Chapter 3
Objects, types, and values

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Input and output

```
// read first name:
#include <iostream>
using namespace std;

int main()
{
    cout << "Enter name: ";
    string name;
    cin >> name;
    cout << "Hello, " << name << endl;
}
// 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
```

string is the first time we see a class that we don't know what it does underneath the hood

Input and type

- We read into a variable
  - Here, **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, …

known as an object in C++

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';
}
```

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”)

	bool	char	int	double	string
assignment	=	=	=	=	=
addition			+	+	
concatenation					+
subtraction			-	-	
multiplication			*	*	
division			/	/	
remainder (modulo)			%		
increment by 1			++	++	
decrement by 1			--	--	
increment by **n**			+= n	+= n	
add to end					+=
decrement by **n**			-= n	-= n	
multiply and assign			*=	*=	
divide and assign			/=	/=	
remainder and assign			%=		
read from **s** into **x**	s >> x	s >> x	s >> x	s >> x	s >> x
write **x** to **s**	s << x	s << x	s << x	s << x	s << x
equals	==	==	==	==	==
not equal	!=	!=	!=	!=	!=
greater than	>	>	>	>	>
greater than or equal	>=	>=	>=	>=	>=
less than	<	<	<	<	<
less than or equal	<=	<=	<=	<=	<=

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";
    }
}
```

simpbad.cpp
simplecomp.cpp

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

Types and literals

- Built-in types
  - Boolean type
    - **bool**
  - Character types
    - **char**
  - Integer types
    - **int**
      - **and short** and **long**
  - Floating-point types
    - **double**
      - and **float**
- Standard-library types
  - **string**
  - **complex<Scalar>**

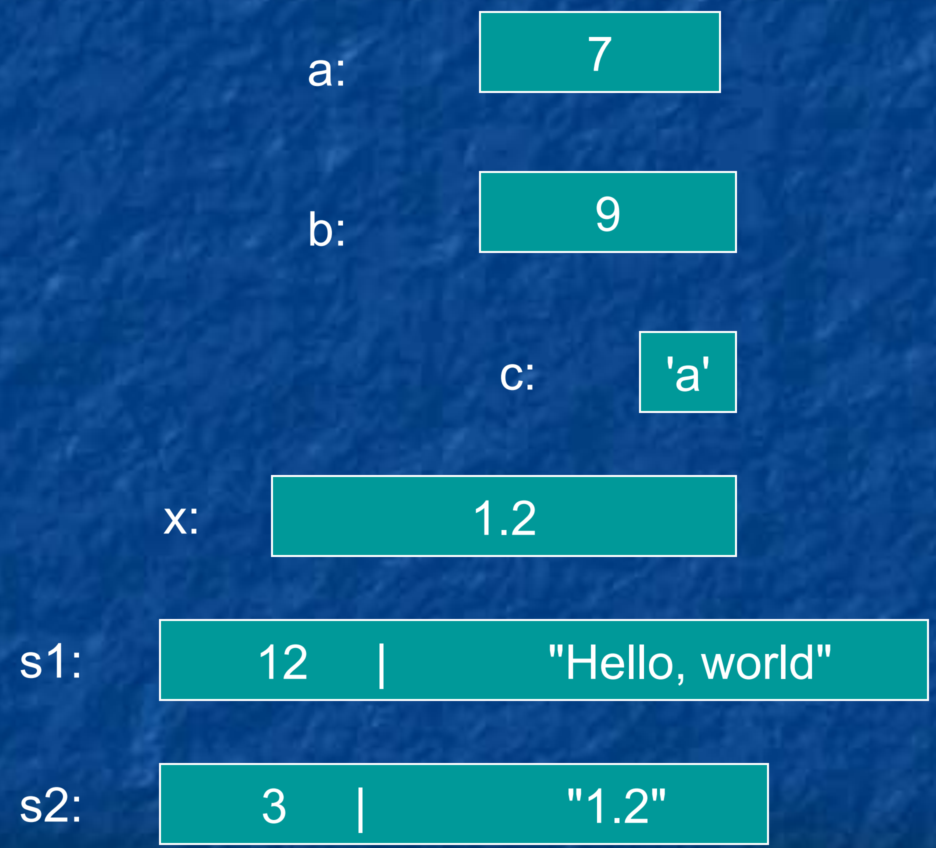
- Boolean literals
  - **true false**
- Character literals
  - **'a', 'x', '4', '\n', '$'**
- Integer literals
  - **0, 1, 123, -6, 034, 0xa3**
- Floating point literals
  - **1.2, 13.345, .3, -0.54, 1.2e3, .3F**
- String literals **"asdf"**,
  "Howdy, all y'all!"
- Complex literals
  - **complex<double>(12.3,99)**
  - **complex<float>(1.3F)**

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

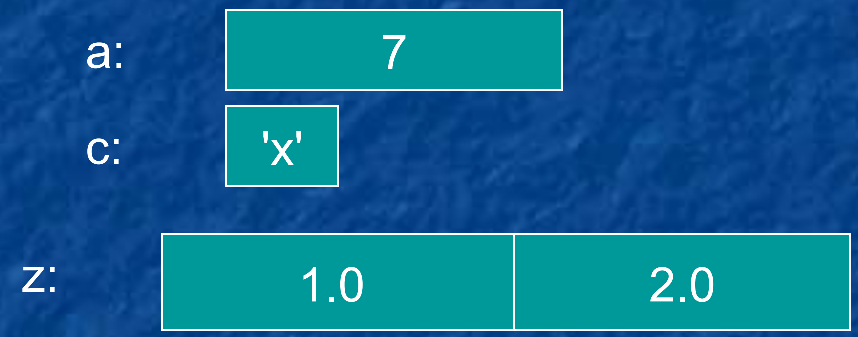
```
int a = 7;

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
- C++ is not (completely) statically type safe
  - No widely-used language is (completely) statically type safe
  - Being completely statically type safe may interfere with your ability to express ideas
- C++ is not (completely) dynamically type safe
  - 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

Initialization Notation

- C++ introduced a notation that outlaws narrowing conversions
- Uses {} for setting an object

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
    - 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
- 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
- By default, aim for type safety and portability

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*