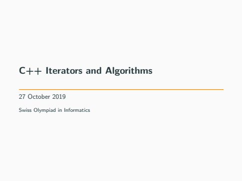
C++ Iterators and Algorithms

27 October 2019

Swiss Olympiad in Informatics



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Iterators

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Iterator - Example

Iterate a `vector<int>` a:

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for (int i = 0; i < a.size(); ++i) {
    print(a[i]);
}
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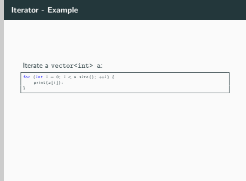

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```

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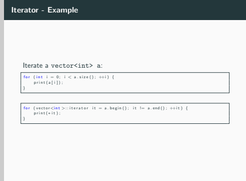
C++ Iterators and Algorithms
└Iterators
└Iterator - Example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Iterator - Definition

Definition : An iterator is a pointer that points to an element of a data structure. It allows to iterate over a data structure.

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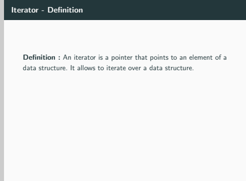
C++ Iterators and Algorithms

└Iterators

└Iterator - Definition



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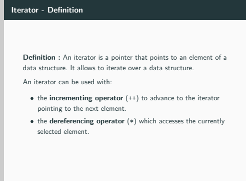
- the **incrementing operator** (++) to advance to the iterator pointing to the next element.
- the **dereferencing operator** ($*$) which accesses the currently selected element.



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└─Iterators
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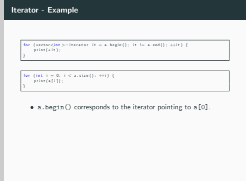
- `a.begin()` corresponds to the iterator pointing to `a[0]`.



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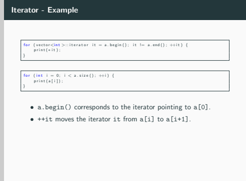
- `++it` moves the iterator `it` from `a[i]` to `a[i+1]`.



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- `a.begin()` corresponds to the iterator pointing to `a[0]`.
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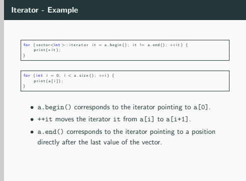
- `a.end()` corresponds to the iterator pointing to a position directly after the last value of the vector.



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└Iterators
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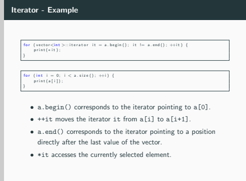

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Watch out!

If a is of type vector<vector<int> >:

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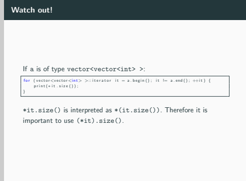
`*it.size()` is interpreted as `*(it.size())`. Therefore it is important to use `(*it).size()`.



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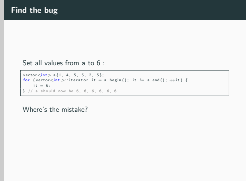
Find the bug

Set all values from a to 6 :

```cpp
vector<int> a{1, 4, 5, 5, 2, 5};
for (vector<int>::iterator it = a.begin(); it != a.end(); ++it) {
    it = 6;
} // a should now be 6, 6, 6, 6, 6, 6
```

Where's the mistake?



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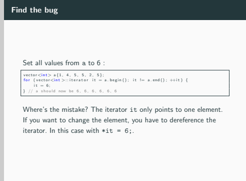
Where's the mistake? The iterator `it` only points to one element. If you want to change the element, you have to dereference the iterator. In this case with `*it = 6;`.



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Applications of iterators

- You can iterate in the same way as index variables.
- The syntax is more complicated.

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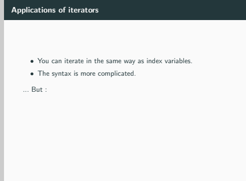

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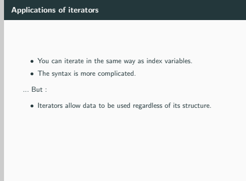

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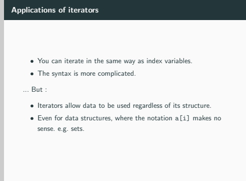

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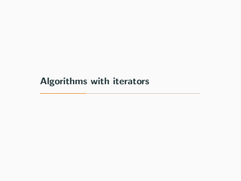
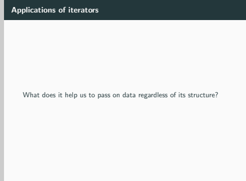
Algorithms with iterators



Algorithms with iterators

Applications of iterators

What does it help us to pass on data regardless of its structure?



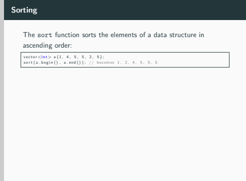
Applications of iterators

What does it help us to pass on data regardless of its structure?

Sorting

The `sort` function sorts the elements of a data structure in ascending order:

```
vector<int> a{1, 4, 5, 5, 2, 5};
sort(a.begin(), a.end()); // becomes 1, 2, 4, 5, 5, 5
```



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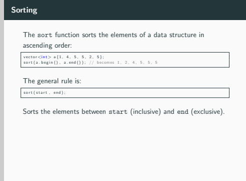
The general rule is:

```
sort(start, end);
```

Sorts the elements between `start` (inclusive) and `end` (exclusive).



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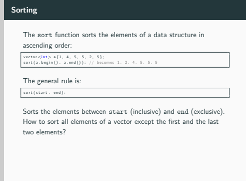
Sorts the elements between start (inclusive) and end (exclusive). How to sort all elements of a vector except the first and the last two elements?



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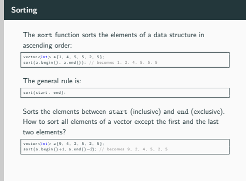
```
vector<int> a{9, 4, 2, 5, 2, 5};
sort(a.begin()+1, a.end()-2); // becomes 9, 2, 4, 5, 2, 5
```



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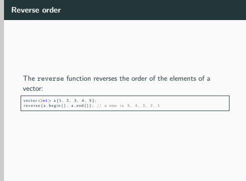
vector<int> a{9, 4, 2, 5, 2, 5};
sort(a.begin()+1, a.end()-2); // becomes 9, 2, 4, 5, 2, 5

Reverse order

The `reverse` function reverses the order of the elements of a vector:

```
vector<int> a{1, 2, 3, 4, 5};
reverse(a.begin(), a.end()); // a now is 5, 4, 3, 2, 1
```



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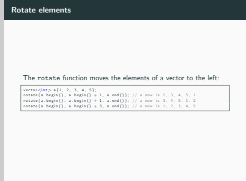
Rotate elements

The `rotate` function moves the elements of a vector to the left:

```
vector<int> a{1, 2, 3, 4, 5};
rotate(a.begin(), a.begin() + 1, a.end()); // a now is 2, 3, 4, 5, 1
rotate(a.begin(), a.begin() + 1, a.end()); // a now is 3, 4, 5, 1, 2
rotate(a.begin(), a.begin() + 3, a.end()); // a now is 1, 2, 3, 4, 5
```



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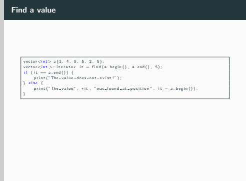
rotate(a.begin(), a.begin() + 1, a.end()); // a now is 3, 4, 5, 1, 2
rotate(a.begin(), a.begin() + 3, a.end()); // a now is 1, 2, 3, 4, 5

Find a value

```
vector<int> a{1, 4, 5, 5, 2, 5};
vector<int>::iterator it = find(a.begin(), a.end(), 5);
if (it == a.end()) {
    print("The␣value␣does␣not␣exist!");
} else {
    print("The␣value", *it, "was␣found␣at␣position", it − a.begin());
}
```



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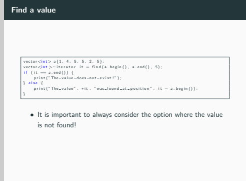

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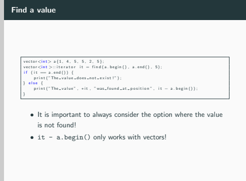

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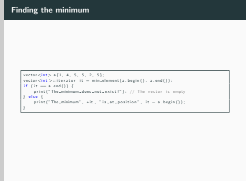
Finding the minimum

```
vector<int> a{1, 4, 5, 5, 2, 5};
vector<int >::iterator it = min_element(a.begin(), a.end());
if (it == a.end()) {
    print("The␣minimum␣does␣not␣exist!"); // The vector is empty
} else {
    print("The␣minimum", *it, "is␣at␣position", it - a.begin());
}
```

2019-10-27

C++ Iterators and Algorithms
└Algorithms with iterators

└Finding the minimum



Finding the minimum

```
vector<int> a{1, 4, 5, 5, 2, 5};
vector<int >::iterator it = min_element(a.begin(), a.end());
if (it == a.end()) {
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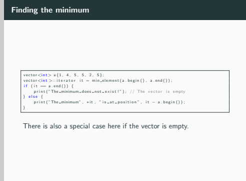
There is also a special case here if the vector is empty.



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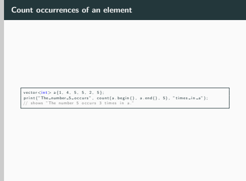
}
```

There is also a special case here if the vector is empty.

Count occurrences of an element

```
vector<int> a{1, 4, 5, 5, 2, 5};
print("The␣number␣5␣occurs", count(a.begin(), a.end(), 5), "times␣in␣a");
// shows "The number 5 occurs 3 times in a."
```



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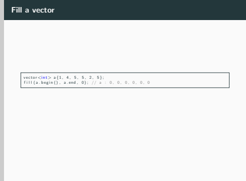
// shows "The number 5 occurs 3 times in a."

Fill a vector

```
vector<int> a{1, 4, 5, 5, 2, 5};
fill(a.begin(), a.end, 0); // a : 0, 0, 0, 0, 0, 0
```



Fill a vector

```
vector<int> a{1, 4, 5, 5, 2, 5};
fill(a.begin(), a.end, 0); // a : 0, 0, 0, 0, 0, 0
```

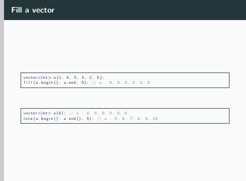
Fill a vector

```
vector<int> a{1, 4, 5, 5, 2, 5};
fill(a.begin(), a.end, 0); // a : 0, 0, 0, 0, 0, 0
```

```
vector<int> a(6); // a : 0, 0, 0, 0, 0, 0
iota(a.begin(), a.end(), 5); // a : 5, 6, 7, 8, 9, 10
```

2019-10-27

C++ Iterators and Algorithms
└─Algorithms with iterators
└─Fill a vector



Fill a vector

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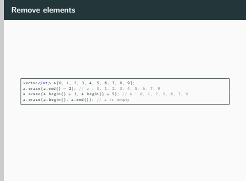
fill(a.begin(), a.end, 0); // a : 0, 0, 0, 0, 0, 0
```

```
vector<int> a(6); // a : 0, 0, 0, 0, 0, 0
iota(a.begin(), a.end(), 5); // a : 5, 6, 7, 8, 9, 10
```

Remove elements

```
vector<int> a{0, 1, 2, 3, 4, 5, 6, 7, 8, 9};
a.erase(a.end() - 2); // a : 0, 1, 2, 3, 4, 5, 6, 7, 9
a.erase(a.begin() + 3, a.begin() + 5); // a : 0, 1, 2, 5, 6, 7, 9
a.erase(a.begin(), a.end()); // a is empty
```



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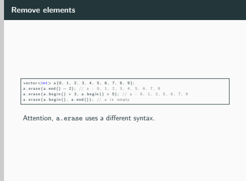
```

Attention, `a.erase` uses a different syntax.

2019-10-27

C++ Iterators and Algorithms
└Algorithms with iterators
└Remove elements


Remove elements

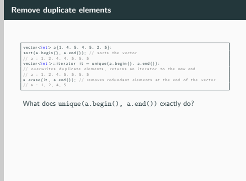
```
vector<int> a{0, 1, 2, 3, 4, 5, 6, 7, 8, 9};
a.erase(a.end() - 2); // a : 0, 1, 2, 3, 4, 5, 6, 7, 9
a.erase(a.begin() + 3, a.begin() + 5); // a : 0, 1, 2, 5, 6, 7, 9
a.erase(a.begin(), a.end()); // a is empty
```

Attention, a.erase uses a different syntax.

Remove duplicate elements

```
vector<int> a{1, 4, 5, 4, 5, 2, 5};
sort(a.begin(), a.end()); // sorts the vector
// a : 1, 2, 4, 4, 5, 5, 5
vector<int >::iterator it = unique(a.begin(), a.end());
// overwrites duplicate elements, returns an iterator to the new end
// a : 1, 2, 4, 5, 5, 5, 5
a.erase(it , a.end()); // removes redundant elements at the end of the vector
// a : 1, 2, 4, 5
```

What does `unique(a.begin(), a.end())` exactly do?



Remove duplicate elements

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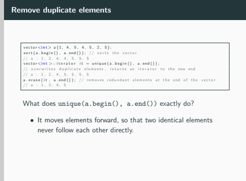
What does `unique(a.begin(), a.end())` exactly do?

- It moves elements forward, so that two identical elements never follow each other directly.



Remove duplicate elements

```
vector<int> a{1, 4, 5, 4, 5, 2, 5};
sort(a.begin(), a.end()); // sorts the vector
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- It moves elements forward, so that two identical elements never follow each other directly.
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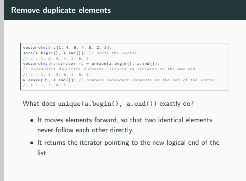

Remove duplicate elements

```
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sort(a.begin(), a.end()); // sorts the vector
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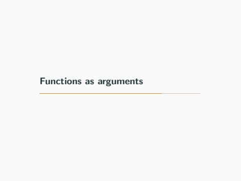
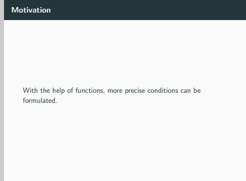
Functions as arguments



Functions as arguments

Motivation

With the help of functions, more precise conditions can be formulated.



Motivation

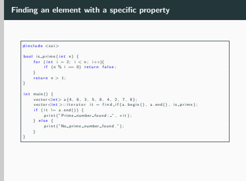
With the help of functions, more precise conditions can be formulated.

Finding an element with a specific property

```
#include <soi>

bool is_prime(int n) {
    for (int i = 2; i < n; i++){
        if (n % i == 0) return false;
    }
    return n > 1;
}

int main() {
    vector<int> a{4, 6, 3, 5, 8, 4, 2, 7, 8};
    vector<int>::iterator it = find_if(a.begin(), a.end(), is_prime);
    if (it != a.end()) {
        print("Prime␣number␣found:␣", *it);
    } else {
        print("No␣prime␣number␣found.");
    }
}
```



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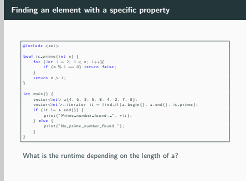
What is the runtime depending on the length of a?



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}
```

What is the runtime depending on the length of a?

Remove all values that fulfill a condition.

```
#include <soi>

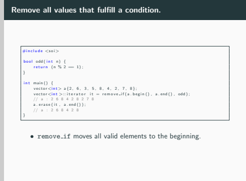
bool odd(int n) {
    return (n % 2 == 1);
}

int main() {
    vector<int> a{2, 6, 3, 5, 8, 4, 2, 7, 8};
    vector<int >::iterator it = remove_if(a.begin(), a.end(), odd);
    // a : 2 6 8 4 2 8 2 7 8
    a.erase(it, a.end());
    // a : 2 6 8 4 2 8
}
```

- `remove_if` moves all valid elements to the beginning.

2019-10-27

└Remove all values that fulfill a condition.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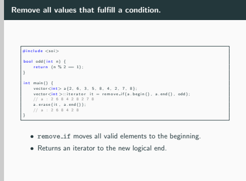
}
```

- `remove_if` moves all valid elements to the beginning.
- Returns an iterator to the new logical end.



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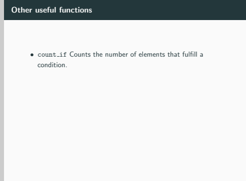
```

- `remove_if` moves all valid elements to the beginning.
- Returns an iterator to the new logical end.

Other useful functions

- `count_if` Counts the number of elements that fulfill a condition.



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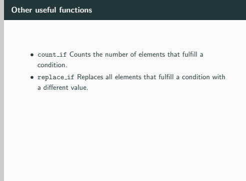

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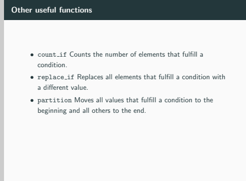
- `count_if` Counts the number of elements that fulfill a condition.
- `replace_if` Replaces all elements that fulfill a condition with a different value.
- `partition` Moves all values that fulfill a condition to the beginning and all others to the end.



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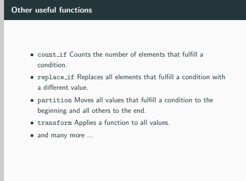
- `transform` Applies a function to all values.
- and many more ...



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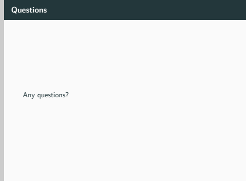
Questions

Any questions?



Questions

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