Foundational Concepts for the C++0x Standard Library (Revision 3)

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Introduction

This document proposes basic support for concepts in the C++0x Standard Library. It describes a new header `<concepts>` that contains concepts that require compiler support (such as SameType and ObjectType) and concepts that describe common type behaviors likely to be used in many templates, including those in the Standard Library (such as CopyConstructible and EqualityComparable).

Within the proposed wording, text that has been added will be presented in blue and underlined when possible. Text that has been removed will be presented in red, with strike through when possible. Removals from the previous draft strike out text in green, additions are underlined in green.

Purely editorial comments will be written in a separate, shaded box.
Chapter 20  General utilities library

The following clauses describe utility and allocator requirements, utility components, tuples, type traits templates, function objects, dynamic memory management utilities, and date/time utilities, as summarized in Table 30.

Table 30: General utilities library summary

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Replace the section [utility.requirements] with the following section [utility.concepts]

20.1 Concepts

The <concepts> header describes requirements on template arguments used throughout the C++ Standard Library.

Header <concepts> synopsis

```cpp
namespace std {
    // 20.1.1, support concepts:
    concept Returnable<typename T> { }
    concept PointeeType<typename T> { }
    concept MemberPointeeType<typename T> see below;
    concept ReferentType<typename T> { }
    concept VariableType<typename T> { }
    concept ObjectTypenametypename T> see below;
    concept ClassType<typename T> see below;
    concept Class<typename T> see below;
    concept Union<typename T> see below;
    concept TrivialType<typename T> see below;
    concept StandardLayoutType<typename T> see below;
```
concept LiteralType<typename T> see below;
concept ScalarType<typename T> see below;
concept NonTypeTemplateParameterType<typename T> see below;
concept IntegralConstantExpressionType<typename T> see below;
concept IntegralType<typename T> see below;
concept EnumerationType<typename T> see below;
concept SameType<typename T, typename U> { }
concept DerivedFrom<typename Derived, typename Base> { }

// 20.1.2, true:
concept True<bool> { }
concept_map True<true> { }

// 20.1.3, operator concepts:
auto concept HasPlus<typename T, typename U=typename T> see below;
auto concept HasMinus<typename T, typename U=typename T> see below;
auto concept HasMultiply<typename T, typename U=typename T> see below;
auto concept HasDivide<typename T, typename U=typename T> see below;
auto concept HasModulus<typename T, typename U=typename T> see below;
auto concept HasUnaryPlus<typename T> see below;
auto concept HasNegate<typename T> see below;
auto concept HasLess<typename T, typename U=typename T> see below;
auto concept HasGreater<typename T, typename U=typename T> see below;
auto concept HasLessEqual<typename T, typename U=typename T> see below;
auto concept HasGreaterEqual<typename T, typename U=typename T> see below;
auto concept HasEqualTo<typename T, typename U=typename T> see below;
auto concept HasNotEqualTo<typename T, typename U=typename T> see below;
auto concept HasLogicalAnd<typename T, typename U=typename T> see below;
auto concept HasLogicalOr<typename T, typename U=typename T> see below;
auto concept HasLogicalNot<typename T> see below;
auto concept HasBitAnd<typename T, typename U=typename T> see below;
auto concept HasBitOr<typename T, typename U=typename T> see below;
auto concept HasBitXor<typename T, typename U=typename T> see below;
auto concept HasComplement<typename T> see below;
auto concept HasLeftShift<typename T, typename U=typename T> see below;
auto concept HasRightShift<typename T, typename U=typename T> see below;
auto concept HasDereferenceable<typename T> see below;
auto concept AddressableHasAddressOf<typename T> see below;
auto concept Callable<typename F, typename... Args> see below;
auto concept HasMoveAssign<typename T, typename U=typename T> see below;
auto concept HasCopyAssign<typename T, typename U=typename T> see below;
auto concept HasAssign<typename T, typename U> see below;
auto concept HasPlusAssign<typename T, typename U=typename T> see below;
auto concept HasMinusAssign<typename T, typename U=typename T> see below;
auto concept HasMultiplyAssign<typename T, typename U=typename T> see below;
auto concept HasDivideAssign<typename T, typename U=typename T> see below;
auto concept HasModulusAssign<typename T, typename U=typename T> see below;
auto concept HasBitAndAssign<typename T, typename U=typename T> see below;
auto concept HasBitOrAssign<typename T, typename U=typename T> see below;
auto concept HasBitXorAssign<typename T, typename U=typename T> see below;

auto concept HasLeftShiftAssign<typename T, typename U> see below;
auto concept HasRightShiftAssign<typename T, typename U> see below;
auto concept HasPreincrement<typename T> see below;
auto concept HasPostincrement<typename T> see below;
auto concept HasPredecrement<typename T> see below;
auto concept HasPostdecrement<typename T> see below;
auto concept HasComma<typename T, typename U> see below;

// 20.1.4, predicates:
auto concept Predicate<typename F, typename... Args> see below;

// 20.1.5, comparisons:
auto concept LessThanComparable<typename T> see below;
auto concept EqualityComparable<typename T> see below;
concept TriviallyEqualityComparable<typename T> see below;
auto concept StrictWeakOrder<typename F, typename T> see below;

// 20.1.6, construction:
auto concept HasConstructor<typename T, typename... Args> see below;
auto concept DefaultConstructible<typename T> see below;
concept TriviallyDefaultConstructible<typename T> see below;

// 20.1.7, destruction:
auto concept DestructibleHasDestructor<typename T> see below;
auto concept NothrowDestructible<typename T> see below;
concept TriviallyDestructible<typename T> see below;

// 20.1.8, copy and move:
auto concept MoveConstructible<typename T> see below;
auto concept CopyConstructible<typename T> see below;
concept TriviallyCopyConstructible<typename T> see below;
auto concept MoveAssignable<typename T> see below;
auto concept CopyAssignable<typename T> see below;
concept TriviallyCopyAssignable<typename T> see below;
auto concept HasSwap<typename T, typename U> see below;
auto concept Swappable<typename T> see below;

// 20.1.9, memory allocation:
auto concept HasPlacementNew<typename T> see below;
auto concept FreeStoreAllocatable<typename T> see below;

// 20.1.10, regular types:
auto concept Semiregular<typename T> see below;
auto concept Regular<typename T> see below;

// 20.1.11, convertibility:
auto concept ExplicitlyConvertible<typename T, typename U> see below;
auto concept Convertible<typename T, typename U> see below;
20.1.1 Support concepts

The concepts in [concept.support] provide the ability to state template requirements for C++ type classifications ([basic.types]) and type relationships that cannot be expressed directly with concepts ([concept]). Concept maps for these concepts are implicitly defined. A program shall not provide concept maps for any concept in [concept.support].

```cpp
concept Returnable<typename T> { }
// Note: Describes types that can be used as the return type of a function.
// Requires: for every non-array type T that is cv void or that meets the requirement MoveConstructible<T> (20.1.8), the concept map Returnable<T> shall be implicitly defined in namespace std.
```

```cpp
concept PointeeType<typename T> { }
// Note: describes types to which a pointer can be created.
// Requires: for every type T that is an object type, function type, or cv void, a concept map PointeeType shall be implicitly defined in namespace std.
```

```cpp
concept MemberPointeeType<typename T> : PointeeType<T> { }
// Note: describes types to which a pointer-to-member can be created.
// Requires: for every type T that is an object type or function type, a concept map MemberPointeeType shall be implicitly defined in namespace std.
```

```cpp
concept ReferentType<typename T> { }
// Note: describes types to which a reference can be created, including reference types (since references to references can be formed during substitution of template arguments).
// Requires: for every type T that is an object type, a function type, or a reference type, a concept map ReferentType shall be implicitly defined in namespace std.
```

```cpp
concept VariableType<typename T> { }
// Note: describes types that can be used to declare a variable.
// Requires: for every type T that is an object type or reference type, a concept map VariableType<T> shall be implicitly defined in namespace std.
```

```cpp
concept ObjectType<typename T> : VariableType<T>, MemberPointeeType<T>
// Note: describes object types ([basic.types]), for which storage can be allocated.
```
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Requires: for every type T that is an object type, a concept map ObjectType<T> shall be implicitly defined in namespace std.

concept ClassType<typename T> : ObjectType<T> {

Note: describes class types (i.e., unions, classes, and structs).

Requires: for every type T that is a class type ([class]), a concept map ClassType<T> shall be implicitly defined in namespace std.

concept Class<typename T> : ClassType<T> {

Note: describes classes and structs ([class]).

Requires: for every type T that is a class or struct, a concept map Class<T> shall be implicitly defined in namespace std.

concept Union<typename T> : ClassType<T> {

Note: describes union types ([class.union]).

Requires: for every type T that is a union, a concept map Union<T> shall be implicitly defined in namespace std.

concept TrivialType<typename T> : ObjectType<T> {

Note: describes trivial types ([basic.types]).

Requires: for every type T that is a trivial type, a concept map TrivialType<T> shall be implicitly defined in namespace std.

concept StandardLayoutType<typename T> : ObjectType<T> {

Note: describes standard-layout types ([basic.types]).

Requires: for every type T that is a standard-layout type, a concept map StandardLayoutType<T> shall be implicitly defined in namespace std.

concept LiteralType<typename T> : ObjectType<T> {

Note: describes literal types ([basic.types]).

Requires: for every type T that is a literal type, a concept map LiteralType<T> shall be implicitly defined in namespace std.

concept ScalarType<typename T> : TrivialType<T>, LiteralType<T>, StandardLayoutType<T> {

Note: describes scalar types ([basic.types]).

Requires: for every type T that is a scalar type, a concept map ScalarType<T> shall be implicitly defined in namespace std.

concept NonTypeTemplateParameterType<typename T> : VariableType<T> {

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Note: describes type that can be used as the type of a non-type template parameter ([temp.param]).

Requires: for every type T that can be the type of a non-type template-parameter ([temp.param]), a concept map NonTypeTemplateParameterType<T> shall be implicitly defined in namespace std.

concept IntegralConstantExpressionType<typename T> : ScalarType<T>, NonTypeTemplateParameterType<T> { }

Note: describes types that can be the type of an integral constant expression ([expr.const]).

Requires: for every type T that is an integral type or enumeration type, a concept map IntegralConstantExpressionType<T> shall be implicitly defined in namespace std.

concept IntegralType<typename T> : IntegralConstantExpressionType<T> { }

Note: describes integral types ([basic.fundamental]).

Requires: for every type T that is an integral type, a concept map IntegralType<T> shall be implicitly defined in namespace std.

concept EnumerationType<typename T> : IntegralConstantExpressionType<T> { }

Note: describes enumeration types ([dcl.enum]).

Requires: for every type T that is an enumeration type, a concept map EnumerationType<T> shall be implicitly defined in namespace std.

concept SameType<typename T, typename U> { }

Note: describes a same-type requirement ([temp.req]).

concept DerivedFrom<typename Derived, typename Base> { }

Requires: for every pair of class types (T, U), such that T is either the same as or publicly and unambiguously derived from U, a concept map DerivedFrom<T, U> shall be implicitly defined in namespace std.

20.1.2 True [concept.true]

concept True<bool> { }

concept_map True<true> { }

Note: used to express the requirement that a particular integral constant expression evaluate true.

Requires: a program shall not provide a concept map for the True concept.

20.1.3 Operator concepts [concept.operator]

auto concept HasPlus<typename T, typename U=U> { 
    typename result_type;
    result_type operator+(const T&, const U&);
}
20.1 Concepts

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1. **Note:** describes types with a binary operator `+`.

   ```cpp
   auto concept HasMinus<typename T, typename U = T> {
      typename result_type;
      result_type operator-(const T&, const U&);
   }
   ```

2. **Note:** describes types with a binary operator `-`.

   ```cpp
   auto concept HasMultiply<typename T, typename U = T> {
      typename result_type;
      result_type operator*(const T&, const U&);
   }
   ```

3. **Note:** describes types with a binary operator `*`.

   ```cpp
   auto concept HasDivide<typename T, typename U = T> {
      typename result_type;
      result_type operator/(const T&, const U&);
   }
   ```

4. **Note:** describes types with an operator `/`.

   ```cpp
   auto concept HasModulus<typename T, typename U = T> {
      typename result_type;
      result_type operator%(const T&, const U&);
   }
   ```

5. **Note:** describes types with an operator `%`.

   ```cpp
   auto concept HasUnaryPlus<typename T> {
      typename result_type;
      result_type operator+(const T&);
   }
   ```

6. **Note:** describes types with a unary operator `+`.

   ```cpp
   auto concept HasNegate<typename T> {
      typename result_type;
      result_type operator-(const T&);
   }
   ```

7. **Note:** describes types with a unary operator `-`.

   ```cpp
   auto concept HasLess<typename T, typename U = T> {
      bool operator<(const T& a, const U& b);
   }
   ```

8. **Note:** describes types with an operator `<`.

   ```cpp
   auto concept HasGreater<typename T, typename U> {
      bool operator>(const T& a, const U& b);
   }
   ```

Draft
9  
   \textit{Note}: describes types with an operator $\lt$.

   auto concept HasLessEqual<typename T, typename U> {
      bool operator<=(const T& a, const U& b);
   }

10  
   \textit{Note}: describes types with an operator $\leq$.

   auto concept HasGreaterEqual<typename T, typename U> {
      bool operator>=(const T& a, const U& b);
   }

11  
   \textit{Note}: describes types with an operator $\geq$.

   auto concept HasEqualTo<typename T, typename U> {
      bool operator==(const T& a, const U& b);
   }

12  
   \textit{Note}: describes types with an operator $\neq$.

   auto concept HasNotEqualTo<typename T, typename U> {
      bool operator!=(const T& a, const U& b);
   }

13  
   \textit{Note}: describes types with a logical conjunction operator.

   auto concept HasLogicalAnd<typename T, typename U> {
      bool operator&&(const T&, const U&);
   }

14  
   \textit{Note}: describes types with a logical disjunction operator.

   auto concept HasLogicalOr<typename T, typename U> {
      bool operator||(const T&, const U&);
   }

15  
   \textit{Note}: describes types with a logical negation operator.

   auto concept HasLogicalNot<typename T> {
      bool operator!(const T&);
   }

16  
   \textit{Note}: describes types with a binary operator $\&$.

   auto concept HasBitAnd<typename T, typename U> {
      typename result_type;
      result_type operator&(const T&, const U&);
   }

17  
   \textit{Note}: describes types with a binary operator $\|$.

   auto concept HasBitOr<typename T, typename U> {
      typename result_type;
result_type operator|(const T&, const U&);
}

**Note:** describes types with an operator |.

auto concept HasBitXor<typename T, typename U = T> {
  typename result_type;
  result_type operator^(const T&, const U&);
}

**Note:** describes types with an operator ^.

auto concept HasComplement<typename T> {
  typename result_type;
  result_type operator~(const T&);
}

**Note:** describes types with an operator ~.

auto concept HasLeftShift<typename T, typename U = T> {
  typename result_type;
  result_type operator<<(const T&, const U&);
}

**Note:** describes types with an operator <<.

auto concept HasRightShift<typename T, typename U = T> {
  typename result_type;
  result_type operator>>(const T&, const U&);
}

**Note:** describes types with an operator >>.

auto concept Has Dereferenceable<typename T> {
  typename reference result_type;
  reference operator*(const T&);
}

**Note:** describes types with a dereferencing operator *.

auto concept HasAddressableAddressOf<typename T> {
  typename pointer result_type;
  pointer operator&(T&);
}

**Note:** describes types with an address-of operator &.

auto concept Callable<typename F, typename... Args> {
  typename result_type;
  result_type operator()(F&, Args...);
}

**Note:** describes function object types callable given arguments of types Args ....
auto concept HasMoveAssign<typename T, typename U = T> {  
    typename result_type;  
    result_type T::operator=(U&&);  
};

Note: describes types with the ability to assign to an object from an rvalue (which may have a different type), potentially altering the rvalue.

auto concept HasCopyAssign<typename T, typename U = T> : HasMoveAssign<T, U> {  
    result_type T::operator=(const U&);  
};

Note: describes types with the ability to assign to an object (which may have a different type).

auto concept HasPlusAssign<typename T, typename U = T> {  
    typename result_type;  
    result_type operator+=(T&, const U&);  
};

Note: describes types with an operator +=.

auto concept HasMinusAssign<typename T, typename U = T> {  
    typename result_type;  
    result_type operator-=(T&, const U&);  
};

Note: describes types with an operator -=.

auto concept HasMultiplyAssign<typename T, typename U = T> {  
    typename result_type;  
    result_type operator*=(T&, const U&);  
};

Note: describes types with an operator *=.

auto concept HasDivideAssign<typename T, typename U = T> {  
    typename result_type;  
    result_type operator/=(T&, const U&);  
};

Note: describes types with an operator /=.

auto concept HasModulusAssign<typename T, typename U = T> {  
    typename result_type;  
    result_type operator%=(T&, const U&);  
};

Note: describes types with an operator %=.

auto concept HasBitAndAssign<typename T, typename U = T> {  
    typename result_type;  
    result_type operator&=(T&, const U&);  
};

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Note: describes types with an operator\&\&=.

```cpp
auto concept HasBitOrAssign<typename T, typename U> {
    typename result_type;
    result_type operator|=(T&, const U&);
}
```

Note: describes types with an operator\|=.

```cpp
auto concept HasBitXorAssign<typename T, typename U> {
    typename result_type;
    result_type operator^=(T&, const U&);
}
```

Note: describes types with an operator\^=.

```cpp
auto concept HasLeftShiftAssign<typename T, typename U> {
    typename result_type;
    result_type operator<<=(T&, const U&);
}
```

Note: describes types with an operator<<=.

```cpp
auto concept HasRightShiftAssign<typename T, typename U> {
    typename result_type;
    result_type operator>>=(T&, const U&);
}
```

Note: describes types with an operator>>=.

```cpp
auto concept HasPreincrement<typename T> {
    typename result_type;
    result_type operator++(T&);
}
```

Note: describes types with a pre-increment operator.

```cpp
auto concept HasPostincrement<typename T> {
    typename result_type;
    result_type operator++(T&, int);
}
```

Note: describes types with a post-increment operator.

```cpp
auto concept HasPredecrement<typename T> {
    typename result_type;
    result_type operator--(T&);
}
```

Note: describes types with a pre-decrement operator.

```cpp
auto concept HasPostdecrement<typename T> {
    typename result_type;
```
result_type operator--(T&, int);
}

Note: describes types with a post-decrement operator.

auto concept HasComma<typename T, typename U> {
    typename result_type
    result_type operator,(const T&, const U&);
}

Note: describes types with a comma operator.

20.1.4 Predicates

Note: describes function objects callable with some set of arguments, the result of which can be used in a context that requires a bool.

Requires: predicate function objects shall not apply any non-constant function through the predicate arguments.

20.1.5 Comparisons

Note: describes types with a comparison operator.

x = y
axiom Consistency(T a, T b) {
(a > b) == (b < a);
(a <= b) == !(b < a);
(a >= b) == !(a < b);
}

axiom Irreflexivity(T a) { (a < a) == false; }

axiom Antisymmetry(T a, T b) {
if (a < b)
    (b < a) == false;
}

axiom Transitivity(T a, T b, T c) {
if (a < b && b < c)
    (a < c) == true;
}

axiom TransitivityOfEquivalence(T a, T b, T c) {

Draft
if (!(a < b) && !(b < a) && !(b < c) && !(c < b))
    (!!(a < c) && !(c < a)) == true;
}
}

Note: describes types whose values can be ordered, where operator< is a strict weak ordering relation ([alg.sorting]).

auto concept StrictWeakOrder<typename F, typename T> : Predicate<F, T, T> {
    axiom Irreflexivity(F f, T a) { f(a, a) == false; }

    axiom Antisymmetry(F f, T a, T b) {
        if (f(a, b))
            f(b, a) == false;
    }

    axiom Transitivity(F f, T a, T b, T c) {
        if (f(a, b) && f(b, c))
            f(a, c) == true;
    }

    axiom TransitivityOfEquivalence(F f, T a, T b, T c) {
        if (!f(a, b) && !f(b, a) && !f(b, c) && !f(c, b))
            (!f(a, c) && !f(c, a)) == true;
    }
}

Note: describes a strict weak ordering relation ([alg.sorting]), F, on a type T.

auto concept EqualityComparable<typename T> : HasEqualTo<T, T> {
    bool operator!=(const T& a, const T& b) { return !(a == b); }

    axiom Consistency(T a, T b) {
        (a == b) == !(a != b);
    }

    axiom Reflexivity(T a) { a == a; }

    axiom Symmetry(T a, T b) {
        if (a == b)
            b == a;
    }

    axiom Transitivity(T a, T b, T c) {
        if (a == b && b == c)
            a == c;
    }
}

Note: describes types whose values can be compared for equality with operator==, which is an equivalence relation.
concept TriviallyEqualityComparable<typename T> : EqualityComparable<T> { }

Note: describes types whose equality comparison operators (==, !=) can be implemented via a bitwise equality comparison, as with memcmp. [Note: such types should not have padding, i.e. the size of the type is the sum of the sizes of its elements. If padding exists, the comparison may provide false negatives, but never false positives. — end note]

Requires: for every integral type T and pointer type, a concept map TriviallyEqualityComparable<T> shall be defined in namespace std.

## 20.1.6 Construction [concept.construct]

auto concept HasConstructor<typename T, typename... Args> : Destructible<T> { 
    T::T(Args...);
}

Note: describes types that can be constructed from a given set of arguments.

auto concept DefaultConstructible<typename T> : HasConstructor<T> { }

Note: describes types for which an object can be constructed without initializing the object to any particular value.

concept TriviallyDefaultConstructible<typename T> : DefaultConstructible<T> {} 

Note: describes types whose default constructor is trivial.

Requires: for every type T that is a trivial type ([basic.types]) or a class type with a trivial default constructor ([class.ctor]), a concept map TriviallyDefaultConstructible<T> shall be implicitly defined in namespace std.

## 20.1.7 Destruction [concept.destruct]

auto concept DestructibleHasDestructor<typename T> : VariableType<T> { 
    T::~T();
}

Note: describes types that can be destroyed, including. These are scalar types, references, and class types with a public non-deleted destructor.

Requires: following destruction of an object, all resources owned by the object are reclaimed.

auto concept NothrowDestructible<typename T> : HasDestructor<T> { }

T::~T() // inherited from HasDestructor<T>

Requires: no exception is propagated.

concept TriviallyDestructible<typename T> : NothrowDestructible<T> {} 

Note: describes types whose destructors do not need to be executed when the object is destroyed.
5 Requires: for every type T that is a trivial type (\([\text{basic.types}]\)), reference, or class type with a trivial destructor (\([\text{class.dtor}]\)), a concept map TriviallyDestructible\(<T>\) shall be implicitly defined in namespace std.

20.1.8 Copy and move [concept.copymove]

auto concept MoveConstructible<typename T> : HasConstructor<T, T&&> { }

1 Note: describes types that can move-construct an object from a value of the same type, possibly altering that value.

T::T(T&& rv); // note: inherited from HasConstructor<T, T&&>

2 Postcondition: the constructed T object is equivalent to the value of rv before the construction. [Note: there is no requirement on the value of rv after the construction. — end note]

auto concept CopyConstructible<typename T> : MoveConstructible<T>, HasConstructor<T, const T&> { 
   axiom CopyPreservation(T x) {
      T(x) == x;
   }
}

3 Note: describes types with a public copy constructor.

concept TriviallyCopyConstructible<typename T> : CopyConstructible<T> { }

4 Note: describes types whose copy constructor is equivalent to memcpy.

5 Requires: for every type T that is a trivial type (\([\text{basic.types}]\)), a reference, or a class type with a trivial copy constructor (\([\text{class.copy}]\)), a concept map TriviallyCopyConstructible\(<T>\) shall be implicitly defined in namespace std.

auto concept MoveAssignable<typename T> : HasMoveAssign<T, T&&> { }

6 Note: describes types with the ability to assign to an object from an rvalue, potentially altering the rvalue.

result_type T::operator=(T&& rv); // inherited from HasMoveAssign, HasAssign<T, T&&>

7 Postconditions: the constructed T object is equivalent to the value of rv before the assignment. [Note: there is no requirement on the value of rv after the assignment. — end note]

auto concept CopyAssignable<typename T> : HasAssign<T, const T&>, MoveAssignable<T> { 
   axiom CopyPreservation(T& x, T y) {
      (x = y, x) == y;
   }
}

8 Note: describes types with the ability to assign to an object.

The CopyAssignable requirements in N2461 specify that operator= must return a T&. This is too strong a requirement for most of the uses of CopyAssignable, so we have weakened CopyAssignable to not require anything of its return type. When we need a T&, we’ll add that as an explicit requirement. See, e.g., the IntegralLike concept.

concept TriviallyCopyAssignable<typename T> : CopyAssignable<T> { }

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Note: describes types whose copy-assignment operator is equivalent to `memcpy`.

Requires: for every type T that is a trivial type ([basic.types]) or a class type with a trivial copy assignment operator ([class.copy]), a concept map `TriviallyCopyAssignable<T>` shall be implicitly defined in namespace std.

```cpp
auto concept HasSwap<typename T, typename U> {  
    void swap(T, U);  
};

Note: describes types that have a swap operation.

```cpp
auto concept Swappable<typename T> : HasSwap<T, T> {  
    void swap(T& t, T& u);  
};

Note: describes types for which two values of that type can be swapped.

```cpp
void swap(T& t, T& u); // inherited from HasSwap<T, T>
```

Postconditions: t has the value originally held by u, and u has the value originally held by t.

### 20.1.9 Memory allocation

[concept.memory]

```cpp
auto concept HasPlacementNew<typename T> {  
    void* T::operator new(size_t size, void*);  
};

Note: Describes types that have a placement new.

```cpp
auto concept FreeStoreAllocatable<typename T> {  
    void* T::operator new(size_t size);  
    void* T::operator new(size_t size, void*);  
    void* T::operator new[](size_t size);  
    void T::operator delete(void*);  
    void T::operator delete[](void*);  
    void* T::operator new(size_t size, const noexcept_t&) {  
        try {  
            return T::operator new(size);  
        } catch(...) {  
            return 0;  
        }  
    }  
    void* T::operator new[](size_t size, const noexcept_t&) {  
        try {  
            return T::operator new[](size);  
        } catch(...) {  
            return 0;  
        }  
    }
```

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void T::operator delete(void* ptr, const nothrow_t&) {
    T::operator delete(ptr);
}

void T::operator delete[](void* ptr, const nothrow_t&) {
    T::operator delete[](ptr);
}

\textit{Note:} describes types for which objects and arrays of objects can be allocated on or freed from the free store with \texttt{new} and \texttt{delete}.

\section*{20.1.10 Regular types \hfill [concept.regular]}

auto concept Semiregular<typename T>:
    NothrowDestructible<T>, CopyConstructible<T>, CopyAssignable<T>, FreeStoreAllocatable<T> {
    requires SameType<CopyAssignable<T>::result_type, T&>;
}

\textit{Note:} collects several common requirements supported by most types.

auto concept Regular<typename T>:
    Semiregular<T>, DefaultConstructible<T>, EqualityComparable<T> { }

\textit{Note:} describes semi-regular types that are default constructible and have equality comparison operators.

\section*{20.1.11 Convertibility \hfill [concept.convertible]}

auto concept ExplicitlyConvertible<typename T, typename U>:
    VariableType<T> {
    explicit operator U(const T&);
}

\textit{Note:} describes types with a conversion (explicit or implicit) from T to U.

auto concept Convertible<typename T, typename U>:
    ExplicitlyConvertible<T, U> {
    operator U(const T&);
}

\textit{Note:} describes types with an implicit conversion from T to U.

\section*{20.1.12 Arithmetic concepts \hfill [concept.arithmetic]}

concept ArithmeticLike<typename T>:
    Regular<T>, LessThanComparable<T>, HasUnaryPlus<T>, HasNegate<T>,
    HasPlus<T, T>, HasMinus<T, T>, HasMultiply<T, T>, HasDivide<T, T>,
    HasLess<T, T>, HasGreater<T, T>, HasLessEqual<T, T>, HasGreaterEqual<T, T>,
    HasPreincrement<T>, HasPostincrement<T>, HasPredecrement<T>, HasPostdecrement<T>,
    HasPlusAssign<T, const T&>, HasMinusAssign<T, const T&>,
HasMultiplyAssign<T, const T&>, HasDivideAssign<T, const T&> {
T::T(intmax_t);
T::T(uintmax_t);
T::T(long double);

T& operator++(T&);
T operator++(T& t, int);
T operator--(T&);
T operator--(T& t, int);

requires Convertible<HasUnaryPlus<T>::result_type, T>
&& Convertible<HasNegate<T>::result_type, T>
&& Convertible<HasPlus<T, T>::result_type, T>
&& Convertible<HasMinus<T, T>::result_type, T>
&& Convertible<HasMultiply<T, T>::result_type, T>
&& SameType<HasPreincrement<T>::result_type, T&>,
&& SameType<HasPostincrement<T>::result_type, T>,
&& SameType<HasPredecrement<T>::result_type, T&>,
&& SameType<HasPostdecrement<T>::result_type, T>,
&& SameType<HasPlusAssign<T, const T&>::result_type, T&>,
&& SameType<HasMinusAssign<T, const T&>::result_type, T&>,
&& SameType<HasMultiplyAssign<T, const T&>::result_type, T&>,
&& SameType<HasDivideAssign<T, const T&>::result_type, T&>;

T& operator*=(T&, T);
T& operator/=(T&, T);
T& operator+=(T&, T);
T& operator-=(T&, T);

T& operator--(T&, T);
T& operator==(T&, T);
T& operator!=(T&, T);

Note: describes types that provide all of the operations available on arithmetic types ([basic.fundamental]).

concept IntegralLike<typename T>:
    ArithmeticLike<T>, LessThanComparable<T>,
    HasComplement<T, T>, HasModulus<T, T>, HasBitAnd<T, T>, HasBitXor<T, T>, HasBitOr<T, T>,
    HasLeftShift<T, T>, HasRightShift<T, T>,
    HasModulusAssign<T, const T>, HasLeftShiftAssign<T, const T>, HasRightShiftAssign<T, const T>,
    HasBitAndAssign<T, const T>, HasBitXorAssign<T, const T>, HasBitOrAssign<T, const T> {
requires Convertible<HasComplement<T>::result_type, T>
&& Convertible<HasModulus<T, T>::result_type, T>
&& Convertible<HasBitAnd<T, T>::result_type, T>
&& Convertible<HasBitXor<T, T>::result_type, T>
&& Convertible<HasBitOr<T, T>::result_type, T>
&& Convertible<HasLeftShift<T, T>::result_type, T>
&& Convertible<HasRightShift<T, T>::result_type, T>,
&& SameType<HasModulusAssign<T, const T>::result_type, T&>,
&& SameType<HasLeftShiftAssign<T, const T>::result_type, T&>,
&& SameType<HasRightShiftAssign<T, const T>::result_type, T&>,
&& SameType<HasBitAndAssign<T, const T>::result_type, T&>,
&& SameType<HasBitXorAssign<T, const T>::result_type, T&>,
&& SameType<HasBitOrAssign<T, const T>::result_type, T&>;

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20.1 Concepts

```cpp
#include <type_traits>

using namespace std;

template<typename T, typename U>
struct SameType;

// Cell

// Note: describes types that provide all of the operations available on integral types.
concept SignedIntegralLike<typename T> : IntegralLike<T> { }

// Note: describes types that provide all of the operations available on signed integral types.
concept UnsignedIntegralLike<typename T> : IntegralLike<T> { }

// Requires: for every signed integral type T ([basic.fundamental]), including signed extended integral types, an empty concept map SignedIntegralLike<T> shall be defined in namespace std.

// Note: describes types that provide all of the operations available on unsigned integral types.
concept FloatingPointLike<typename T> : ArithmeticLike<T> { }

// Requires: for every floating point type T ([basic.fundamental]), an empty concept map FloatingPointLike<T> shall be defined in namespace std.

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```