



REAL-TIME SAFETY - GUARANTEED BY THE COMPILER!

Anders Schau Knatten

Squarehead / cppquiz.org

NDC TechTown 2025-09-24





C++ Quiz

You've answered 0 of 178 questions correctly. ([Clear](#))

Question #197 Difficulty: ●●●

According to the C++23 standard, what is the output of this program?

```
#include <iostream>

int j = 1;

int main() {
    int& i = j, j;
    j = 2;
    std::cout << i << j;
}
```

Answer:

Problems? View a [hint](#) or try [another question](#).

[I give up, show me the answer](#) (make 3 more attempts first).

Mode : Training

You are currently in training mode, answering random questions. Why not [Start a new quiz](#)? Then you can boast about your score, and invite your friends.

Contribute

[Create your own!](#)

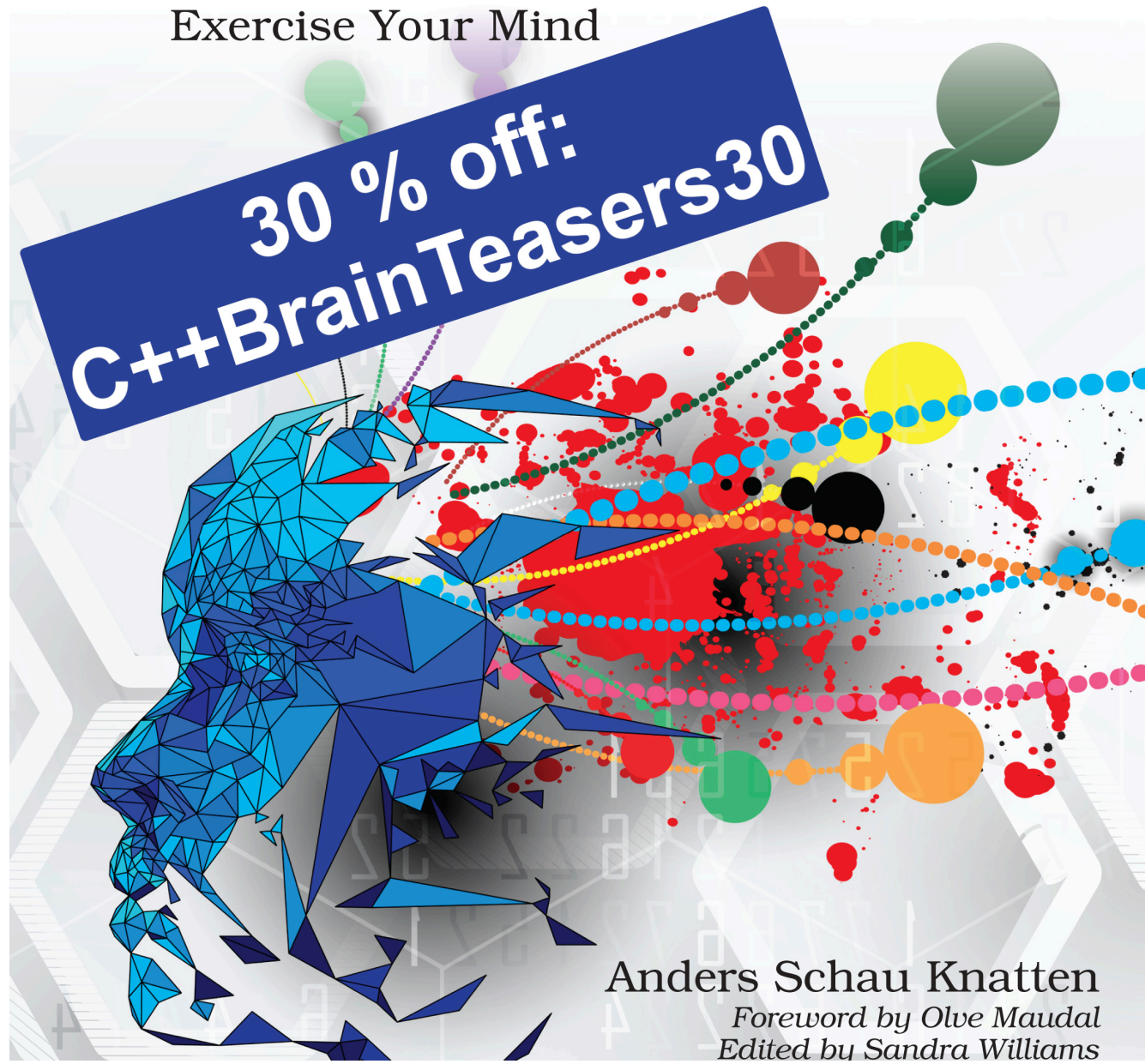
Android app

Get Sergey Vasilchenko's [CppQuiz Android app](#).



C++ Brain Teasers

Exercise Your Mind



30 % off:
C++BrainTeasers30

Anders Schau Knatten

Foreword by Olve Maudal

Edited by Sandra Williams



REAL-TIME SAFETY - GUARANTEED BY THE
COMPILER!



| DEADLINES



| HARD / SOFT REAL-TIME



| REAL-TIME == PERFORMANCE?



| REAL-TIME != PERFORMANCE



PREDICTABILITY



PREDICTABILITY

- Time $\leq$ deadline



PREDICTABILITY

- Time $\leq$ deadline
- Every time!



| JUST BENCHMARK IT?



JUST BENCHMARK IT?

- Must not vary!



| HOW CAN IT VARY?



MIGHT WANT TO AVOID

- Locks
- Allocations / deallocations
- Exceptions
- Syscalls
- I/O
- Swapping
- Descheduling



| NOT EASY!

Dave Rowland @ C++ on Sea 2024

Catching Real-time Safety Violations in C++

https://www.youtube.com/watch?v=n_jeX1s1rkg



CLANG 20

- Function Effect Analysis (FEA)
- RealTimeSanitizer



| CLANG 20

- Function Effect Analysis (FEA)
- RealTimeSanitizer

(AppleClang 17 has FEA but not RTSan)



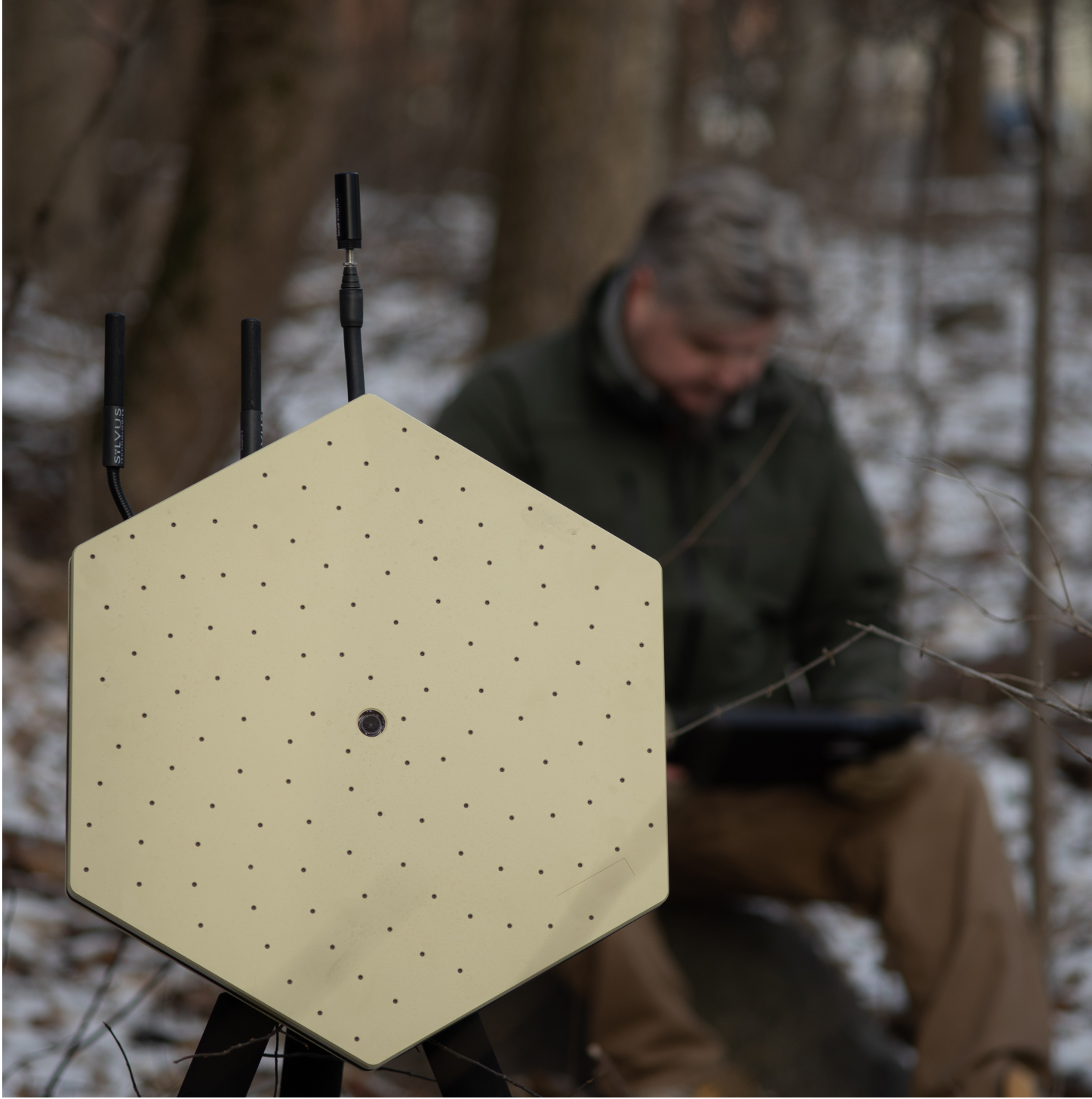
MIGHT WANT TO AVOID

- Locks
- Allocations / deallocations
- Exceptions
- Syscalls
- I/O
- Swapping
- Descheduling



| FEA / RTSAN CAN HELP WITH

- Locks
- Allocations / deallocations
- Exceptions
- Syscalls
- I/O
- ~~Swapping~~
- ~~Descheduling~~





PERFORMANCE CONSTRAINTS

- Attributes on functions for certain guarantees
- Kinda like `const` or `noexcept`
- Can promise that a function



PERFORMANCE CONSTRAINTS

- Attributes on functions for certain guarantees
- Kinda like `const` or `noexcept`
- Can promise that a function
 - Doesn't throw exceptions



PERFORMANCE CONSTRAINTS

- Attributes on functions for certain guarantees
- Kinda like `const` or `noexcept`
- Can promise that a function
 - Doesn't throw exceptions
 - Doesn't allocate / deallocate



PERFORMANCE CONSTRAINTS

- Attributes on functions for certain guarantees
- Kinda like `const` or `noexcept`
- Can promise that a function
 - Doesn't throw exceptions
 - Doesn't allocate / deallocate
 - Doesn't block on a lock



PERFORMANCE CONSTRAINTS

- Function Effect Analysis (FEA)
 - Compile time check (`-Wfunction-effects`)



PERFORMANCE CONSTRAINTS

- Function Effect Analysis (FEA)
 - Compile time check (`-Wfunction-effects`)
- RealTimeSanitizer
 - Run-time sanitizer (`-fsanitize=realtime`)



PERFORMANCE CONSTRAINT ATTRIBUTES



PERFORMANCE CONSTRAINT ATTRIBUTES

`[[clang::nonallocating]]`

- Will not allocate or deallocate on the heap
- Will not throw or catch exceptions



PERFORMANCE CONSTRAINT ATTRIBUTES

`[[clang::nonallocating]]`

- Will not allocate or deallocate on the heap
- Will not throw or catch exceptions

`[[clang::nonblocking]]`

- All of the above
- Will also not take a lock



| FUNCTION EFFECT ANALYSIS (FEA)



```
int get_value() [[clang::nonallocating]]
{
    int* i = new int{42};
    return *i;
}
```




```
int get_value() [[clang::nonallocating]]
{
    int* i = new int{42};
    return *i;
}
```

-Wfunction-effects



```
int get_value() [[clang::nonallocating]]
{
    int* i = new int{42};
    return *i;
}
```

-Wfunction-effects

```
warning: function with 'nonallocating' attribute must not
allocate or deallocate memory [-Wfunction-effects]
int* i = new int{42};
        ^
```



```
int get_value() [[clang::nonallocating]]
{
    int* i = new int{42};
    return *i;
}
```

`-Wfunction-effects`

```
warning: function with 'nonallocating' attribute must not
allocate or deallocate memory [-Wfunction-effects]
int* i = new int{42};
        ^
```

`-Wfunction-effects -Werror`



```
int get_value() [[clang::nonallocating]]  
{  
    int* i = new int{42};  
    return *i;  
}
```

```
-Wfunction-effects
```

```
warning: function with 'nonallocating' attribute must not  
allocate or deallocate memory [-Wfunction-effects]  
int* i = new int{42};  
        ^
```

```
-Wfunction-effects -Werror
```

```
error: function with 'nonallocating' attribute must not  
allocate or deallocate memory [-Werror,-Wfunction-effects]  
int* i = new int{42};  
        ^
```



```
int f() [[clang::nonallocating]]  
{  
    throw 42;  
}
```



```
int f() [[clang::nonallocating]]  
{  
    throw 42;  
}
```

```
warning: function with 'nonallocating' attribute must not  
throw or catch exceptions
```



```
int g();  
int f() [[clang::nonallocating]]  
{  
    return g();  
}
```



```
int g();  
  
int f() [[clang::nonallocating]]  
{  
    return g();  
}
```

```
warning: function with 'nonallocating' attribute must not call  
non-'nonallocating' function 'g'
```




```
int g()
{
    return 42;
}

int f() [[clang::nonallocating]]
{
    return g();
}
```



```
int g()
{
    return 42;
}

int f() [[clang::nonallocating]]
{
    return g();
}
```





```
double squared(double x) [[clang::nonallocating]]  
{  
    return std::pow(x, 2);  
}
```





```
template <typename T>
T simple(T t)
{
    return t;
}

int f(int i) [[clang::nonallocating]]
{
    return simple(i);
}
```



```
template <typename T>
T simple(T t)
{
    return t;
}

std::vector<int> f(std::vector<int> i) [[clang::nonallocating]]
{
    return simple(i);
}
```



```
template <typename T>
T simple(T t)
{
    return t;
}

std::vector<int> f(std::vector<int> i) [[clang::nonallocating]]
{
    return simple(i);
}
```

warning: function with 'nonallocating' attribute must not call non-'nonallocating' function 'simple<std::vector<int>>'

note: function cannot be inferred 'nonallocating' because it calls non-'nonallocating' destructor 'std::vector<int>::~~vector'



```
int f() [[clang::nonallocating]]
{
    int* i = new int{42};
    return *i;
}
```



```
int f() [[clang::nonallocating]]
{
    int* i = new int{42};
    return *i;
}
```

warning: function with 'nonallocating' attribute must not allocate or deallocate memory



```
int f() [[clang::nonallocating]]
{
    auto i = std::make_unique<int>(42);
    return *i;
}
```



```
int f() [[clang::nonallocating]]  
{  
    auto i = std::make_unique<int>(42);  
    return *i;  
}
```

```
warning: function with 'nonallocating' attribute must not call  
non-'nonallocating'function 'std::make_unique<int, int, 0>'
```



```
1 int (*getter)() [[clang::nonallocating]];
2
3 int get();
4
5 int f()
6 {
7     getter = &get;
8     return getter();
9 }
```



```
1 int (*getter)() [[clang::nonallocating]];
2
3 int get();
4
5 int f()
6 {
7     getter = &get;
8     return getter();
9 }
```



```
1 int (*getter)() [[clang::nonallocating]];
2
3 int get();
4
5 int f()
6 {
7     getter = &get;
8     return getter();
9 }
```

warning: attribute 'nonallocating' should not be added via type conversion
getter = &get;



```
1 struct Base
2 {
3     virtual int get() [[clang::nonallocating]] = 0;
4 };
5
6 struct Derived : public Base
7 {
8     int get() override
9     {
10         auto* i = new int{42};
11         return *i;
12     }
13 };
```



```
1 struct Base
2 {
3     virtual int get() [[clang::nonallocating]] = 0;
4 };
5
6 struct Derived : public Base
7 {
8     int get() override
9     {
10         auto* i = new int{42};
11         return *i;
12     }
13 };
```



```
1 struct Base
2 {
3     virtual int get() [[clang::nonallocating]] = 0;
4 };
5
6 struct Derived : public Base
7 {
8     int get() override
9     {
10         auto* i = new int{42};
11         return *i;
12     }
13 };
```

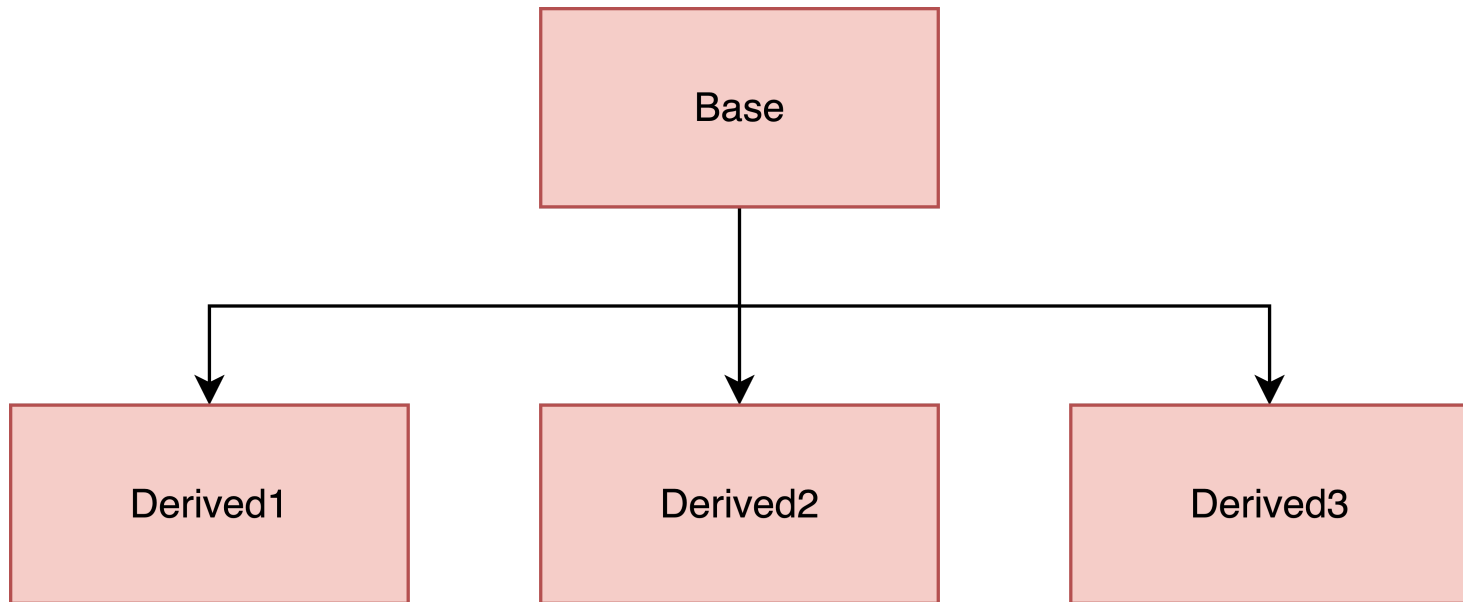
```
warning: function with 'nonallocating' attribute must not
allocate or deallocate memory
auto* i = new int{42};
      ^
```

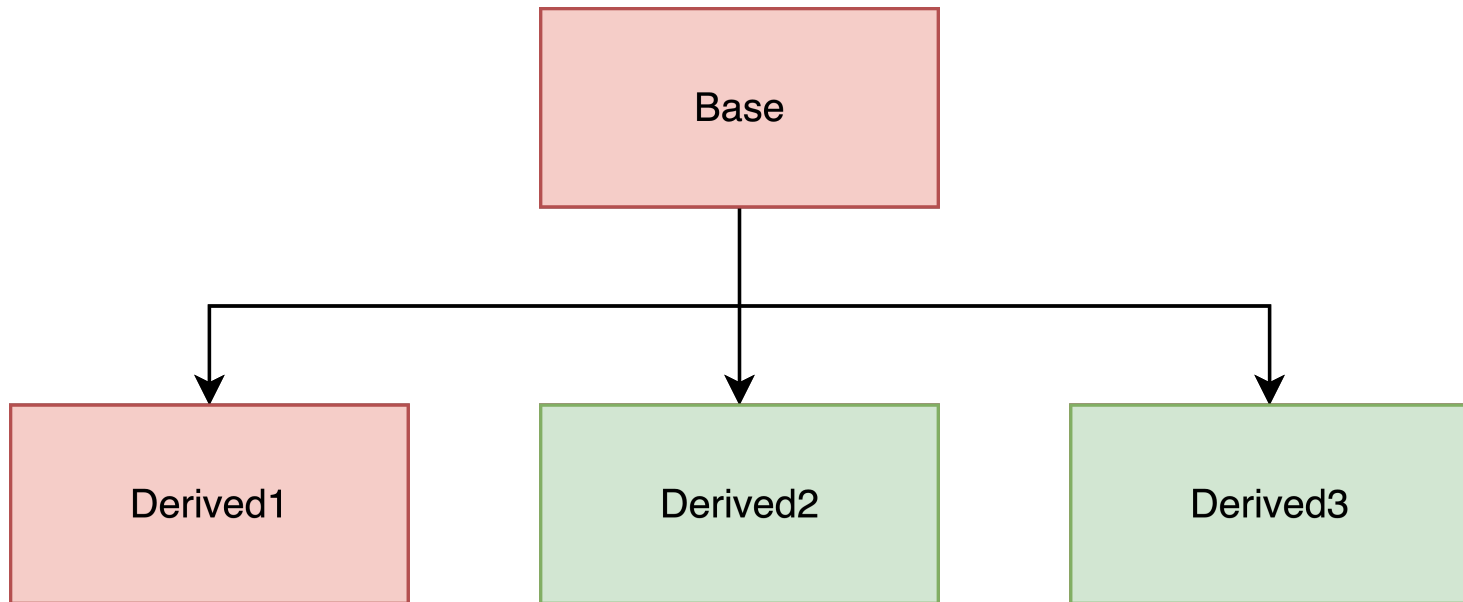


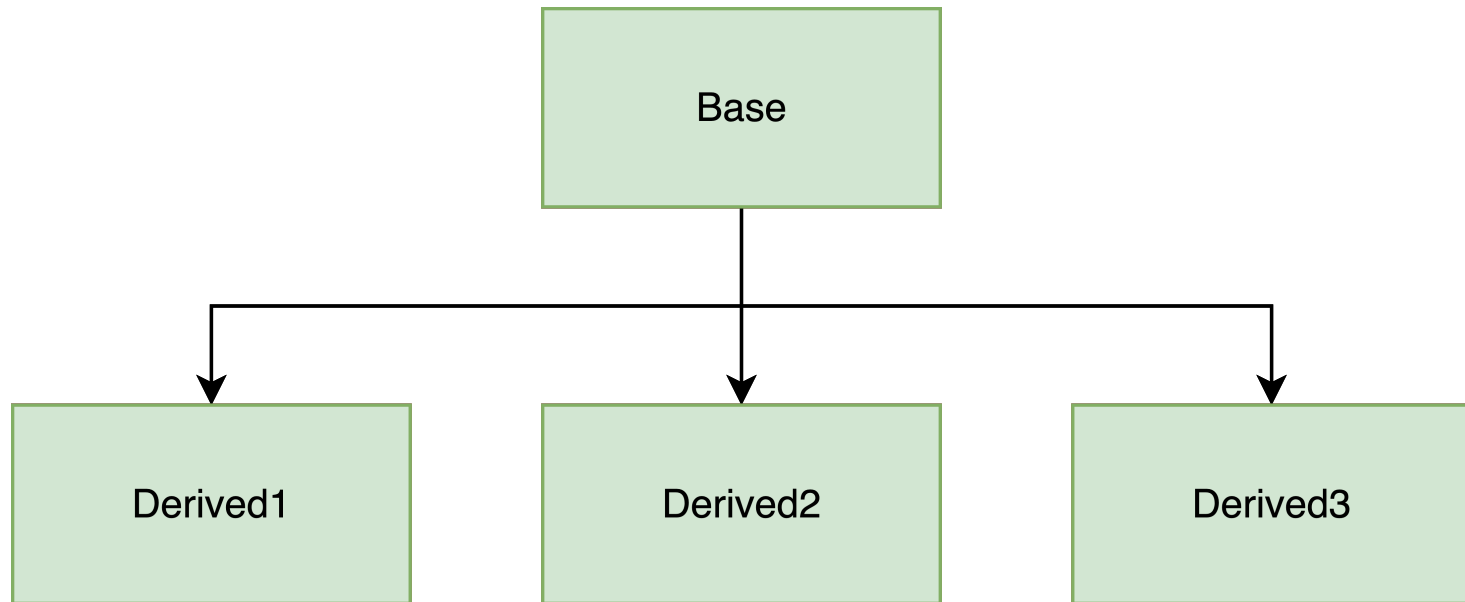

```
1 struct Base
2 {
3     virtual int get() = 0;
4 };
5
6 struct Derived : public Base
7 {
8     int get() [[clang::nonallocating]] override
9     {
10         return 42;
11     }
12 };
```



```
1 struct Base
2 {
3     virtual int get() = 0;
4 };
5
6 struct Derived : public Base
7 {
8     int get() [[clang::nonallocating]] override
9     {
10         return 42;
11     }
12 };
```







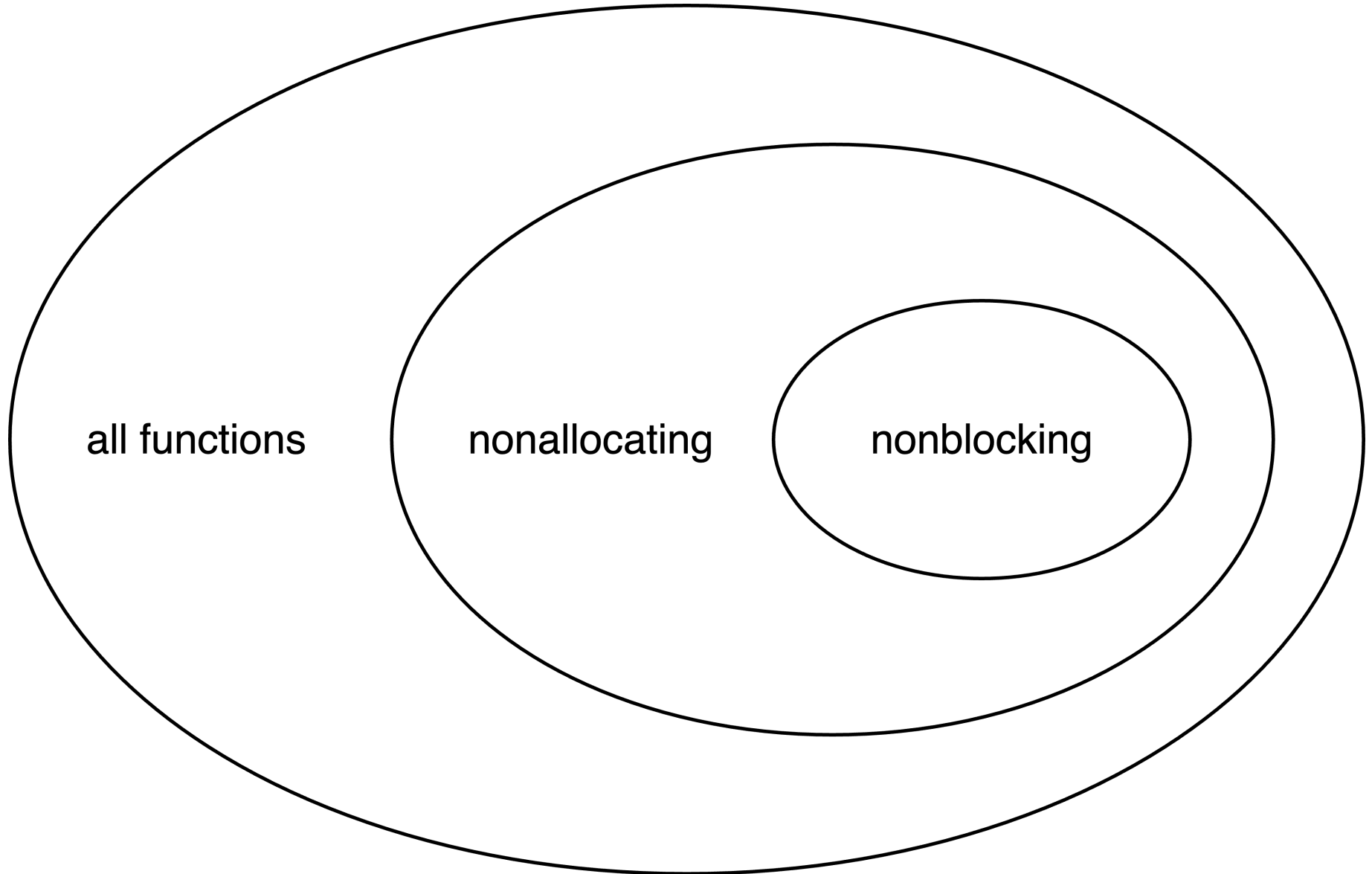
SEMANTICS



all functions

nonallocating

SEMANTICS





```
int f() [[clang::nonblocking]];
int g() [[clang::nonallocating]]
{
    return f();
}
```



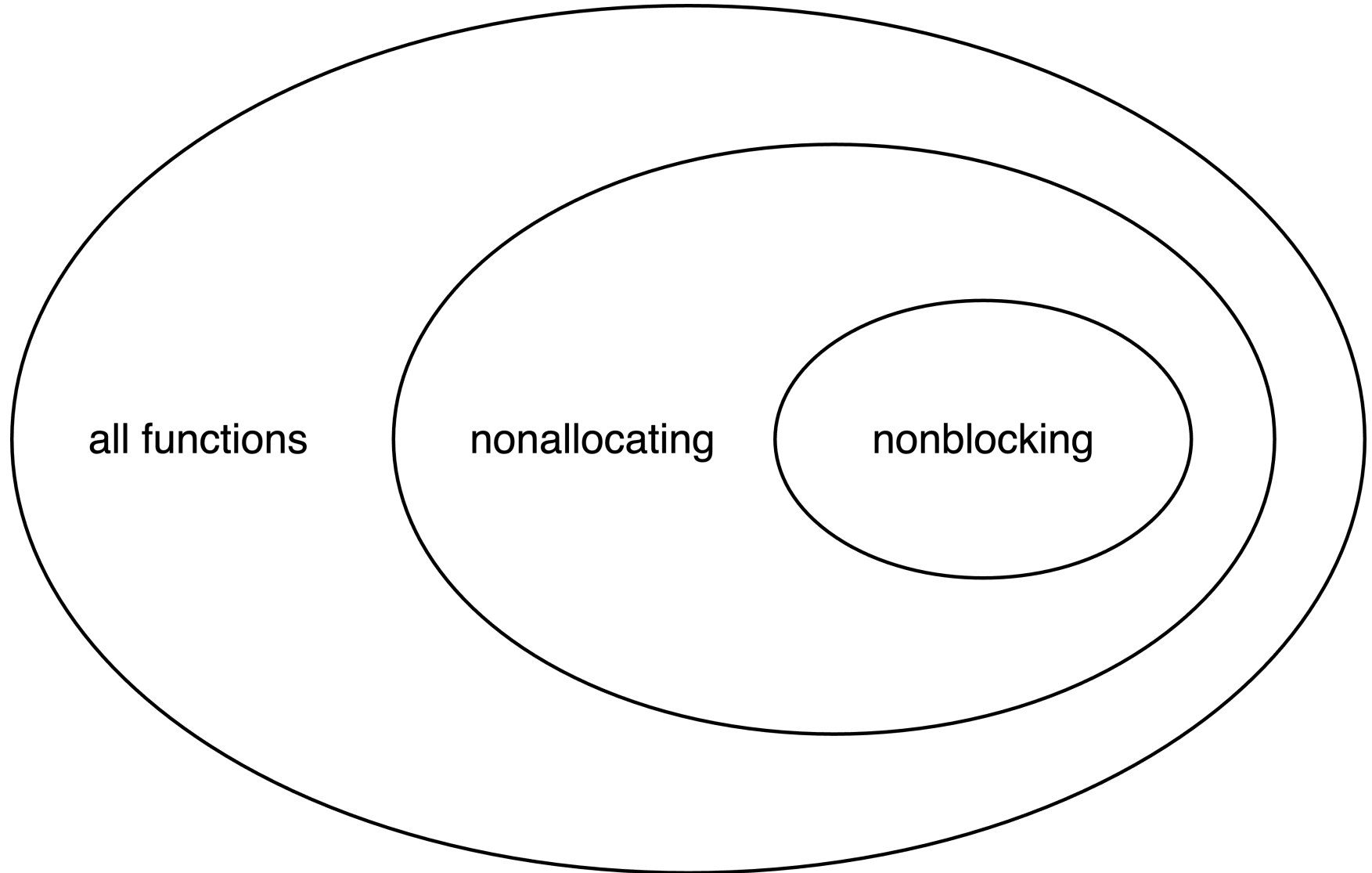
```
int f() [[clang::nonallocating]];
int g() [[clang::nonblocking]]
{
    return f();
}
```



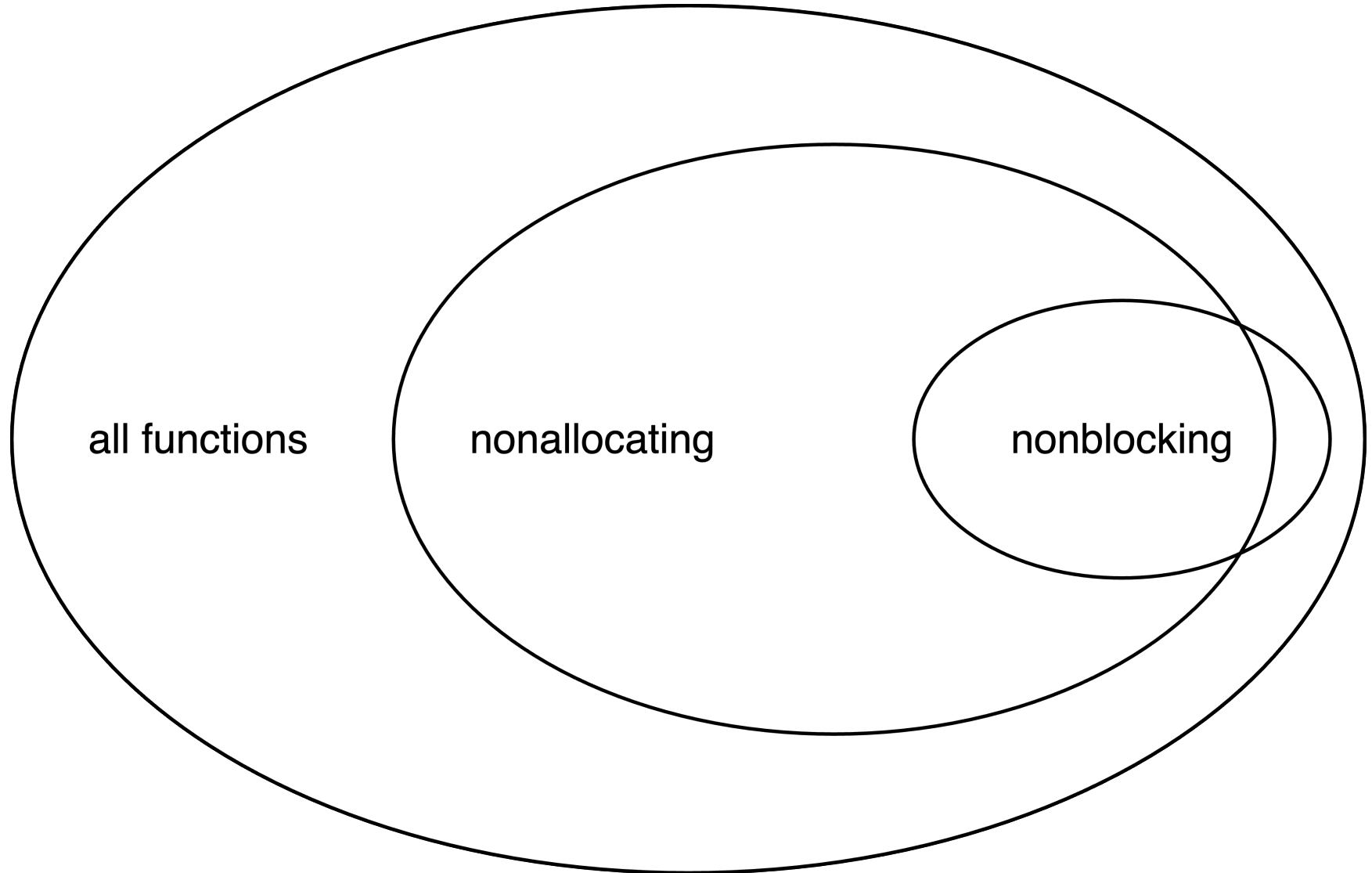
```
int f() [[clang::nonallocating]];
int g() [[clang::nonblocking]]
{
    return f();
}
```

```
warning: function with 'nonblocking' attribute must not call
non-'nonblocking' function 'f'
```

SEMANTICS



SEMANTICS





Just use `nonblocking`



Just use `nonblocking`

- Simpler



Just use `nonblocking`

- Simpler
- Locks are worse(?) than allocations



Just use `nonblocking`

- Simpler
- Locks are worse(?) than allocations
- Better compatibility with RealtimeSanitizer



What about `noexcept`?



```
std::string f() noexcept
{
    try
    {
        throw std::runtime_error("ohai");
    } catch (const std::exception& e)
    {
        return e.what();
    }
}
```



```
std::string f() noexcept  
{  
    throw std::runtime_error("ohai");  
}
```



```
void throwy()
{
    throw std::runtime_error("ohai");
}

std::string f() noexcept
{
    throwy();
    return "foo";
}
```



```
void throwy()
{
    throw std::runtime_error("ohai");
}

std::string f() noexcept [[clang::nonblocking]]
{
    throwy();
    return "foo";
}
```



```
void throwy()  
{  
    throw std::runtime_error("ohai");  
}  
  
std::string f() noexcept [[clang::nonblocking]]  
{  
    throwy();  
    return "foo";  
}
```

warning: function with 'nonblocking' attribute must not call
non-'nonblocking' function 'throwy'

note: function cannot be inferred 'nonblocking'
because it throws or catches exceptions



CHALLENGES, LESSONS LEARNED, TIPS & TRICKS



| CHALLENGES, LESSONS LEARNED, TIPS & TRICKS: COMPILERS



COMPILERS

- Clang 20
- AppleClang 17 (FEA only, no RTSan)



OUR COMPILERS

- Clang 21
- AppleClang 17
- *GCC 13*



```
1 if((CMAKE_CXX_COMPILER_ID STREQUAL "AppleClang"
2     AND CMAKE_CXX_COMPILER_VERSION VERSION_GREATER_EQUAL "17.0")
3     OR (CMAKE_CXX_COMPILER_ID STREQUAL "Clang"
4         AND CMAKE_CXX_COMPILER_VERSION VERSION_GREATER_EQUAL "20.0")
5 )
6     add_compile_options(-Wfunction-effects)
7     add_compile_definitions(ENABLE_FEA)
8 endif()
```



```
1 if((CMAKE_CXX_COMPILER_ID STREQUAL "AppleClang"
2     AND CMAKE_CXX_COMPILER_VERSION VERSION_GREATER_EQUAL "17.0")
3     OR (CMAKE_CXX_COMPILER_ID STREQUAL "Clang"
4         AND CMAKE_CXX_COMPILER_VERSION VERSION_GREATER_EQUAL "20.0")
5 )
6     add_compile_options(-Wfunction-effects)
7     add_compile_definitions(ENABLE_FEA)
8 endif()
```



```
1 if((CMAKE_CXX_COMPILER_ID STREQUAL "AppleClang"
2     AND CMAKE_CXX_COMPILER_VERSION VERSION_GREATER_EQUAL "17.0")
3     OR (CMAKE_CXX_COMPILER_ID STREQUAL "Clang"
4         AND CMAKE_CXX_COMPILER_VERSION VERSION_GREATER_EQUAL "20.0")
5 )
6     add_compile_options(-Wfunction-effects)
7     add_compile_definitions(ENABLE_FEA)
8 endif()
```



```
// FunctionEffectAnalysis.h:  
  
#ifdef ENABLE_FEA  
    #define SQ_NONBLOCKING [[clang::nonblocking]]  
#else  
    #define SQ_NONBLOCKING  
#endif
```




```
// FunctionEffectAnalysis.h:
```

```
#ifdef ENABLE_FEA
    #define SQ_NONBLOCKING [[clang::nonblocking]]
#else
    #define SQ_NONBLOCKING
#endif
```

```
void f() SQ_NONBLOCKING;
```



| CHALLENGES, LESSONS LEARNED, TIPS & TRICKS: THIRD-PARTY CODE



```
void process(std::span<char> buffer) [[clang::nonblocking]]
{
    libproc(buffer.data(), buffer.size());
}
```



```
void process(std::span<char> buffer) [[clang::nonblocking]]  
{  
    libproc(buffer.data(), buffer.size());  
}
```

```
warning: function with 'nonblocking' attribute must not call  
non-'nonblocking' function 'libproc'
```



```
void process(std::span<char> buffer) [[clang::nonblocking]]
{
    libproc(buffer.data(), buffer.size());
}
```

warning: function with 'nonblocking' attribute must not call non-'nonblocking' function 'libproc'

```
void process(std::span<char> buffer) [[clang::nonblocking]]
{
    #pragma clang diagnostic push
    #pragma clang diagnostic ignored "-Wfunction-effects"
    libproc(buffer.data(), buffer.size());
    #pragma clang diagnostic pop
}
```



```
1 #ifdef ENABLE_FEA
2     #define SQ_NONBLOCKING [[clang::nonblocking]]
3     #define SQ_FEA_IGNORE(...) \
4         _Pragma("clang diagnostic push") \
5         _Pragma("clang diagnostic ignored \\"-Wunknown-warning-option\\") \
6         _Pragma("clang diagnostic ignored \\"-Wfunction-effects\\") \
7         __VA_ARGS__ _Pragma("clang diagnostic pop")
8
9 #else
10     #define SQ_NONBLOCKING
11     #define SQ_FEA_IGNORE(...) __VA_ARGS__
12 #endif
```



```
1 #ifdef ENABLE_FEA
2     #define SQ_NONBLOCKING [[clang::nonblocking]]
3     #define SQ_FEA_IGNORE(...) \
4         _Pragma("clang diagnostic push") \
5         _Pragma("clang diagnostic ignored \\"-Wunknown-warning-option\\") \
6         _Pragma("clang diagnostic ignored \\"-Wfunction-effects\\") \
7         __VA_ARGS__ _Pragma("clang diagnostic pop")
8
9 #else
10     #define SQ_NONBLOCKING
11     #define SQ_FEA_IGNORE(...) __VA_ARGS__
12 #endif
```



```
1 #ifdef ENABLE_FEA
2     #define SQ_NONBLOCKING [[clang::nonblocking]]
3     #define SQ_FEA_IGNORE(...) \
4         _Pragma("clang diagnostic push") \
5         _Pragma("clang diagnostic ignored \"-Wunknown-warning-option\"") \
6         _Pragma("clang diagnostic ignored \"-Wfunction-effects\"") \
7         __VA_ARGS__ _Pragma("clang diagnostic pop")
8
9 #else
10     #define SQ_NONBLOCKING
11     #define SQ_FEA_IGNORE(...) __VA_ARGS__
12 #endif
```

```
void process(std::span<char> buffer) SQ_NONBLOCKING
{
    SQ_FEA_IGNORE(
        libproc(buffer.data(), buffer.size());
    )
}
```




```
void process(std::span<char> buffer) [[clang::nonblocking]]
{
    SQ_FEA_IGNORE(
        libproc(buffer.data(), buffer.size());
    )
}
```



```
void process(std::span<char> buffer) [[clang::nonblocking]]
{
    SQ_FEA_IGNORE(
        libproc(buffer.data(), buffer.size());
    )
}
```

```
-fsanitize=realtime
```



```
void process(std::span<char> buffer) [[clang::nonblocking]]
{
    SQ_FEA_IGNORE(
        libproc(buffer.data(), buffer.size());
    )
}
```

-fsanitize=realtime

==72564==ERROR: RealtimeSanitizer: unsafe-library-call

Intercepted call to real-time unsafe function `malloc` in real-time context!

```
#0 0x0001012932dc in malloc+0x20 (libclang_rt.rtsan_osx_dynamic.dylib:arm64+0x32dc)
#1 0x00019cbfb9d4 in _malloc_type_malloc_outlined+0x60 (libsystem_malloc.dylib:arm64+0x1d9d4)
#2 0x00019cd993dc in operator new(unsigned long)+0x30 (libc++abi.dylib:arm64+0x1a3dc)
#3 0x000100f51258 in libproc(char*, unsigned long)+0x18 (third-party:arm64+0x100001258)
#4 0x000100f512c0 in process(std::__1::span<char, 18446744073709551615ul>)+0x4c (third-party:arm64+0x1000012c0)
#5 0x000100f513f8 in main+0x34 (third-party:arm64+0x1000013f8)
#6 0x00019ca3eb94 in start+0x17b8 (dyld:arm64+0xfffffffffff3ab94)
```

SUMMARY: RealtimeSanitizer: unsafe-library-call (libsystem_malloc.dylib:arm64+0x1d9d4) in _malloc_ty



```
// libproc.h:  
void libproc(char *buffer, size_t size);
```



```
// libproc.h:  
void libproc(char *buffer, size_t size);
```

```
// libproc_redeclare.h:  
void libproc(char *buffer, size_t size) [[clang::nonblocking]];
```



```
// libproc.h:  
void libproc(char *buffer, size_t size);
```

```
// libproc_redeclare.h:  
void libproc(char *buffer, size_t size) [[clang::nonblocking]];
```

```
# include <libproc_redeclare.h>  
void process(std::span<char> buffer) [[clang::nonblocking]]  
{  
    libproc(buffer.data(), buffer.size());  
}
```



| CHALLENGES, LESSONS LEARNED, TIPS & TRICKS: *LAMBDA*S, CALLBACKS AND TYPE ERASURE



```
void f() [[clang::nonblocking]]
{
    auto lambda = [](int i) { return i * 2; };
}
```




```
void f() [[clang::nonblocking]]
{
    auto lambda = [](int i) { return i * 2; };
}
```

```
void f() [[clang::nonblocking]]
{
    auto lambda = [](int i) [[clang::nonblocking]] { return i * 2; };
}
```



```
void process(std::vector<int> &ints) [[clang::nonblocking]]
{
    std::transform(ints.begin(), ints.end(), ints.begin(),
        [](int i) { return i * 2; });
}
```



```
void process(std::vector<int> &ints) [[clang::nonblocking]]
{
    std::transform(ints.begin(), ints.end(), ints.begin(),
        [](int i) { return i * 2; });
}
```

```
void process(std::vector<int> &ints) [[clang::nonblocking]]
{
    std::transform(ints.begin(), ints.end(), ints.begin(),
        [](int i)
        {
            new int{};
            return i * 2;
        });
}
```



```
void process(std::vector<int> &ints) [[clang::nonblocking]]
{
    std::transform(ints.begin(), ints.end(), ints.begin(),
        [](int i) { return i * 2; });
}
```

```
void process(std::vector<int> &ints) [[clang::nonblocking]]
{
    std::transform(ints.begin(), ints.end(), ints.begin(),
        [](int i)
        {
            new int{};
            return i * 2;
        });
}
```

```
1 warning: function with 'nonblocking' attribute must not call
2     non-'nonblocking' function 'std::transform(...)'
3 note: function cannot be inferred 'nonblocking' because it calls non-'nonblocking' lambda (...)
4 (...)
5 note: lambda cannot be inferred 'nonblocking' because it allocates or deallocates memory
6         [](int i) { new int{};return i * 2; });
7                     ^
```



```
void process(std::vector<int> &ints) [[clang::nonblocking]]
{
    std::transform(ints.begin(), ints.end(), ints.begin(),
        [](int i) { return i * 2; });
}
```

```
void process(std::vector<int> &ints) [[clang::nonblocking]]
{
    std::transform(ints.begin(), ints.end(), ints.begin(),
        [](int i)
        {
            new int{};
            return i * 2;
        });
}
```

```
1 warning: function with 'nonblocking' attribute must not call
2     non-'nonblocking' function 'std::transform(...)'
3 note: function cannot be inferred 'nonblocking' because it calls non-'nonblocking' lambda (...)
4 (...)
5 note: lambda cannot be inferred 'nonblocking' because it allocates or deallocates memory
6         [](int i) { new int{};return i * 2; });
7                     ^
```



```
void process(std::vector<int> &ints) [[clang::nonblocking]]
{
    std::transform(ints.begin(), ints.end(), ints.begin(),
        [](int i) { return i * 2; });
}
```

```
void process(std::vector<int> &ints) [[clang::nonblocking]]
{
    std::transform(ints.begin(), ints.end(), ints.begin(),
        [](int i)
        {
            new int{};
            return i * 2;
        });
}
```

```
1 warning: function with 'nonblocking' attribute must not call
2     non-'nonblocking' function 'std::transform(...)'
3 note: function cannot be inferred 'nonblocking' because it calls non-'nonblocking' lambda (...)
4 (...)
5 note: lambda cannot be inferred 'nonblocking' because it allocates or deallocates memory
6         [](int i) { new int{};return i * 2; });
7                     ^
```



| CHALLENGES, LESSONS LEARNED, TIPS & TRICKS: LAMBDA, *CALLBACKS* AND TYPE ERASURE



```
1 template <typename Callback>
2 struct EvenNumberProcessor
3 {
4     Callback callback;
5
6     void process(int i)
7     {
8         if (i % 2 == 0) { callback(i); }
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```
1 size_t real_time_code() [[clang::nonblocking]]
2 {
3     size_t sum = 0;
4     EvenNumberProcessor processor{&sum}(int i) { sum += i; };
5     for (int i = 0; i < 5; ++i)
6     {
7         processor.process(i);
8     }
9     return sum;
10 }
```



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8     }
9     return sum;
10 }
```

```
1 void chill_code()
2 {
3     EvenNumberProcessor processor{[](int i) { std::cout << i << " "; }};
4     for (int i = 0; i < 5; ++i)
5     {
6         processor.process(i);
7     }
8 }
```




```
1 template <typename Callback>
2 struct EvenNumberProcessor
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1 size_t real_time_code() [[clang::nonblocking]]
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| CHALLENGES, LESSONS LEARNED, TIPS & TRICKS: LAMBDA, CALLBACKS AND *TYPE ERASURE*



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1 struct EvenNumberProcessor
2 {
3     std::function<void(int)> callback;
4     void process(int i);
5 };
6
7 void EvenNumberProcessor::process(int i)
8 {
9     if (i % 2 == 0) { callback(i); }
10 }
11
12 size_t real_time_code() [[clang::nonblocking]]
13 {
14     size_t sum = 0;
15     EvenNumberProcessor processor{[&sum](int i) { sum += i; }};
16     for (int i = 0; i < 5; ++i) { processor.process(i); }
17     return sum;
18 }
19
20 int main()
21 {
22     std::cout << real_time_code();
23 }
```



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20 int main()
21 {
22     std::cout << real_time_code();
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```

warning: function with 'nonblocking' attribute must not call non-'nonblocking' constructor 'std::function(...)'



```
1 struct EvenNumberProcessor
2 {
3     std::function<void(int)> callback;
4     void process(int i) [[clang::nonblocking]];
5 };
6
7 void EvenNumberProcessor::process(int i) [[clang::nonblocking]]
8 {
9     if (i % 2 == 0) { callback(i); }
10 }
11
12 void real_time_code(EvenNumberProcessor &processor) [[clang::nonblocking]]
13 {
14     for (int i = 0; i < 5; ++i) { processor.process(i); }
15 }
16
17 int main()
18 {
19     size_t sum = 0;
20     EvenNumberProcessor processor{&sum}(int i) { sum += i; };
21     real_time_code(processor);
22     std::cout << sum;
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21     real_time_code(processor);
22     std::cout << sum;
23 }
```

```
warning: function with 'nonblocking' attribute must not call
non-'nonblocking' function 'std::function<void (int)>::operator()'
    callback(i);
    ^
```



```
1 template <typename Return, typename... Args>
2 class nonblocking_function<Return(Args...)> {
3 public:
4     Return operator()(Args... args) const noexcept [[clang::nonblocking]]
5     {
6         return std::invoke(*mCallable, std::forward<Args>(args)...);
7     }
8 private:
9     std::unique_ptr<Concept> mCallable;
10 }
```



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1 template <typename Return, typename... Args>
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7 void EvenNumberProcessor::process(int i) [[clang::nonblocking]]
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```



```
1 template <bool NonBlocking>
2 struct EvenNumberProcessor
3 {
4     using CallbackT =
5         std::conditional_t<NonBlocking, nonblocking_function<void(int)>,
6                             std::function<void(int)>>;
7     CallbackT callback;
8     void process(int i) [[clang::nonblocking(NonBlocking)]];
9 };
```



```
1 template <bool NonBlocking>
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8     void process(int i) [[clang::nonblocking(NonBlocking)]];
9 };
```

```
1 void real_time_code(EvenNumberProcessor<true> &processor) [[clang::nonblocking]]
2 {
3     for (int i = 0; i < 5; ++i) { processor.process(i); }
4 }
5
6 void chill_code(EvenNumberProcessor<false> &processor)
7 {
8     for (int i = 0; i < 5; ++i) { processor.process(i); }
9 }
```



```
1 template <bool NonBlocking>
2 struct EvenNumberProcessor
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FINAL TIPS AND TRICKS



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- Easiest for regular procedural/functional/OO code



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- Can manually annotate `[[clang::blocking]]`



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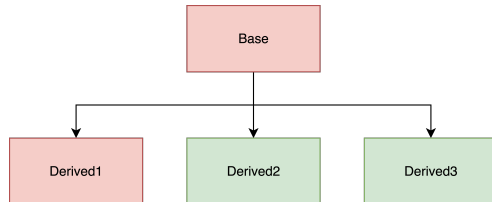
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FINAL TIPS AND TRICKS

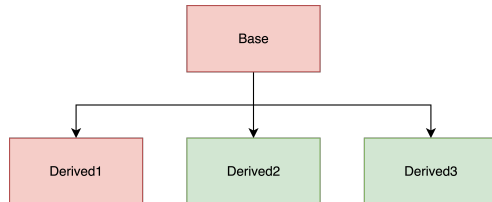
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- Don't use it everywhere!



REAL-TIME SAFETY - GUARANTEED BY THE COMPILER!

Anders Schau Knatten

Squarehead / cppquiz.org

NDC TechTown 2025-09-24