Public-Service Announcement

"Cal Actuarial League will be hosting their First General Meeting on Tuesday, September 5th at 8 pm in [TBD] and Actuarial Career Panel on Thursday, September 7th at 8 pm in [TBD]. See Facebook for location updates. Free food and refreshments will be provided.
An actuary conducts mathematical and statistical analysis alongside data science techniques to estimate financial risks. The actuarial career is consistently ranked as one of the best jobs. For those of you who are looking for a challenging and rewarding career with a remarkable social reputation, becoming an actuary would be a great choice. A panel of professionals at our Actuarial Career Panel will share their experiences and answer your questions."

Recreation

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

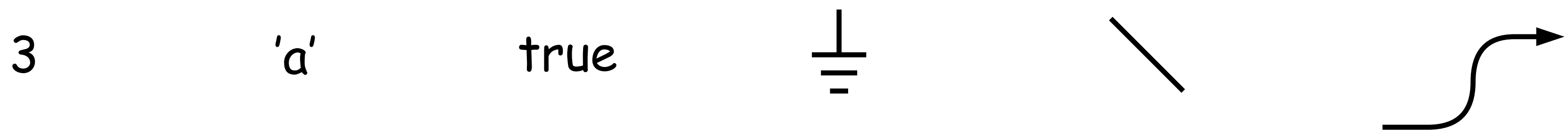
[Source: D. O. Shklarsky, N. N. Chentzov, I. M. Yaglom, *The USSR Olympiad Problem Book*, Dover ed. (1993), from the W. H. Freeman edition, 1962.]

CS61B Lecture #4: Values and Containers

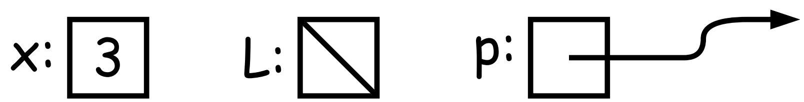
- Labs are normally due at midnight Friday.
- **Today.** Simple classes. Scheme-like lists. Destructive vs. non-destructive operations. Models of memory.

Values and Containers

- *Values* are numbers, booleans, and pointers. Values never change.



- *Simple containers* contain values:

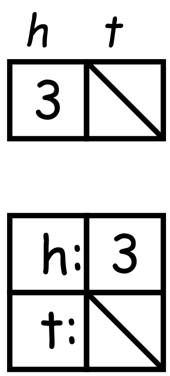


Examples: variables, fields, individual array elements, parameters.

Structured Containers

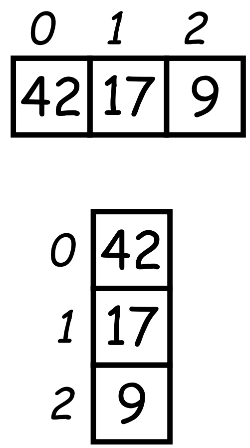
Structured containers contain (0 or more) other containers:

Class Object



Alternative Notation

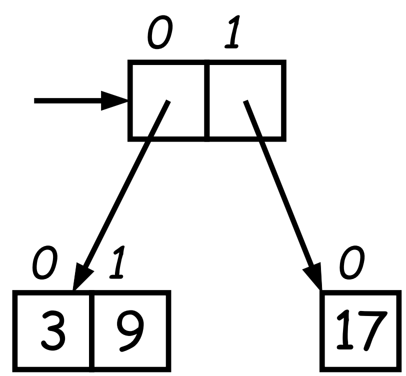
Array Object



Empty Object

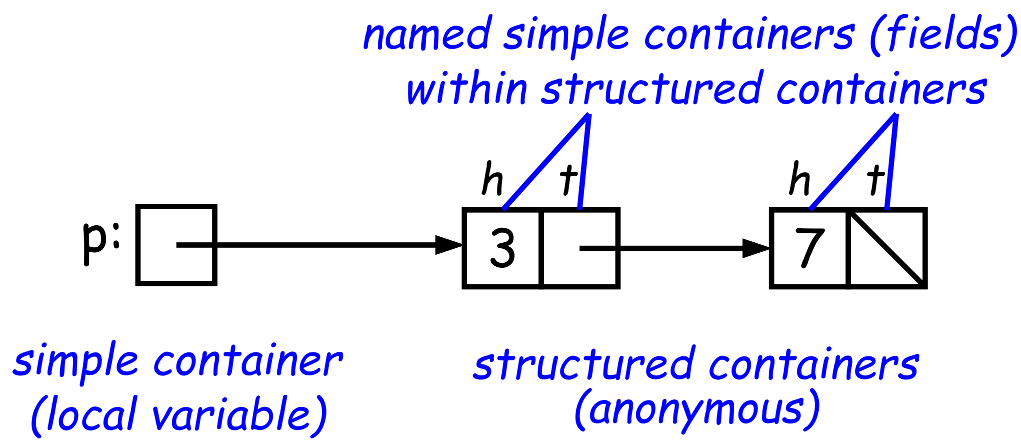
Pointers

- *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.)

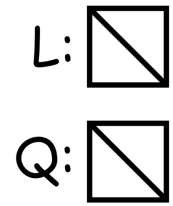
Defining New Types of Object

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

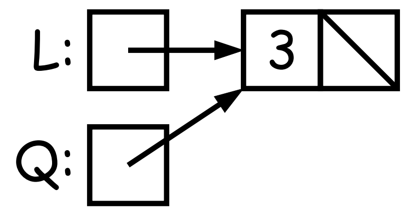
```
public class IntList {
  // Constructor function (used to initialize new object)
  /** List cell containing (HEAD, TAIL). */
  public IntList(int head, IntList tail) {
    this.head = head; this.tail = tail;
  }

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

Primitive Operations

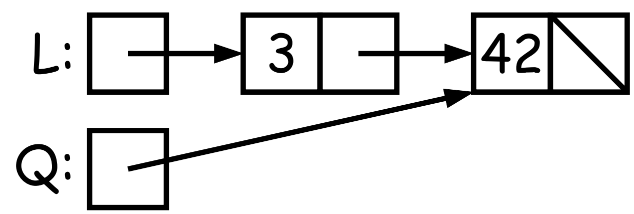
```
IntList Q, L;
```



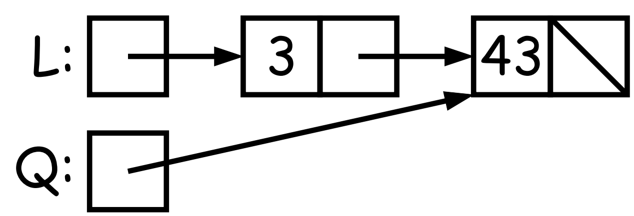

```
L = new IntList(3, null);
Q = L;
```




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

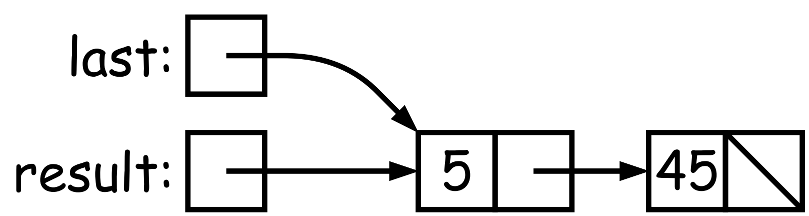



```
L.tail.head += 1;
// Now Q.head == 43
// and L.tail.head == 43
```

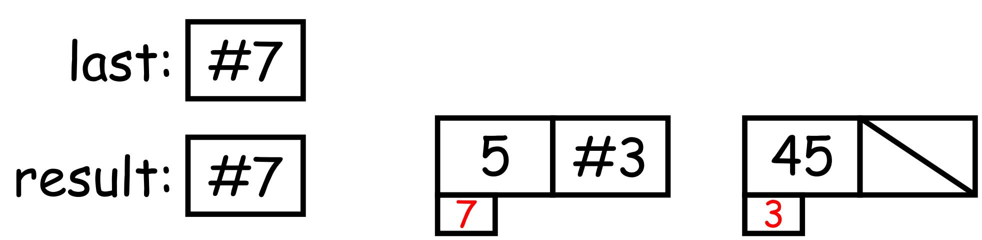


Side Excursion: Another Way to View Pointers

- 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:

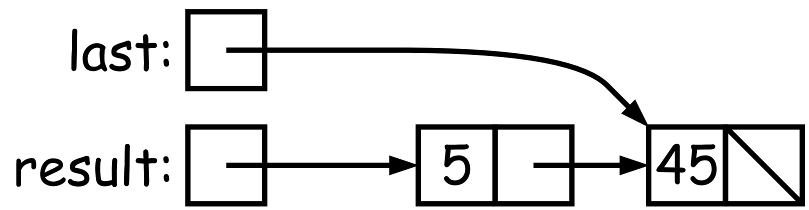


- Alternative view:

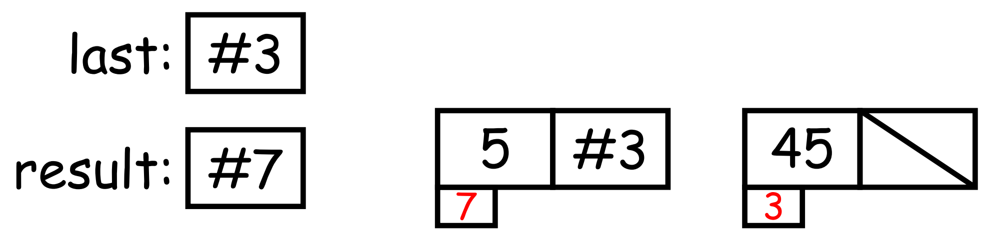


Another Way to View Pointers (II)

- 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.

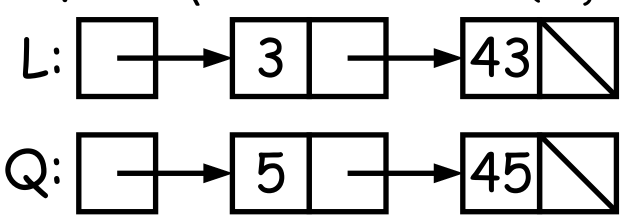
Destructive vs. Non-destructive

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.

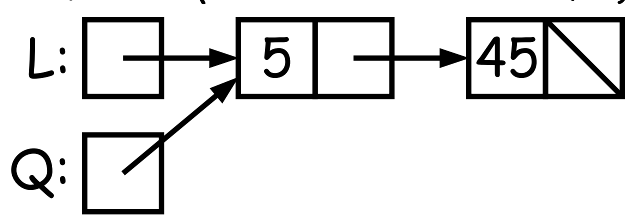
```
/** List of all items in P incremented by n. Does not modify
 *  existing IntLists. */
static IntList incrList(IntList P, int n) {
    return /*( P, with each element incremented by n )*/
}
```

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

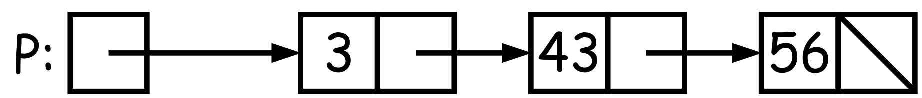
```
/** List of all items in P incremented by n. */
static IntList incrList(IntList P, int n) {
  if (P == null)
    return null;
  else return new IntList(P.head+n, incrList(P.tail, n));
}
```

- Why does `incrList` have to return its result, rather than just setting `P`?
- In the call `incrList(P, 2)`, where `P` contains 3 and 43, which `IntList` object gets created first?

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;
  result = last
     = new IntList(P.head+n, null);
  while (P.tail != null) {
    P = P.tail;
    last.tail
      = new IntList(P.head+n, null);
    last = last.tail;
  }
  return result;
}
```



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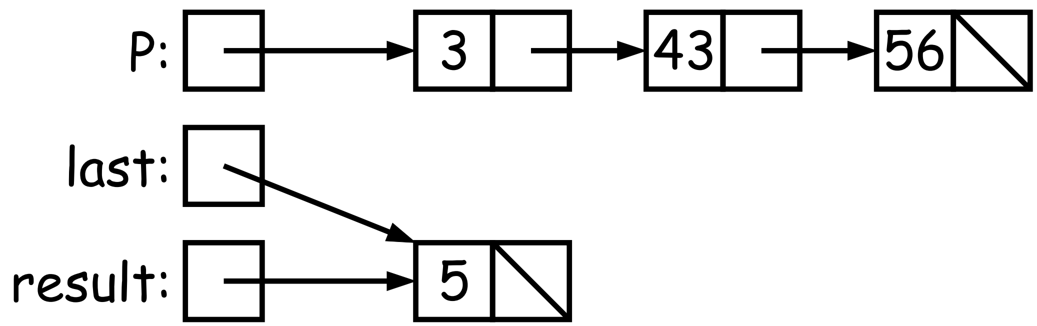

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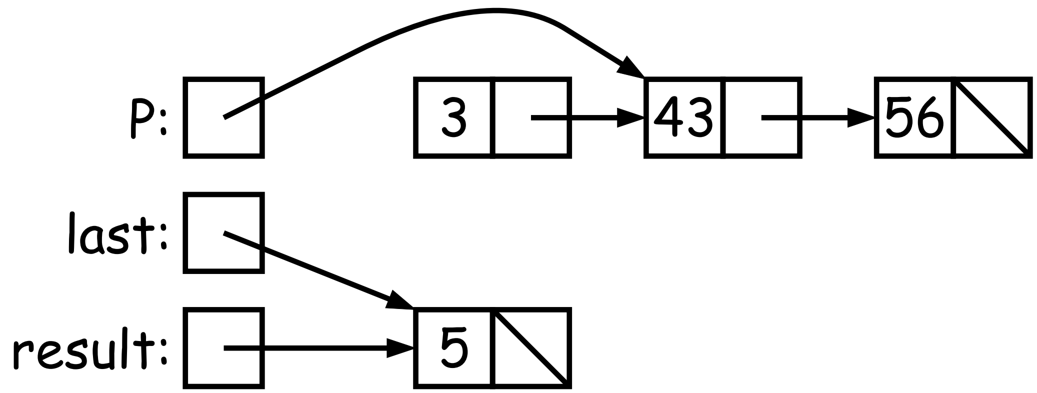

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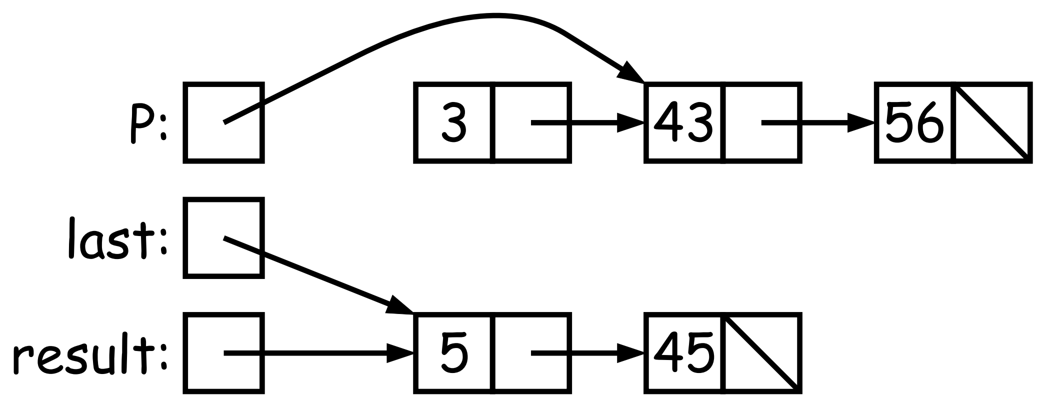

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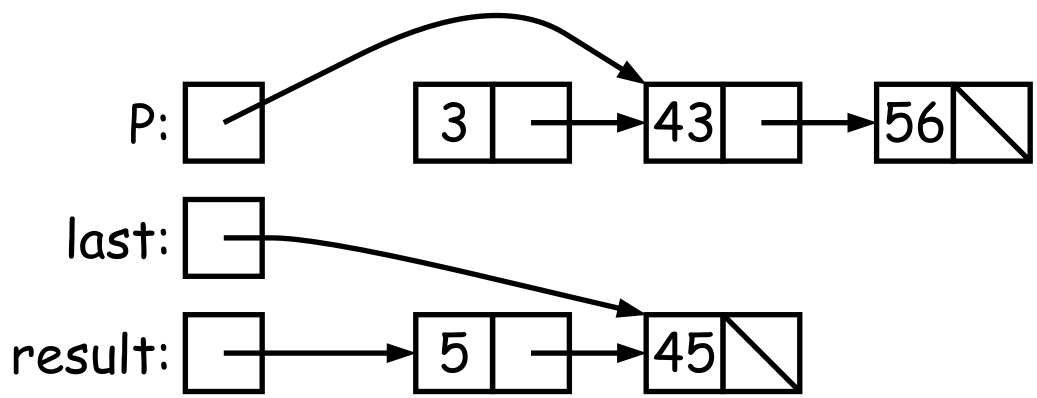

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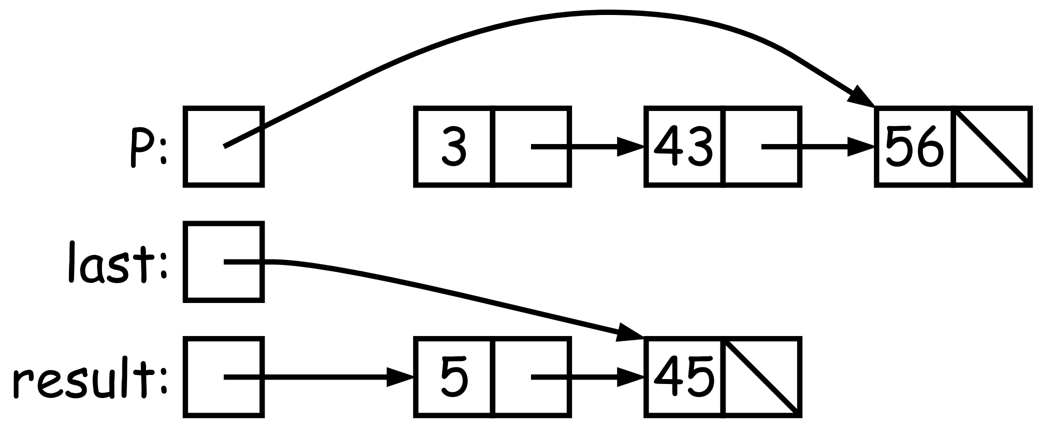

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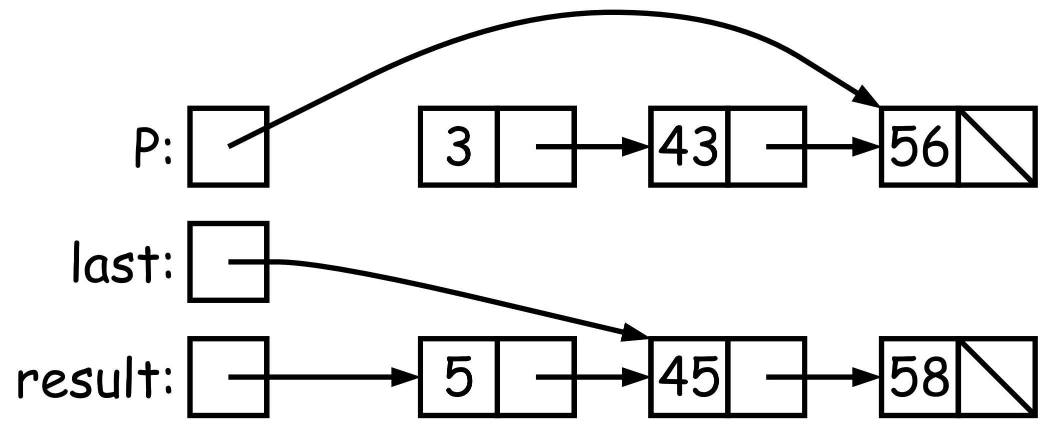

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