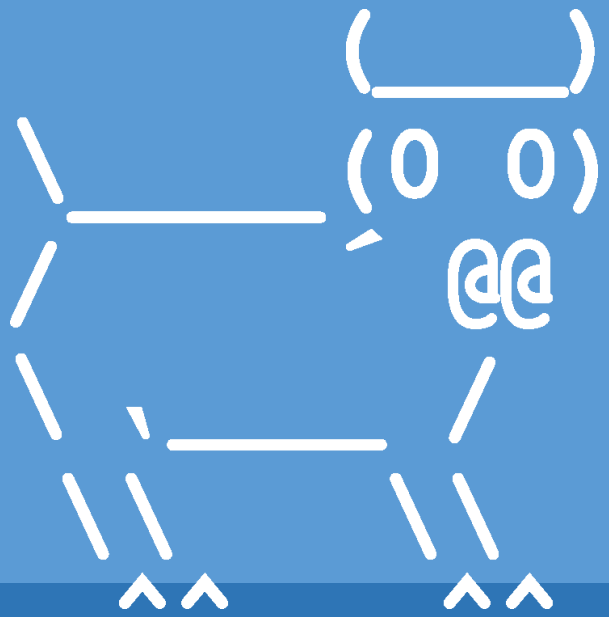
Hashing



Introduction to Computer Science

Iris Howley

TODAY'S LESSON

Hashing

(Arranging dictionary keys to find values quickly)

Dictionary Keys

```
>>> d = dict()
>>> d[['a',1]] = 'testing'
TypeError: unhashable type: 'list'
>>> d[('a',1)] = 'testing'
```

What's the difference?

Dictionary Keys

Dictionary keys must be immutable types

int, float, string, bool, tuple, frozenset

Why?

Mutable Types as Dictionary Keys (*No!*)

- Lists are mutable
- When you `append()` to a list, it changes that list object
- If you used a list object as a key in a dictionary, you wouldn't be able to find it again, after it's been changed

We're going to see why!

Mutable Types as Dictionary Keys (*No!*)

If you used a list object as a key in a dictionary, you wouldn't be able to find it again, after it's been changed

```
mylist = ['a', 'b']
mydict = dict()
mydict[mylist] = 'throws an error'
mylist.append('c')
print(mydict[mylist])
# Now mylist is no longer findable in the dict!
```

We're going to see why!

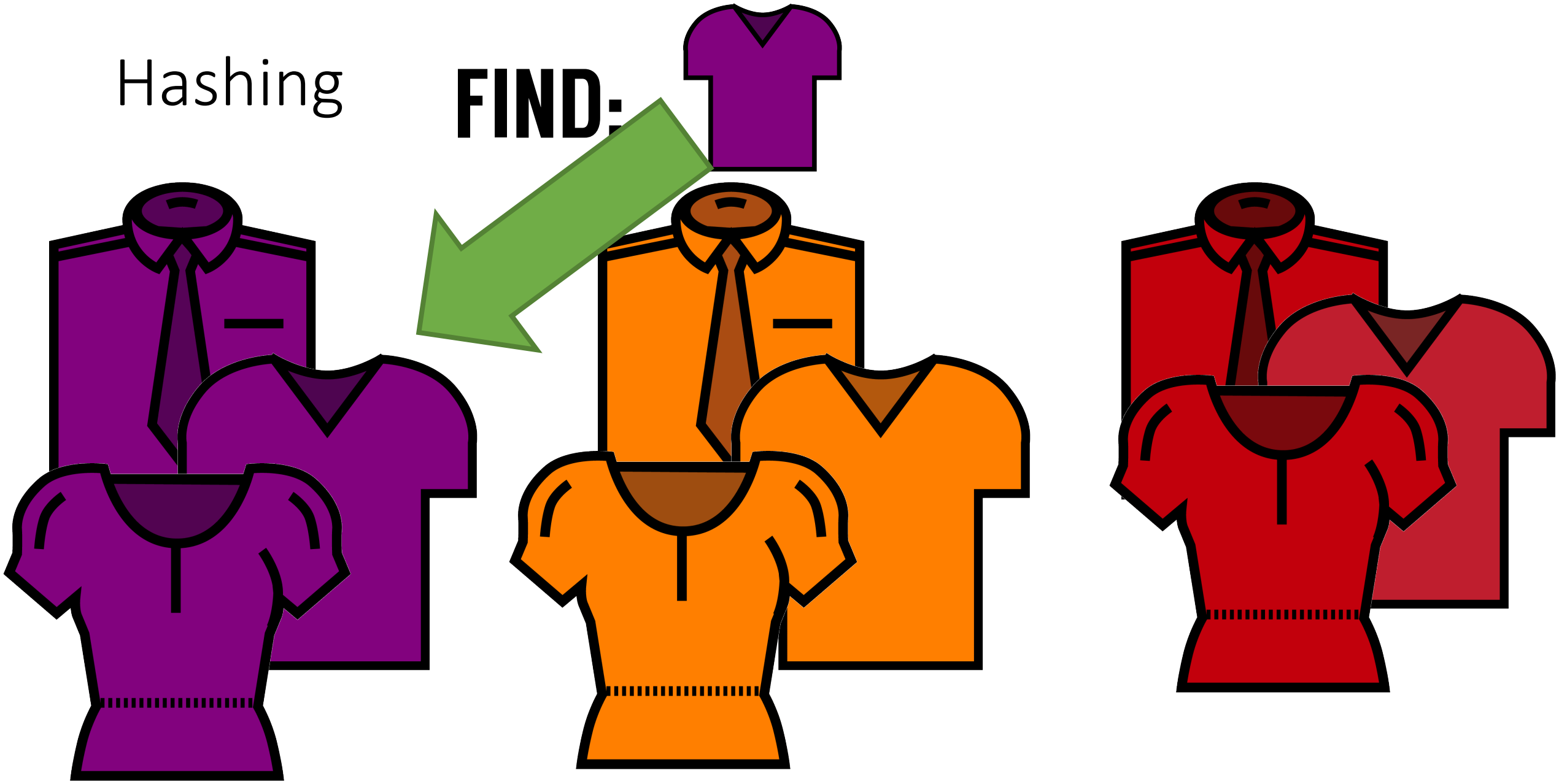
Dictionary Keys

- Dictionaries index their items by a hash
- A hash is a fixed sized integer that identifies a particular value.
- Each value needs to have its own hash
  - For the same value you will get the same hash even if it's not the same object.

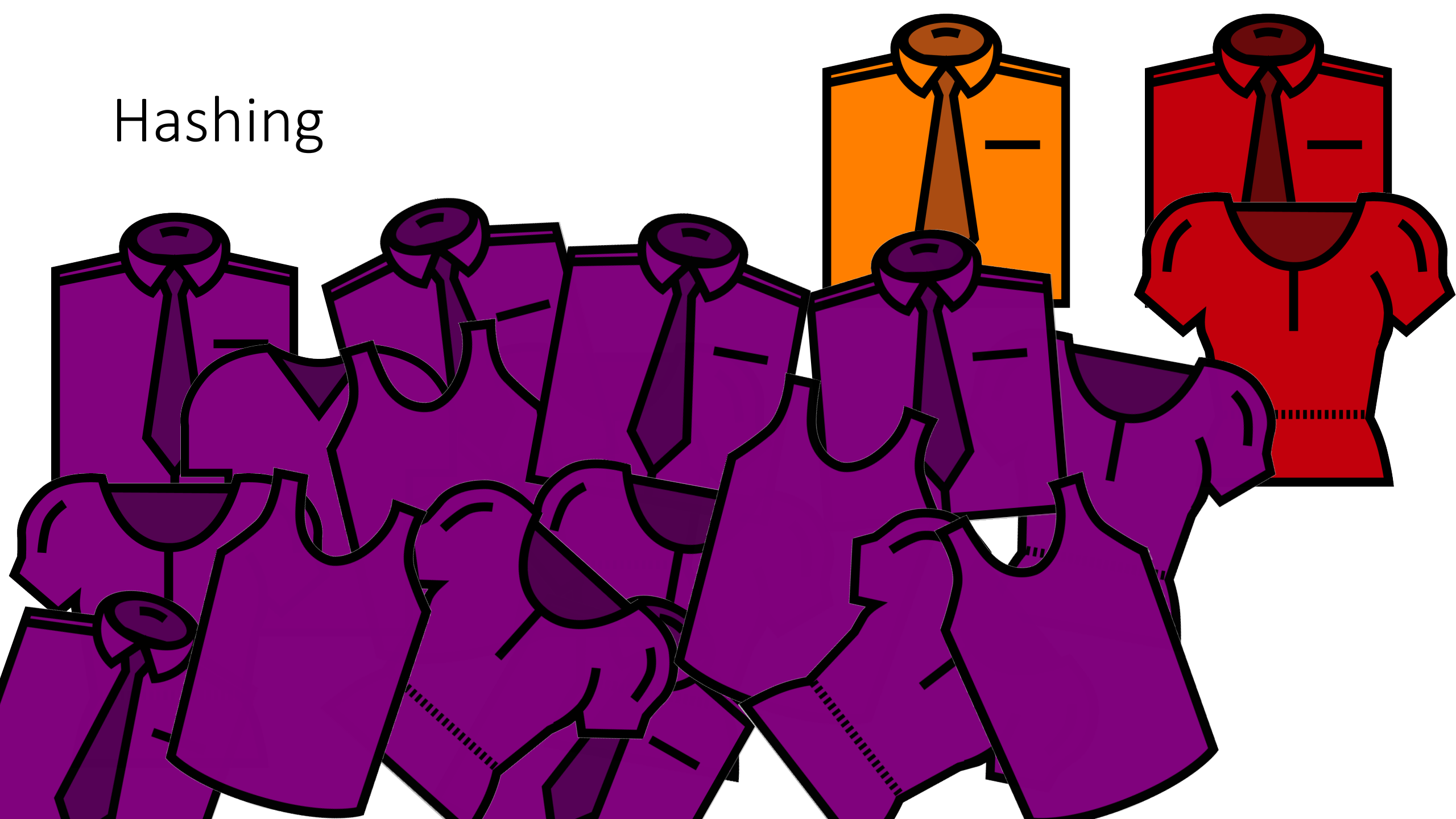
Why not just index items based on their value?

Hashing

Hashing



Hashing



Hashing

Hashing

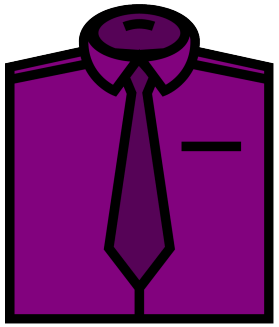
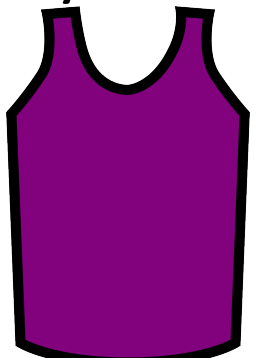
Hashing

Why not just index items based on their value?

- We could organize all words in memory by the letter they start with…

- But words that start with ‘A’ could be numerous
- Compared to words that start with ‘Z’
  - …Sort of like arranging clothes by color

- Hashing is a different way of mapping items to make them easier to find

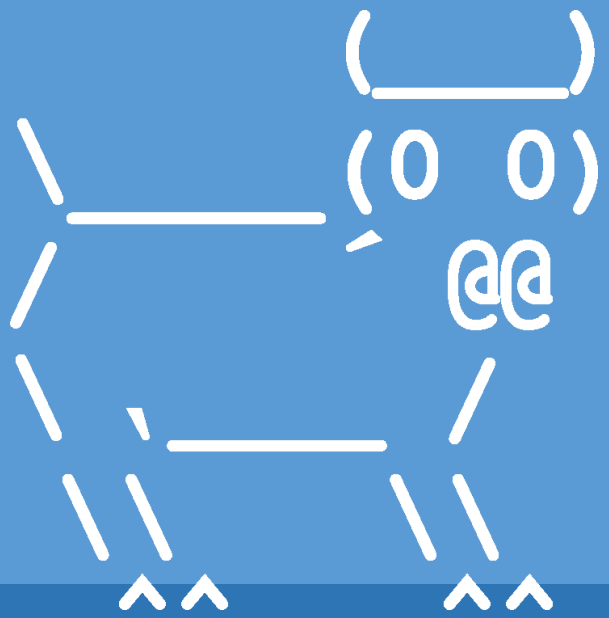
Hashing

- Other concerns
  - Bad hashing function for your data, resulting in clustering
  - Running out of space in the pile you've assigned
  - Placing shirts in the wrong pile

- *Goal*: store in the order that makes it easiest to look them up

Please contact me!

Hash Function



Introduction to Computer Science

Iris Howley

Prior to this lecture…

Complete:

1. POGIL: Hashing
    - Glow > Modules

TODAY'S LESSON

Hashing - How

(How we arrange dictionary keys to find values quickly)

Python Hash Function

`hash(obj)`

- It calls special method: `obj.__hash__(self)`
- Used for dictionary keys and sets
- Calculates an `int` for `obj` that ideally results in:
  - Minimal clustering (i.e., even distribution)
  - Same values generate the same hash value

hash(obj)

- `>>> s = 'hello world'`
- `>>> s2 = 'hello world'`
- `>>> hash(s)` → `4963799451833479185`
- `>>> hash(s2)` → `4963799451833479185`
- `>>> s is s2` → `False`

If the 2 strings are the same, they'll get the same hash

…even if they're different objects!

hash(obj)

- >>> s = 'hello world'
- >>> hash(s) → 4963799451833479185
- >>> exit()
- -> python3
- >>> s = 'hello world'
- >>> hash(s) → 4686556288558268365

You cannot assume that the same values will get the same hash values across different sessions of python!

hash(obj)

- `s = 'hello world'`
- `t = s + '!'`
- `hash(s)` → 4963799451833479185
- `hash(t)` → -8774050965770600213
- `hash(t[:-1])` → 4960501519247167238

If the 2 strings are different, they *might* get a different hash.

(an even distribution of objects may result in some overlap)

`hash(obj)`

Some hash codes are expensive (million-long tuple)

- `hash(1)` → `1`
- `hash(2)` → `2`
- `hash(10000000000000000000)` → `10000000000000000000`
- `hash(10000000000000000000)` → `7766279631452241960`

At some length, it starts treating the numbers like a string

If the hash codes are the same, the values *might* be the same

Hash Tables

- Python's dictionary is an implementation of a more widely know data structure called a *Hash Table*

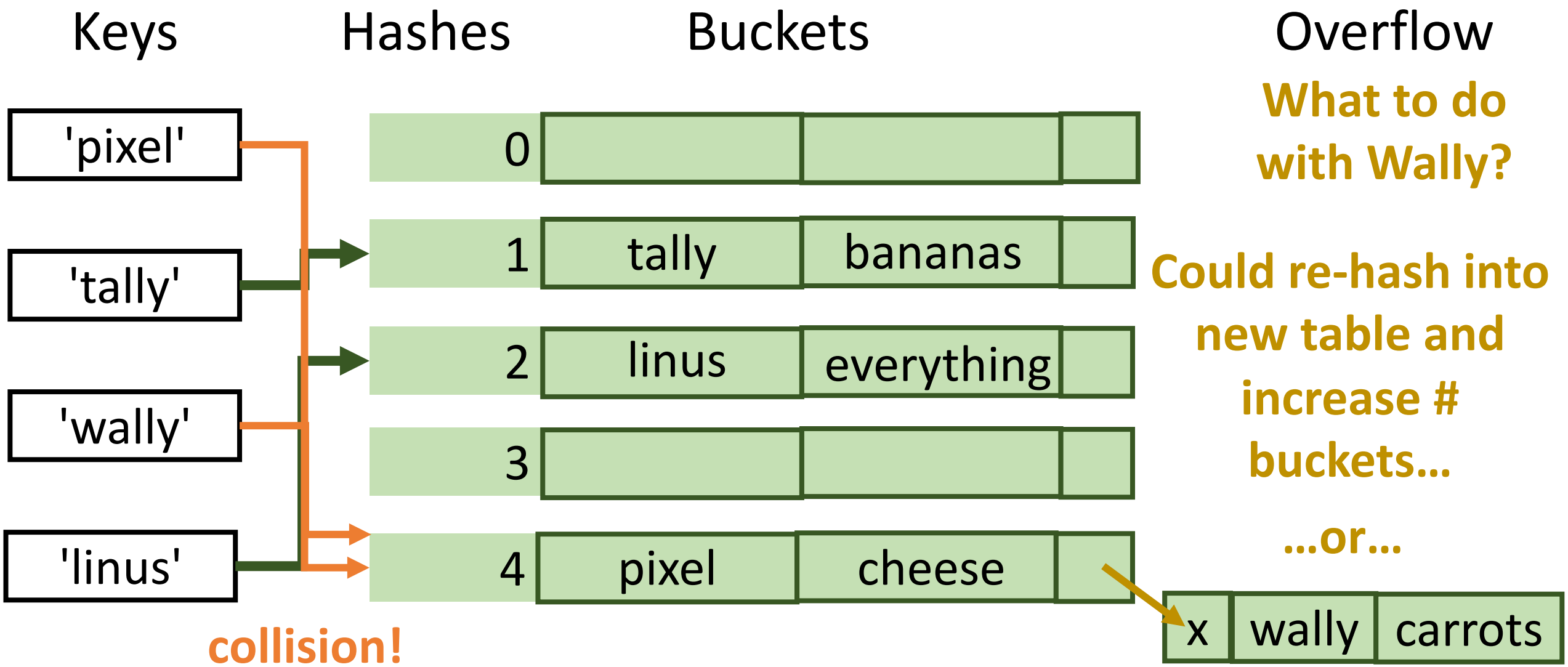
- Let's walk through an example with this dictionary :

```
d = {'tally':'bananas', 'linus':'everything',
'pixel':'cheese', 'wally':'carrots'}
```

- (dog names mapped to their favorite foods)

Hash Tables

How to access mydict['wally']?



Immutable Objects

- Have no way to set/change the attributes, without creating a new object
  - Like `int, string`, etc.
  - User-defined types: `__slots__ = []`
- Can be used as keys for `dictionaries`
  - If the class has `__hash__()` and `__eq__()` methods defined!

https://docs.python.org/3/reference/datamodel.html#object.__hash__

Immutable Objects

- Have no way to set/change the attributes, without creating a new object
  - Like `int`, `string`, etc.
  - `__slots__ = []`

- Can be used in `sets`
  - i.e., you cannot have a `set` of `lists`

```
>>> s = {[1,2,3], [1], [2,3]}
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unhashable type: 'list'
```

Thought Question

How would we implement a good hash function for a user-defined class?

```
0 >>> class Flower:
1 ...         slots = ['sepals', 'petals']
2 ...         def __hash__(self):
3 ...             return self.petals + self.sepals
4 >>> rose = Flower()
5 >>> rose.petals = 10
6 >>> rose.sepals = 5
7 >>> hash(rose)
8 15
```

Would this be evenly distributed?

How to improve?!

Thought Question

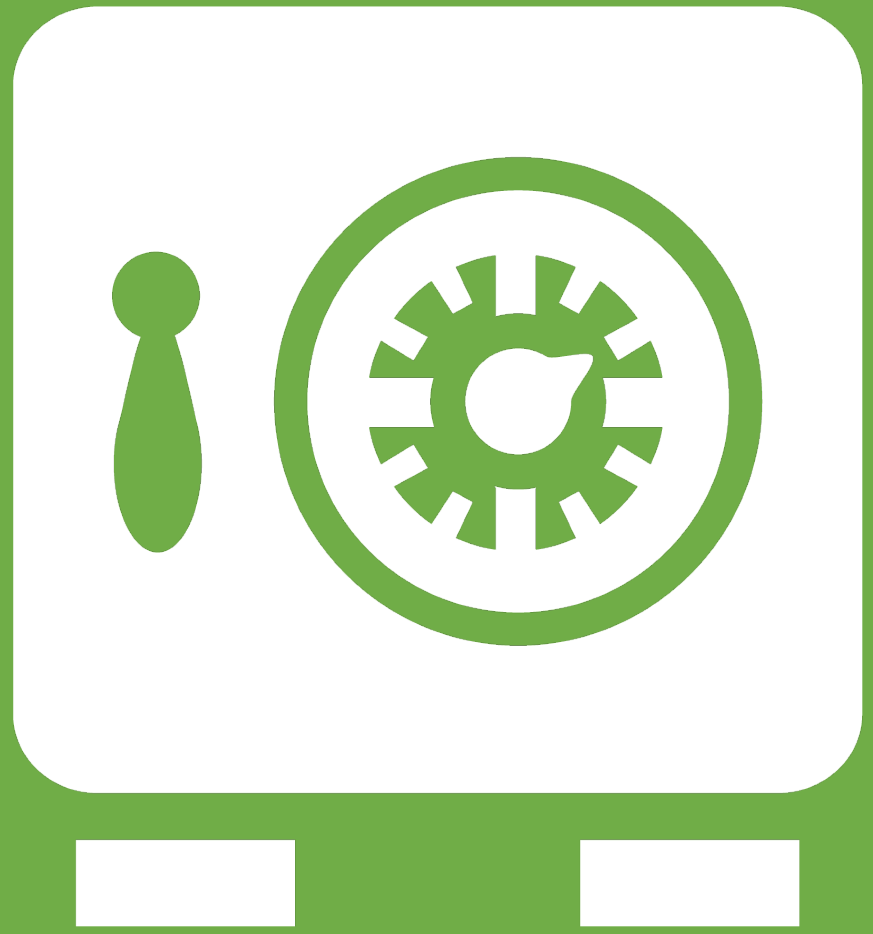
How would we implement a good hash function for a user-defined class?

What about for the `Scotus` class?

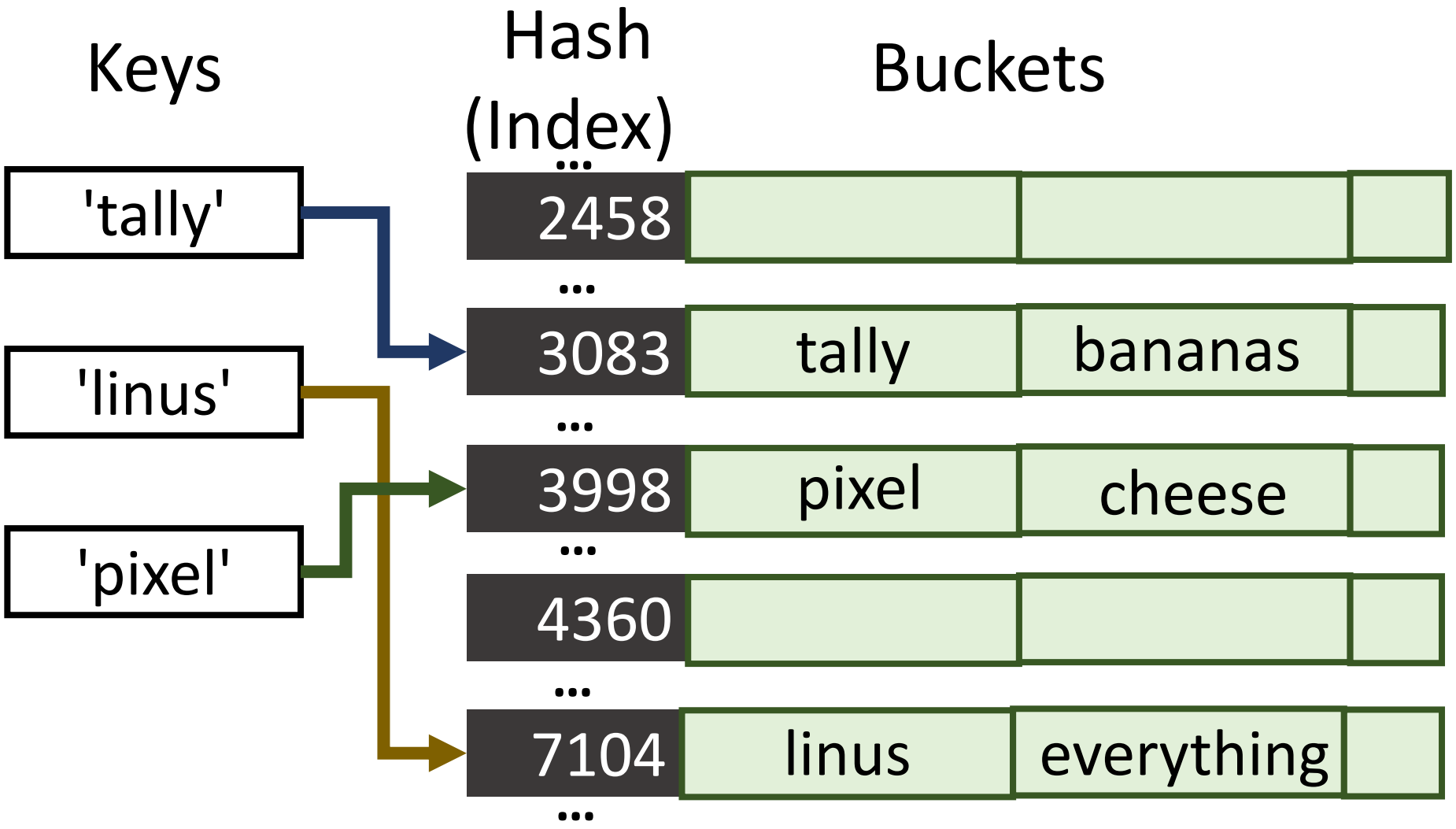
What about for `Plaintext` class?

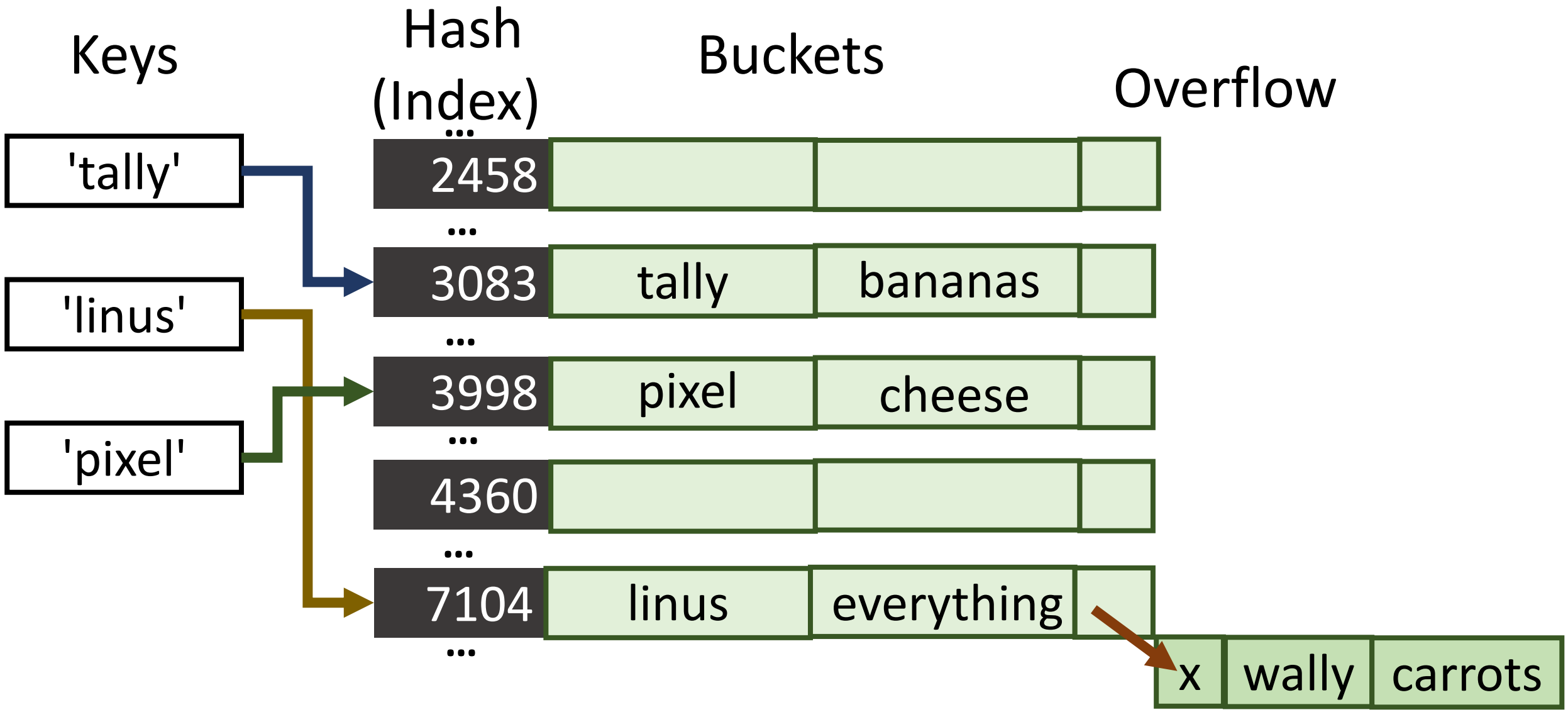
```
def __hash__(self):
  return '???'
```

Please contact me!



Leftover Slides


Keys
Hash (Index)
Buckets
'tally'
'linus'
'pixel'
2458
3083
tally
bananas
3998
pixel
cheese
4360
7104
linus
everything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