Merge Sort

(break down the array, then merge the pieces back together)

0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

Slides by **Sean Szumlanski**

for **COP 3502**, Computer Science I

Summer 2018

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10	18	2	14	3	12	1	8

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Do you agree we can merge two **sorted** arrays into **one** sorted array in **linear** time?

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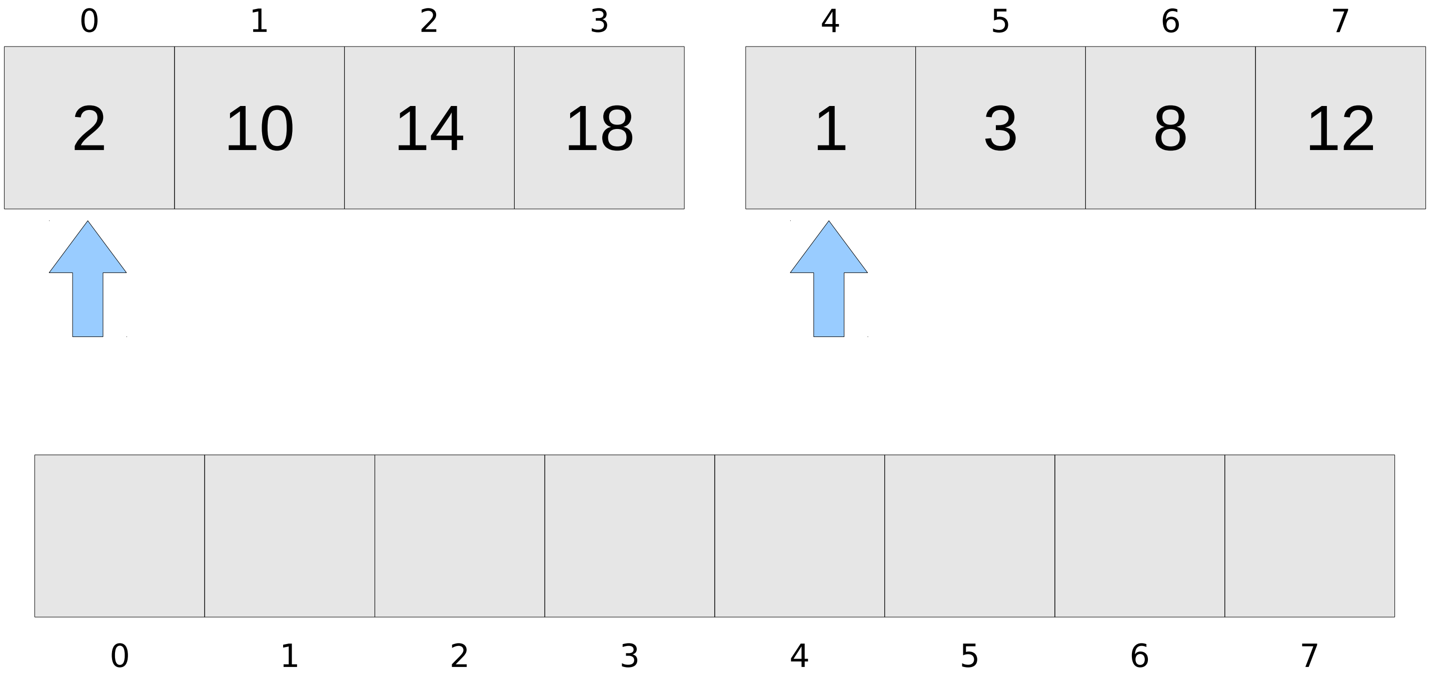

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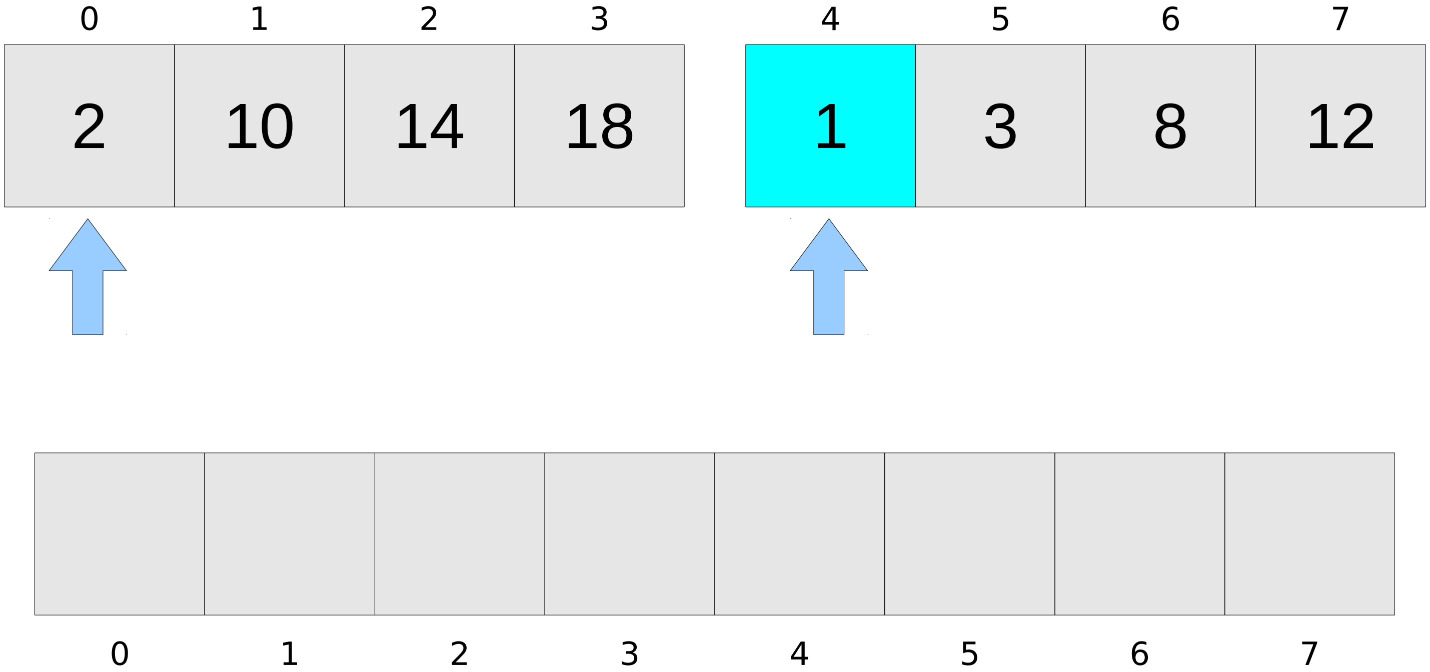

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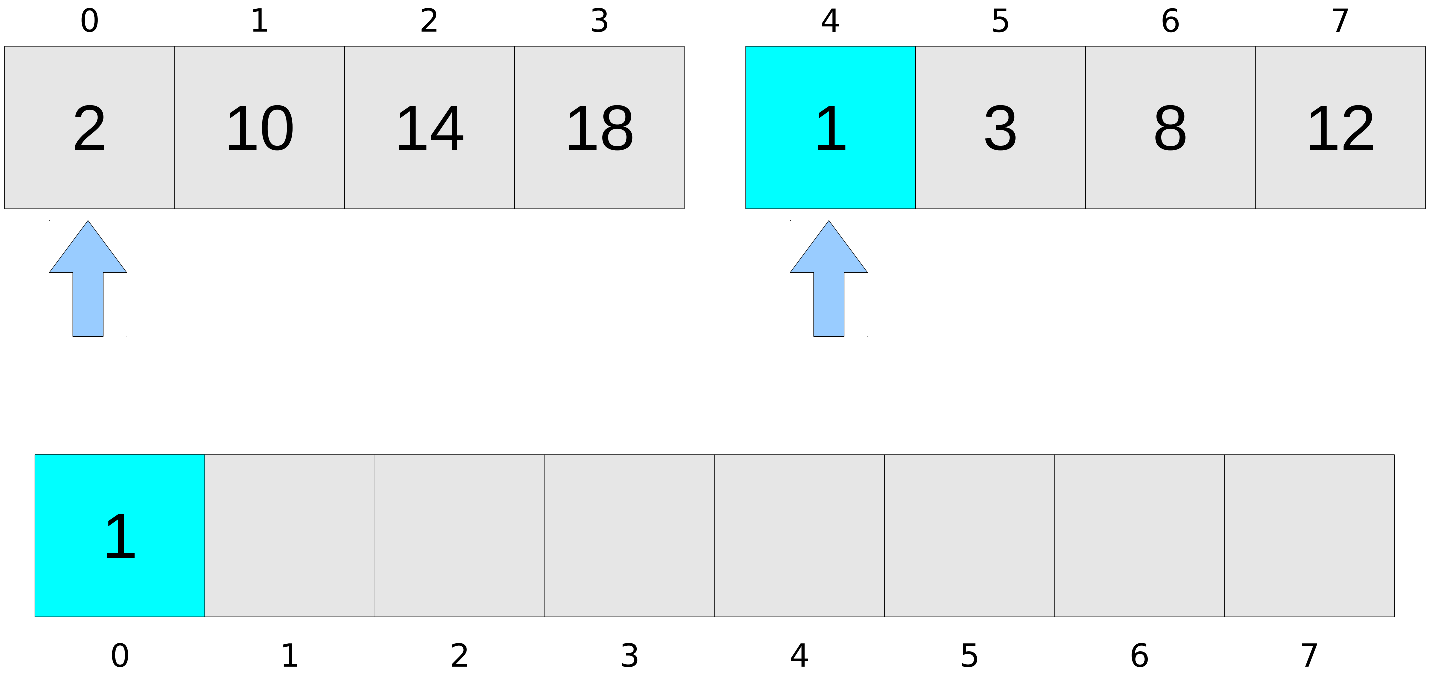

0	1	2	3	4	5	6	7
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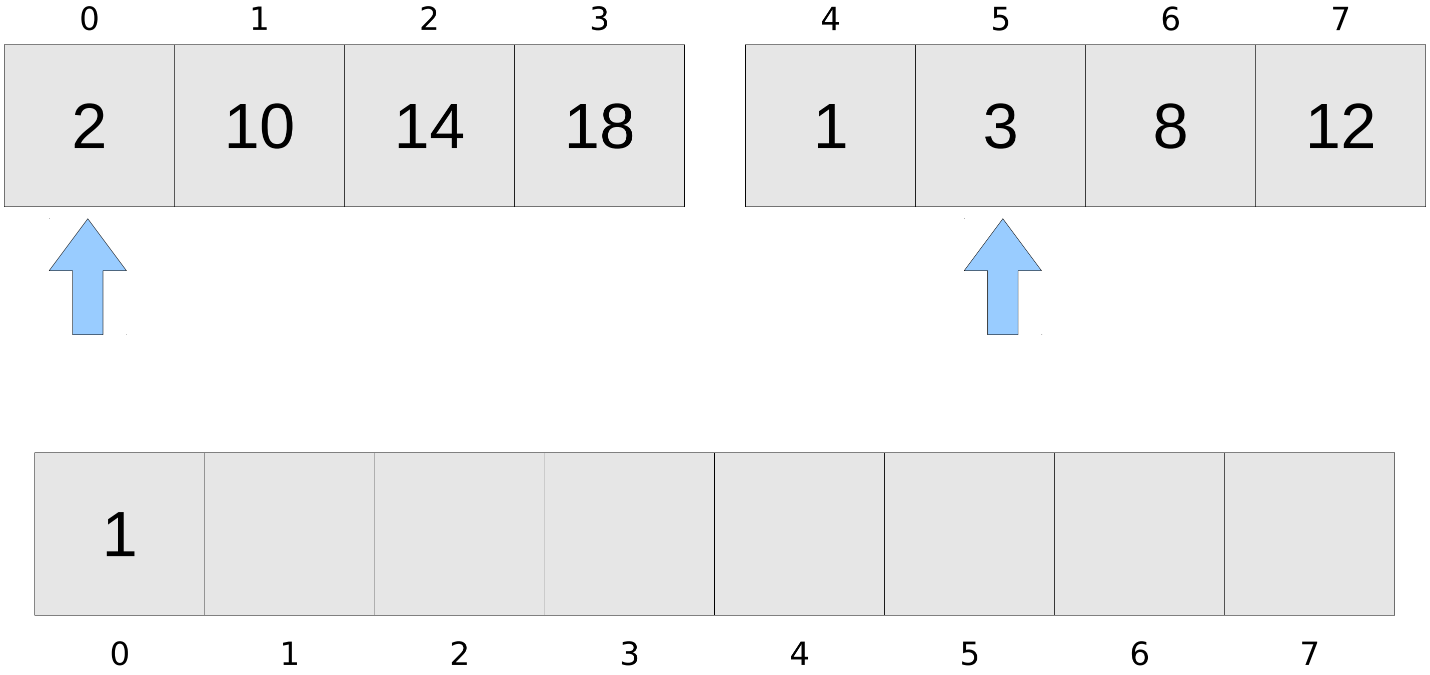

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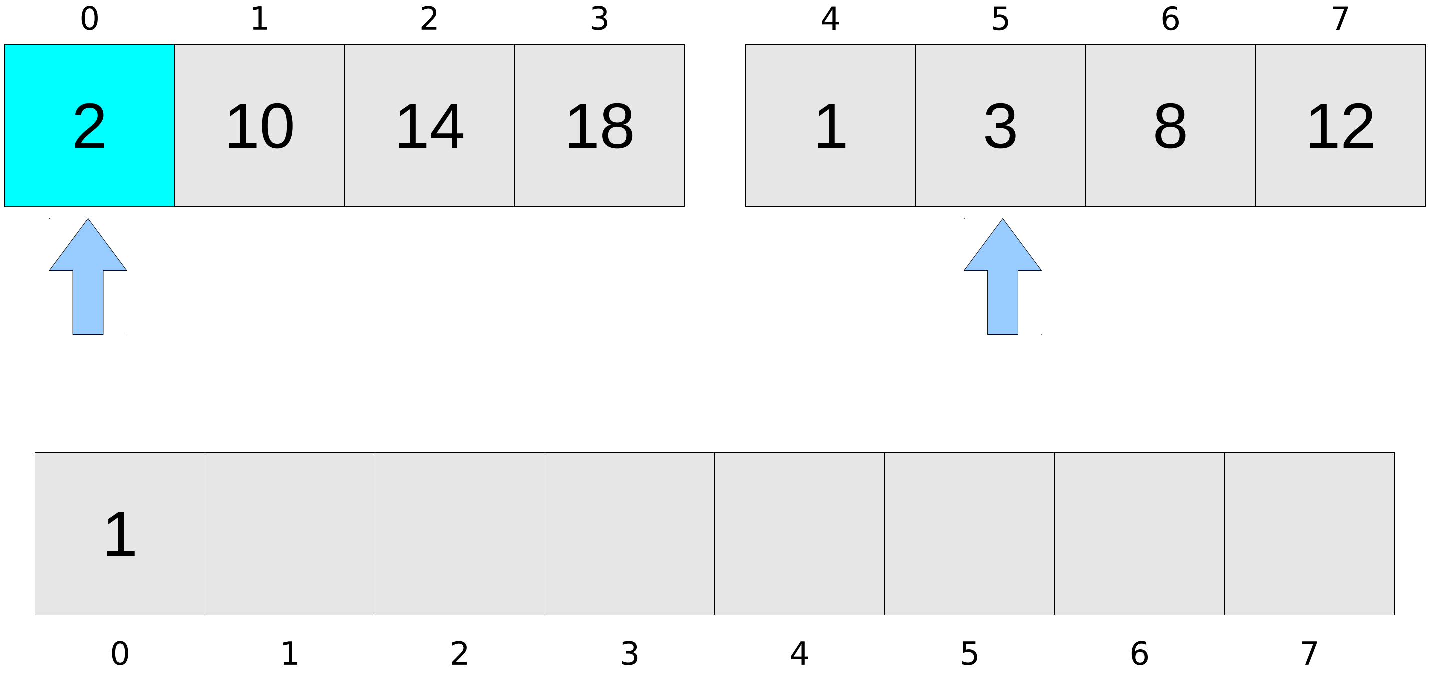

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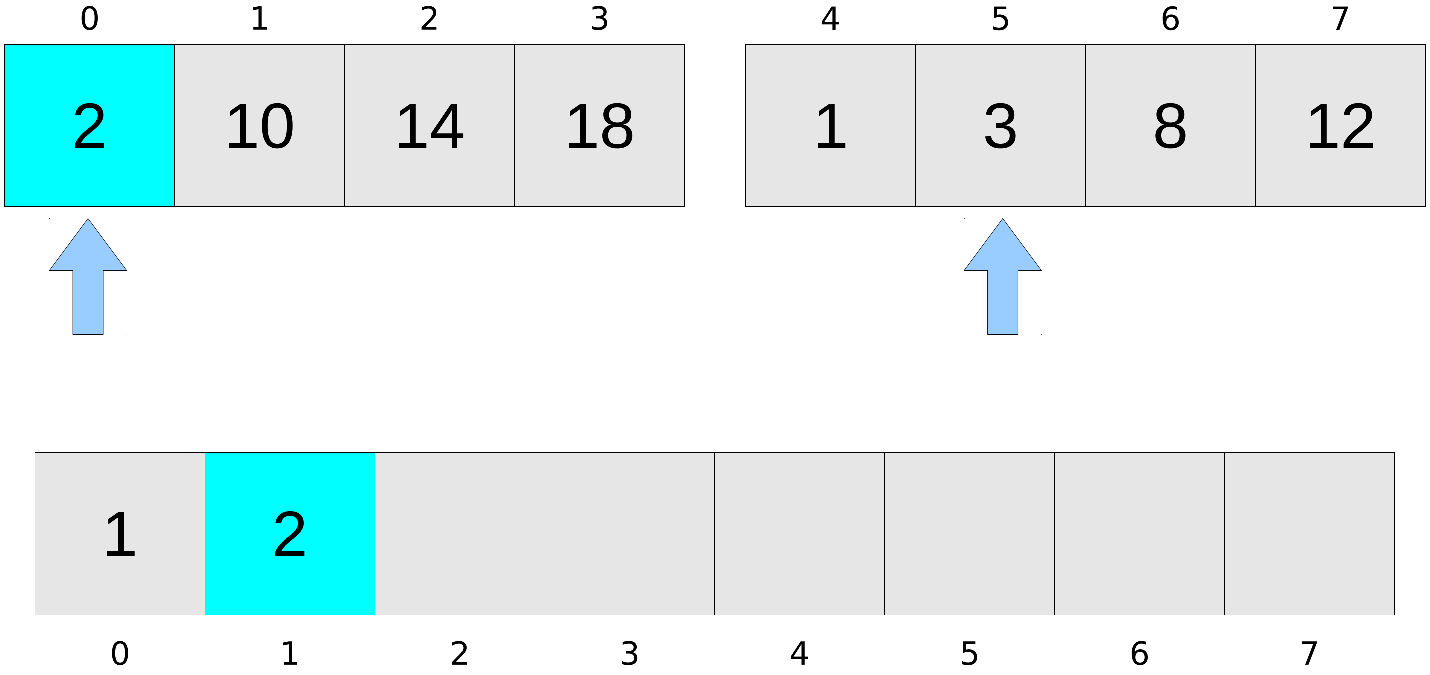

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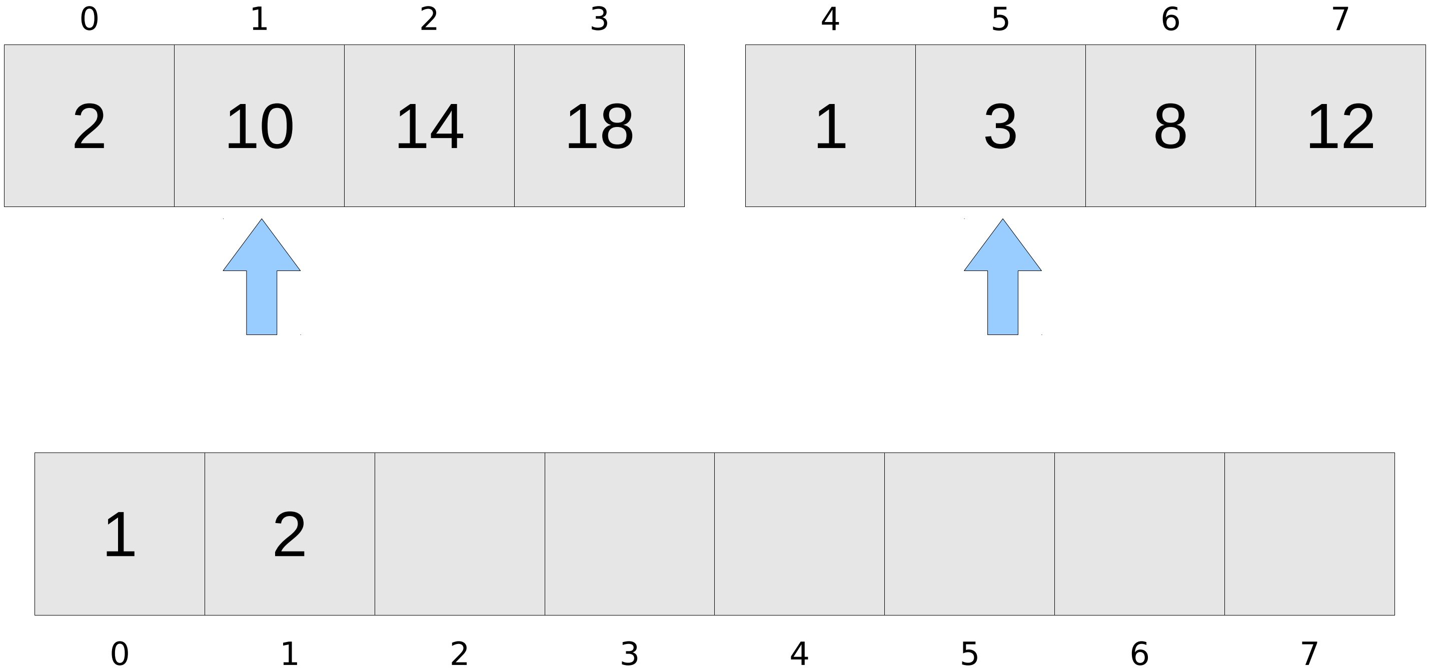

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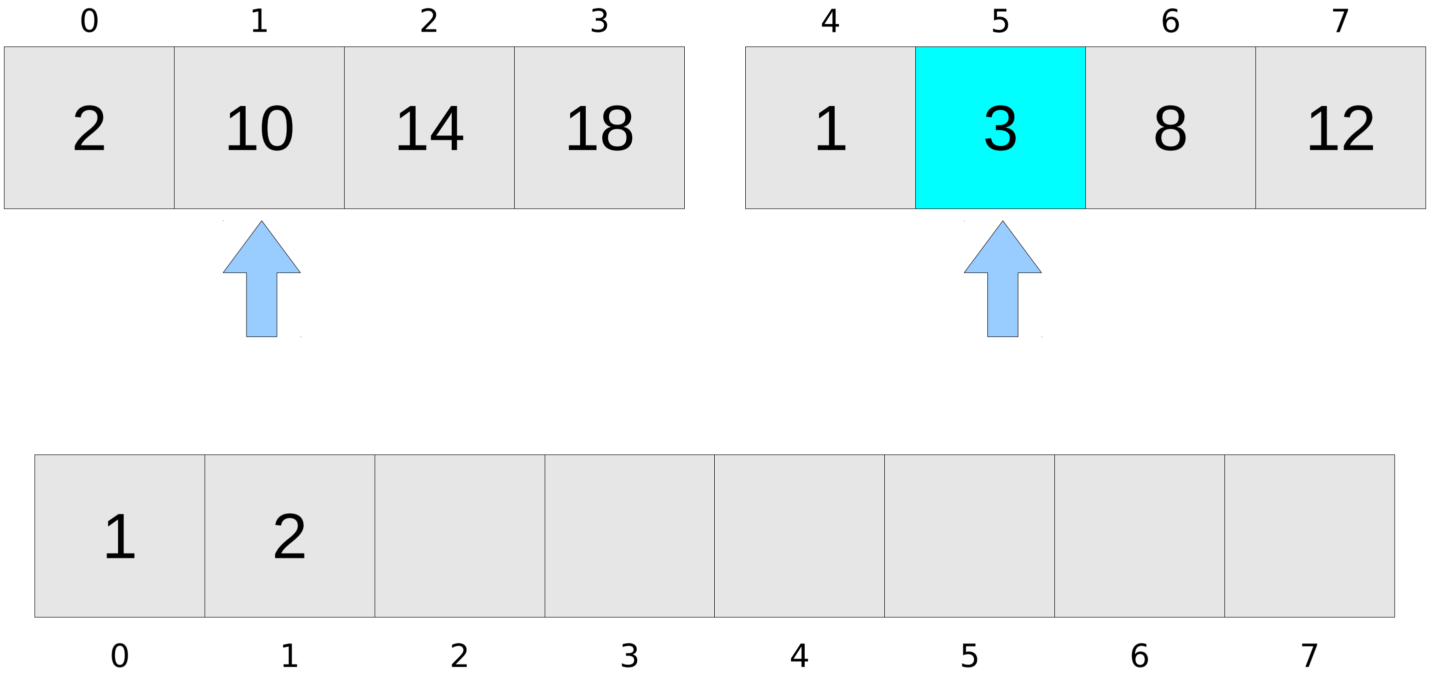

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1	2						
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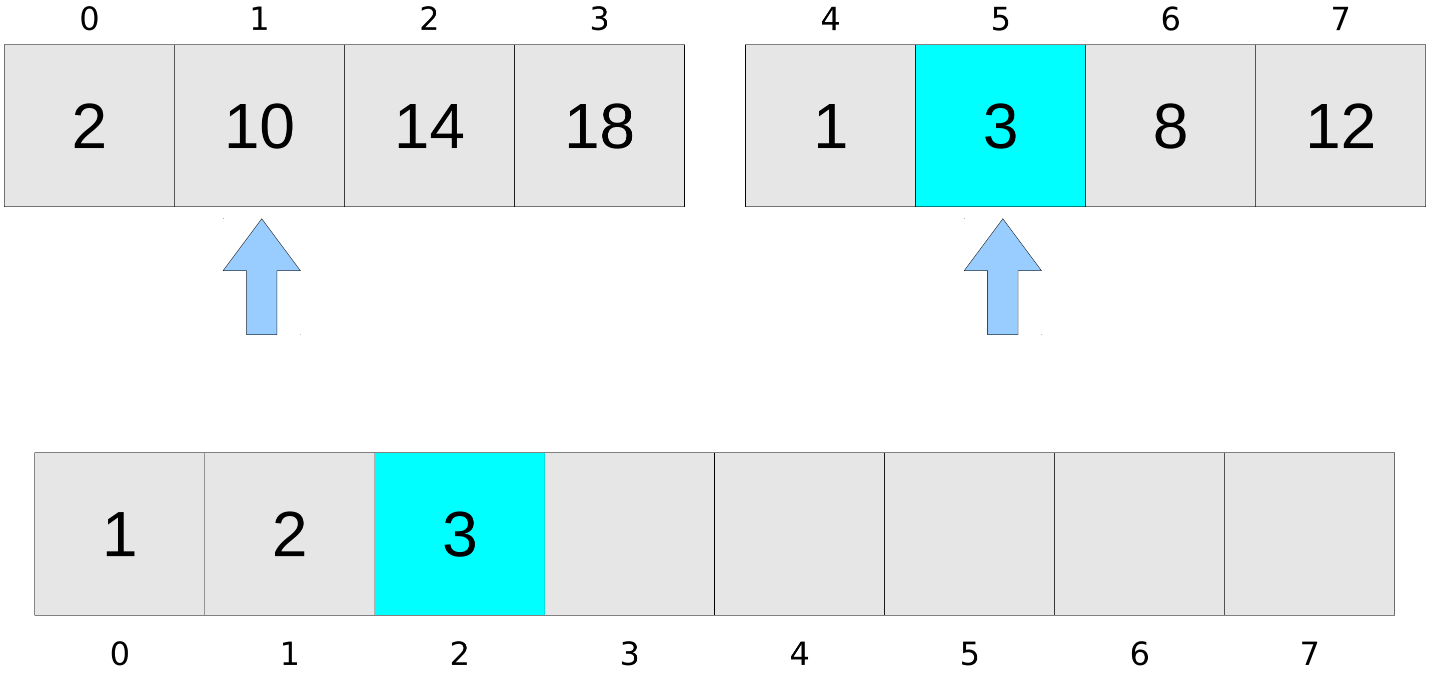

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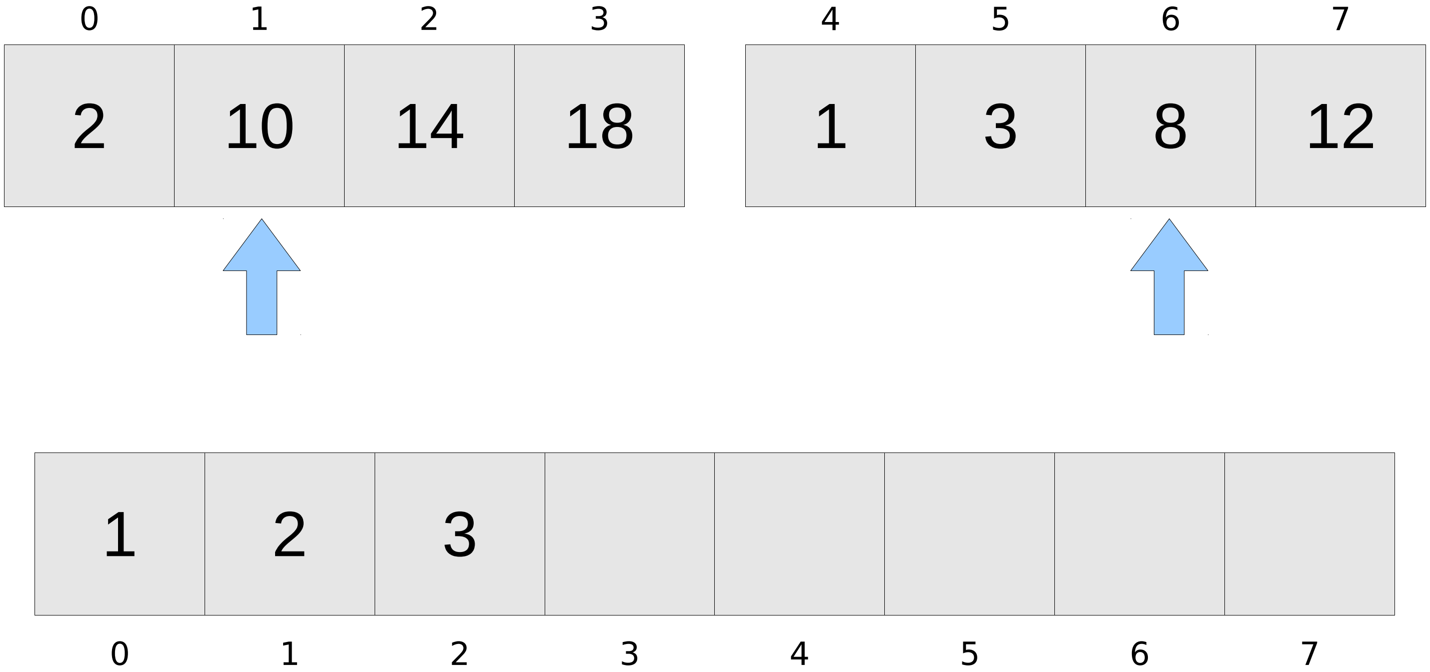

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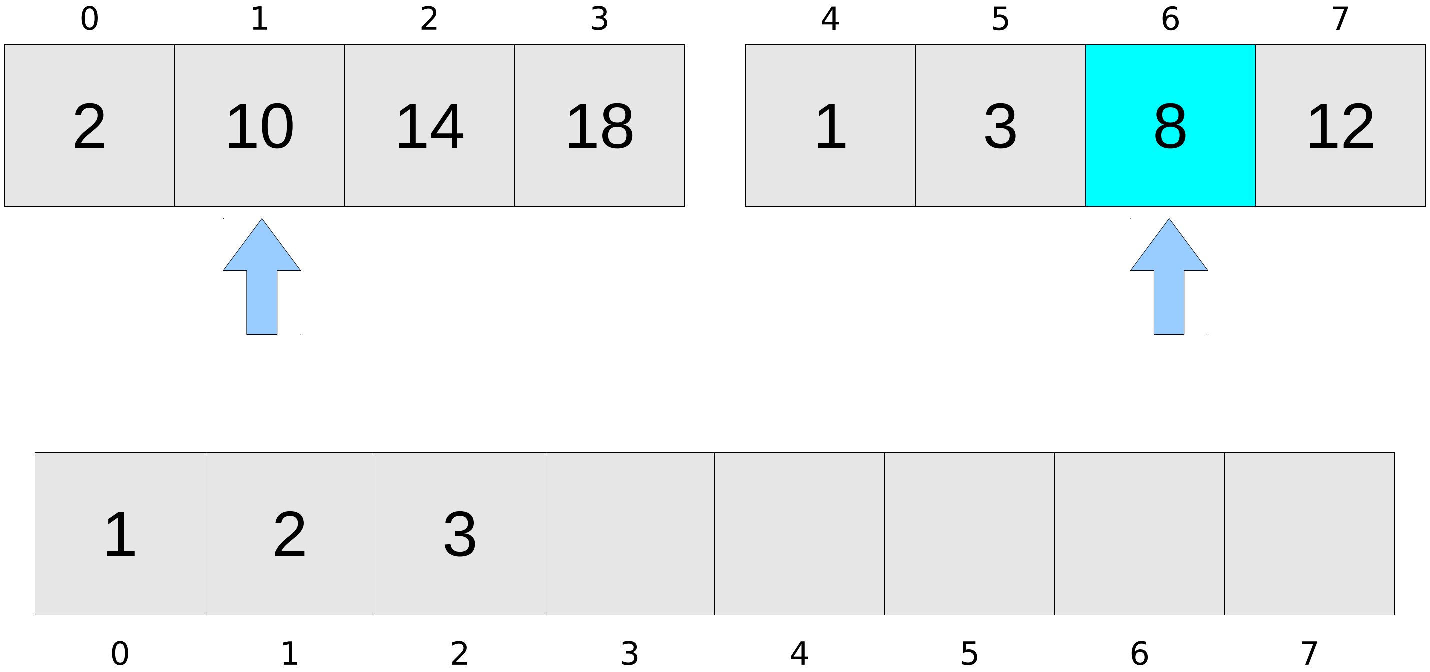

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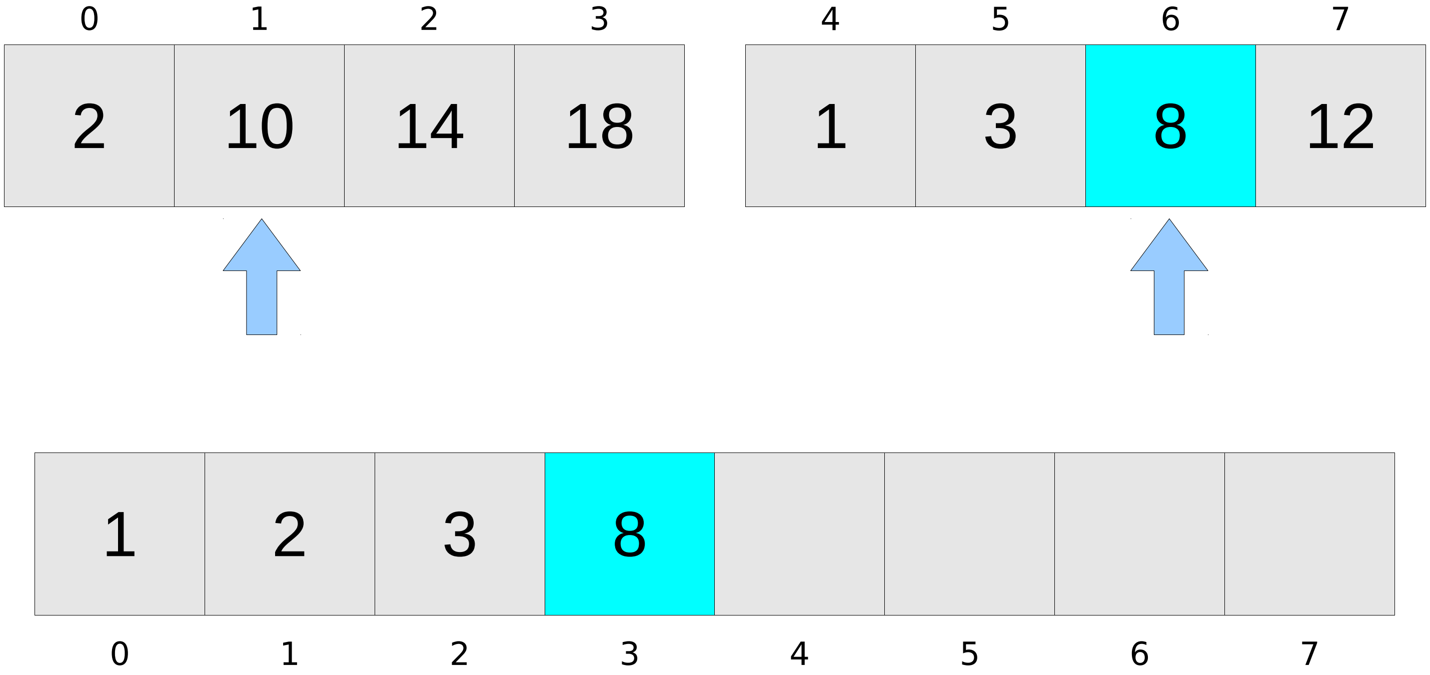

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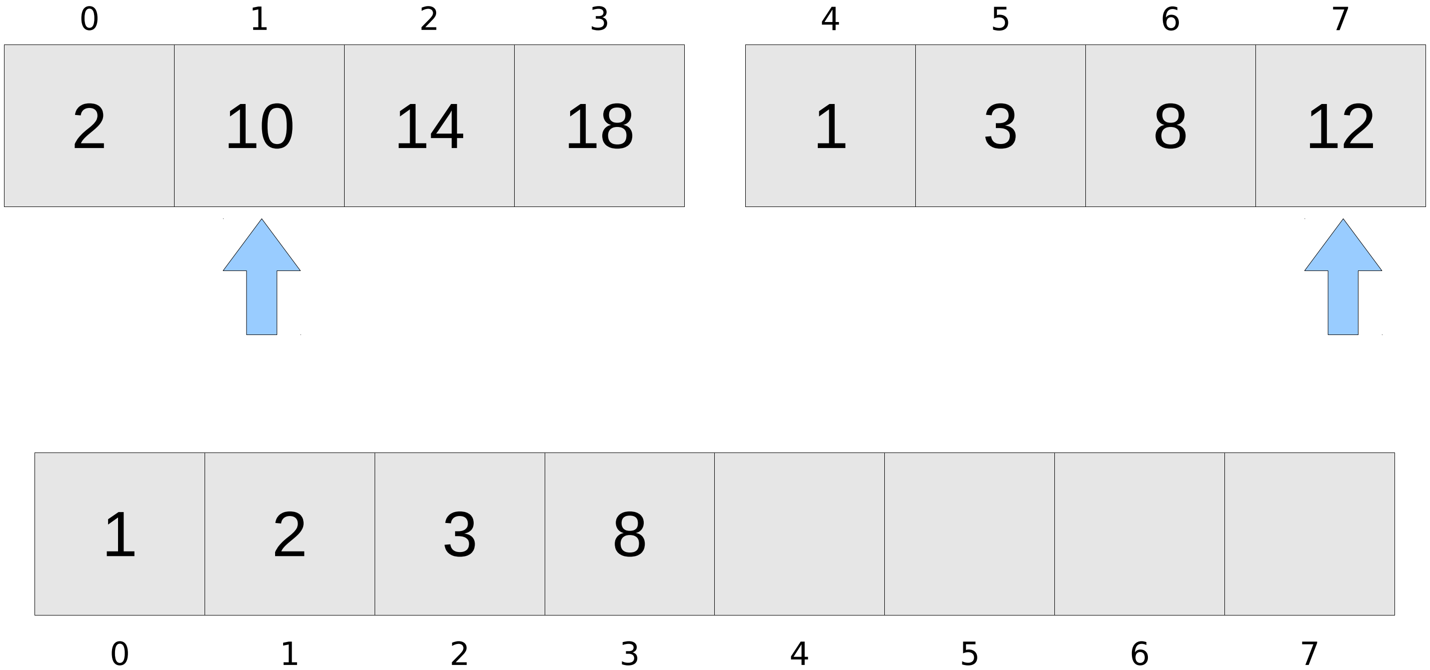

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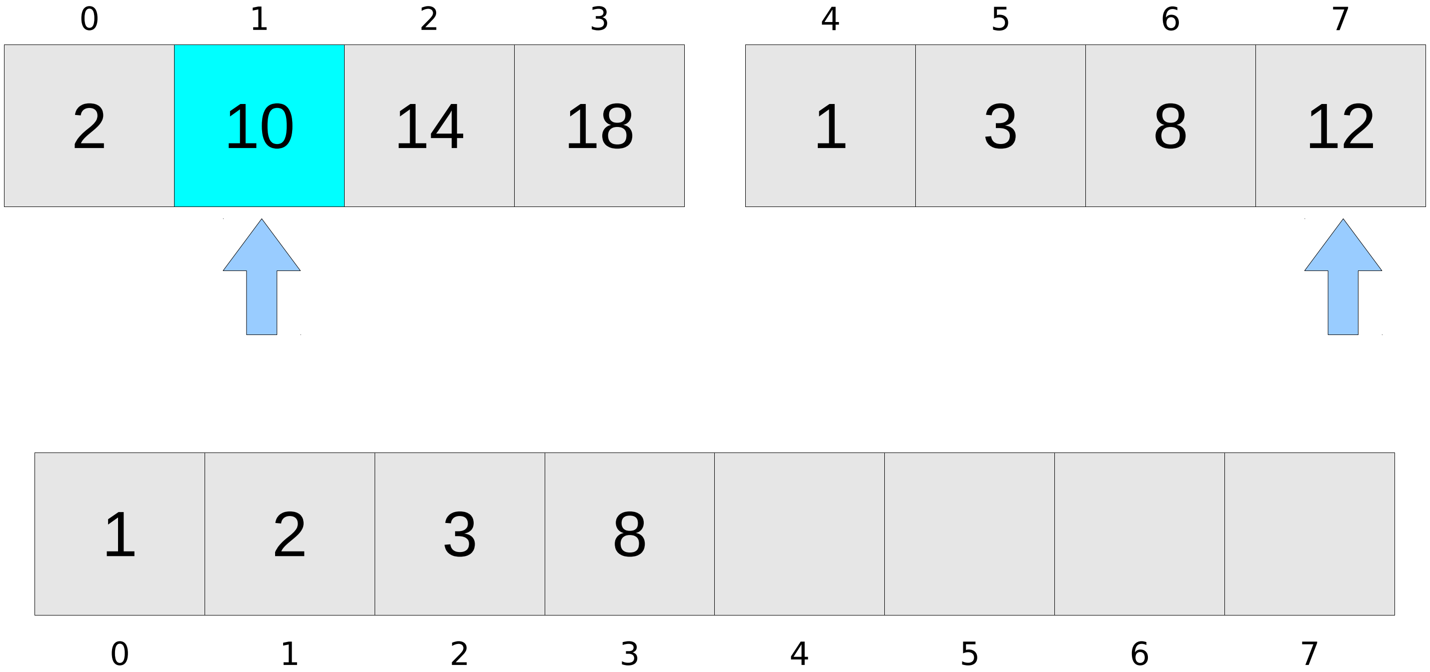

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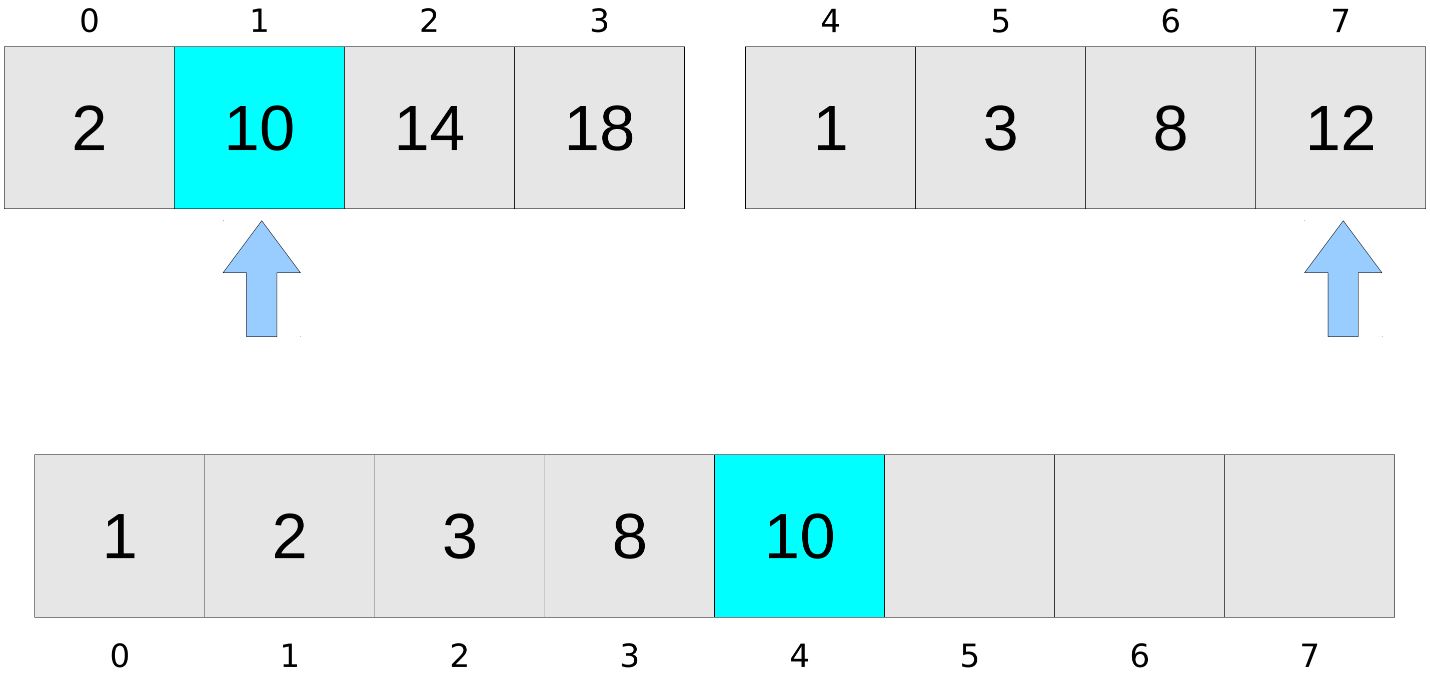

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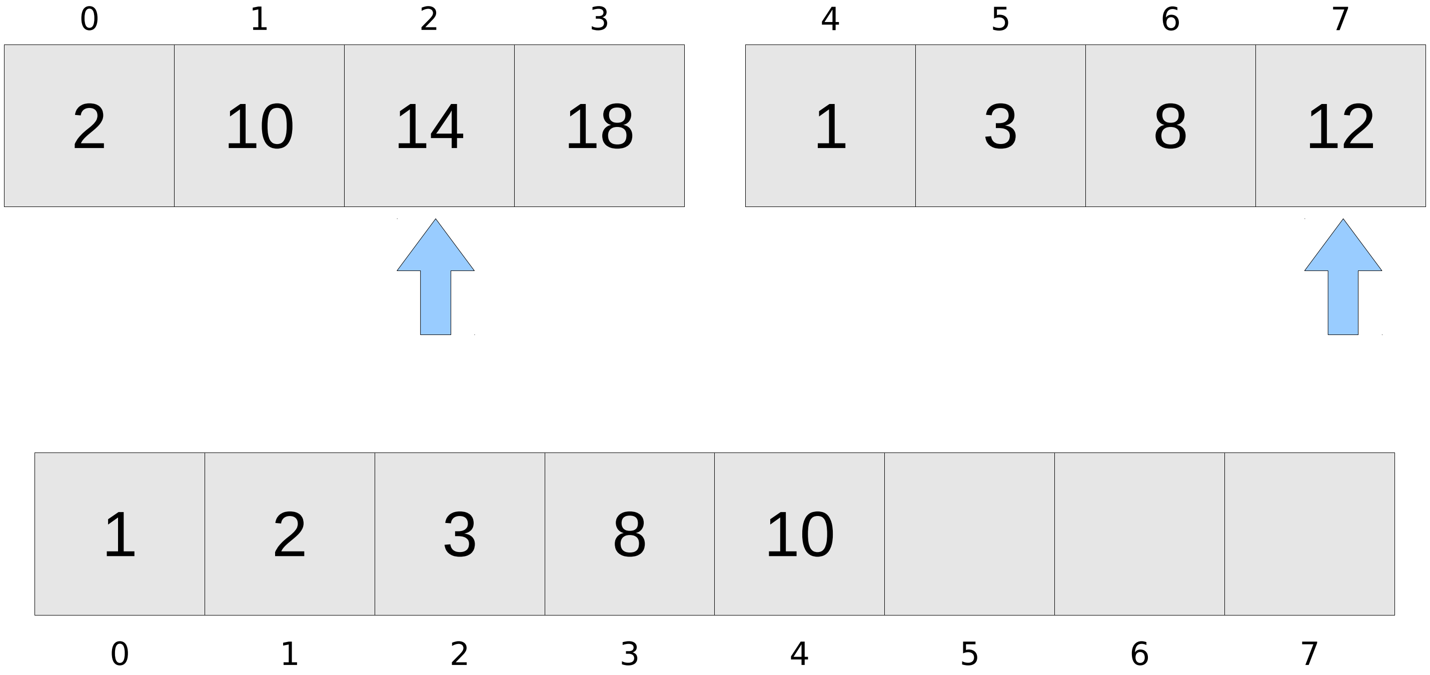

0	1	2	3
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1	2	3	8	10			

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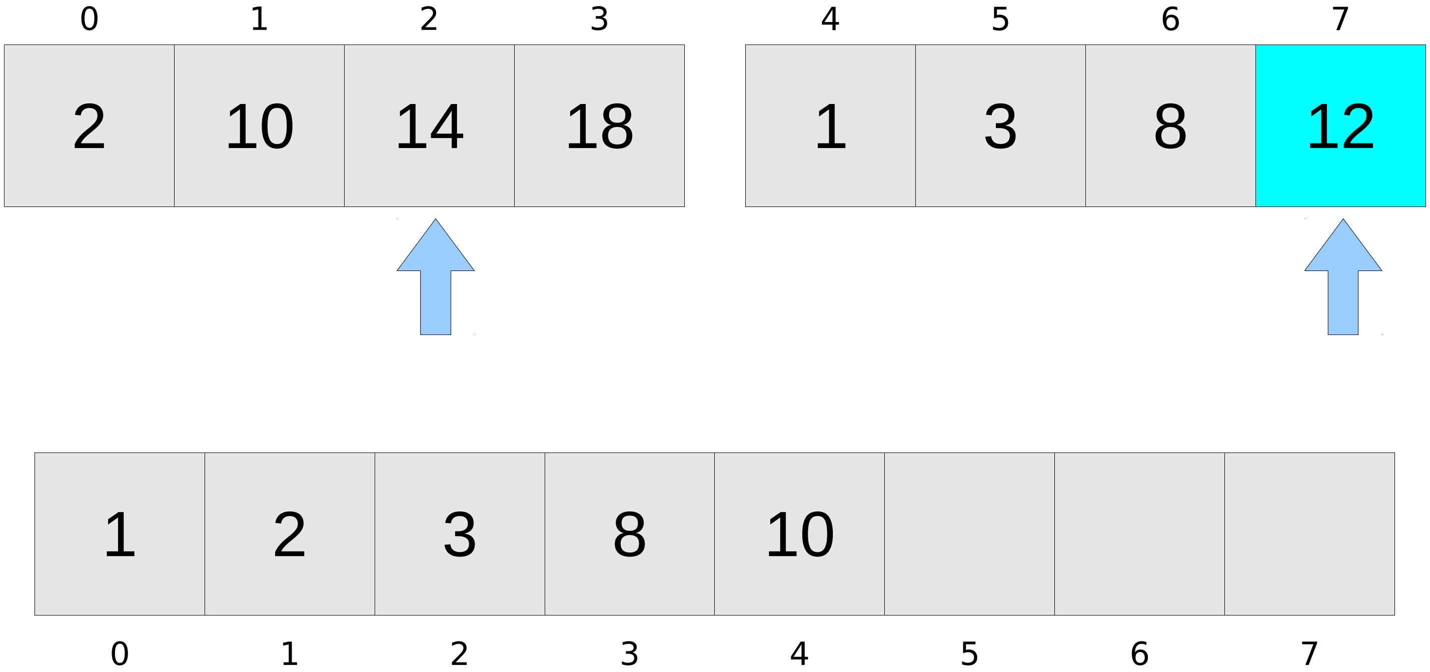

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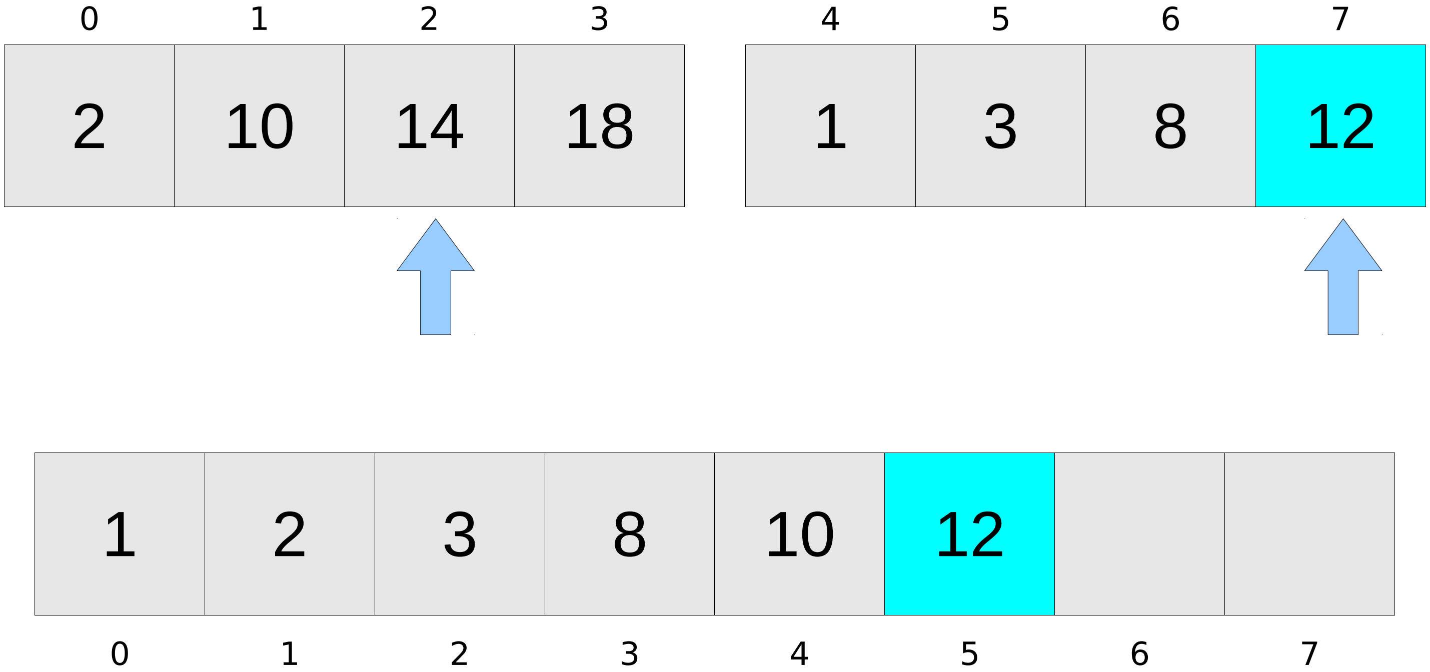

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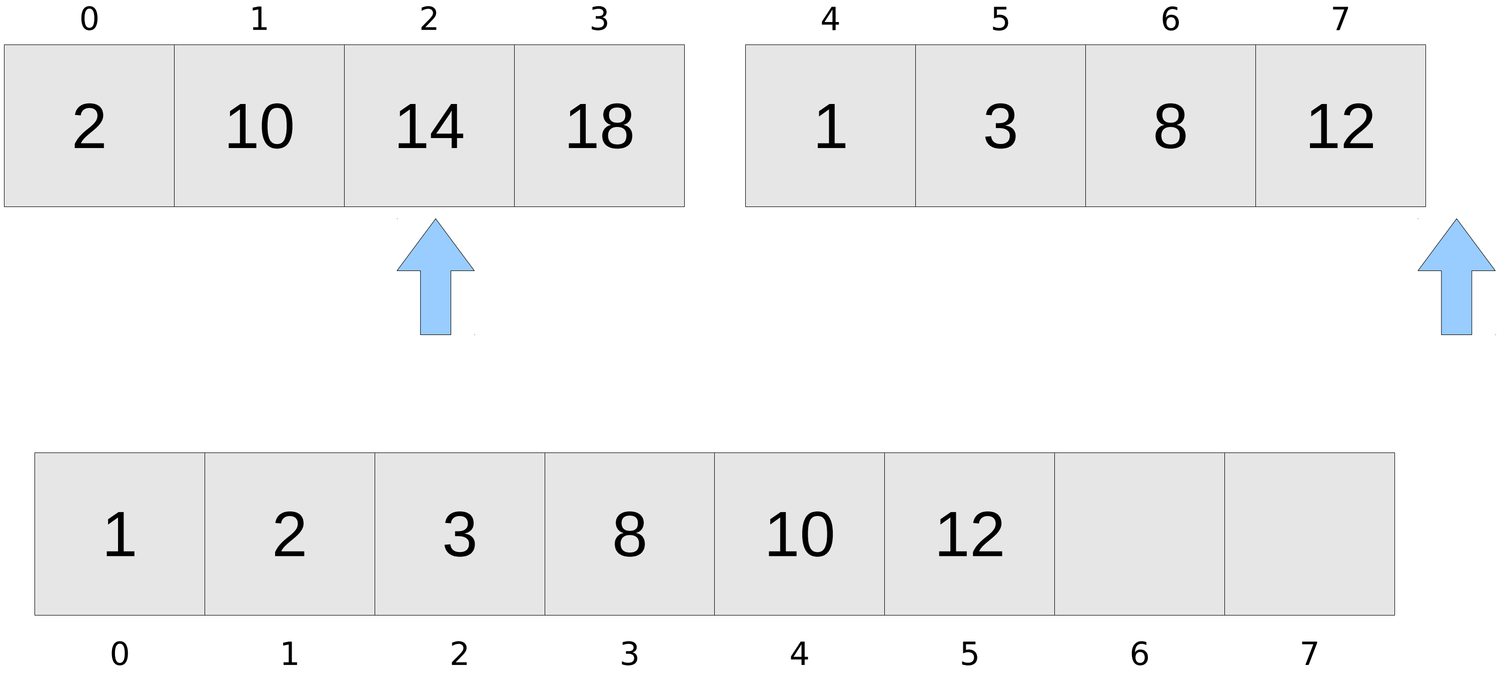

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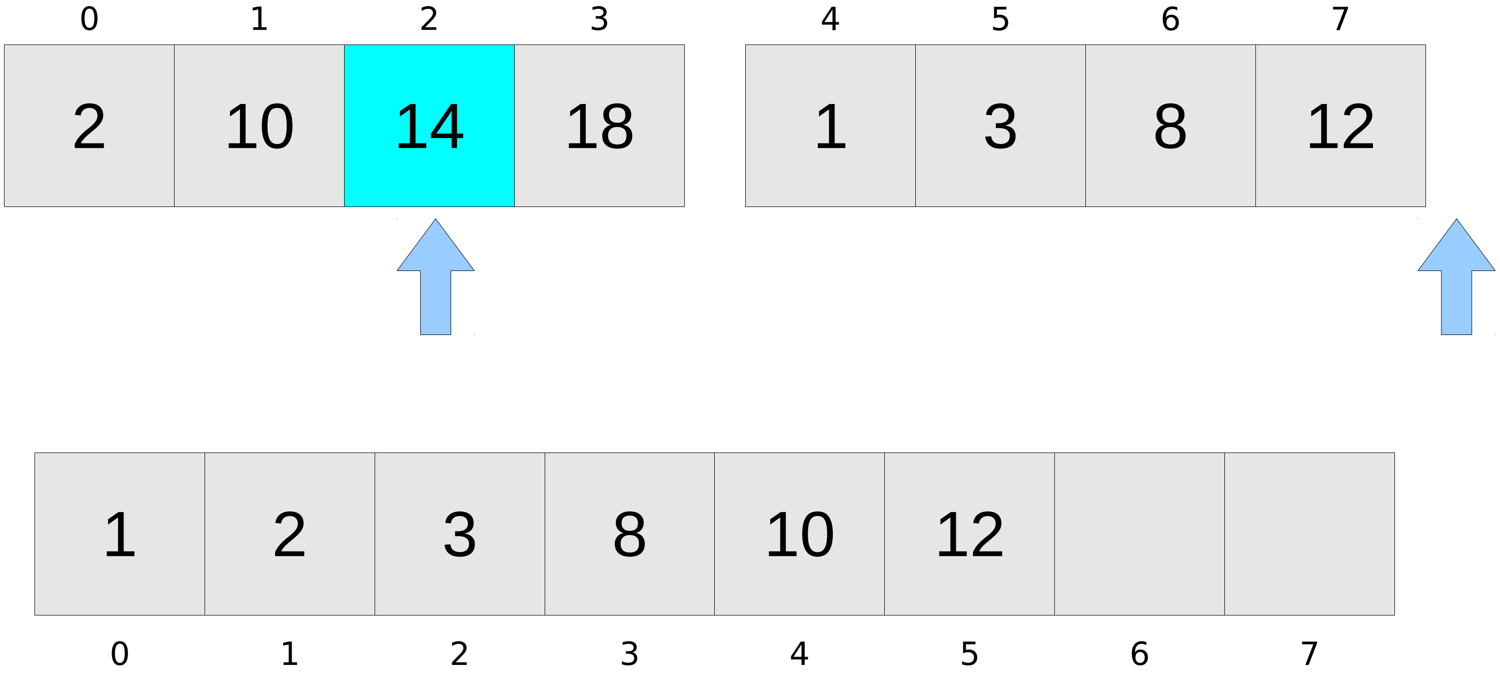

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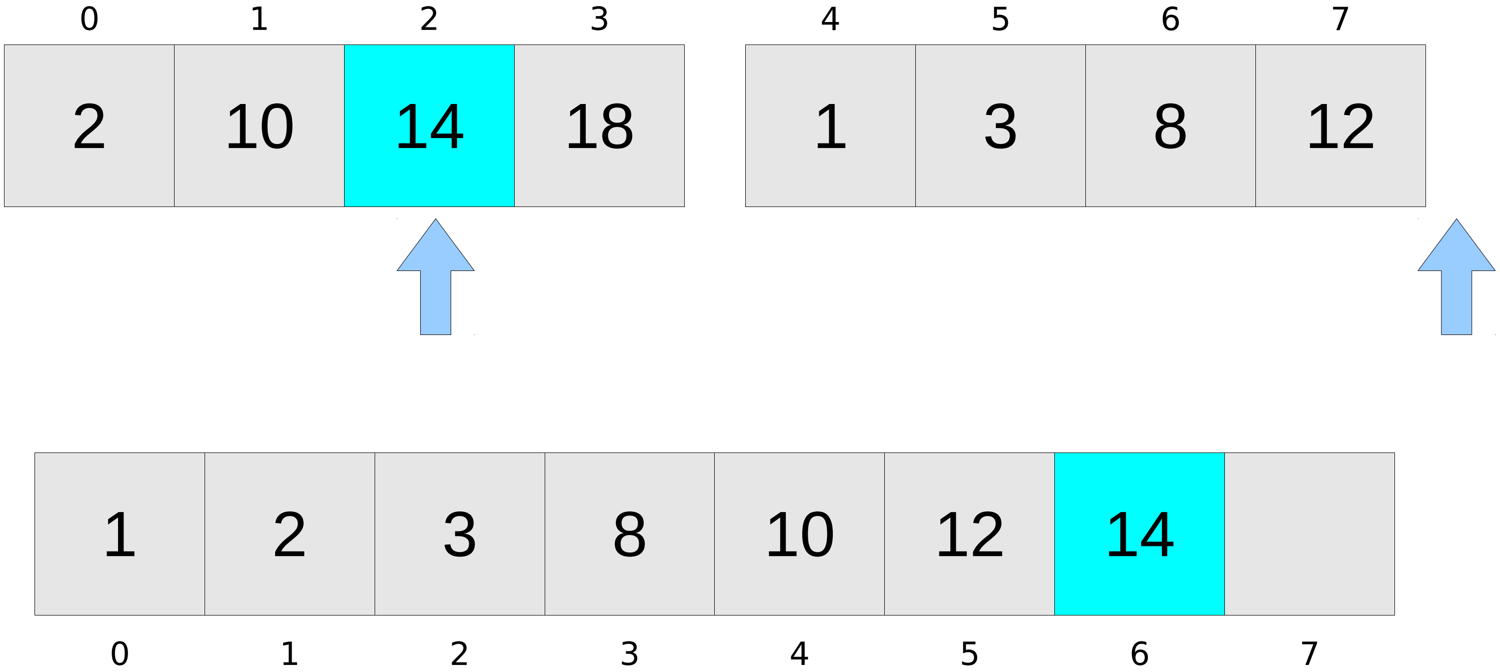

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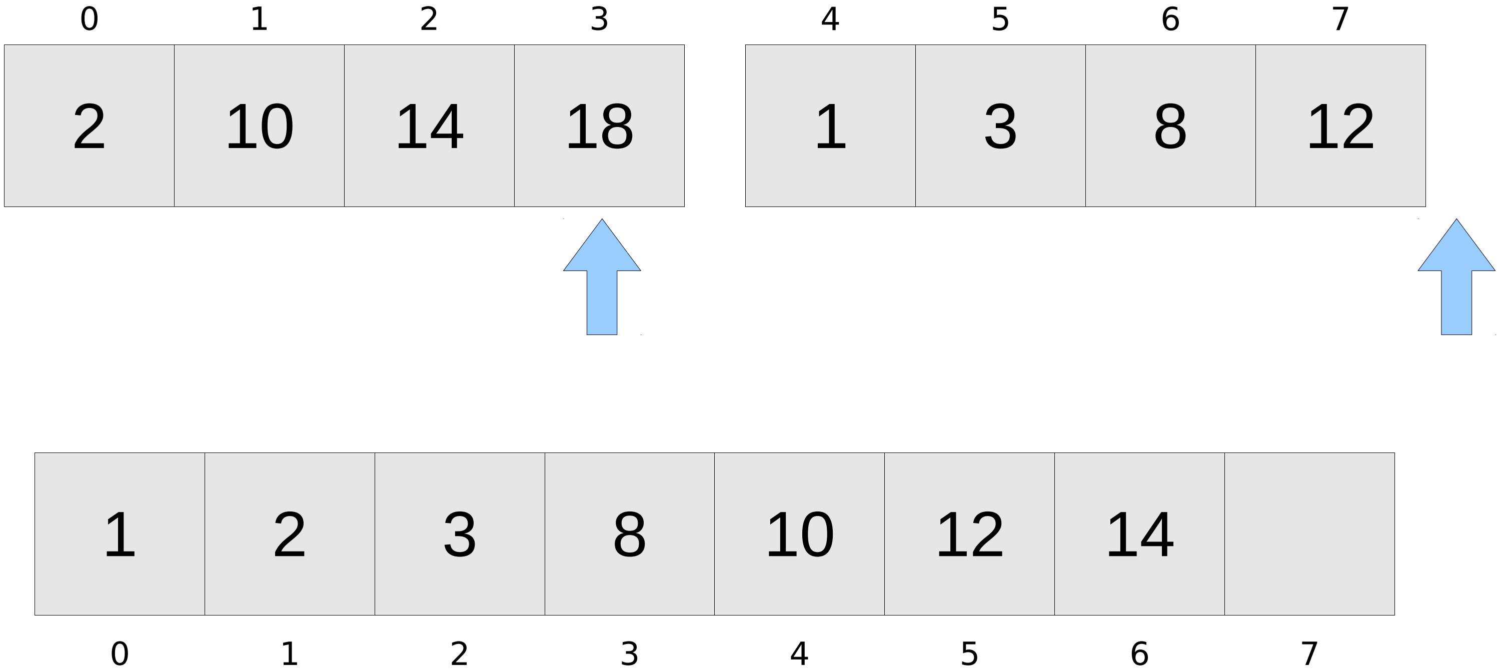

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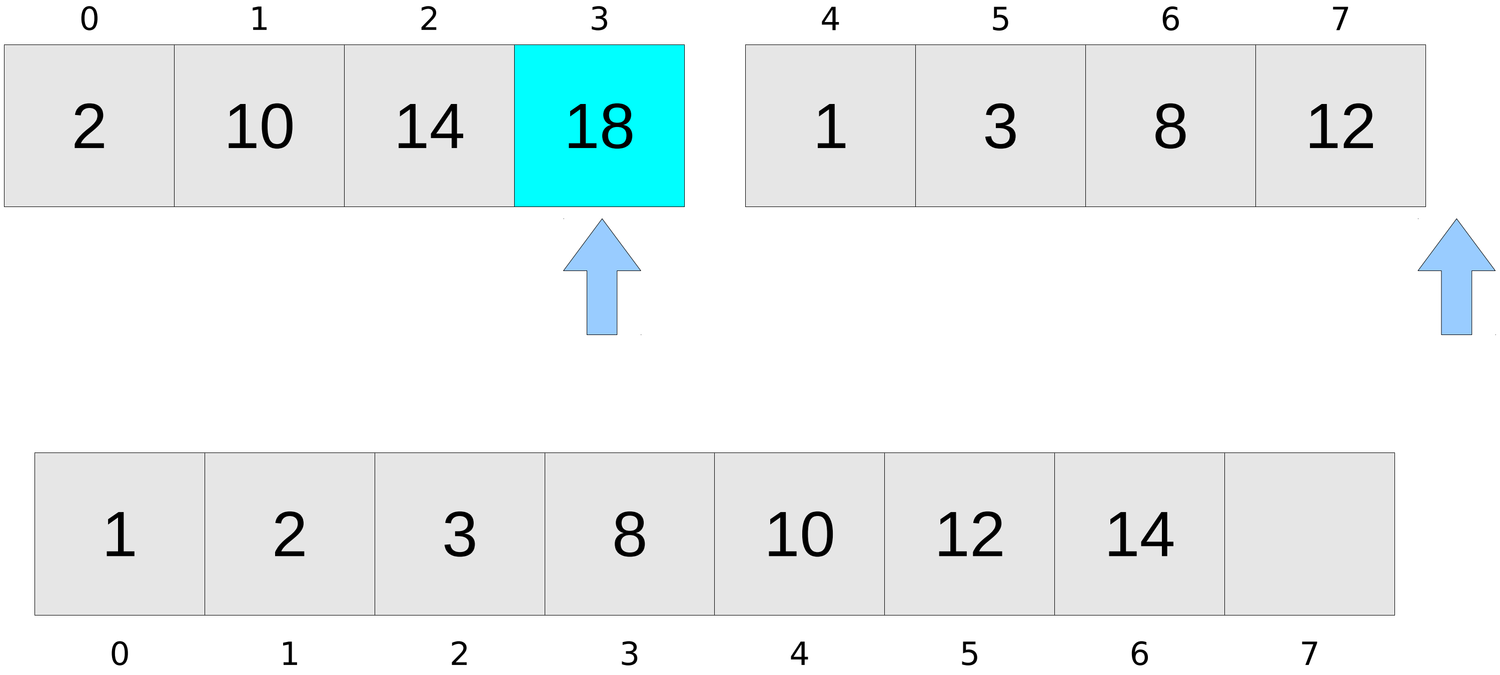

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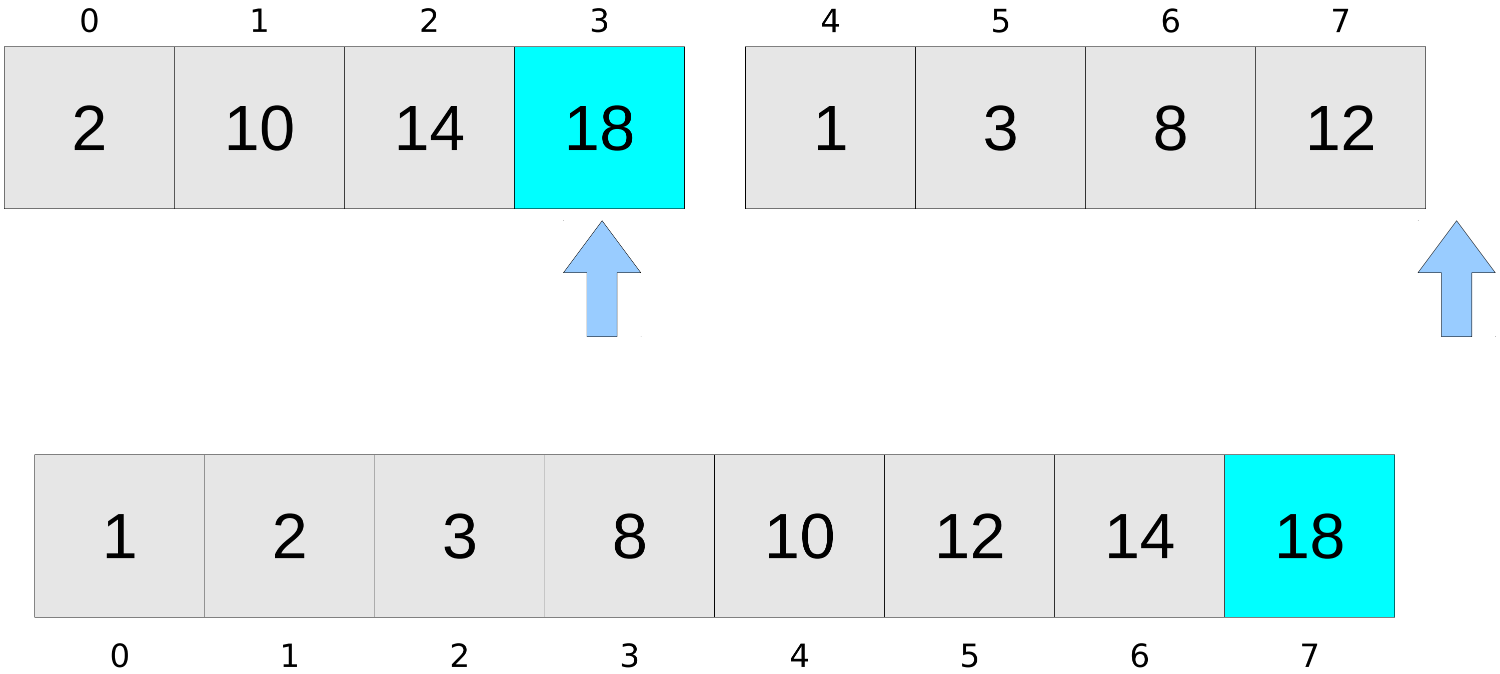

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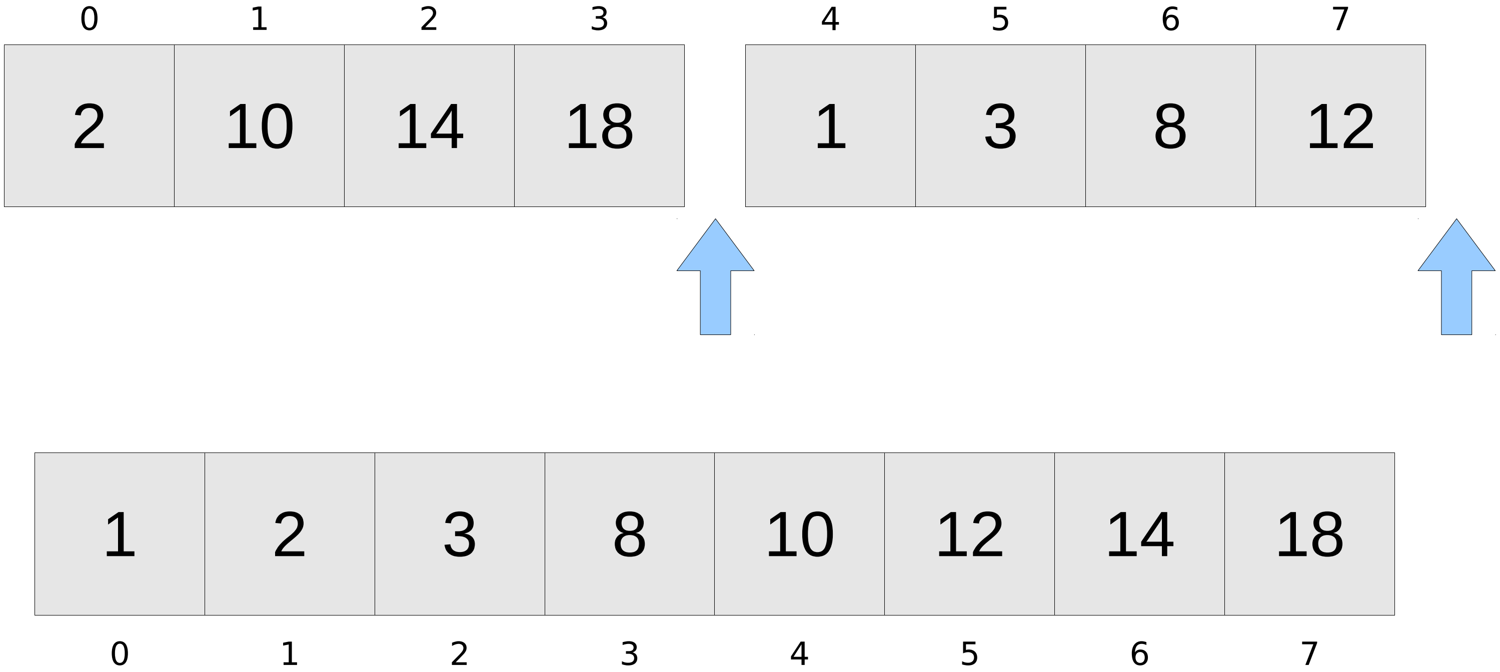

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4	5	6	7
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TADA

1	2	3	8	10	12	14	18
0	1	2	3	4	5	6	7

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(break down the array, then merge the pieces back together)

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Recall: mid = lo + (hi – lo) / 2;

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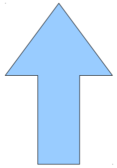

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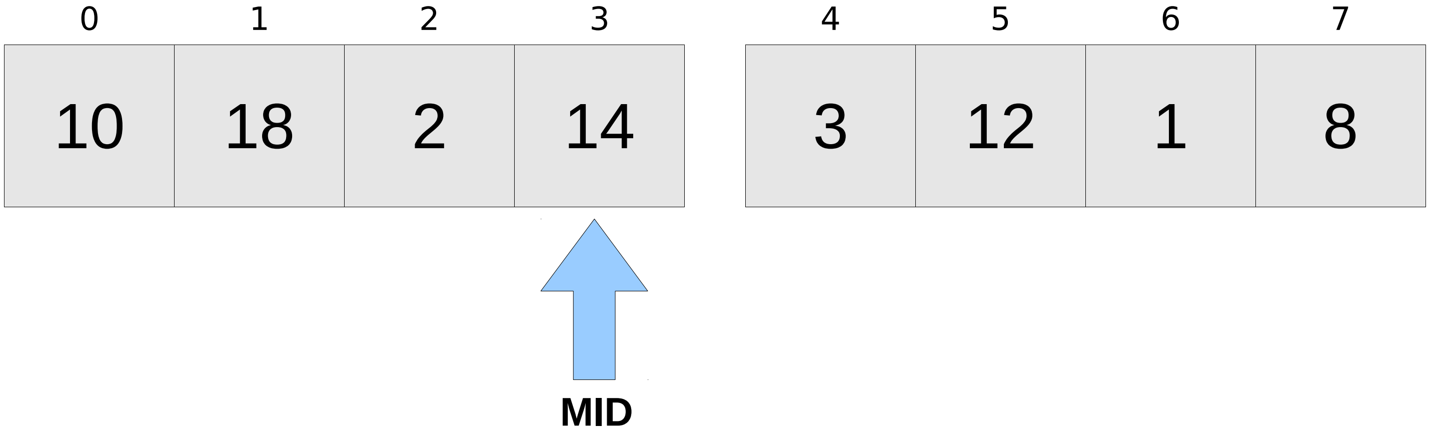

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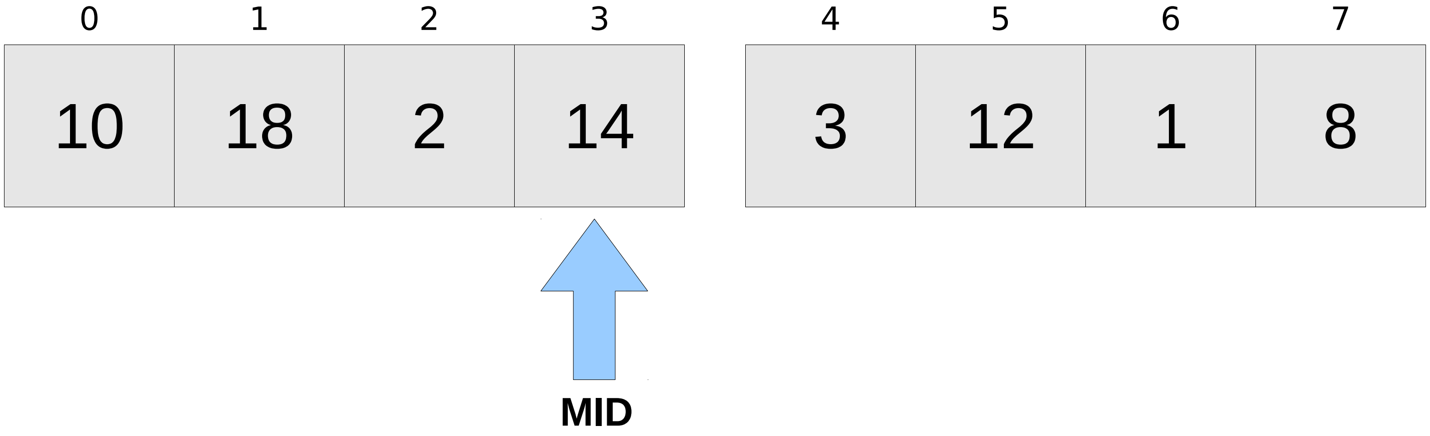

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Recall: mid = lo + (hi – lo) / 2;

MergeSort(array, lo, hi) → **MergeSort**(array, lo, mid)
MergeSort(array, mid + 1, hi)

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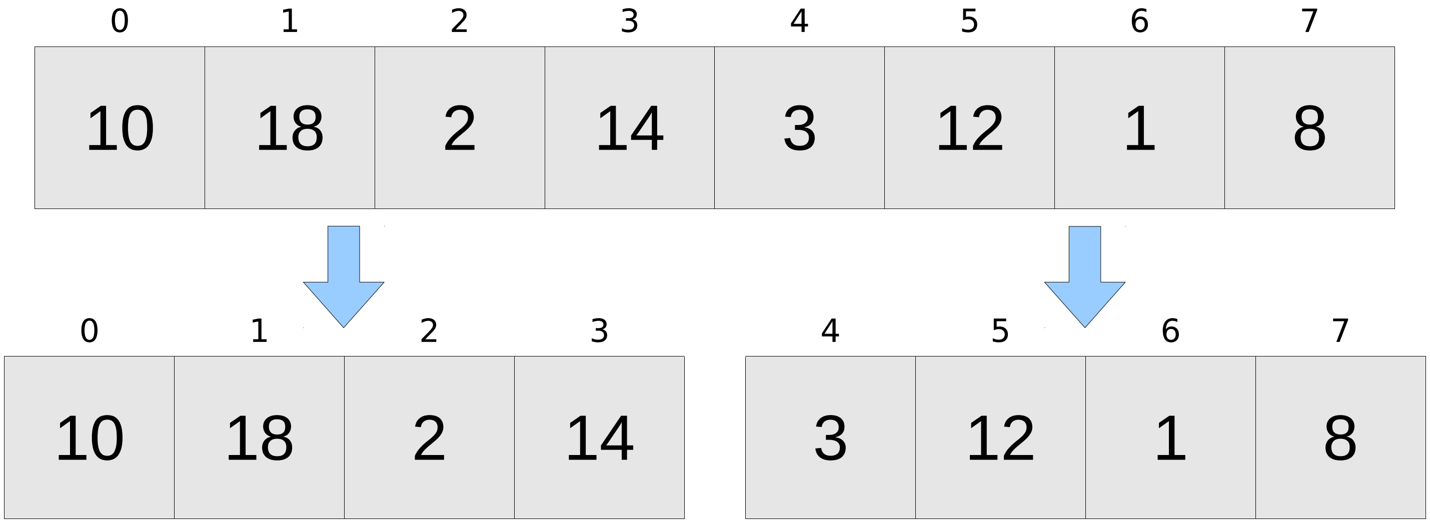

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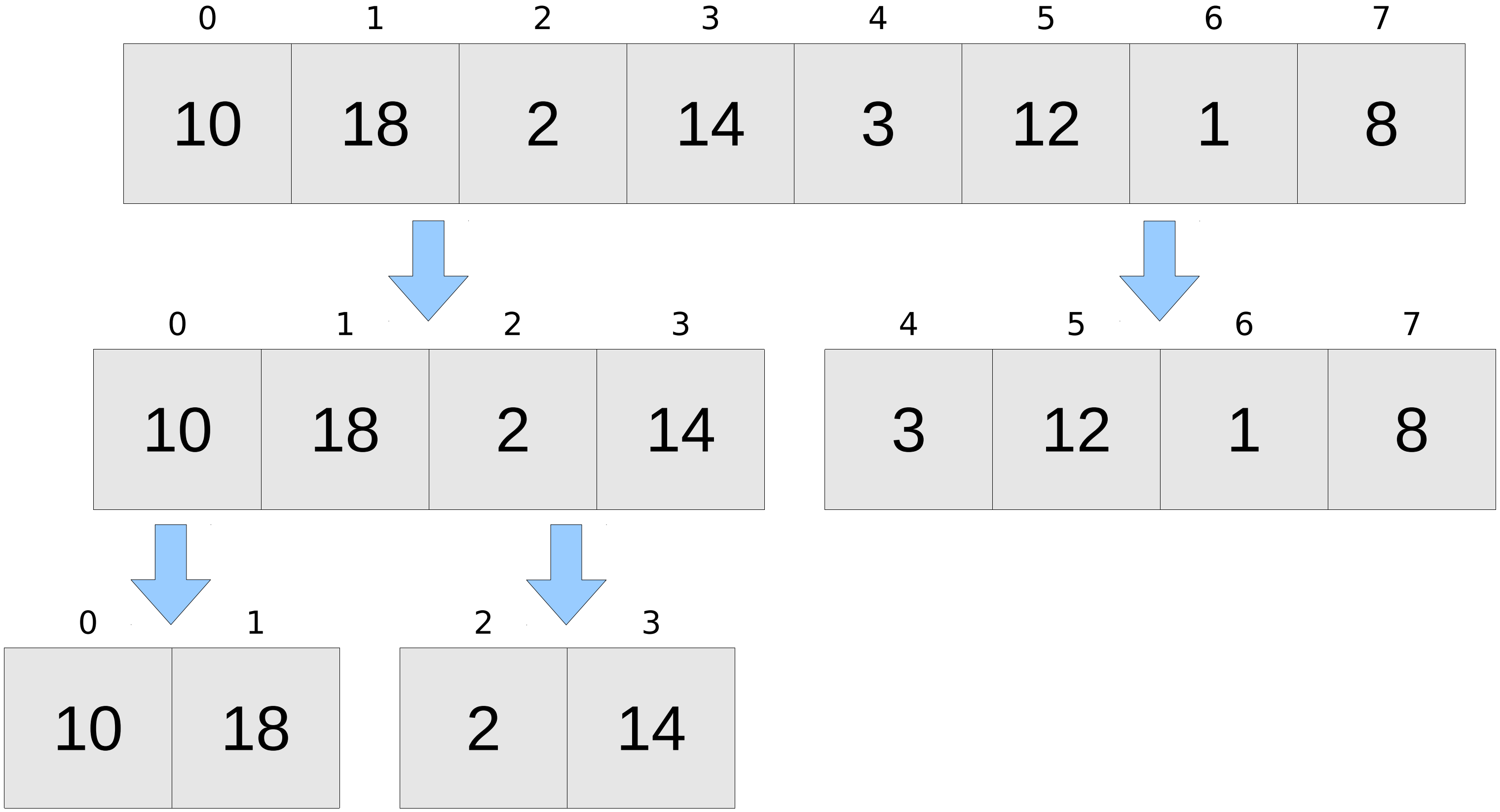

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10	18	2	14

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0	1
10	18

2	3
2	14

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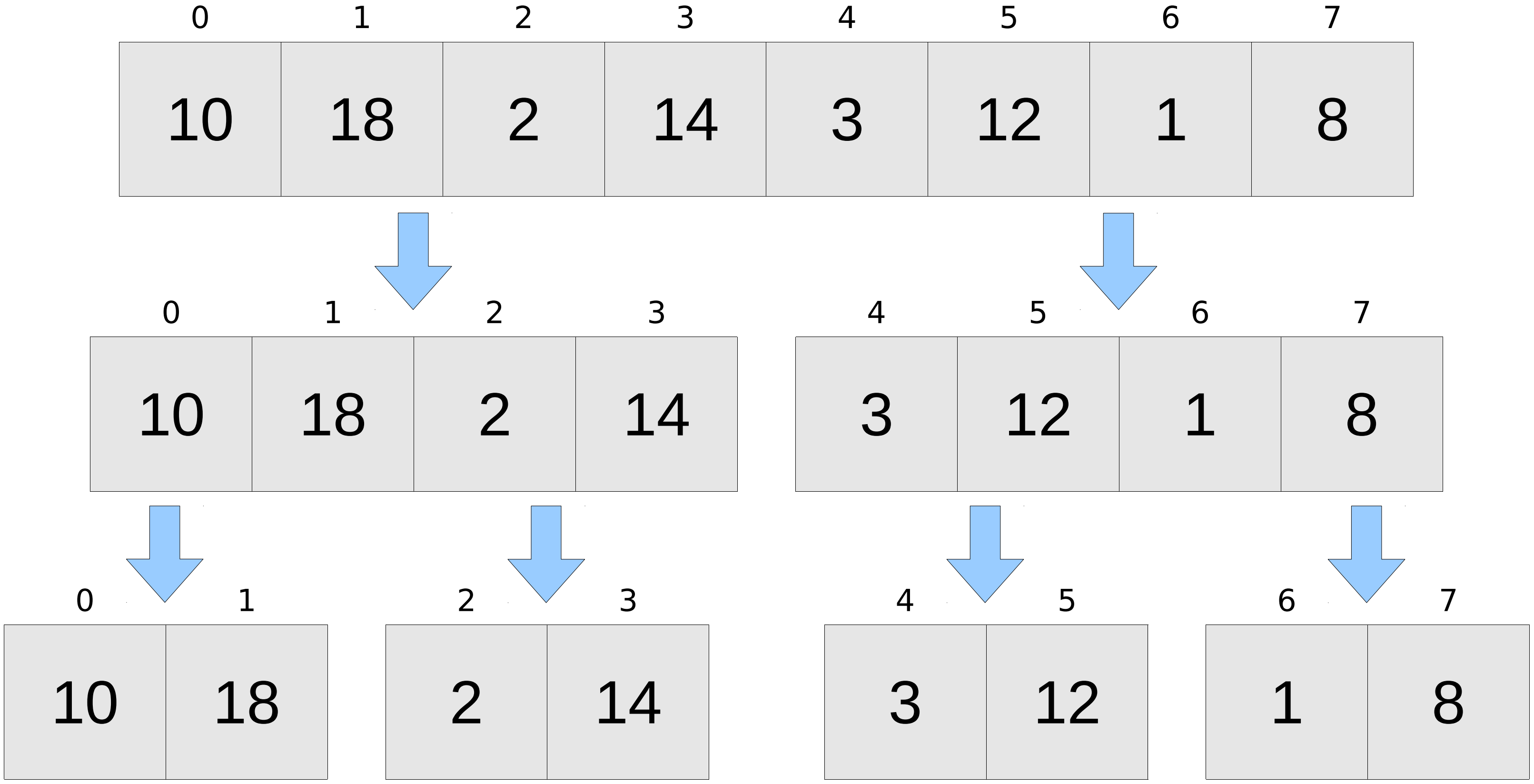

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0	1
10	18

2	3
2	14

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6	7
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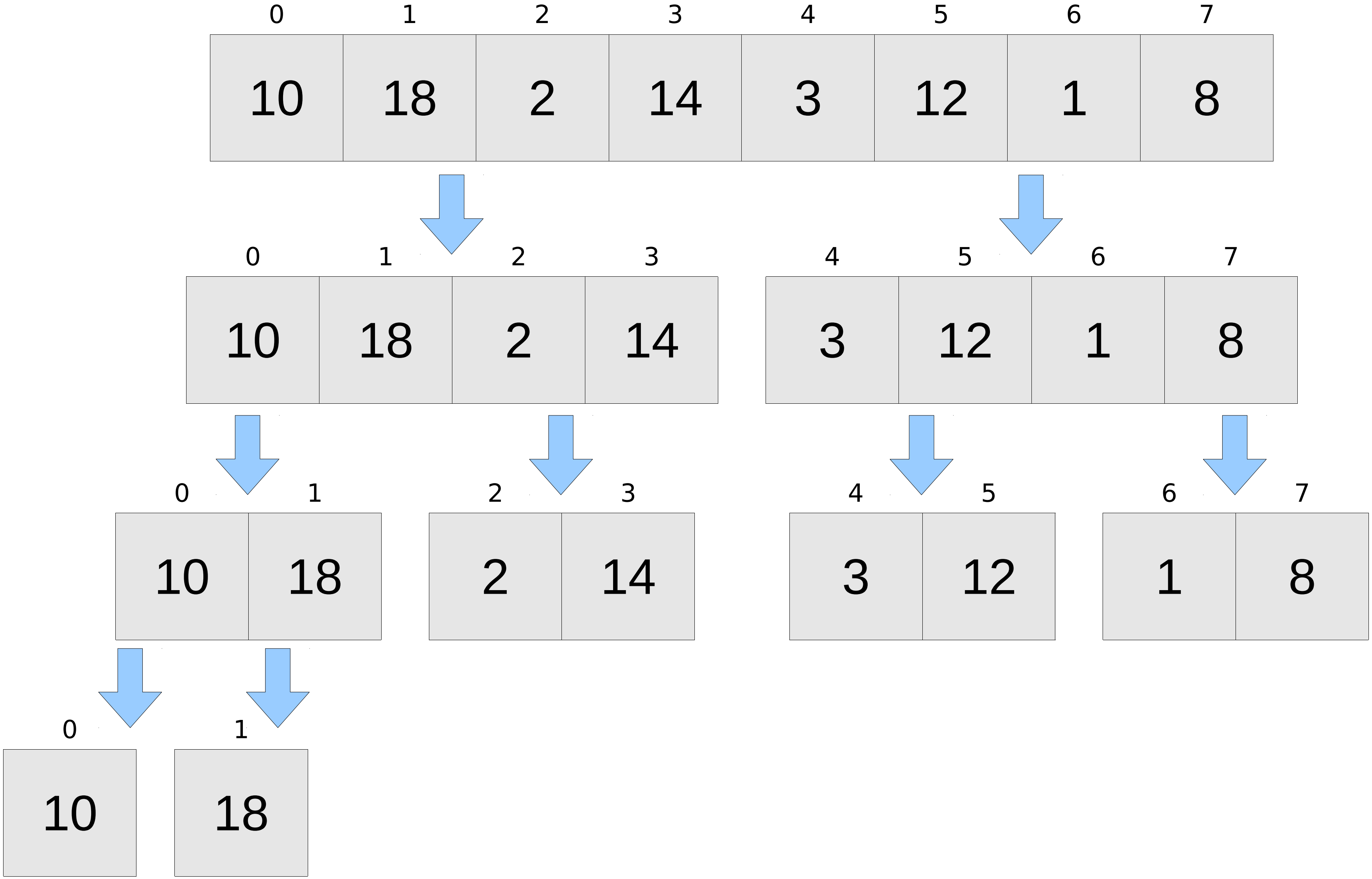

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10	18	2	14	3	12	1	8

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10	18	2	14

4	5	6	7
3	12	1	8

0	1
10	18

2	3
2	14

4	5
3	12

6	7
1	8

0
10

1
18

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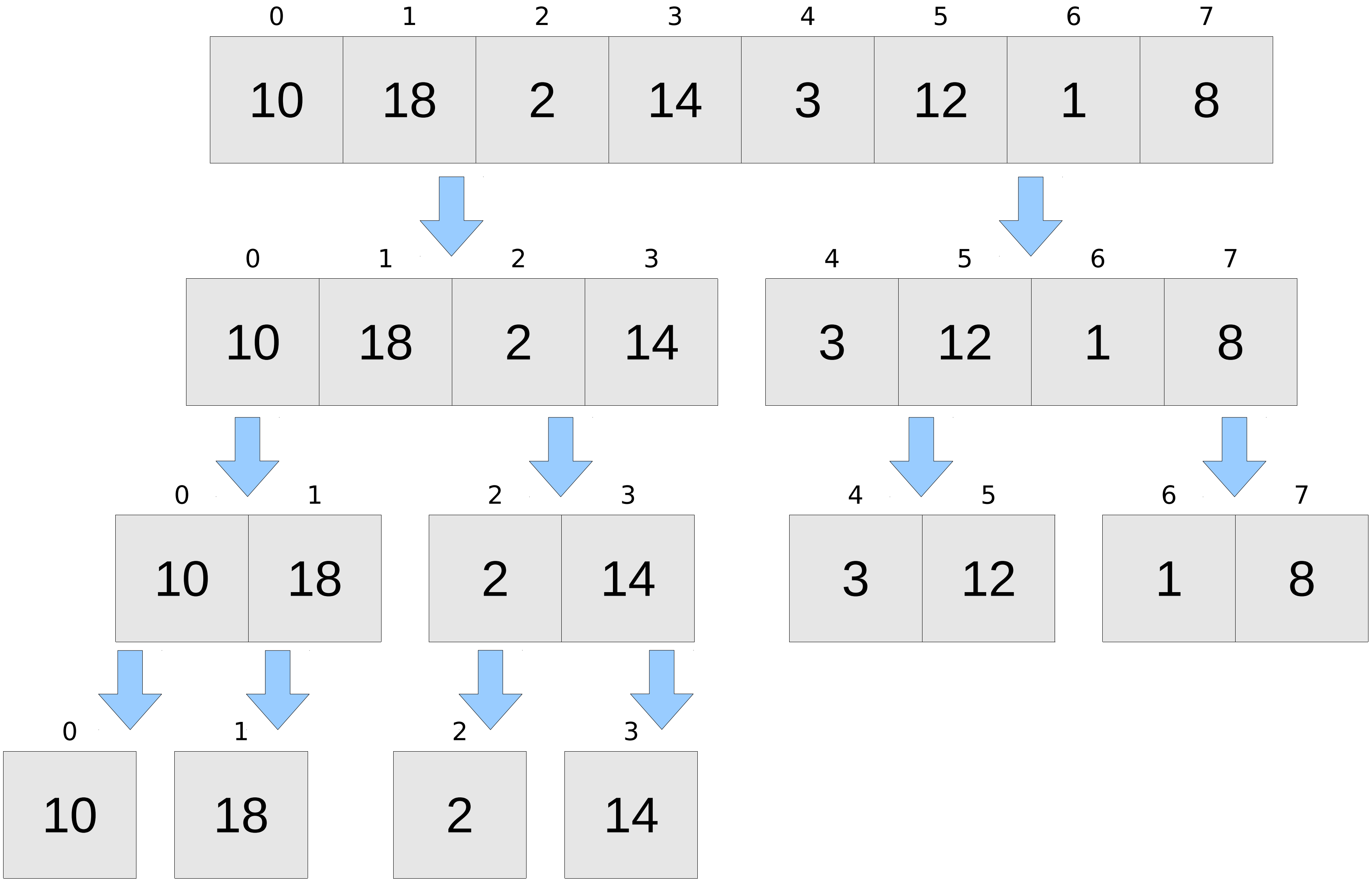

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0	1
10	18

2	3
2	14

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3	12

6	7
1	8

0
10

1
18

2
2

3
14

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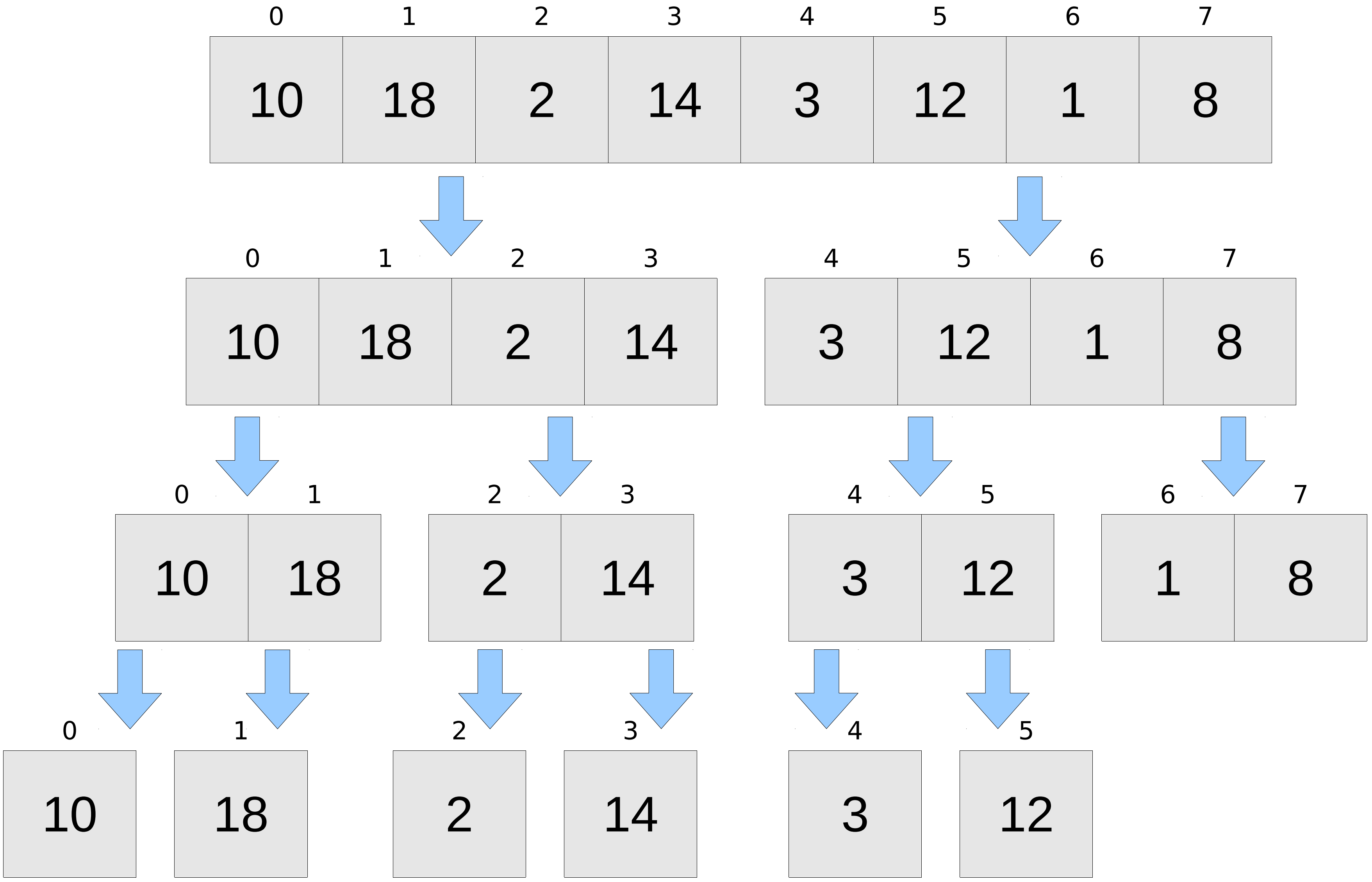

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3	12	1	8

0	1
10	18

2	3
2	14

4	5
3	12

6	7
1	8

0
10

1
18

2
2

3
14

4
3

5
12

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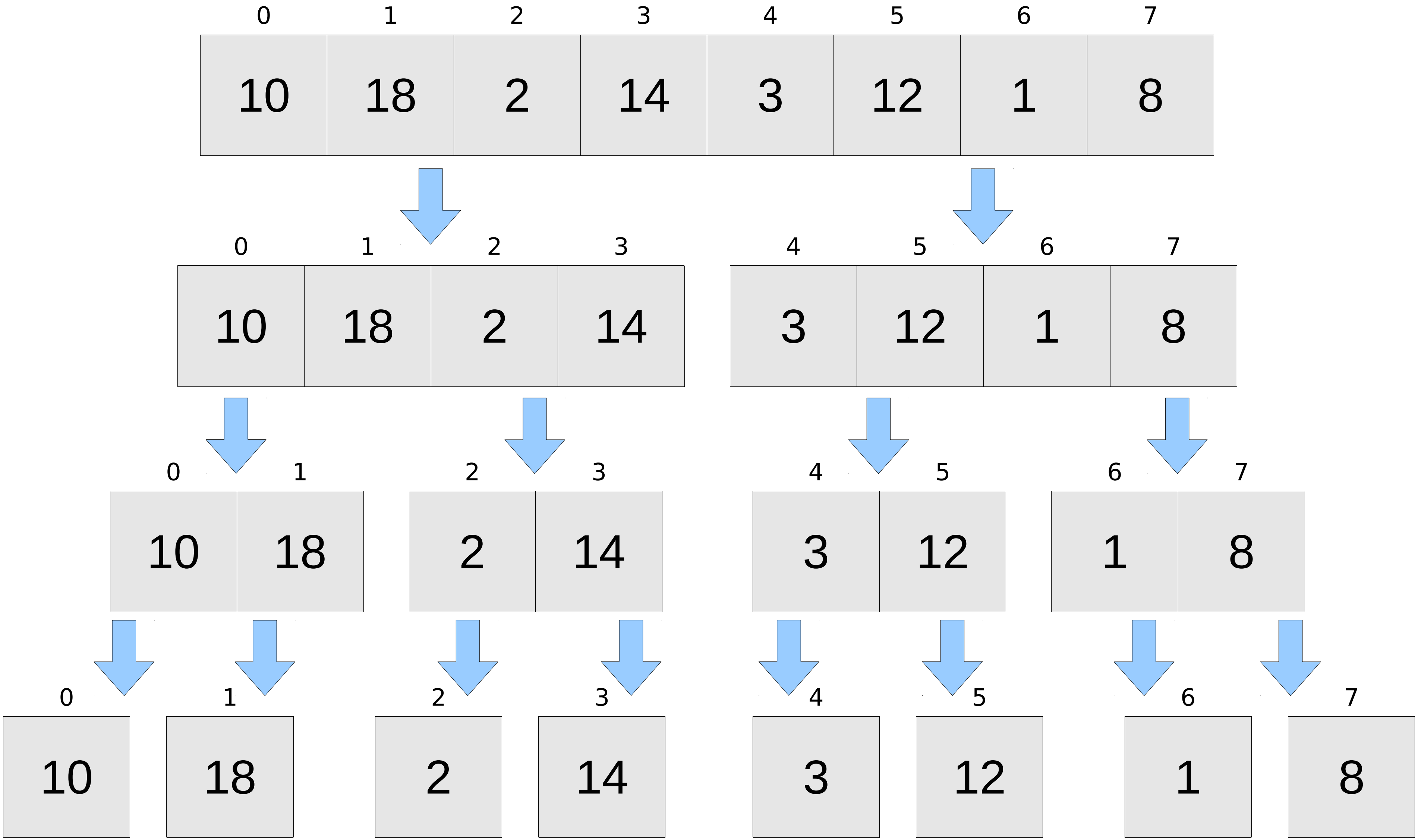

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10	18	2	14

4	5	6	7
3	12	1	8

0	1
10	18

2	3
2	14

4	5
3	12

6	7
1	8

0
10

1
18

2
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3
14

4
3

5
12

6
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7
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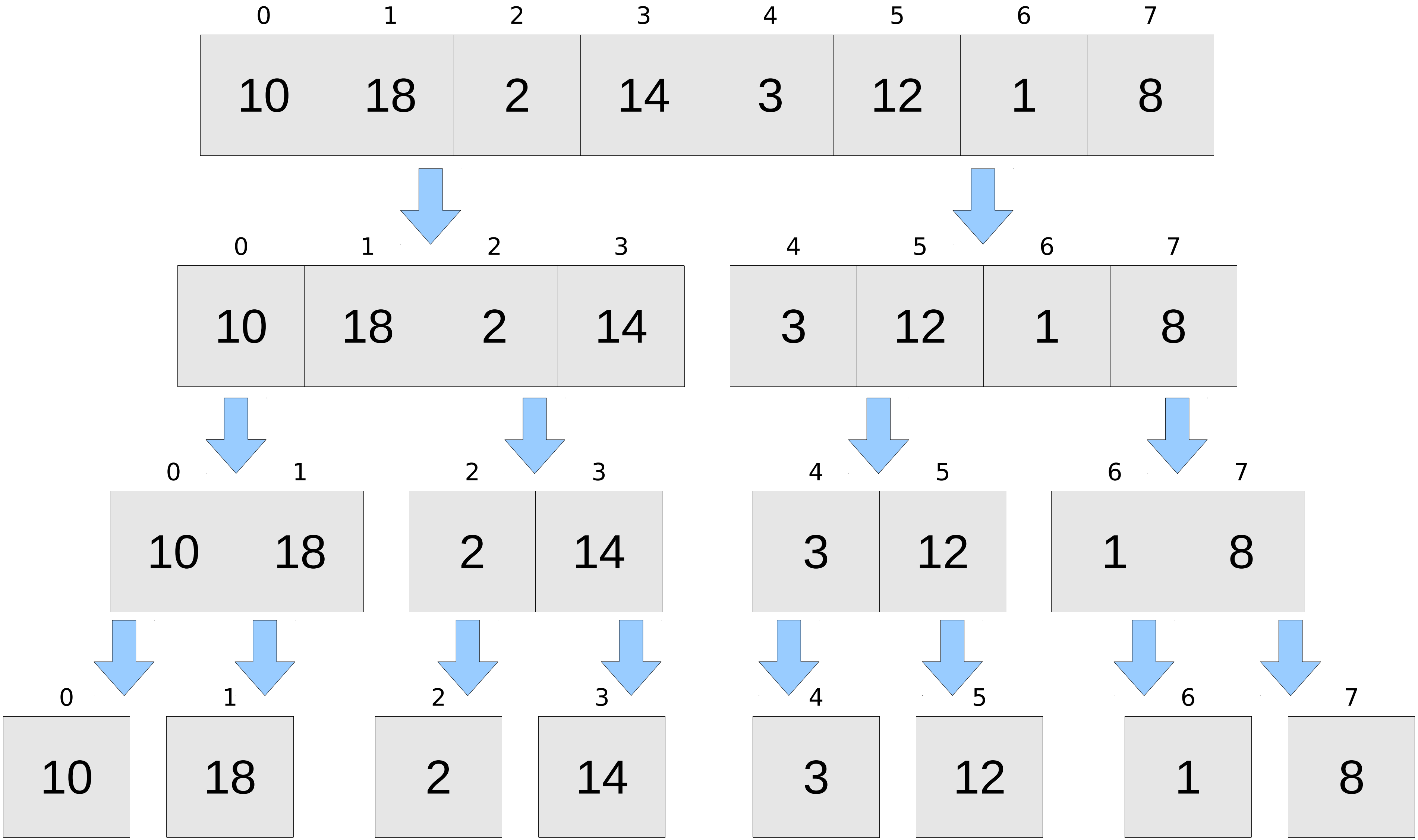

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4	5	6	7
3	12	1	8

0	1
10	18

2	3
2	14

4	5
3	12

6	7
1	8

0
10

1
18

2
2

3
14

4
3

5
12

6
1

7
8

We’ve reached our **base cases**. An array with one element is **sorted**.

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0	1	2	3		4	5	6	7
10	18	2	14		3	12	1	8

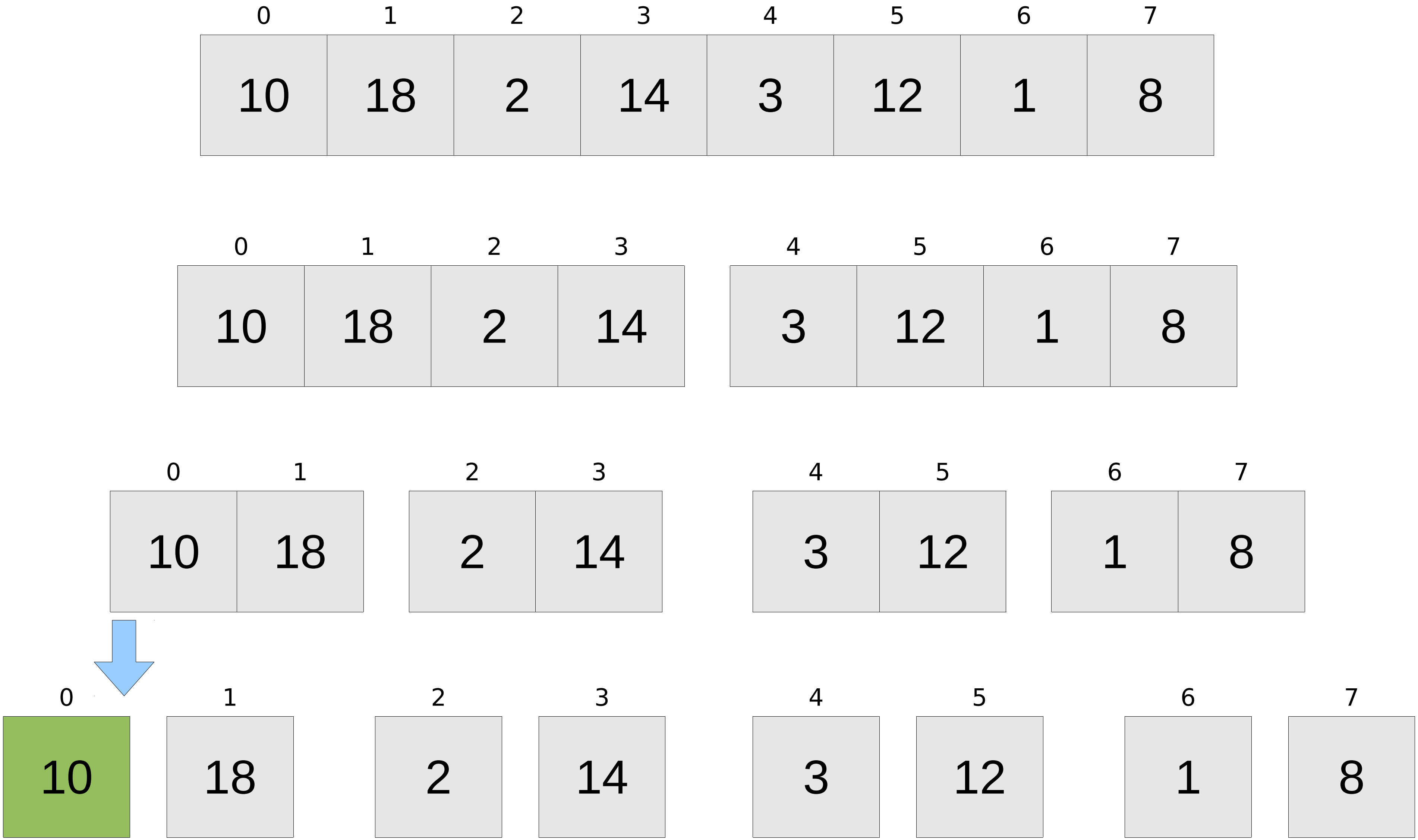
0	1		2	3		4	5		6	7
10	18		2	14		3	12		1	8

0		1		2		3		4		5		6		7
10		18		2		14		3		12		1		8

We've reached our **base cases**. An array with one element is **sorted**.

Merge Sort

(break down the array, then merge the pieces back together)



0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

0	1	2	3
10	18	2	14

4	5	6	7
3	12	1	8

0	1
10	18

2	3
2	14

4	5
3	12

6	7
1	8

0
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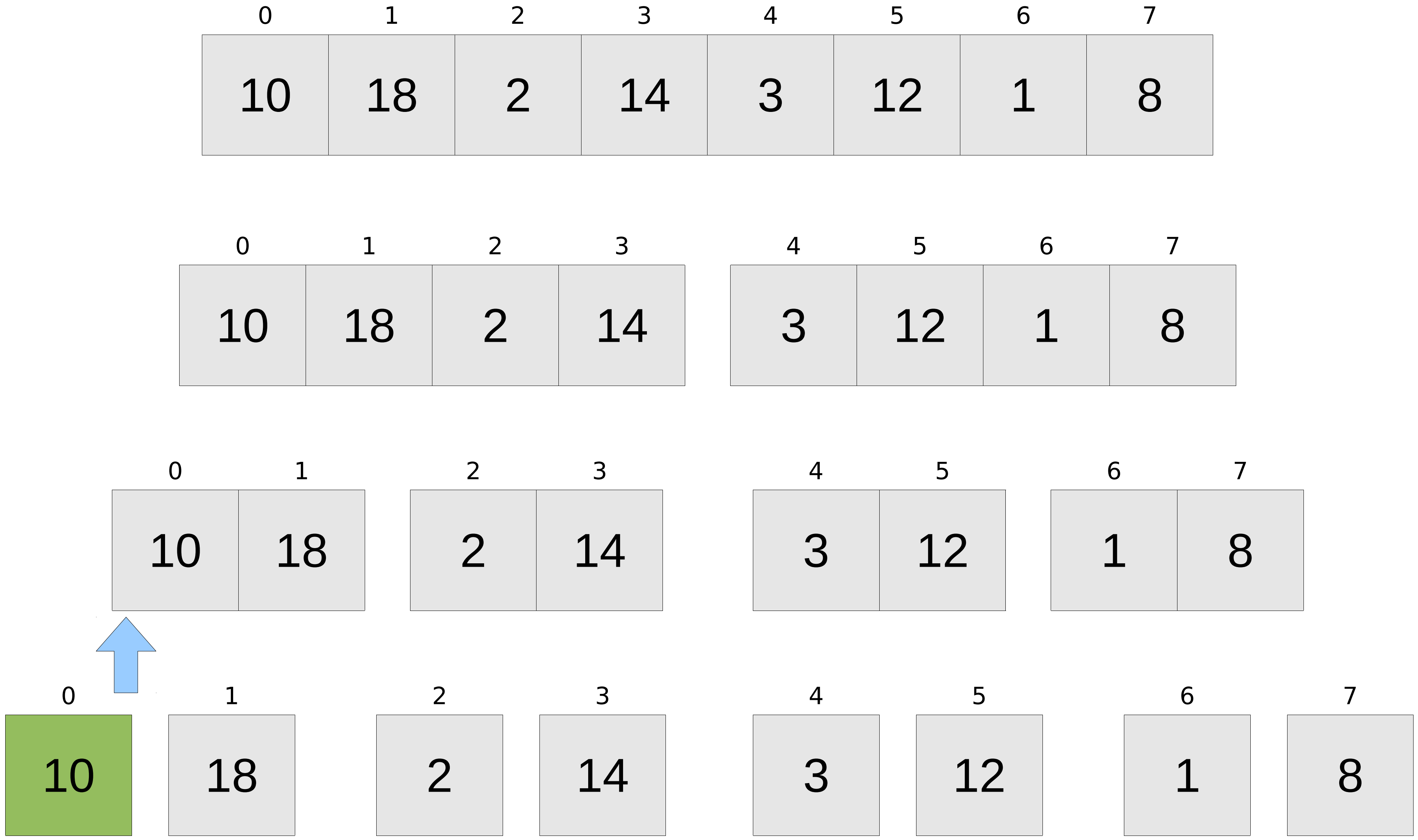

0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

0	1	2	3
10	18	2	14

4	5	6	7
3	12	1	8

0	1
10	18

2	3
2	14

4	5
3	12

6	7
1	8

0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

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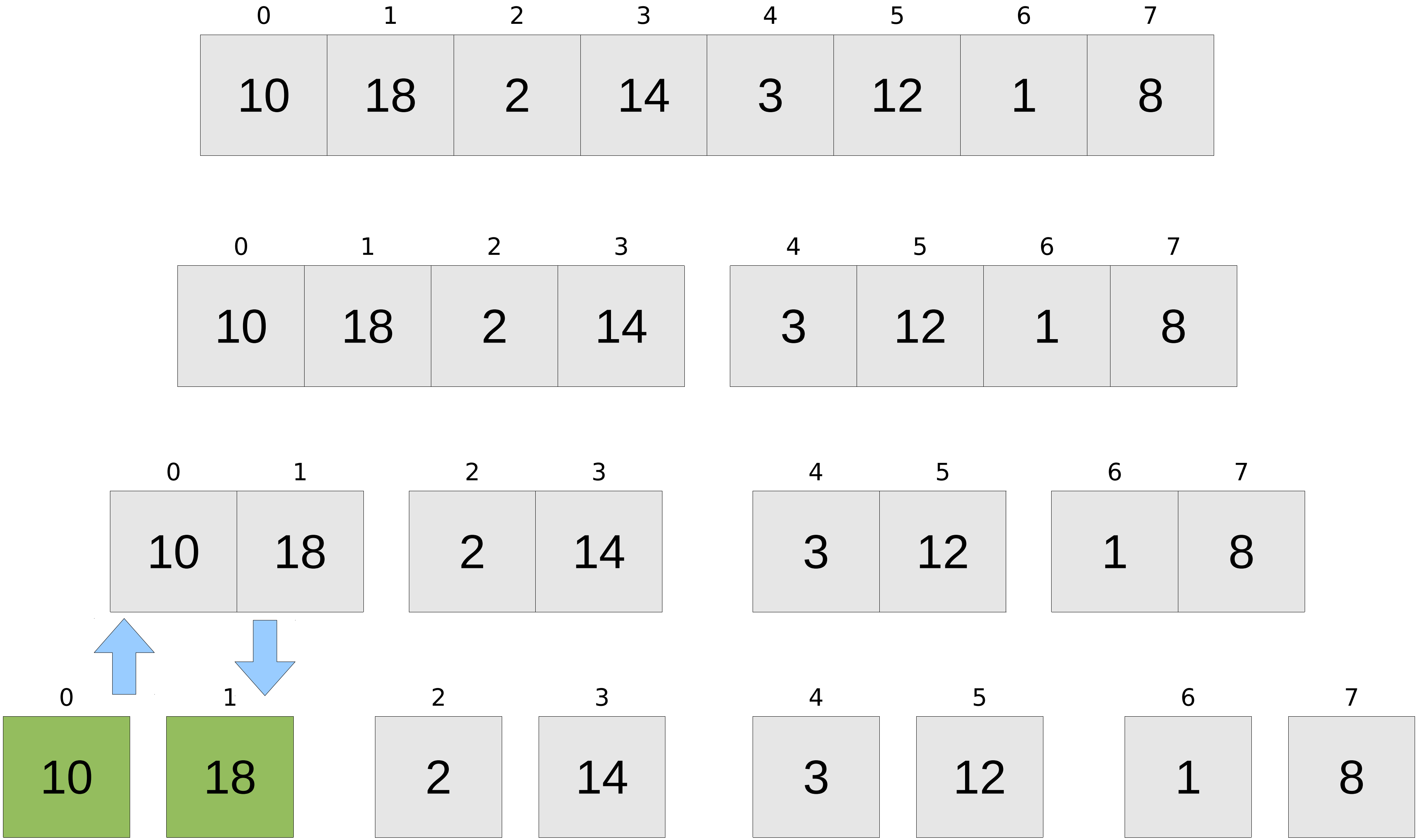

0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

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10	18	2	14

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3	12	1	8

0	1
10	18

2	3
2	14

4	5
3	12

6	7
1	8

0
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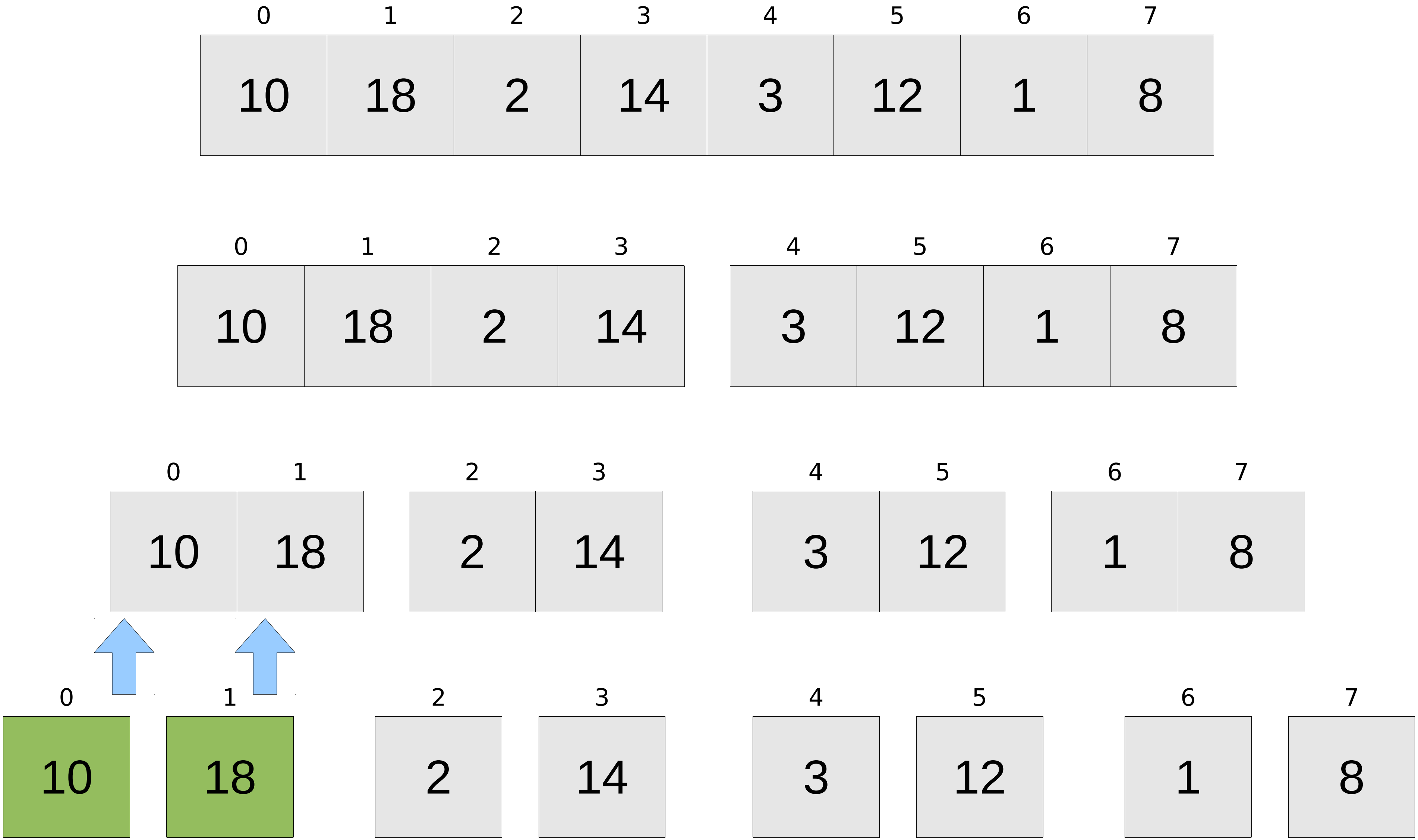

0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

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10	18	2	14

4	5	6	7
3	12	1	8

0	1
10	18

2	3
2	14

4	5
3	12

6	7
1	8

0
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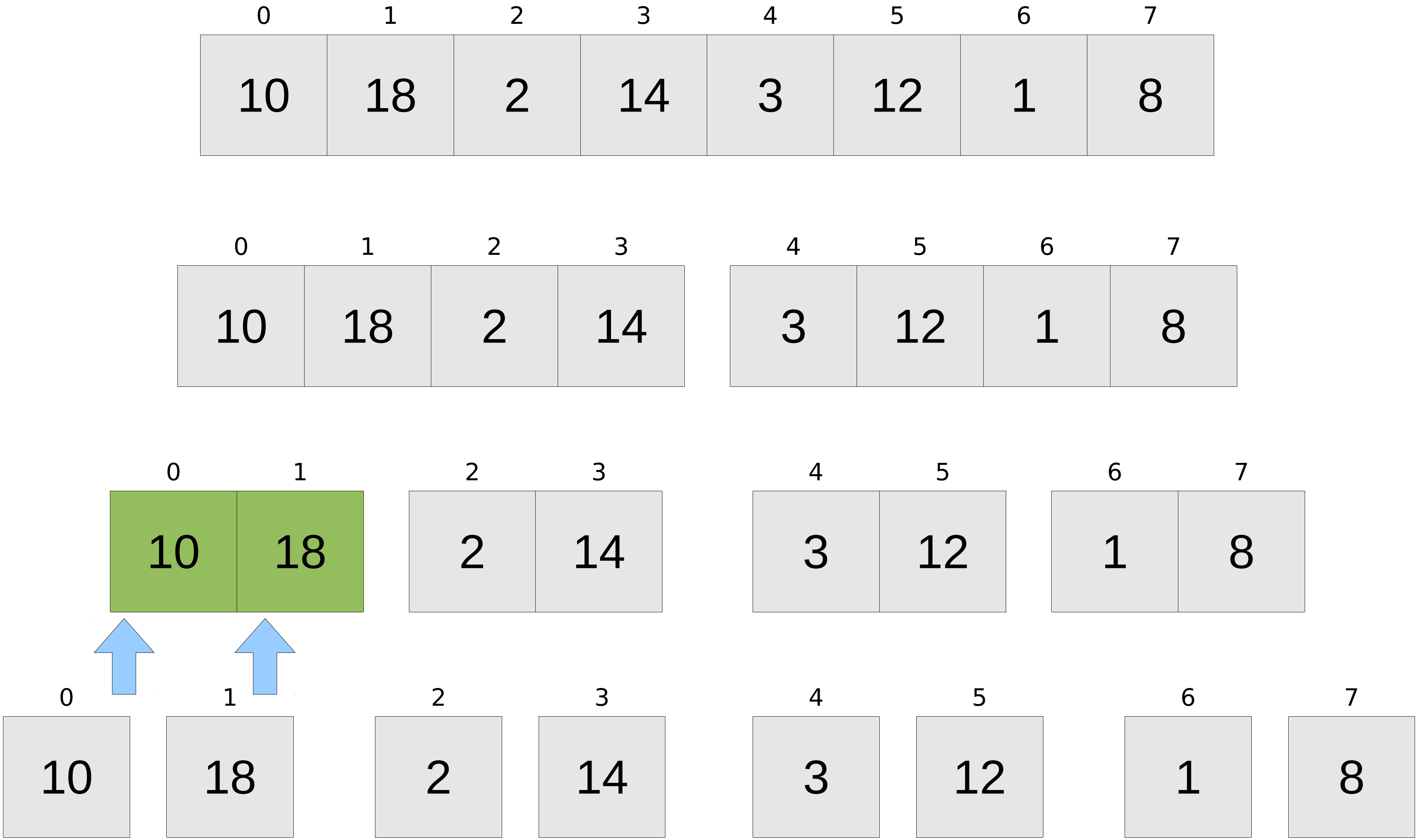

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3	12	1	8

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10	18

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2	14

4	5
3	12

6	7
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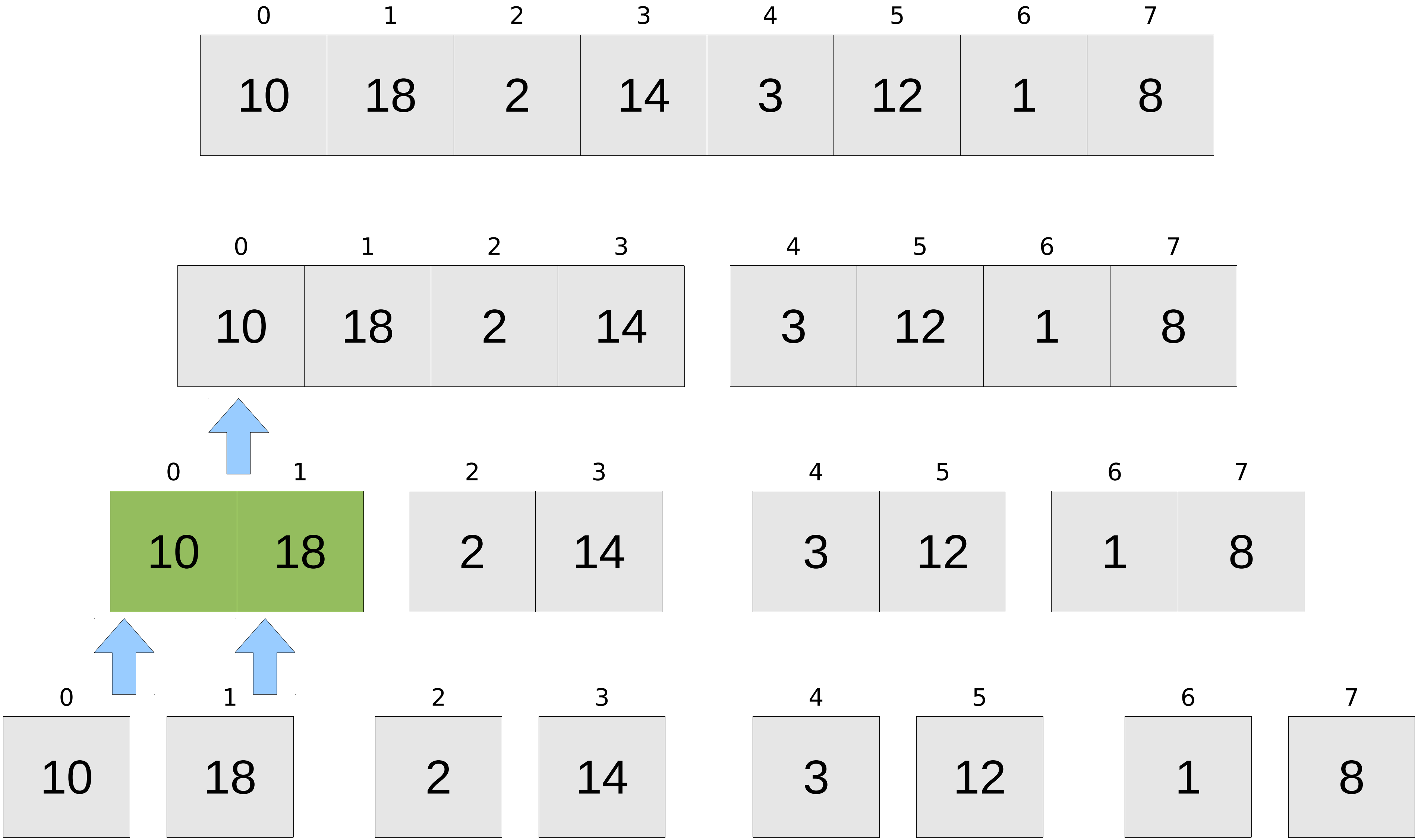

0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

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10	18	2	14

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3	12	1	8

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10	18

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2	14

4	5
3	12

6	7
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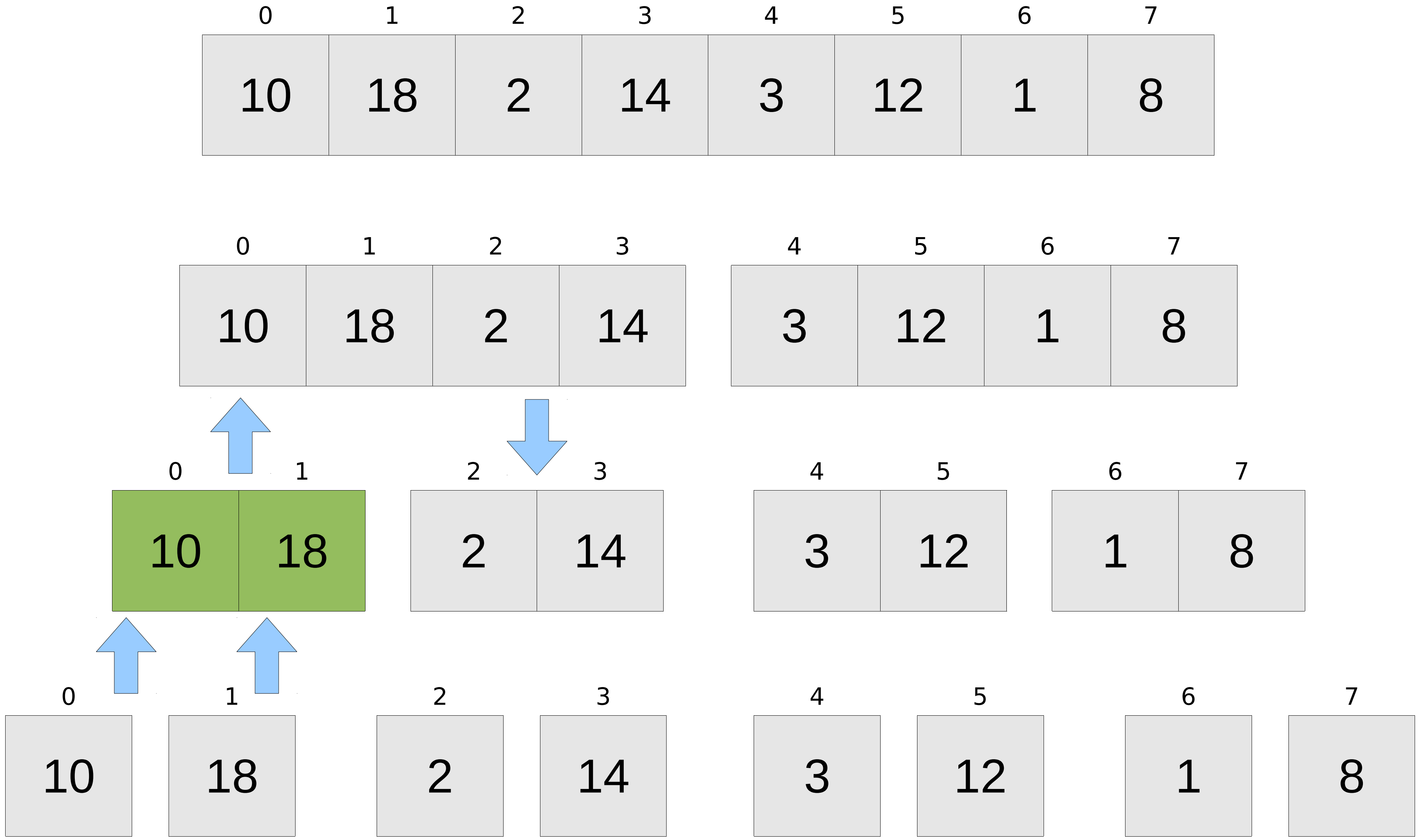

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3	12	1	8

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2	14

4	5
3	12

6	7
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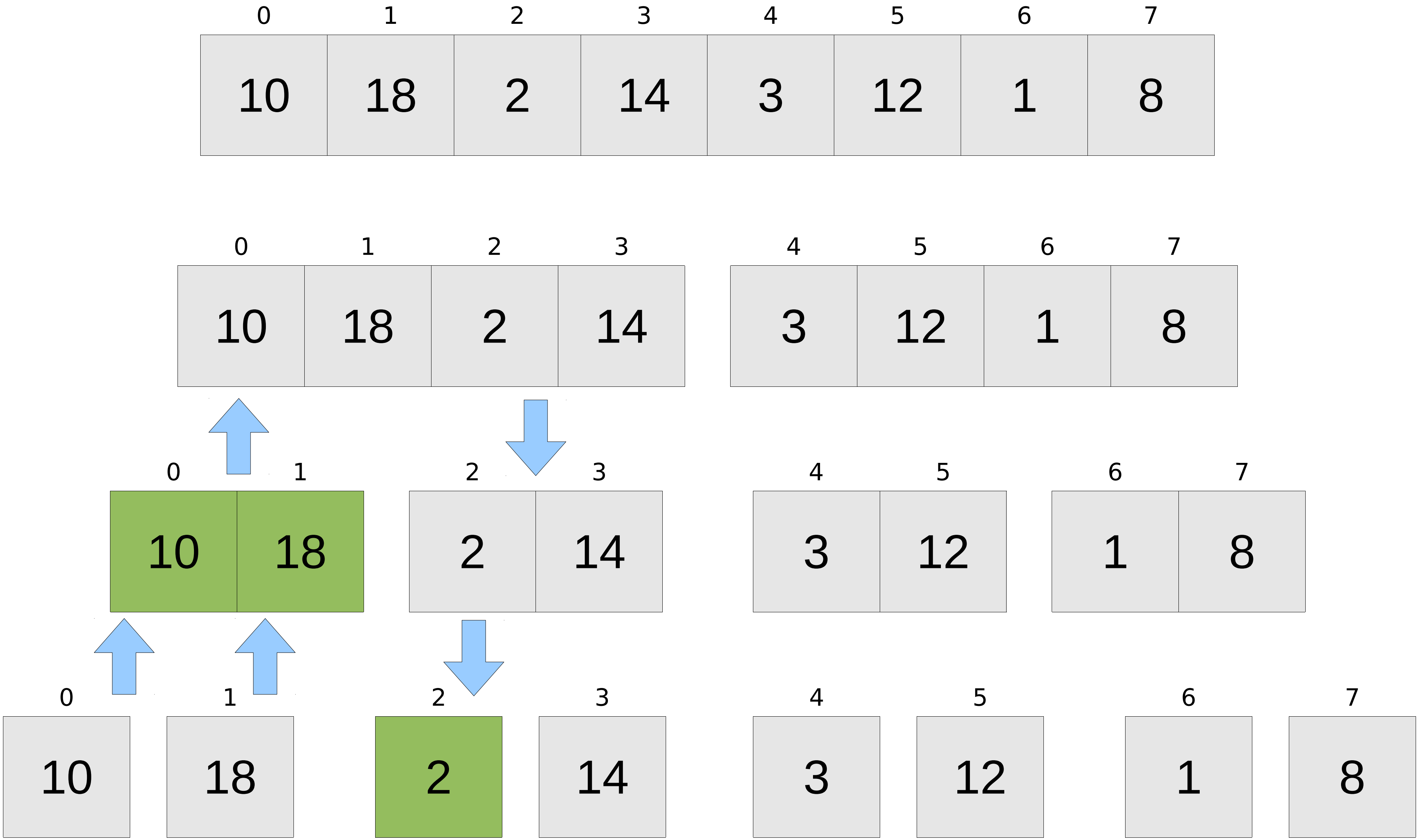

0	1	2	3	4	5	6	7
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3	12	1	8

0	1
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2	14

4	5
3	12

6	7
1	8

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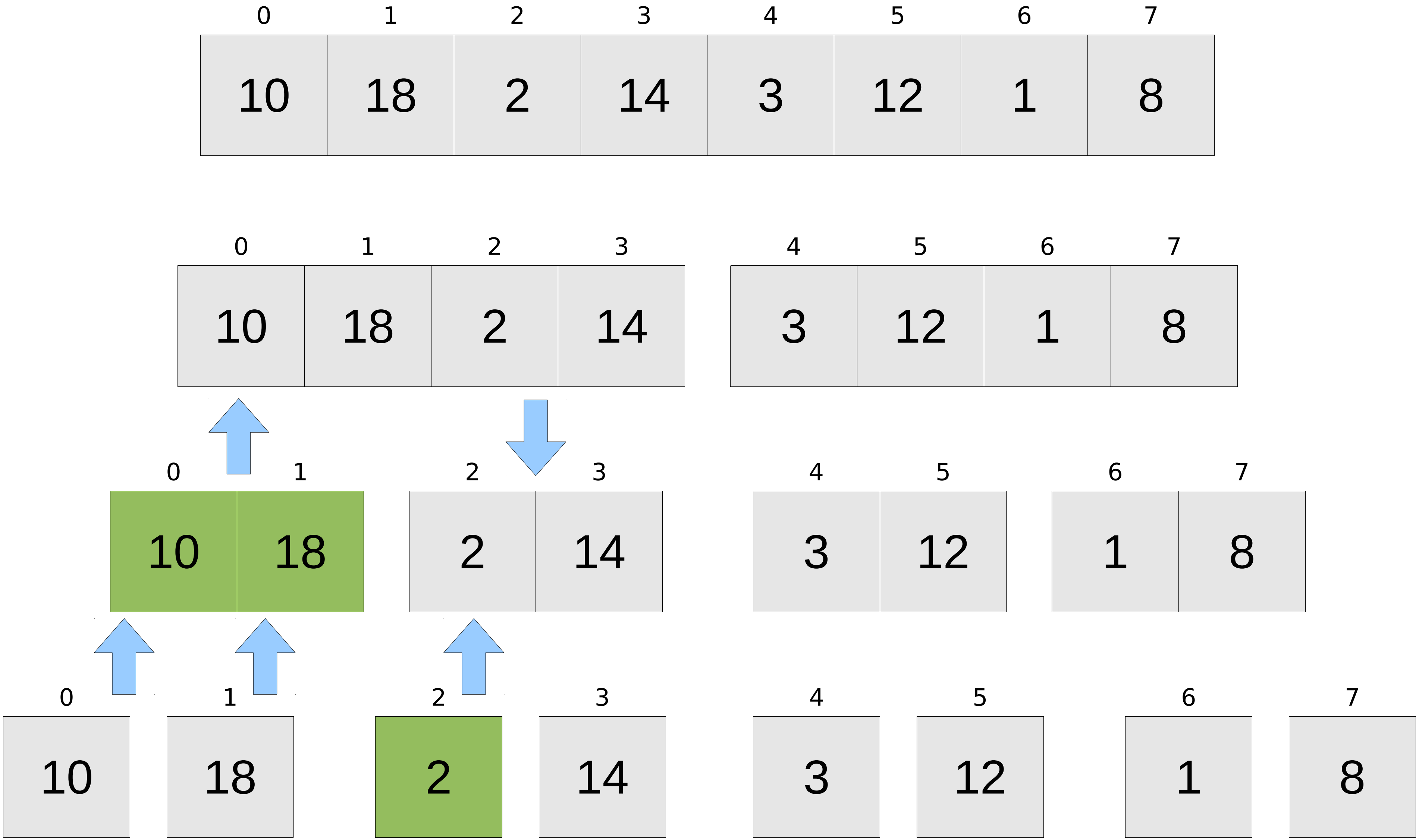

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3	12	1	8

0	1
10	18

2	3
2	14

4	5
3	12

6	7
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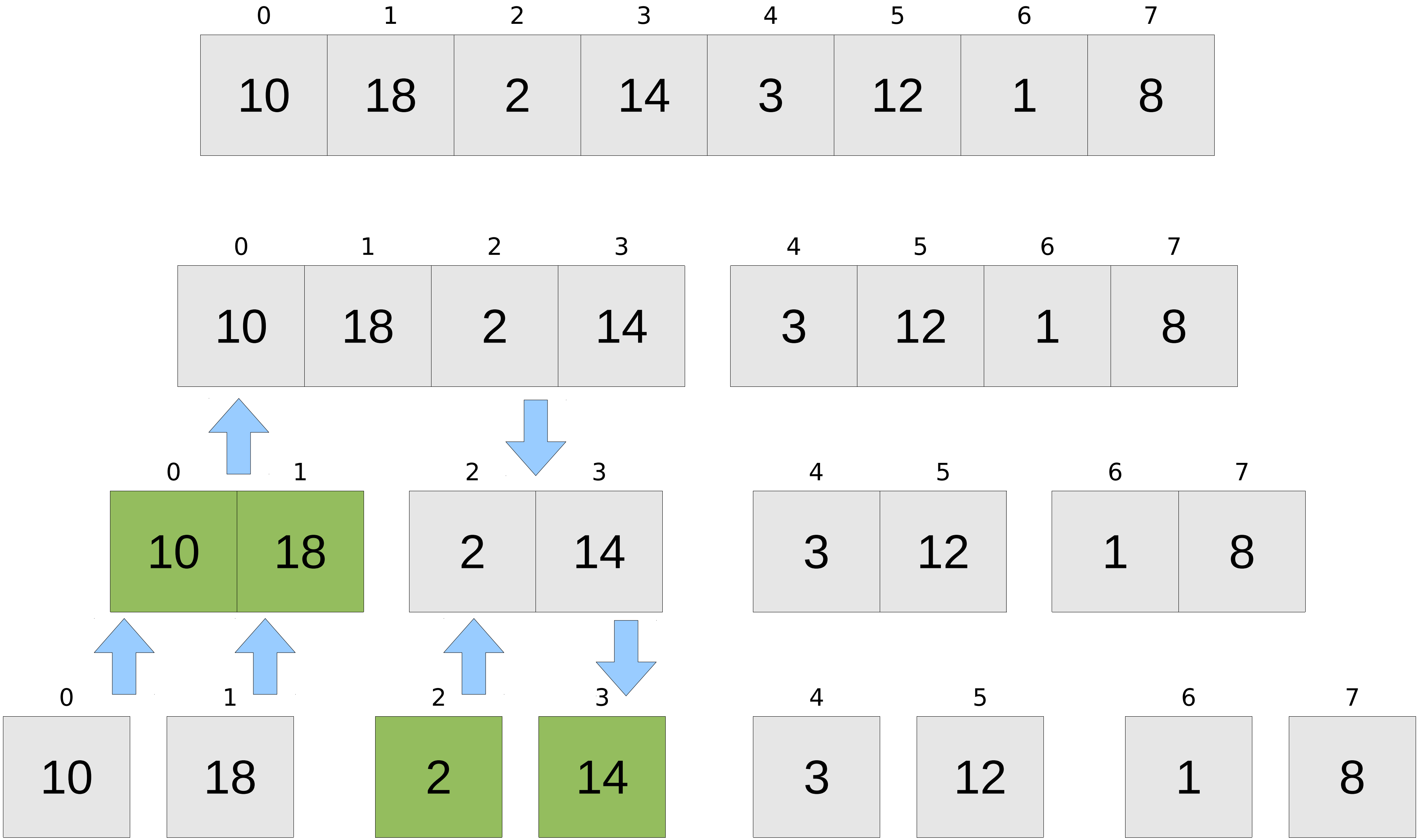

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0	1	2	3
10	18	2	14

4	5	6	7
3	12	1	8

0	1
10	18

2	3
2	14

4	5
3	12

6	7
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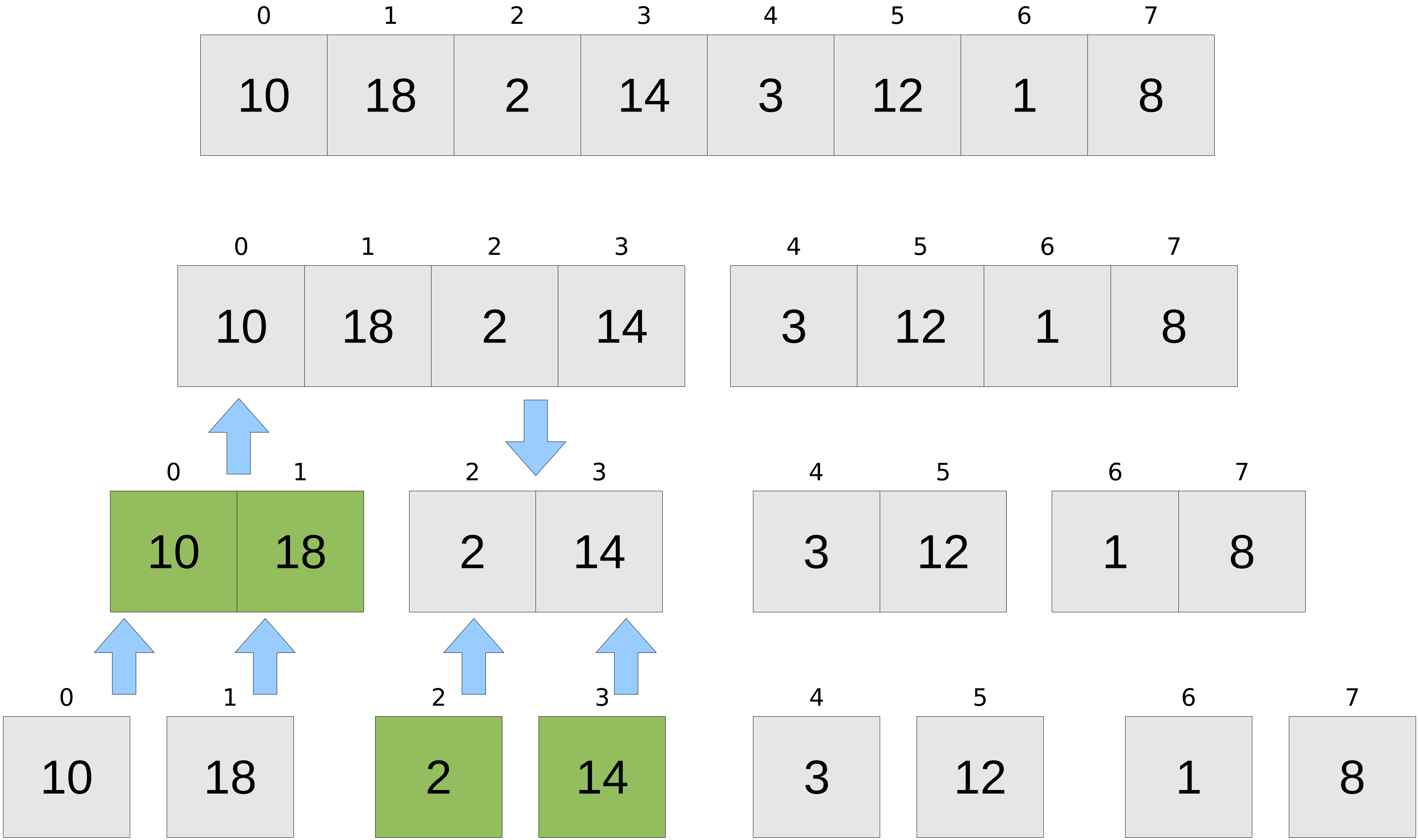

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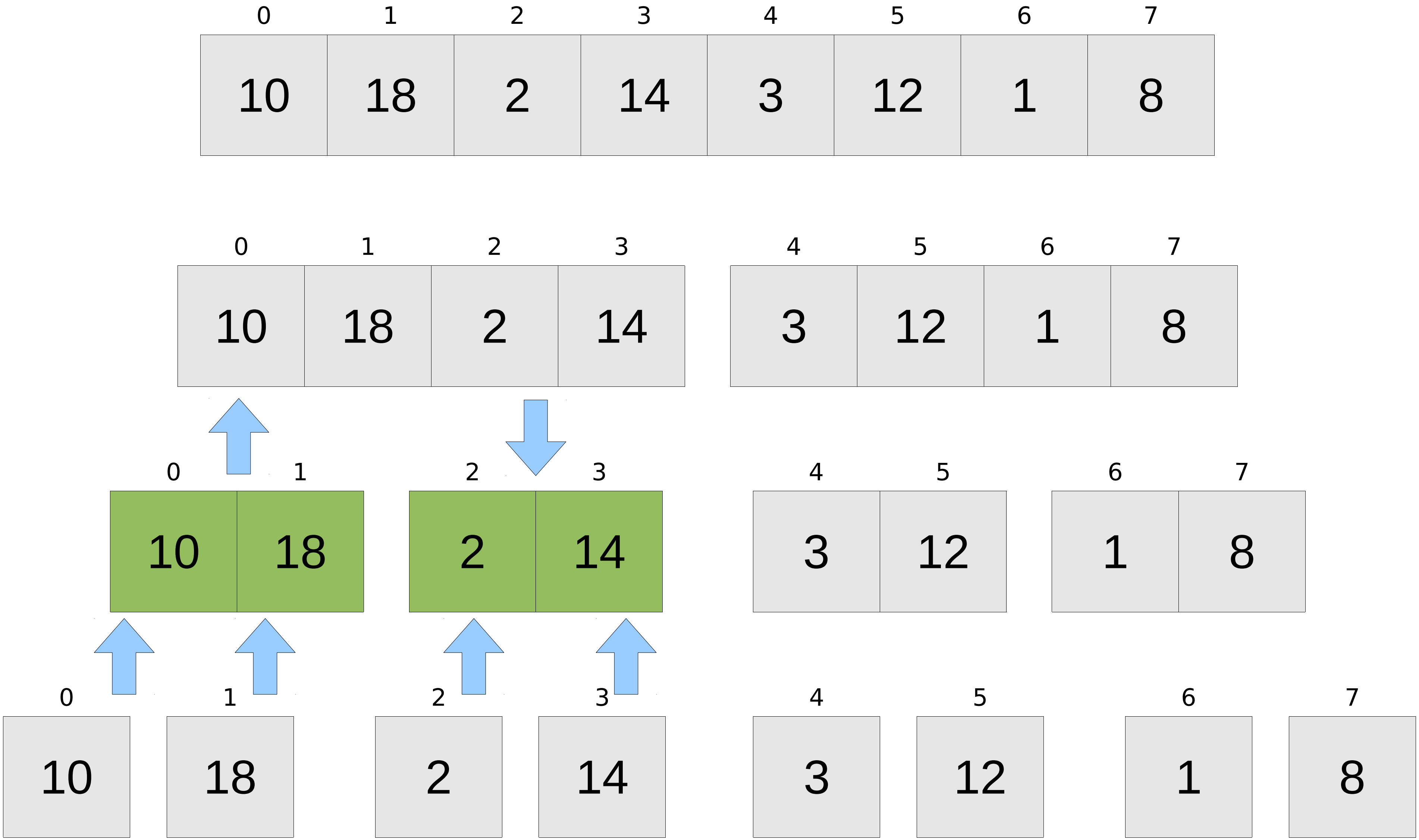
Merge Sort

(break down the array, then merge the pieces back together)



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3	12	1	8

0	1
10	18

2	3
2	14

4	5
3	12

6	7
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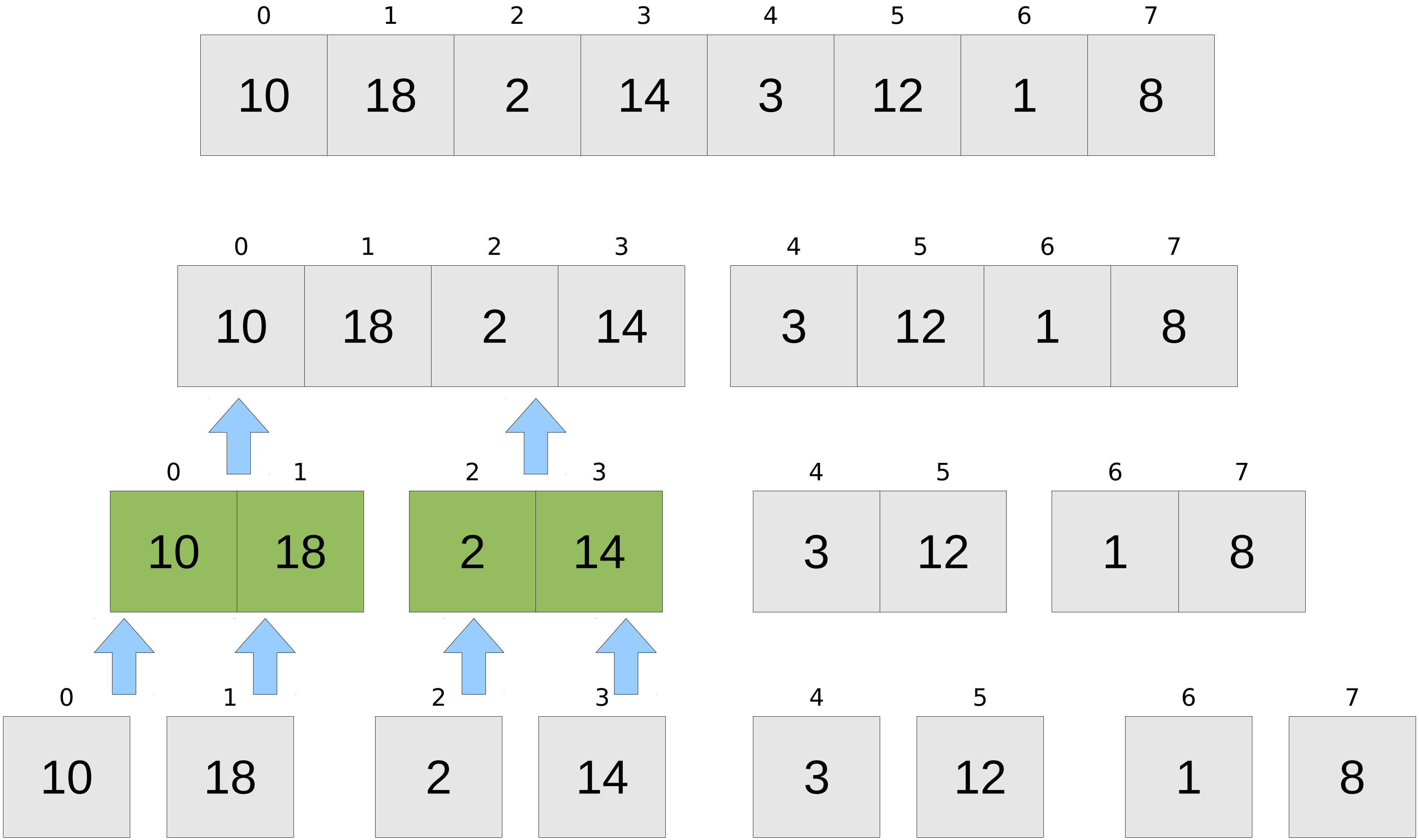

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10	18	2	14

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3	12	1	8

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10	18

2	3
2	14

4	5
3	12

6	7
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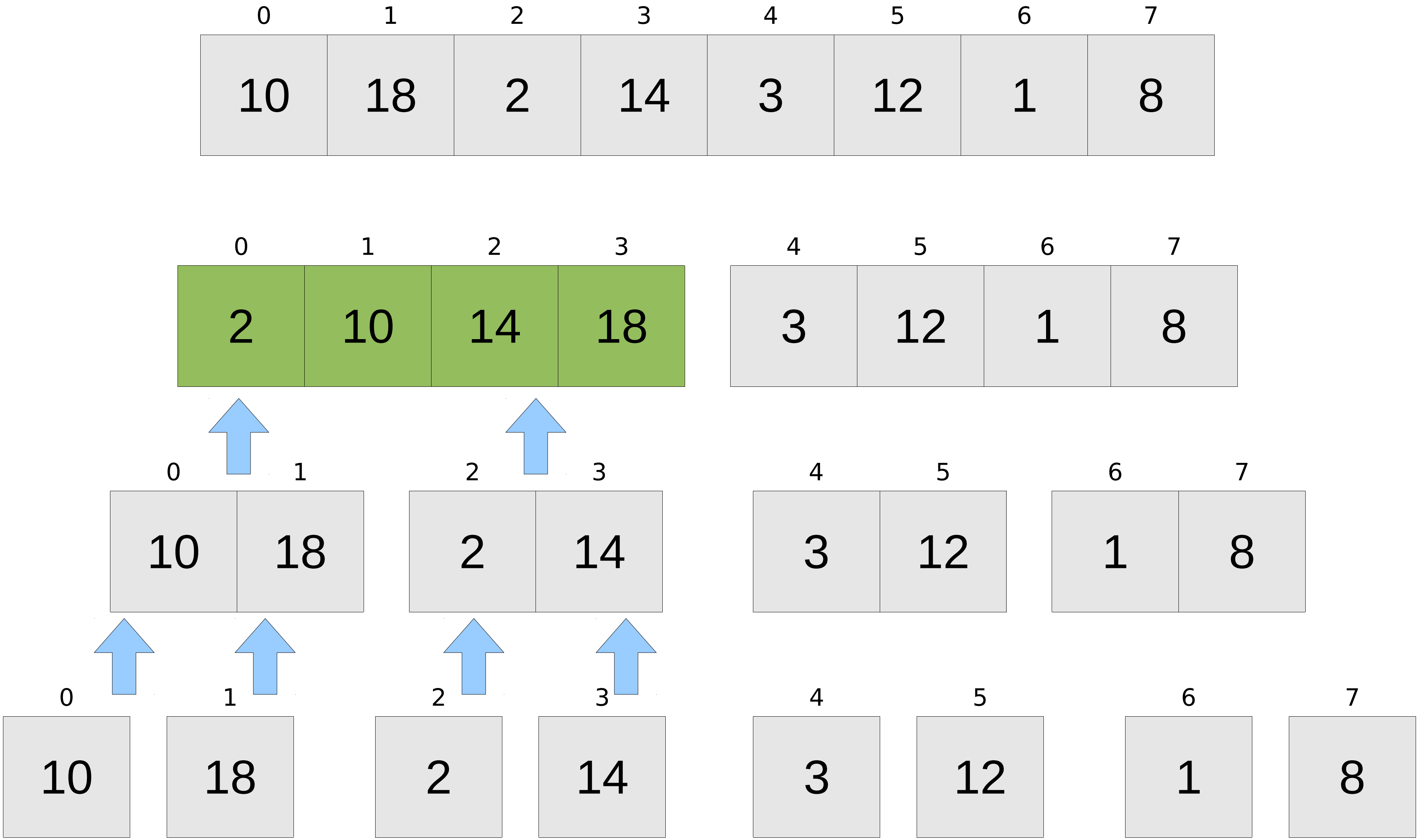

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2	10	14	18

4	5	6	7
3	12	1	8

0	1
10	18

2	3
2	14

4	5
3	12

6	7
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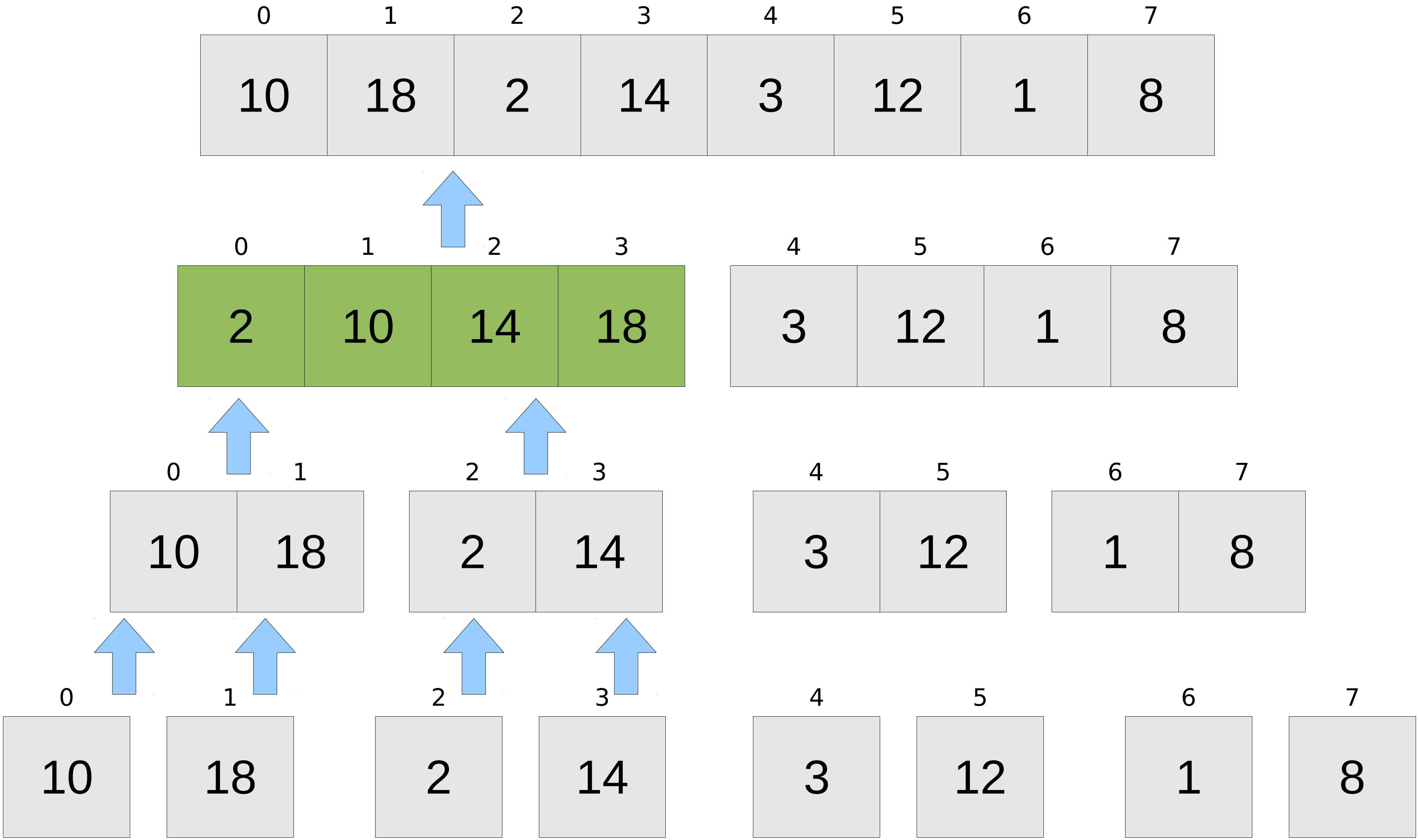

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4	5	6	7
3	12	1	8

0	1
10	18

2	3
2	14

4	5
3	12

6	7
1	8

0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

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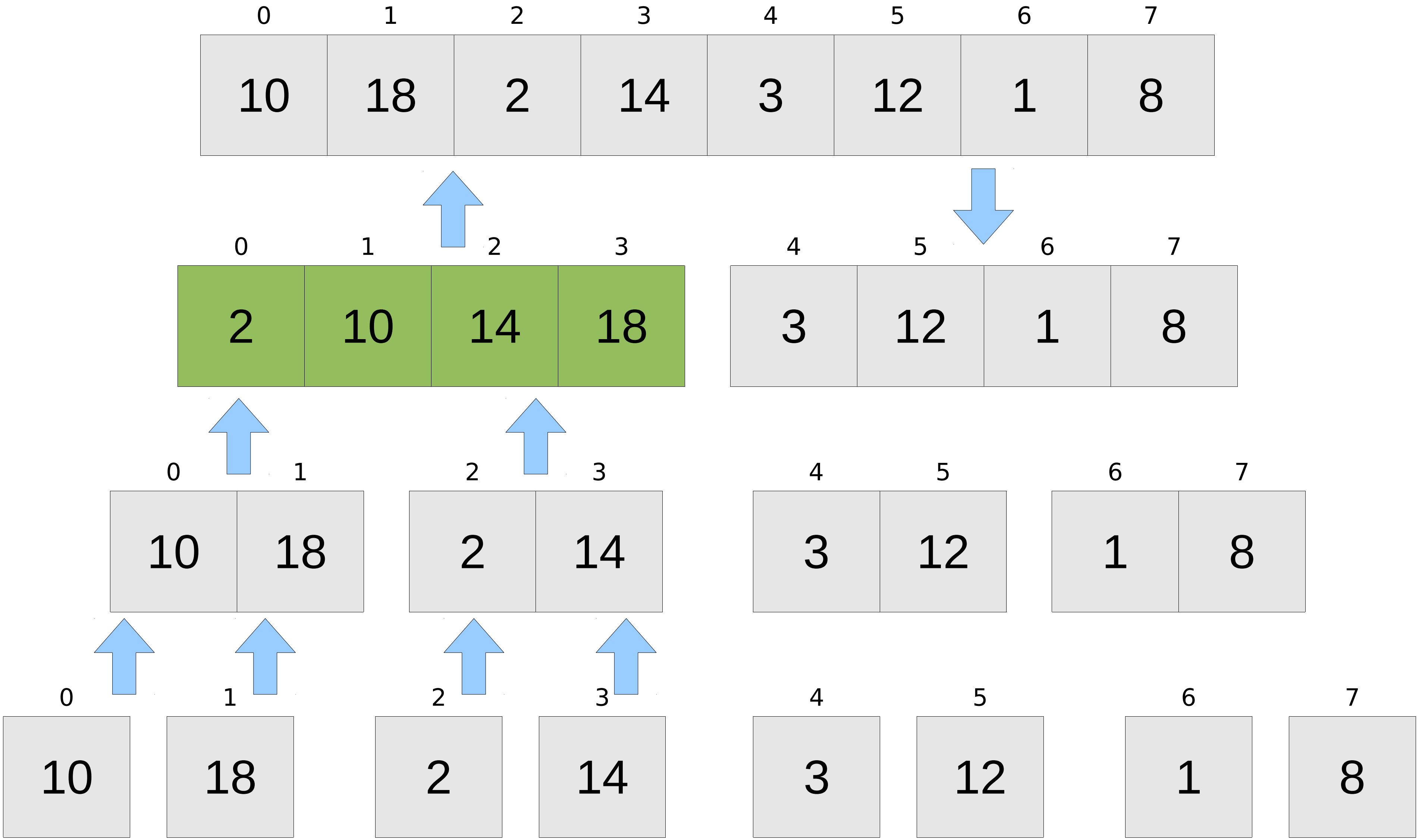

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10	18	2	14	3	12	1	8

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2	10	14	18

4	5	6	7
3	12	1	8

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4	5
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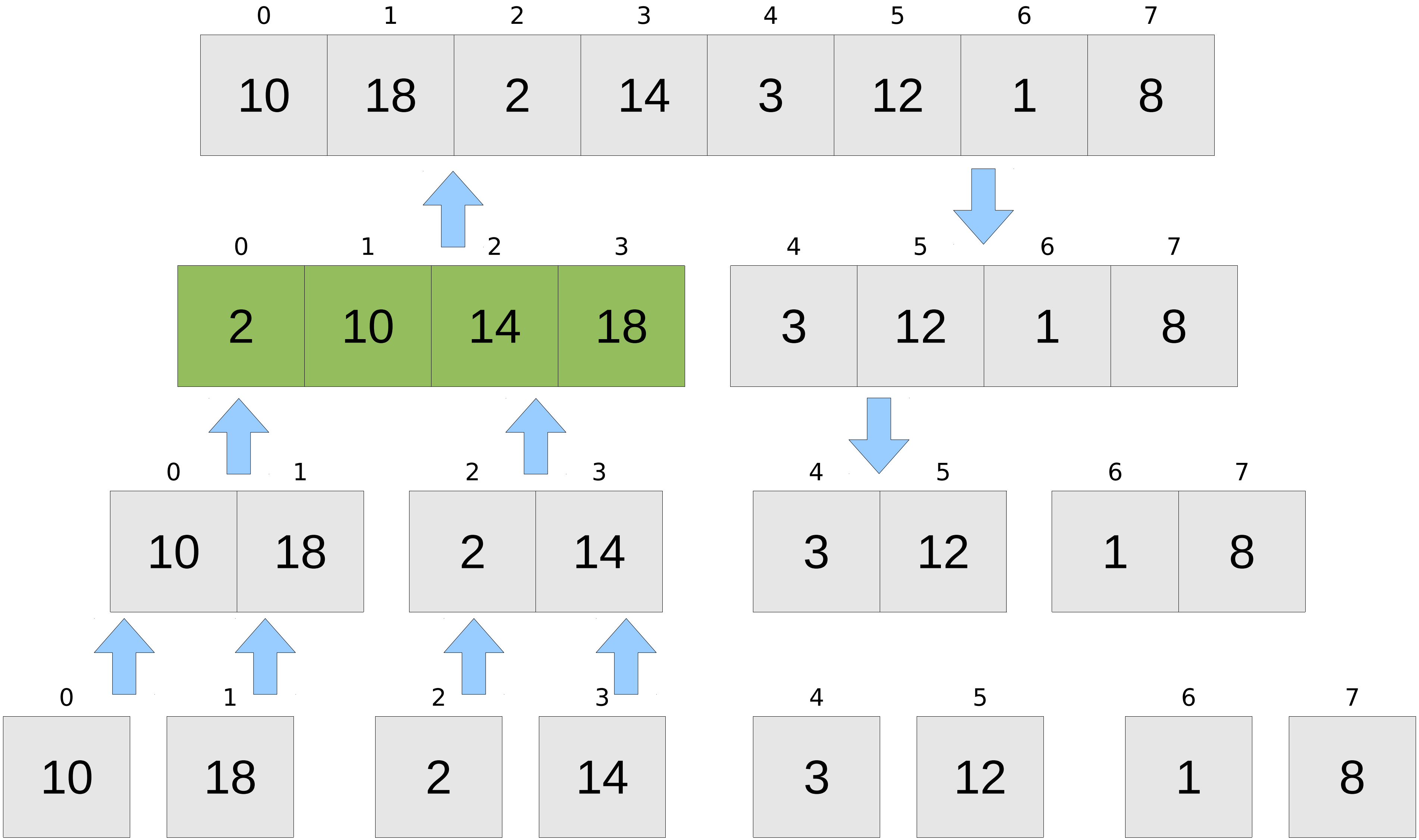

0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

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2	10	14	18

4	5	6	7
3	12	1	8

0	1
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4	5
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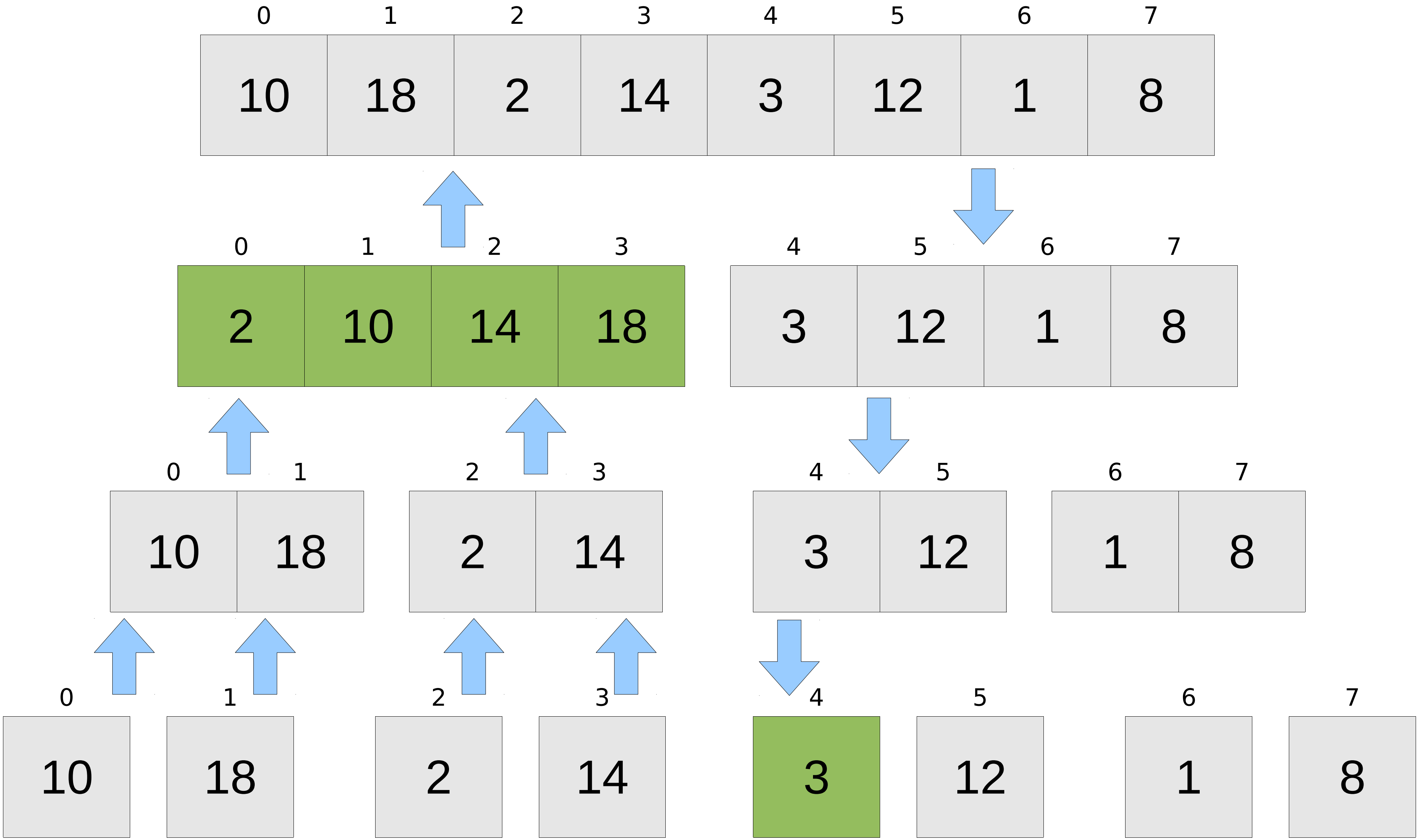

0	1	2	3	4	5	6	7
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2	10	14	18

4	5	6	7
3	12	1	8

0	1
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4	5
3	12

6	7
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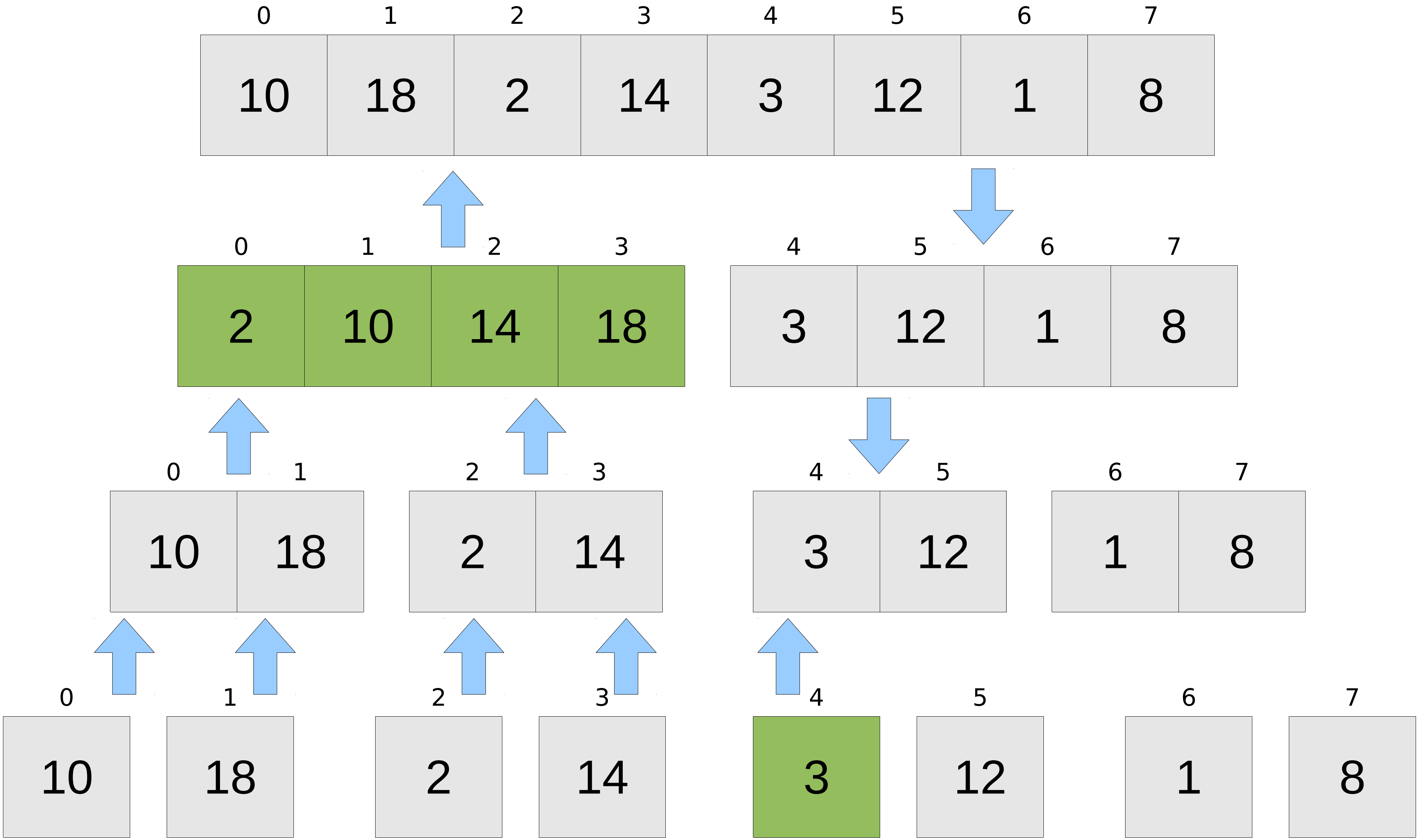

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10	18	2	14	3	12	1	8

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2	10	14	18	3	12	1	8

0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

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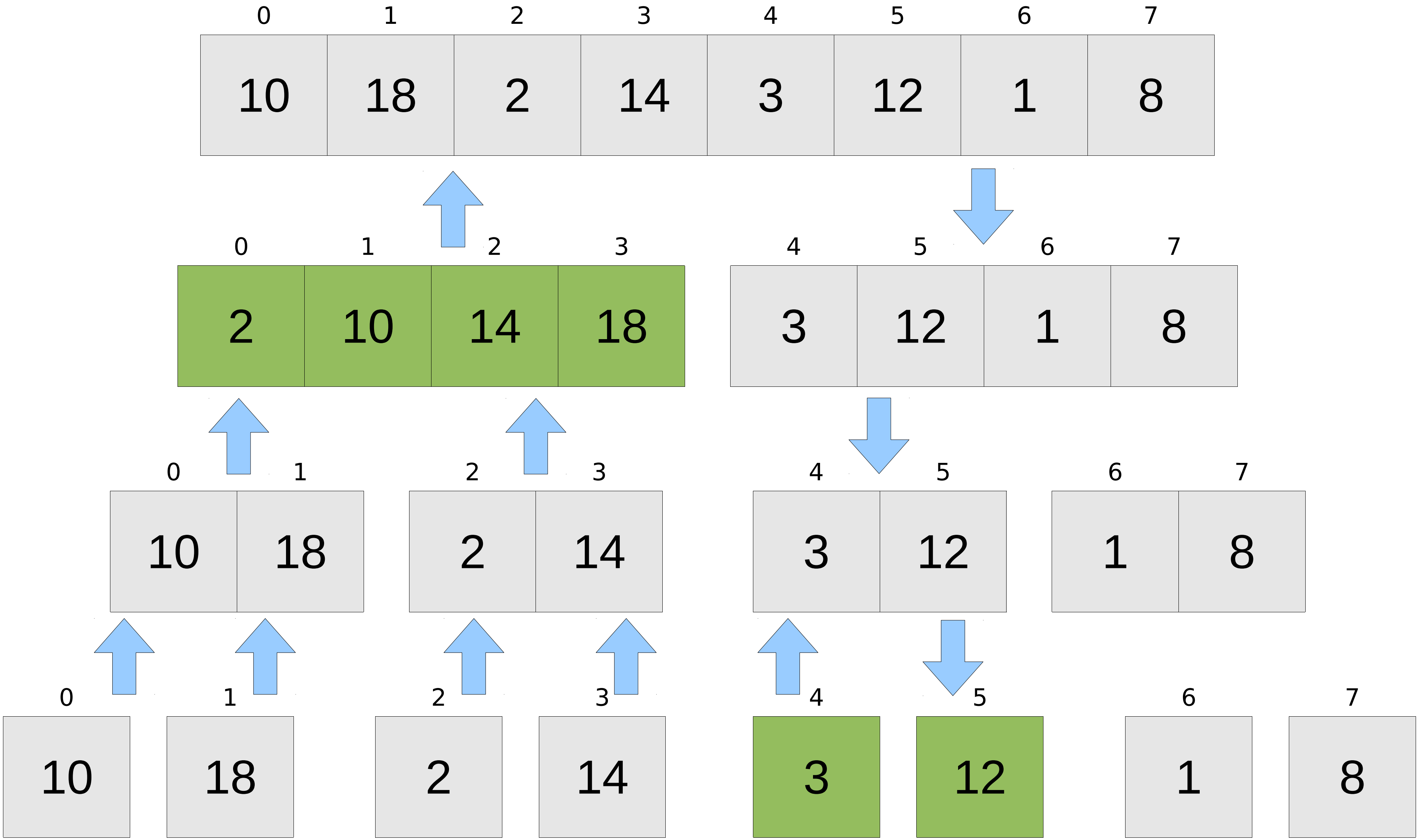

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10	18	2	14	3	12	1	8

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2	10	14	18

4	5	6	7
3	12	1	8

0	1
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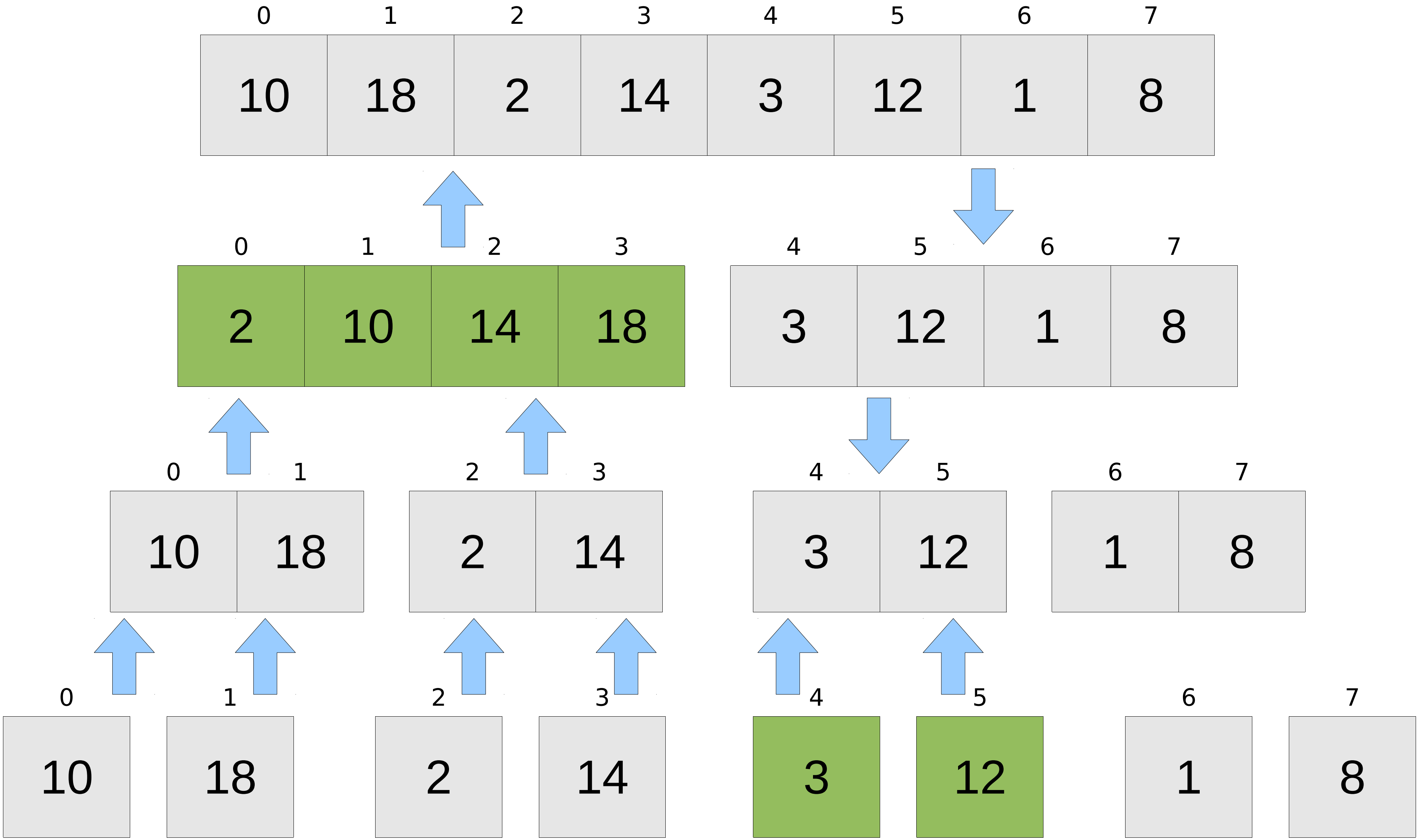

0	1	2	3	4	5	6	7
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2	10	14	18

4	5	6	7
3	12	1	8

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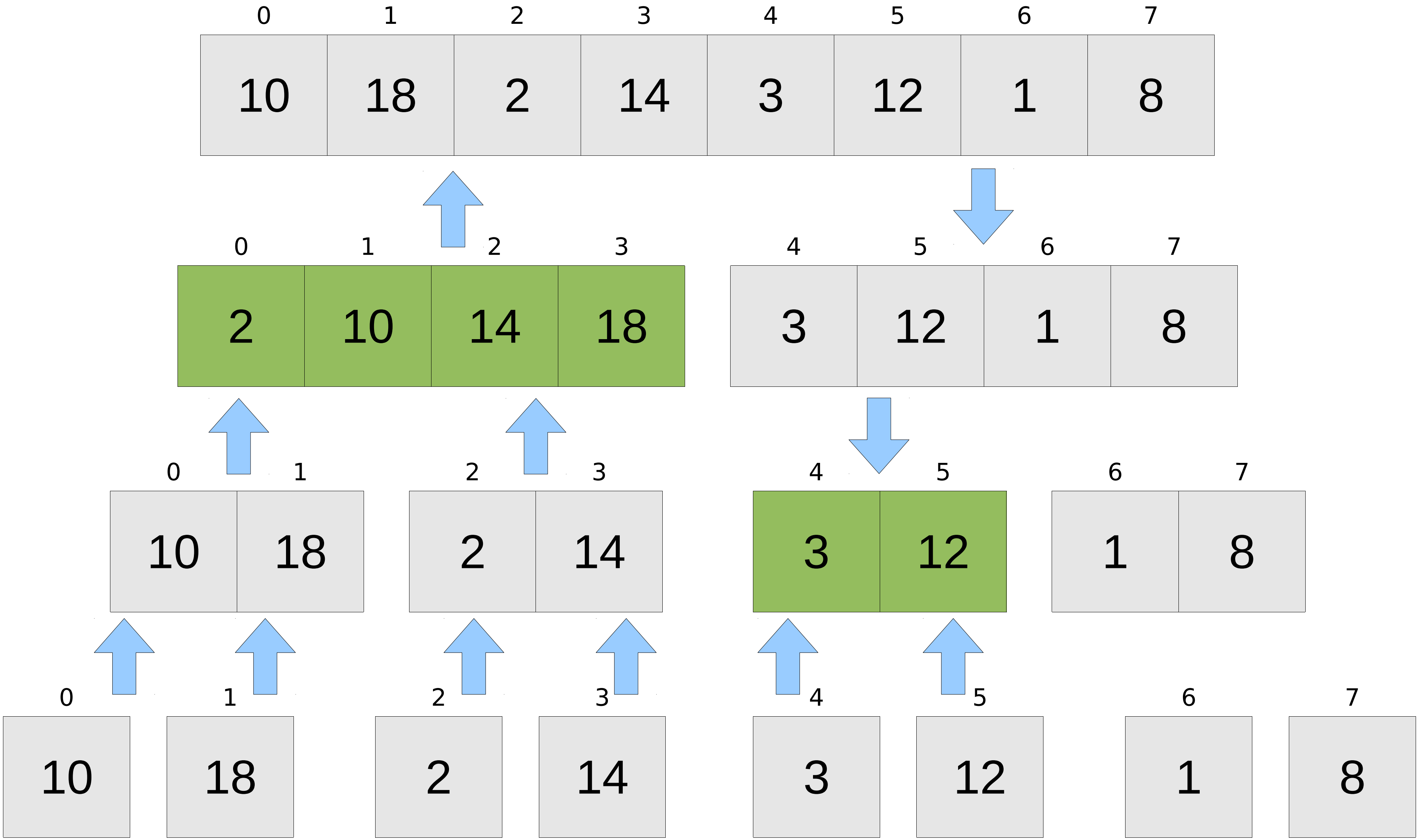

0	1	2	3	4	5	6	7
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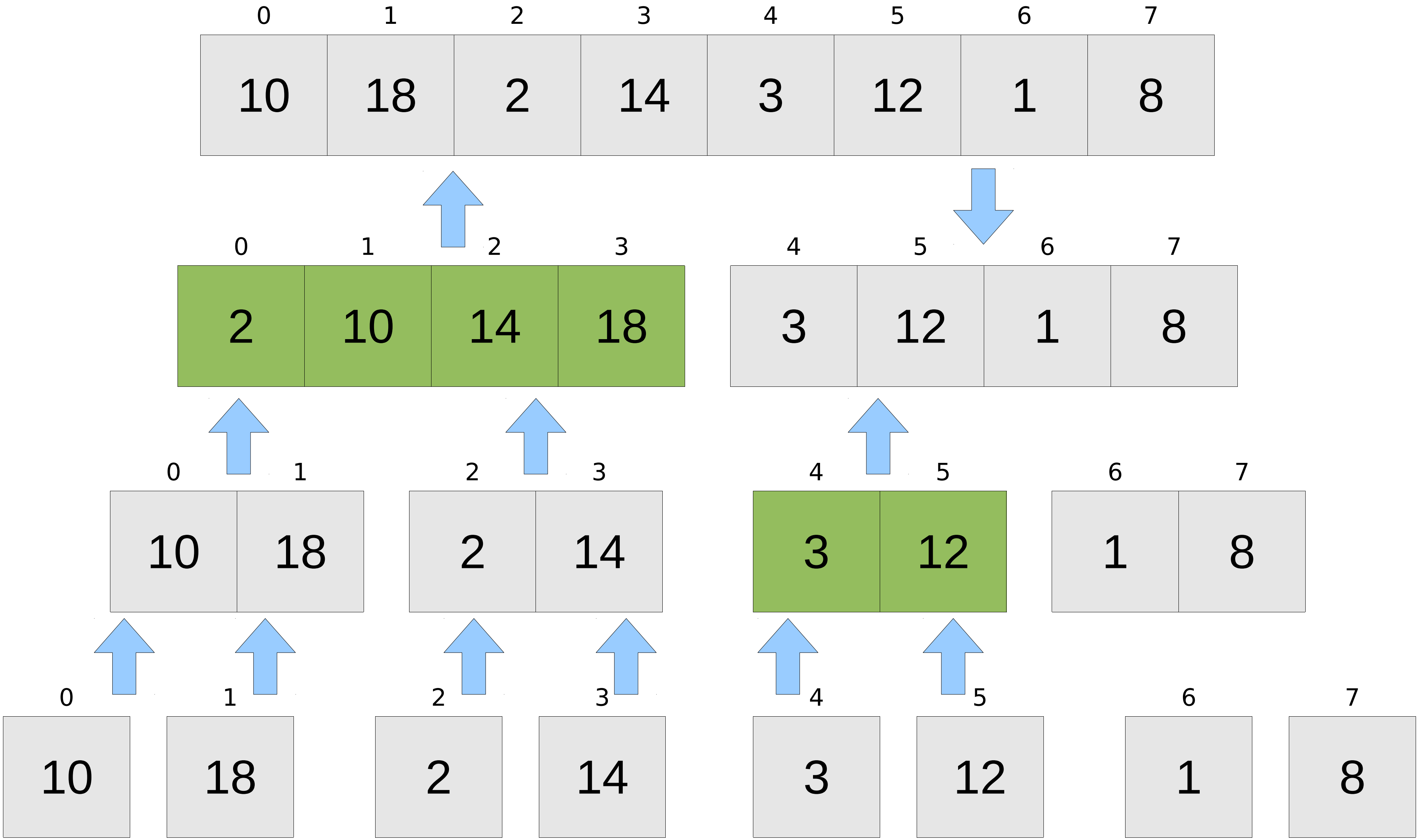

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3	12

6	7
1	8

0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

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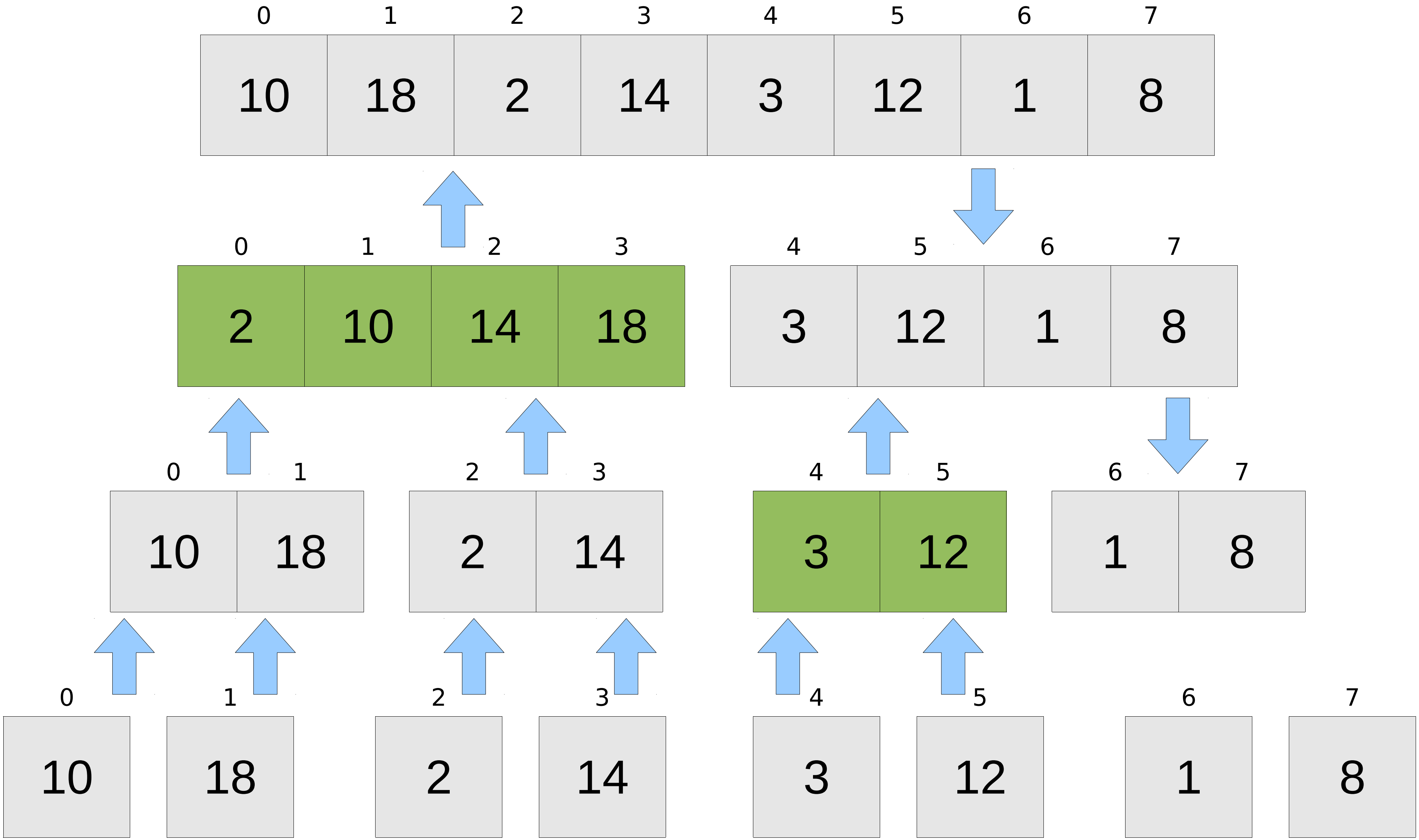

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1	8

0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

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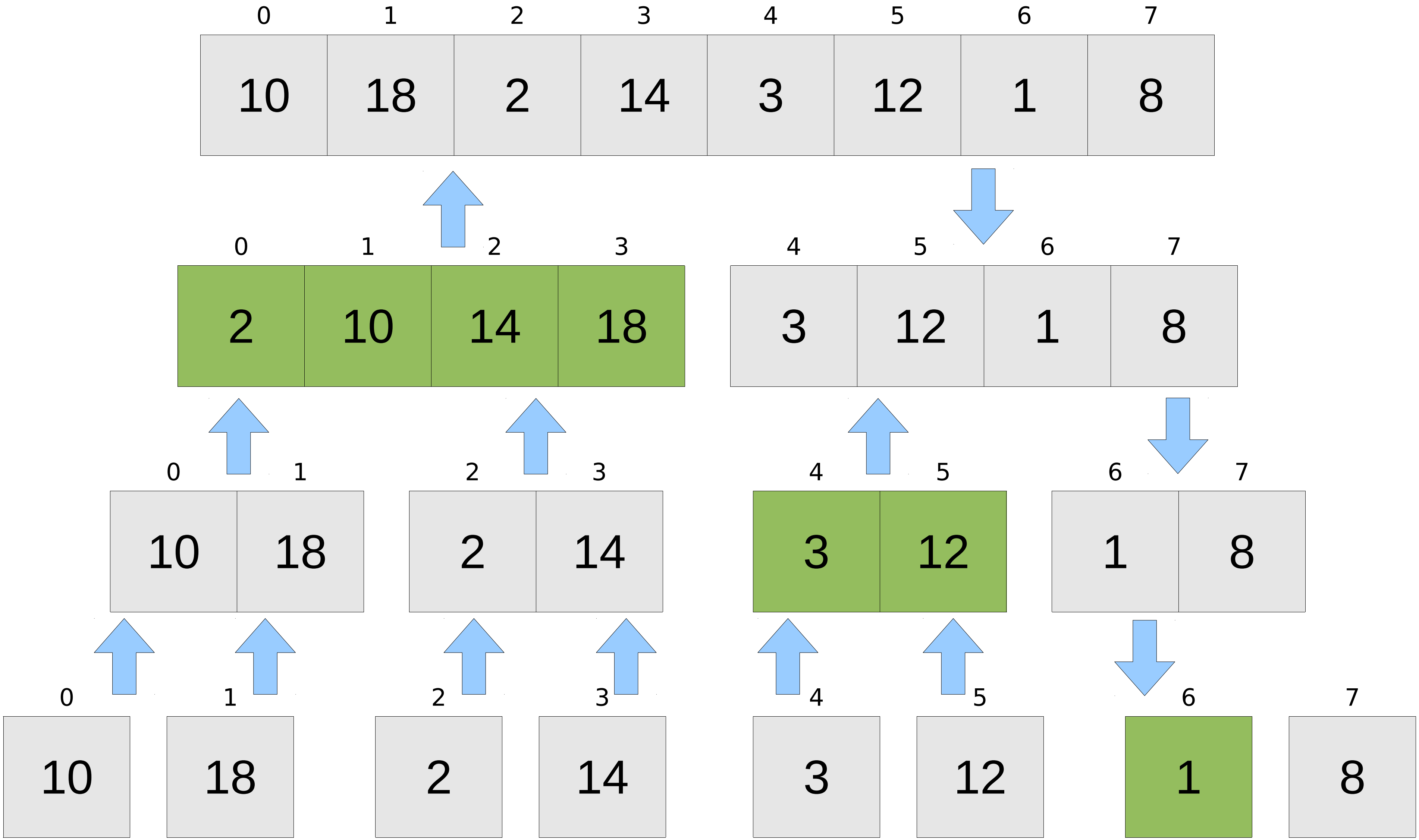

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3	12	1	8

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0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

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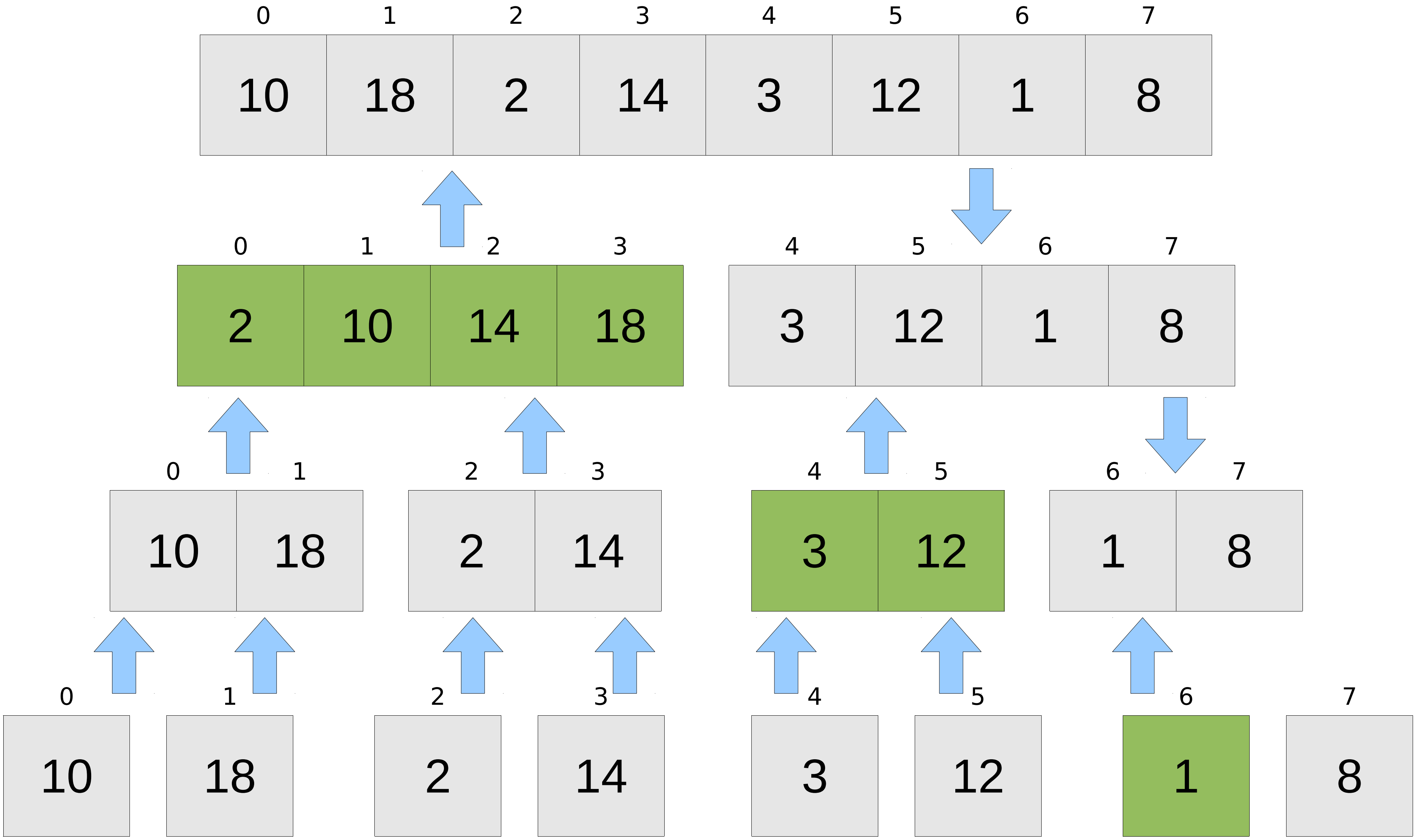

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2	10	14	18

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3	12	1	8

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0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

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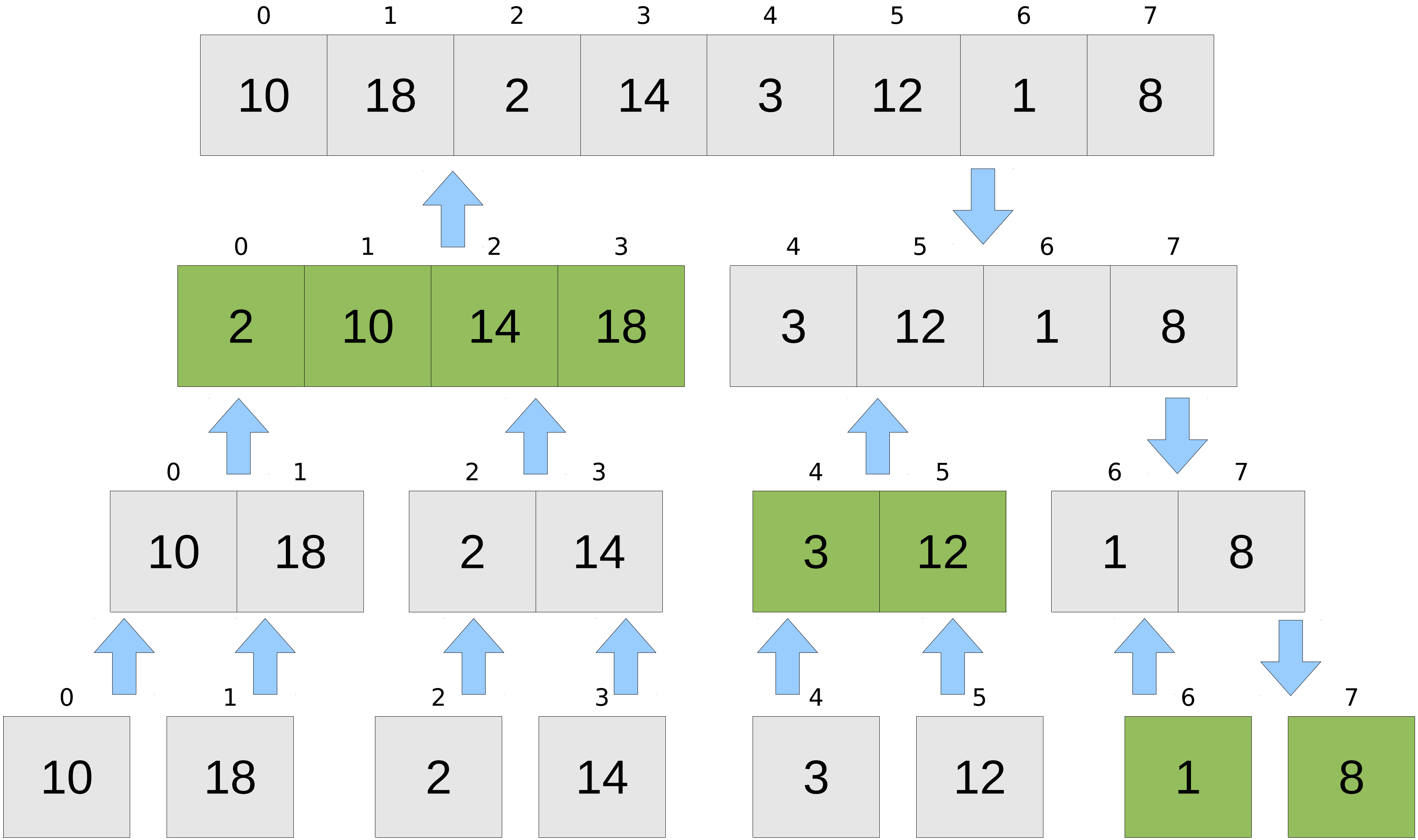

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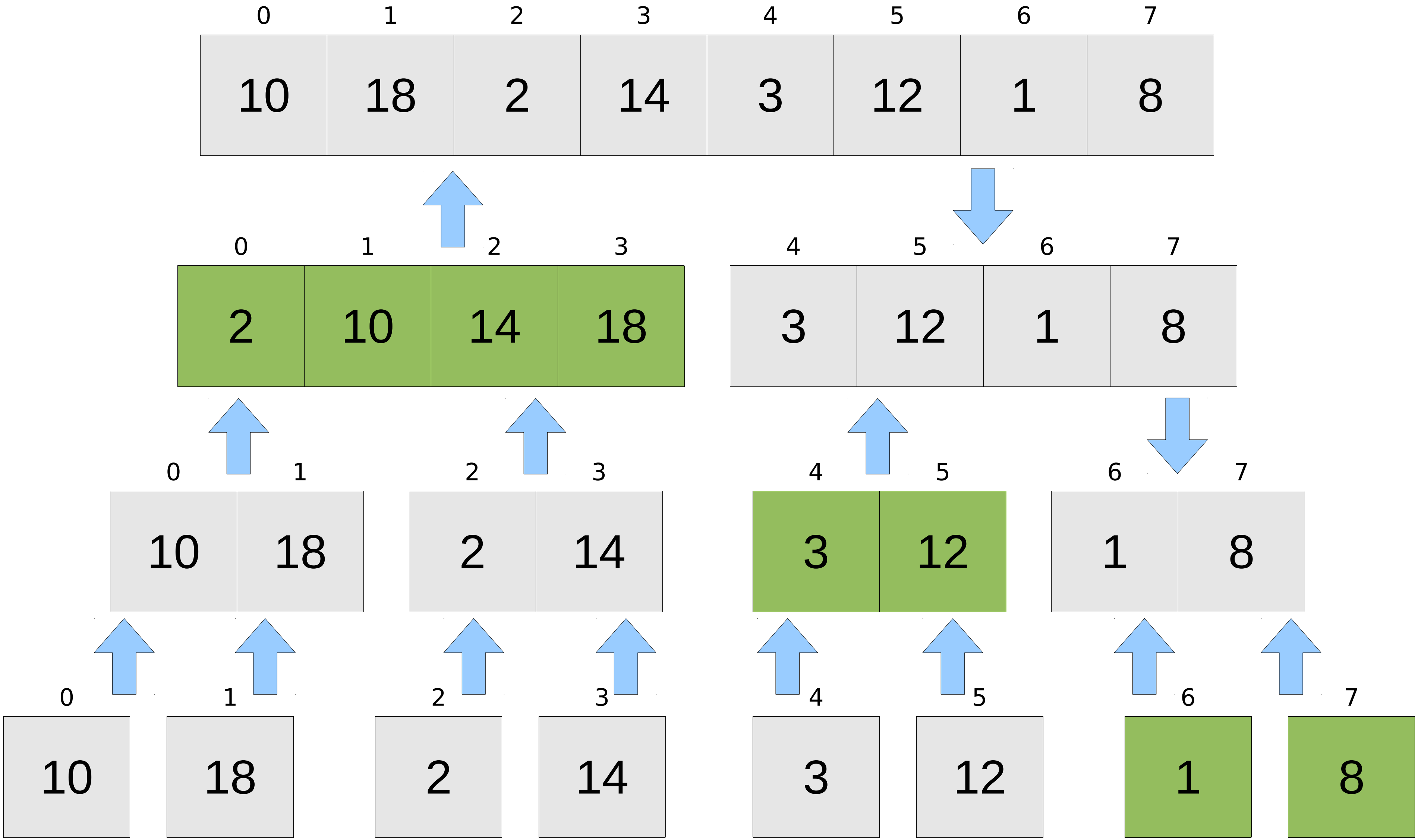


0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

0	1	2	3
2	10	14	18

4	5	6	7
3	12	1	8

0	1
10	18

2	3
2	14

4	5
3	12

6	7
1	8

0
10

1
18

2
2

3
14

4
3

5
12

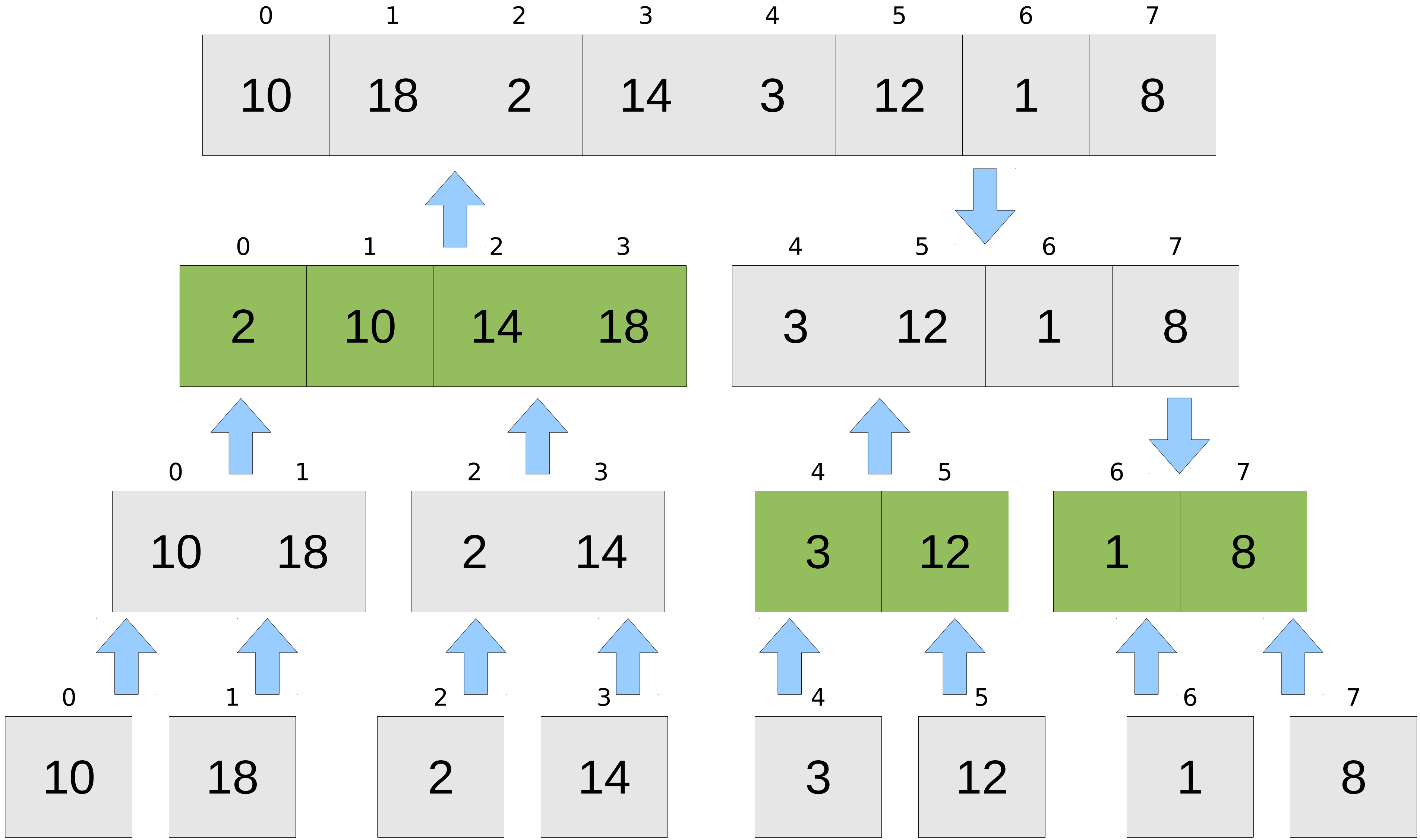
6
1

7
8

We’ve reached our **base cases**. An array with one element is **sorted**.

Merge Sort

(break down the array, then merge the pieces back together)



0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

0	1	2	3
2	10	14	18

4	5	6	7
3	12	1	8

0	1
10	18

2	3
2	14

4	5
3	12

6	7
1	8

0
10

1
18

2
2

3
14

4
3

5
12

6
1

7
8

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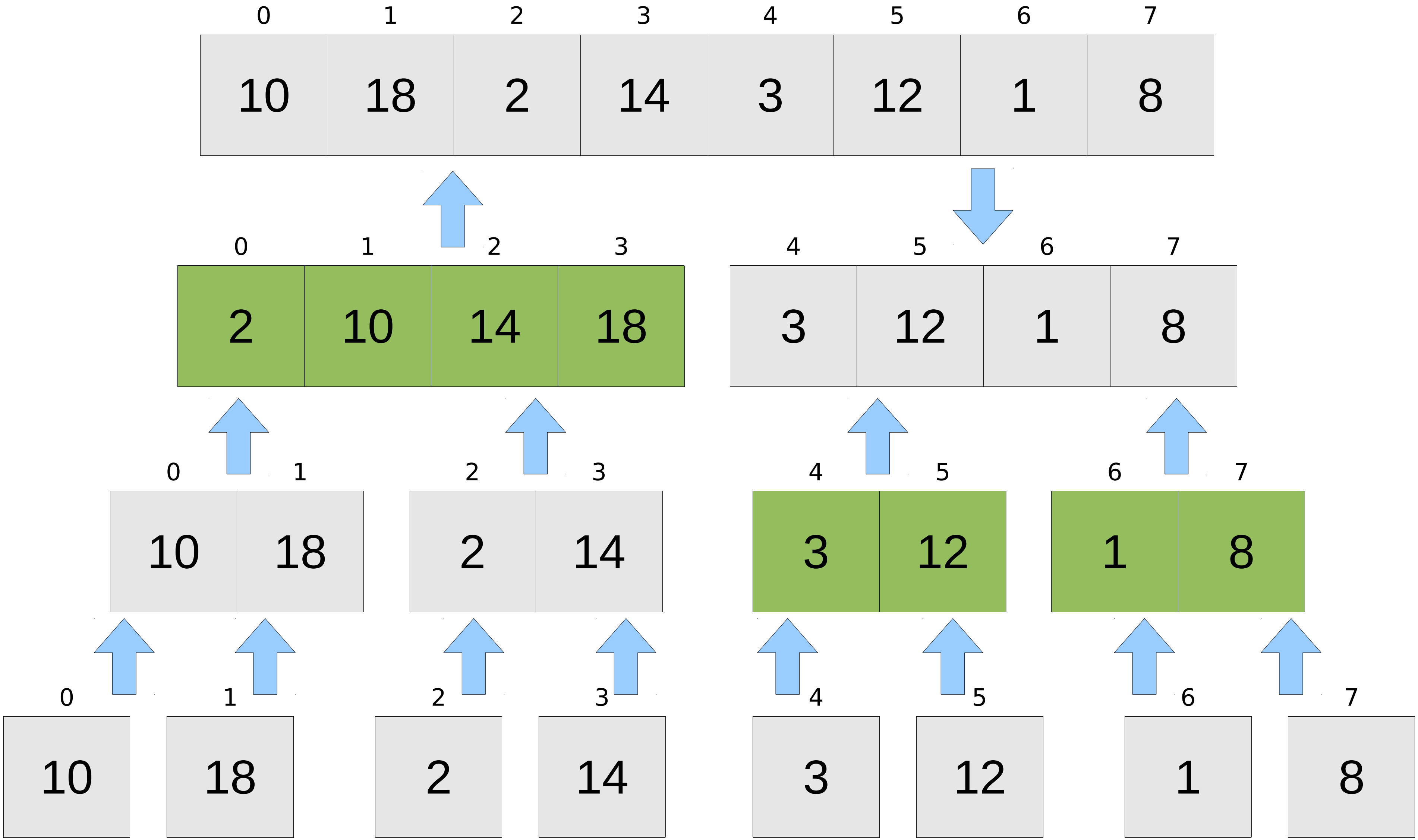
Merge Sort

(break down the array, then merge the pieces back together)



0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

0	1	2	3
2	10	14	18

4	5	6	7
3	12	1	8

0	1
10	18

2	3
2	14

4	5
3	12

6	7
1	8

0
10

1
18

2
2

3
14

4
3

5
12

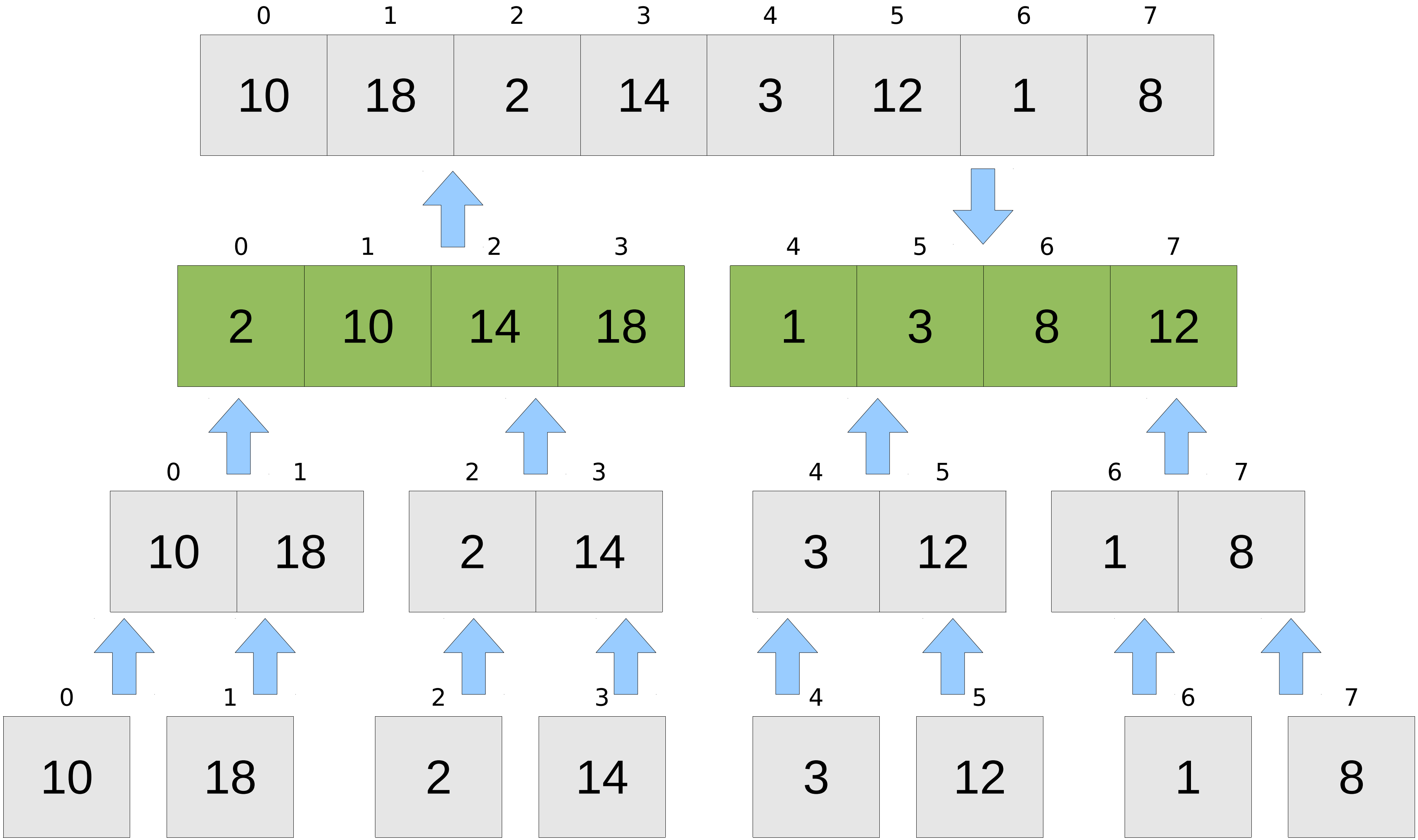
6
1

7
8

We’ve reached our **base cases**. An array with one element is **sorted**.

Merge Sort

(break down the array, then merge the pieces back together)



0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

0	1	2	3
2	10	14	18

4	5	6	7
1	3	8	12

0	1
10	18

2	3
2	14

4	5
3	12

6	7
1	8

0
10

1
18

2
2

3
14

4
3

5
12

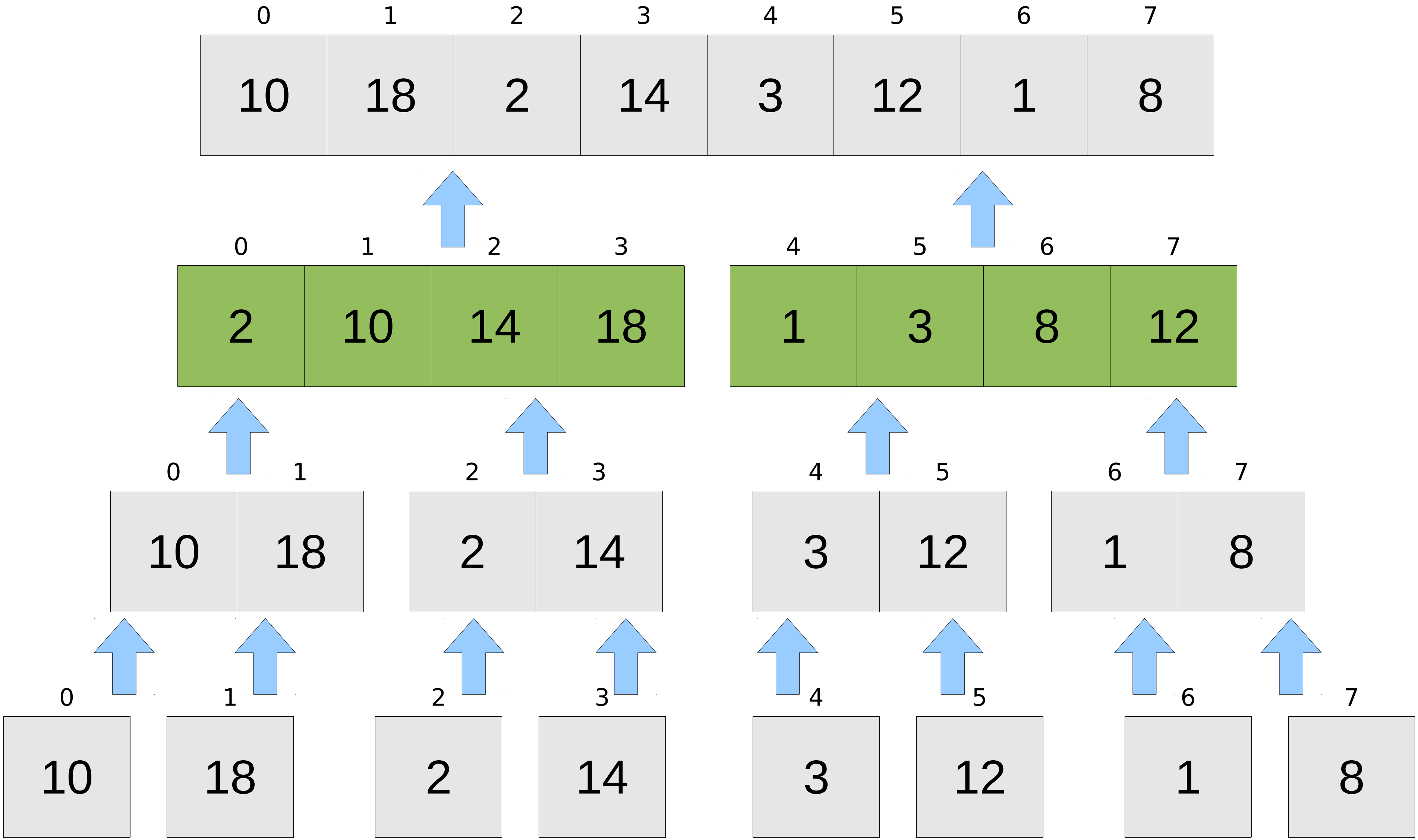
6
1

7
8

We’ve reached our **base cases**. An array with one element is **sorted**.

Merge Sort

(break down the array, then merge the pieces back together)



0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

0	1	2	3
2	10	14	18

4	5	6	7
1	3	8	12

0	1
10	18

2	3
2	14

4	5
3	12

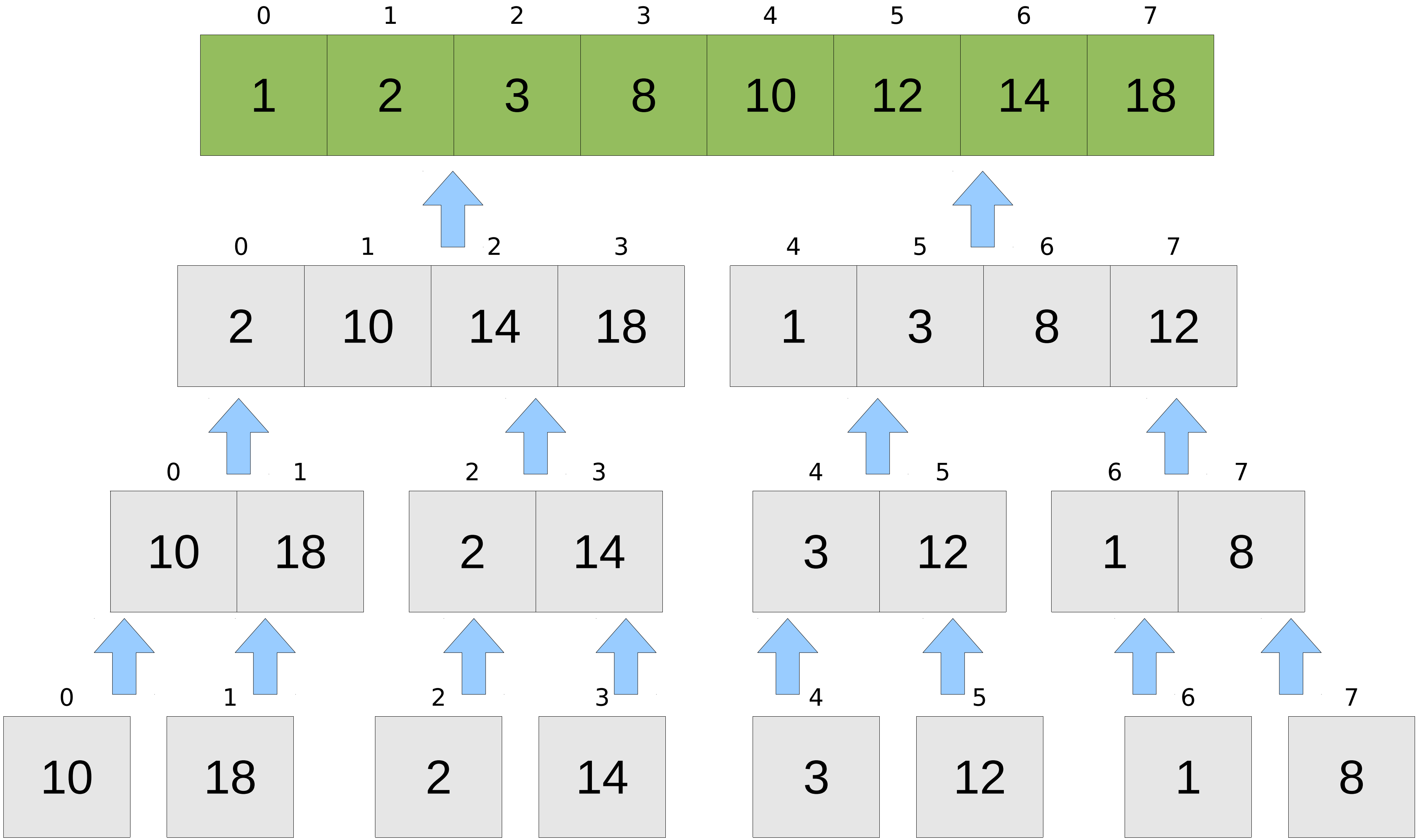
6	7
1	8

0	1	2	3	4	5	6	7
10	18	2	14	3	12	1	8

We’ve reached our **base cases**. An array with one element is **sorted**.

Merge Sort

(break down the array, then merge the pieces back together)



0	1	2	3	4	5	6	7
1	2	3	8	10	12	14	18

0	1	2	3
2	10	14	18

4	5	6	7
1	3	8	12

0	1
10	18

2	3
2	14

4	5
3	12

6	7
1	8

0
10

1
18

2
2

3
14

4
3

5
12

6
1

7
8

We’ve reached our **base cases**. An array with one element is **sorted**.

Merge Sort

(break down the array, then merge the pieces back together)

0	1	2	3	4	5	6	7
1	2	3	8	10	12	14	18

*** TADA! ***

Merge Sort

(break down the array, then merge the pieces back together)

0	1	2	3	4	5	6	7
1	2	3	8	10	12	14	18

1. What’s the **worst-case** Big-Oh runtime?

2. What’s the **best-case** Big-Oh runtime?

3. On an exam: trace the results of **each recursive sub-call** to Merge Sort.

Merge Sort

(break down the array, then merge the pieces back together)

0	1	2	3	4	5	6	7
1	2	3	8	10	12	14	18

Let’s code it up!