CSE 373

OCTOBER 16TH – HASHING

TODAY'S LECTURE

- Hashing

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- **Hashing**
  - Basic Concept

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- **Hashing**
  - Basic Concept
  - Hash functions

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- **Hashing**
  - Basic Concept
  - Hash functions
  - Collision Resolution

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  - Basic Concept
  - Hash functions
  - Collision Resolution
  - Runtimes

HASHING

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  - Any data we might want to store is a member of this set. For example, **M** might be the set of all strings
  - There is a set of data that we actually care about storing **D**, where **D** << **M**
  - For an English Dictionary, **D** might be the set of English words

HASHING

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  - The operation should run in O(1) time
    - Accesses should be as fast as possible

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  - Need to know the size of **D** in advance or lose memory to pointer overhead
  - Hard to go from **M** -> **D** in O(1) time

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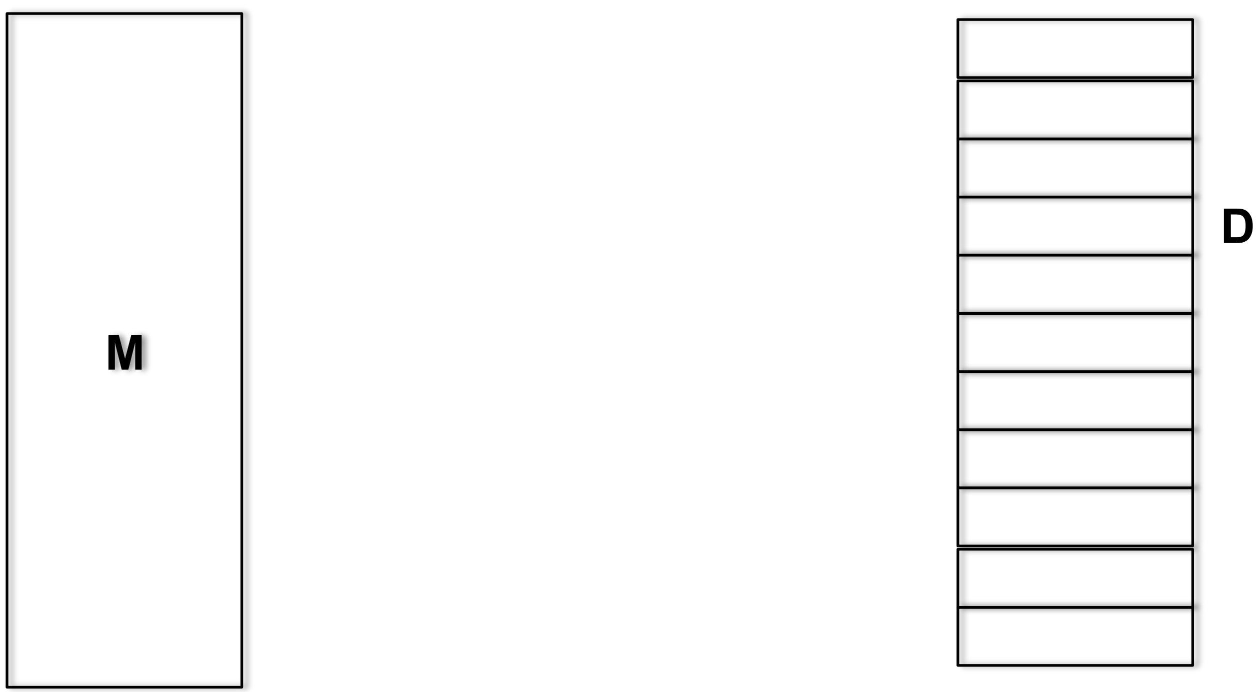
  - Each index in the array corresponds to *some* element in **M** that we want to store.
  - The data in **D** does not need any particular ordering.

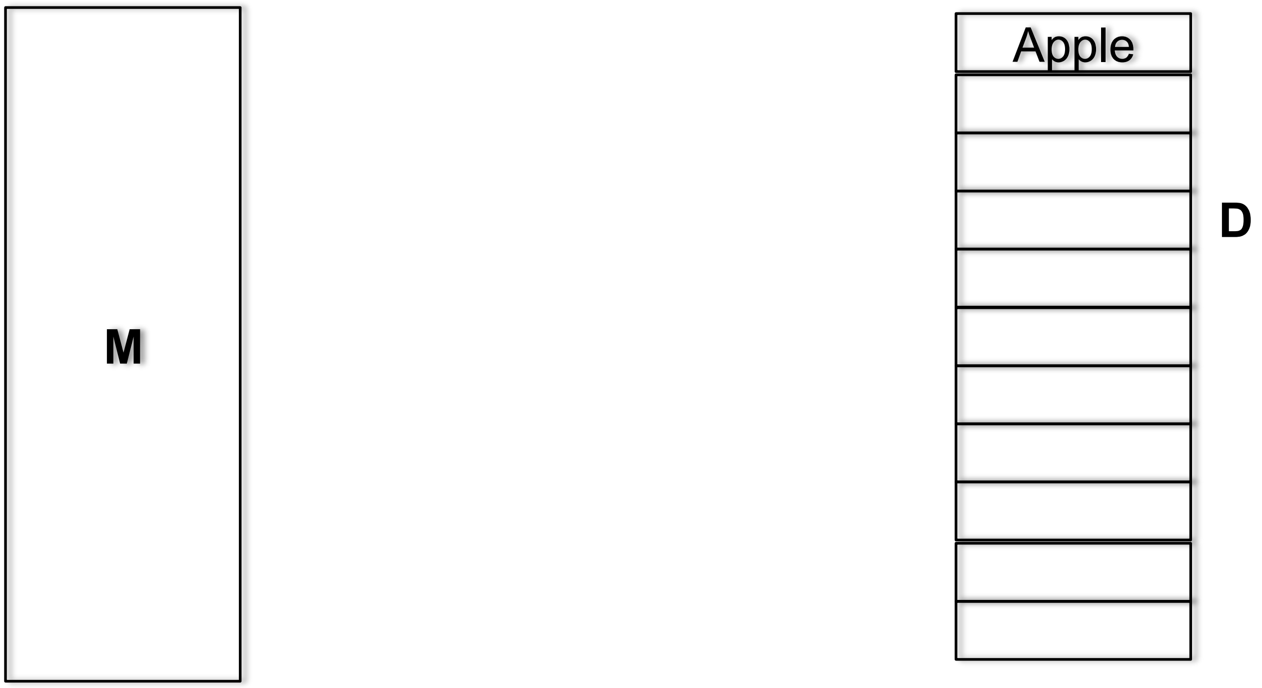
THE HASH TABLE

- How can we do this?



THE HASH TABLE

- **How can we do this?**
  - Unsorted Array



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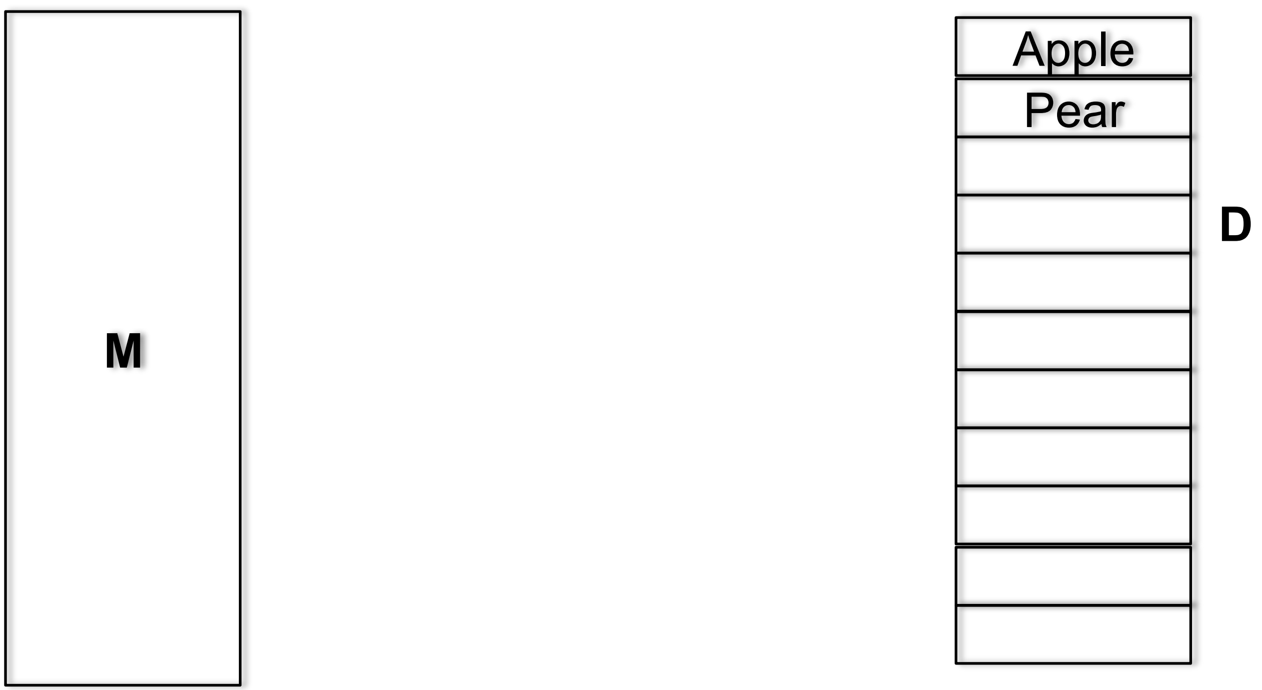

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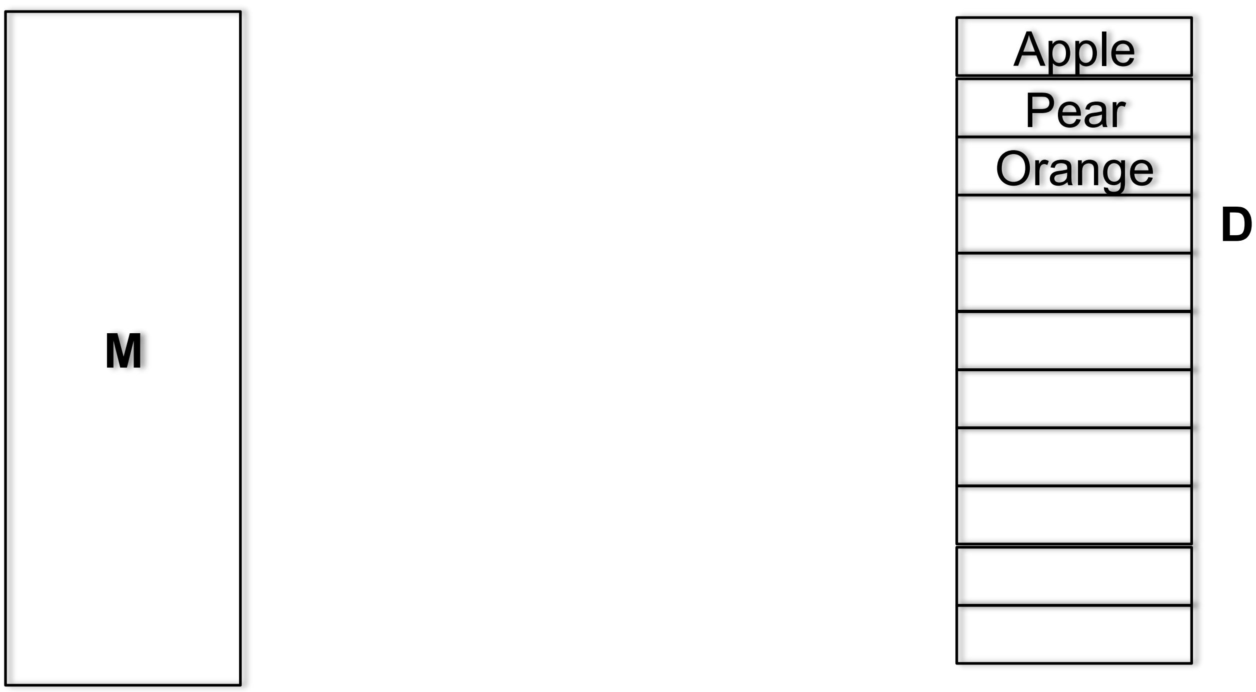

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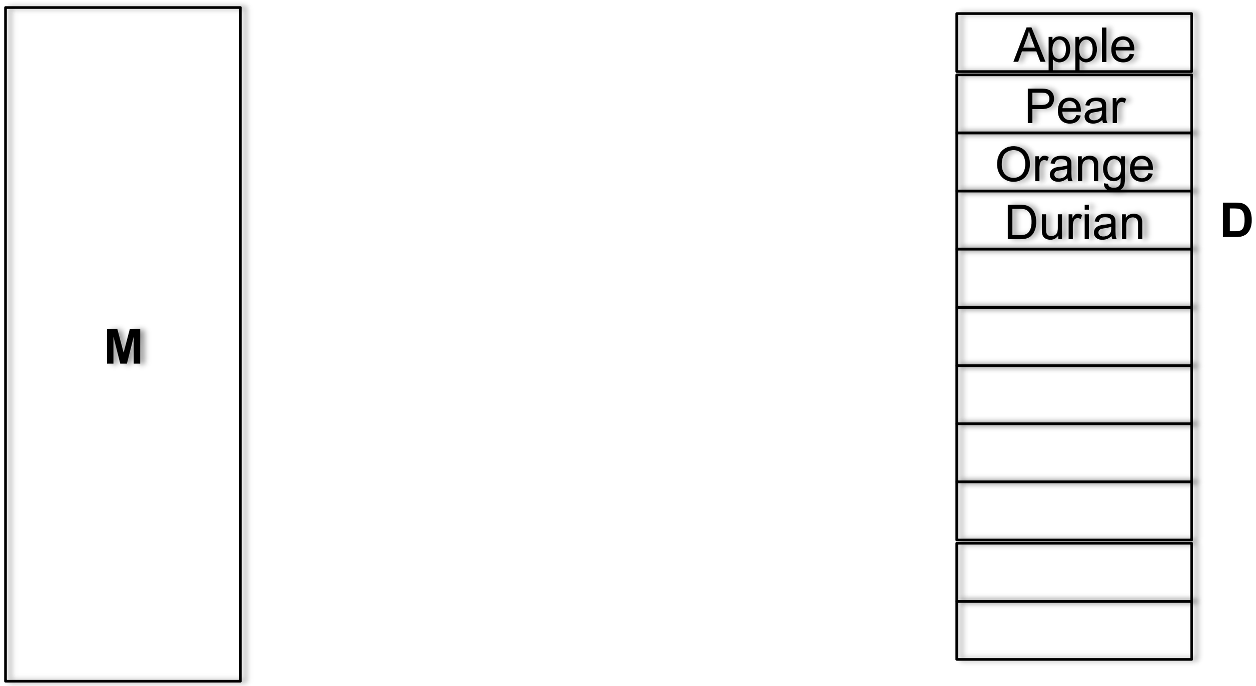

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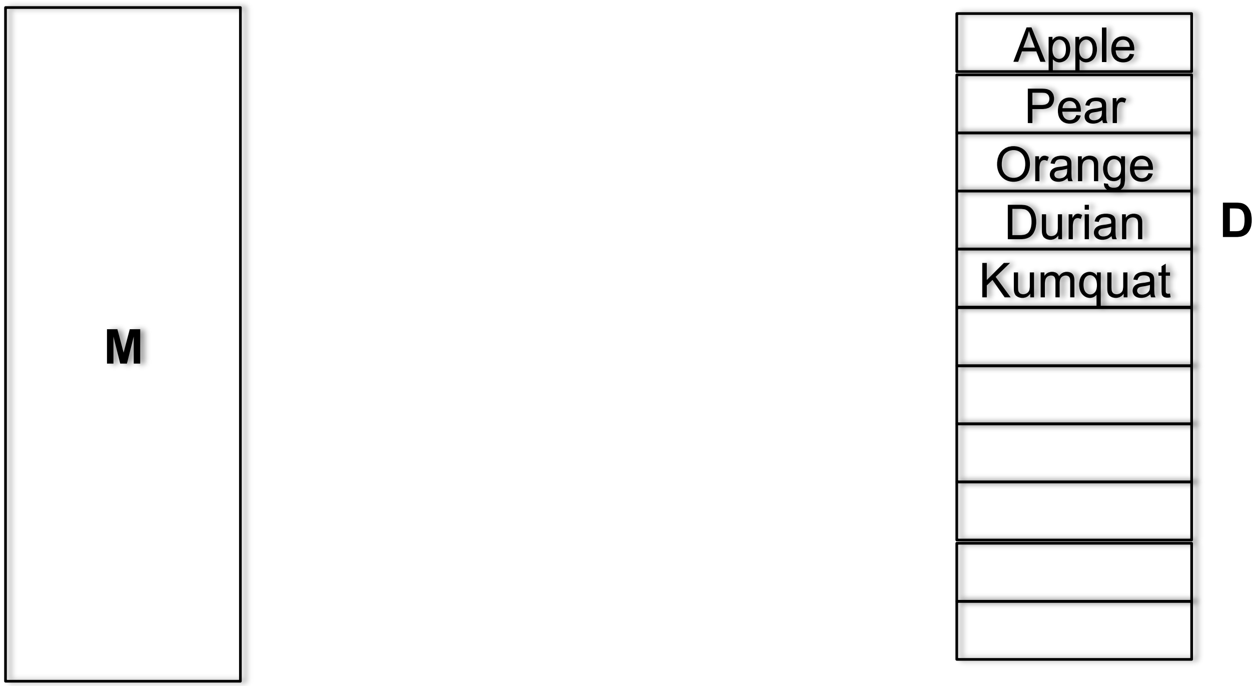

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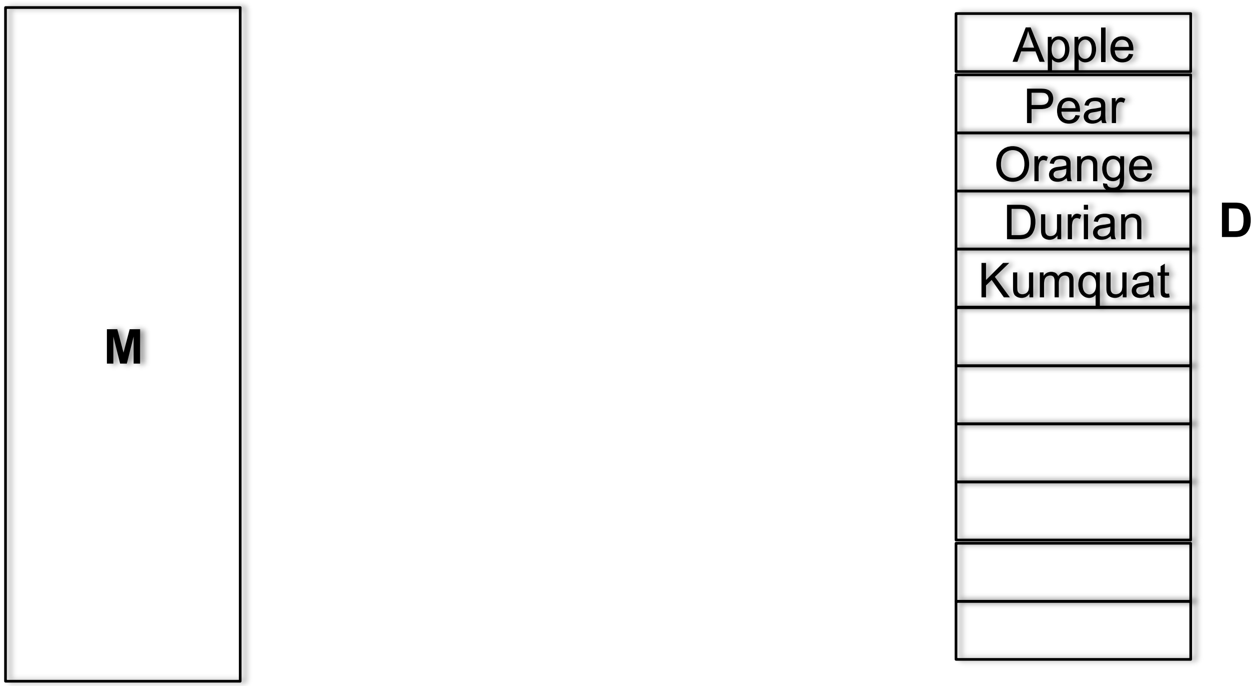

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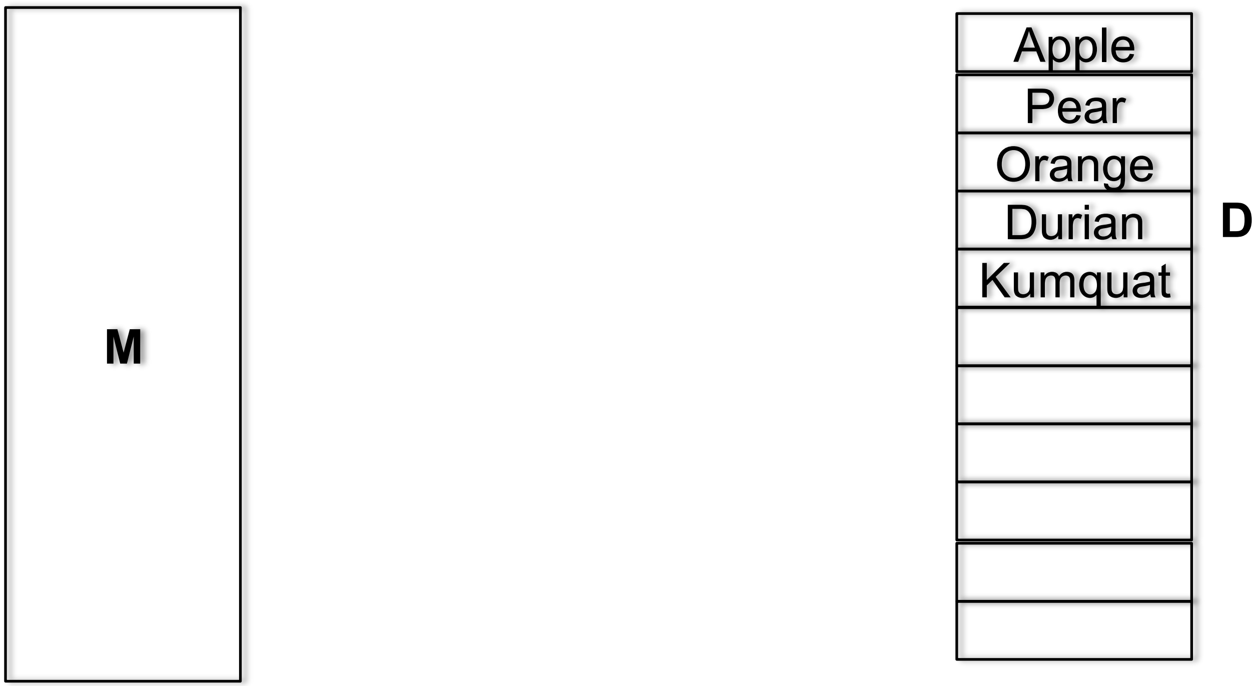

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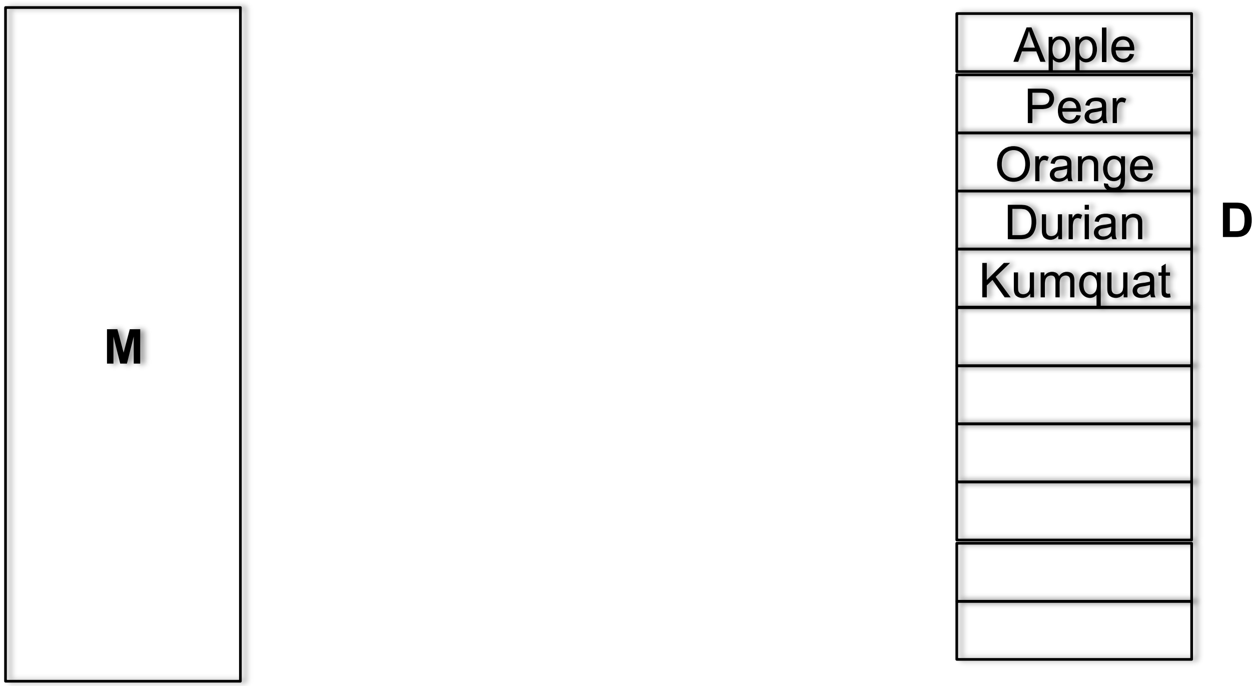
  - Same problem with sorted arrays!



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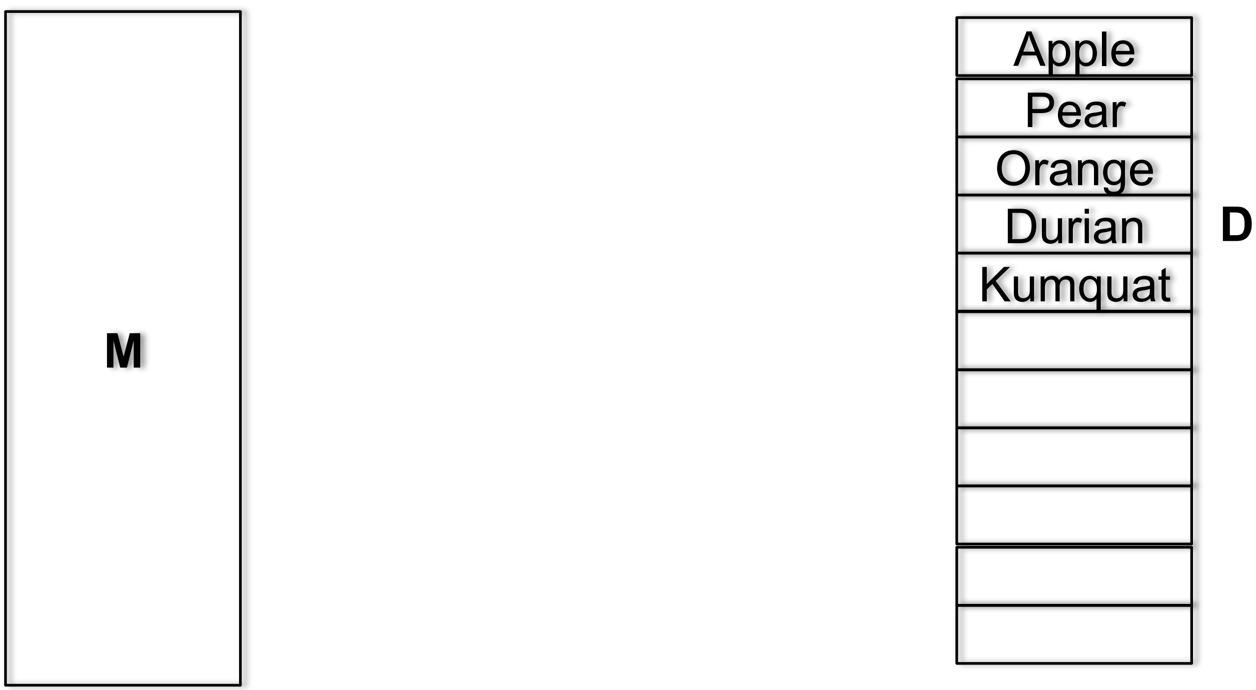
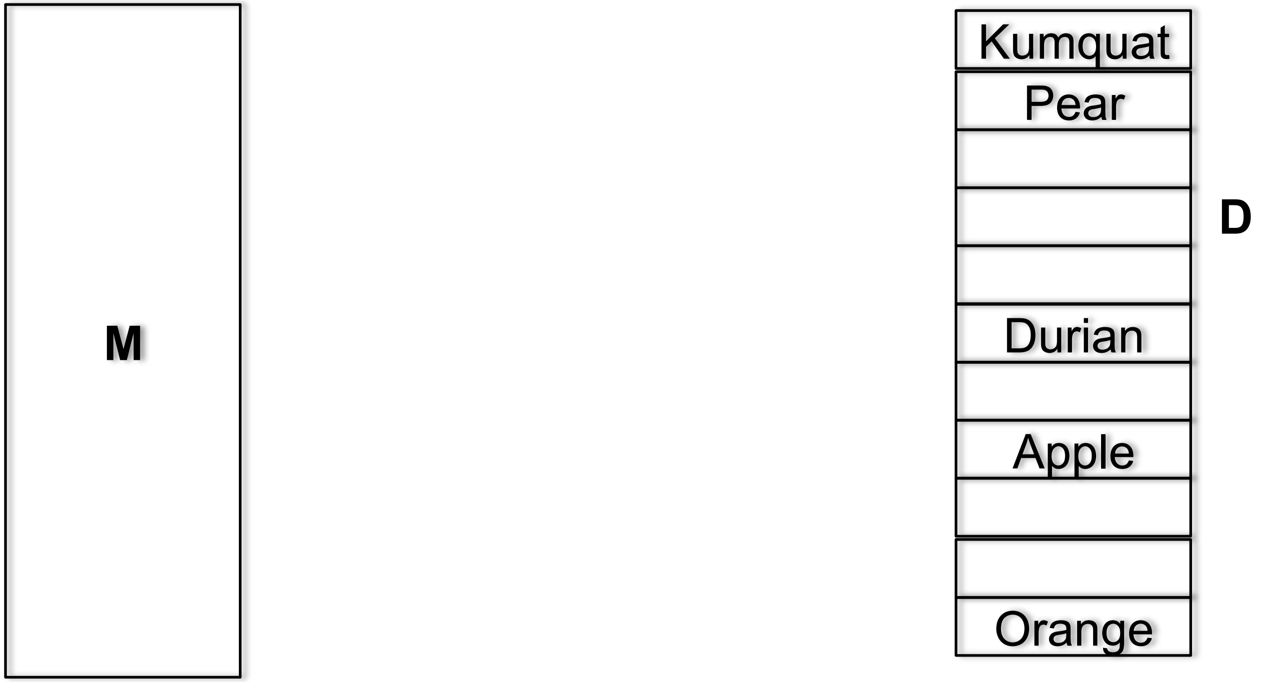


THE HASH TABLE

- **What is another solution?**
  - Random mapping



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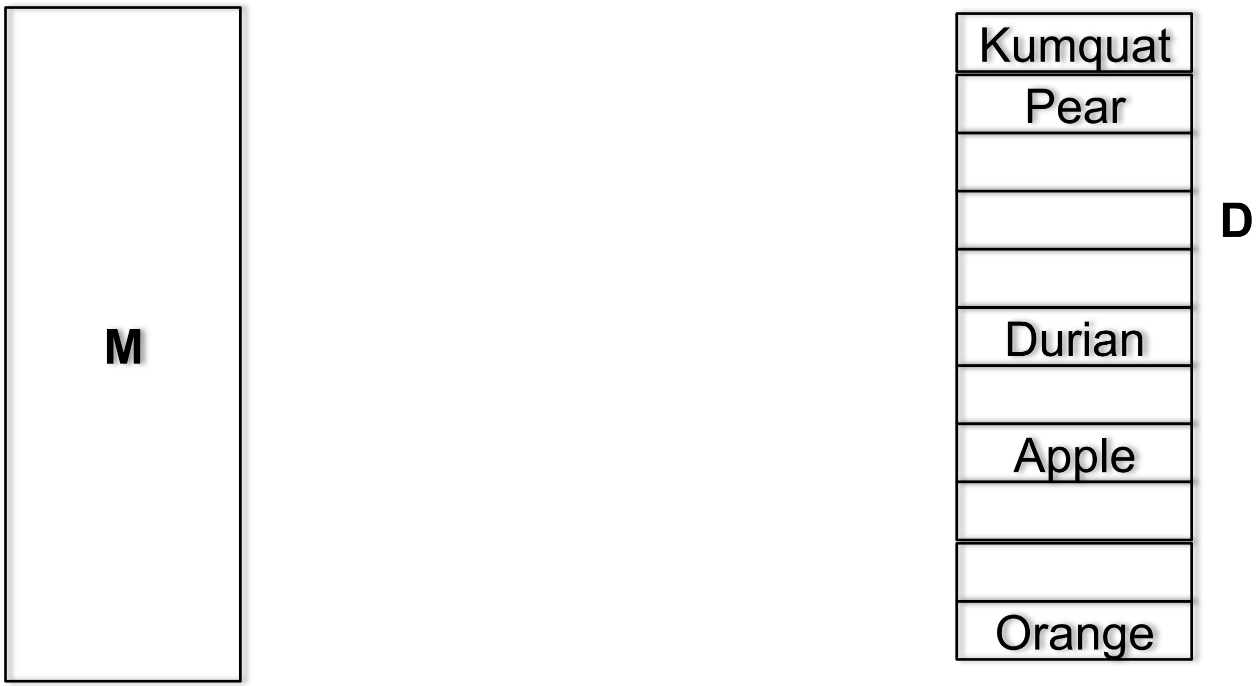
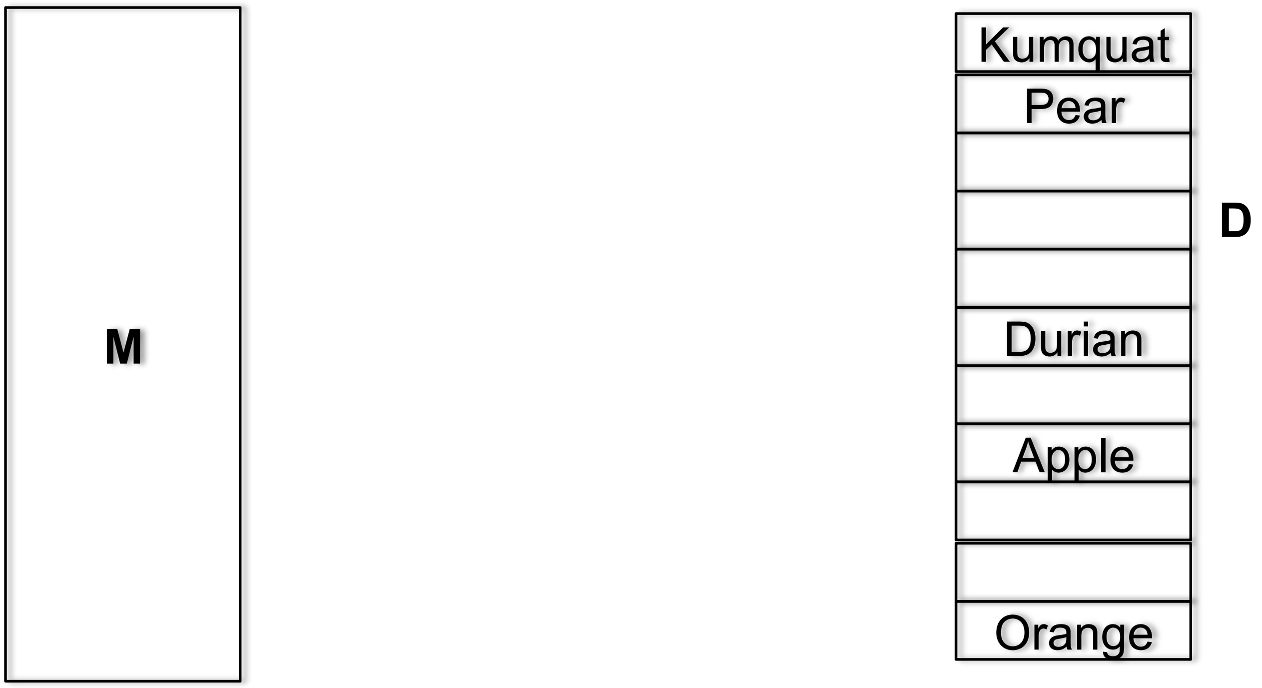


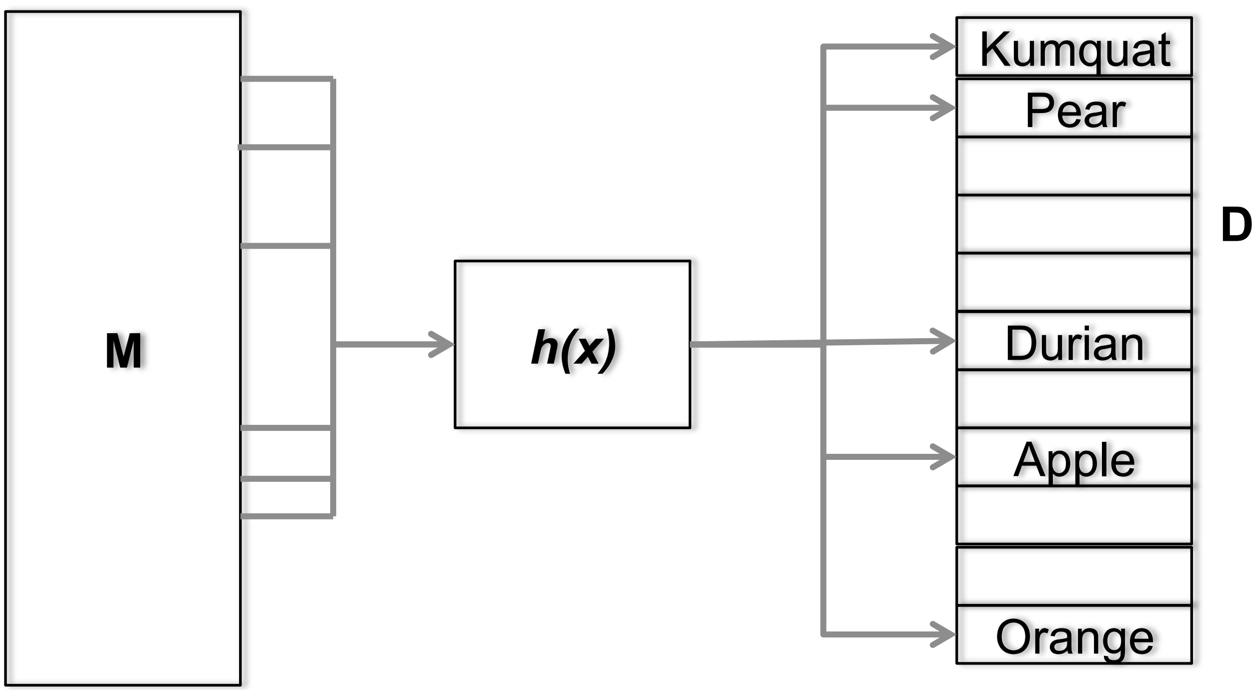
THE HASH TABLE

- **What's the problem here?**
  - Can't retrieve the random variable, O(D) search!



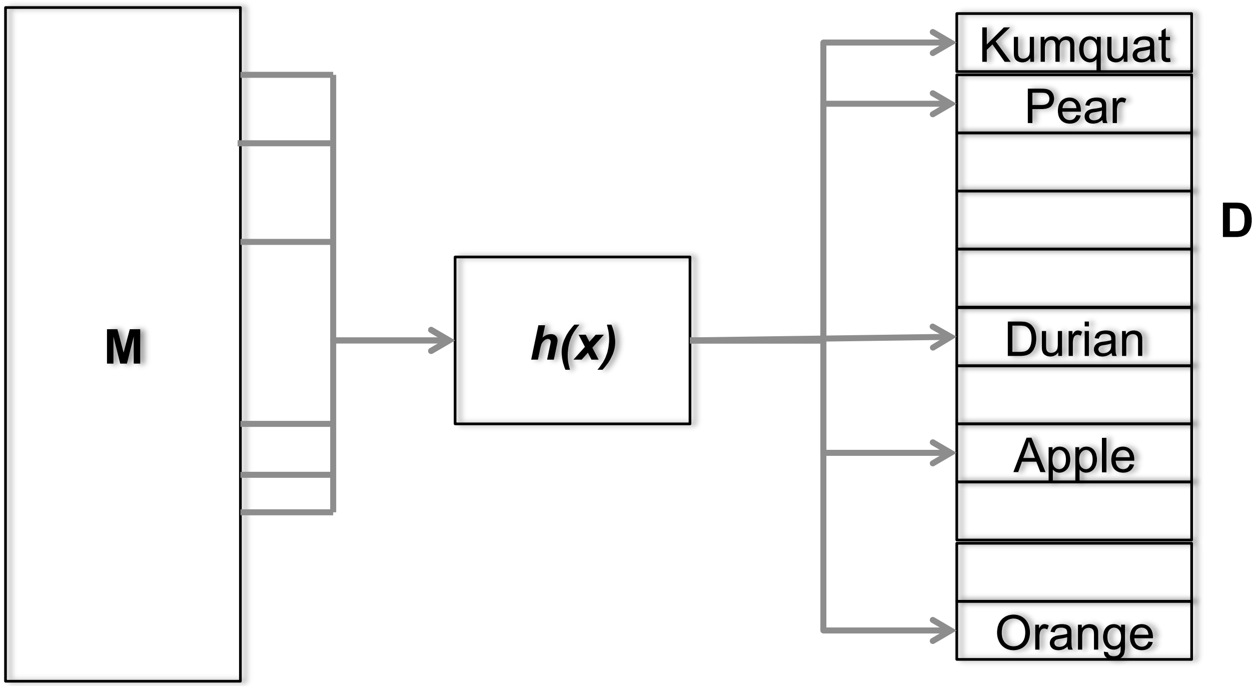
THE HASH TABLE

- **What about a pseudo-random mapping?**



THE HASH TABLE

- **What about a pseudo-random mapping?**
  - This is "the hash function"



HASH FUNCTIONS

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- **We want our hash function to do the following:**
  - Be repeatable: `H(x) = H(x)` every run
  - Be equally distributed: For all y,z in D, `P(H(y)) = P(H(z))`
  - Run in constant time: `H(x) = O(1)`

HASH EXAMPLE

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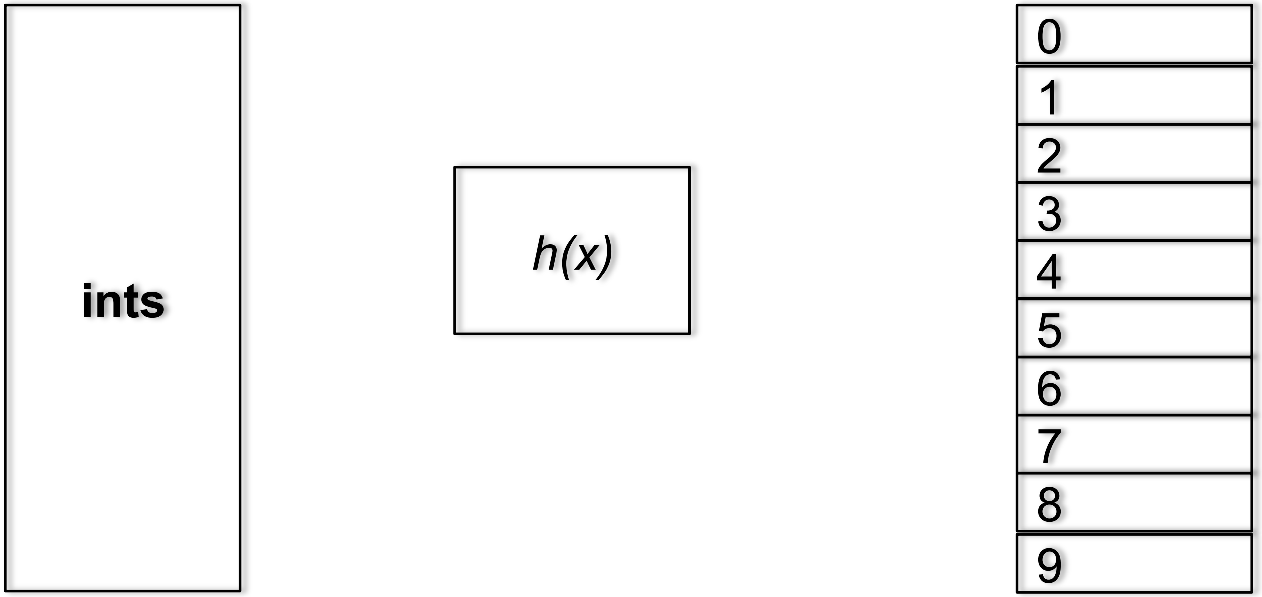
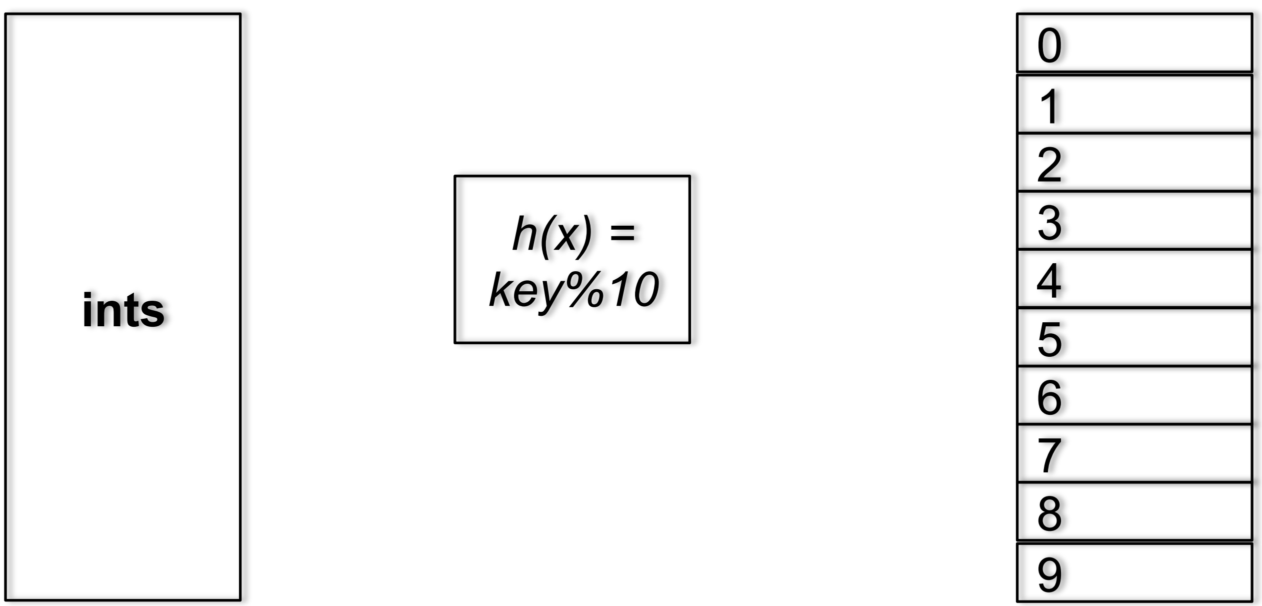
- **Let's consider an example. We want to save 10 numbers from all possible Java ints**
  - What is a simple hash function?



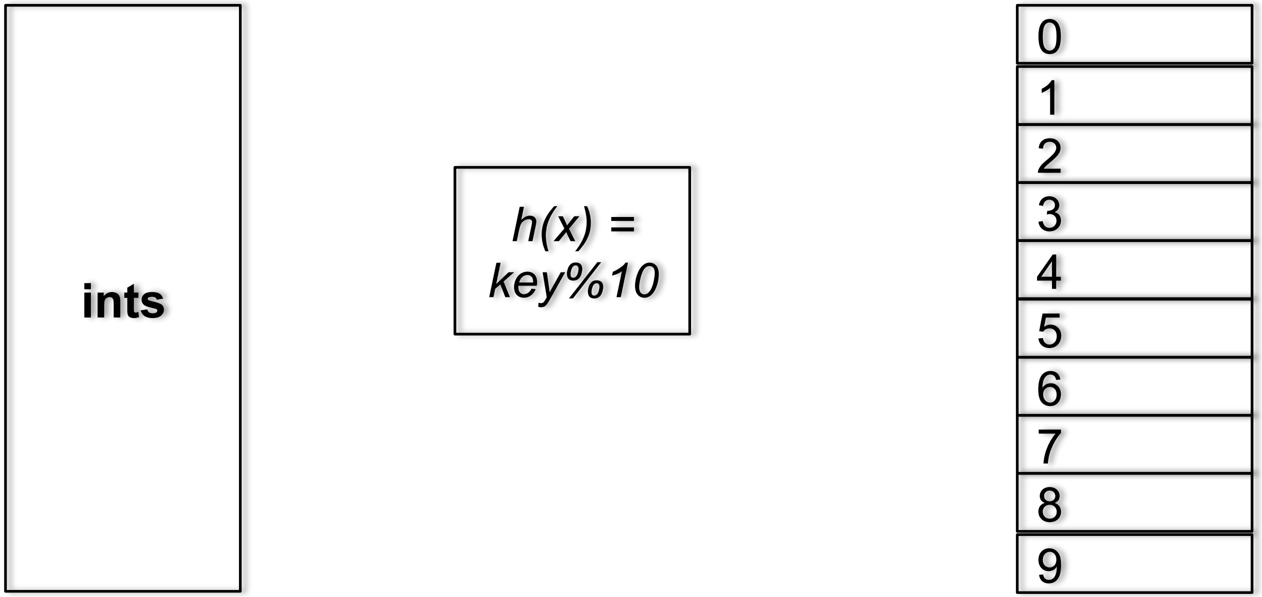
HASH EXAMPLE

- **Let's consider an example. We want to save 10 numbers from all possible Java ints**
  - Just use the number, but we need to mod by the table size to prevent OOB



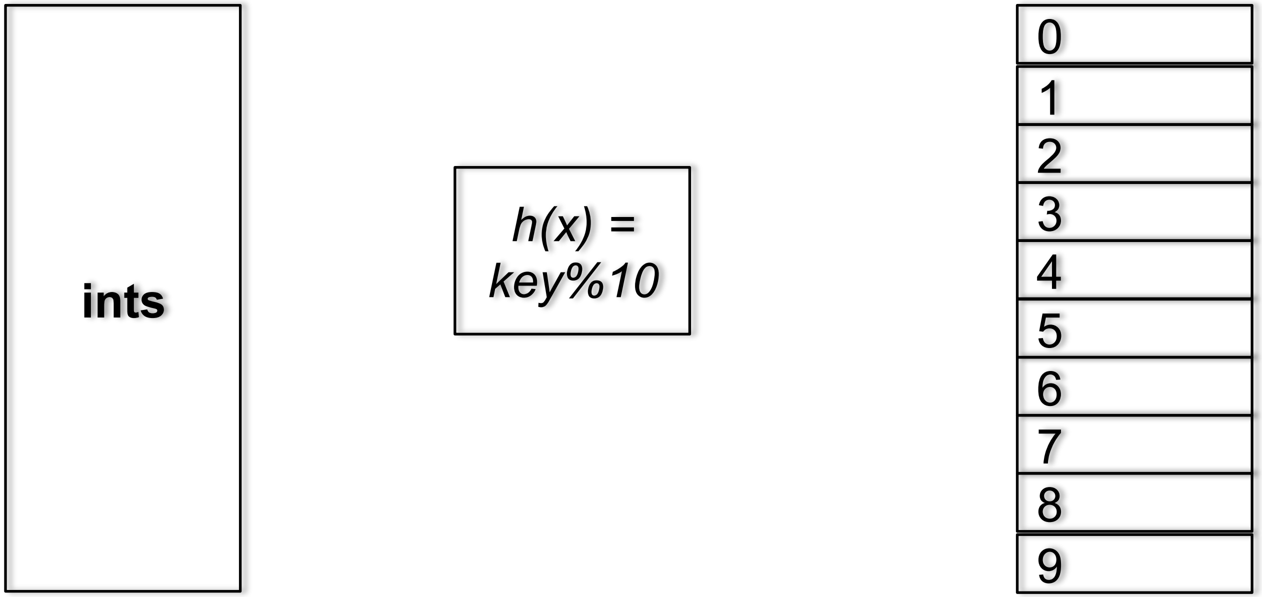
HASH EXAMPLE

- Let's insert(519) table



HASH EXAMPLE

- **Let's insert(519) table**
  - Where does it go?



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- **Let's insert(519) table**
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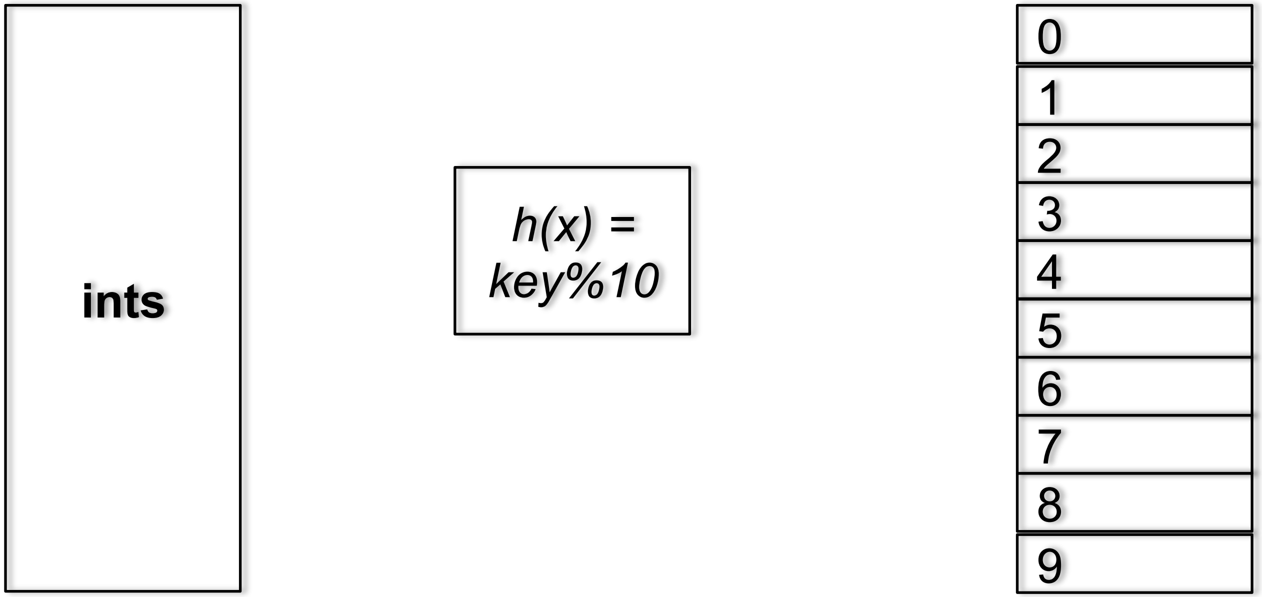

HASH EXAMPLE

- **Let's insert(519) table**
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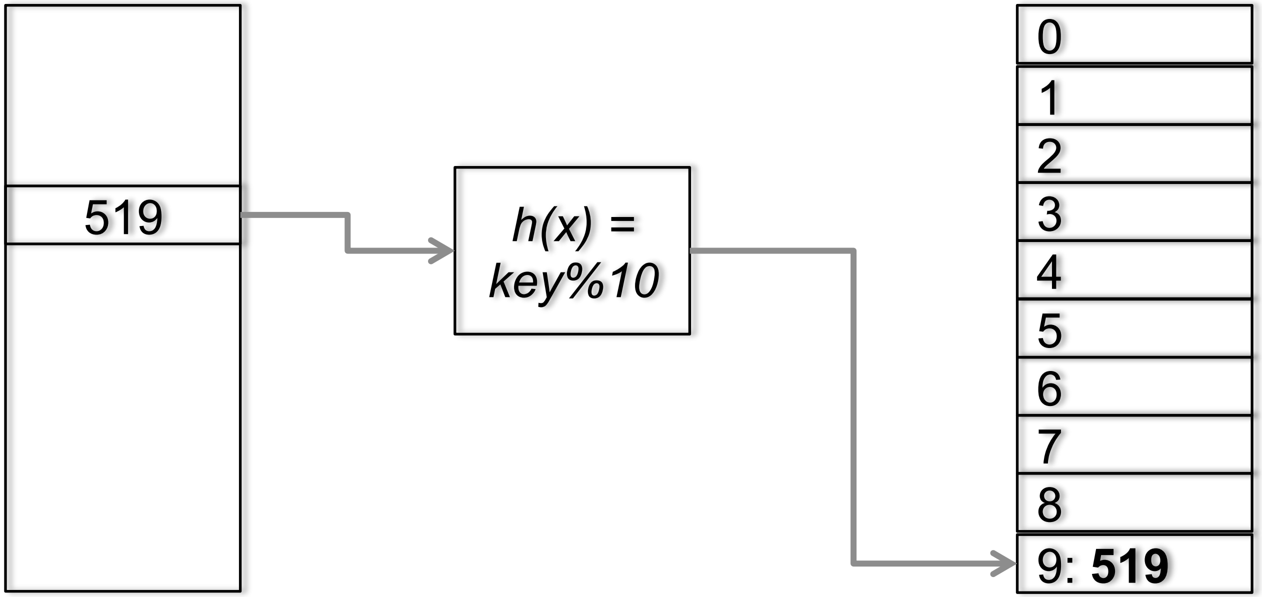
  - 519%10 = 9



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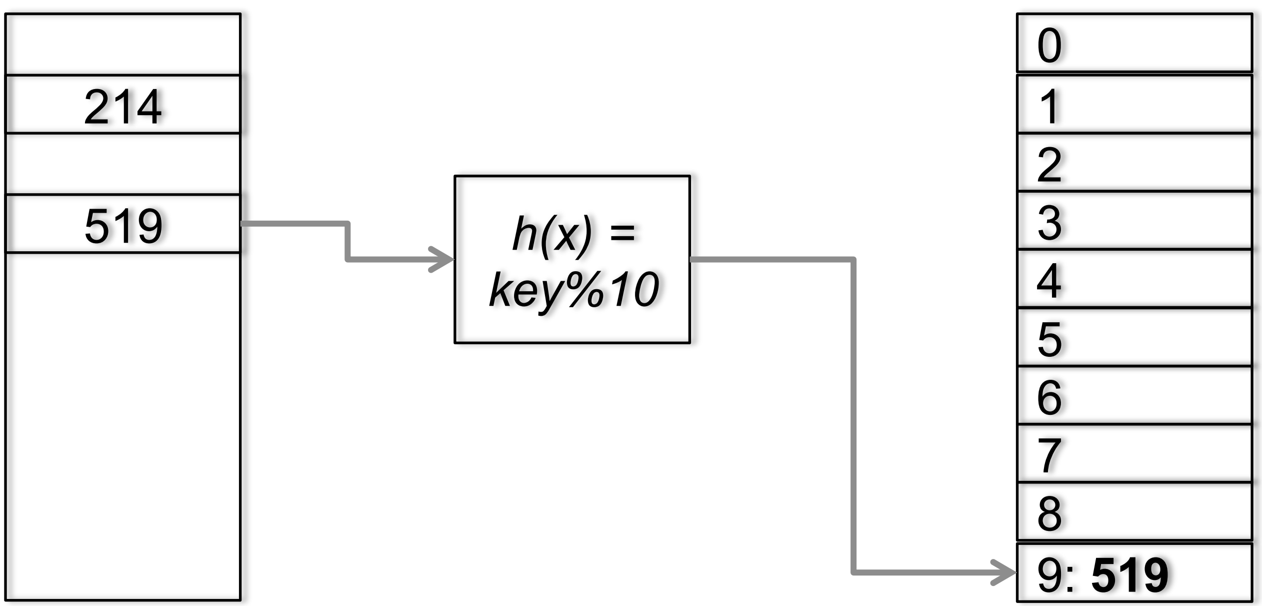
- **Insert(214)**



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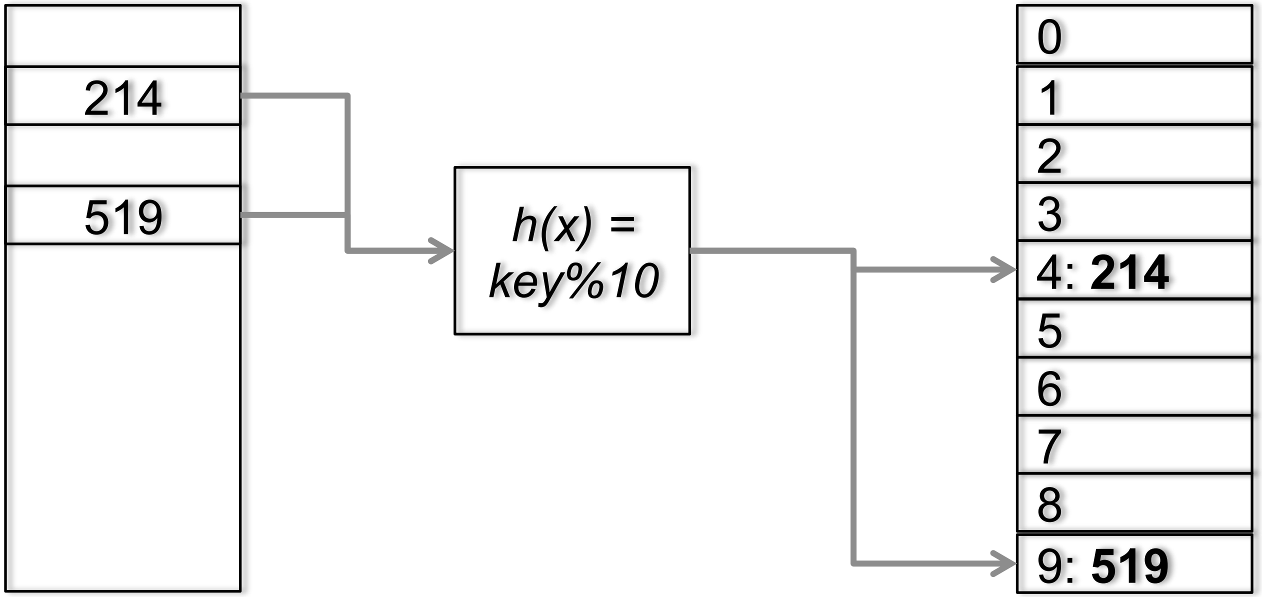

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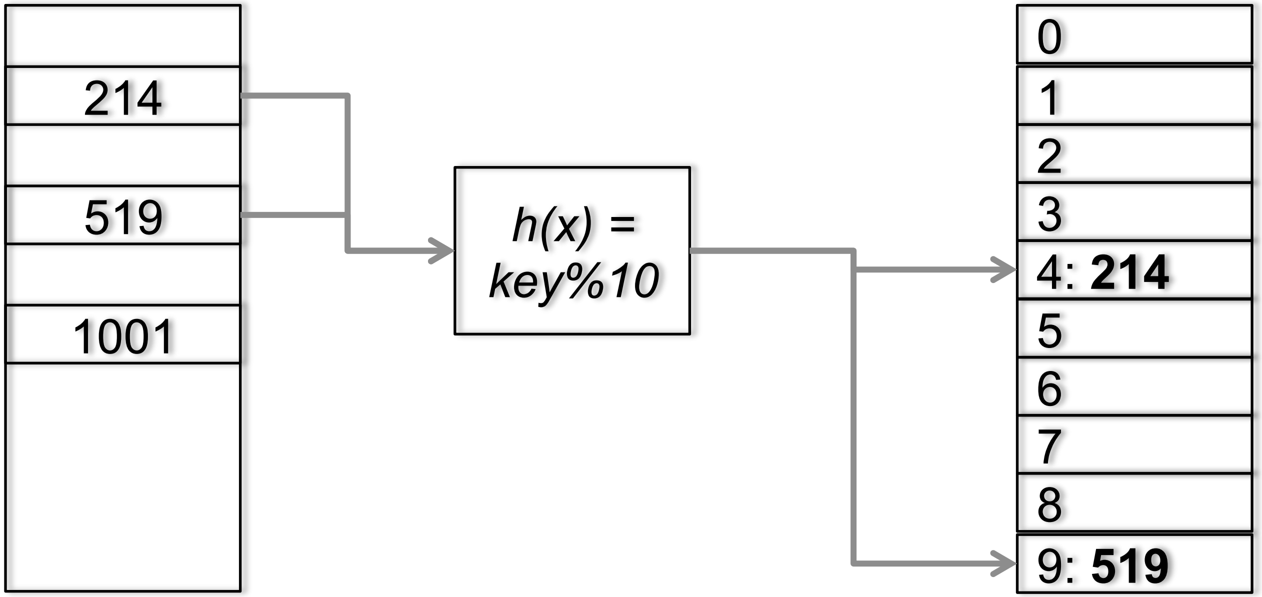
- insert(1001)



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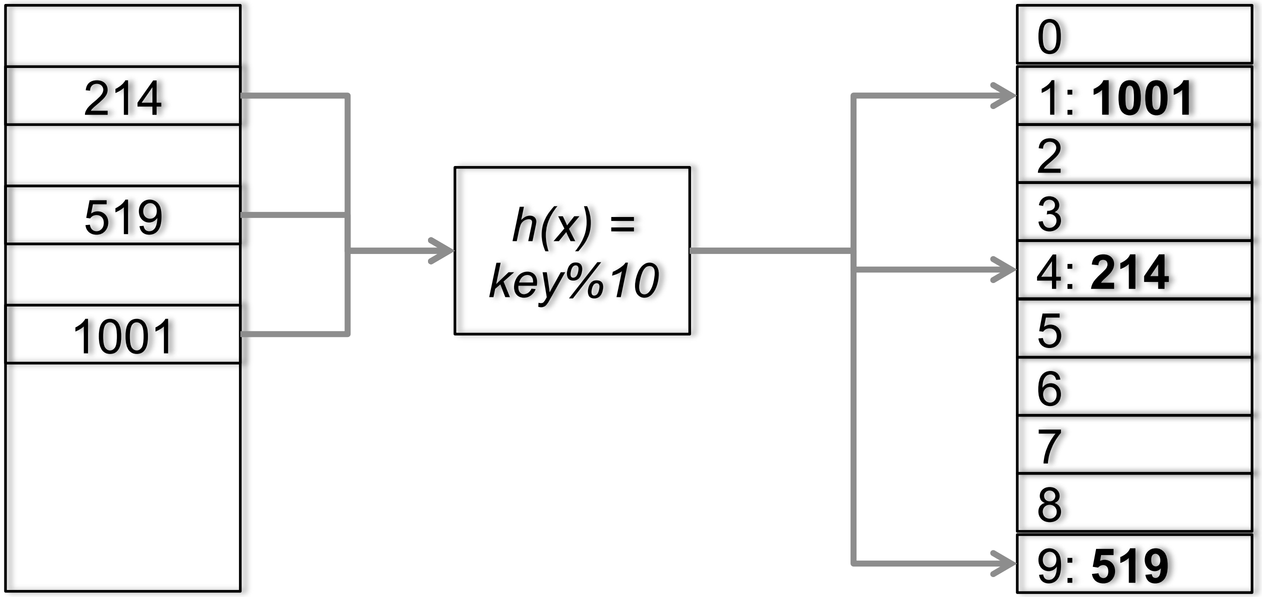

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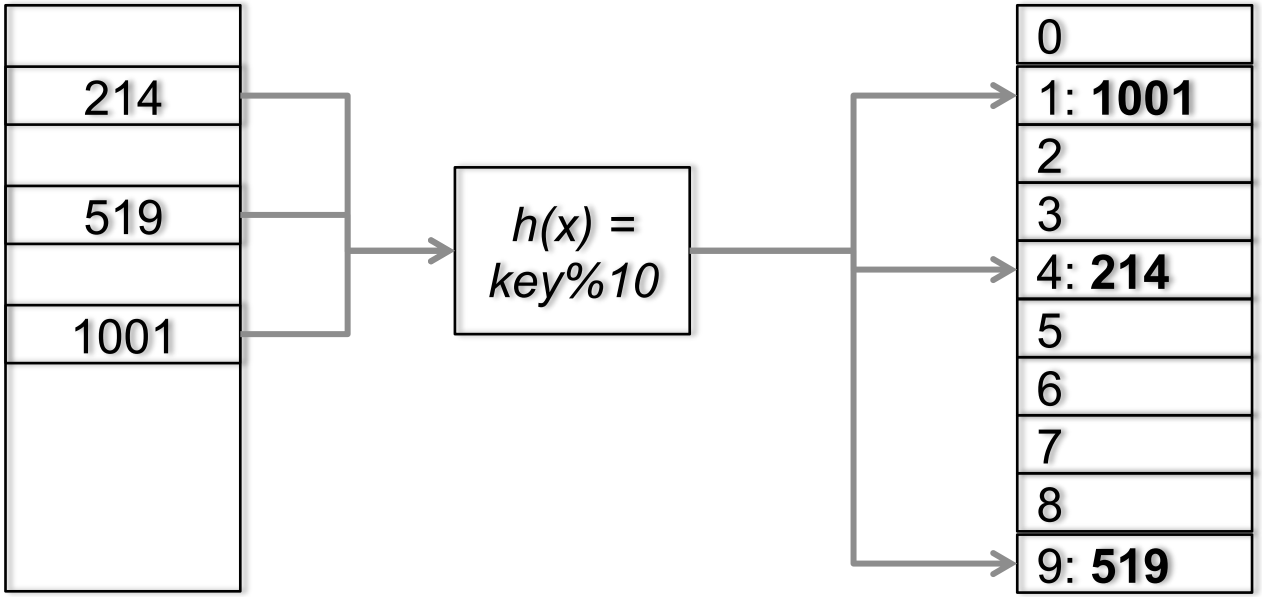

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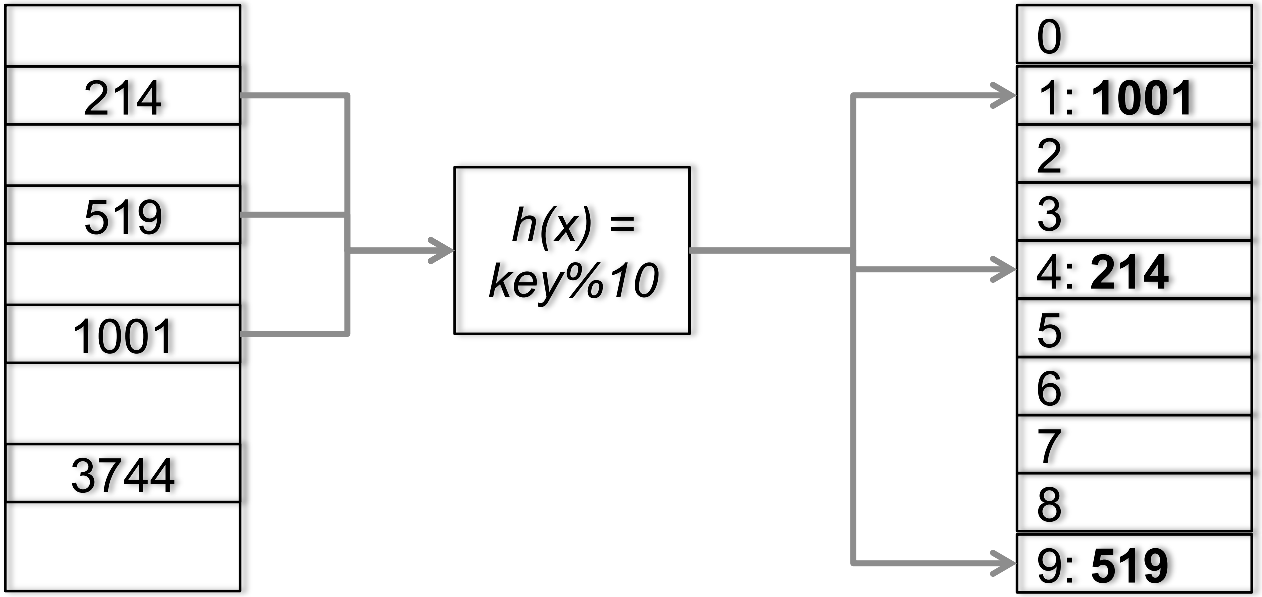

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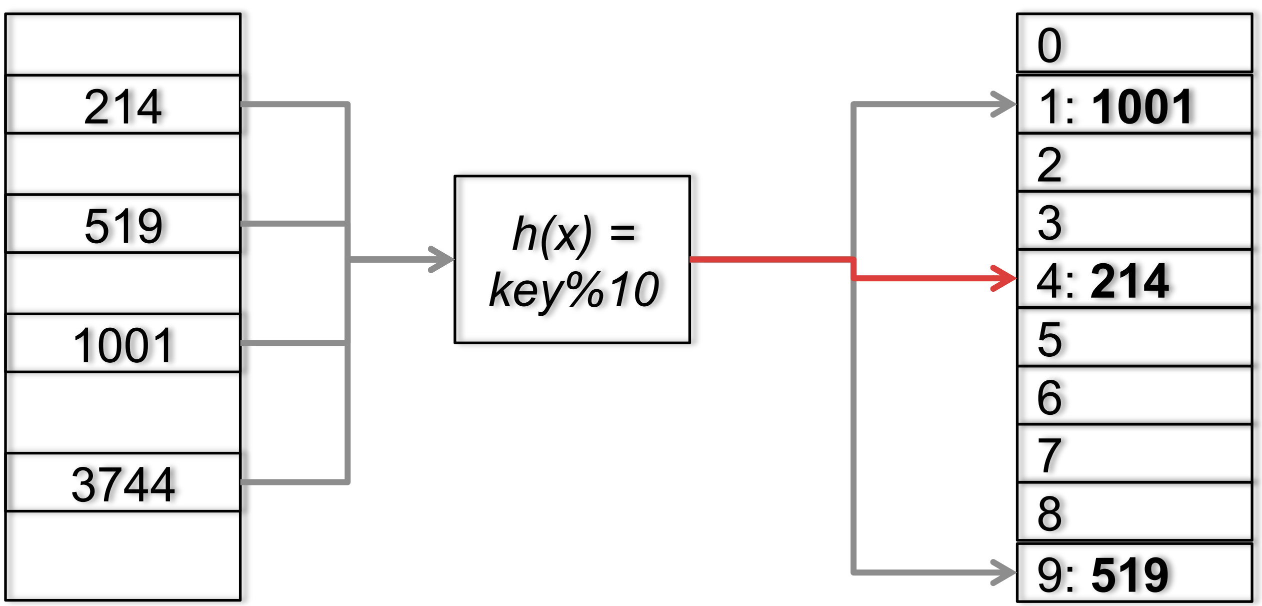

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- **Is there a problem here?**
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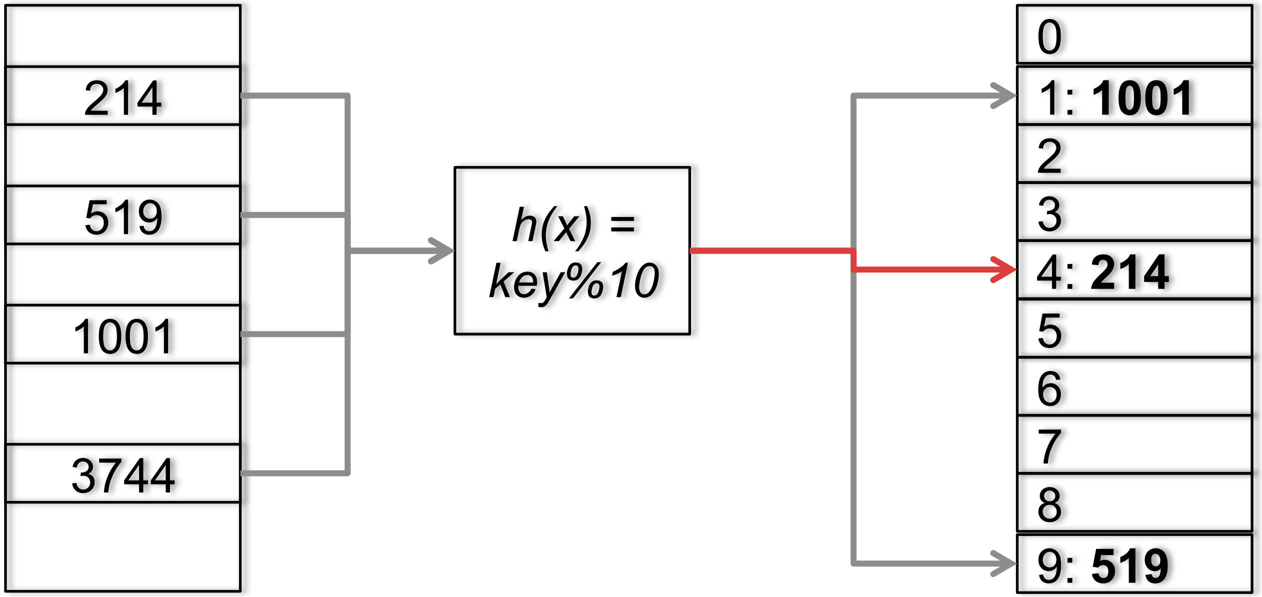
  - This is called a collision!



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  - Needs to incorporate all the data in the keys

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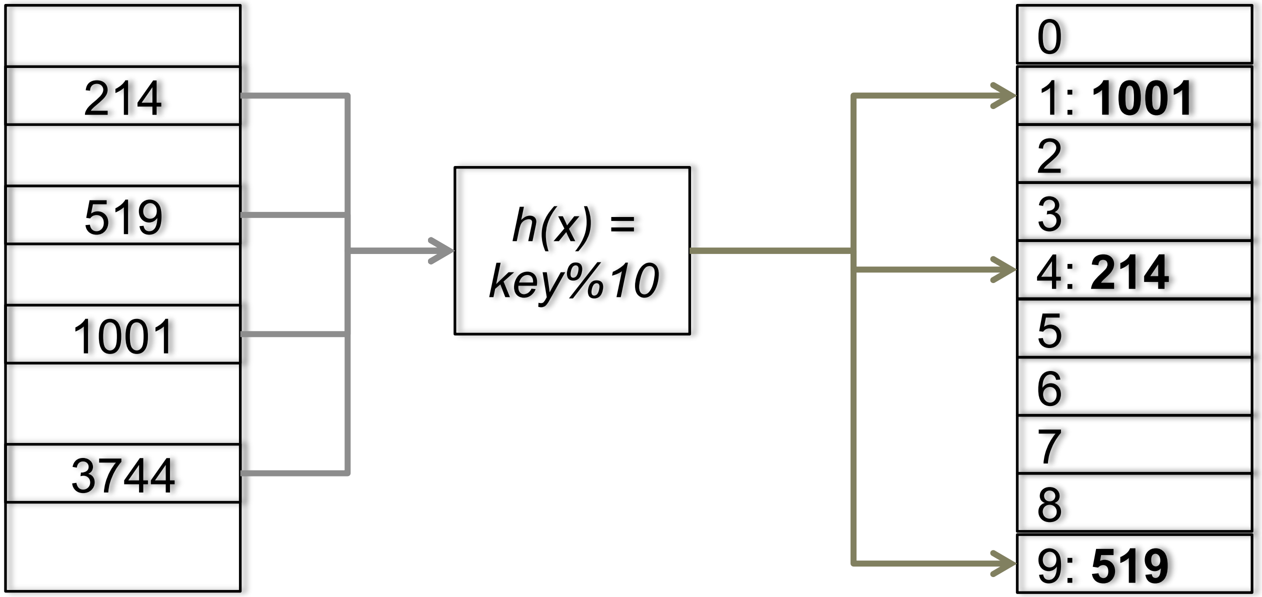

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    - This is called **clustering**

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    - The time it takes to find something in the cluster increases. **This isn't O(1) time!**

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    - We'll discuss it later

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    - Try the appropriate hash table row first
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    - If the array is too full, its operations reach O(n) time

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    - Rather than increasing by one each time, we increase by the squares
    - k+1, k+4, k+9, k+16, k+25
    - Certain tables can cause **secondary clustering**
    - Can fail to insert if the table is over half full

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    - If two keys collide in the hash table, then a secondary hash indicates the probing size

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    - If two keys collide in the hash table, then a secondary hash indicates the probing size
    - Need to be careful, possible for infinite loops with a very empty array