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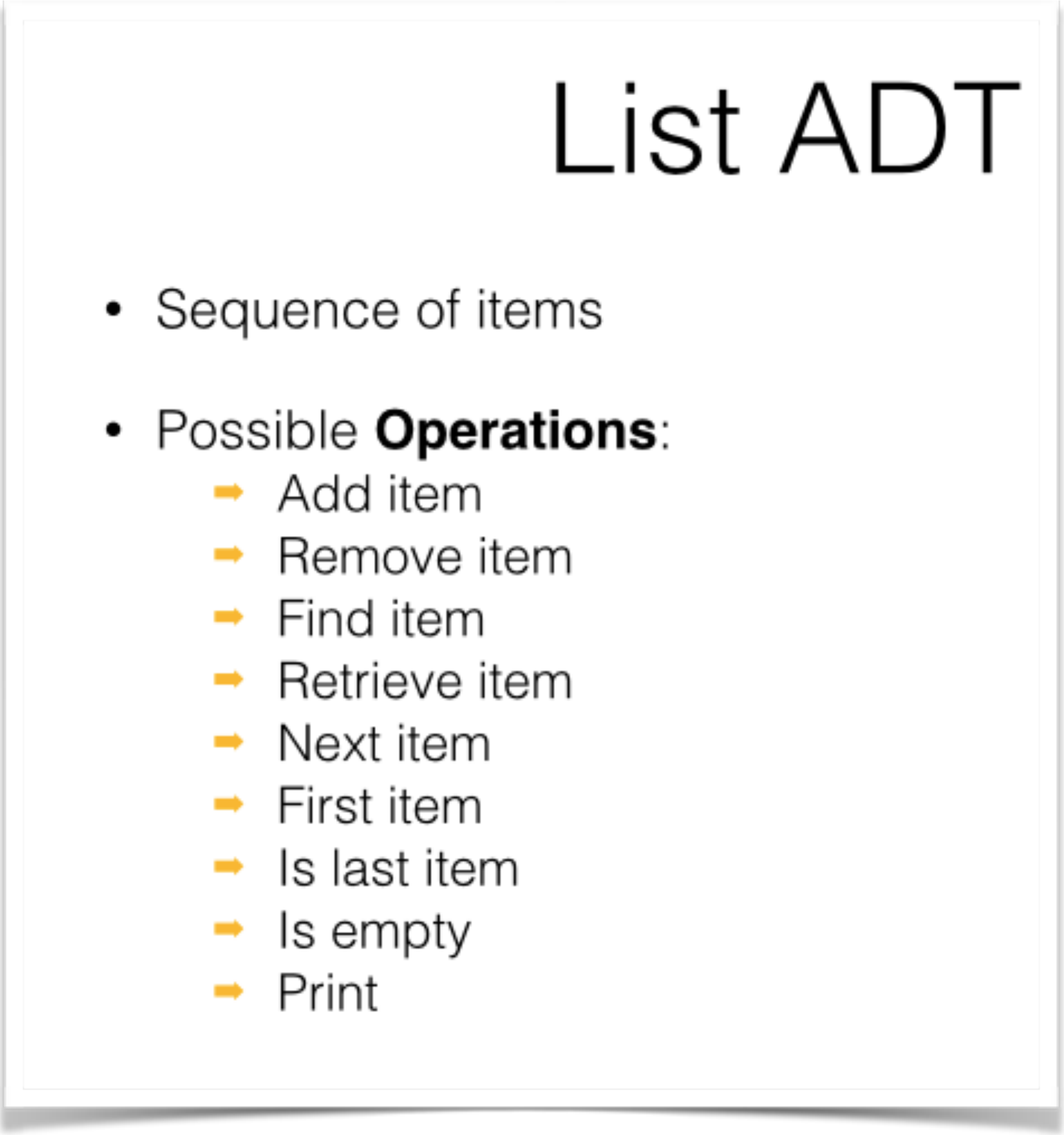
Lecture 16
Lists and Sorted List
(Array Implementation)

FIT 1008
Introduction to Computer Science

MONASH University
Information Technology

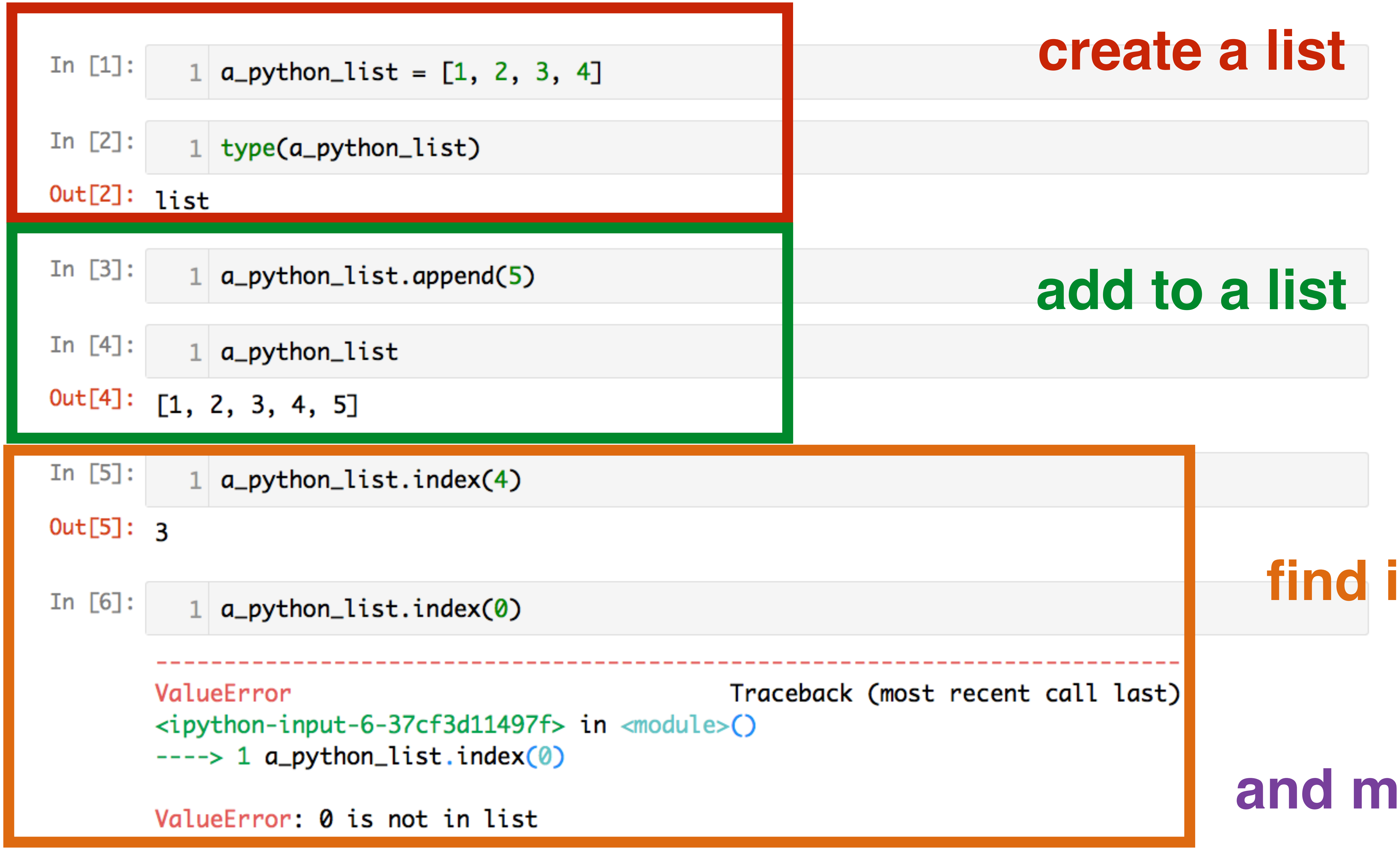
Put everything together…
and implement some
Abstract Data Types



List ADT

- Sequence of items
- Possible **Operations**:
  - ➡ Add item
  - ➡ Remove item
  - ➡ Find item
  - ➡ Retrieve item
  - ➡ Next item
  - ➡ First item
  - ➡ Is last item
  - ➡ Is empty
  - ➡ Print

We already use one implementation of a List ADT



```
In [1]: a_python_list = [1, 2, 3, 4]

In [2]: type(a_python_list)
Out[2]: list

In [3]: a_python_list.append(5)

In [4]: a_python_list
Out[4]: [1, 2, 3, 4, 5]

In [5]: a_python_list.index(4)
Out[5]: 3

In [6]: a_python_list.index(0)

        ---------------------------------------------------------------------------
        ValueError                                Traceback (most recent call last)
        <ipython-input-6-37cf3d11497f> in <module>()
        ----> 1 a_python_list.index(0)

        ValueError: 0 is not in list
```

create a list

add to a list

find item

and more…

Implementing your own List ADT

- How do we start? Easy:
  - Create a **new file** (called *my_list.py*)
  - Import the build_array function so that you can create arrays.
  - Add any **operations/methods** users my need to use.

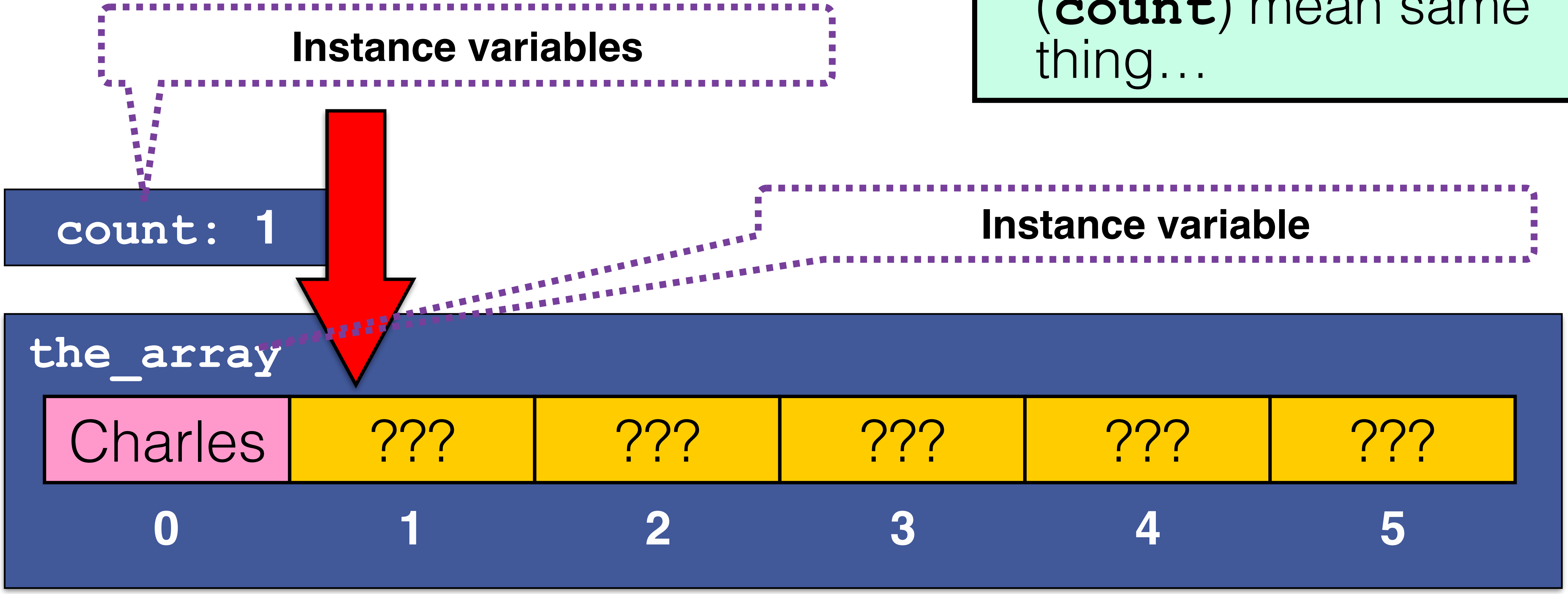
- What operations?
  - **Create a list**, **access** an element, compute the **length**
  - Determine whether **is empty**
  - Determine whether it **has a given item**
  - Find the **position of an item** (if in)
  - **Add/delete** an item
  - **Delete/insert** the item in position *i*

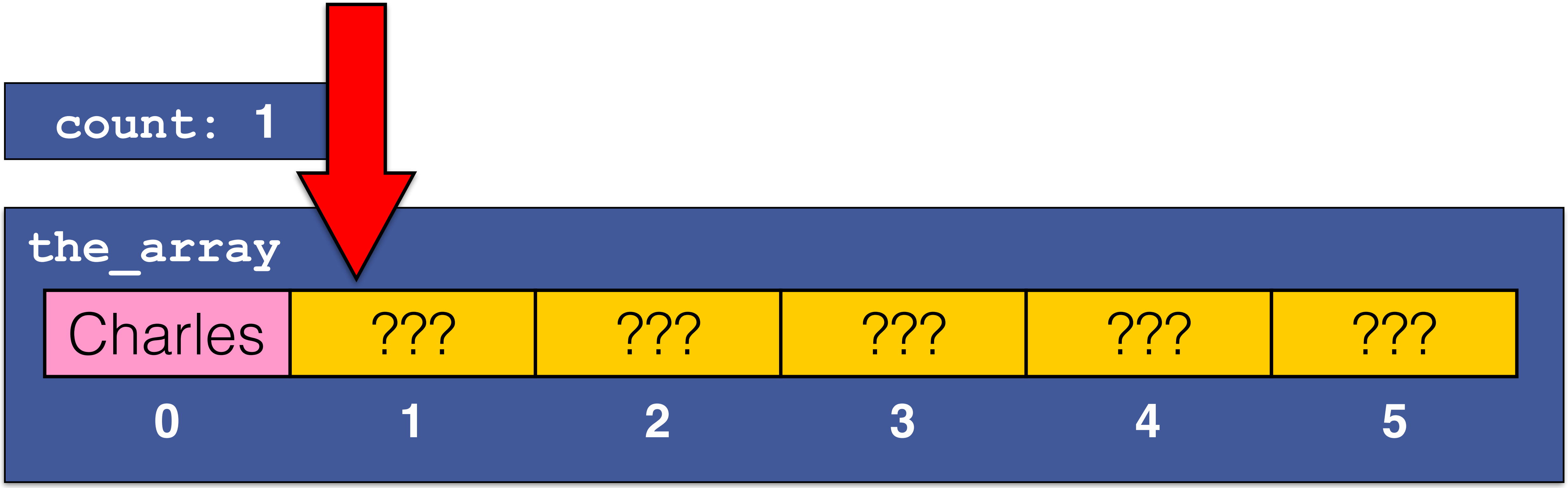
Visualising lists implemented with arrays

- Consider a list defined:
  - Over an array of size 6
  - Currently with one element (Charles)

- We will visualise it like this:

Visual Clarity:
Arrow, **Colour**, Counter (`count`) mean same thing…

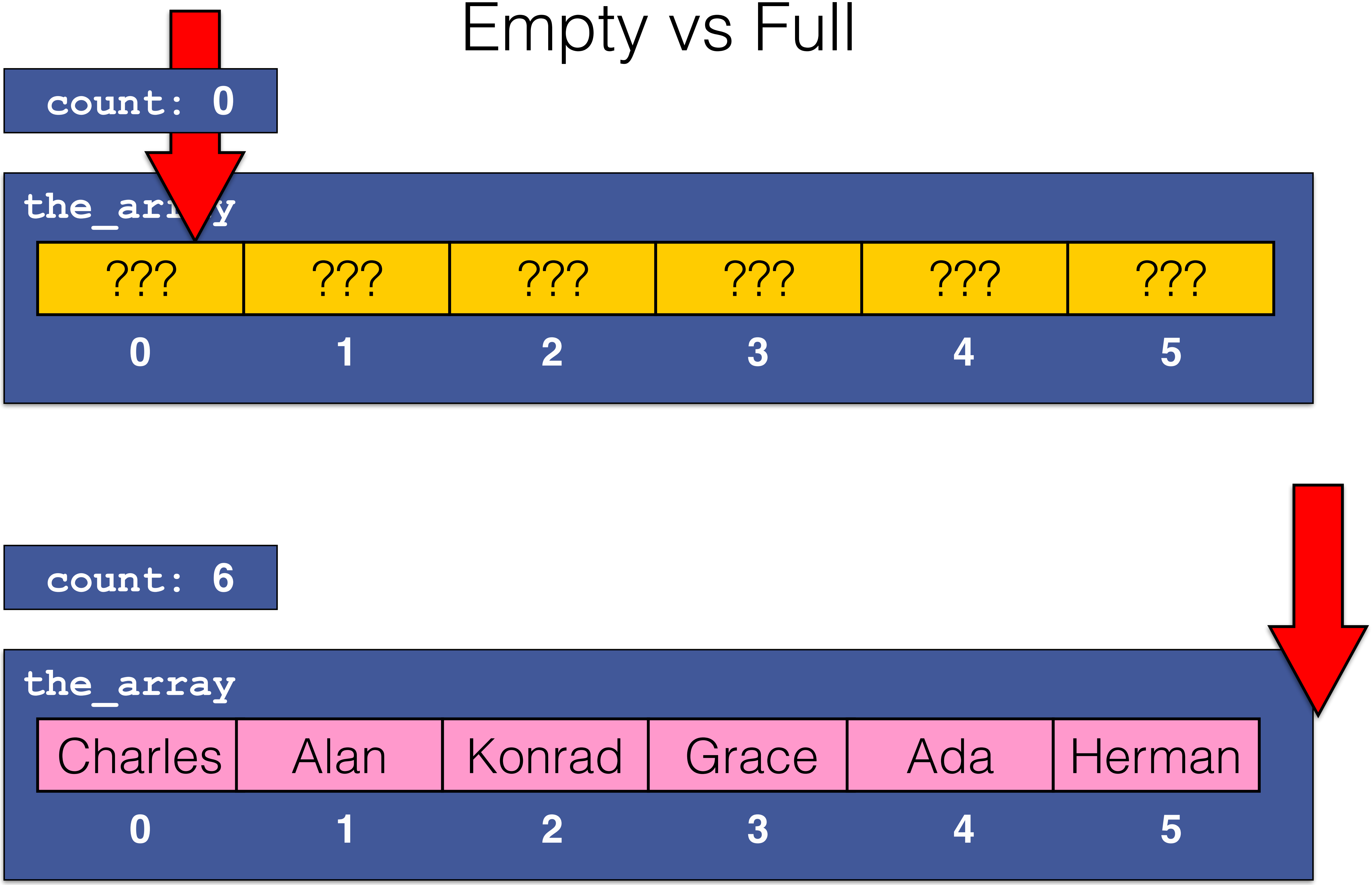




Invariant: count points to the first free position in the array

In other words: valid data appear in the 0..count-1 positions

Empty vs Full



count: 0

the_array

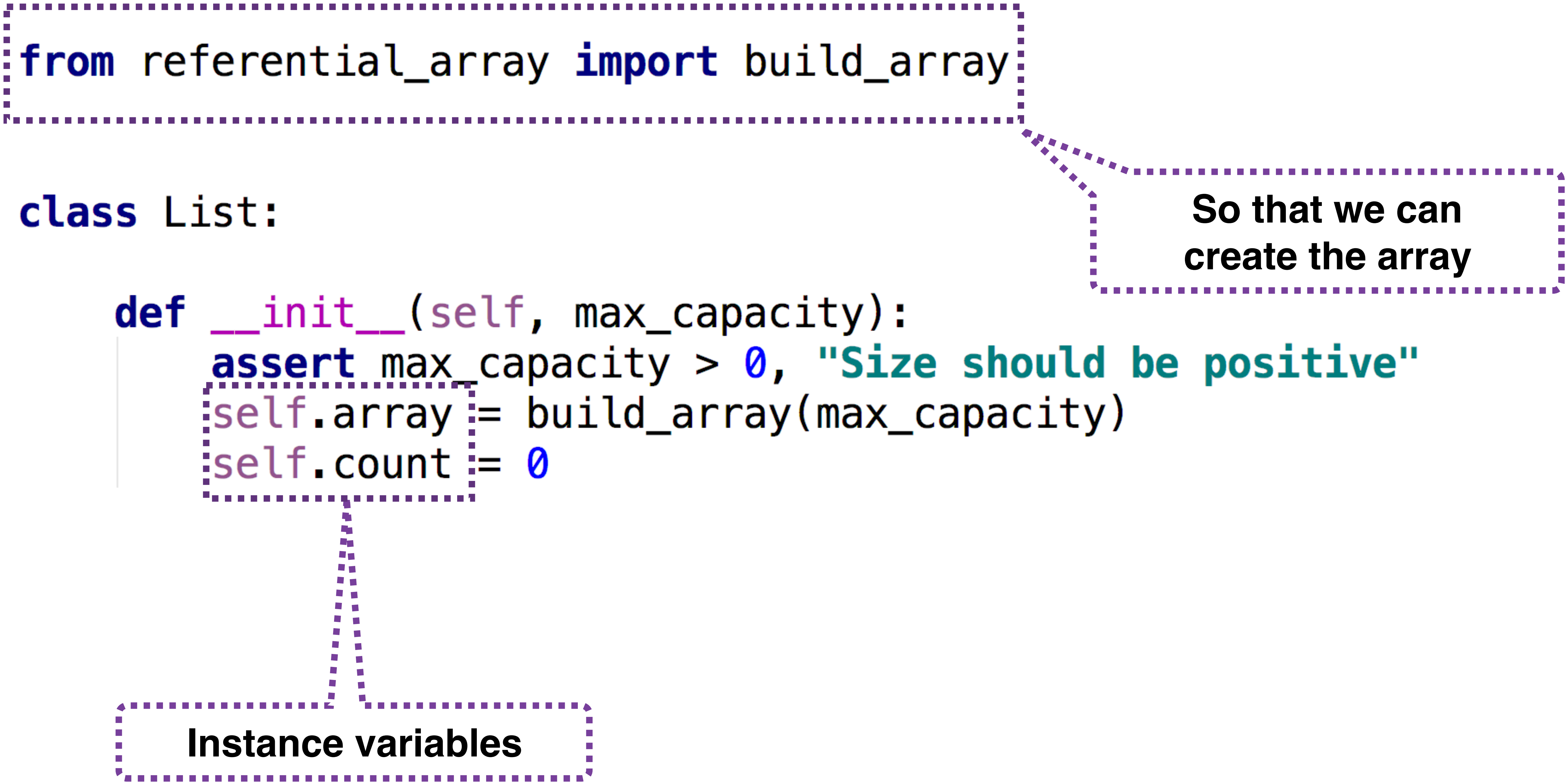
???	???	???	???	???	???
0	1	2	3	4	5

count: 6

the_array

Charles	Alan	Konrad	Grace	Ada	Herman
0	1	2	3	4	5

Creating a list

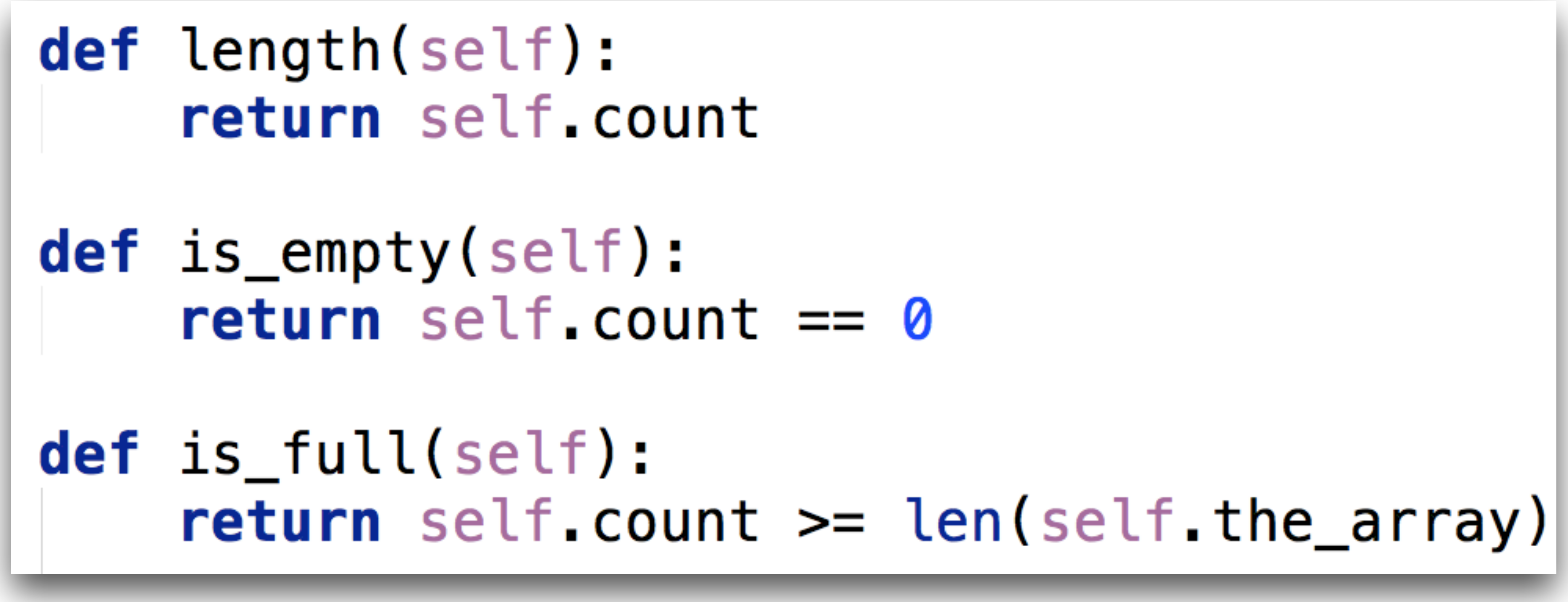


```
from referential_array import build_array

class List:

    def __init__(self, max_capacity):
        assert max_capacity > 0, "Size should be positive"
        self.array = build_array(max_capacity)
        self.count = 0
```

So that we can create the array

Instance variables

Simple methods



```python
def length(self):
    return self.count

def is_empty(self):
    return self.count == 0

def is_full(self):
    return self.count >= len(self.the_array)
```

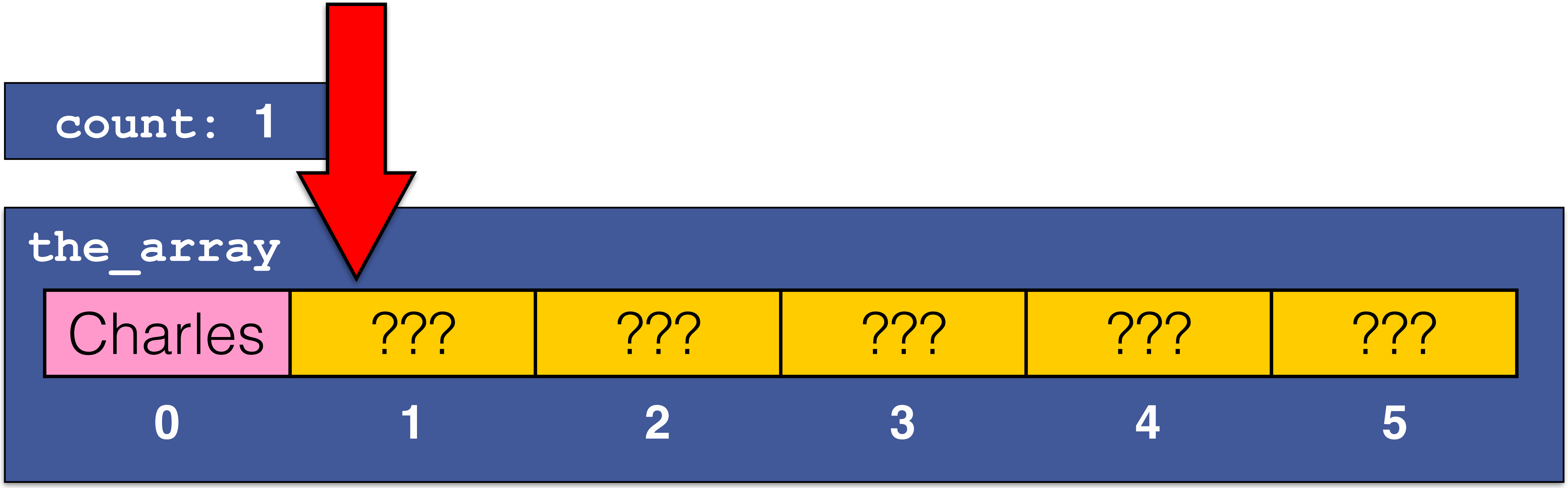
Adding an element to a list

- **Input:**
  - List (in our case: array + count)
  - **Element to be added**
- **Output:**
  - List
  - Contains all original elements in the same order AND the input one (this is the *post-condition*)

Adding an element

Recall: count indicates the first empty position (if any)

`Example: add "Ada"`



`count: 1`

`the_array`

Charles	???	???	???	???	???
0	1	2	3	4	5

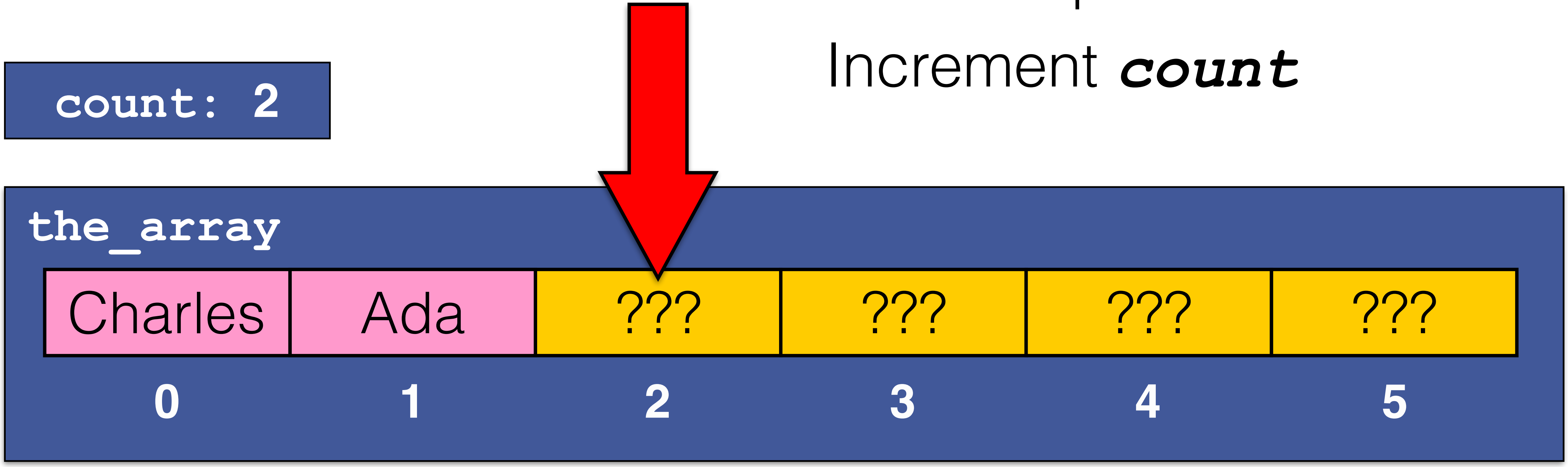
Adding an element

Recall: count indicates the first empty position (if any)

`Example: add "Ada"`

Add the item at position ***`count`***

Increment ***`count`***



`count: 2`

`the_array`

Charles	Ada	???	???	???	???
0	**1**	**2**	**3**	**4**	**5**

Adding an element

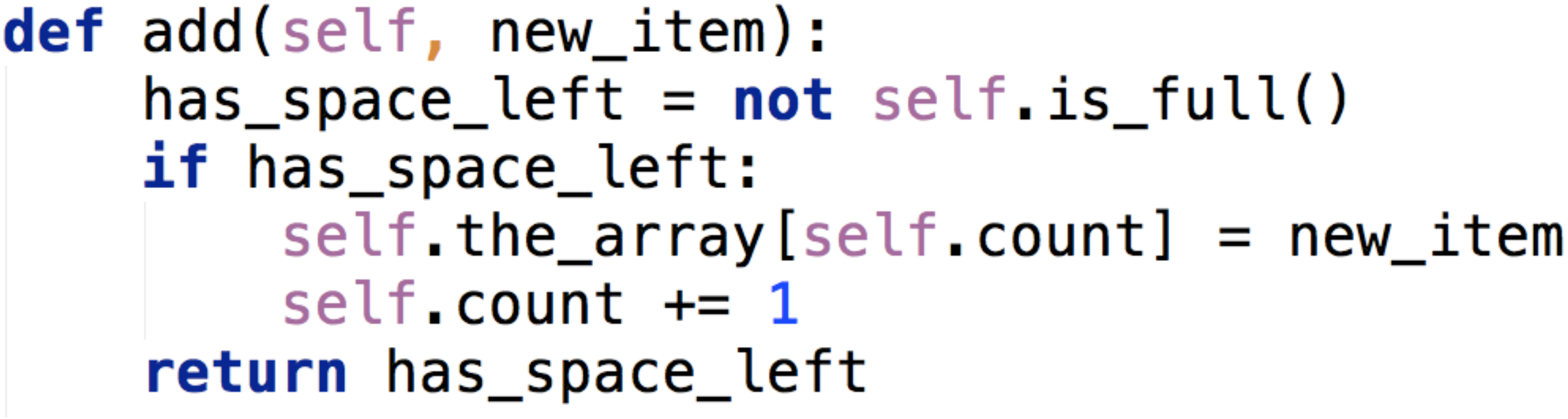
- Algorithm: add item to the_array, then increment count

- Does it always work?

- We are assuming we can always add…

- What if it is full? What to do then?
  - One possibility: return **True** if we can, **False** otherwise
  - This changes the output AND the postcondition
  - Create a new larger array copy things over?
  - What does Python do with its own lists? lists are never full…

Function add



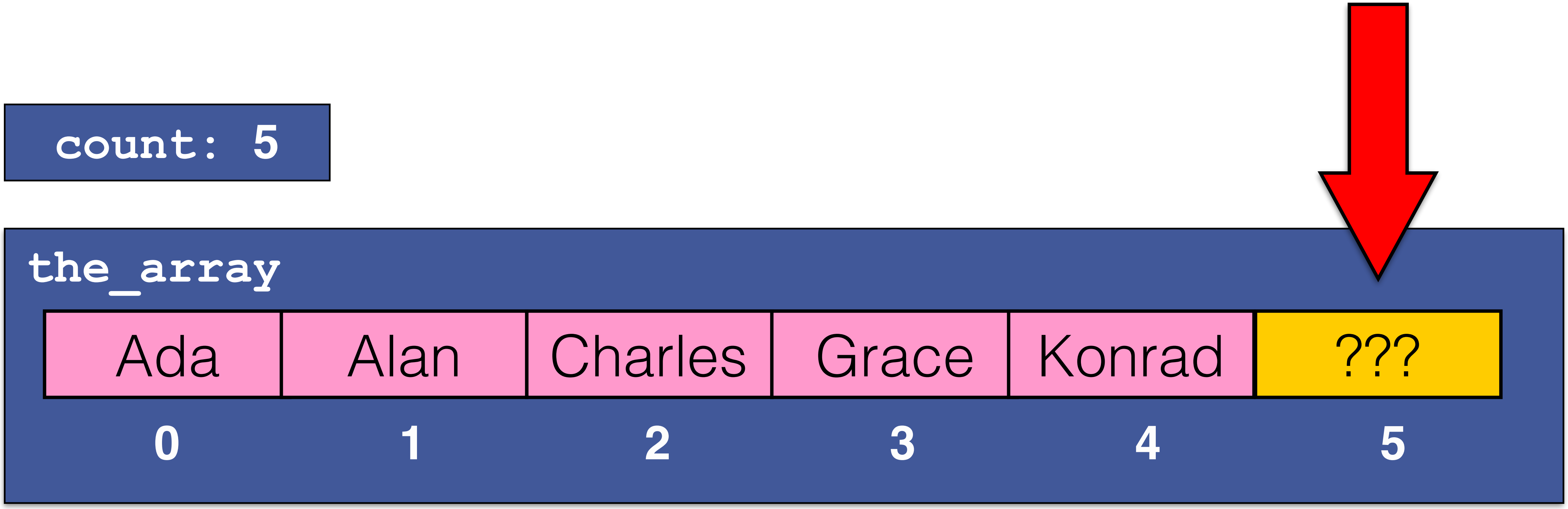
```python
def add(self, new_item):
    has_space_left = not self.is_full()
    if has_space_left:
        self.the_array[self.count] = new_item
        self.count += 1
    return has_space_left
```

What if this raises an Exception instead of returning a boolean?

Deleting an element from a list

- **Input:**
  - List (in our case: array + count)
  - **<u>Position of the element to be deleted</u>**
- **Output:**
  - List
  - Contains <u>all original elements</u> <u>EXCEPT the deleted element</u>
  - **Assume:** Remaining elements retain initial ordering.

`Example: delete item in position 2`

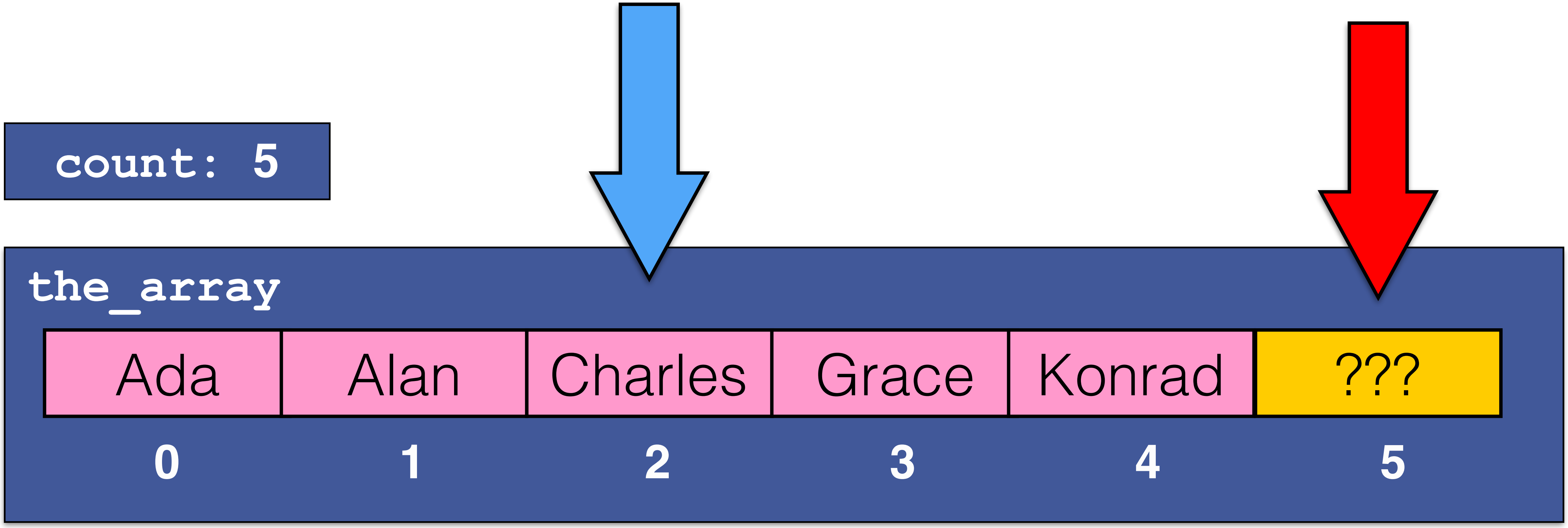


`count: 5`

`the_array`

0	1	2	3	4	5
Ada	Alan	Charles	Grace	Konrad	???

Example: delete item in position 2

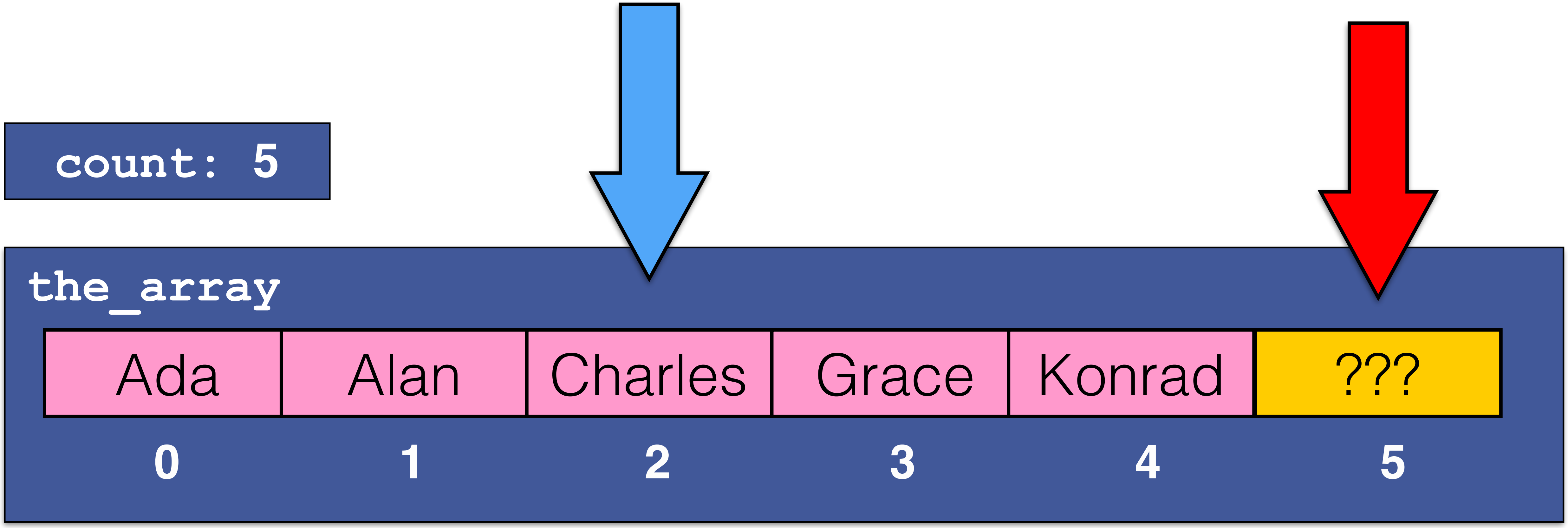


count: 5

the_array

Ada	Alan	Charles	Grace	Konrad	???
0	1	2	3	4	5

Example: delete item in position 2



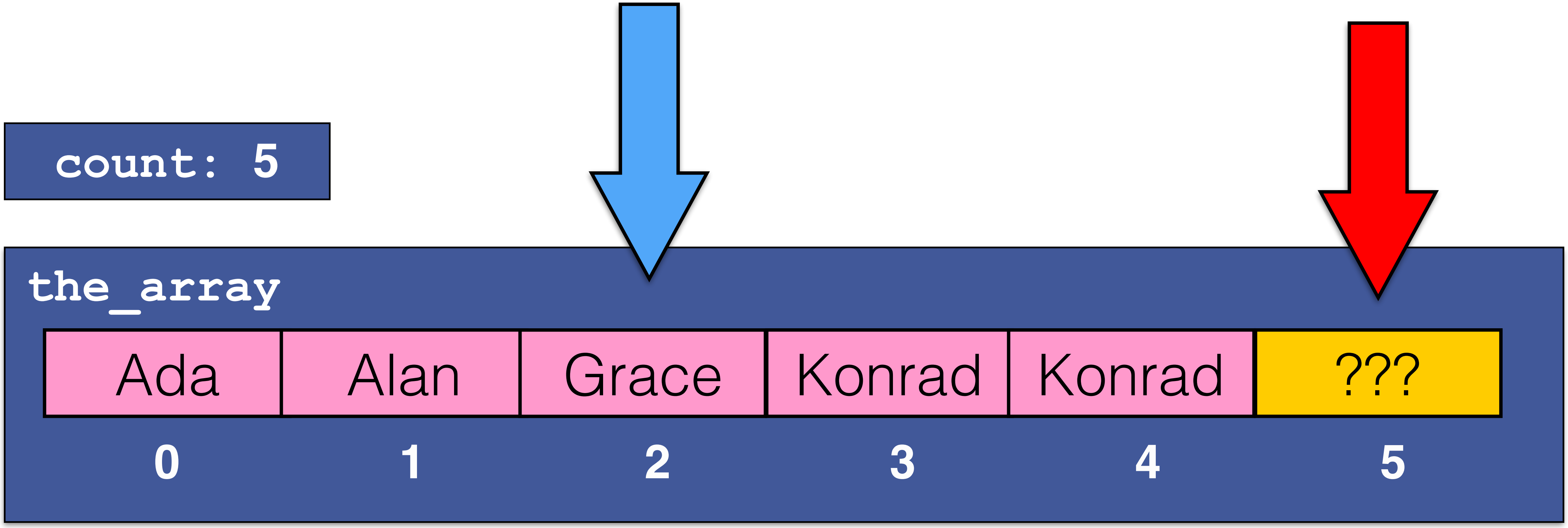
count: 5

the_array

Ada	Alan	Charles	Grace	Konrad	???
0	1	2	3	4	5

Move items appearing after the deleted item

Example: delete item in position 2



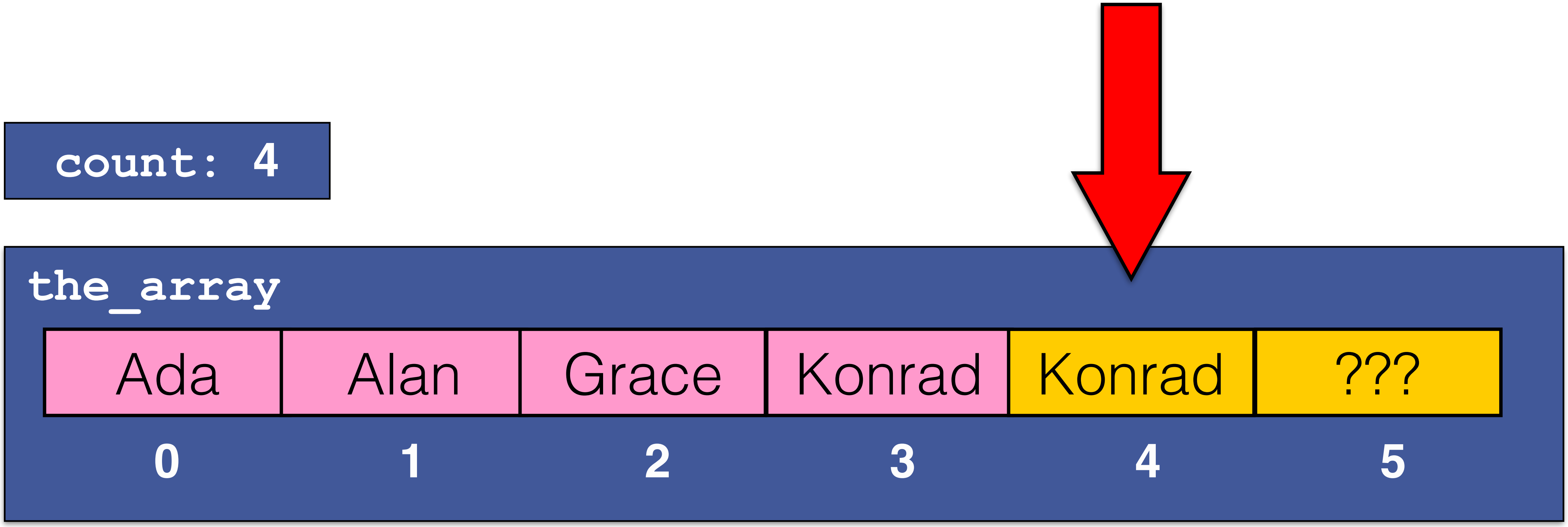
count: 5

the_array

Ada	Alan	Grace	Konrad	Konrad	???
0	1	2	3	4	5

Move items appearing after the deleted item

`Example: delete item in position 2`



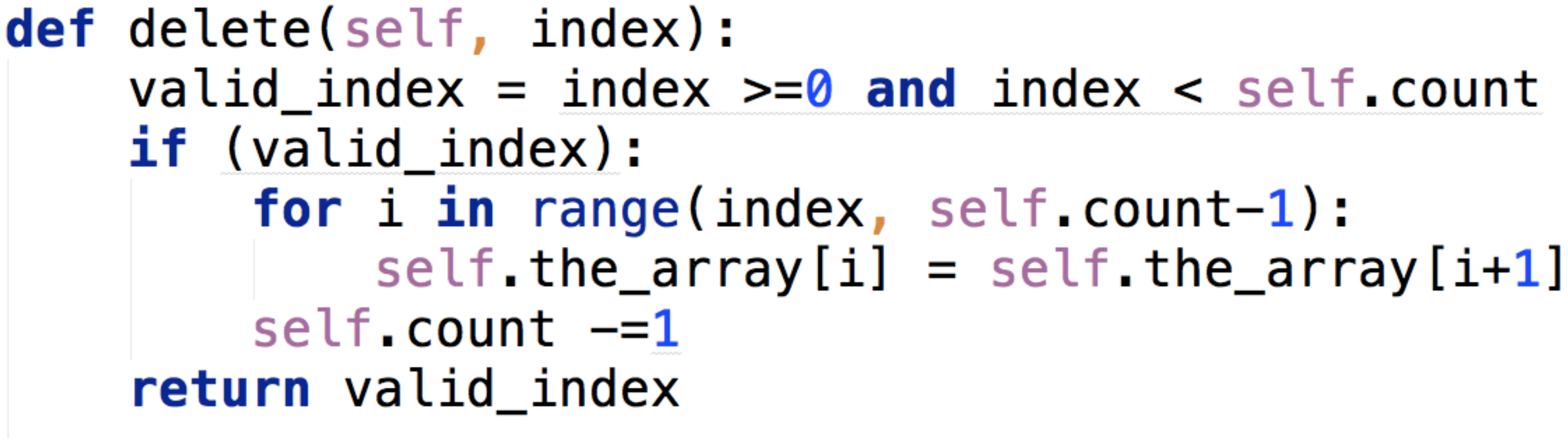
`count: 4`

`the_array`

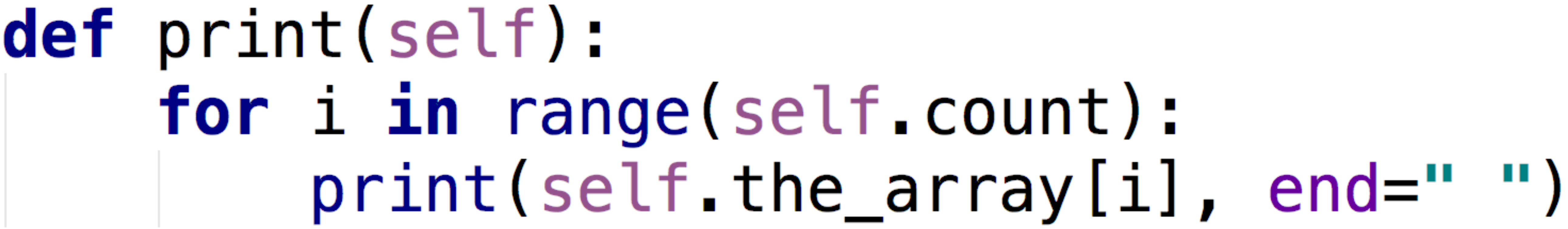
Ada	Alan	Grace	Konrad	Konrad	???
0	1	2	3	4	5

Move items appearing after the deleted item

Decrement count



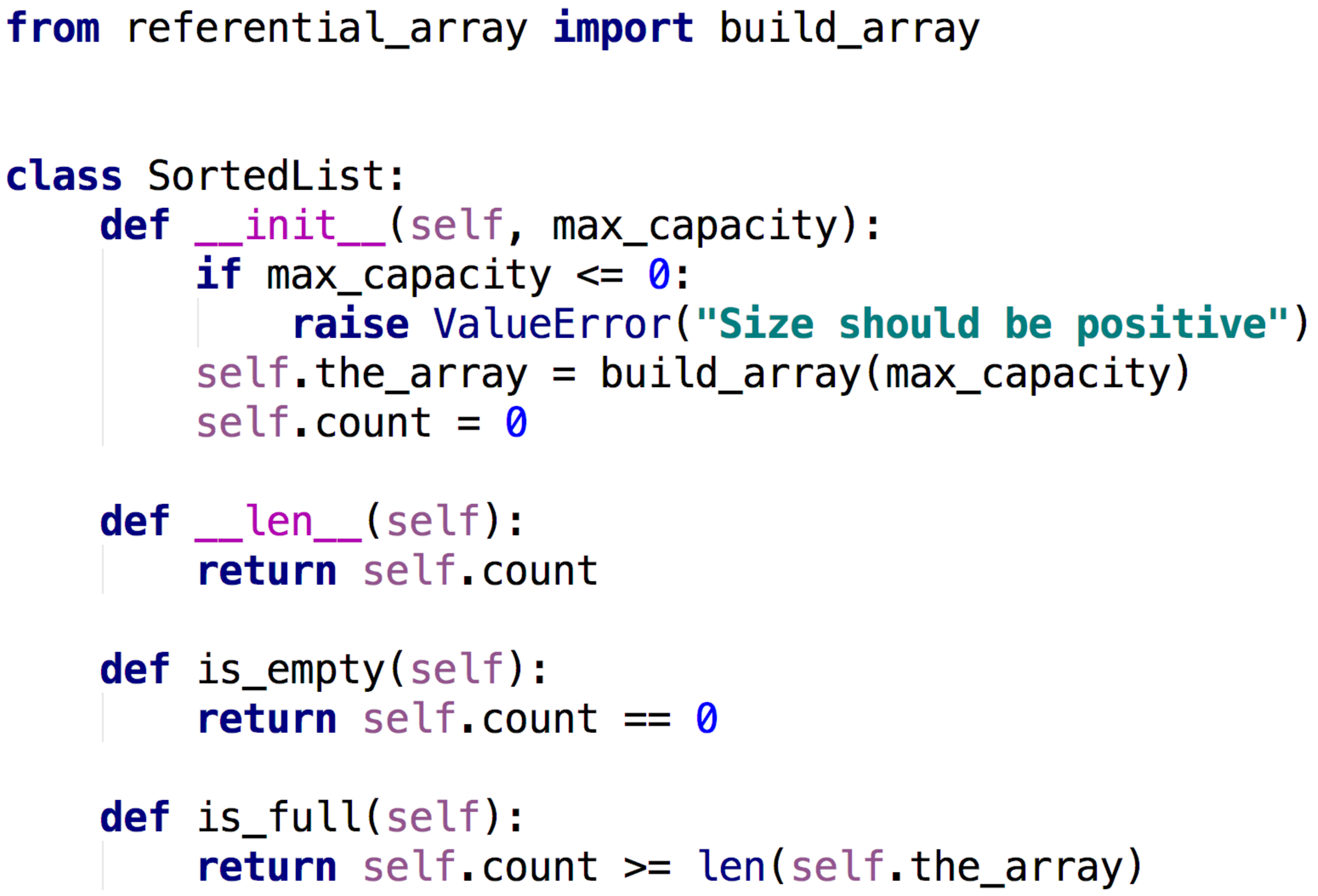
```python
def delete(self, index):
    valid_index = index >=0 and index < self.count
    if (valid_index):
        for i in range(index, self.count-1):
            self.the_array[i] = self.the_array[i+1]
        self.count -=1
    return valid_index
```



```python
def print(self):
    for i in range(self.count):
        print(self.the_array[i], end=" ")
```

SortedList ADT

- Sequence of items in increasing order
- Possible Operations:
    - **Create** a list
    - **Add item** to the list
    - **Delete** an **item** at a given position from the list
    - Check whether the list **is empty**
    - Check whether the list **is full**
    - Get the **length** of the list.



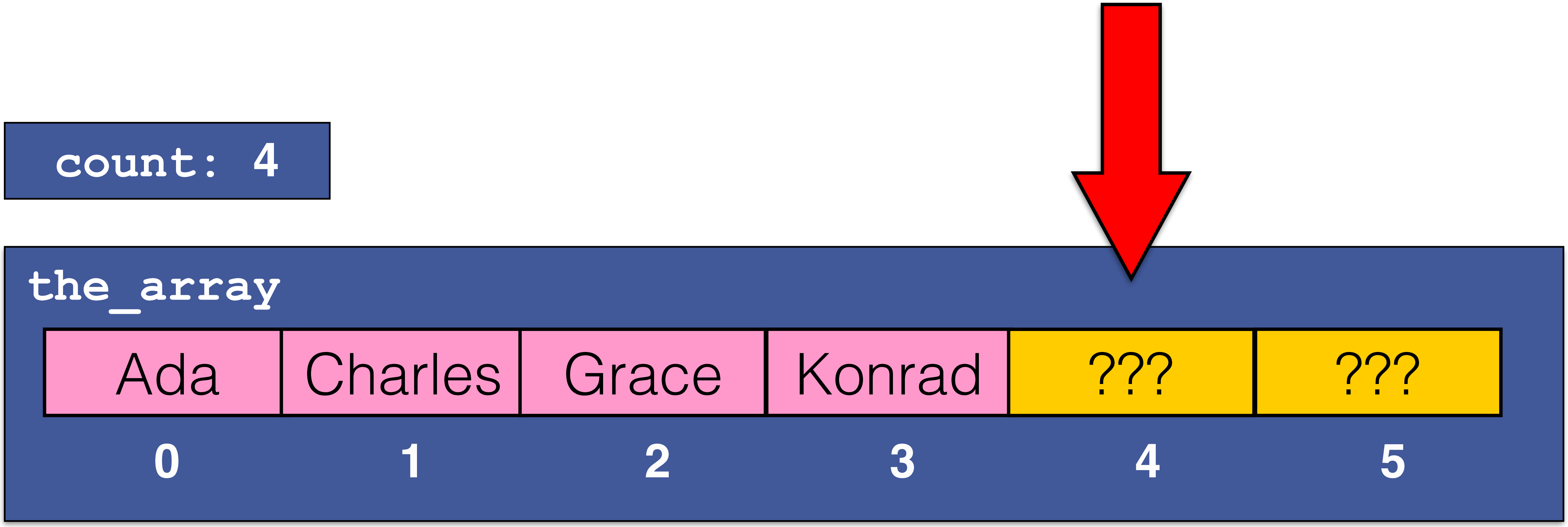
```
from referential_array import build_array


class SortedList:
    def __init__(self, max_capacity):
        if max_capacity <= 0:
            raise ValueError("Size should be positive")
        self.the_array = build_array(max_capacity)
        self.count = 0

    def __len__(self):
        return self.count

    def is_empty(self):
        return self.count == 0

    def is_full(self):
        return self.count >= len(self.the_array)
```

Adding an element to a sorted list

- **Sorted list**: Element at position i is <= than that at postion i+1

- **Input:**
  - Sorted list
  - new_item to be added
- **Output:**
  - Sorted list
  - **False** if the list was full; **True**, then the list contains all original elements in the same order together with the new_item (postcondition)
- **Note**:
  - the "Sorted" is also a pre/postcondition

Example: add “Alan”
to the sorted list.

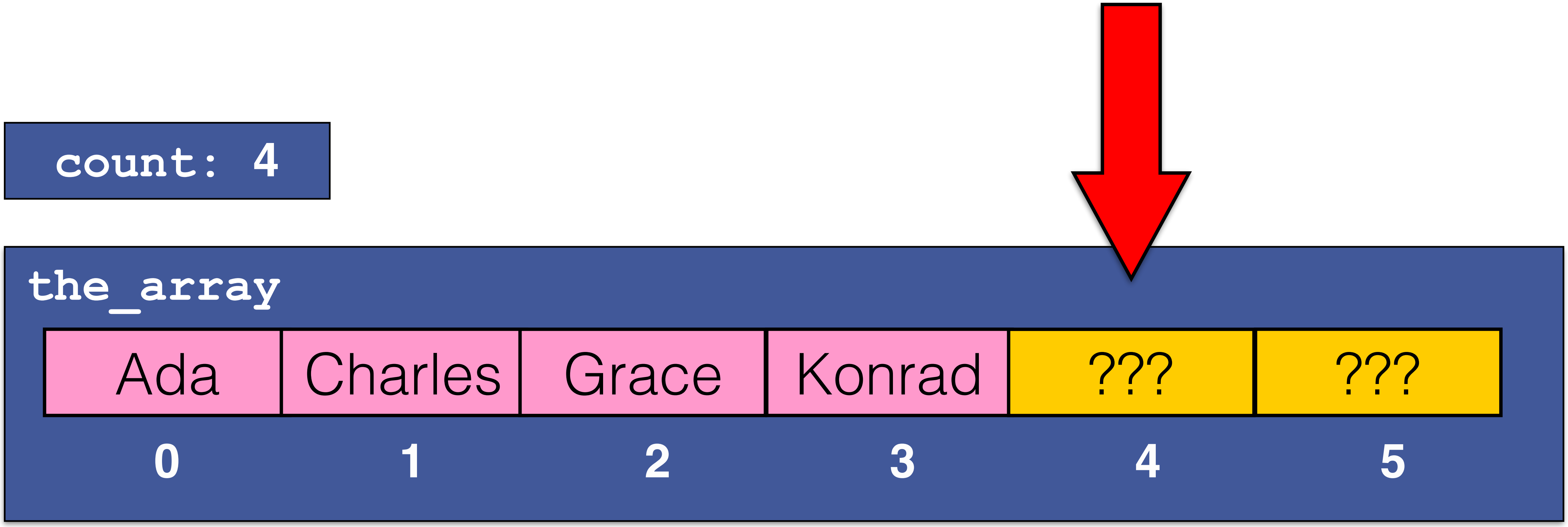


count: 4

the_array

0	1	2	3	4	5
Ada	Charles	Grace	Konrad	???	???

Example: add “Alan” to the sorted list.



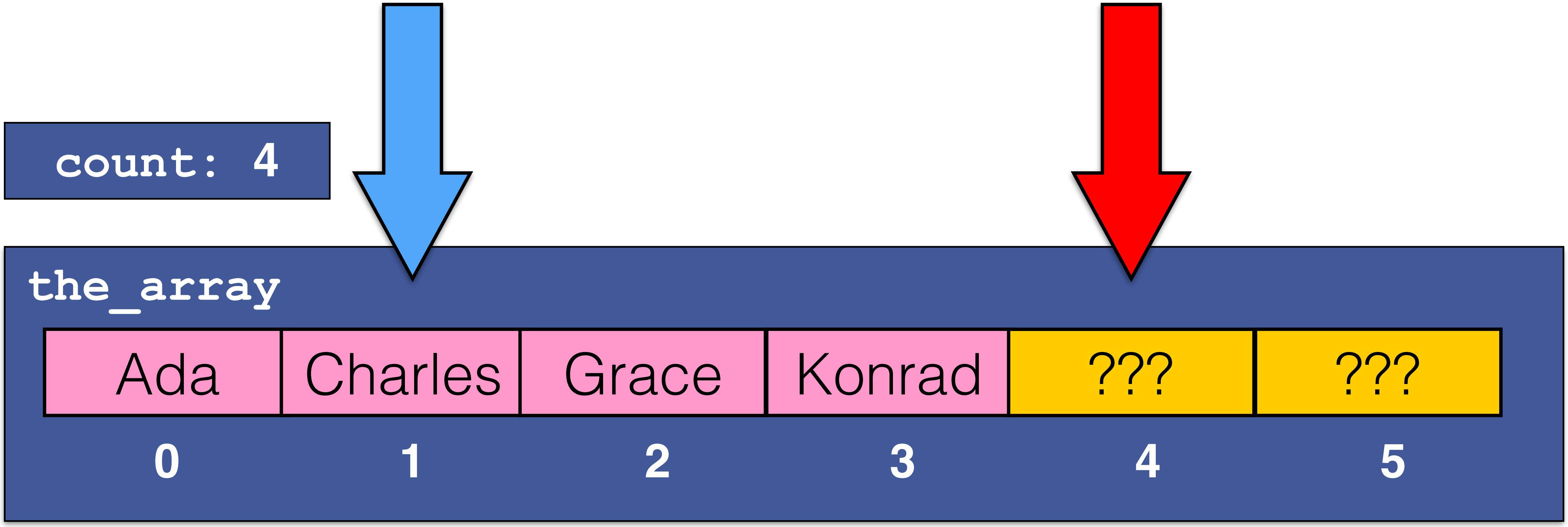
count: 4

the_array

0	1	2	3	4	5
Ada	Charles	Grace	Konrad	???	???

If there is space, find the correct position

Example: add “Alan”
to the sorted list.



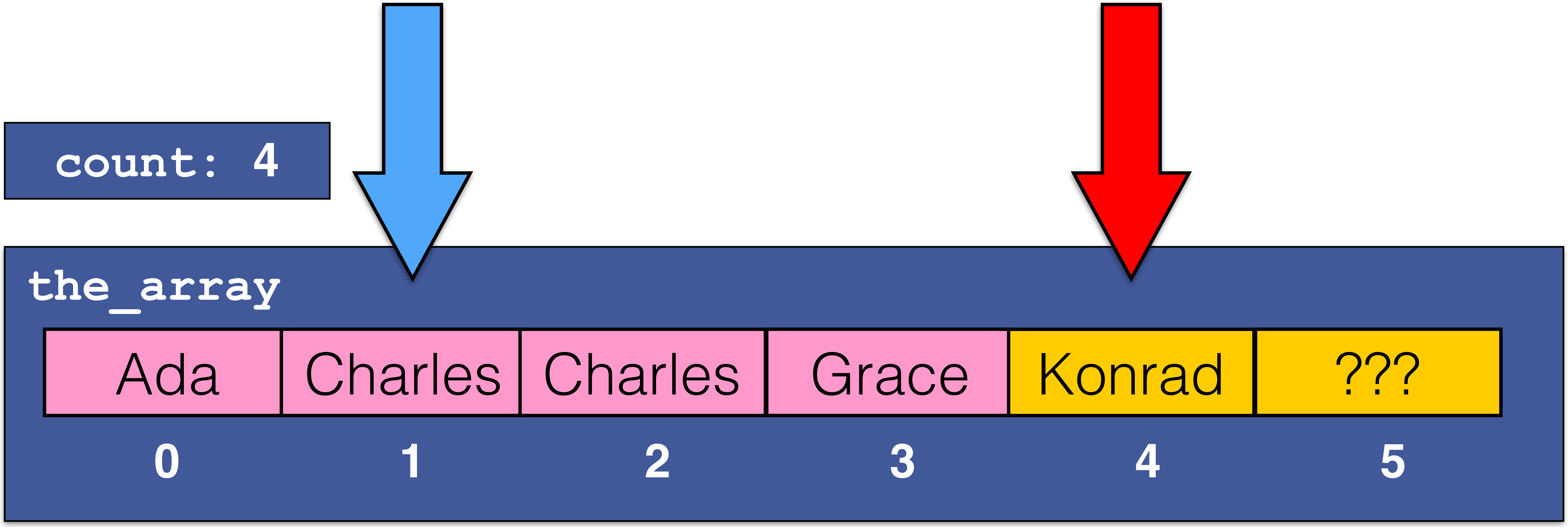
count: 4

the_array

0	1	2	3	4	5
Ada	Charles	Grace	Konrad	???	???

If there is space, find the correct position

Example: add "Alan" to the sorted list.



count: 4

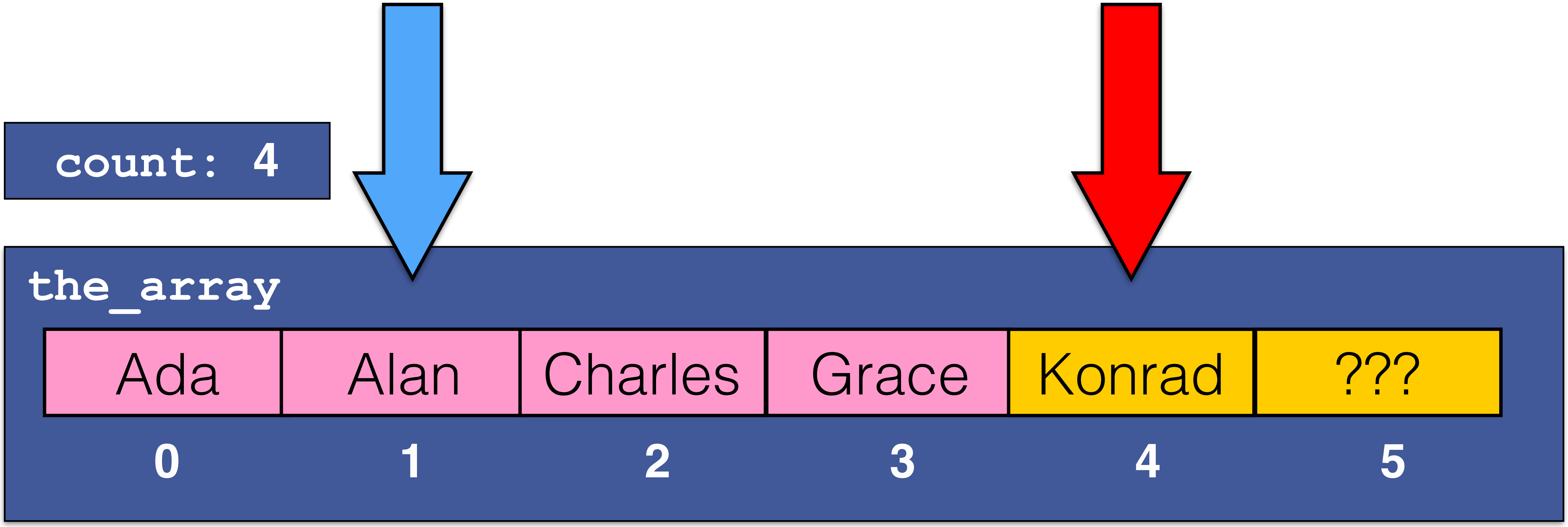
the_array

Ada	Charles	Charles	Grace	Konrad	???
0	1	2	3	4	5

If there is space, find the correct position

Make room by moving all to the right.

Example: add “Alan” to the sorted list.



count: 4

the_array

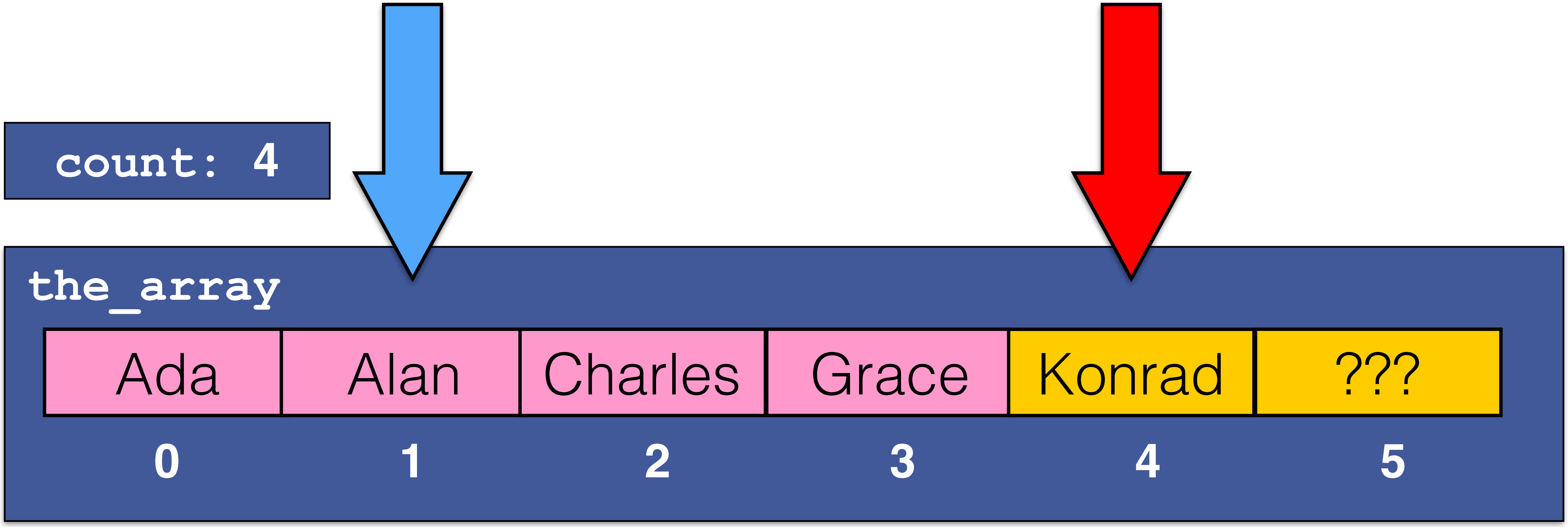
0	1	2	3	4	5
Ada	Alan	Charles	Grace	Konrad	???

If there is space, find the correct position

Make room by moving all to the right.

Put item in position.

Example: add "Alan" to the sorted list.



count: 4

the_array

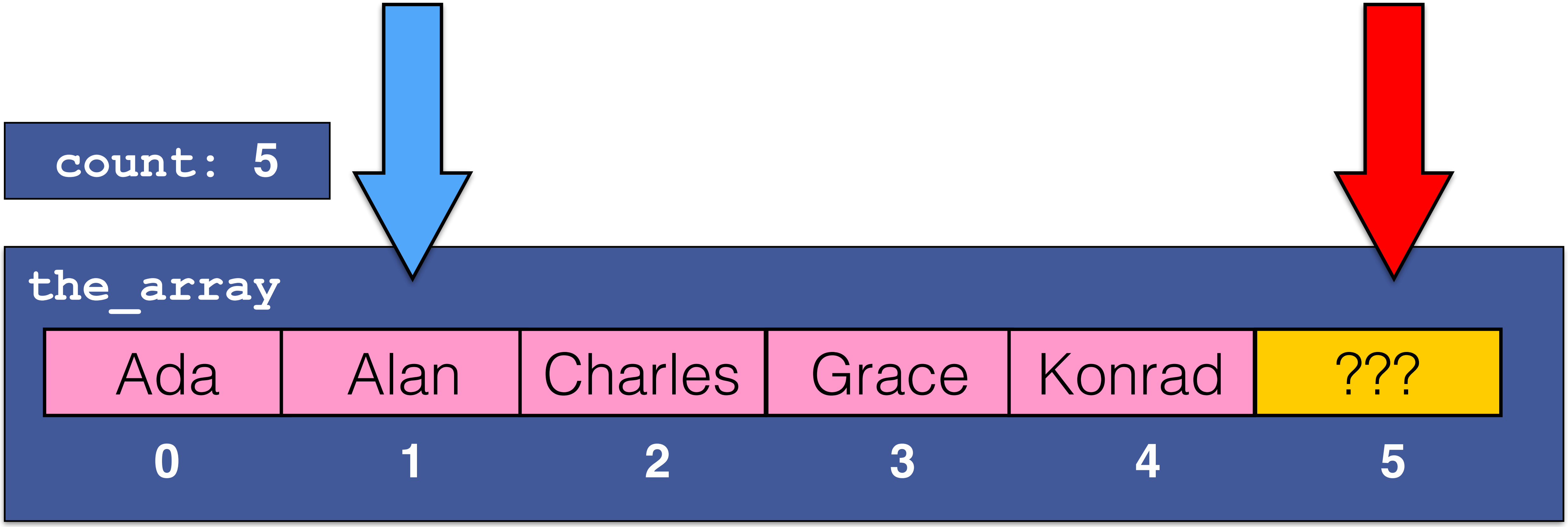
Ada	Alan	Charles	Grace	Konrad	???
0	1	2	3	4	5

If there is space, find the correct position

Make room by moving all to the right.

Put item in position.

Example: add "Alan" to the sorted list.



count: 5

the_array

0	1	2	3	4	5
Ada	Alan	Charles	Grace	Konrad	???

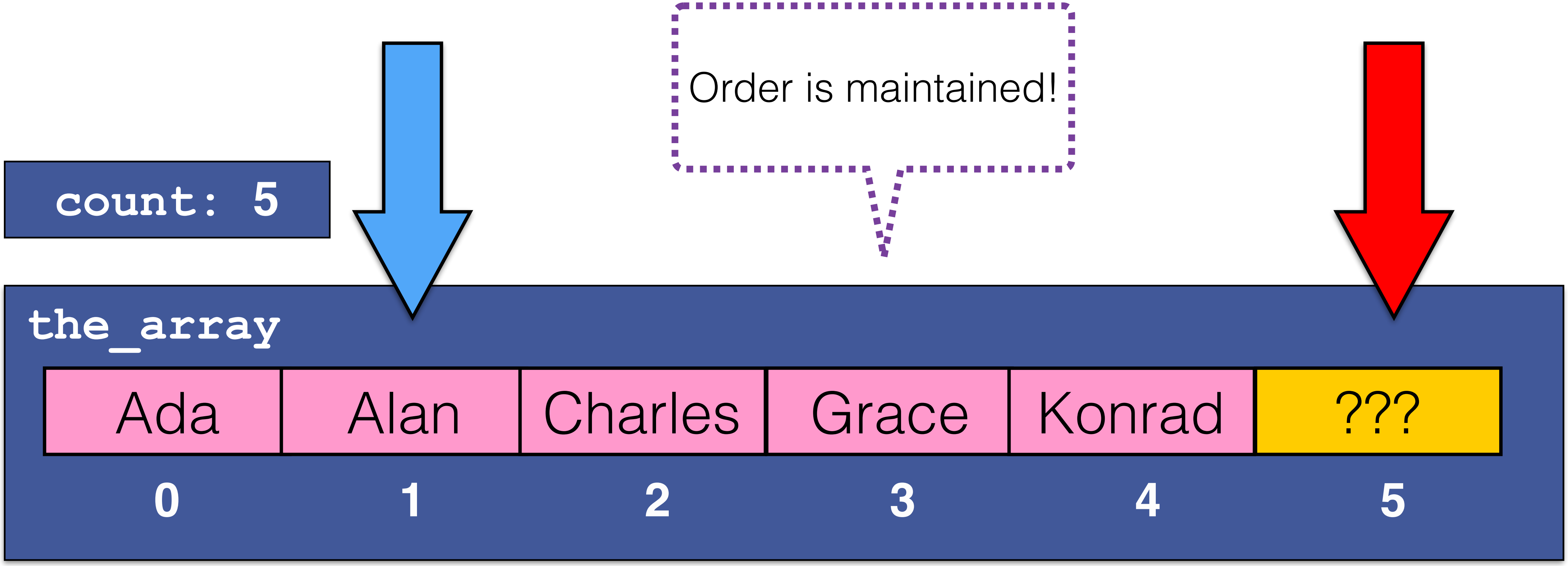
If there is space, find the correct position

Make room by moving all to the right.

Put item in position.

Update count

Example: add "Alan" to the sorted list.



Order is maintained!

count: 5

the_array

Ada	Alan	Charles	Grace	Konrad	???
0	1	2	3	4	5

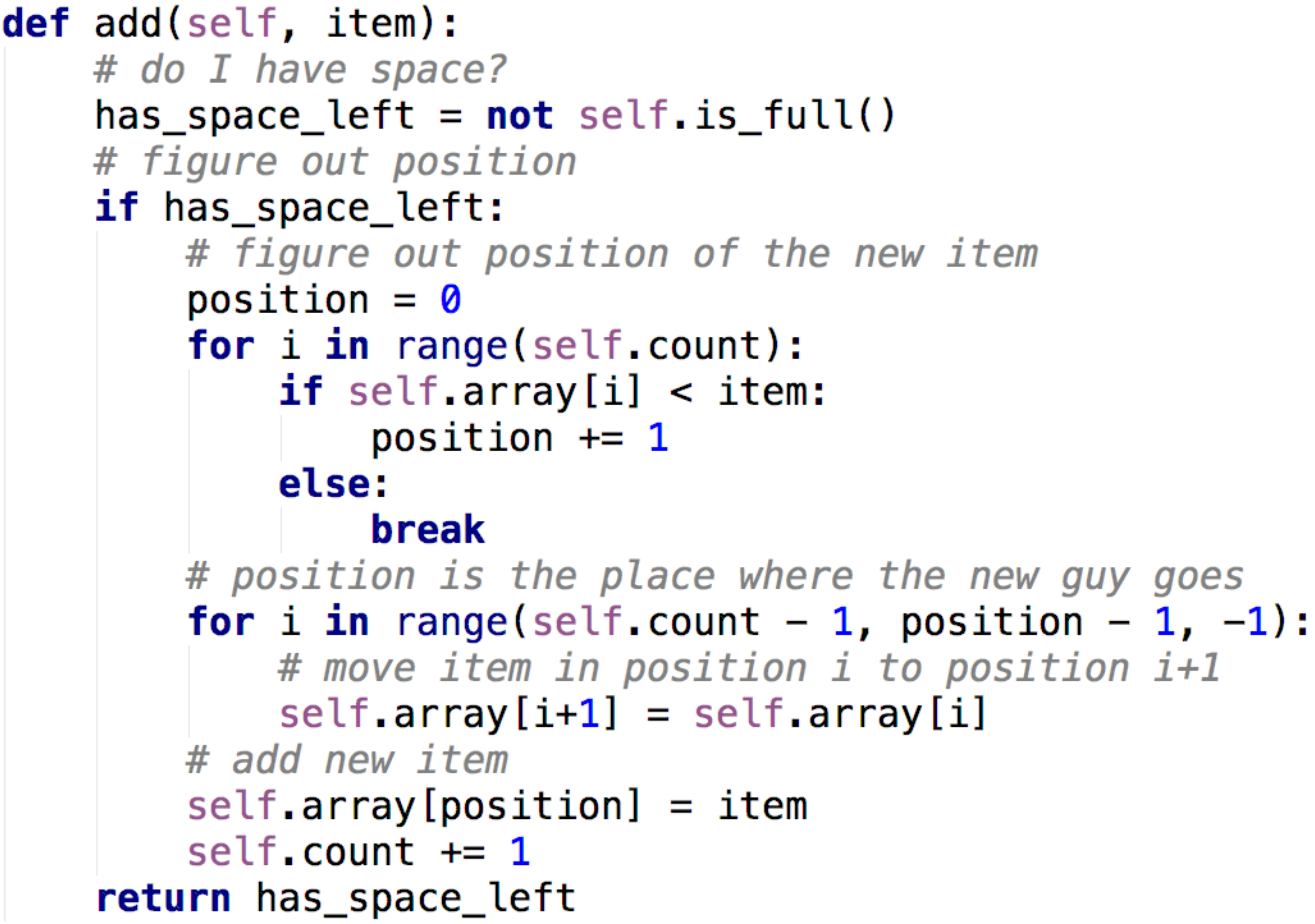
If there is space, find the correct position

Make room by moving all to the right.

Put item in position.

Update count then **return True**

```
If the array has some space left:
    find correct index at which to add item.
    make room: move all items from index to count-1 to the right
    put item in position index.
    increment count
    return True.
else:
    return False.
```



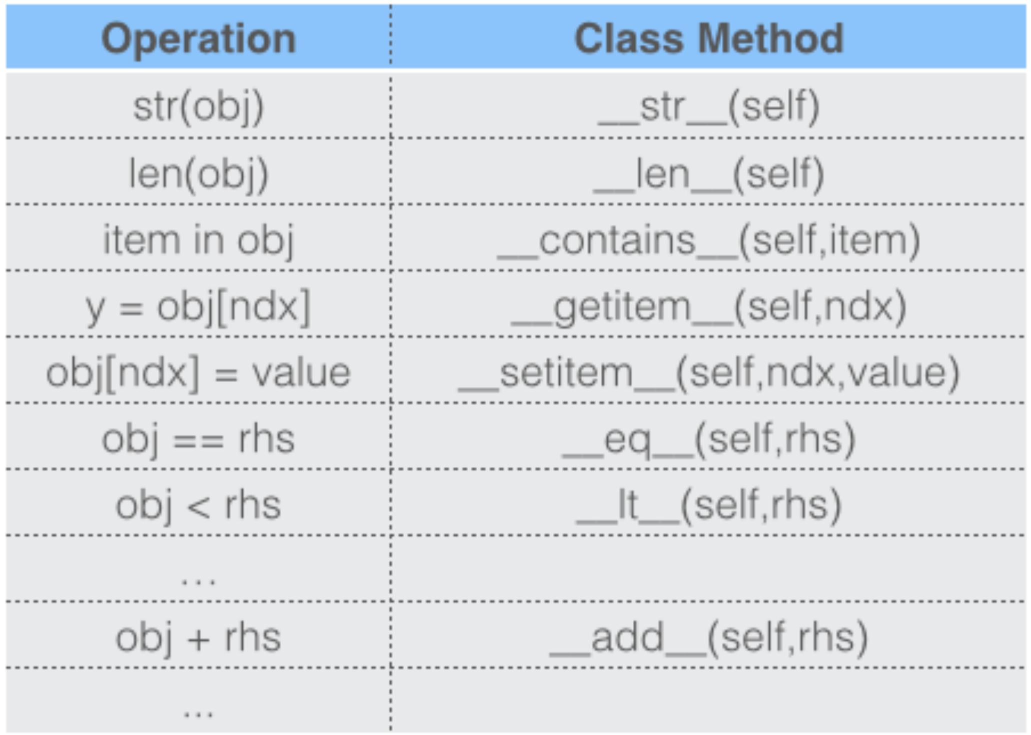
```python
def add(self, item):
    # do I have space?
    has_space_left = not self.is_full()
    # figure out position
    if has_space_left:
        # figure out position of the new item
        position = 0
        for i in range(self.count):
            if self.array[i] < item:
                position += 1
            else:
                break
        # position is the place where the new guy goes
        for i in range(self.count - 1, position - 1, -1):
            # move item in position i to position i+1
            self.array[i+1] = self.array[i]
        # add new item
        self.array[position] = item
        self.count += 1
    return has_space_left
```

Overloading operators

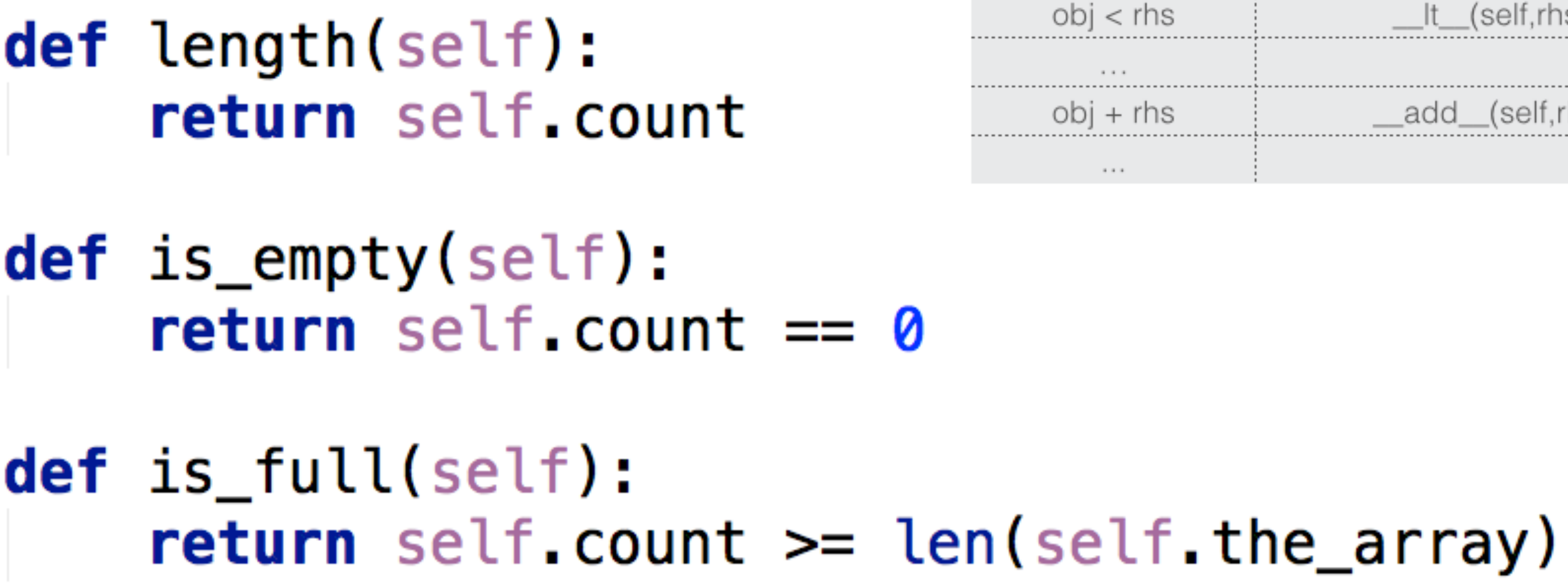
- Any class can **redefine** certain special operations:
- By simply defining the **associated method** inside the class

Operation	Class Method
str(obj)	__str__(self)
len(obj)	__len__(self)
item in obj	__contains__(self,item)
y = obj[ndx]	__getitem__(self,ndx)
obj[ndx] = value	__setitem__(self,ndx,value)
obj == rhs	
obj < rhs	
...	
obj + rhs	
...	

Python checks whether the appropriate method is available to the object. If **not defined**, the **built-in operation** (if any) is used.

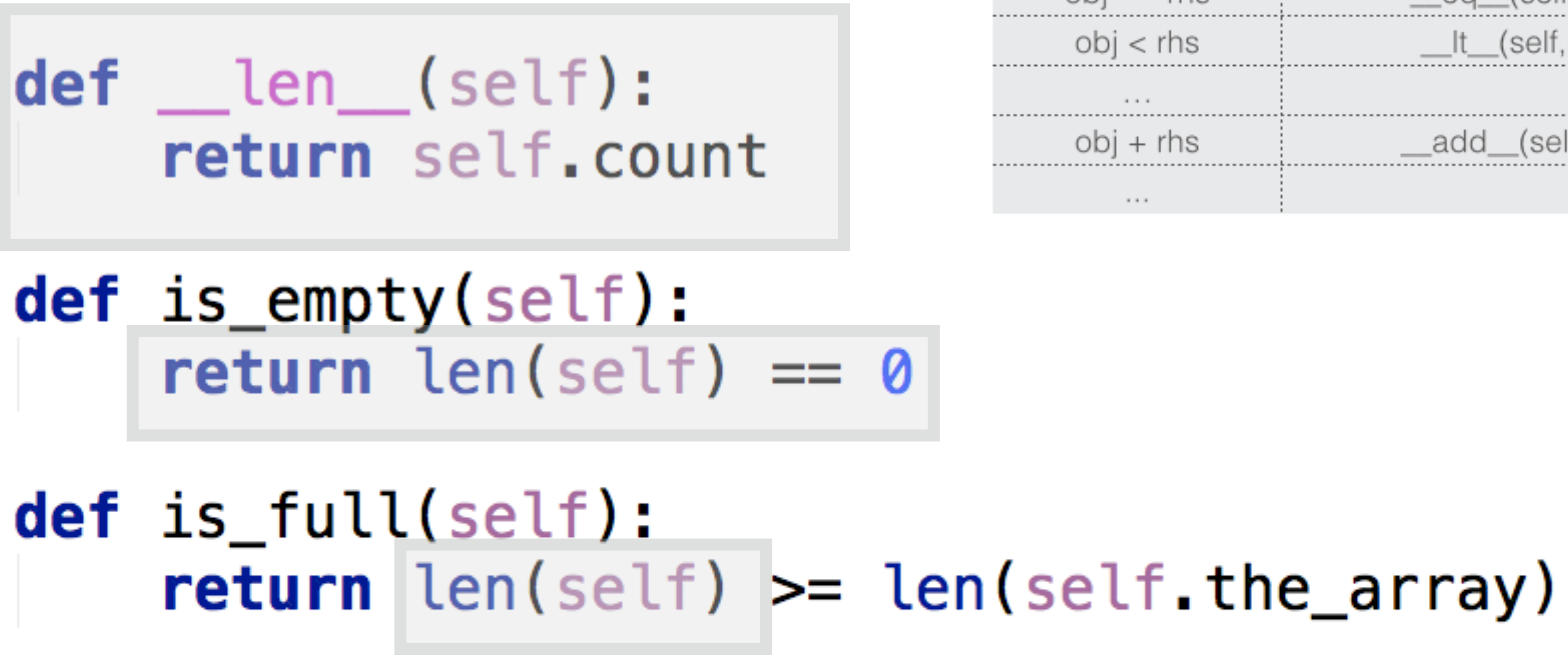


Operation	Class Method
str(obj)	__str__(self)
len(obj)	__len__(self)
item in obj	__contains__(self,item)
y = obj[ndx]	__getitem__(self,ndx)
obj[ndx] = value	__setitem__(self,ndx,value)
obj == rhs	__eq__(self,rhs)
obj < rhs	__lt__(self,rhs)
...	
obj + rhs	__add__(self,rhs)
...	



```
def length(self):
    return self.count

def is_empty(self):
    return self.count == 0

def is_full(self):
    return self.count >= len(self.the_array)
```

Operation	Class Method
str(obj)	__str__(self)
len(obj)	__len__(self)
item in obj	__contains__(self,item)
y = obj[ndx]	__getitem__(self,ndx)
obj[ndx] = value	__setitem__(self,ndx,value)
obj == rhs	__eq__(self,rhs)
obj < rhs	__lt__(self,rhs)
…	
obj + rhs	__add__(self,rhs)
…	



```python
def __len__(self):
    return self.count

def is_empty(self):
    return len(self) == 0

def is_full(self):
    return len(self) >= len(self.the_array)
```

Operation	Class Method	
str(obj)	__str__(self)	
len(obj)	__len__(self)	☑
item in obj	__contains__(self,item)	
y = obj[ndx]	__getitem__(self,ndx)	
obj[ndx] = value	__setitem__(self,ndx,value)	
obj == rhs	__eq__(self,rhs)	
obj < rhs	__lt__(self,rhs)	
…		
obj + rhs	__add__(self,rhs)	
...		

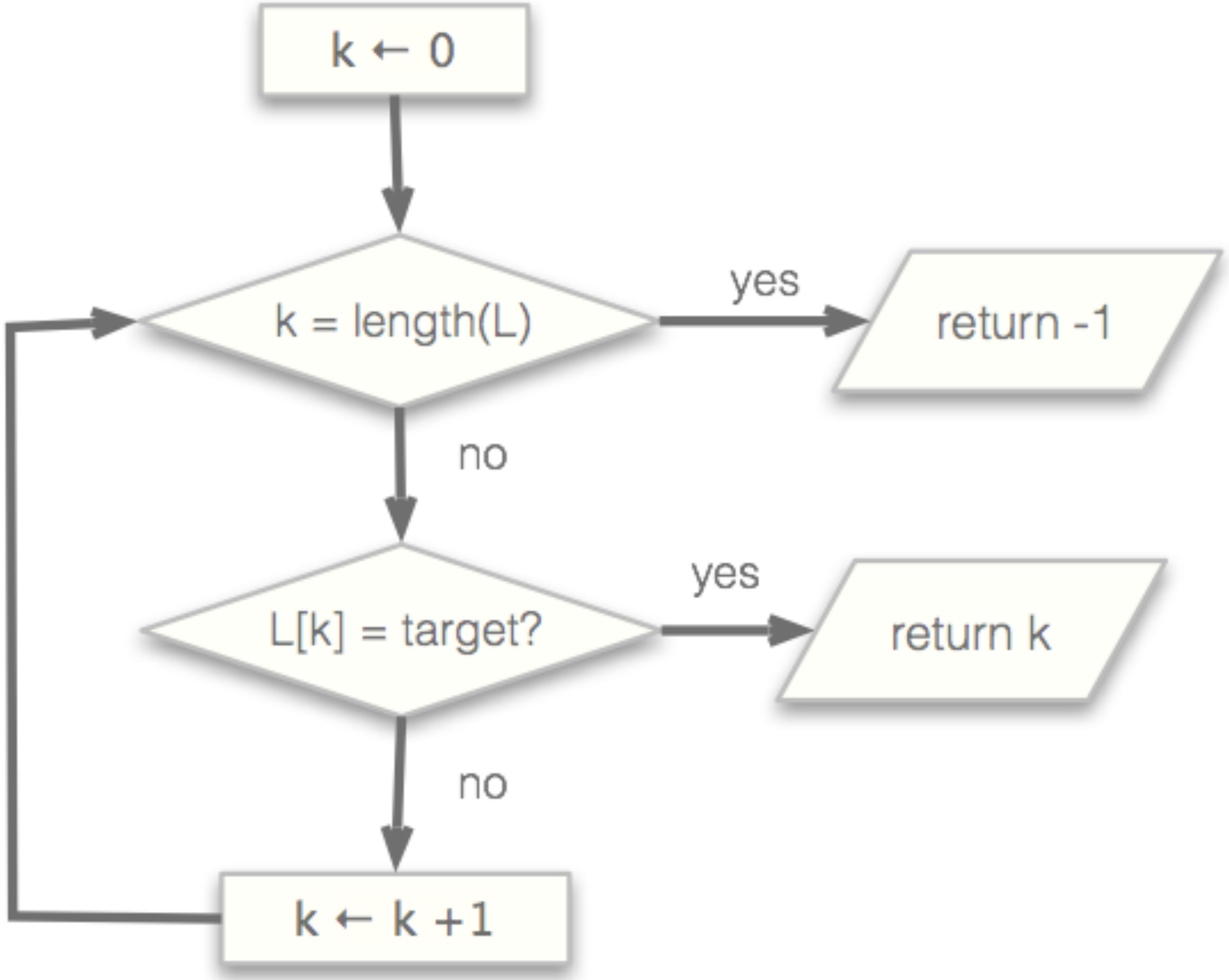
Item in List

```
>>> the_list = [1, 2, 3, 4, 5]
>>> x = 3
>>> x in the_list
True
>>> y = 8
>>> y in the_list
False
```

Item in List

```
def __contains__(self, item):
    for k in range(len(self)):
        if item == self.the_array[k]:
            return True
    return False
```

Linear Search



Can you do Binary Search
since the list is always sorted?

Summary

- Implementing lists using arrays:
  - Class structure for a list
    - Add an element to an unsorted list
    - Delete an element
  - A list that is always sorted
    - Add / Delete/ Search