AUBURN
UNIVERSITY

SAMUEL GINN
COLLEGE OF ENGINEERING

Linked Structures

COMP 2210 – Dr. Hendrix

A Bag collection

Revisit the Bag collection with a look at an alternate implementation that uses dynamic memory for the physical storage instead of an array.

```
public interface Bag<T> {
   boolean     add(T element);
   boolean     remove(T element);
   boolean     contains(T element);
   int         size();
   boolean     isEmpty();
   Iterator<T> iterator();
}
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public class ArrayBag<T> implements Bag<T> {

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public class LinkedBag<T> implements Bag<T> {

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   . . .
}
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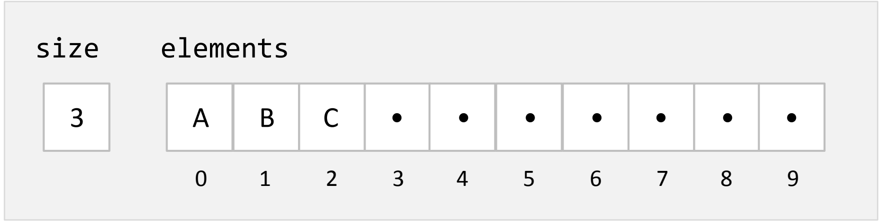

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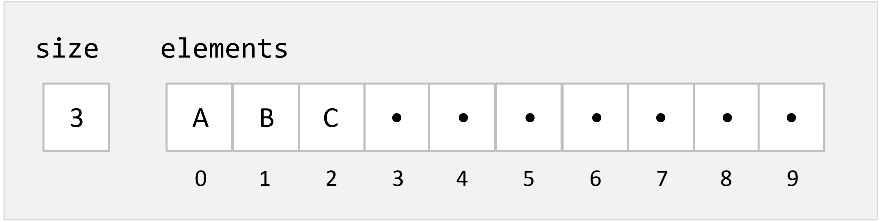

Advantages of using an array:

- fast random access to any element
- efficient use of memory
- built into the language; a “common currency” for any data storage scheme

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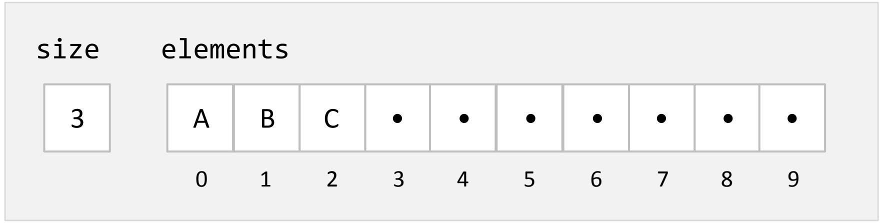

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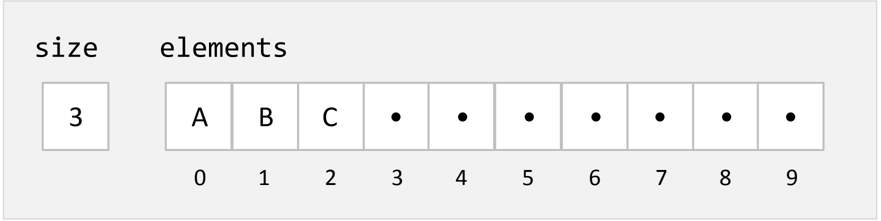

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A storage scheme using dynamic memory will address these disadvantages at the cost of losing random access.

LinkedBag

```java
public class LinkedBag<T> implements Bag<T> {

    private ??? front;
    private int size;
    . . .
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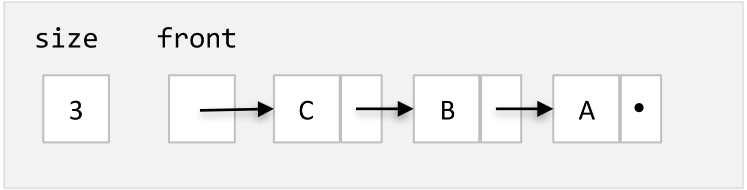

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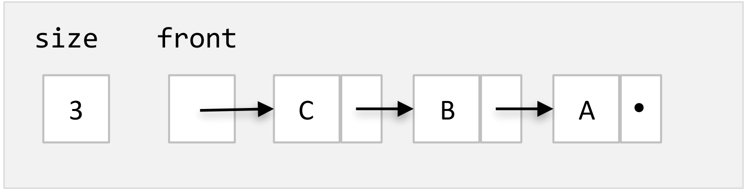

Individual containers are explicitly linked together. Each container holds one element and a reference to another container.

LinkedBag

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   private Node front;
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   . . .






}
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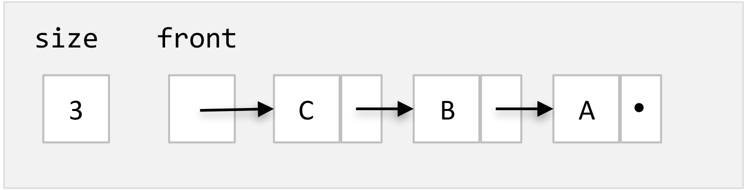

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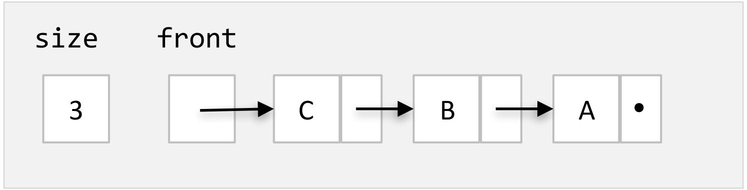

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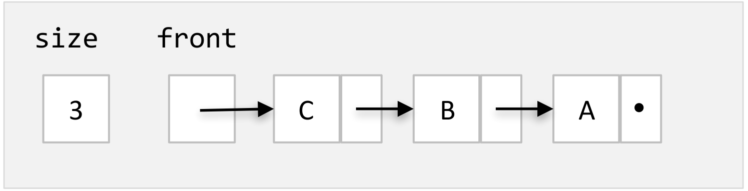

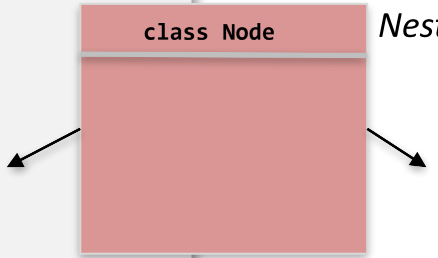

Nested or top-level?

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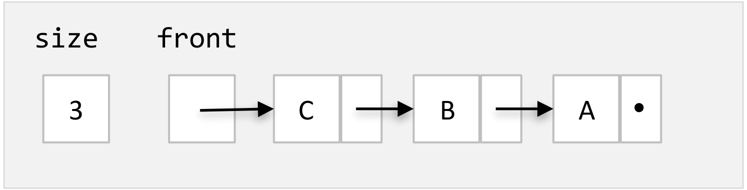

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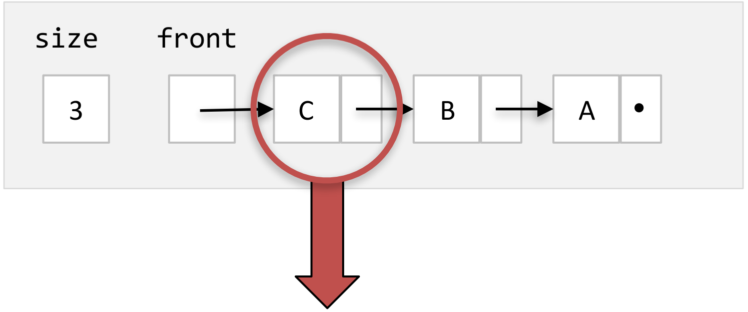

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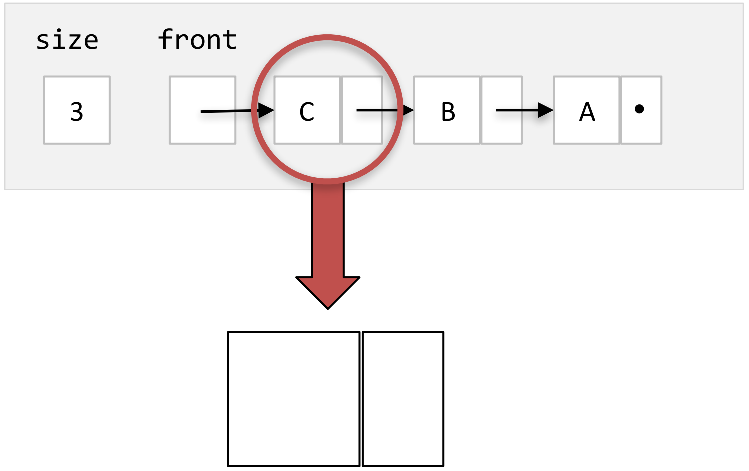

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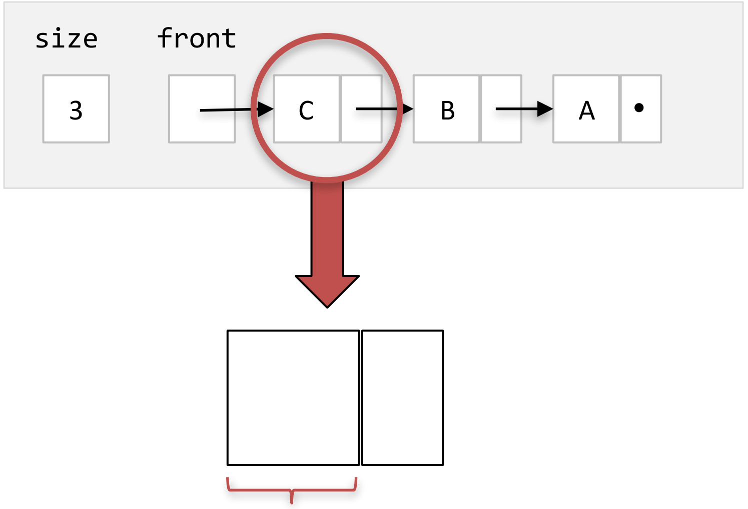

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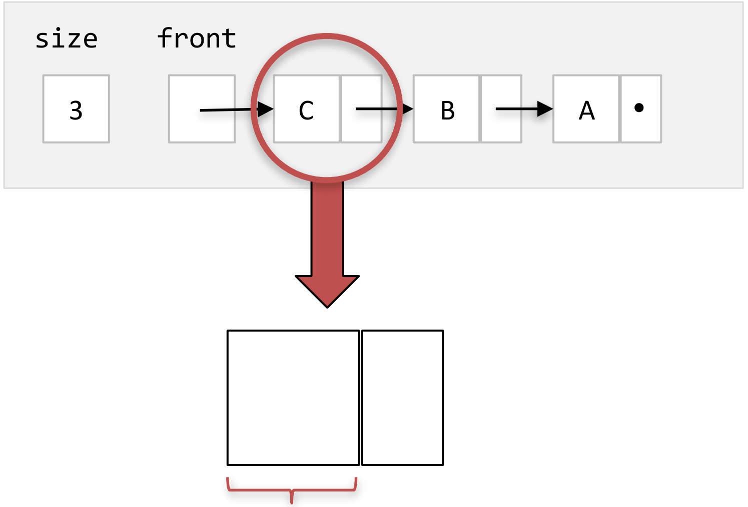

A reference to the element/value this node stores.

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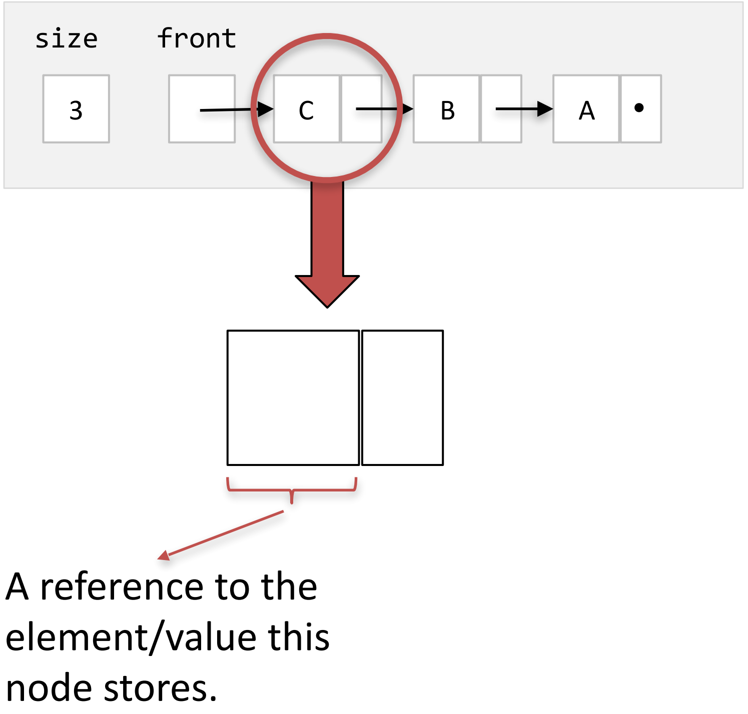

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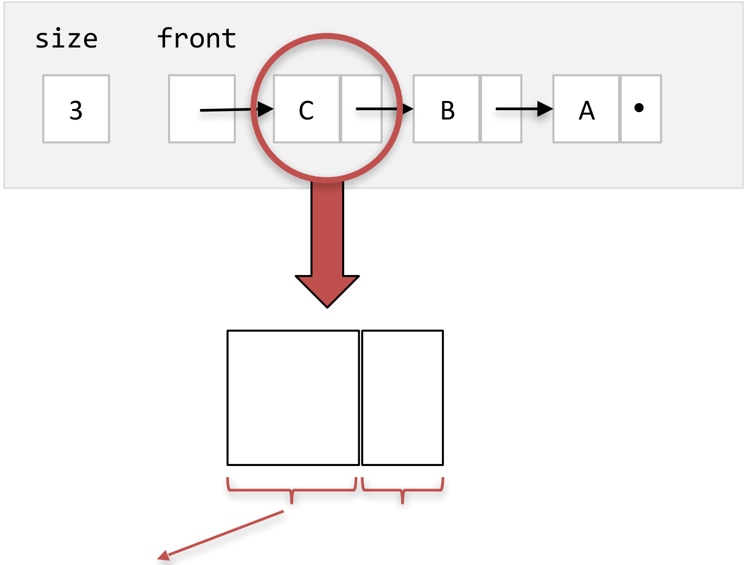

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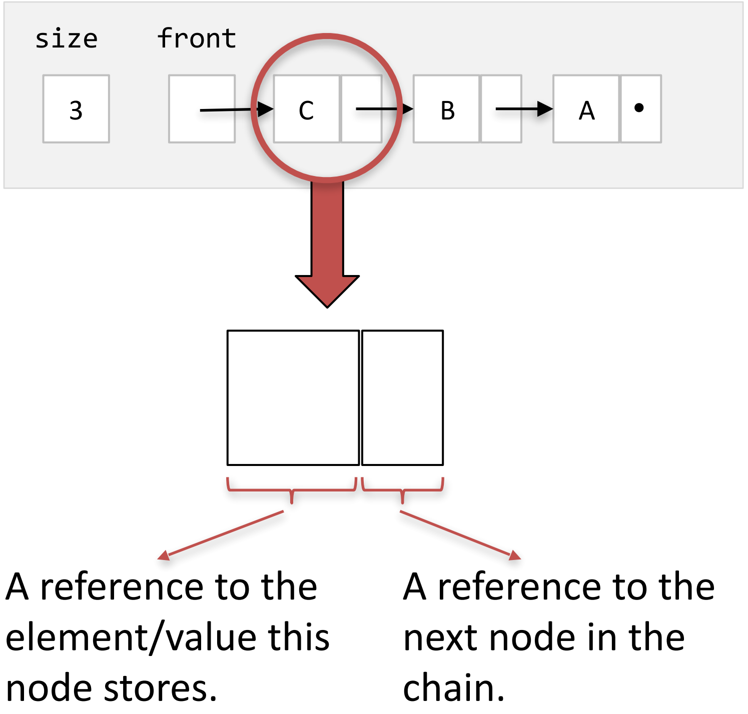

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A reference to the next node in the chain.

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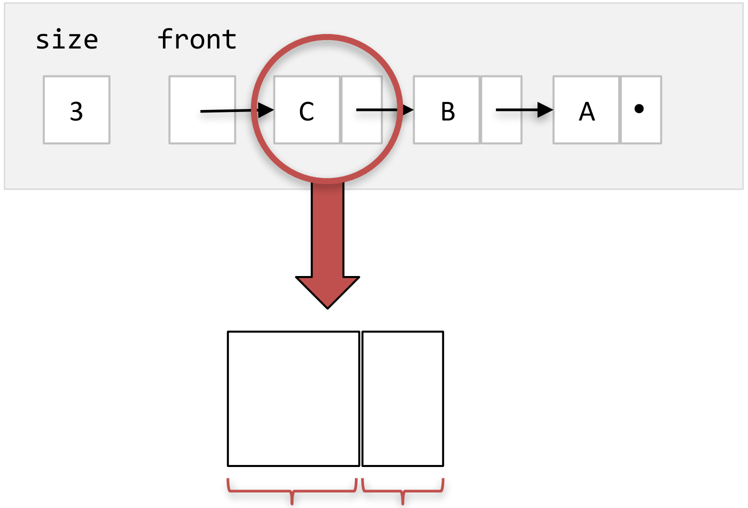

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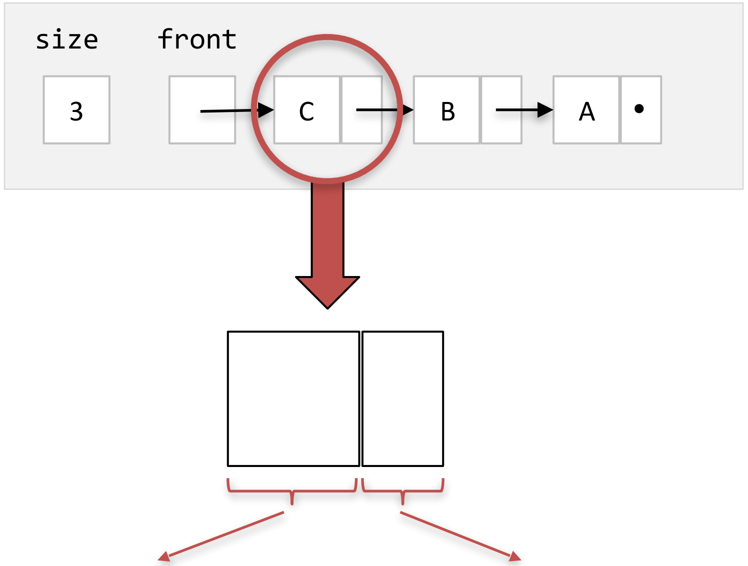
A recursive structure [more to come…]



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The Node class

```
private class Node {
   private Object element;
   private Node next;

   public Node(Object e) {
      element = e;
   }

   public Node(Object e, Node n) {
      element = e;
      next = n;
   }
}
```

Constructors, garbage

```
n = new Node(1);

n = new Node(2, n);

n = new Node(3);

n = null;
```

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```

Basic linking

```
n = new Node(1);
n = new Node(2, n);
n.next = new Node(3, n.next);
```

```
n = new Node(1, new Node(2));
n.next.next = new Node(3, null);
n = new Node(4, n.next);
```

Participation

Q: Which chain of nodes is created by the following code?

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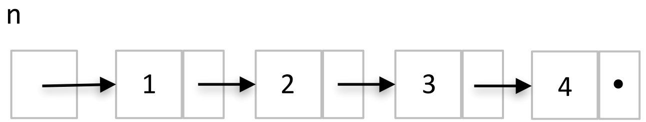

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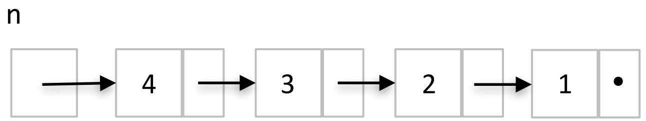

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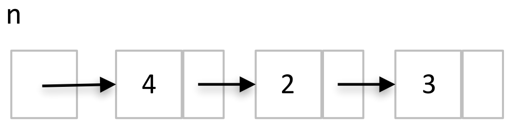

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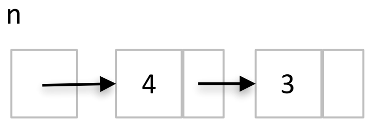

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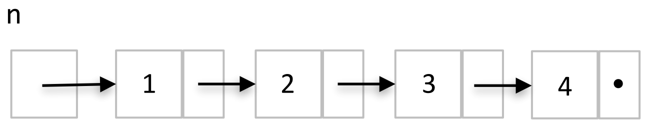

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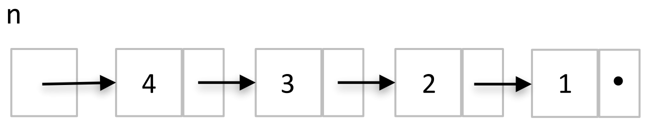

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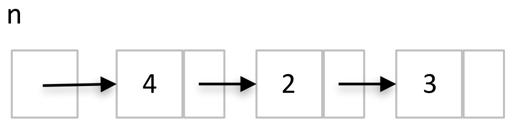

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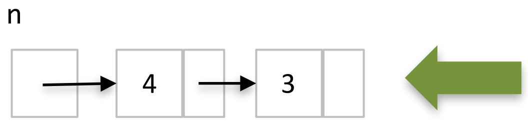

Calculating length

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public int length(Node n) {





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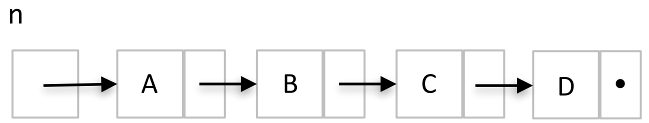

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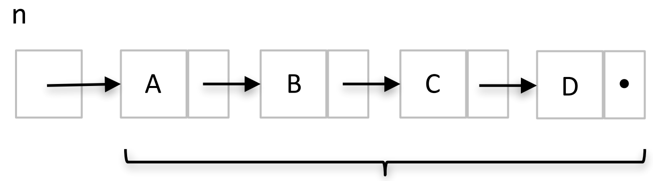

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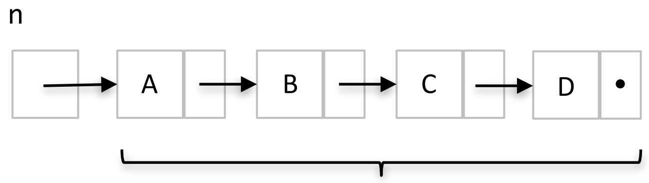

There are four nodes reachable from n, so the "length" of the chain is 4.

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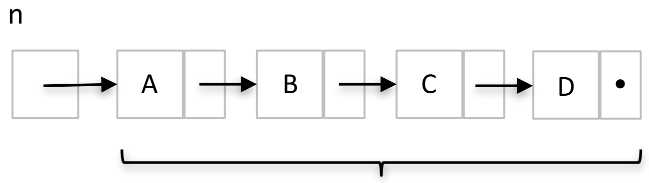

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What solution pattern can we apply here?

Calculating length

```
public int length(Node n) {

        Linear scan

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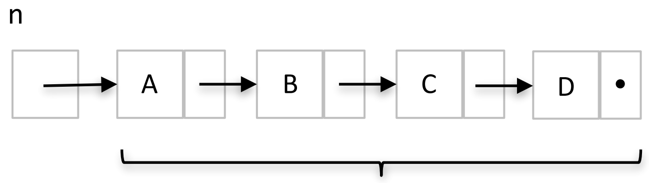

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```
public int length(Node n) {
   Node p = n;

   while (p != null) {

      p = p.next;
   }

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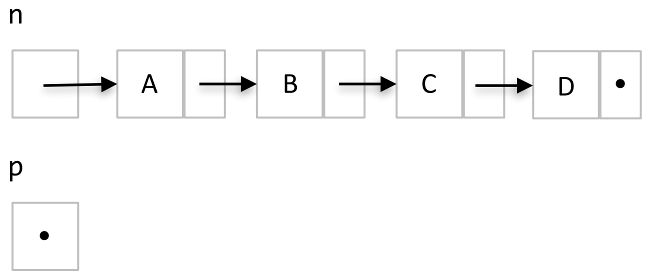

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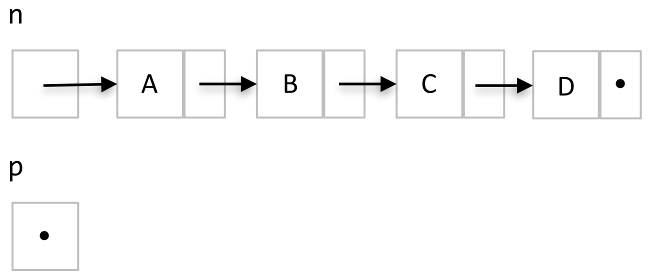

This is a common **traversal** pattern that you will use in many different situations when you have perform a linear scan on a chain of nodes.

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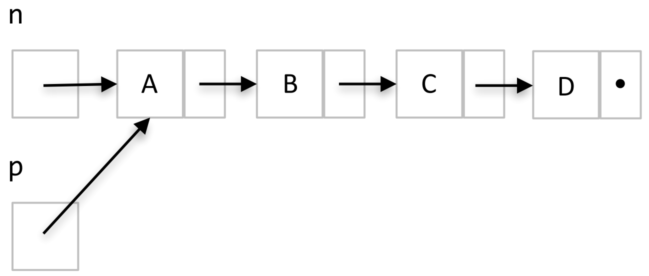

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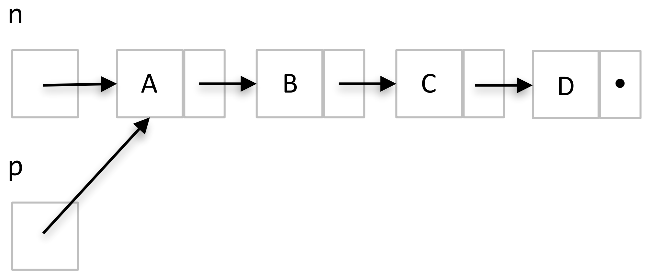

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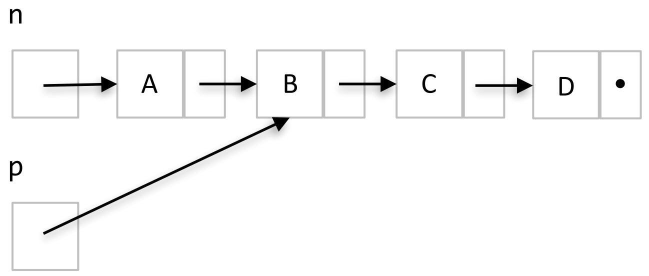

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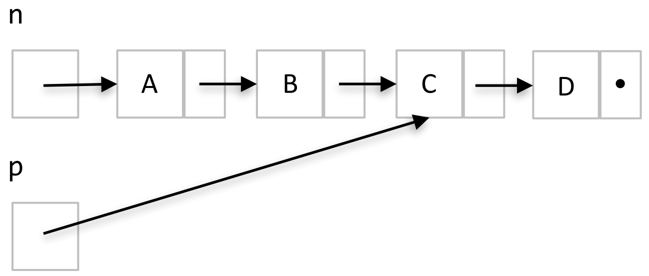

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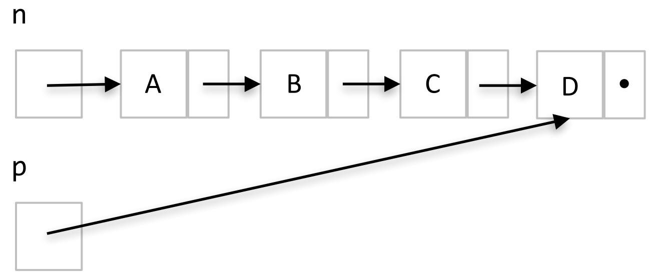

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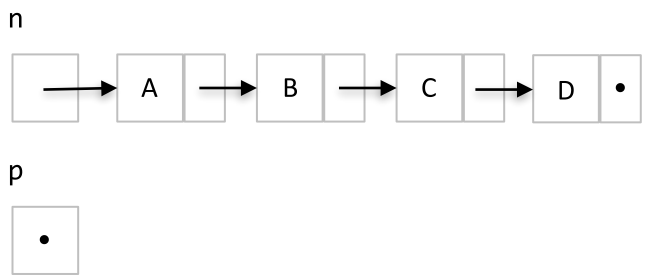

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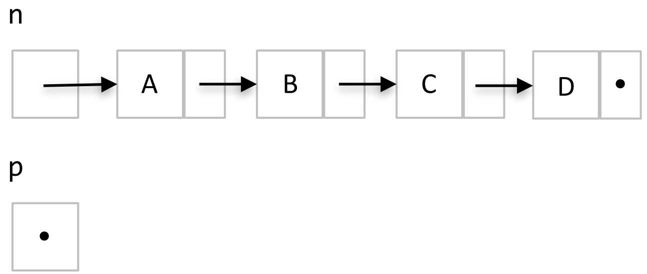

To compute the length of the pointer chain, simply add the statements to count each node that is accessed during the linear scan.

Calculating length

```
public int length(Node n) {
   Node p = n;
   int len = 0;
   while (p != null) {
      len++;
      p = p.next;
   }
   return len;
}
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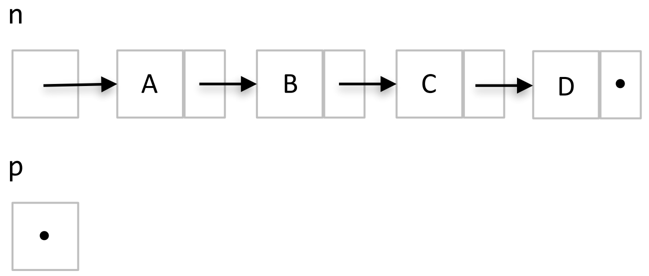

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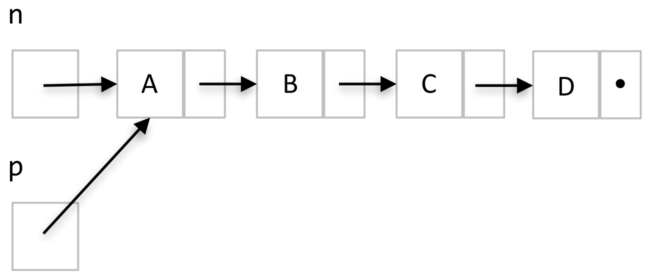

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}
```
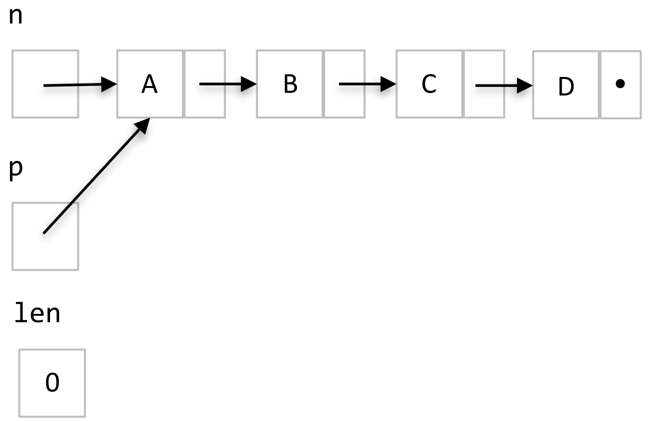
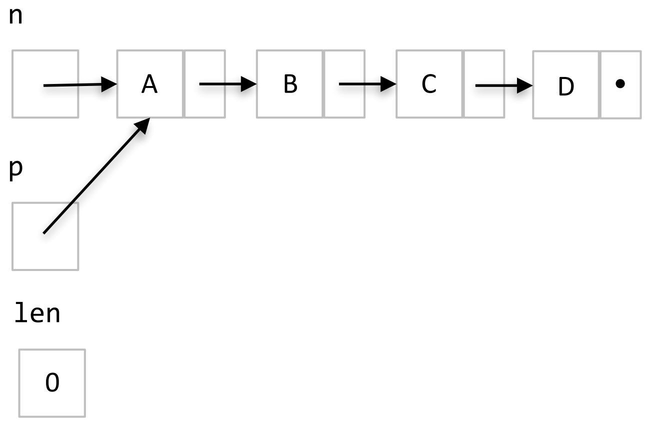



To compute the length of the pointer chain, simply add the statements to count each node that is accessed during the linear scan.

Calculating length

```
public int length(Node n) {
   Node p = n;
   int len = 0;
   while (p != null) {
      len++;
      p = p.next;
   }
   return len;
}
```



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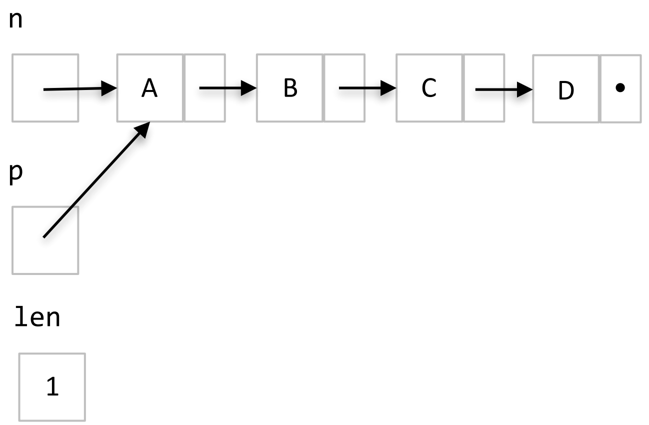

Calculating length

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      len++;
      p = p.next;
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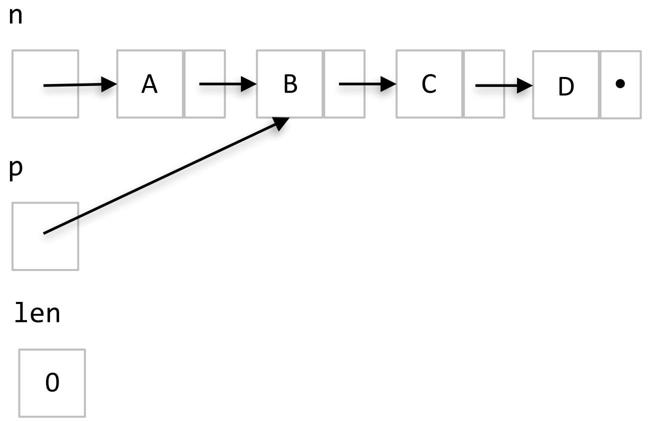

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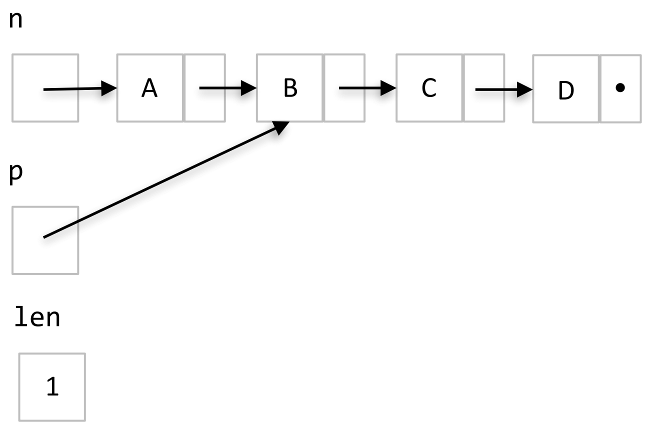

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      p = p.next;
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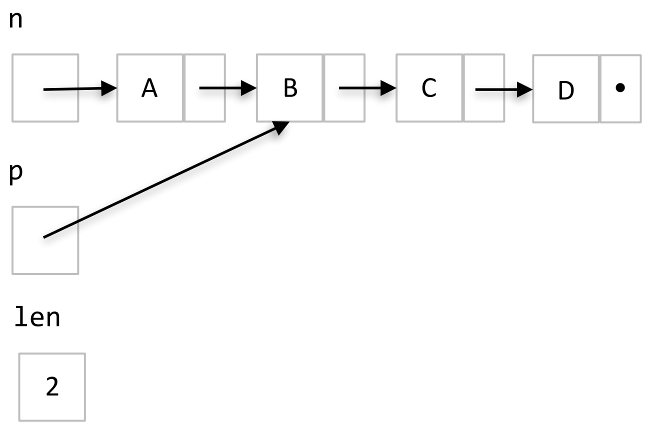

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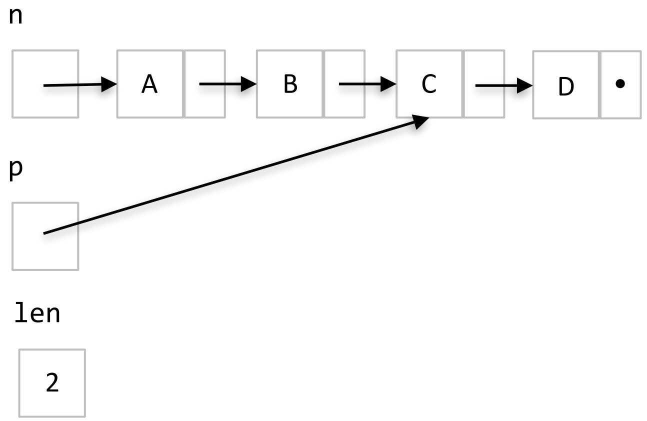
      len++;
      p = p.next;
   }
   return len;
}
```



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      len++;
      p = p.next;
   }
   return len;
}
```

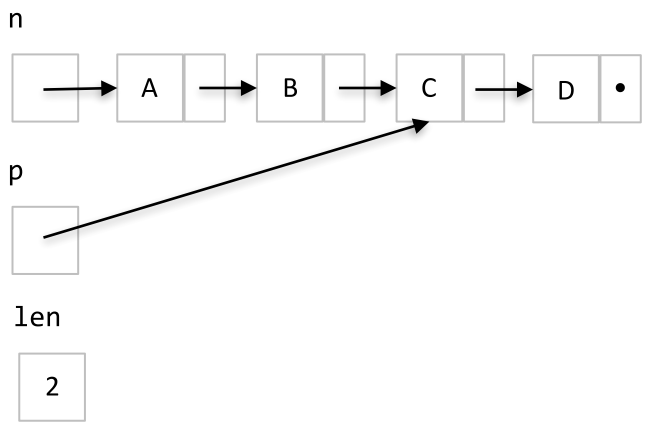

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      len++;
      p = p.next;
   }
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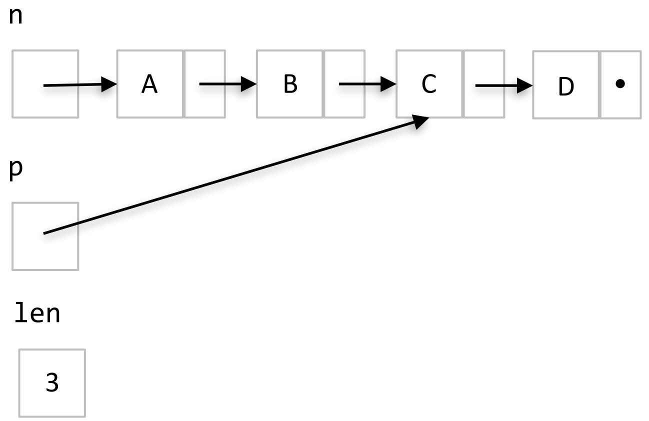
}
```



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   int len = 0;
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      len++;
      p = p.next;
   }
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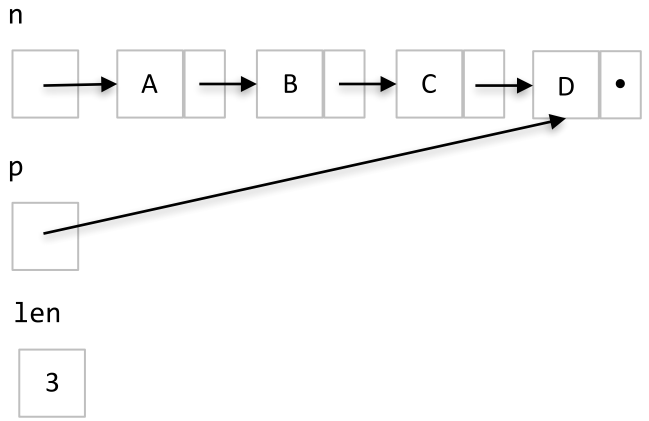

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Calculating length

```
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   int len = 0;
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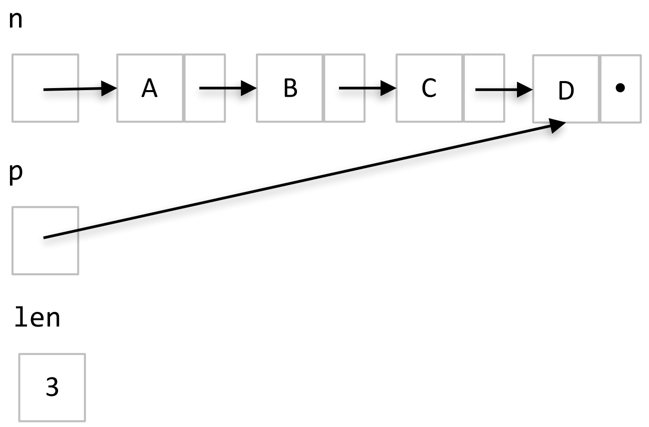
      len++;
      p = p.next;
   }
   return len;
}
```



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Calculating length

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   Node p = n;
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   while (p != null) {
      len++;
      p = p.next;
   }
   return len;
}
```
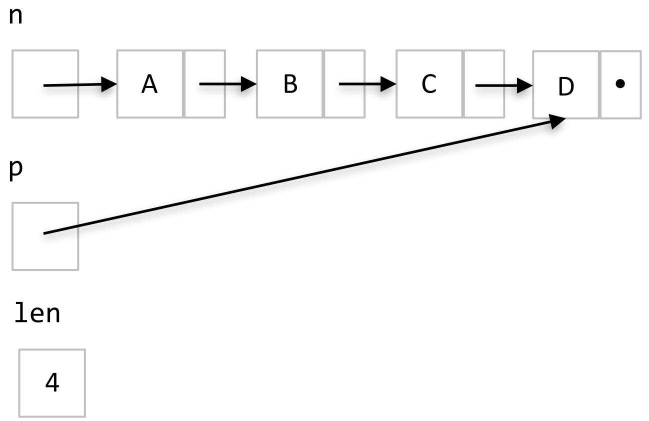
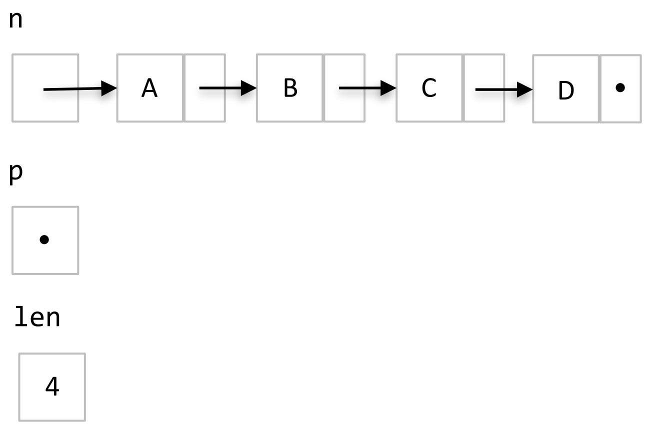



To compute the length of the pointer chain, simply add the statements to count each node that is accessed during the linear scan.

Calculating length

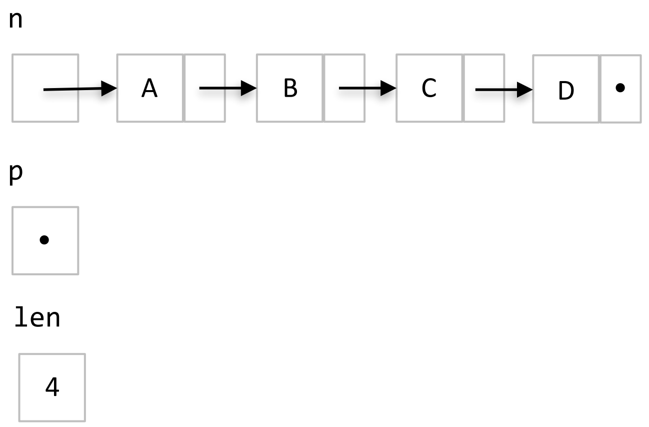
```java
public int length(Node n) {
   Node p = n;
   int len = 0;
   while (p != null) {
      len++;
      p = p.next;
   }
   return len;
}
```



To compute the length of the pointer chain, simply add the statements to count each node that is accessed during the linear scan.

Calculating length

```
public int length(Node n) {
   Node p = n;
   int len = 0;
   while (p != null) {
      len++;
      p = p.next;
   }
   return len;
}
```



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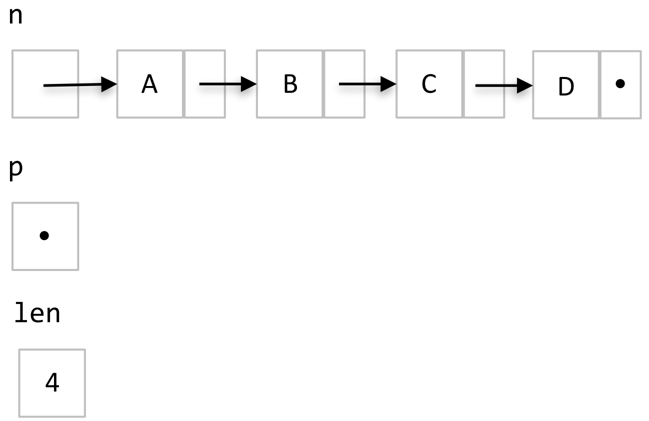
   Node p = n;
   int len = 0;
   while (p != null) {
      len++;
      p = p.next;
   }
   return len;
}
```



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Calculating length

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   Node p = n;
   int len = 0;
   while (p != null) {
      len++;
      p = p.next;
   }
   return len;
}
```
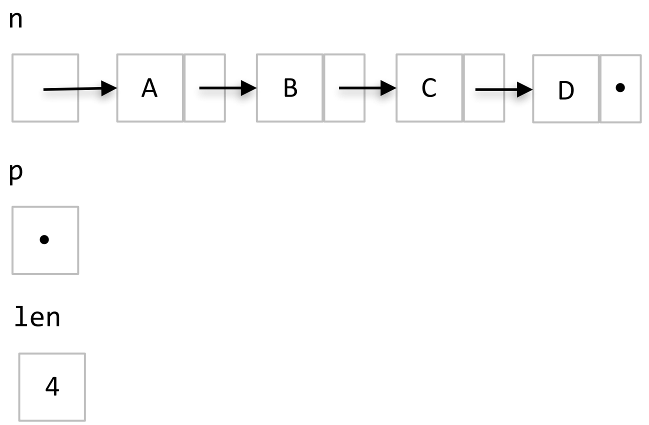
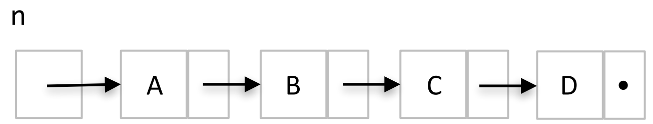



To compute the length of the pointer chain, simply add the statements to count each node that is accessed during the linear scan.

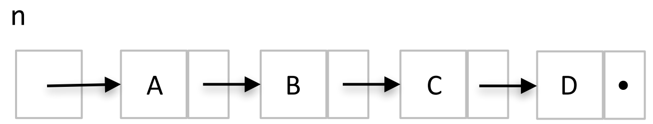
Linear search

```
public boolean contains(Node n, Object target) {







}
```



Linear search

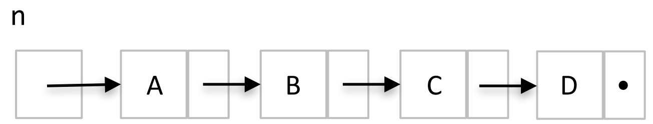
```
public boolean contains(Node n, Object target) {
    Node p = n;
    while (p != null) {



        p = p.next;
    }

}
```



Linear scan pattern

Linear search

```
public boolean contains(Node n, Object target) {
   Node p = n;
   while (p != null) {
      if (p.element.equals(target)) {
         return true;
      }
      p = p.next;
   }
   return false;
}
```



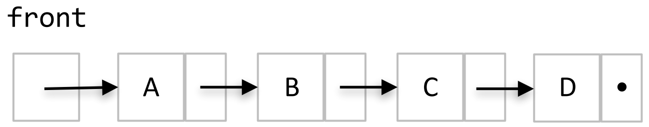
Linear scan pattern

+

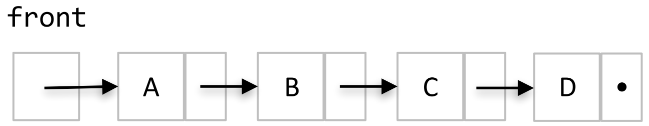
Problem-specific code

Inserting nodes

Inserting a new first node

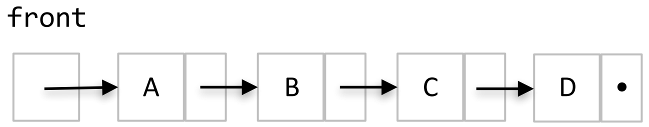


Inserting a new node somewhere else

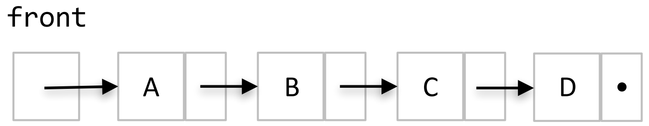


Inserting nodes

Inserting a new first node



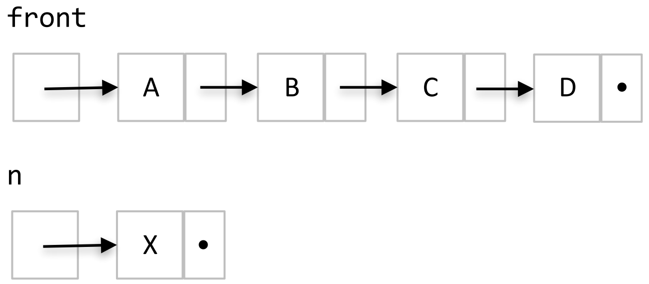
Inserting a new node somewhere else



```
Node n = new Node(“X”);
```

Inserting nodes

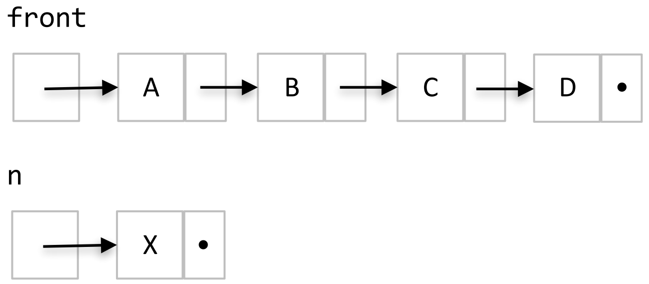
Inserting a new first node



```
Node n = new Node("X");
```

Inserting nodes

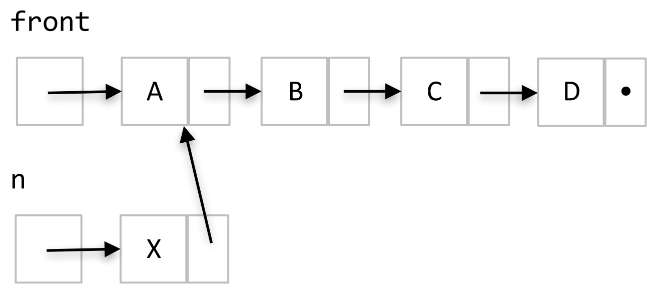
Inserting a new first node



```
Node n = new Node("X");


if (inserting a new first node) {


}
```

Inserting nodes

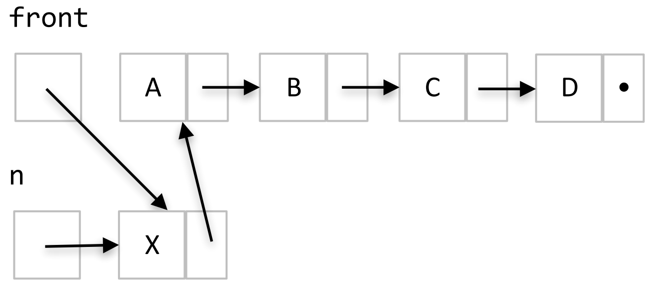
Inserting a new first node



```
Node n = new Node("X");


if (inserting a new first node) {
   n.next = front;

}
```

Inserting nodes

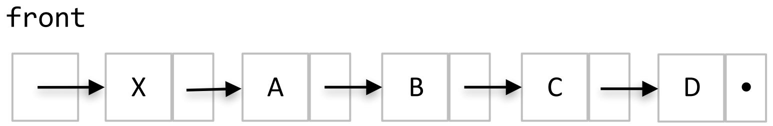
Inserting a new first node



```
Node n = new Node(“X”);


if (inserting a new first node) {
   n.next = front;
   front = n;
}
```

Inserting nodes

Inserting a new first node

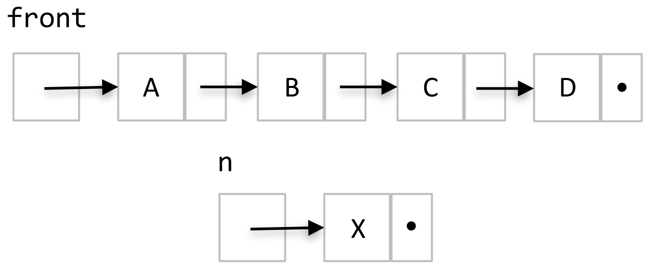


```
Node n = new Node(“X”);


if (inserting a new first node) {
   n.next = front;
   front = n;
}
```

Inserting nodes

```
Node n = new Node(“X”);


if (inserting a new first node) {
   n.next = front;
   front = n;
}


else {




}
```

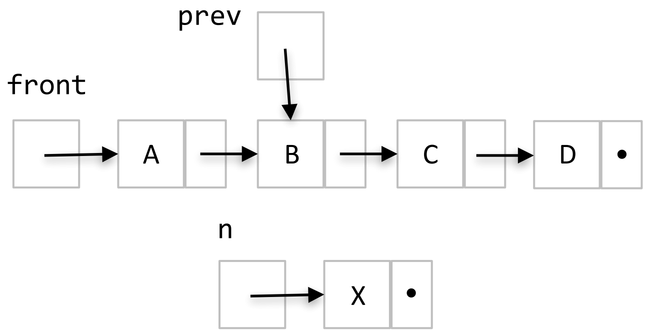
Inserting a new node somewhere else



Inserting nodes

```
Node n = new Node("X");


if (inserting a new first node) {
   n.next = front;
   front = n;
}


else {
   Node prev;
   // find the right spot with prev


}
```

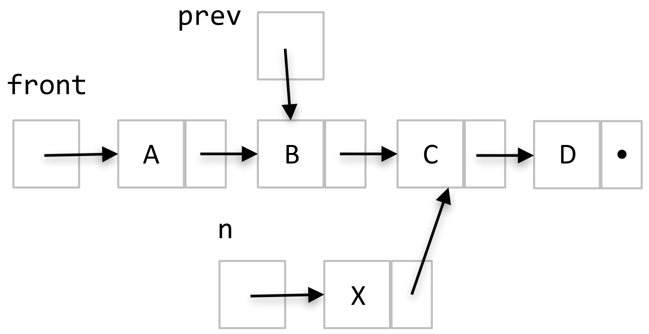
Inserting a new node somewhere else



Inserting nodes

```
Node n = new Node(“X”);


if (inserting a new first node) {
   n.next = front;
   front = n;
}


else {
   Node prev;
   // find the right spot with prev
   n.next = prev.next;

}
```

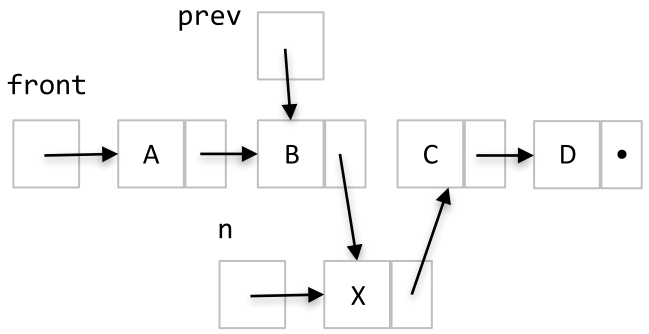
Inserting a new node somewhere else



Inserting nodes

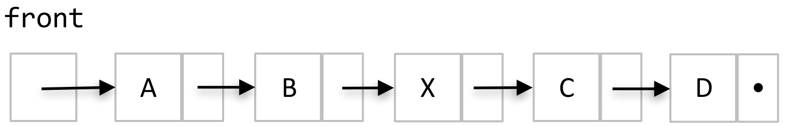
```
Node n = new Node(“X”);


if (inserting a new first node) {
   n.next = front;
   front = n;
}


else {
   Node prev;
   // find the right spot with prev
   n.next = prev.next;
   prev.next = n;
}
```

Inserting a new node somewhere else



Inserting nodes

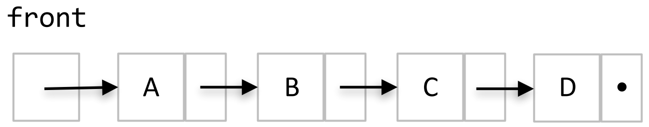
Inserting a new node somewhere else



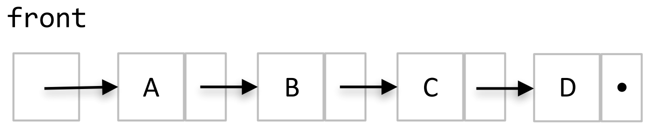
```
Node n = new Node("X");


if (inserting a new first node) {
   n.next = front;
   front = n;
}


else {
   Node prev;
   // find the right spot with prev
   n.next = prev.next;
   prev.next = n;
}
```

Deleting nodes

Deleting the first node



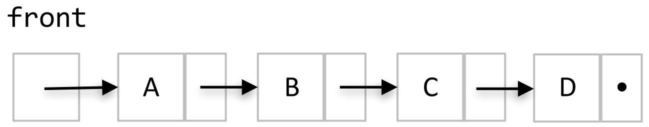
Deleting any other node



```
if (deleting the first node) {

}

else {


}
```

Deleting nodes

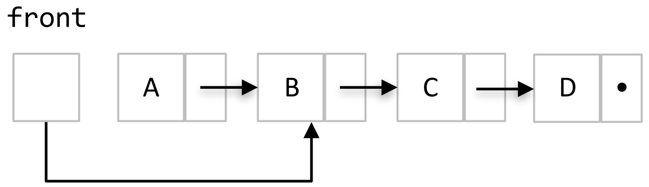
Deleting the first node



```
if (deleting the first node) {
   front = front.next;

}


else {




}
```

Deleting nodes

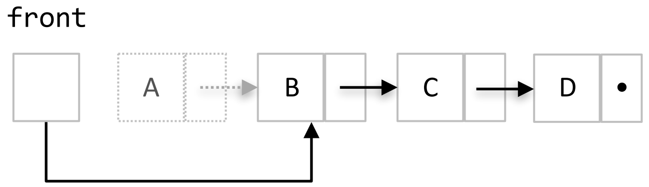
Deleting the first node



```
if (deleting the first node) {
   front = front.next;
}



else {




}
```

Deleting nodes

Deleting the first node

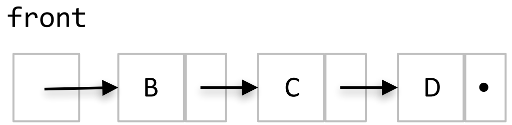


The node containing A is now garbage.

```
if (deleting the first node) {
   front = front.next;
}



else {




}
```

Deleting nodes

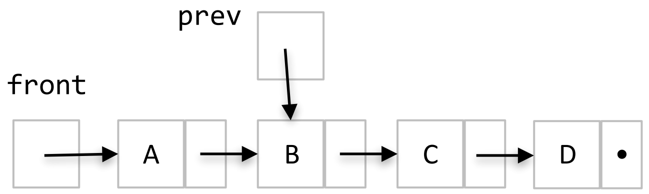
Deleting the first node



```
if (deleting the first node) {
   front = front.next;
}



else {




}
```

Deleting nodes

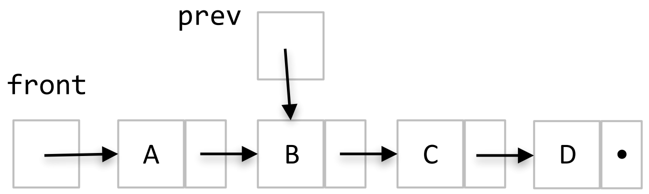
Deleting any other node



```
if (deleting the first node) {
   front = front.next;
}



else {
   Node prev;
   // find the right spot with prev


}
```

Deleting nodes

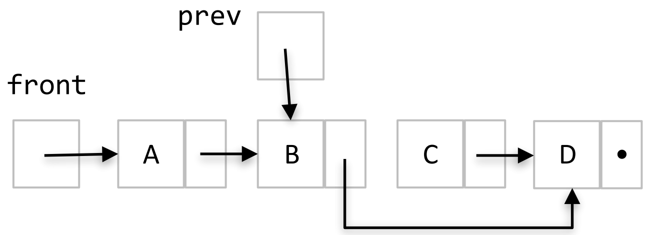
Deleting any other node



```
if (deleting the first node) {
   front = front.next;
}



else {
   Node prev;
   // find the right spot with prev
   prev.next = prev.next.next;

}
```

Deleting nodes

Deleting any other node

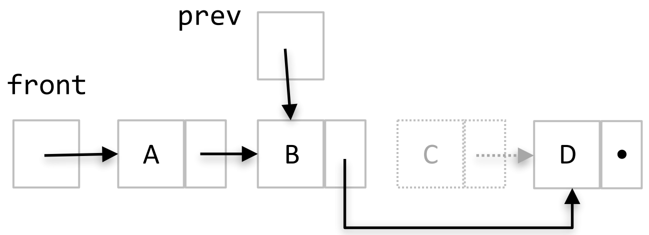


```
if (deleting the first node) {
   front = front.next;
}



else {
   Node prev;
   // find the right spot with prev
   prev.next = prev.next.next;

}
```

Deleting nodes

The node containing C is now garbage.

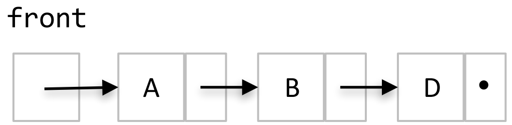
Deleting any other node



```
if (deleting the first node) {
   front = front.next;
}



else {
   Node prev;
   // find the right spot with prev
   prev.next = prev.next.next;

}
```

Deleting nodes

Deleting any other node



```
if (deleting the first node) {
   front = front.next;
}



else {
   Node prev;
   // find the right spot with prev
   prev.next = prev.next.next;

}
```