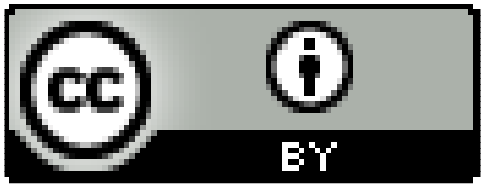
Sets and Dictionaries

Storage



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>>> things.add('a string')
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And what does the error message mean?

How are sets stored in a computer's memory?

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```
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  return []
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```
def set_create():
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def set_in(set_list, item):
  for thing in set_list:
    if thing == item:
      return True
  return False
```

```
def set_add(set_list, item):
  for thing in set_list:
    if thing == item:
      return
  set.append(item)
```

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But the solution puts some constraints on programs

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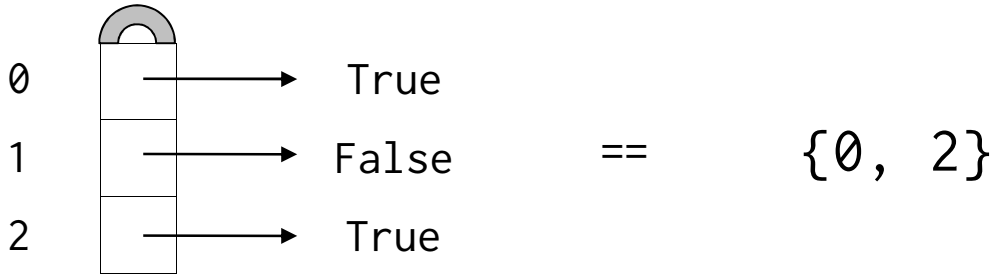

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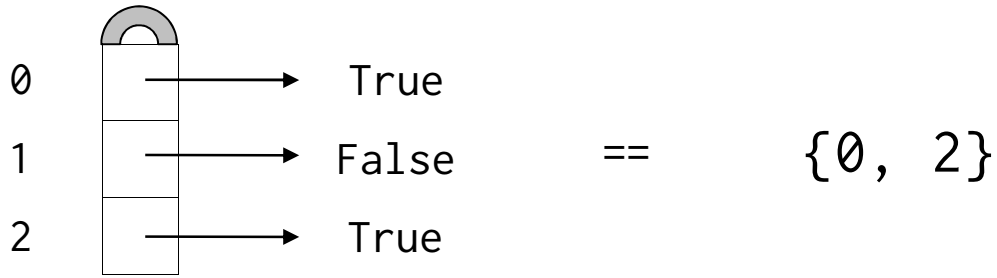

But what if the range of values is large, or can

change over time?

Use a fixed-size *hash table* of length L

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Store the integer I at location I % L

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'%' is the remainder operator

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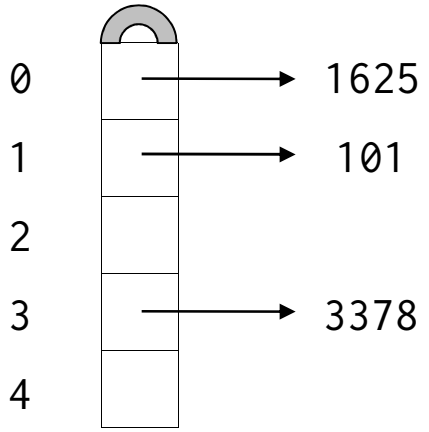
'%' is the remainder operator

```
{3378, 1625, 101}      ==
```



Time to insert or look up is constant (!)

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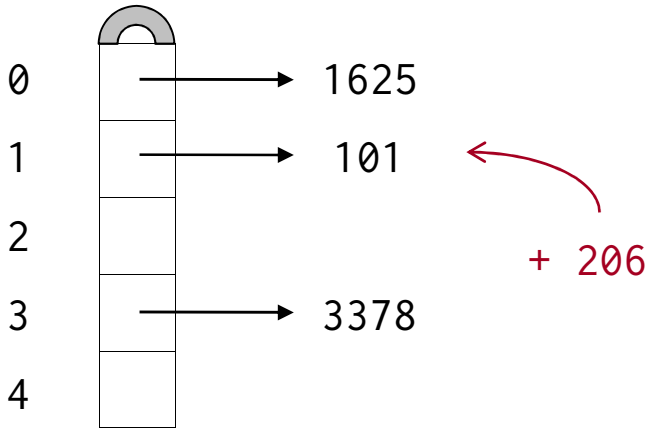
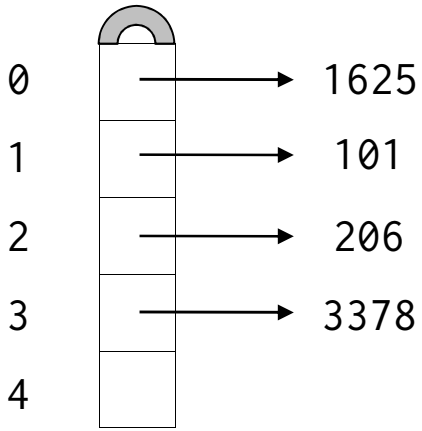
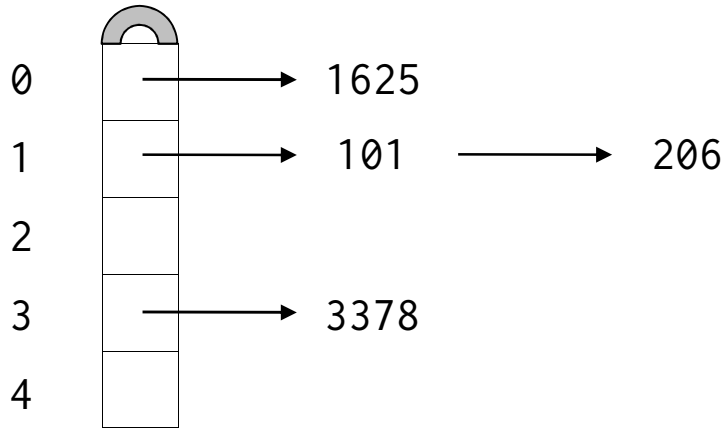


Option #1: store it in the next empty slot



Option #2: chain values together



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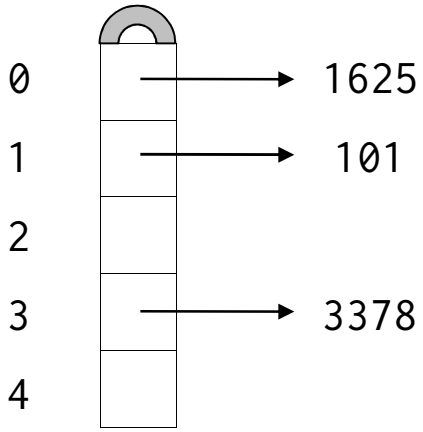

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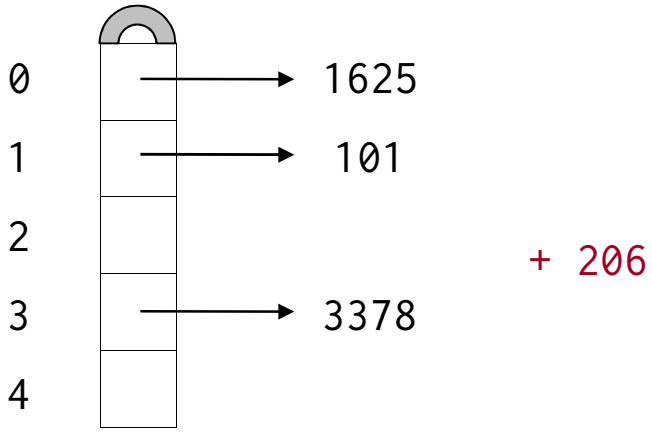


```
+ 206
```

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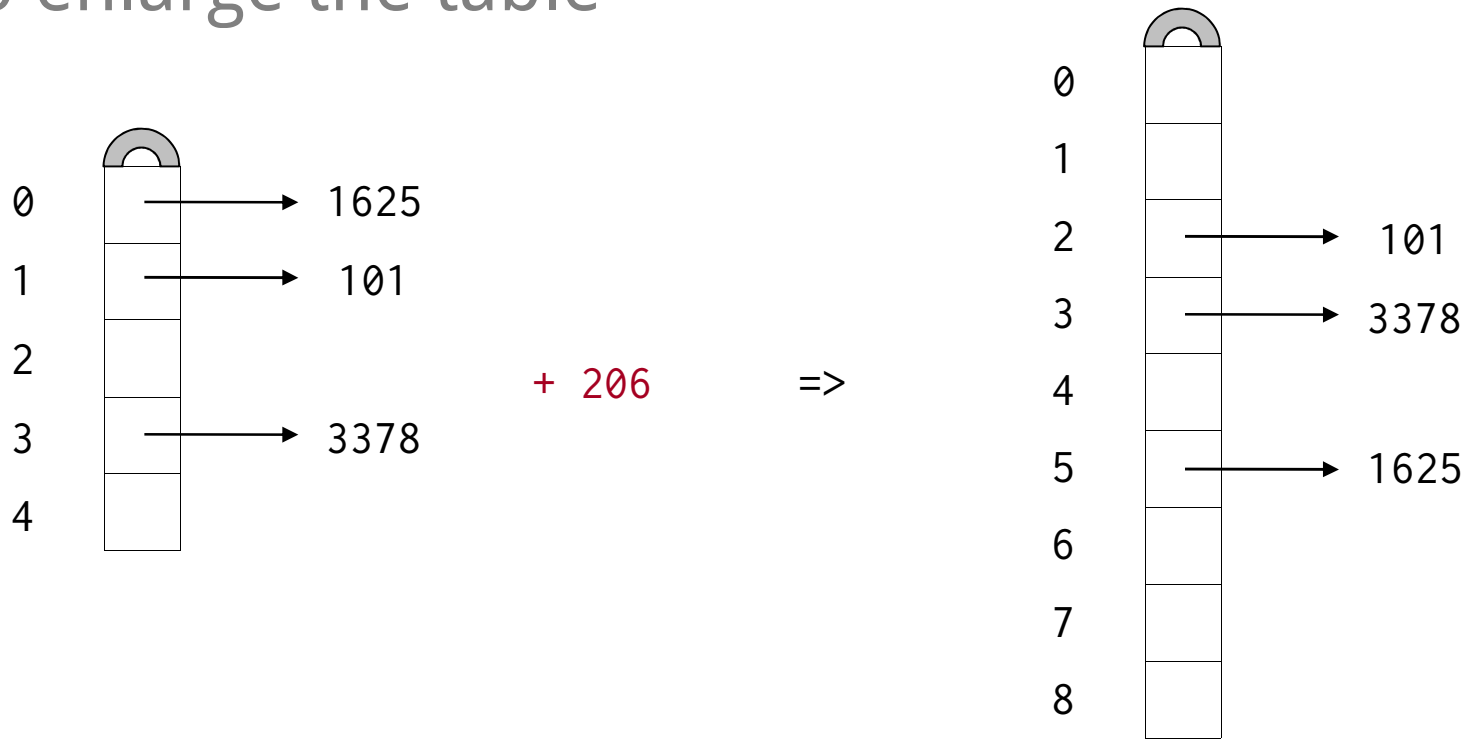

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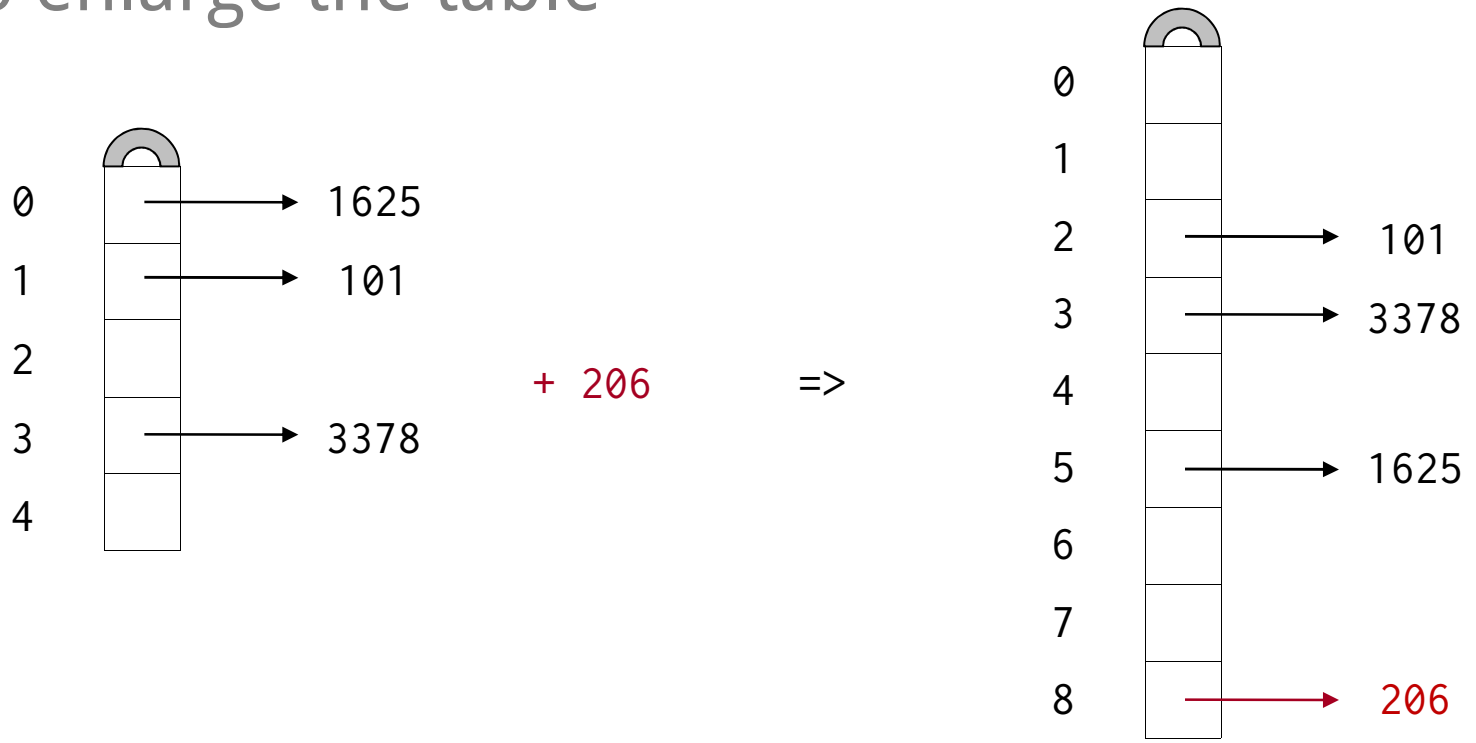

How do we store strings?

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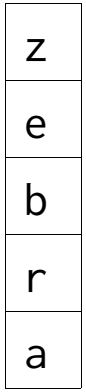
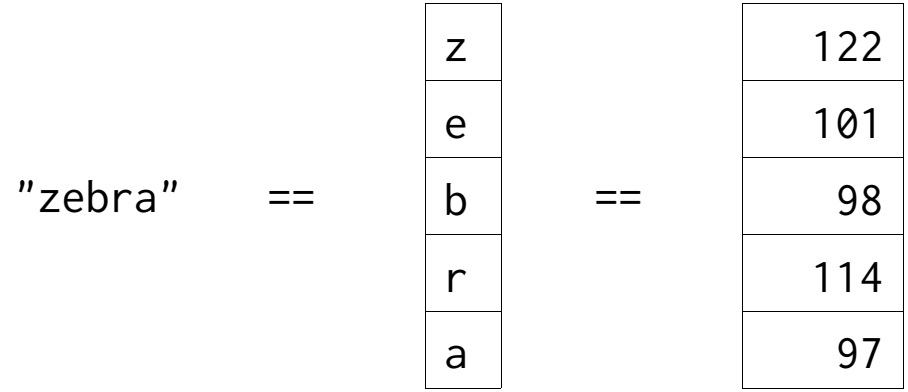
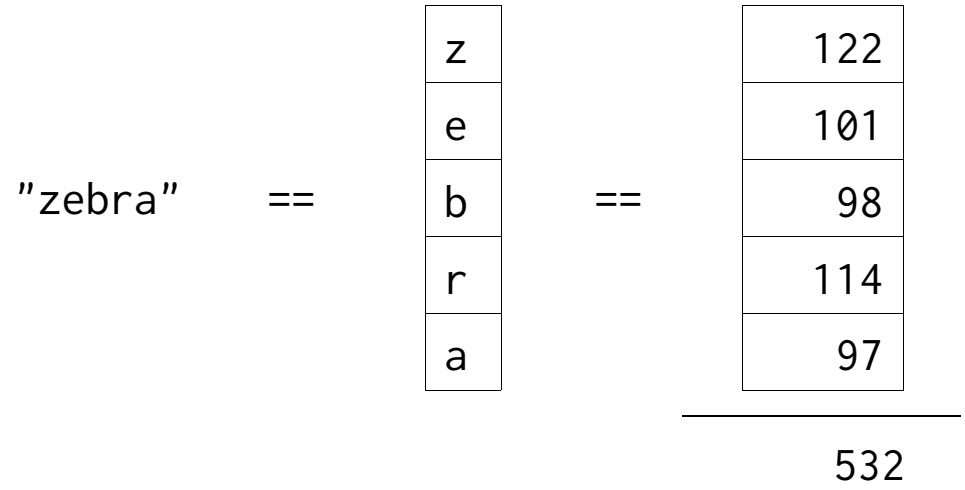
Use a *hash function* to generate an integer index based on the characters in the string

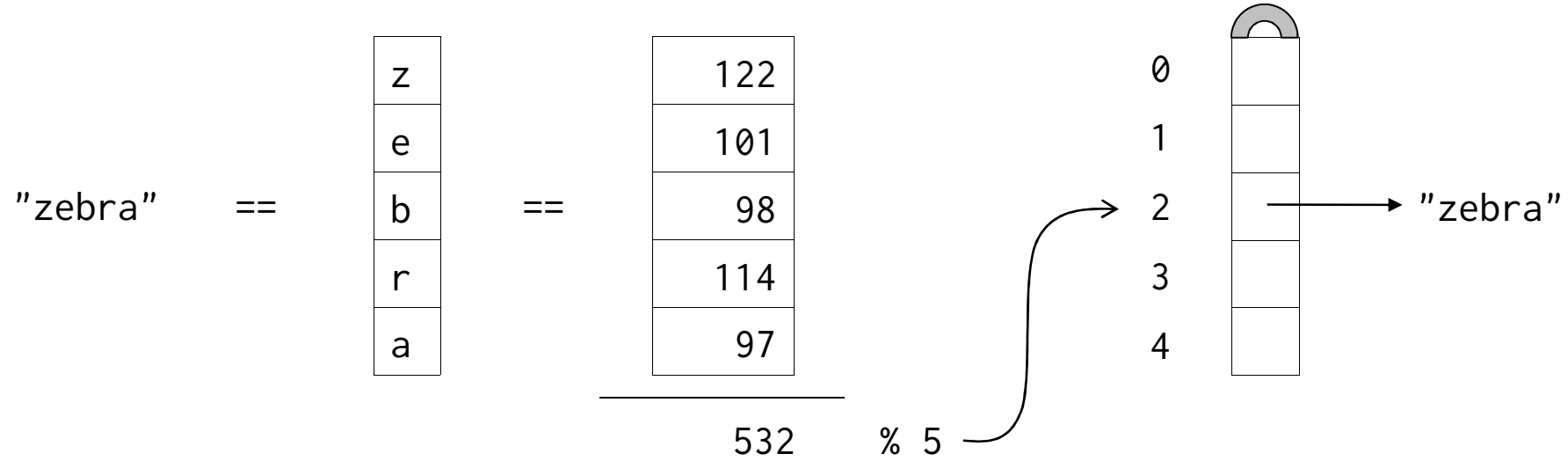
```
"zebra"
```

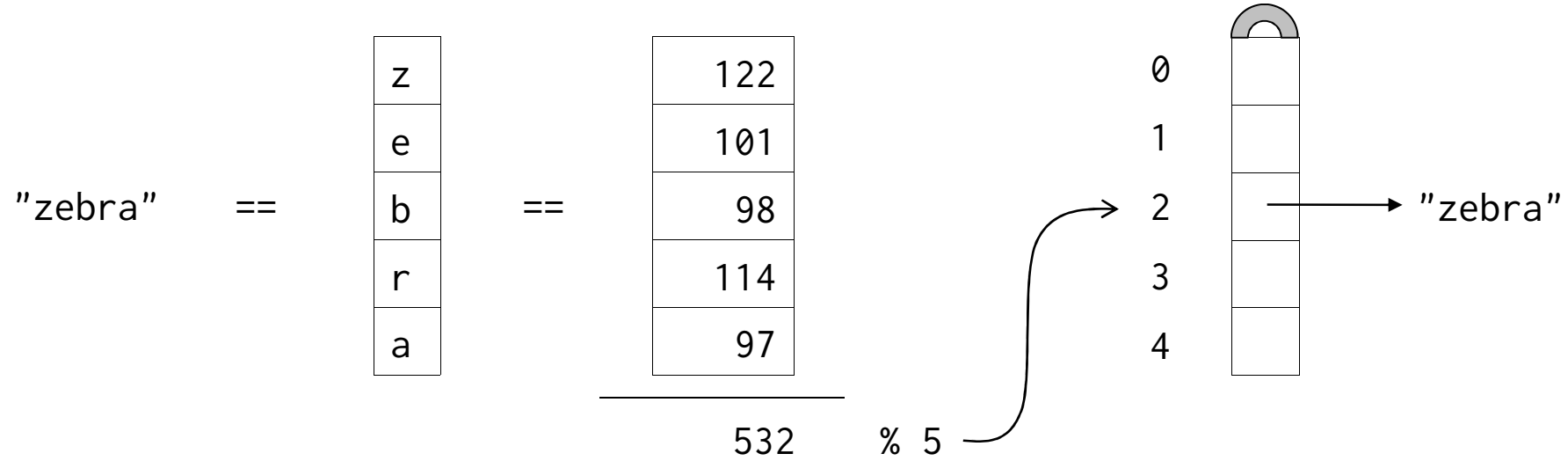
"zebra" ==




"zebra"
==
z
e
b
r
a
==
122
101
98
114
97

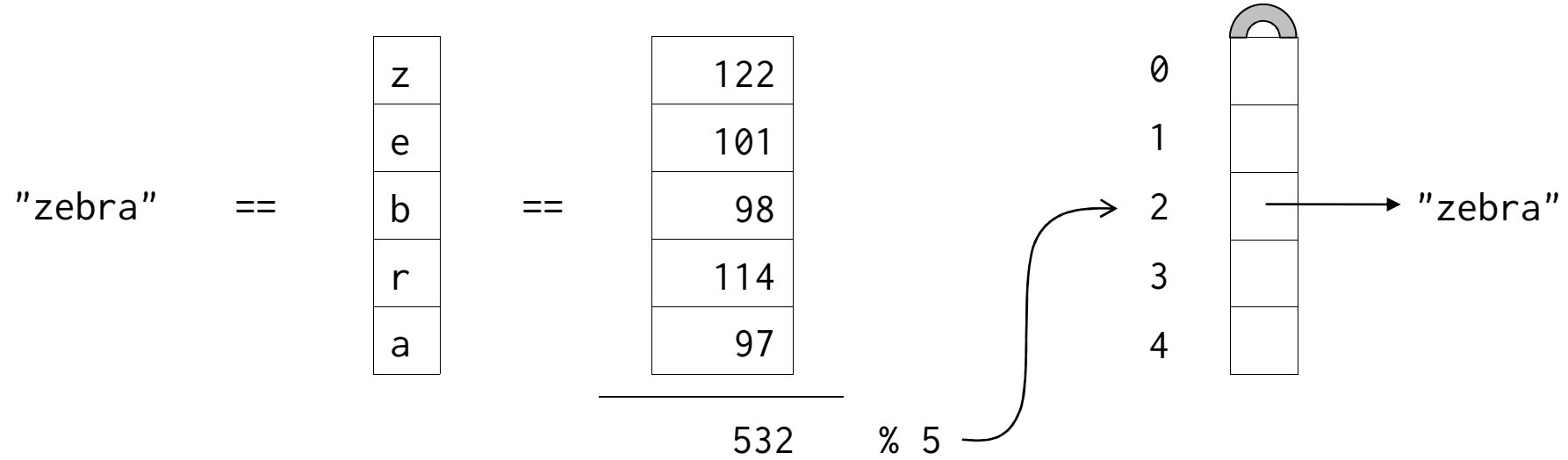

"zebra"
==
z
e
b
r
a
==
122
101
98
114
97
532


"zebra"
==
z
e
b
r
a
==
122
101
98
114
97
532
% 5
0
1
2
3
4
"zebra"



If we can define a hash function for something,

we can store it in a set



If we can define a hash function for something,

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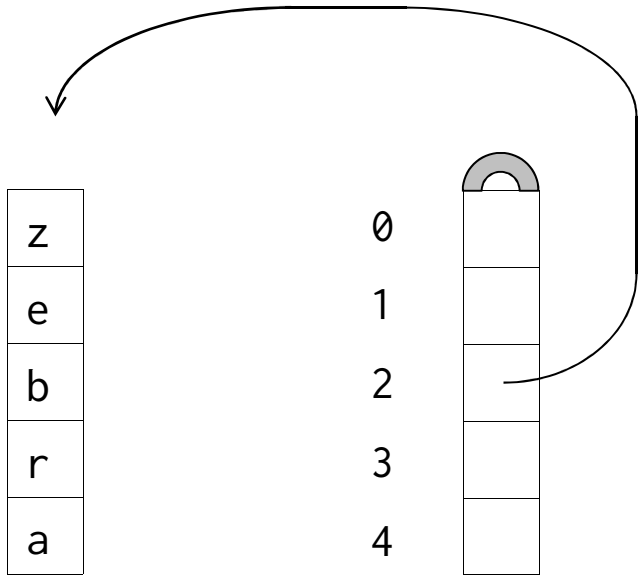
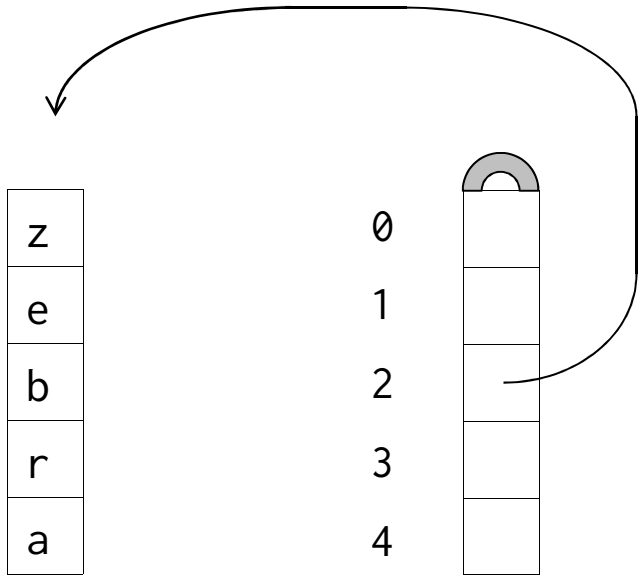
So long as nothing changes behind our back



This is what the previous example really looks like in memory

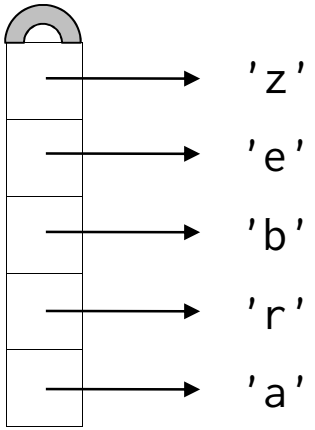


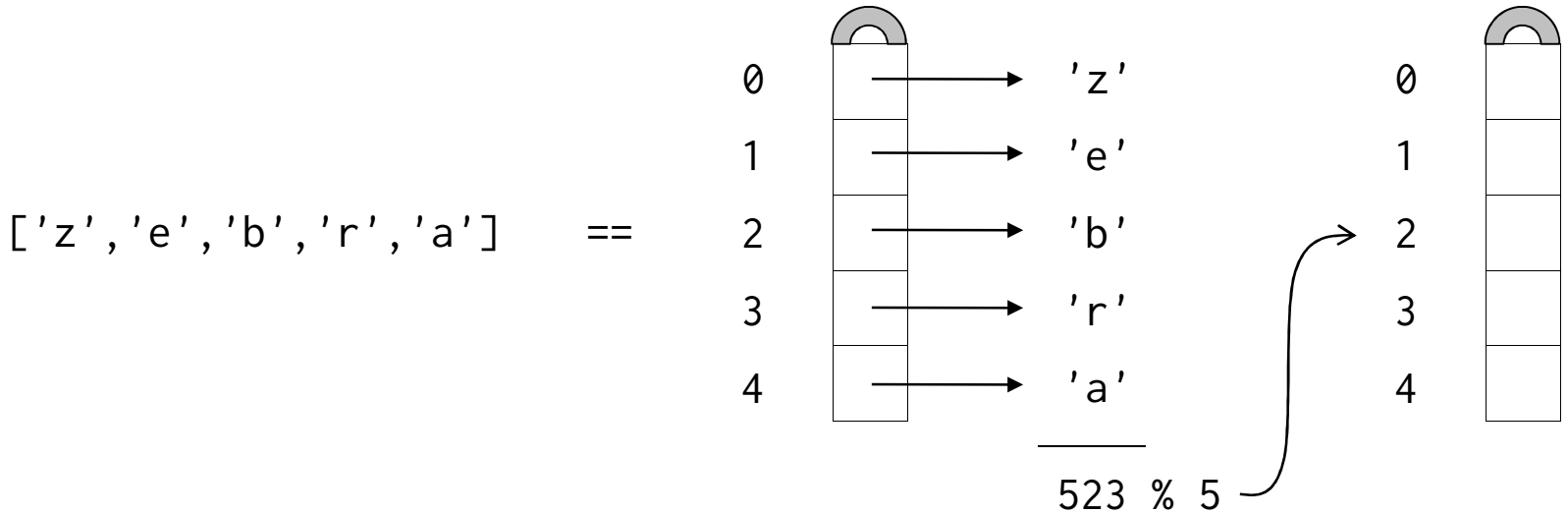
This is what the previous example really looks like in memory

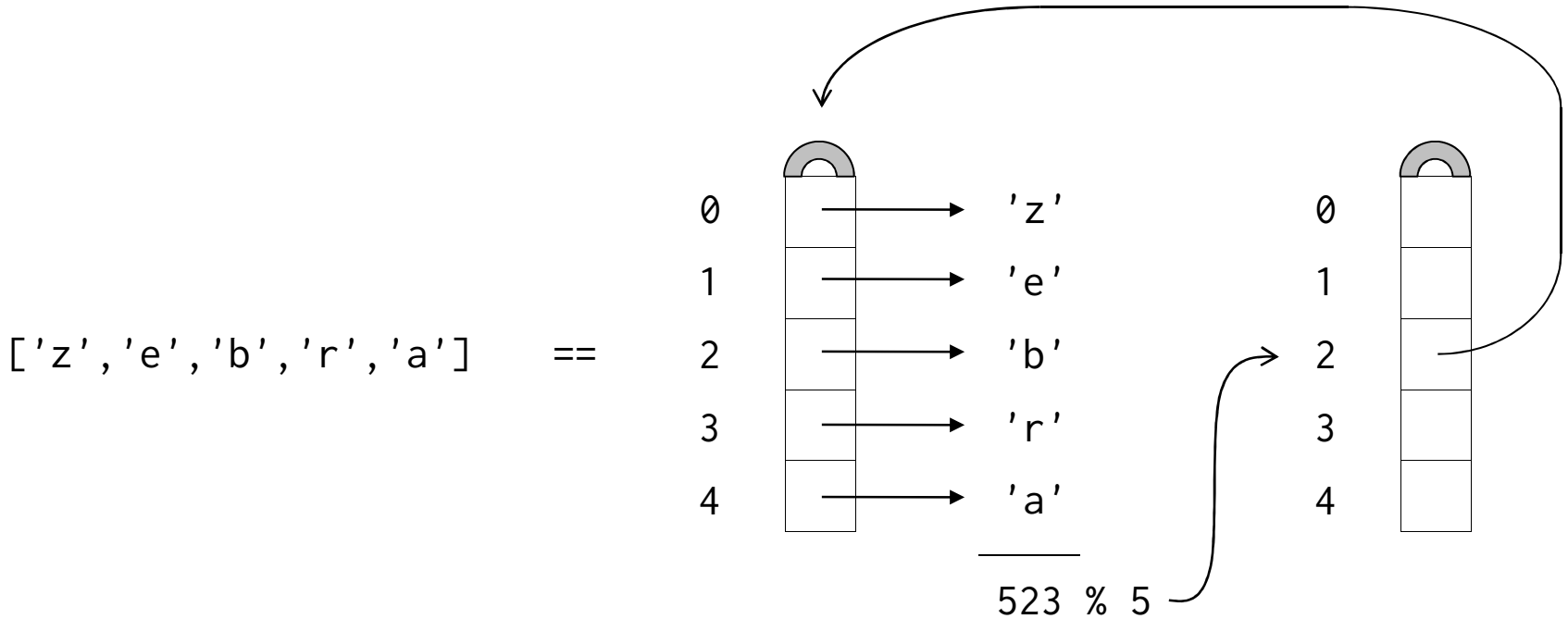
Let's take a look at what happens if we use a list

```
['z','e','b','r','a']
```

```
['z','e','b','r','a']    ==
```




['z','e','b','r','a'] ==
0
1
2
3
4
'z'
'e'
'b'
'r'
'a'
523 % 5
0
1
2
3
4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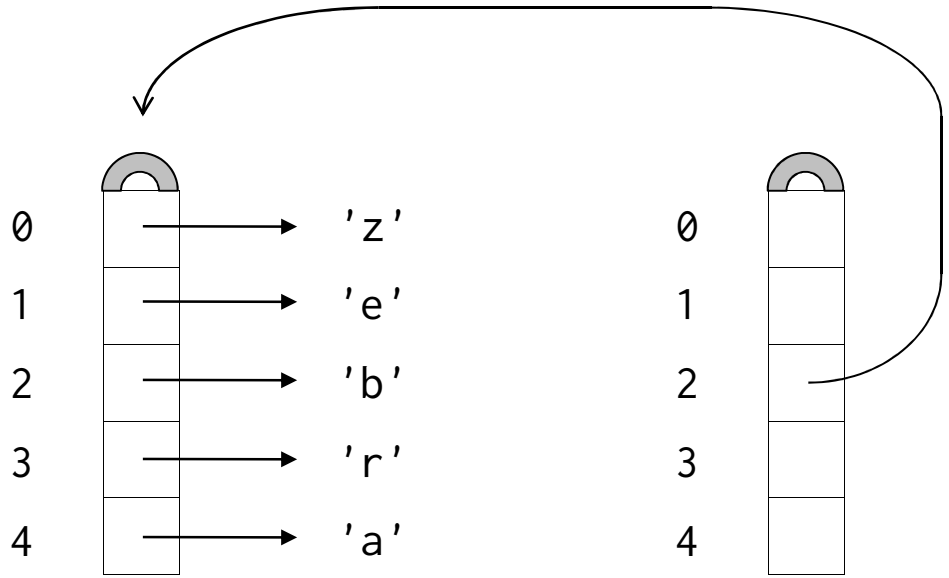
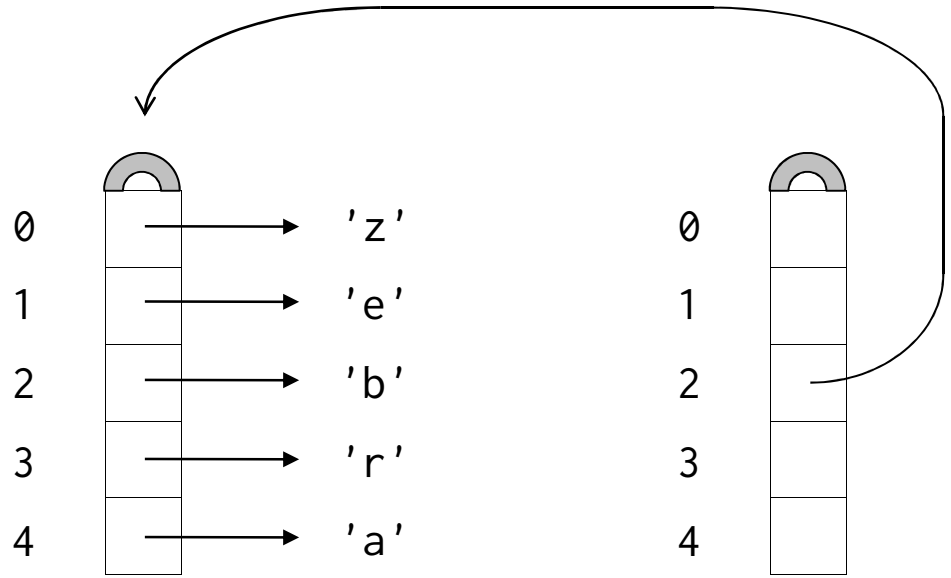
2
3
4



This is what's actually in memory



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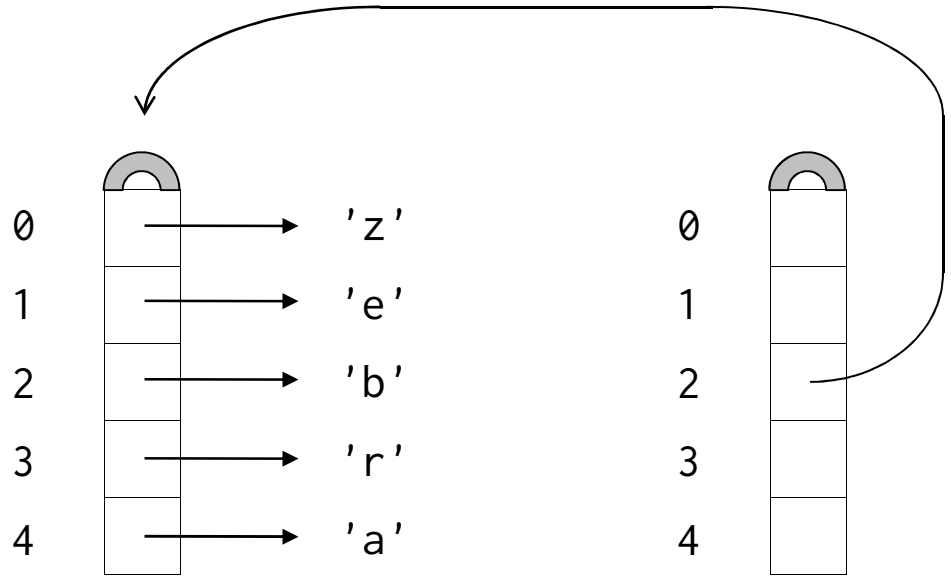
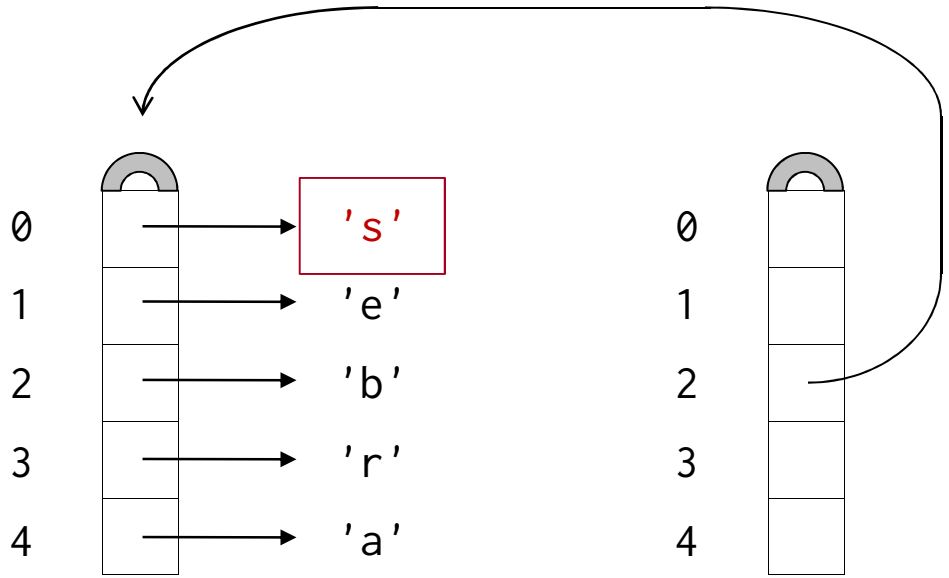
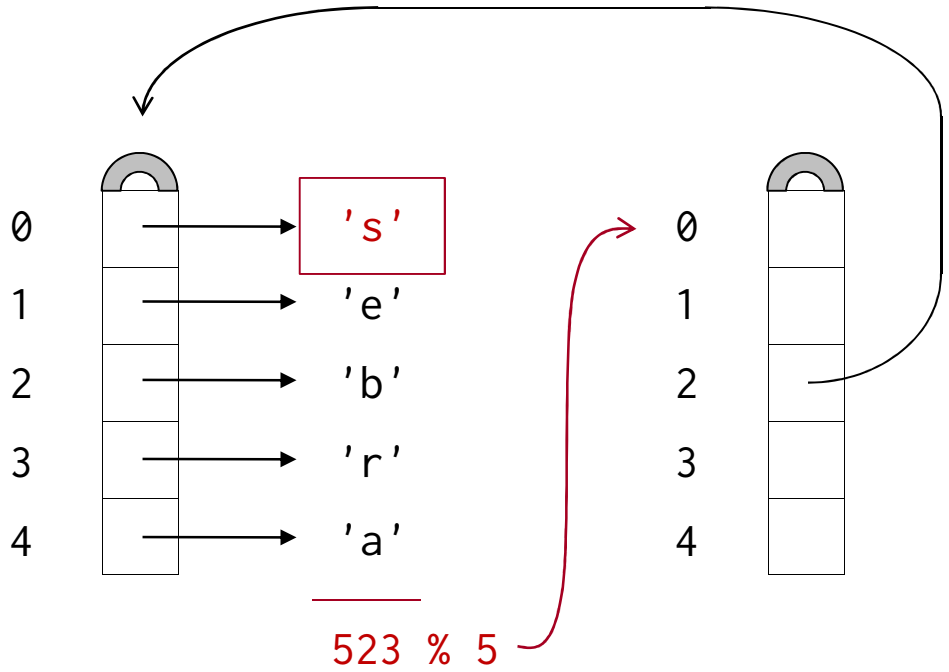
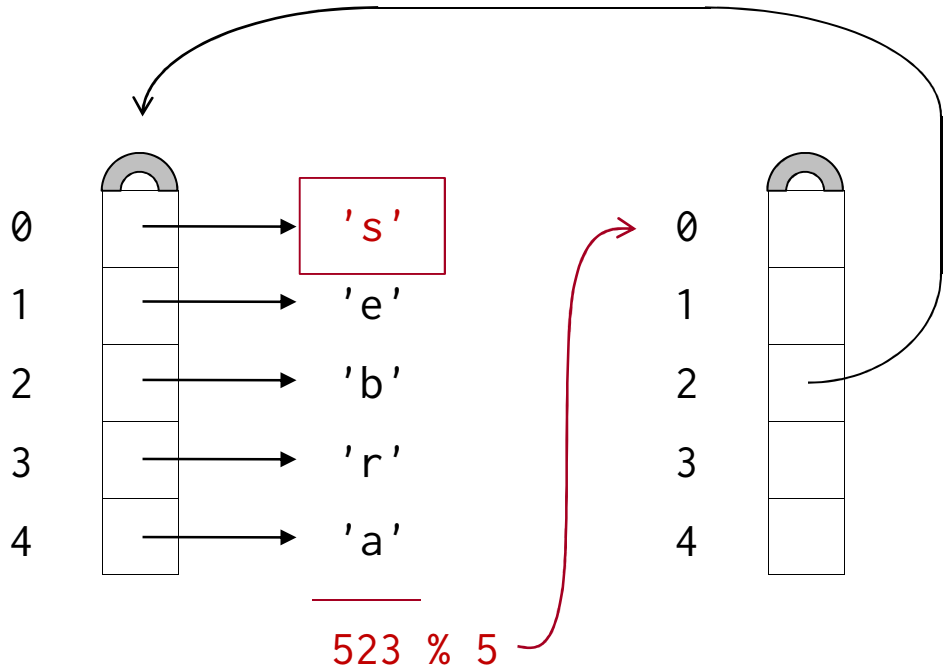
What happens if we change the values in the list?


0
1
2
3
4
'z'
'e'
'b'
'r'
'a'
0
1
2
3
4


0
1
2
3
4
's'
'e'
'b'
'r'
'a'
0
1
2
3
4


0
1
2
3
4
's'
'e'
'b'
'r'
'a'
523 % 5
0
1
2
3
4

The list is stored in the wrong place!



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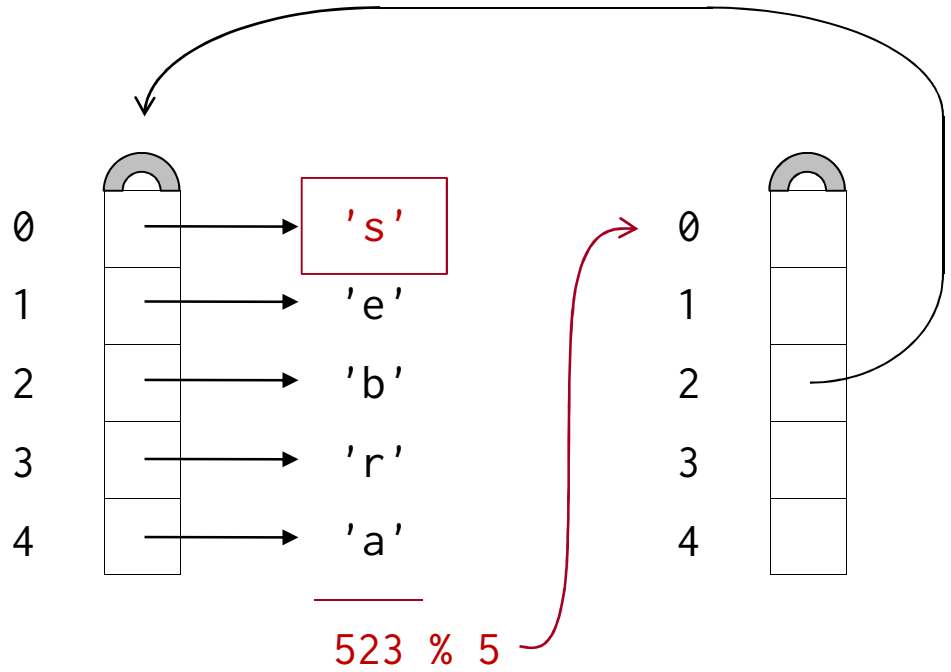


```
['s','e','b','r','a'] in S
```

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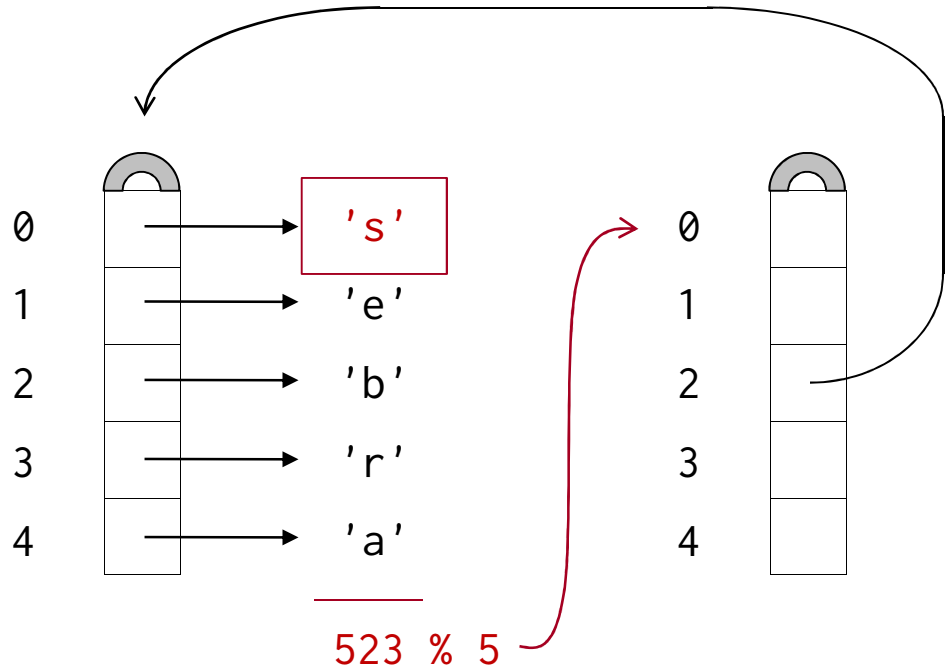
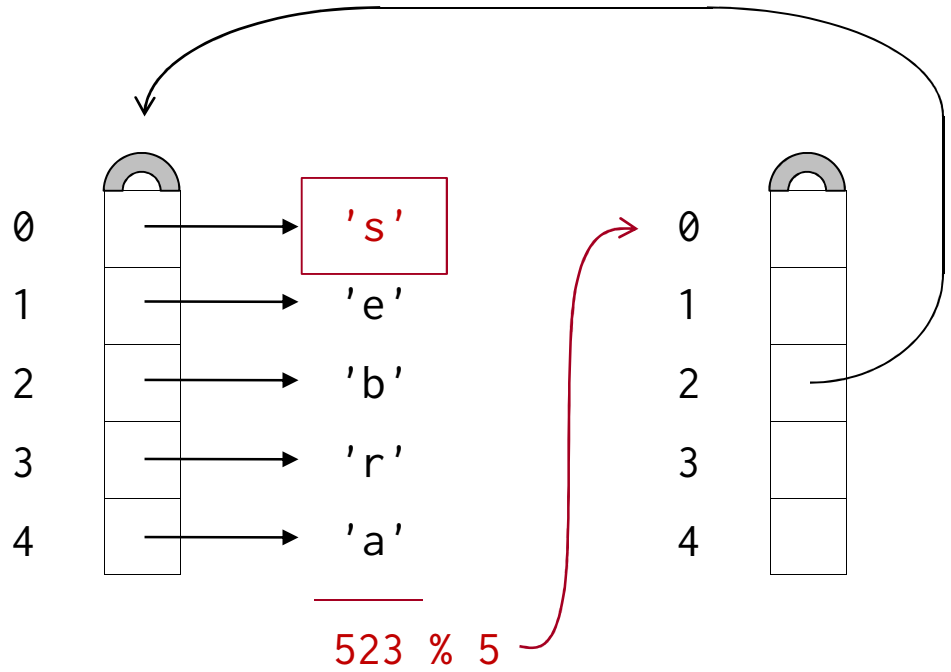


`['s','e','b','r','a'] in S`

looks at index 0 and says `False`

The list is stored in the wrong place!

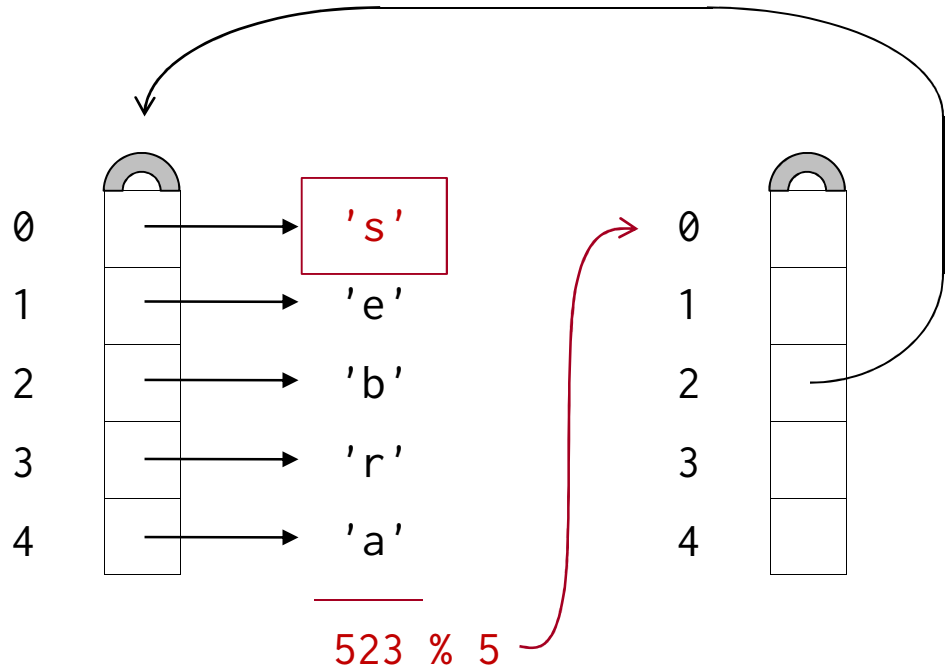


`['s','e','b','r','a'] in S`

looks at index 0 and says `False`

`['z','e','b','r','a'] in S`

The list is stored in the wrong place!



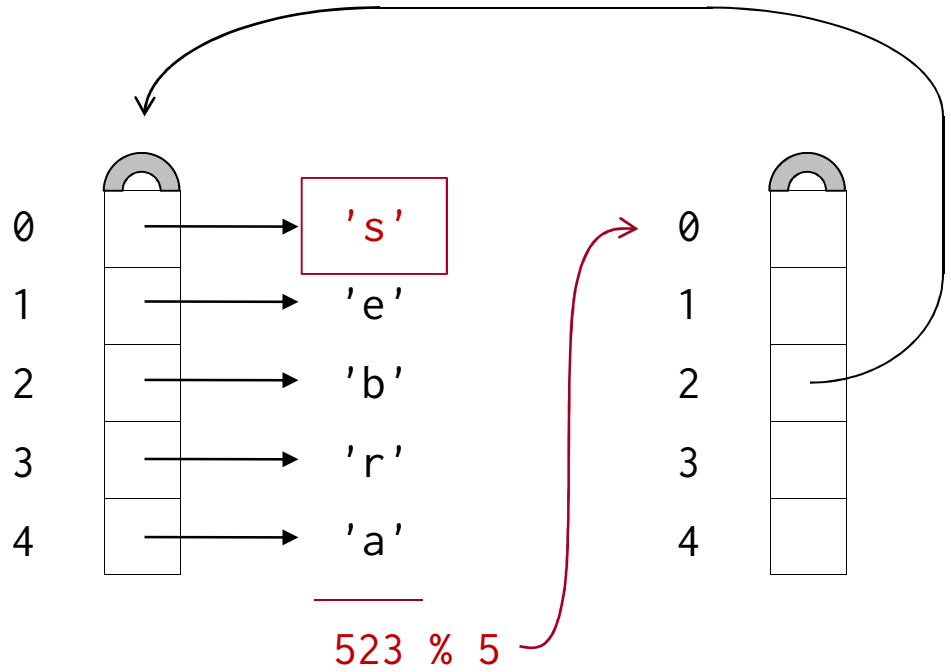
`['s','e','b','r','a'] in S`

looks at index 0 and says `False`

`['z','e','b','r','a'] in S`

looks at index 2 and says `True`

The list is stored in the wrong place!



`['s','e','b','r','a'] in S`

looks at index 0 and says `False`

`['z','e','b','r','a'] in S`

looks at index 2 and says `True` (or blows up)

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Option #1: keep track of the sets an object is in,

and update pointers every time the object changes

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(If an object can't change, neither can its hash value)

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Very expensive when it goes wrong

Option #3: only permit *immutable* objects in sets

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Slightly restrictive, but never disastrous

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But data *always* changes...

Code has to be littered with joins and splits

Option #2 (in Python): use a *tuple*

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An immutable list

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An immutable list

Contents cannot be changed after tuple is created

```
>>> full_name = ('Charles', 'Darwin')
```

```
>>> full_name = ('Charles', 'Darwin')
```

Use '()' instead of '[]'

```
>>> full_name = ('Charles', 'Darwin')
>>> full_name[0]
Charles
```

```
>>> full_name = ('Charles', 'Darwin')
>>> full_name[0]
Charles

>>> full_name[0] = 'Erasmus'
TypeError: 'tuple' object does not support item
assignment
```

```
>>> full_name = ('Charles', 'Darwin)
>>> full_name[0]
Charles

>>> full_name[0] = 'Erasmus'
TypeError: 'tuple' object does not support item
assignment

>>> names = set()
>>> names.add(full_name)
>>> names
set([('Charles', 'Darwin')])
```

This episode has been about the science of computer science

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- Designs for hash tables

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- Designs for hash tables
- Mutability, usability, and performance

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It's a lot to digest in one go...

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It's a lot to digest in one go...

...but sometimes you need a little theory to make sense of practice

created by

Greg Wilson

July 2010