C++11 was only the beginning

DO NOT STAY BEHIND

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Confidential Information

What is C++?

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- *C++ is no longer C with classes*

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  - *imperative*, *object-based*, *object-oriented*, *generic*, and *functional programming* features
  - developer is not tied to any specific programming paradigm by the language

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C++ motto:
You don't pay for what you don't use

Modern C++

- Philosophy of code design

Modern C++

- Philosophy of code design
  - Extensive and wise usage of a *subset of C++ language features and C++ standard library*
  - *Implementing the code with performance in mind*, achieved by the awareness of interactions between the software and the hardware
  - Following the *best practices, coding guidelines, and idioms*
  - Following the *latest versions of the C++ standard* to make the code development more efficient for engineers, and the resulting products safer, and even faster

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Within C++, there is a much smaller and cleaner language struggling to get out.

-- Bjarne Stroustrup'2007

C++11 (ISO/IEC 14882:2011)

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CORE LANGUAGE RUNTIME PERFORMANCE

- Move Semantics
- Constant Expressions

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CORE LANGUAGE USABILITY

- Lambdas
- Object construction improvements
- Explicit and final overrides
- Range-based-for-loop
- Scoped enumeration

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- Variadic templates
- Multitasking memory model
- Explicit defaulted and deleted functions
- Static assertions

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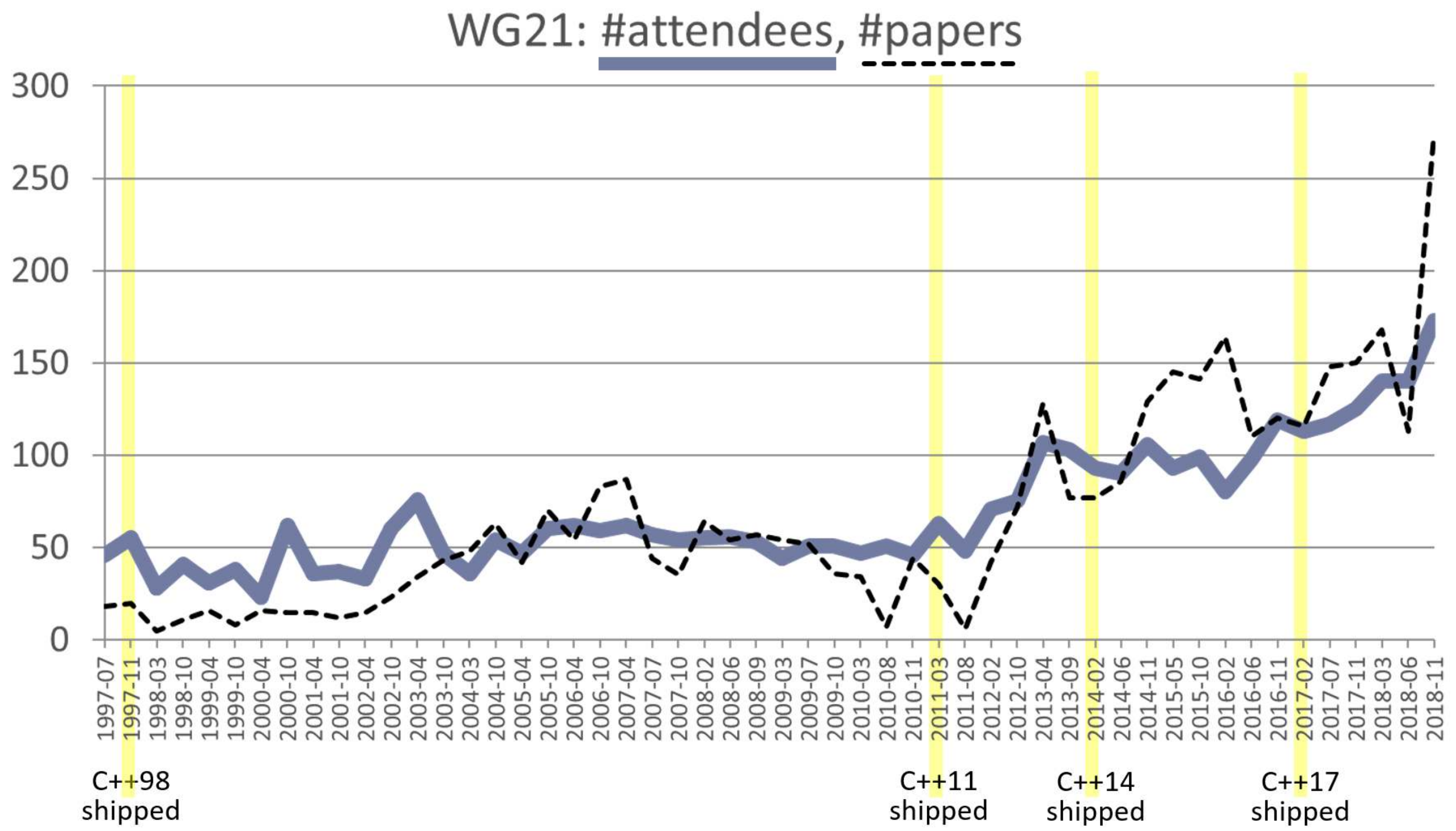
- Multitasking memory model
- Explicit defaulted and deleted functions
- Static assertions

C++ STANDARD LIBRARY

- Threading facilities
- Smart pointers and more containers
- Type traits
- Tools (regexp, chrono, random)

C++ Momentum



WG21: #attendees, #papers
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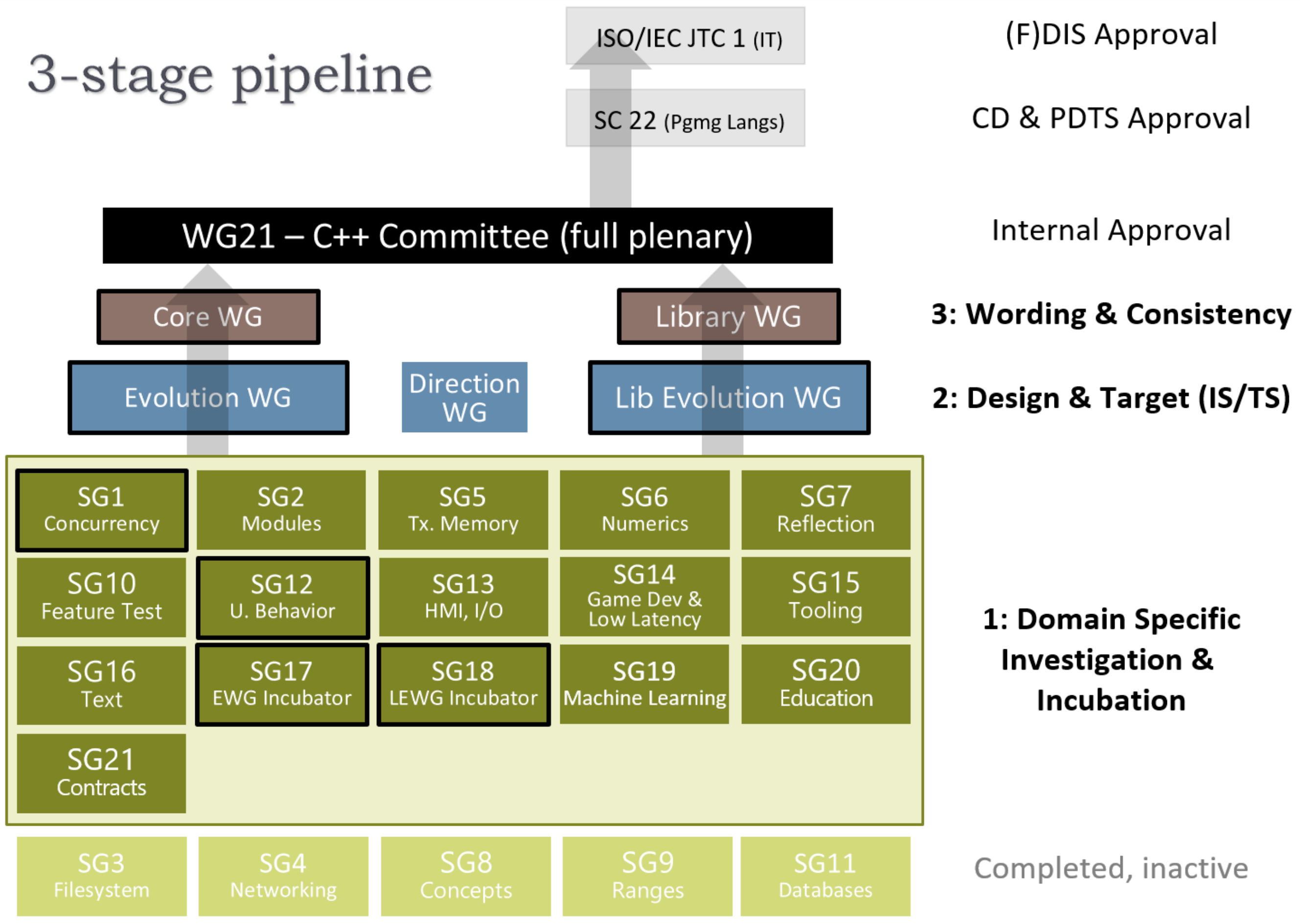
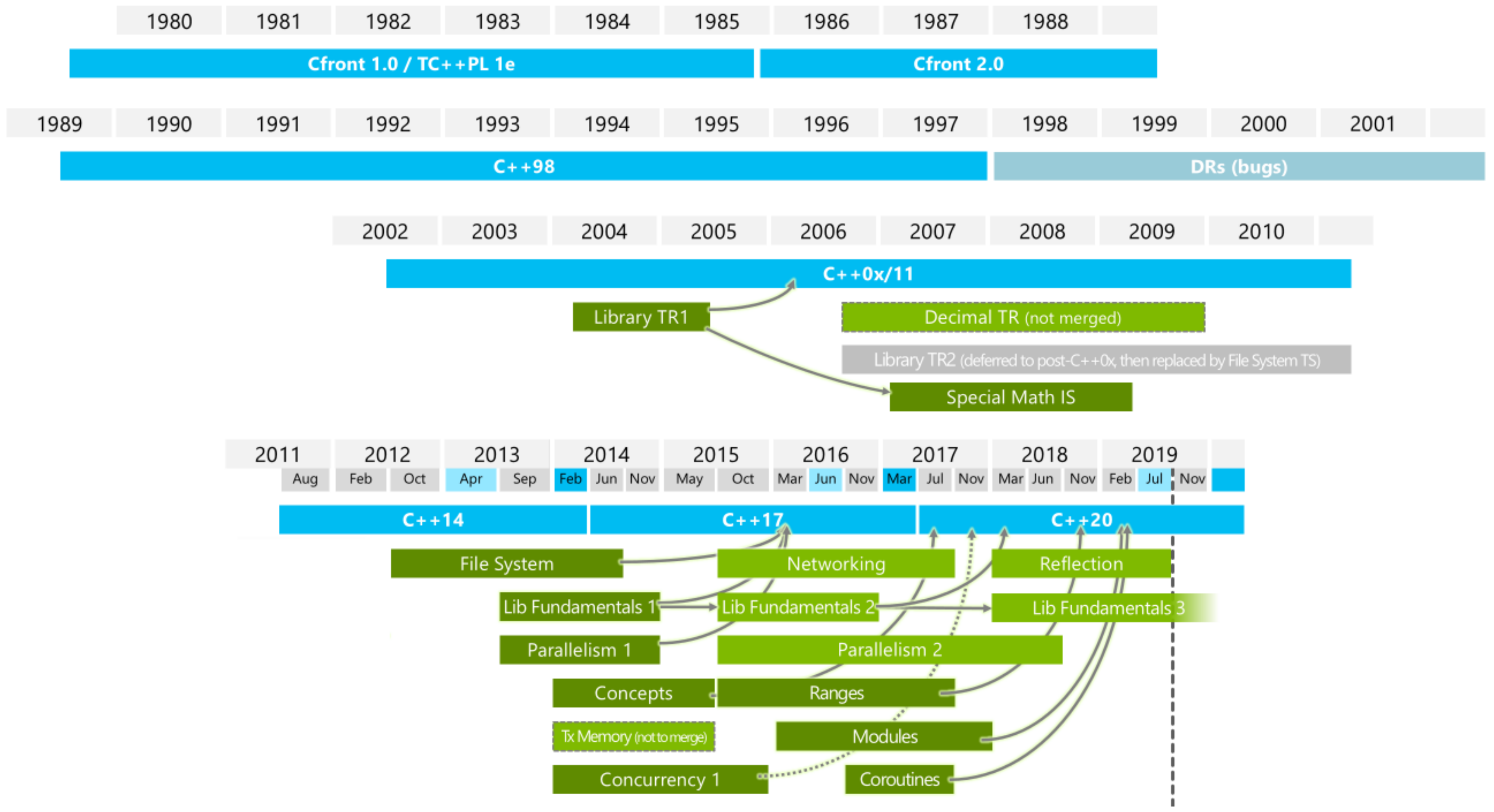
C++98 shipped
C++11 shipped
C++14 shipped
C++17 shipped

ISO C++ Committee structure



C++ Timeline



1980
1981
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1986
1987
1988
Cfront 1.0 / TC++PL 1e
Cfront 2.0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
C++98
DRs (bugs)
2002
2003
2004
2005
2006
2007
2008
2009
2010
C++0x/11
Library TR1
Decimal TR (not merged)
Library TR2 (deferred to post-C++0x, then replaced by File System TS)
Special Math IS
2011
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Nov
Feb
Jul
Nov
C++14
C++17
C++20
File System
Networking
Reflection
Lib Fundamentals 1
Lib Fundamentals 2
Lib Fundamentals 3
Parallelism 1
Parallelism 2
Concepts
Ranges
Tx Memory (not to merge)
Modules
Concurrency 1
Coroutines

Why do we need so many changes?

- Each new C++ release introduces a lot of new features
- They are *not about* "complicating stuff" even more
- They are here to
  - make our code **easier to design, develop, and maintain**
  - make our products **more stable, secure, and even faster**

HOW THOSE CHANGES AFFECT THE CODE WE WRITE EVERY DAY?

10 REAL-LIFE CASES

Case #1: Variable number of function parameters

Implement non-member function template that will allow pushing any number of values to the **`std::vector`** container.

```
std::vector<T> v;
push_back(v, args...);
```

Case #1: Variable number of function parameters

C++98

```
template<typename T>
void push_back(std::vector<T>&)
{
}

template<typename T, typename Arg1>
void push_back(std::vector<T>& v, const Arg1& arg1)
{
  v.push_back(arg1);
}

template<typename T, typename Arg1, typename Arg2>
void push_back(std::vector<T>& v, const Arg1& arg1, const Arg2& arg2)
{
  v.push_back(arg1);
  v.push_back(arg2);
}

template<typename T, typename Arg1, typename Arg2, typename Arg3>
void push_back(std::vector<T>& v, const Arg1& arg1, const Arg2& arg2, const Arg3& arg3)
// ...
```

Case #1: Variable number of function parameters

C++11

```cpp
template<typename T>
void push_back(std::vector<T>&)
{
}

template<typename T, typename Arg, typename... Rest>
void push_back(std::vector<T>& v, Arg&& arg, Rest&&... rest)
{
  v.push_back(std::forward<Arg>(arg));
  push_back(v, std::forward<Rest>(rest)...);
}
```

Case #1: Variable number of function parameters

C++17

```cpp
template<typename T, typename... Args>
void push_back(std::vector<T>& v, Args&&... args)
{
  (v.push_back(std::forward<Args>(args)), ...);
}
```

Case #2: Time handing

Implement **`run_until(timeout)`** function that will call **`run()`** function in a simple spin-loop until the timeout occurs.

Case #2: Time handing

C++98

```cpp
void run_until(const timespec& timeout)
{
  const int64_t timeout_ns = 1000000000L * timeout.tv_sec + timeout.tv_nsec;

  // simple spin-loop
  while(true) {
    timespec now;
    clock_gettime(CLOCK_MONOTONIC, &now);
    if(1000000000L * now.tv_sec + now.tv_nsec >= timeout_ns)
      break;
    run();
  }
}
```

Case #2: Time handing

C++98

```
void run_until(const timespec& timeout);
```

```
timespec now;
clock_gettime(CLOCK_MONOTONIC, &now);
const int64_t end = 1000000000L * now.tv_sec + now.tv_nsec + 300000000L;
const int64_t end_s = end / 1000000000L;
const int64_t end_ns = end - end_s;
const timespec timeout = { end_s, static_cast<long>(end_ns) };
run_until(timeout);
```

Case #2: Time handing

C++98

```cpp
void run_until(const timespec& timeout);
```

```cpp
timespec now;
clock_gettime(CLOCK_MONOTONIC, &now);
const int64_t end = 1000000000L * now.tv_sec + now.tv_nsec + 300000000L;
const int64_t end_s = end / 1000000000L;
const int64_t end_ns = end - end_s;
const timespec timeout = { end_s, static_cast<long>(end_ns) };
run_until(timeout);
```

Not portable!

Case #2: Time handing

C++11

```
using namespace std::chrono;
```

Case #2: Time handing

C++11

```
using namespace std::chrono;
```

```
void run_until(steady_clock::time_point timeout)
{
  // simple spin-loop
  while(steady_clock::now() < timeout)
    run();
}
```

Case #2: Time handing

C++11

```
using namespace std::chrono;
```

```
void run_until(steady_clock::time_point timeout)
{
  // simple spin-loop
  while(steady_clock::now() < timeout)
    run();
}
```

```
const auto start = steady_clock::now();
run_until(start + milliseconds(300));
```

Case #2: Time handing

C++14

```
using namespace std::chrono;
```

```
void run_until(steady_clock::time_point timeout)
{
  // simple spin-loop
  while(steady_clock::now() < timeout)
    run();
}
```

```
const auto start = steady_clock::now();
run_until(start + 300ms);
```

Case #3: Date handling

What day of the week is July 4, 2001?

Case #3: Date handling

C++98

```cpp
static const char* const wday[] =
{
    "Sunday", "Monday", "Tuesday", "Wednesday",
    "Thursday", "Friday", "Saturday", "-unknown-"
};
```

```cpp
tm time_str;
time_str.tm_year   = 2001 - 1900;
time_str.tm_mon    = 7 - 1;
time_str.tm_mday   = 4;
time_str.tm_hour   = 0;
time_str.tm_min    = 0;
time_str.tm_sec    = 0;
time_str.tm_isdst  = -1;
if(mktime(&time_str) == static_cast<time_t>(-1))
  time_str.tm_wday = 7;
std::cout << wday[time_str.tm_wday] << '\n';
```

Case #3: Date handling

C++20

```
using namespace std::chrono;
```

Case #3: Date handling

C++20

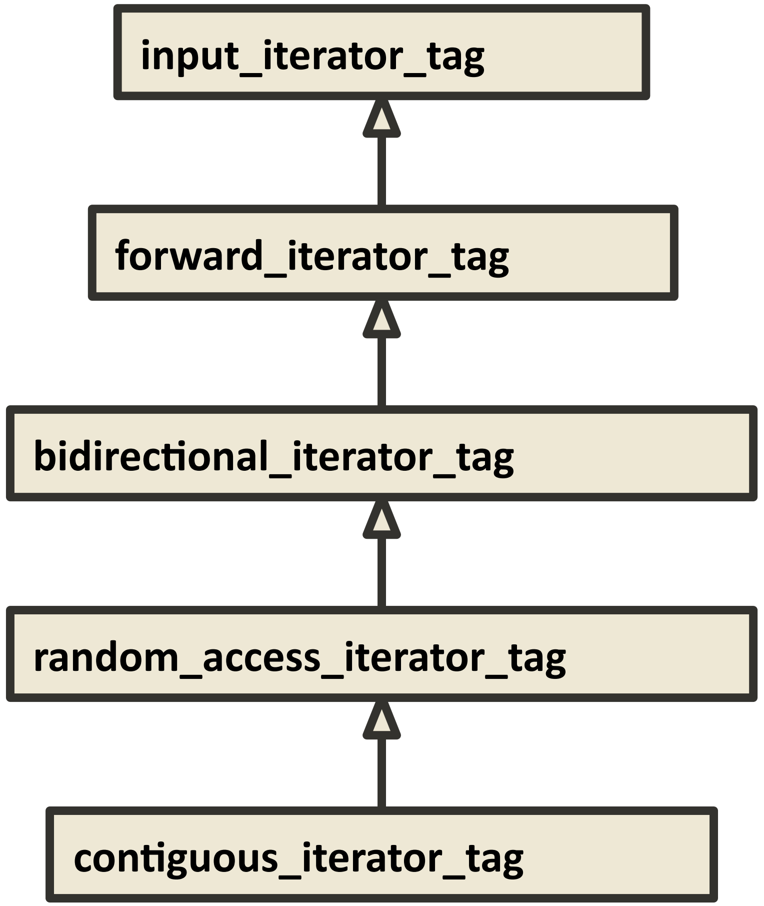
```
using namespace std::chrono;
```

```
std::cout << weekday{jul/4/2001} << '\n';
```

Case #4: Compile-time dispatch

Implement efficient input iterator advance algorithm.

```
advance(iterator, distance);
```



Case #4: Compile-time dispatch

C++98

```
template<typename InputIt, typename Distance>
void advance(InputIt& it, Distance n)
{
  typedef std::iterator_traits<InputIt> traits;
  advance(it, n, typename traits::iterator_category());
}
```

Case #4: Compile-time dispatch

C++98

```
template<typename InputIt, typename Distance>
void advance(InputIt& it, Distance n)
{
  typedef std::iterator_traits<InputIt> traits;
  advance(it, n, typename traits::iterator_category());
}
```

```
template<typename InputIt, typename Distance>
void advance(InputIt& it, Distance n,
             std::input_iterator_tag)
{
  assert(n >= 0);
  for(; 0 < n; --n)
    ++it;
}
```

Case #4: Compile-time dispatch

C++98

```
template<typename InputIt, typename Distance>
void advance(InputIt& it, Distance n)
{
  typedef std::iterator_traits<InputIt> traits;
  advance(it, n, typename traits::iterator_category());
}
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template<typename InputIt, typename Distance>
void advance(InputIt& it, Distance n,
             std::input_iterator_tag)
{
  assert(n >= 0);
  for(; 0 < n; --n)
    ++it;
}
```

```
template<typename InputIt, typename Distance>
void advance(InputIt& it, Distance n,
             std::bidirectional_iterator_tag)
{
  for(; 0 < n; --n)
    ++it;
  for(; n < 0; ++n)
    --it;
}
```

Case #4: Compile-time dispatch

C++98

```cpp
template<typename InputIt, typename Distance>
void advance(InputIt& it, Distance n)
{
  typedef std::iterator_traits<InputIt> traits;
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}
```

```cpp
template<typename InputIt, typename Distance>
void advance(InputIt& it, Distance n,
             std::input_iterator_tag)
{
  assert(n >= 0);
  for(; 0 < n; --n)
    ++it;
}
```

```cpp
template<typename InputIt, typename Distance>
void advance(InputIt& it, Distance n,
             std::bidirectional_iterator_tag)
{
  for(; 0 < n; --n)
    ++it;
  for(; n < 0; ++n)
    --it;
}
```

```cpp
template<typename InputIt, typename Distance>
void advance(InputIt& it, Distance n,
             std::random_access_iterator_tag)
{
  it += n;
}
```

Case #4: Compile-time dispatch

C++11

```
template<typename InputIt, typename Distance>
void advance(InputIt& it, Distance n)
{
  using traits = std::iterator_traits<InputIt>;
  advance(it, n, typename traits::iterator_category());
}
```

```
template<typename InputIt, typename Distance>
void advance(InputIt& it, Distance n,
             std::input_iterator_tag)
{
  assert(n >= 0);
  for(; 0 < n; --n)
    ++it;
}
```

```
template<typename InputIt, typename Distance>
void advance(InputIt& it, Distance n,
             std::bidirectional_iterator_tag)
{
  for(; 0 < n; --n)
    ++it;
  for(; n < 0; ++n)
    --it;
}
```

```
template<typename InputIt, typename Distance>
void advance(InputIt& it, Distance n,
             std::random_access_iterator_tag)
{
  it += n;
}
```

Case #4: Compile-time dispatch

C++17

```
template<typename InputIt, typename Distance>
constexpr void advance(InputIt& it, Distance n)
{
  using category = typename std::iterator_traits<InputIt>::iterator_category;
  if constexpr(std::is_base_of_v<std::random_access_iterator_tag, category>) {
    it += n;
  }
  else if constexpr(std::is_base_of_v<std::bidirectional_iterator_tag, category>) {
    for(; 0 < n; --n)
      ++it;
    for(; n < 0; ++n)
      --it;
  }
  else {
    assert(n >= 0);
    for(; 0 < n; --n)
      ++it;
  }
}
```

Case #4: Compile-time dispatch

C++20

```
template<std::InputIterator It>
constexpr void my_advance(It& it, std::iter_difference_t<It> n)
{
  if constexpr(std::RandomAccessIterator<It>) {
    it += n;
  }
  else if constexpr(std::BidirectionalIterator<It>) {
    for(; 0 < n; --n)
      ++it;
    for(; n < 0; ++n)
      --it;
  }
  else {
    assert(n >= 0);
    for(; 0 < n; --n)
      ++it;
  }
}
```

Case #5: Compile-time calculations

Provide the implementation of some calculation algorithm that will work in run-time and will allow to pre-calculate an array of typical values in the compile-time.

Case #5: Compile-time calculations

C++98

```
int factorial(int n)
{
  int result = n;
  while(n > 1)
    result *= --n;
  return result;
}
```

```
foo(factorial(n));   // not compile-time
foo(factorial(4));   // not compile-time
```

Case #5: Compile-time calculations

C++98

```
int factorial(int n)
{
  int result = n;
  while(n > 1)
    result *= --n;
  return result;
}
```

```
foo(factorial(n));  // not compile-time
foo(factorial(4));  // not compile-time
```

```
template<int N>
struct Factorial {
  static const int value =
      N * Factorial<N - 1>::value;
};

template<>
struct Factorial<0> {
  static const int value = 1;
};
```

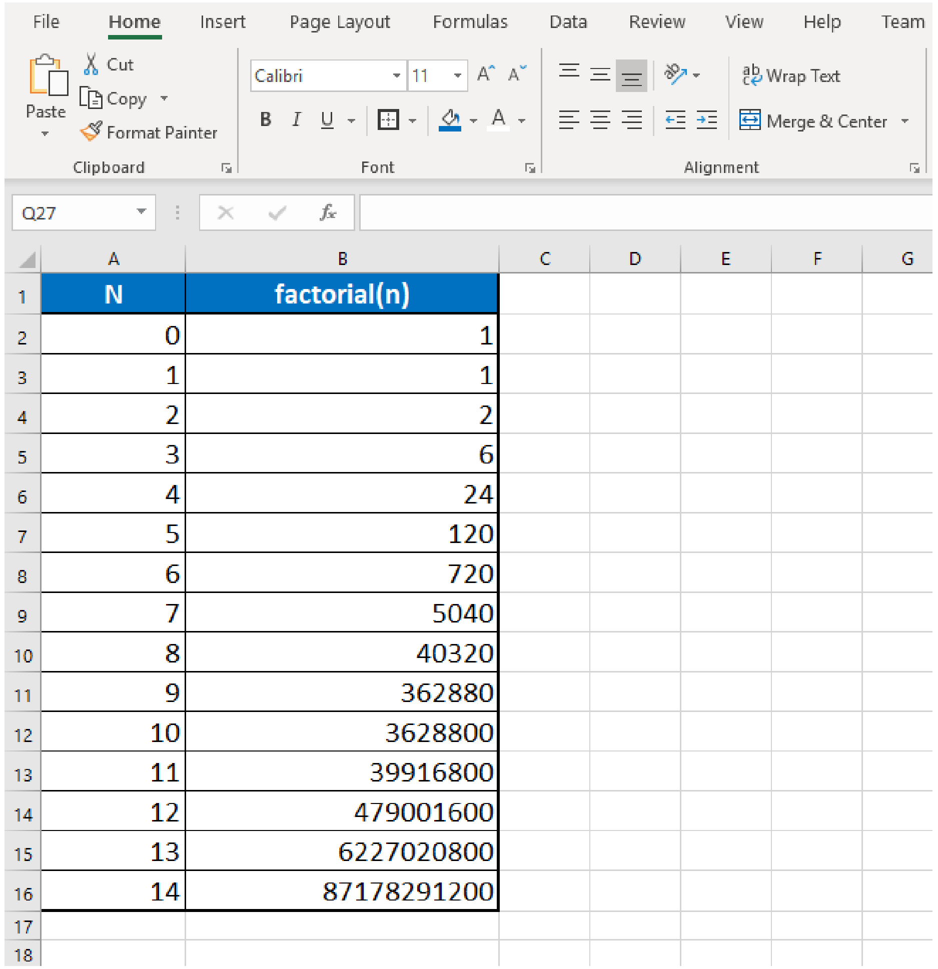
```
int array[Factorial<4>::value];
```

```
const int precalc_values[] = {
  Factorial<0>::value,
  Factorial<1>::value,
  Factorial<2>::value
};
```

```
foo(factorial<4>::value);  // compile-time
// foo(factorial<n>::value);  // compile-time error
```

Case #5: Just too hard!

- 2 separate implementations
  - hard to keep in sync
- Template *metaprogramming* is hard!
- Easier to precalculate in Excel and hardcode results in the code ;-)



N	factorial(n)
0	1
1	1
2	2
3	6
4	24
5	120
6	720
7	5040
8	40320
9	362880
10	3628800
11	39916800
12	479001600
13	6227020800
14	87178291200

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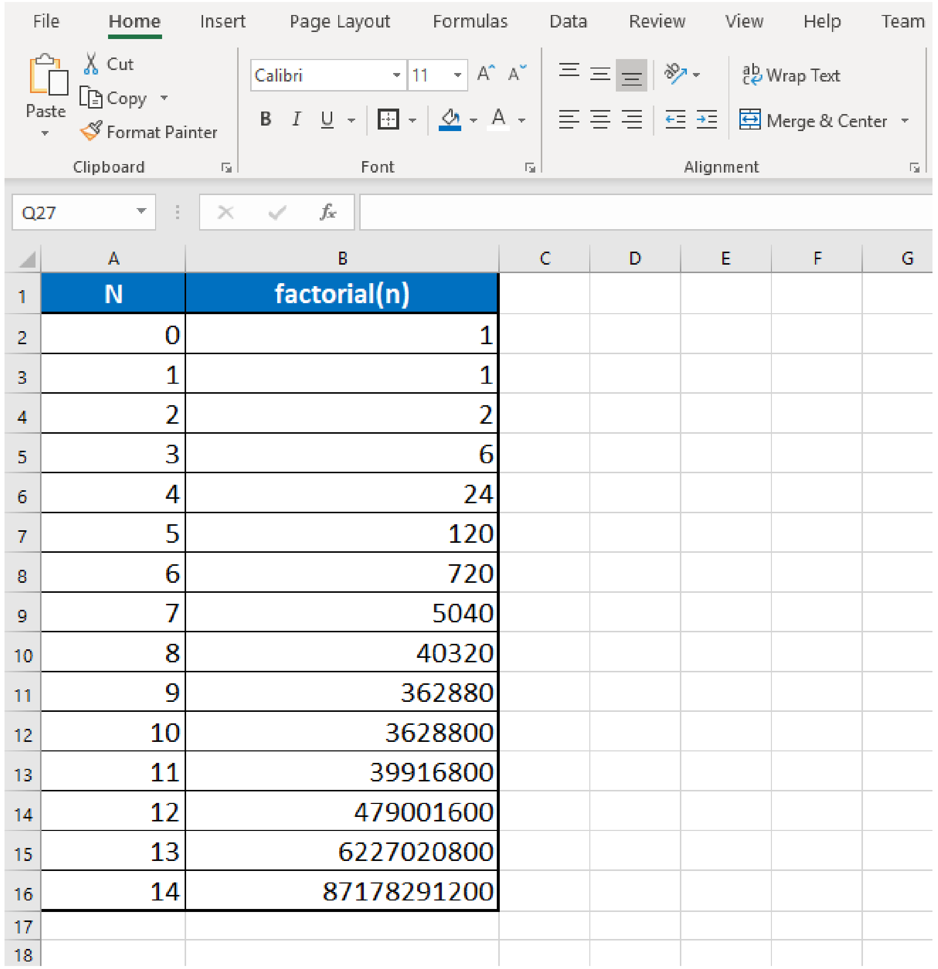
  - hard to keep in sync
- Template *metaprogramming* is hard!
- Easier to precalculate in Excel and hardcode results in the code ;-)

```
const int precalc_values[] = {
   1,
   1,
   2,
   6,
   24,
   120,
   720,
   // ...
};
```



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12	479001600
13	6227020800
14	87178291200

Case #5: Compile-time calculations

C++11

```cpp
constexpr int factorial(int n)
{
  return n <= 1 ? 1 : (n * factorial(n - 1));
}
```

```cpp
std::array<int, factorial(4)> array;
```

```cpp
constexpr std::array<int, 3> precalc_values = {
  factorial(0),
  factorial(1),
  factorial(2)
};
```

```cpp
static_assert(factorial(4) == 24, "Error");
foo(factorial(4));  // compile-time not guaranteed
foo(factorial(n));  // not compile-time
```

Case #5: Compile-time calculations

C++11

```
constexpr int factorial(int n)
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  return n <= 1 ? 1 : (n * factorial(n - 1));
}
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constexpr std::array<int, 3> precalc_values = {
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};
```

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foo(factorial(4));  // compile-time not guaranteed
foo(factorial(n));  // not compile-time
```

C++14

```
constexpr int factorial(int n)
{
  int result = n;
  while(n > 1)
    result *= --n;
  return result;
}
```

```
std::array<int, factorial(4)> array;
```

```
constexpr std::array<int, 3> precalc_values = {
  factorial(0),
  factorial(1),
  factorial(2)
};
```

```
static_assert(factorial(4) == 24, "Error");
foo(factorial(4));  // compile-time not guaranteed
foo(factorial(n));  // not compile-time
```

Case #5: Compile-time calculations

C++17

```
constexpr int factorial(int n)
{
  int result = n;
  while(n > 1)
    result *= --n;
  return result;
}
```

```
std::array<int, factorial(4)> array;
```

```
constexpr std::array precalc_values = {
  factorial(0),
  factorial(1),
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Case #5: Compile-time calculations

C++17

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constexpr int factorial(int n)
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  int result = n;
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  return result;
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```cpp
std::array<int, factorial(4)> array;
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```cpp
constexpr std::array precalc_values = {
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  factorial(2)
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```

```cpp
static_assert(factorial(4) == 24);
foo(factorial(4));  // compile-time not guaranteed
foo(factorial(n));  // not compile-time
```

C++20

```cpp
consteval int factorial(int n)
{
  int result = n;
  while(n > 1)
    result *= --n;
  return result;
}
```

```cpp
std::array<int, factorial(4)> array;
```

```cpp
constexpr std::array precalc_values = {
  factorial(0),
  factorial(1),
  factorial(2)
};
```

```cpp
static_assert(factorial(4) == 24);
foo(factorial(4));  // compile-time
// foo(factorial(n));  // compile-time error
```

Case #6: What does that function do? Is it correct?

```cpp
auto foo(const orders& o, client_id c)
{
  auto first = o.begin();
  orders::const_iterator it;
  typename std::iterator_traits<orders::const_iterator>::difference_type count, step;
  count = std::distance(first, o.end());

  while(count > 0) {
    it = o.begin();
    step = count / 2;
    std::advance(it, step);
    if(get_by_client_id(*it, c)) {
      first = ++it;
      count -= step + 1;
    }
    else
      count = step;
  }
  return first;
}
```

Case #6: What does that function do? Is it correct?

```
auto foo(const orders& o, client_id c)
{
  return std::lower_bound(begin(o), end(o), c, get_by_client_id);
}
```

Case #6: What does that function do? Is it correct?

```
auto foo(const orders& o, client_id c)
{
  return std::lower_bound(begin(o), end(o), c, get_by_client_id);
}
```

Code that says **WHAT** is just as readable as code that says **HOW**.
We are used to seeing code that says **HOW**. It's more familiar.
Code that says **WHAT** is more likely to remain robust.

Case #7: Evolution of algorithms

Implement a **get_order** that will return an iterator to **order** for a given **client_id** from a range of orders sorted by **client_id**.

```cpp
using client_id = int;

struct account {
  client_id client;
  // ...
};

struct order {
  client_id client;
  // ...
};

using orders = std::vector<order>;
```

```cpp
orders get_orders();
```

```cpp
auto get_order(const orders& o, client_id c);
```

Case #7: Evolution of algorithms

C++98

```
struct compare_orders_by_client_id {
  bool operator()(const order& l, const order& r) const { return l.client < r.client; };
};

void sort_orders_by_client_id(orders& o)
{
  std::sort(o.begin(), o.end(), compare_orders_by_client_id());
}
```

Case #7: Evolution of algorithms

C++98

```
struct compare_orders_by_client_id {
  bool operator()(const order& l, const order& r) const { return l.client < r.client; };
};

void sort_orders_by_client_id(orders& o)
{
  std::sort(o.begin(), o.end(), compare_orders_by_client_id());
}
```

```
struct get_order_by_client_id {
  bool operator()(const order& o, const client_id& c) const { return o.client < c; };
};

orders::const_iterator get_order(const orders& o, client_id c)
{
  return std::lower_bound(o.begin(), o.end(), c, get_order_by_client_id());
}
```

Case #7: Evolution of algorithms

C++98

```
struct compare_orders_by_client_id {
  bool operator()(const order& l, const order& r) const { return l.client < r.client; };
};

void sort_orders_by_client_id(orders& o)
{
  std::sort(o.begin(), o.end(), compare_orders_by_client_id());
}
```

```
struct get_order_by_client_id {
  bool operator()(const order& o, const client_id& c) const { return o.client < c; };
};

orders::const_iterator get_order(const orders& o, client_id c)
{
  return std::lower_bound(o.begin(), o.end(), c, get_order_by_client_id());
}
```

```
orders::const_iterator it = get_order(get_orders(), 123);
use(*it);
```

Case #7: Evolution of algorithms

C++98

```
struct get_account_by_client_id {
  bool operator()(const account& a, const client_id& c) const { return a.client < c; };
};

struct compare_accounts_by_client_id {
  bool operator()(const account& l, const account& r) const { return l.client < r.client; };
};
```

Case #7: Evolution of algorithms

C++11

```
void sort_orders_by_client_id(orders& o)
{
  auto compare_orders_by_client_id = [](const order& l, const order& r){ return l.client < r.client; };
  std::sort(begin(o), end(o), compare_orders_by_client_id);
}
```

```
orders::const_iterator get_order(const orders& o, client_id c)
{
  auto get_order_by_client_id = [](const order& o, const client_id& c){ return o.client < c; };
  return std::lower_bound(begin(o), end(o), c, get_order_by_client_id);
}
```

```
auto it = get_order(get_orders(), 123);
use(*it);
```

Case #7: Evolution of algorithms

C++11

```
void sort_orders_by_client_id(orders& o)
{
  auto compare_orders_by_client_id = [](const order& l, const order& r){ return l.client < r.client; };
  std::sort(begin(o), end(o), compare_orders_by_client_id);
}
```

```
orders::const_iterator get_order(const orders& o, client_id c)
{
  auto get_order_by_client_id = [](const order& o, const client_id& c){ return o.client < c; };
  return std::lower_bound(begin(o), end(o), c, get_order_by_client_id);
}
```

```
auto it = get_order(get_orders(), 123);
use(*it);
```

```
auto get_account_by_client_id = [](const account& a, const client_id& c){ return a.client < c; };
auto compare_accounts_by_client_id = [](const account& l, const account& r){ return l.client < r.client; };
```

Case #7: Evolution of algorithms

C++14

```
auto compare_by_client_id = [](const auto& l, const auto& r){ return l.client < r.client; };
auto get_by_client_id = [](const auto& e, const client_id& c){ return e.client < c; };
```

Case #7: Evolution of algorithms

C++14

```
auto compare_by_client_id = [](const auto& l, const auto& r){ return l.client < r.client; };
auto get_by_client_id = [](const auto& e, const client_id& c){ return e.client < c; };
```

```
void sort_orders_by_client_id(orders& o)
{
  std::sort(begin(o), end(o), compare_by_client_id);
}
```

```
orders::const_iterator get_order(const orders& o, client_id c)
{
  return std::lower_bound(begin(o), end(o), c, get_by_client_id);
}
```

```
auto it = get_order(get_orders(), 123);
use(*it);
```

Case #7: Evolution of algorithms

C++20

```
auto to_client_id = [](const auto& e){ return e.client; };
```

Case #7: Evolution of algorithms

C++20

```
auto to_client_id = [](const auto& e){ return e.client; };
```

```
void sort_orders_by_client_id(orders& o)
{
  std::ranges::sort(o, std::ranges::less(), to_client_id);
}
```

```
orders::const_iterator get_order(const orders& o, client_id c)
{
  return std::ranges::lower_bound(o, c, std::ranges::less(), to_client_id);
}
```

```
auto it = get_order(get_orders(), 123);
use(*it);
```

DID YOU SPOT A BUG ON THE LAST SLIDE?

Case #7: New family of lifetime issues

```
orders get_orders();
```

Case #7: New family of lifetime issues

```
orders get_orders();
```

```
orders::const_iterator get_order(const orders& o, client_id c)
{
  return std::ranges::lower_bound(o, c, std::ranges::less(), to_client_id);
}
```

```
auto it = get_order(get_orders(), 123);
use(*it);
```

Case #7: Safety included

```
orders get_orders();
```

```
template<std::ranges::ForwardRange R>
auto get_order(R&& o, client_id c)
{
  return std::ranges::lower_bound(std::forward<R>(o), c, std::ranges::less(), to_client_id);
}
```

```
auto it = get_order(get_orders(), 123);
use(*it);
```

Case #7: Safety included

```
orders get_orders();
```

```
template<std::ranges::ForwardRange R>
auto get_order(R&& o, client_id c)
{
  return std::ranges::lower_bound(std::forward<R>(o), c, std::ranges::less(), to_client_id);
}
```

```
auto it = get_order(get_orders(), 123);
use(*it);
```

```
<source>:53:7: error: no match for 'operator*' (operand type is 'std::ranges::dangling')
   53 |   use(*it);
      |       ^~~
```

Case #7: Safety included

```
orders get_orders();
```

```
template<std::ranges::ForwardRange R>
auto get_order(R&& o, client_id c)
{
  return std::ranges::lower_bound(std::forward<R>(o), c, std::ranges::less(), to_client_id);
}
```

```
auto orders = get_orders();
auto it = get_order(orders, 123);
use(*it);
```

Case #8: Data range processing

Print the age of the first N adult persons in any range of persons.

```cpp
struct person {
  std::string name;
  std::string age;
};
```

```cpp
std::vector<person> people;
print_age_of_first_n_adults(people, 10);
```

Case #8: Data range processing

C++98

```
template<typename InputRange>
void print_age_of_first_n_adults(const InputRange& people, int n)
{
  int count = 0;
  for(typename InputRange::const_iterator it = people.begin(); it != people.end(); ++it) {
    const int age = std::atoi(it->age.c_str());
    if(age >= 18) {
      if(count++ == n)
        break;
      std::cout << age << '\n';
    }
  }
}
```

Case #8: Data range processing

C++98

```
template<typename InputRange>
void print_age_of_first_n_adults(const InputRange& people, int n)
{
  int count = 0;
  for(typename InputRange::const_iterator it = people.begin(); it != people.end(); ++it) {
    const int age = std::atoi(it->age.c_str());
    if(age >= 18) {
      if(count++ == n)
        break;
      std::cout << age << '\n';
    }
  }
}
```

Does not work with C-arrays

Case #8: Data range processing

C++11

```
template<typename InputRange>
void print_age_of_first_n_adults(const InputRange& people, int n)
{
  static_assert(std::is_same<typename std::iterator_traits<decltype(std::begin(people))>::value_type,
                             person>::value, "Bad type");
  int count = 0;
  for(const person& p : people) {
    const int age = std::stoi(p.age);
    if(age >= 18) {
      if(count++ == n)
        break;
      std::cout << age << '\n';
    }
  }
}
```

Case #8: Data range processing

C++17

```
template<typename InputRange>
void print_age_of_first_n_adults(const InputRange& people, int n)
{
  static_assert(std::is_same_v<typename std::iterator_traits<decltype(std::begin(people))>::value_type,
                               person>);
  int count = 0;
  for(const person& p : people) {
    const int age = to_int(p.age);
    if(age >= 18) {
      if(count++ == n)
        break;
      std::cout << age << '\n';
    }
  }
}
```

```
int to_int(const std::string_view& txt)
{
  int age = 0;
  std::from_chars(begin(txt), end(txt), age);
  return age;
}
```

Case #8: Data range processing

C++20

```
using namespace std::ranges;

template<InputRange R>
  requires Same<range_value_t<R>, person>
void print_age_of_first_n_adults(const R& people, int n)
{
  using namespace std::ranges;

  auto to_age = [](const person& p) { return to_int(p.age); };
  auto adult = [](int age) { return age >= 18; };

  for(int age : people | view::transform(to_age) | view::filter(adult) | view::take(n))
    std::cout << age << '\n';
}
```

```
int to_int(const std::string_view& txt)
{
  int age = 0;
  std::from_chars(begin(txt), end(txt), age);
  return age;
}
```

Case #9: Custom regular types

Implement custom string type and make it constructible from and comparable with C-like strings.

Case #9: Custom regular types

C++11

```
class ci_string {
  std::string s;
public:
  // ...
  friend bool operator==(const ci_string& a, const ci_string& b) { return ci_compare(a.s.c_str(), b.s.c_str()) != 0; }
  friend bool operator< (const ci_string& a, const ci_string& b) { return ci_compare(a.s.c_str(), b.s.c_str()) <  0; }
  friend bool operator!=(const ci_string& a, const ci_string& b) { return !(a == b); }
  friend bool operator> (const ci_string& a, const ci_string& b) { return b < a; }
  friend bool operator>=(const ci_string& a, const ci_string& b) { return !(a < b); }
  friend bool operator<=(const ci_string& a, const ci_string& b) { return !(b < a); }
  friend bool operator==(const ci_string& a, const char* b) { return ci_compare(a.s.c_str(), b) != 0; }
  friend bool operator< (const ci_string& a, const char* b) { return ci_compare(a.s.c_str(), b) <  0; }
  friend bool operator!=(const ci_string& a, const char* b) { return !(a == b); }
  friend bool operator> (const ci_string& a, const char* b) { return b < a; }
  friend bool operator>=(const ci_string& a, const char* b) { return !(a < b); }
  friend bool operator<=(const ci_string& a, const char* b) { return !(b < a); }
  friend bool operator==(const char* a, const ci_string& b) { return ci_compare(a, b.s.c_str()) != 0; }
  friend bool operator< (const char* a, const ci_string& b) { return ci_compare(a, b.s.c_str()) <  0; }
  friend bool operator!=(const char* a, const ci_string& b) { return !(a == b); }
  friend bool operator> (const char* a, const ci_string& b) { return b < a; }
  friend bool operator>=(const char* a, const ci_string& b) { return !(a < b); }
  friend bool operator<=(const char* a, const ci_string& b) { return !(b < a); }
};
```

Case #9: Custom regular types

C++20

```
class ci_string {
  std::string s;
public:
  // ...

  std::weak_ordering operator<=>(const ci_string& b) const { return ci_compare(s.c_str(), b.s.c_str()); }
  std::weak_ordering operator<=>(const char* b) const      { return ci_compare(s.c_str(), b); }
};
```

Case #10: Reflection

Check if provided integral value is legal value of an enumeration type.

Case #10: Reflection

C++98

```
enum fruit { apple = 1; banana; orange; };
```

```
bool is_valid_fruit(int value)
{
  return value == apple || value == banana || value == orange;
}
```

```
bool not_true = is_valid_fruit(55);
```

Case #10: Reflection

C++23 (???)

```
template<typename Enum, typename Integral>
  requires std::is_enum_v<Enum> && std::is_integral_v<Integral>
constexpr bool is_one_of_enumerators(Integral value)
{
  for(constexpr e : reflexpr(Enum).enumerators())
    if(e.value() == value)
      return true;
  return false;
}
```

```
enum fruit { apple = 1; banana; orange; };
constexpr bool not_true = is_one_of_enumerators<fruit>(55);
```

C++ Language Evolution

C++11 was a game changer on the market, C++14 and C++17 provided a lot of important improvements that allow us to write portable, safer, and faster programs in a shorter time.

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Do not stay behind...