

C++ Style Guide

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Header Files^{oo}

In general, every `.cc` file should have an associated `.h` file. There are some common exceptions, such as unittests and small `.cc` files containing just a `main()` function.

Correct use of header files can make a huge difference to the readability, size and performance of your code.

The following rules will guide you through the various pitfalls of using header files.

Self-contained Headers^{oo}

Header files should be self-contained (compile on their own) and end in `.h`. Non-header files that are meant for inclusion should end in `.inc` and be used sparingly.

All header files should be self-contained. Users and refactoring tools should not have to adhere to special conditions to include the header. Specifically, a header should have [header guards](#) and include all other headers it needs.

Prefer placing the definitions for template and inline functions in the same file as their declarations. The definitions of these constructs must be included into every `.cc` file that uses them, or the program may fail to link in some build configurations. If declarations and definitions are in different files, including the former should transitively include the latter. Do not move these definitions to separately included header files (`-inl.h`); this practice was common in the past, but is no longer allowed.

As an exception, a template that is explicitly instantiated for all relevant sets of template arguments, or that is a private implementation detail of a class, is allowed to be defined in the one and only `.cc` file that instantiates the template.

There are rare cases where a file designed to be included is not self-contained. These are typically intended to be included at unusual locations, such as the middle of another file. They might not use [header guards](#), and might not include their prerequisites. Name such files with the `.inc` extension. Use sparingly, and prefer self-contained headers when possible.

The #define Guard^{oo}

All header files should have `#define` guards to prevent multiple inclusion. The format of the symbol name should be `<PROJECT>_<PATH>_<FILE>_H_`.

To guarantee uniqueness, they should be based on the full path in a project's source tree. For example, the file `foo/src/bar/baz.h` in project `foo` should have the following guard:

```
#ifndef FOO_BAR_BAZ_H_
#define FOO_BAR_BAZ_H_

...

#endif // FOO_BAR_BAZ_H_
```

Forward Declarations

Avoid using forward declarations where possible. Just `#include` the headers you need.

A "forward declaration" is a declaration of a class, function, or template without an associated definition.

- Forward declarations can save compile time, as `#includes` force the compiler to open more files and process more input.
- Forward declarations can save on unnecessary recompilation. `#includes` can force your code to be recompiled more often, due to unrelated changes in the header.
- Forward declarations can hide a dependency, allowing user code to skip necessary recompilation when headers change.
- A forward declaration may be broken by subsequent changes to the library. Forward declarations of functions and templates can prevent the header owners from making otherwise-compatible changes to their APIs, such as widening a parameter type, adding a template parameter with a default value, or migrating to a new namespace.
- Forward declaring symbols from namespace `std::` yields undefined behavior.
- It can be difficult to determine whether a forward declaration or a full `#include` is needed. Replacing an `#include` with a forward declaration can silently change the meaning of code:

```
• // b.h:
• struct B {};
• struct D : B {};
•
• // good_user.cc:
• #include "b.h"
• void f(B*);
• void f(void*);
• void test(D* x) { f(x); } // calls f(B*)
```

If the `#include` was replaced with forward decls for `B` and `D`, `test()` would call `f(void*)`.

- Forward declaring multiple symbols from a header can be more verbose than simply `#include`ing the header.
- Structuring code to enable forward declarations (e.g. using pointer members instead of object members) can make the code slower and more complex.
- Try to avoid forward declarations of entities defined in another project.
- When using a function declared in a header file, always `#include` that header.
- When using a class template, prefer to `#include` its header file.

Please see [Names and Order of Includes](#) for rules about when to `#include` a header.

Inline Functions

Define functions inline only when they are small, say, 10 lines or fewer.

You can declare functions in a way that allows the compiler to expand them inline rather than calling them through the usual function call mechanism.

Inlining a function can generate more efficient object code, as long as the inlined function is small. Feel free to inline accessors and mutators, and other short, performance-critical functions.

Overuse of inlining can actually make programs slower. Depending on a function's size, inlining it can cause the code size to increase or decrease. Inlining a very small accessor function will usually decrease code size while inlining a very large function can dramatically increase code size. On modern processors smaller code usually runs faster due to better use of the instruction cache.

A decent rule of thumb is to not inline a function if it is more than 10 lines long. Beware of destructors, which are often longer than they appear because of implicit member- and base-destructor calls!

Another useful rule of thumb: it's typically not cost effective to inline functions with loops or switch statements (unless, in the common case, the loop or switch statement is never executed).

It is important to know that functions are not always inlined even if they are declared as such; for example, virtual and recursive functions are not normally inlined. Usually recursive functions should not be inline. The main reason for making a virtual function inline is to place its definition in the class, either for convenience or to document its behavior, e.g., for accessors and mutators.

Names and Order of Includes

Use standard order for readability and to avoid hidden dependencies: Related header, C library, C++ library, other libraries' `.h`, your project's `.h`.

All of a project's header files should be listed as descendants of the project's source directory without use of UNIX directory shortcuts `.` (the current directory) or `..` (the parent directory). For example, `google-awesome-project/src/base/logging.h` should be included as:

```
#include "base/logging.h"
```

In `dir/foo.cc` or `dir/foo_test.cc`, whose main purpose is to implement or test the stuff in `dir2/foo2.h`, order your includes as follows:

1. `dir2/foo2.h`.
2. C system files.
3. C++ system files.
4. Other libraries' `.h` files.
5. Your project's `.h` files.

With the preferred ordering, if `dir2/foo2.h` omits any necessary includes, the build of `dir/foo.cc` or `dir/foo_test.cc` will break. Thus, this rule ensures that build breaks show up first for the people working on these files, not for innocent people in other packages.

`dir/foo.cc` and `dir2/foo2.h` are usually in the same directory (e.g. `base/basictypes_test.cc` and `base/basictypes.h`), but may sometimes be in different directories too.

Within each section the includes should be ordered alphabetically. Note that older code might not conform to this rule and should be fixed when convenient.

You should include all the headers that define the symbols you rely upon, except in the unusual case of [forward declaration](#). If you rely on symbols from `bar.h`, don't count on the fact that you included `foo.h` which (currently) includes `bar.h`: include `bar.h` yourself, unless `foo.h` explicitly demonstrates its intent to provide you the symbols of `bar.h`. However, any includes present in the related header do not need to be included again in the related `cc` (i.e., `foo.cc` can rely on `foo.h`'s includes).

For example, the includes in `google-awesome-project/src/foo/internal/fooserver.cc` might look like this:

```
#include "foo/server/fooserver.h"

#include <sys/types.h>
#include <unistd.h>

#include <hash_map>
#include <vector>

#include "base/basictypes.h"
#include "base/commandlineflags.h"
#include "foo/server/bar.h"
```

Sometimes, system-specific code needs conditional includes. Such code can put conditional includes after other includes. Of course, keep your system-specific code small and localized. Example:

```
#include "foo/public/fooserver.h"

#include "base/port.h" // For LANG_CXX11.

#ifdef LANG_CXX11
#include <initializer_list>
```



```
#endif // LANG_CXX11
```

Scoping⁰⁰

Namespaces⁰⁰

With few exceptions, place code in a namespace. Namespaces should have unique names based on the project name, and possibly its path. Do not use *using-directives* (e.g. `using namespace foo`). Do not use inline namespaces. For unnamed namespaces, see [Unnamed Namespaces and Static Variables](#).

Namespaces subdivide the global scope into distinct, named scopes, and so are useful for preventing name collisions in the global scope.

Namespaces provide a method for preventing name conflicts in large programs while allowing most code to use reasonably short names.

For example, if two different projects have a class `Foo` in the global scope, these symbols may collide at compile time or at runtime. If each project places their code in a namespace, `project1::Foo` and `project2::Foo` are now distinct symbols that do not collide, and code within each project's namespace can continue to refer to `Foo` without the prefix.

Inline namespaces automatically place their names in the enclosing scope. Consider the following snippet, for example:

```
namespace X {  
  inline namespace Y {  
    void foo();  
  } // namespace Y  
} // namespace X
```

The expressions `X::Y::foo()` and `X::foo()` are interchangeable. Inline namespaces are primarily intended for ABI compatibility across versions.

Namespaces can be confusing, because they complicate the mechanics of figuring out what definition a name refers to.

Inline namespaces, in particular, can be confusing because names aren't actually restricted to the namespace where they are declared. They are only useful as part of some larger versioning policy.

In some contexts, it's necessary to repeatedly refer to symbols by their fully-qualified names. For deeply-nested namespaces, this can add a lot of clutter.

Namespaces should be used as follows:

- Follow the rules on [Namespace Names](#).
- Terminate namespaces with comments as shown in the given examples.

- Namespaces wrap the entire source file after includes, [gflags](#) definitions/declarations and forward declarations of classes from other namespaces.

```

• // In the .h file
• namespace mynamespace {
•
• // All declarations are within the namespace scope.
• // Notice the lack of indentation.
• class MyClass {
•     public:
•
•     ...
•     void Foo();
• };
•
• } // namespace mynamespace
• // In the .cc file
• namespace mynamespace {
•
• // Definition of functions is within scope of the namespace.
• void MyClass::Foo() {
•     ...
• }
•
• } // namespace mynamespace

```

More complex .cc files might have additional details, like flags or using-declarations.

```

#include "a.h"

DEFINE_FLAG(bool, someflag, false, "dummy flag");

namespace a {

using ::foo::bar;

...code for a...           // Code goes against the left margin.

} // namespace a

```

- Do not declare anything in namespace `std`, including forward declarations of standard library classes. Declaring entities in namespace `std` is undefined behavior, i.e., not portable. To declare entities from the standard library, include the appropriate header file.
- You may not use a *using-directive* to make all names from a namespace available.

```

• // Forbidden -- This pollutes the namespace.
• using namespace foo;

```

- Do not use *Namespace aliases* at namespace scope in header files except in explicitly marked internal-only namespaces, because anything imported into a namespace in a header file becomes part of the public API exported by that file.

- `// Shorten access to some commonly used names in .cc files.`
- `namespace baz = ::foo::bar::baz;`
- `// Shorten access to some commonly used names (in a .h file).`
- `namespace librarian {`
- `namespace impl { // Internal, not part of the API.`
- `namespace sidetable = ::pipeline_diagnostics::sidetable;`
- `} // namespace impl`
-
- `inline void my_inline_function() {`
- `// namespace alias local to a function (or method).`
- `namespace baz = ::foo::bar::baz;`
- `...`
- `}`
- `} // namespace librarian`
- Do not use inline namespaces.

Unnamed Namespaces and Static Variables

When definitions in a `.cc` file do not need to be referenced outside that file, place them in an unnamed namespace or declare them `static`. Do not use either of these constructs in `.h` files.

All declarations can be given internal linkage by placing them in unnamed namespaces, and functions and variables can be given internal linkage by declaring them `static`. This means that anything you're declaring can't be accessed from another file. If a different file declares something with the same name, then the two entities are completely independent.

Use of internal linkage in `.cc` files is encouraged for all code that does not need to be referenced elsewhere. Do not use internal linkage in `.h` files.

Format unnamed namespaces like named namespaces. In the terminating comment, leave the namespace name empty:

```
namespace {
...
} // namespace
```

Nonmember, Static Member, and Global Functions

Prefer placing nonmember functions in a namespace; use completely global functions rarely. Prefer grouping functions with a namespace instead of using a class as if it were a namespace. Static methods of a class should generally be closely related to instances of the class or the class's static data.

Nonmember and static member functions can be useful in some situations. Putting nonmember functions in a namespace avoids polluting the global namespace.

Nonmember and static member functions may make more sense as members of a new class, especially if they access external resources or have significant dependencies.

Sometimes it is useful to define a function not bound to a class instance. Such a function can be either a static member or a nonmember function. Nonmember functions should not depend on external variables, and should nearly always exist in a namespace. Rather than creating classes only to group static member functions which do not share static data, use [namespaces](#) instead. For a header `myproject/foo_bar.h`, for example, write

```
namespace myproject {
namespace foo_bar {
void Function1();
void Function2();
} // namespace foo_bar
} // namespace myproject
```

instead of

```
namespace myproject {
class FooBar {
public:
    static void Function1();
    static void Function2();
};
} // namespace myproject
```

If you define a nonmember function and it is only needed in its `.cc` file, use [internal linkage](#) to limit its scope.

Local Variables

Place a function's variables in the narrowest scope possible, and initialize variables in the declaration.

C++ allows you to declare variables anywhere in a function. We encourage you to declare them in as local a scope as possible, and as close to the first use as possible. This makes it easier for the reader to find the declaration and see what type the variable is and what it was initialized to. In particular, initialization should be used instead of declaration and assignment, e.g.:

```
int i;
i = f();      // Bad -- initialization separate from declaration.
```

```
int j = g();  // Good -- declaration has initialization.
```

```
std::vector<int> v;
v.push_back(1); // Prefer initializing using brace initialization.
v.push_back(2);
```

```
std::vector<int> v = {1, 2}; // Good -- v starts initialized.
```

Variables needed for `if`, `while` and `for` statements should normally be declared within those statements, so that such variables are confined to those scopes. E.g.:

```
while (const char* p = strchr(str, '/')) str = p + 1;
```

There is one caveat: if the variable is an object, its constructor is invoked every time it enters scope and is created, and its destructor is invoked every time it goes out of scope.

```
// Inefficient implementation:
for (int i = 0; i < 1000000; ++i) {
    Foo f; // My ctor and dtor get called 1000000 times each.
    f.DoSomething(i);
}
```

It may be more efficient to declare such a variable used in a loop outside that loop:

```
Foo f; // My ctor and dtor get called once each.
for (int i = 0; i < 1000000; ++i) {
    f.DoSomething(i);
}
```

Static and Global Variables

Variables of class type with [static storage duration](#) are forbidden: they cause hard-to-find bugs due to indeterminate order of construction and destruction. However, such variables are allowed if they are `constexpr`: they have no dynamic initialization or destruction.

Objects with static storage duration, including global variables, static variables, static class member variables, and function static variables, must be Plain Old Data (POD): only ints, chars, floats, or pointers, or arrays/structs of POD.

The order in which class constructors and initializers for static variables are called is only partially specified in C++ and can even change from build to build, which can cause bugs that are difficult to find. Therefore in addition to banning globals of class type, we do not allow non-local static variables to be initialized with the result of a function, unless that function (such as `getenv()`, or `getpid()`) does not itself depend on any other globals. However, a static POD variable within function scope may be initialized with the result of a function, since its initialization order is well-defined and does not occur until control passes through its declaration.

Likewise, global and static variables are destroyed when the program terminates, regardless of whether the termination is by returning from `main()` or by calling `exit()`. The order in which destructors are called is defined to be the reverse of the order in which the constructors were called. Since constructor order is indeterminate, so is destructor order. For example, at program-end time a static variable might have been destroyed, but code still running — perhaps in another thread — tries to access it and fails. Or the destructor for a static `string` variable might be run prior to the destructor for another variable that contains a reference to that string.

One way to alleviate the destructor problem is to terminate the program by calling `quick_exit()` instead of `exit()`. The difference is that `quick_exit()` does not invoke destructors and does not invoke any handlers that were registered by calling `atexit()`. If you have a handler that needs to run when a program terminates

via `quick_exit()` (flushing logs, for example), you can register it using `at_quick_exit()`. (If you have a handler that needs to run at both `exit()` and `quick_exit()`, you need to register it in both places.)

As a result we only allow static variables to contain POD data. This rule completely disallows `std::vector` (use C arrays instead), or `string` (use `const char []`).

If you need a static or global variable of a class type, consider initializing a pointer (which will never be freed), from either your `main()` function or from `pthread_once()`. Note that this must be a raw pointer, not a "smart" pointer, since the smart pointer's destructor will have the order-of-destructor issue that we are trying to avoid.

Classes

Classes are the fundamental unit of code in C++. Naturally, we use them extensively. This section lists the main dos and don'ts you should follow when writing a class.

Doing Work in Constructors

Avoid virtual method calls in constructors, and avoid initialization that can fail if you can't signal an error.

It is possible to perform arbitrary initialization in the body of the constructor.

- No need to worry about whether the class has been initialized or not.
- Objects that are fully initialized by constructor call can be `const` and may also be easier to use with standard containers or algorithms.
- If the work calls virtual functions, these calls will not get dispatched to the subclass implementations. Future modification to your class can quietly introduce this problem even if your class is not currently subclassed, causing much confusion.
- There is no easy way for constructors to signal errors, short of crashing the program (not always appropriate) or using exceptions (which are [forbidden](#)).
- If the work fails, we now have an object whose initialization code failed, so it may be an unusual state requiring a `bool IsValid()` state checking mechanism (or similar) which is easy to forget to call.
- You cannot take the address of a constructor, so whatever work is done in the constructor cannot easily be handed off to, for example, another thread.

Constructors should never call virtual functions. If appropriate for your code, terminating the program may be an appropriate error handling response. Otherwise, consider a factory function or `Init()` method.

Avoid `Init()` methods on objects with no other states that affect which public methods may be called (semi-constructed objects of this form are particularly hard to work with correctly).

Implicit Conversions

Do not define implicit conversions. Use the `explicit` keyword for conversion operators and single-argument constructors.

Implicit conversions allow an object of one type (called the *source type*) to be used where a different type (called the *destination type*) is expected, such as when passing an `int` argument to a function that takes a `double` parameter.

In addition to the implicit conversions defined by the language, users can define their own, by adding appropriate members to the class definition of the source or destination type. An implicit conversion in the source type is defined by a type conversion operator named after the destination type (e.g. `operator bool()`). An implicit conversion in the destination type is defined by a constructor that can take the source type as its only argument (or only argument with no default value).

The `explicit` keyword can be applied to a constructor or (since C++11) a conversion operator, to ensure that it can only be used when the destination type is explicit at the point of use, e.g. with a cast. This applies not only to implicit conversions, but to C++11's list initialization syntax:

```
class Foo {  
    explicit Foo(int x, double y);  
    ...  
};
```

```
void Func(Foo f);
```

```
Func({42, 3.14}); // Error
```

This kind of code isn't technically an implicit conversion, but the language treats it as one as far as `explicit` is concerned.

- Implicit conversions can make a type more usable and expressive by eliminating the need to explicitly name a type when it's obvious.
- Implicit conversions can be a simpler alternative to overloading.
- List initialization syntax is a concise and expressive way of initializing objects.
- Implicit conversions can hide type-mismatch bugs, where the destination type does not match the user's expectation, or the user is unaware that any conversion will take place.
- Implicit conversions can make code harder to read, particularly in the presence of overloading, by making it less obvious what code is actually getting called.
- Constructors that take a single argument may accidentally be usable as implicit type conversions, even if they are not intended to do so.
- When a single-argument constructor is not marked `explicit`, there's no reliable way to tell whether it's intended to define an implicit conversion, or the author simply forgot to mark it.
- It's not always clear which type should provide the conversion, and if they both do, the code becomes ambiguous.
- List initialization can suffer from the same problems if the destination type is implicit, particularly if the list has only a single element.

Type conversion operators, and constructors that are callable with a single argument, must be marked `explicit` in the class definition. As an exception, copy and move constructors should not be `explicit`, since they do not perform type conversion. Implicit conversions can sometimes be necessary and appropriate for types that are designed to transparently wrap other types. In that case, contact your project leads to request a waiver of this rule.

Constructors that cannot be called with a single argument should usually omit `explicit`. Constructors that take a single `std::initializer_list` parameter should also omit `explicit`, in order to support copy-initialization (e.g. `MyType m = {1, 2};`).

Copyable and Movable Types

Support copying and/or moving if these operations are clear and meaningful for your type. Otherwise, disable the implicitly generated special functions that perform copies and moves.

A copyable type allows its objects to be initialized or assigned from any other object of the same type, without changing the value of the source. For user-defined types, the copy behavior is defined by the copy constructor and the copy-assignment operator. `string` is an example of a copyable type.

A movable type is one that can be initialized and assigned from temporaries (all copyable types are therefore movable). `std::unique_ptr<int>` is an example of a movable but not copyable type. For user-defined types, the move behavior is defined by the move constructor and the move-assignment operator.

The copy/move constructors can be implicitly invoked by the compiler in some situations, e.g. when passing objects by value.

Objects of copyable and movable types can be passed and returned by value, which makes APIs simpler, safer, and more general. Unlike when passing objects by pointer or reference, there's no risk of confusion over ownership, lifetime, mutability, and similar issues, and no need to specify them in the contract. It also prevents non-local interactions between the client and the implementation, which makes them easier to understand, maintain, and optimize by the compiler. Further, such objects can be used with generic APIs that require pass-by-value, such as most containers, and they allow for additional flexibility in e.g., type composition.

Copy/move constructors and assignment operators are usually easier to define correctly than alternatives like `Clone()`, `CopyFrom()` or `Swap()`, because they can be generated by the compiler, either implicitly or with `= default`. They are concise, and ensure that all data members are copied. Copy and move constructors are also generally more efficient, because they don't require heap allocation or separate initialization and assignment steps, and they're eligible for optimizations such as [copy elision](#).

Move operations allow the implicit and efficient transfer of resources out of rvalue objects. This allows a plainer coding style in some cases.

Some types do not need to be copyable, and providing copy operations for such types can be confusing, nonsensical, or outright incorrect. Types representing singleton objects (`Registerer`), objects tied to a specific scope (`Cleanup`), or closely coupled to object identity (`Mutex`) cannot be copied meaningfully. Copy operations for base class types that are to be used polymorphically are hazardous, because use of them can lead to [object slicing](#). Defaulted or carelessly-implemented copy operations can be incorrect, and the resulting bugs can be confusing and difficult to diagnose.

Copy constructors are invoked implicitly, which makes the invocation easy to miss. This may cause confusion for programmers used to languages where pass-by-reference is conventional or mandatory. It may also encourage excessive copying, which can cause performance problems.

Provide the copy and move operations if their meaning is clear to a casual user and the copying/moving does not incur unexpected costs. If you define a copy or move constructor, define the corresponding assignment operator, and vice-versa. If your type is copyable, do not define move operations unless they are significantly more efficient than the

corresponding copy operations. If your type is not copyable, but the correctness of a move is obvious to users of the type, you may make the type move-only by defining both of the move operations.

If your type provides copy operations, it is recommended that you design your class so that the default implementation of those operations is correct. Remember to review the correctness of any defaulted operations as you would any other code, and to document that your class is copyable and/or cheaply movable if that's an API guarantee.

```
class Foo {
public:
    Foo(Foo&& other) : field_(other.field) {}
    // Bad, defines only move constructor, but not operator=.

private:
    Field field_;
};
```

Due to the risk of slicing, avoid providing an assignment operator or public copy/move constructor for a class that's intended to be derived from (and avoid deriving from a class with such members). If your base class needs to be copyable, provide a public virtual `Clone()` method, and a protected copy constructor that derived classes can use to implement it.

If you do not want to support copy/move operations on your type, explicitly disable them using `= delete` in the `public:` section:

```
// MyClass is neither copyable nor movable.
MyClass(const MyClass&) = delete;
MyClass& operator=(const MyClass&) = delete;
```

Structs vs. Classes⁰⁰

Use a `struct` only for passive objects that carry data; everything else is a `class`.

The `struct` and `class` keywords behave almost identically in C++. We add our own semantic meanings to each keyword, so you should use the appropriate keyword for the data-type you're defining.

`structs` should be used for passive objects that carry data, and may have associated constants, but lack any functionality other than access/setting the data members. The accessing/setting of fields is done by directly accessing the fields rather than through method invocations. Methods should not provide behavior but should only be used to set up the data members, e.g., `constructor`, `destructor`, `Initialize()`, `Reset()`, `Validate()`.

If more functionality is required, a `class` is more appropriate. If in doubt, make it a `class`.

For consistency with STL, you can use `struct` instead of `class` for functors and traits.

Note that member variables in structs and classes have [different naming rules](#).

Inheritance⁰⁰

Composition is often more appropriate than inheritance. When using inheritance, make it `public`.

When a sub-class inherits from a base class, it includes the definitions of all the data and operations that the parent base class defines. In practice, inheritance is used in two major ways in C++: implementation inheritance, in which actual code is inherited by the child, and [interface inheritance](#), in which only method names are inherited.

Implementation inheritance reduces code size by re-using the base class code as it specializes an existing type. Because inheritance is a compile-time declaration, you and the compiler can understand the operation and detect errors. Interface inheritance can be used to programmatically enforce that a class expose a particular API. Again, the compiler can detect errors, in this case, when a class does not define a necessary method of the API.

For implementation inheritance, because the code implementing a sub-class is spread between the base and the sub-class, it can be more difficult to understand an implementation. The sub-class cannot override functions that are not virtual, so the sub-class cannot change implementation. The base class may also define some data members, so that specifies physical layout of the base class.

All inheritance should be `public`. If you want to do private inheritance, you should be including an instance of the base class as a member instead.

Do not overuse implementation inheritance. Composition is often more appropriate. Try to restrict use of inheritance to the "is-a" case: `Bar` subclasses `Foo` if it can reasonably be said that `Bar` "is a kind of" `Foo`.

Make your destructor `virtual` if necessary. If your class has virtual methods, its destructor should be virtual.

Limit the use of `protected` to those member functions that might need to be accessed from subclasses. Note that [data members should be private](#).

Explicitly annotate overrides of virtual functions or virtual destructors with an `override` or (less frequently) `final` specifier. Older (pre-C++11) code will use the `virtual` keyword as an inferior alternative annotation. For clarity, use exactly one of `override`, `final`, or `virtual` when declaring an override. Rationale: A function or destructor marked `override` or `final` that is not an override of a base class virtual function will not compile, and this helps catch common errors. The specifiers serve as documentation; if no specifier is present, the reader has to check all ancestors of the class in question to determine if the function or destructor is virtual or not.

Multiple Inheritance⁰⁰

Only very rarely is multiple implementation inheritance actually useful. We allow multiple inheritance only when at most one of the base classes has an implementation; all other base classes must be [pure interface](#) classes tagged with the `Interface` suffix.

Multiple inheritance allows a sub-class to have more than one base class. We distinguish between base classes that are *pure interfaces* and those that have an *implementation*.

Multiple implementation inheritance may let you re-use even more code than single inheritance (see [Inheritance](#)).

Only very rarely is multiple *implementation* inheritance actually useful. When multiple implementation inheritance seems like the solution, you can usually find a different, more explicit, and cleaner solution.

Multiple inheritance is allowed only when all superclasses, with the possible exception of the first one, are [pure interfaces](#). In order to ensure that they remain pure interfaces, they must end with the `Interface` suffix.

There is an [exception](#) to this rule on Windows.

Interfaces^{oo}

Classes that satisfy certain conditions are allowed, but not required, to end with an `Interface` suffix.

A class is a pure interface if it meets the following requirements:

- It has only public pure virtual ("`= 0`") methods and static methods (but see below for destructor).
- It may not have non-static data members.
- It need not have any constructors defined. If a constructor is provided, it must take no arguments and it must be protected.
- If it is a subclass, it may only be derived from classes that satisfy these conditions and are tagged with the `Interface` suffix.

An interface class can never be directly instantiated because of the pure virtual method(s) it declares. To make sure all implementations of the interface can be destroyed correctly, the interface must also declare a virtual destructor (in an exception to the first rule, this should not be pure). See Stroustrup, *The C++ Programming Language*, 3rd edition, section 12.4 for details.

Tagging a class with the `Interface` suffix lets others know that they must not add implemented methods or non static data members. This is particularly important in the case of [multiple inheritance](#). Additionally, the interface concept is already well-understood by Java programmers.

The `Interface` suffix lengthens the class name, which can make it harder to read and understand. Also, the interface property may be considered an implementation detail that shouldn't be exposed to clients.

A class may end with `Interface` only if it meets the above requirements. We do not require the converse, however: classes that meet the above requirements are not required to end with `Interface`.

Operator Overloading^{oo}

Overload operators judiciously. Do not create user-defined literals.

C++ permits user code to [declare overloaded versions of the built-in operators](#) using the `operator` keyword, so long as one of the parameters is a user-defined type. The `operator` keyword also permits user code to define new kinds of literals using `operator""`, and to define type-conversion functions such as `operator bool()`.

Operator overloading can make code more concise and intuitive by enabling user-defined types to behave the same as built-in types. Overloaded operators are the idiomatic names for certain operations (e.g. `==`, `<`, `=`, and `<<`), and adhering to those conventions can make user-defined types more readable and enable them to interoperate with libraries that expect those names.

User-defined literals are a very concise notation for creating objects of user-defined types.

- Providing a correct, consistent, and unsurprising set of operator overloads requires some care, and failure to do so can lead to confusion and bugs.
- Overuse of operators can lead to obfuscated code, particularly if the overloaded operator's semantics don't follow convention.
- The hazards of function overloading apply just as much to operator overloading, if not more so.
- Operator overloads can fool our intuition into thinking that expensive operations are cheap, built-in operations.
- Finding the call sites for overloaded operators may require a search tool that's aware of C++ syntax, rather than e.g. `grep`.
- If you get the argument type of an overloaded operator wrong, you may get a different overload rather than a compiler error. For example, `foo < bar` may do one thing, while `&foo < &bar` does something totally different.
- Certain operator overloads are inherently hazardous. Overloading unary `&` can cause the same code to have different meanings depending on whether the overload declaration is visible. Overloads of `&&`, `||`, and `,` (comma) cannot match the evaluation-order semantics of the built-in operators.
- Operators are often defined outside the class, so there's a risk of different files introducing different definitions of the same operator. If both definitions are linked into the same binary, this results in undefined behavior, which can manifest as subtle run-time bugs.
- User-defined literals allow the creation of new syntactic forms that are unfamiliar even to experienced C++ programmers.

Define overloaded operators only if their meaning is obvious, unsurprising, and consistent with the corresponding built-in operators. For example, use `|` as a bitwise- or logical-or, not as a shell-style pipe.

Define operators only on your own types. More precisely, define them in the same headers, `.cc` files, and namespaces as the types they operate on. That way, the operators are available wherever the type is, minimizing the risk of multiple definitions. If possible, avoid defining operators as templates, because they must satisfy this rule for any possible template arguments. If you define an operator, also define any related operators that make sense, and make sure they are defined consistently. For example, if you overload `<`, overload all the comparison operators, and make sure `<` and `>` never return true for the same arguments.

Prefer to define non-modifying binary operators as non-member functions. If a binary operator is defined as a class member, implicit conversions will apply to the right-hand argument, but not the left-hand one. It will confuse your users if `a < b` compiles but `b < a` doesn't.

Don't go out of your way to avoid defining operator overloads. For example, prefer to define `==`, `=`, and `<<`, rather than `Equals()`, `CopyFrom()`, and `PrintTo()`. Conversely, don't define operator overloads just because other libraries expect them. For example, if your type doesn't have a natural ordering, but you want to store it in a `std::set`, use a custom comparator rather than overloading `<`.

Do not overload `&&`, `||`, `,` (comma), or unary `&`. Do not overload `operator""`, i.e. do not introduce user-defined literals.

Type conversion operators are covered in the section on [implicit conversions](#). The `=` operator is covered in the section on [copy constructors](#). Overloading `<<` for use with streams is covered in the section on [streams](#). See also the rules on [function overloading](#), which apply to operator overloading as well.

Access Control

Make data members `private`, unless they are `static const` (and follow the [naming convention for constants](#)). For technical reasons, we allow data members of a test fixture class to be `protected` when using [Google Test](#).

Declaration Order

Group similar declarations together, placing public parts earlier.

A class definition should usually start with a `public:` section, followed by `protected:`, then `private:`. Omit sections that would be empty.

Within each section, generally prefer grouping similar kinds of declarations together, and generally prefer the following order: types (including `typedef`, `using`, and nested structs and classes), constants, factory functions, constructors, assignment operators, destructor, all other methods, data members.

Do not put large method definitions inline in the class definition. Usually, only trivial or performance-critical, and very short, methods may be defined inline. See [Inline Functions](#) for more details.

Functions

Parameter Ordering

When defining a function, parameter order is: inputs, then outputs.

Parameters to C/C++ functions are either input to the function, output from the function, or both. Input parameters are usually values or `const` references, while output and input/output parameters will be pointers to non-`const`. When ordering function parameters, put all input-only parameters before any output parameters. In particular, do not add new parameters to the end of the function just because they are new; place new input-only parameters before the output parameters.

This is not a hard-and-fast rule. Parameters that are both input and output (often classes/structs) muddy the waters, and, as always, consistency with related functions may require you to bend the rule.

Write Short Functions

Prefer small and focused functions.

We recognize that long functions are sometimes appropriate, so no hard limit is placed on functions length. If a function exceeds about 40 lines, think about whether it can be broken up without harming the structure of the program.

Even if your long function works perfectly now, someone modifying it in a few months may add new behavior. This could result in bugs that are hard to find. Keeping your functions short and simple makes it easier for other people to read and modify your code.

You could find long and complicated functions when working with some code. Do not be intimidated by modifying existing code: if working with such a function proves to be difficult, you find that errors are hard to debug, or you want

to use a piece of it in several different contexts, consider breaking up the function into smaller and more manageable pieces.

Reference Arguments

All parameters passed by reference must be labeled `const`.

In C, if a function needs to modify a variable, the parameter must use a pointer, eg `int foo(int *pval)`. In C++, the function can alternatively declare a reference parameter: `int foo(int &val)`.

Defining a parameter as reference avoids ugly code like `(*pval)++`. Necessary for some applications like copy constructors. Makes it clear, unlike with pointers, that a null pointer is not a possible value.

References can be confusing, as they have value syntax but pointer semantics.

Within function parameter lists all references must be `const`:

```
void Foo(const string &in, string *out);
```

In fact it is a very strong convention in Google code that input arguments are values or `const` references while output arguments are pointers. Input parameters may be `const` pointers, but we never allow non-`const` reference parameters except when required by convention, e.g., `swap()`.

However, there are some instances where using `const T*` is preferable to `const T&` for input parameters. For example:

- You want to pass in a null pointer.
- The function saves a pointer or reference to the input.

Remember that most of the time input parameters are going to be specified as `const T&`. Using `const T*` instead communicates to the reader that the input is somehow treated differently. So if you choose `const T*` rather than `const T&`, do so for a concrete reason; otherwise it will likely confuse readers by making them look for an explanation that doesn't exist.

Function Overloading

Use overloaded functions (including constructors) only if a reader looking at a call site can get a good idea of what is happening without having to first figure out exactly which overload is being called.

You may write a function that takes a `const string&` and overload it with another that takes `const char*`.

```
class MyClass {  
    public:  
        void Analyze(const string &text);  
        void Analyze(const char *text, size_t textlen);  
};
```

Overloading can make code more intuitive by allowing an identically-named function to take different arguments. It may be necessary for templated code, and it can be convenient for Visitors.

If a function is overloaded by the argument types alone, a reader may have to understand C++'s complex matching rules in order to tell what's going on. Also many people are confused by the semantics of inheritance if a derived class overrides only some of the variants of a function.

If you want to overload a function, consider qualifying the name with some information about the arguments, e.g., `AppendString()`, `AppendInt()` rather than just `Append()`. If you are overloading a function to support variable number of arguments of the same type, consider making it take a `std::vector` so that the user can use an [initializer list](#) to specify the arguments.

Default Arguments

Default arguments are allowed on non-virtual functions when the default is guaranteed to always have the same value. Follow the same restrictions as for [function overloading](#), and prefer overloaded functions if the readability gained with default arguments doesn't outweigh the downsides below.

Often you have a function that uses default values, but occasionally you want to override the defaults. Default parameters allow an easy way to do this without having to define many functions for the rare exceptions. Compared to overloading the function, default arguments have a cleaner syntax, with less boilerplate and a clearer distinction between 'required' and 'optional' arguments.

Defaulted arguments are another way to achieve the semantics of overloaded functions, so all the [reasons not to overload functions](#) apply.

The defaults for arguments in a virtual function call are determined by the static type of the target object, and there's no guarantee that all overrides of a given function declare the same defaults.

Default parameters are re-evaluated at each call site, which can bloat the generated code. Readers may also expect the default's value to be fixed at the declaration instead of varying at each call.

Function pointers are confusing in the presence of default arguments, since the function signature often doesn't match the call signature. Adding function overloads avoids these problems.

Default arguments are banned on virtual functions, where they don't work properly, and in cases where the specified default might not evaluate to the same value depending on when it was evaluated. (For example, don't write `void f(int n = counter++);`.)

In some other cases, default arguments can improve the readability of their function declarations enough to overcome the downsides above, so they are allowed. When in doubt, use overloads.

Trailing Return Type Syntax

Use trailing return types only where using the ordinary syntax (leading return types) is impractical or much less readable.

C++ allows two different forms of function declarations. In the older form, the return type appears before the function name. For example:

```
int foo(int x);
```

The new form, introduced in C++11, uses the `auto` keyword before the function name and a trailing return type after the argument list. For example, the declaration above could equivalently be written:

```
auto foo(int x) -> int;
```

The trailing return type is in the function's scope. This doesn't make a difference for a simple case like `int` but it matters for more complicated cases, like types declared in class scope or types written in terms of the function parameters.

Trailing return types are the only way to explicitly specify the return type of a [lambda expression](#). In some cases the compiler is able to deduce a lambda's return type, but not in all cases. Even when the compiler can deduce it automatically, sometimes specifying it explicitly would be clearer for readers.

Sometimes it's easier and more readable to specify a return type after the function's parameter list has already appeared. This is particularly true when the return type depends on template parameters. For example:

```
template <class T, class U> auto add(T t, U u) -> decltype(t + u);
```

versus

```
template <class T, class U> decltype(declval<T&>() + declval<U&>()) add(T t, U u);
```

Trailing return type syntax is relatively new and it has no analogue in C++-like languages like C and Java, so some readers may find it unfamiliar.

Existing code bases have an enormous number of function declarations that aren't going to get changed to use the new syntax, so the realistic choices are using the old syntax only or using a mixture of the two. Using a single version is better for uniformity of style.

In most cases, continue to use the older style of function declaration where the return type goes before the function name. Use the new trailing-return-type form only in cases where it's required (such as lambdas) or where, by putting the type after the function's parameter list, it allows you to write the type in a much more readable way. The latter case should be rare; it's mostly an issue in fairly complicated template code, which is [discouraged in most cases](#).

Google-Specific Magic^{oo}

There are various tricks and utilities that we use to make C++ code more robust, and various ways we use C++ that may differ from what you see elsewhere.

Ownership and Smart Pointers^{oo}

Prefer to have single, fixed owners for dynamically allocated objects. Prefer to transfer ownership with smart pointers.

"Ownership" is a bookkeeping technique for managing dynamically allocated memory (and other resources). The owner of a dynamically allocated object is an object or function that is responsible for ensuring that it is deleted when no longer needed. Ownership can sometimes be shared, in which case the last owner is typically responsible for deleting it. Even when ownership is not shared, it can be transferred from one piece of code to another.

"Smart" pointers are classes that act like pointers, e.g. by overloading the `*` and `->` operators. Some smart pointer types can be used to automate ownership bookkeeping, to ensure these responsibilities are met. `std::unique_ptr` is a smart pointer type introduced in C++11, which expresses exclusive ownership of a dynamically allocated object; the object is deleted when the `std::unique_ptr` goes out of scope. It cannot be copied, but can be *moved* to represent ownership transfer. `std::shared_ptr` is a smart pointer type that expresses shared ownership of a dynamically allocated object. `std::shared_ptr`s can be copied; ownership of the object is shared among all copies, and the object is deleted when the last `std::shared_ptr` is destroyed.

- It's virtually impossible to manage dynamically allocated memory without some sort of ownership logic.
- Transferring ownership of an object can be cheaper than copying it (if copying it is even possible).
- Transferring ownership can be simpler than 'borrowing' a pointer or reference, because it reduces the need to coordinate the lifetime of the object between the two users.
- Smart pointers can improve readability by making ownership logic explicit, self-documenting, and unambiguous.
- Smart pointers can eliminate manual ownership bookkeeping, simplifying the code and ruling out large classes of errors.
- For const objects, shared ownership can be a simple and efficient alternative to deep copying.
- Ownership must be represented and transferred via pointers (whether smart or plain). Pointer semantics are more complicated than value semantics, especially in APIs: you have to worry not just about ownership, but also aliasing, lifetime, and mutability, among other issues.
- The performance costs of value semantics are often overestimated, so the performance benefits of ownership transfer might not justify the readability and complexity costs.
- APIs that transfer ownership force their clients into a single memory management model.
- Code using smart pointers is less explicit about where the resource releases take place.
- `std::unique_ptr` expresses ownership transfer using C++11's move semantics, which are relatively new and may confuse some programmers.
- Shared ownership can be a tempting alternative to careful ownership design, obfuscating the design of a system.
- Shared ownership requires explicit bookkeeping at run-time, which can be costly.
- In some cases (e.g. cyclic references), objects with shared ownership may never be deleted.
- Smart pointers are not perfect substitutes for plain pointers.

If dynamic allocation is necessary, prefer to keep ownership with the code that allocated it. If other code needs access to the object, consider passing it a copy, or passing a pointer or reference without transferring ownership. Prefer to use `std::unique_ptr` to make ownership transfer explicit. For example:

```
std::unique_ptr<Foo> FooFactory();  
void FooConsumer(std::unique_ptr<Foo> ptr);
```

Do not design your code to use shared ownership without a very good reason. One such reason is to avoid expensive copy operations, but you should only do this if the performance benefits are significant, and the underlying object is immutable (i.e. `std::shared_ptr<const Foo>`). If you do use shared ownership, prefer to use `std::shared_ptr`.

Never use `std::auto_ptr`. Instead, use `std::unique_ptr`.

cpplint^{oo}

Use `cpplint.py` to detect style errors.

`cpplint.py` is a tool that reads a source file and identifies many style errors. It is not perfect, and has both false positives and false negatives, but it is still a valuable tool. False positives can be ignored by putting `// NOLINT` at the end of the line or `// NOLINTNEXTLINE` in the previous line.

Some projects have instructions on how to run `cpplint.py` from their project tools. If the project you are contributing to does not, you can download [cpplint.py](#) separately.

Other C++ Features^{oo}

Rvalue References^{oo}

Use rvalue references only to define move constructors and move assignment operators, or for perfect forwarding.

Rvalue references are a type of reference that can only bind to temporary objects. The syntax is similar to traditional reference syntax. For example, `void f(string&& s);` declares a function whose argument is an rvalue reference to a string.

- Defining a move constructor (a constructor taking an rvalue reference to the class type) makes it possible to move a value instead of copying it. If `v1` is a `std::vector<string>`, for example, then `auto v2(std::move(v1))` will probably just result in some simple pointer manipulation instead of copying a large amount of data. In some cases this can result in a major performance improvement.
- Rvalue references make it possible to write a generic function wrapper that forwards its arguments to another function, and works whether or not its arguments are temporary objects. (This is sometimes called "perfect forwarding".)
- Rvalue references make it possible to implement types that are movable but not copyable, which can be useful for types that have no sensible definition of copying but where you might still want to pass them as function arguments, put them in containers, etc.
- `std::move` is necessary to make effective use of some standard-library types, such as `std::unique_ptr`.
- Rvalue references are a relatively new feature (introduced as part of C++11), and not yet widely understood. Rules like reference collapsing, and automatic synthesis of move constructors, are complicated.

Use rvalue references only to define move constructors and move assignment operators (as described in [Copyable and Movable Types](#)) and, in conjunction with [std::forward](#), to support perfect forwarding. You may use `std::move` to express moving a value from one object to another rather than copying it.

Friends^{oo}

We allow use of `friend` classes and functions, within reason.

Friends should usually be defined in the same file so that the reader does not have to look in another file to find uses of the private members of a class. A common use of `friend` is to have a `FooBuilder` class be a friend of `Foo` so that it can construct the inner state of `Foo` correctly, without exposing this state to the world. In some cases it may be useful to make a unittest class a friend of the class it tests.

Friends extend, but do not break, the encapsulation boundary of a class. In some cases this is better than making a member public when you want to give only one other class access to it. However, most classes should interact with other classes solely through their public members.

Exceptions

We do not use C++ exceptions.

- Exceptions allow higher levels of an application to decide how to handle "can't happen" failures in deeply nested functions, without the obscuring and error-prone bookkeeping of error codes.
- Exceptions are used by most other modern languages. Using them in C++ would make it more consistent with Python, Java, and the C++ that others are familiar with.
- Some third-party C++ libraries use exceptions, and turning them off internally makes it harder to integrate with those libraries.
- Exceptions are the only way for a constructor to fail. We can simulate this with a factory function or an `Init()` method, but these require heap allocation or a new "invalid" state, respectively.
- Exceptions are really handy in testing frameworks.
- When you add a `throw` statement to an existing function, you must examine all of its transitive callers. Either they must make at least the basic exception safety guarantee, or they must never catch the exception and be happy with the program terminating as a result. For instance, if `f()` calls `g()` calls `h()`, and `h` throws an exception that `f` catches, `g` has to be careful or it may not clean up properly.
- More generally, exceptions make the control flow of programs difficult to evaluate by looking at code: functions may return in places you don't expect. This causes maintainability and debugging difficulties. You can minimize this cost via some rules on how and where exceptions can be used, but at the cost of more that a developer needs to know and understand.
- Exception safety requires both RAI and different coding practices. Lots of supporting machinery is needed to make writing correct exception-safe code easy. Further, to avoid requiring readers to understand the entire call graph, exception-safe code must isolate logic that writes to persistent state into a "commit" phase. This will have both benefits and costs (perhaps where you're forced to obfuscate code to isolate the commit). Allowing exceptions would force us to always pay those costs even when they're not worth it.
- Turning on exceptions adds data to each binary produced, increasing compile time (probably slightly) and possibly increasing address space pressure.
- The availability of exceptions may encourage developers to throw them when they are not appropriate or recover from them when it's not safe to do so. For example, invalid user input should not cause exceptions to be thrown. We would need to make the style guide even longer to document these restrictions!

On their face, the benefits of using exceptions outweigh the costs, especially in new projects. However, for existing code, the introduction of exceptions has implications on all dependent code. If exceptions can be propagated beyond a new project, it also becomes problematic to integrate the new project into existing exception-free code. Because most existing C++ code at Google is not prepared to deal with exceptions, it is comparatively difficult to adopt new code that generates exceptions.

Given that Google's existing code is not exception-tolerant, the costs of using exceptions are somewhat greater than the costs in a new project. The conversion process would be slow and error-prone. We don't believe that the available alternatives to exceptions, such as error codes and assertions, introduce a significant burden.

Our advice against using exceptions is not predicated on philosophical or moral grounds, but practical ones. Because we'd like to use our open-source projects at Google and it's difficult to do so if those projects use exceptions, we need to advise against exceptions in Google open-source projects as well. Things would probably be different if we had to do it all over again from scratch.

This prohibition also applies to the exception-related features added in C++11, such as `noexcept`, `std::exception_ptr`, and `std::nested_exception`.

There is an [exception](#) to this rule (no pun intended) for Windows code.

Run-Time Type Information (RTTI)

Avoid using Run Time Type Information (RTTI).

RTTI allows a programmer to query the C++ class of an object at run time. This is done by use of `typeid` or `dynamic_cast`.

Querying the type of an object at run-time frequently means a design problem. Needing to know the type of an object at runtime is often an indication that the design of your class hierarchy is flawed.

Undisciplined use of RTTI makes code hard to maintain. It can lead to type-based decision trees or switch statements scattered throughout the code, all of which must be examined when making further changes.

The standard alternatives to RTTI (described below) require modification or redesign of the class hierarchy in question. Sometimes such modifications are infeasible or undesirable, particularly in widely-used or mature code.

RTTI can be useful in some unit tests. For example, it is useful in tests of factory classes where the test has to verify that a newly created object has the expected dynamic type. It is also useful in managing the relationship between objects and their mocks.

RTTI is useful when considering multiple abstract objects. Consider

```
bool Base::Equal(Base* other) = 0;
bool Derived::Equal(Base* other) {
    Derived* that = dynamic_cast<Derived*>(other);
    if (that == NULL)
        return false;
    ...
}
```

RTTI has legitimate uses but is prone to abuse, so you must be careful when using it. You may use it freely in unit tests, but avoid it when possible in other code. In particular, think twice before using RTTI in new code. If you find yourself needing to write code that behaves differently based on the class of an object, consider one of the following alternatives to querying the type:

- Virtual methods are the preferred way of executing different code paths depending on a specific subclass type. This puts the work within the object itself.
- If the work belongs outside the object and instead in some processing code, consider a double-dispatch solution, such as the Visitor design pattern. This allows a facility outside the object itself to determine the type of class using the built-in type system.

When the logic of a program guarantees that a given instance of a base class is in fact an instance of a particular derived class, then a `dynamic_cast` may be used freely on the object. Usually one can use a `static_cast` as an alternative in such situations.

Decision trees based on type are a strong indication that your code is on the wrong track.

```
if (typeid(*data) == typeid(D1)) {
    ...
} else if (typeid(*data) == typeid(D2)) {
    ...
} else if (typeid(*data) == typeid(D3)) {
    ...
}
```

Code such as this usually breaks when additional subclasses are added to the class hierarchy. Moreover, when properties of a subclass change, it is difficult to find and modify all the affected code segments.

Do not hand-implement an RTTI-like workaround. The arguments against RTTI apply just as much to workarounds like class hierarchies with type tags. Moreover, workarounds disguise your true intent.

Casting

Use C++-style casts like `static_cast<float>(double_value)`, or brace initialization for conversion of arithmetic types like `int64 y = int64{1} << 42`. Do not use cast formats like `int y = (int)x` or `int y = int(x)` (but the latter is okay when invoking a constructor of a class type).

C++ introduced a different cast system from C that distinguishes the types of cast operations.

The problem with C casts is the ambiguity of the operation; sometimes you are doing a *conversion* (e.g., `(int)3.5`) and sometimes you are doing a *cast* (e.g., `(int)"hello"`). Brace initialization and C++ casts can often help avoid this ambiguity. Additionally, C++ casts are more visible when searching for them.

The C++-style cast syntax is verbose and cumbersome.

Do not use C-style casts. Instead, use these C++-style casts when explicit type conversion is necessary.

- Use brace initialization to convert arithmetic types (e.g. `int64{x}`). This is the safest approach because code will not compile if conversion can result in information loss. The syntax is also concise.
- Use `static_cast` as the equivalent of a C-style cast that does value conversion, when you need to explicitly up-cast a pointer from a class to its superclass, or when you need to explicitly cast a pointer from a superclass to a subclass. In this last case, you must be sure your object is actually an instance of the subclass.
- Use `const_cast` to remove the `const` qualifier (see [const](#)).

- Use `reinterpret_cast` to do unsafe conversions of pointer types to and from integer and other pointer types. Use this only if you know what you are doing and you understand the aliasing issues.

See the [RTTI section](#) for guidance on the use of `dynamic_cast`.

Streams^{ad}

Use streams where appropriate, and stick to "simple" usages.

Streams are the standard I/O abstraction in C++, as exemplified by the standard header `<iostream>`. They are widely used in Google code, but only for debug logging and test diagnostics.

The `<<` and `>>` stream operators provide an API for formatted I/O that is easily learned, portable, reusable, and extensible. `printf`, by contrast, doesn't even support `string`, to say nothing of user-defined types, and is very difficult to use portably. `printf` also obliges you to choose among the numerous slightly different versions of that function, and navigate the dozens of conversion specifiers.

Streams provide first-class support for console I/O via `std::cin`, `std::cout`, `std::cerr`, and `std::clog`. The C APIs do as well, but are hampered by the need to manually buffer the input.

- Stream formatting can be configured by mutating the state of the stream. Such mutations are persistent, so the behavior of your code can be affected by the entire previous history of the stream, unless you go out of your way to restore it to a known state every time other code might have touched it. User code can not only modify the built-in state, it can add new state variables and behaviors through a registration system.
- It is difficult to precisely control stream output, due to the above issues, the way code and data are mixed in streaming code, and the use of operator overloading (which may select a different overload than you expect).
- The practice of building up output through chains of `<<` operators interferes with internationalization, because it bakes word order into the code, and streams' support for localization is [flawed](#).
- The streams API is subtle and complex, so programmers must develop experience with it in order to use it effectively. However, streams were historically banned in Google code (except for logging and diagnostics), so Google engineers tend not to have that experience. Consequently, streams-based code is likely to be less readable and maintainable by Googlers than code based on more familiar abstractions.
- Resolving the many overloads of `<<` is extremely costly for the compiler. When used pervasively in a large code base, it can consume as much as 20% of the parsing and semantic analysis time.

Use streams only when they are the best tool for the job. This is typically the case when the I/O is ad-hoc, local, human-readable, and targeted at other developers rather than end-users. Be consistent with the code around you, and with the codebase as a whole; if there's an established tool for your problem, use that tool instead.

Avoid using streams for I/O that faces external users or handles untrusted data. Instead, find and use the appropriate templating libraries to handle issues like internationalization, localization, and security hardening.

If you do use streams, avoid the stateful parts of the streams API (other than error state), such as `imbue()`, `xalloc()`, and `register_callback()`. Use explicit formatting functions rather than stream manipulators or formatting flags to control formatting details such as number base, precision, or padding.

Overload `<<` as a streaming operator for your type only if your type represents a value, and `<<` writes out a human-readable string representation of that value. Avoid exposing implementation details in the output of `<<`; if you need to

print object internals for debugging, use named functions instead (a method named `DebugString()` is the most common convention).

Preincrement and Predecrement^{oo}

Use prefix form (`++i`) of the increment and decrement operators with iterators and other template objects.

When a variable is incremented (`++i` or `i++`) or decremented (`--i` or `i--`) and the value of the expression is not used, one must decide whether to preincrement (decrement) or postincrement (decrement).

When the return value is ignored, the "pre" form (`++i`) is never less efficient than the "post" form (`i++`), and is often more efficient. This is because post-increment (or decrement) requires a copy of `i` to be made, which is the value of the expression. If `i` is an iterator or other non-scalar type, copying `i` could be expensive. Since the two types of increment behave the same when the value is ignored, why not just always pre-increment?

The tradition developed, in C, of using post-increment when the expression value is not used, especially in `for` loops. Some find post-increment easier to read, since the "subject" (`i`) precedes the "verb" (`++`), just like in English.

For simple scalar (non-object) values there is no reason to prefer one form and we allow either. For iterators and other template types, use pre-increment.

Use of `const`^{oo}

Use `const` whenever it makes sense. With C++11, `constexpr` is a better choice for some uses of `const`.

Declared variables and parameters can be preceded by the keyword `const` to indicate the variables are not changed (e.g., `const int foo`). Class functions can have the `const` qualifier to indicate the function does not change the state of the class member variables (e.g., `class Foo { int Bar(char c) const; };`).

Easier for people to understand how variables are being used. Allows the compiler to do better type checking, and, conceivably, generate better code. Helps people convince themselves of program correctness because they know the functions they call are limited in how they can modify your variables. Helps people know what functions are safe to use without locks in multi-threaded programs.

`const` is viral: if you pass a `const` variable to a function, that function must have `const` in its prototype (or the variable will need a `const_cast`). This can be a particular problem when calling library functions.

`const` variables, data members, methods and arguments add a level of compile-time type checking; it is better to detect errors as soon as possible. Therefore we strongly recommend that you use `const` whenever it makes sense to do so:

- If a function guarantees that it will not modify an argument passed by reference or by pointer, the corresponding function parameter should be a reference-to-const (`const T&`) or pointer-to-const (`const T*`), respectively.
- Declare methods to be `const` whenever possible. Accessors should almost always be `const`. Other methods should be `const` if they do not modify any data members, do not call any non-`const` methods, and do not return a non-`const` pointer or non-`const` reference to a data member.
- Consider making data members `const` whenever they do not need to be modified after construction.

The `mutable` keyword is allowed but is unsafe when used with threads, so thread safety should be carefully considered first.

Where to put the `const`

Some people favor the form `int const *foo` to `const int* foo`. They argue that this is more readable because it's more consistent: it keeps the rule that `const` always follows the object it's describing. However, this consistency argument doesn't apply in codebases with few deeply-nested pointer expressions since most `const` expressions have only one `const`, and it applies to the underlying value. In such cases, there's no consistency to maintain. Putting the `const` first is arguably more readable, since it follows English in putting the "adjective" (`const`) before the "noun" (`int`).

That said, while we encourage putting `const` first, we do not require it. But be consistent with the code around you!

Use of `constexpr`

In C++11, use `constexpr` to define true constants or to ensure constant initialization.

Some variables can be declared `constexpr` to indicate the variables are true constants, i.e. fixed at compilation/link time. Some functions and constructors can be declared `constexpr` which enables them to be used in defining a `constexpr` variable.

Use of `constexpr` enables definition of constants with floating-point expressions rather than just literals; definition of constants of user-defined types; and definition of constants with function calls.

Prematurely marking something as `constexpr` may cause migration problems if later on it has to be downgraded. Current restrictions on what is allowed in `constexpr` functions and constructors may invite obscure workarounds in these definitions.

`constexpr` definitions enable a more robust specification of the constant parts of an interface. Use `constexpr` to specify true constants and the functions that support their definitions. Avoid complexifying function definitions to enable their use with `constexpr`. Do not use `constexpr` to force inlining.

Integer Types

Of the built-in C++ integer types, the only one used is `int`. If a program needs a variable of a different size, use a precise-width integer type from `<stdint.h>`, such as `int16_t`. If your variable represents a value that could ever be greater than or equal to 2^{31} (2GiB), use a 64-bit type such as `int64_t`. Keep in mind that even if your value won't ever be too large for an `int`, it may be used in intermediate calculations which may require a larger type. When in doubt, choose a larger type.

C++ does not specify the sizes of its integer types. Typically people assume that `short` is 16 bits, `int` is 32 bits, `long` is 32 bits and `long long` is 64 bits.

Uniformity of declaration.

The sizes of integral types in C++ can vary based on compiler and architecture.

`<stdint.h>` defines types like `int16_t`, `uint32_t`, `int64_t`, etc. You should always use those in preference to `short`, `unsigned long` and the like, when you need a guarantee on the size of an integer. Of the C integer types, only `int` should be used. When appropriate, you are welcome to use standard types like `size_t` and `ptrdiff_t`.

We use `int` very often, for integers we know are not going to be too big, e.g., loop counters. Use plain old `int` for such things. You should assume that an `int` is at least 32 bits, but don't assume that it has more than 32 bits. If you need a 64-bit integer type, use `int64_t` or `uint64_t`.

For integers we know can be "big", use `int64_t`.

You should not use the unsigned integer types such as `uint32_t`, unless there is a valid reason such as representing a bit pattern rather than a number, or you need defined overflow modulo 2^N . In particular, do not use unsigned types to say a number will never be negative. Instead, use assertions for this.

If your code is a container that returns a size, be sure to use a type that will accommodate any possible usage of your container. When in doubt, use a larger type rather than a smaller type.

Use care when converting integer types. Integer conversions and promotions can cause non-intuitive behavior.

On Unsigned Integers

Some people, including some textbook authors, recommend using unsigned types to represent numbers that are never negative. This is intended as a form of self-documentation. However, in C, the advantages of such documentation are outweighed by the real bugs it can introduce. Consider:

```
for (unsigned int i = foo.Length()-1; i >= 0; --i) ...
```

This code will never terminate! Sometimes gcc will notice this bug and warn you, but often it will not. Equally bad bugs can occur when comparing signed and unsigned variables. Basically, C's type-promotion scheme causes unsigned types to behave differently than one might expect.

So, document that a variable is non-negative using assertions. Don't use an unsigned type.

64-bit Portability

Code should be 64-bit and 32-bit friendly. Bear in mind problems of printing, comparisons, and structure alignment.

- `printf()` specifiers for some types are not cleanly portable between 32-bit and 64-bit systems. C99 defines some portable format specifiers. Unfortunately, MSVC 7.1 does not understand some of these specifiers and the standard is missing a few, so we have to define our own ugly versions in some cases (in the style of the standard include `fileinttypes.h`):

- `// printf macros for size_t, in the style of inttypes.h`
- `#ifdef _LP64`
- `#define __PRIS_PREFIX "z"`
- `#else`
- `#define __PRIS_PREFIX`
- `#endif`

-
- `// Use these macros after a % in a printf format string`
- `// to get correct 32/64 bit behavior, like this:`
- `// size_t size = records.size();`
- `// printf("%" PRIuS "\n", size);`
-
- `#define PRIdS __PRIS_PREFIX "d"`
- `#define PRIxS __PRIS_PREFIX "x"`
- `#define PRIuS __PRIS_PREFIX "u"`
- `#define PRIXS __PRIS_PREFIX "X"`
- `#define PRIoS __PRIS_PREFIX "o"`

Type	DO NOT use	DO
<code>void *</code> (or any pointer)	<code>%lx</code>	
<code>int64_t</code>	<code>%qd, %lld</code>	<code>%" PRIdS</code>
<code>uint64_t</code>	<code>%qu, %llu, %llx</code>	<code>%" PRIu64 "</code>
<code>size_t</code>	<code>%u</code>	<code>%" PRIuS "</code>
<code>ptrdiff_t</code>	<code>%d</code>	<code>%" PRIdS</code>

Note that the `PRI*` macros expand to independent strings which are concatenated by the compiler. Hence if you are using a non-constant format string, you need to insert the value of the macro into the format, rather than the name. Note also that spaces are required around the macro identifier to separate it from the string literal. It is still possible, as usual, to include length specifiers, etc., after the `%` when using the `PRI*` macros. So, e.g. `printf("x = %30" PRIuS "\n", x)` would expand on 32-bit Linux to `printf("x = %30" "u" "\n", x)`, which the compiler will treat as `printf("x = %30u\n", x)`.

- Remember that `sizeof(void *) != sizeof(int)`. Use `intptr_t` if you want a pointer-sized integer.
- You may need to be careful with structure alignments, particularly for structures being stored on disk. Any class/structure with a `int64_t/uint64_t` member will by default end up being 8-byte aligned on a 64-bit system. If you have such structures being shared on disk between 32-bit and 64-bit code, you will need to ensure that they are packed the same on both architectures. Most compilers offer a way to alter structure alignment. For gcc, you can use `__attribute__((packed))`. MSVC offers `#pragma pack()` and `__declspec(align())`.
- Use the `LL` or `ULL` suffixes as needed to create 64-bit constants. For example:

- `int64_t my_value = 0x123456789LL;`
- `uint64_t my_mask = 3ULL << 48;`

Avoid defining macros, especially in headers; prefer inline functions, enums, and `const` variables. Name macros with a project-specific prefix. Do not use macros to define pieces of a C++ API.

Macros mean that the code you see is not the same as the code the compiler sees. This can introduce unexpected behavior, especially since macros have global scope.

The problems introduced by macros are especially severe when they are used to define pieces of a C++ API, and still more so for public APIs. Every error message from the compiler when developers incorrectly use that interface now must explain how the macros formed the interface. Refactoring and analysis tools have a dramatically harder time updating the interface. As a consequence, we specifically disallow using macros in this way. For example, avoid patterns like:

```
class WOMBAT_TYPE(Foo) {  
    // ...  
  
public:  
    EXPAND_PUBLIC_WOMBAT_API(Foo)  
  
    EXPAND_WOMBAT_COMPARISONS(Foo, ==, <)  
};
```

Luckily, macros are not nearly as necessary in C++ as they are in C. Instead of using a macro to inline performance-critical code, use an inline function. Instead of using a macro to store a constant, use a `const` variable. Instead of using a macro to "abbreviate" a long variable name, use a reference. Instead of using a macro to conditionally compile code ... well, don't do that at all (except, of course, for the `#define` guards to prevent double inclusion of header files). It makes testing much more difficult.

Macros can do things these other techniques cannot, and you do see them in the codebase, especially in the lower-level libraries. And some of their special features (like stringifying, concatenation, and so forth) are not available through the language proper. But before using a macro, consider carefully whether there's a non-macro way to achieve the same result. If you need to use a macro to define an interface, contact your project leads to request a waiver of this rule.

The following usage pattern will avoid many problems with macros; if you use macros, follow it whenever possible:

- Don't define macros in a `.h` file.
- `#define` macros right before you use them, and `#undef` them right after.
- Do not just `#undef` an existing macro before replacing it with your own; instead, pick a name that's likely to be unique.
- Try not to use macros that expand to unbalanced C++ constructs, or at least document that behavior well.
- Prefer not using `##` to generate function/class/variable names.

Exporting macros from headers (i.e. defining them in a header without `#undef`ing them before the end of the header) is extremely strongly discouraged. If you do export a macro from a header, it must have a globally unique name. To achieve this, it must be named with a prefix consisting of your project's namespace name (but upper case).

0 and nullptr/NULL

Use `0` for integers, `0.0` for reals, `nullptr` (or `NULL`) for pointers, and `'\0'` for chars.

Use `0` for integers and `0.0` for reals. This is not controversial.

For pointers (address values), there is a choice between `0`, `NULL`, and `nullptr`. For projects that allow C++11 features, use `nullptr`. For C++03 projects, we prefer `NULL` because it looks like a pointer. In fact, some C++ compilers provide special definitions of `NULL` which enable them to give useful warnings, particularly in situations where `sizeof(NULL)` is not equal to `sizeof(0)`.

Use `'\0'` for chars. This is the correct type and also makes code more readable.

sizeof

Prefer `sizeof(varname)` to `sizeof(type)`.

Use `sizeof(varname)` when you take the size of a particular variable. `sizeof(varname)` will update appropriately if someone changes the variable type either now or later. You may use `sizeof(type)` for code unrelated to any particular variable, such as code that manages an external or internal data format where a variable of an appropriate C++ type is not convenient.

```
Struct data;
memset(&data, 0, sizeof(data));

memset(&data, 0, sizeof(Struct));

if (raw_size < sizeof(int)) {
    LOG(ERROR) << "compressed record not big enough for count: " << raw_size;
    return false;
}
```

auto

Use `auto` to avoid type names that are noisy, obvious, or unimportant - cases where the type doesn't aid in clarity for the reader. Continue to use manifest type declarations when it helps readability.

- C++ type names can be long and cumbersome, especially when they involve templates or namespaces.
- When a C++ type name is repeated within a single declaration or a small code region, the repetition may not be aiding readability.
- It is sometimes safer to let the type be specified by the type of the initialization expression, since that avoids the possibility of unintended copies or type conversions.

Sometimes code is clearer when types are manifest, especially when a variable's initialization depends on things that were declared far away. In expressions like:

```
auto foo = x.add_foo();
auto i = y.Find(key);
```

it may not be obvious what the resulting types are if the type of `y` isn't very well known, or if `y` was declared many lines earlier.

Programmers have to understand the difference between `auto` and `const auto&` or they'll get copies when they didn't mean to.

If an `auto` variable is used as part of an interface, e.g. as a constant in a header, then a programmer might change its type while only intending to change its value, leading to a more radical API change than intended.

`auto` is permitted when it increases readability, particularly as described below. Never initialize an `auto`-typed variable with a braced initializer list.

Specific cases where `auto` is allowed or encouraged:

- (Encouraged) For iterators and other long/clutterly type names, particularly when the type is clear from context (calls to `find`, `begin`, or `end` for instance).
- (Allowed) When the type is clear from local context (in the same expression or within a few lines). Initialization of a pointer or smart pointer with calls to `new` commonly falls into this category, as does use of `auto` in a range-based loop over a container whose type is spelled out nearby.
- (Allowed) When the type doesn't matter because it isn't being used for anything other than equality comparison.
- (Encouraged) When iterating over a map with a range-based loop (because it is often assumed that the correct type is `std::pair<KeyType, ValueType>` whereas it is actually `std::pair<const KeyType, ValueType>`). This is particularly well paired with local `key` and `value` aliases for `.first` and `.second` (often `const-ref`).

```
• for (const auto& item : some_map) {  
•     const KeyType& key = item.first;  
•     const ValType& value = item.second;  
•     // The rest of the loop can now just refer to key and value,  
•     // a reader can see the types in question, and we've avoided  
•     // the too-common case of extra copies in this iteration.  
• }
```

Braced Initializer List⁰⁰

You may use braced initializer lists.

In C++03, aggregate types (arrays and structs with no constructor) could be initialized with braced initializer lists.

```
struct Point { int x; int y; };  
Point p = {1, 2};
```

In C++11, this syntax was generalized, and any object type can now be created with a braced initializer list, known as a *braced-init-list* in the C++ grammar. Here are a few examples of its use.

```
// Vector takes a braced-init-list of elements.  
std::vector<string> v{"foo", "bar"};
```

```
// Basically the same, ignoring some small technicalities.
// You may choose to use either form.
std::vector<string> v = {"foo", "bar"};

// Usable with 'new' expressions.
auto p = new vector<string>{"foo", "bar"};

// A map can take a list of pairs. Nested braced-init-lists work.
std::map<int, string> m = {{1, "one"}, {2, "2"}};

// A braced-init-list can be implicitly converted to a return type.
std::vector<int> test_function() { return {1, 2, 3}; }

// Iterate over a braced-init-list.
for (int i : {-1, -2, -3}) {}

// Call a function using a braced-init-list.
void TestFunction2(std::vector<int> v) {}
TestFunction2({1, 2, 3});
```

A user-defined type can also define a constructor and/or assignment operator that take `std::initializer_list<T>`, which is automatically created from *braced-init-list*:

```
class MyType {
public:
    // std::initializer_list references the underlying init list.
    // It should be passed by value.
    MyType(std::initializer_list<int> init_list) {
        for (int i : init_list) append(i);
    }
    MyType& operator=(std::initializer_list<int> init_list) {
        clear();
        for (int i : init_list) append(i);
    }
};
MyType m{2, 3, 5, 7};
```

Finally, brace initialization can also call ordinary constructors of data types, even if they do not have `std::initializer_list<T>` constructors.

```
double d{1.23};
// Calls ordinary constructor as long as MyOtherType has no
// std::initializer_list constructor.
class MyOtherType {
public:
    explicit MyOtherType(string);
```

```

    MyOtherType(int, string);
};
MyOtherType m = {1, "b"};
// If the constructor is explicit, you can't use the "= {}" form.
MyOtherType m{"b"};

```

Never assign a *braced-init-list* to an auto local variable. In the single element case, what this means can be confusing.

```

auto d = {1.23};           // d is a std::initializer_list<double>

auto d = double{1.23};    // Good -- d is a double, not a std::initializer_list.

```

See [Braced Initializer List Format](#) for formatting.

Lambda expressions

Use lambda expressions where appropriate. Prefer explicit captures when the lambda will escape the current scope.

Lambda expressions are a concise way of creating anonymous function objects. They're often useful when passing functions as arguments. For example:

```

std::sort(v.begin(), v.end(), [](int x, int y) {
    return Weight(x) < Weight(y);
});

```

They further allow capturing variables from the enclosing scope either explicitly by name, or implicitly using a default capture. Explicit captures require each variable to be listed, as either a value or reference capture:

```

int weight = 3;
int sum = 0;
// Captures `weight` by value and `sum` by reference.
std::for_each(v.begin(), v.end(), [weight, &sum](int x) {
    sum += weight * x;
});

```

Default captures implicitly capture any variable referenced in the lambda body, including `this` if any members are used:

```

const std::vector<int> lookup_table = ...;
std::vector<int> indices = ...;
// Captures `lookup_table` by reference, sorts `indices` by the value
// of the associated element in `lookup_table`.
std::sort(indices.begin(), indices.end(), [&](int a, int b) {
    return lookup_table[a] < lookup_table[b];
});

```

Lambdas were introduced in C++11 along with a set of utilities for working with function objects, such as the polymorphic wrapper `std::function`.

- Lambdas are much more concise than other ways of defining function objects to be passed to STL algorithms, which can be a readability improvement.
- Appropriate use of default captures can remove redundancy and highlight important exceptions from the default.
- Lambdas, `std::function`, and `std::bind` can be used in combination as a general purpose callback mechanism; they make it easy to write functions that take bound functions as arguments.
- Variable capture in lambdas can be a source of dangling-pointer bugs, particularly if a lambda escapes the current scope.
- Default captures by value can be misleading because they do not prevent dangling-pointer bugs. Capturing a pointer by value doesn't cause a deep copy, so it often has the same lifetime issues as capture by reference. This is especially confusing when capturing 'this' by value, since the use of 'this' is often implicit.
- It's possible for use of lambdas to get out of hand; very long nested anonymous functions can make code harder to understand.
- Use lambda expressions where appropriate, with formatting as described [below](#).
- Prefer explicit captures if the lambda may escape the current scope. For example, instead of:

```
• {
•   Foo foo;
•   ...
•   executor->Schedule([&] { Frobnicate(foo); })
•   ...
• }
• // BAD! The fact that the lambda makes use of a reference to `foo` and
• // possibly `this` (if `Frobnicate` is a member function) may not be
• // apparent on a cursory inspection. If the lambda is invoked after
• // the function returns, that would be bad, because both `foo`
• // and the enclosing object could have been destroyed.
```

prefer to write:

```
{
  Foo foo;
  ...
  executor->Schedule([&foo] { Frobnicate(foo); })
  ...
}
// BETTER - The compile will fail if `Frobnicate` is a member
// function, and it's clearer that `foo` is dangerously captured by
// reference.
```

- Use default capture by reference (`&`) only when the lifetime of the lambda is obviously shorter than any potential captures.

- Use default capture by value (`[=]`) only as a means of binding a few variables for a short lambda, where the set of captured variables is obvious at a glance. Prefer not to write long or complex lambdas with default capture by value.
- Keep unnamed lambdas short. If a lambda body is more than maybe five lines long, prefer to give the lambda a name, or to use a named function instead of a lambda.
- Specify the return type of the lambda explicitly if that will make it more obvious to readers, as with [auto](#).

Template metaprogramming

Avoid complicated template programming.

Template metaprogramming refers to a family of techniques that exploit the fact that the C++ template instantiation mechanism is Turing complete and can be used to perform arbitrary compile-time computation in the type domain.

Template metaprogramming allows extremely flexible interfaces that are type safe and high performance. Facilities like [Google Test](#), `std::tuple`, `std::function`, and `Boost.Spirit` would be impossible without it.

The techniques used in template metaprogramming are often obscure to anyone but language experts. Code that uses templates in complicated ways is often unreadable, and is hard to debug or maintain.

Template metaprogramming often leads to extremely poor compiler time error messages: even if an interface is simple, the complicated implementation details become visible when the user does something wrong.

Template metaprogramming interferes with large scale refactoring by making the job of refactoring tools harder. First, the template code is expanded in multiple contexts, and it's hard to verify that the transformation makes sense in all of them. Second, some refactoring tools work with an AST that only represents the structure of the code after template expansion. It can be difficult to automatically work back to the original source construct that needs to be rewritten.

Template metaprogramming sometimes allows cleaner and easier-to-use interfaces than would be possible without it, but it's also often a temptation to be overly clever. It's best used in a small number of low level components where the extra maintenance burden is spread out over a large number of uses.

Think twice before using template metaprogramming or other complicated template techniques; think about whether the average member of your team will be able to understand your code well enough to maintain it after you switch to another project, or whether a non-C++ programmer or someone casually browsing the code base will be able to understand the error messages or trace the flow of a function they want to call. If you're using recursive template instantiations or type lists or metafunctions or expression templates, or relying on SFINAE or on the `sizeof` trick for detecting function overload resolution, then there's a good chance you've gone too far.

If you use template metaprogramming, you should expect to put considerable effort into minimizing and isolating the complexity. You should hide metaprogramming as an implementation detail whenever possible, so that user-facing headers are readable, and you should make sure that tricky code is especially well commented. You should carefully document how the code is used, and you should say something about what the "generated" code looks like. Pay extra attention to the error messages that the compiler emits when users make mistakes. The error messages are part of your user interface, and your code should be tweaked as necessary so that the error messages are understandable and actionable from a user point of view.

Use only approved libraries from the Boost library collection.

The [Boost library collection](#) is a popular collection of peer-reviewed, free, open-source C++ libraries.

Boost code is generally very high-quality, is widely portable, and fills many important gaps in the C++ standard library, such as type traits and better binders.

Some Boost libraries encourage coding practices which can hamper readability, such as metaprogramming and other advanced template techniques, and an excessively "functional" style of programming.

In order to maintain a high level of readability for all contributors who might read and maintain code, we only allow an approved subset of Boost features. Currently, the following libraries are permitted:

- [Call Traits](#) from `boost/call_traits.hpp`
- [Compressed Pair](#) from `boost/compressed_pair.hpp`
- [The Boost Graph Library \(BGL\)](#) from `boost/graph`, except serialization (`adj_list_serialize.hpp`) and parallel/distributed algorithms and data structures (`boost/graph/parallel/*` and `boost/graph/distributed/*`).
- [Property Map](#) from `boost/property_map`, except parallel/distributed property maps (`boost/property_map/parallel/*`).
- [Iterator](#) from `boost/iterator`
- The part of [Polygon](#) that deals with Voronoi diagram construction and doesn't depend on the rest of Polygon: `boost/polygon/voronoi_builder.hpp`, `boost/polygon/voronoi_diagram.hpp`, and `boost/polygon/voronoi_geometry_type.hpp`
- [Bimap](#) from `boost/bimap`
- [Statistical Distributions and Functions](#) from `boost/math/distributions`
- [Special Functions](#) from `boost/math/special_functions`
- [Multi-index](#) from `boost/multi_index`
- [Heap](#) from `boost/heap`
- The flat containers from [Container](#): `boost/container/flat_map`, and `boost/container/flat_set`
- [Intrusive](#) from `boost/intrusive`.
- [The boost/sort library](#).
- [Preprocessor](#) from `boost/preprocessor`.

We are actively considering adding other Boost features to the list, so this list may be expanded in the future.

The following libraries are permitted, but their use is discouraged because they've been superseded by standard libraries in C++11:

- [Array](#) from `boost/array.hpp`: use `std::array` instead.
- [Pointer Container](#) from `boost/ptr_container`: use containers of `std::unique_ptr` instead.

`std::hash`

Do not define specializations of `std::hash`.

`std::hash<T>` is the function object that the C++11 hash containers use to hash keys of type `T`, unless the user explicitly specifies a different hash function. For example, `std::unordered_map<int, string>` is a hash map

that uses `std::hash<int>` to hash its keys, whereas `std::unordered_map<int, string, MyIntHash>` uses `MyIntHash`.

`std::hash` is defined for all integral, floating-point, pointer, and `enum` types, as well as some standard library types such as `string` and `unique_ptr`. Users can enable it to work for their own types by defining specializations of it for those types.

`std::hash` is easy to use, and simplifies the code since you don't have to name it explicitly.

Specializing `std::hash` is the standard way of specifying how to hash a type, so it's what outside resources will teach, and what new engineers will expect.

`std::hash` is hard to specialize. It requires a lot of boilerplate code, and more importantly, it combines responsibility for identifying the hash inputs with responsibility for executing the hashing algorithm itself. The type author has to be responsible for the former, but the latter requires expertise that a type author usually doesn't have, and shouldn't need. The stakes here are high because low-quality hash functions can be security vulnerabilities, due to the emergence of [hash flooding attacks](#).

Even for experts, `std::hash` specializations are inordinately difficult to implement correctly for compound types, because the implementation cannot recursively call `std::hash` on data members. High-quality hash algorithms maintain large amounts of internal state, and reducing that state to the `size_t` bytes that `std::hash` returns is usually the slowest part of the computation, so it should not be done more than once.

Due to exactly that issue, `std::hash` does not work with `std::pair` or `std::tuple`, and the language does not allow us to extend it to support them.

You can use `std::hash` with the types that it supports "out of the box", but do not specialize it to support additional types. If you need a hash table with a key type that `std::hash` does not support, consider using legacy hash containers (e.g. `hash_map`) for now; they use a different default hasher, which is unaffected by this prohibition.

If you want to use the standard hash containers anyway, you will need to specify a custom hasher for the key type, e.g.

```
std::unordered_map<MyKeyType, Value, MyKeyTypeHasher> my_map;
```

Consult with the type's owners to see if there is an existing hasher that you can use; otherwise work with them to provide one, or roll your own.

We are planning to provide a hash function that can work with any type, using a new customization mechanism that doesn't have the drawbacks of `std::hash`.

C++11

Use libraries and language extensions from C++11 when appropriate. Consider portability to other environments before using C++11 features in your project.

C++11 contains [significant changes](#) both to the language and libraries.

C++11 was the official standard until August 2014, and is supported by most C++ compilers. It standardizes some common C++ extensions that we use already, allows shorthands for some operations, and has some performance and safety improvements.

The C++11 standard is substantially more complex than its predecessor (1,300 pages versus 800 pages), and is unfamiliar to many developers. The long-term effects of some features on code readability and maintenance are unknown. We cannot predict when its various features will be implemented uniformly by tools that may be of interest, particularly in the case of projects that are forced to use older versions of tools.

As with [Boost](#), some C++11 extensions encourage coding practices that hamper readability—for example by removing checked redundancy (such as type names) that may be helpful to readers, or by encouraging template metaprogramming. Other extensions duplicate functionality available through existing mechanisms, which may lead to confusion and conversion costs.

C++11 features may be used unless specified otherwise. In addition to what's described in the rest of the style guide, the following C++11 features may not be used:

- Compile-time rational numbers (`<ratio>`), because of concerns that it's tied to a more template-heavy interface style.
- The `<cfenv>` and `<fenv.h>` headers, because many compilers do not support those features reliably.
- Ref-qualifiers on member functions, such as `void X::Foo() &` or `void X::Foo() &&`, because of concerns that they're an overly obscure feature.

Nonstandard Extensions

Nonstandard extensions to C++ may not be used unless otherwise specified.

Compilers support various extensions that are not part of standard C++. Such extensions include GCC's `__attribute__`, intrinsic functions such as `__builtin_prefetch`, designated initializers (e.g. `Foo f = { .field = 3 }`), inline assembly, `__COUNTER__`, `__PRETTY_FUNCTION__`, compound statement expressions (e.g. `foo = ({ int x; Bar(&x); x })`), variable-length arrays and `alloca()`, and the `a?:b` syntax.

- Nonstandard extensions may provide useful features that do not exist in standard C++. For example, some people think that designated initializers are more readable than standard C++ features like constructors.
- Important performance guidance to the compiler can only be specified using extensions.
- Nonstandard extensions do not work in all compilers. Use of nonstandard extensions reduces portability of code.
- Even if they are supported in all targeted compilers, the extensions are often not well-specified, and there may be subtle behavior differences between compilers.
- Nonstandard extensions add to the language features that a reader must know to understand the code.

Do not use nonstandard extensions. You may use portability wrappers that are implemented using nonstandard extensions, so long as those wrappers are provided by a designated project-wide portability header.

Aliases

Public aliases are for the benefit of an API's user, and should be clearly documented.

There are several ways to create names that are aliases of other entities:

```
typedef Foo Bar;  
using Bar = Foo;  
using other_namespace::Foo;
```

Like other declarations, aliases declared in a header file are part of that header's public API unless they're in a function definition, in the private portion of a class, or in an explicitly-marked internal namespace. Aliases in such areas or in .cc files are implementation details (because client code can't refer to them), and are not restricted by this rule.

- Aliases can improve readability by simplifying a long or complicated name.
- Aliases can reduce duplication by naming in one place a type used repeatedly in an API, which *might* make it easier to change the type later.
- When placed in a header where client code can refer to them, aliases increase the number of entities in that header's API, increasing its complexity.
- Clients can easily rely on unintended details of public aliases, making changes difficult.
- It can be tempting to create a public alias that is only intended for use in the implementation, without considering its impact on the API, or on maintainability.
- Aliases can create risk of name collisions
- Aliases can reduce readability by giving a familiar construct an unfamiliar name
- Type aliases can create an unclear API contract: it is unclear whether the alias is guaranteed to be identical to the type it aliases, to have the same API, or only to be usable in specified narrow ways

Don't put an alias in your public API just to save typing in the implementation; do so only if you intend it to be used by your clients.

When defining a public alias, document the intent of the new name, including whether it is guaranteed to always be the same as the type it's currently aliased to, or whether a more limited compatibility is intended. This lets the user know whether they can treat the types as substitutable or whether more specific rules must be followed, and can help the implementation retain some degree of freedom to change the alias.

Don't put namespace aliases in your public API. (See also [Namespaces](#)).

For example, these aliases document how they are intended to be used in client code:

```
namespace a {  
// Used to store field measurements. DataPoint may change from Bar* to some internal  
type.  
// Client code should treat it as an opaque pointer.  
using DataPoint = foo::bar::Bar*;  
  
// A set of measurements. Just an alias for user convenience.  
using TimeSeries = std::unordered_set<DataPoint, std::hash<DataPoint>,  
DataPointComparator>;  
} // namespace a
```

These aliases don't document intended use, and half of them aren't meant for client use:

```
namespace a {  
// Bad: none of these say how they should be used.  
using DataPoint = foo::bar::Bar*;  
using std::unordered_set; // Bad: just for local convenience  
using std::hash;          // Bad: just for local convenience  
typedef unordered_set<DataPoint, hash<DataPoint>, DataPointComparator> TimeSeries;  
} // namespace a
```

However, local convenience aliases are fine in function definitions, private sections of classes, explicitly marked internal namespaces, and in .cc files:

```
// In a .cc file  
using std::unordered_set;
```

Naming

The most important consistency rules are those that govern naming. The style of a name immediately informs us what sort of thing the named entity is: a type, a variable, a function, a constant, a macro, etc., without requiring us to search for the declaration of that entity. The pattern-matching engine in our brains relies a great deal on these naming rules.

Naming rules are pretty arbitrary, but we feel that consistency is more important than individual preferences in this area, so regardless of whether you find them sensible or not, the rules are the rules.

General Naming Rules

Names should be descriptive; avoid abbreviation.

Give as descriptive a name as possible, within reason. Do not worry about saving horizontal space as it is far more important to make your code immediately understandable by a new reader. Do not use abbreviations that are ambiguous or unfamiliar to readers outside your project, and do not abbreviate by deleting letters within a word.

```
int price_count_reader; // No abbreviation.  
int num_errors;         // "num" is a widespread convention.  
int num_dns_connections; // Most people know what "DNS" stands for.
```

```
int n; // Meaningless.  
int nerr; // Ambiguous abbreviation.  
int n_comp_conns; // Ambiguous abbreviation.  
int wgc_connections; // Only your group knows what this stands for.  
int pc_reader; // Lots of things can be abbreviated "pc".  
int cstmr_id; // Deletes internal letters.
```

Note that certain universally-known abbreviations are OK, such as `i` for an iteration variable and `T` for a template parameter.

Template parameters should follow the naming style for their category: type template parameters should follow the rules for [type names](#), and non-type template parameters should follow the rules for [variable names](#).

File Names^{CC}

Filenames should be all lowercase and can include underscores (`_`) or dashes (`-`). Follow the convention that your project uses. If there is no consistent local pattern to follow, prefer `"_"`.

Examples of acceptable file names:

- `my_useful_class.cc`
- `my-useful-class.cc`
- `myusefulclass.cc`
- `myusefulclass_test.cc` // `_unittest` and `_regtest` are deprecated.

C++ files should end in `.cc` and header files should end in `.h`. Files that rely on being textually included at specific points should end in `.inc` (see also the section on [self-contained headers](#)).

Do not use filenames that already exist in `/usr/include`, such as `db.h`.

In general, make your filenames very specific. For example, use `http_server_logs.h` rather than `logs.h`. A very common case is to have a pair of files called, e.g., `foo_bar.h` and `foo_bar.cc`, defining a class called `FooBar`.

Inline functions must be in a `.h` file. If your inline functions are very short, they should go directly into your `.h` file.

Type Names^{CC}

Type names start with a capital letter and have a capital letter for each new word, with no underscores: `MyExcitingClass`, `MyExcitingEnum`.

The names of all types — classes, structs, type aliases, enums, and type template parameters — have the same naming convention. Type names should start with a capital letter and have a capital letter for each new word. No underscores. For example:

```
// classes and structs
class UrlTable { ...
class UrlTableTester { ...
struct UrlTableProperties { ...

// typedefs
typedef hash_map<UrlTableProperties *, string> PropertiesMap;

// using aliases
using PropertiesMap = hash_map<UrlTableProperties *, string>;

// enums
enum UrlTableErrors { ...
```

Variable Names^{ad}

The names of variables (including function parameters) and data members are all lowercase, with underscores between words. Data members of classes (but not structs) additionally have trailing underscores. For instance: `a_local_variable`, `a_struct_data_member`, `a_class_data_member_`.

Common Variable names

For example:

```
string table_name;  // OK - uses underscore.
string tablename;   // OK - all lowercase.

string tableName;   // Bad - mixed case.
```

Class Data Members

Data members of classes, both static and non-static, are named like ordinary nonmember variables, but with a trailing underscore.

```
class TableInfo {
    ...
private:
    string table_name_; // OK - underscore at end.
    string tablename_;  // OK.
    static Pool<TableInfo>* pool_; // OK.
};
```

Struct Data Members

Data members of structs, both static and non-static, are named like ordinary nonmember variables. They do not have the trailing underscores that data members in classes have.

```
struct UrlTableProperties {
    string name;
    int num_entries;
    static Pool<UrlTableProperties>* pool;
};
```

See [Structs vs. Classes](#) for a discussion of when to use a struct versus a class.

Constant Names^{ad}

Variables declared `constexpr` or `const`, and whose value is fixed for the duration of the program, are named with a leading "k" followed by mixed case. For example:


```
const int kDaysInAWeek = 7;
```

All such variables with static storage duration (i.e. statics and globals, see [Storage Duration](#) for details) should be named this way. This convention is optional for variables of other storage classes, e.g. automatic variables, otherwise the usual variable naming rules apply.

Function Names

Regular functions have mixed case; accessors and mutators may be named like variables.

Ordinarily, functions should start with a capital letter and have a capital letter for each new word (a.k.a. "[Camel Case](#)" or "Pascal case"). Such names should not have underscores. Prefer to capitalize acronyms as single words (i.e. `StartRpc()`, not `StartRPC()`).

```
AddTableEntry()  
DeleteUrl()  
OpenFileOrDie()
```

(The same naming rule applies to class- and namespace-scope constants that are exposed as part of an API and that are intended to look like functions, because the fact that they're objects rather than functions is an unimportant implementation detail.)

Accessors and mutators (get and set functions) may be named like variables. These often correspond to actual member variables, but this is not required. For example, `int count()` and `void set_count(int count)`.

Namespace Names

Namespace names are all lower-case. Top-level namespace names are based on the project name. Avoid collisions between nested namespaces and well-known top-level namespaces.

The name of a top-level namespace should usually be the name of the project or team whose code is contained in that namespace. The code in that namespace should usually be in a directory whose basename matches the namespace name (or subdirectories thereof).

Keep in mind that the [rule against abbreviated names](#) applies to namespaces just as much as variable names. Code inside the namespace seldom needs to mention the namespace name, so there's usually no particular need for abbreviation anyway.

Avoid nested namespaces that match well-known top-level namespaces. Collisions between namespace names can lead to surprising build breaks because of name lookup rules. In particular, do not create any nested `std` namespaces. Prefer unique project identifiers (`websearch::index`, `websearch::index_util`) over collision-prone names like `websearch::util`.

For `internal` namespaces, be wary of other code being added to the same `internal` namespace causing a collision (internal helpers within a team tend to be related and may lead to collisions). In such a situation, using the filename to make a unique internal name is helpful (`websearch::index::frobber_internal` for use in `frobber.h`).

Enumerator Names^{GD}

Enumerators (for both scoped and unscoped enums) should be named *either* like [constants](#) or like [macros](#): either `kEnumName` or `ENUM_NAME`.

Preferably, the individual enumerators should be named like [constants](#). However, it is also acceptable to name them like [macros](#). The enumeration name, `UrlTableErrors` (and `AlternateUrlTableErrors`), is a type, and therefore mixed case.

```
enum UrlTableErrors {
    kOK = 0,
    kErrorOutOfMemory,
    kErrorMalformedInput,
};
enum AlternateUrlTableErrors {
    OK = 0,
    OUT_OF_MEMORY = 1,
    MALFORMED_INPUT = 2,
};
```

Until January 2009, the style was to name enum values like [macros](#). This caused problems with name collisions between enum values and macros. Hence, the change to prefer constant-style naming was put in place. New code should prefer constant-style naming if possible. However, there is no reason to change old code to use constant-style names, unless the old names are actually causing a compile-time problem.

Macro Names^{GD}

You're not really going to [define a macro](#), are you? If you do, they're like this: `MY_MACRO_THAT_SCARES_SMALL_CHILDREN`.

Please see the [description of macros](#); in general macros should *not* be used. However, if they are absolutely needed, then they should be named with all capitals and underscores.

```
#define ROUND(x) ...
#define PI_ROUNDED 3.0
```

Exceptions to Naming Rules^{GD}

If you are naming something that is analogous to an existing C or C++ entity then you can follow the existing naming convention scheme.

```
bigopen()
    function name, follows form of open()
uint
    typedef
```

`bigpos`

`struct` or `class`, follows form of `pos`

`sparse_hash_map`

STL-like entity; follows STL naming conventions

`LONG_LONG_MAX`

a constant, as in `INT_MAX`

Comments

Though a pain to write, comments are absolutely vital to keeping our code readable. The following rules describe what you should comment and where. But remember: while comments are very important, the best code is self-documenting. Giving sensible names to types and variables is much better than using obscure names that you must then explain through comments.

When writing your comments, write for your audience: the next contributor who will need to understand your code. Be generous — the next one may be you!

Comment Style

Use either the `//` or `/* */` syntax, as long as you are consistent.

You can use either the `//` or the `/* */` syntax; however, `//` is *much* more common. Be consistent with how you comment and what style you use where.

File Comments

Start each file with license boilerplate.

File comments describe the contents of a file. If a file declares, implements, or tests exactly one abstraction that is documented by a comment at the point of declaration, file comments are not required. All other files must have file comments.

Legal Notice and Author Line

Every file should contain license boilerplate. Choose the appropriate boilerplate for the license used by the project (for example, Apache 2.0, BSD, LGPL, GPL).

If you make significant changes to a file with an author line, consider deleting the author line.

File Contents

If a `.h` declares multiple abstractions, the file-level comment should broadly describe the contents of the file, and how the abstractions are related. A 1 or 2 sentence file-level comment may be sufficient. The detailed documentation about individual abstractions belongs with those abstractions, not at the file level.

Do not duplicate comments in both the `.h` and the `.cc`. Duplicated comments diverge.

Class Comments

Every non-obvious class declaration should have an accompanying comment that describes what it is for and how it should be used.

```
// Iterates over the contents of a GargantuanTable.
// Example:
//     GargantuanTableIterator* iter = table->NewIterator();
//     for (iter->Seek("foo"); !iter->done(); iter->Next()) {
//         process(iter->key(), iter->value());
//     }
//     delete iter;
class GargantuanTableIterator {
    ...
};
```

The class comment should provide the reader with enough information to know how and when to use the class, as well as any additional considerations necessary to correctly use the class. Document the synchronization assumptions the class makes, if any. If an instance of the class can be accessed by multiple threads, take extra care to document the rules and invariants surrounding multithreaded use.

The class comment is often a good place for a small example code snippet demonstrating a simple and focused usage of the class.

When sufficiently separated (e.g. `.h` and `.cc` files), comments describing the use of the class should go together with its interface definition; comments about the class operation and implementation should accompany the implementation of the class's methods.

Function Comments

Declaration comments describe use of the function (when it is non-obvious); comments at the definition of a function describe operation.

Function Declarations

Almost every function declaration should have comments immediately preceding it that describe what the function does and how to use it. These comments may be omitted only if the function is simple and obvious (e.g. simple accessors for obvious properties of the class). These comments should be descriptive ("Opens the file") rather than imperative ("Open the file"); the comment describes the function, it does not tell the function what to do. In general, these comments do not describe how the function performs its task. Instead, that should be left to comments in the function definition.

Types of things to mention in comments at the function declaration:

- What the inputs and outputs are.
- For class member functions: whether the object remembers reference arguments beyond the duration of the method call, and whether it will free them or not.

- If the function allocates memory that the caller must free.
- Whether any of the arguments can be a null pointer.
- If there are any performance implications of how a function is used.
- If the function is re-entrant. What are its synchronization assumptions?

Here is an example:

```
// Returns an iterator for this table.  It is the client's
// responsibility to delete the iterator when it is done with it,
// and it must not use the iterator once the GargantuanTable object
// on which the iterator was created has been deleted.
//
// The iterator is initially positioned at the beginning of the table.
//
// This method is equivalent to:
//   Iterator* iter = table->NewIterator();
//   iter->Seek("");
//   return iter;
// If you are going to immediately seek to another place in the
// returned iterator, it will be faster to use NewIterator()
// and avoid the extra seek.
Iterator* GetIterator() const;
```

However, do not be unnecessarily verbose or state the completely obvious. Notice below that it is not necessary to say "returns false otherwise" because this is implied.

```
// Returns true if the table cannot hold any more entries.
bool IsTableFull();
```

When documenting function overrides, focus on the specifics of the override itself, rather than repeating the comment from the overridden function. In many of these cases, the override needs no additional documentation and thus no comment is required.

When commenting constructors and destructors, remember that the person reading your code knows what constructors and destructors are for, so comments that just say something like "destroys this object" are not useful. Document what constructors do with their arguments (for example, if they take ownership of pointers), and what cleanup the destructor does. If this is trivial, just skip the comment. It is quite common for destructors not to have a header comment.

Function Definitions

If there is anything tricky about how a function does its job, the function definition should have an explanatory comment. For example, in the definition comment you might describe any coding tricks you use, give an overview of the steps you go through, or explain why you chose to implement the function in the way you did rather than using a viable alternative. For instance, you might mention why it must acquire a lock for the first half of the function but why it is not needed for the second half.

Note you should *not* just repeat the comments given with the function declaration, in the `.h` file or wherever. It's okay to recapitulate briefly what the function does, but the focus of the comments should be on how it does it.

Variable Comments

In general the actual name of the variable should be descriptive enough to give a good idea of what the variable is used for. In certain cases, more comments are required.

Class Data Members

The purpose of each class data member (also called an instance variable or member variable) must be clear. If there are any invariants (special values, relationships between members, lifetime requirements) not clearly expressed by the type and name, they must be commented. However, if the type and name suffice (`int num_events_;`), no comment is needed.

In particular, add comments to describe the existence and meaning of sentinel values, such as `nullptr` or `-1`, when they are not obvious. For example:

```
private:
    // Used to bounds-check table accesses. -1 means
    // that we don't yet know how many entries the table has.
    int num_total_entries_;
```

Global Variables

All global variables should have a comment describing what they are, what they are used for, and (if unclear) why it needs to be global. For example:

```
// The total number of tests cases that we run through in this regression test.
const int kNumTestCases = 6;
```

Implementation Comments

In your implementation you should have comments in tricky, non-obvious, interesting, or important parts of your code.

Explanatory Comments

Tricky or complicated code blocks should have comments before them. Example:

```
// Divide result by two, taking into account that x
// contains the carry from the add.
for (int i = 0; i < result->size(); i++) {
    x = (x << 8) + (*result)[i];
    (*result)[i] = x >> 1;
    x &= 1;
```

```
}
```

Line Comments

Also, lines that are non-obvious should get a comment at the end of the line. These end-of-line comments should be separated from the code by 2 spaces. Example:

```
// If we have enough memory, mmap the data portion too.
mmap_budget = max<int64>(0, mmap_budget - index_>length());
if (mmap_budget >= data_size_ && !MmapData(mmap_chunk_bytes, mlock))
    return; // Error already logged.
```

Note that there are both comments that describe what the code is doing, and comments that mention that an error has already been logged when the function returns.

If you have several comments on subsequent lines, it can often be more readable to line them up:

```
DoSomething(); // Comment here so the comments line up.
DoSomethingElseThatIsLonger(); // Two spaces between the code and the comment.
{ // One space before comment when opening a new scope is allowed,
  // thus the comment lines up with the following comments and code.
  DoSomethingElse(); // Two spaces before line comments normally.
}
std::vector<string> list{
    // Comments in braced lists describe the next element...
    "First item",
    // .. and should be aligned appropriately.
    "Second item"};
DoSomething(); /* For trailing block comments, one space is fine. */
```

Function Argument Comments

When the meaning of a function argument is nonobvious, consider one of the following remedies:

- If the argument is a literal constant, and the same constant is used in multiple function calls in a way that tacitly assumes they're the same, you should use a named constant to make that constraint explicit, and to guarantee that it holds.
- Consider changing the function signature to replace a `bool` argument with an `enum` argument. This will make the argument values self-describing.
- For functions that have several configuration options, consider defining a single class or struct to hold all the options, and pass an instance of that. This approach has several advantages. Options are referenced by name at the call site, which clarifies their meaning. It also reduces function argument count, which makes function calls easier to read and write. As an added benefit, you don't have to change call sites when you add another option.
- Replace large or complex nested expressions with named variables.
- As a last resort, use comments to clarify argument meanings at the call site.

Consider the following example:

```
// What are these arguments?  
const DecimalNumber product = CalculateProduct(values, 7, false, nullptr);
```

versus:

```
ProductOptions options;  
options.set_precision_decimals(7);  
options.set_use_cache(ProductOptions::kDontUseCache);  
const DecimalNumber product =  
    CalculateProduct(values, options, /*completion_callback=*/nullptr);
```

Don'ts

Do not state the obvious. In particular, don't literally describe what code does, unless the behavior is nonobvious to a reader who understands C++ well. Instead, provide higher level comments that describe *why* the code does what it does, or make the code self describing.

Compare this:

```
// Find the element in the vector.  <-- Bad: obvious!  
auto iter = std::find(v.begin(), v.end(), element);  
if (iter != v.end()) {  
    Process(element);  
}
```

To this:

```
// Process "element" unless it was already processed.  
auto iter = std::find(v.begin(), v.end(), element);  
if (iter != v.end()) {  
    Process(element);  
}
```

Self-describing code doesn't need a comment. The comment from the example above would be obvious:

```
if (!IsAlreadyProcessed(element)) {  
    Process(element);  
}
```

Punctuation, Spelling and Grammar^{ad}

Pay attention to punctuation, spelling, and grammar; it is easier to read well-written comments than badly written ones.

Comments should be as readable as narrative text, with proper capitalization and punctuation. In many cases, complete sentences are more readable than sentence fragments. Shorter comments, such as comments at the end of a line of code, can sometimes be less formal, but you should be consistent with your style.

Although it can be frustrating to have a code reviewer point out that you are using a comma when you should be using a semicolon, it is very important that source code maintain a high level of clarity and readability. Proper punctuation, spelling, and grammar help with that goal.

TODO Comments

Use `TODO` comments for code that is temporary, a short-term solution, or good-enough but not perfect.

`TODO`s should include the string `TODO` in all caps, followed by the name, e-mail address, bug ID, or other identifier of the person or issue with the best context about the problem referenced by the `TODO`. The main purpose is to have a consistent `TODO` that can be searched to find out how to get more details upon request. A `TODO` is not a commitment that the person referenced will fix the problem. Thus when you create a `TODO` with a name, it is almost always your name that is given.

```
// TODO(kl@gmail.com): Use a "*" here for concatenation operator.  
// TODO(Zeke) change this to use relations.  
// TODO(bug 12345): remove the "Last visitors" feature
```

If your `TODO` is of the form "At a future date do something" make sure that you either include a very specific date ("Fix by November 2005") or a very specific event ("Remove this code when all clients can handle XML responses.").

Deprecation Comments

Mark deprecated interface points with `DEPRECATED` comments.

You can mark an interface as deprecated by writing a comment containing the word `DEPRECATED` in all caps. The comment goes either before the declaration of the interface or on the same line as the declaration.

After the word `DEPRECATED`, write your name, e-mail address, or other identifier in parentheses.

A deprecation comment must include simple, clear directions for people to fix their callsites. In C++, you can implement a deprecated function as an inline function that calls the new interface point.

Marking an interface point `DEPRECATED` will not magically cause any callsites to change. If you want people to actually stop using the deprecated facility, you will have to fix the callsites yourself or recruit a crew to help you.

New code should not contain calls to deprecated interface points. Use the new interface point instead. If you cannot understand the directions, find the person who created the deprecation and ask them for help using the new interface point.

Formatting

Coding style and formatting are pretty arbitrary, but a project is much easier to follow if everyone uses the same style. Individuals may not agree with every aspect of the formatting rules, and some of the rules may take some getting used to, but it is important that all project contributors follow the style rules so that they can all read and understand everyone's code easily.

To help you format code correctly, we've created a [settings file for emacs](#).

Line Length^{oo}

Each line of text in your code should be at most 80 characters long.

We recognize that this rule is controversial, but so much existing code already adheres to it, and we feel that consistency is important.

Those who favor this rule argue that it is rude to force them to resize their windows and there is no need for anything longer. Some folks are used to having several code windows side-by-side, and thus don't have room to widen their windows in any case. People set up their work environment assuming a particular maximum window width, and 80 columns has been the traditional standard. Why change it?

Proponents of change argue that a wider line can make code more readable. The 80-column limit is an hidebound throwback to 1960s mainframes; modern equipment has wide screens that can easily show longer lines.

80 characters is the maximum.

Comment lines can be longer than 80 characters if it is not feasible to split them without harming readability, ease of cut and paste or auto-linking -- e.g. if a line contains an example command or a literal URL longer than 80 characters.

A raw-string literal may have content that exceeds 80 characters. Except for test code, such literals should appear near the top of a file.

An `#include` statement with a long path may exceed 80 columns.

You needn't be concerned about [header guards](#) that exceed the maximum length.

Non-ASCII Characters^{oo}

Non-ASCII characters should be rare, and must use UTF-8 formatting.

You shouldn't hard-code user-facing text in source, even English, so use of non-ASCII characters should be rare. However, in certain cases it is appropriate to include such words in your code. For example, if your code parses data files from foreign sources, it may be appropriate to hard-code the non-ASCII string(s) used in those data files as delimiters. More commonly, unittest code (which does not need to be localized) might contain non-ASCII strings. In such cases, you should use UTF-8, since that is an encoding understood by most tools able to handle more than just ASCII.

Hex encoding is also OK, and encouraged where it enhances readability — for example, `"\xEF\xBB\xBF"`, or, even more simply, `u8"\uFEFF"`, is the Unicode zero-width no-break space character, which would be invisible if included in the source as straight UTF-8.

Use the `u8` prefix to guarantee that a string literal containing `\uXXXX` escape sequences is encoded as UTF-8. Do not use it for strings containing non-ASCII characters encoded as UTF-8, because that will produce incorrect output if the compiler does not interpret the source file as UTF-8.

You shouldn't use the C++11 `char16_t` and `char32_t` character types, since they're for non-UTF-8 text. For similar reasons you also shouldn't use `wchar_t` (unless you're writing code that interacts with the Windows API, which uses `wchar_t` extensively).

Spaces vs. Tabs

Use only spaces, and indent 2 spaces at a time.

We use spaces for indentation. Do not use tabs in your code. You should set your editor to emit spaces when you hit the tab key.

Function Declarations and Definitions

Return type on the same line as function name, parameters on the same line if they fit. Wrap parameter lists which do not fit on a single line as you would wrap arguments in a [function call](#).

Functions look like this:

```
ReturnType ClassName::FunctionName(Type par_name1, Type par_name2) {
    DoSomething();
    ...
}
```

If you have too much text to fit on one line:

```
ReturnType ClassName::ReallyLongFunctionName(Type par_name1, Type par_name2,
                                              Type par_name3) {
    DoSomething();
    ...
}
```

or if you cannot fit even the first parameter:

```
ReturnType LongClassName::ReallyReallyReallyLongFunctionName(
    Type par_name1, // 4 space indent
    Type par_name2,
    Type par_name3) {
    DoSomething(); // 2 space indent
    ...
}
```

Some points to note:

- Choose good parameter names.
- Parameter names may be omitted only if the parameter is unused and its purpose is obvious.
- If you cannot fit the return type and the function name on a single line, break between them.

- If you break after the return type of a function declaration or definition, do not indent.
- The open parenthesis is always on the same line as the function name.
- There is never a space between the function name and the open parenthesis.
- There is never a space between the parentheses and the parameters.
- The open curly brace is always on the end of the last line of the function declaration, not the start of the next line.
- The close curly brace is either on the last line by itself or on the same line as the open curly brace.
- There should be a space between the close parenthesis and the open curly brace.
- All parameters should be aligned if possible.
- Default indentation is 2 spaces.
- Wrapped parameters have a 4 space indent.

Unused parameters that are obvious from context may be omitted:

```
class Foo {
public:
    Foo(Foo&&);
    Foo(const Foo&);
    Foo& operator=(Foo&&);
    Foo& operator=(const Foo&);
};
```

Unused parameters that might not be obvious should comment out the variable name in the function definition:

```
class Shape {
public:
    virtual void Rotate(double radians) = 0;
};
```

```
class Circle : public Shape {
public:
    void Rotate(double radians) override;
};
```

```
void Circle::Rotate(double /*radians*/) {}
```

```
// Bad - if someone wants to implement later, it's not clear what the
// variable means.
```

```
void Circle::Rotate(double) {}
```

Attributes, and macros that expand to attributes, appear at the very beginning of the function declaration or definition, before the return type:

```
MUST_USE_RESULT bool IsOK();
```

Format parameters and bodies as for any other function, and capture lists like other comma-separated lists.

For by-reference captures, do not leave a space between the ampersand (&) and the variable name.

```
int x = 0;
auto x_plus_n = [&x](int n) -> int { return x + n; }
```

Short lambdas may be written inline as function arguments.

```
std::set<int> blacklist = {7, 8, 9};
std::vector<int> digits = {3, 9, 1, 8, 4, 7, 1};
digits.erase(std::remove_if(digits.begin(), digits.end(), [&blacklist](int i) {
    return blacklist.find(i) != blacklist.end();
}),
    digits.end());
```

Function Calls

Either write the call all on a single line, wrap the arguments at the parenthesis, or start the arguments on a new line indented by four spaces and continue at that 4 space indent. In the absence of other considerations, use the minimum number of lines, including placing multiple arguments on each line where appropriate.

Function calls have the following format:

```
bool result = DoSomething(argument1, argument2, argument3);
```

If the arguments do not all fit on one line, they should be broken up onto multiple lines, with each subsequent line aligned with the first argument. Do not add spaces after the open paren or before the close paren:

```
bool result = DoSomething(averyveryveryverylongargument1,
    argument2, argument3);
```

Arguments may optionally all be placed on subsequent lines with a four space indent:

```
if (...) {
    ...
    ...
    if (...) {
        bool result = DoSomething(
            argument1, argument2, // 4 space indent
            argument3, argument4);
        ...
    }
}
```

Put multiple arguments on a single line to reduce the number of lines necessary for calling a function unless there is a specific readability problem. Some find that formatting with strictly one argument on each line is more readable and simplifies editing of the arguments. However, we prioritize for the reader over the ease of editing arguments, and most readability problems are better addressed with the following techniques.

If having multiple arguments in a single line decreases readability due to the complexity or confusing nature of the expressions that make up some arguments, try creating variables that capture those arguments in a descriptive name:

```
int my_heuristic = scores[x] * y + bases[x];
bool result = DoSomething(my_heuristic, x, y, z);
```

Or put the confusing argument on its own line with an explanatory comment:

```
bool result = DoSomething(scores[x] * y + bases[x],    // Score heuristic.
                          x, y, z);
```

If there is still a case where one argument is significantly more readable on its own line, then put it on its own line. The decision should be specific to the argument which is made more readable rather than a general policy.

Sometimes arguments form a structure that is important for readability. In those cases, feel free to format the arguments according to that structure:

```
// Transform the widget by a 3x3 matrix.
my_widget.Transform(x1, x2, x3,
                   y1, y2, y3,
                   z1, z2, z3);
```

Braced Initializer List Format

Format a [braced initializer list](#) exactly like you would format a function call in its place.

If the braced list follows a name (e.g. a type or variable name), format as if the `{ }` were the parentheses of a function call with that name. If there is no name, assume a zero-length name.

```
// Examples of braced init list on a single line.
return {foo, bar};
functioncall({foo, bar});
std::pair<int, int> p{foo, bar};

// When you have to wrap.
SomeFunction(
    {"assume a zero-length name before {"},
    some_other_function_parameter);
SomeType variable{
    some, other, values,
    {"assume a zero-length name before {"},
```

```

SomeOtherType{
    "Very long string requiring the surrounding breaks.",
    some, other values},
SomeOtherType{"Slightly shorter string",
    some, other, values}}};
SomeType variable{
    "This is too long to fit all in one line";
MyType m = { // Here, you could also break before {.
    superlongvariablename1,
    superlongvariablename2,
    {short, interior, list},
    {interiorwrappinglist,
    interiorwrappinglist2}}};

```

Conditionals

Prefer no spaces inside parentheses. The `if` and `else` keywords belong on separate lines.

There are two acceptable formats for a basic conditional statement. One includes spaces between the parentheses and the condition, and one does not.

The most common form is without spaces. Either is fine, but *be consistent*. If you are modifying a file, use the format that is already present. If you are writing new code, use the format that the other files in that directory or project use. If in doubt and you have no personal preference, do not add the spaces.

```

if (condition) { // no spaces inside parentheses
    ... // 2 space indent.
} else if (...) { // The else goes on the same line as the closing brace.
    ...
} else {
    ...
}

```

If you prefer you may add spaces inside the parentheses:

```

if ( condition ) { // spaces inside parentheses - rare
    ... // 2 space indent.
} else { // The else goes on the same line as the closing brace.
    ...
}

```

Note that in all cases you must have a space between the `if` and the open parenthesis. You must also have a space between the close parenthesis and the curly brace, if you're using one.

```

if(condition) { // Bad - space missing after IF.
if (condition){ // Bad - space missing before {.

```

```
if(condition){    // Doubly bad.
```

```
if (condition) {  // Good - proper space after IF and before {.
```

Short conditional statements may be written on one line if this enhances readability. You may use this only when the line is brief and the statement does not use the `else` clause.

```
if (x == kFoo) return new Foo();  
if (x == kBar) return new Bar();
```

This is not allowed when the `if` statement has an `else`:

```
// Not allowed - IF statement on one line when there is an ELSE clause  
if (x) DoThis();  
else DoThat();
```

In general, curly braces are not required for single-line statements, but they are allowed if you like them; conditional or loop statements with complex conditions or statements may be more readable with curly braces. Some projects require that an `if` must always always have an accompanying brace.

```
if (condition)  
    DoSomething(); // 2 space indent.  
  
if (condition) {  
    DoSomething(); // 2 space indent.  
}
```

However, if one part of an `if-else` statement uses curly braces, the other part must too:

```
// Not allowed - curly on IF but not ELSE  
if (condition) {  
    foo;  
} else  
    bar;
```

```
// Not allowed - curly on ELSE but not IF  
if (condition)  
    foo;  
else {  
    bar;  
}
```

```
// Curly braces around both IF and ELSE required because  
// one of the clauses used braces.  
if (condition) {  
    foo;  
} else {
```



```
    bar;
}
```

Loops and Switch Statements

Switch statements may use braces for blocks. Annotate non-trivial fall-through between cases. Braces are optional for single-statement loops. Empty loop bodies should use empty braces or `continue`.

case blocks in `switch` statements can have curly braces or not, depending on your preference. If you do include curly braces they should be placed as shown below.

If not conditional on an enumerated value, switch statements should always have a `default` case (in the case of an enumerated value, the compiler will warn you if any values are not handled). If the default case should never execute, simply `assert`:

```
switch (var) {
    case 0: { // 2 space indent
        ... // 4 space indent
        break;
    }
    case 1: {
        ...
        break;
    }
    default: {
        assert(false);
    }
}
```

Braces are optional for single-statement loops.

```
for (int i = 0; i < kSomeNumber; ++i)
    printf("I love you\n");

for (int i = 0; i < kSomeNumber; ++i) {
    printf("I take it back\n");
}
```

Empty loop bodies should use an empty pair of braces or `continue`, but not a single semicolon.

```
while (condition) {
    // Repeat test until it returns false.
}
for (int i = 0; i < kSomeNumber; ++i) {} // Good - one newline is also OK.
while (condition) continue; // Good - continue indicates no logic.
```

```
while (condition); // Bad - looks like part of do/while loop.
```

Pointer and Reference Expressions^{CD}

No spaces around period or arrow. Pointer operators do not have trailing spaces.

The following are examples of correctly-formatted pointer and reference expressions:

```
x = *p;  
p = &x;  
x = r.y;  
x = r->y;
```

Note that:

- There are no spaces around the period or arrow when accessing a member.
- Pointer operators have no space after the `*` or `&`.

When declaring a pointer variable or argument, you may place the asterisk adjacent to either the type or to the variable name:

```
// These are fine, space preceding.  
char *c;  
const string &str;  
  
// These are fine, space following.  
char* c;  
const string& str;
```

It is allowed (if unusual) to declare multiple variables in the same declaration, but it is disallowed if any of those have pointer or reference decorations. Such declarations are easily misread.

```
// Fine if helpful for readability.  
int x, y;
```

```
int x, *y; // Disallowed - no & or * in multiple declaration  
char * c; // Bad - spaces on both sides of *  
const string & str; // Bad - spaces on both sides of &
```

You should do this consistently within a single file, so, when modifying an existing file, use the style in that file.

Boolean Expressions^{CD}

When you have a boolean expression that is longer than the [standard line length](#), be consistent in how you break up the lines.

In this example, the logical AND operator is always at the end of the lines:

```

if (this_one_thing > this_other_thing &&
    a_third_thing == a_fourth_thing &&
    yet_another && last_one) {
    ...
}

```

Note that when the code wraps in this example, both of the `&&` logical AND operators are at the end of the line. This is more common in Google code, though wrapping all operators at the beginning of the line is also allowed. Feel free to insert extra parentheses judiciously because they can be very helpful in increasing readability when used appropriately. Also note that you should always use the punctuation operators, such as `&&` and `~`, rather than the word operators, such as `and` and `compl`.

Return Values

Do not needlessly surround the `return` expression with parentheses.

Use parentheses in `return expr;` only where you would use them in `x = expr;`.

```

return result;           // No parentheses in the simple case.
// Parentheses OK to make a complex expression more readable.
return (some_long_condition &&
        another_condition);

```

```

return (value);           // You wouldn't write var = (value);
return(result);           // return is not a function!

```

Variable and Array Initialization

Your choice of `=`, `()`, or `{}`.

You may choose between `=`, `()`, and `{}`; the following are all correct:

```

int x = 3;
int x(3);
int x{3};
string name = "Some Name";
string name("Some Name");
string name{"Some Name"};

```

Be careful when using a braced initialization list `{...}` on a type with an `std::initializer_list` constructor. A nonempty *braced-init-list* prefers the `std::initializer_list` constructor whenever possible. Note that empty braces `{}` are special, and will call a default constructor if available. To force the non-`std::initializer_list` constructor, use parentheses instead of braces.

```

std::vector<int> v(100, 1); // A vector of 100 1s.

```

```
std::vector<int> v{100, 1}; // A vector of 100, 1.
```

Also, the brace form prevents narrowing of integral types. This can prevent some types of programming errors.

```
int pi(3.14); // OK -- pi == 3.
int pi{3.14}; // Compile error: narrowing conversion.
```

Preprocessor Directives

The hash mark that starts a preprocessor directive should always be at the beginning of the line.

Even when preprocessor directives are within the body of indented code, the directives should start at the beginning of the line.

```
// Good - directives at beginning of line
if (lopsided_score) {
#ifdef DISASTER_PENDING // Correct -- Starts at beginning of line
    DropEverything();
# if NOTIFY // OK but not required -- Spaces after #
    NotifyClient();
# endif
#endif
    BackToNormal();
}
```

```
// Bad - indented directives
if (lopsided_score) {
    #ifdef DISASTER_PENDING // Wrong! The "#if" should be at beginning of line
        DropEverything();
    #endif // Wrong! Do not indent "#endif"
    BackToNormal();
}
```

Class Format

Sections in `public`, `protected` and `private` order, each indented one space.

The basic format for a class definition (lacking the comments, see [Class Comments](#) for a discussion of what comments are needed) is:

```
class MyClass : public OtherClass {
public: // Note the 1 space indent!
    MyClass(); // Regular 2 space indent.
    explicit MyClass(int var);
    ~MyClass() {}
```

```

void SomeFunction();
void SomeFunctionThatDoesNothing() {
}

void set_some_var(int var) { some_var_ = var; }
int some_var() const { return some_var_; }

private:
    bool SomeInternalFunction();

    int some_var_;
    int some_other_var_;
};

```

Things to note:

- Any base class name should be on the same line as the subclass name, subject to the 80-column limit.
- The `public:`, `protected:`, and `private:` keywords should be indented one space.
- Except for the first instance, these keywords should be preceded by a blank line. This rule is optional in small classes.
- Do not leave a blank line after these keywords.
- The `public` section should be first, followed by the `protected` and finally the `private` section.
- See [Declaration Order](#) for rules on ordering declarations within each of these sections.

Constructor Initializer Lists^{oo}

Constructor initializer lists can be all on one line or with subsequent lines indented four spaces.

The acceptable formats for initializer lists are:

```

// When everything fits on one line:
MyClass::MyClass(int var) : some_var_(var) {
    DoSomething();
}

// If the signature and initializer list are not all on one line,
// you must wrap before the colon and indent 4 spaces:
MyClass::MyClass(int var)
    : some_var_(var), some_other_var_(var + 1) {
    DoSomething();
}

// When the list spans multiple lines, put each member on its own line
// and align them:
MyClass::MyClass(int var)
    : some_var_(var),           // 4 space indent

```

```
    some_other_var_(var + 1) { // lined up
DoSomething();
}

// As with any other code block, the close curly can be on the same
// line as the open curly, if it fits.
MyClass::MyClass(int var)
    : some_var_(var) {}
```

Namespace Formatting⁰⁰

The contents of namespaces are not indented.

[Namespaces](#) do not add an extra level of indentation. For example, use:

```
namespace {

void foo() { // Correct.  No extra indentation within namespace.
    ...
}

} // namespace
```

Do not indent within a namespace:

```
namespace {

    // Wrong.  Indented when it should not be.
    void foo() {
        ...
    }

} // namespace
```

When declaring nested namespaces, put each namespace on its own line.

```
namespace foo {
namespace bar {
```

Horizontal Whitespace⁰⁰

Use of horizontal whitespace depends on location. Never put trailing whitespace at the end of a line.

General

```

void f(bool b) { // Open braces should always have a space before them.
    ...
int i = 0; // Semicolons usually have no space before them.
// Spaces inside braces for braced-init-list are optional. If you use them,
// put them on both sides!
int x[] = { 0 };
int x[] = {0};

// Spaces around the colon in inheritance and initializer lists.
class Foo : public Bar {
public:
    // For inline function implementations, put spaces between the braces
    // and the implementation itself.
    Foo(int b) : Bar(), baz_(b) {} // No spaces inside empty braces.
    void Reset() { baz_ = 0; } // Spaces separating braces from implementation.
    ...

```

Adding trailing whitespace can cause extra work for others editing the same file, when they merge, as can removing existing trailing whitespace. So: Don't introduce trailing whitespace. Remove it if you're already changing that line, or do it in a separate clean-up operation (preferably when no-one else is working on the file).

Loops and Conditionals

```

if (b) { // Space after the keyword in conditions and loops.
} else { // Spaces around else.
}

while (test) {} // There is usually no space inside parentheses.
switch (i) {
for (int i = 0; i < 5; ++i) {
// Loops and conditions may have spaces inside parentheses, but this
// is rare. Be consistent.
switch ( i ) {
if ( test ) {
for ( int i = 0; i < 5; ++i ) {
// For loops always have a space after the semicolon. They may have a space
// before the semicolon, but this is rare.
for ( ; i < 5 ; ++i) {
    ...

// Range-based for loops always have a space before and after the colon.
for (auto x : counts) {
    ...
}
switch (i) {
    case 1: // No space before colon in a switch case.
        ...
    case 2: break; // Use a space after a colon if there's code after it.

```

Operators

```
// Assignment operators always have spaces around them.
x = 0;

// Other binary operators usually have spaces around them, but it's
// OK to remove spaces around factors.  Parentheses should have no
// internal padding.
v = w * x + y / z;
v = w*x + y/z;
v = w * (x + z);

// No spaces separating unary operators and their arguments.
x = -5;
++x;
if (x && !y)
    ...
```

Templates and Casts

```
// No spaces inside the angle brackets (< and >), before
// <, or between >( in a cast
std::vector<string> x;
y = static_cast<char*>(x);

// Spaces between type and pointer are OK, but be consistent.
std::vector<char *> x;
```

Vertical Whitespace^{oo}

Minimize use of vertical whitespace.

This is more a principle than a rule: don't use blank lines when you don't have to. In particular, don't put more than one or two blank lines between functions, resist starting functions with a blank line, don't end functions with a blank line, and be discriminating with your use of blank lines inside functions.

The basic principle is: The more code that fits on one screen, the easier it is to follow and understand the control flow of the program. Of course, readability can suffer from code being too dense as well as too spread out, so use your judgement. But in general, minimize use of vertical whitespace.

Some rules of thumb to help when blank lines may be useful:

- Blank lines at the beginning or end of a function very rarely help readability.
- Blank lines inside a chain of if-else blocks may well help readability.

Exceptions to the Rules^{oo}

The coding conventions described above are mandatory. However, like all good rules, these sometimes have exceptions, which we discuss here.

Existing Non-conformant Code

You may diverge from the rules when dealing with code that does not conform to this style guide.

If you find yourself modifying code that was written to specifications other than those presented by this guide, you may have to diverge from these rules in order to stay consistent with the local conventions in that code. If you are in doubt about how to do this, ask the original author or the person currently responsible for the code. Remember that *consistency* includes local consistency, too.

Windows Code

Windows programmers have developed their own set of coding conventions, mainly derived from the conventions in Windows headers and other Microsoft code. We want to make it easy for anyone to understand your code, so we have a single set of guidelines for everyone writing C++ on any platform.

It is worth reiterating a few of the guidelines that you might forget if you are used to the prevalent Windows style:

- Do not use Hungarian notation (for example, naming an integer `iNum`). Use the Google naming conventions, including the `.cc` extension for source files.
- Windows defines many of its own synonyms for primitive types, such as `DWORD`, `HANDLE`, etc. It is perfectly acceptable, and encouraged, that you use these types when calling Windows API functions. Even so, keep as close as you can to the underlying C++ types. For example, use `const TCHAR *` instead of `LPCTSTR`.
- When compiling with Microsoft Visual C++, set the compiler to warning level 3 or higher, and treat all warnings as errors.
- Do not use `#pragma once`; instead use the standard Google include guards. The path in the include guards should be relative to the top of your project tree.
- In fact, do not use any nonstandard extensions, like `#pragma` and `__declspec`, unless you absolutely must. Using `__declspec(dllimport)` and `__declspec(dllexport)` is allowed; however, you must use them through macros such as `DLLIMPORT` and `DLLEXPORT`, so that someone can easily disable the extensions if they share the code.

However, there are just a few rules that we occasionally need to break on Windows:

- Normally we [forbid the use of multiple implementation inheritance](#); however, it is required when using COM and some ATL/WTL classes. You may use multiple implementation inheritance to implement COM or ATL/WTL classes and interfaces.
- Although you should not use exceptions in your own code, they are used extensively in the ATL and some STLs, including the one that comes with Visual C++. When using the ATL, you should define `_ATL_NO_EXCEPTIONS` to disable exceptions. You should investigate whether you can also disable exceptions in your STL, but if not, it is OK to turn on exceptions in the compiler. (Note that this is only to get the STL to compile. You should still not write exception handling code yourself.)
- The usual way of working with precompiled headers is to include a header file at the top of each source file, typically with a name like `StdAfx.h` or `precompile.h`. To make your code easier to share with other

projects, avoid including this file explicitly (except in `precompile.cc`), and use the `/FI` compiler option to include the file automatically.

- Resource headers, which are usually named `resource.h` and contain only macros, do not need to conform to these style guidelines.

Parting Words

Use common sense and *BE CONSISTENT*.

If you are editing code, take a few minutes to look at the code around you and determine its style. If they use spaces around their `if` clauses, you should, too. If their comments have little boxes of stars around them, make your comments have little boxes of stars around them too.

The point of having style guidelines is to have a common vocabulary of coding so people can concentrate on what you are saying, rather than on how you are saying it. We present global style rules here so people know the vocabulary. But local style is also important. If code you add to a file looks drastically different from the existing code around it, the discontinuity throws readers out of their rhythm when they go to read it. Try to avoid this.

Java Style Guide

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1 Introduction

This document serves as the **complete** definition of Google's coding standards for source code in the Java™ Programming Language. A Java source file is described as being *in Google Style* if and only if it adheres to the rules herein.

Like other programming style guides, the issues covered span not only aesthetic issues of formatting, but other types of conventions or coding standards as well. However, this document focuses primarily on the **hard-and-fast rules** that we follow universally, and avoids giving *advice* that isn't clearly enforceable (whether by human or tool).

1.1 Terminology notes

In this document, unless otherwise clarified:

1. The term *class* is used inclusively to mean an "ordinary" class, enum class, interface or annotation type ([@interface](#)).
2. The term *member* (of a class) is used inclusively to mean a nested class, field, method, *or constructor*; that is, all top-level contents of a class except initializers and comments.
3. The term *comment* always refers to *implementation* comments. We do not use the phrase "documentation comments", instead using the common term "Javadoc."

Other "terminology notes" will appear occasionally throughout the document.

1.2 Guide notes

Example code in this document is **non-normative**. That is, while the examples are in Google Style, they may not illustrate the *only* stylish way to represent the code. Optional formatting choices made in examples should not be enforced as rules.

2 Source file basics

2.1 File name

The source file name consists of the case-sensitive name of the top-level class it contains (of which there is [exactly one](#)), plus the `.java` extension.

2.2 File encoding: UTF-8

Source files are encoded in UTF-8.

2.3 Special characters

2.3.1 Whitespace characters

Aside from the line terminator sequence, the ASCII **horizontal space character** (0x20) is the only whitespace character that appears anywhere in a source file. This implies that:

- 1. All other whitespace characters in string and character literals are escaped.
- 2. Tab characters are **not** used for indentation.

2.3.2 Special escape sequences

For any character that has a [special escape sequence](#) (`\b`, `\t`, `\n`, `\f`, `\r`, `\"`, `\'` and `\\`), that sequence is used rather than the corresponding octal (e.g. `\012`) or Unicode (e.g. `\u000a`) escape.

2.3.3 Non-ASCII characters

For the remaining non-ASCII characters, either the actual Unicode character (e.g. `∞`) or the equivalent Unicode escape (e.g. `\u221e`) is used. The choice depends only on which makes the code **easier to read and understand**, although Unicode escapes outside string literals and comments are strongly discouraged.

Tip: In the Unicode escape case, and occasionally even when actual Unicode characters are used, an explanatory comment can be very helpful.

Examples:

Example	Discussion
<code>String unitAbbrev = "μs";</code>	Best: perfectly clear even without a comment.
<code>String unitAbbrev = "\u03bcs"; // "μs"</code>	Allowed, but there's no reason to do this.
<code>String unitAbbrev = "\u03bcs"; // Greek letter mu, "s"</code>	Allowed, but awkward and prone to mistakes.
<code>String unitAbbrev = "\u03bcs";</code>	Poor: the reader has no idea what this is.
<code>return "\uffff" + content; // byte order mark</code>	Good: use escapes for non-printable characters, and c

Tip: Never make your code less readable simply out of fear that some programs might not handle non-ASCII characters properly. If that should happen, those programs are **broken** and they must be **fixed**.

3 Source file structure

A source file consists of, **in order**:

- 1. License or copyright information, if present
- 2. Package statement
- 3. Import statements
- 4. Exactly one top-level class

Exactly one blank line separates each section that is present.

3.1 License or copyright information, if present

If license or copyright information belongs in a file, it belongs here.

3.2 Package statement

The package statement is **not line-wrapped**. The column limit (Section 4.4, [Column limit: 100](#)) does not apply to package statements.

3.3 Import statements

3.3.1 No wildcard imports

Wildcard imports, static or otherwise, **are not used**.

3.3.2 No line-wrapping

Import statements are **not line-wrapped**. The column limit (Section 4.4, [Column limit: 100](#)) does not apply to import statements.

3.3.3 Ordering and spacing

Imports are ordered as follows:

1. All static imports in a single block.
2. All non-static imports in a single block.

If there are both static and non-static imports, a single blank line separates the two blocks. There are no other blank lines between import statements.

Within each block the imported names appear in ASCII sort order. (**Note:** this is not the same as the import *statements* being in ASCII sort order, since '.' sorts before ';'.)

3.3.4 No static import for classes

Static import is not used for static nested classes. They are imported with normal imports.

3.4 Class declaration

3.4.1 Exactly one top-level class declaration

Each top-level class resides in a source file of its own.

3.4.2 Ordering of class contents

The order you choose for the members and initializers of your class can have a great effect on learnability. However, there's no single correct recipe for how to do it; different classes may order their contents in different ways.

What is important is that each class uses **some logical order**, which its maintainer could explain if asked. For example, new methods are not just habitually added to the end of the class, as that would yield "chronological by date added" ordering, which is not a logical ordering.

3.4.2.1 Overloads: never split

When a class has multiple constructors, or multiple methods with the same name, these appear sequentially, with no other code in between (not even private members).

4 Formatting

Terminology Note: *block-like construct* refers to the body of a class, method or constructor. Note that, by Section 4.8.3.1 on [array initializers](#), any array initializer *may* optionally be treated as if it were a block-like construct.

4.1 Braces

4.1.1 Braces are used where optional^{oo}

Braces are used with `if`, `else`, `for`, `do` and `while` statements, even when the body is empty or contains only a single statement.

4.1.2 Nonempty blocks: K & R style^{oo}

Braces follow the Kernighan and Ritchie style ("[Egyptian brackets](#)") for *nonempty* blocks and block-like constructs:

- No line break before the opening brace.
- Line break after the opening brace.
- Line break before the closing brace.
- Line break after the closing brace, *only if* that brace terminates a statement or terminates the body of a method, constructor, or *named* class. For example, there is *no* line break after the brace if it is followed by `else` or a comma.

Examples:

```
return () -> {
    while (condition()) {
        method();
    }
};

return new MyClass() {
    @Override public void method() {
        if (condition()) {
            try {
                something();
            } catch (ProblemException e) {
                recover();
            }
        } else if (otherCondition()) {
            somethingElse();
        } else {
            lastThing();
        }
    }
};
```

A few exceptions for enum classes are given in Section 4.8.1, [Enum classes](#).

4.1.3 Empty blocks: may be concise^{oo}

An empty block or block-like construct may be in K & R style (as described in [Section 4.1.2](#)). Alternatively, it may be closed immediately after it is opened, with no characters or line break in between (`{}`), **unless** it is part of a *multi-block statement* (one that directly contains multiple blocks: `if/else` or `try/catch/finally`).

Examples:

```
// This is acceptable
void doNothing() {}

// This is equally acceptable
void doNothingElse() {
}
```

```
// This is not acceptable: No concise empty blocks in a multi-block statement
```

```
try {  
    doSomething();  
} catch (Exception e) {}
```

4.2 Block indentation: +2 spaces^{☐☐}

Each time a new block or block-like construct is opened, the indent increases by two spaces. When the block ends, the indent returns to the previous indent level. The indent level applies to both code and comments throughout the block. (See the example in Section 4.1.2, [Nonempty blocks: K & R Style](#).)

4.3 One statement per line^{☐☐}

Each statement is followed by a line break.

4.4 Column limit: 100^{☐☐}

Java code has a column limit of 100 characters. Except as noted below, any line that would exceed this limit must be line-wrapped, as explained in Section 4.5, [Line-wrapping](#).

Exceptions:

1. Lines where obeying the column limit is not possible (for example, a long URL in Javadoc, or a long JSNI method reference).
2. `package` and `import` statements (see Sections 3.2 [Package statement](#) and 3.3 [Import statements](#)).
3. Command lines in a comment that may be cut-and-pasted into a shell.

4.5 Line-wrapping^{☐☐}

Terminology Note: When code that might otherwise legally occupy a single line is divided into multiple lines, this activity is called *line-wrapping*.

There is no comprehensive, deterministic formula showing *exactly* how to line-wrap in every situation. Very often there are several valid ways to line-wrap the same piece of code.

Note: While the typical reason for line-wrapping is to avoid overflowing the column limit, even code that would in fact fit within the column limit *may* be line-wrapped at the author's discretion.

Tip: Extracting a method or local variable may solve the problem without the need to line-wrap.

4.5.1 Where to break^{☐☐}

The prime directive of line-wrapping is: prefer to break at a **higher syntactic level**. Also:

1. When a line is broken at a *non-assignment* operator the break comes *before* the symbol. (Note that this is not the same practice used in Google style for other languages, such as C++ and JavaScript.)
 - This also applies to the following "operator-like" symbols:
 - the dot separator (`.`)
 - the two colons of a method reference (`::`)
 - an ampersand in a type bound (`<T extends Foo & Bar>`)
 - a pipe in a catch block (`catch (FooException | BarException e)`).
2. When a line is broken at an *assignment* operator the break typically comes *after* the symbol, but either way is acceptable.
 - This also applies to the "assignment-operator-like" colon in an enhanced `for` ("foreach") statement.
3. A method or constructor name stays attached to the open parenthesis (`()`) that follows it.
4. A comma (`,`) stays attached to the token that precedes it.

5. A line is never broken adjacent to the arrow in a lambda, except that a break may come immediately after the arrow if the body of the lambda consists of a single unbraced expression. Examples:

```
6. MyLambda<String, Long, Object> lambda =  
7.     (String label, Long value, Object obj) -> {  
8.         ...  
9.     };  
10.  
11. Predicate<String> predicate = str ->
```

```
    longExpressionInvolving(str);
```

Note: The primary goal for line wrapping is to have clear code, *not necessarily* code that fits in the smallest number of lines.

4.5.2 Indent continuation lines at least +4 spaces

When line-wrapping, each line after the first (each *continuation line*) is indented at least +4 from the original line.

When there are multiple continuation lines, indentation may be varied beyond +4 as desired. In general, two continuation lines use the same indentation level if and only if they begin with syntactically parallel elements.

Section 4.6.3 on [Horizontal alignment](#) addresses the discouraged practice of using a variable number of spaces to align certain tokens with previous lines.

4.6 Whitespace

4.6.1 Vertical Whitespace

A single blank line appears:

1. *Between* consecutive members or initializers of a class: fields, constructors, methods, nested classes, static initializers, and instance initializers.
 - o **Exception:** A blank line between two consecutive fields (having no other code between them) is optional. Such blank lines are used as needed to create *logical groupings* of fields.
 - o **Exception:** Blank lines between enum constants are covered in [Section 4.8.1](#).
2. Between statements, *as needed* to organize the code into logical subsections.
3. *Optionally* before the first member or initializer, or after the last member or initializer of the class (neither encouraged nor discouraged).
4. As required by other sections of this document (such as Section 3, [Source file structure](#), and Section 3.3, [Import statements](#)). *Multiple* consecutive blank lines are permitted, but never required (or encouraged).

4.6.2 Horizontal whitespace

Beyond where required by the language or other style rules, and apart from literals, comments and Javadoc, a single ASCII space also appears in the following places **only**.

1. Separating any reserved word, such as **if**, **for** or **catch**, from an open parenthesis (`()`) that follows it on that line
2. Separating any reserved word, such as **else** or **catch**, from a closing curly brace (`}`) that precedes it on that line
3. Before any open curly brace (`{}`), with two exceptions:
 - o `@SomeAnnotation({a, b})` (no space is used)
 - o `String[][] x = {{"foo"}};` (no space is required between `{{`, by item 8 below)
4. On both sides of any binary or ternary operator. This also applies to the following "operator-like" symbols:
 - o the ampersand in a conjunctive type bound: `<T extends Foo & Bar>`
 - o the pipe for a catch block that handles multiple exceptions: `catch (FooException | BarException e)`
 - o the colon (`:`) in an enhanced **for** ("foreach") statement

- the arrow in a lambda expression: `(String str) -> str.length()`
but not
 - the two colons (`::`) of a method reference, which is written like `Object::toString`
 - the dot separator (`.`), which is written like `object.toString()`
5. After `::` or the closing parenthesis (`)` of a cast
 6. On both sides of the double slash (`//`) that begins an end-of-line comment. Here, multiple spaces are allowed, but not required.
 7. Between the type and variable of a declaration: `List<String> list`
 8. *Optional* just inside both braces of an array initializer
- `new int[] {5, 6}` and `new int[] { 5, 6 }` are both valid
- This rule is never interpreted as requiring or forbidding additional space at the start or end of a line; it addresses only *interior* space.

4.6.3 Horizontal alignment: never required

Terminology Note: *Horizontal alignment* is the practice of adding a variable number of additional spaces in your code with the goal of making certain tokens appear directly below certain other tokens on previous lines.

This practice is permitted, but is **never required** by Google Style. It is not even required to *maintain* horizontal alignment in places where it was already used.

Here is an example without alignment, then using alignment:

```
private int x; // this is fine
private Color color; // this too

private int    x;      // permitted, but future edits
private Color color;  // may leave it unaligned
```

Tip: Alignment can aid readability, but it creates problems for future maintenance. Consider a future change that needs to touch just one line. This change may leave the formerly-pleasing formatting mangled, and that is **allowed**. More often it prompts the coder (perhaps you) to adjust whitespace on nearby lines as well, possibly triggering a cascading series of reformatting. That one-line change now has a "blast radius." This can at worst result in pointless busywork, but at best it still corrupts version history information, slows down reviewers and exacerbates merge conflicts.

4.7 Grouping parentheses: recommended

Optional grouping parentheses are omitted only when author and reviewer agree that there is no reasonable chance the code will be misinterpreted without them, nor would they have made the code easier to read. It is *not* reasonable to assume that every reader has the entire Java operator precedence table memorized.

4.8 Specific constructs

4.8.1 Enum classes

After each comma that follows an enum constant, a line break is optional. Additional blank lines (usually just one) are also allowed. This is one possibility:

```
private enum Answer {
    YES {
        @Override public String toString() {
            return "yes";
        }
    },
}
```

```
NO,  
MAYBE  
}
```

An enum class with no methods and no documentation on its constants may optionally be formatted as if it were an array initializer (see Section 4.8.3.1 on [array initializers](#)).

```
private enum Suit { CLUBS, HEARTS, SPADES, DIAMONDS }
```

Since enum classes *are classes*, all other rules for formatting classes apply.

4.8.2 Variable declarations

4.8.2.1 One variable per declaration

Every variable declaration (field or local) declares only one variable: declarations such as `int a, b;` are not used.

4.8.2.2 Declared when needed

Local variables are **not** habitually declared at the start of their containing block or block-like construct. Instead, local variables are declared close to the point they are first used (within reason), to minimize their scope. Local variable declarations typically have initializers, or are initialized immediately after declaration.

4.8.3 Arrays

4.8.3.1 Array initializers: can be "block-like"

Any array initializer may *optionally* be formatted as if it were a "block-like construct." For example, the following are all valid (**not** an exhaustive list):

```
new int[] {          new int[] {  
    0, 1, 2, 3      0,  
}                1,  
                2,  
new int[] {        3,  
    0, 1,          }  
    2, 3  
}  
                new int[]  
                {0, 1, 2, 3}
```

4.8.3.2 No C-style array declarations

The square brackets form a part of the *type*, not the variable: `String[] args`, not `String args[]`.

4.8.4 Switch statements

Terminology Note: Inside the braces of a *switch block* are one or more *statement groups*. Each statement group consists of one or more *switch labels* (either `case FOO:` or `default:`), followed by one or more statements (or, for the *last* statement group, *zero* or more statements).

4.8.4.1 Indentation

As with any other block, the contents of a switch block are indented +2.

After a switch label, there is a line break, and the indentation level is increased +2, exactly as if a block were being opened. The following switch label returns to the previous indentation level, as if a block had been closed.

4.8.4.2 Fall-through: commented

Within a switch block, each statement group either terminates abruptly (with a [break](#), [continue](#), [return](#) or thrown exception), or is marked with a comment to indicate that execution will or *might* continue into the next statement group. Any comment that communicates the idea of fall-through is sufficient (typically `// fall through`). This special comment is not required in the last statement group of the switch block. Example:

```
switch (input) {  
    case 1:  
    case 2:  
        prepareOneOrTwo();  
        // fall through  
    case 3:  
        handleOneTwoOrThree();  
        break;  
    default:  
        handleLargeNumber(input);  
}
```

Notice that no comment is needed after `case 1:`, only at the end of the statement group.

4.8.4.3 The `default` case is present

Each switch statement includes a `default` statement group, even if it contains no code.

Exception: A switch statement for an `enum` type *may* omit the `default` statement group, *if* it includes explicit cases covering *all* possible values of that type. This enables IDEs or other static analysis tools to issue a warning if any cases were missed.

4.8.5 Annotations

Annotations applying to a class, method or constructor appear immediately after the documentation block, and each annotation is listed on a line of its own (that is, one annotation per line). These line breaks do not constitute line-wrapping (Section 4.5, [Line-wrapping](#)), so the indentation level is not increased. Example:

```
@Override  
@Nullable  
public String getNameIfPresent() { ... }
```

Exception: A *single* parameterless annotation *may* instead appear together with the first line of the signature, for example:

```
@Override public int hashCode() { ... }
```

Annotations applying to a field also appear immediately after the documentation block, but in this case, *multiple* annotations (possibly parameterized) may be listed on the same line; for example:

```
@Partial @Mock DataLoader loader;
```

There are no specific rules for formatting annotations on parameters, local variables, or types.

4.8.6 Comments

This section addresses *implementation comments*. Javadoc is addressed separately in Section 7, [Javadoc](#).

Any line break may be preceded by arbitrary whitespace followed by an implementation comment. Such a comment renders the line non-blank.

4.8.6.1 Block comment style

Block comments are indented at the same level as the surrounding code. They may be in `/* ... */` style or `// ...` style. For multi-line `/* ... */` comments, subsequent lines must start with `*` aligned with the `*` on the previous line.

```
/*
 * This is           // And so           /* Or you can
 * okay.             // is this.         * even do this. */
 */
```

Comments are not enclosed in boxes drawn with asterisks or other characters.

Tip: When writing multi-line comments, use the `/* ... */` style if you want automatic code formatters to re-wrap the lines when necessary (paragraph-style). Most formatters don't re-wrap lines in `// ...` style comment blocks.

4.8.7 Modifiers

Class and member modifiers, when present, appear in the order recommended by the Java Language Specification:

```
public protected private abstract default static final transient volatile synchronized
native strictfp
```

4.8.8 Numeric Literals

long-valued integer literals use an uppercase `L` suffix, never lowercase (to avoid confusion with the digit `1`). For example, `3000000000L` rather than `3000000000l`.

5 Naming

5.1 Rules common to all identifiers

Identifiers use only ASCII letters and digits, and, in a small number of cases noted below, underscores. Thus each valid identifier name is matched by the regular expression `\w+`.

In Google Style special prefixes or suffixes, like those seen in the examples `name_`, `mName`, `s_name` and `kName`, are **not** used.

5.2 Rules by identifier type

5.2.1 Package names

Package names are all lowercase, with consecutive words simply concatenated together (no underscores). For example, `com.example.deepspace`, not `com.example.deepSpace` or `com.example.deep_space`.

5.2.2 Class names

Class names are written in [UpperCamelCase](#).

Class names are typically nouns or noun phrases. For example, `Character` or `ImmutableList`. Interface names may also be nouns or noun phrases (for example, `List`), but may sometimes be adjectives or adjective phrases instead (for example, `Readable`).

There are no specific rules or even well-established conventions for naming annotation types.

Test classes are named starting with the name of the class they are testing, and ending with **Test**. For example, **HashTest** or **HashIntegrationTest**.

5.2.3 Method names

Method names are written in [lowerCamelCase](#).

Method names are typically verbs or verb phrases. For example, `sendMessage` or `stop`.

Underscores may appear in JUnit *test* method names to separate logical components of the name. One typical pattern is `test<MethodUnderTest>_<state>`, for example `testPop_emptyStack`. There is no One Correct Way to name test methods.

5.2.4 Constant names

Constant names use `CONSTANT_CASE`: all uppercase letters, with words separated by underscores. But what *is* a constant, exactly?

Constants are static final fields whose contents are deeply immutable and whose methods have no detectable side effects. This includes primitives, Strings, immutable types, and immutable collections of immutable types. If any of the instance's observable state can change, it is not a constant. Merely *intending* to never mutate the object is not enough. Examples:

```
// Constants
static final int NUMBER = 5;
static final ImmutableList<String> NAMES = ImmutableList.of("Ed", "Ann");
static final ImmutableMap<String, Integer> AGES = ImmutableMap.of("Ed", 35, "Ann", 32);
static final Joiner COMMA_JOINER = Joiner.on(','); // because Joiner is immutable
static final SomeMutableType[] EMPTY_ARRAY = {};
enum SomeEnum { ENUM_CONSTANT }

// Not constants
static String nonFinal = "non-final";
final String nonStatic = "non-static";
static final Set<String> mutableCollection = new HashSet<String>();
static final ImmutableSet<SomeMutableType> mutableElements = ImmutableSet.of(mutable);
static final ImmutableMap<String, SomeMutableType> mutableValues =
    ImmutableMap.of("Ed", mutableInstance, "Ann", mutableInstance2);
static final Logger logger = Logger.getLogger(MyClass.getName());
static final String[] nonEmptyArray = {"these", "can", "change"};
```

These names are typically nouns or noun phrases.

5.2.5 Non-constant field names

Non-constant field names (static or otherwise) are written in [lowerCamelCase](#).

These names are typically nouns or noun phrases. For example, `computedValues` or `index`.

5.2.6 Parameter names

Parameter names are written in [lowerCamelCase](#).

One-character parameter names in public methods should be avoided.

5.2.7 Local variable names

Local variable names are written in [lowerCamelCase](#).

Even when final and immutable, local variables are not considered to be constants, and should not be styled as constants.

5.2.8 Type variable names

Each type variable is named in one of two styles:

- A single capital letter, optionally followed by a single numeral (such as E, T, X, T2)
- A name in the form used for classes (see Section 5.2.2, [Class names](#)), followed by the capital letter T (examples: `RequestT`, `FooBarT`).

5.3 Camel case: defined

Sometimes there is more than one reasonable way to convert an English phrase into camel case, such as when acronyms or unusual constructs like "IPv6" or "iOS" are present. To improve predictability, Google Style specifies the following (nearly) deterministic scheme.

Beginning with the prose form of the name:

1. Convert the phrase to plain ASCII and remove any apostrophes. For example, "Müller's algorithm" might become "Muellers algorithm".
2. Divide this result into words, splitting on spaces and any remaining punctuation (typically hyphens).
 - *Recommended*: if any word already has a conventional camel-case appearance in common usage, split this into its constituent parts (e.g., "AdWords" becomes "ad words"). Note that a word such as "iOS" is not really in camel case *per se*; it defies *any* convention, so this recommendation does not apply.
3. Now lowercase *everything* (including acronyms), then uppercase only the first character of:
 - ... each word, to yield *upper camel case*, or
 - ... each word except the first, to yield *lower camel case*
4. Finally, join all the words into a single identifier.

Note that the casing of the original words is almost entirely disregarded. Examples:

Prose form	Correct	Incorrect
"XML HTTP request"	<code>XmlHttpRequest</code>	<code>XMLHTTPREQUEST</code>
"new customer ID"	<code>newCustomerId</code>	<code>newCustomerId</code>
"inner stopwatch"	<code>innerStopwatch</code>	<code>innerStopwatch</code>
"supports IPv6 on iOS?"	<code>supportsIpv6OnIos</code>	<code>supportsIPv6OniOS</code>
"YouTube importer"	<code>YouTubeImporter</code> <code>YoutubeImporter*</code>	

*Acceptable, but not recommended.

Note: Some words are ambiguously hyphenated in the English language: for example "nonempty" and "non-empty" are both correct, so the method names `checkNonempty` and `checkNonEmpty` are likewise both correct.

6 Programming Practices

6.1 `@Override`: always used

A method is marked with the `@Override` annotation whenever it is legal. This includes a class method overriding a superclass method, a class method implementing an interface method, and an interface method respecifying a superinterface method.

Exception: `@Override` may be omitted when the parent method is `@Deprecated`.

6.2 Caught exceptions: not ignored^{oo}

Except as noted below, it is very rarely correct to do nothing in response to a caught exception. (Typical responses are to log it, or if it is considered "impossible", rethrow it as an [AssertionError](#).)

When it truly is appropriate to take no action whatsoever in a catch block, the reason this is justified is explained in a comment.

```
try {
    int i = Integer.parseInt(response);
    return handleNumericResponse(i);
} catch (NumberFormatException ok) {
    // it's not numeric; that's fine, just continue
}
return handleTextResponse(response);
```

Exception: In tests, a caught exception may be ignored without comment *if* its name is or begins with `expected`. The following is a very common idiom for ensuring that the code under test *does* throw an exception of the expected type, so a comment is unnecessary here.

```
try {
    emptyStack.pop();
    fail();
} catch (NoSuchElementException expected) {
}
```

6.3 Static members: qualified using class^{oo}

When a reference to a static class member must be qualified, it is qualified with that class's name, not with a reference or expression of that class's type.

```
Foo aFoo = ...;
Foo.aStaticMethod(); // good
aFoo.aStaticMethod(); // bad
somethingThatYieldsAFoo().aStaticMethod(); // very bad
```

6.4 Finalizers: not used^{oo}

It is **extremely rare** to override `Object.finalize`.

Tip: Don't do it. If you absolutely must, first read and understand [Effective Java Item 7](#), "Avoid Finalizers," very carefully, and *then* don't do it.

7 Javadoc^{oo}

7.1 Formatting^{oo}

7.1.1 General form^{oo}

The *basic* formatting of Javadoc blocks is as seen in this example:

```
/**
 * Multiple lines of Javadoc text are written here,
 * wrapped normally...
 */
public int method(String p1) { ... }
```

... or in this single-line example:

```
/** An especially short bit of Javadoc. */
```

The basic form is always acceptable. The single-line form may be substituted when the entirety of the Javadoc block (including comment markers) can fit on a single line. Note that this only applies when there are no block tags such as `@return`.

7.1.2 Paragraphs

One blank line—that is, a line containing only the aligned leading asterisk (*)—appears between paragraphs, and before the group of block tags if present. Each paragraph but the first has `<p>` immediately before the first word, with no space after.

7.1.3 Block tags

Any of the standard "block tags" that are used appear in the order `@param`, `@return`, `@throws`, `@deprecated`, and these four types never appear with an empty description. When a block tag doesn't fit on a single line, continuation lines are indented four (or more) spaces from the position of the `@`.

7.2 The summary fragment

Each Javadoc block begins with a brief **summary fragment**. This fragment is very important: it is the only part of the text that appears in certain contexts such as class and method indexes.

This is a fragment—a noun phrase or verb phrase, not a complete sentence. It does **not** begin with `A {@code Foo} is a...`, or `This method returns...`, nor does it form a complete imperative sentence like `Save the record..`. However, the fragment is capitalized and punctuated as if it were a complete sentence.

Tip: A common mistake is to write simple Javadoc in the form `/** @return the customer ID */`. This is incorrect, and should be changed to `/** Returns the customer ID. */`.

7.3 Where Javadoc is used

At the *minimum*, Javadoc is present for every `public` class, and every `public` or `protected` member of such a class, with a few exceptions noted below.

Additional Javadoc content may also be present, as explained in Section 7.3.4, [Non-required Javadoc](#).

7.3.1 Exception: self-explanatory methods

Javadoc is optional for "simple, obvious" methods like `getFoo`, in cases where there *really and truly* is nothing else worthwhile to say but "Returns the foo".

Important: it is not appropriate to cite this exception to justify omitting relevant information that a typical reader might need to know. For example, for a method named `getCanonicalName`, don't omit its documentation (with the rationale that it would say only `/** Returns the canonical name. */`) if a typical reader may have no idea what the term "canonical name" means!

7.3.2 Exception: overrides

Javadoc is not always present on a method that overrides a supertype method.

7.3.4 Non-required Javadoc

Other classes and members have Javadoc *as needed or desired*.

Whenever an implementation comment would be used to define the overall purpose or behavior of a class or member, that comment is written as Javadoc instead (using `/**`).

Non-required Javadoc is not strictly required to follow the formatting rules of Sections 7.1.2, 7.1.3, and 7.2, though it is of course recommended.

Google HTML/CSS Style Guide

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1 Background^{oo}

This document defines formatting and style rules for HTML and CSS. It aims at improving collaboration, code quality, and enabling supporting infrastructure. It applies to raw, working files that use HTML and CSS, including GSS files. Tools are free to obfuscate, minify, and compile as long as the general code quality is maintained.

2 General^{oo}

2.1 General Style Rules^{oo}

2.1.1 Protocol^{oo}

Use the HTTPS protocol for embedded resources where possible.

Always use the HTTPS protocol (<https://>) for images and other media files, style sheets, and scripts, unless the respective files are not available over HTTPS.

`<!-- Not recommended: omits the protocol -->`

`<script src="//ajax.googleapis.com/ajax/libs/jquery/3.1.0/jquery.min.js"></script>`

`<!-- Not recommended: uses the HTTP protocol -->`

`<script src="http://ajax.googleapis.com/ajax/libs/jquery/3.1.0/jquery.min.js"></script>`

`<!-- Recommended -->`

`<script src="https://ajax.googleapis.com/ajax/libs/jquery/3.1.0/jquery.min.js"></script>`

`/* Not recommended: omits the protocol */`

`@import '//fonts.googleapis.com/css?family=Open+Sans';`

`/* Not recommended: uses the HTTP protocol */`

`@import 'http://fonts.googleapis.com/css?family=Open+Sans';`

`/* Recommended */`

`@import 'https://fonts.googleapis.com/css?family=Open+Sans';`

2.2 General Formatting Rules^{oo}

2.2.1 Indentation^{oo}

Indent by 2 spaces at a time.

Don't use tabs or mix tabs and spaces for indentation.

```
<ul>
  <i>Fantastic
  <i>Great
</ul>
.example {
  color: blue;
}
```

2.2.2 Capitalization^{oo}

Use only lowercase.

All code has to be lowercase: This applies to HTML element names, attributes, attribute values (unless `text/CDATA`), CSS selectors, properties, and property values (with the exception of strings).

```
<!-- Not recommended -->
<A HREF="/">Home</A>

<!-- Recommended -->


/* Not recommended */
color: #E5E5E5;

/* Recommended */
color: #e5e5e5;
```

2.2.3 Trailing Whitespace^{oo}

Remove trailing white spaces.

Trailing white spaces are unnecessary and can complicate diffs.

```
<!-- Not recommended -->
<p>What?_

<!-- Recommended -->
<p>Yes please.
```

2.3 General Meta Rules^{oo}

2.3.1 Encoding^{oo}

Use UTF-8 (no BOM).

Make sure your editor uses UTF-8 as character encoding, without a byte order mark.

Specify the encoding in HTML templates and documents via `<meta charset="utf-8">`. Do not specify the encoding of style sheets as these assume UTF-8.
(More on encodings and when and how to specify them can be found in [Handling character encodings in HTML and CSS](#).)

2.3.2 Comments

Explain code as needed, where possible.

Use comments to explain code: What does it cover, what purpose does it serve, why is respective solution used or preferred?

(This item is optional as it is not deemed a realistic expectation to always demand fully documented code. Mileage may vary heavily for HTML and CSS code and depends on the project's complexity.)

2.3.3 Action Items

Mark todos and action items with `TODO`.

Highlight todos by using the keyword `TODO` only, not other common formats like `@@`.

Append a contact (username or mailing list) in parentheses as with the format `TODO (contact)`.

Append action items after a colon as in `TODO: action item`.

```
{# TODO(john.doe): revisit centering #}  
<center>Test</center>  
<!-- TODO: remove optional tags -->  
<ul>  
  <li>Apples</li>  
  <li>Oranges</li>  
</ul>
```

3 HTML

3.1 HTML Style Rules

3.1.1 Document Type

Use HTML5.

HTML5 (HTML syntax) is preferred for all HTML documents: `<!DOCTYPE html>`.

(It's recommended to use HTML, as `text/html`. Do not use XHTML. XHTML, as `application/xhtml+xml`, lacks both browser and infrastructure support and offers less room for optimization than HTML.)

Although fine with HTML, do not close void elements, i.e. write `
`, not `
`.

3.1.2 HTML Validity

Use valid HTML where possible.

Use valid HTML code unless that is not possible due to otherwise unattainable performance goals regarding file size.

Use tools such as the [W3C HTML validator](#) to test.

Using valid HTML is a measurable baseline quality attribute that contributes to learning about technical requirements and constraints, and that ensures proper HTML usage.

```

<!-- Not recommended -->
<title>Test</title>
<article>This is only a test.
<!-- Recommended -->
<!DOCTYPE html>
<meta charset="utf-8">
<title>Test</title>
<article>This is only a test.</article>

```

3.1.3 Semantics

Use HTML according to its purpose.

Use elements (sometimes incorrectly called “tags”) for what they have been created for. For example, use heading elements for headings, `p` elements for paragraphs, `a` elements for anchors, etc.

Using HTML according to its purpose is important for accessibility, reuse, and code efficiency reasons.

```

<!-- Not recommended -->
<div onclick="goToRecommendations();">All recommendations</div>
<!-- Recommended -->
<a href="recommendations/">All recommendations</a>

```

3.1.4 Multimedia Fallback

Provide alternative contents for multimedia.

For multimedia, such as images, videos, animated objects via `canvas`, make sure to offer alternative access. For images that means use of meaningful alternative text (`alt`) and for video and audio transcripts and captions, if available.

Providing alternative contents is important for accessibility reasons: A blind user has few cues to tell what an image is about without `@alt`, and other users may have no way of understanding what video or audio contents are about either.

(For images whose `alt` attributes would introduce redundancy, and for images whose purpose is purely decorative which you cannot immediately use CSS for, use no alternative text, as in `alt=""`.)

```

<!-- Not recommended -->

<!-- Recommended -->


```

3.1.5 Separation of Concerns

Separate structure from presentation from behavior.

Strictly keep structure (markup), presentation (styling), and behavior (scripting) apart, and try to keep the interaction between the three to an absolute minimum.

That is, make sure documents and templates contain only HTML and HTML that is solely serving structural purposes. Move everything presentational into style sheets, and everything behavioral into scripts.

In addition, keep the contact area as small as possible by linking as few style sheets and scripts as possible from documents and templates.

Separating structure from presentation from behavior is important for maintenance reasons. It is always more expensive to change HTML documents and templates than it is to update style sheets and scripts.

```
<!-- Not recommended -->
<!DOCTYPE html>
<title>HTML sucks</title>
<link rel="stylesheet" href="base.css" media="screen">
<link rel="stylesheet" href="grid.css" media="screen">
<link rel="stylesheet" href="print.css" media="print">
<h1 style="font-size: 1em;">HTML sucks</h1>
<p>I've read about this on a few sites but now I'm sure:
  <u>HTML is stupid!!1</u>
<center>I can't believe there's no way to control the styling of
  my website without doing everything all over again!</center>

<!-- Recommended -->
<!DOCTYPE html>
<title>My first CSS-only redesign</title>
<link rel="stylesheet" href="default.css">
<h1>My first CSS-only redesign</h1>
<p>I've read about this on a few sites but today I'm actually
  doing it: separating concerns and avoiding anything in the HTML of
  my website that is presentational.
<p>It's awesome!
```

3.1.6 Entity References^{oo}

Do not use entity references.

There is no need to use entity references like `—`, `”`, or `☺`, assuming the same encoding (UTF-8) is used for files and editors as well as among teams.

The only exceptions apply to characters with special meaning in HTML (like `<` and `&`) as well as control or “invisible” characters (like no-break spaces).

```
<!-- Not recommended -->
The currency symbol for the Euro is &ldquo;&eur;&rdquo;.

<!-- Recommended -->
The currency symbol for the Euro is “€”.
```

3.1.7 Optional Tags^{oo}

Omit optional tags (optional).

For file size optimization and scannability purposes, consider omitting optional tags. The [HTML5 specification](#) defines what tags can be omitted.

(This approach may require a grace period to be established as a wider guideline as it’s significantly different from what web developers are typically taught. For consistency and simplicity reasons it’s best served omitting all optional tags, not just a selection.)

```
<!-- Not recommended -->
<!DOCTYPE html>
<html>
  <head>
    <title>Spending money, spending bytes</title>
  </head>
  <body>
    <p>Sic.</p>
  </body>
</html>
```

```
<!-- Recommended -->
<!DOCTYPE html>
<title>Saving money, saving bytes</title>
<p>Qed.
```

3.1.8 `type` Attributes

Omit `type` attributes for style sheets and scripts.

Do not use `type` attributes for style sheets (unless not using CSS) and scripts (unless not using JavaScript).

Specifying `type` attributes in these contexts is not necessary as HTML5

implies `text/css` and `text/javascript` as defaults. This can be safely done even for older browsers.

```
<!-- Not recommended -->
<link rel="stylesheet" href="https://www.google.com/css/maia.css"
      type="text/css">
<!-- Recommended -->
<link rel="stylesheet" href="https://www.google.com/css/maia.css">
<!-- Not recommended -->
<script src="https://www.google.com/js/gweb/analytics/autotrack.js"
        type="text/javascript"></script>
<!-- Recommended -->
<script src="https://www.google.com/js/gweb/analytics/autotrack.js"></script>
```

3.2 HTML Formatting Rules

3.2.1 General Formatting

Use a new line for every block, list, or table element, and indent every such child element.

Independent of the styling of an element (as CSS allows elements to assume a different role per `display` property), put every block, list, or table element on a new line.

Also, indent them if they are child elements of a block, list, or table element.

(If you run into issues around whitespace between list items it's acceptable to put all `li` elements in one line. A linter is encouraged to throw a warning instead of an error.)

```
<blockquote>
  <p><em>Space</em>, the final frontier.</p>
</blockquote>
<ul>
  <li>Moe
  <li>Larry
```

```
<i>Curly
</ul>
<table>
  <thead>
    <tr>
      <th scope="col">Income
      <th scope="col">Taxes
    </tr>
  </thead>
  <tbody>
    <tr>
      <td>$ 5.00
      <td>$ 4.50
    </tr>
  </tbody>
</table>
```

3.2.2 HTML Quotation Marks^{oo}

When quoting attributes values, use double quotation marks.

Use double ("") rather than single quotation marks (' ') around attribute values.

```
<!-- Not recommended -->
<a class='maia-button maia-button-secondary'>Sign in</a>
<!-- Recommended -->
<a class="maia-button maia-button-secondary">Sign in</a>
```

4 CSS^{oo}

4.1 CSS Style Rules^{oo}

4.1.1 CSS Validity^{oo}

Use valid CSS where possible.

Unless dealing with CSS validator bugs or requiring proprietary syntax, use valid CSS code.

Use tools such as the [W3C CSS validator](#) to test.

Using valid CSS is a measurable baseline quality attribute that allows to spot CSS code that may not have any effect and can be removed, and that ensures proper CSS usage.

4.1.2 ID and Class Naming^{oo}

Use meaningful or generic ID and class names.

Instead of presentational or cryptic names, always use ID and class names that reflect the purpose of the element in question, or that are otherwise generic.

Names that are specific and reflect the purpose of the element should be preferred as these are most understandable and the least likely to change.

Generic names are simply a fallback for elements that have no particular or no meaning different from their siblings. They are typically needed as “helpers.”

Using functional or generic names reduces the probability of unnecessary document or template changes.

```
/* Not recommended: meaningless */
```

```
#yee-1901 {}
```

```
/* Not recommended: presentational */
```

```
.button-green {}
```

```
.clear {}
```

```
/* Recommended: specific */
```

```
#gallery {}
```

```
#login {}
```

```
.video {}
```

```
/* Recommended: generic */
```

```
.aux {}
```

```
.alt {}
```

4.1.3 ID and Class Name Style

Use ID and class names that are as short as possible but as long as necessary.

Try to convey what an ID or class is about while being as brief as possible.

Using ID and class names this way contributes to acceptable levels of understandability and code efficiency.

```
/* Not recommended */
```

```
#navigation {}
```

```
.atr {}
```

```
/* Recommended */
```

```
#nav {}
```

```
.author {}
```

4.1.4 Type Selectors

Avoid qualifying ID and class names with type selectors.

Unless necessary (for example with helper classes), do not use element names in conjunction with IDs or classes.

Avoiding unnecessary ancestor selectors is useful for [performance reasons](#).

```
/* Not recommended */
```

```
ul#example {}
```

```
div.error {}
```

```
/* Recommended */
```

```
#example {}
```

```
.error {}
```

4.1.5 Shorthand Properties

Use shorthand properties where possible.

CSS offers a variety of [shorthand](#) properties (like `font`) that should be used whenever possible, even in cases where only one value is explicitly set.

Using shorthand properties is useful for code efficiency and understandability.

```
/* Not recommended */
border-top-style: none;
font-family: palatino, georgia, serif;
font-size: 100%;
line-height: 1.6;
padding-bottom: 2em;
padding-left: 1em;
padding-right: 1em;
padding-top: 0;

/* Recommended */
border-top: 0;
font: 100%/1.6 palatino, georgia, serif;
padding: 0 1em 2em;
```

4.1.6 0 and Units^{ad}

Omit unit specification after “0” values, unless required.

Do not use units after 0 values unless they are required.

```
flex: 0px; /* This flex-basis component requires a unit. */
flex: 1 1 0px; /* Not ambiguous without the unit, but needed in IE11. */
margin: 0;
padding: 0;
```

4.1.7 Leading 0s^{ad}

Omit leading “0”s in values.

Do not use put 0s in front of values or lengths between -1 and 1.

```
font-size: .8em;
```

4.1.8 Hexadecimal Notation^{ad}

Use 3 character hexadecimal notation where possible.

For color values that permit it, 3 character hexadecimal notation is shorter and more succinct.

```
/* Not recommended */
color: #eebbcc;

/* Recommended */
color: #ebc;
```

4.1.9 Prefixes^{ad}

Prefix selectors with an application-specific prefix (optional).

In large projects as well as for code that gets embedded in other projects or on external sites use prefixes (as namespaces) for ID and class names. Use short, unique identifiers followed by a dash.

Using namespaces helps preventing naming conflicts and can make maintenance easier, for example in search and replace operations.

```
.adw-help {} /* AdWords */  
#maia-note {} /* Maia */
```

4.1.10 ID and Class Name Delimiters

Separate words in ID and class names by a hyphen.

Do not concatenate words and abbreviations in selectors by any characters (including none at all) other than hyphens, in order to improve understanding and scannability.

```
/* Not recommended: does not separate the words “demo” and “image” */  
.demoimage {}  
  
/* Not recommended: uses underscore instead of hyphen */  
.error_status {}  
  
/* Recommended */  
#video-id {}  
.ads-sample {}
```

4.1.11 Hacks

Avoid user agent detection as well as CSS “hacks”—try a different approach first.

It’s tempting to address styling differences over user agent detection or special CSS filters, workarounds, and hacks. Both approaches should be considered last resort in order to achieve and maintain an efficient and manageable code base. Put another way, giving detection and hacks a free pass will hurt projects in the long run as projects tend to take the way of least resistance. That is, allowing and making it easy to use detection and hacks means using detection and hacks more frequently—and more frequently is too frequently.

4.2 CSS Formatting Rules

4.2.1 Declaration Order

Alphabetize declarations.

Put declarations in alphabetical order in order to achieve consistent code in a way that is easy to remember and maintain.

Ignore vendor-specific prefixes for sorting purposes. However, multiple vendor-specific prefixes for a certain CSS property should be kept sorted (e.g. -moz prefix comes before -webkit).

```
background: fuchsia;  
border: 1px solid;
```

```
-moz-border-radius: 4px;
-webkit-border-radius: 4px;
border-radius: 4px;
color: black;
text-align: center;
text-indent: 2em;
```

4.2.2 Block Content Indentation

Indent all block content.

Indent all [block content](#), that is rules within rules as well as declarations, so to reflect hierarchy and improve understanding.

```
@media screen, projection {

  html {
    background: #fff;
    color: #444;
  }

}
```

4.2.3 Declaration Stops

Use a semicolon after every declaration.

End every declaration with a semicolon for consistency and extensibility reasons.

```
/* Not recommended */
.test {
  display: block;
  height: 100px
}

/* Recommended */
.test {
  display: block;
  height: 100px;
}
```

4.2.4 Property Name Stops

Use a space after a property name's colon.

Always use a single space between property and value (but no space between property and colon) for consistency reasons.

```
/* Not recommended */
h3 {
  font-weight:bold;
}
```

```
/* Recommended */
```

```
h3 {  
  font-weight: bold;  
}
```

4.2.5 Declaration Block Separation

Use a space between the last selector and the declaration block.

Always use a single space between the last selector and the opening brace that begins the [declaration block](#).

The opening brace should be on the same line as the last selector in a given rule.

```
/* Not recommended: missing space */
```

```
#video{  
  margin-top: 1em;  
}
```

```
/* Not recommended: unnecessary line break */
```

```
#video  
{  
  margin-top: 1em;  
}
```

```
/* Recommended */
```

```
#video {  
  margin-top: 1em;  
}
```

4.2.6 Selector and Declaration Separation

Separate selectors and declarations by new lines.

Always start a new line for each selector and declaration.

```
/* Not recommended */
```

```
a:focus, a:active {  
  position: relative; top: 1px;  
}
```

```
/* Recommended */
```

```
h1,  
h2,  
h3 {  
  font-weight: normal;  
  line-height: 1.2;  
}
```

4.2.7 Rule Separation

Separate rules by new lines.

Always put a blank line (two line breaks) between rules.

```
html {  
    background: #fff;  
}  
  
body {  
    margin: auto;  
    width: 50%;  
}
```

4.2.8 CSS Quotation Marks

Use single quotation marks for attribute selectors and property values.

Use single (' ') rather than double (" ") quotation marks for attribute selectors or property values. Do not use quotation marks in URI values (url ()).

Exception: If you do need to use the @charset rule, use double quotation marks—[single quotation marks are not permitted](#).

```
/* Not recommended */  
@import url("https://www.google.com/css/maia.css");  
  
html {  
    font-family: "open sans", arial, sans-serif;  
}  
  
/* Recommended */  
@import url(https://www.google.com/css/maia.css);  
  
html {  
    font-family: 'open sans', arial, sans-serif;  
}
```

4.3 CSS Meta Rules

4.3.1 Section Comments

Group sections by a section comment (optional).

If possible, group style sheet sections together by using comments. Separate sections with new lines.

```
/* Header */  
  
#adw-header {}  
  
/* Footer */  
  
#adw-footer {}  
  
/* Gallery */  
  
.adw-gallery {}
```

Parting Words^{oo}

Be consistent.

If you're editing code, take a few minutes to look at the code around you and determine its style. If they use spaces around all their arithmetic operators, you should too. If their comments have little boxes of hash marks around them, make your comments have little boxes of hash marks around them too.

The point of having style guidelines is to have a common vocabulary of coding so people can concentrate on what you're saying rather than on how you're saying it. We present global style rules here so people know the vocabulary, but local style is also important. If code you add to a file looks drastically different from the existing code around it, it throws readers out of their rhythm when they go to read it. Avoid this.

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1 Introduction^{oo}

This document serves as the **complete** definition of Google's coding standards for source code in the JavaScript programming language. A JavaScript source file is described as being *in Google Style* if and only if it adheres to the rules herein.

Like other programming style guides, the issues covered span not only aesthetic issues of formatting, but other types of conventions or coding standards as well. However, this document focuses primarily on the hard-and-fast rules that we follow universally, and avoids giving advice that isn't clearly enforceable (whether by human or tool).

1.1 Terminology notes^{oo}

In this document, unless otherwise clarified:

1. The term *comment* always refers to *implementation* comments. We do not use the phrase *documentation comments*, instead using the common term “JSDoc” for both human-readable text and machine-readable annotations within `/** ... */`.
2. This Style Guide uses [RFC 2119](#) terminology when using the phrases *must*, *must not*, *should*, *should not*, and *may*. The terms *prefer* and *avoid* correspond to *should* and *should not*, respectively. Imperative and declarative statements are prescriptive and correspond to *must*.

Other terminology notes will appear occasionally throughout the document.

1.2 Guide notes

Example code in this document is **non-normative**. That is, while the examples are in Google Style, they may not illustrate the *only* stylish way to represent the code. Optional formatting choices made in examples must not be enforced as rules.

2 Source file basics

2.1 File name

File names must be all lowercase and may include underscores (`_`) or dashes (`-`), but no additional punctuation. Follow the convention that your project uses. Filenames' extension must be `.js`.

2.2 File encoding: UTF-8

Source files are encoded in **UTF-8**.

2.3 Special characters

2.3.1 Whitespace characters

Aside from the line terminator sequence, the ASCII horizontal space character (0x20) is the only whitespace character that appears anywhere in a source file. This implies that

1. All other whitespace characters in string literals are escaped, and
2. Tab characters are **not** used for indentation.

2.3.2 Special escape sequences

For any character that has a special escape sequence (`\'`, `\"`, `\\`, `\b`, `\f`, `\n`, `\r`, `\t`, `\v`), that sequence is used rather than the corresponding numeric escape (e.g. `\x0a`, `\u000a`, or `\u{a}`). Legacy octal escapes are never used.

2.3.3 Non-ASCII characters

For the remaining non-ASCII characters, either the actual Unicode character (e.g. `∞`) or the equivalent hex or Unicode escape (e.g. `\u221e`) is used, depending only on which makes the code **easier to read and understand**.

Tip: In the Unicode escape case, and occasionally even when actual Unicode characters are used, an explanatory comment can be very helpful.

Example	Discussion
<code>const units = 'μs';</code>	Best: perfectly clear even without a comment.
<code>const units = '\u03bc'; // 'μs'</code>	Allowed, but there's no reason to do this.
<code>const units = '\u03bc'; // Greek letter mu, 's'</code>	Allowed, but awkward and prone to mistakes.
<code>const units = '\u03bc';</code>	Poor: the reader has no idea what this is.
<code>return '\uffeff' + content; // byte order mark</code>	Good: use escapes for non-printable characters, and comment it

Tip: Never make your code less readable simply out of fear that some programs might not handle non-ASCII characters properly. If that happens, those programs are **broken** and they must be **fixed**.

3 Source file structure^{oo}

A source file consists of, **in order**:

1. License or copyright information, if present
2. `@fileoverview` JSDoc, if present
3. `goog.module` statement
4. `goog.require` statements
5. The file's implementation

Exactly one blank line separates each section that is present, except the file's implementation, which may be preceded by 1 or 2 blank lines.

3.1 License or copyright information, if present^{oo}

If license or copyright information belongs in a file, it belongs here.

3.2 `@fileoverview` JSDoc, if present^{oo}

See [7.5 Top/file-level comments](#) for formatting rules.

3.3 `goog.module` statement^{oo}

All files must declare exactly one `goog.module` name on a single line: lines containing a `goog.module` declaration must not be wrapped, and are therefore an exception to the 80-column limit.

The single `goog.module` statement may optionally be followed by calls

to `goog.module.declareLegacyNamespace()`; and/or `goog.setTestOnly()`; Avoid `goog.module.declareLegacyNamespace()` when possible.

Example:

```
goog.module('my.test.helpers');
goog.module.declareLegacyNamespace();
goog.setTestOnly();
```

3.3.1 `goog.module.declareLegacyNamespace`^{oo}

`goog.module.declareLegacyNamespace` exists to ease the transition from traditional namespaces but comes with some naming restrictions. As the child module name must be created after the parent namespace, this name **must not** be a child or parent of any other `goog.module` (for example, `goog.module('parent')`; and `goog.module('parent.child')`; cannot both exist, nor can `goog.module('parent')`; and `goog.module('parent.child.grandchild')`).

3.3.2 ES6 Modules^{oo}

Do not use ES6 modules yet (i.e. the `export` and `import` keywords), as their semantics are not yet finalized. Note that this policy will be revisited once the semantics are fully-standard.

3.4 `goog.require` statements^{oo}

Imports are done with `goog.require` statements, grouped together immediately following the module declaration.

Each `goog.require` is assigned to a single constant alias, or else destructured into several constant aliases. These aliases are the only acceptable way to refer to the `required` dependency, whether in code or in type annotations: the fully qualified name is never used except as the argument to `goog.require`. If a module is imported only for its side

effects, the assignment may be omitted, but the fully qualified name may not appear anywhere else in the file. Alias names should match the final dot-separated component of the imported module name when possible, though additional components may be included (with appropriate casing such that the alias' casing still correctly identifies its type) if necessary to disambiguate, or if it significantly improves readability. `goog.require` statements may not appear anywhere else in the file.

The lines are sorted via standard ASCII ordering of the entire line, with uppercase letters, then lowercase letters, then open-braces (for destructuring). Aliases within a destructured expression are sorted the same way.

Tip: There's no need to memorize this order and enforce it manually. You can rely on your IDE or even `sort` to sort your imports automatically.

If a long alias or module name would cause a line to exceed the 80-column limit, it **must not** be wrapped: `goog.require` lines are an exception to the 80-column limit.

Example:

```
const MyClass = goog.require('some.package.MyClass');
const NsMyClass = goog.require('other.ns.MyClass');
const googAsserts = goog.require('goog.asserts');
const testingAsserts = goog.require('goog.testing.asserts');
const than80columns = goog.require('pretend.this.is.longer.than80columns');
const {clear, forEach, map} = goog.require('goog.array');
```

Illegal:

```
const randomName = goog.require('something.else'); // name must match

const {clear, forEach, map} = // don't break lines
  goog.require('goog.array');

function someFunction() {
  const alias = goog.require('my.long.name.alias'); // must be at top level
  // ...
}
```

3.5 The file's implementation^{aa}

The actual implementation follows after all dependency information is declared (separated by at least one blank line).

This may consist of any module-local declarations (constants, variables, classes, functions, etc), as well as any exported symbols.

4 Formatting^{aa}

Terminology Note: *block-like construct* refers to the body of a class, function, method, or brace-delimited block of code. Note that, by [5.2 Array literals](#) and [5.3 Object literals](#), any array or object literal may optionally be treated as if it were a block-like construct.

Tip: Use clang-format. The JavaScript community has invested effort to make sure clang-format does the right thing on JavaScript files.

4.1 Braces

4.1.1 Braces are used for all control structures

Braces are required for all control structures (i.e. `if`, `else`, `for`, `do`, `while`, as well as any others), even if the body contains only a single statement. The first statement of a non-empty block must begin on its own line.

Illegal:

```
if(someVeryLongCondition())
  doSomething();

for (let i = 0; i < foo.length; i++) bar(foo[i]);
```

Exception: A simple if statement that can fit entirely on a single line with no wrapping (and that doesn't have an else) may be kept on a single line with no braces when it improves readability. This is the only case in which a control structure may omit braces and newlines.

```
if (shortCondition()) return;
```

4.1.2 Nonempty blocks: K&R style

Braces follow the Kernighan and Ritchie style ([Egyptian brackets](#)) for *nonempty* blocks and block-like constructs:

- No line break before the opening brace.
- Line break after the opening brace.
- Line break before the closing brace.
- Line break after the closing brace *if* that brace terminates a statement or the body of a function or class statement, or a class method. Specifically, there is *no* line break after the brace if it is followed by `else`, `catch`, `while`, or a comma, semicolon, or right-parenthesis.

Example:

```
class InnerClass {
  constructor() {}

  /** @param {number} foo */
  method(foo) {
    if (condition(foo)) {
      try {
        // Note: this might fail.
        something();
      } catch (err) {
        recover();
      }
    }
  }
}
```

4.1.3 Empty blocks: may be concise

An empty block or block-like construct *may* be closed immediately after it is opened, with no characters, space, or line break in between (i.e. `{ }`), **unless** it is a part of a *multi-block statement* (one that directly contains multiple blocks: `if/else` or `try/catch/finally`).

Example:

```
function doNothing() {}
```

Illegal:

```
if (condition) {  
    // ...  
} else if (otherCondition) {} else {  
    // ...  
}  
  
try {  
    // ...  
} catch (e) {}
```

4.2 Block indentation: +2 spaces^{ad}

Each time a new block or block-like construct is opened, the indent increases by two spaces. When the block ends, the indent returns to the previous indent level. The indent level applies to both code and comments throughout the block. (See the example in [4.1.2 Nonempty blocks: K&R style](#)).

4.2.1 Array literals: optionally block-like^{ad}

Any array literal may optionally be formatted as if it were a “block-like construct.” For example, the following are all valid (**not** an exhaustive list):

```
const a = [  
    0, 1, 2,  
];  
  
const b =  
    [0, 1, 2];  
const c = [0, 1, 2];  
  
someMethod(foo, [  
    0,  
    1,  
    2,  
], bar);
```

Other combinations are allowed, particularly when emphasizing semantic groupings between elements, but should not be used only to reduce the vertical size of larger arrays.

4.2.2 Object literals: optionally block-like^{ad}

Any object literal may optionally be formatted as if it were a “block-like construct.” The same examples apply as [4.2.1 Array literals: optionally block-like](#). For example, the following are all valid (**not** an exhaustive list):

```

const a = {
  a: 0, b: 1
};

const b =
  {a: 0, b: 1};
const c = {a: 0, b: 1};

someMethod(foo, {
  a: 0,
  b: 1,
}, bar);

```

4.2.3 Class literals

Class literals (whether declarations or expressions) are indented as blocks. Do not add commas after methods, or a semicolon after the closing brace of a class *declaration* (statements—such as assignments—that contain class *expressions* are still terminated with a semicolon).

Example:

```

class Foo {
  constructor() {
    /** @type {number} */
    this.x = 42;
  }

  /** @return {number} */
  method() {
    return this.x;
  }
}

Foo.Empty = class {};
foo.Bar = class extends Foo {
  /** @override */
  method() {
    return super.method() / 2;
  }
};

/** @interface */
class Frobnicator {
  /** @param {string} message */
  frobnicate(message) {}
}

```

4.2.4 Function expressions

When declaring an anonymous function in the list of arguments for a function call, the body of the function is indented two spaces more than the preceding indentation depth.

Example:

```
prefix.something.reallyLongFunctionName('whatever', (a1, a2) => {  
  // Indent the function body +2 relative to indentation depth  
  // of the 'prefix' statement one line above.  
  if (a1.equals(a2)) {  
    someOtherLongFunctionName(a1);  
  } else {  
    andNowForSomethingCompletelyDifferent(a2.parrot);  
  }  
});  
  
some.reallyLongFunctionCall(arg1, arg2, arg3)  
  .thatsWrapped()  
  .then((result) => {  
    // Indent the function body +2 relative to the indentation depth  
    // of the '.then()' call.  
    if (result) {  
      result.use();  
    }  
  });
```

4.2.5 Switch statements

As with any other block, the contents of a switch block are indented +2.

After a switch label, a newline appears, and the indentation level is increased +2, exactly as if a block were being opened. An explicit block may be used if required by lexical scoping. The following switch label returns to the previous indentation level, as if a block had been closed.

A blank line is optional between a `break` and the following case.

Example:

```
switch (animal) {  
  case Animal.BANDERSNATCH:  
    handleBandersnatch();  
    break;  
  
  case Animal.JABBERWOCK:  
    handleJabberwock();  
    break;  
  
  default:  
    throw new Error('Unknown animal');  
}
```

4.3 Statements

4.3.1 One statement per line

Each statement is followed by a line-break.

4.3.2 Semicolons are required^{oo}

Every statement must be terminated with a semicolon. Relying on automatic semicolon insertion is forbidden.

4.4 Column limit: 80^{oo}

JavaScript code has a column limit of 80 characters. Except as noted below, any line that would exceed this limit must be line-wrapped, as explained in [4.5 Line-wrapping](#).

Exceptions:

1. Lines where obeying the column limit is not possible (for example, a long URL in JSDoc or a shell command intended to be copied-and-pasted).
2. `goog.module` and `goog.require` statements (see [3.3 goog.module statement](#) and [3.4 goog.require statements](#)).

4.5 Line-wrapping^{oo}

Terminology Note: *Line-wrapping* is defined as breaking a single expression into multiple lines.

There is no comprehensive, deterministic formula showing *exactly* how to line-wrap in every situation. Very often there are several valid ways to line-wrap the same piece of code.

Note: While the typical reason for line-wrapping is to avoid overflowing the column limit, even code that would in fact fit within the column limit may be line-wrapped at the author's discretion.

Tip: Extracting a method or local variable may solve the problem without the need to line-wrap.

4.5.1 Where to break^{oo}

The prime directive of line-wrapping is: prefer to break at a **higher syntactic level**. Also:

1. When a line is broken at an operator the break comes after the symbol. (Note that this is not the same practice used in Google style for Java.)
 - a. This does not apply to the dot (`.`), which is not actually an operator.
2. A method or constructor name stays attached to the open parenthesis (`(`) that follows it.
3. A comma (`,`) stays attached to the token that precedes it.

Preferred:

```
this.foo =  
  foo(  
    firstArg,  
    1 + someLongFunctionName());
```

Discouraged:

```
this.foo = foo(firstArg, 1 +  
  someLongFunctionName());
```

In the preceding example, the syntactic levels from highest to lowest are as follows: assignment, outer function call, parameters, plus, inner function call.

Note: The primary goal for line wrapping is to have clear code, not necessarily code that fits in the smallest number of lines.

See also [4.6.3 Rectangle Rule](#).

4.5.2 Indent continuation lines at least +4 spaces^{oo}

When line-wrapping, each line after the first (each *continuation line*) is indented at least +4 from the original line, unless it falls under the rules of block indentation.

When there are multiple continuation lines, indentation may be varied beyond +4 as appropriate. In general, continuation lines at a deeper syntactic level are indented by larger multiples of 4, and two lines use the same indentation level if and only if they begin with syntactically parallel elements.

[4.6.4 Horizontal alignment: discouraged](#) addresses the discouraged practice of using a variable number of spaces to align certain tokens with previous lines.

4.6 Whitespace^{oo}

4.6.1 Vertical whitespace^{oo}

A single blank line appears:

1. Between consecutive methods in a class or object literal
- a. Exception: A blank line between two consecutive properties definitions in an object literal (with no other code between them) is optional. Such blank lines are used as needed to create *logical groupings* of fields.
2. Within method bodies, sparingly to create *logical groupings* of statements. Blank lines at the start or end of a function body are not allowed.
3. *Optionally* before the first or after the last method in a class or object literal (neither encouraged nor discouraged).
4. As required by other sections of this document (e.g. [3.4 goog.require statements](#)).
Multiple consecutive blank lines are permitted, but never required (nor encouraged).

4.6.2 Horizontal whitespace^{oo}

Use of horizontal whitespace depends on location, and falls into three broad categories: *leading* (at the start of a line), *trailing* (at the end of a line), and *internal*. Leading whitespace (i.e., indentation) is addressed elsewhere. Trailing whitespace is forbidden.

Beyond where required by the language or other style rules, and apart from literals, comments, and JSDoc, a single internal ASCII space also appears in the following places **only**.

1. Separating any reserved word (such as `if`, `for`, or `catch`) from an open parenthesis (`(`) that follows it on that line.
2. Separating any reserved word (such as `else` or `catch`) from a closing curly brace (`}`) that precedes it on that line.
3. Before any open curly brace (`{`), with two exceptions:
 - a. Before an object literal that is the first argument of a function or the first element in an array literal (e.g. `foo({a: [{c: d}]})`).
 - b. In a template expansion, as it is forbidden by the language (e.g. `abc${1 + 2}def`).
4. On both sides of any binary or ternary operator.
5. After a comma (`,`) or semicolon (`;`). Note that spaces are *never* allowed before these characters.
6. After the colon (`:`) in an object literal.
7. On both sides of the double slash (`//`) that begins an end-of-line comment. Here, multiple spaces are allowed, but not required.

8. After an open-JSDoc comment character and on both sides of close characters (e.g. for short-form type declarations or casts: `this.foo = /** @type {number} */ (bar);` or `function(/** string */ foo) {}`).

4.6.3 Rectangle Rule^{aa}

All code should follow the Rectangle Rule.

When a source file is formatted, each subtree gets its own bounding rectangle, containing all of that subtree's text and none of any other subtree's.

What does this mean? Take the well formatted example below, and draw a rectangle around just the subexpression `x / currentEstimate`:

```
currentEstimate =  
    (currentEstimate + x / currentEstimate)  
    / 2.0f;
```

This is possible—good! But in the badly formatted example, there is no rectangle containing just that subexpression and nothing more—bad!

```
currentEstimate = (currentEstimate + x  
    / currentEstimate) / 2.0f;
```

In the well formatted example, every subtree has its own rectangle; for instance, the right-hand side (RHS) of the assignment has its own rectangle in the well formatted example, but not in the other. This promotes readability by exposing program structure in the physical layout; the RHS is in just one place, not partly in one place and partly another.

4.6.4 Horizontal alignment: discouraged^{aa}

Terminology Note: *Horizontal alignment* is the practice of adding a variable number of additional spaces in your code with the goal of making certain tokens appear directly below certain other tokens on previous lines.

This practice is permitted, but it is **generally discouraged** by Google Style. It is not even required to *maintain* horizontal alignment in places where it was already used.

Here is an example without alignment, followed by one with alignment. Both are allowed, but the latter is discouraged:

```
{  
    tiny: 42, // this is great  
    longer: 435, // this too  
};  
  
{  
    tiny:    42,  // permitted, but future edits  
    longer: 435, // may leave it unaligned  
};
```

Tip: Alignment can aid readability, but it creates problems for future maintenance. Consider a future change that needs to touch just one line. This change may leave the formerly-pleasing formatting mangled, and that is allowed. More often it prompts the coder (perhaps you) to adjust whitespace on nearby lines as well, possibly triggering a cascading series of reformatting. That one-line change now has a blast radius. This can at worst result in pointless busywork, but at best it still corrupts version history information, slows down reviewers and exacerbates merge conflicts.

4.6.5 Function arguments^{ad}

Prefer to put all function arguments on the same line as the function name. If doing so would exceed the 80-column limit, the arguments must be line-wrapped in a readable way. To save space, you may wrap as close to 80 as possible, or put each argument on its own line to enhance readability. Indentation should be four spaces. Aligning to the parenthesis is allowed, but discouraged. Below are the most common patterns for argument wrapping:

```
// Arguments start on a new line, indented four spaces. Preferred when the
// arguments don't fit on the same line with the function name (or the keyword
// "function") but fit entirely on the second line. Works with very long
// function names, survives renaming without reindenting, low on space.
doSomething(
    descriptiveArgumentOne, descriptiveArgumentTwo, descriptiveArgumentThree) {
    // ...
}

// If the argument list is longer, wrap at 80. Uses less vertical space,
// but violates the rectangle rule and is thus not recommended.
doSomething(veryDescriptiveArgumentNumberOne, veryDescriptiveArgumentTwo,
    tableModelEventHandlerProxy, artichokeDescriptorAdapterIterator) {
    // ...
}

// Four-space, one argument per line. Works with long function names,
// survives renaming, and emphasizes each argument.
doSomething(
    veryDescriptiveArgumentNumberOne,
    veryDescriptiveArgumentTwo,
    tableModelEventHandlerProxy,
    artichokeDescriptorAdapterIterator) {
    // ...
}
```

4.7 Grouping parentheses: recommended^{ad}

Optional grouping parentheses are omitted only when the author and reviewer agree that there is no reasonable chance that the code will be misinterpreted without them, nor would they have made the code easier to read. It is *not* reasonable to assume that every reader has the entire operator precedence table memorized.

Do not use unnecessary parentheses around the entire expression following `delete`, `typeof`, `void`, `return`, `throw`, `case`, `in`, or `of`.

Parentheses are required for type casts: `/** @type {!Foo} */ (foo).`

4.8 Comments^{ad}

This section addresses *implementation comments*. JSDoc is addressed separately in [7.JSDoc](#).

4.8.1 Block comment style^{ad}

Block comments are indented at the same level as the surrounding code. They may be in `/* ... */` or `/** ... */`-style. For multi-line `/* ... */` comments, subsequent lines must start with `*` aligned with the `*` on the previous line, to make

comments obvious with no extra context. "Parameter name" comments should appear after values whenever the value and method name do not sufficiently convey the meaning.

```
/*
 * This is
 * okay.
 */

// And so
// is this.

/* This is fine, too. */

someFunction(obviousParam, true /* shouldRender */, 'hello' /* name */);
```

Comments are not enclosed in boxes drawn with asterisks or other characters.

Do not use JSDoc (`/** ... */`) for any of the above implementation comments.

```
TODO(username): comment
TODO(b/buganizer_id): comment
TODO(tashana): Remove this code after the UrlTable2 has been checked in.
TODO(b/6002235): remove the "Last visitors" feature
```

5 Language features^{oo}

JavaScript includes many dubious (and even dangerous) features. This section delineates which features may or may not be used, and any additional constraints on their use.

5.1 Local variable declarations^{oo}

5.1.1 Use `const` and `let`^{oo}

Declare all local variables with either `const` or `let`. Use `const` by default, unless a variable needs to be reassigned. The `var` keyword must not be used.

5.1.2 One variable per declaration^{oo}

Every local variable declaration declares only one variable: declarations such as `let a = 1, b = 2;` are not used.

5.1.3 Declared when needed, initialized as soon as possible^{oo}

Local variables are **not** habitually declared at the start of their containing block or block-like construct. Instead, local variables are declared close to the point they are first used (within reason), to minimize their scope.

5.1.4 Declare types as needed^{oo}

JSDoc type annotations may be added either on the line above the declaration, or else inline before the variable name.

Example:

```
const /** !Array<number> */ data = [];
```

```
/** @type {!Array<number>} */  
const data = [];
```

Tip: There are many cases where the compiler can infer a templated type but not its parameters. This is particularly the case when the initializing literal or constructor call does not include any values of the template parameter type (e.g., empty arrays, objects, `Maps`, or `Sets`), or if the variable is modified in a closure. Local variable type annotations are particularly helpful in these cases since otherwise the compiler will infer the template parameter as unknown.

5.2 Array literals

5.2.1 Use trailing commas

Include a trailing comma whenever there is a line break between the final element and the closing bracket.

Example:

```
const values = [  
  'first value',  
  'second value',  
];
```

5.2.2 Do not use the variadic `Array` constructor

The constructor is error-prone if arguments are added or removed. Use a literal instead.

Illegal:

```
const a1 = new Array(x1, x2, x3);  
const a2 = new Array(x1, x2);  
const a3 = new Array(x1);  
const a4 = new Array();
```

This works as expected except for the third case: if `x1` is a whole number then `a3` is an array of size `x1` where all elements are `undefined`. If `x1` is any other number, then an exception will be thrown, and if it is anything else then it will be a single-element array.

Instead, write

```
const a1 = [x1, x2, x3];  
const a2 = [x1, x2];  
const a3 = [x1];  
const a4 = [];
```

Explicitly allocating an array of a given length using `new Array(length)` is allowed when appropriate.

5.2.3 Non-numeric properties

Do not define or use non-numeric properties on an array (other than `length`). Use a `Map` (or `Object`) instead.

5.2.4 Destructuring

Array literals may be used on the left-hand side of an assignment to perform destructuring (such as when unpacking multiple values from a single array or iterable. A final rest element may be included (with no space between the `...` and the variable name). Elements should be omitted if they are unused.

```
const [a, b, c, ...rest] = generateResults();
let [ , b,, d] = someArray;
```

Destructuring may also be used for function parameters (note that a parameter name is required but ignored). Always specify `[]` as the default value if a destructured array parameter is optional, and provide default values on the left hand side:

```
/** @param {!Array<number>=} param1 */
function optionalDestructuring([a = 4, b = 2] = []) { ... };
```

Illegal:

```
function badDestructuring([a, b] = [4, 2]) { ... };
```

Tip: For (un)packing multiple values into a function's parameter or return, prefer object destructuring to array destructuring when possible, as it allows naming the individual elements and specifying a different type for each.*

5.2.5 Spread operator

Array literals may include the spread operator (`...`) to flatten elements out of one or more other iterables. The spread operator should be used instead of more awkward constructs with `Array.prototype`. There is no space after the `...`.

Example:

```
[...foo]    // preferred over Array.prototype.slice.call(foo)
[...foo, ...bar] // preferred over foo.concat(bar)
```

5.3 Object literals

5.3.1 Use trailing commas

Include a trailing comma whenever there is a line break between the final property and the closing brace.

5.3.2 Do not use the `Object` constructor

While `Object` does not have the same problems as `Array`, it is still disallowed for consistency. Use an object literal (`{}` or `{a: 0, b: 1, c: 2}`) instead.

5.3.3 Do not mix quoted and unquoted keys

Object literals may represent either *structs* (with unquoted keys and/or symbols) or *dicts* (with quoted and/or computed keys). Do not mix these key types in a single object literal.

Illegal:

```
{
  a: 42, // struct-style unquoted key
  'b': 43, // dict-style quoted key
}
```

5.3.4 Computed property names

Computed property names (e.g., `{['key' + foo()]: 42}`) are allowed, and are considered dict-style (quoted) keys (i.e., must not be mixed with non-quoted keys) unless the computed property is a symbol

(e.g., `[Symbol.iterator]`). Enum values may also be used for computed keys, but should not be mixed with non-enum keys in the same literal.

5.3.5 Method shorthand

Methods can be defined on object literals using the method shorthand (`{method() {...}}`) in place of a colon immediately followed by a `function` or arrow function literal.

Example:

```
return {
  stuff: 'candy',
  method() {
    return this.stuff; // Returns 'candy'
  },
};
```

Note that `this` in a method shorthand or `function` refers to the object literal itself whereas `this` in an arrow function refers to the scope outside the object literal.

Example:

```
class {
  getObjectLiteral() {
    this.stuff = 'fruit';
    return {
      stuff: 'candy',
      method: () => this.stuff, // Returns 'fruit'
    };
  }
}
```

5.3.6 Shorthand properties

Shorthand properties are allowed on object literals.

Example:

```
const foo = 1;
const bar = 2;
const obj = {
  foo,
  bar,
  method() { return this.foo + this.bar; },
};
assertEquals(3, obj.method());
```

5.3.7 Destructuring

Object destructuring patterns may be used on the left-hand side of an assignment to perform destructuring and unpack multiple values from a single object.

Destructured objects may also be used as function parameters, but should be kept as simple as possible: a single level of unquoted shorthand properties. Deeper levels of nesting and computed properties may not be used in parameter destructuring. Specify any default values in the left-hand-side of the destructured parameter (`{str = 'some default'} = {}`, rather than `{str} = {str: 'some default'}`), and if a destructured object is itself optional, it must default to `{}`. The JSDoc for the destructured parameter may be given any name (the name is unused but is required by the compiler).

Example:

```
/**
 * @param {string} ordinary
 * @param {{num: (number|undefined), str: (string|undefined)}} param1
 *   num: The number of times to do something.
 *   str: A string to do stuff to.
 */
function destructured(ordinary, {num, str = 'some default'} = {})
```

Illegal:

```
/** @param {{x: {num: (number|undefined), str: (string|undefined)}}} param1 */
function nestedTooDeeply({x: {num, str}}) {};
/** @param {{num: (number|undefined), str: (string|undefined)}} param1 */
function nonShorthandProperty({num: a, str: b} = {}) {};
/** @param {{a: number, b: number}} param1 */
function computedKey({a, b, [a + b]: c}) {};
/** @param {{a: number, b: string}} param1 */
function nontrivialDefault({a, b} = {a: 2, b: 4}) {};
```

Destructuring may also be used for `goog.require` statements, and in this case must not be wrapped: the entire statement occupies one line, regardless of how long it is (see [3.4 goog.require statements](#)).

5.3.8 Enums

Enumerations are defined by adding the `@enum` annotation to an object literal. Additional properties may not be added to an enum after it is defined. Enums must be constant, and all enum values must be deeply immutable.

```
/**
 * Supported temperature scales.
 * @enum {string}
 */
const TemperatureScale = {
  CELSIUS: 'celsius',
  FAHRENHEIT: 'fahrenheit',
};

/**
 * An enum with two options.
 * @enum {number}
 */
const Option = {
  /** The option used shall have been the first. */
  FIRST_OPTION: 1,
  /** The second among two options. */
}
```

```
SECOND_OPTION: 2,
};
```

5.4 Classes^{oo}

5.4.1 Constructors^{oo}

Constructors are optional for concrete classes, and when present must be the first method defined in the class literal. Subclass constructors must call `super()` before setting any fields or otherwise accessing `this`. Interfaces must not define a constructor.

5.4.2 Fields^{oo}

Set all of a concrete object's fields (i.e. all properties other than methods) in the constructor. Annotate fields that are never reassigned with `@const` (these need not be deeply immutable). Private fields must be annotated with `@private` and their names must end with a trailing underscore. Fields are never set on a concrete class' `prototype`.

Example:

```
class Foo {
  constructor() {
    /** @private @const {!Bar} */
    this.bar_ = computeBar();
  }
}
```

Tip: Properties should never be added to or removed from an instance after the constructor is finished, since it significantly hinders VMS' ability to optimize. If necessary, fields that are initialized later should be explicitly set to `undefined` in the constructor to prevent later shape changes. Adding `@struct` to an object will check that undeclared properties are not added/accessed. Classes have this added by default.

5.4.3 Computed properties^{oo}

Computed properties may only be used in classes when the property is a symbol. Dict-style properties (that is, quoted or computed non-symbol keys, as defined in [5.3.3 Do not mix quoted and unquoted keys](#)) are not allowed.

A `[Symbol.iterator]` method should be defined for any classes that are logically iterable. Beyond this, `Symbol` should be used sparingly.

Tip: be careful of using any other built-in symbols (e.g., `Symbol.isConcatSpreadable`) as they are not polyfilled by the compiler and will therefore not work in older browsers.

5.4.4 Static methods^{oo}

Where it does not interfere with readability, prefer module-local functions over private static methods.

Static methods should only be called on the base class itself. Static methods should not be called on variables containing a dynamic instance that may be either the constructor or a subclass constructor (and must be defined with `@nocollapse` if this is done), and must not be called directly on a subclass that doesn't define the method itself.

Illegal:

```
class Base { /** @nocollapse */ static foo() {} }
class Sub extends Base {}
function callFoo(cls) { cls.foo(); } // discouraged: don't call static methods dynamically
```



```
Sub.foo(); // illegal: don't call static methods on subclasses that don't define it themselves
```

5.4.5 Old-style class declarations^{oo}

Old-style class declarations (either using a `/** @constructor */`-annotated function, or else `goog.defineClass`) are *not* allowed.

5.4.6 Do not manipulate prototypes directly^{oo}

The `class` keyword allows clearer and more readable class definitions than defining `prototype` properties. Ordinary implementation code has no business manipulating these objects, though they are still useful for defining `@record` interfaces. Mixins and modifying the prototypes of builtin objects are explicitly forbidden.

Exception: Framework code (such as Polymer, or Angular) may need to use `prototype`s, and should not resort to even-worse workarounds to avoid doing so.

5.4.7 Getters and Setters^{oo}

Do not use [JavaScript getter and setter properties](#). They are potentially surprising and difficult to reason about, and have limited support in the compiler. Provide ordinary methods instead.

Exception: when working with data binding frameworks (such as Angular and Polymer), getters and setters may be used sparingly. Note, however, that compiler support is limited. When they are used, they must be defined either with `get foo()` and `set foo(value)` in the class or object literal, or if that is not possible, with `Object.defineProperties`. Do not use `Object.defineProperty`, which interferes with property renaming. Getters **must not** change observable state.

Illegal:

```
class Foo {  
  get next() { return this.nextId++; }  
}
```

5.4.8 Overriding toString^{oo}

The `toString` method may be overridden, but must always succeed and never have visible side effects.

Tip: Beware, in particular, of calling other methods from `toString`, since exceptional conditions could lead to infinite loops.

5.4.9 Interfaces^{oo}

Interfaces may be declared with `@interface` or `@record`. Interfaces declared with `@record` can be explicitly (i.e. via `@implements`) or implicitly implemented by a class or object literal. In particular, do not use a `@typedef` to define a record literal.

All non-static method bodies on an interface must be empty blocks. Fields must be defined after the interface body as stubs on the `prototype`.

Example:

```
/**  
 * Something that can frobnicate.  
 * @record  
 */  
class Frobnicator {  
  /**  
   * Performs the frobnication according to the given strategy.  }  
}
```

```

    * @param {!FrobnicationStrategy} strategy
    */
    frobnicate(strategy) {}
}

/** @type {number} The number of attempts before giving up. */
Frobnicator.prototype.attempts;

```

5.5 Functions

5.5.1 Top-level functions

Exported functions may be defined directly on the `exports` object, or else declared locally and exported separately. Non-exported functions are encouraged and should not be declared `@private`.

Examples:

```

/** @return {number} */
function helperFunction() {
    return 42;
}

/** @return {number} */
function exportedFunction() {
    return helperFunction() * 2;
}

/**
 * @param {string} arg
 * @return {number}
 */
function anotherExportedFunction(arg) {
    return helperFunction() / arg.length;
}

/** @const */
exports = {exportedFunction, anotherExportedFunction};

/** @param {string} arg */
exports.foo = (arg) => {
    // do some stuff ...
};

```

5.5.2 Nested functions and closures

Functions may contain nested function definitions. If it is useful to give the function a name, it should be assigned to a local `const`.

5.5.3 Arrow functions

Arrow functions provide a concise syntax and fix a number of difficulties with `this`. Prefer arrow functions over the `function` keyword, particularly for nested functions (but see [5.3.5 Method shorthand](#)).

Never call `f.bind(this)` or `goog.bind(f, this)` (and avoid writing `const self = this`). All of these can be expressed more clearly and less error-prone with an arrow function. This is particularly useful for callbacks, which sometimes pass unexpected additional arguments.

The right-hand side of the arrow may be a single expression or a block. Parentheses around the arguments are optional if there is only a single non-destructured argument.

Tip: It is a good practice to use parentheses even for single-argument arrows, since the code may still parse reasonably (but incorrectly) if the parentheses are forgotten when an additional argument is added.

5.5.4 Generators

Generators enable a number of useful abstractions and may be used as needed.

When defining generator functions, attach the `*` to the `function` keyword when present, and separate it with a space from the name of the function. When using delegating yields, attach the `*` to the `yield` keyword.

Example:

```
/** @return {!Iterator<number>} */
function* gen1() {
  yield 42;
}

/** @return {!Iterator<number>} */
const gen2 = function*() {
  yield* gen1();
}

class SomeClass {
  /** @return {!Iterator<number>} */
  * gen() {
    yield 42;
  }
}
```

5.5.5 Parameters

Function parameters must be typed with JSDoc annotations in the JSDoc preceding the function's definition, except in the case of same-signature `@overrides`, where all types are omitted.

For anonymous functions (arrows and unnamed function expressions), parameter types *may* be specified inline, immediately before the parameter name (as in `(/** number */ foo, /** string */ bar) => foo + bar`). This is not allowed for other functions, including class methods and those that are assigned to variables or properties, in which case the parameter and/or return type annotations must be specified on the field, variable, or method.

Illegal:

```
const func = (/** number */ foo) => 2 * foo; // use ordinary @param instead
```

5.5.5.1 Default parameters

Optional parameters are permitted using the equals operator in the parameter list. Optional parameters must include spaces on both sides of the equals operator, be named exactly like required parameters (i.e., not prefixed with `opt_`), use the `=` suffix in their JSDoc type, come after required parameters, and not use initializers that produce observable

side effects. All optional parameters must have a default value in the function declaration, even if that value is `undefined`.

Example:

```
/**
 * @param {string} required This parameter is always needed.
 * @param {string=} optional This parameter can be omitted.
 * @param {!Node=} node Another optional parameter.
 */
function maybeDoSomething(required, optional = "", node = undefined) {}
```

Use default parameters sparingly. Prefer destructuring (as in [5.3.7 Destructuring](#)) to create readable APIs when there are more than a small handful of optional parameters that do not have a natural order.

Note: Unlike Python's default parameters, it is okay to use initializers that return new mutable objects (such as `{}` or `[]`) because the initializer is evaluated each time the default value is used, so a single object won't be shared across invocations.

Tip: While arbitrary expressions including function calls may be used as initializers, these should be kept as simple as possible. Avoid initializers that expose shared mutable state, as that can easily introduce unintended coupling between function calls.

5.5.5.2 Rest parameters

Use a *rest* parameter instead of accessing `arguments`. Rest parameters are typed with a `...` prefix in their JSDoc. The rest parameter must be the last parameter in the list. There is no space between the `...` and the parameter name. Do not name the rest parameter `var_args`. Never name a local variable or parameter `arguments`, which confusingly shadows the built-in name.

Example:

```
/**
 * @param {!Array<string>} array This is an ordinary parameter.
 * @param {...number} numbers The remainder of arguments are all numbers.
 */
function variadic(array, ...numbers) {}
```

5.5.6 Returns

Function return types must be specified in the JSDoc directly above the function definition, except in the case of same-signature `@overrides` where all types are omitted.

5.5.7 Generics

Declare generic functions and methods when necessary with `@template TYPE` in the JSDoc above the class definition.

5.5.8 Spread operator

Function calls may use the spread operator (`...`). Prefer the spread operator to `Function.prototype.apply` when an array or iterable is unpacked into multiple parameters of a variadic function. There is no space after the `...`.

Example:

```
function myFunction(...elements) {}
```

```
myFunction(...array, ...iterable, ...generator());
```

5.6 String literals

5.6.1 Use single quotes

Ordinary string literals are delimited with single quotes (`'`), rather than double quotes (`"`).

Tip: if a string contains a single quote character, consider using a template string to avoid having to escape the quote.

Ordinary string literals may not span multiple lines.

5.6.2 Template strings

Use template strings (delimited with ```) over complex string concatenation, particularly if multiple string literals are involved. Template strings may span multiple lines.

If a template string spans multiple lines, it does not need to follow the indentation of the enclosing block, though it may if the added whitespace does not matter.

Example:

```
function arithmetic(a, b) {  
  return `Here is a table of arithmetic operations:  
  ${a} + ${b} = ${a + b}  
  ${a} - ${b} = ${a - b}  
  ${a} * ${b} = ${a * b}  
  ${a} / ${b} = ${a / b}`;  
}
```

5.6.3 No line continuations

Do not use *line continuations* (that is, ending a line inside a string literal with a backslash) in either ordinary or template string literals. Even though ES5 allows this, it can lead to tricky errors if any trailing whitespace comes after the slash, and is less obvious to readers.

Illegal:

```
const longString = 'This is a very long string that far exceeds the 80 \\  
  column limit. It unfortunately contains long stretches of spaces due \\  
  to how the continued lines are indented.';
```

Instead, write

```
const longString = 'This is a very long string that far exceeds the 80 ' +  
  'column limit. It does not contains long stretches of spaces since ' +  
  'the concatenated strings are cleaner.';
```

5.7 Number literals

Numbers may be specified in decimal, hex, octal, or binary. Use exactly `0x`, `0o`, and `0b` prefixes, with lowercase letters, for hex, octal, and binary, respectively. Never include a leading zero unless it is immediately followed by `x`, `o`, or `b`.

5.8 Control structures

5.8.1 For loops

With ES6, the language now has three different kinds of `for` loops. All may be used, though `for-of` loops should be preferred when possible.

`for-in` loops may only be used on dict-style objects (see [5.3.3 Do not mix quoted and unquoted keys](#)), and should not be used to iterate over an array. `Object.prototype.hasOwnProperty` should be used in `for-in` loops to exclude unwanted prototype properties. Prefer `for-of` and `Object.keys` over `for-in` when possible.

5.8.2 Exceptions

Exceptions are an important part of the language and should be used whenever exceptional cases occur. Always throw `Errors` or subclasses of `Error`: never throw string literals or other objects. Always use `new` when constructing an `Error`.

Custom exceptions provide a great way to convey additional error information from functions. They should be defined and used wherever the native `Error` type is insufficient.

Prefer throwing exceptions over ad-hoc error-handling approaches (such as passing an error container reference type, or returning an object with an error property).

5.8.2.1 Empty catch blocks

It is very rarely correct to do nothing in response to a caught exception. When it truly is appropriate to take no action whatsoever in a catch block, the reason this is justified is explained in a comment.

```
try {  
  return handleNumericResponse(response);  
} catch (ok) {  
  // it's not numeric; that's fine, just continue  
}  
return handleTextResponse(response);
```

Illegal:

```
try {  
  shouldFail();  
  fail('expected an error');  
}  
catch (expected) {}
```

Tip: Unlike in some other languages, patterns like the above simply don't work since this will catch the error thrown by `fail`. Use `assertThrows()` instead.

5.8.3 Switch statements

Terminology Note: Inside the braces of a switch block are one or more statement groups. Each statement group consists of one or more switch labels (either `case FOO:` or `default:`), followed by one or more statements.

5.8.3.1 Fall-through: commented

Within a switch block, each statement group either terminates abruptly (with a `break`, `return` or `throw` exception), or is marked with a comment to indicate that execution will or might continue into the next statement group. Any

comment that communicates the idea of fall-through is sufficient (typically `// fall through`). This special comment is not required in the last statement group of the switch block.

Example:

```
switch (input) {  
  case 1:  
  case 2:  
    prepareOneOrTwo();  
    // fall through  
  case 3:  
    handleOneTwoOrThree();  
    break;  
  default:  
    handleLargeNumber(input);  
}
```

5.8.3.2 The `default` case is present

Each switch statement includes a `default` statement group, even if it contains no code.

5.9 `this`

Only use `this` in class constructors and methods, or in arrow functions defined within class constructors and methods. Any other uses of `this` must have an explicit `@this` declared in the immediately-enclosing function's JSDoc.

Never use `this` to refer to the global object, the context of an `eval`, the target of an event, or unnecessarily `call()`ed or `apply()`ed functions.

5.10 Disallowed features

5.10.1 `with`

Do not use the `with` keyword. It makes your code harder to understand and has been banned in strict mode since ES5.

5.10.2 Dynamic code evaluation

Do not use `eval` or the `Function(...string)` constructor (except for code loaders). These features are potentially dangerous and simply do not work in CSP environments.

5.10.3 Automatic semicolon insertion

Always terminate statements with semicolons (except function and class declarations, as noted above).

5.10.4 Non-standard features

Do not use non-standard features. This includes old features that have been removed (e.g., `WeakMap.clear`), new features that are not yet standardized (e.g., the current TC39 working draft, proposals at any stage, or proposed but not-yet-complete web standards), or proprietary features that are only implemented in some browsers. Use only features defined in the current ECMA-262 or WHATWG standards. (Note that projects writing against specific APIs, such as Chrome extensions or Node.js, can obviously use those APIs). Non-standard language “extensions” (such as those provided by some external transpilers) are forbidden.

5.10.5 Wrapper objects for primitive types

Never use `new` on the primitive object wrappers (`Boolean`, `Number`, `String`, `Symbol`), nor include them in type annotations.

Illegal:

```
const /** Boolean */ x = new Boolean(false);
if (x) alert(typeof x); // alerts 'object' - WAT?
```

The wrappers may be called as functions for coercing (which is preferred over using `+` or concatenating the empty string) or creating symbols.

Example:

```
const /** boolean */ x = Boolean(0);
if (!x) alert(typeof x); // alerts 'boolean', as expected
```

5.10.6 Modifying builtin objects

Never modify builtin types, either by adding methods to their constructors or to their prototypes. Avoid depending on libraries that do this. Note that the JSCompiler's runtime library will provide standards-compliant polyfills where possible; nothing else may modify builtin objects.

Do not add symbols to the global object unless absolutely necessary (e.g. required by a third-party API).

6 Naming

6.1 Rules common to all identifiers

Identifiers use only ASCII letters and digits, and, in a small number of cases noted below, underscores and very rarely (when required by frameworks like Angular) dollar signs.

Give as descriptive a name as possible, within reason. Do not worry about saving horizontal space as it is far more important to make your code immediately understandable by a new reader. Do not use abbreviations that are ambiguous or unfamiliar to readers outside your project, and do not abbreviate by deleting letters within a word.

```
priceCountReader    // No abbreviation.
numErrors            // "num" is a widespread convention.
numDnsConnections    // Most people know what "DNS" stands for.
```

Illegal:

```
n                // Meaningless.
nErr             // Ambiguous abbreviation.
nCompConns       // Ambiguous abbreviation.
wgcConnections   // Only your group knows what this stands for.
pcReader         // Lots of things can be abbreviated "pc".
cstmrId          // Deletes internal letters.
kSecondsPerDay    // Do not use Hungarian notation.
```

6.2 Rules by identifier type

6.2.1 Package names

Package names are all `lowerCamelCase`. For example, `my.exampleCode.deepSpace`, but not `my.examplecode.deepspace` or `my.example_code.deep_space`.

6.2.1.1 Hierarchy

Module namespaces may never be named as a *direct* child of another namespace.

Illegal:

```
goog.module('foo.bar');    // 'foo.bar.qux' would be fine, though
goog.module('foo.bar.baz');
```

The directory hierarchy reflects the namespace hierarchy, so that deeper-nested children are subdirectories of higher-level parent directories. Note that this implies that owners of “parent” namespace groups are necessarily aware of all child namespaces, since they exist in the same directory.

```
goog.module('googleyhats.BowlerHat'); // internal name

const RoundHat = goog.require('foo.hats.RoundHat'); // external name

const BowlerHat = class extends RoundHat {
  ...
};
exports = BowlerHat;

goog.exportSymbol('foo.hats.BowlerHat', BowlerHat); // export external name
```

6.2.2 Class names

Class, interface, record, and typedef names are written in `UpperCamelCase`. Unexported classes are simply locals: they are not marked `@private` and therefore are not named with a trailing underscore.

Type names are typically nouns or noun phrases. For example, `Request`, `ImmutableList`, or `VisibilityMode`. Additionally, interface names may sometimes be adjectives or adjective phrases instead (for example, `Readable`).

6.2.3 Method names

Method names are written in `lowerCamelCase`. Private methods’ names must end with a trailing underscore.

Method names are typically verbs or verb phrases. For example, `sendMessage` or `stop_`. Getter and setter methods for properties are never required, but if they are used they should be named `getFoo` (or optionally `isFoo` or `hasFoo` for booleans), or `setFoo(value)` for setters.

Underscores may also appear in JsUnit test method names to separate logical components of the name. One typical pattern is `test<MethodUnderTest>_<state>`, for example `testPop_emptyStack`. There is no One Correct Way to name test methods.

6.2.4 Enum names

Enum names are written in `UpperCamelCase`, similar to classes, and should generally be singular nouns. Individual items within the enum are named in `CONSTANT_CASE`.

6.2.5 Constant names

Constant names use `CONSTANT_CASE`: all uppercase letters, with words separated by underscores. There is no reason for a constant to be named with a trailing underscore, since private static properties can be replaced by (implicitly private) module locals.

6.2.5.1 Definition of “constant”

Every constant is a `@const` static property or a module-local `const` declaration, but not all `@const` static properties and module-local `consts` are constants. Before choosing constant case, consider whether the field really feels like a *deeply immutable* constant. For example, if any of that instance's observable state can change, it is almost certainly not a constant. Merely intending to never mutate the object is generally not enough.

Examples:

```
// Constants
const NUMBER = 5;
/** @const */ exports.NAMES = ImmutableList.of('Ed', 'Ann');
/** @enum */ exports.SomeEnum = { ENUM_CONSTANT: 'value' };

// Not constants
let letVariable = 'non-const';
class MyClass { constructor() { /** @const */ this.nonStatic = 'non-static'; } };
/** @type {string} */ MyClass.staticButMutable = 'not @const, can be reassigned';
const /** Set<String> */ mutableCollection = new Set();
const /** ImmutableSet<SomeMutableType> */ mutableElements = ImmutableSet.of(mutable);
const Foo = goog.require('my.Foo'); // mirrors imported name
const logger = log.getLogger('loggers.are.not.immutable');
```

Constants' names are typically nouns or noun phrases.

6.2.5.1 Local aliases

Local aliases should be used whenever they improve readability over fully-qualified names. Follow the same rules as `goog.requires` ([3.4 goog.require statements](#)), maintaining the last part of the aliased name. Aliases may also be used within functions. Aliases must be `const`.

Examples:

```
const staticHelper = importedNamespace.staticHelper;
const CONSTANT_NAME = ImportedClass.CONSTANT_NAME;
const {assert, assertInstanceOf} = asserts;
```

6.2.6 Non-constant field names

Non-constant field names (static or otherwise) are written in `lowerCamelCase`, with a trailing underscore for private fields.

These names are typically nouns or noun phrases. For example, `computedValues` or `index_`.

6.2.7 Parameter names

Parameter names are written in `lowerCamelCase`. Note that this applies even if the parameter expects a constructor. One-character parameter names should not be used in public methods.

Exception: When required by a third-party framework, parameter names may begin with a `$`. This exception does not apply to any other identifiers (e.g. local variables or properties).

6.2.8 Local variable names

Local variable names are written in `lowerCamelCase`, except for module-local (top-level) constants, as described above. Constants in function scopes are still named in `lowerCamelCase`. Note that `lowerCamelCase` applies even if the variable holds a constructor.

6.2.9 Template parameter names^{oo}

Template parameter names should be concise, single-word or single-letter identifiers, and must be all-caps, such as `TYPE` or `THIS`.

6.3 Camel case: defined^{oo}

Sometimes there is more than one reasonable way to convert an English phrase into camel case, such as when acronyms or unusual constructs like IPv6 or iOS are present. To improve predictability, Google Style specifies the following (nearly) deterministic scheme.

Beginning with the prose form of the name:

1. Convert the phrase to plain ASCII and remove any apostrophes. For example, Müller's algorithm might become Muellers algorithm.
2. Divide this result into words, splitting on spaces and any remaining punctuation (typically hyphens).
 - a. Recommended: if any word already has a conventional camel case appearance in common usage, split this into its constituent parts (e.g., AdWords becomes ad words). Note that a word such as iOS is not really in camel case per se; it defies any convention, so this recommendation does not apply.
3. Now lowercase everything (including acronyms), then uppercase only the first character of:
 - a. ... each word, to yield upper camel case, or
 - b. ... each word except the first, to yield lower camel case
4. Finally, join all the words into a single identifier.

Note that the casing of the original words is almost entirely disregarded.

Examples:

Prose form	Correct	
XML HTTP request	XmlHttpRequest	
new customer ID	newCustomerId	
inner stopwatch	innerStopwatch	
supports IPv6 on iOS?	supportsIpv6OnIos	
YouTube importer	YouTubeImporter	

*Acceptable, but not recommended.

Note: Some words are ambiguously hyphenated in the English language: for example `nonempty` and `non-empty` are both correct, so the method names `checkNonempty` and `checkNonEmpty` are likewise both correct.

7 JSDoc^{oo}

[JSDoc](#) is used on all classes, fields, and methods.

7.1 General form^{oo}

The basic formatting of JSDoc blocks is as seen in this example:

```
/**
 * Multiple lines of JSDoc text are written here,
 * wrapped normally.
 * @param {number} arg A number to do something to.
 */
function doSomething(arg) { ... }
```

or in this single-line example:

```
/** @const @private {!Foo} A short bit of JSDoc. */
this.foo_ = foo;
```

If a single-line comment overflows into multiple lines, it must use the multi-line style with `/**` and `*/` on their own lines.

Many tools extract metadata from JSDoc comments to perform code validation and optimization. As such, these comments **must** be well-formed.

7.2 Markdown^{oo}

JSDoc is written in Markdown, though it may include HTML when necessary.

Note that tools that automatically extract JSDoc (e.g. [JsDossier](#)) will often ignore plain text formatting, so if you did this:

```
/**
 * Computes weight based on three factors:
 *   items sent
 *   items received
 *   last timestamp
 */
```

it would come out like this:

```
Computes weight based on three factors: items sent items received last timestamp
```

Instead, write a Markdown list:

```
/**
 * Computes weight based on three factors:
 * - items sent
 * - items received
 * - last timestamp
 */
```

7.3 JSDoc tags^{oo}

Google style allows a subset of JSDoc tags. See [9.1 JSDoc tag reference](#) for the complete list. Most tags must occupy their own line, with the tag at the beginning of the line.

Illegal:

```
/**
 * The "param" tag must occupy its own line and may not be combined.
 * @param {number} left @param {number} right
 */
function add(left, right) { ... }
```

Simple tags that do not require any additional data (such as `@private`, `@const`, `@final`, `@export`) may be combined onto the same line, along with an optional type when appropriate.

```
/**
 * Place more complex annotations (like "implements" and "template")
 * on their own lines. Multiple simple tags (like "export" and "final")
 * may be combined in one line.
 * @export @final
 * @implements {Iterable<TYPE>}
 * @template TYPE
 */
class MyClass {
  /**
   * @param {!ObjType} obj Some object.
   * @param {number=} num An optional number.
   */
  constructor(obj, num = 42) {
    /** @private @const {!Array<!ObjType|number>} */
    this.data_ = [obj, num];
  }
}
```

There is no hard rule for when to combine tags, or in which order, but be consistent.

For general information about annotating types in JavaScript see [Annotating JavaScript for the Closure Compiler](#) and [Types in the Closure Type System](#).

7.4 Line wrapping^{oo}

Line-wrapped block tags are indented four spaces. Wrapped description text may be lined up with the description on previous lines, but this horizontal alignment is discouraged.

```
/**
 * Illustrates line wrapping for long param/return descriptions.
 * @param {string} foo This is a param with a description too long to fit in
 *   one line.
 * @return {number} This returns something that has a description too long to
 *   fit in one line.
 */
exports.method = function(foo) {
  return 5;
};
```

Do not indent when wrapping a `@fileoverview` description.

7.5 Top/file-level comments^{oo}

A file may have a top-level file overview. A copyright notice , author information, and default [visibility level](#) are optional. File overviews are generally recommended whenever a file consists of more than a single class definition. The top level comment is designed to orient readers unfamiliar with the code to what is in this file. If present, it may provide a description of the file's contents and any dependencies or compatibility information. Wrapped lines are not indented. Example:

```
/**
 * @fileoverview Description of file, its uses and information
 * about its dependencies.
 * @package
 */
```

7.6 Class comments

Classes, interfaces and records must be documented with a description and any template parameters, implemented interfaces, visibility, or other appropriate tags. The class description should provide the reader with enough information to know how and when to use the class, as well as any additional considerations necessary to correctly use the class. Textual descriptions may be omitted on the constructor. `@constructor` and `@extends` annotations are not used with the `class` keyword unless the class is being used to declare an `@interface` or it extends a generic class.

```
/**
 * A fancier event target that does cool things.
 * @implements {Iterable<string>}
 */
class MyFancyTarget extends EventTarget {
  /**
   * @param {string} arg1 An argument that makes this more interesting.
   * @param {!Array<number>} arg2 List of numbers to be processed.
   */
  constructor(arg1, arg2) {
    // ...
  }
};

/**
 * Records are also helpful.
 * @extends {Iterator<TYPE>}
 * @record
 * @template TYPE
 */
class Listable {
  /** @return {TYPE} The next item in line to be returned. */
  next() {}
}
```

7.7 Enum and typedef comments

Enums and typedefs must be documented. Public enums and typedefs must have a non-empty description. Individual enum items may be documented with a JSDoc comment on the preceding line.

```
/**
```

```

* A useful type union, which is reused often.
* @typedef {!Bandersnatch|!BandersnatchType}
*/
let CoolUnionType;

```

```

/**
 * Types of bandersnatches.
 * @enum {string}
 */
const BandersnatchType = {
  /** This kind is really frumious. */
  FRUMIOUS: 'frumious',
  /** The less-frumious kind. */
  MANXOME: 'manxome',
};

```

Typedefs should be limited to defining aliases for unions or complex function or generic types, and should be avoided for record literals (e.g. `@typedef {{foo: number, bar: string}}`) since it does not allow documenting individual fields, nor using templates or recursive references. Prefer `@record` for anything beyond the simplest `@typedef`'d record literal.

7.8 Method and function comments

Parameter and return types must be documented. The `this` type should be documented when necessary. Method, parameter, and return descriptions (but not types) may be omitted if they are obvious from the rest of the method's JSDoc or from its signature. Method descriptions should start with a sentence written in the third person declarative voice. If a method overrides a superclass method, it must include an `@override` annotation. Overridden methods must include all `@param` and `@return` annotations if any types are refined, but should omit them if the types are all the same.

```

/** This is a class. */
class SomeClass extends SomeBaseClass {
  /**
   * Operates on an instance of MyClass and returns something.
   * @param {!MyClass} obj An object that for some reason needs detailed
   *     explanation that spans multiple lines.
   * @param {!OtherClass} obviousOtherClass
   * @return {boolean} Whether something occurred.
   */
  someMethod(obj, obviousOtherClass) { ... }

  /** @override */
  overriddenMethod(param) { ... }
}

/**
 * Top-level functions follow the same rules. This one makes an array.
 * @param {TYPE} arg
 * @return {!Array<TYPE>}
 * @template TYPE

```

```
*/  
function makeArray(arg) { ... }
```

Anonymous functions do not require JSDoc, though parameter types may be specified inline if the automatic type inference is insufficient.

```
promise.then(  
  (** !Array<number|string> */ items) => {  
    doSomethingWith(items);  
    return /** @type {string} */ (items[0]);  
  });
```

7.9 Property comments^{oo}

Property types must be documented. The description may be omitted for private properties, if name and type provide enough documentation for understanding the code.

Publicly exported constants are commented the same way as properties. Explicit types may be omitted for `@const` properties initialized from an expression with an obviously known type.

Tip: A `@const` property's type can be considered "obviously known" if it is assigned directly from a constructor parameter with a declared type, or directly from a function call with a declared return type. Non-const properties and properties assigned from more complex expressions should have their types declared explicitly.

```
/** My class. */  
class MyClass {  
  /** @param {string=} someString */  
  constructor(someString = 'default string') {  
    /** @private @const */  
    this.someString_ = someString;  
  
    /** @private @const {!OtherType} */  
    this.someOtherThing_ = functionThatReturnsAThing();  
  
    /**  
     * Maximum number of things per pane.  
     * @type {number}  
     */  
    this.someProperty = 4;  
  }  
}  
  
/**  
 * The number of times we'll try before giving up.  
 * @const  
 */  
MyClass.RETRY_COUNT = 33;
```

7.10 Type annotations^{oo}

Type annotations are found on `@param`, `@return`, `@this`, and `@type` tags, and optionally on `@const`, `@export`, and any visibility tags. Type annotations attached to JSDoc tags must always be enclosed in braces.

7.10.1 Nullability^{oo}

The type system defines modifiers `!` and `?` for non-null and nullable, respectively. Primitive types (`undefined`, `string`, `number`, `boolean`, `symbol`, and `function(...): ...`) and record literals (`{foo: string, bar: number}`) are non-null by default. Do not add an explicit `!` to these types. Object types (`Array`, `Element`, `MyClass`, etc) are nullable by default, but cannot be immediately distinguished from a name that is `@typedef`'d to a non-null-by-default type. As such, all types except primitives and record literals must be annotated explicitly with either `?` or `!` to indicate whether they are nullable or not.

7.10.2 Type Casts^{oo}

In cases where type checking doesn't accurately infer the type of an expression, it is possible to tighten the type by adding a type annotation comment and enclosing the expression in parentheses. Note that the parentheses are required.

```
/** @type {number} */ (x)
```

7.10.3 Template Parameter Types^{oo}

Always specify template parameters. This way compiler can do a better job and it makes it easier for readers to understand what code does.

Bad:

```
/** @type {!Object} */ var users;  
/** @type {!Array} */ var books;  
/** @type {!Promise} */ var response;
```

Good:

```
/** @type {!Object<string, !User>} */ const users;  
/** @type {!Array<string>} */ const books;  
/** @type {!Promise<!Response>} */ const response;  
  
/** @type {!Promise<undefined>} */ const thisPromiseReturnsNothingButParameterIsStillUseful;  
/** @type {!Object<string, *>} */ const mapOfEverything;
```

Cases when template parameters should not be used:

- `Object` is used for type hierarchy and not as map-like structure.

7.11 Visibility annotations^{oo}

Visibility annotations (`@private`, `@package`, `@protected`) may be specified in a `@fileoverview` block, or on any exported symbol or property. Do not specify visibility for local variables, whether within a function or at the top level of a module. All `@private` names must end with an underscore.

8 Policies^{oo}

8.1 Issues unspecified by Google Style: Be Consistent!^{oo}

For any style question that isn't settled definitively by this specification, prefer to do what the other code in the same file is already doing. If that doesn't resolve the question, consider emulating the other files in the same package.

8.2 Compiler warnings

8.2.1 Use a standard warning set

As far as possible projects should use `--warning_level=VERBOSE`.

8.2.2 How to handle a warning

Before doing anything, make sure you understand exactly what the warning is telling you. If you're not positive why a warning is appearing, ask for help .

Once you understand the warning, attempt the following solutions in order:

1. **First, fix it or work around it.** Make a strong attempt to actually address the warning, or find another way to accomplish the task that avoids the situation entirely.
2. **Otherwise, determine if it's a false alarm.** If you are convinced that the warning is invalid and that the code is actually safe and correct, add a comment to convince the reader of this fact and apply the `@suppress` annotation.
3. **Otherwise, leave a TODO comment.** This is a **last resort**. If you do this, **do not suppress the warning**. The warning should be visible until it can be taken care of properly.

8.2.3 Suppress a warning at the narrowest reasonable scope

Warnings are suppressed at the narrowest reasonable scope, usually that of a single local variable or very small method. Often a variable or method is extracted for that reason alone.

Example

```
/** @suppress {uselessCode} Unrecognized 'use asm' declaration */  
function fn() {  
  'use asm';  
  return 0;  
}
```

Even a large number of suppressions in a class is still better than blinding the entire class to this type of warning.

8.3 Deprecation

Mark deprecated methods, classes or interfaces with `@deprecated` annotations. A deprecation comment must include simple, clear directions for people to fix their call sites.

8.4 Code not in Google Style

You will occasionally encounter files in your codebase that are not in proper Google Style. These may have come from an acquisition, or may have been written before Google Style took a position on some issue, or may be in non-Google Style for any other reason.

8.4.1 Reformatting existing code

When updating the style of existing code, follow these guidelines.

1. It is not required to change all existing code to meet current style guidelines. Reformatting existing code is a trade-off between code churn and consistency. Style rules evolve over time and these kinds of tweaks to maintain compliance would

create unnecessary churn. However, if significant changes are being made to a file it is expected that the file will be in Google Style.

2. Be careful not to allow opportunistic style fixes to muddle the focus of a CL. If you find yourself making a lot of style changes that aren't critical to the central focus of a CL, promote those changes to a separate CL.

8.4.2 Newly added code: use Google Style

Brand new files use Google Style, regardless of the style choices of other files in the same package.

When adding new code to a file that is not in Google Style, reformatting the existing code first is recommended, subject to the advice in [8.4.1 Reformatting existing code](#).

If this reformatting is not done, then new code should be as consistent as possible with existing code in the same file, but must not violate the style guide.

8.5 Local style rules

Teams and projects may adopt additional style rules beyond those in this document, but must accept that cleanup changes may not abide by these additional rules, and must not block such cleanup changes due to violating any additional rules. Beware of excessive rules which serve no purpose. The style guide does not seek to define style in every possible scenario and neither should you.

8.6 Generated code: mostly exempt

Source code generated by the build process is not required to be in Google Style. However, any generated identifiers that will be referenced from hand-written source code must follow the naming requirements. As a special exception, such identifiers are allowed to contain underscores, which may help to avoid conflicts with hand-written identifiers.

9 Appendices

9.1 JSDoc tag reference

JSDoc serves multiple purposes in JavaScript. In addition to being used to generate documentation it is also used to control tooling. The best known are the Closure Compiler type annotations.

9.1.1 Type annotations and other Closure Compiler annotations

Documentation for JSDoc used by the Closure Compiler is described in [Annotating JavaScript for the Closure Compiler](#) and [Types in the Closure Type System](#).

9.1.2 Documentation annotations

In addition to the JSDoc described in [Annotating JavaScript for the Closure Compiler](#) the following tags are common and well supported by various documentation generations tools (such as [JsDossier](#)) for purely documentation purposes.

Tag	Template & Examples	Description
@author or @owner	@author username@google.com (First Last) <i>For example:</i>	Document the author of a file or the owner of a test, generally The @owner tag is used by the unit test dashboard to determine Not recommended.
	/** * @fileoverview Utilities for handling textareas.	

Tag	Template & Examples	Description
	<pre> * @author kuth@google.com (Uthur Pendragon) */ </pre>	
@bug	<pre> @bug bugnumber </pre> <p>For example:</p>	Indicates what bugs the given test function regression tests. Multiple bugs should each have their own @bug line, to make
	<pre> /** @bug 1234567 */ function testSomething() { // ... } </pre>	
	<pre> /** * @bug 1234568 * @bug 1234569 */ function testTwoBugs() { // ... } </pre>	
@code	<pre> {@code ...} </pre> <p>For example:</p>	Indicates that a term in a JSDoc description is code so it may b
	<pre> /** * Moves to the next position in the selection. * Throws {@code goog.iter.StopIteration} when it * passes the end of the range. * @return {!Node} The node at the next position. */ goog.dom.RangeIterator.prototype.next = function() { // ... }; </pre>	
@see	<pre> @see Link </pre> <p>For example:</p>	Reference a lookup to another class function or method.
	<pre> /** * Adds a single item, recklessly. * @see #addSafely * @see goog.Collect * @see goog.RecklessAdder#add */ </pre>	
@supported	<pre> @supported Description </pre> <p>For example:</p>	Used in a fileoverview to indicate what browsers are supported
	<pre> /** </pre>	

Tag	Template & Examples	Description
	<pre>* @fileoverview Event Manager * Provides an abstracted interface to the * browsers' event systems. * @supported IE10+, Chrome, Safari */</pre>	

You may also see other types of JSDoc annotations in third-party code. These annotations appear in the [JSDoc Toolkit Tag Reference](#) but are not considered part of valid Google style.

9.1.3 Framework specific annotations

The following annotations are specific to a particular framework.

Framework	Tag	Documentation
Angular 1	<code>@ngInject</code>	
Polymer	<code>@polymerBehavior</code>	https://github.com/google/closure-compiler/wiki/Polymer-Pas

9.1.4 Notes about standard Closure Compiler annotations

The following tags used to be standard but are now deprecated.

Tag	Template & Examples	Description
<code>@expose</code>	<code>@expose</code>	Deprecated. Do not use. Use <code>@export</code> and/or <code>@nocollapse</code>
<code>@inheritDoc</code>	<code>@inheritDoc</code>	Deprecated. Do not use. Use <code>@override</code> instead.

9.2 Commonly misunderstood style rules

Here is a collection of lesser-known or commonly misunderstood facts about Google Style for JavaScript. (The following are true statements; this is not a list of myths.)

- Neither a copyright statement nor `@author` credit is required in a source file. (Neither is explicitly recommended, either.)
- Aside from the constructor coming first ([5.4.1 Constructors](#)), there is no hard and fast rule governing how to order the members of a class ([5.4 Classes](#)).
- Empty blocks can usually be represented concisely as `{ }`, as detailed in ([4.1.3 Empty blocks: may be concise](#)).
- The prime directive of line-wrapping is: prefer to break at a higher syntactic level ([4.5.1 Where to break](#)).
- Non-ASCII characters are allowed in string literals, comments and Javadoc, and in fact are recommended when they make the code easier to read than the equivalent Unicode escape would ([2.3.3 Non-ASCII characters](#)).

9.3 Style-related tools

The following tools exist to support various aspects of Google Style.

9.4.1 Closure Compiler

This program performs type checking and other checks, optimizations and other transformations (such as EcmaScript 6 to EcmaScript 5 code lowering).

9.4.2 `clang-format`

This program reformats JavaScript source code into Google Style, and also follows a number of non-required but frequently readability-enhancing formatting practices.

`clang-format` is not required. Authors are allowed to change its output, and reviewers are allowed to ask for such changes; disputes are worked out in the usual way. However, subtrees may choose to opt in to such enforcement locally.

9.4.3 Closure compiler linter^{ad}

This program checks for a variety of missteps and anti-patterns.

9.4.4 Conformance framework^{ad}

The JS Conformance Framework is a tool that is part of the Closure Compiler that provides developers a simple means to specify a set of additional checks to be run against their code base above the standard checks.

Conformance checks can, for example, forbid access to a certain property, or calls to a certain function, or missing type information (unknowns).

These rules are commonly used to enforce critical restrictions (such as defining globals, which could break the codebase) and security patterns (such as using `eval` or assigning to `innerHTML`), or more loosely to improve code quality.

For additional information see the official documentation for the [JS Conformance Framework](#).

```
tricorder: {  
  enable: JavaScript  
}
```