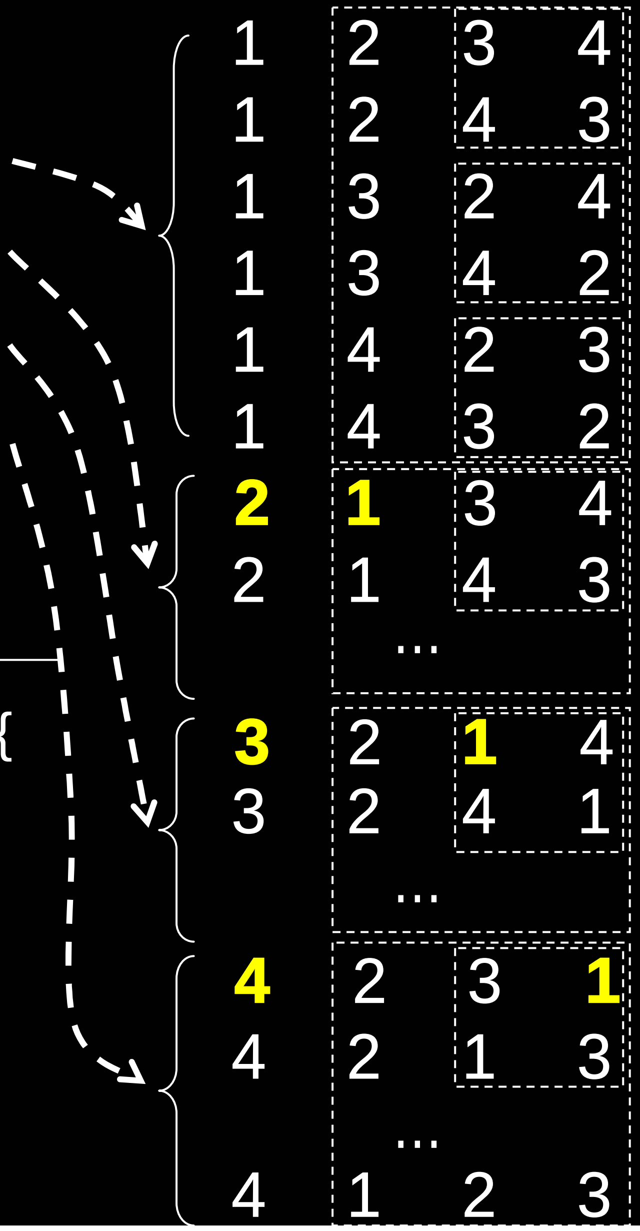
Permutation from Swapping (1/4)

- **Recursive**
  - 1 + permutations of {2, 3, 4}
  - 2 + permutations of {1, 3, 4}
  - 3 + permutations of {2, 1, 4}
  - 4 + permutations of {2, 3, 1}

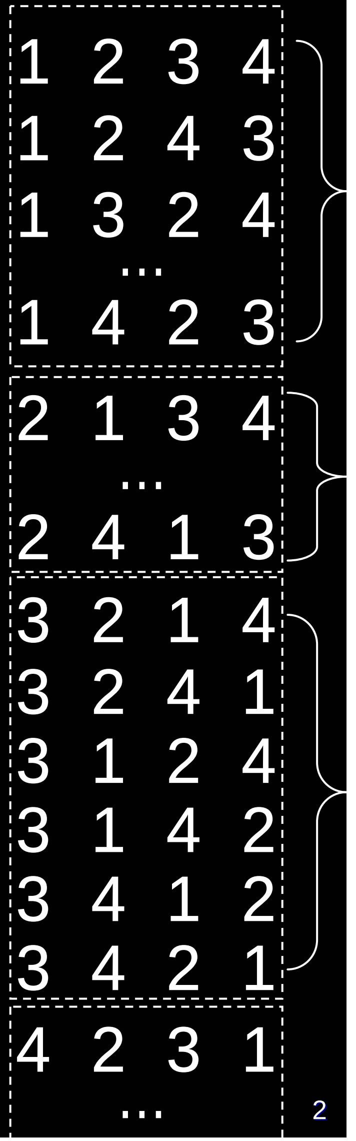
```
for (i=0; i<n; i++) a[i] = i+1;
permutation(a, 0, n-1);
```

```
void permutation(int perm[], int start, int end) {
    if (start == end) printPerm(perm, end+1);
    for (int i=start; i<=end; i++) {
        swap(&perm[start], &perm[i]);
        permutation(perm, start+1, end);
        swap(&perm[start], &perm[i]);
    }
}
```



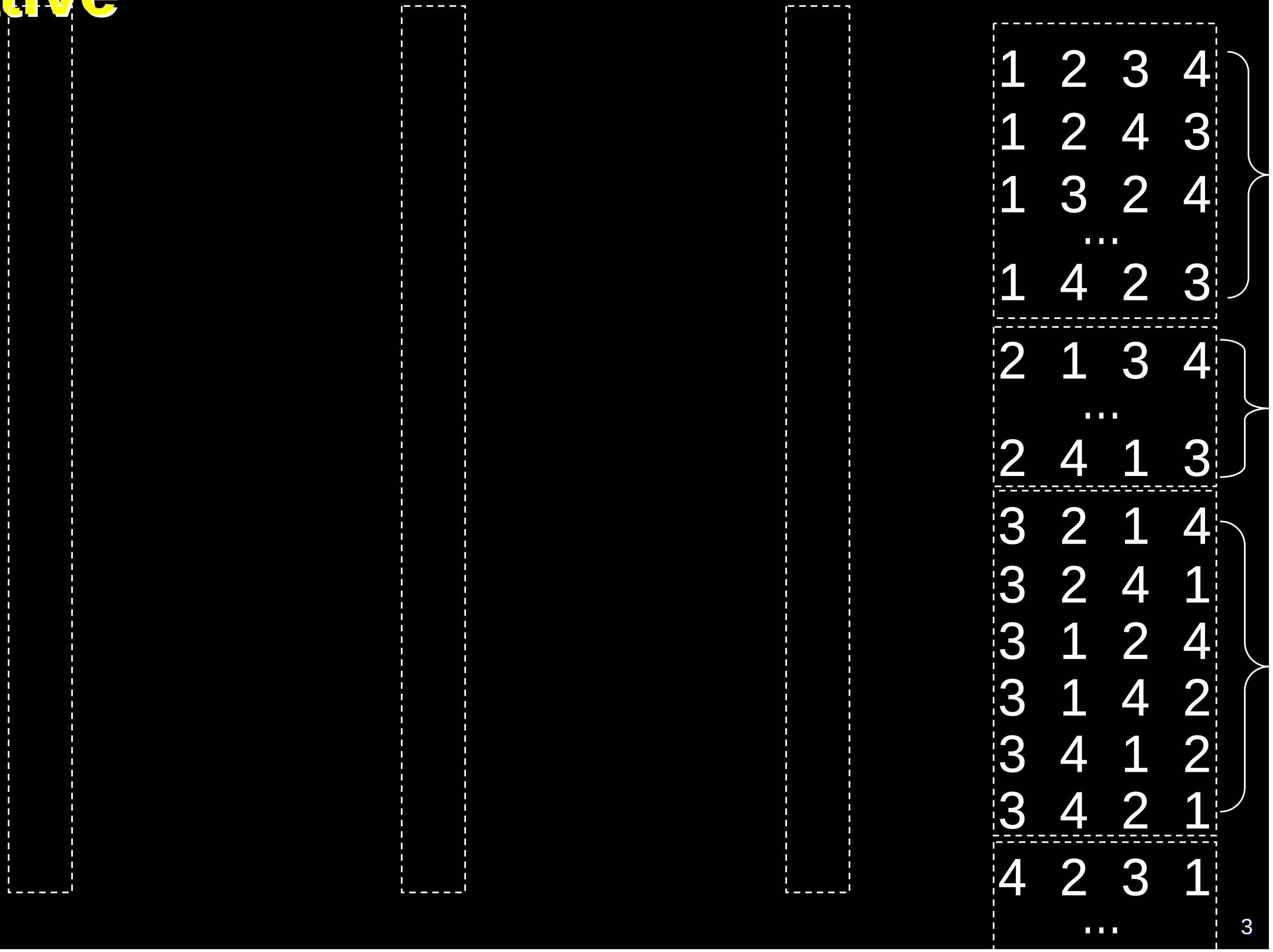
Permutation from Swapping (2/4)

- **Iterative**



Permutation from Swapping (2/4)

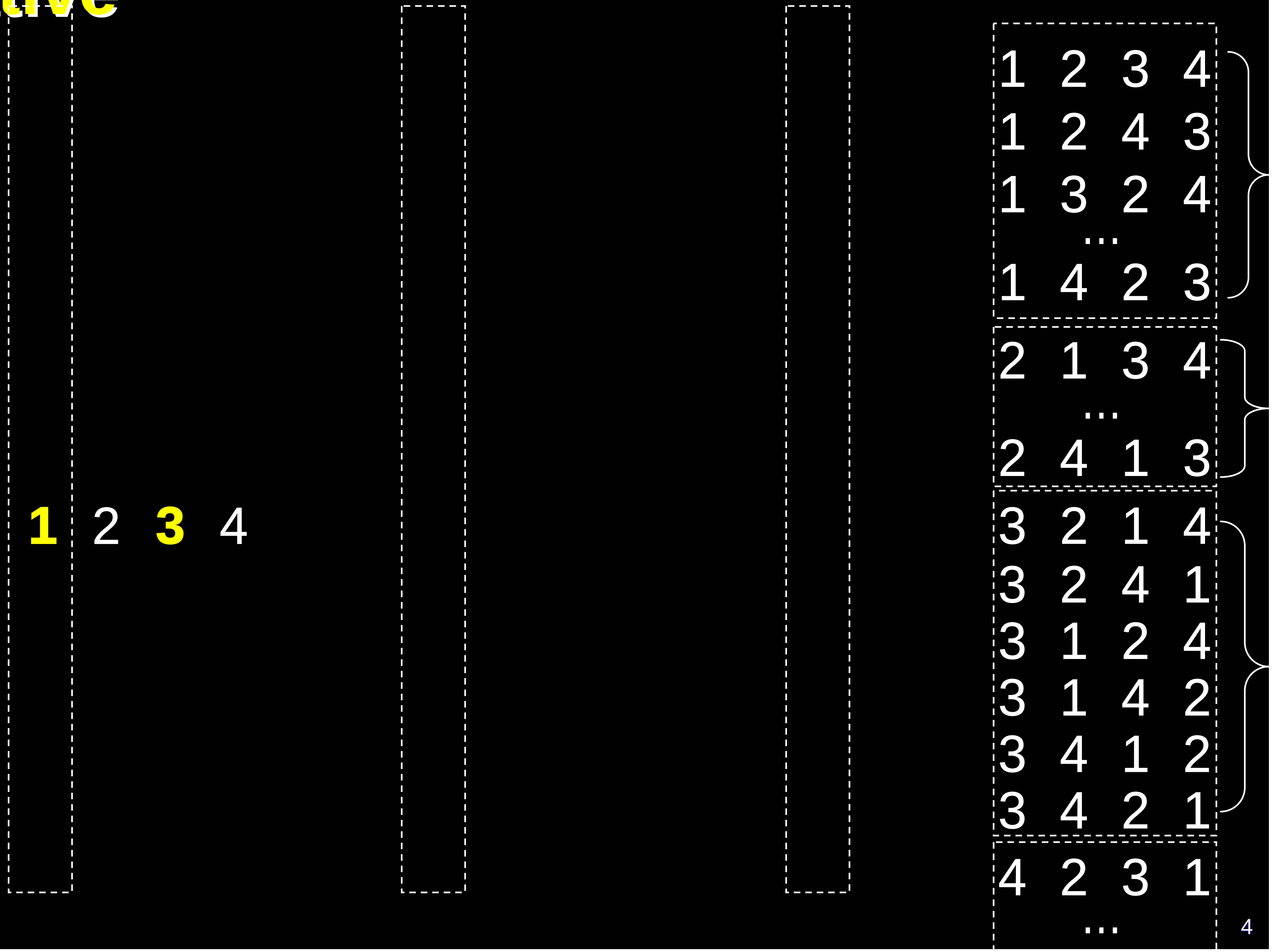
- **Iterative**



```
1 2 3 4
1 2 4 3
1 3 2 4
  ...
1 4 2 3

2 1 3 4
  ...
2 4 1 3

3 2 1 4
3 2 4 1
3 1 2 4
3 1 4 2
3 4 1 2
3 4 2 1

4 2 3 1
  ...
```

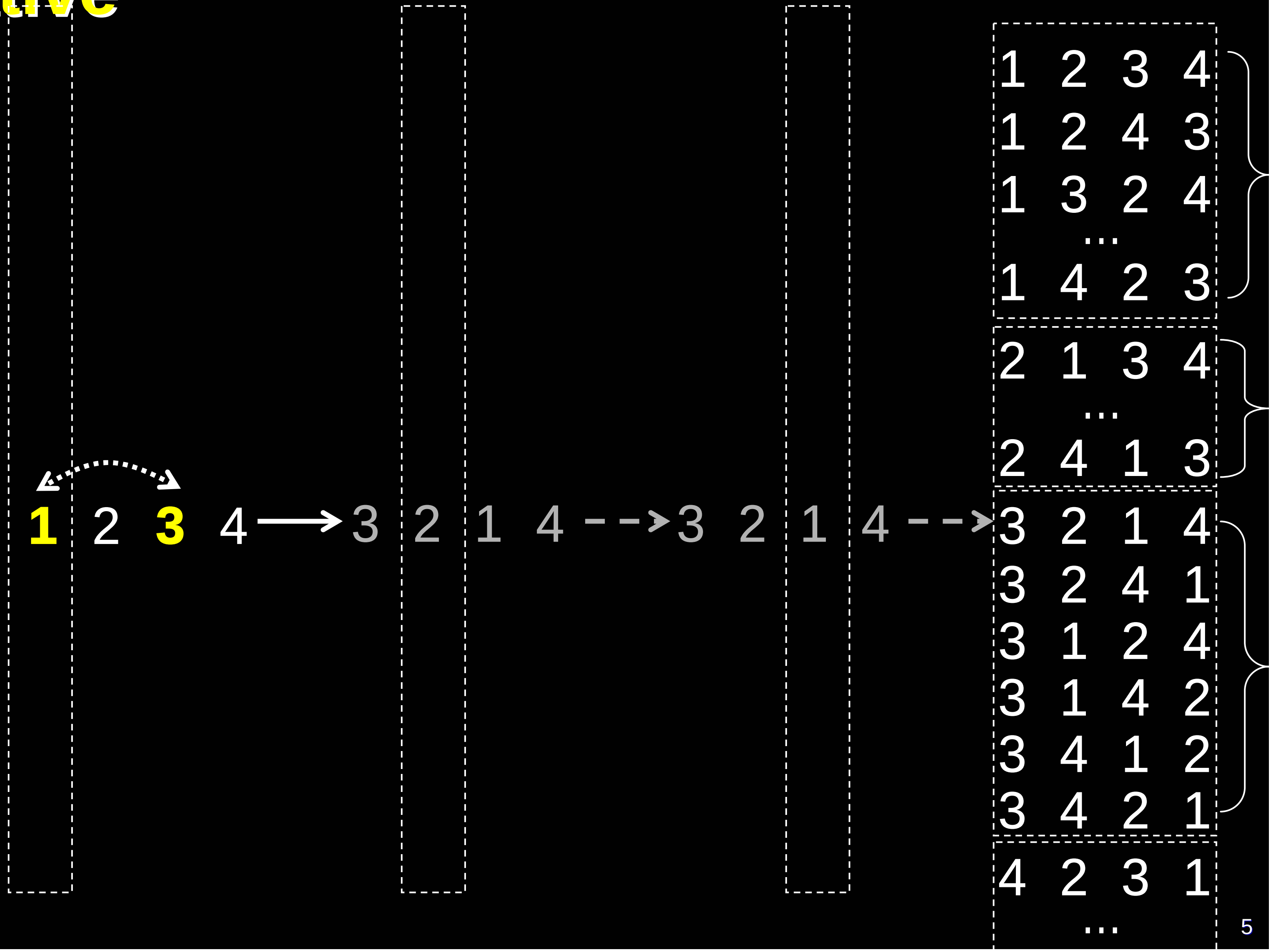
Permutation from Swapping (2/4)

- **Iterative**



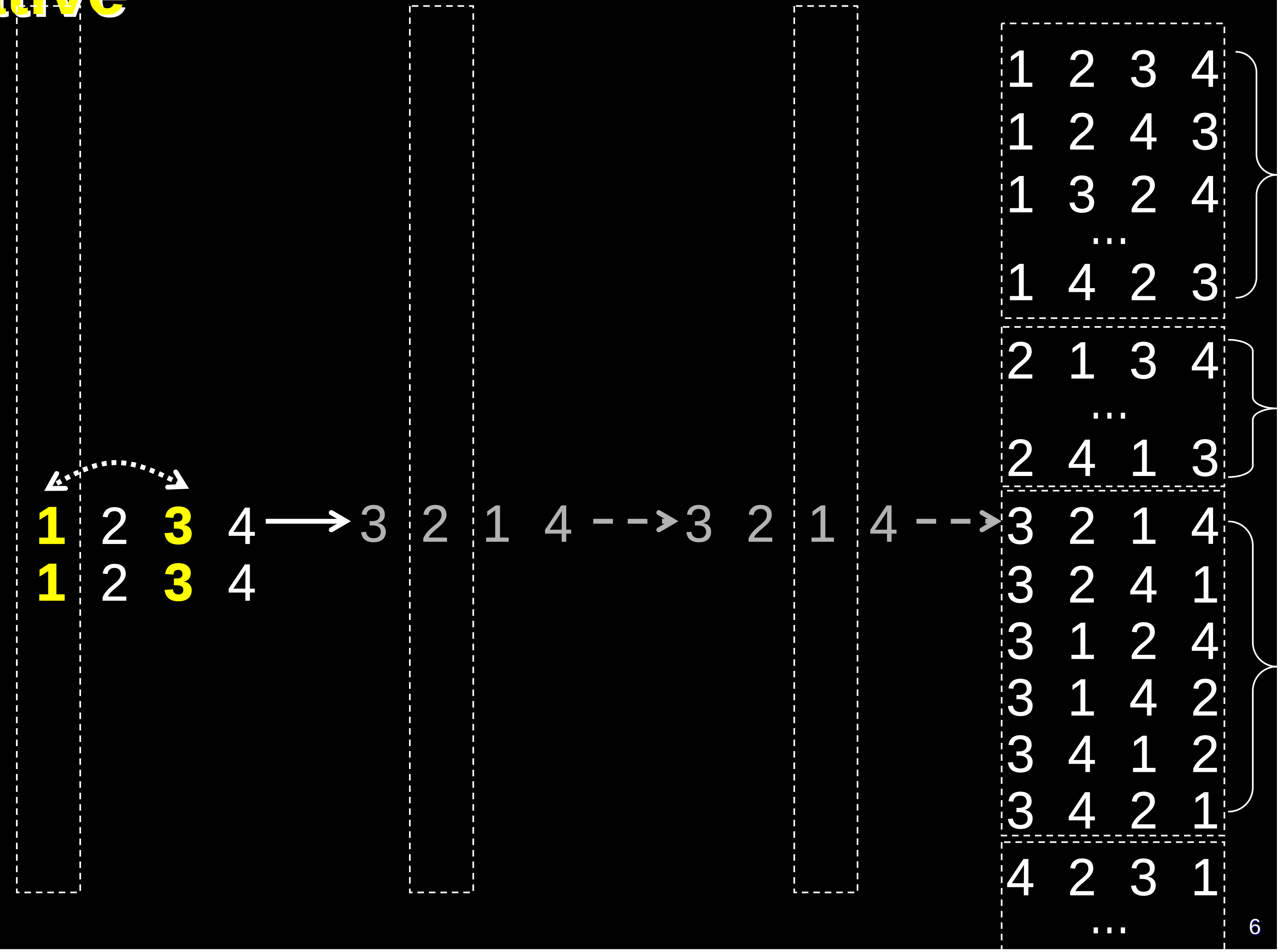
Permutation from Swapping (2/4)

- **Iterative**



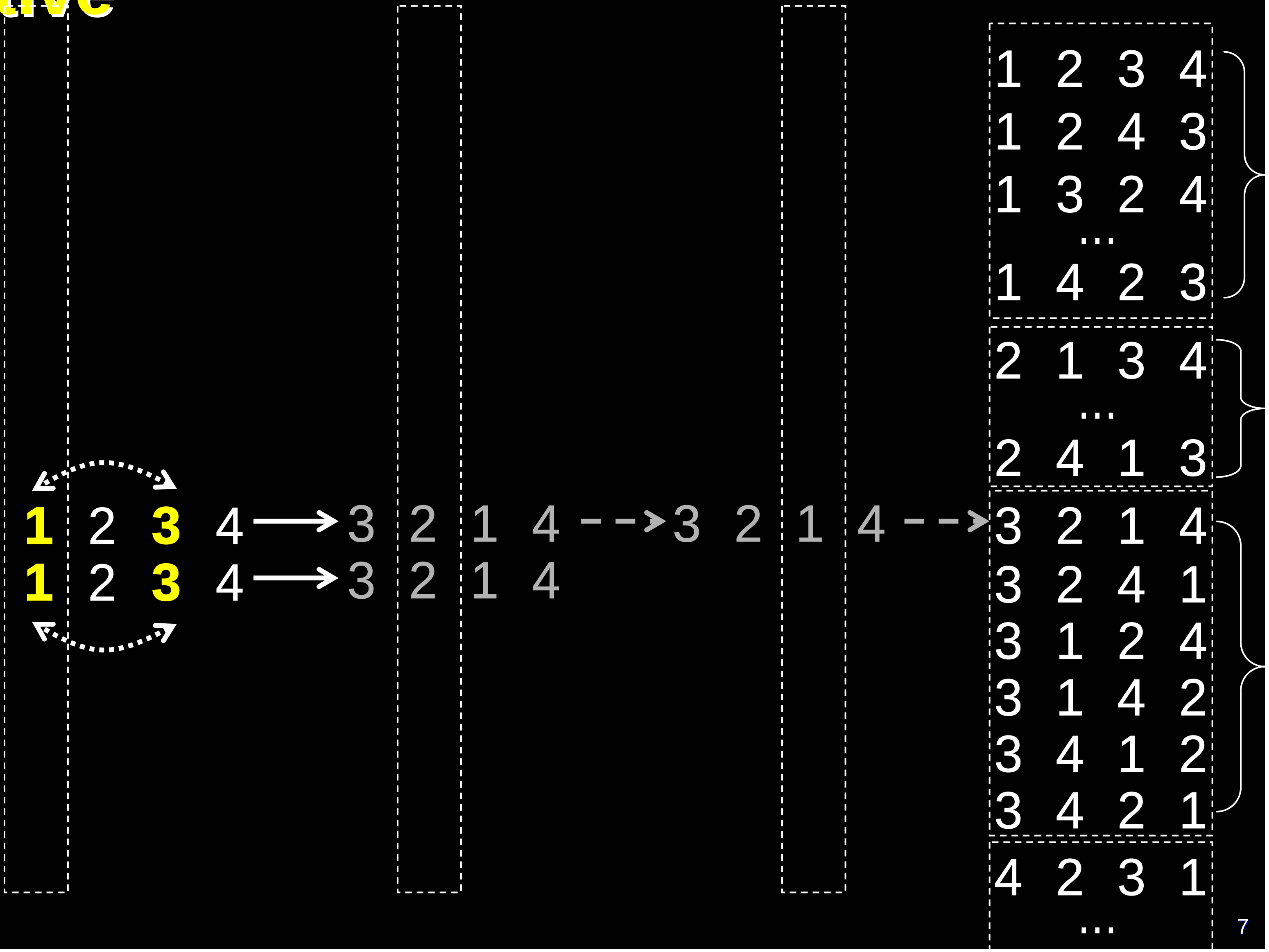
Permutation from Swapping (2/4)

- **Iterative**



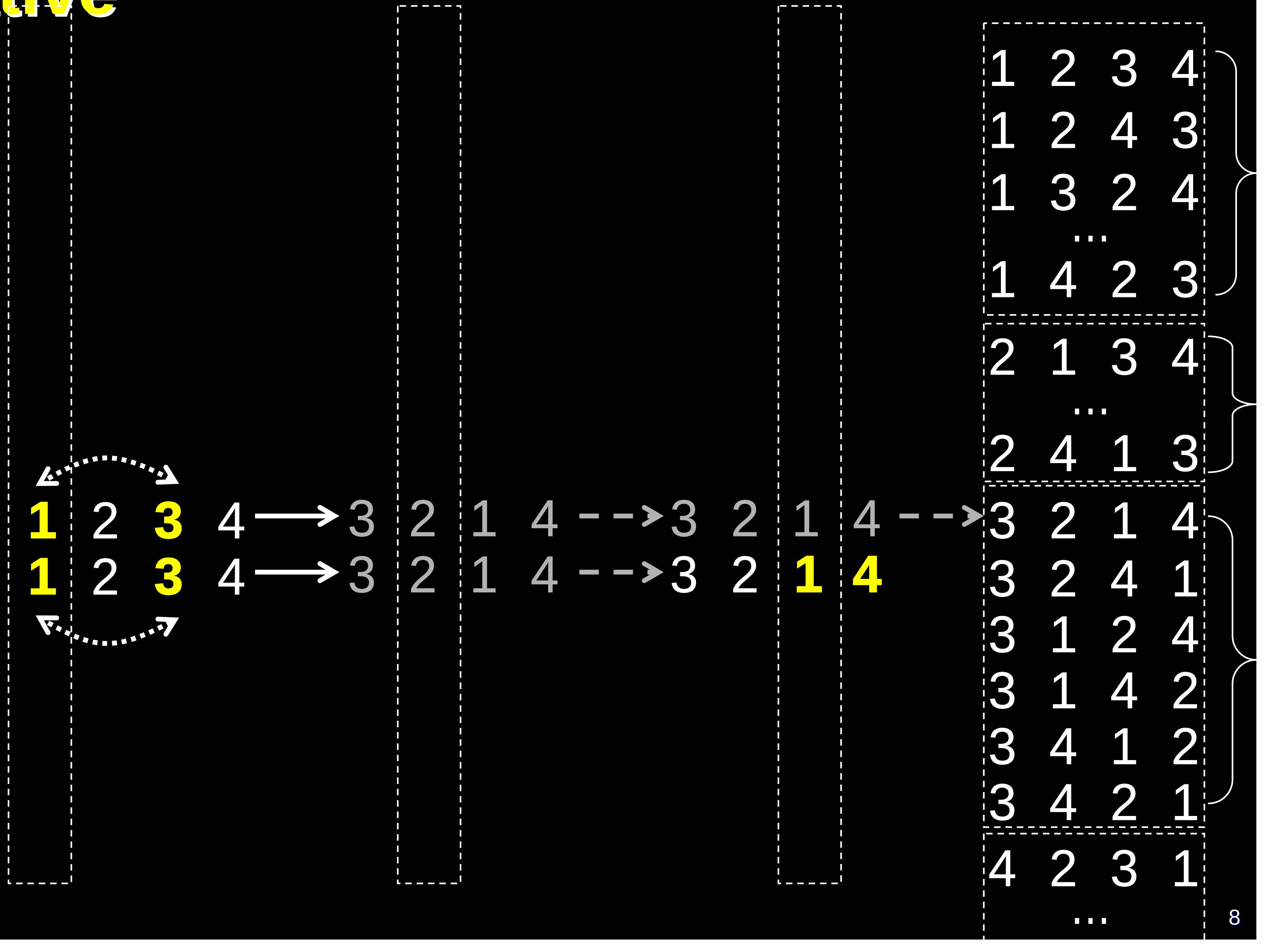
Permutation from Swapping (2/4)

- **Iterative**



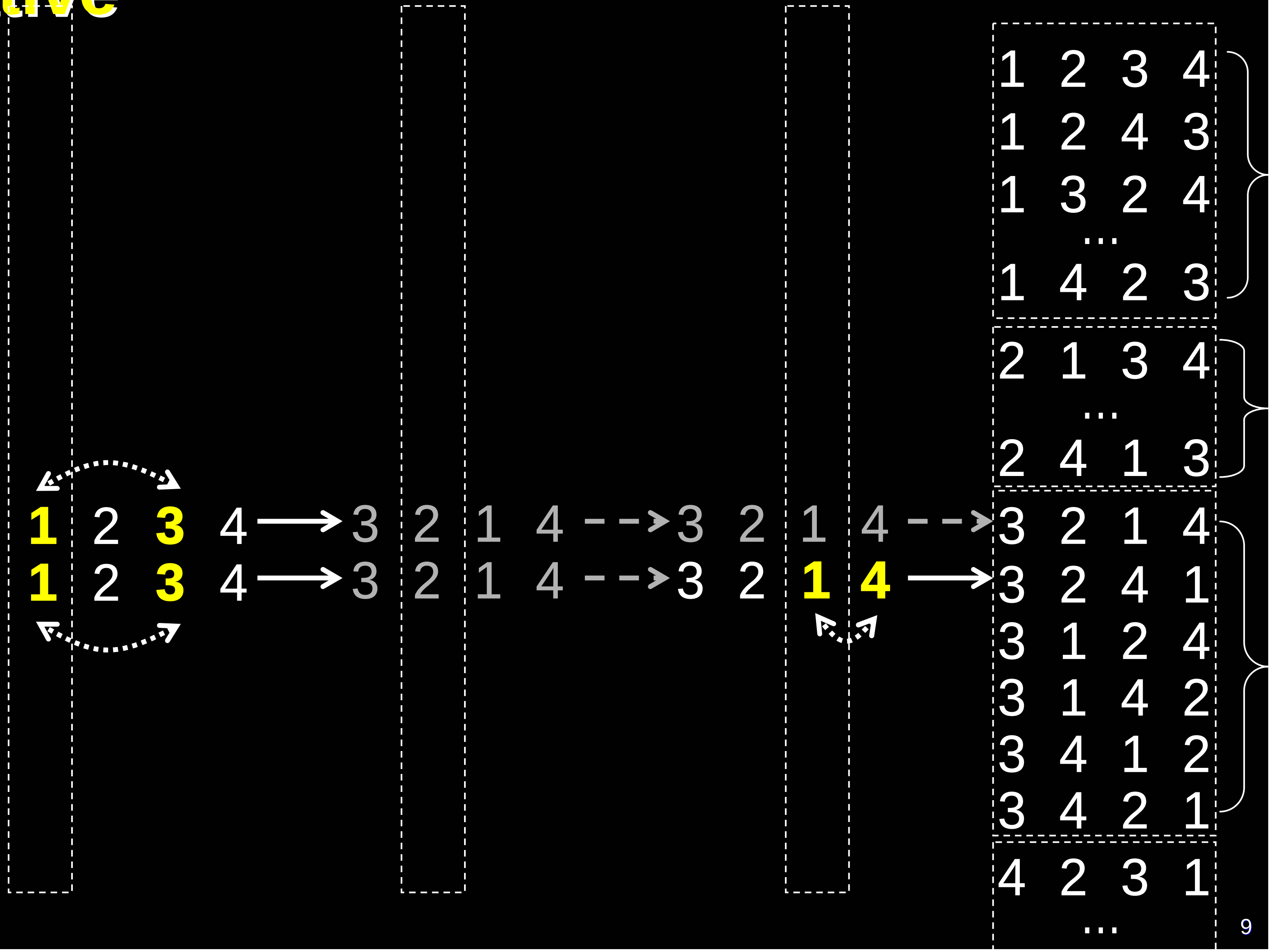
Permutation from Swapping (2/4)

- **Iterative**



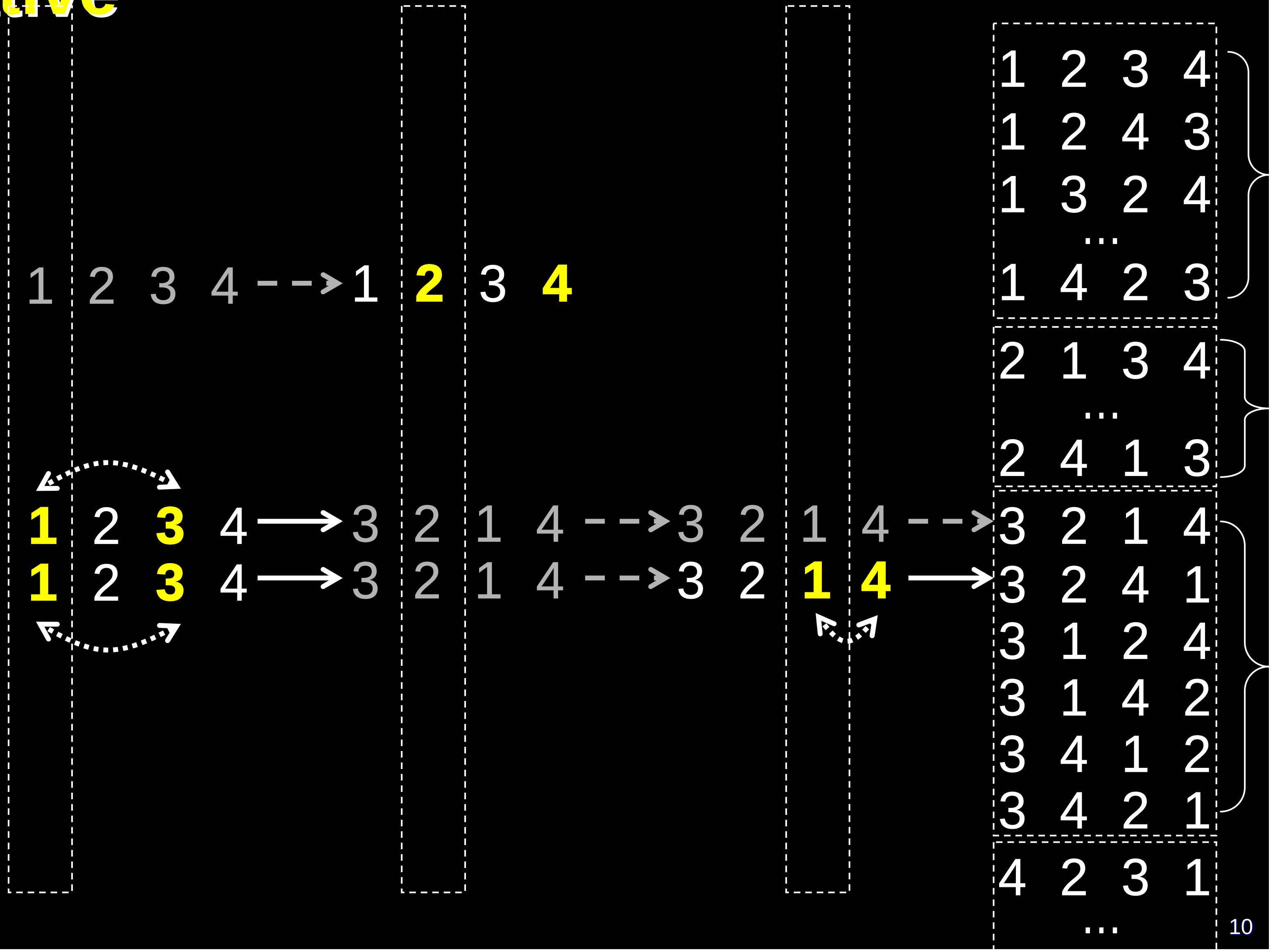
Permutation from Swapping (2/4)

- **Iterative**



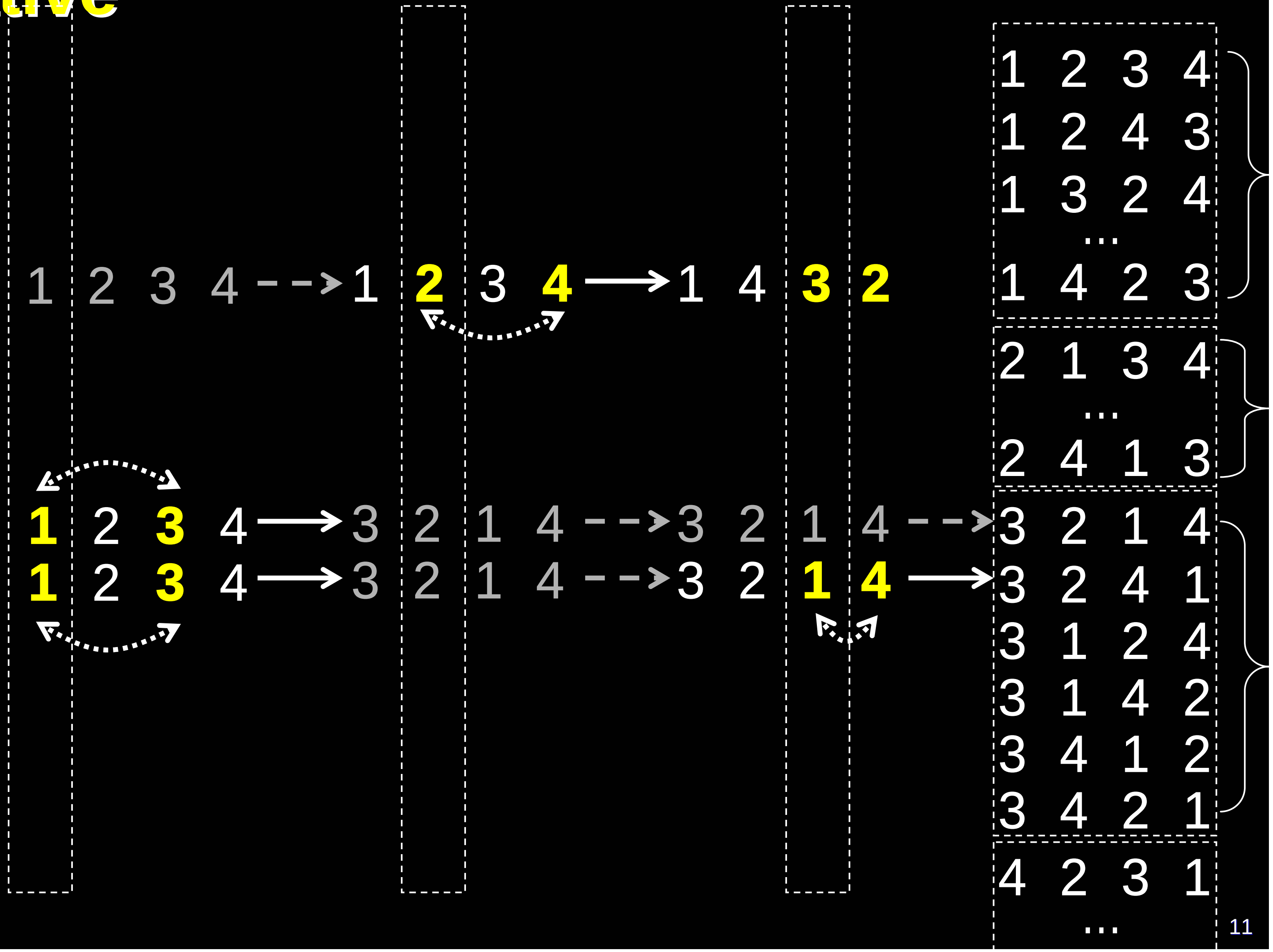
Permutation from Swapping (2/4)

- **Iterative**



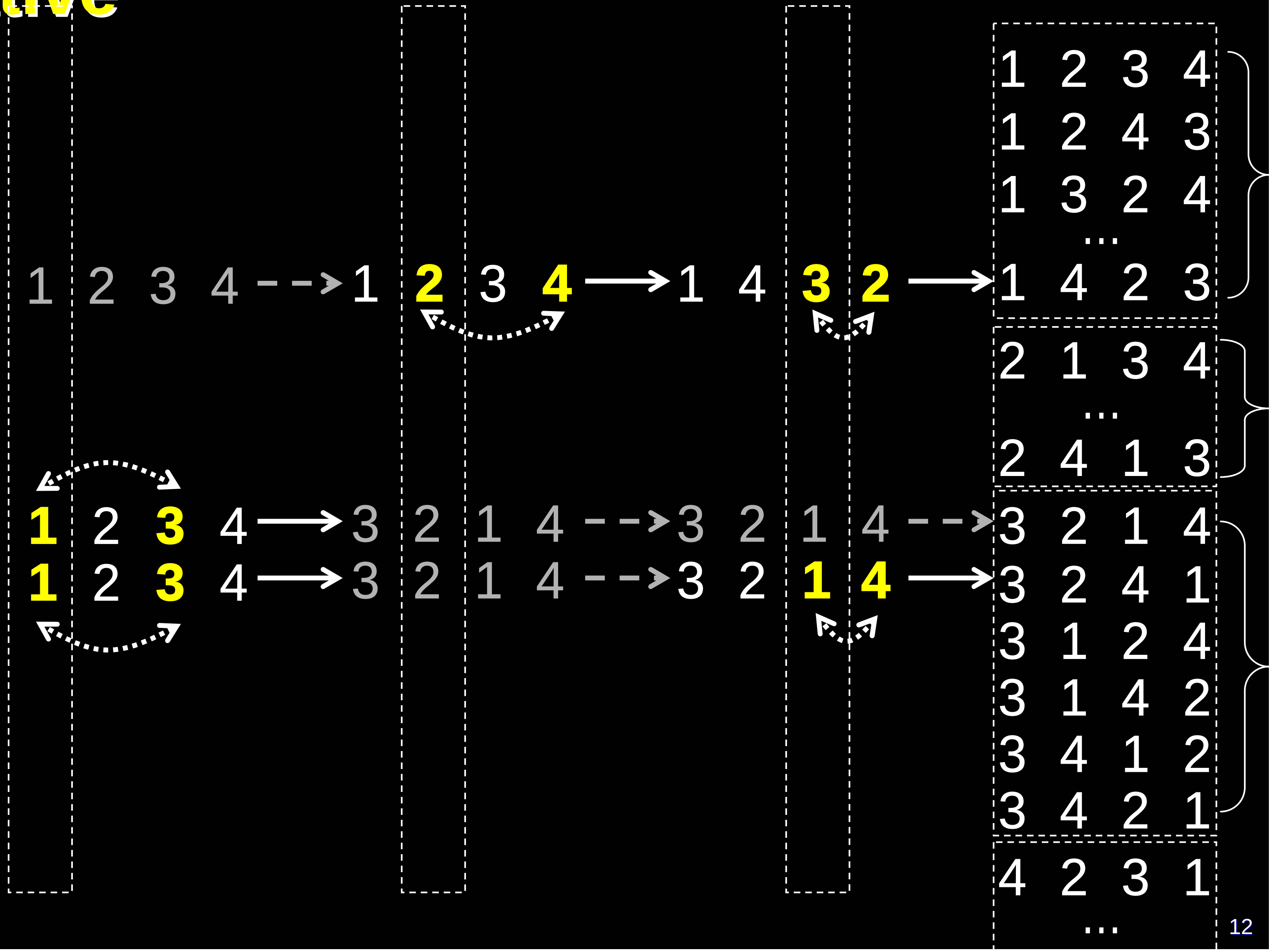
Permutation from Swapping (2/4)

- **Iterative**



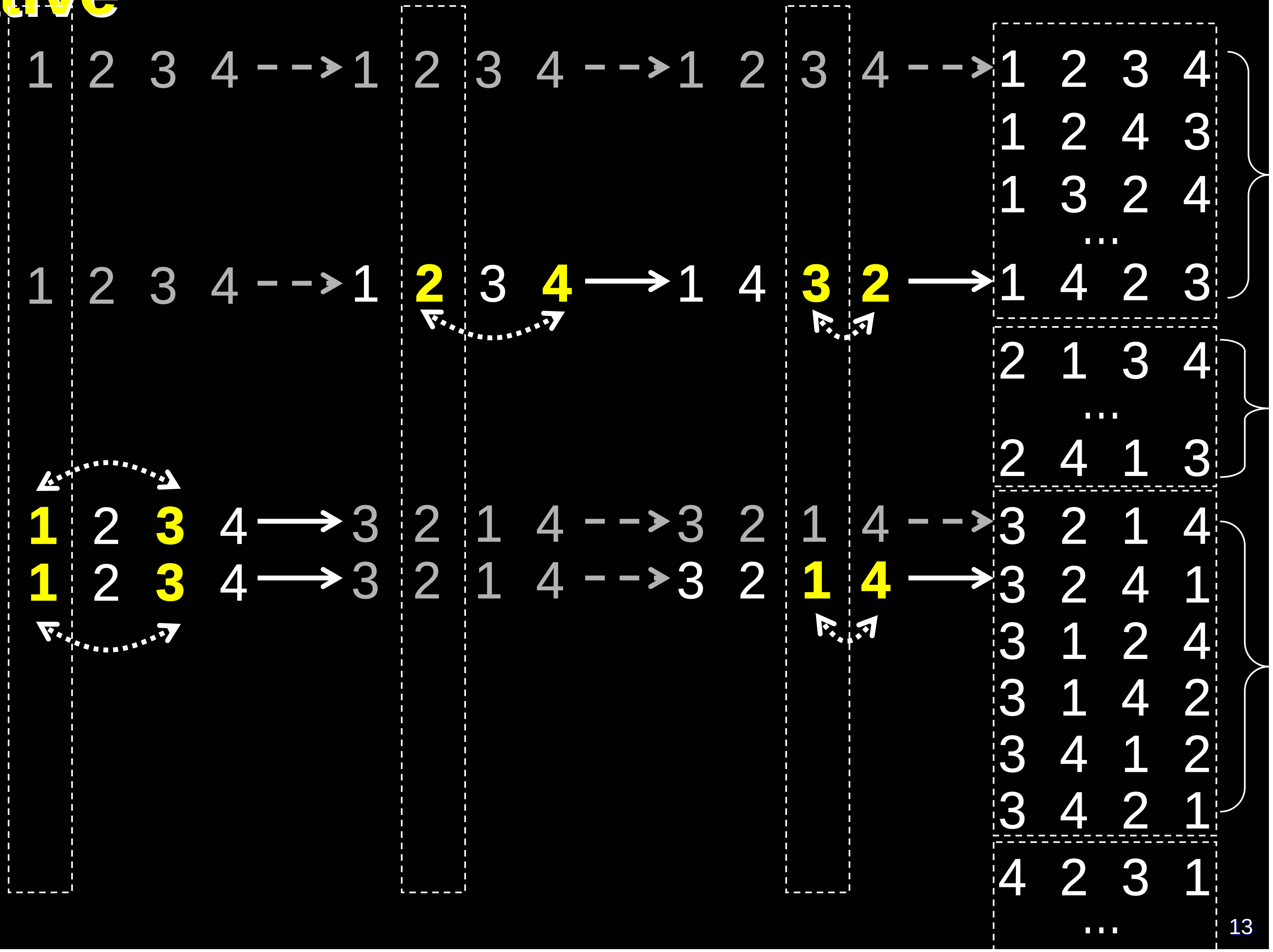
Permutation from Swapping (2/4)

- **Iterative**



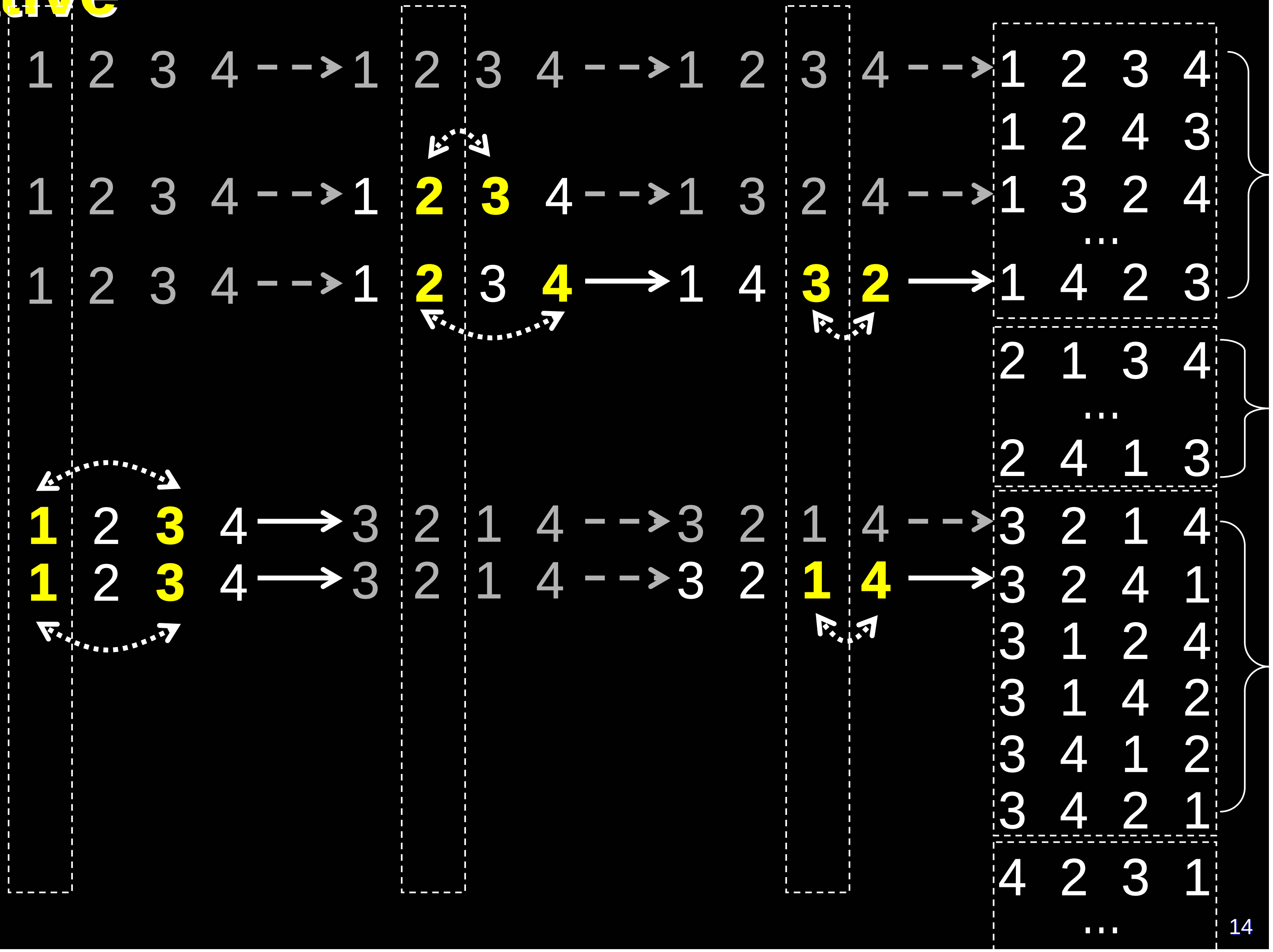
Permutation from Swapping (2/4)

- **Iterative**



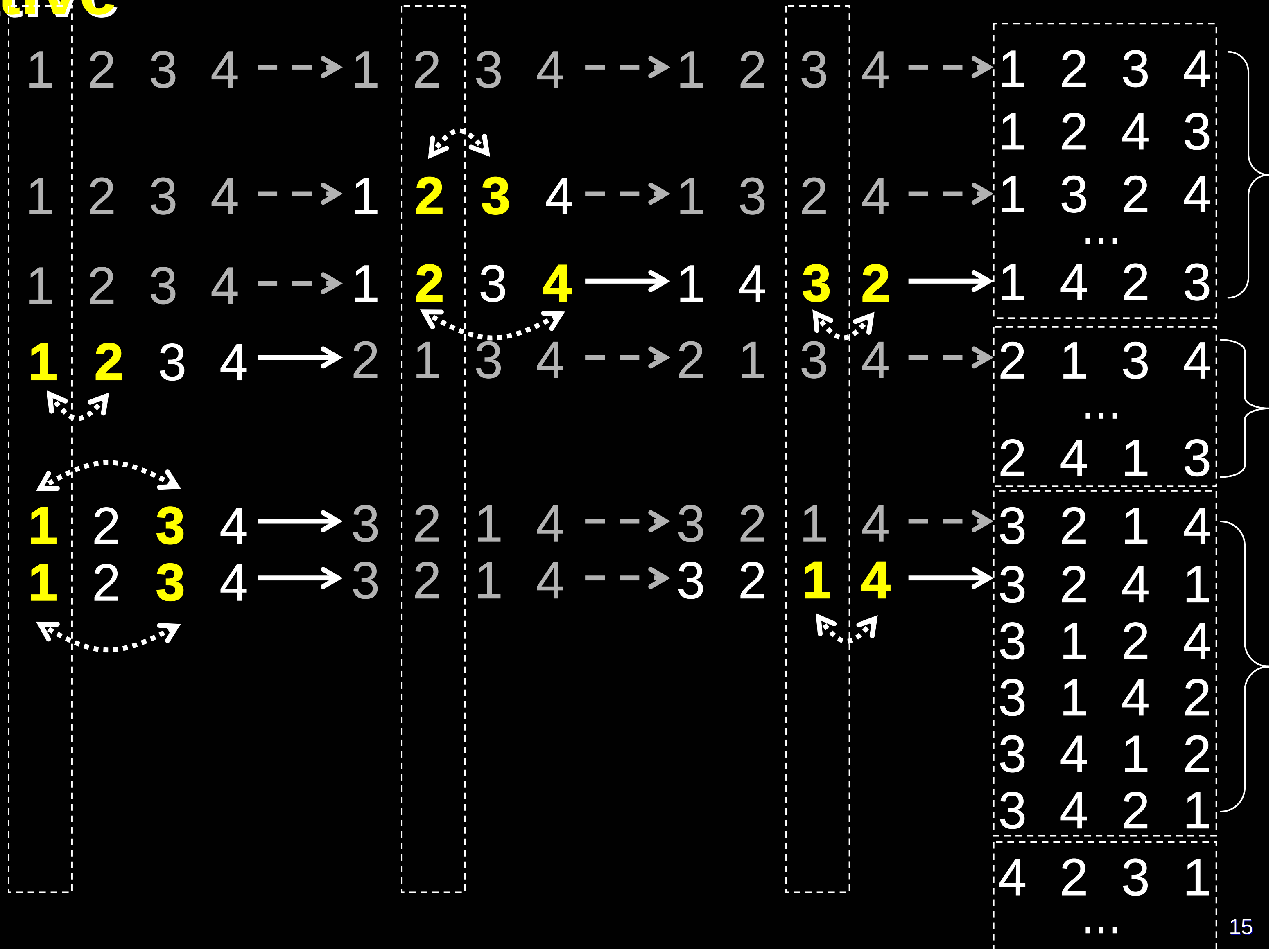
Permutation from Swapping (2/4)

- **Iterative**



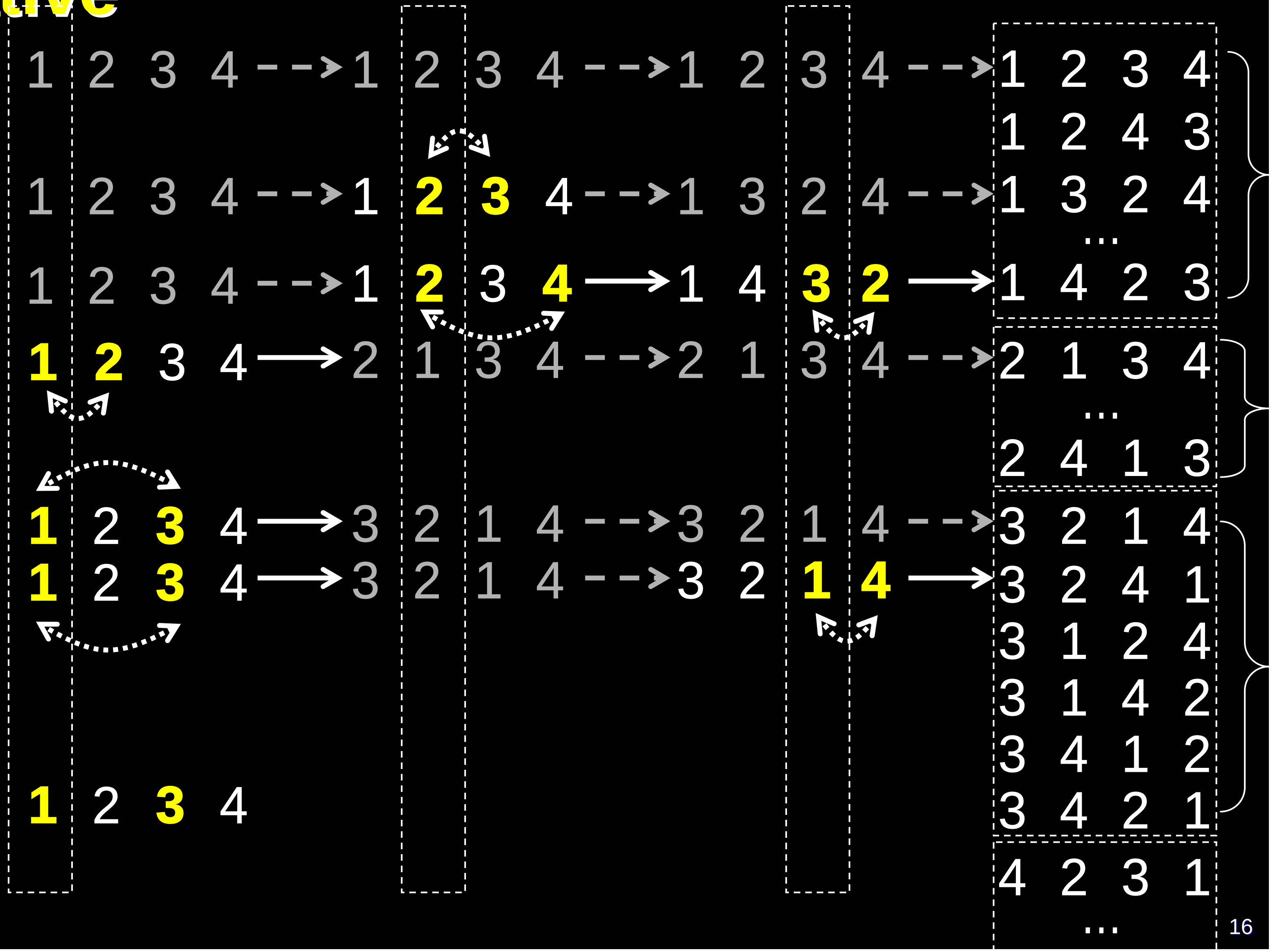
Permutation from Swapping (2/4)

- **Iterative**



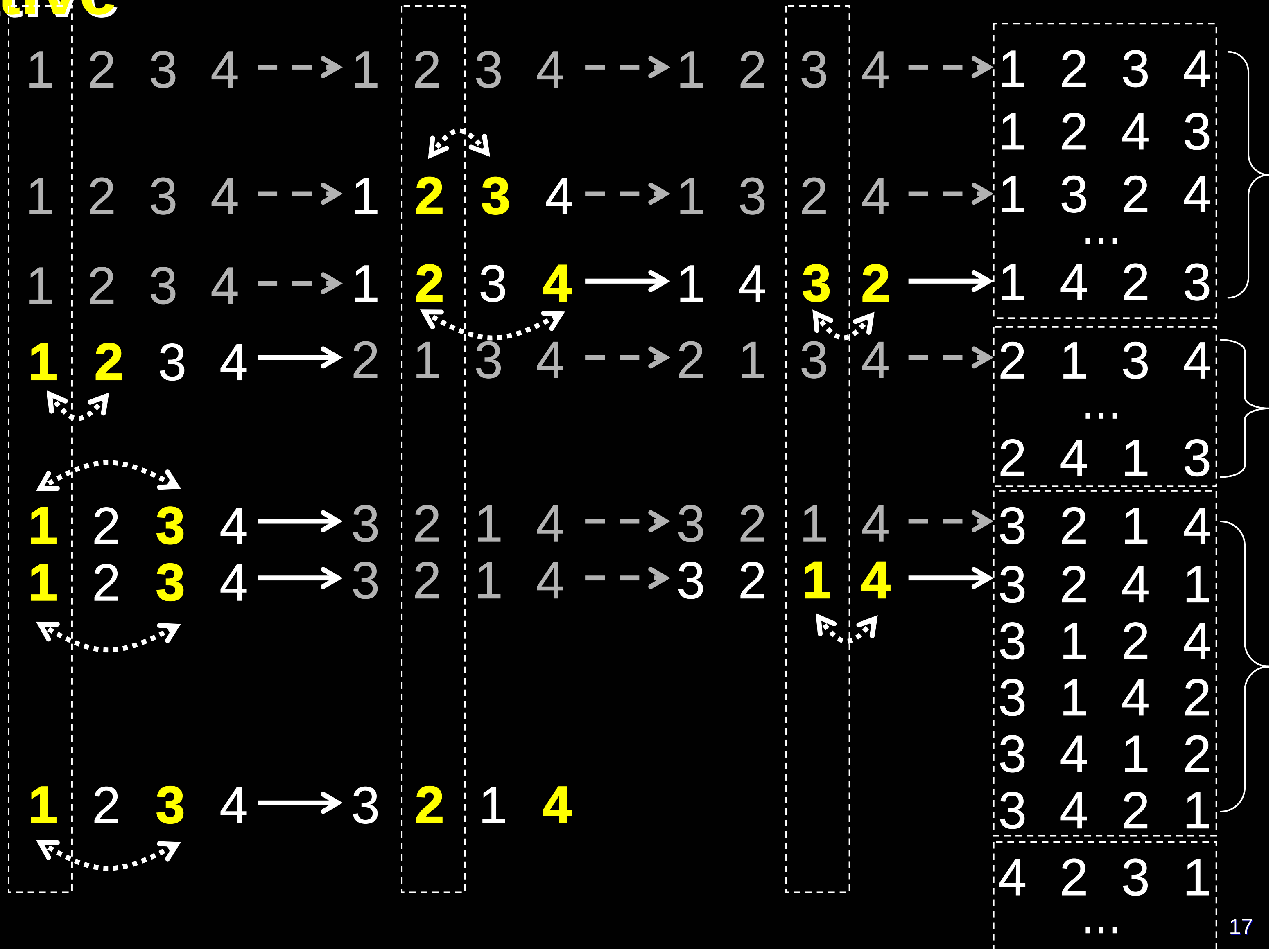
Permutation from Swapping (2/4)

- Iterative



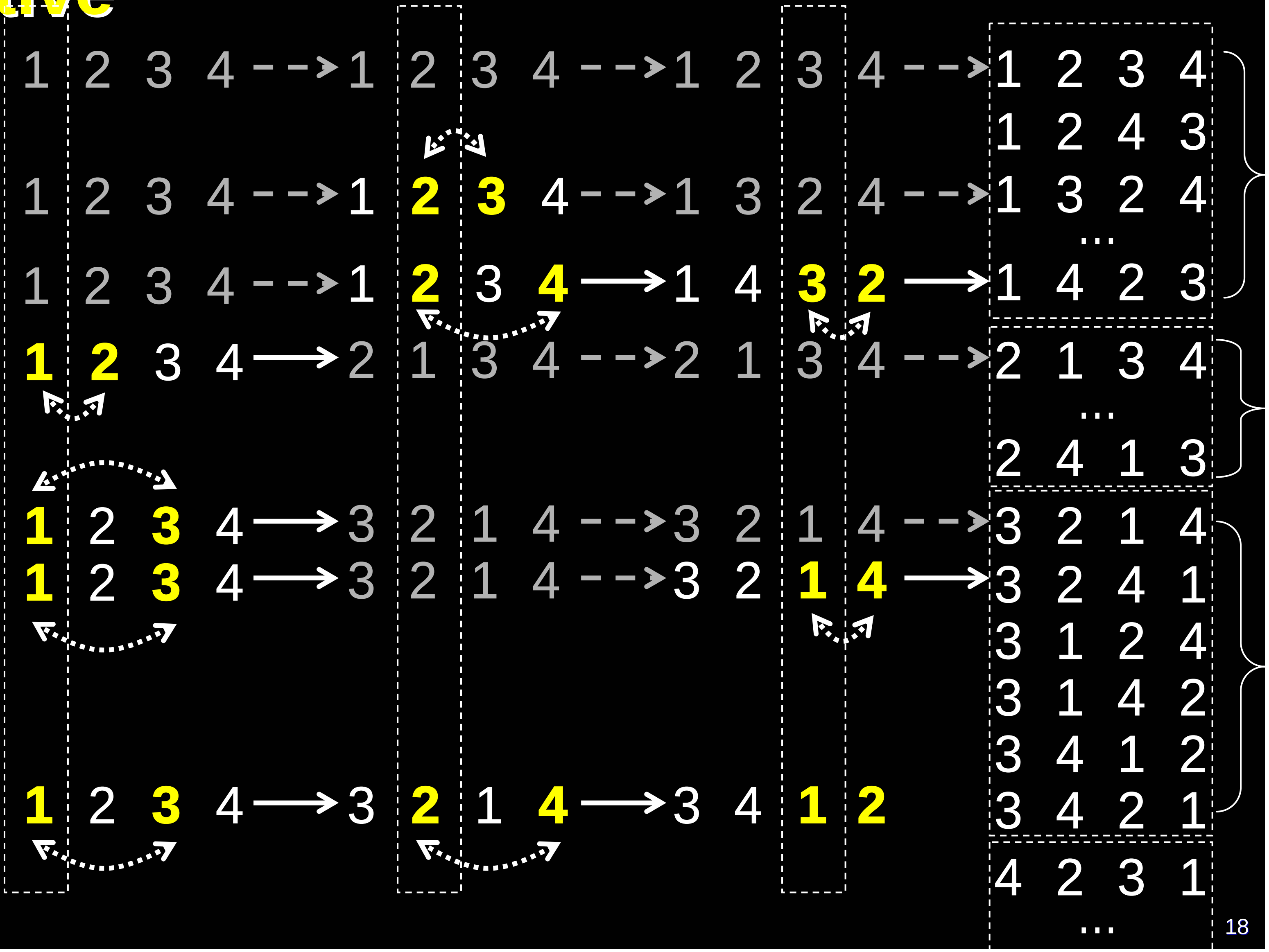
Permutation from Swapping (2/4)

- **Iterative**



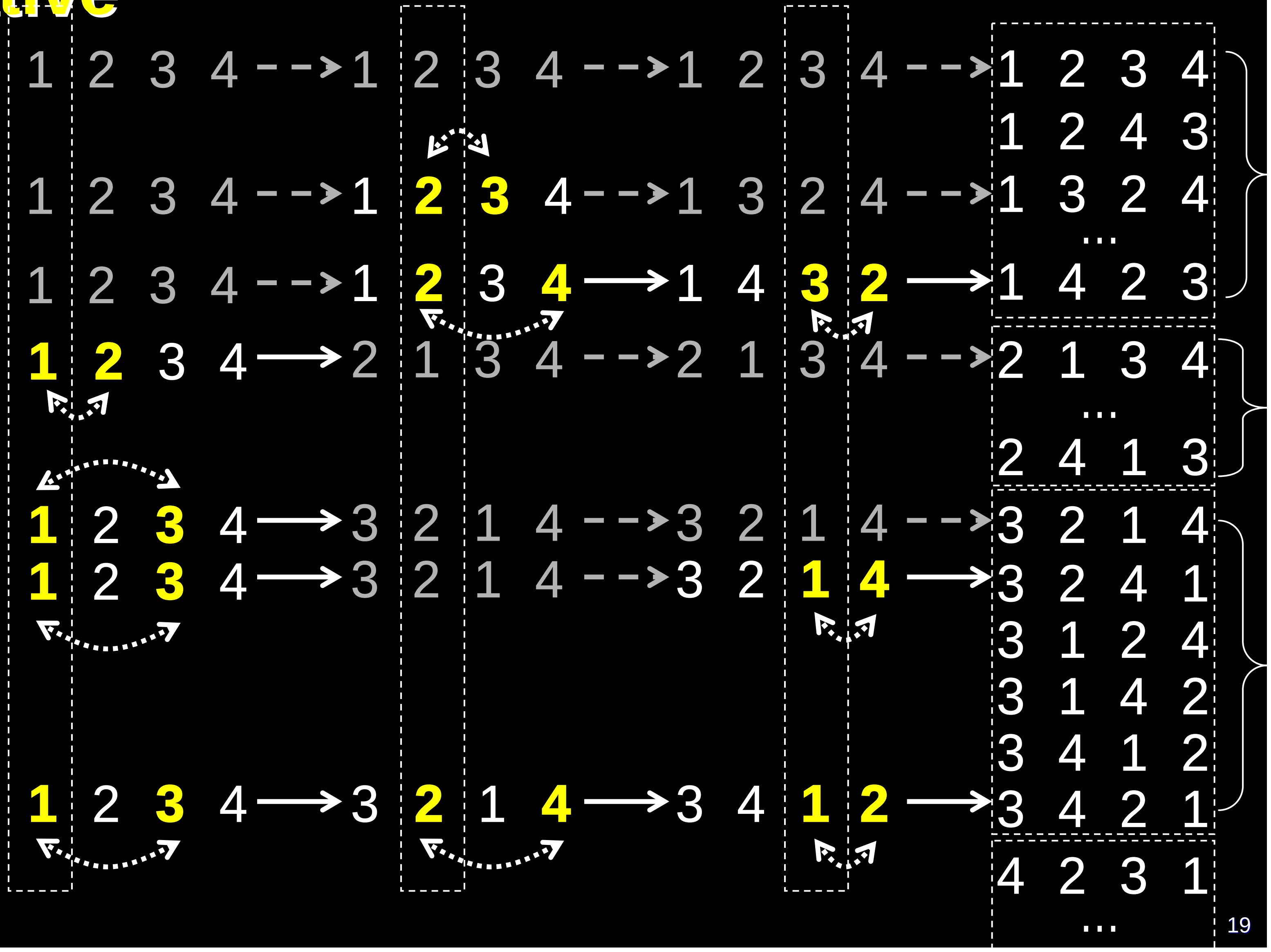
Permutation from Swapping (2/4)

- **Iterative**



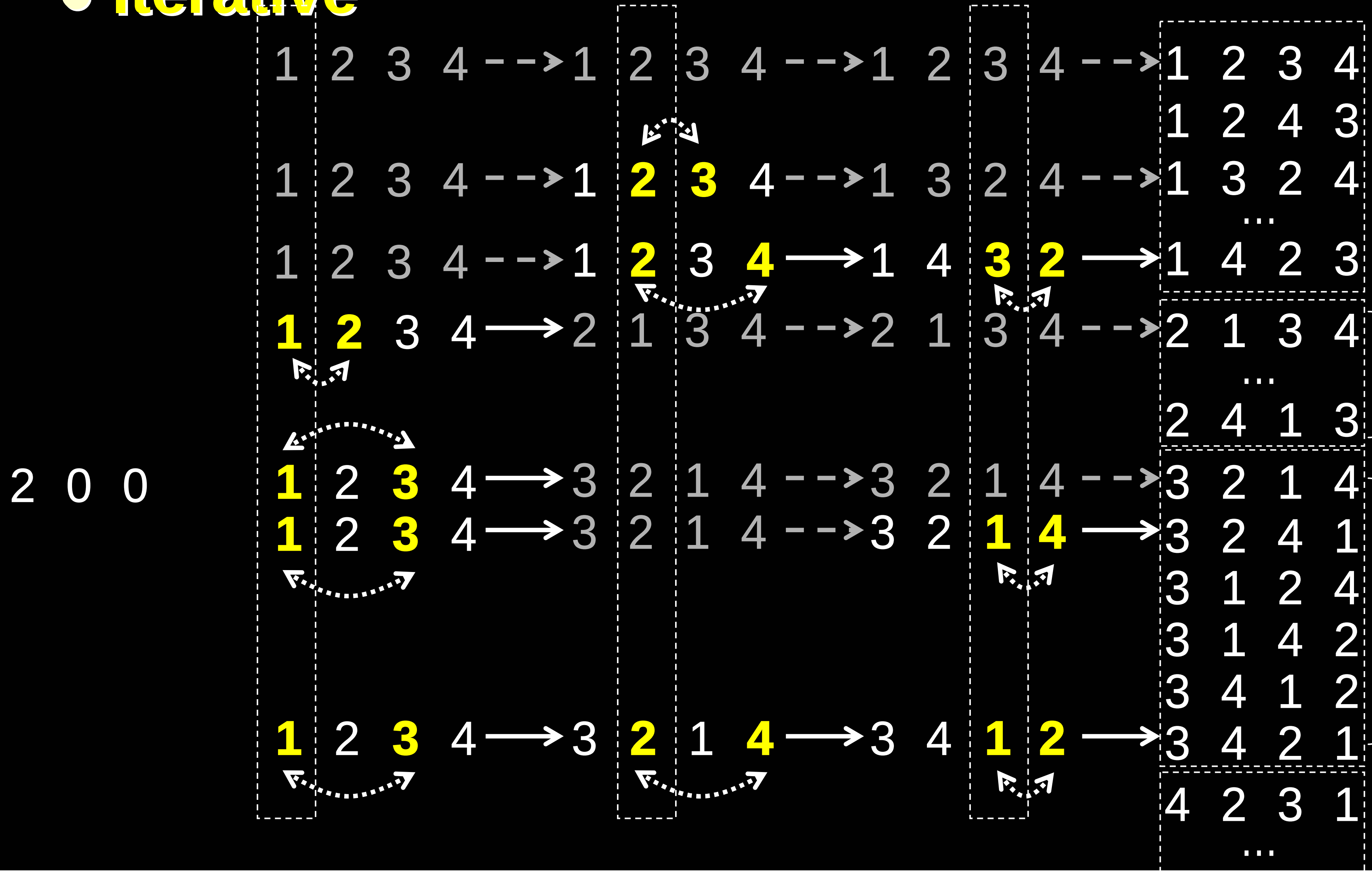
Permutation from Swapping (2/4)

- **Iterative**



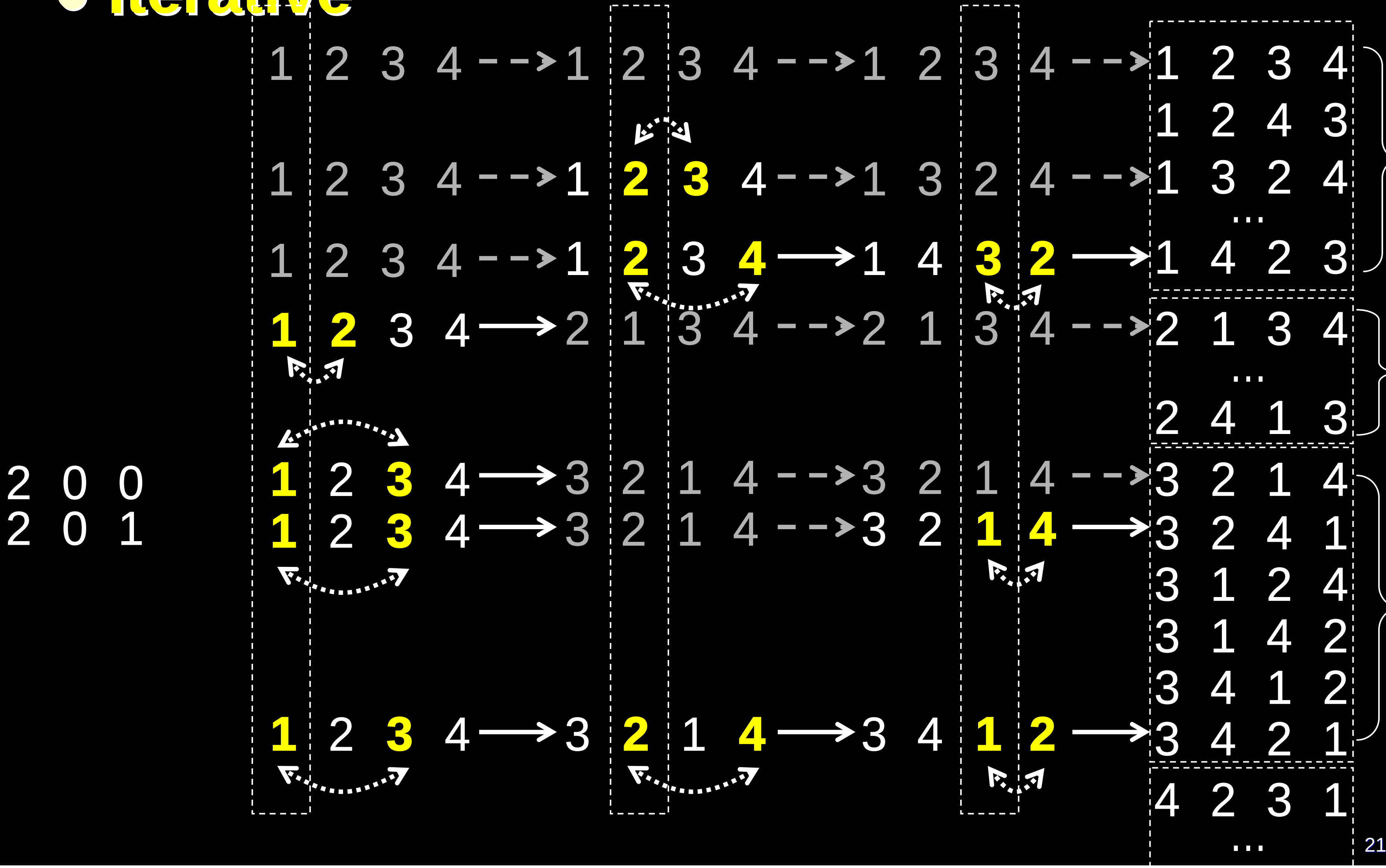
Permutation from Swapping (2/4)

- **Iterative**



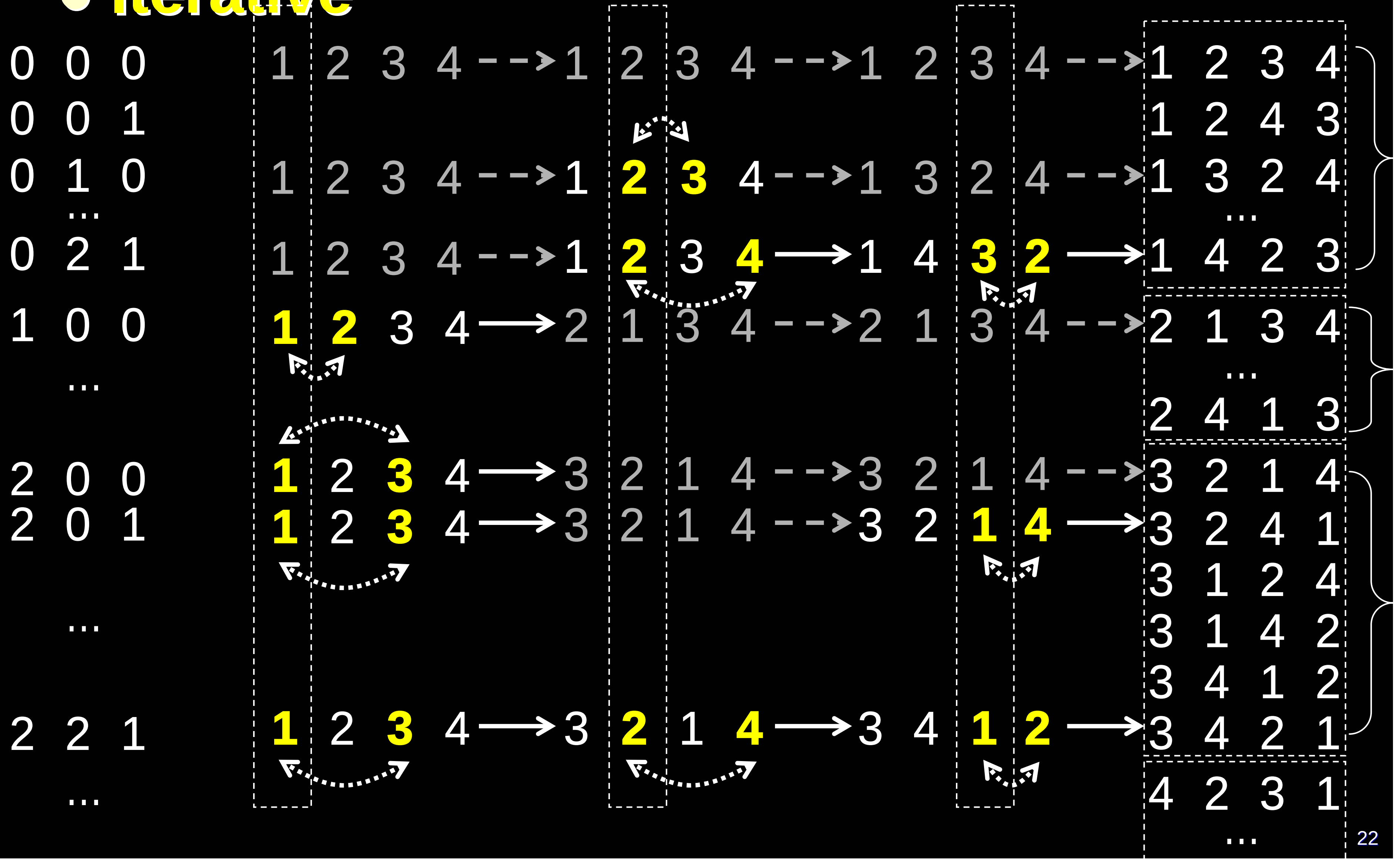
Permutation from Swapping (2/4)

- **Iterative**



Permutation from Swapping (2/4)

- **Iterative**

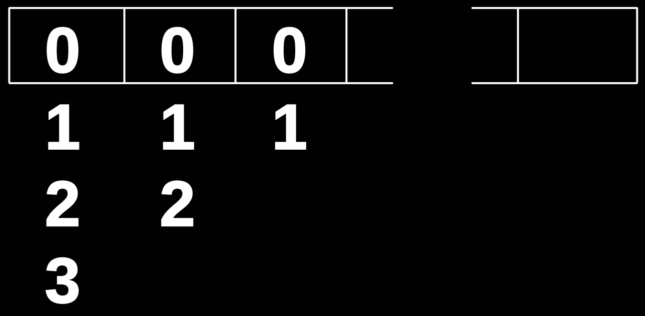


Permutation from Swapping (3/4)

- counting up

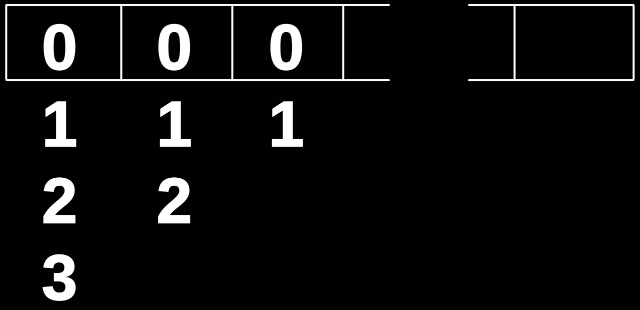
Permutation from Swapping (3/4)

- counting up



Permutation from Swapping (3/4)

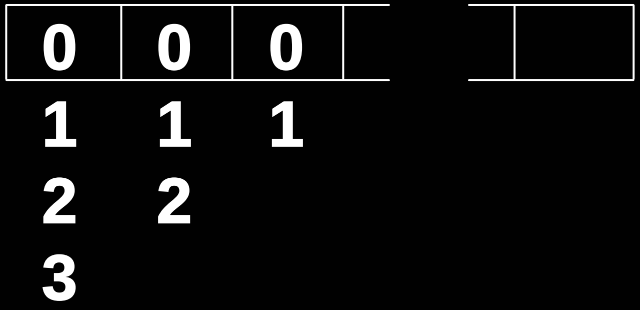
- counting up



```
0 0 0
0 0 1
0 1 0
0 1 1
0 2 0
0 2 1
```

Permutation from Swapping (3/4)

- counting up



```
0 0 0
0 0 1
0 1 0
0 1 1
0 2 0
0 2 1

1 0 0
1 0 1
1 1 0
1 1 1
1 2 0
1 2 1
```

Permutation from Swapping (3/4)

- counting up

0	**0**	**0**		
1	**1**	**1**		
2	**2**			
3				

```
0  0  0      2  0  0
0  0  1      2  0  1
0  1  0      2  1  0
0  1  1      2  1  1
0  2  0      2  2  0
0  2  1      2  2  1

1  0  0
1  0  1
1  1  0
1  1  1
1  2  0
1  2  1
```

Permutation from Swapping (3/4)

- counting up

```
| 0 | 0 | 0 |      |   |
  1   1   1
  2   2
  3
```

```
0 0 0    2 0 0
0 0 1    2 0 1
0 1 0    2 1 0
0 1 1    2 1 1
0 2 0    2 2 0
0 2 1    2 2 1

1 0 0    3 0 0
1 0 1    3 0 1
1 1 0    3 1 0
1 1 1    3 1 1
1 2 0    3 2 0
1 2 1    3 2 1
```

n-layer for Loop Implementation

```
int i1, i2, i3, i4;
for (i1=1; i1<=4; i1++) {
    for (i2=1; i2<=4; i2++) {
        if (i2 == i1) continue;
        for (i3=1; i3<=4; i3++) {
            if ((i3==i2)||(i3==i1)) continue;
            for (i4=1; i4<=4; i4++) {
                if ((i4==i3)||(i4==i2)||(i4==i1)) continue;
                printf("%d %d %d %d\n", i1, i2, i3, i4);
            }
        }
    }
}
```

i1	i2	i3	i4

This is a quick implementation but **NOT** **scalable**.

2-layer for loop Implementation

- Consider this simplified loop without collision constraints

```
int i1, i2, i3, i4;
for (i1=1; i1<=4; i1++) {
    for (i2=1; i2<=4; i2++) {
        for (i3=1; i3<=4; i3++) {
            for (i4=1; i4<=4; i4++) {
                printf("%d %d %d %d\n",
                                 i1,  i2,  i3,  i4);
            }
        }
    }
}
```

i1	i2	i3	i4
1	1	1	1
1	1	1	2
1	1	1	3
1	1	1	4
1	1	2	1
1	1	2	2
1	1	2	3
1	1	2	4
1	1	3	1

...

- Is there other ***scalable*** program structure to generate the same (i1, i2, i3, i4) sequence? yes

Equivalent 2-layer for loop

```
void nextIndex(int index[], int n) {
    int i;
    for (i=n-1; i>0; i--)
        if (index[i]<n)
            { index[i]++; return; }
        else
            index[i] = 1;
    index[0]++;
}
```

index

1	1	1	1
1	1	1	2
1	1	1	3
1	1	1	4
1	1	2	1
1	1	2	2
1	1	2	3
1	1	2	4
1	1	3	1

...

```
int index[4], n=4;
for (i=0; i<n; i++)
    index[i] = 1;
for (; index[0]<=n; nextIndex(index, n))
    printArray(index, n);
```

Scalable

2-layer for loop for Permutation

index	1	2	3	4
	1	2	4	3
	1	3	2	4
	1	3	4	2
	1	4	2	3
	1	4	3	2
	2	1	3	4
	2	1	4	3

...