CSE 373

APRIL 24TH – HASHING

EXAM FRIDAY

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

EXAM FRIDAY

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

EXAM FRIDAY

- **No Java material on the exam**
- **Looking for theoretical understanding**
  - Explanations are important (where indicated)
- **If you get stuck on a problem, move on**
- **Any questions?**

TODAY'S LECTURE

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

HASHING

- **Introduction**
  - Suppose there is a set of data **M**
  - 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

- **What is our ideal data structure?**
  - The data structure should use O(D) memory
    - No extra memory is allocated
  - The operation should run in O(1) time
    - Accesses should be as fast as possible

HASHING

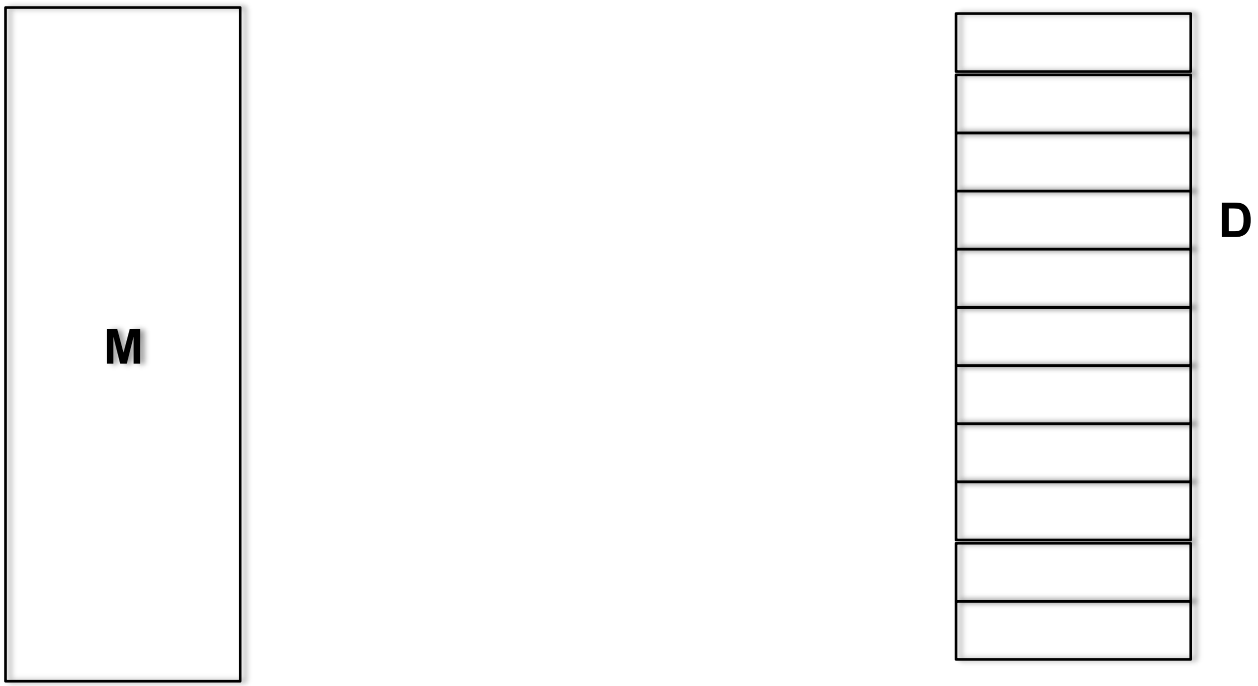
- **What are some difficulties with this?**
  - Need to know the size of **D** in advance or lose memory to pointer overhead
  - Hard to go from **M** -> **D** in O(1) time

HASHING

- **Memory: The Hash Table**
  - Consider an array of size **c * D**
  - 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.

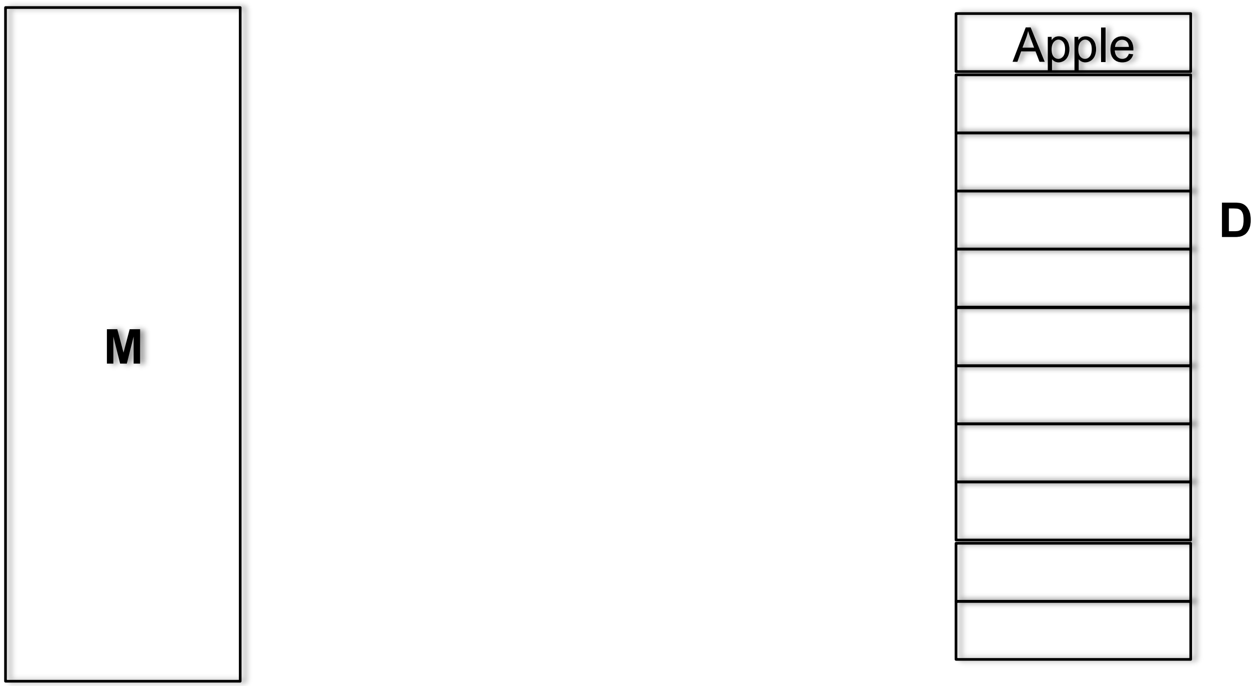
THE HASH TABLE

- How can we do this?



THE HASH TABLE

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



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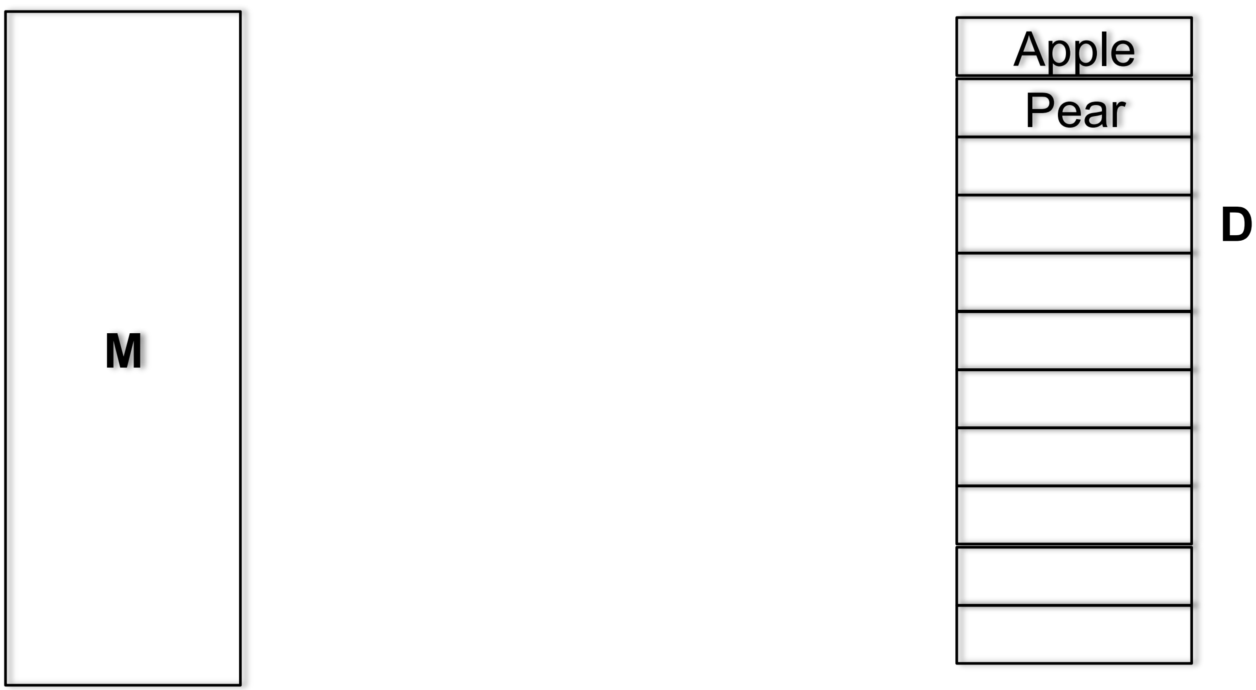

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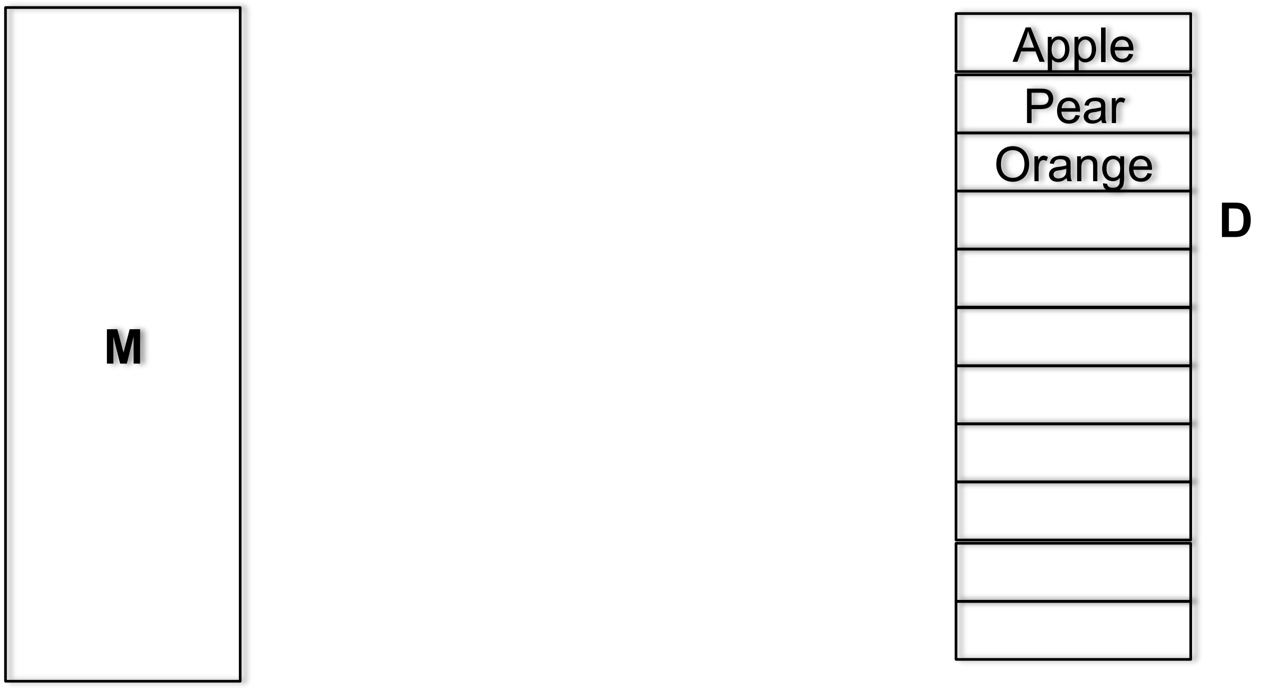

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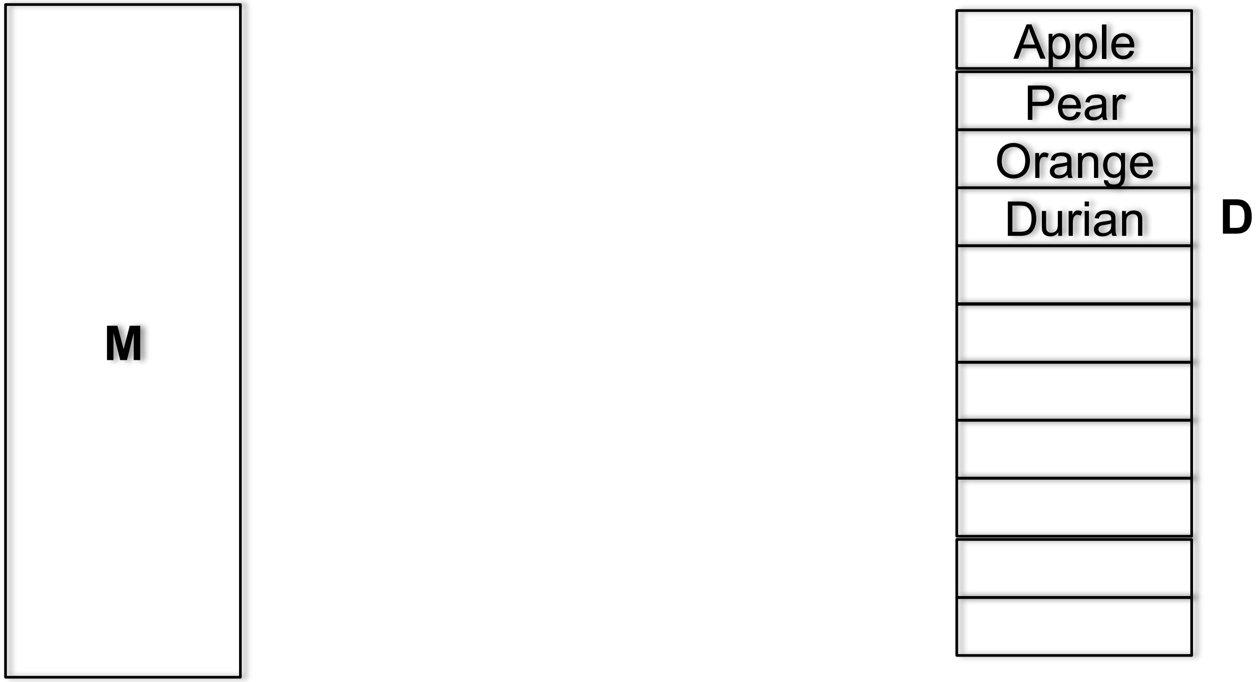

THE HASH TABLE

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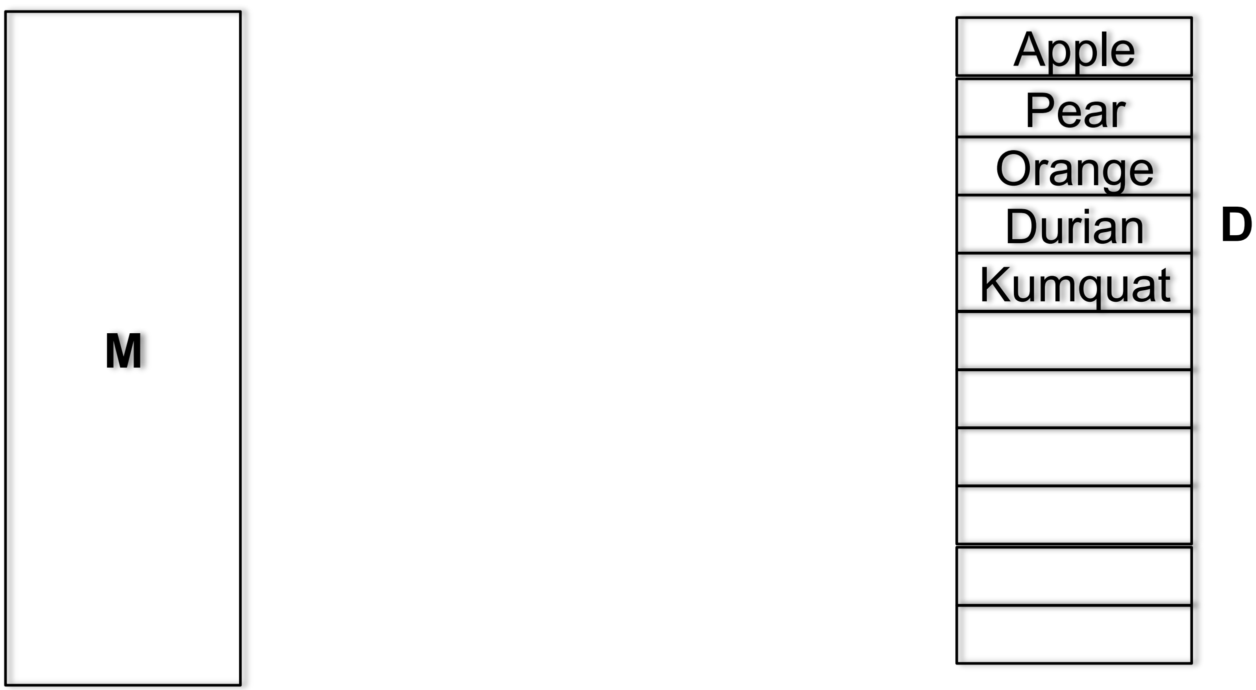
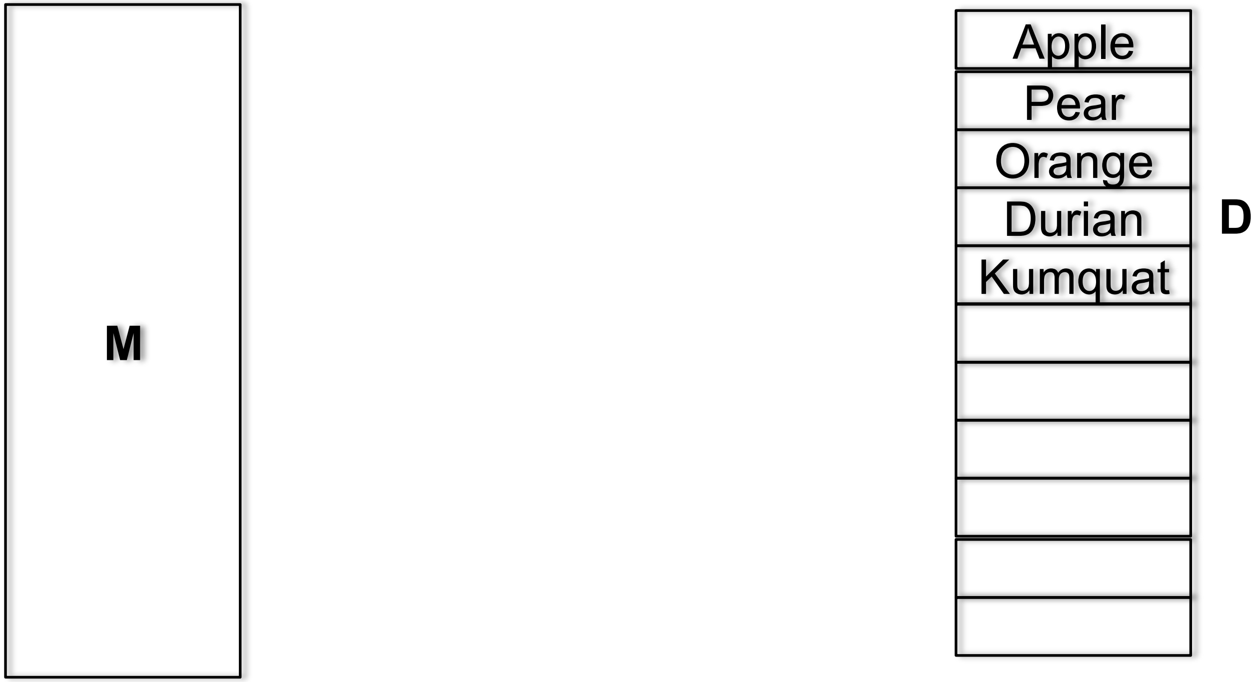


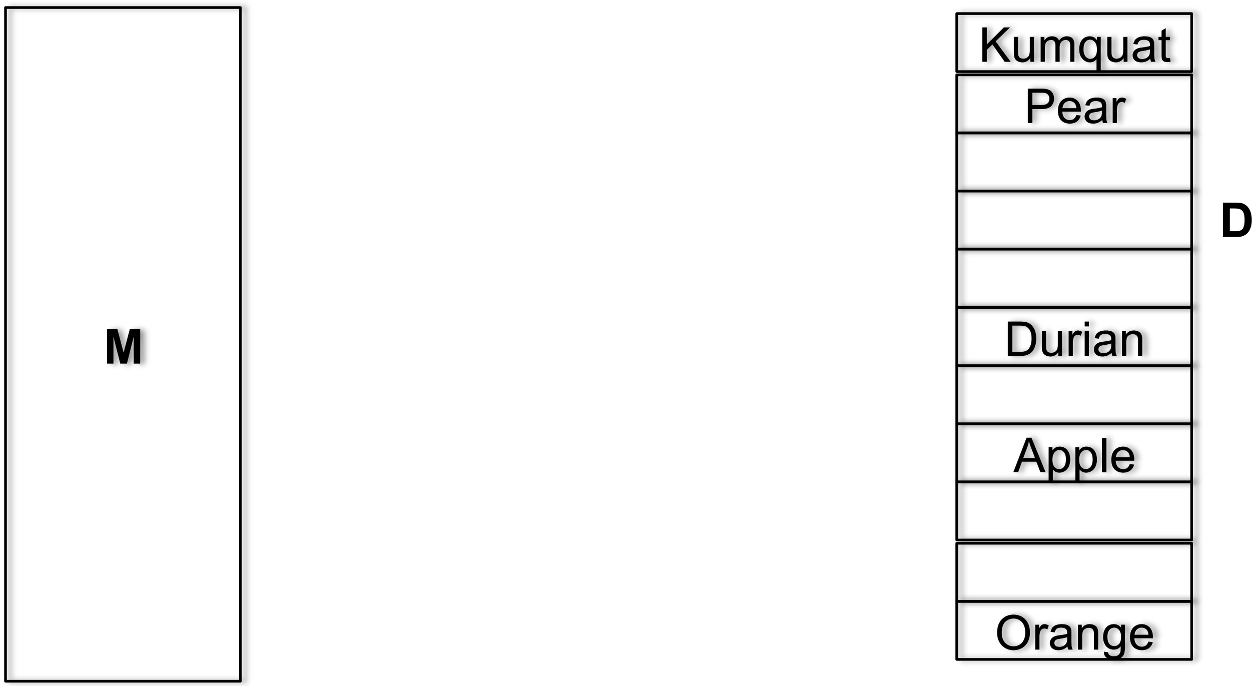
THE HASH TABLE

- **What is the problem here?**
  - Takes O(D) time to find the word in the list
  - Same problem with sorted arrays!



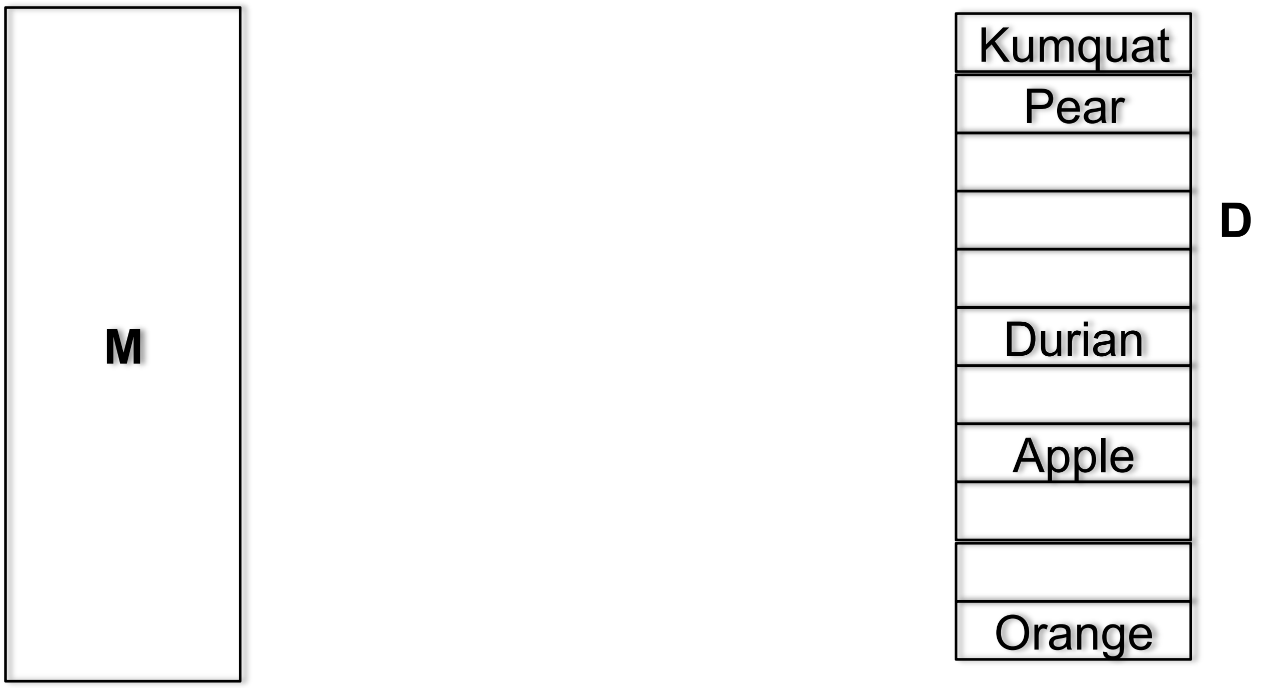
THE HASH TABLE

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



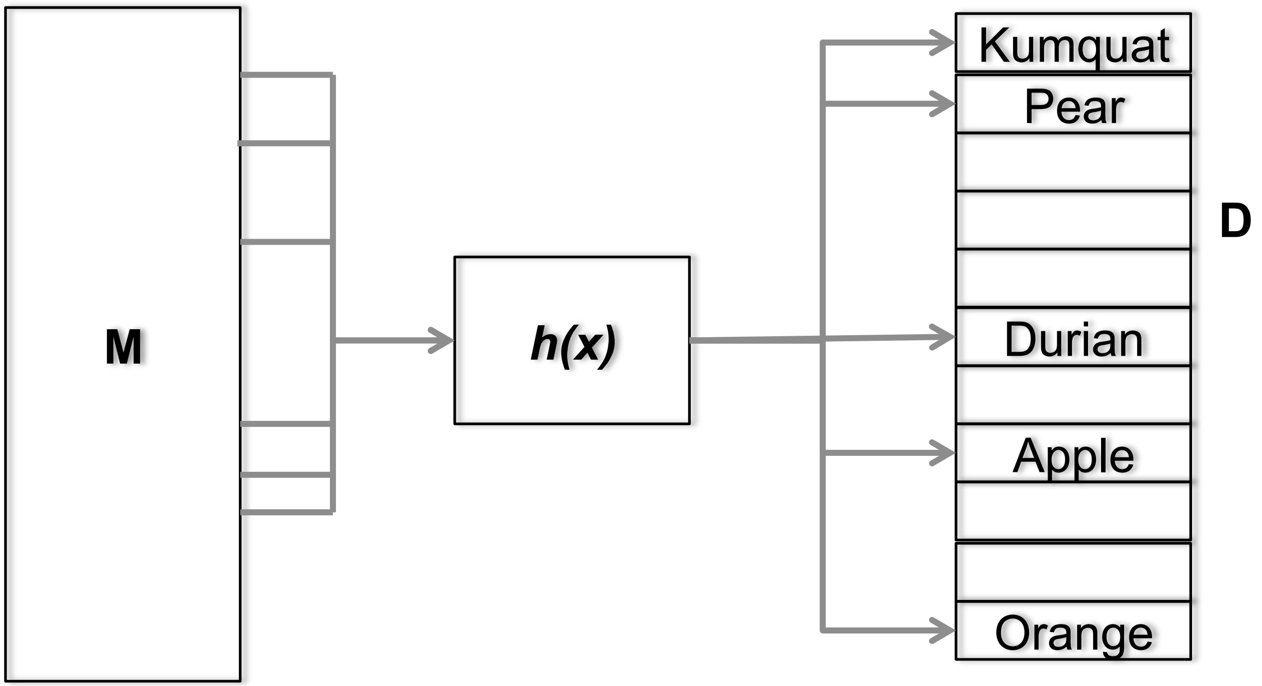
THE HASH TABLE

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



THE HASH TABLE

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

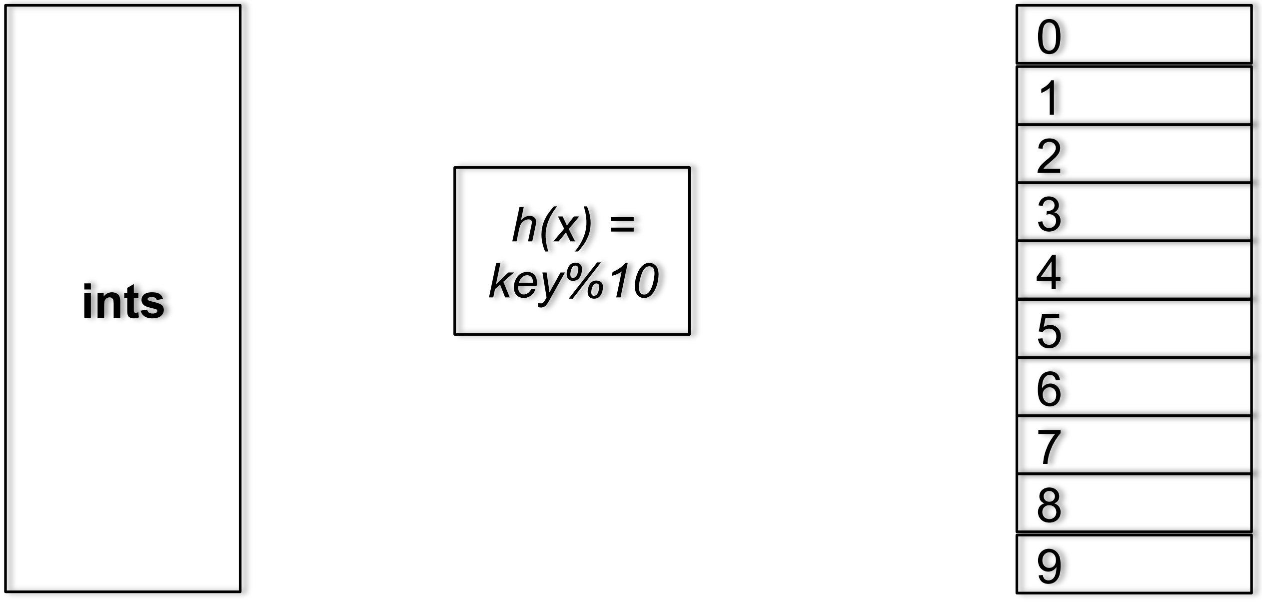


HASH FUNCTIONS

- **The Hash Function maps the large space M to our target space D.**
- **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)`

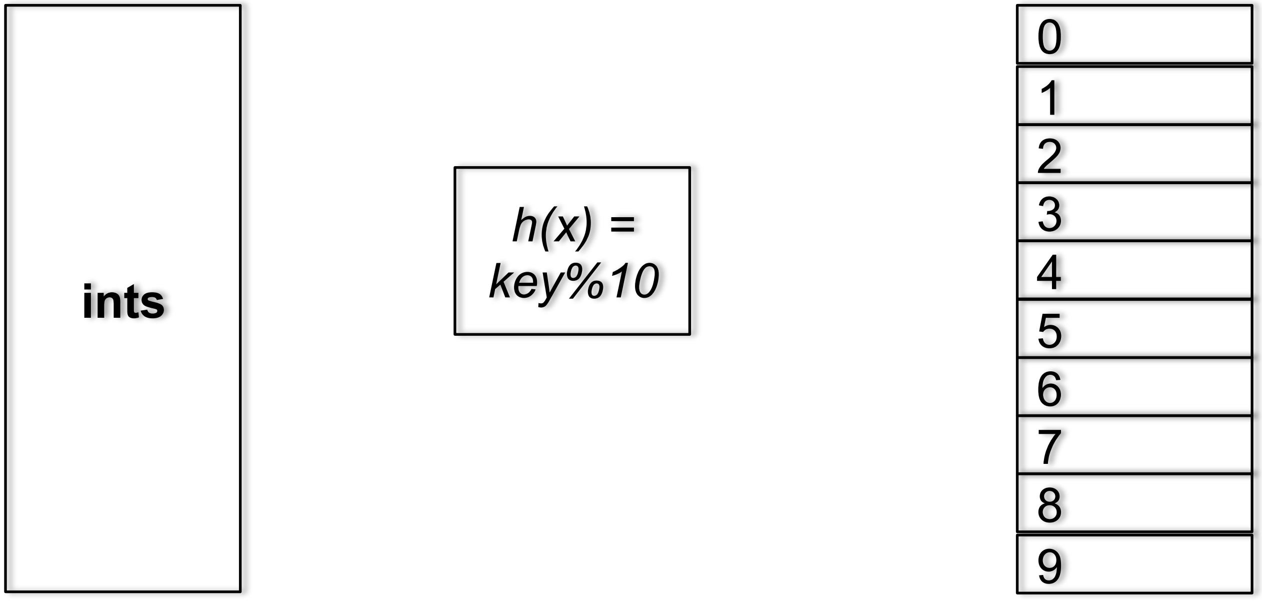
HASH EXAMPLE

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



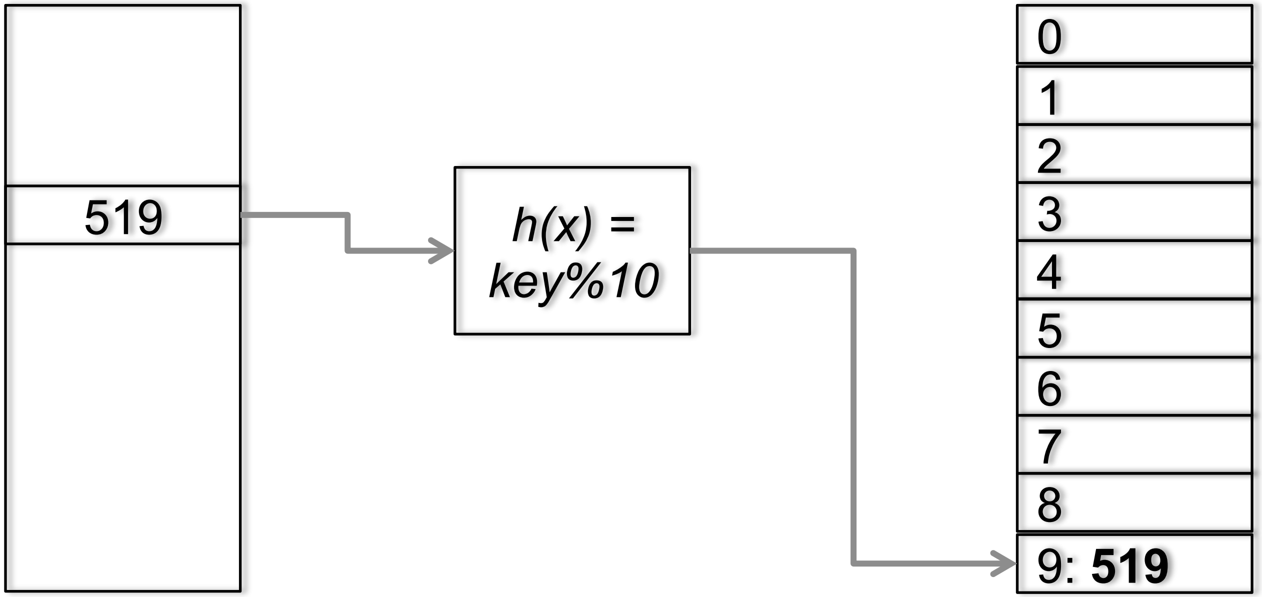
HASH EXAMPLE

- **Let's insert(519) table**
  - Where does it go?
  - 519%10 =



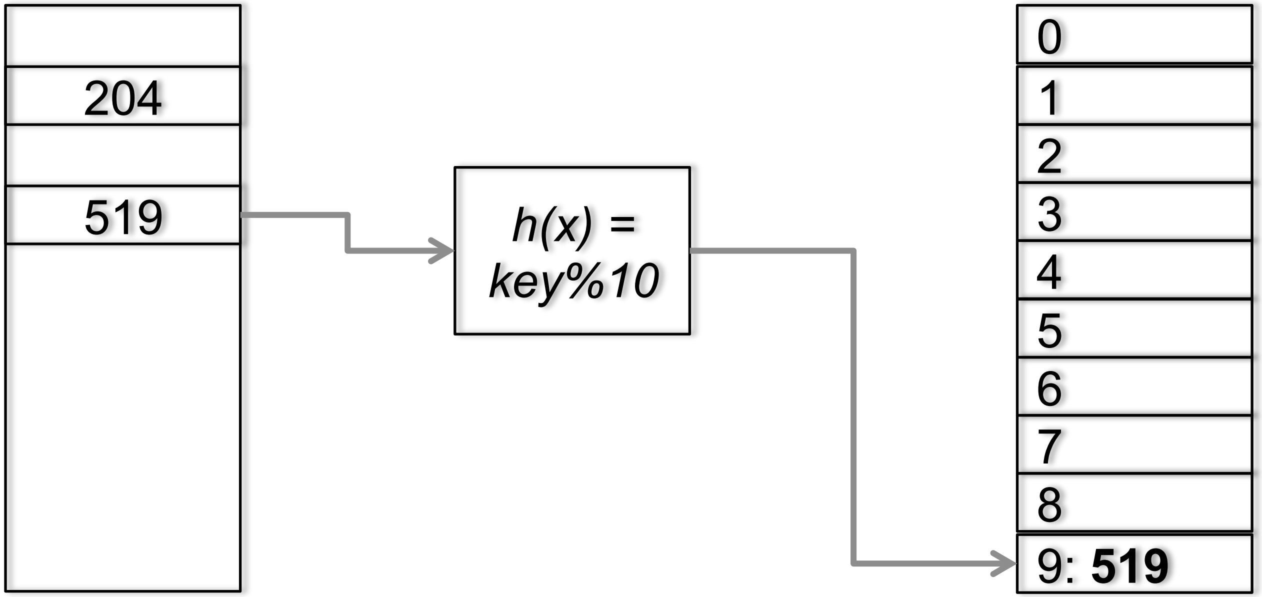
HASH EXAMPLE

- **Let's insert(519) table**
  - Where does it go?
  - 519%10 = 9



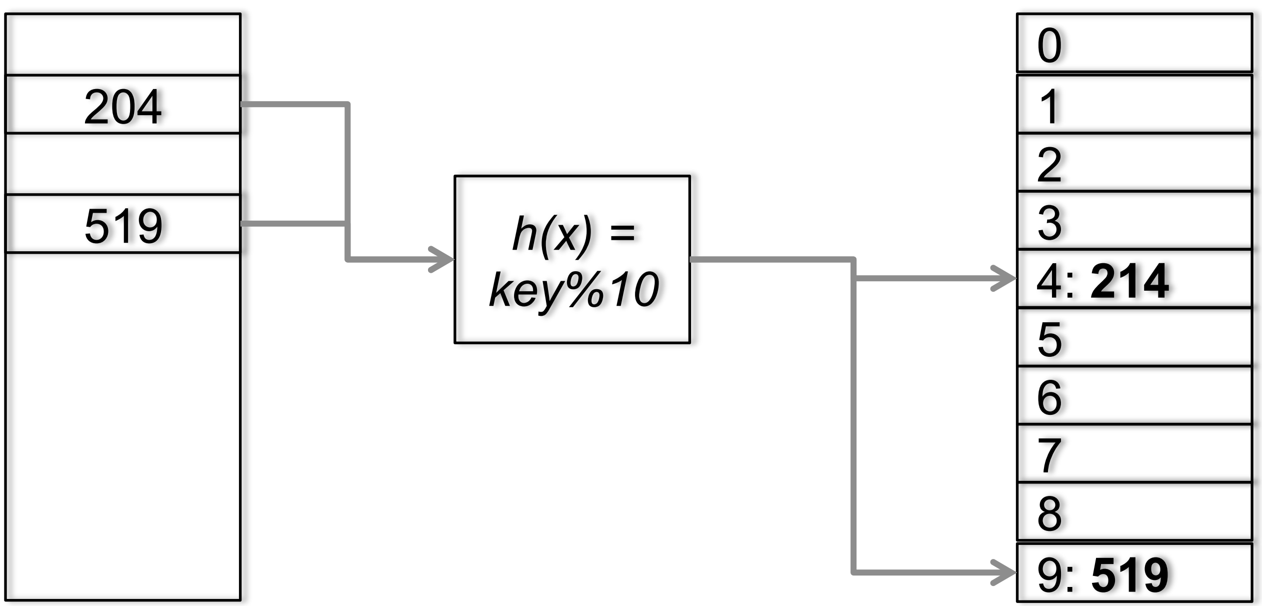
HASH EXAMPLE

- **Insert(204)**



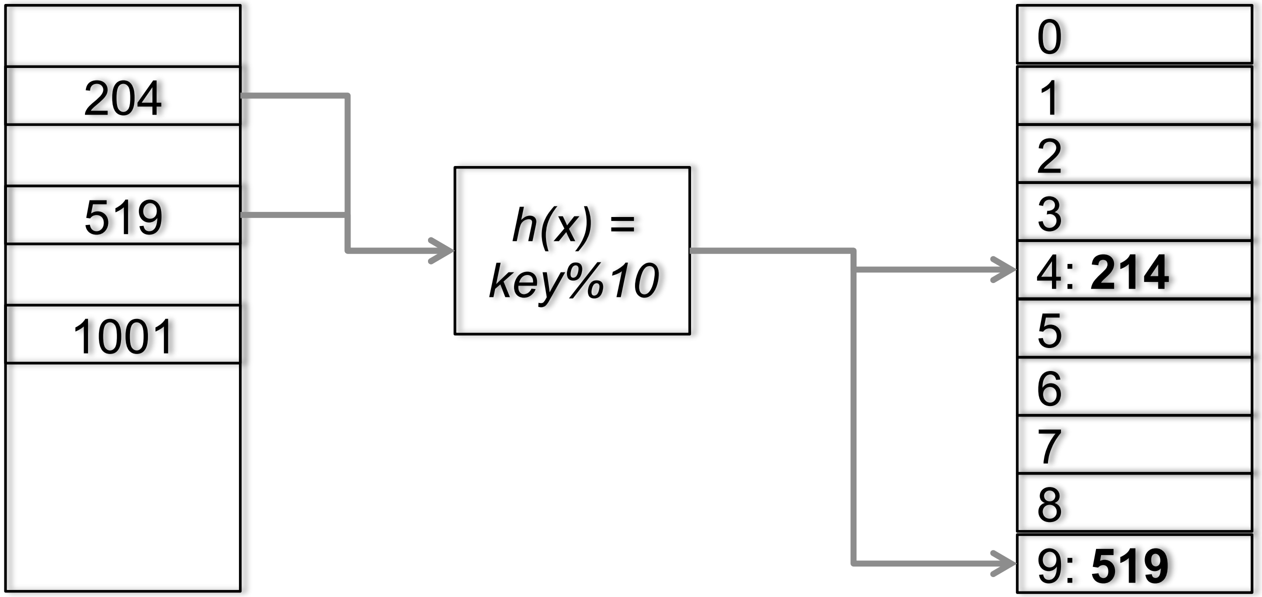
HASH EXAMPLE

- **Insert(204)**



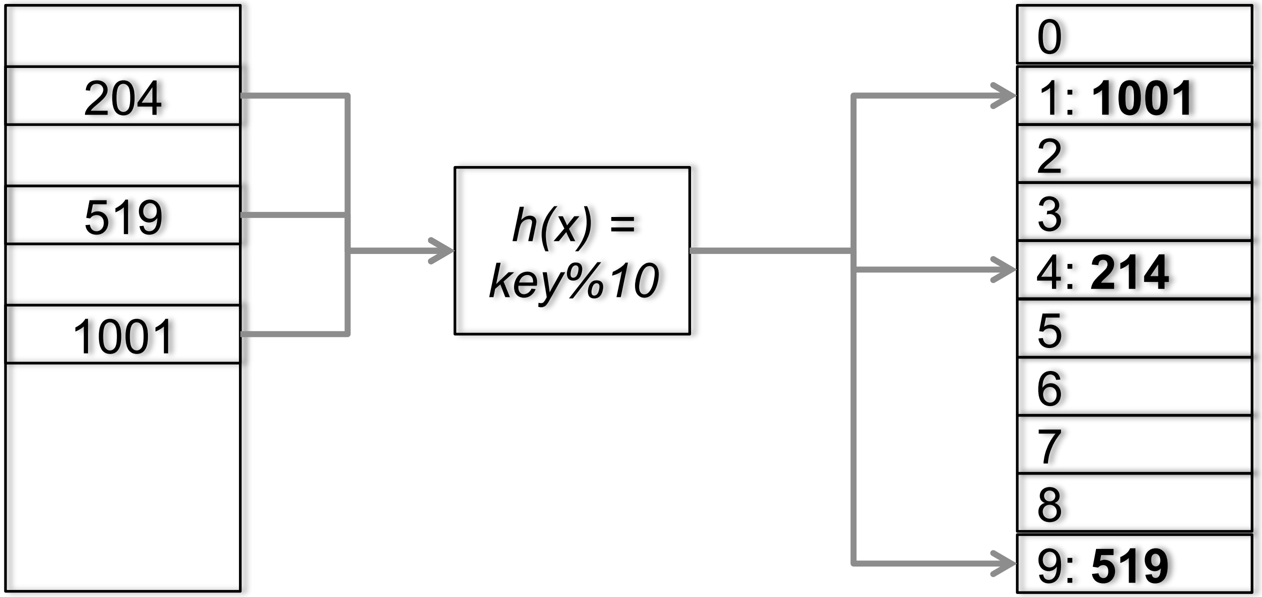
HASH EXAMPLE

- **insert(1001)**



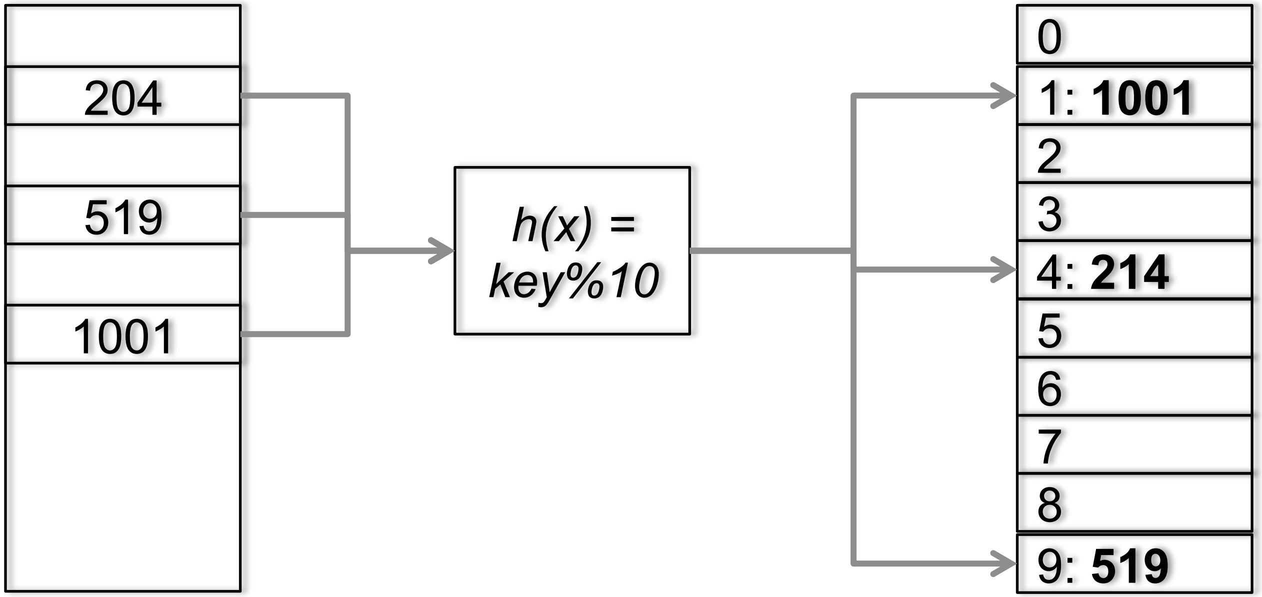
HASH EXAMPLE

- insert(1001)



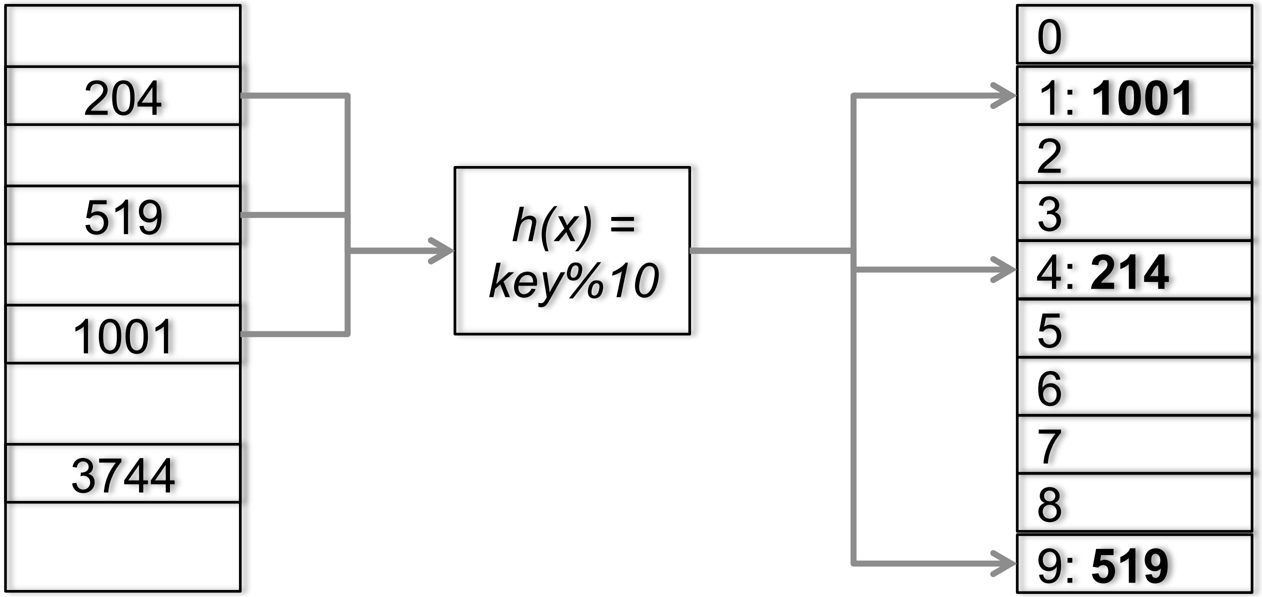
HASH EXAMPLE

- **Is there a problem here?**



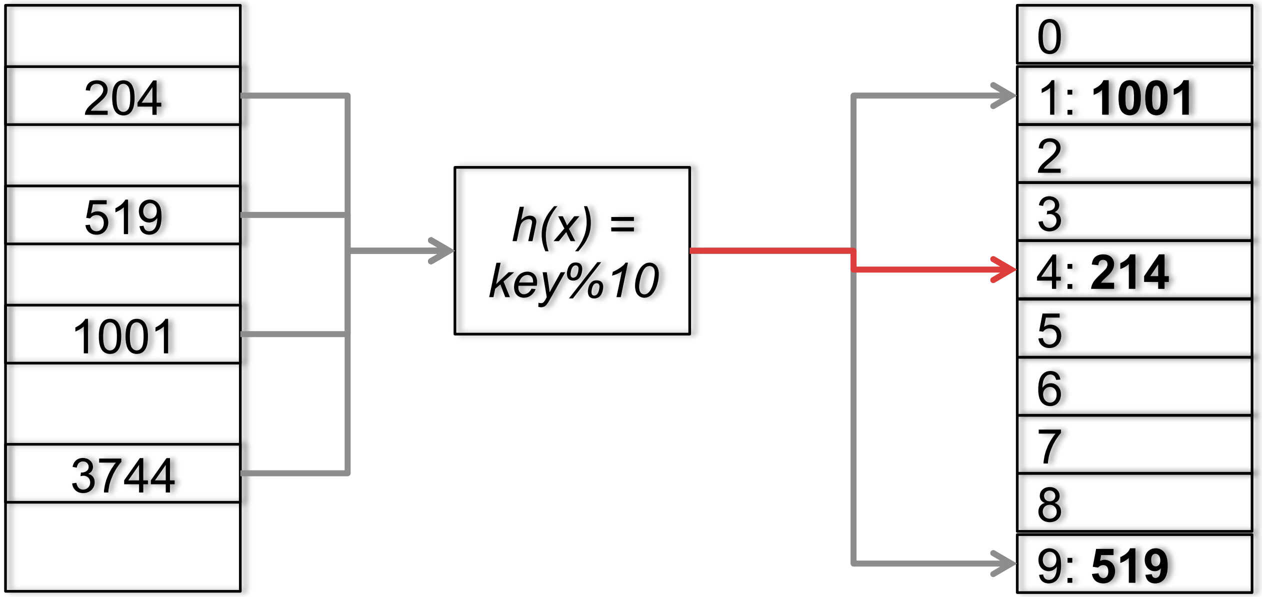
HASH EXAMPLE

- **Is there a problem here?**
  - insert(3744)



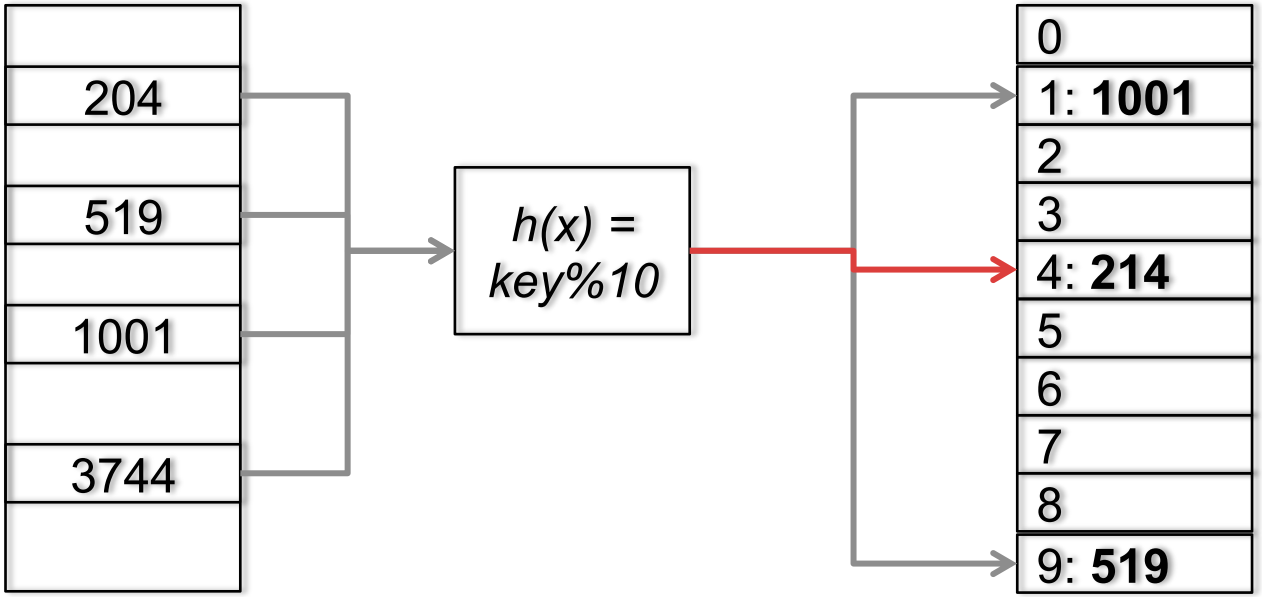
HASH EXAMPLE

- **Is there a problem here?**
  - insert(3744)



HASH EXAMPLE

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

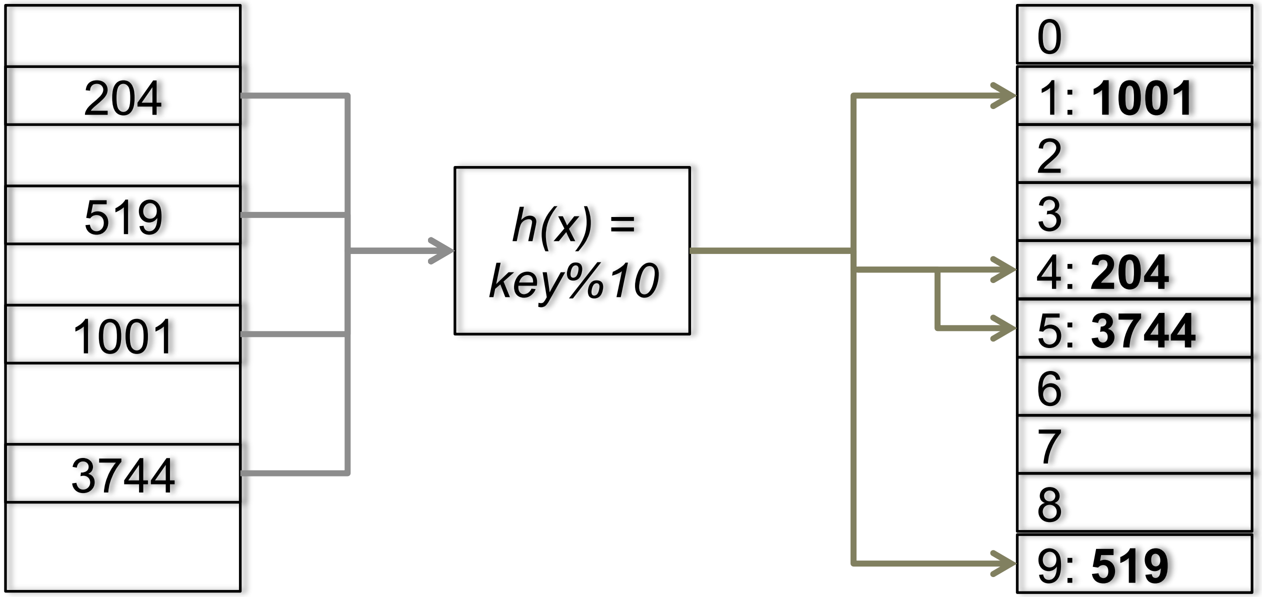


HASH EXAMPLE

- **How to rectify collisions?**
  - Think of a strategy for a few minutes
- **Possible solutions:**
  - Store in the next available space
  - Store both in the same space
  - Try a different hash
  - Resize the array

LINEAR PROBING

- **Consider the simplest solution**
  - Find the next available spot in the array
  - This solution is called **linear probing**



LINEAR PROBING

- **What are the problems with this?**
  - How do we search for 3744?
    - Need to go to 4, and then cycle through all of the entries until we find the element or find a blank space
  - What if we need to add something that ends in 5?
    - It also ends up in this problem area
    - This is called **clustering**

CLUSTERING

- **What are the negative effects of clustering?**
  - If the cluster becomes too large, two things happen:
    - The chances of colliding with the cluster increase
    - The time it takes to find something in the cluster increases. **This isn't O(1) time!**

CLUSTERING

- **How can we solve this problem?**
  - Resize the array
    - Give the elements more space to avoid clusters. *How long does this take?* **O(n)! all of the elements need to be rehashed.**
  - Store multiple items in one location
    - This is called **chaining**
    - We'll discuss it after the midterm

HASH TABLES

- **Take-aways for the midterm**
  - Hashtables should provide O(1) dictionary operations
  - Collisions make this problem difficult to achieve
  - Hashtables rely on a array and a hash function
  - The array should be relative to the size of the data you want to keep
  - 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
  - No new theory
- **Exam review**