Recreation

Prove that $\lfloor (2+\sqrt{3})^n \rfloor$ is odd for all integer $n \geq 0$.

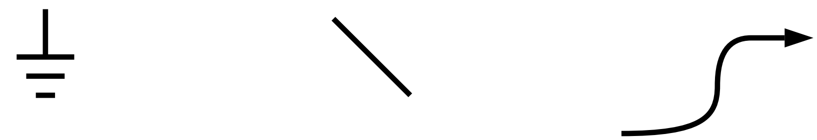
[Source: D. O. Shklarsky, N. N. Chentzov, I. M. Yaglom, *The USSR Olympiad Problem Book*, Dover ed. (1993), from the W. H. Freeman edition, 1962.]

CS61B Lecture #3: Values and Containers

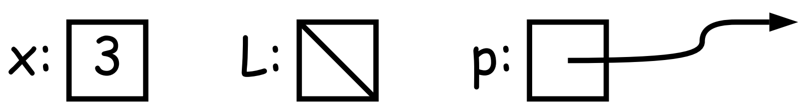
- Labs are normally due at midnight Friday. Last week's lab, however, is due this coming Friday at midnight.
- **Today.** Simple classes. Scheme-like lists. Destructive vs. non-destructive operations. Models of memory.

Values and Containers

- *Values* are numbers, booleans, and pointers. Values never change. (So, for example, the assignment `3 = 2` would be invalid.)

3 'a' true 

- *Simple containers* contain values:

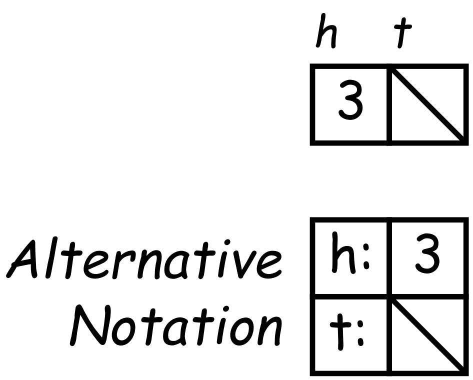


Examples: variables, fields, individual array elements, parameters. The *contents* of containers can change.

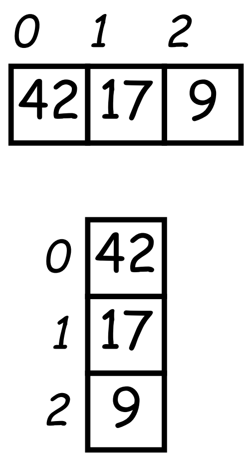
Structured Containers

Structured containers contain (0 or more) other containers:

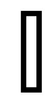
Class Object



Array Object

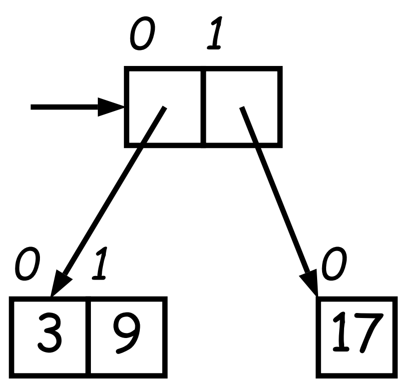


Empty Object



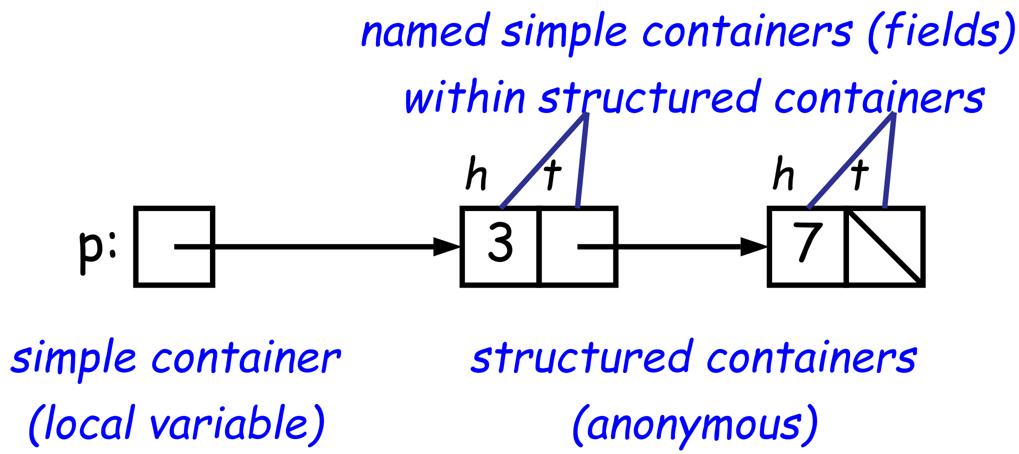
Pointers

- *Pointers* (or *references*) are values that *reference* (point to) containers.
- One particular pointer, called **null**, points to nothing.
- In Java, structured containers contain only simple containers, but pointers allow us to build arbitrarily big or complex structures anyway.



Containers in Java

- Containers may be *named* or *anonymous*.
- In Java, *all* simple containers are named, *all* structured containers are anonymous, and pointers point only to structured containers. (Therefore, structured containers contain only simple containers).



- In Java, assignment copies values into simple containers.
- *Exactly* like Scheme and Python!
- (Python also has slice assignment, as in `x[3:7]=...`, which is shorthand for something else entirely.)

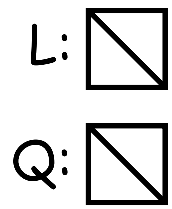
Defining New Types of Object

- Class declarations introduce new types of objects.
- Example: list of integers:

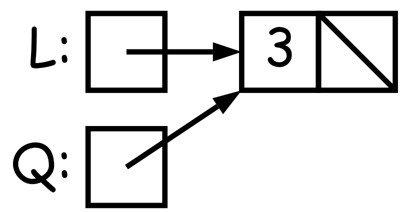
```
public class IntList {
  // Constructor function (used to initialize new object)
  /** List cell containing (HEAD, TAIL). */
  public IntList(int head, IntList tail) {
    this.head = head; this.tail = tail;
  }

  // Names of simple containers (fields)
  // WARNING: public instance variables usually bad style!
  public int head;
  public IntList tail;
}
```

Primitive Operations

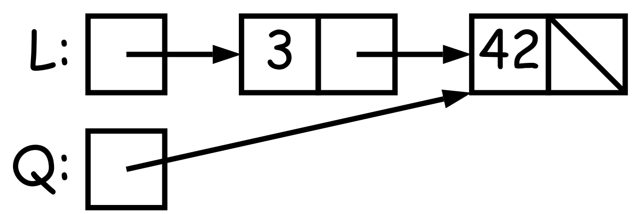
```
IntList Q, L;
```



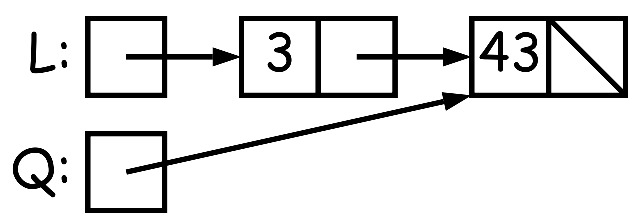

```
L = new IntList(3, null);
Q = L;
```




```
Q = new IntList(42, null);
L.tail = Q;
```

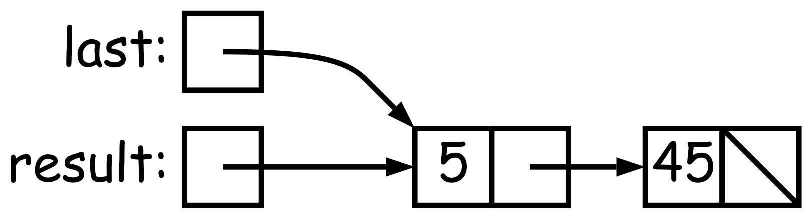



```
L.tail.head += 1;
// Now Q.head == 43
// and L.tail.head == 43
```

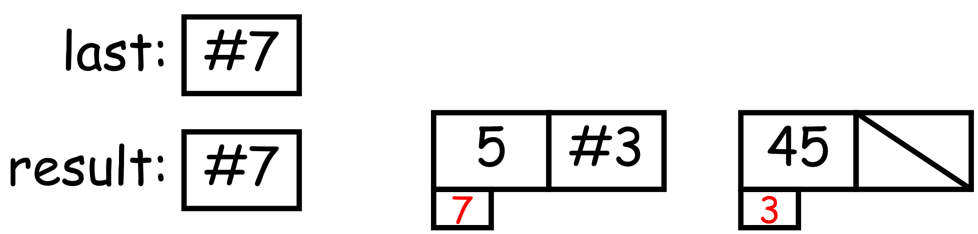


Side Excursion: Another Way to View Pointers

- 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:

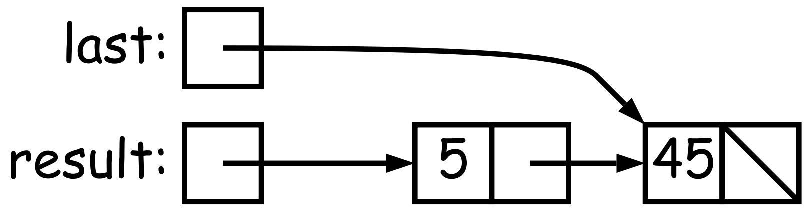


- Alternative view:

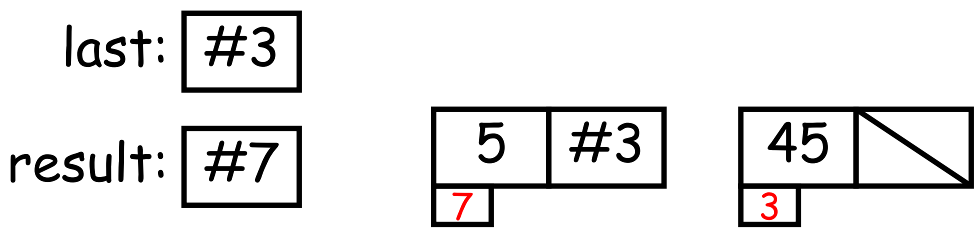


Another Way to View Pointers (II)

- 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.

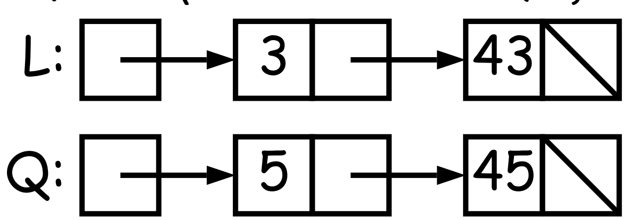
Destructive vs. Non-destructive

Problem: Given a (pointer to a) list of integers, L, and an integer increment n, return a list created by incrementing all elements of the list by n.

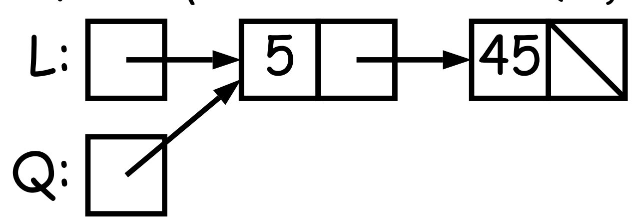
```
/** List of all items in P incremented by n. Does not modify
 *  existing IntLists. */
static IntList incrList(IntList P, int n) {
    return /*( P, with each element incremented by n )*/
}
```

We say `incrList` is *non-destructive,* because it leaves the input objects unchanged, as shown on the left. A *destructive* method may modify the input objects, so that the original data is no longer available, as shown on the right:

After `Q = incrList(L, 2)`:



After `Q = dincrList(L, 2)` (destructive):



Nondestructive IncrList: Recursive

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

- In the call `incrList(P, 2)`, where `P` contains 3 and 43, which `IntList` object gets created first?

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```

- In the call `incrList(P, 2)`, where `P` contains 3 and 43, which `IntList` object gets created first?
- *Answer*: The last one.

Nondestructive IncrList: Why Return the Value?

- If I want to update Q to an incremented list, why must I write

```
Q = incrList(Q, 4); ?
```

- Couldn't I instead just write

```
incrList2(Q, 4);
```

and define

```
/** List of all items in P incremented by n. */
static IntList incrList2(IntList P, int n) {
  if (P == null) {
    P = null;
  } else {
    P = new IntList(P.head+n, incrList2(P.tail, n));
  }
  return P;
} ?
```

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  }
  return P;
} ?
```

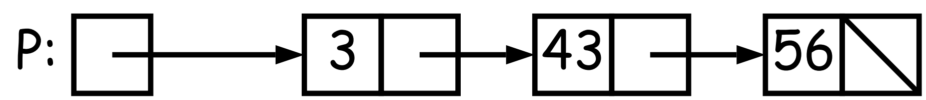
- No. Assigning to the formal parameter does not affect the actual. Java uses call by value, just like Python.

An Iterative Version

An iterative `incrList` is tricky, because it is *not* tail recursive.
Easier to build things first-to-last, unlike recursive version:

```
static IntList incrList(IntList P, int n) {
  if (P == null)
    return null;
  IntList result, last;

  return result;
}
```



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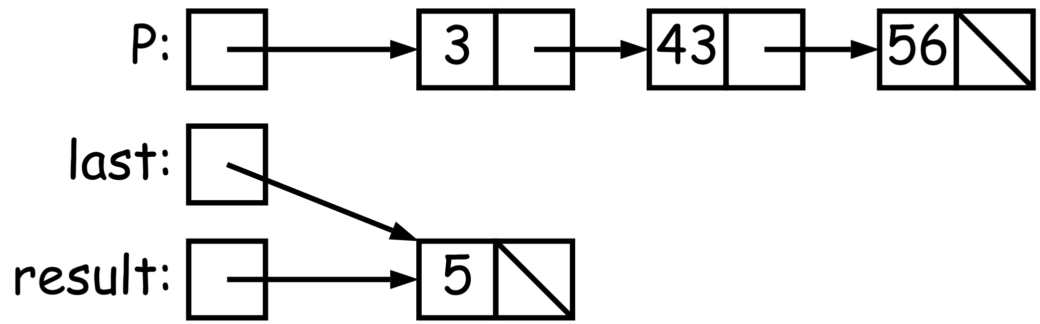

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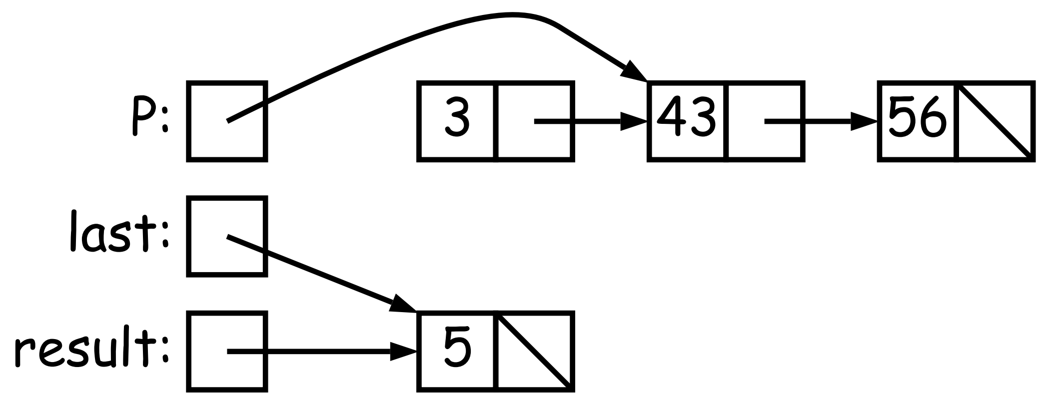

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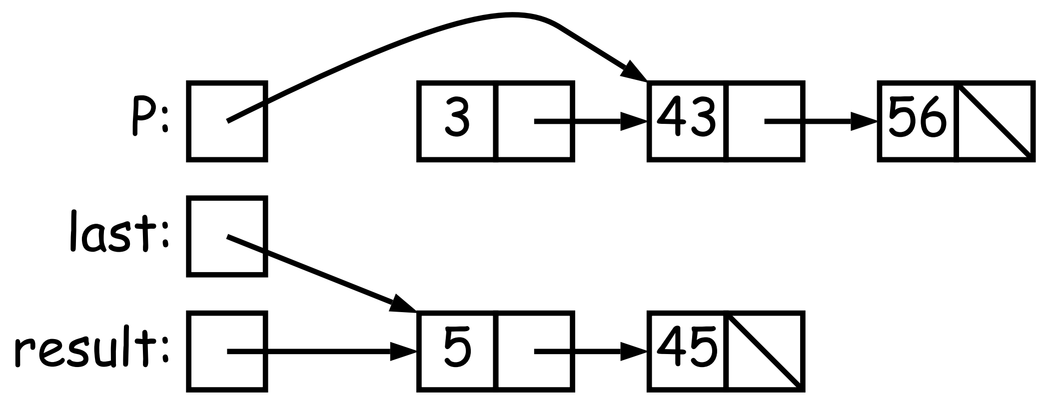

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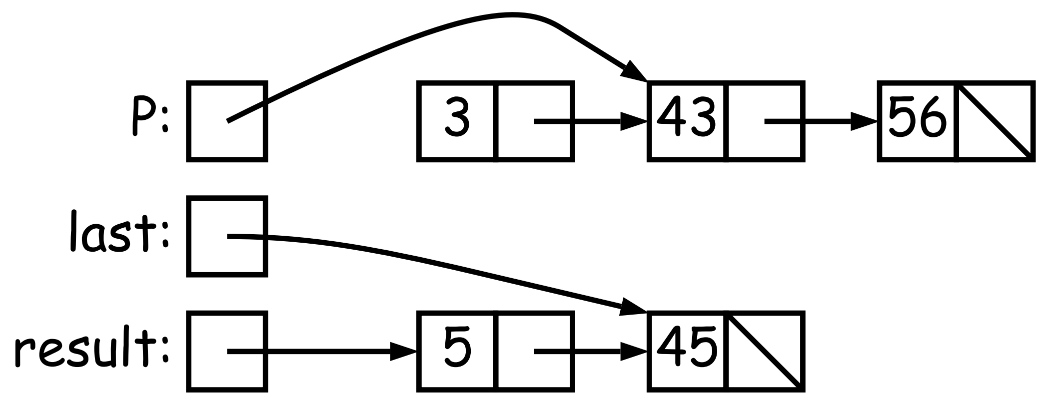

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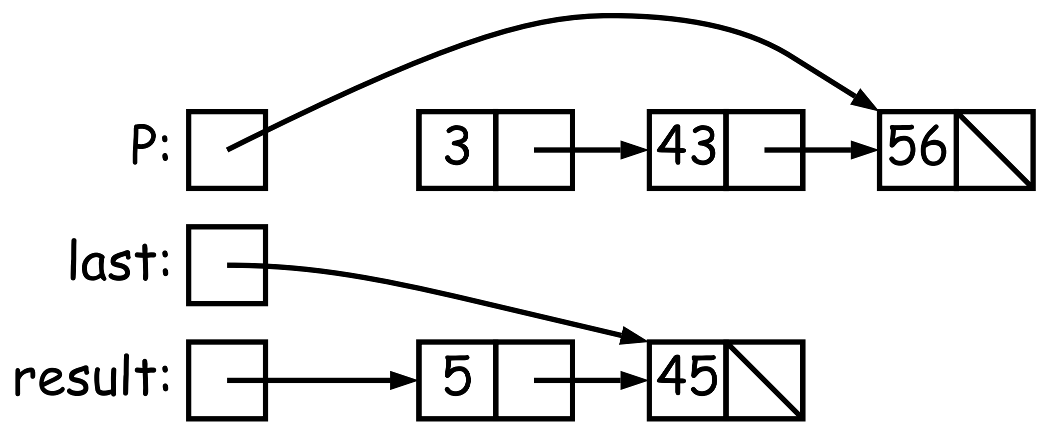

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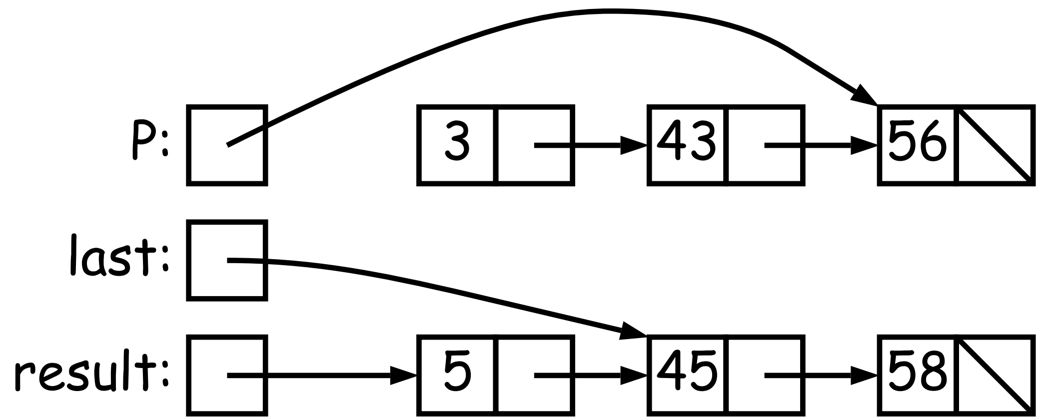

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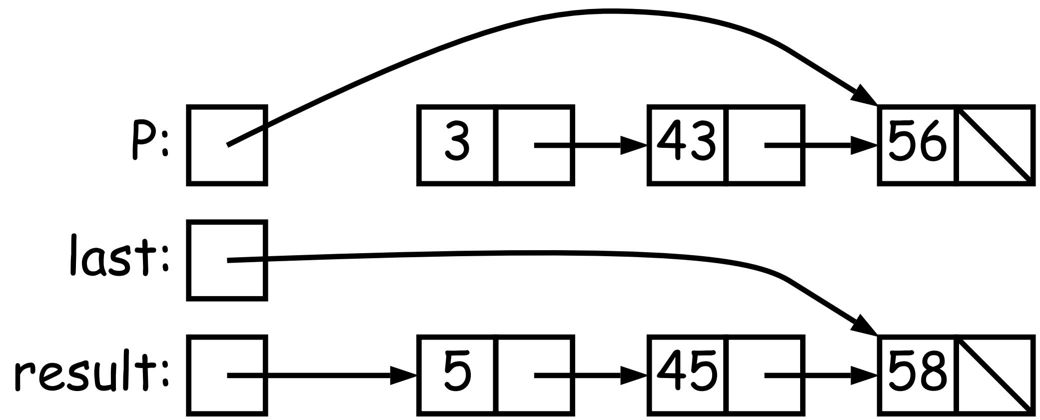

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  IntList result, last;
  result = last
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  while (P.tail != null) {
    P = P.tail;
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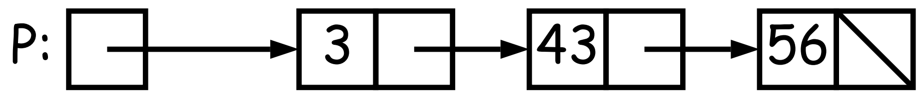

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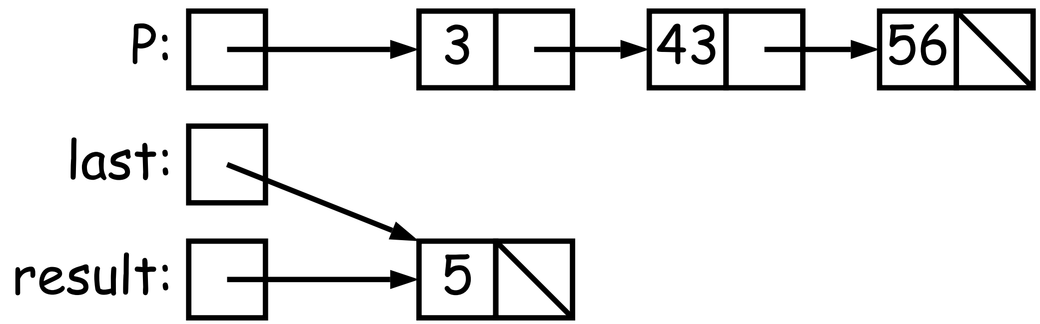

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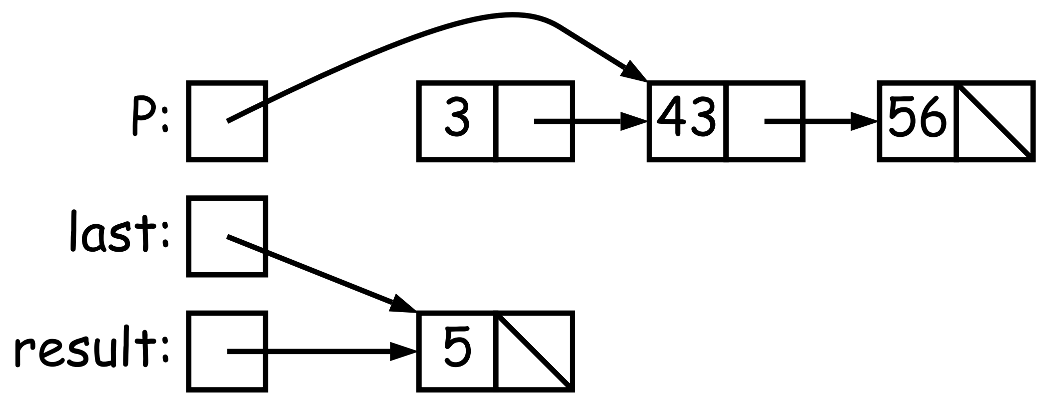

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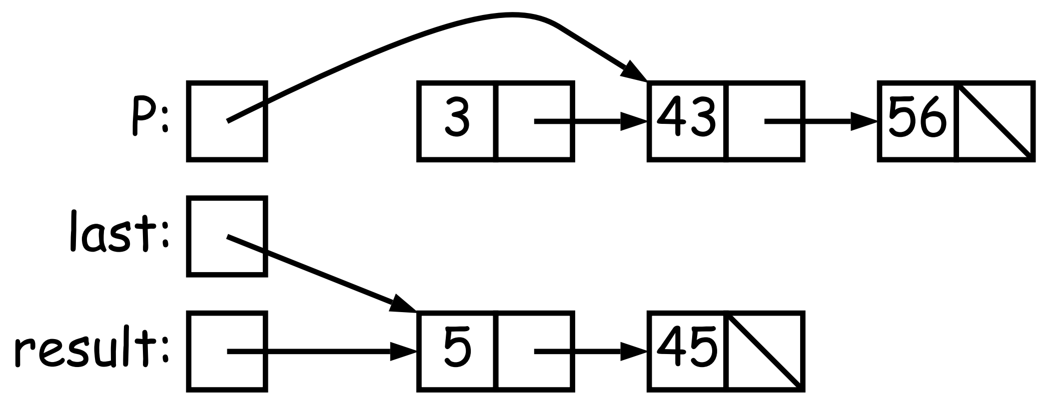

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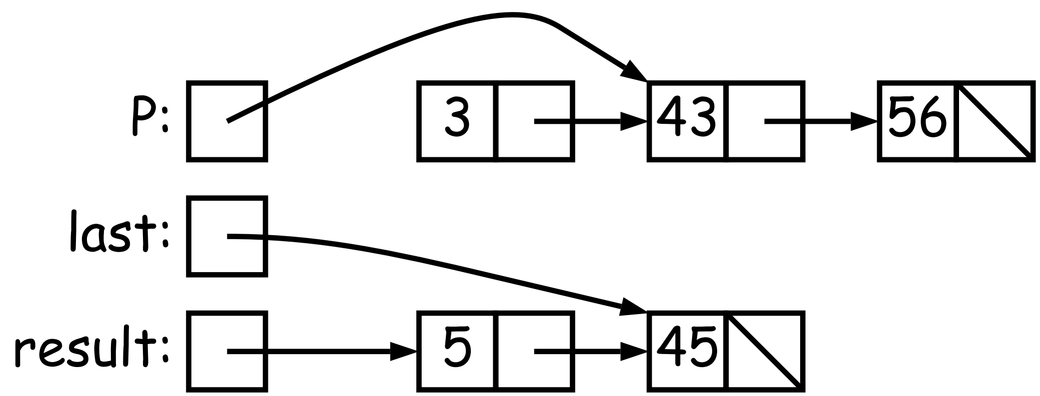

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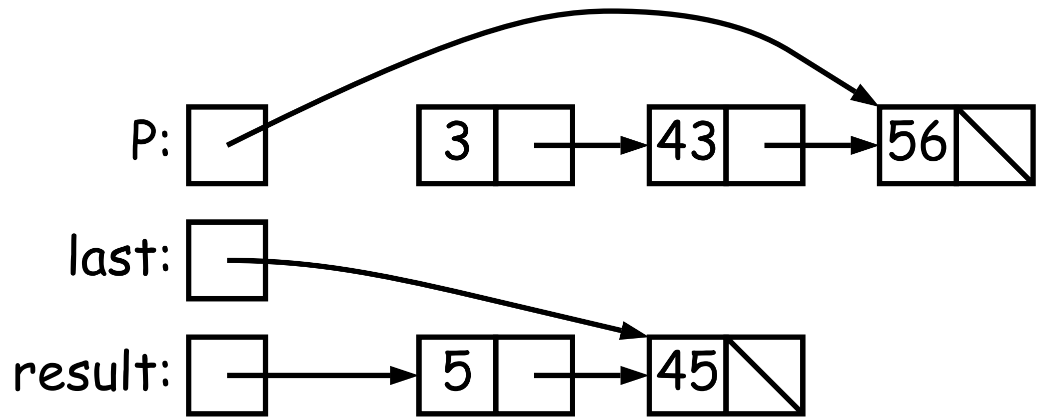

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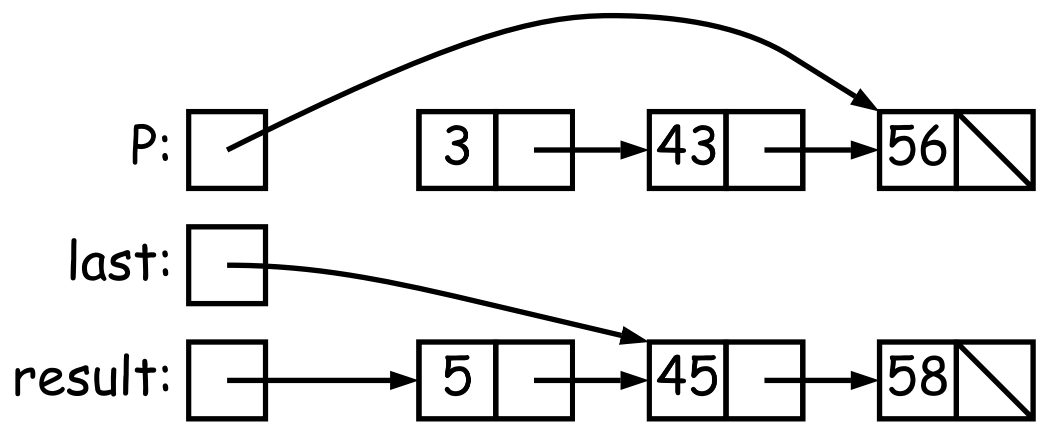

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