}
```

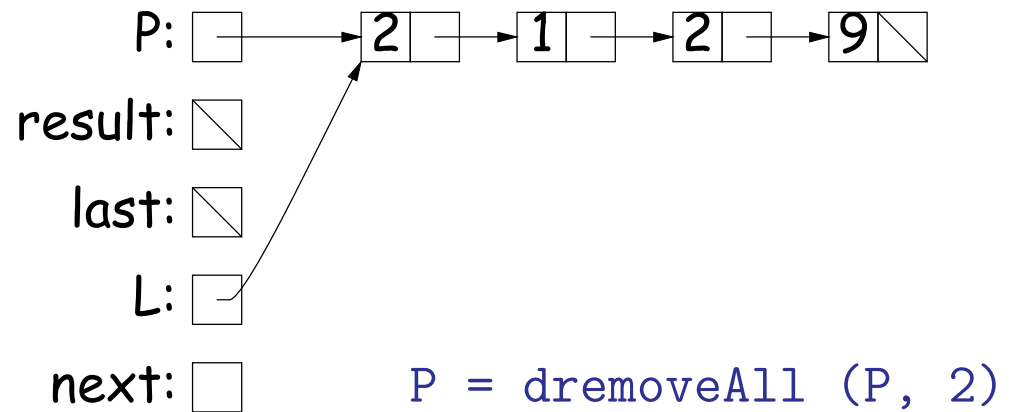
Iterative Destructive Deletion

```
/** The list resulting from removing all instances of X from L.
 * Original contents of L may be destroyed. */
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;
}
```



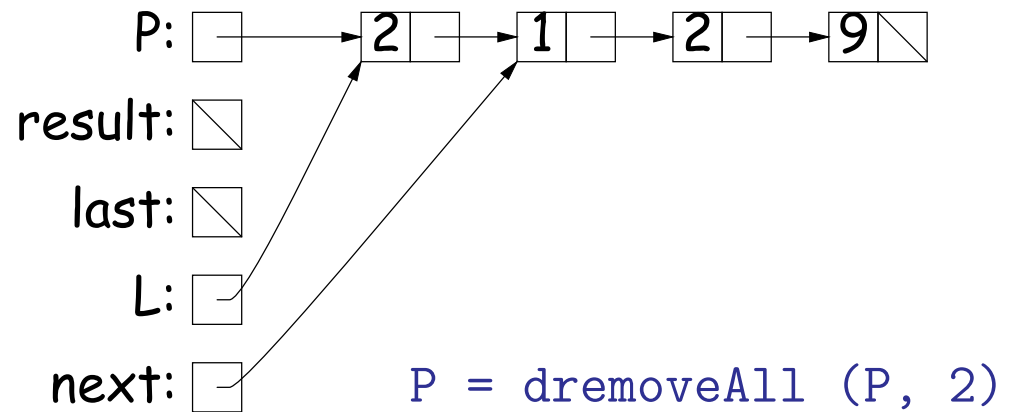
Iterative Destructive Deletion

```
/** The list resulting from removing all instances of X from L.
 * Original contents of L may be destroyed. */
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;
}
```



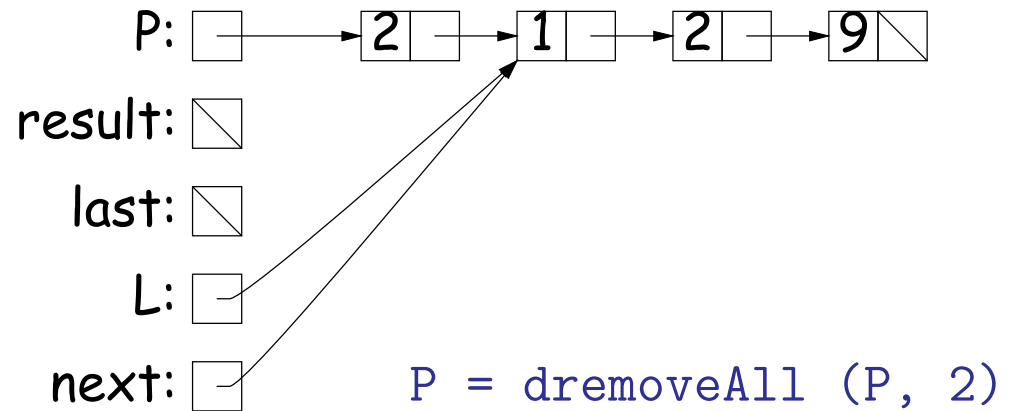
Iterative Destructive Deletion

```
/** The list resulting from removing all instances of X from L.
 * Original contents of L may be destroyed. */
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 instances of X from L.
 * Original contents of L may be destroyed. */
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;
}
```

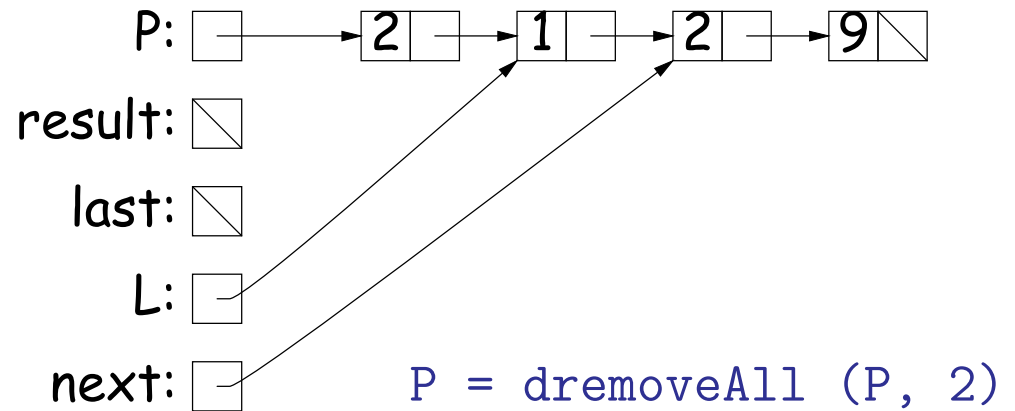


Iterative Destructive Deletion

```

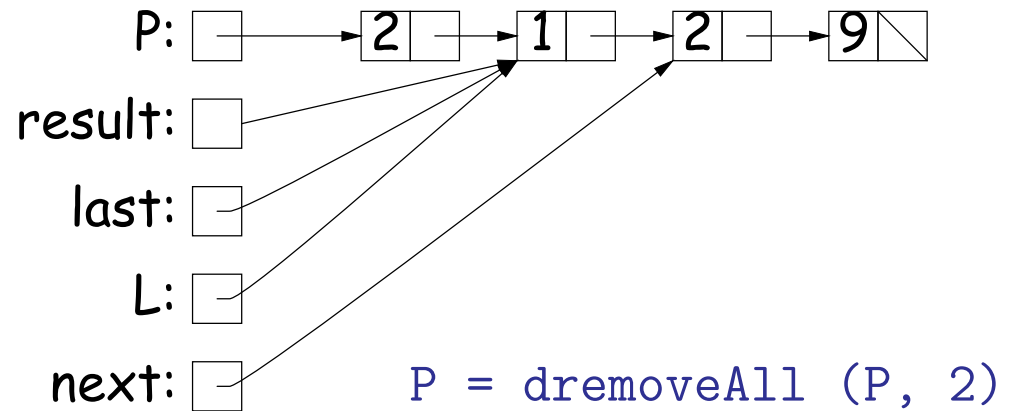
/** The list resulting from removing all instances of X from L.
 * Original contents of L may be destroyed. */
static IntList dremoveAll (IntList L, int x) {
    IntList result, last;
    result = last = null;
    while (L != null) {
        IntList next = L.tail;
        if (x != L.head) {
            if (last == null)
                result = last = L;
            else
                last = last.tail = L;
            L.tail = null;
        }
        L = next;
    }
    return result;
}

```



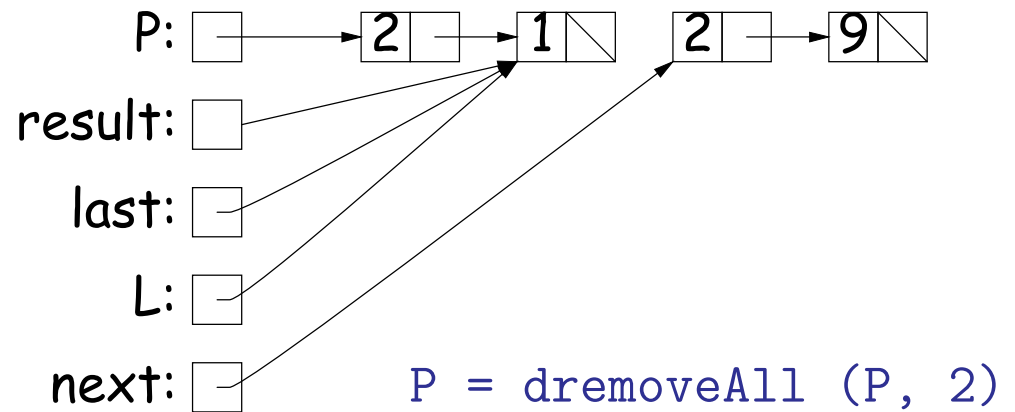
Iterative Destructive Deletion

```
/** The list resulting from removing all instances of X from L.
 * Original contents of L may be destroyed. */
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 instances of X from L.
 * Original contents of L may be destroyed. */
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;
}
```

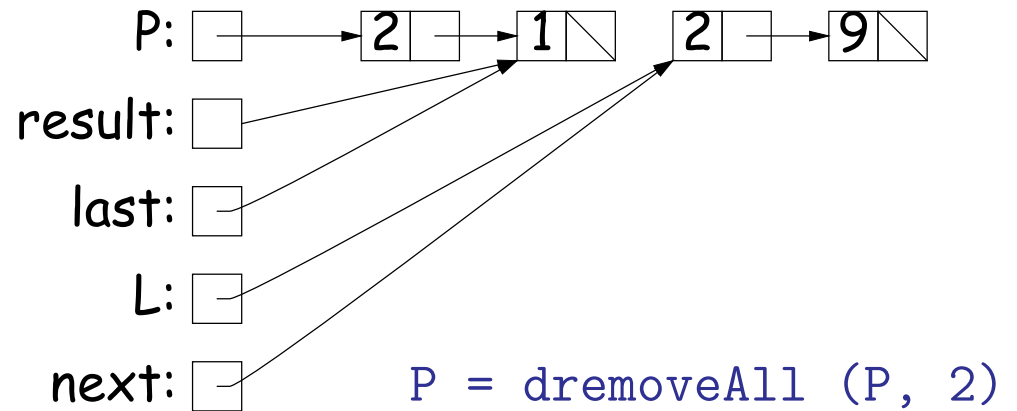


Iterative Destructive Deletion

```

/** The list resulting from removing all instances of X from L.
 * Original contents of L may be destroyed. */
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;
}

```

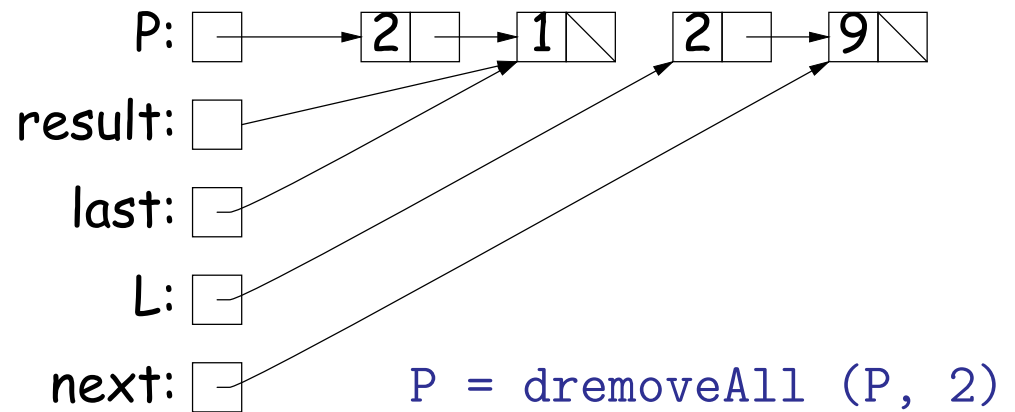


Iterative Destructive Deletion

```

/** The list resulting from removing all instances of X from L.
 * Original contents of L may be destroyed. */
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;
}

```

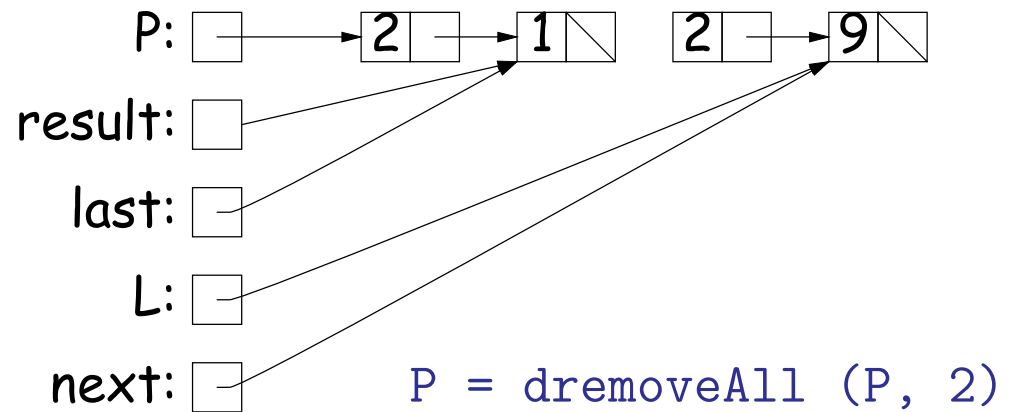


Iterative Destructive Deletion

```

/** The list resulting from removing all instances of X from L.
 * Original contents of L may be destroyed. */
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;
}

```

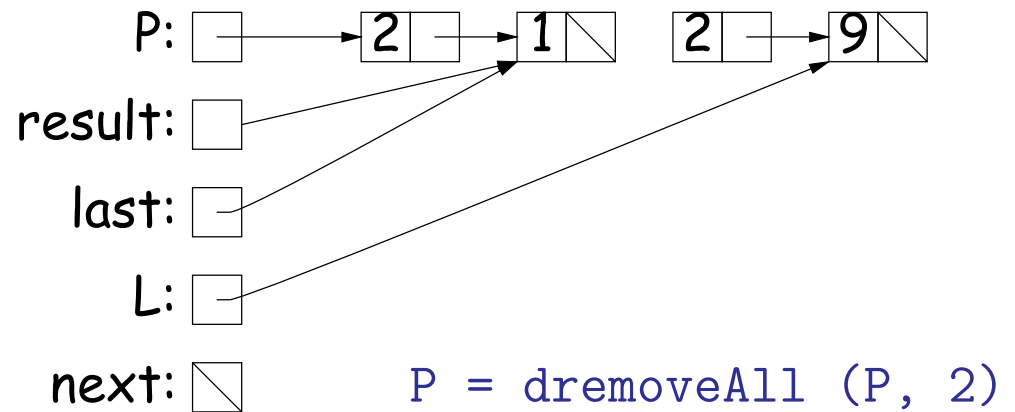


Iterative Destructive Deletion

```

/** The list resulting from removing all instances of X from L.
 * Original contents of L may be destroyed. */
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;
}

```

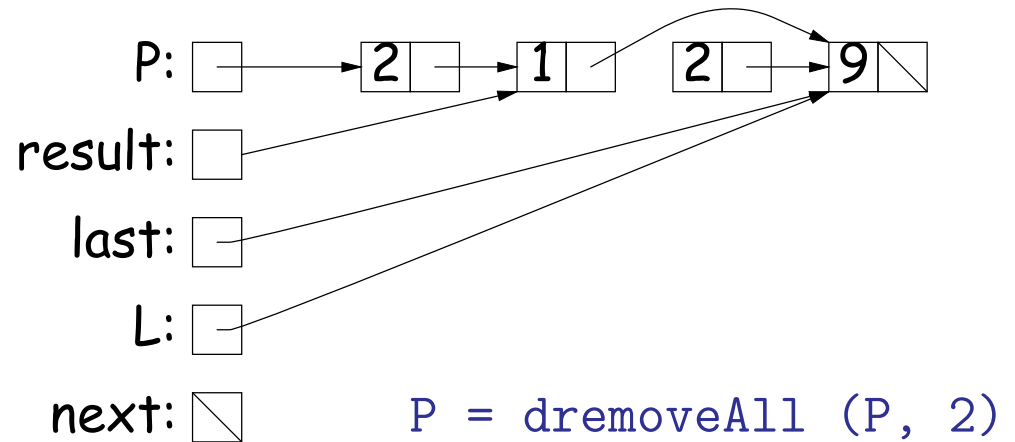


Iterative Destructive Deletion

```

/** The list resulting from removing all instances of X from L.
 * Original contents of L may be destroyed. */
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;
}

```

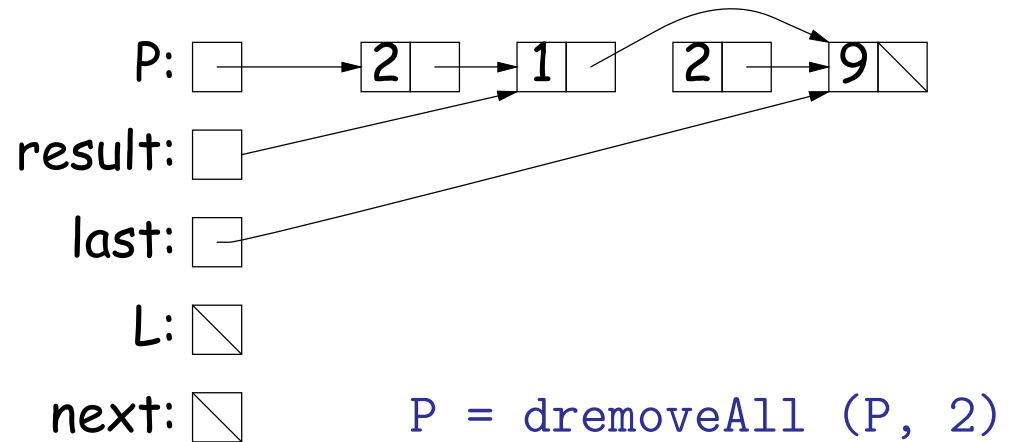


Iterative Destructive Deletion

```

/** The list resulting from removing all instances of X from L.
 * Original contents of L may be destroyed. */
static IntList dremoveAll (IntList L, int x) {
    IntList result, last;
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        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

```

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    if (x != L.head) {
      if (last == null)
        result = last = L;
      else
        last = last.tail = L;
      L.tail = null;
    }
    L = next;
  }
  return result;
}

```

