CSE 332

JULY 10TH – HASHING

EXAM FRIDAY

- **Practice exam after class today**
- **Topics:**
  - Stacks and Queues
  - BigO Notation and runtime Analysis
  - Heaps
  - Trees (BST and AVL)
  - Design Tradeoffs

EXAM FRIDAY

- **Format**

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  - No note sheet

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  - No note sheet
  - One section of short answer

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  - 4-5 Technical Questions

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  - 4-5 Technical Questions
  - 1 Design Decision Question

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  - No note sheet
  - One section of short answer
  - 4-5 Technical Questions
  - 1 Design Decision Question
  - Less than 10 minutes per problem

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- **No Java material on the exam**

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- **If you get stuck on a problem, move on**
- **Any questions?**

TODAY'S LECTURE

- Hashing

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- **Hashing**
  - Basic Concept

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  - Hash functions

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  - Collision Resolution

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  - Collision Resolution
  - Runtimes

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  - 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

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    - Accesses should be as fast as possible

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  - Hard to go from **M** -> **D** in O(1) time

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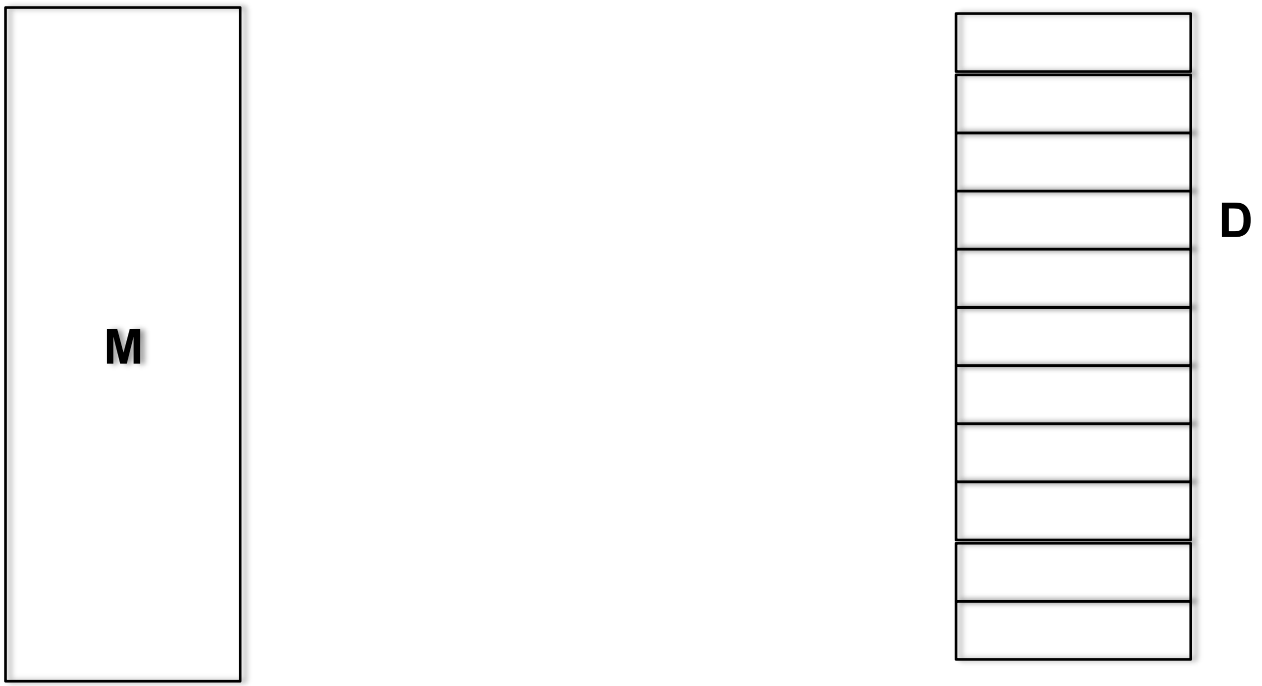
  - The data in **D** does not need any particular ordering.

THE HASH TABLE

- How can we do this?



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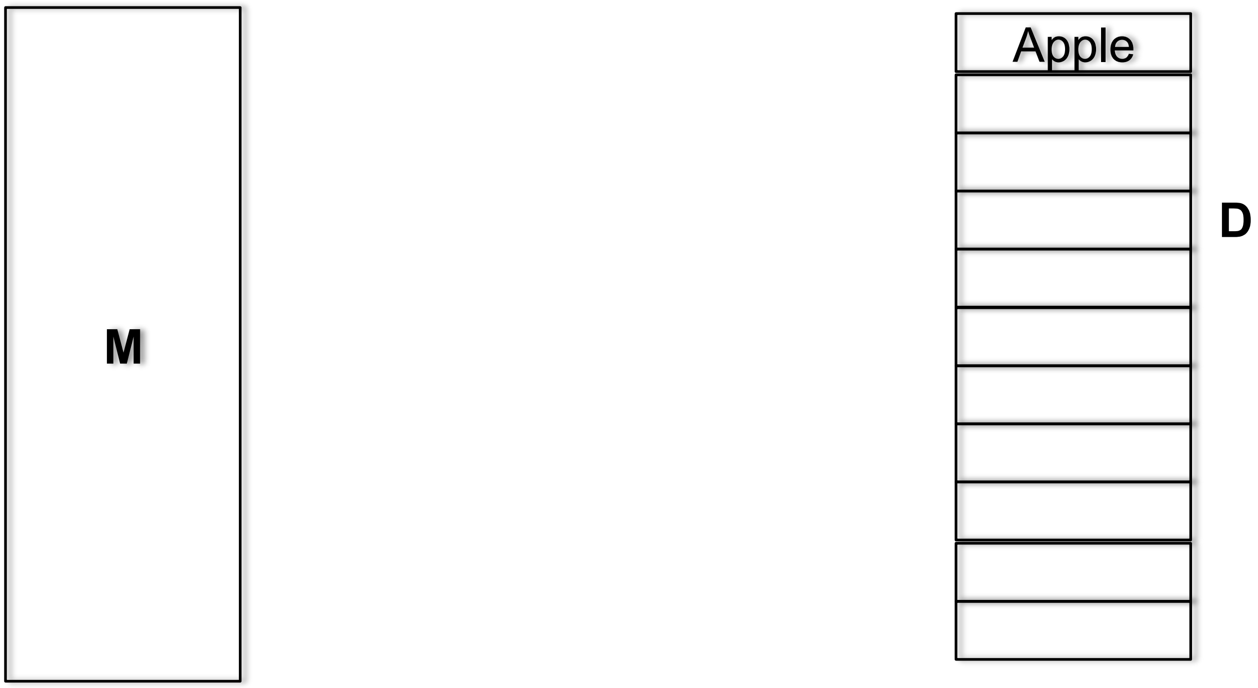

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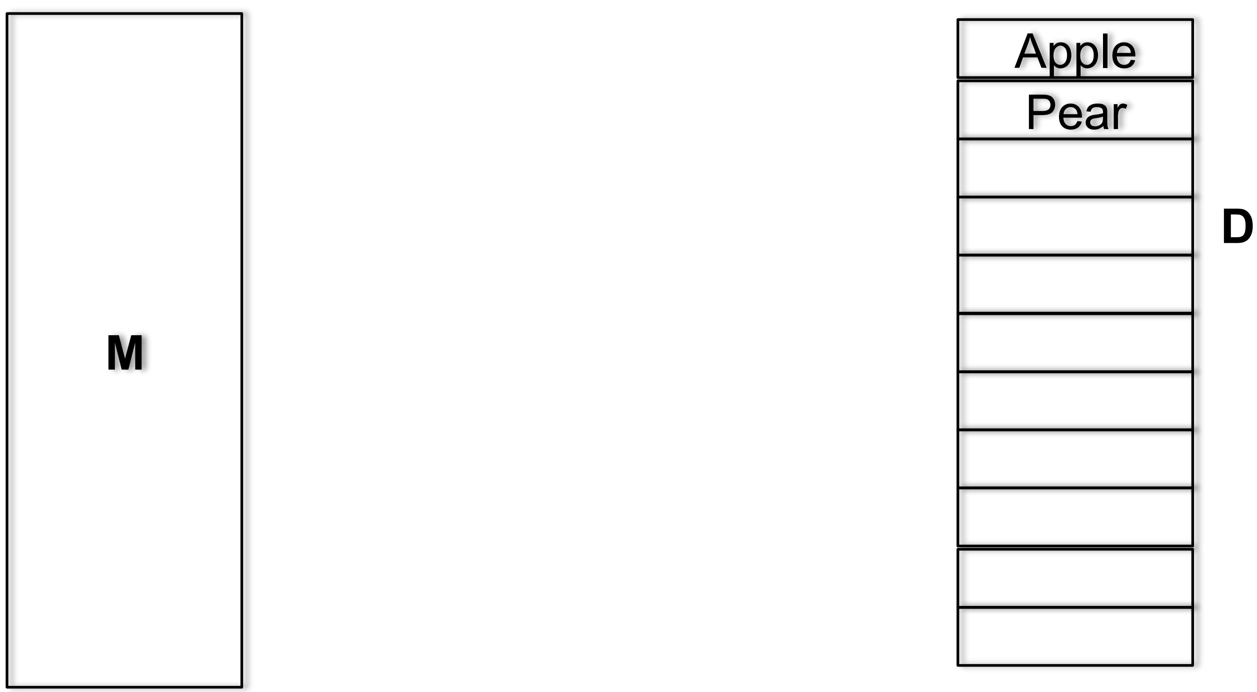

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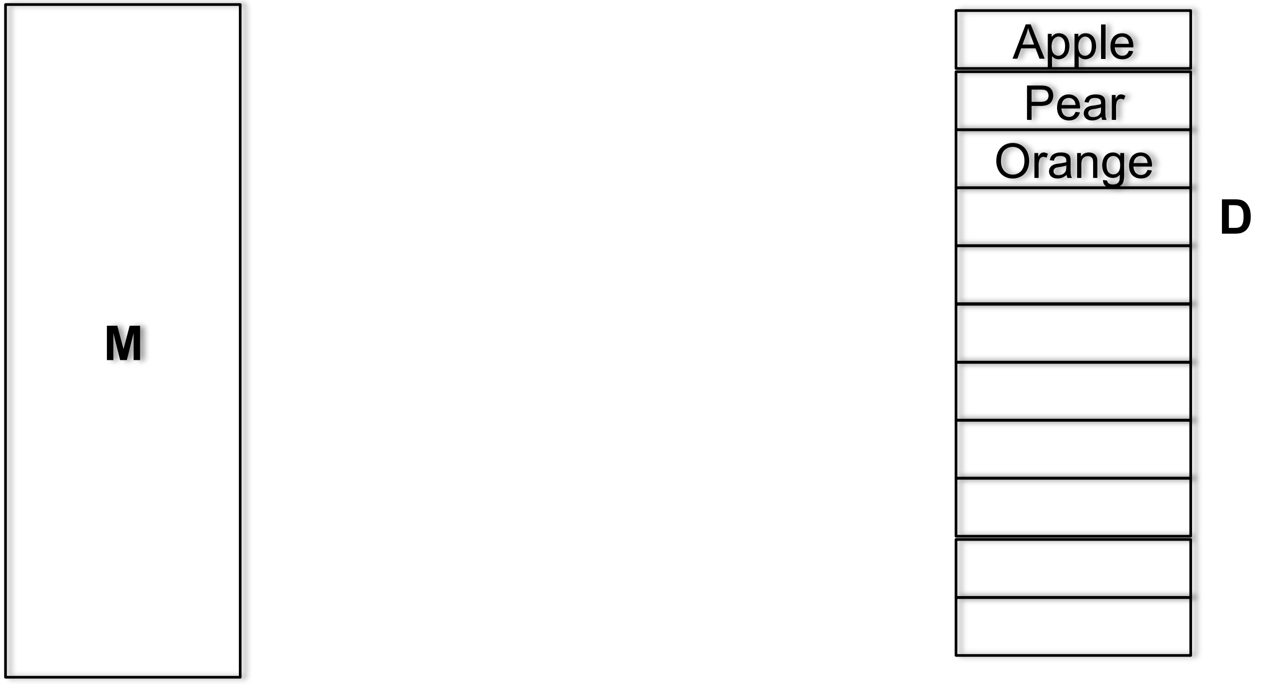

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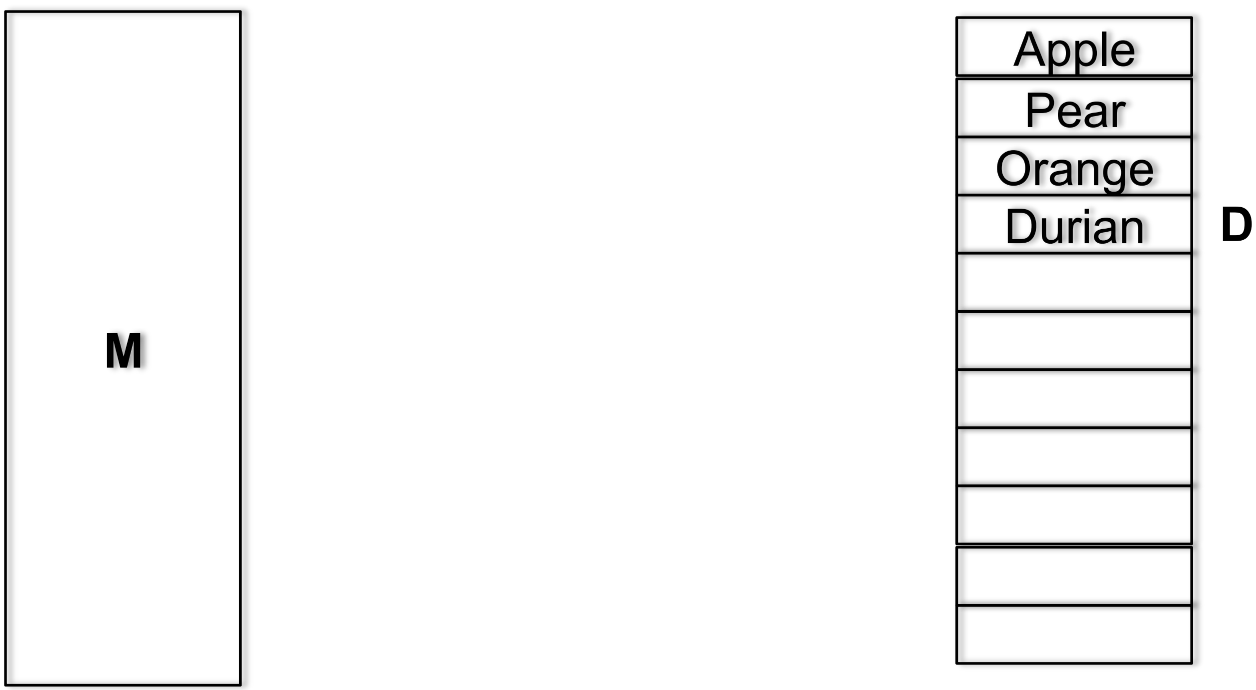

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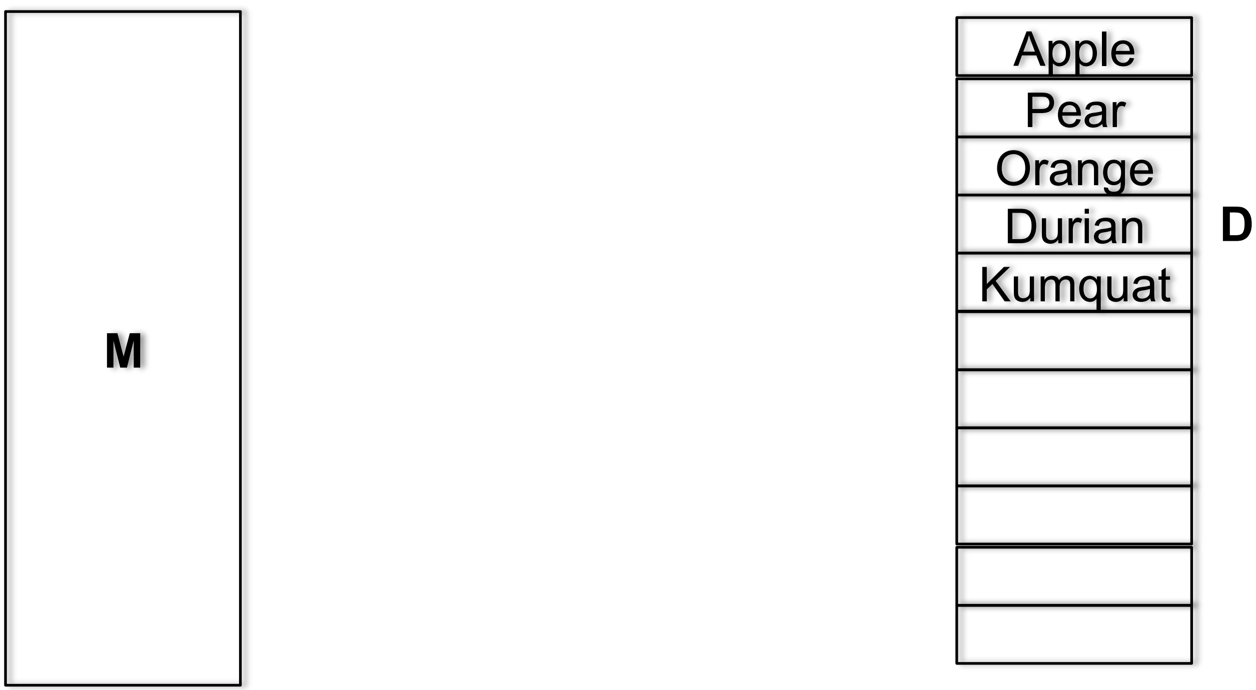

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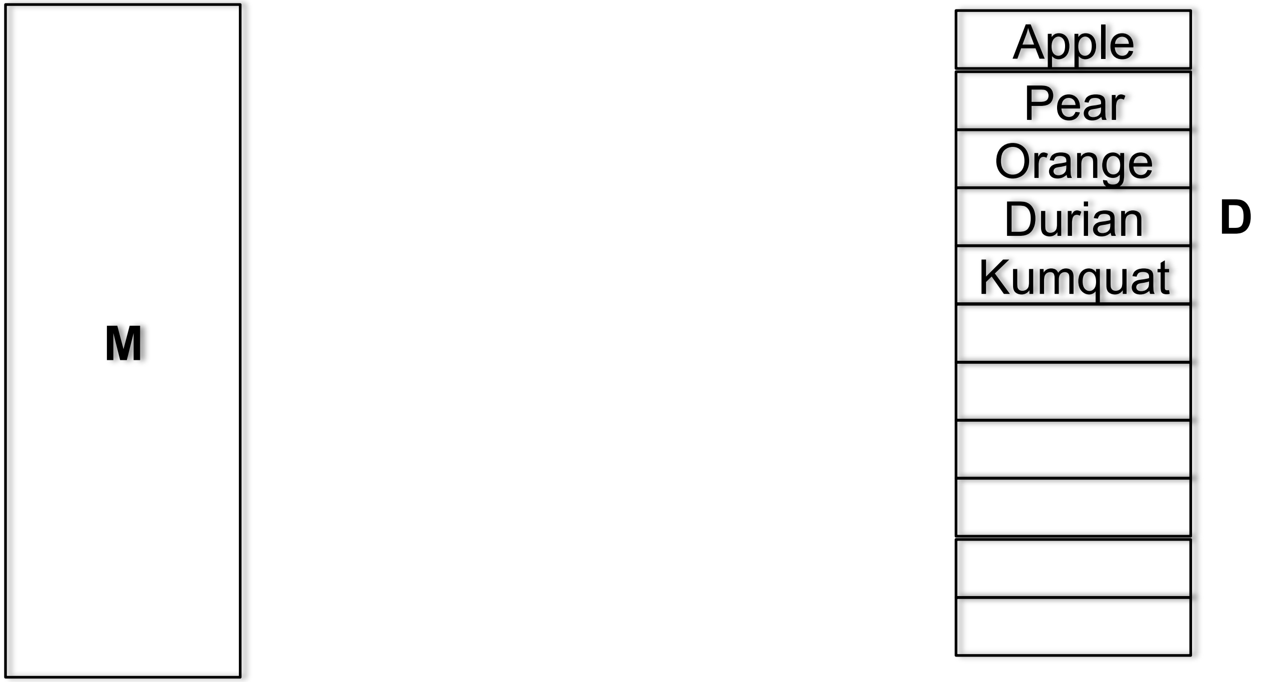

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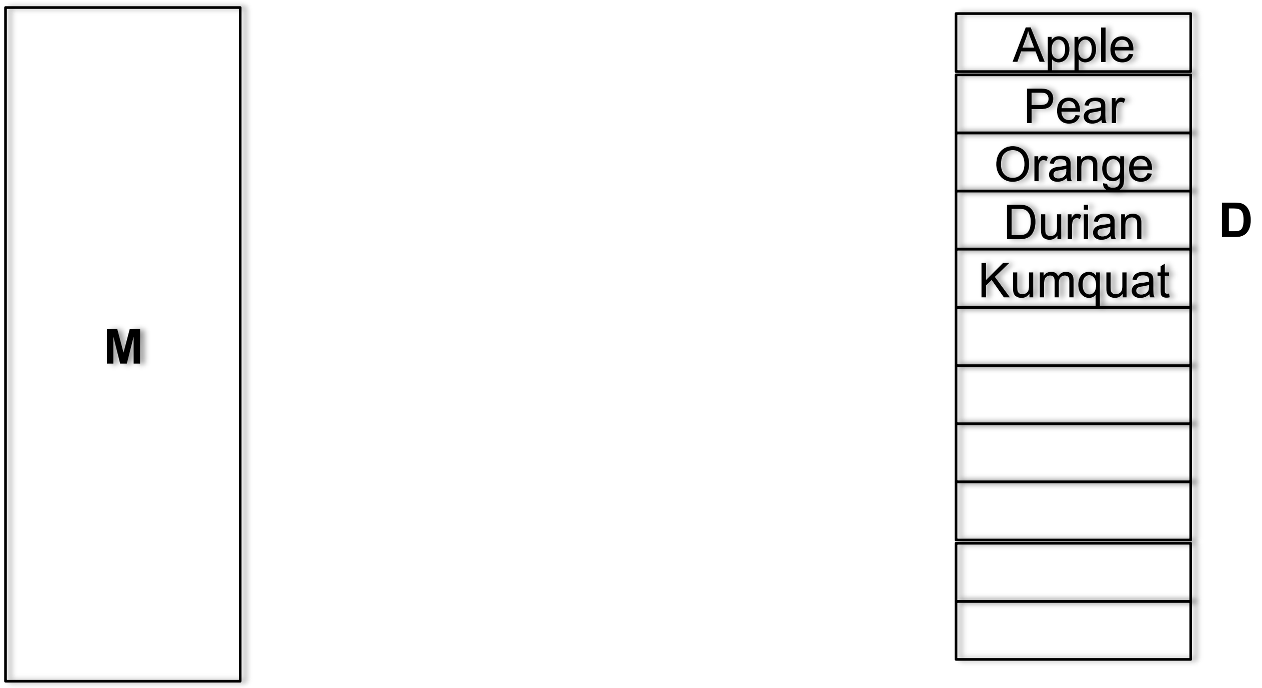

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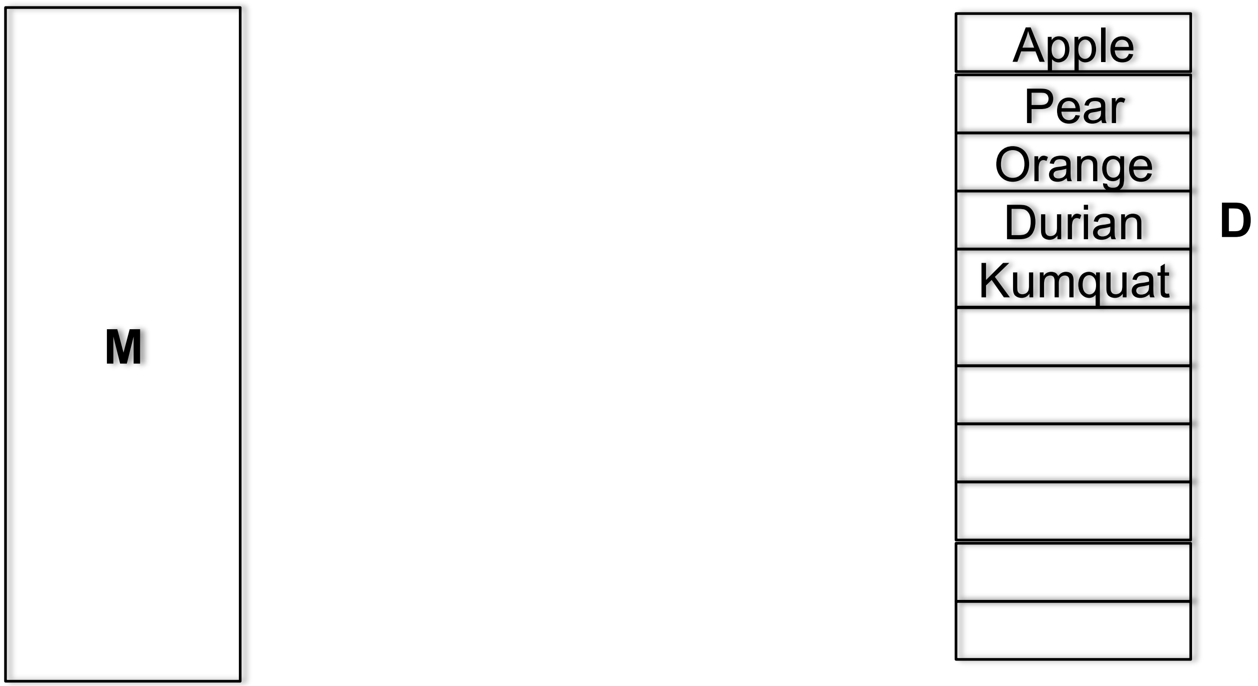
  - Same problem with sorted arrays!



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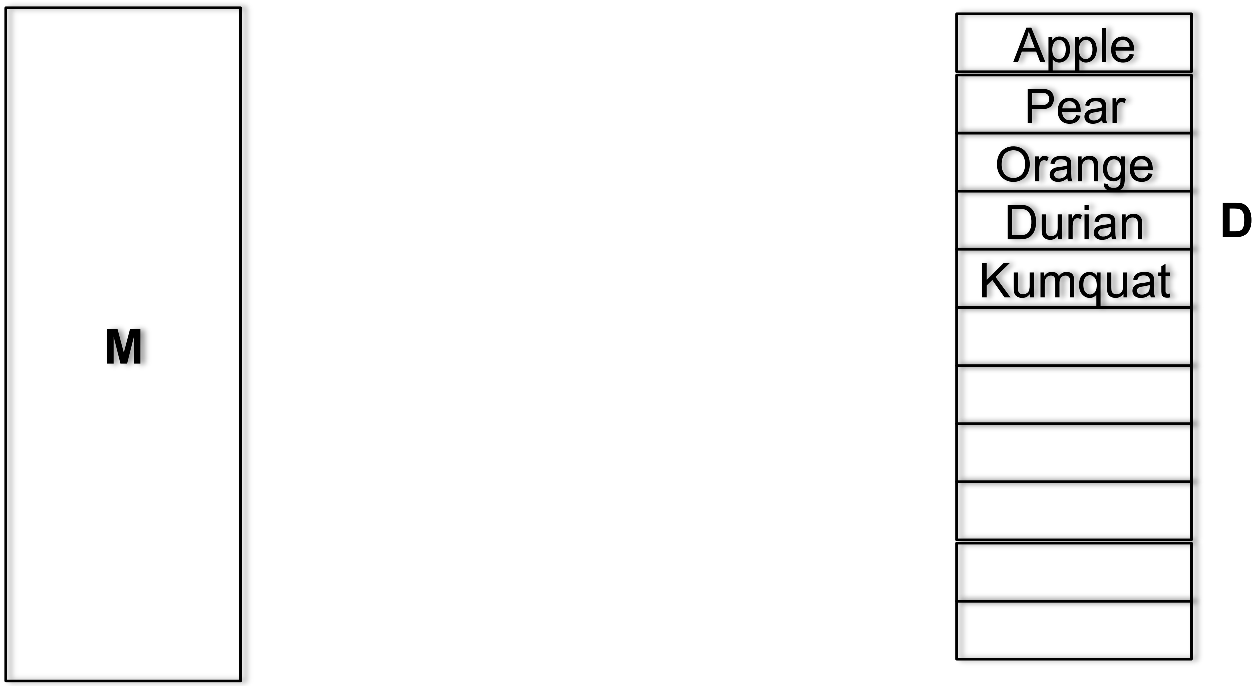
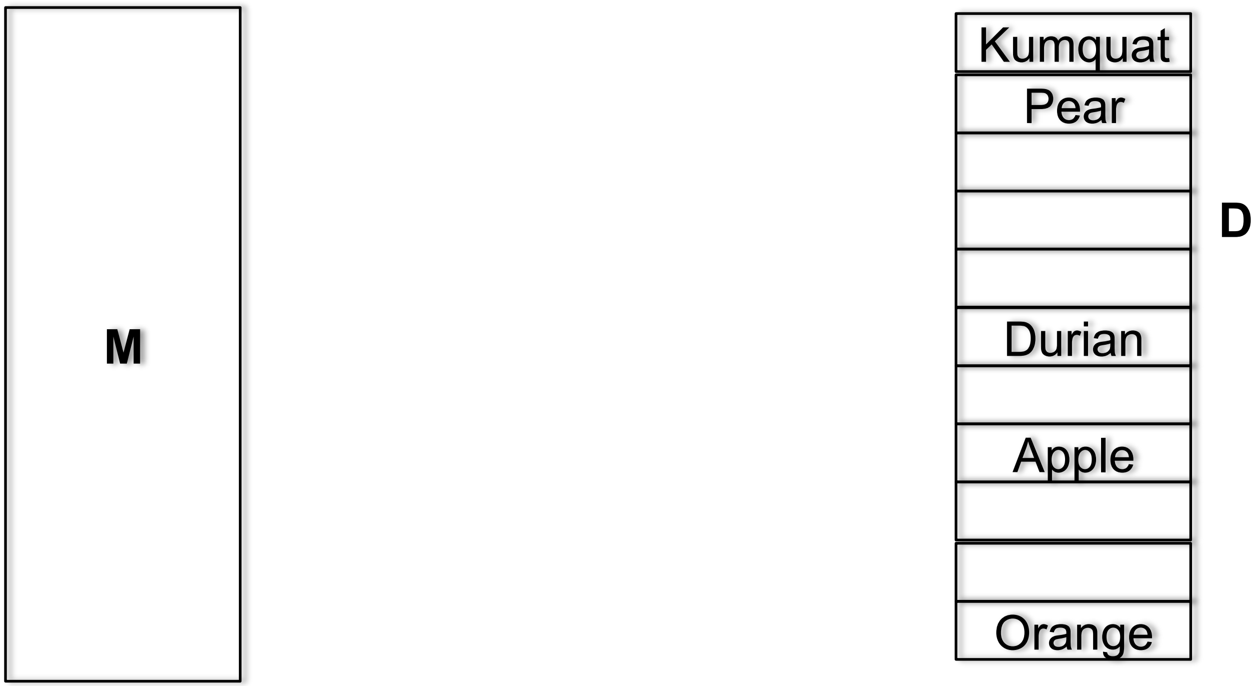


THE HASH TABLE

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



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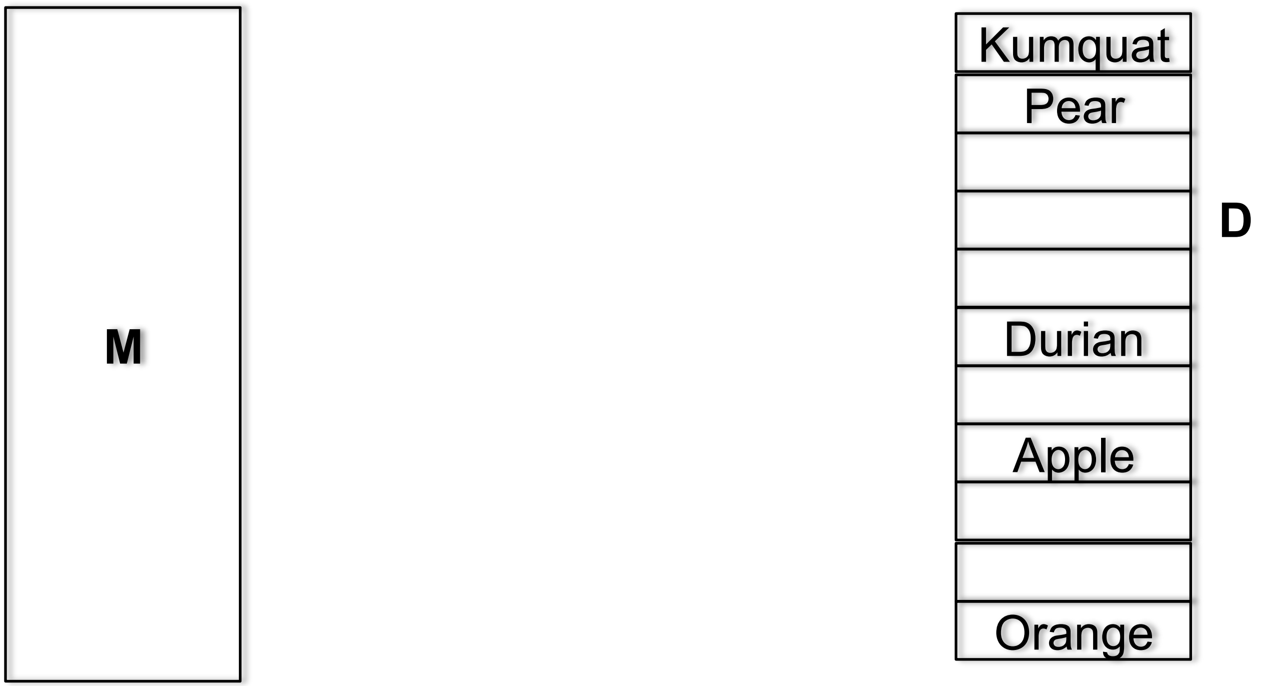
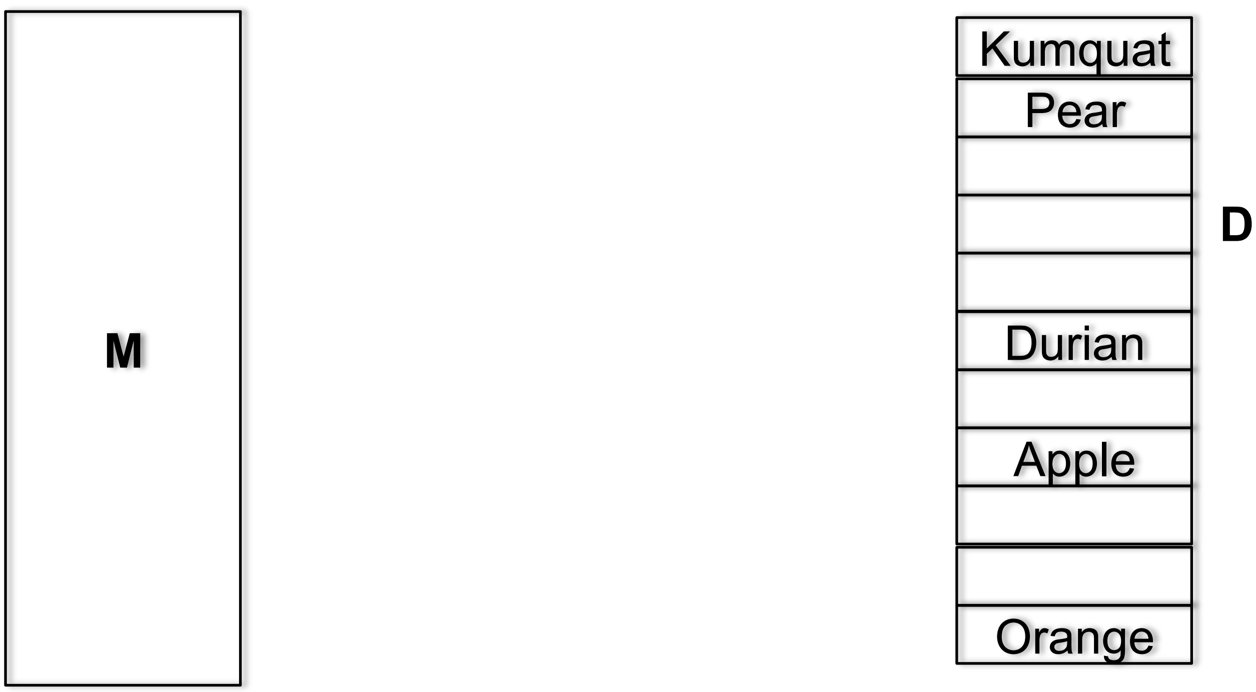


THE HASH TABLE

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



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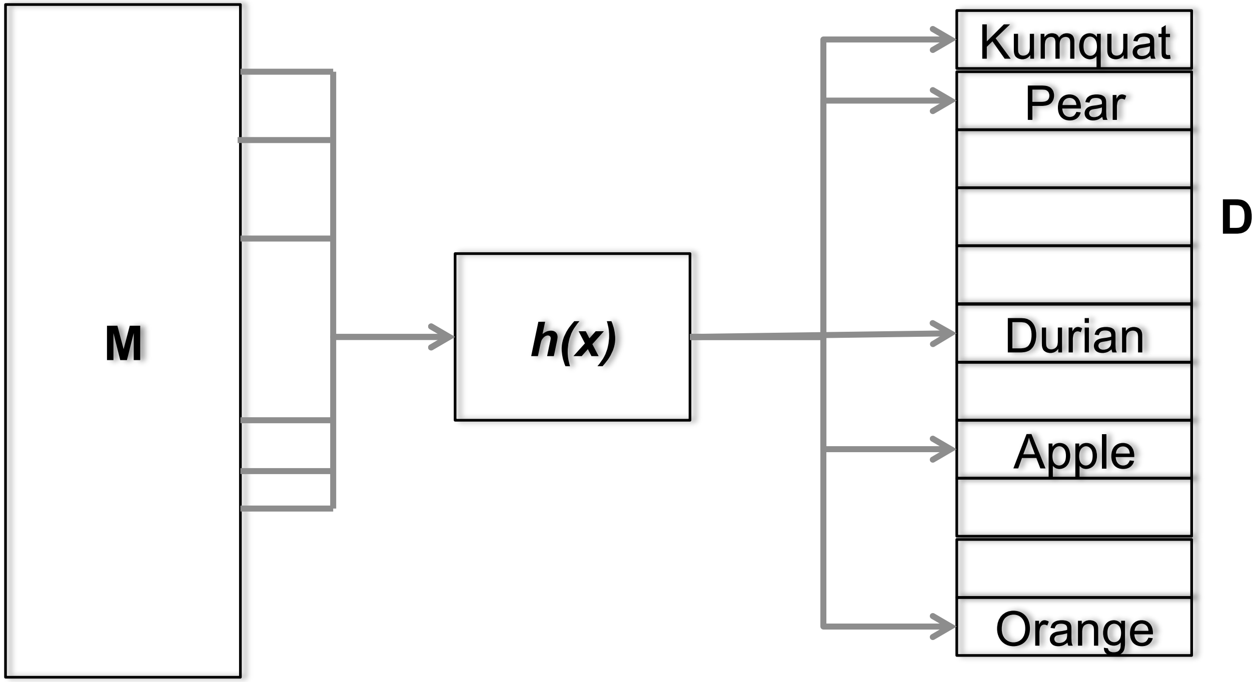
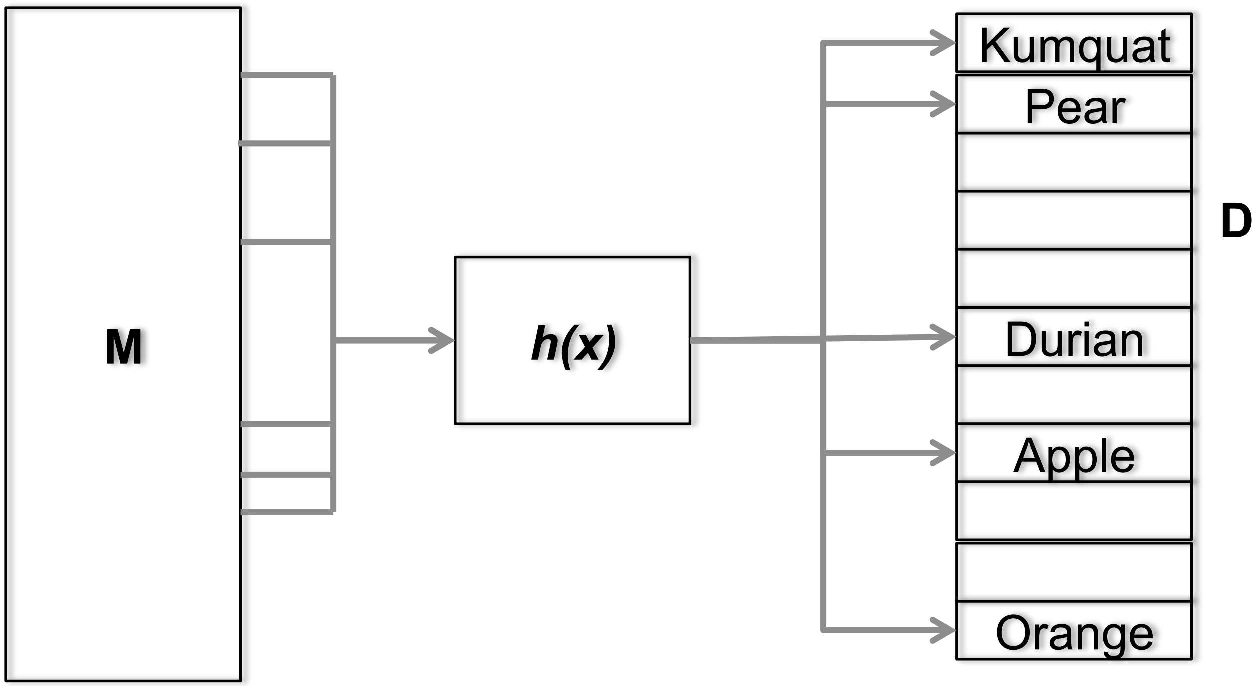
- **What about a pseudo-random mapping?**



THE HASH TABLE

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



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  - 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)`

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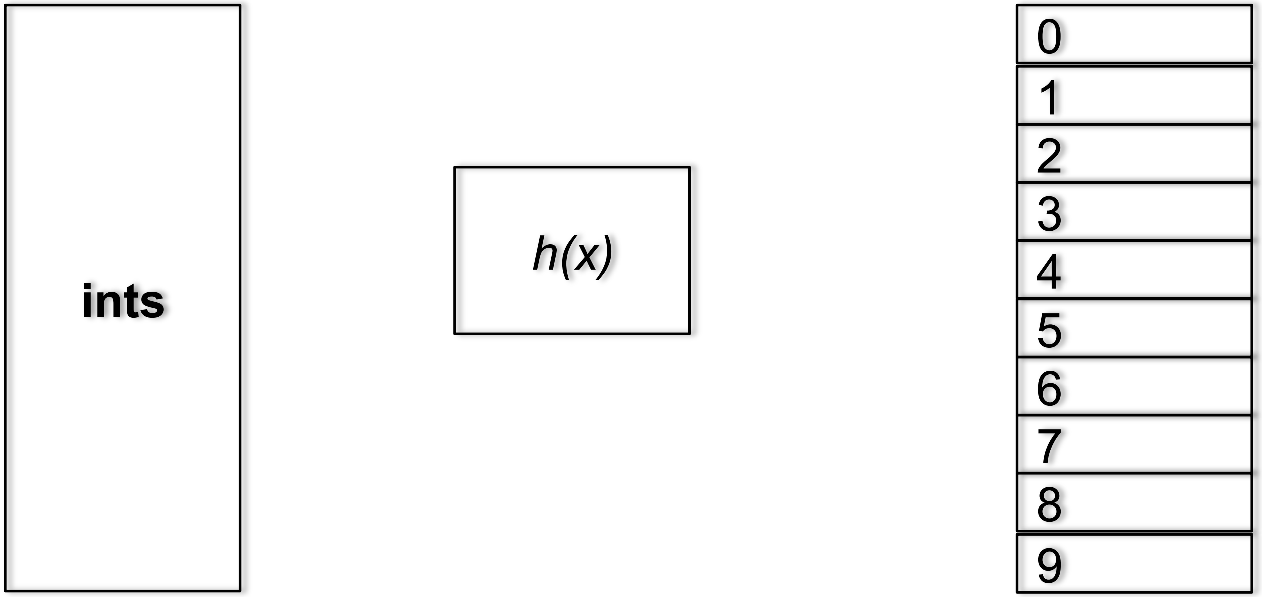

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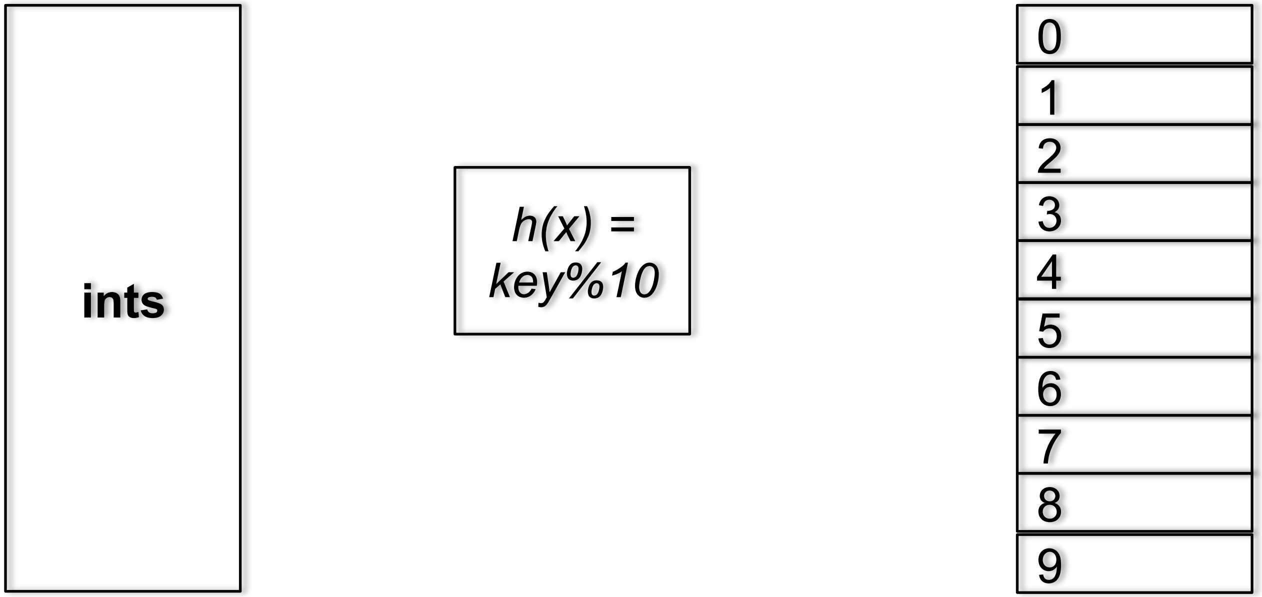
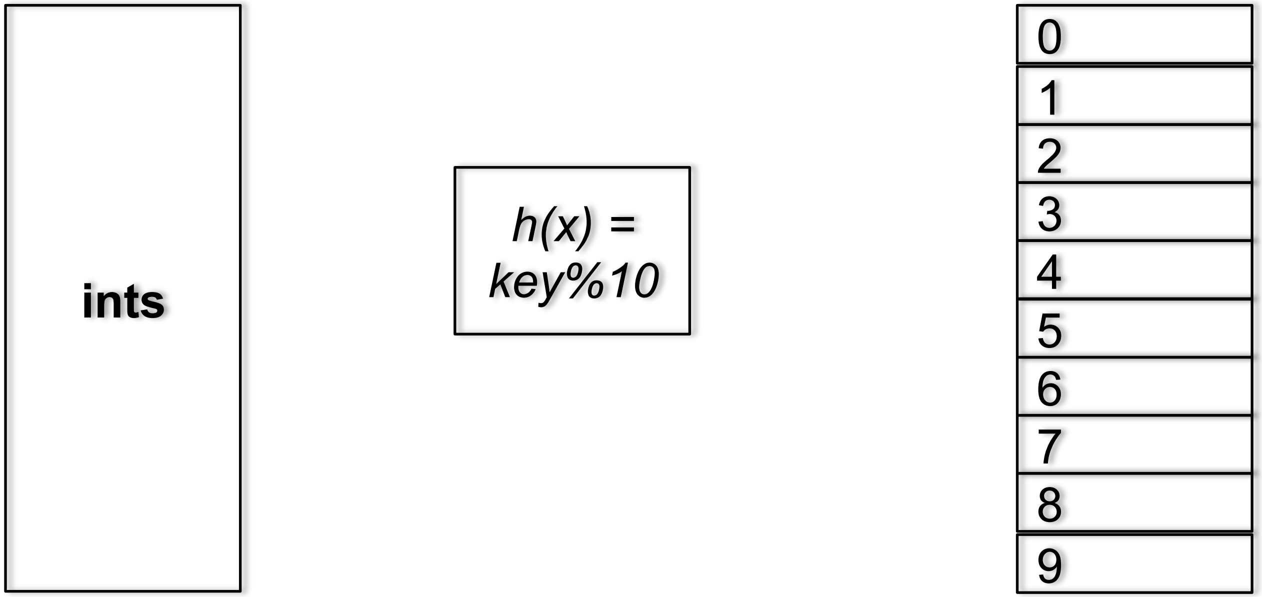


HASH EXAMPLE

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



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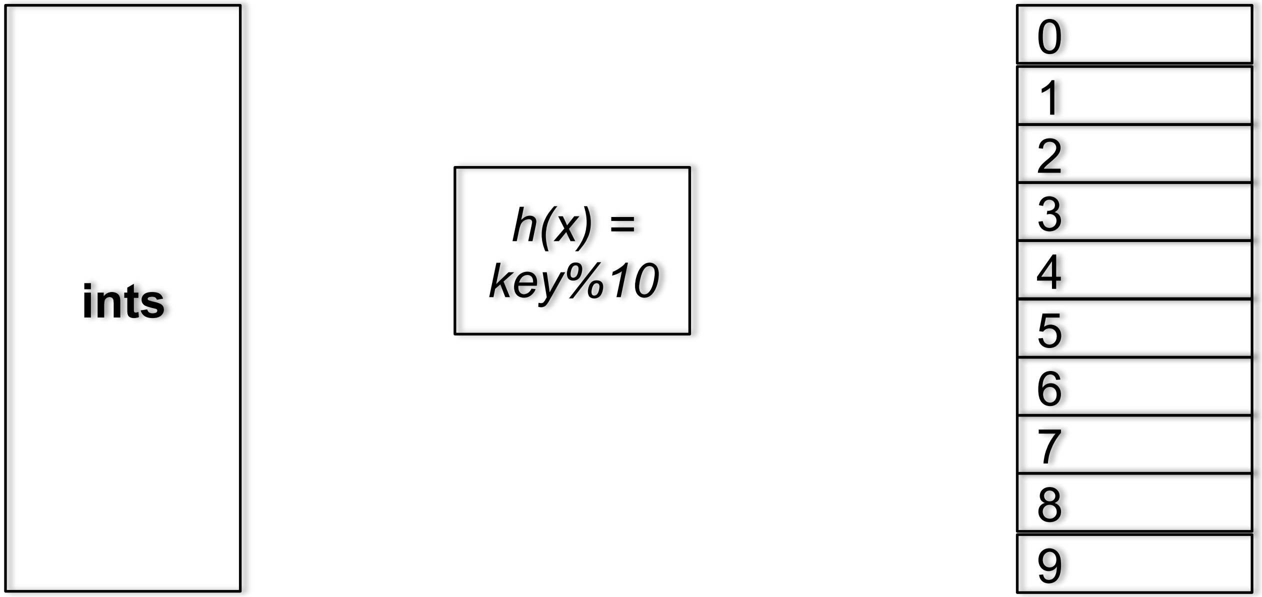

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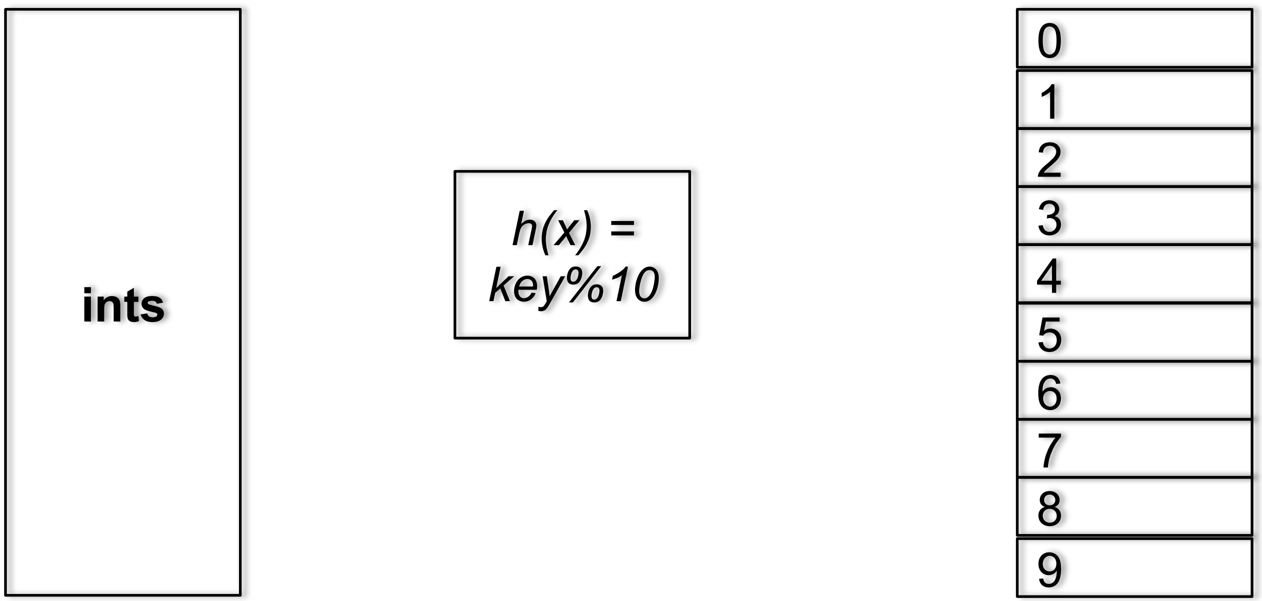

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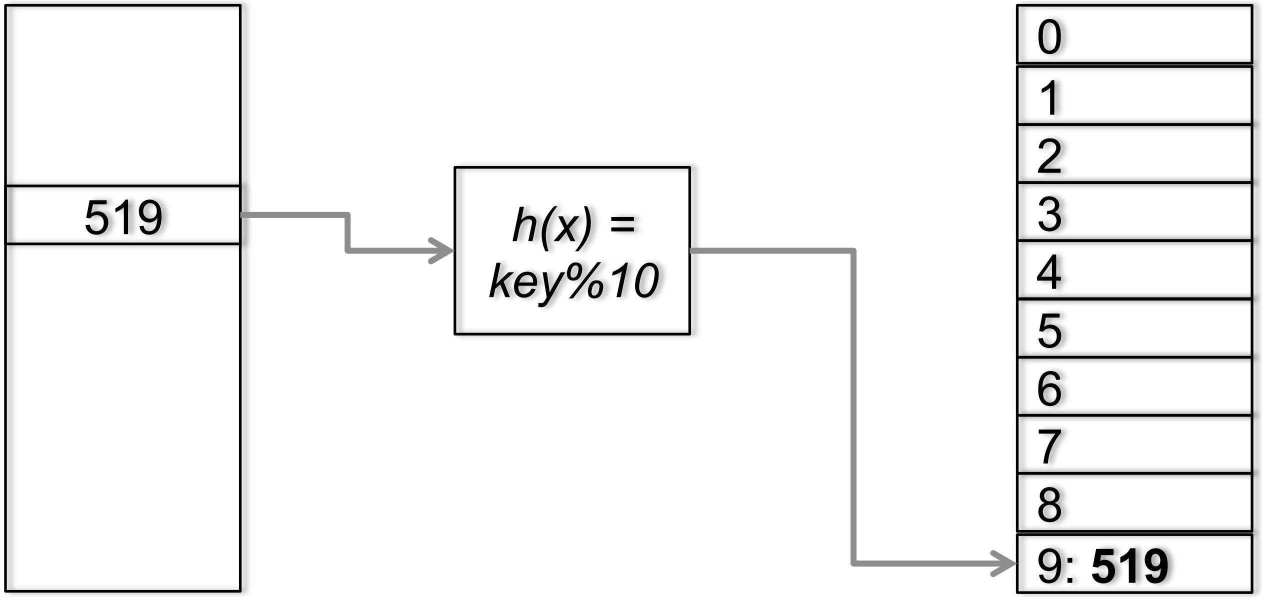
  - 519%10 = 9



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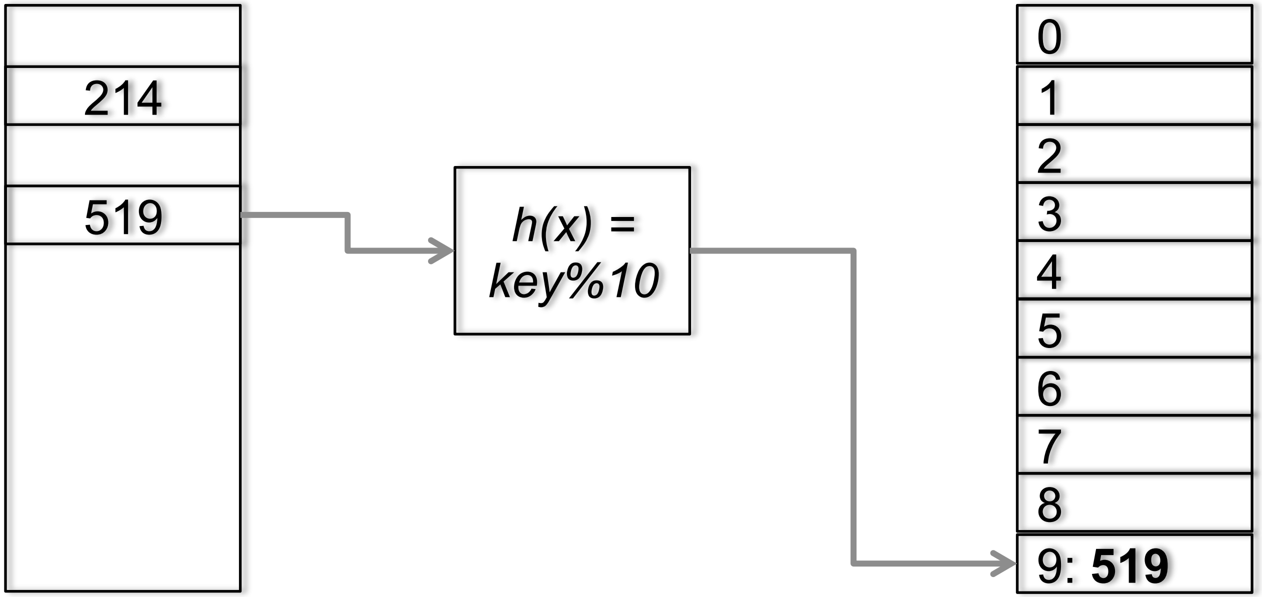
- **Insert(214)**



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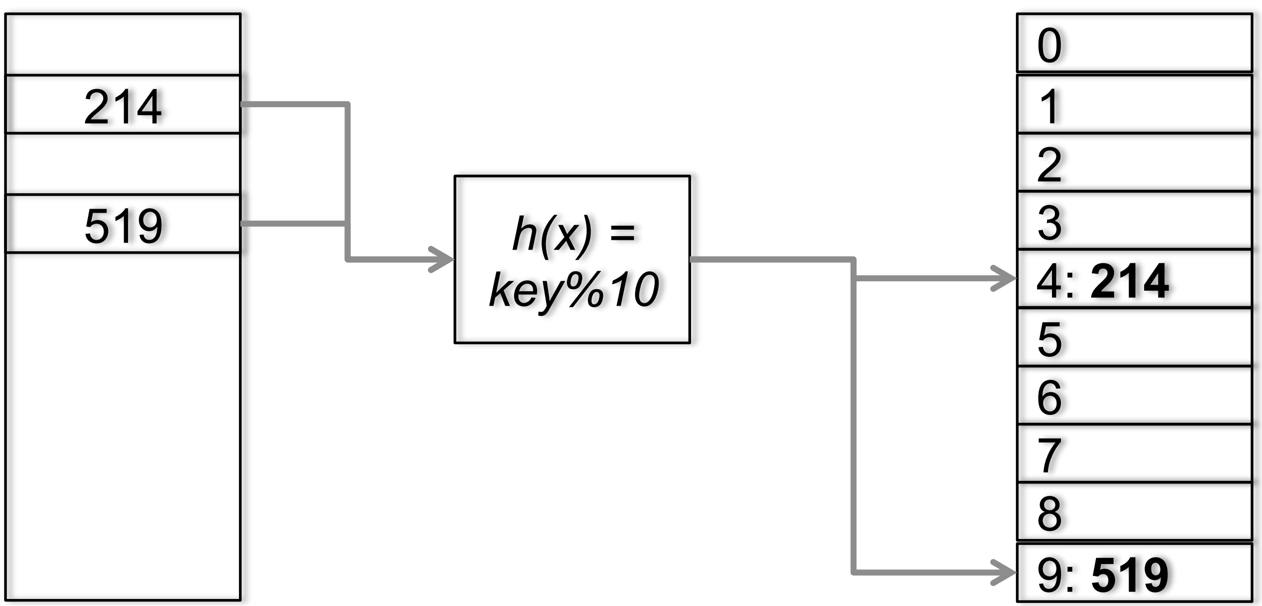

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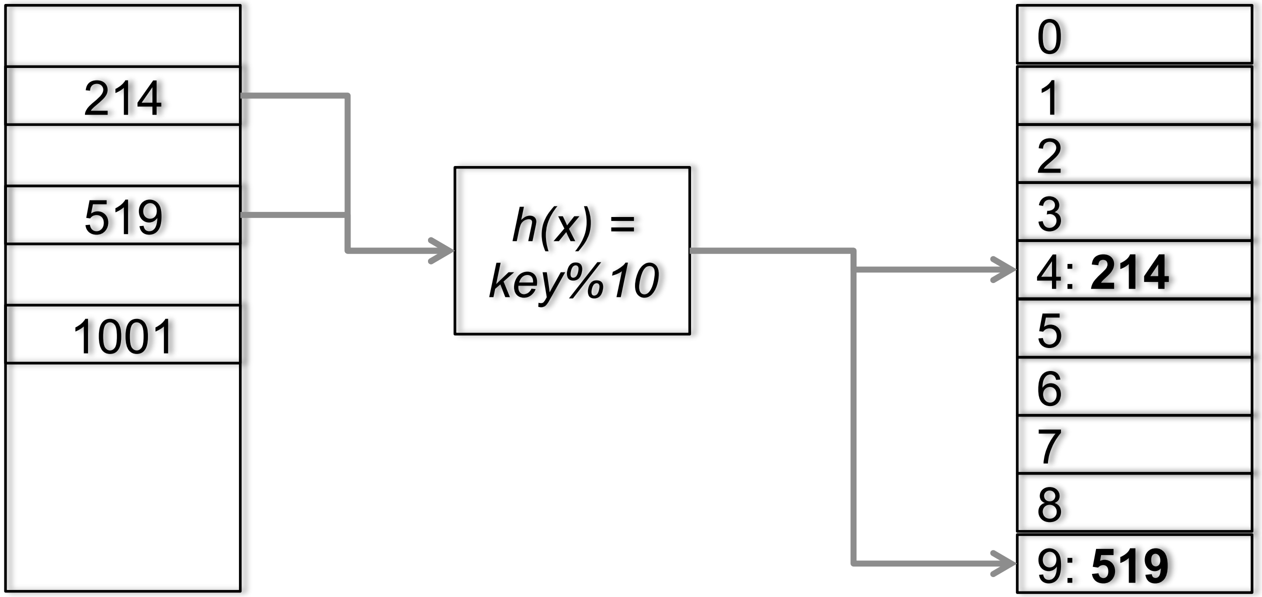
- **insert(1001)**



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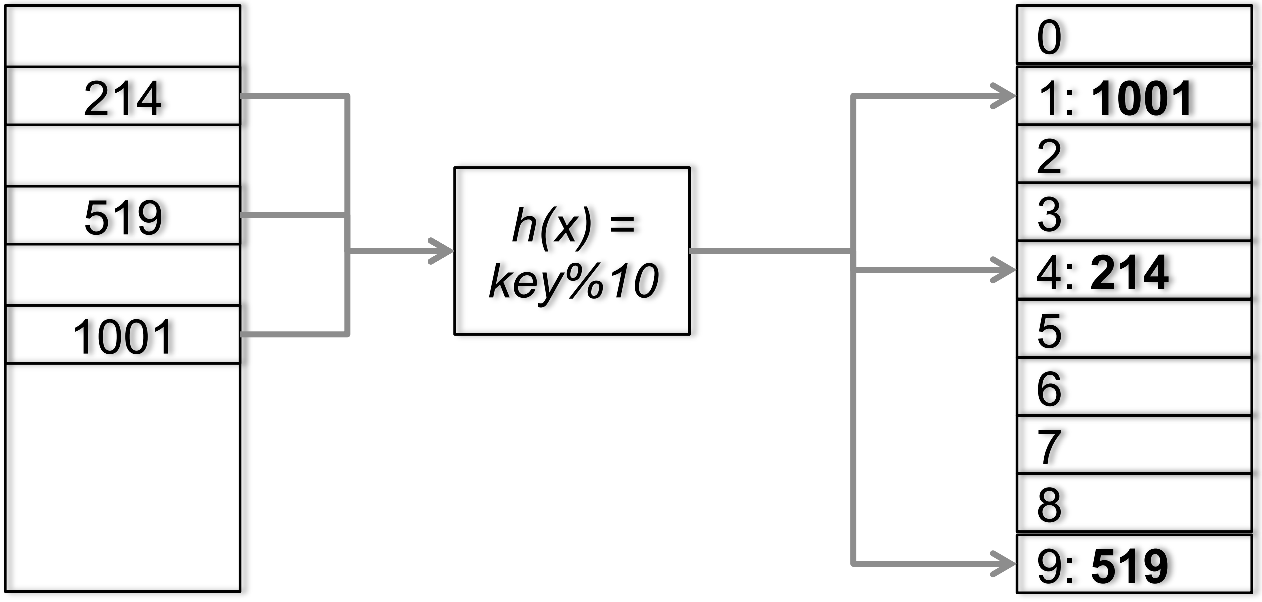

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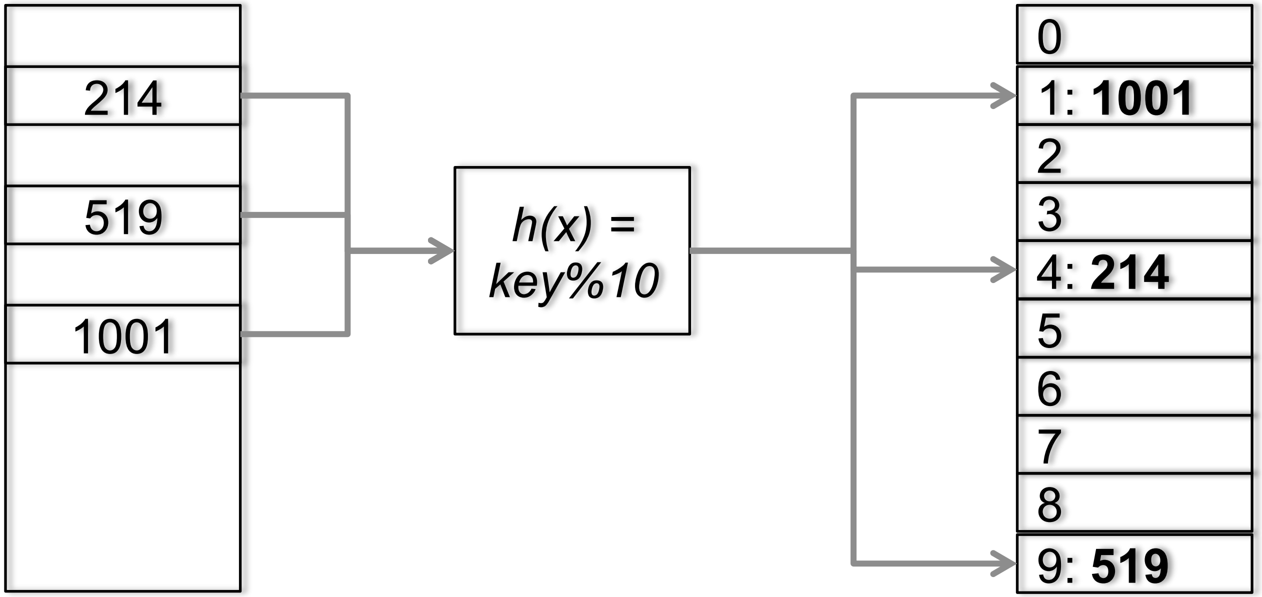

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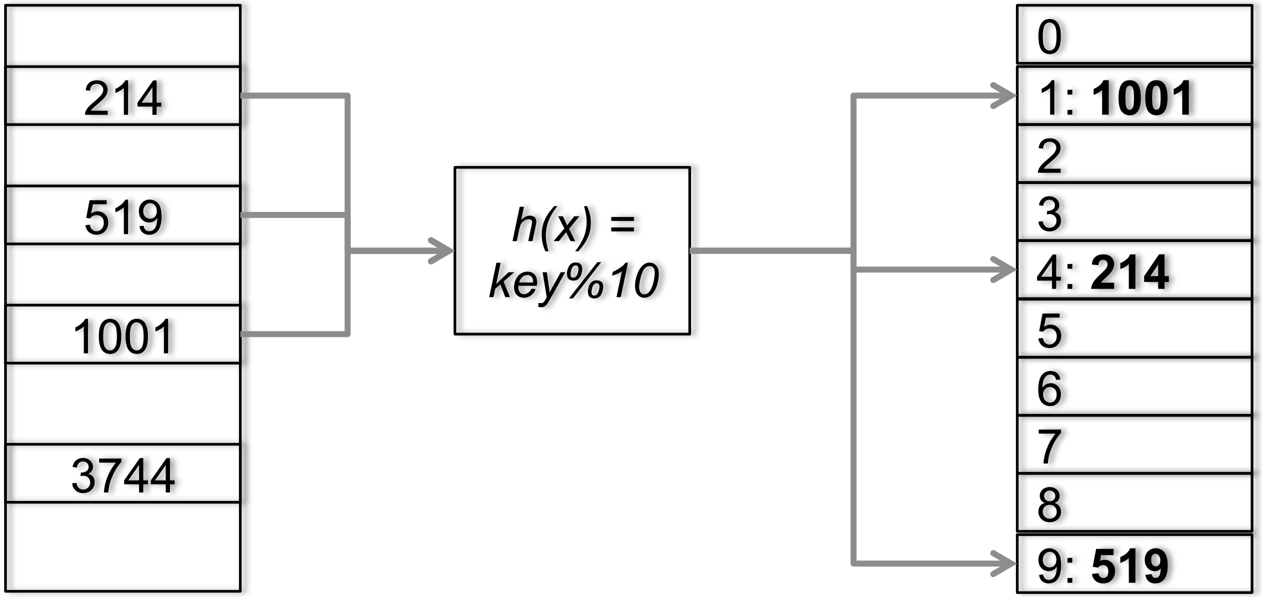

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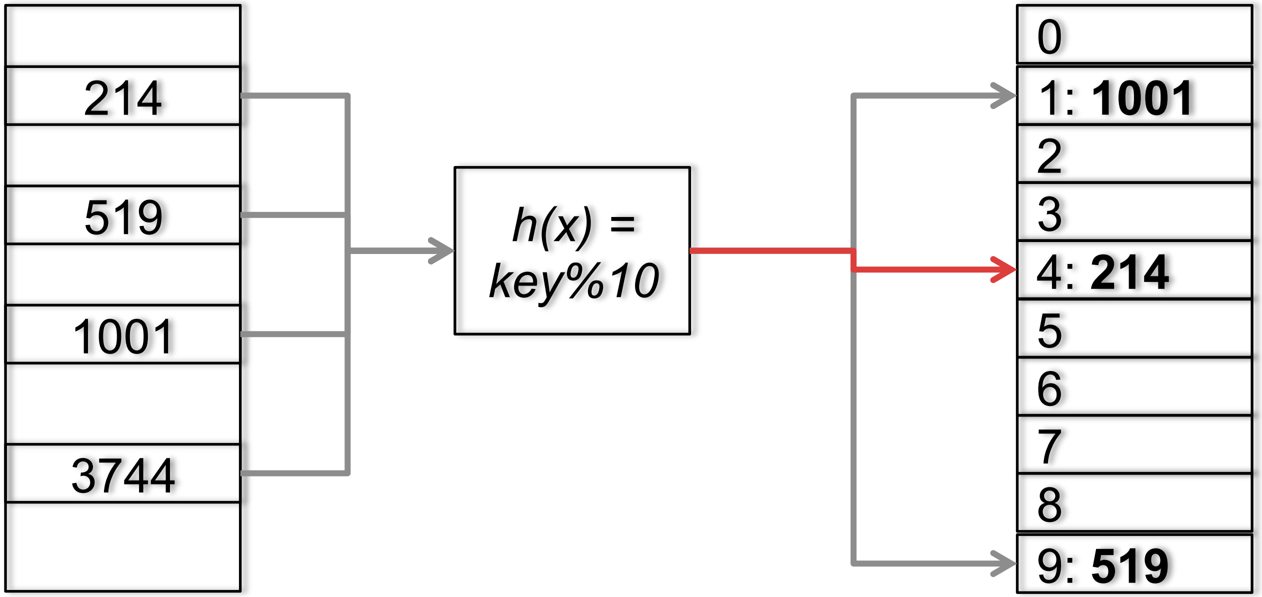
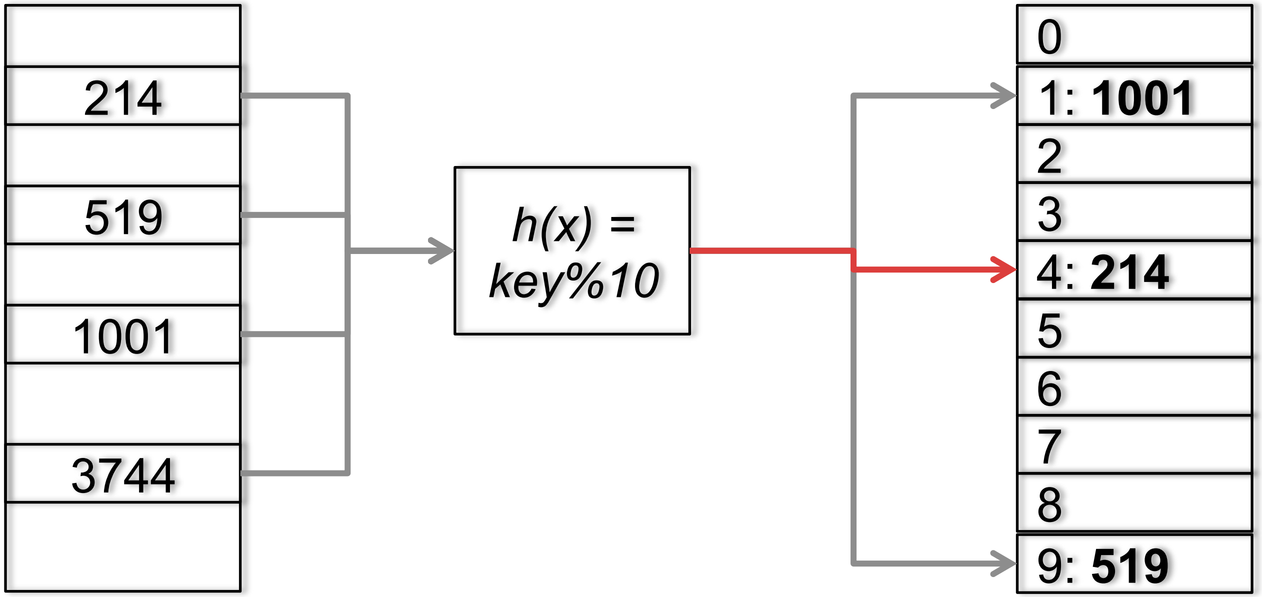


HASH EXAMPLE

- **Is there a problem here?**
  - insert(3744)
  - This is called a collision!



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  - Needs to incorporate all the data in the keys

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- **These hash functions are chosen in advance, you should not pick a hash function relative to your data**

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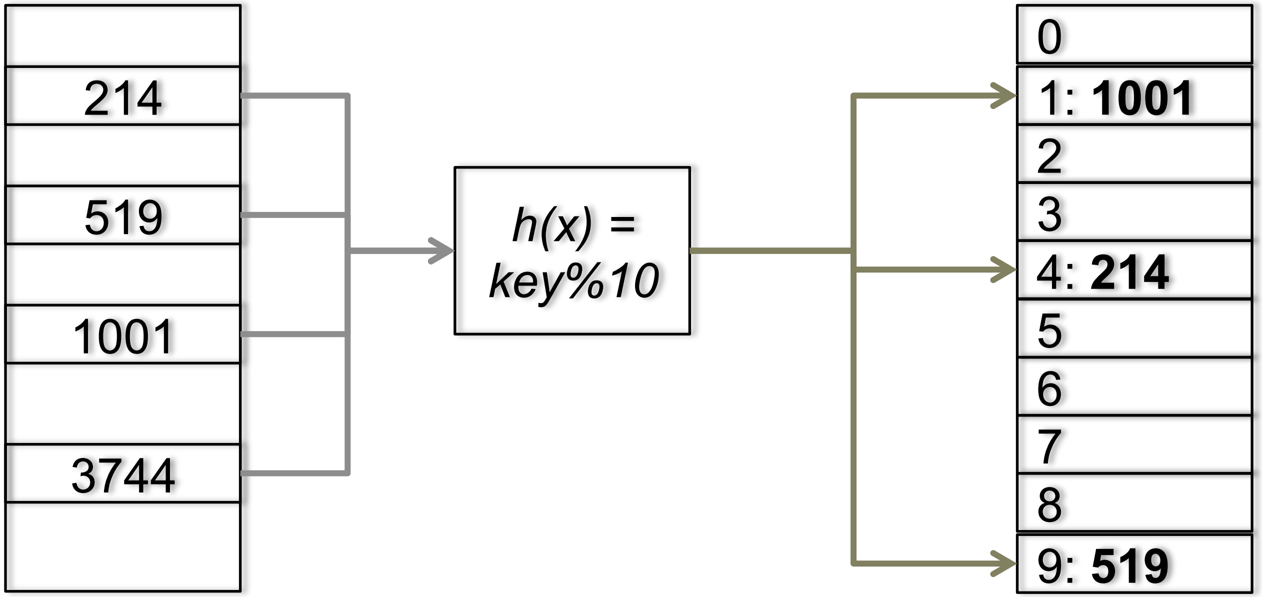

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    - This is called **clustering**

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    - We'll discuss it later

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    - Increase the index by one until a spot is found
    - Guaranteed to find a spot if it is available
    - If the array is too full, its operations reach O(n) time

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    - 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

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  - Some data structure is necessary here
  - Commonly a linked list, AVL tree or secondary hash table.
  - Resizing isn't **necessary**, but if you don't, you will get O(n) runtime.

PRIMALITY

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  - Two numbers x and y are **coprime** if they do not share any common factors.
  - If the hash table size and the secondary hash value are coprime, then the search will succeed if there is space available
  - However, many primes cause secondary clustering when used with quadratic probing

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  - We've discussed this a bit implicitly before
  - What are good load-factor (λ) values for each of our collision techniques?

LOAD FACTOR

- Linear Probing?
- Quadratic Probing?
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- **Linear Probing?** $0.25 < \lambda < 0.5$
- **Quadratic Probing?** $0.10 < \lambda < 0.30$
  - If it gets to 0.5, then there is a chance of failure, and a high chance of O(n) runtime
- **Secondary Hashing?**
- **Chaining?**

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- **Quadratic Probing?** $0.10 < \lambda < 0.30$
- **Secondary Hashing?** $0.25 < \lambda < 0.5$
  - But we've eliminated primary clustering
- **Chaining?**

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  - Because we allow multiple items in each space, we can increase memory efficiency by taking advantage
  - As long as there are a constant number in each space, we get O(1) runtimes.

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- **As with most array data structures, you will need to resize when they get too full**
  - Here, these resizes are often for performance, rather than failure.
  - Hash table maintenance is important
  - Resizing is costly (but still O(n)) because you have to resize the array and rehash every element into the new table.

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  - Can be memory inefficient
  - Probing can fail, and delete with probing mechanisms is difficult
  - Chaining can be a good balance, but there is a lot of overhead maintaining all those data structures

HASH TABLES

- Understand these tradeoffs and how these implementations work

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- **Understand these tradeoffs and how these implementations work**
- **Section tomorrow will provide practice problems for each of these hash table methods**

HASH TABLES

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  - The hash function should run in constant time and should distribute among the indices in the target array
  - Linear probing is a solution for collisions, but only works when there is lots of free space
  - Resizing is very costly

NEXT CLASS

- **Hash Tables**
  - Examples, examples, examples
  - Finish discussion
- **Exam review**