Modern C++ by Example

unless specified otherwise, all these code snippets should compile cleanly with a modern C++ compiler

```
#include <iostream>
#include <vector>

static void transmit_item(int i)
{
    std::cout << i << std::endl;
    // ...
}

static void transmit_log(const std::vector<int> & log)
{
    for (std::vector<int>::const_iterator it = log.cbegin();
         it != log.cend(); ++it)
        transmit_item(*it);
}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    transmit_log(log);
}
```

Consider this small toy program...

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        transmit_item(*it);
}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    transmit_log(log);
}
```

```
$ g++-4.9 -std=c++1y -Wall -Wextra -pedantic -Werror foo.cpp && ./a.out
20
24
37
42
23
45
37
$
```

```
#include <iostream>
#include <vector>

static void transmit_item(int i)
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    std::cout << i << std::endl;
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int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
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}
```

This shows a "traditional" way of looping through a collection of objects.

```cpp
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#include <vector>

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    std::cout << i << std::endl;
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}

static void transmit_log(const std::vector<int> & log)
{
    for (std::vector<int>::const_iterator it = log.cbegin();
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}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    transmit_log(log);
}
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```cpp
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#include <vector>

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{
    std::cout << i << std::endl;
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    for (std::vector<int>::const_iterator it = log.cbegin();
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        transmit_item(*it);
}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    transmit_log(log);
}
```

But why do we have to write all this stuff? In this case, wouldn't it be nice if the compiler could just figure out which type we need to store the return value from `log.cbegin()`?

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    std::cout << i << std::endl;
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static void transmit_log(const std::vector<int> & log)
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    for (std::vector<int>::const_iterator it = log.cbegin();
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static void transmit_item(int i)
{
    std::cout << i << std::endl;
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}

static void transmit_log(const std::vector<int> & log)
{
    for (decltype(log.cbegin()) it = log.cbegin();
         it != log.cend(); ++it)
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}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
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int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
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```

`decltype` gives us type deduction in C++. Or even better...

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static void transmit_item(int i)
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    std::cout << i << std::endl;
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static void transmit_log(const std::vector<int> & log)
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    for (auto it = log.cbegin();
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int main()
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    std::vector<int> log{20,24,37,42,23,45,37};
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    for (auto it = log.cbegin();
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int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
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```

We can just use the new meaning of the keyword `auto`

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static void transmit_item(int i)
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    // ...
}

static void transmit_log(const std::vector<int> & log)
{
    for (auto it = log.cbegin();
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{
    std::vector<int> log{20,24,37,42,23,45,37};
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    std::vector<int> log{20,24,37,42,23,45,37};
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    std::vector<int> log{20,24,37,42,23,45,37};
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int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
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```

Looping through an array like this is something C++ programmers often do. So the language now provides a new way of looping through ranges of objects.

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#include <vector>

static void transmit_item(int i)
{
    std::cout << i << std::endl;
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static void transmit_log(const std::vector<int> & log)
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    for (auto i : log)
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int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
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```

Introducing:
range based for-loop.

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#include <vector>

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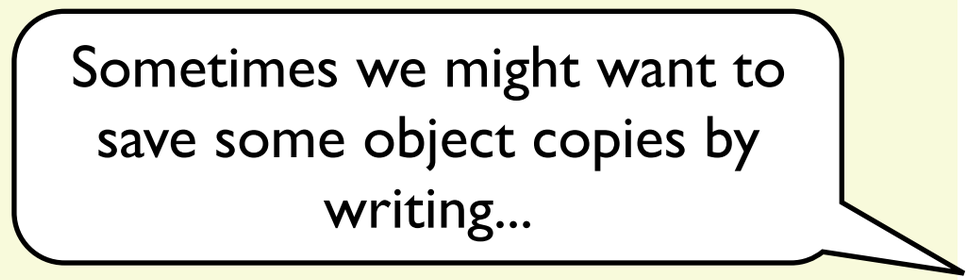

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int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
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```

Sometimes we might want to save some object copies by writing...

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static void transmit_item(int i)
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static void transmit_log(const std::vector<int> & log)
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{
    std::vector<int> log{20,24,37,42,23,45,37};
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```

But even for simple loops like this you will often see that **STL algorithms** are used instead.

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You will often see this written as...

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```

Because it now works on both containers and arrays.

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```

Suppose we would like to sort the array before transmitting the items...

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Suppose we would like to sort the array before transmitting the items...

First we make a local copy of the log through a **pass-by-value**

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int main()
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int main()
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But wait! What if the log has million of entries? Perhaps we should do **pass-by-reference** instead?

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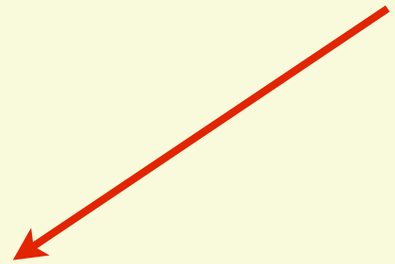

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This is an **rvalue reference**.

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And here we basically say: Just take this data object, it is yours, do whatever you want with it. I promise to never refer to it again after this.

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rvalue references and the corresponding **move semantics** are very important contributions to modern C++. It reduces the need to create copies of objects while still being able to use **value semantics** as a programming style (ie, avoiding the need to use pointers for everything).

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Typical for most algorithms in the C++ library is that you can adapt them to your own needs. Let's try to change the sorting order by writing our own comparator function.

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static void transmit_log(std::vector<int> && log, bool comp(int, int))
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This is an example of
parameterize from above

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I am now going to introduce function objects and lambdas. Let's simplify the code, before introducing a algorithms for filtering out and removing log values.

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    struct filter {
        filter(int limit) : lim(limit) {}
        bool operator()(int i) { return i <= lim; };
        int lim;
    } myfilter(23);
    log.erase(std::remove_if(std::begin(log), std::end(log), myfilter),
              std::end(log));
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        int lim;
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Here we have created code to remove all log items that are 23 or below.

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#include <vector>
#include <algorithm>

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    std::cout << i << std::endl;
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    struct filter {
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Notice how we have created a "function" on the fly by overloading the call operator on an object. This is an example of a **function object**, sometimes called a **functor**.

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Such function objects are sometimes very useful. New in C++11 is a convenient syntax for creating these functions.

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This is a lambda expression that creates a function object on the "fly". We are **capturing** the value of the variable `limit` and using it to initialize the function object.

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You can of course also pass function objects around as any other objects.

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template <typename Filt>
static void transmit_log(std::vector<int> && log, Filt myfilter)
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int main()
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`transmit_log` and `transmit_item` are now **type independent code**. This is a fine example of **generic programming**. Notice how we can change both the type of the log items and the container and it should still work (given some restrictions)

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It would be nice to specify exactly what expectations we have to the types and objects that are passed into our generic code. A "poor man" solution is to use **type traits** and `static_assert`.

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    std::cout << i << std::endl;
    // ...
}

template <typename Log, typename Filt>
static void transmit_log(Log && log, Filt myfilter)
{
    log.erase(std::remove_if(std::begin(log), std::end(log), myfilter),
              std::end(log));
    std::sort(std::begin(log), std::end(log));
    std::for_each(std::begin(log), std::end(log),
                  transmit_item<typename Log::value_type>);
}

int main()
{
    using log_item_type = long;
    std::vector<log_item_type> log{20,24,37,42,23,45,37};
    transmit_log(std::move(log), [](log_item_type i) { return i <= 23; });
}
```

Here we will get an understandable compile error if the type of the log items are not of integral type. However, you can, with some work, define your own traits and constraints. Eg, something like this:

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#include <iostream>
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#include <algorithm>
#include <functional>
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template <typename T>
static void transmit_item(T i)
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    std::cout << i << std::endl;
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int main()
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```
#include <iostream>
#include <vector>
#include <algorithm>
#include <functional>
#include <type_traits>
#include "mystuff"

template <typename T>
static void transmit_item(T i)
{
    static_assert(my::is_transmittable<T>::value, "transmittable type expected");
    std::cout << i << std::endl;
    // ...
}

template <typename Log, typename Filt>
static void transmit_log(Log && log, Filt myfilter)
{
    log.erase(std::remove_if(std::begin(log), std::end(log), myfilter),
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this is just an example that does not compile

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    transmit_log(std::move(log), [](log_item_type i) { return i <= 23; });
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There are some proposals for the next versions of C++ to include better syntax for such constraints.

this is just an example that does not compile

```cpp
#include <iostream>
#include <vector>
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template <typename T>
static void transmit_item(T i)
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There are some proposals for the next versions of C++ to include better syntax for such constraints.

this is just an example that does not compile

```
#include <iostream>
#include <vector>
#include <algorithm>
#include <functional>
#include <type_traits>
#include "mystuff"

template <typename T> require Transmittable<T>
static void transmit_item(T i)
{
    
    std::cout << i << std::endl;
    // ...
}

template <typename Log, typename Filt>
static void transmit_log(Log && log, Filt myfilter)
{
    log.erase(std::remove_if(std::begin(log), std::end(log), myfilter),
              std::end(log));
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static void transmit_item(T i)
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    std::cout << i << std::endl;
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}

template <Iterable Log, UnaryFunctionPredicate Filt>
static void transmit_log(Log && log, Filt myfilter)
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              std::end(log));
    std::sort(std::begin(log), std::end(log));
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    transmit_log(std::move(log), [](log_item_type i) { return i <= 23; });
}
```

This proposal is a step towards something called Concepts. I am not going to explain that, so let's clean up the code so I can show a final thing.

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#include <algorithm>
#include <functional>
#include <type_traits>
#include "mystuff"

template <Transmittable T>
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int main()
{
    using log_item_type = long;
    std::vector<log_item_type> log{20,24,37,42,23,45,37};
    transmit_log(std::move(log), [](log_item_type i) { return i <= 23; });
}
```

```
#include <iostream>
#include <vector>
#include <algorithm>

static void transmit_item(int i)
{
    std::cout << i << std::endl;
    // ...
}

static size_t transmit_log(const std::vector<int> & log)
{
    std::for_each(std::begin(log), std::end(log), transmit_item);
    return log.size();
}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    size_t items = transmit_log(log);
    std::cout << "# " << items << std::endl;
}
```

```
#include <iostream>
#include <vector>
#include <algorithm>

static void transmit_item(int i)
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{
    std::vector<int> log{20,24,37,42,23,45,37};
    size_t items = transmit_log(log);
    std::cout << "# " << items << std::endl;
}
```

Transmitting the data probably takes some time, and we might want to do something else while waiting for the log to be transmitted. Let's simulate that, and show an example of how concurrency is supported in modern C++.

```
#include <iostream>
#include <vector>
#include <algorithm>

static void transmit_item(int i)
{
    std::cout << i << std::endl;
    // ...
}

static size_t transmit_log(const std::vector<int> & log)
{
    std::for_each(std::begin(log), std::end(log), transmit_item);
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int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    size_t items = transmit_log(log);
    std::cout << "# " << items << std::endl;
}
```

```cpp
#include <iostream>
#include <vector>
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static void transmit_item(int i)
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    std::cout << i << std::endl;
    // ...
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static size_t transmit_log(const std::vector<int> & log)
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    std::for_each(std::begin(log), std::end(log), transmit_item);
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int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    size_t items = transmit_log(log);
    std::cout << "# " << items << std::endl;
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#include <iostream>
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static void transmit_item(int i)
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    std::cout << i << std::endl;
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static size_t transmit_log(const std::vector<int> & log)
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    std::for_each(std::begin(log), std::end(log), transmit_item);
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}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    size_t items = transmit_log(log);
    std::cout << "# " << items << std::endl;
}
```

```cpp
#include <iostream>
#include <vector>
#include <algorithm>
#include <chrono>
#include <thread>

static void transmit_item(int i)
{
    std::cout << i << std::endl;
    std::this_thread::sleep_for(std::chrono::milliseconds(200));
    // ...
}

static size_t transmit_log(const std::vector<int> & log)
{
    std::for_each(std::begin(log), std::end(log), transmit_item);
    return log.size();
}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    size_t items = transmit_log(log);
    std::cout << "# " << items << std::endl;
}
```

```
#include <iostream>
#include <vector>
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{
    std::vector<int> log{20,24,37,42,23,45,37};
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int main()
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    std::vector<int> log{20,24,37,42,23,45,37};
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static size_t transmit_log(const std::vector<int> & log)
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int main()
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    std::vector<int> log{20,24,37,42,23,45,37};
    size_t items = transmit_log(log);
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```

```cpp
#include <iostream>
#include <vector>
#include <algorithm>
#include <chrono>
#include <thread>
#include <future>

static void transmit_item(int i)
{
    std::cout << i << std::endl;
    std::this_thread::sleep_for(std::chrono::milliseconds(200));
    // ...
}

static size_t transmit_log(const std::vector<int> & log)
{
    std::for_each(std::begin(log), std::end(log), transmit_item);
    return log.size();
}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    auto res = std::async(std::launch::async, transmit_log, log);
    size_t items = res.get();
    std::cout << "# " << items << std::endl;
}
```

```
#include <iostream>
#include <vector>
#include <algorithm>
#include <chrono>
#include <thread>
#include <future>

static void transmit_item(int i)
{
    std::cout << i << std::endl;
    std::this_thread::sleep_for(std::chrono::milliseconds(200));
    // ...
}

static size_t transmit_log(const std::vector<int> & log)
{
    std::for_each(std::begin(log), std::end(log), transmit_item);
    return log.size();
}

int main()
{
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    auto res = std::async(std::launch::async, transmit_log, log);
    size_t items = res.get();
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}
```

```
$ g++-4.9 -std=c++1y -Wall -Wextra -pedantic -Werror -pthread foo.cpp
```

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    std::cout << "# " << items << std::endl;
}
```

... and now we can do some stuff between calling transmit_log until we need the result from calling that function.

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#include <chrono>
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#include <future>

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{
    std::cout << i << std::endl;
    std::this_thread::sleep_for(std::chrono::milliseconds(200));
    // ...
}

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    std::for_each(std::begin(log), std::end(log), transmit_item);
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int main()
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    std::vector<int> log{20,24,37,42,23,45,37};
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static size_t transmit_log(const std::vector<int> & log)
{
    std::for_each(std::begin(log), std::end(log), transmit_item);
    return log.size();
}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    auto res = std::async(std::launch::async, transmit_log, log);
    for (int i=0; i<5; i++) {
        std::this_thread::sleep_for(std::chrono::milliseconds(77));
        std::cout << "do something else..." << std::endl;
    }
    size_t items = res.get();
    std::cout << "# " << items << std::endl;
}
```

```
#include <iostream>
#include <vector>
#include <algorithm>
#include <chrono>
#include <thread>
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static void transmit_item(int i)
{
    std::cout << i << std::endl;
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    return log.size();
}

int main()
{
    std::vector<int> log{20,24,37,42,23,45,37};
    auto res = std::async(std::launch::async, transmit_log, log);
    for (int i=0; i<5; i++) {
        std::this_thread::sleep_for(std::chrono::milliseconds(123));
        std::cout << "do something else..." << std::endl;
    }
    size_t items = res.get();
    std::cout << "# " << items << std::endl;
}
```

```cpp
#include <iostream>
#include <vector>
#include <algorithm>
#include <chrono>
#include <thread>
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static void transmit_item(int i)
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    std::cout << i << std::endl;
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    for (int i=0; i<5; i++) {
        std::this_thread::sleep_for(std::chrono::milliseconds(123));
        std::cout << "do something else..." << std::endl;
    }
    size_t items = res.get();
    std::cout << "# " << items << std::endl;
}
```

```
20
do something else...
24
do something else...
do something else...
37
do something else...
42
do something else...
23
45
37
# 7
```

Modern C++
- move semantics (rvalue references, value semantics)
- type deduction (decltype, auto)
- better support for OOP (attributes, member initialization, delegation)
- compile time computation (templates, static_assert, constexpr)
- template metaprogramming (traits, constraints, concepts)
- robust resource management (RAII, unique, shared)
- high-order parallelism (atomic, mutex, async, promises and futures)
- functional programming (algorithms, lamdas, closures, lazy evaluation)
- misc (chrono, user-defined literals, regex, uniform initialization)

!

http://en.wikipedia.org/wiki/C++11
http://en.wikipedia.org/wiki/C++14
http://www.open-std.org/jtc1/sc22/wg21/
http://en.cppreference.com/w/
http://isocpp.org