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 $A_1, A_2, \ldots, A_N$
- 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

Insert Z in kth position

0	1	2	3	4	5			MAX_SIZE-1
A	B	C	D	E	F			

0	1	2	3	4	5	6		MAX_SIZE-1
A	B	Z	C	D	E	F		

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

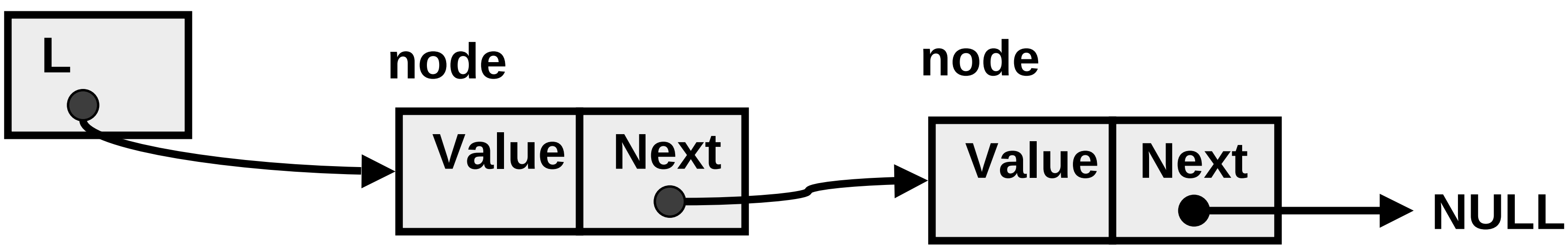
- $T(N) = O(f(N))$ if there are positive constants c and n_0 such that:

  $$T(N) \leq c\, f(N) \text{ when } N \geq n_0$$

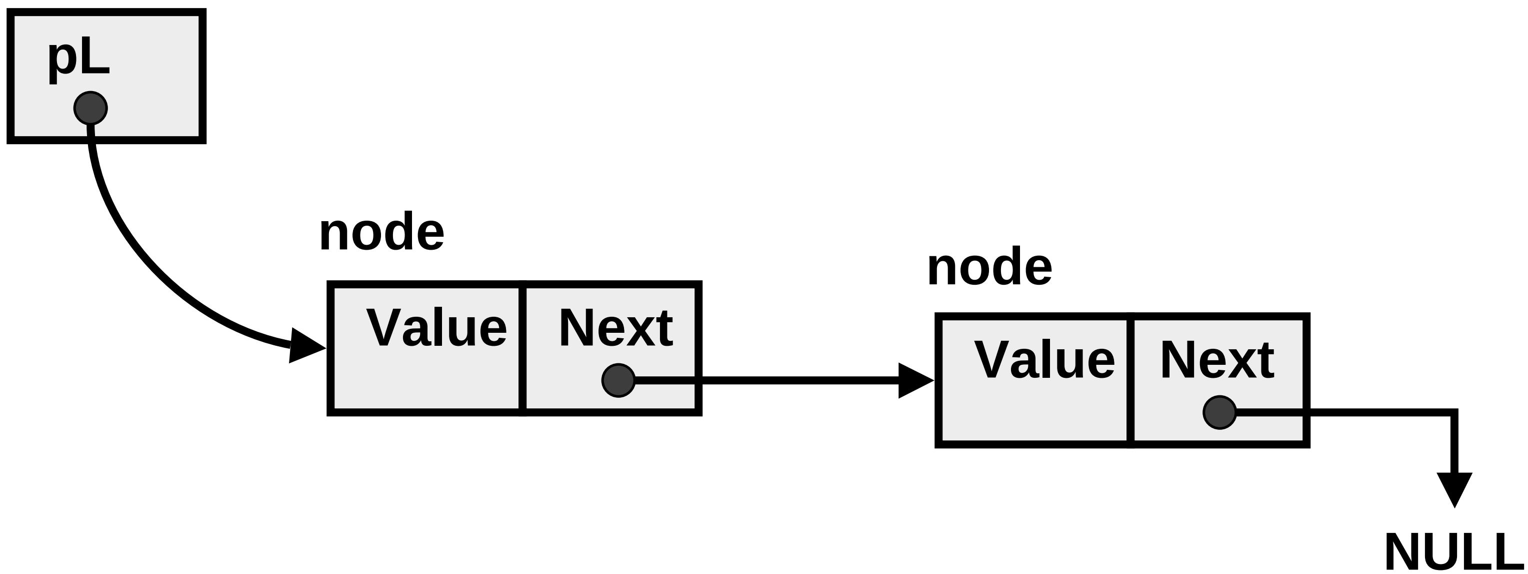
- $T(N) = O(N)$ linear

List: Pointer Implementation

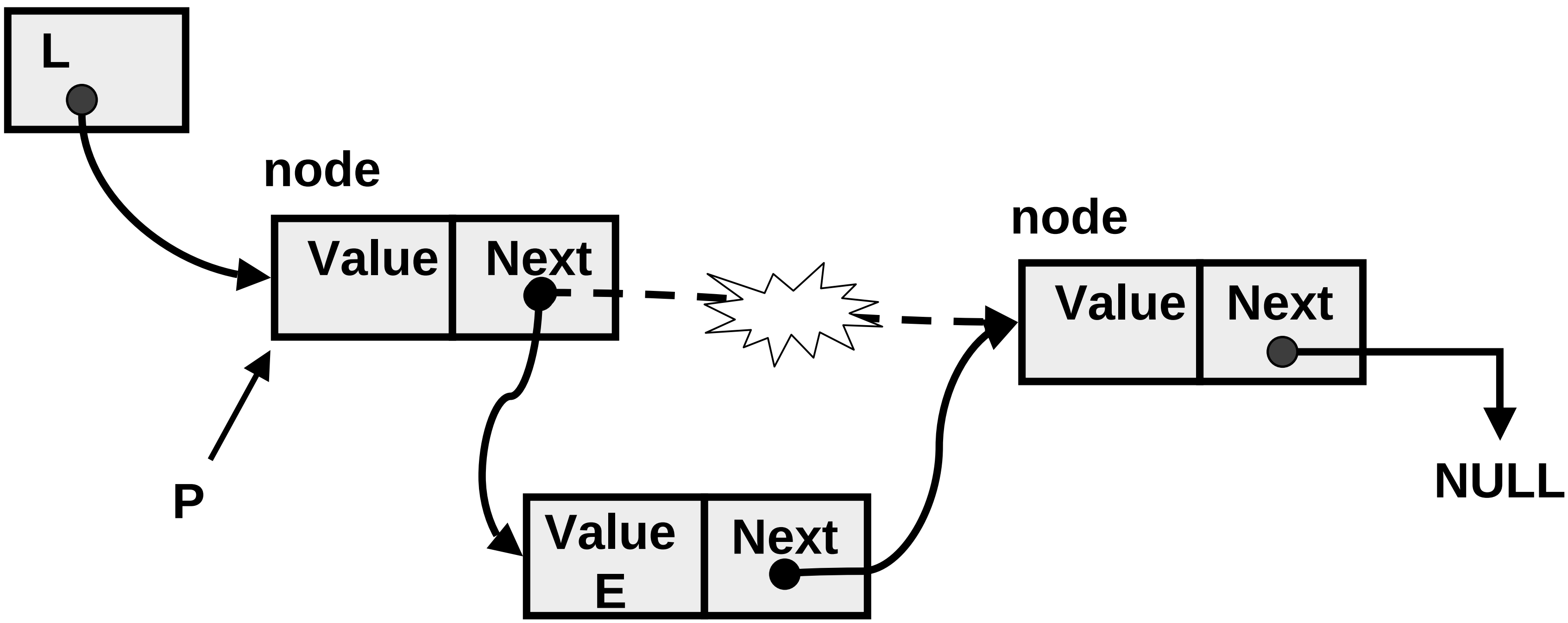
- Basic Idea:
  - › Allocate little blocks of memory (nodes) as elements are added to the list
  - › Keep track of list by linking the nodes together
  - › Change links when you want to insert or delete



Pointer-Based Linked List



Pointer-based Insert (after p)

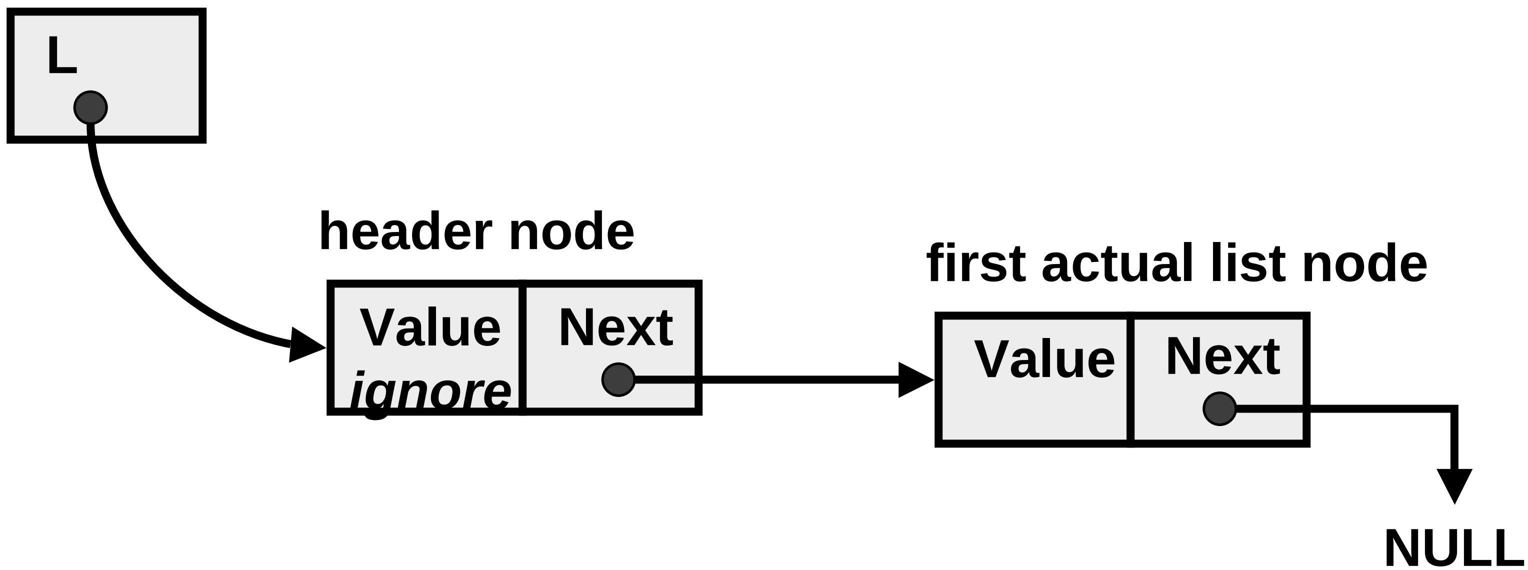


Insert the value E after P

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.

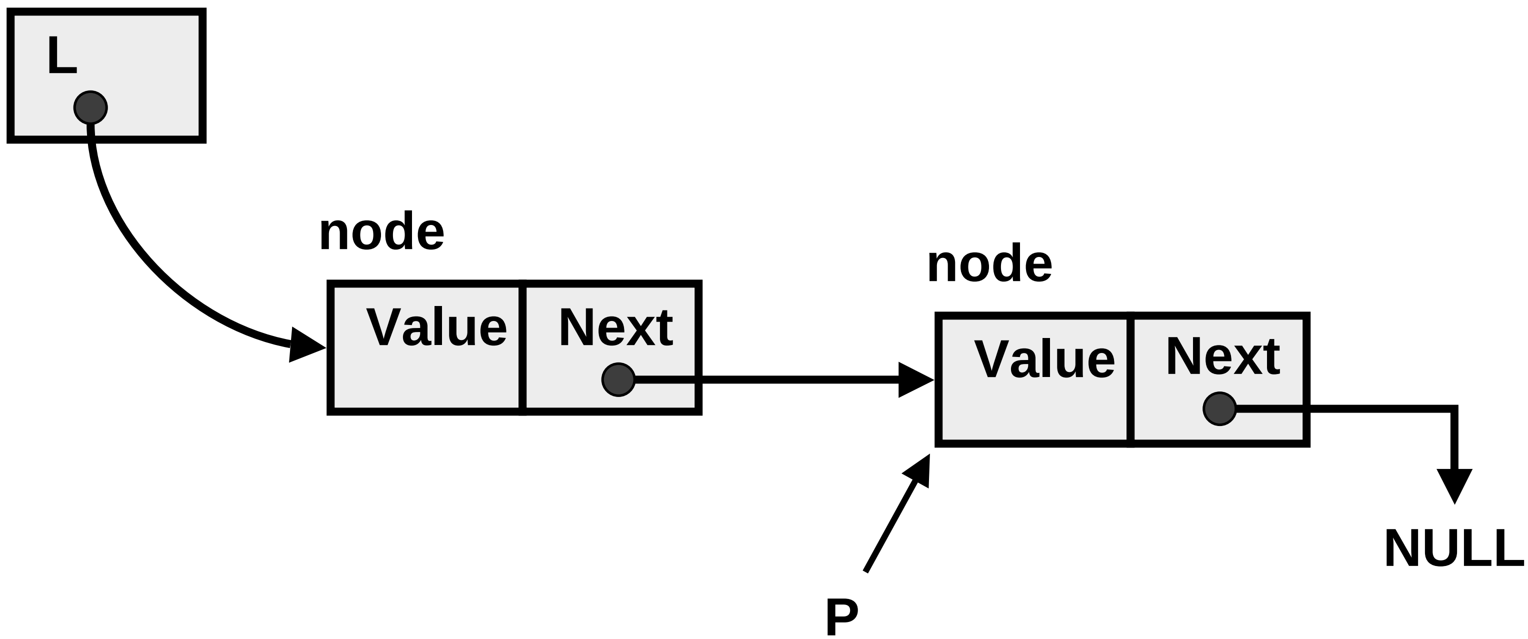
Pointer Implementation Issues

- 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)

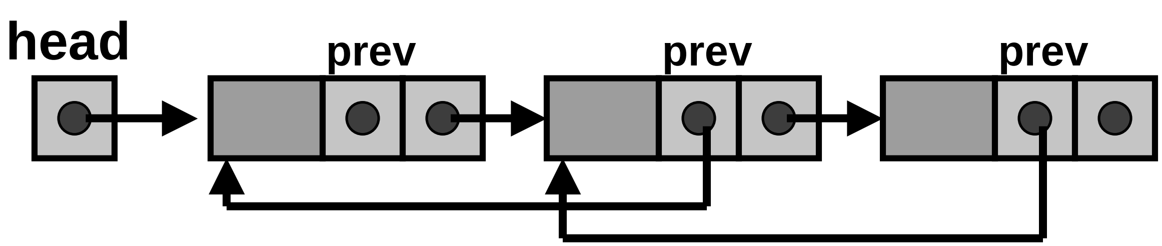
Linked List Delete



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

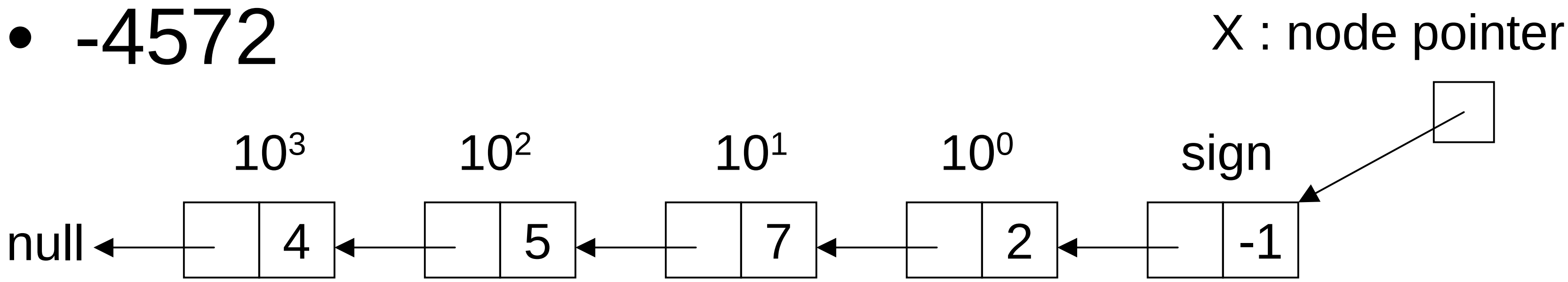


Double Link Pros and Cons

- 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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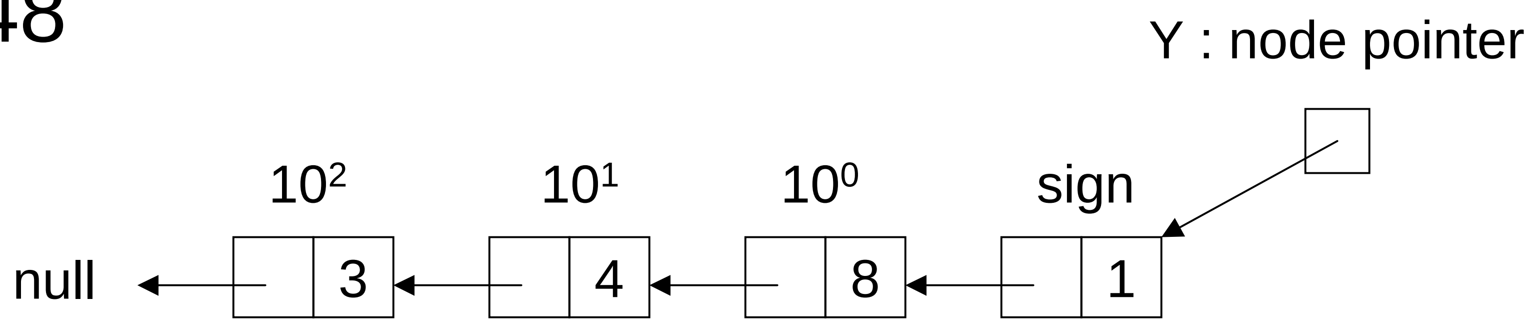
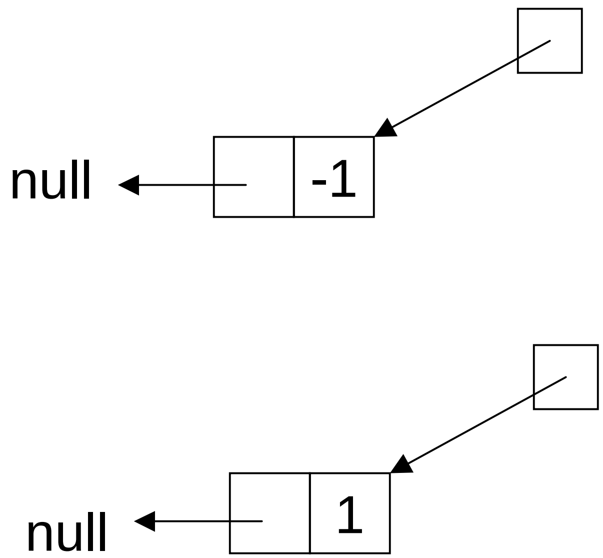
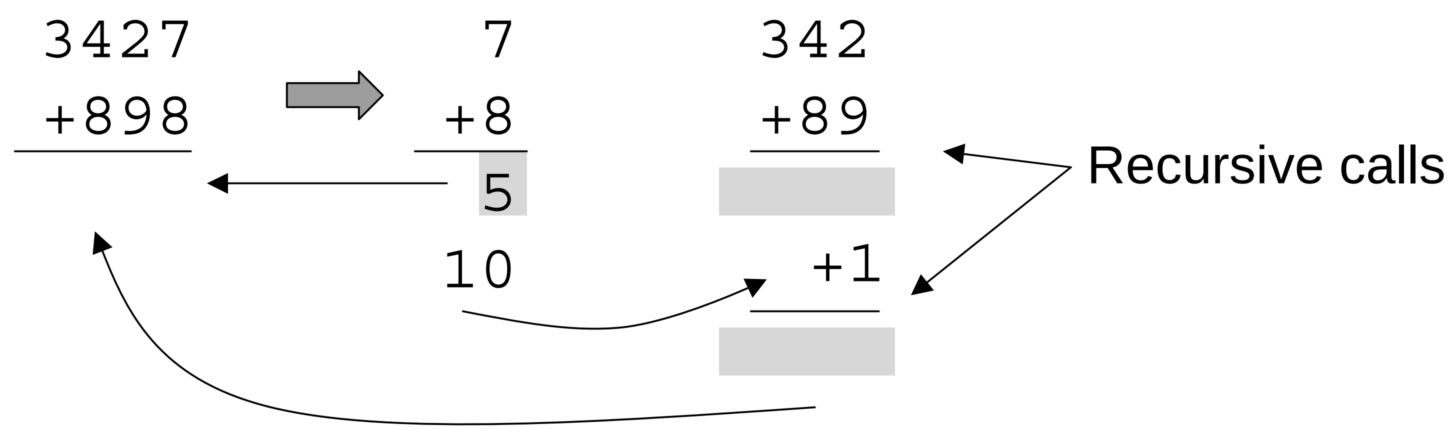


Zero



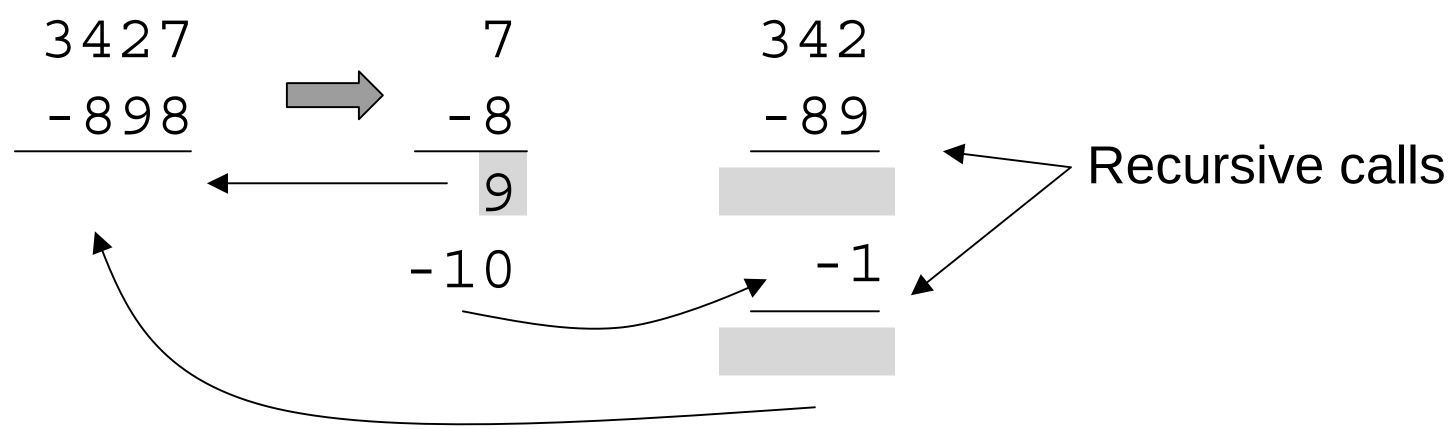
Recursive Addition

- Positive numbers (or negative numbers)



Recursive Addition

- Mixed numbers



Example

- Mixed numbers