# Interface Map

`Map` is an ADT (abstract data type). The values of this ADT are objects that map *keys* to *values*. The best way to understand this is to look at an example. To the right is part of an index of a book. Given a word, like "abort", it tells you the page number, 114, where that word is defined or used. The index *maps* words to page numbers.

abort, 114
abs, 314
abstraction, 149
ambiguity, 308

Here is how we would declare a variable `index` that can contain such a map:

```
Map<String, Integer> index;
```

The first type parameter gives the type of the keys; the second gives the type of the values.

After building `index` to contain the four key-value pairs in the box above, we say that "abort maps to 114" and that "`index` contains the pair ("abort", 114)."

Note that the keys form a *set*; the same key cannot map to two different values.[1] Secondly, unless specifically prohibited by an implementation, **`null`** can be used as both a key and a value.

### Implementation HashMap of Map

Java provides over twenty different implementations of interface `Map`! We mention only one of them here, `HashMap`, since you will use it most often. `HashMap` should generally be used like this:

```
Map<String, Integer> index= new HashMap<>();
```

Here, a `HashMap` object is created and is immediately cast to `Map` and stored in `index`. From then on, only operations declared in `Map` can be used, even though `HashMap` may provide others. Always cast to the interface for maximum flexibility in choosing an implementation later on.

`HashMap` has expected constant time for many operations, which is why we use it, although the worst case is linear in the size of the map. The implementation is based on a technique called *hashing*. You don't have to know how it works to use it, although you will learn about hashing in your data structure course if you haven't already.

### Major operations on a Map

A type consists of a bunch of values and a bunch of operations on them. We introduce the major operations defined in interface `Map`:

1. **`put(k, v)`** . Use this call to add the key-value pair (`k`, `v`) to the map. If a pair (`k`, `v1`) is already in the map, the new pair replaces. *You don't have to delete the old pair* (`k`, `v1`) *before adding the new pair* (`k`, `v`).
   The call `put(k, v)` actually returns a value. If a pair (`k`, `v1`) is already in the map, `v1` is returned, otherwise **`null`** is returned. We rarely use this feature and just use the call as a statement.
2. **size()** . This tells you how many key-value pairs are in the map.
3. **isEmpty()** . This tells you whether the map contains any key-value pairs.
4. **get(k)** . If there is a key-value pair (`k`, `v`) in the map, return `v`; otherwise, return **`null`**.
5. **remove(k)** . If there is a key-value pair in the map with key `k`, remove the pair.
   If a pair (`k`, `v1`) was already in the map, return `v1`; otherwise return **`null`**. We rarely use this feature and just use the call as a statement.
6. **clear()** . Remove all the pairs from the map; change the size of the map to 0.

Interface `Map` more operations. For example, you can ask whether a map contains a key, or contains a value. You can get the set of all keys, and a collection of all values. There are also ways to process all keys, or all values, using a foreach statement. If you feel you need them, look them up in the Java API documentation for interface `Map`.

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[1] In our example of an index, we cannot have these two key-value pairs in the map: (abort, 114) and (abort, 205). To allow several page numbers for the same word, redefine the values to be lists, like this:
`Map<String, List<Integer>> index`.

# Interface Map

### Example code

The code snippet in the box to the right does the following:

(1) Create a new `HashMap` and store it in variable `index`;
(2) Add four key-value pairs to the map.

```
Map<String, Integer> index=
                    new HashMap<>();
index.put("abort", 114);
index.put("abs", 314);
index.put("abstraction", 149);
index.put("ambiguity", 308);
```

The second box contains JUnit testing code that illustrates the following:

Line 1 shows that method `size` returns the size of the map.

Line 2 uses method `get` to retrieve the value corresponding to a key.

Line 3 illustrates that **`null`** is returned when the argument of a call on `get` is not in the set of keys.

Lines 4..5 illustrate that `put` returns the old value corresponding to its key parameter. The previous pair was ("abs", 314), and 314 was stored in d.

Lines 4 and 6 show that `put` replaced the old value, 314, with the new value, 80.

```
1. assertEquals(4, index.size());
2. assertEquals(314, index.get("abs"));
3. assertEquals(null, index.get(55));
4. int d= index.put("abs", 80);
5. assertEquals(314, d);
6. assertEquals(80, index.get("abs"));
```

### Useful examples of Maps

Most of the examples of `Map` and `HashMap` that you see as you look for them on the web have keys and values that are of types `String` or `Integer`. However, others can be just as useful, as our second example below shows. Whenever you have pairings of keys and values that require fast, efficient changing of pairs and efficient lookup, think of using a `Map`, with implementation `HashMap` or another one.

**1. zip codes to cities**. For example, the pair ("14853", "Ithaca") could be in it.

```
Map<String, String>
```

**2. Dates to times.** What about mapping a date to the time of day when the sun sets on that date (at a particular location)?

```
Map<Date, Time>
```

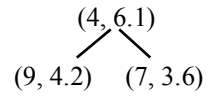
### 3. Making priority-change in a heap efficient

This example shows how an operation in a data structure can be made more efficient by introducing a `HashMap`. We assume knowledge of the data structure *heap*. Read this only if you have that knowledge. To the right, is a barebones view of a class that implements a max-heap. The values in the heap are of type `E`, and a priority, a `double`, is associated with each heap value. `ArrayList b` contains the values (and their priorities) in the heap.

```
class MaxHeap<E> {
    class Element {
        E value;
        double priority;
        …
    }
    ArrayList<Element> b;
    Map<E, Integer> m;
}
```

For example, suppose `E` is `Integer` and `ArrayList b` contains the following, which represents the heap shown to the right under class `MaxHeap`.

[(4, 6.1), (9, 4.2), (7, 3.6)]




m contains the pairs
(4, 0), (9, 1), (7, 3.6)

Now consider implementing a method `changePriority(v, p)` , which is to change the priority of value `v` in the heap to `p`. The implementation of this method must fine the node in the heap with value `v`, which can take time proportional to the size of the heap. NO GOOD! We must find a way to implement this method in expected logarithmic (in heap size) time, just like `insert` and `poll` are logarithmic.

To do this, we add an additional data structure, `Map m`, shown in red in the box above. Here's its definition:

For each value `v` in the heap, `m` contains the pair (`v`, `i`) where `i` is the index of `v` in `ArrayList b`.

Therefore, to find the index of `v` in the heap, use `m.get(v)`. That operation takes constant expected time.

Many methods in class `MaxHeap` are now more complicated, because the definition of `m` has to be maintained.