Standard Template Library

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1. Standard Template Library

- C++ is language plus STL:
  headers such as `vector`
- Some people (read: large companies) write their own STL.
- Here are some useful bits from the STL;
  there are many more.

Random

2. Random generators and distributions

- Random device

```
std::default_random_engine generator;
% random seed:
std::random_device r;
std::default_random_engine generator{ r() };
```

- Distributions:

```
std::uniform_real_distribution<float> distribution(0.,1.);
std::uniform_int_distribution<int> distribution(1,6);
```

- Sample from the distribution:

```
std::default_random_engine generator;
std::uniform_int_distribution<> distribution(0,nbuckets-1);
random_number = distribution(generator);
```

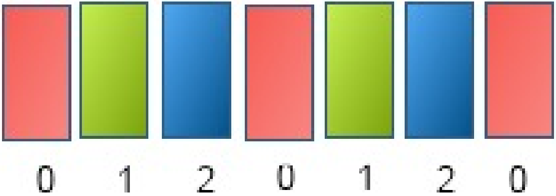
- Do not use the old C-style `random`!

3. Why so complicated?

- Large period wanted; C random has 2^{15}.
- Multiple generators, guarantee on quality.
- Simple transforms have a bias:

```
int under100 = rand() % 100
```

Simple example: period 7, mod 3



4. Dice throw

```
// set the default generator
std::default_random_engine generator;

// distribution: ints 1..6
std::uniform_int_distribution<int> distribution(1,6);

// apply distribution to generator:
int dice_roll = distribution(generator);
  // generates number in the range 1..6
```

5. Poisson distribution

Another distribution is the Poisson distribution:

```
std::default_random_engine generator;
float mean = 3.5;
std::poisson_distribution<int> distribution(mean);
int number = distribution(generator);
```

6. Global engine

Wrong approach:

Code:

```
int nonrandom_int(int max) {
  std::default_random_engine engine;
  std::uniform_int_distribution<> ints
     (1,max);
  return ints(engine);
};
```

Output
[rand] nonrandom:

```
Three ints: 15, 15,
    15.
```

Good approach:

Code:

```
int realrandom_int(int max) {
  static  std::default_random_engine
     static_engine;
  std::uniform_int_distribution<> ints
     (1,max);
  return ints(static_engine);
};
```

Output
[rand] truerandom:

```
Three ints: 15, 98,
    70.
```

Time

7. Chrono

```
#include <chrono>

// several clocks
using myclock = std::chrono::high_resolution_clock;

// time and duration
auto start_time = myclock::now();
auto duration = myclock::now()-start_time;
auto microsec_duration =
    std::chrono::duration_cast<std::chrono::microseconds>
                (duration);
cout << "This took "
     << microsec_duration.count() << "usec\n"
```

More

8. Complex numbers

```
#include <complex>

complex<float> f;
f.re = 1.; f.im = 2.;
complex<double> d(1.,3.);

using std::complex_literals::i;
std::complex<double> c = 1.0 + 1i;

conj(c); exp(c);
```

Tuples; Union-like stuff

9. C++11 style tuples

```
std::tuple<int,double> id = \
    std::make_tuple<int,double>(3,5.12);
double result = std::get<1>(id);
std::get<0>(id) += 1;
```

10. Function returning tuple

Return type deduction:

```
auto maybe_root1(float x) {
  if (x<0)
    return make_tuple
      <bool,float>(false,-1);
  else
    return make_tuple
      <bool,float>(true,sqrt(x)
    );
};
```

Alternative:

```
tuple<bool,float>
    maybe_root2(float x) {
  if (x<0)
    return {false,-1};
  else
    return {true,sqrt(x)};
};
```

11. Catching a returned tuple

The calling code is particularly elegant:

Code:

```
auto [succeed,y] = maybe_root2(x);
if (succeed)
  cout << "Root of " << x
       << " is " << y << endl;
else
  cout << "Sorry, " << x
       << " is negative" << endl;
```

Output
[stl] tuple:

```
Root of 2 is 1.41421
Sorry, -2 is negative
```

This is known as structured binding.

12. Returning two things

simple solution:

```
bool RootOrError(float &x) {
  if (x<0)
    return false;
  else
    x = sqrt(x);
  return true;
};
  /* ... */
  for ( auto x : {2.f,-2.f} )
    if (RootOrError(x))
      cout << "Root is " << x << endl;
    else
      cout << "could not take root of " << x << endl;
```

other solution: tuples

13. Tuple solution

```
tuple<bool,float> RootAndValid(float x) {
  if (x<0)
    return {false,x};
  else
    return {true,sqrt(x)};
};
  /* ... */
  for ( auto x : {2.f,-2.f} )
    if ( auto [ok,root] = RootAndValid(x) ; ok )
      cout << "Root is " << root << endl;
    else
      cout << "could not take root of " << x << endl;
```

14. Optional results (C++17)

The most elegant solution to 'a number or an error' is to have a single quantity that you can query whether it's valid.

```
optional<float> MaybeRootPtr(float x) {
  if (x<0)
    return {};
  else
    return sqrt(x);
};
  /* ... */
  for ( auto x : {2.f,-2.f} )
    if ( auto root = MaybeRootPtr(x) ; root.has_value() )
      cout << "Root is " << *root << endl;
    else
      cout << "could not take root of " << x << endl;
```

Exercise 1

Write a function *first_factor* that optionally returns the smallest factor of a given input.

```
  auto factor = first_factor(number);
  if (factor.has_value())
    cout << "Found factor: " << factor.value() << endl;
  //answersnippet optfactortest
  /* ... */
  else
    cout << "Prime number\n";

  return 0;
}
```

15. Variant

```
variant<int,double,string> union_ids;

union_ids = 3.5;
switch ( union_ids.index() ) {
case 1 :
  cout << "Double case: " << std::get<double>(union_ids) << endl;
}

union_ids = "Hello world";
if ( auto union_int = get_if<int>(&union_ids) ; union_int )
  cout << "Int: " << *union_int << endl;
else if ( auto union_string = get_if<string>(&union_ids) ; union_string
     )
  cout << "String: " << *union_string << endl;
```

Exercise 2

Write a routine that computes the roots of the quadratic equation

$$ax^2 + bx + c = 0.$$

The routine should return two roots, or one root, or an indication that the equation has no solutions.

Code:

```
for ( auto coefficients :
        { make_tuple(2.0, 1.5, 2.5),
          make_tuple(1.0, 4.0, 4.0),
          make_tuple(2.2, 5.1, 2.5)
        } ) {
  auto [a,b,c] = coefficients;
  cout << "With a=" << a << " b=" <<
    b << " c=" << c << "\n";
  auto result = compute_roots(
   coefficients);
```

Output
[union] quadratic:

```
With a=2 b=1.5 c=2.5
No root
With a=2.2 b=5.1 c
     =2.5
Root1: -0.703978
     root2: -1.6142
With a=1 b=4 c=4
Single root: -2
```

16. Problem setup

Represent the polynomial

$$ax^2 + bx + c$$

as

```
using quadratic = tuple<double,double,double>;
```

Unpack:

```
auto [a,b,c] = coefficients;
```

`assert` something here?

Exercise 3

Write a function

```
auto discriminant( quadratic coefficients );
```

that computes $b^2 - 4ac$.

Exercise 4

Write a function

```
bool discriminant_zero( quadratic coefficients );
```

that passes the test

```
quadratic coefficients = make_tuple(a,b,c);
d = discriminant( coefficients );
z = discriminant_zero( coefficients );
INFO( a << "," << b << "," << c << " d=" << d );
REQUIRE( z );
```

Using for instance the values:

```
a = 2; b = 4; c = 2;
a = 2; b = sqrt(40); c = 5; // !!!
a = 3; b = 0; c = 0.;
```

Exercise 5

Write the function *simple_root* that returns the single root. For confirmation, test

```
auto r = simple_root(coefficients);
REQUIRE( std::abs( evaluate(coefficients,r) )<1.e-12 );
```

Exercise 6

Write a function that returns the two roots as a `std::pair`:

```
pair<double,double> double_root( quadratic coefficients );
```

Test:

```
quadratic coefficients = make_tuple(a,b,c);
auto [r1,r2] = double_root(coefficients);
auto
  e1 = evaluate(coefficients,r1),
  e2 = evaluate(coefficients,r2);
REQUIRE( evaluate(coefficients,r1)==Catch::Approx(0.) );
REQUIRE( evaluate(coefficients,r2)==Catch::Approx(0.) );
```

Exercise 7

Write a function

```
variant< bool,double, pair<double,double> >
    compute_roots( quadratic coefficients);
```

Test:

```
TEST_CASE( "full test" ) {
  double a,b,c; int index;
  SECTION( "no root" ) {
    a=2.0; b=1.5; c=2.5;
    index = 0;
  }
  SECTION( "single root" ) {
    a=1.0; b=4.0; c=4.0;
    index = 1;
  }
  SECTION( "double root" ) {
    a=2.2; b=5.1; c=2.5;
    index = 2;
  }
  quadratic coefficients =
     make_tuple(a,b,c);
  auto result = compute_roots(
     coefficients);
  REQUIRE( result.index()==index );
}
```