# Lists

CSE 373

Data Structures

Lecture 3

# Readings

- Reading
  - › Section 3.1 ADT (recall, lecture 1):
    - Abstract Data Type (ADT): Mathematical description of an object with set of operations on the object.
  - › Section 3.2 The List ADT

# List ADT

- What is a List?
  - Ordered sequence of elements $A_1$, $A_2$, …, $A_N$
- Elements may be of arbitrary type, but all are of the same type
- Common List operations are:
  - Insert, Find, Delete, IsEmpty, IsLast, FindPrevious, First, Kth, Last, Print, etc.

# Simple Examples of List Use

- Polynomials
  - $25 + 4x^2 + 75x^{85}$
- Unbounded Integers
  - 4576809099383658390187457649494578
- Text
  - “This is an example of text”

# List Implementations

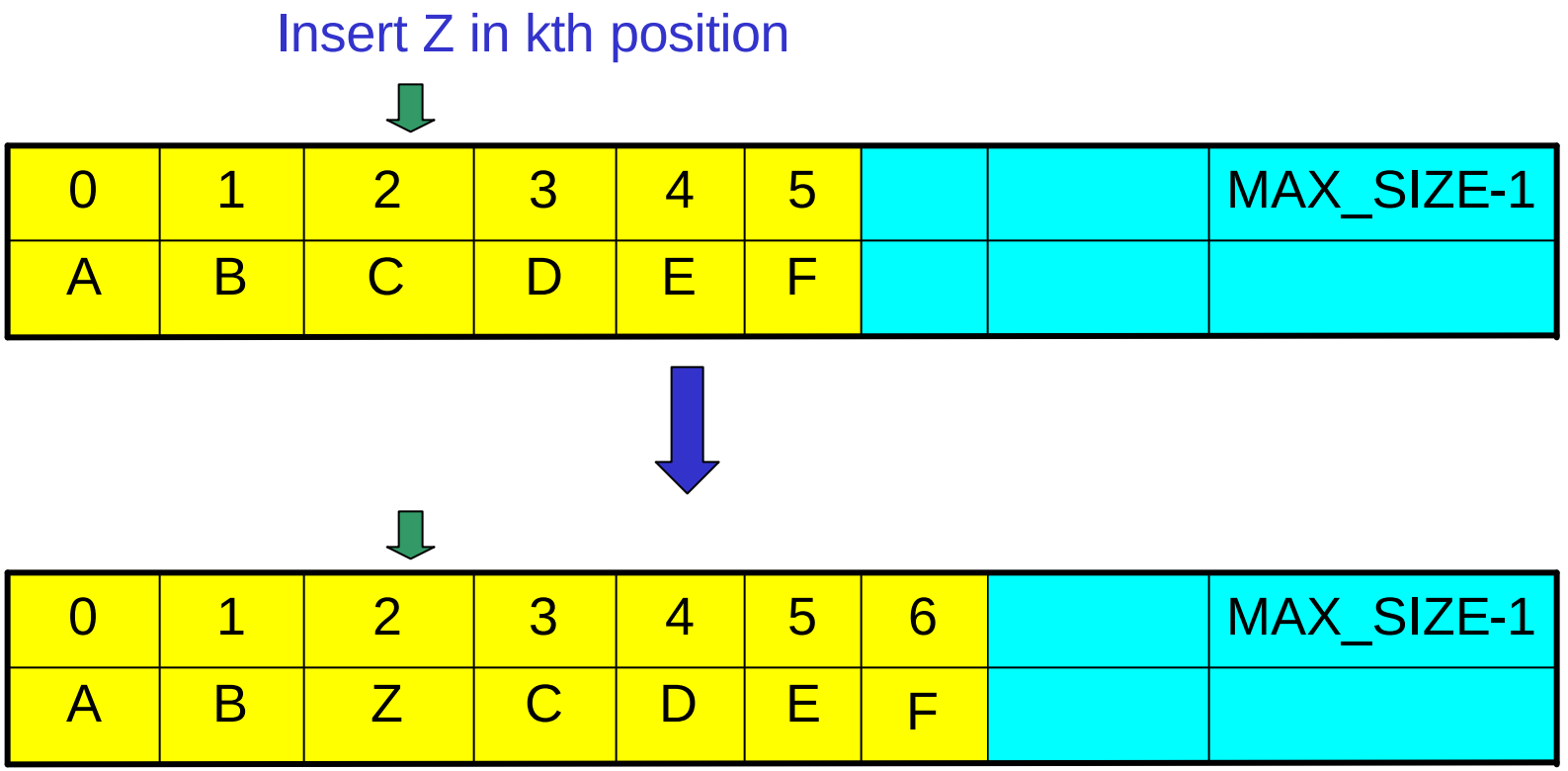
- Two types of implementation:
  - Array-Based
  - Pointer-Based

# List: Array Implementation

- Basic Idea:
  - Pre-allocate a big array of size MAX_SIZE
  - Keep track of current size using a variable **count**
  - Shift elements when you have to insert or delete

| 0 | 1 | 2 | 3 | … | count-1 | | MAX_SIZE-1 |
|---|---|---|---|---|---|---|---|
| $A_1$ | $A_2$ | $A_3$ | $A_4$ | … | $A_N$ | | |

# List: Array Implementation



# Array List Insert Running Time

- Running time for N elements?
- On average, must move half the elements to make room – assuming insertions at positions are equally likely
- Worst case is insert at position 0. Must move all N items one position before the insert
- This is O(N) running time. Probably too slow

# Review Big Oh Notation

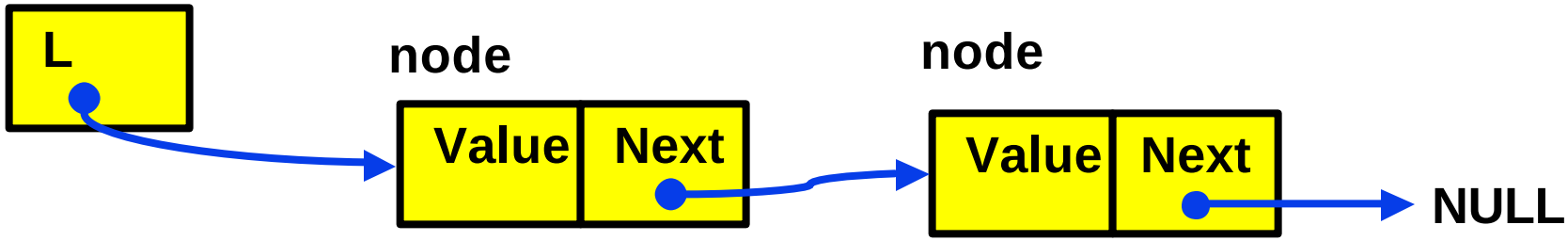
- T(N) = O(f(N)) if there are positive constants c and $n_0$ such that:

  $T(N) \leq c\ f(N)$ when $N \geq n_0$

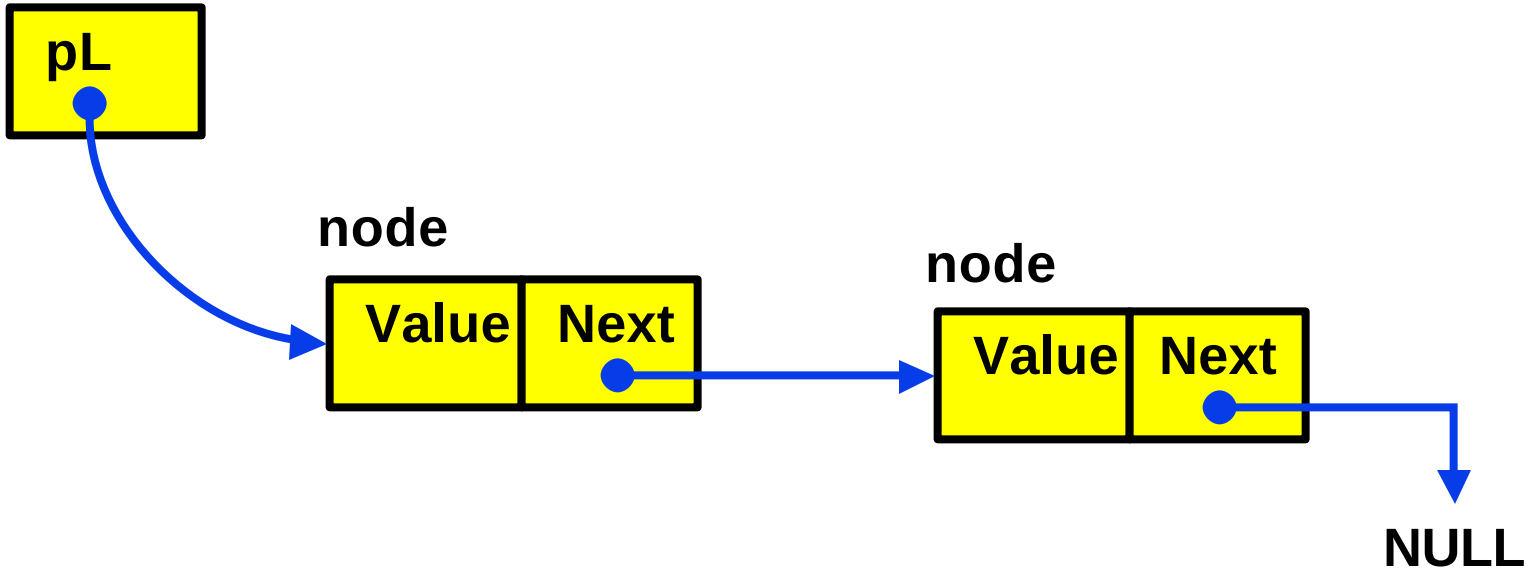
- T(N) = O(N) linear

# List: Pointer Implementation

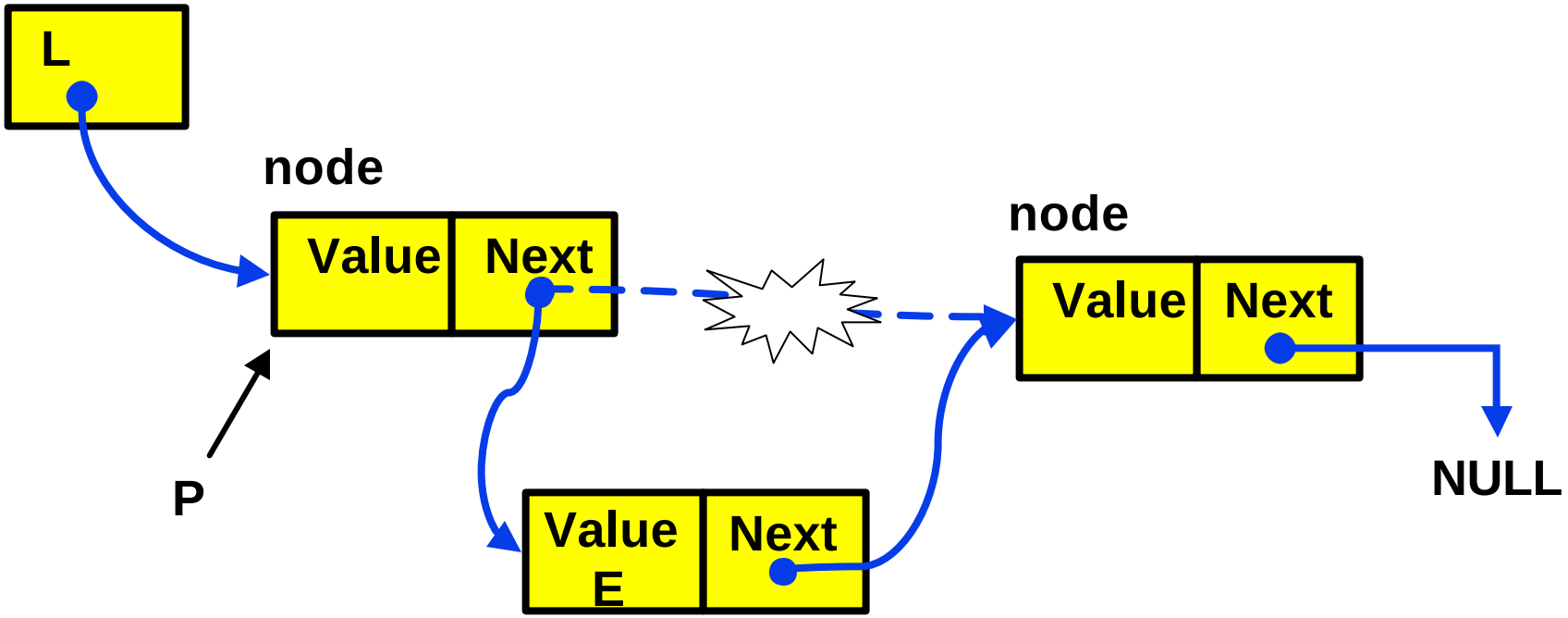
- Basic Idea:
  - › Allocate little blocks of memory (nodes) as elements are added to the list
  - › Keep track of list by linking the nodes together
  - › Change links when you want to insert or delete



# Pointer-Based Linked List



# Pointer-based Insert (after p)

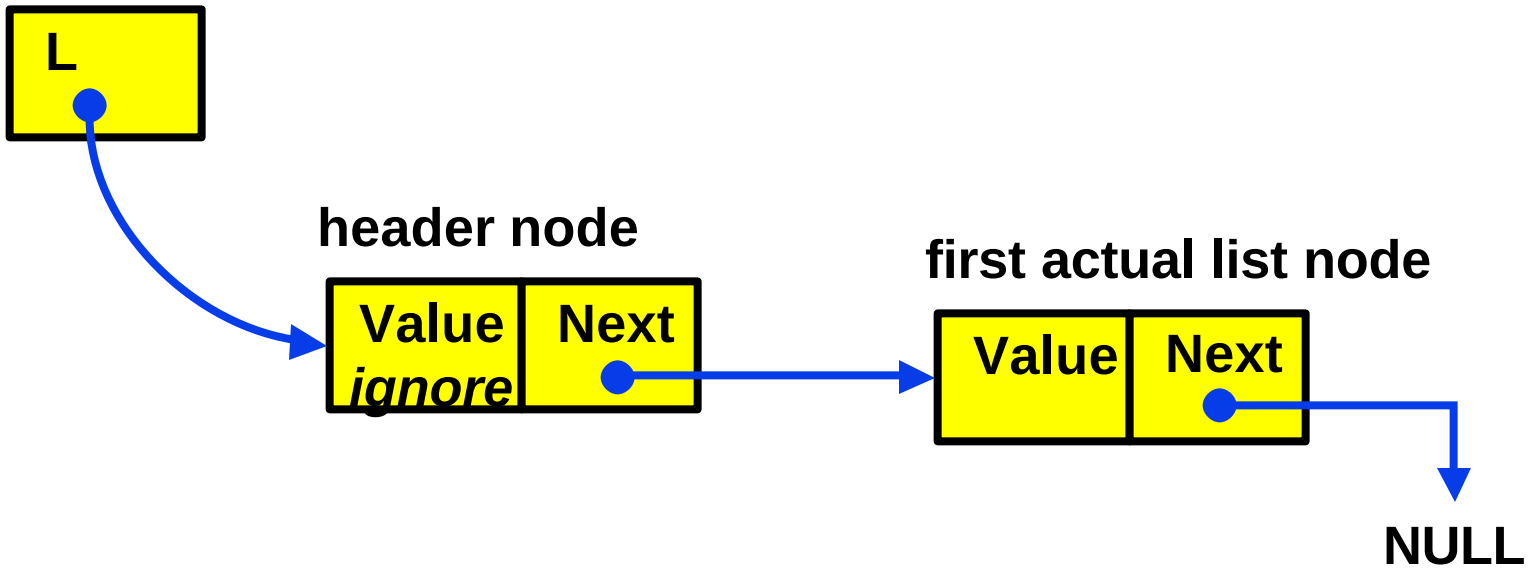



**Insert the value E after P**

# Insertion After

```
InsertAfter(p : node pointer, v : thing): {
x : node pointer;
x := new node;
x.value := v;
x.next := p.next;
p.next := x;
}
```

# Linked List with Header Node




Advantage: “insert after” and “delete after” can be done at the beginning of the list.

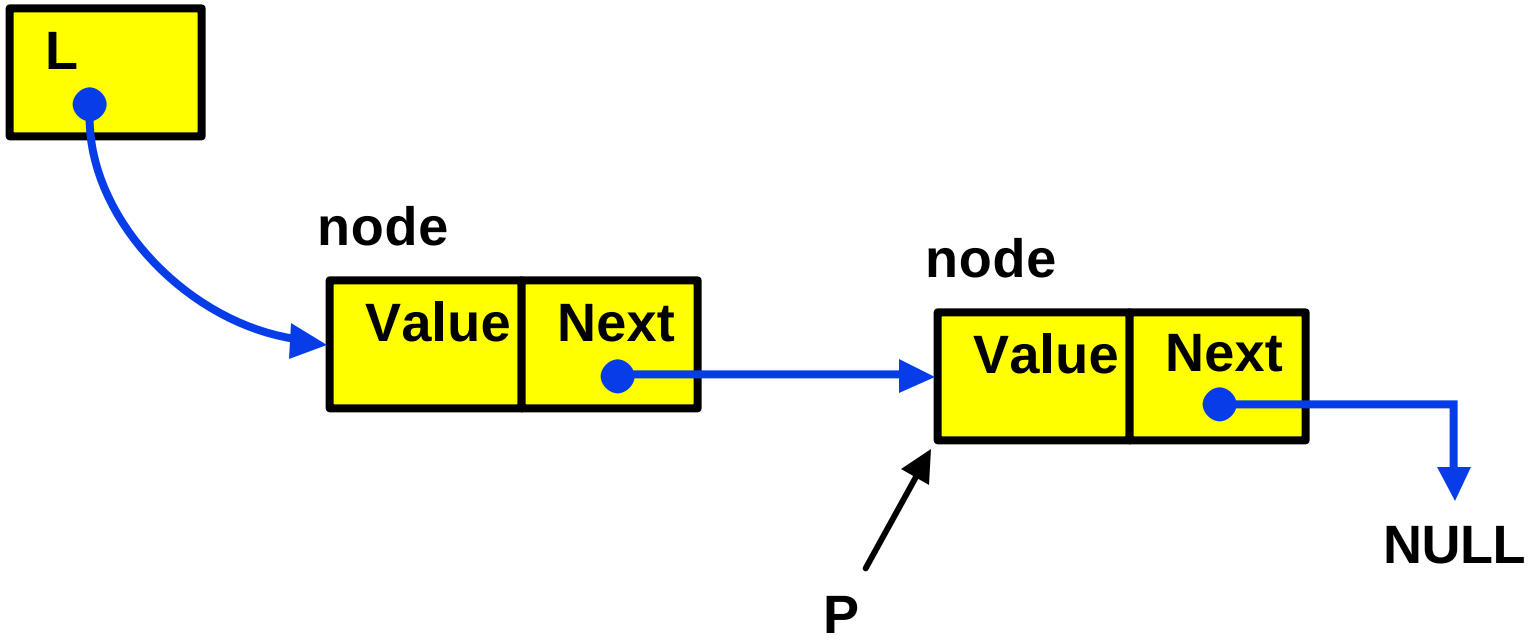
# Pointer Implementation Issues

- Whenever you break a list, your code should fix the list up as soon as possible
  - Draw pictures of the list to visualize what needs to be done
- Pay special attention to boundary conditions:
  - Empty list
  - Single item – same item is both first and last
  - Two items – first, last, but no middle items
  - Three or more items – first, last, and middle items

# Pointer List Insert Running Time

- Running time for N elements?
- Insert takes constant time (O(1))
- Does not depend on input size
- Compare to array based list which is O(N)

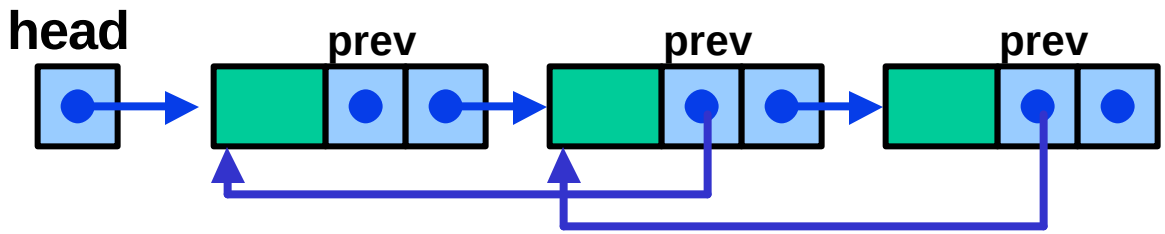
# Linked List Delete




**To delete the node pointed to by P, need a pointer to the previous node; See book for findPrevious method**

# Doubly Linked Lists

- findPrevious (and hence Delete) is slow [O(N)] because we cannot go directly to previous node
- Solution: Keep a "previous" pointer at each node

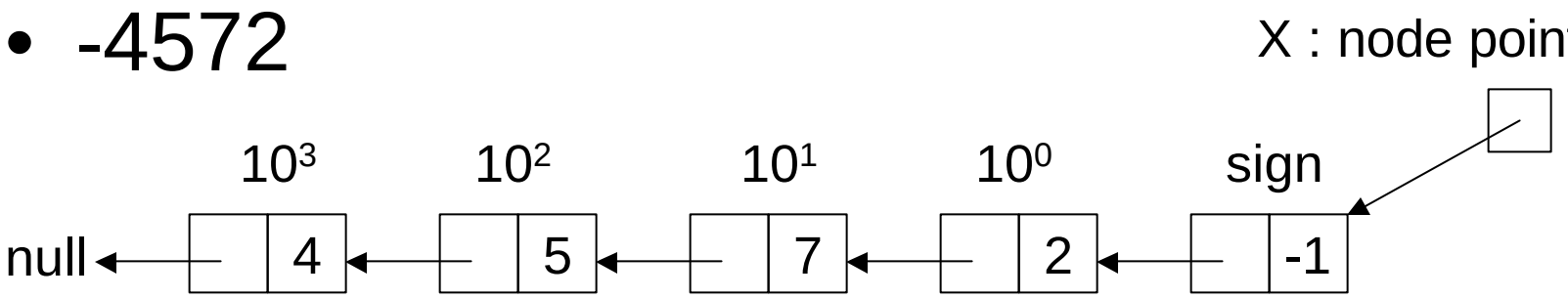


# Double Link Pros and Cons

- Advantage
  - Delete (not DeleteAfter) and FindPrev are faster
- Disadvantages:
  - More space used up (double the number of pointers at each node)
  - More book-keeping for updating the two pointers at each node (pretty negligible overhead)

# Unbounded Integers Base 10

- -4572

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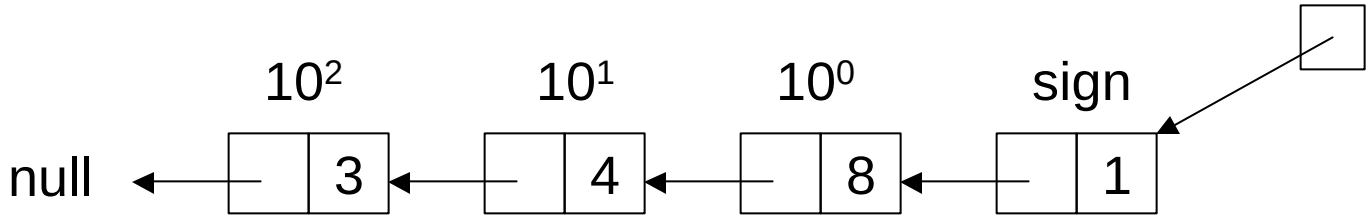
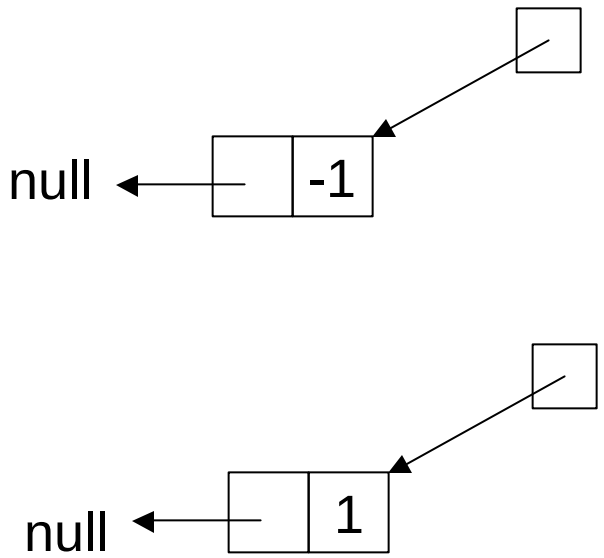
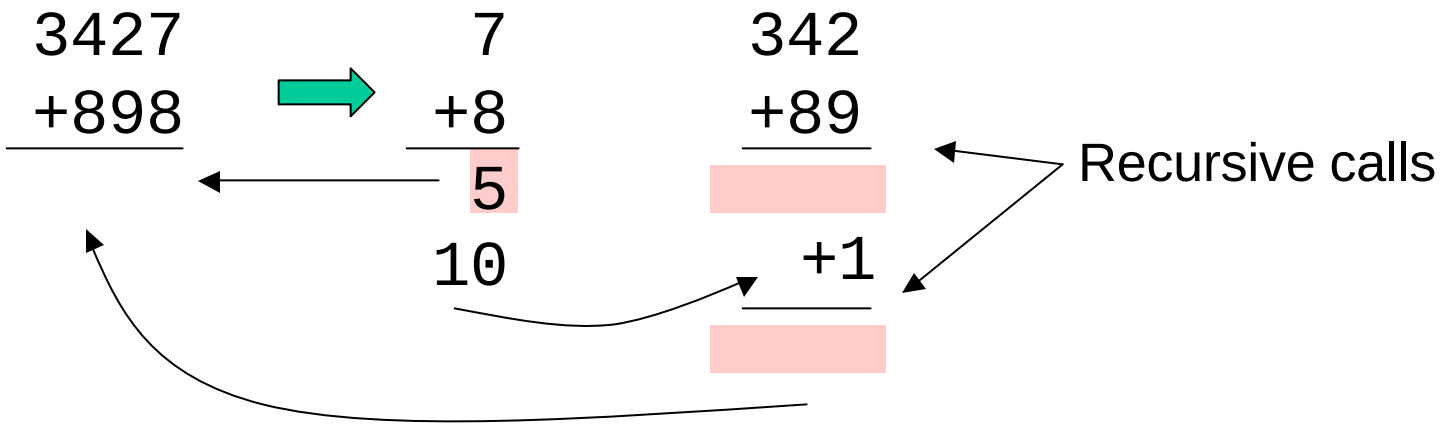


# Zero



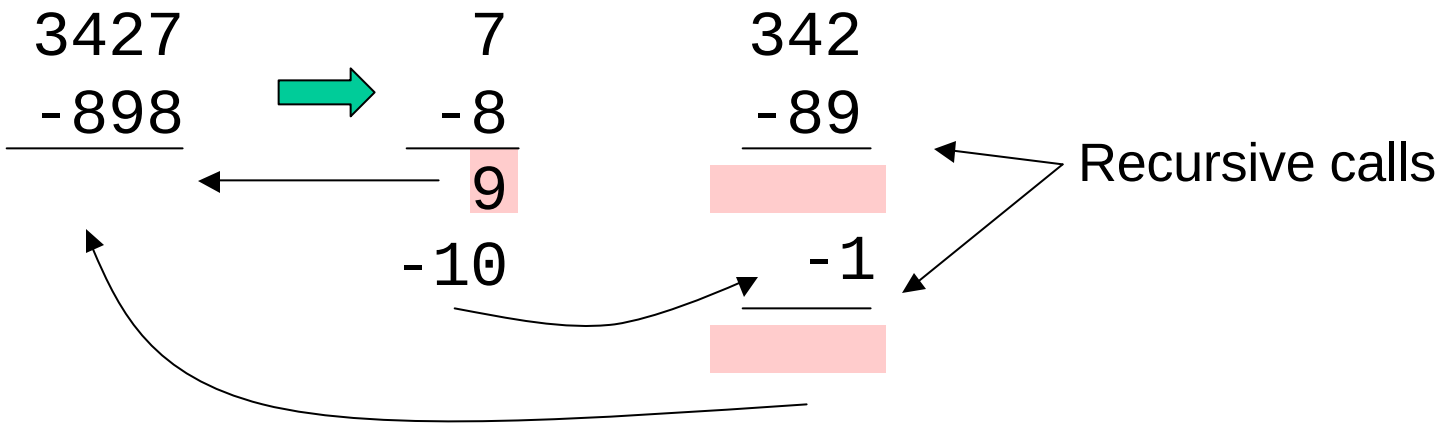
# Recursive Addition

- Positive numbers (or negative numbers)



# Recursive Addition

- Mixed numbers



# Example

- Mixed numbers