

Hash Tables

CSCI 232

Dictionary

Key

Value

Apple	A tasty red fruit.
Banana	A nasty yellow fruit.
Cantaloupe	An okay orange fruit.
Dandelion	Allegedly can be made into wine.
Eggplant	Not nearly as good as chicken parmesan.
Flower	Pretty plants.
Gravity	The thing that makes falls hurt.
Hellroaring	Best huckleberry picking in Gallatin County.
Insect	Crunchy things sleeping in your cereal.

Dictionary

Key

Value

16372	Joe Schmo, 3.14, Computer Science
22617	Nancy Anderson, 3.62, Mathematics
37261	Watson Bassethound, 2.31, English
37483	Michael, 3.81, History
73821	Patrick, 2.50, Engineering
35564	Elizabeth, 3.5, Chemistry
11635	Katie, 3.7, English
95766	Drew, 3.6, Education
25142	Ben, 3.25, Nursing

Dictionary

How could we implement
this desired functionality?

Key

Value

Apple

A tasty red fruit.

Banana

A nasty yellow fruit.

Cantaloupe

An okay orange fruit.

Dandelion

Allegedly can be made into wine.

Eggplant

Not nearly as good as chicken parmesan.

Flower

Pretty plants.

Gravity

The thing that makes falls hurt.

Hellroaring

Best huckleberry picking in Gallatin County.

Insect

Crunchy things sleeping in your cereal.

Dictionary - BST

Key

Apple

Banana

Cantaloupe

Dandelion

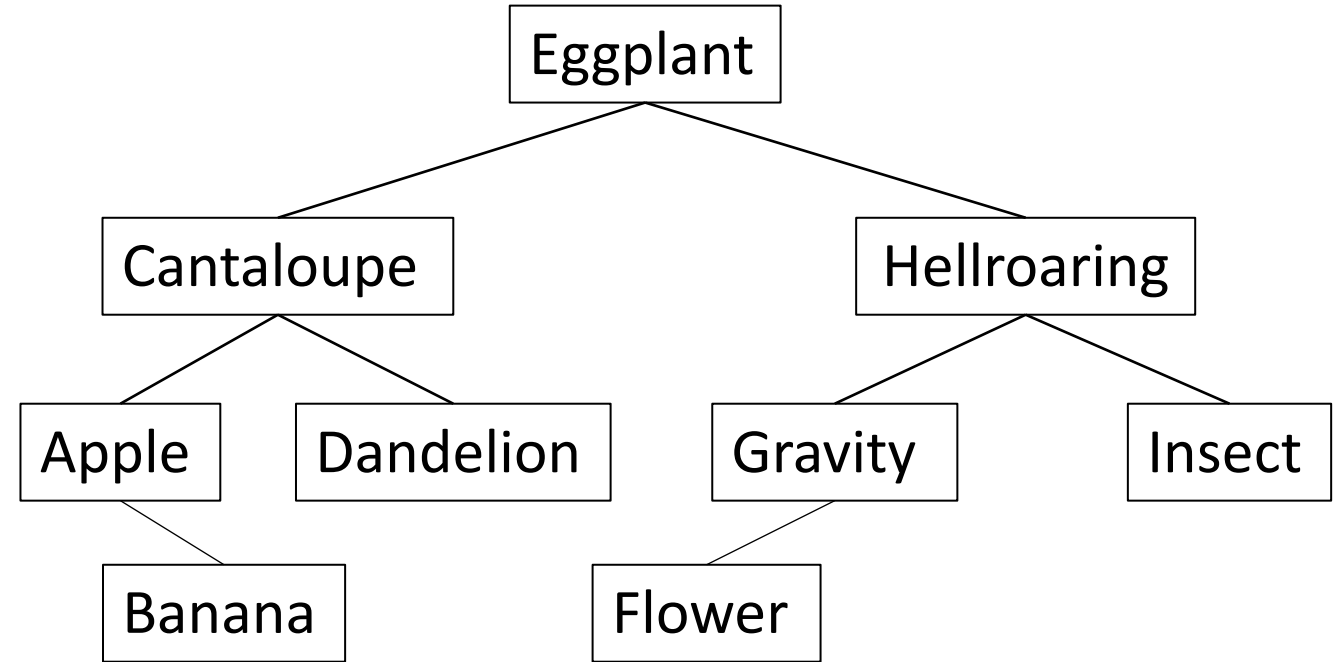
Eggplant

Flower

Gravity

Hellroaring

Insect



```
public class Node {
```

```
}
```

Dictionary - BST

Key

Apple

Banana

Cantaloupe

Dandelion

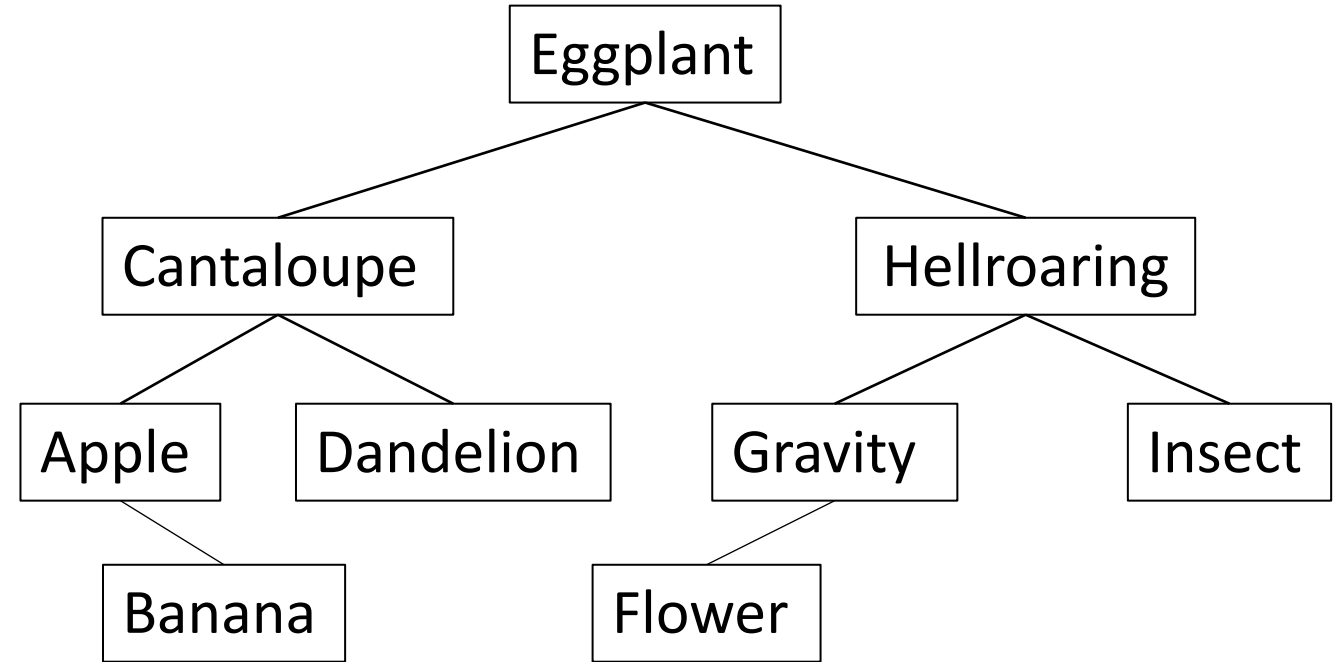
Eggplant

Flower

Gravity

Hellroaring

Insect



```
public class Node {  
    private Node parent;  
    private Node leftChild;  
    private Node rightChild;  
  
    private String key;  
    private String value;  
  
    ...  
}
```

Dictionary - BST

Key

Apple

Banana

Cantaloupe

Dandelion

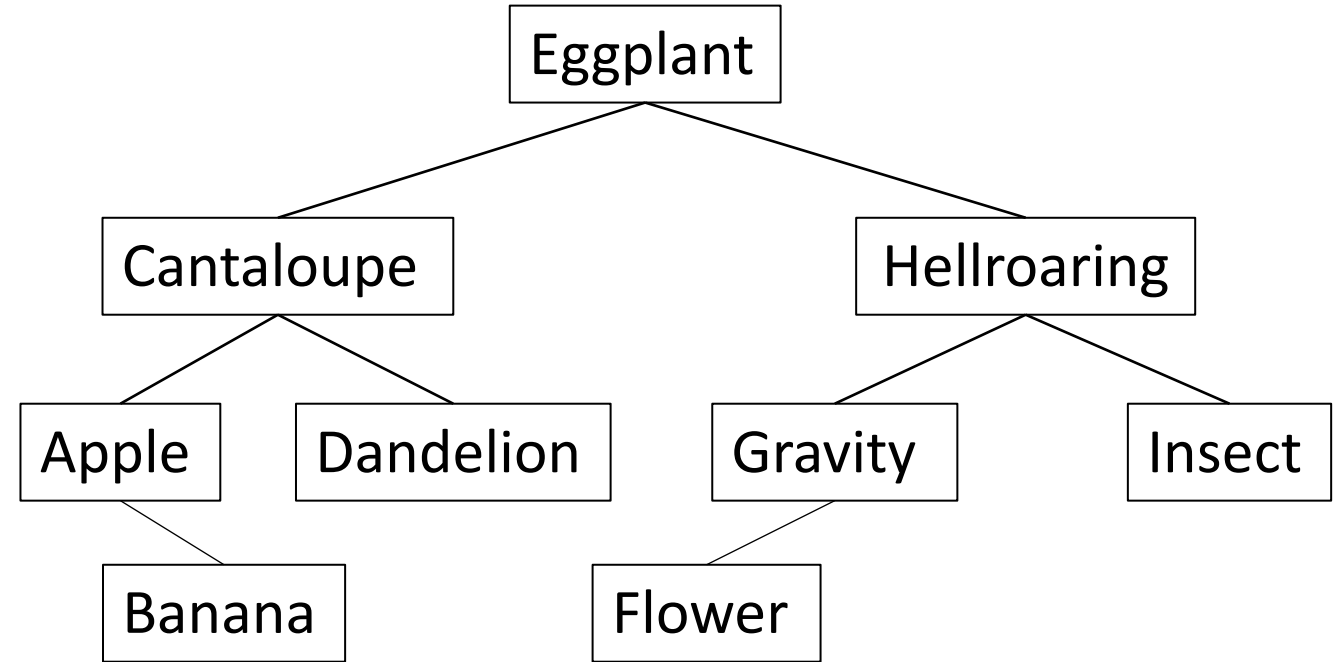
Eggplant

Flower

Gravity

Hellroaring

Insect



```
public class Node {  
    private Node parent;  
    private Node leftChild;  
    private Node rightChild;  
  
    private String key;  
    private String value;  
  
    ...  
}
```

```
public class Dictionary {
```

Dictionary - BST

Key

Apple

Banana

Cantaloupe

Dandelion

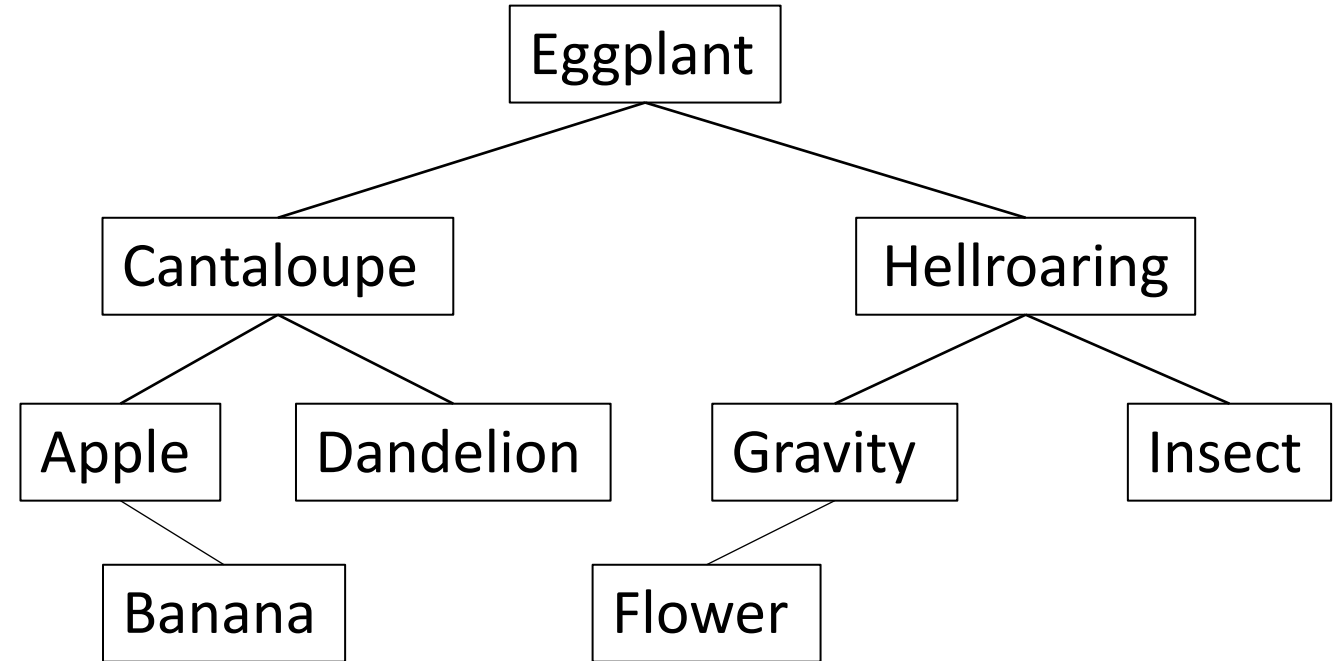
Eggplant

Flower

Gravity

Hellroaring

Insect



```
public class Node {  
    private Node parent;  
    private Node leftChild;  
    private Node rightChild;  
    private String key;  
    private String value;  
    ...  
}
```

```
public class Dictionary {  
    ...  
    public void put(key, value)  
    public Value get(key)  
    public void delete(key)  
    public Boolean contains(key)  
    public Boolean isEmpty()  
    public int size()  
    public Set<Key> keySet()  
}
```


Main Street Tourist Resources

Key

Value

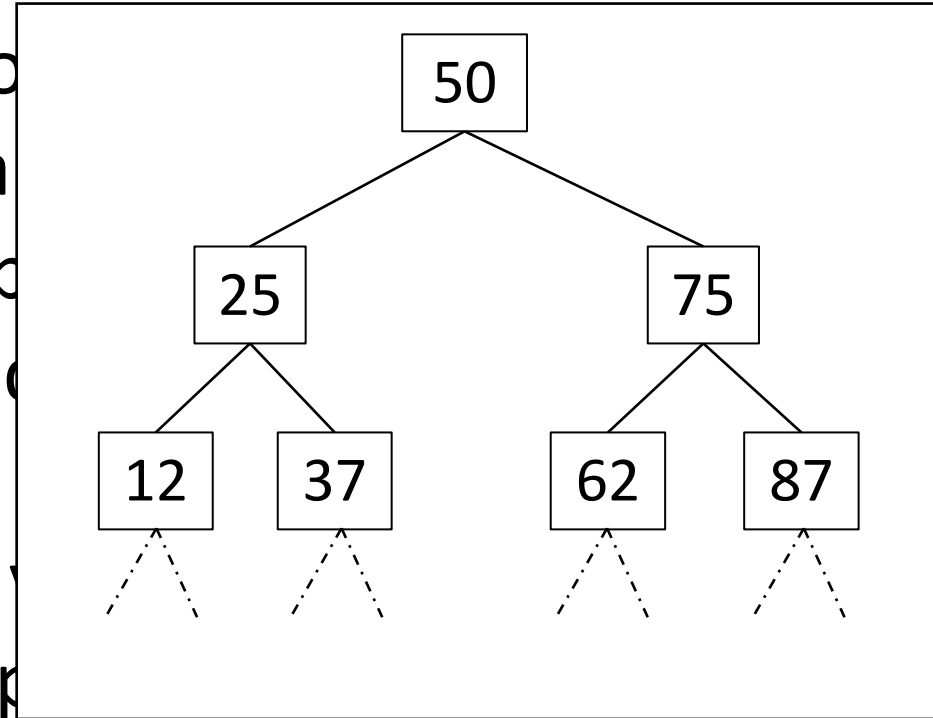
0	Flora's Flowers, flowers, M-F 8am – 3pm
1	The Bank, it's a bank, M-F 9am – 5pm
2	Ted's Drug Store, pharmaceutical items, M-F 6am – 5pm
3	Joe's Gas Station, digestively dangerous burritos, 24hr
:	:
98	Aristocrat Art, art you can't afford, M-F 4pm – 8pm
99	Fire Station, they put out fires, M-F 3pm – 3:05pm

Main Street Tourist Resources

Key

Value

0 Flora's Flowers, florist
1 The Bank, it's a bank
2 Ted's Drug Store, pharmacy
3 Joe's Gas Station, gas
⋮
98 Aristocrat Art, art gallery
99 Fire Station, they put out fires



5am – 5pm
photos, 24hr
– 8pm
5pm

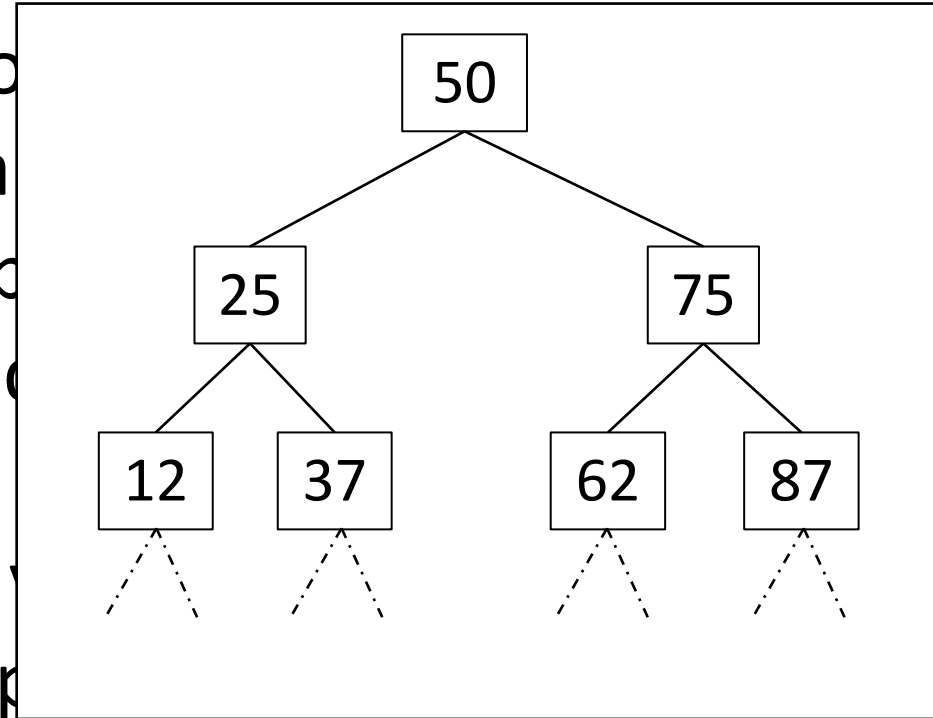
Lookup time?

Main Street Tourist Resources

Key

Value

0 Flora's Flowers, florist
1 The Bank, it's a bank
2 Ted's Drug Store, pharmacy
3 Joe's Gas Station, convenience store
⋮
98 Aristocrat Art, art gallery
99 Fire Station, they put out fires



5am – 5pm
photos, 24hr
– 8pm
5pm

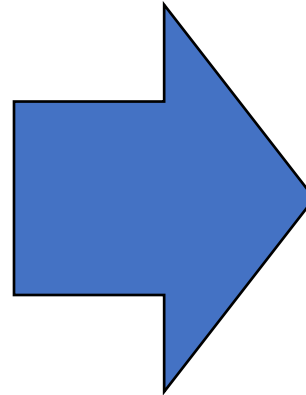
Lookup time? $O(\log n)$

Main Street Tourist Resources

Key

Value

0	Flora's Flowers,...
1	The Bank,...
2	Ted's Drug Store,...
3	Joe's Gas Station,...
:	:
98	Aristocrat Art,...
99	Fire Station,...

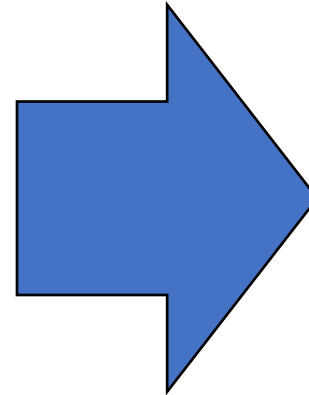
[illegible]

Main Street Tourist Resources

Key

Value

0	Flora's Flowers,...
1	The Bank,...
2	Ted's Drug Store,...
3	Joe's Gas Station,...
:	:
98	Aristocrat Art,...
99	Fire Station,...



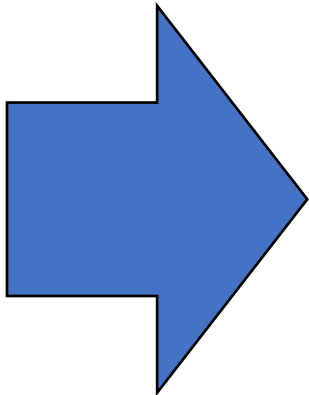
0	
1	
2	
3	
:	:
98	
99	

Main Street Tourist Resources

Key

Value

0	Flora's Flowers,...
1	The Bank,...
2	Ted's Drug Store,...
3	Joe's Gas Station,...
⋮	⋮
98	Aristocrat Art,...
99	Fire Station,...



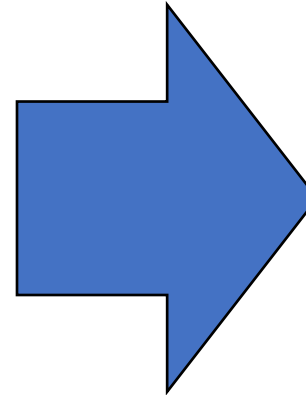
0	0, Flora's Flowers,...
1	1, The Bank,...
2	2, Ted's Drug Store,...
3	3, Joe's Gas Station,...
⋮	⋮
98	98, Aristocrat Art,...
99	99, Fire Station,...

Main Street Tourist Resources

Key

Value

0	Flora's Flowers,...
1	The Bank,...
2	Ted's Drug Store,...
3	Joe's Gas Station,...
⋮	⋮
98	Aristocrat Art,...
99	Fire Station,...



0	0, Flora's Flowers,...
1	1, The Bank,...
2	2, Ted's Drug Store,...
3	3, Joe's Gas Station,...
⋮	⋮
98	98, Aristocrat Art,...
99	99, Fire Station,...

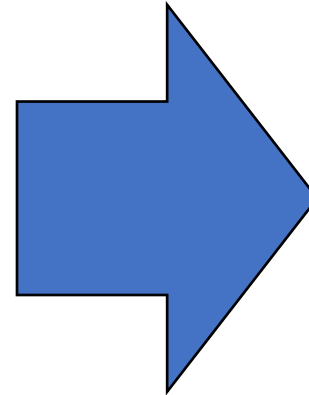
Lookup time?

Main Street Tourist Resources

Key

Value

0	Flora's Flowers,...
1	The Bank,...
2	Ted's Drug Store,...
3	Joe's Gas Station,...
⋮	⋮
98	Aristocrat Art,...
99	Fire Station,...



0	0, Flora's Flowers,...
1	1, The Bank,...
2	2, Ted's Drug Store,...
3	3, Joe's Gas Station,...
⋮	⋮
98	98, Aristocrat Art,...
99	99, Fire Station,...

Lookup time? $O(1)$

Main Street Tourist Resources

Key

Value

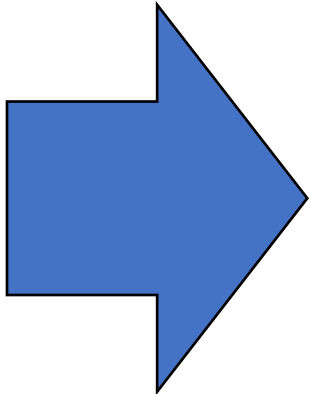
100	Flora's Flowers,...
101	The Bank,...
102	Ted's Drug Store,...
103	Joe's Gas Station,...
:	:
198	Aristocrat Art,...
199	Fire Station,...

Main Street Tourist Resources

Key

Value

100	Flora's Flowers,...
101	The Bank,...
102	Ted's Drug Store,...
103	Joe's Gas Station,...
⋮	⋮
198	Aristocrat Art,...
199	Fire Station,...



0	null
⋮	⋮
99	null
100	100, Flora's Flowers,...
101	101, The Bank,...
102	102, Ted's Drug Store,...
103	103, Joe's Gas Station,...
⋮	⋮
198	198, Aristocrat Art,...
199	199, Fire Station,...

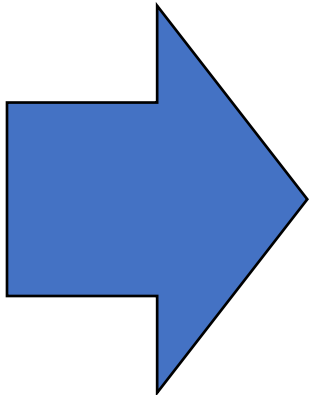
Main Street Tourist Resources

Key

Value

100	Flora's Flowers,...
101	The Bank,...
102	Ted's Drug Store,...
103	Joe's Gas Station,...
⋮	⋮
198	Aristocrat Art,...
199	Fire Station,...

Not
ideal...



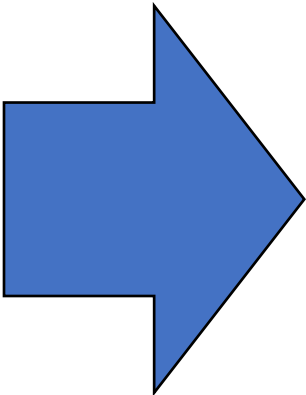
0	null
⋮	⋮
99	null
100	100, Flora's Flowers,...
101	101, The Bank,...
102	102, Ted's Drug Store,...
103	103, Joe's Gas Station,...
⋮	⋮
198	198, Aristocrat Art,...
199	199, Fire Station,...

Main Street Tourist Resources

Key

Value

100 Flora's Flowers,...
101 The Bank,...
102 Ted's Drug Store,...
103 Joe's Gas Station,...
⋮ ⋮
198 Aristocrat Art,...
199 Fire Station,...



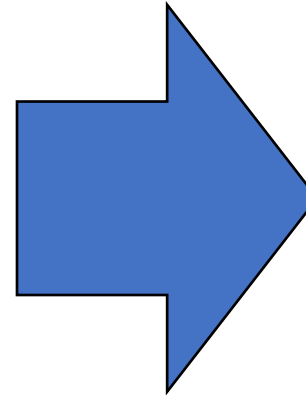
0	100, Flora's Flowers,...
1	101, The Bank,...
2	102, Ted's Drug Store,...
3	103, Joe's Gas Station,...
⋮	⋮
98	198, Aristocrat Art,...
99	199, Fire Station,...

Main Street Tourist Resources

Key

Value

100	Flora's Flowers,...
101	The Bank,...
102	Ted's Drug Store,...
103	Joe's Gas Station,...
⋮	⋮
198	Aristocrat Art,...
199	Fire Station,...



0	100, Flora's Flowers,...
1	101, The Bank,...
2	102, Ted's Drug Store,...
3	103, Joe's Gas Station,...
⋮	⋮
98	198, Aristocrat Art,...
99	199, Fire Station,...

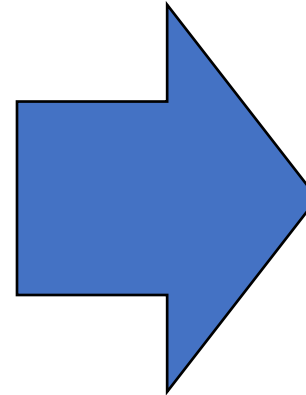
What array index does address x go into?

Main Street Tourist Resources

Key

Value

100	Flora's Flowers,...
101	The Bank,...
102	Ted's Drug Store,...
103	Joe's Gas Station,...
⋮	⋮
198	Aristocrat Art,...
199	Fire Station,...



0	100, Flora's Flowers,...
1	101, The Bank,...
2	102, Ted's Drug Store,...
3	103, Joe's Gas Station,...
⋮	⋮
98	198, Aristocrat Art,...
99	199, Fire Station,...

What array index does address x go into?
 $x \% 100$

Main Street Tourist Resources

Key

Value

100	Flo	% - modulo operator.	wers,...
101	Th	$a \% b$ = remainder when a is divided by b
102	Te		Store,...
103	Jo		Station,...
:	:		
198	Ar		Art,...
199	Fi		n,...

What array index does address x go into?
 $x \% 100$

Main Street Tourist Resources

Key

Value

100	Flo	% - modulo operator.	wers,...
101	Th	$a \% b$ = remainder when a is divided by b
102	Te	$12 \% 7 =$	Store,...
103	Jo		Station,...
:	:		
198	Ar		Art,...
199	Fi		n,...

What array index does address x go into?
 $x \% 100$

Main Street Tourist Resources

Key

Value

100	Flo	% - modulo operator.	wers,...
101	Th	$a \% b$ = remainder when a is divided by b
102	Te	$12 \% 7 = 5$	Store,...
103	Jo	$7 \% 12 =$	Station,...
:	:		
198	Ar		Art,...
199	Fi		n,...

What array index does address x go into?
 $x \% 100$

Main Street Tourist Resources

Key

Value

100	Flowers,...
101	...
102	Store,...
103	Station,...
:	
198	Art,...
199	n,...

% - modulo operator.

$a \% b$ = remainder when a is divided by b .

$12 \% 7 = 5$

$7 \% 12 = 7$

$132 \% 100 =$

What array index does address x go into?

$x \% 100$

Main Street Tourist Resources

Key

Value

100	Flowers,...
101	...
102	Store,...
103	Station,...
:	
198	Art,...
199	n,...

What array index does address x go into?
 $x \% 100$

Main Street Tourist Resources

Key

Value

100	Flowers,...
101	...
102	Store,...
103	Station,...
:	
198	Art,...
199	n,...

% - modulo operator.

$a \% b$ = remainder when a is divided by b .

$12 \% 7 = 5$

$7 \% 12 = 7$

$132 \% 100 = 32$

$100 \% 100 = 0$

What array index does address x go into?

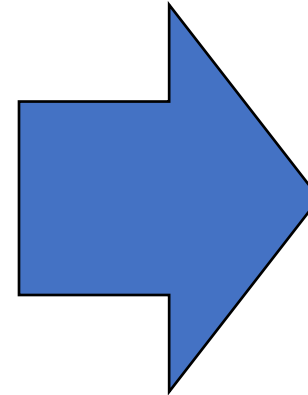
$x \% 100$

Main Street Tourist Resources

Key

Value

100	Flora's Flowers,...
101	The Bank,...
102	Ted's Drug Store,...
103	Joe's Gas Station,...
⋮	⋮
198	Aristocrat Art,...
199	Fire Station,...



0	100, Flora's Flowers,...
1	101, The Bank,...
2	102, Ted's Drug Store,...
3	103, Joe's Gas Station,...
⋮	⋮
98	198, Aristocrat Art,...
99	199, Fire Station,...

What array index does address x go into?

$x \% 100$ ← **Hash Function**

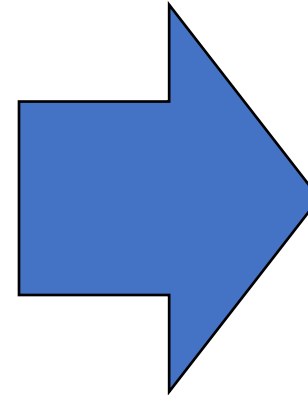
Hash Function: Function that translates keys into array indices (hash value).

Main Street Tourist Resources

Key

Value

100	Flora's Flowers,...
101	The Bank,...
102	Ted's Drug Store,...
103	Joe's Gas Station,...
⋮	⋮
198	Aristocrat Art,...
199	Fire Station,...



0	100, Flora's Flowers,...
1	101, The Bank,...
2	102, Ted's Drug Store,...
3	103, Joe's Gas Station,...
⋮	⋮
98	198, Aristocrat Art,...
99	199, Fire Station,...

200	More Art,...
-----	--------------

Hash Function: Function that translates keys into array indices (hash value).

What array index does address x go into?

$x \% 100$ ← **Hash Function**

Main Street Tourist Resources

Key

Value

100 Flora's Flowers,...
101 The Bank,...
102 Ted's Drug Store,...
103 Joe's Gas Station,...
⋮ ⋮
198 Aristocrat Art,...
199 Fire Station,...

200 More Art,...

0	100, Flora's Flowers,...
1	101, The Bank,...
2	102, Ted's Drug Store,...
3	103, Joe's Gas Station,...
⋮	⋮
98	198, Aristocrat Art,...
99	199, Fire Station,...

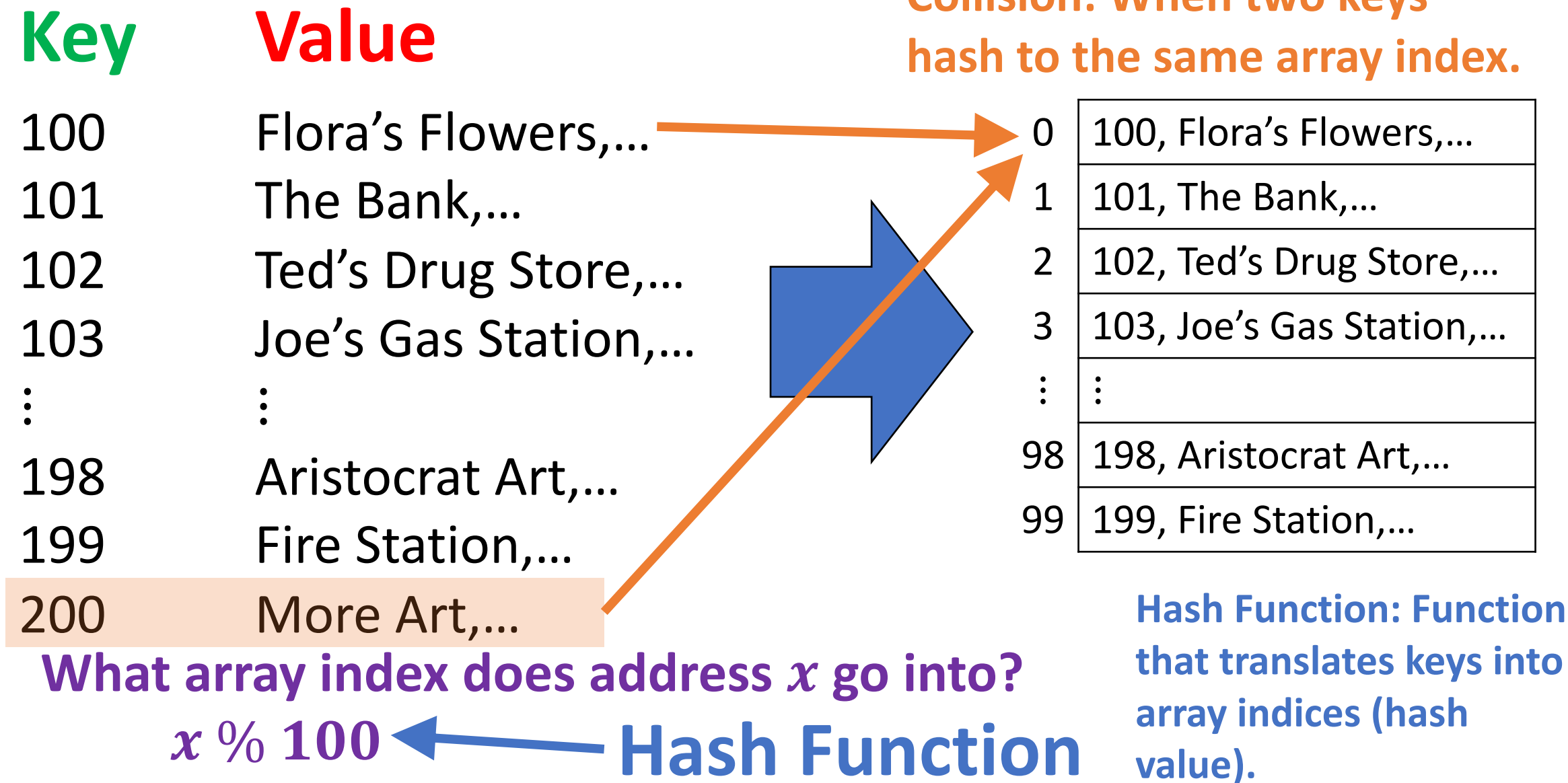
What array index does address x go into?

$x \% 100$ ← **Hash Function**

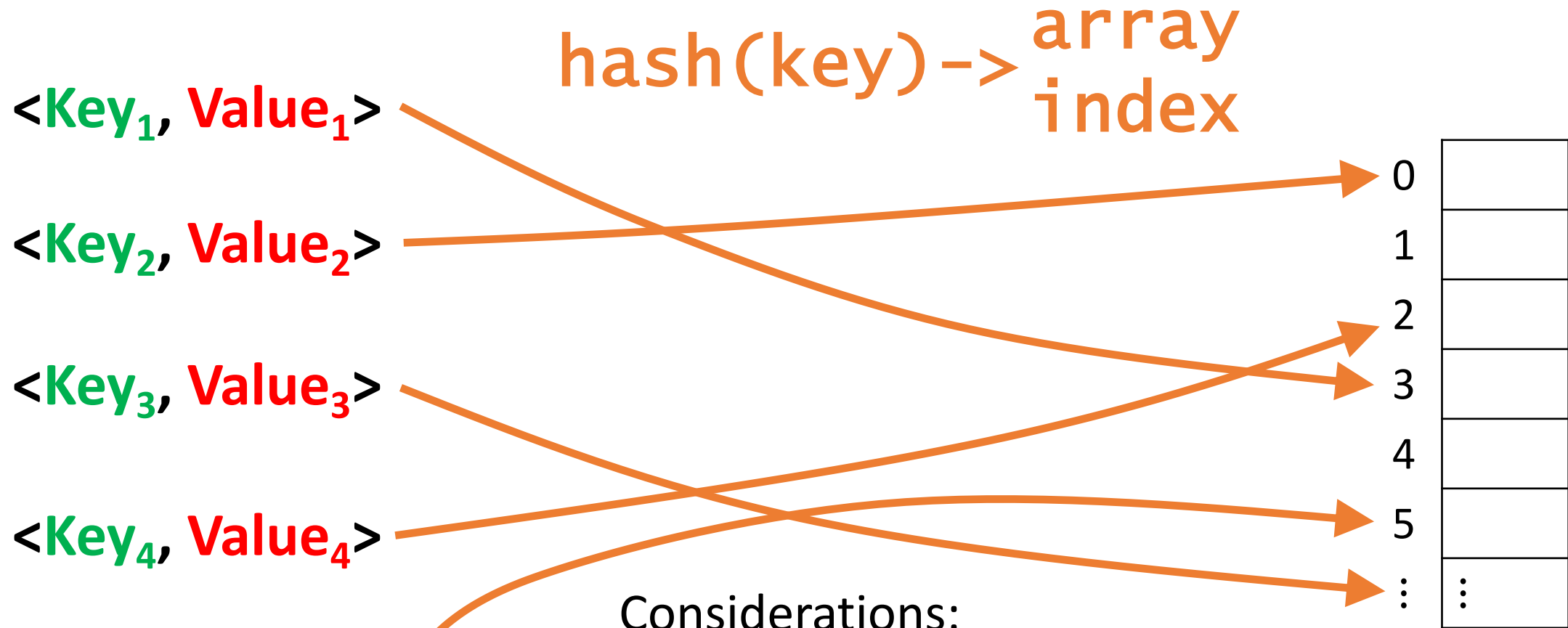
Hash Function: Function that translates keys into array indices (hash value).

Main Street Tourist Resources

Collision: When two keys hash to the same array index.



Hash Tables 101



Considerations:

- How big to make array?
- How to avoid collisions?
- How to handle collisions?

Hash Tables 101



Hash Tables 101

Theory.

Hash Functions.

Statistical likelihood.

Expected performance.



Hash Tables 101

Theory.

Hash Functions.

Statistical likelihood.

Expected performance.

Application.

Tools in hand.

Java functionality.

