Chapter 3
Objects, types, and values

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Overview

- Strings and string I/O
- Integers and integer I/O
- Types and objects
- Type safety

Input and output

```
// read first name:
#include "std_lib_facilities.h"                    // our course header

int main()
{
    cout << "Please enter your first name (followed " << "by 'enter'):\n";
    string first_name;
    cin >> first_name;
    cout << "Hello, " << first_name << '\n';
}

// note how several values can be output by a single statement
// a statement that introduces a variable is called a declaration
// a variable holds a value of a specified type
// the final return 0; is optional in main()
// but you may need to include it to pacify your compiler
```

Source files

std_lib_facilities.h:

Interfaces to libraries
(declarations)

Myfile.cpp:

#include "std_lib_facilities.h"

My code
My data
(definitions)

- "std_lib_facilities.h" is the header for our course

Input and type

- We read into a variable
  - Here, **first_name**
- A variable has a type
  - Here, **string**
- The type of a variable determines what operations we can do on it
  - Here, **cin>>first_name;** reads characters until a whitespace character is seen ("a word")
  - White space: space, tab, newline, …

String input

```
// read first and second name:
int main()
{
    cout << "please enter your first and second names\n";
    string first;
    string second;
    cin >> first >> second;              // read two strings
    string name = first + ' ' + second;  // concatenate strings
                                         // separated by a space
    cout << "Hello, "<< name << '\n';
}

// I left out the #include  "std_lib_facilities.h" to save space and
//  reduce distraction
// Don't forget it in real code
// Similarly, I left out the Windows-specific keep_window_open();
```

Integers

```
// read name and age:

int main()
{
    cout << "please enter your first name and age\n";
    string first_name;                  // string variable
    int age;                            // integer variable
    cin >> first_name >> age;           // read
    cout << "Hello, " << first_name << " age " << age << '\n';
}
```

Integers and Strings

- Strings
  - **cin** >> reads a word
  - **cout** << writes
  - + concatenates
  - += **s** adds the string **s** at end
  - ++ is an error
  - - is an error
  - …
- Integers and floating-point numbers
  - **cin** >> reads a number
  - **cout** << writes
  - + adds
  - += **n** increments by the int **n**
  - ++ increments by **1**
  - - subtracts
  - …

The type of a variable determines which operations are valid and what their meanings are for that type

(that's called "overloading" or "operator overloading")

Names

- A name in a C++ program
  - Starts with a letter, contains letters, digits, and underscores (only)
    - **x, number_of_elements, Fourier_transform, z2**
    - Not names:
      - **12x**
      - **timetomarket**
      - **main line**
    - Do not start names with underscores: **_foo**
      - those are reserved for implementation and systems entities
  - Users can't define names that are taken as keywords
    - E.g.:
      - **int**
      - **if**
      - **while**
      - **double**

Names

- Choose meaningful names
  - Abbreviations and acronyms can confuse people
    - **mtbf, TLA, myw, nbv**
  - Short names can be meaningful
    - (only) when used conventionally:
      - **x** is a local variable
      - **i** is a loop index
  - Don't use overly long names
    - Ok:
      - **partial_sum**
element_count
staple_partition
    - Too long:
      - **the_number_of_elements**
remaining_free_slots_in_the_symbol_table

Simple arithmetic

```
// do a bit of very simple arithmetic:

int main()
{
    cout << "please enter a floating-point number: "; // prompt for a number
    double n;                                          // floating-point variable
    cin >> n;
    cout << "n == " << n
        << "\nn+1 == " << n+1                          // '\n' means "a newline"
        << "\nthree times n == " << 3*n
        << "\ntwice n == " << n+n
        << "\nn squared == " << n*n
        << "\nhalf of n == " << n/2
        << "\nsquare root of n == " << sqrt(n)   // library function
        << '\n';
```

A simple computation

```
int main()                    // inch to cm conversion
{
    const double cm_per_inch = 2.54;    // number of centimeters per inch
    int length = 1;                     // length in inches
    while (length != 0)                 // length == 0 is used to exit the program
    {                         // a compound statement (a block)
        cout << "Please enter a length in inches: ";
        cin >> length;
        cout << length << "in.  = "
            << cm_per_inch*length << "cm.\n";
    }
}
```

- A while-statement repeatedly executes until its condition becomes false

Types and literals

Parasol
Smarter computing.
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- Built-in types
  - Boolean type
    - **bool**
  - Character types
    - **char**
  - Integer types
    - **int**
      - **and** <u>**short**</u> and <u>**long**</u>

16 bits 32 bits.

long long: 64 bits

  - Floating-point types
    - **double**
      - and **float**
- Standard-library types
  - **string**
  - <u>**complex<Scalar>**</u>

e.g., complex<float>, complex<double>, complex<long double> are representing and manipulating complex numbers

- Boolean literals
  - **true false**
- Character literals
  - **'a', 'x', '4', '\n', '$'**
- Integer literals
  - **0, 1, 123, -6, 034,** <u>**0xa3**</u>

hexadecimal? Try it out.

- Floating point literals
  - **1.2, 13.345, .3, -0.54,** <u>**1.2e3**</u>**,** <u>**.3F**</u> ?
- String literals **"asdf"**, **"Howdy, all y'all!"**
- Complex literals
  - **complex<double>(12.3,99)**
  - **complex<float>(1.3F)**

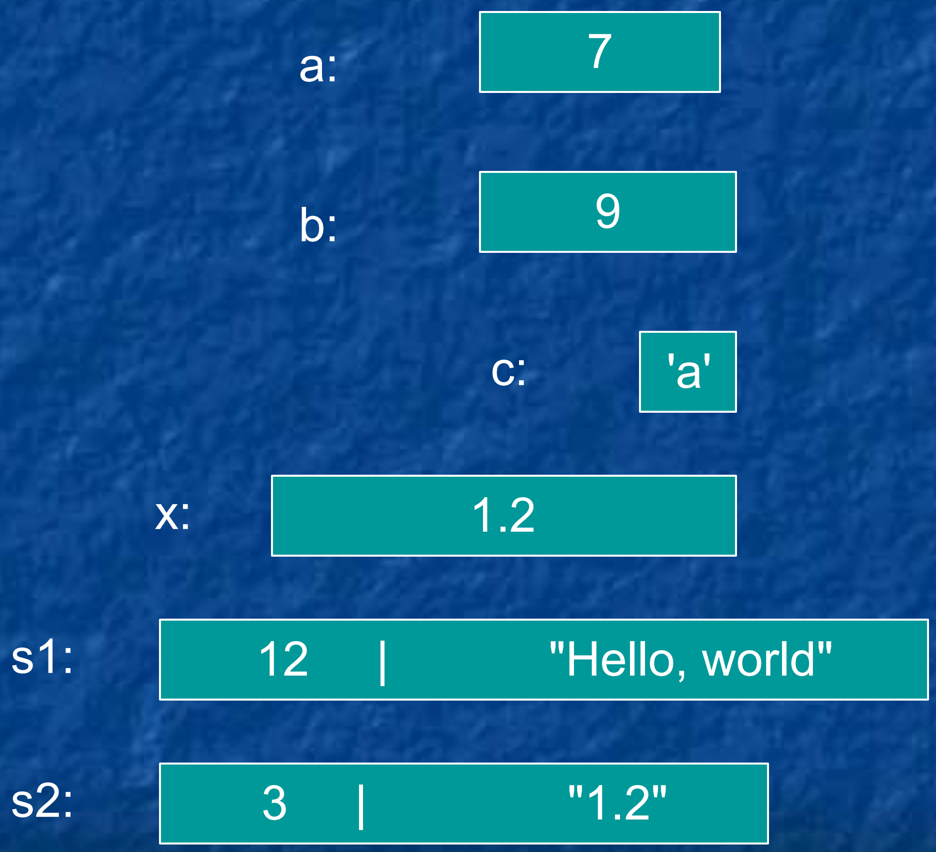
If (and only if) you need more details, see the book!

Types

- C++ provides a set of types
  - E.g. **bool**, **char**, **int**, **double**
  - **Called "built-in types"**
- C++ programmers can define new types
  - Called "user-defined types"
  - We'll get to that eventually
- The C++ standard library provides a set of types
  - E.g. **string**, **vector**, **complex**
  - Technically, these are user-defined types
    - they are built using only facilities available to every user

Declaration and initialization

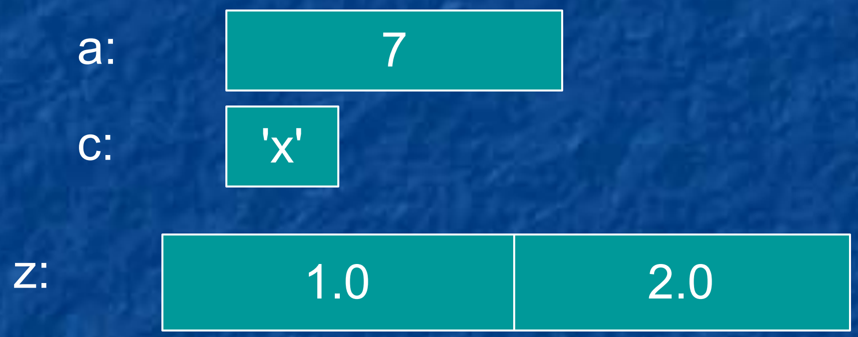
```
int a = 7;

int b = 9;

char c = 'a';

double x = 1.2;

string s1 = "Hello, world";

string s2 = "1.2";
```



Objects

- An object is some memory that can hold a value of a given type
- A variable is a named object
- A declaration names an object

```
int a = 7;
char c = 'x';
complex<double> z(1.0,2.0);
string s = "qwerty";
```



Type safety

- Language rule: type safety
  - Every object will be used only according to its type
    - A variable will be used only after it has been initialized
    - Only operations defined for the variable's declared type will be applied
    - Every operation defined for a variable leaves the variable with a valid value
- Ideal: static type safety
  - A program that violates type safety will not compile
    - The compiler reports every violation (in an ideal system)
- Ideal: dynamic type safety
  - If you write a program that violates type safety it will be detected at run time
    - Some code (typically "the run-time system") detects every violation not found by the compiler (in an ideal system)

Type safety

- Type safety is a very big deal
  - Try very hard not to violate it
  - "when you program, the compiler is your best friend"
    - But it won't feel like that when it rejects code you're sure is correct
- <u>C++ is not (completely) statically type safe</u>
  - No widely-used language is (completely) statically type safe
  - Being completely statically type safe may interfere with your ability to express ideas
- <u>C++ is not (completely) dynamically type safe</u>
  - Many languages are dynamically type safe
  - Being completely dynamically type safe may interfere with the ability to express ideas and often makes generated code bigger and/or slower
- Almost all of what you'll be taught here is type safe
  - We'll specifically mention anything that is not

Assignment and increment

```
// changing the value of a variable
int a = 7;        // a variable of type int called a
                  // initialized to the integer value 7
a = 9;            // assignment: now change a's value to 9

a = a+a;          // assignment: now double a's value

a += 2;           // increment a's value by 2

++a;              // increment a's value (by 1)
```

a:
7
9
18
20
21

A type-safety violation
("implicit narrowing")

```
// Beware: C++ does not prevent you from trying to put a large value
// into a small variable (though a compiler may warn)

int main()
{
    int a = 20000;
    char c = a;
    int b = c;
    if (a != b)                    // != means "not equal"
        cout << "oops!: " << a << "!=" << b << '\n';
    else
        cout << "Wow! We have large characters\n";
}
```

a 20000

c: ???

- Try it to see what value **b** gets on your machine

A type-safety violation (Uninitialized variables)

```
// Beware: C++ does not prevent you from trying to use a variable
// before you have initialized it  (though a compiler typically warns)

int main()
{
    int x;                      // x gets a "random" initial value
    char c;         // c gets a "random" initial value
    double d;       // d gets a "random" initial value
                    //    – not every bit pattern is a valid floating-point value
    double dd = d;              // potential error: some implementations
                                // can't copy invalid floating-point values
    cout << " x: " << x << " c: " << c << " d: " << d << '\n';
}
```

- Always initialize your variables – beware: "debug mode" may initialize (valid exception to this rule: input variable)

A technical detail

- In memory, everything is just bits; type is what gives meaning to the bits

  (bits/binary) **01100001** is the int **97** is the char **'a'**
  (bits/binary) **01000001** is the int **65** is the char **'A'**
  (bits/binary) **00110000** is the int **48** is the char **'0'**

```
char c = 'a';
cout << c;    // print the value of character c, which is a
int i = c;
cout << i;    // print the integer value of the character c, which is 97
```

- This is just as in “the real world”:
  - What does “42” mean?
  - You don’t know until you know the unit used
    - Meters? Feet? Degrees Celsius? $s? a street number? Height in inches? …

About Efficiency

- For now, don't worry about "efficiency"
  - Concentrate on correctness and simplicity of code
- C++ is derived from C, which is a systems programming language
  - C++'s built-in types map directly to computer main memory
    - a **char** is stored in a byte
    - An **int** is stored in a word – 4 bytes
    - A **double** fits in a floating-point register
  - C++'s built-in operations map directly to machine instructions
    - An integer + is implemented by an integer add operation
    - An integer = is implemented by a simple copy operation
  - C++ provides direct access to most of the facilities provided by modern hardware , such as?
- C++ help users build safer, more elegant, and efficient new types and operations using built-in types and operations.
  - E.g., **string**
  - Eventually, we'll show some of how that's done

A bit of philosophy

- One of the ways that programming resembles other kinds of engineering is that it involves tradeoffs.
- You must have ideals, but they often conflict, so you must decide what really matters for a given program.
  - Type safety
  - Run-time performance
  - Ability to run on a given platform
  - Ability to run on multiple platforms with same results
  - Compatibility with other code and systems
  - Ease of construction
  - Ease of maintenance
- Don't skimp on correctness or testing
- <u>By default, aim for type safety and portability</u>

Another simple computation

```
// inch to cm and cm to inch conversion:

int main()
{
    const double cm_per_inch = 2.54;
    int val;
    char unit;
    while (cin >> val >> unit) {       // keep reading
        if (unit == 'i')               // 'i' for inch
            cout << val << "in == " << val*cm_per_inch << "cm\n";
        else if (unit == 'c')          // 'c' for cm
            cout << val << "cm == " << val/cm_per_inch << "in\n";
        else
            return 0;                  // terminate on a "bad unit", e.g. 'q'
    }
}
```

C++11 hint

- All language standards are updated occasionally
  - Often every 5 or 10 years
- The latest standard has the most and the nicest features
  - Currently C++14
- The latest standard is not 100% supported by all compilers
  - GCC (Linux) and Clang (Mac) are fine
  - Microsoft C++ is OK
  - Other implementations (many) vary

C++14 Hint

- You can use the type of an initializer as the type of a variable
  - // "auto" means "the type of the initializer"
  - **auto x = 1;** // ***1*** *is an* ***int****, so* ***x*** *is an* ***int***
  - **auto y = 'c';** // ***'c'*** *is a* ***char****, so* ***y*** *is a* ***char***
  - **auto d = 1.2;** // ***1.2*** *is a* ***double****, so* ***d*** *is a* ***double***
  - **auto s = "Howdy";** // ***"Howdy"*** *is a string literal of type* ***const char[]***
    // *so don't do that until you know what it means!*
  - **auto sq = sqrt(2);** // ***sq*** *is the right type for the result of* ***sqrt(2)***
    // *and you don't have to remember what that is*
  - **auto duh;** // *error: no initializer for auto*

The next lecture

- Will talk about expressions, statements, debugging, simple error handling, and simple rules for program construction