http://algs4.cs.princeton.edu

2.3 PARTITIONING DEMOS (INC. IMPROVEMENTS)

- *Sedgewick 2-way partitioning*
- *Dijkstra 3-way partitioning*
- *Bentley-McIlroy 3-way partitioning*
- *dual-pivot partitioning*

Algorithms

Robert Sedgewick | Kevin Wayne

http://algs4.cs.princeton.edu

2.3 Partitioning Demos

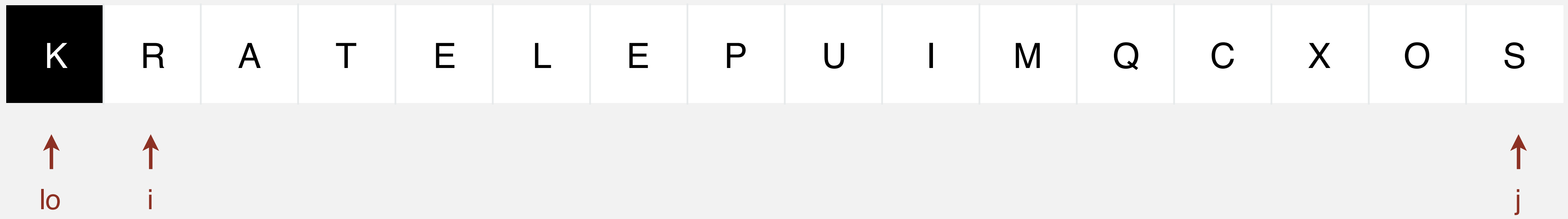
- *Sedgewick 2-way partitioning*
- *Dijkstra 3-way partitioning*
- *Bentley-McIlroy 3-way partitioning*
- *dual-pivot partitioning*

Quicksort partitioning demo

Let v (pivot) = a[lo]

Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].



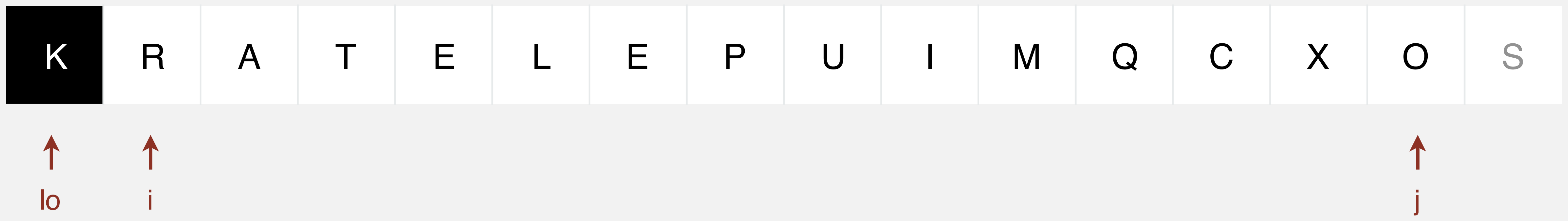
stop i scan because a[i] >= v

Quicksort partitioning demo

Let v (pivot) = a[lo]

Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].

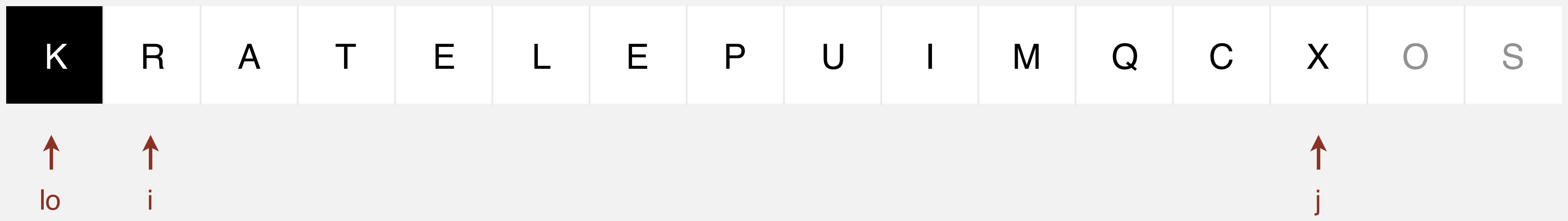


Quicksort partitioning demo

Let v (pivot) = a[lo]

Repeat until i and j pointers cross.

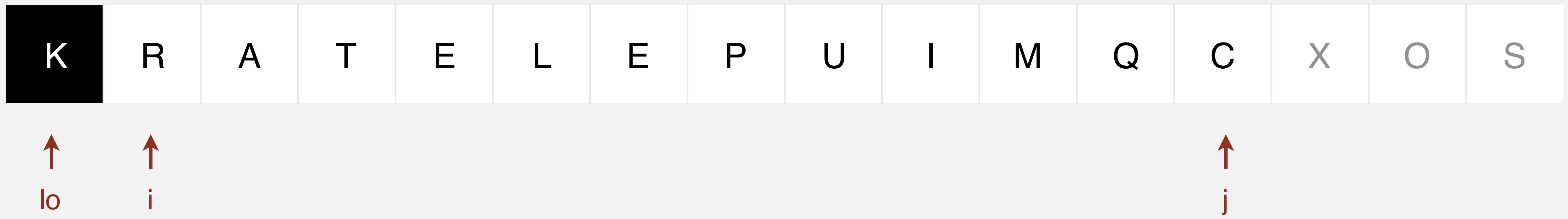
- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].



Quicksort partitioning demo

Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].

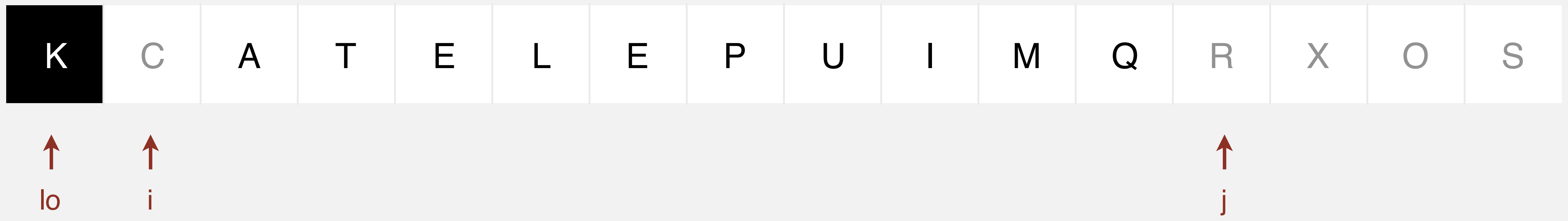


stop j scan and exchange a[i] with a[j]

Quicksort partitioning demo

Repeat until i and j pointers cross.

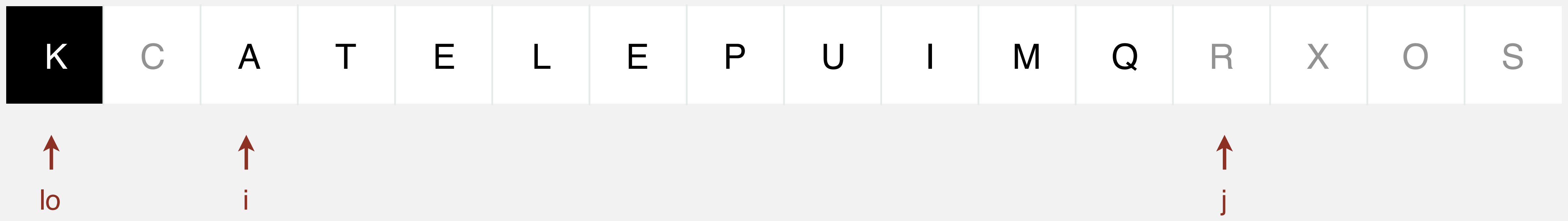
- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].



Quicksort partitioning demo

Repeat until i and j pointers cross.

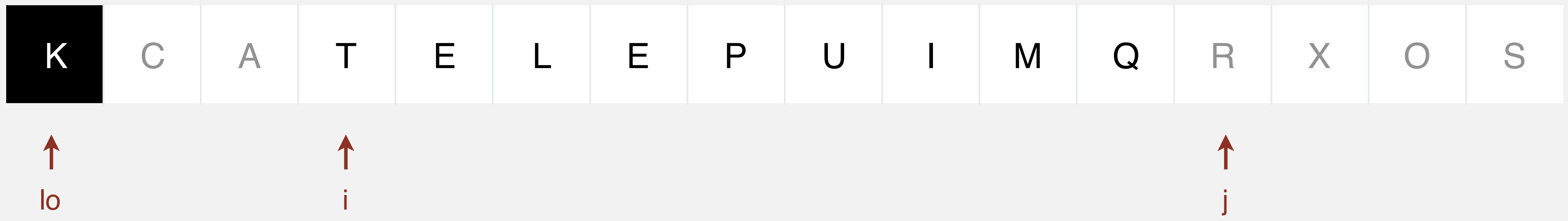
- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].



Quicksort partitioning demo

Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].

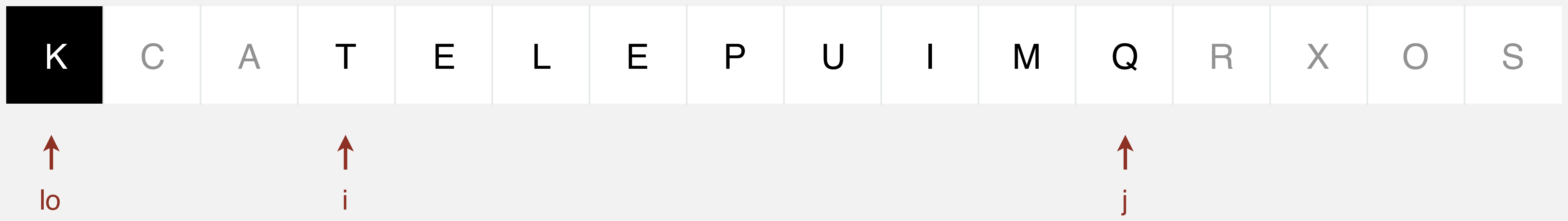


stop i scan because a[i] >= v

Quicksort partitioning demo

Repeat until i and j pointers cross.

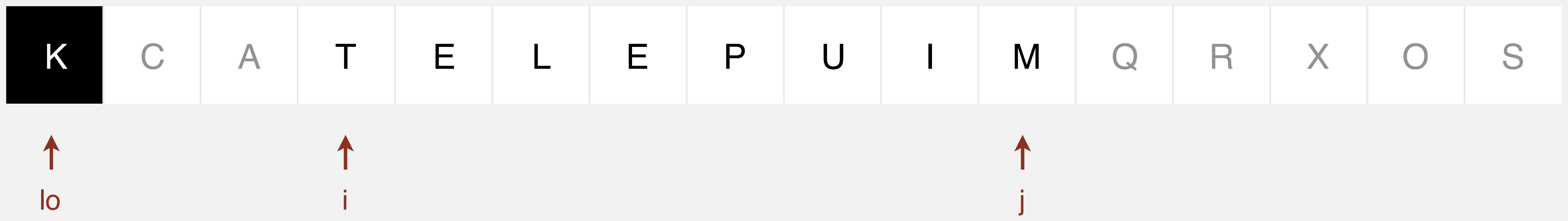
- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].



Quicksort partitioning demo

Repeat until i and j pointers cross.

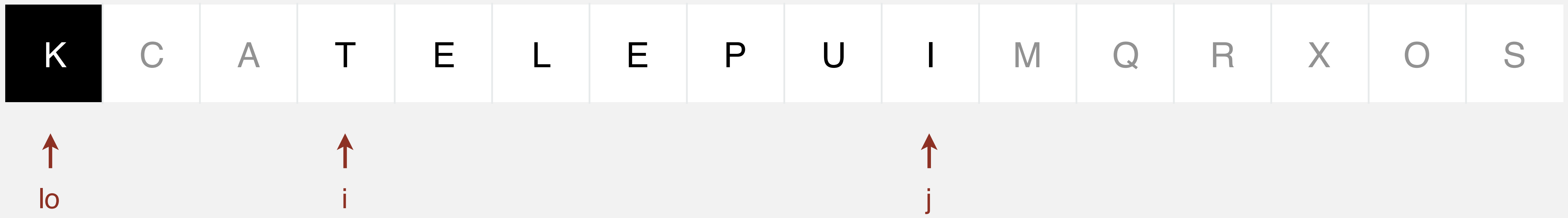
- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].



Quicksort partitioning demo

Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].

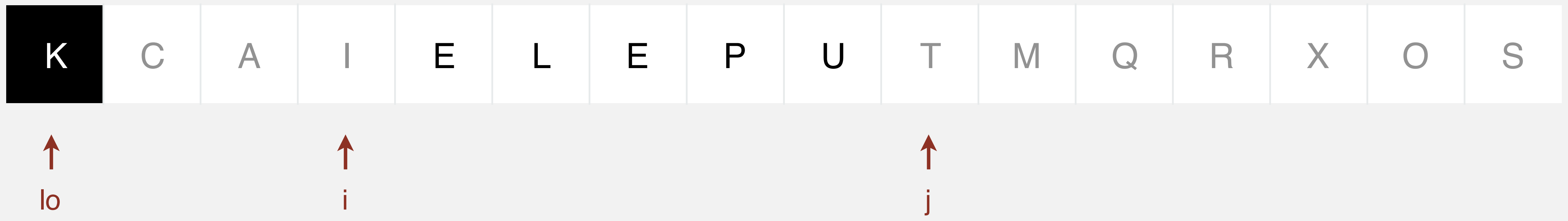


stop j scan and exchange a[i] with a[j]

Quicksort partitioning demo

Repeat until i and j pointers cross.

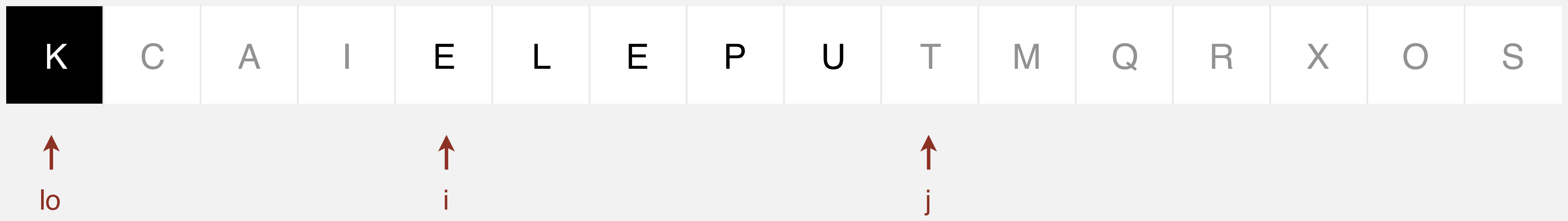
- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].



Quicksort partitioning demo

Repeat until i and j pointers cross.

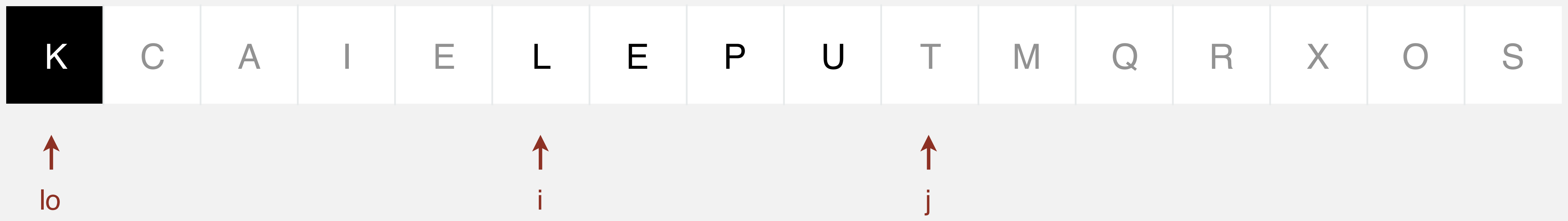
- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].



Quicksort partitioning demo

Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].

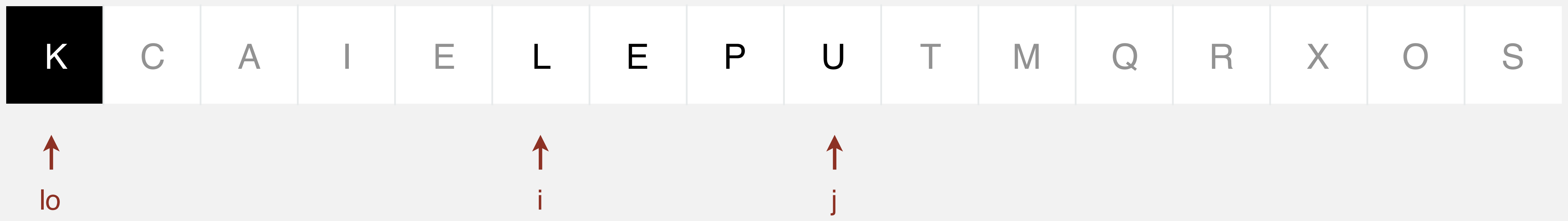


stop i scan because a[i] >= v

Quicksort partitioning demo

Repeat until i and j pointers cross.

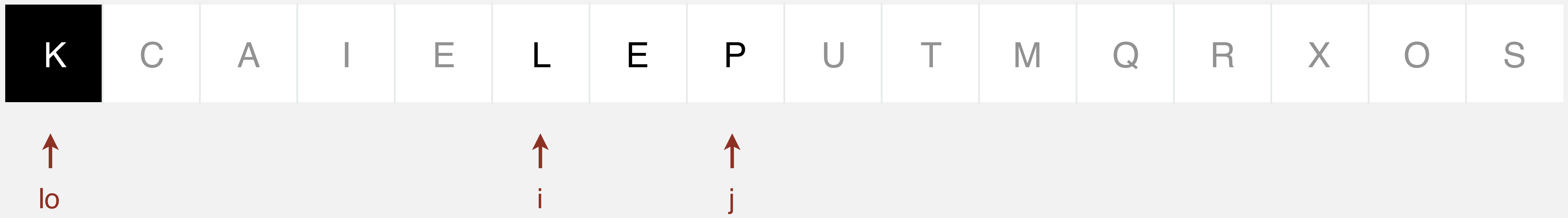
- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].



Quicksort partitioning demo

Repeat until i and j pointers cross.

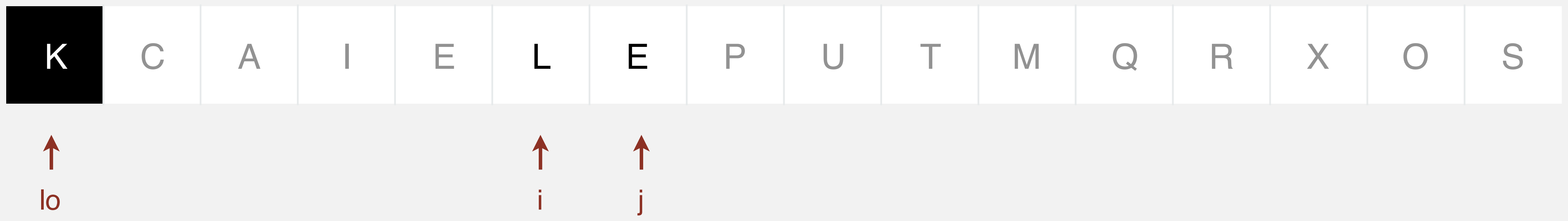
- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].



Quicksort partitioning demo

Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].

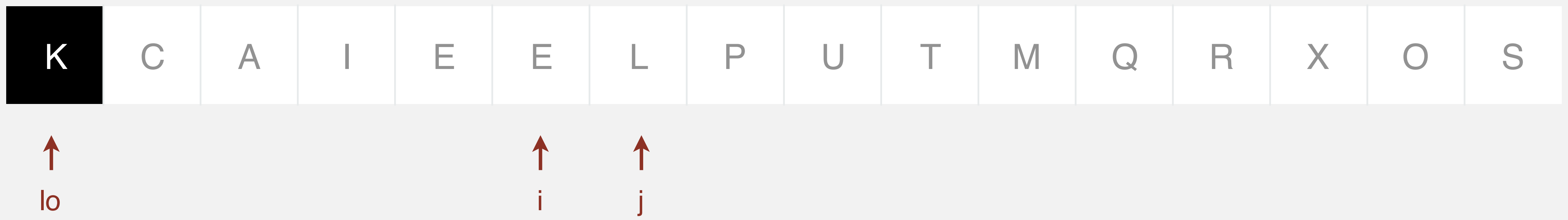


stop j scan and exchange a[i] with a[j]

Quicksort partitioning demo

Repeat until i and j pointers cross.

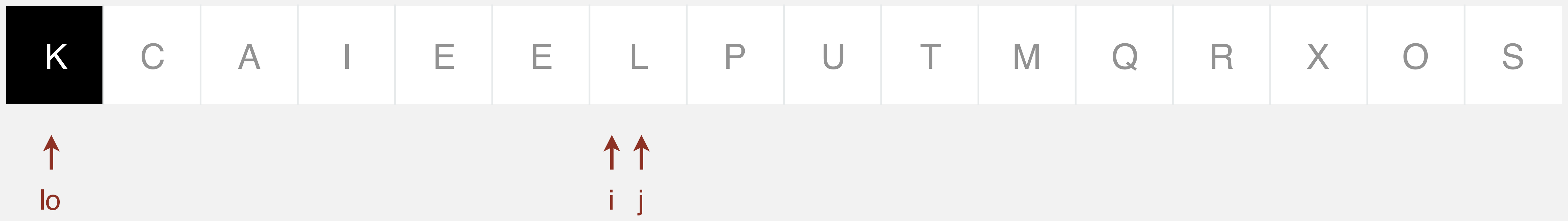
- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].



Quicksort partitioning demo

Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].

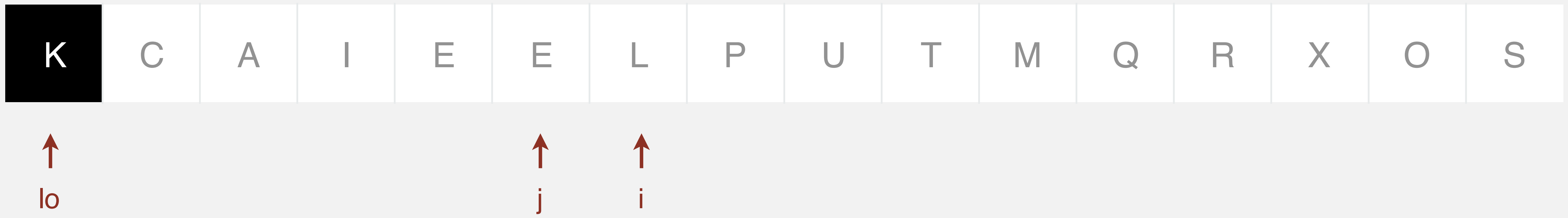


stop i scan because a[i] >= v

Quicksort partitioning demo

Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].



stop j scan because a[j] <= v

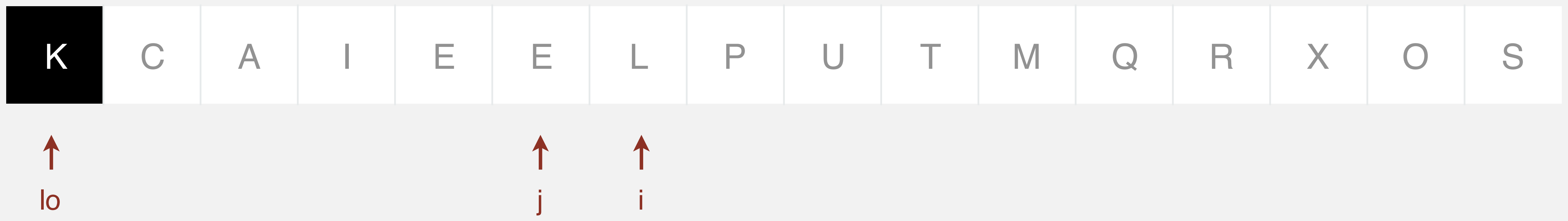
Quicksort partitioning demo

Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].

When pointers cross.

- Exchange a[lo] with a[j].



pointers cross: exchange a[lo] with a[j]

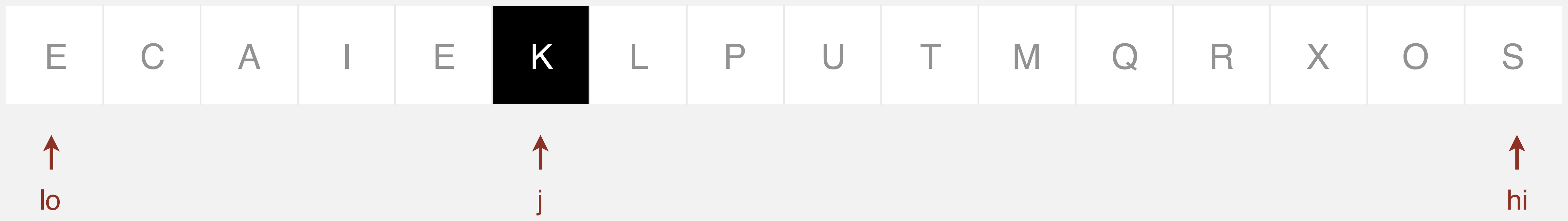
Quicksort partitioning demo

Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < v).
- Scan j from right to left so long as (a[j] > v).
- Exchange a[i] with a[j].

When pointers cross.

- Exchange a[lo] with a[j].



partitioned!

Partition Algorithm: Java

```
private static int partition(Comparable[] a, int lo, int hi)
{  // Partition into a[lo..i-1], a[i], a[i+1..hi].
   int i = lo, j = hi+1;              // left and right scan indices
   Comparable v = a[lo];              // partitioning item
   while (true)
   {  // Scan right, scan left, check for scan complete, and exchange.
      while (less(a[++i], v)) if (i == hi) break;
      while (less(v, a[--j])) if (j == lo) break;
      if (i >= j) break;
      exch(a, i, j);
   }
   exch(a, lo, j);          // Put v = a[j] into position
   return j;                // with a[lo..j-1] <= a[j] <= a[j+1..hi].
}
```

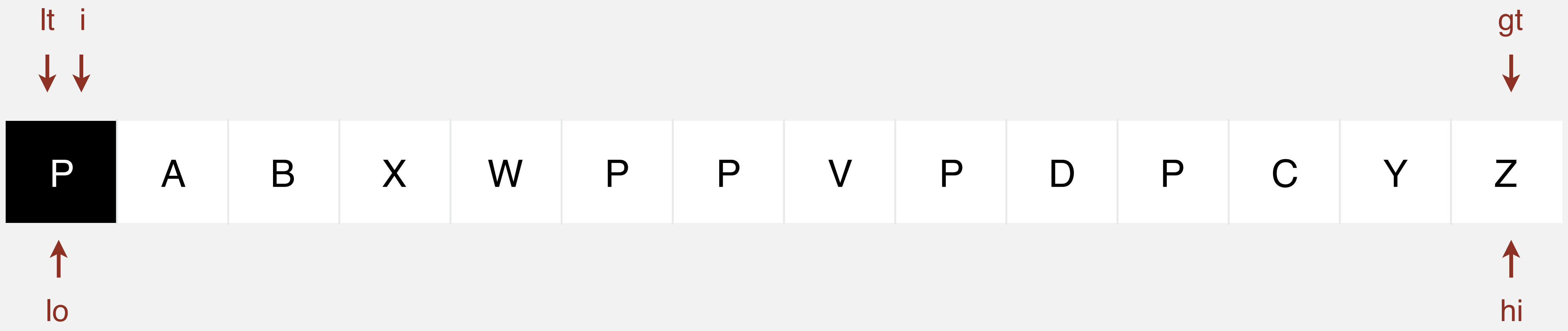
http://algs4.cs.princeton.edu

2.3 Partitioning Demos

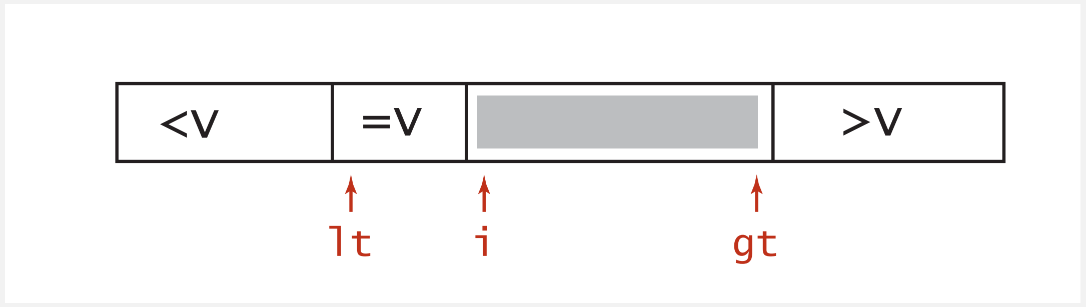
- Sedgewick 2-way partitioning
- Dijkstra 3-way partitioning
- Bentley-McIlroy 3-way partitioning
- dual-pivot partitioning

Dijkstra 3-way partitioning demo

- Let v be partitioning item a[lo].
- Scan i from left to right.
  - (a[i] < v): exchange a[lt] with a[i]; increment both lt and i
  - (a[i] > v): exchange a[gt] with a[i]; decrement gt
  - (a[i] == v): increment i

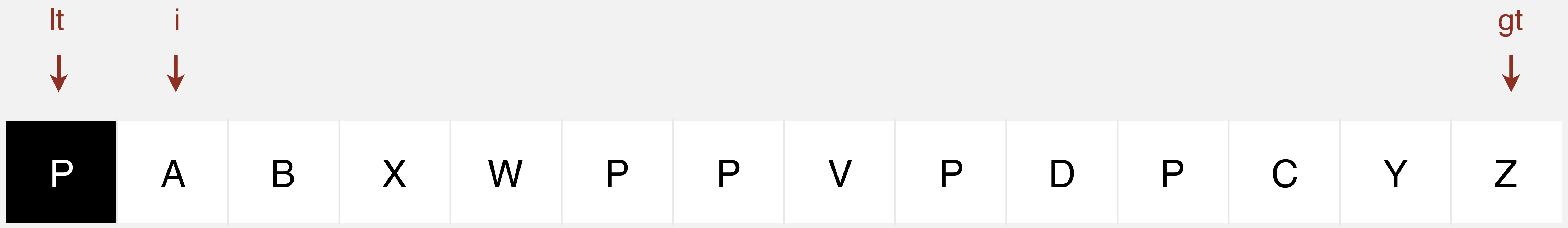


invariant

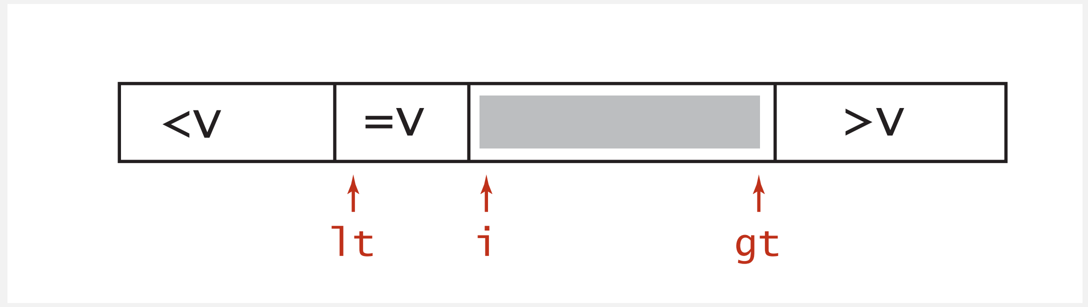


Dijkstra 3-way partitioning demo

- Let v be partitioning item a[lo].
- Scan i from left to right.
  - (a[i] < v): exchange a[lt] with a[i]; increment both lt and i
  - (a[i] > v): exchange a[gt] with a[i]; decrement gt
  - (a[i] == v): increment i

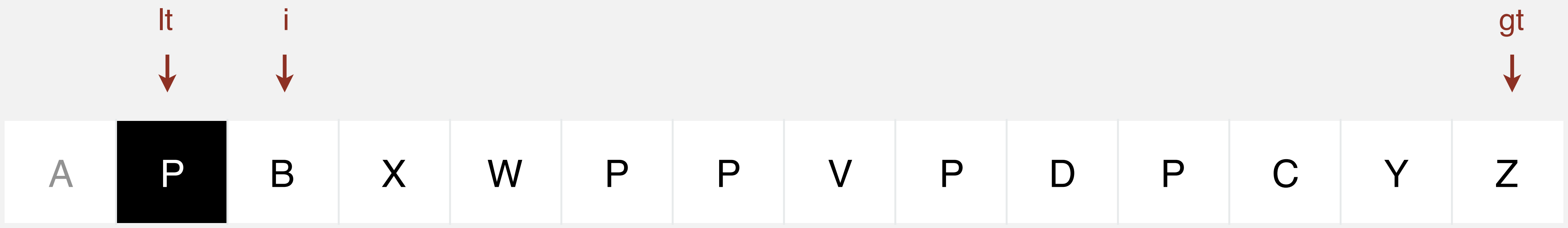


invariant

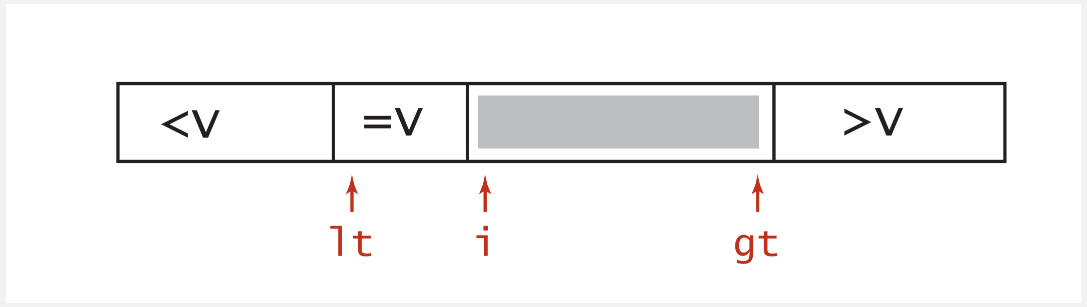


Dijkstra 3-way partitioning demo

- Let v be partitioning item a[lo].
- Scan i from left to right.
  - (a[i] < v): exchange a[lt] with a[i]; increment both lt and i
  - (a[i] > v): exchange a[gt] with a[i]; decrement gt
  - (a[i] == v): increment i

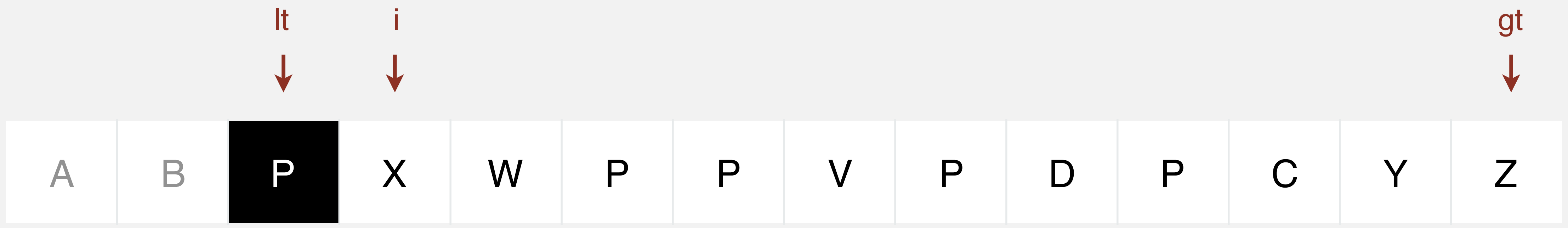


invariant

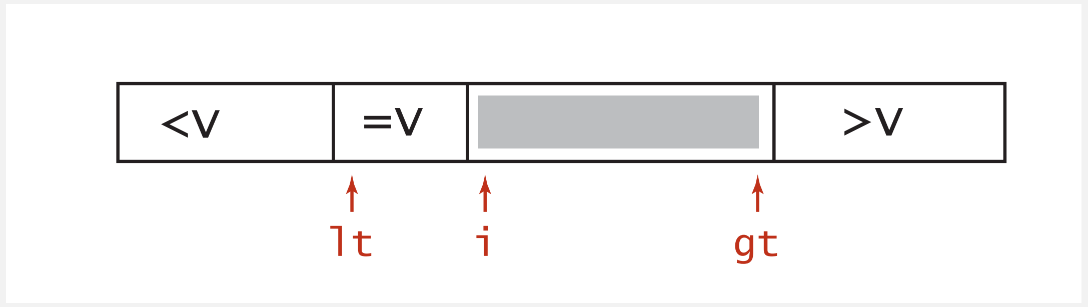


Dijkstra 3-way partitioning demo

- Let v be partitioning item a[lo].
- Scan i from left to right.
  - (a[i] < v): exchange a[lt] with a[i]; increment both lt and i
  - (a[i] > v): exchange a[gt] with a[i]; decrement gt
  - (a[i] == v): increment i



invariant



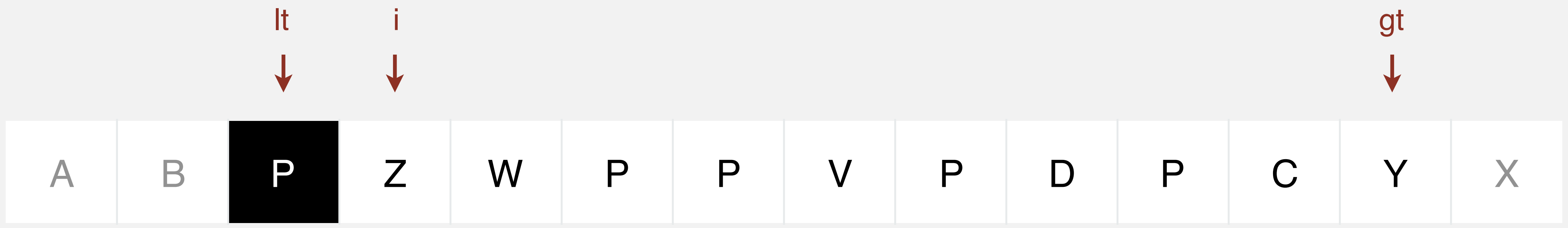
Dijkstra 3-way partitioning demo

- Let v be partitioning item a[lo].
- Scan i from left to right.

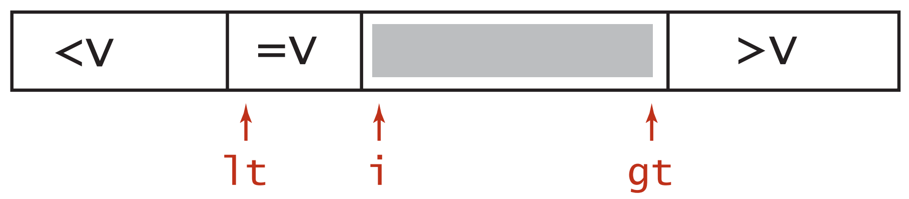
– (a[i] < v): exchange a[lt] with a[i]; increment both lt and i

– (a[i] > v): exchange a[gt] with a[i]; decrement gt

– (a[i] == v): increment i

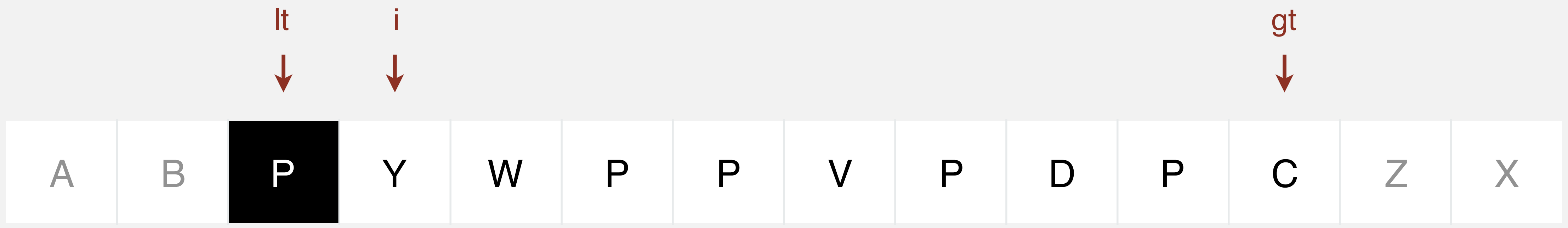


invariant

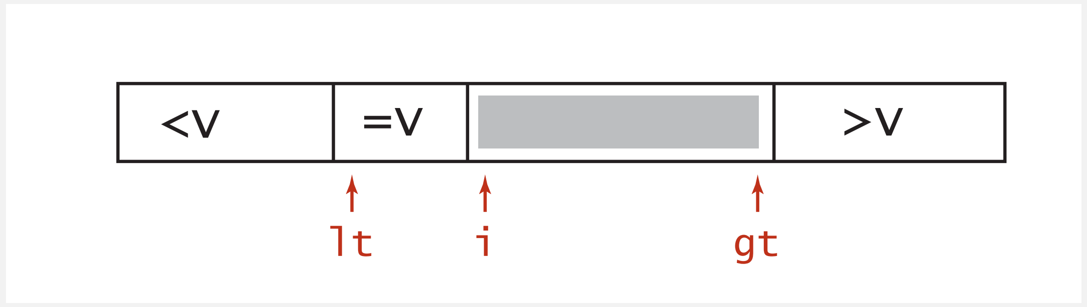


Dijkstra 3-way partitioning demo

- Let v be partitioning item a[lo].
- Scan i from left to right.
  - (a[i] < v): exchange a[lt] with a[i]; increment both lt and i
  - (a[i] > v): exchange a[gt] with a[i]; decrement gt
  - (a[i] == v): increment i

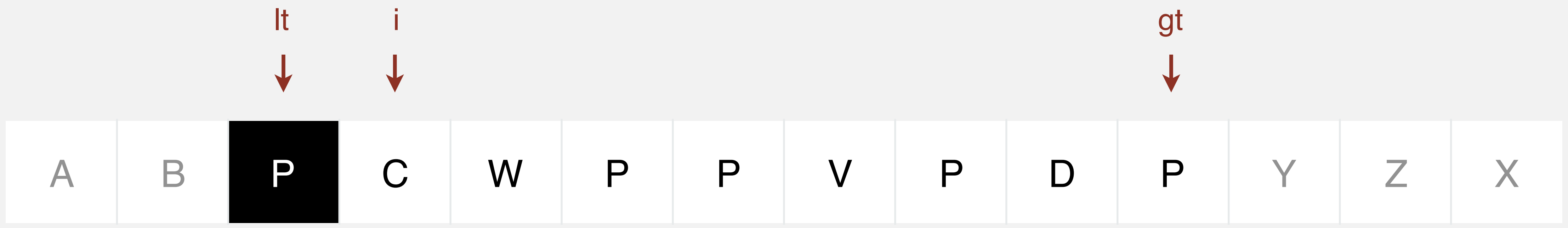


invariant

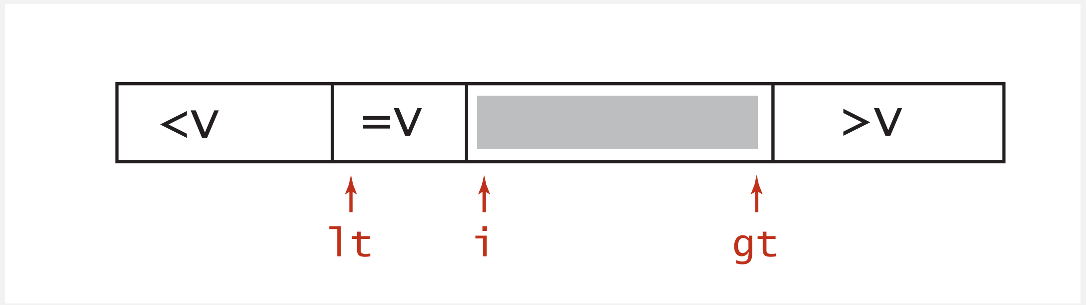


Dijkstra 3-way partitioning demo

- Let v be partitioning item a[lo].
- Scan i from left to right.
  - (a[i] < v): exchange a[lt] with a[i]; increment both lt and i
  - (a[i] > v): exchange a[gt] with a[i]; decrement gt
  - (a[i] == v): increment i

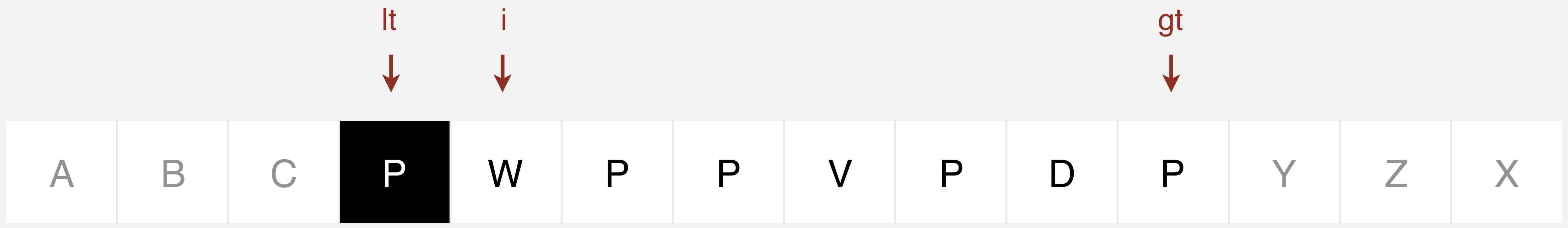


invariant

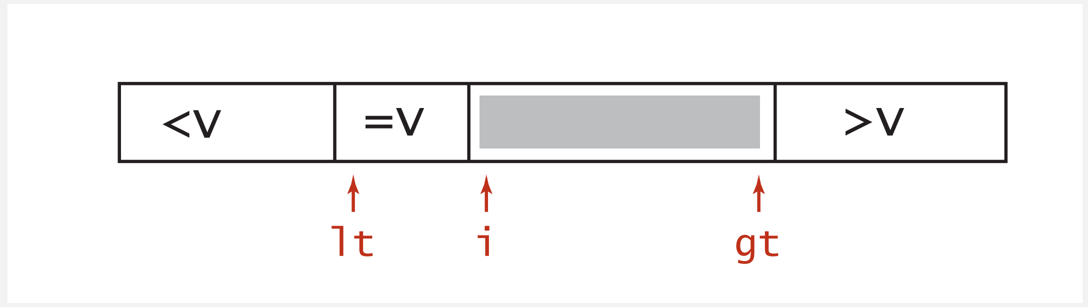


Dijkstra 3-way partitioning demo

- Let v be partitioning item a[lo].
- Scan i from left to right.
  - (a[i] < v): exchange a[lt] with a[i]; increment both lt and i
  - (a[i] > v): exchange a[gt] with a[i]; decrement gt
  - (a[i] == v): increment i

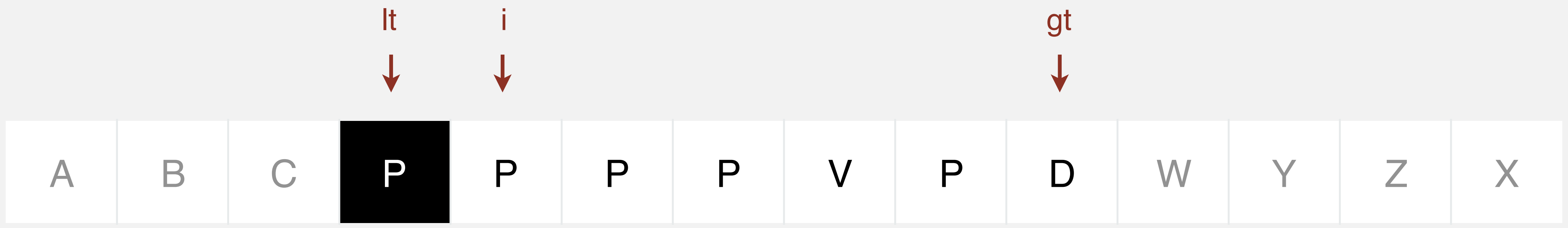


invariant

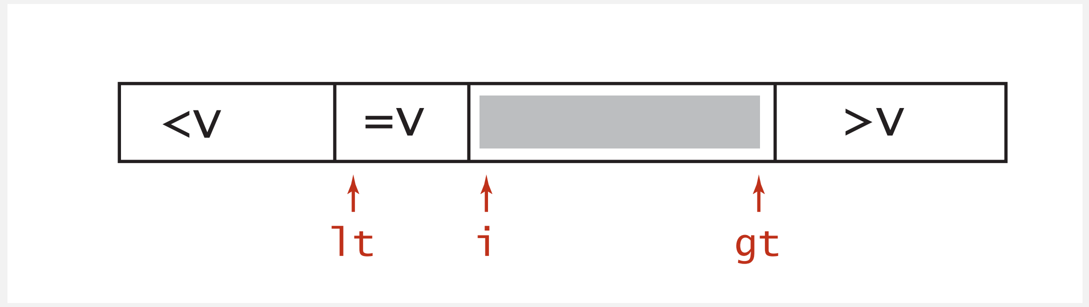


Dijkstra 3-way partitioning demo

- Let v be partitioning item a[lo].
- Scan i from left to right.
  - (a[i] < v): exchange a[lt] with a[i]; increment both lt and i
  - (a[i] > v): exchange a[gt] with a[i]; decrement gt
  - (a[i] == v): increment i

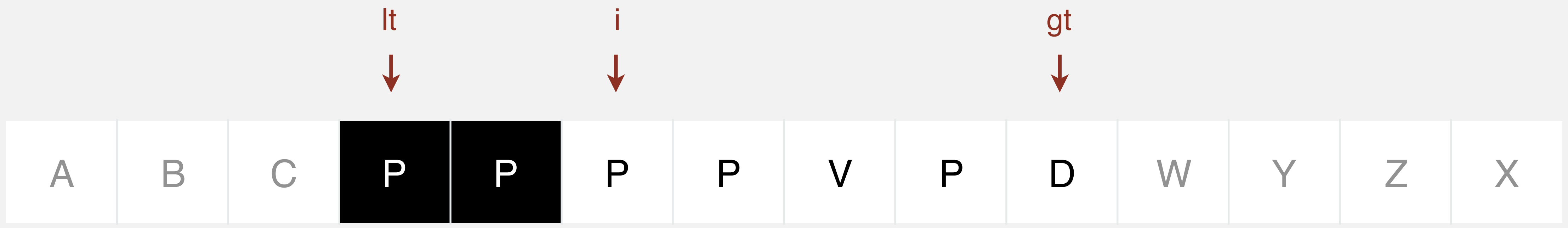


invariant

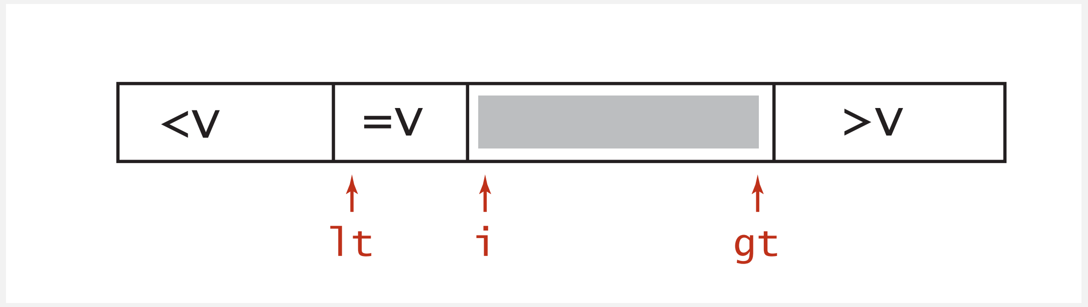


Dijkstra 3-way partitioning demo

- Let v be partitioning item a[lo].
- Scan i from left to right.
  - (a[i] < v): exchange a[lt] with a[i]; increment both lt and i
  - (a[i] > v): exchange a[gt] with a[i]; decrement gt
  - (a[i] == v): increment i

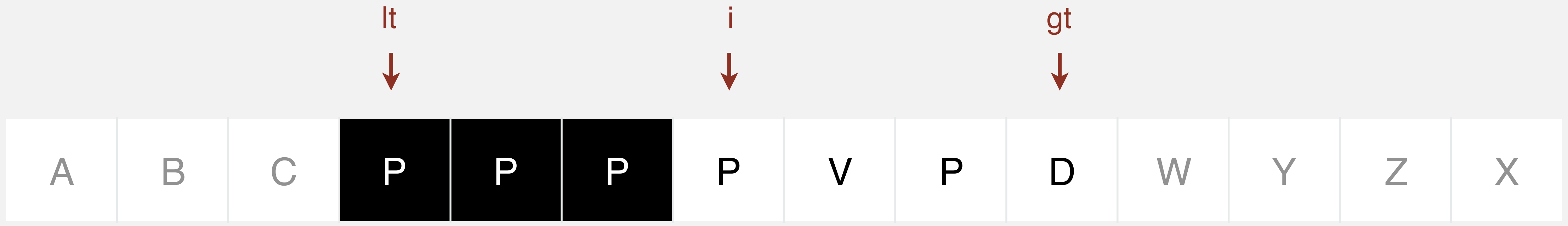


invariant

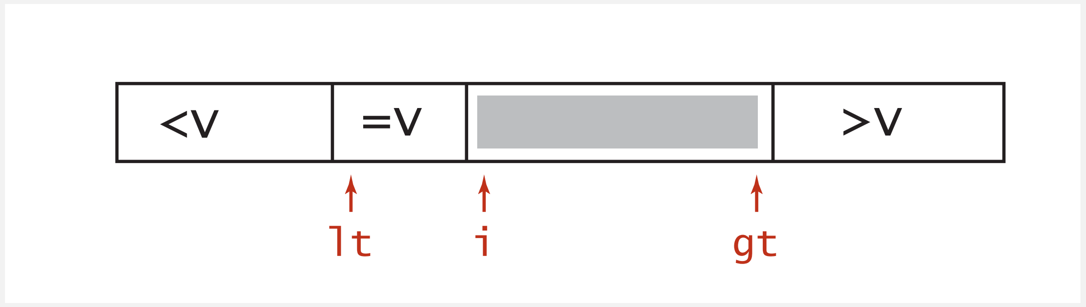


Dijkstra 3-way partitioning demo

- Let v be partitioning item a[lo].
- Scan i from left to right.
  - (a[i] < v): exchange a[lt] with a[i]; increment both lt and i
  - (a[i] > v): exchange a[gt] with a[i]; decrement gt
  - (a[i] == v): increment i

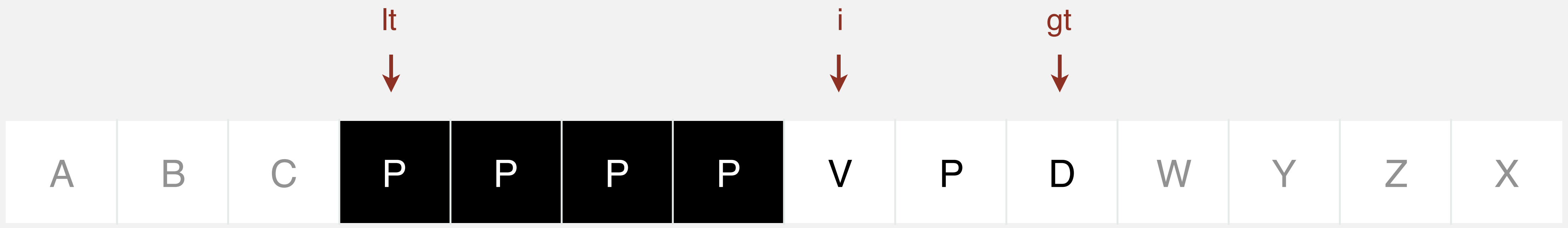


invariant

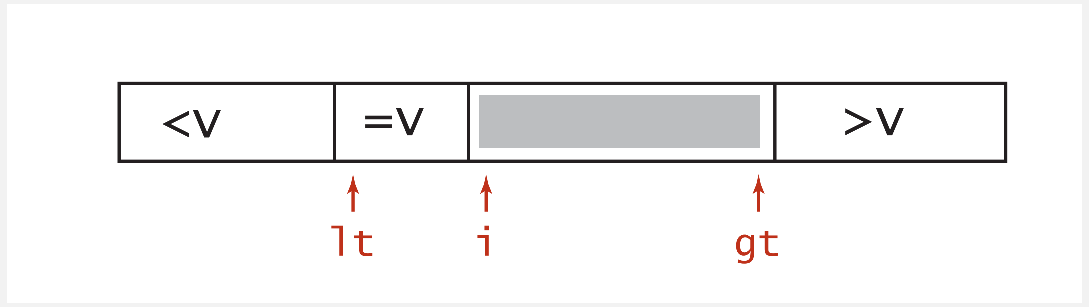


Dijkstra 3-way partitioning demo

- Let v be partitioning item a[lo].
- Scan i from left to right.
  - (a[i] < v): exchange a[lt] with a[i]; increment both lt and i
  - (a[i] > v): exchange a[gt] with a[i]; decrement gt
  - (a[i] == v): increment i

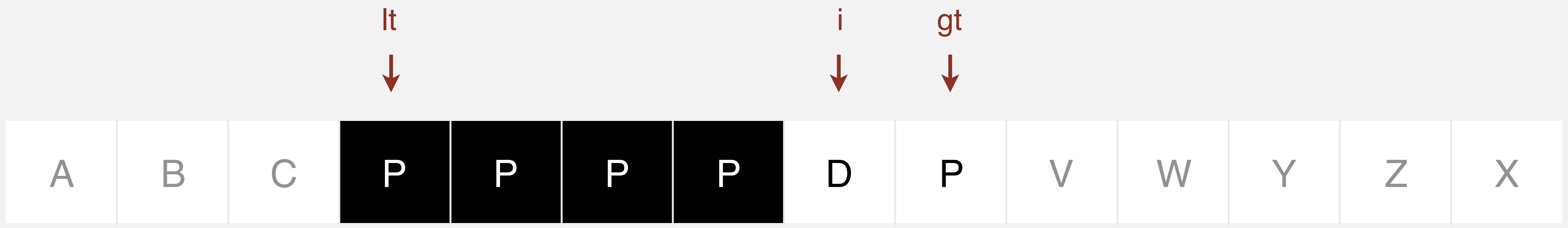


invariant

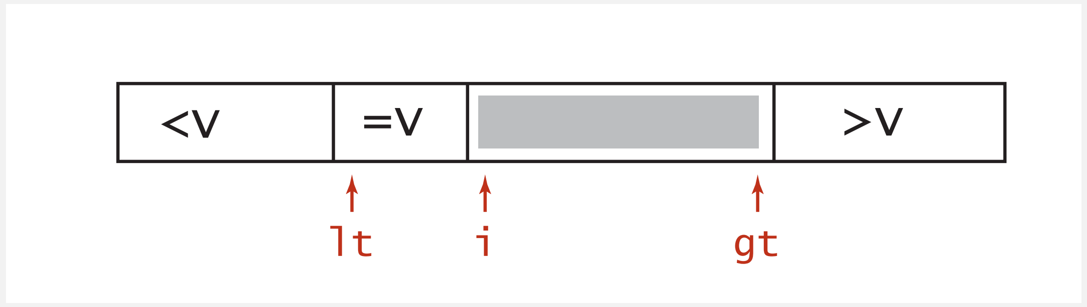


Dijkstra 3-way partitioning demo

- Let v be partitioning item a[lo].
- Scan i from left to right.
  - (a[i] < v): exchange a[lt] with a[i]; increment both lt and i
  - (a[i] > v): exchange a[gt] with a[i]; decrement gt
  - (a[i] == v): increment i

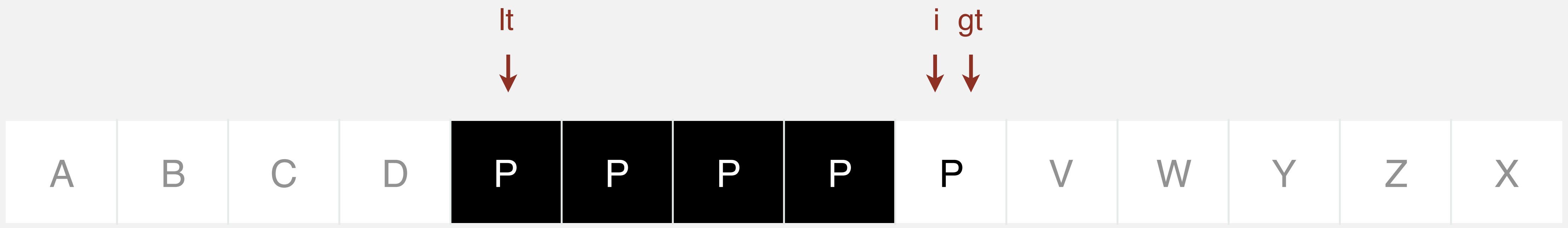


invariant

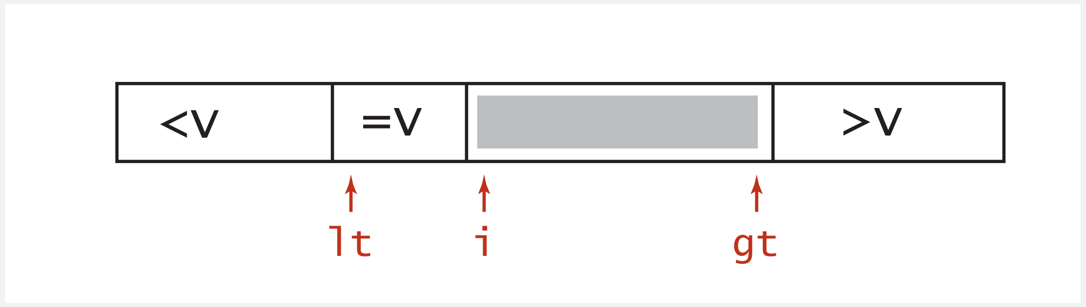


Dijkstra 3-way partitioning demo

- Let v be partitioning item a[lo].
- Scan i from left to right.
  - (a[i] < v): exchange a[lt] with a[i]; increment both lt and i
  - (a[i] > v): exchange a[gt] with a[i]; decrement gt
  - (a[i] == v): increment i

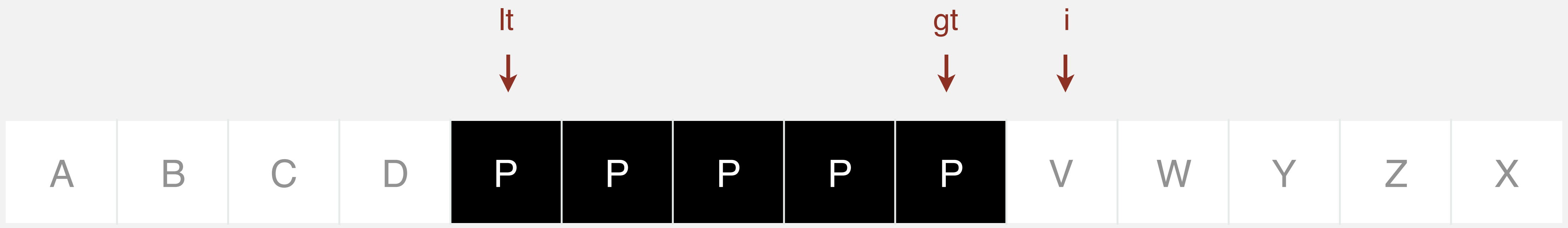


invariant

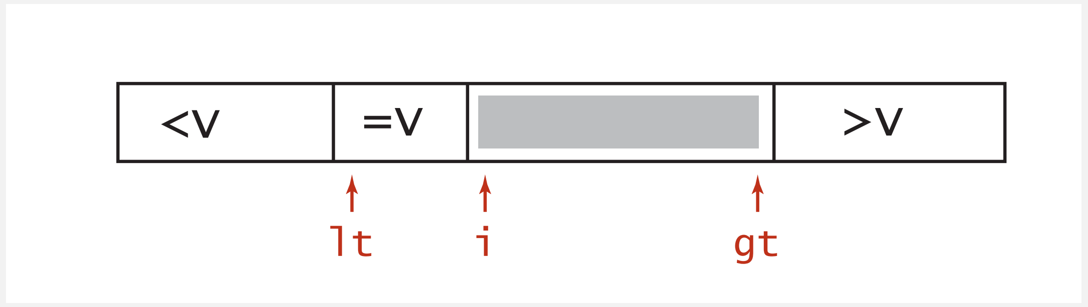


Dijkstra 3-way partitioning demo

- Let v be partitioning item a[lo].
- Scan i from left to right.
  - (a[i] < v): exchange a[lt] with a[i]; increment both lt and i
  - (a[i] > v): exchange a[gt] with a[i]; decrement gt
  - (a[i] == v): increment i

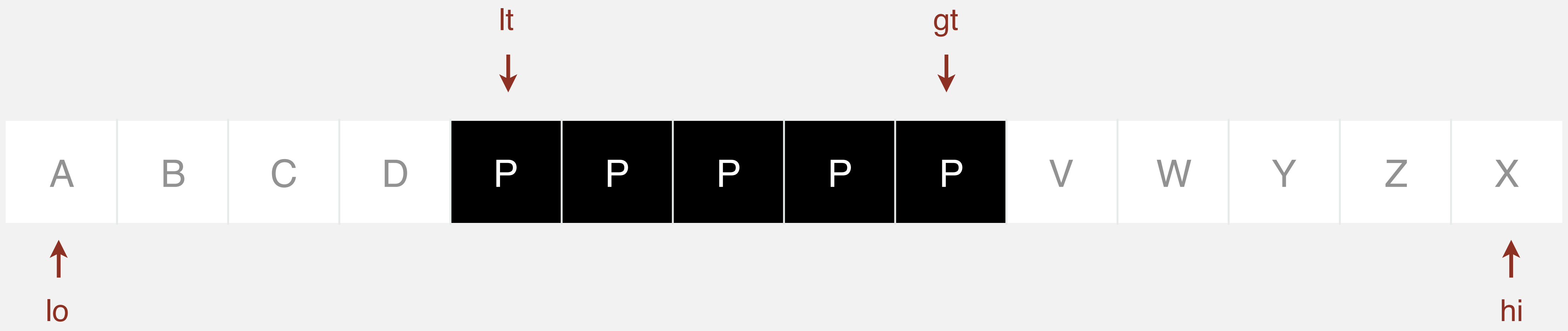


invariant

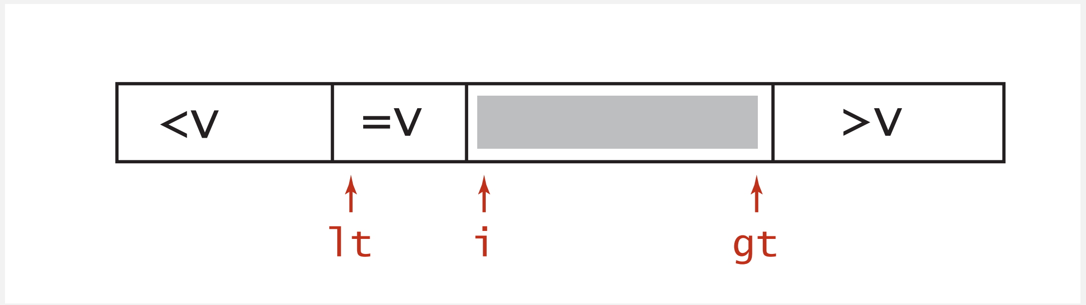


Dijkstra 3-way partitioning demo

- Let v be partitioning item a[lo].
- Scan i from left to right.
  - (a[i] < v): exchange a[lt] with a[i]; increment both lt and i
  - (a[i] > v): exchange a[gt] with a[i]; decrement gt
  - (a[i] == v): increment i



invariant



http://algs4.cs.princeton.edu

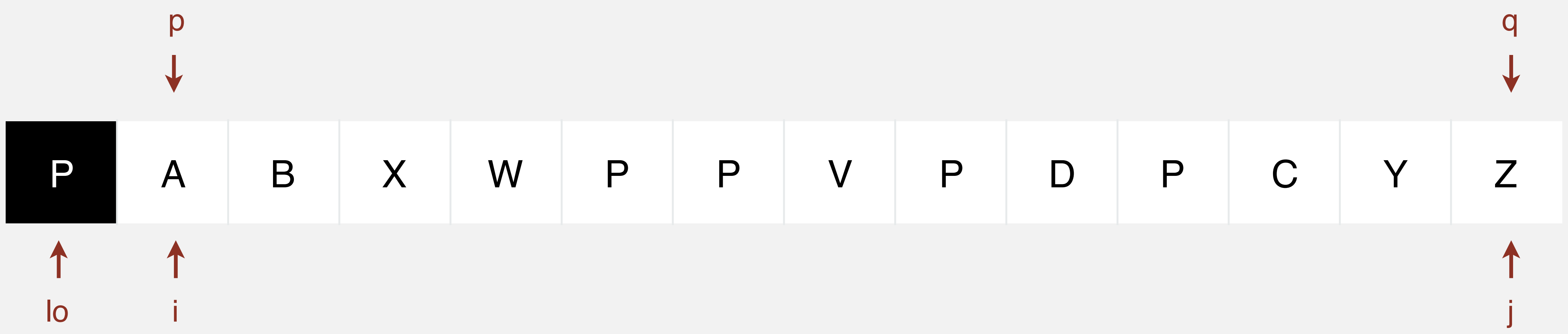
2.3 Partitioning Demos

- Sedgewick 2-way partitioning
- Dijkstra 3-way partitioning
- Bentley-McIlroy 3-way partitioning
- dual-pivot partitioning

Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

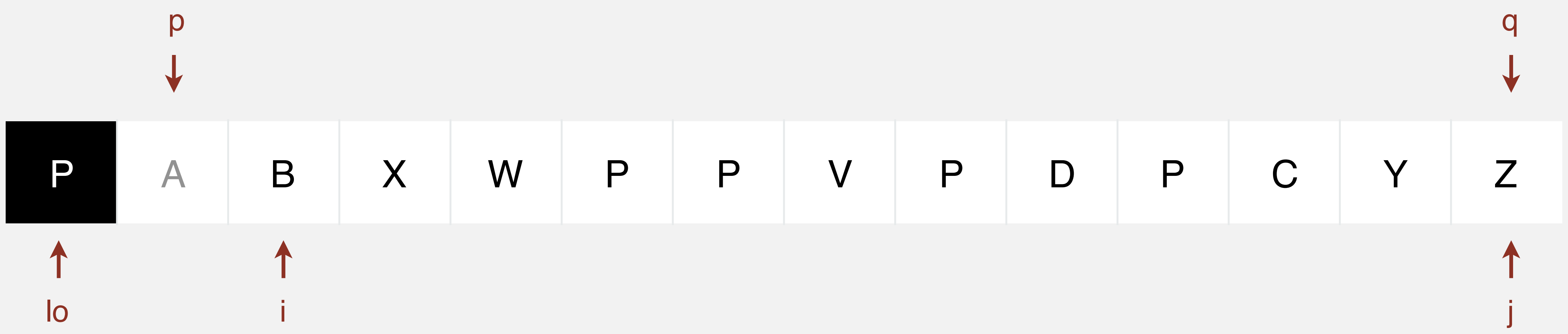
- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[j] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.



Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

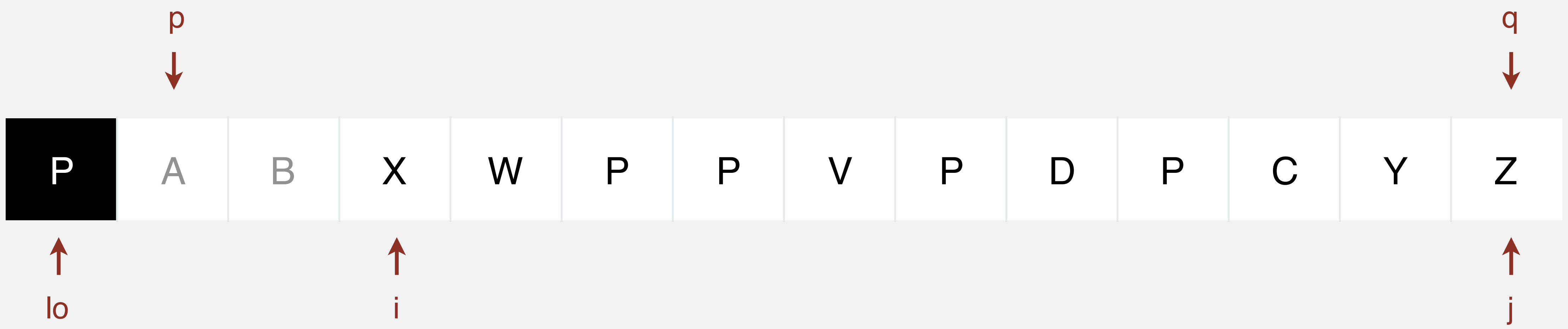
- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[j] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.



Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

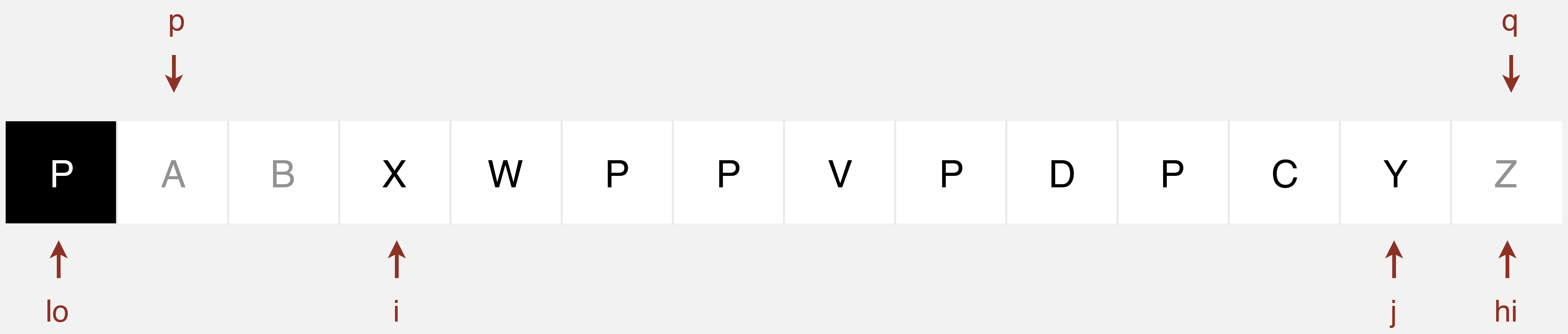
- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[j] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.



Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

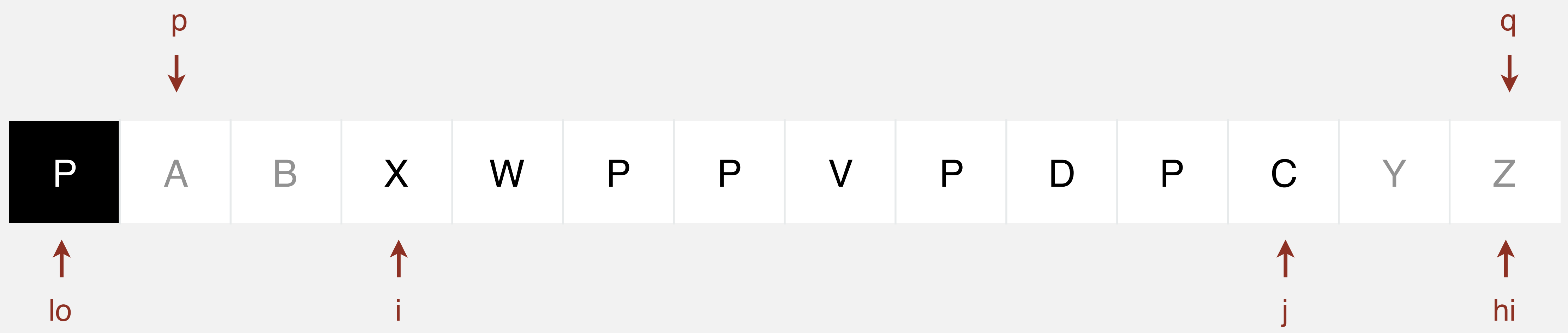
- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[j] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.



Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[i] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.

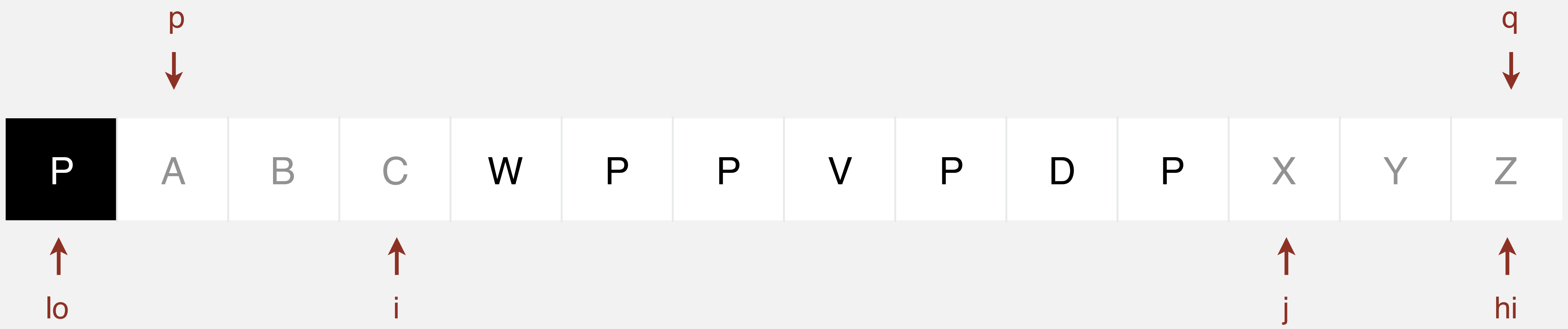


exchange a[i] with a[j]

Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

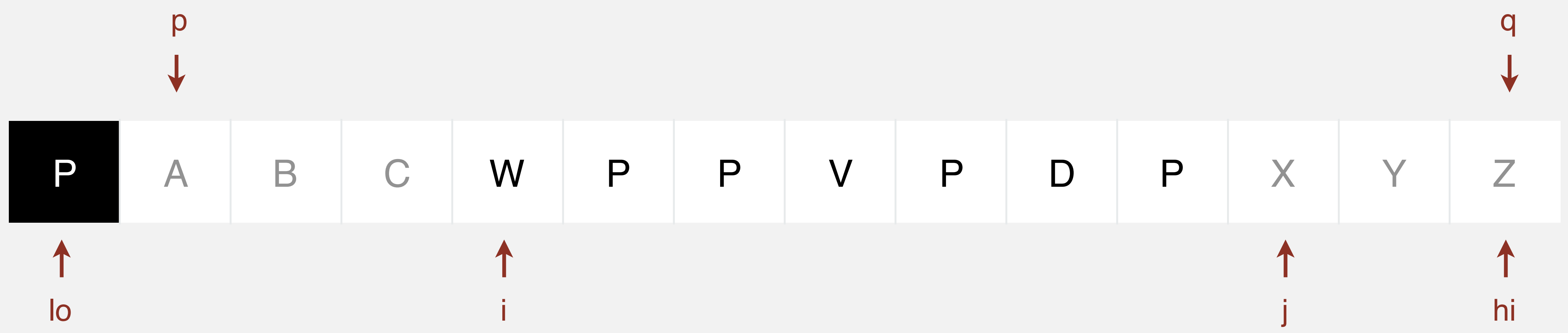
- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[i] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.



Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

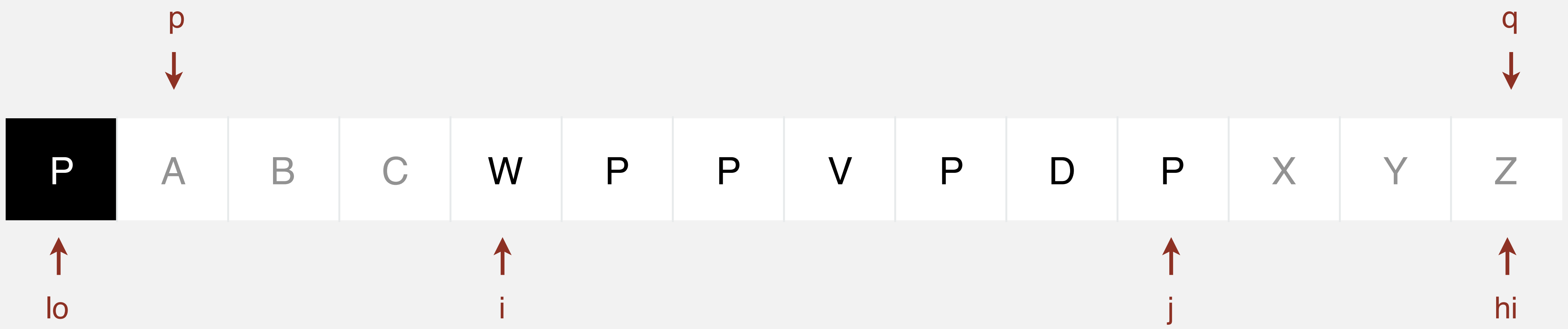
- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[i] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.



Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[i] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.

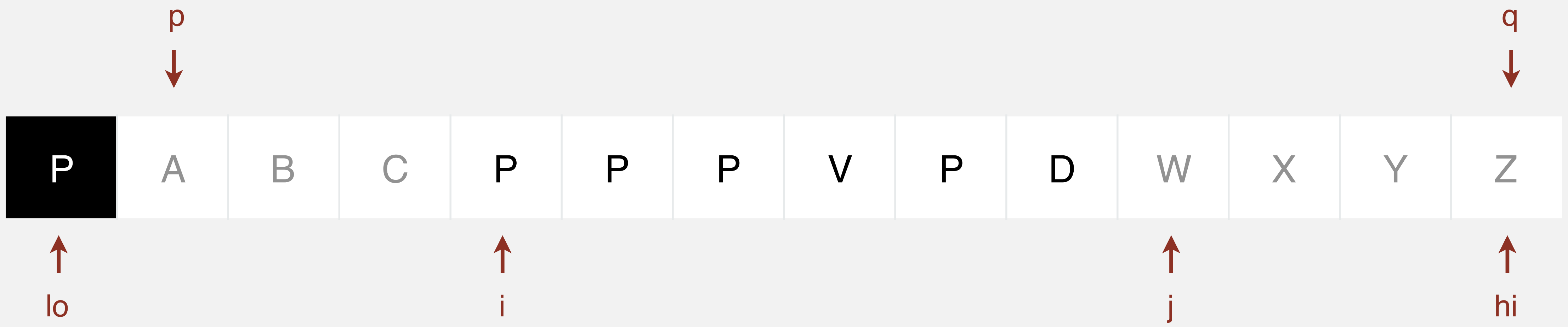


exchange a[i] with a[j]

Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[j] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.

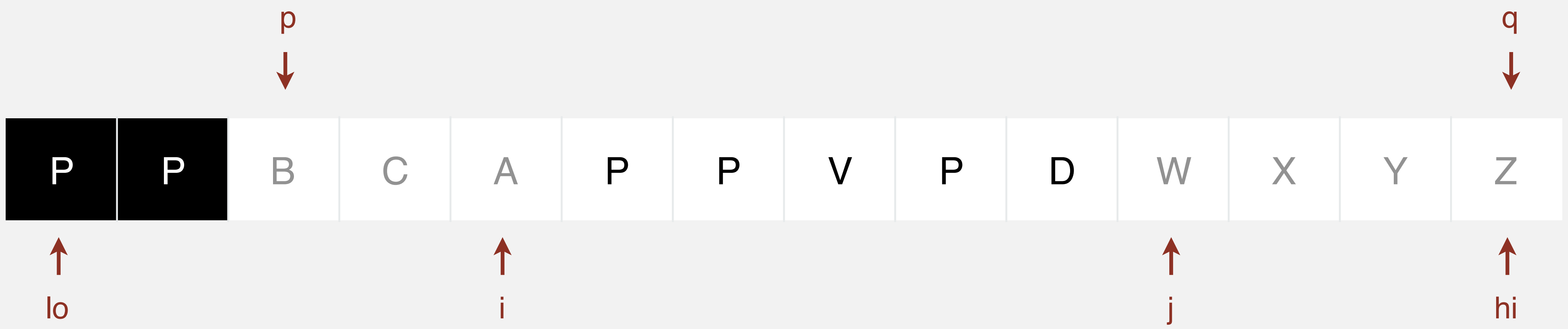


exchange a[i] with a[p] and increment p

Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

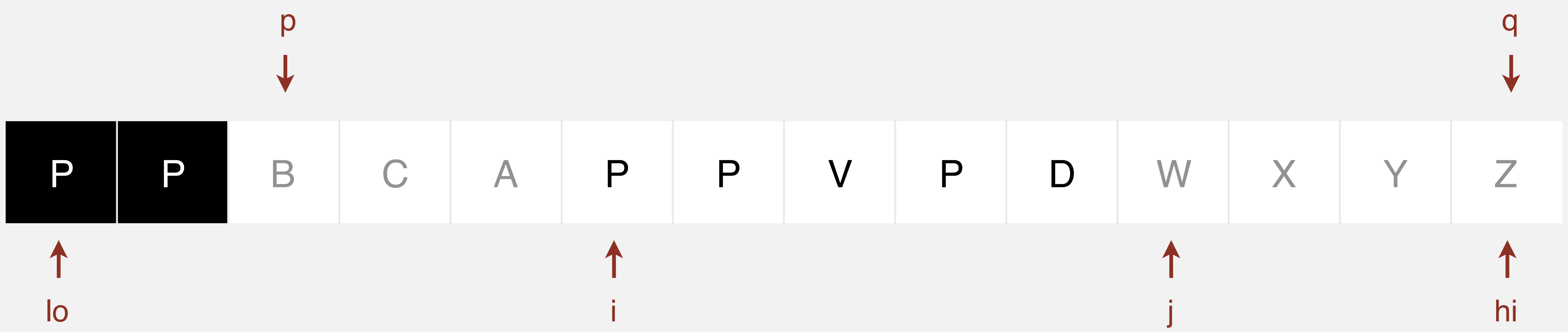
- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[j] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.



Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

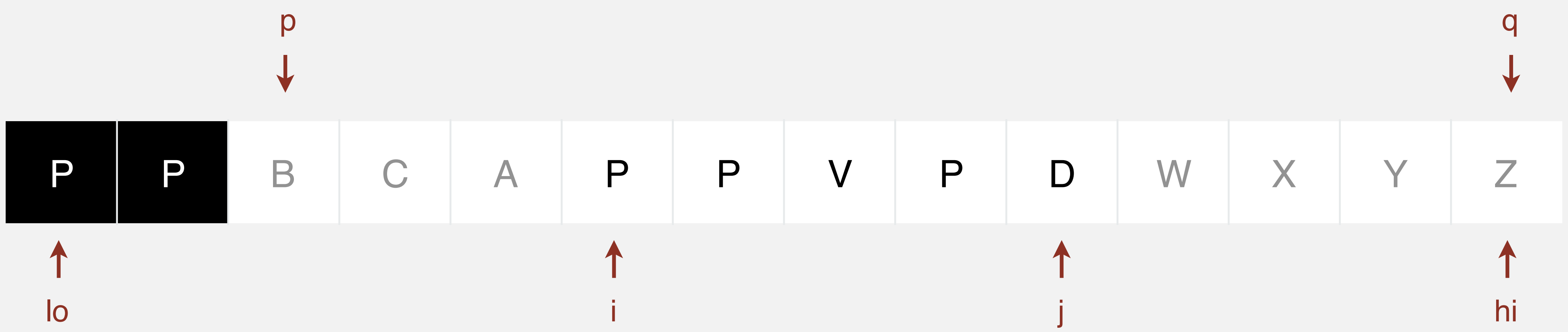
- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[j] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.



Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[j] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.

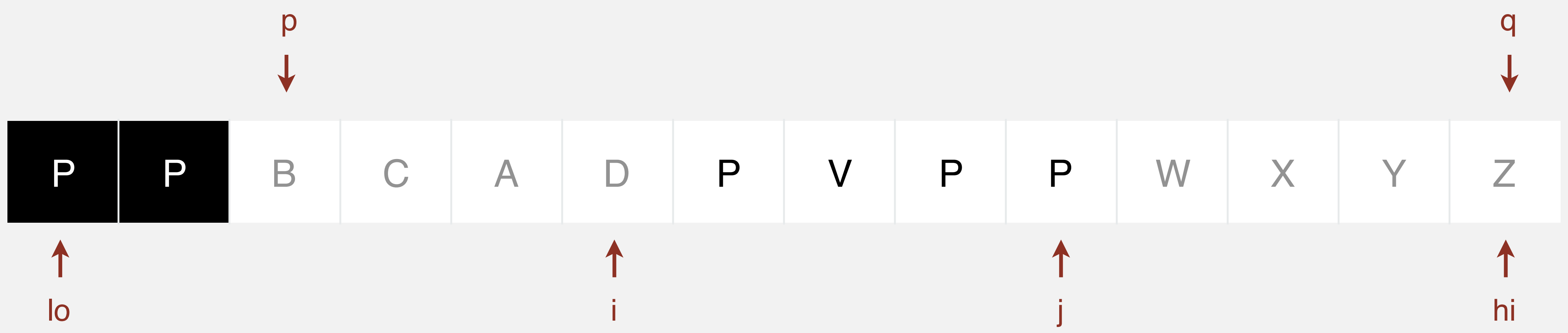


exchange a[i] with a[j]

Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[j] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.

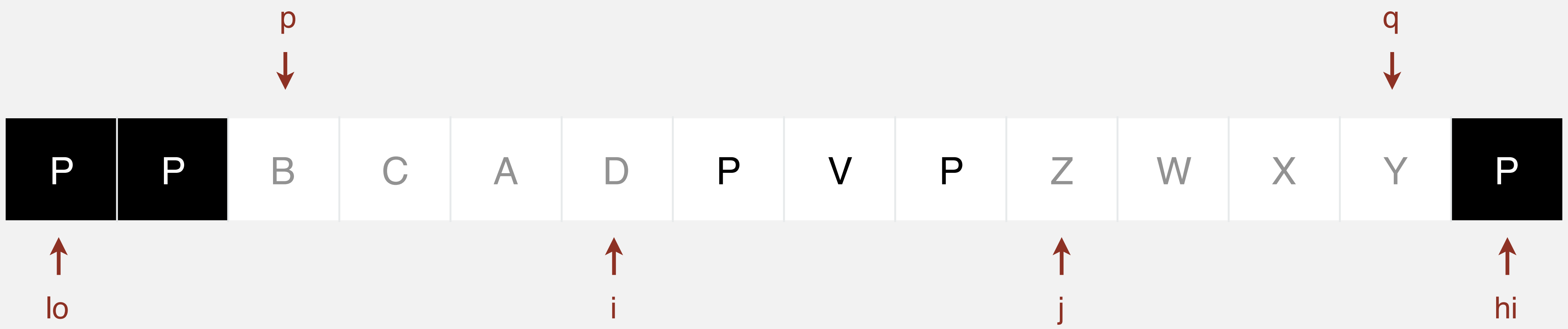


exchange a[j] with a[q] and decrement q

Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

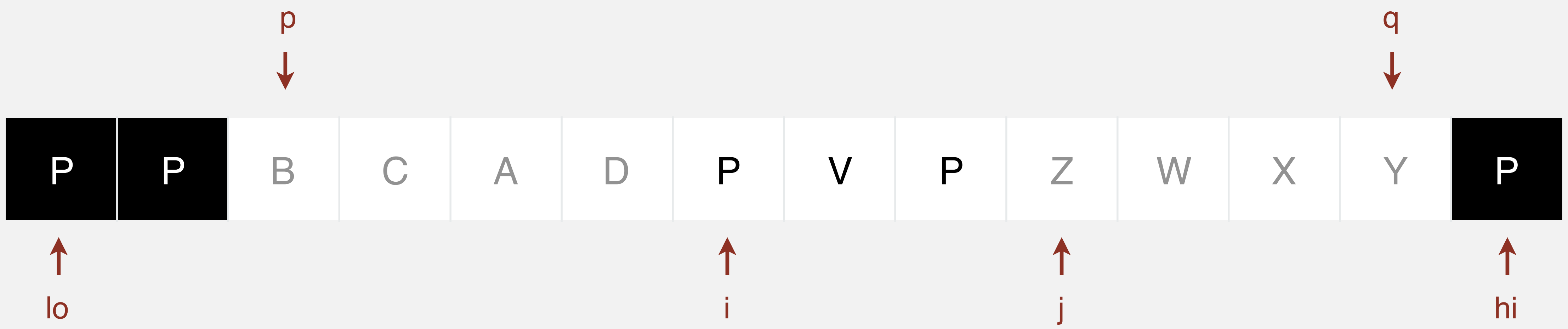
- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[j] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.



Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

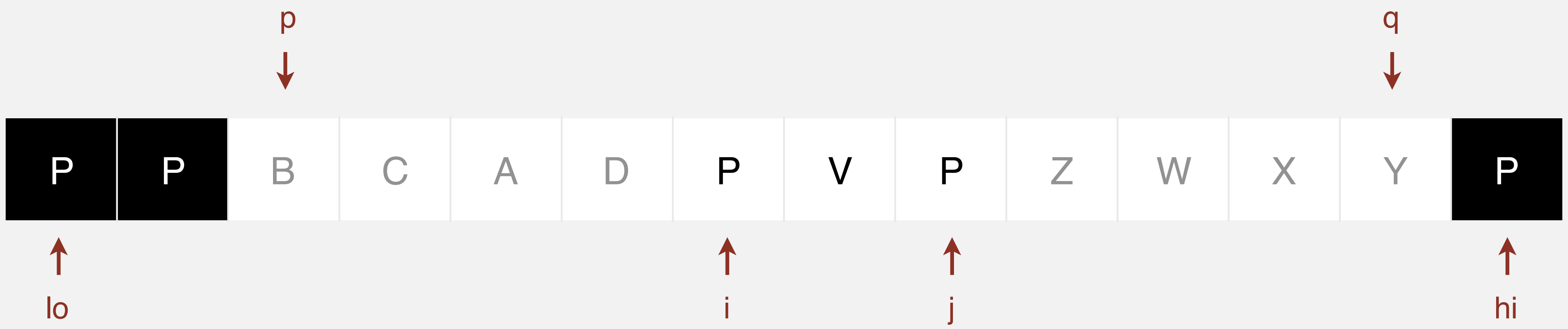
- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[i] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.



Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[i] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.

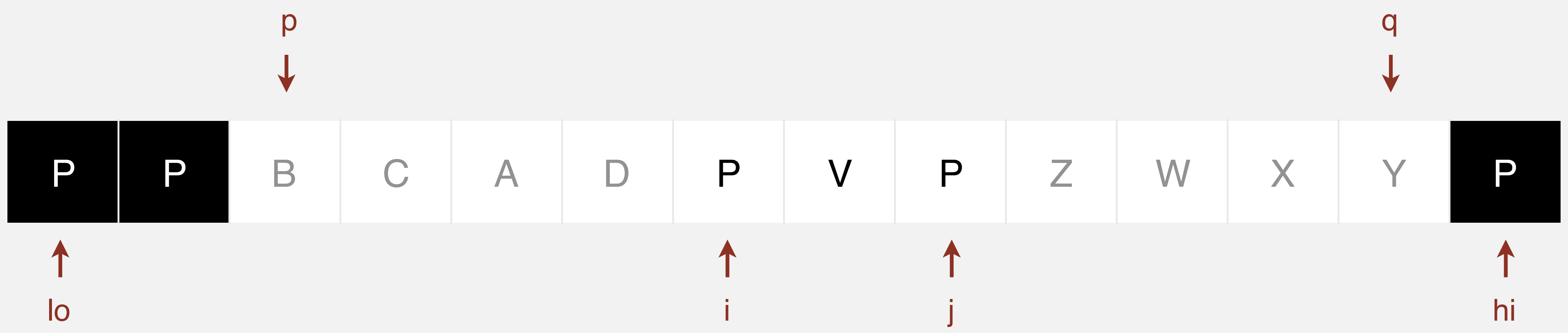


exchange a[i] with a[j]

Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[i] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.

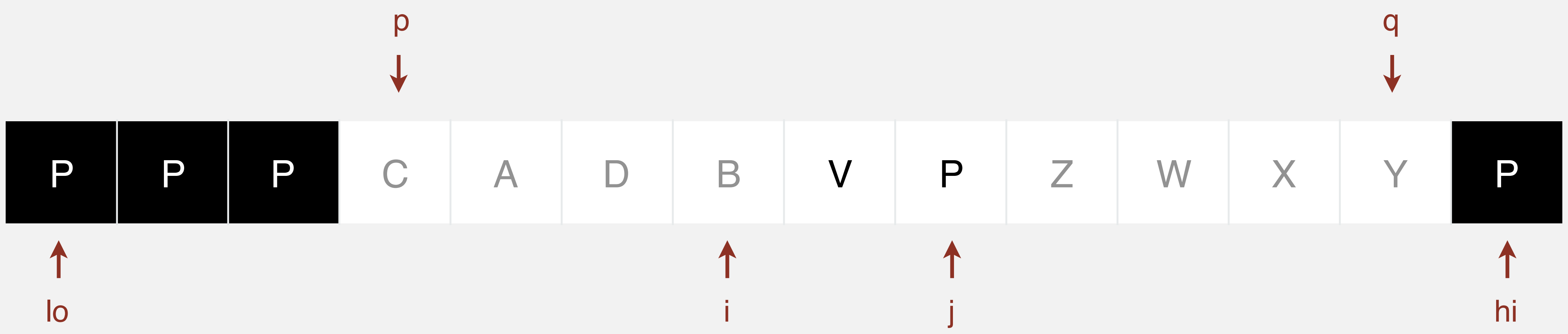


exchange a[i] with a[p] and increment p

Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[i] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.

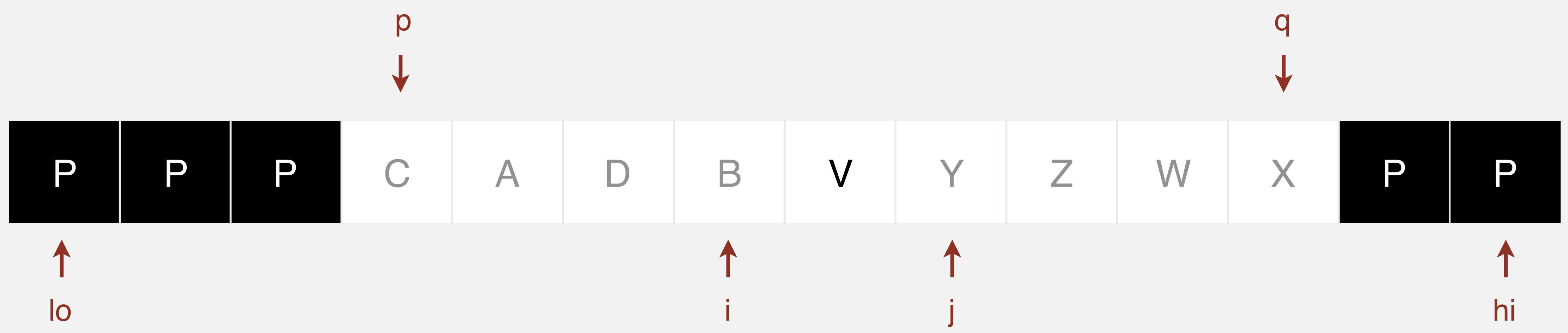


exchange a[j] with a[q] and decrement q

Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

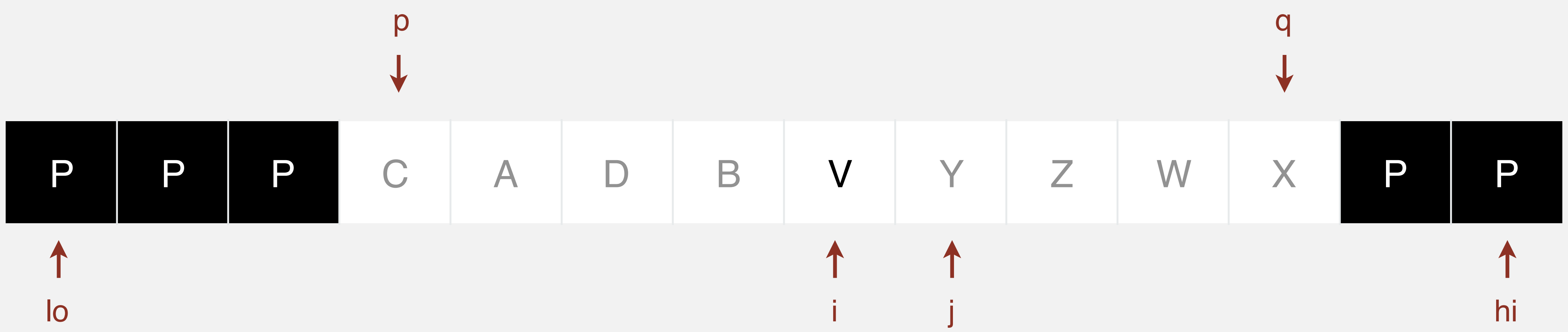
- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[i] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.



Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

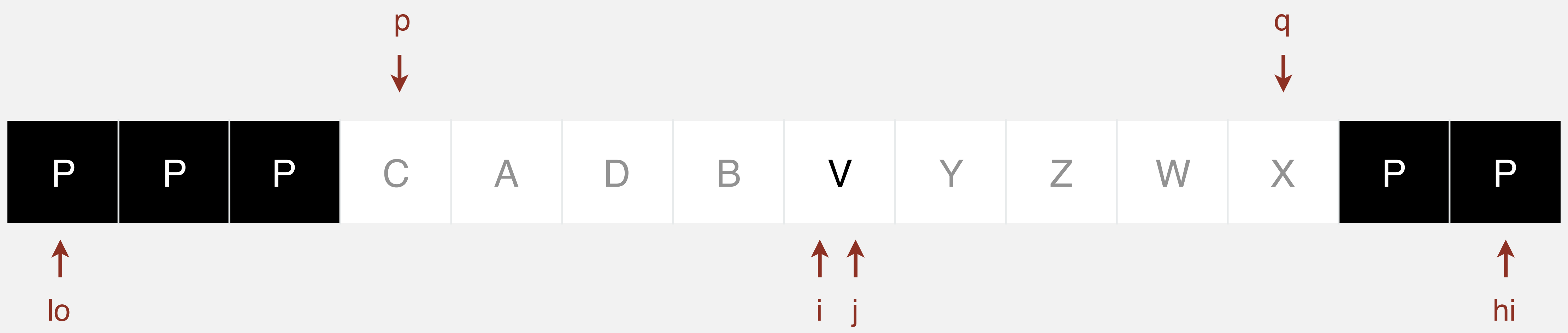
- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[i] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.



Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

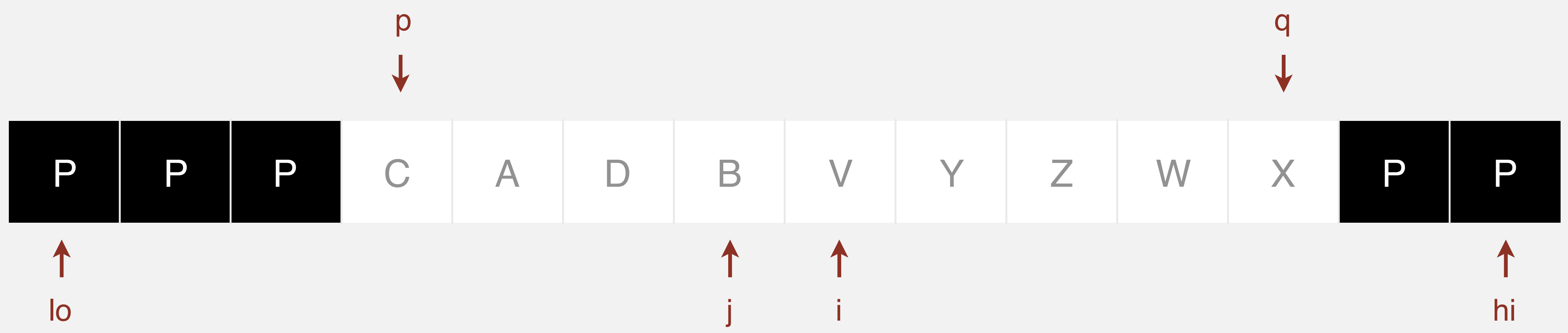
- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[j] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.



Bentley-McIlroy 3-way partitioning demo

Phase I. Repeat until i and j pointers cross.

- Scan i from left to right so long as (a[i] < a[lo]).
- Scan j from right to left so long as (a[j] > a[lo]).
- Exchange a[i] with a[j].
- If (a[i] == a[lo]), exchange a[i] with a[p] and increment p.
- If (a[j] == a[lo]), exchange a[j] with a[q] and decrement q.

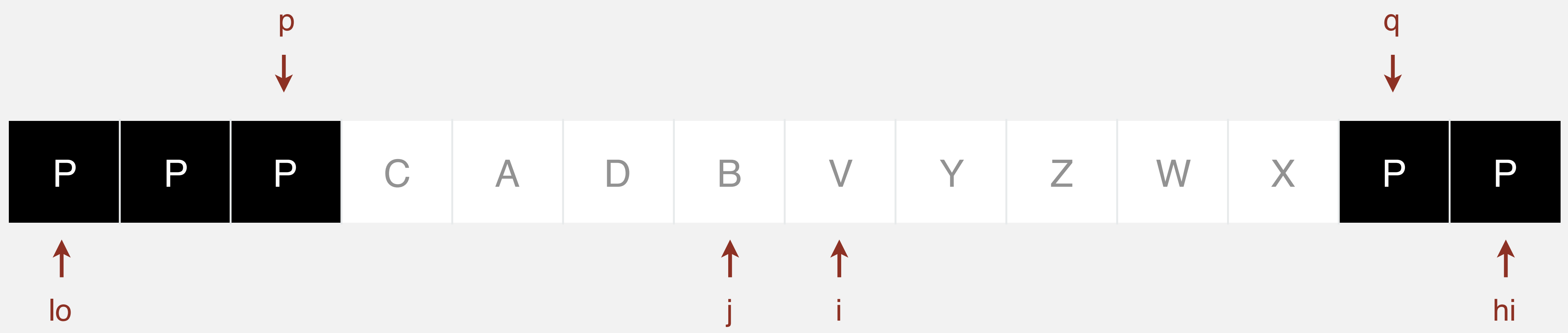


pointers cross

Bentley-McIlroy 3-way partitioning demo

Phase II. Swap equal keys to the center.

- Scan j and p from right to left and exchange a[j] with a[p].
- Scan i and q from left to right and exchange a[i] with a[q].

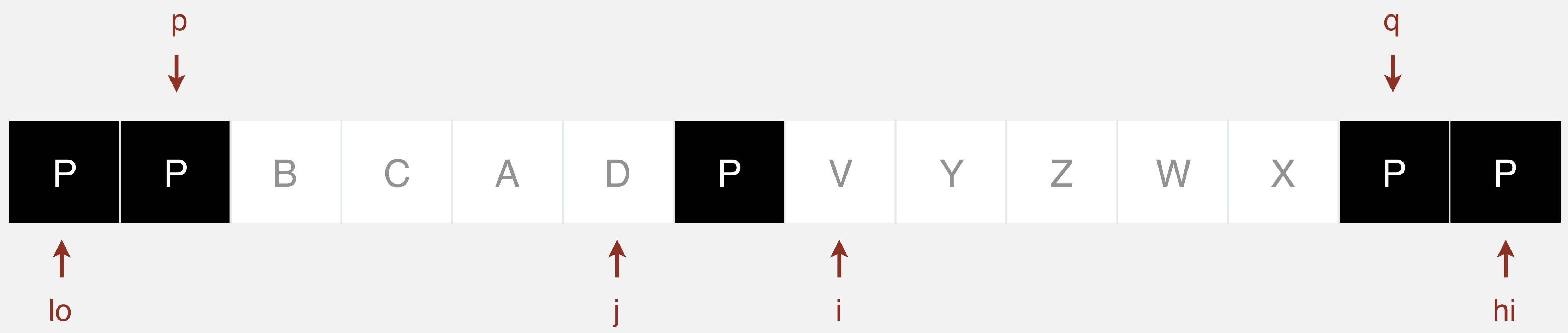


exchange a[j] with a[p]

Bentley-McIlroy 3-way partitioning demo

Phase II. Swap equal keys to the center.

- Scan j and p from right to left and exchange a[j] with a[p].
- Scan i and q from left to right and exchange a[i] with a[q].

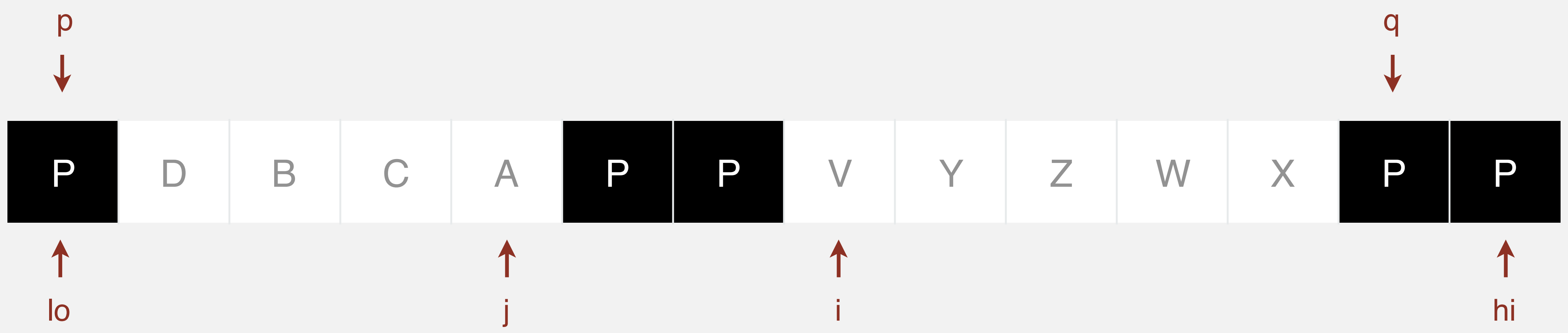


exchange a[j] with a[p]

Bentley-McIlroy 3-way partitioning demo

Phase II. Swap equal keys to the center.

- Scan j and p from right to left and exchange a[j] with a[p].
- Scan i and q from left to right and exchange a[i] with a[q].

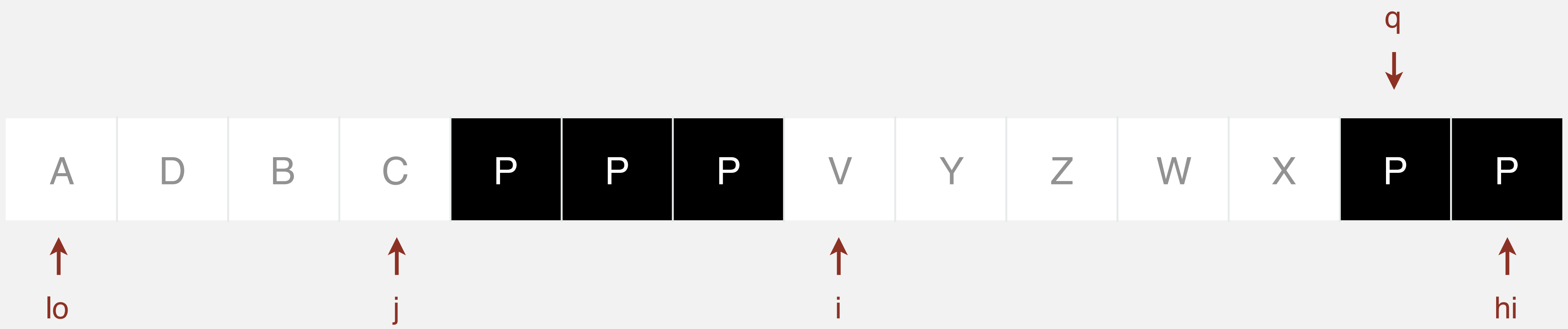


exchange a[j] with a[p]

Bentley-McIlroy 3-way partitioning demo

Phase II. Swap equal keys to the center.

- Scan j and p from right to left and exchange a[j] with a[p].
- Scan i and q from left to right and exchange a[i] with a[q].

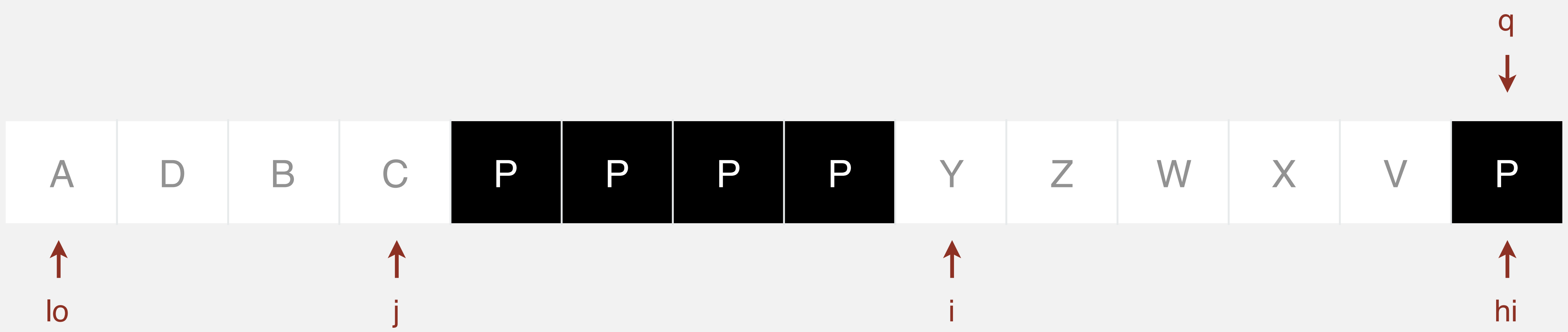


exchange a[i] with a[q]

Bentley-McIlroy 3-way partitioning demo

Phase II. Swap equal keys to the center.

- Scan j and p from right to left and exchange a[j] with a[p].
- Scan i and q from left to right and exchange a[i] with a[q].

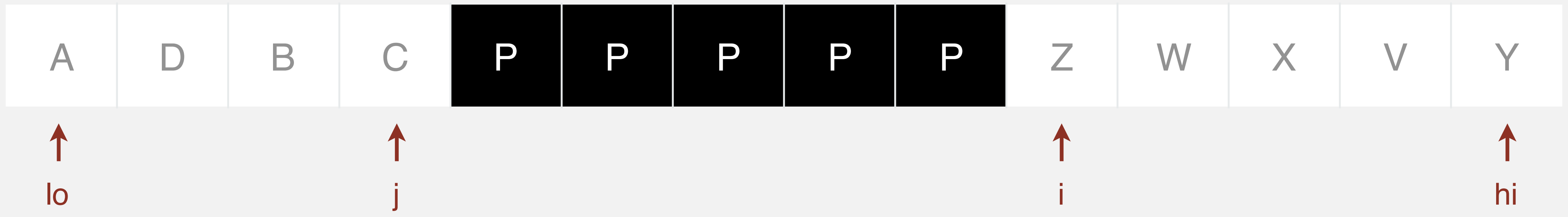


exchange a[i] with a[q]

Bentley-McIlroy 3-way partitioning demo

Phase II. Swap equal keys to the center.

- Scan j and p from right to left and exchange a[j] with a[p].
- Scan i and q from left to right and exchange a[i] with a[q].



3-way partitioned

http://algs4.cs.princeton.edu

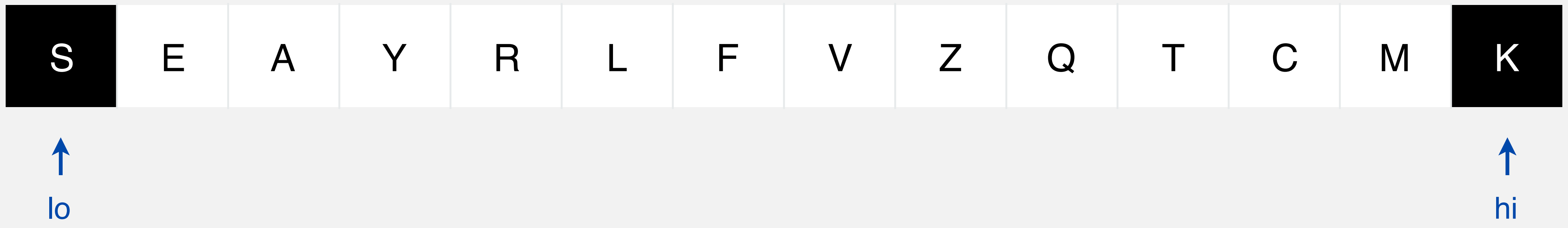
2.3 Partitioning Demos

- *Sedgewick 2-way partitioning*
- *Dijkstra 3-way partitioning*
- *Bentley-McIlroy 3-way partitioning*
- *dual-pivot partitioning*

Dual-pivot partitioning demo

Initialization.

- Choose a[lo] and a[hi] as partitioning items.
- Exchange if necessary to ensure a[lo] ≤ a[hi].

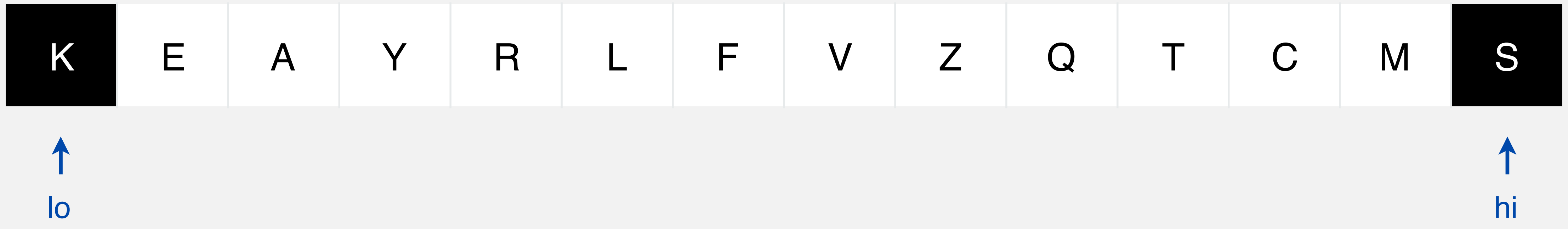


exchange a[lo] and a[hi]

Dual-pivot partitioning demo

Initialization.

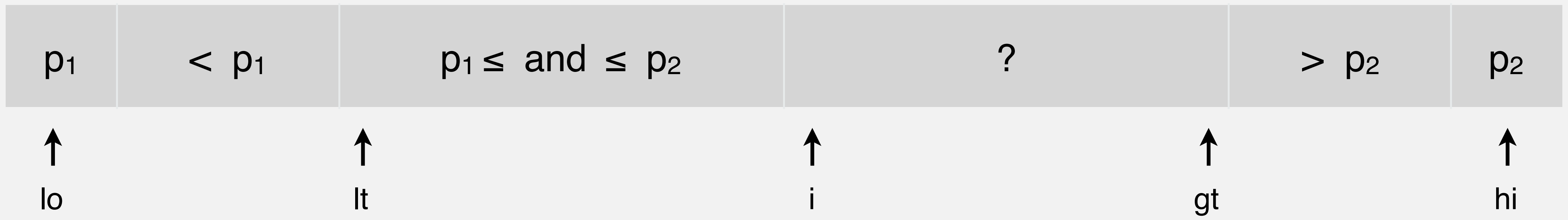
- Choose a[lo] and a[hi] as partitioning items.
- Exchange if necessary to ensure a[lo] ≤ a[hi].

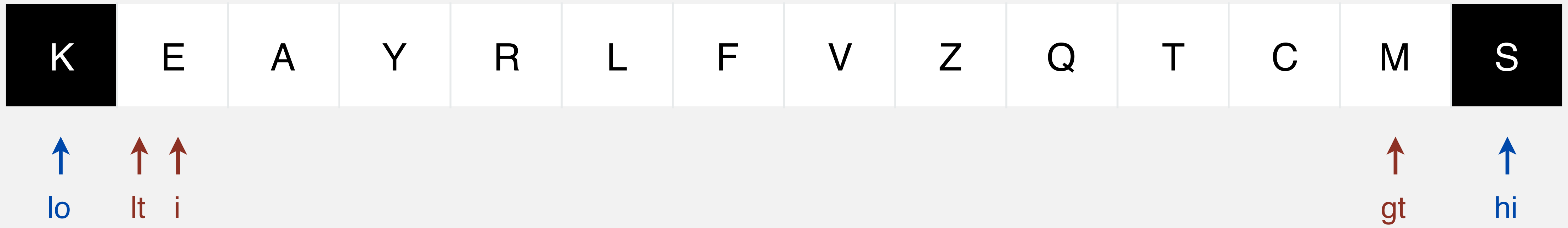


Dual-pivot partitioning demo

Main loop. Repeat until i and gt pointers cross.

- If (a[i] < a[lo]), exchange a[i] with a[lt] and increment lt and i.
- Else if (a[i] > a[hi]), exchange a[i] with a[gt] and decrement gt.
- Else, increment i.



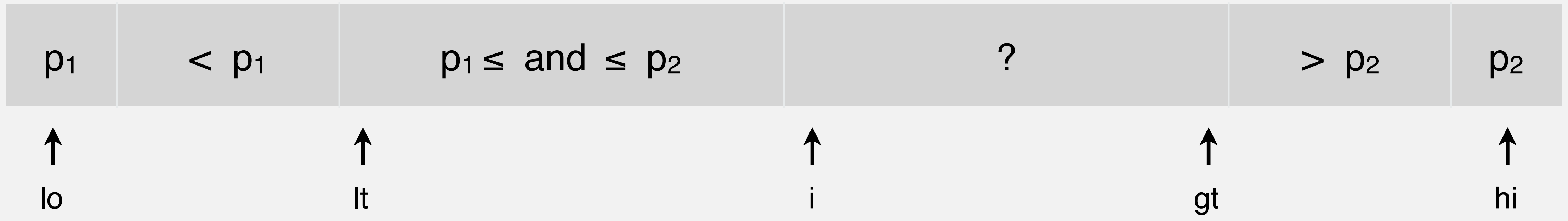


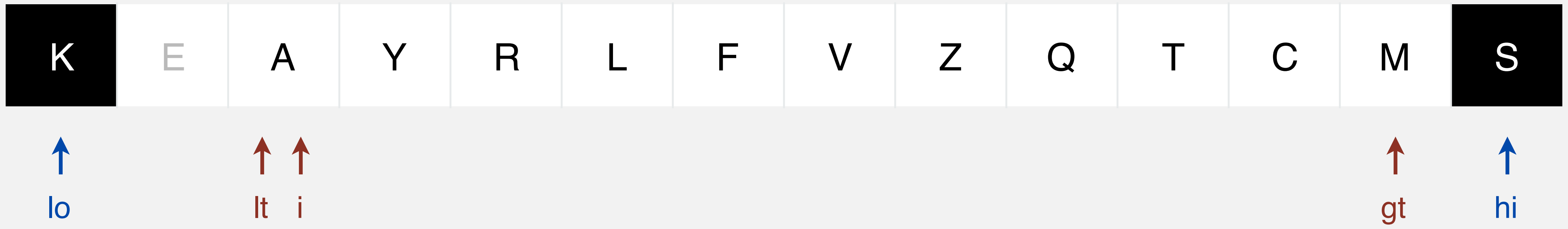
exchange a[i] and a[lt]; increment lt and i

Dual-pivot partitioning demo

Main loop. Repeat until i and gt pointers cross.

- If (a[i] < a[lo]), exchange a[i] with a[lt] and increment lt and i.
- Else if (a[i] > a[hi]), exchange a[i] with a[gt] and decrement gt.
- Else, increment i.



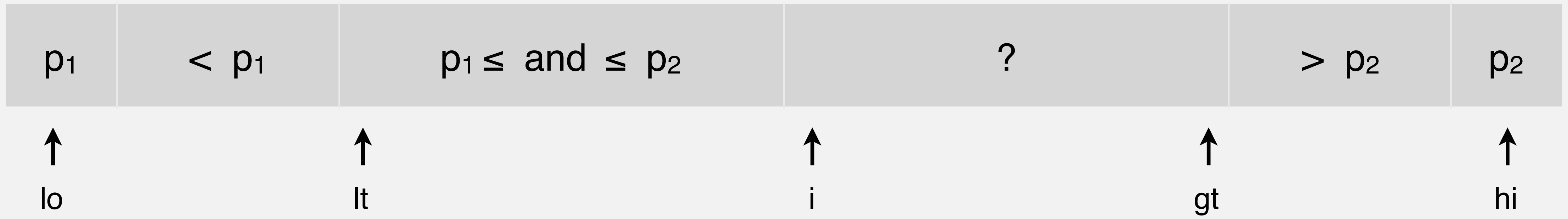


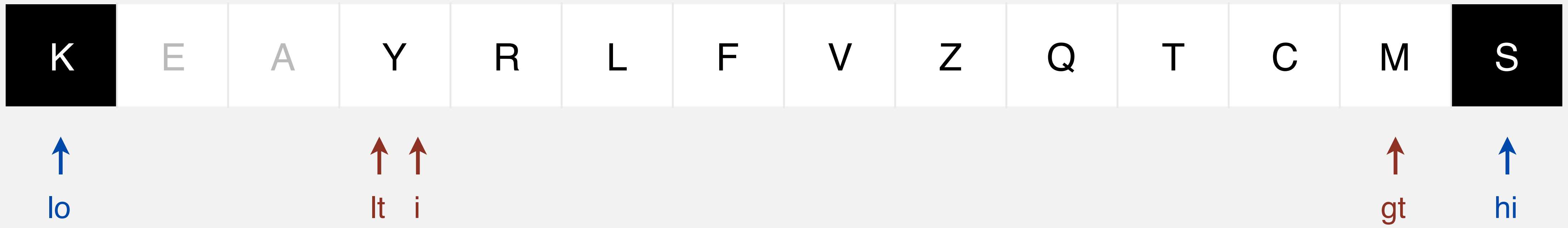
exchange a[i] and a[lt]; increment lt and i

Dual-pivot partitioning demo

Main loop. Repeat until i and gt pointers cross.

- If (a[i] < a[lo]), exchange a[i] with a[lt] and increment lt and i.
- Else if (a[i] > a[hi]), exchange a[i] with a[gt] and decrement gt.
- Else, increment i.



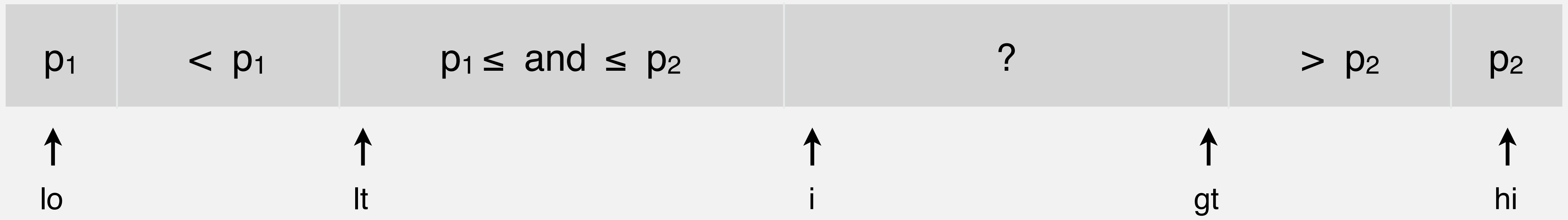


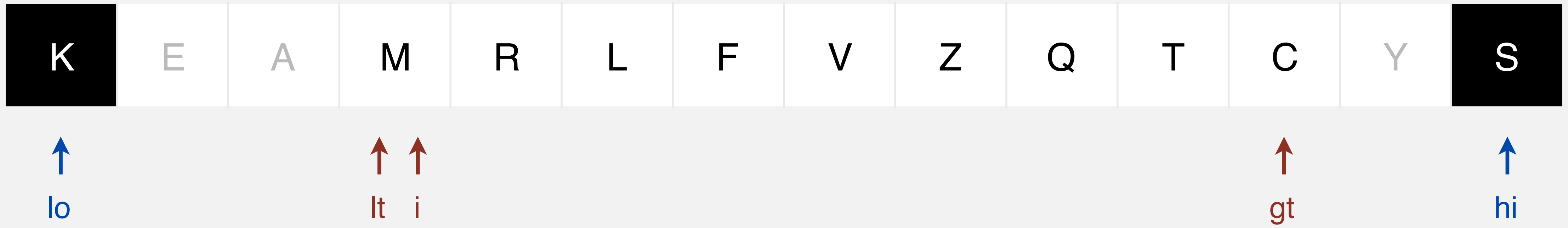
exchange a[i] and a[gt]; decrement gt

Dual-pivot partitioning demo

Main loop. Repeat until i and gt pointers cross.

- If (a[i] < a[lo]), exchange a[i] with a[lt] and increment lt and i.
- Else if (a[i] > a[hi]), exchange a[i] with a[gt] and decrement gt.
- Else, increment i.



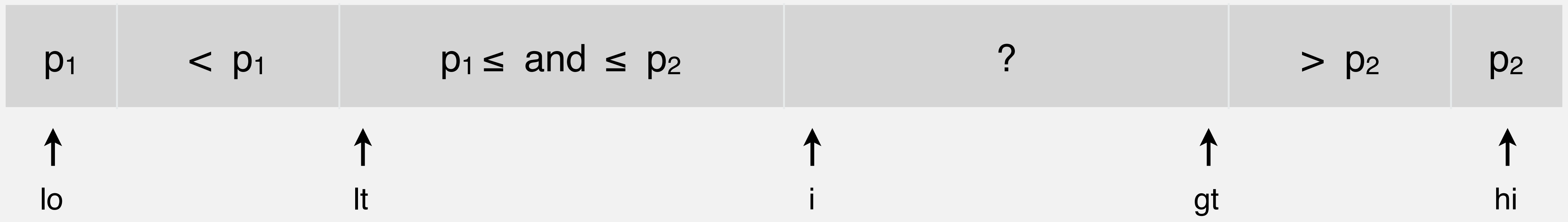


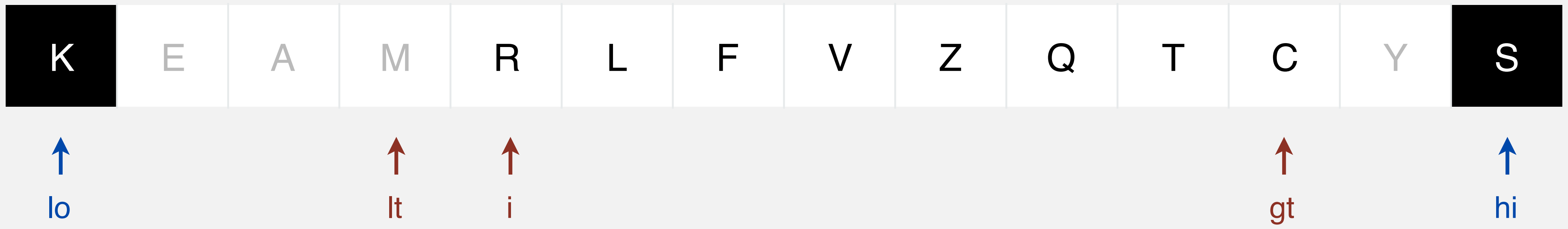
increment i

Dual-pivot partitioning demo

Main loop. Repeat until i and gt pointers cross.

- If (a[i] < a[lo]), exchange a[i] with a[lt] and increment lt and i.
- Else if (a[i] > a[hi]), exchange a[i] with a[gt] and decrement gt.
- Else, increment i.



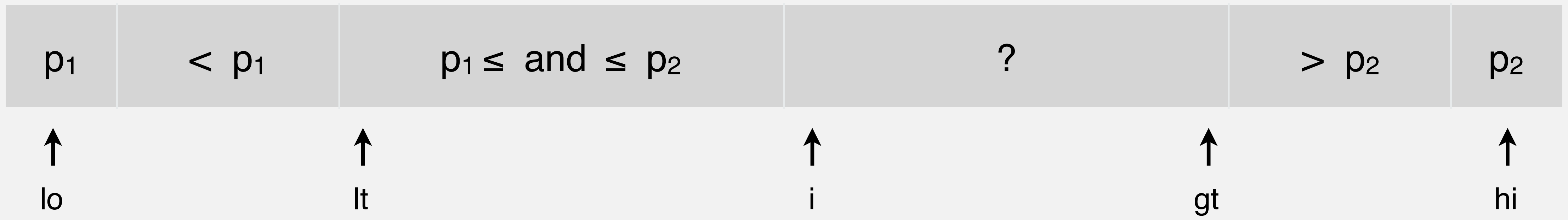


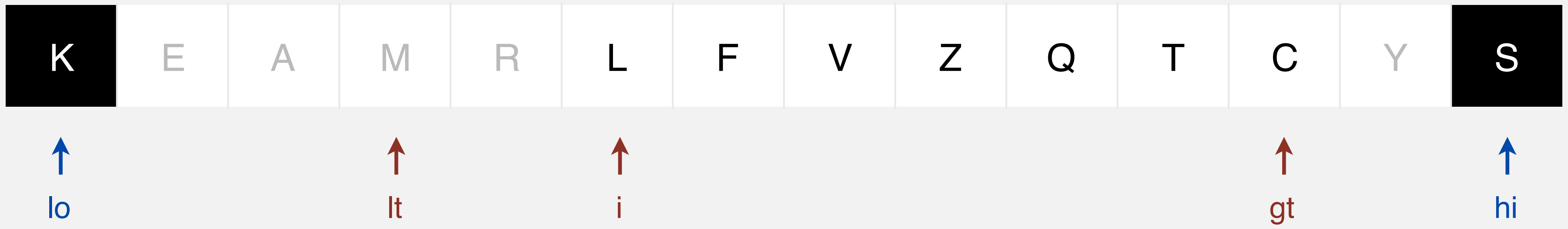
increment i

Dual-pivot partitioning demo

Main loop. Repeat until i and gt pointers cross.

- If (a[i] < a[lo]), exchange a[i] with a[lt] and increment lt and i.
- Else if (a[i] > a[hi]), exchange a[i] with a[gt] and decrement gt.
- Else, increment i.



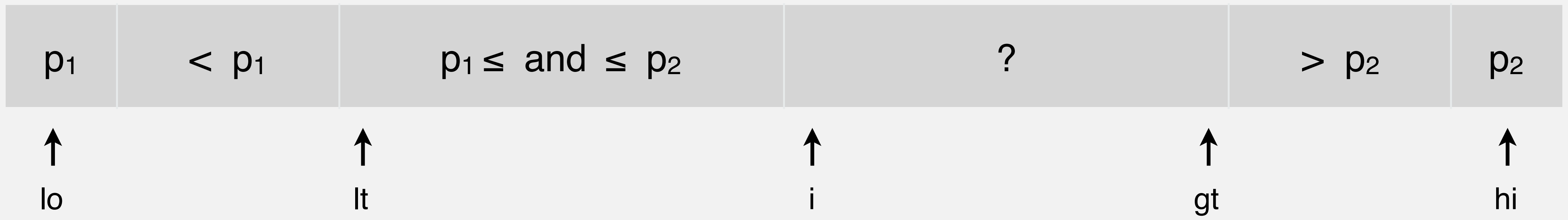


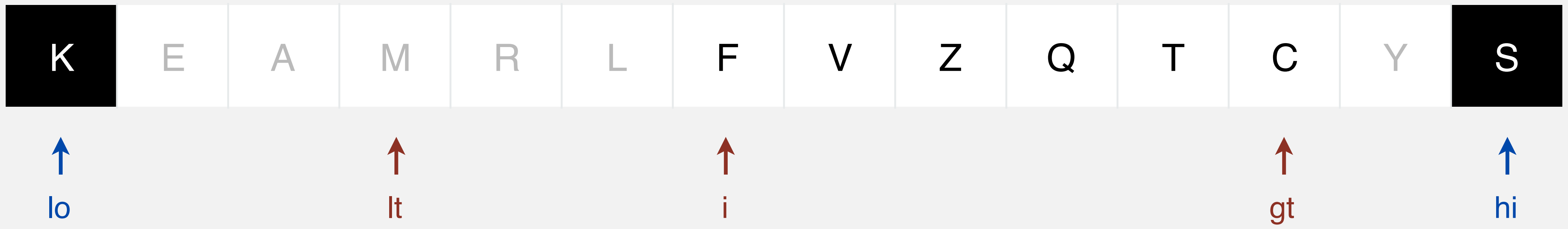
increment i

Dual-pivot partitioning demo

Main loop. Repeat until i and gt pointers cross.

- If (a[i] < a[lo]), exchange a[i] with a[lt] and increment lt and i.
- Else if (a[i] > a[hi]), exchange a[i] with a[gt] and decrement gt.
- Else, increment i.



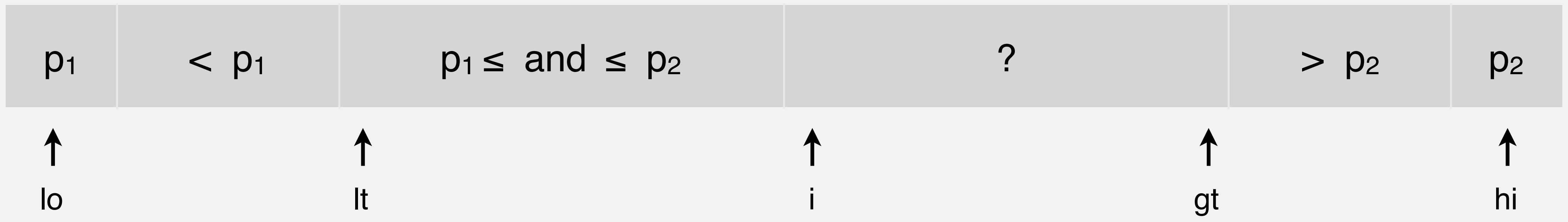


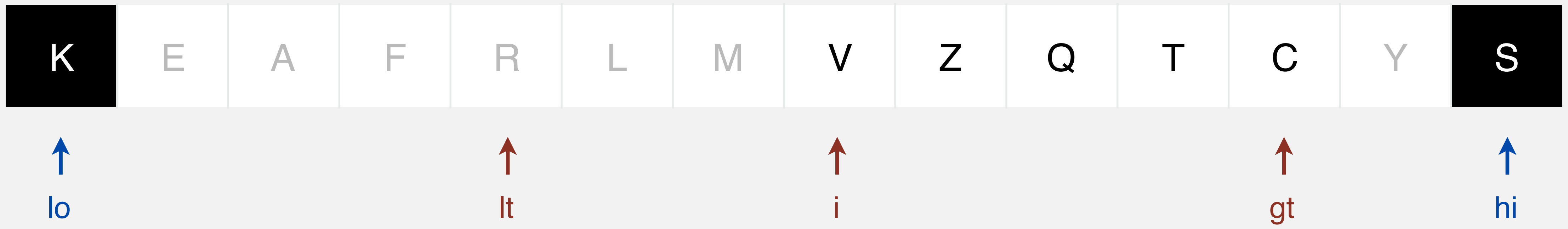
exchange a[i] and a[lt]; increment lt and i

Dual-pivot partitioning demo

Main loop. Repeat until i and gt pointers cross.

- If (a[i] < a[lo]), exchange a[i] with a[lt] and increment lt and i.
- Else if (a[i] > a[hi]), exchange a[i] with a[gt] and decrement gt.
- Else, increment i.



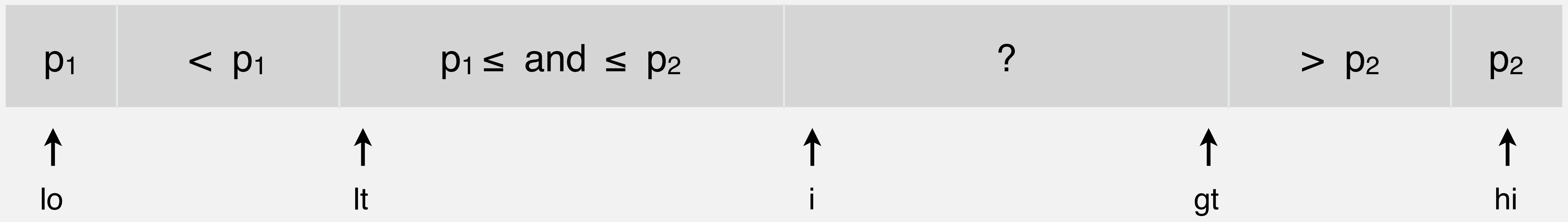


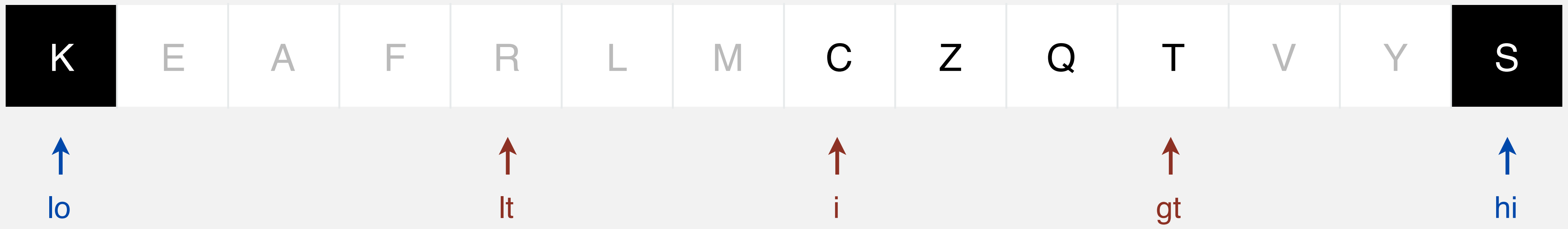
exchange a[i] and a[gt]; decrement gt

Dual-pivot partitioning demo

Main loop. Repeat until i and gt pointers cross.

- If (a[i] < a[lo]), exchange a[i] with a[lt] and increment lt and i.
- Else if (a[i] > a[hi]), exchange a[i] with a[gt] and decrement gt.
- Else, increment i.



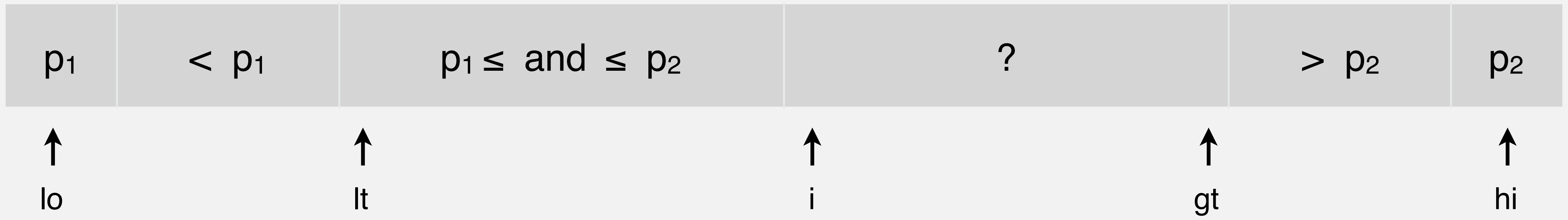


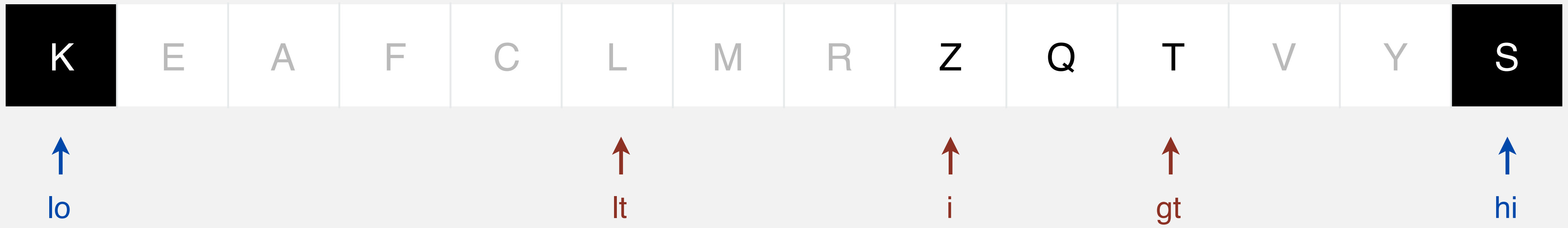
exchange a[i] and a[lt]; increment lt and i

Dual-pivot partitioning demo

Main loop. Repeat until i and gt pointers cross.

- If (a[i] < a[lo]), exchange a[i] with a[lt] and increment lt and i.
- Else if (a[i] > a[hi]), exchange a[i] with a[gt] and decrement gt.
- Else, increment i.



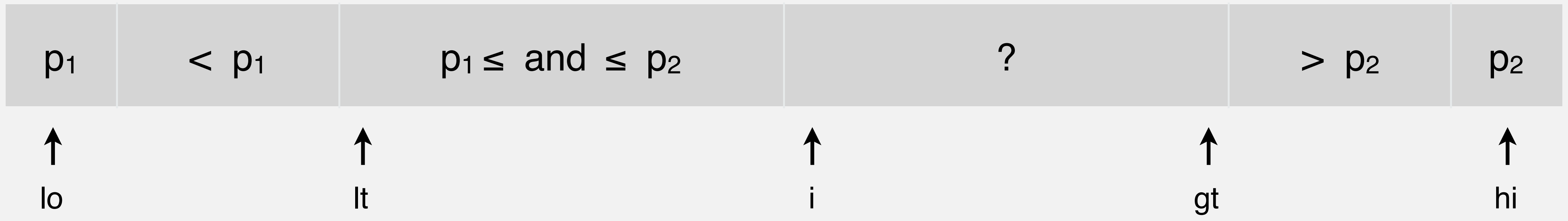


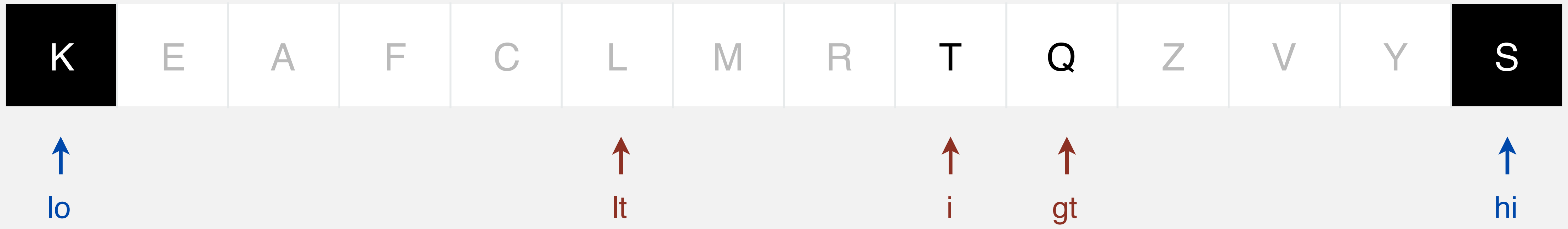
exchange a[i] and a[gt]; decrement gt

Dual-pivot partitioning demo

Main loop. Repeat until i and gt pointers cross.

- If (a[i] < a[lo]), exchange a[i] with a[lt] and increment lt and i.
- Else if (a[i] > a[hi]), exchange a[i] with a[gt] and decrement gt.
- Else, increment i.



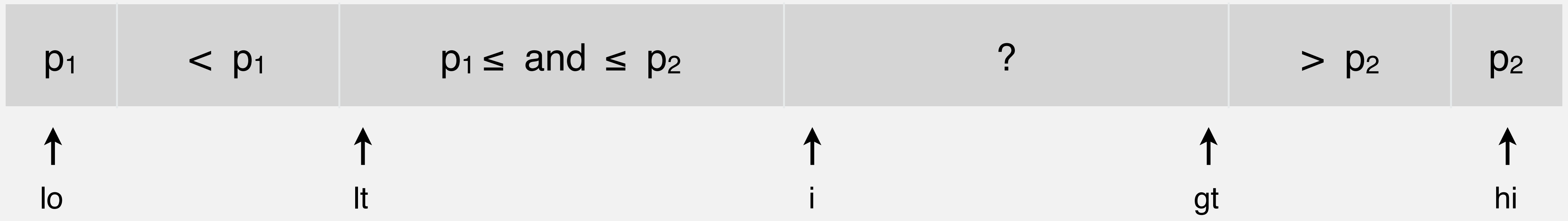


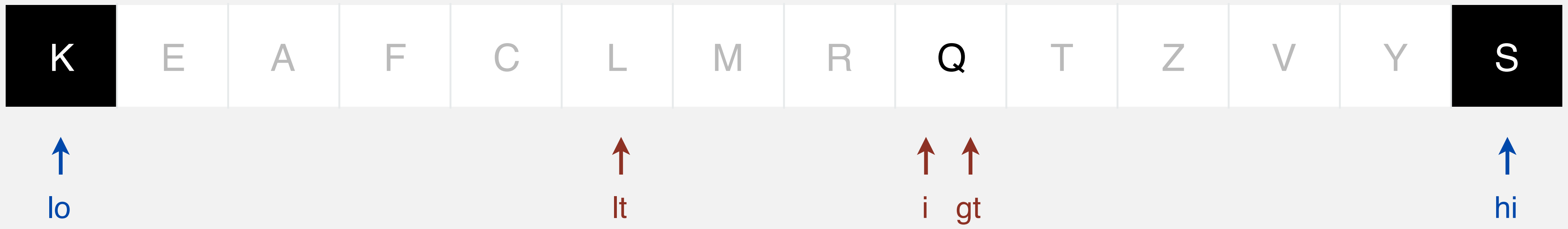
exchange a[i] and a[gt]; decrement gt

Dual-pivot partitioning demo

Main loop. Repeat until i and gt pointers cross.

- If (a[i] < a[lo]), exchange a[i] with a[lt] and increment lt and i.
- Else if (a[i] > a[hi]), exchange a[i] with a[gt] and decrement gt.
- Else, increment i.



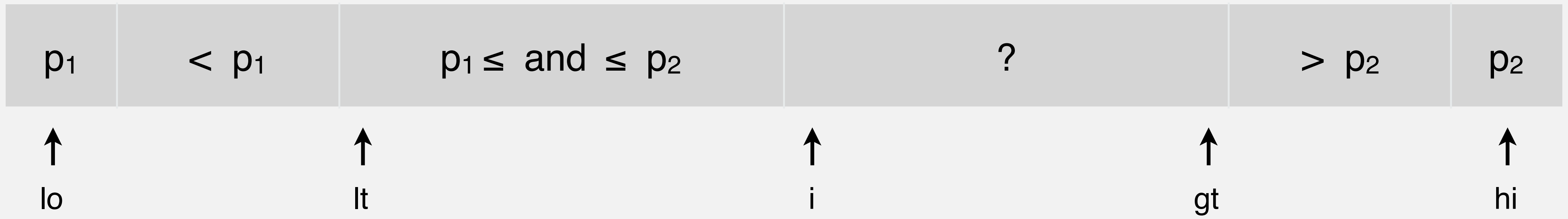


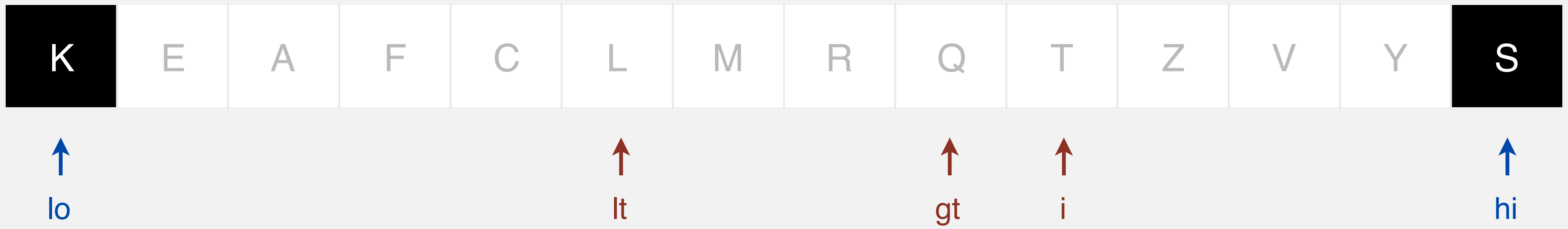
increment i

Dual-pivot partitioning demo

Main loop. Repeat until i and gt pointers cross.

- If (a[i] < a[lo]), exchange a[i] with a[lt] and increment lt and i.
- Else if (a[i] > a[hi]), exchange a[i] with a[gt] and decrement gt.
- Else, increment i.



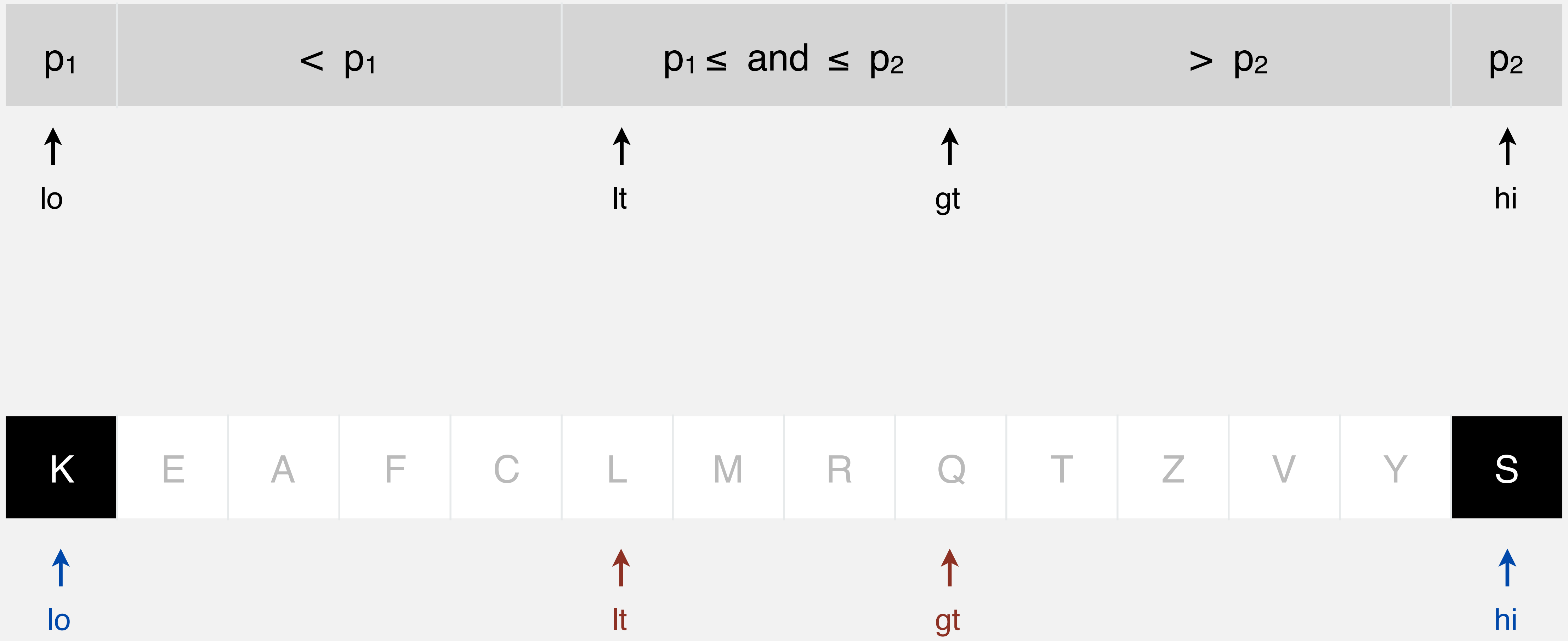


stop when pointers cross

Dual-pivot partitioning demo

Finalize.

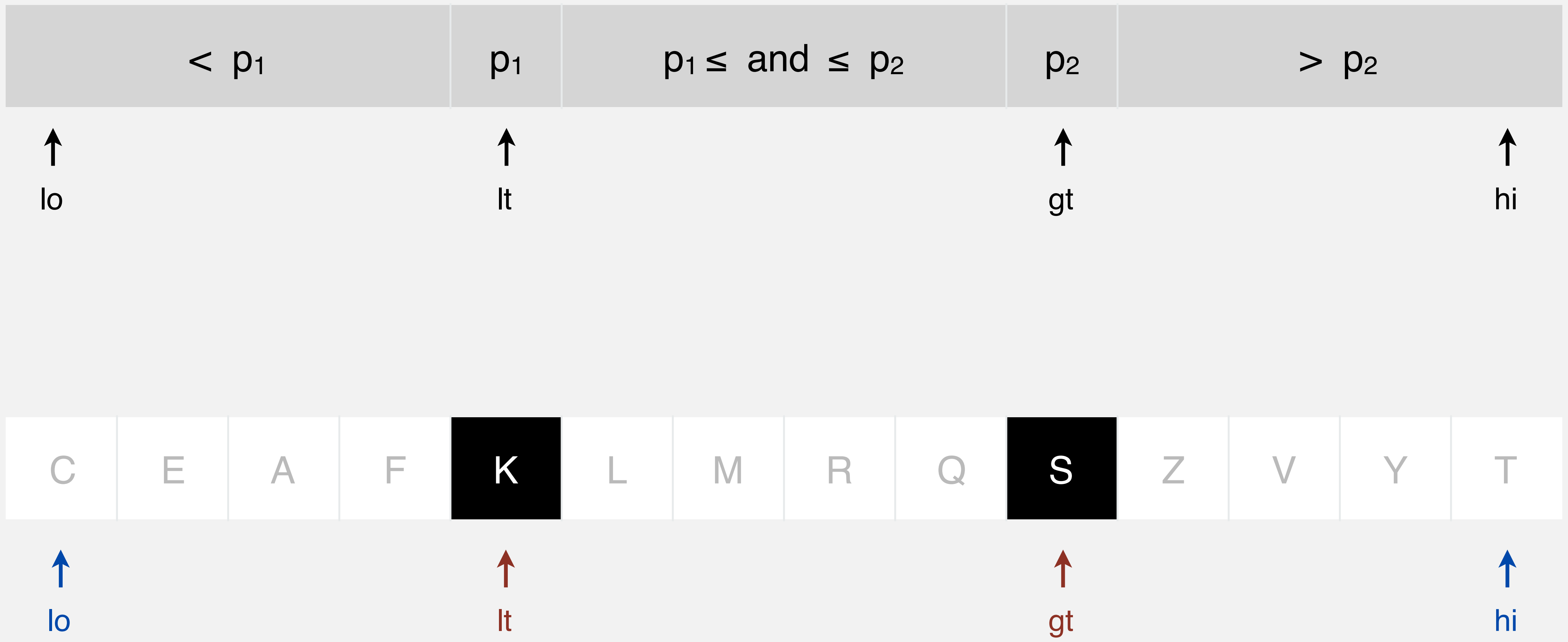
- Exchange a[lo] with a[--lt].
- Exchange a[hi] with a[++gt].



Dual-pivot partitioning demo

Finalize.

- Exchange a[lo] with a[--lt].
- Exchange a[hi] with a[++gt].



3-way partitioned