# EDAF30 – Programming in C++

## *2. Introduction. More on function calls and types.*

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# Outline

The semantics of function argument passing is the same as copy initialization: *(Same as for primitive types in Java)*

- In a function call, the *values of the arguments* are
  - type checked, and
  - with implicit type conversion (if needed)
  - copied to the function parameters

- Example: with a function `double square(double d)`

```
double s2 = square(2);        // 2 is converted to double
                              // double d = 2;

double s3 = square("three"); // error
                              // double d = "three";
```

# Functions
## Function overloading

- Overloading ("överlagring")

```
void print(int);
void print(double);
void print(std::string, int);

void user()
{
    print(42);          // calls print(int);
    print(1.23);        // calls print(double);
    print(4.5f);        // calls print(double);
    print("Hello", 17) // calls print(std::string, int);
}
```

- Cannot differ only in return type
- Must not be ambiguous

- Default arguments (sometimes) similar to overloading
  - `void print(int x, int max_width=20);`
  - The rules are complex. *Only use for trivial cases*
  - Risk of ambiguity if combined with overloading

# Functions
## Call - ambiguity

- With overloaded functions, the compiler selects "the best" function (after implicit type conversion)
- If two alternatives are "equally good matches " it is an error

```
void print2(int, double);
void print2(double, int);

void user()
{
    print2(0, 0);   // Error! ambiguous
}
```

- and also (with `print()` from last slide)

```
void print(int);
void print(double);

long l = 17;
print(l);        // Error! print(int) or print(double)?
```

# Functions
## Rule of thumb

Factor your code into small functions to

- give names to activities and document their dependencies
- avoid writing specific code in the middle of other code
- facilitate testing

- A function should perform a single task
- Keep functions as short as possible
- Rule of thumb
  - Max 24 lines
  - Max 80 columns
  - Max 3 block levels
  - Max 5–10 local variables
  - Inversely proportional to complexity

# Call by value and call by reference
## Call by value(*värdeanrop*)

In a 'normal' function call, the values of the arguments are copied to the formal parameters (which are local variables)

### Example: swap two integer values

```
void swap(int a, int b)
{
   int tmp=a;
   a = b;
   b = tmp;
}
```

. . . and use:

```
int x = 2;
int y = 10;

swap(x, y);

cout << x ", " << y << endl;
```

2,10 x and y are not changed

# Call by value and call by reference
## Call by reference(*referensanrop* )

Use *call by reference* instead of *call by value*:

### Example: swap two integer values

```
void swap(int& a, int& b)
{
   int tmp=a;
   a = b;
   b = tmp;
}
```

. . . and use:

```
int x = 2; int y = 10;

swap(x, y);
```

Here, *references* to the arguments are used , and the values are actually swapped.

# References

- A reference is *an alias* for a variable

The call `swap(x,15);` gives the error message

```
invalid initialization of non-const reference of type "int&"
from an rvalue of type 'int'
```

NB! The argument for a reference parameter must be an *lvalue*

# Data types
## Pointers, Arrays and References

- References
- Pointers (similar to Java references)
- Arrays ("built-in arrays"). Similar to Java arrays of primitive types

# Pointers

Similar to references in Java, but

- a pointer is the *memory address of an object*
- a pointer *is an object* (a C++ reference is not)
  - can be assigned and copied
  - has an address
  - can be declared without initialization, but then it gets an *undefined value* , as do other variables
- four possible states
  1. point to an object
  2. point to the address immediately past the end of an object
  3. point to nothing: `nullptr`. Before C++11: `NULL`
  4. invalid
- can be used as an iteger value
  - arithmetic, comparisons, etc.

Be very careful!

# Pointers
## Syntax, operatorers $*$ and &

- In a *declaration*:
  - prefix $*$: "pointer to"

    `int *p;` : p is *a pointer to an int*

    `void swap(int*, int*);` : *function taking two pointers*
  - prefix &: "reference to"

    `int &r;` : r is *a reference to an* **int**

- In an *expression*:
  - prefix $*$: dereference, "contents of" (*pointer* $\rightarrow$ *object* )

    `*p = 17;` *the object that p points to* is assigned $17$
  - prefix &: "address of", "pointer to" (*object* $\rightarrow$ *pointer*)

```
int x = 17;
int y = 42;

swap(&x, &y);
```

Call `swap(int*, int*)` with *pointers to* `x` *and* `y`

# Pointers
## Be careful with declarations

### Advice: One declaration per line

```
int *a;       // pointer to int
int* b;       // pointer to int
int c;        // int

int* d, e;    // d is a pointer, e is an int
int* f, *g;   // f and g are both pointers
```

*Choose a style, either* **int** *a *or* **int*** b*, and be consistent.*

# References

References are similar to pointers, but

- A reference is *an alias to* a variable
  - must be initialized
  - cannot be changed (*reseated* to refer to another variable)
  - is not an object (has no address)

  - Dereferencing does not use the operator `*`
    - Using a reference *is* to use the referenced object.

*Use a reference if you don't have (a good reason) to use a pointer*.

- E.g., if it may have the value `nullptr` (*"no object"*)
- or if you need to change("reseat") the pointer
- More on this later.

# Pointers and references
## Call by pointer

In some cases, a *pointer* is used instead of a *reference* to "call by reference:

### Example: swap two integers

```
void swap2(int* a, int* b)
{
  if(a != nullptr && b != nullptr) {
    int tmp=*a;
    *a = *b;
    *b = tmp;
  }
}  ...  and use:             int x, y;
                             ...
                             swap2(&x, &y);
```

NB!:

- a pointer can be `nullptr` or uninitialized
- dereferencing such a pointer gives *undefined behaviour*

# Pointers and references

## Pointer and reference versions of swap

```
// References
void swap(int& a, int& b)
{

   int tmp = a;
   a = b;
   b = tmp;
}
```

```
// Pointers
void swap(int* pa, int* pb)
{
  if(pa != nullptr && pb != nullptr) {
    int tmp = *pa;
    *pa = *pb;
    *pb = tmp;
  }
}
```

```
int m=3, n=4;
swap(m,n);   Reference version is called

swap(&m,&n); Pointer version is called
```

NB! Pointers are *called by value*: *the address* is copied

# Arrays ("C-arrays", "*built-in arrays*")

- A sequence of values of the same type (homogeneous sequence)
- Similar to Java for primitive types
  - but *no safety net* – difference from Java
  - an array does not know its size – the programmer's responsibility
- *Can contain elements of any type*
  - Java arrays *can only contain references* (or primitive types)
- Can be a local (or member) variable (Difference from Java)
- Is declared `T a[size];` (Difference from Java)
  - The size must be *a (compile-time) constant*.
    (Different from C99 which has VLAs)

# Arrays
## Representation in memory

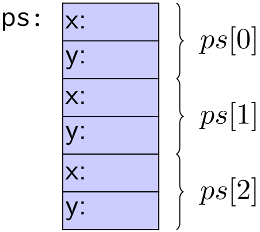
The elements of an array can be of any type

- Java: only primitive types or a reference to an object
- C++: an object or a pointer

Example: array of `Point`

```
class Point{
    signed char x;
    signed char y;
};

Point ps[3];
```




*Important difference from Java: no fundamental difference between built-in and user defined types.*

# Data types
## C strings

- C strings are `char[]` that are *null terminated*.
  Example: `char s[6] = "Hello";`

| s: | 'H' | 'e' | 'l' | 'l' | 'o' | '\0' |
|---|---|---|---|---|---|---|

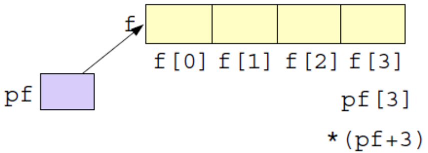
NB! A *string literal* is a C-style string (not a `std::string`)
The type of `"Hello"` is `const char[6]`.

# Pointers and arrays

## Arrays are accessed through pointers

```
float f[4];           // 4 floats
float* pf;            // pointer to float

pf = f;               // same as = &f[0]
float x = *(pf+3);    // Alt. x = pf[3];
x = pf[3];            // Alt. x = *(pf+3);
```



# Pointers and arrays
## What does array indexing really mean?

The expression `a[b]` is equivalent to `*(a + b)` (and, thus, to `b[a]`)

### Definition

For a pointer, `T* p`, and an integer `i`, the expression `p + i` is defined as `p + i * sizeof(T)`

That is,

- `p+1` points to the address after the object pointed to by `p`
- `p+i` is an address *$i$ objects of type* `T` *after* `p`.

### Example: confusing code (Don't do this)

```
int a[] {1,4,5,7,9};

cout << a[2] << " == "<< 2[a] << endl;
```

```
5 == 5
```

# Pointers and arrays
## Function calls

### Function for zeroing an array

```
void zero(int* x, size_t n) {
   for (int* p=x; p != x+n; ++p)
      *p = 0;
}

    ...
    int a[5];

    zero(a,5);
```

- *The name of an array variable* in an expression is interpreted as *"a pointer to the first element"*: *array decay*
- `a` ⇔ `&a[0]`
- arrays cannot be copied (passed by value)

### Array subscripting

```
void zero(int x[], size_t n) {
  for (size_t i=0; i < n; ++i)
    x[i] = 0;
}
```

- In function parameters `T a[]` *is equivalent to* `T* a`. (Syntactic sugar)
- `T*` is more common

- An array is passed as *a pointer and a size*.

# Two types from the standard library
## Alternatives to C-style arrays

Do not use built-in arrays unless you have (a strong reason) to.
Instead of

- **char**`[]` – Strings – use `std::string`
- `T[]` – Sequences – use `std::vector<T>`

More like in Java:

- more functionality – *“behaves like a built-in type”*
- safety net

# Strings: `std::string`

`std::string` has operations for

- assigning
- copying
- concatenation
- comparison
- input and output (<< >>)

and

- knows its size

Similar to `java.lang.String` *but is mutable*.

# Sequences: `std::vector<T>`

A `std::vector<T>` is

- an ordered collection of objects (of the same type, `T`)
- every element has an index

which, in contrast to a built-in array

- knows its size
  - `vector<T>::`**`operator`**`[]` does no bounds checking
  - `vector<T>::at(size_type)` throws `out_of_range`
- can grow (and shrink)
- can be assigned, compared, etc.

Similar to `java.util.ArrayList`

Is a *class template*

# Example: std::string

```
#include <iostream>
#include <string>
using std::string;
using std::cout;
using std::endl;

string make_email(string fname,
                  string lname,
                  const string& domain)
{
    fname[0] = toupper(fname[0]);
    lname[0] = toupper(lname[0]);
    return fname + '.' + lname + '@' + domain;
}

void test_string()
{
    string sr = make_email("sven", "robertz", "cs.lth.se");

    cout << sr << endl;
}
```

```
  Sven.Robertz@cs.lth.se
```

# Example: std::vector<int> initialisation

```
void print_vec(const std::string& s, const std::vector<int>& v)
{
    std::cout << s << " : " ;
    for(int e : v) {
        std::cout << e << " ";
    }
    std::cout << std::endl;
}
void test_vector_init()
{
    std::vector<int> x(7);
    print_vec("x", x);

    std::vector<int> y(7,5);
    print_vec("y", y);

    std::vector<int> z{1,2,3};
    print_vec("z", z);
}
```

```
x: 0 0 0 0 0 0 0
y: 5 5 5 5 5 5 5
z: 1 2 3
```

# Example: `std::vector<int>` assignment

```
void test_vector_assign()
{
    std::vector<int> x {1,2,3,4,5};
    print_vec("x", x);
    std::vector<int> y {10,20,30,40,50};
    print_vec("y", y);
    std::vector<int> z;
    print_vec("z", z);
    z = {1,2,3,4,5,6,7,8,9};
    print_vec("z", z);
    z = x;
    print_vec("z", z);
}
```

```
x : 1 2 3 4 5
y : 10 20 30 40 50
z :
z : 1 2 3 4 5 6 7 8 9
z : 1 2 3 4 5
```

# Example: std::vector<int> insertion and comparison

```
void test_vector_eq()
{
    std::vector<int> x {1,2,3};
    std::vector<int> y;
    y.push_back(1);
    y.push_back(2);
    y.push_back(3);

    if(x == y) {
        std::cout << "equal" << std::endl;
    } else {
        std::cout << "not equal" << std::endl;
    }
}
```

```
equal
```

# User defined types

- Built-in types (e.g., **`char`**, **`int`**, **`double`**, pointers, ...) and operations
  - Rich, but deliberately low-level
  - Directly and efficiently reflect the capabilites of conventional computer hardware
- User-defined types
  - Built using the *built-in types* and *abstraction mechanisms*
  - **`struct`**, **`class`** (cf. **`class`** i Java)
  - Examples from the standard library
    - `std::string` (cf. `java.lang.String`)
    - `std::vector`, `std::list` ... (cf. corresponding class in `java.util`)
  - **`enum class`**: enumeration (cf. **`enum`** in Java)
- A *concrete type* can behave "just like a built-in type".

# Structures

The first step in building a new type is to organize the elements it needs into a data structure, a *struct*.
Exempel: Person

```
struct Person{
    string first_name;
    string last_name;
};
```

A variable of the type `Person` is created with

```
Person p;
```

but now *the member variables* have *default initialized values*.
NB! that sometimes means *undefined*

More on object initialization later.

# Structures
## Initialization

A function for initializing a Person:

```
void init_person(Person& p, const string& fn,  const string& ln)
  {
      p.first_name = fn;
      p.last_name = ln;
  }
```

A variable of type Person, can be created and initialized with

```
Person sven;
init_person(sven, "Sven", "Robertz");
```

- call by reference: the object sven is changed

Use:

```
std::cout << sven.first_name << " " << sven.last_name << '\n'.
```

# Structures
## Use

Now we can use our type Person:

```
#include <iostream>
Person read_person()
{
    cout << "Enter first name:" << endl;
    string fn;
    cin >> fn;

    cout << "Enter last name:" << endl;
    string ln;
    cin >> ln;

    Person p;
    init_person(p, fn, ln);
    return p;
}
```

- `>>` is *the input operator*
- the standard library `<iostream>`
- `std::cin` is *standard input*

# Classes

Make a type behave like a built-in type

- Tight coupling of data and operations
- Often make the representation inaccessible to users

A class has

- data members (“attributes”)
- member functions (“methods”)
- members kan be
  - **`public`**
  - **`private`**
  - **`protected`**
  - like in Java

# Classes
## Example

```
class Person{
public:
    Person(string fn, string ln) :first_name{fn}, last_name{ln} {}
    string get_name();
    string get_initials();
private:
    string first_name;
    string last_name;
};
```

- *constructor*, like in Java
  - Creates an object and *initializes members*
  - the statements
    ```
    Person sven;
    init_person(sven, "Sven", "Robertz");
    ```
    become `Person sven("Sven", "Robertz");`

***class** and **struct** are (mostly) synonyms in C++.*

# Classes
## Example

```
Person read_person()
{
    cout << "Enter first name:" << endl;
    string fn;
    cin >> fn;
    cout << "Enter last name:" << endl;
    string ln;
    cin >> ln;
    return Person(fn, ln);
}

void test_read()
{
    Person p = read_person();
    cout << p.get_initials() << " : " << p.get_name() << endl;
}
```

# Class definitions
## Declarations and definitions of member functions

Member functions (⇔ methods in Java)

### Definition of a class

```
class Foo {
public:
    int fun(int, int);    // Declaration of member function

    int times_two(int x) {return 2*x;} // ... incl definition
};
```

NB! Semicolon after class

### Definition of member function (outside the class)

```
int Foo::fun(int x, int y) {
    // ...
}
```

No semicolon after function

# File structure for classes

- The class definition is put in a header file (.h or .hpp)
- To avoid defining a class more than once, use *include guards*:

```
#ifndef FOO_H
#define FOO_H
//...
class Foo {
//...
};
#endif
```

- Member function definitions are put in a source file (.cc)

# Stream I/O

- The C++ standard library contains facilities for
  - Structured I/O ( "formatted I/O")
    - reading values of a certain type, T
    - overload **operator**`>>(istream&, T&)` and
    - **operator**`<<(ostream&,` **const** `T&)`
  - Character I/O ("raw I/O")
    - `istream& getline(istream&, string&)`
    - `istream& istream::getline(`**char**`*, streamsize)`
    - **int** `istream::get()`
    - `istream& istream::ignore()`
    - ...
- NB! `getline()` as free function and member of `istream`.
- `std::getline()` has an overload for using another delimiter than newline.
- Choose raw or formatted I/O based on your application

# Variables
## Automatic type inference

**auto**: The compiler deduces the type from the initialization.

### Declaration and initialization

```
auto x = 7;                  // int x
auto c = 'c';                // char c
auto b = true;               // bool b
auto d = 7.8;                // double d

std::vector<int> v;
auto it = v.begin();         // std::vector<int>::iterator it

double calc_epsilon();
auto ep = static_cast<float>(calc_epsilon());  // float ep
```

*In* `float ep = calc_epsilon();` *the narrowing is not obvious* NB!

with **auto** there is no risk of narrowing type conversion, so using = is safe.

# Exception to 'almost always auto'

Don't use **auto** if you need to be explicit about the declared type:

- if naming the type makes the code more readable.
- to specify the value range or precision
  (e.g., **int**/ **long** or **float**/ **double**)

But that can also be achieved by using a cast to fix the type.

# Data types
## Two kinds of constants

- A variable declared **`const`** must not be changed(`final` in Java)
  - Roughly:"I promise not to change this variable."
  - Is checked by the compiler
  - Use when specifying function interfaces
    - A function that does not change its (reference) argument
    - A member function ("method") that does not change the state of the object.
  - Important for function overloading
    - T and **`const`** T are different types
    - One can overload `int f(T&)` and `int f(const T&)` (for some type T)
- A variable declared **`constexpr`** must have a value that can be computed at compile time.
  - Use to specify constants
  - Functions can be **`constexpr`**
  - Introduced in C++-11

# `char[]`, `char*` och `const char*`
# `const` is important for C-strings

A *string literal* (e.g., `"I am a string literal"`) is **const**.

- Can be stored in read-only memory
- `char* str1 = "Hello";` — *deprecated* in C++ – gives a warning
- `const char* str2 = "Hello";` — OK, the string is **const**
- `char str3[] = "Hello";` — `str3` can be modified

# const and pointers

**const** modifies everything to the left (exception: if **const** is first, it modifies what is directly after)

## Example

```
      int* ptr;
const int* ptrToConst;  //NB! (const int) *
int const* ptrToConst,  // equivalent, clearer?

int* const  constPtr;   // the pointer is constant

const int* const constPtrToConst; // Both pointer and object
int const* const constPtrToConst; // equivalent, clearer?
```

## Be careful when reading:

```
char *strcpy(char *dest, const char *src);
```

**(const char)*, not const (char*)**

# const and pointers
## Example:

```
void Exempel( int* ptr,
              int const * ptrToConst,
              int* const constPtr,
              int const * const constPtrToConst )
{
    *ptr = 0;                       // OK: changes the value of the object
    ptr  = nullptr;                 // OK: changes the pointer

    *ptrToConst = 0;                // Error! cannot change the value
    ptrToConst  = nullptr;          // OK: changes the pointer

    *constPtr = 0;                  // OK: changes the value
    constPtr  = nullptr;            // Error! cannot change the pointer

    *constPtrToConst = 0;           // Error! cannot change the value
    constPtrToConst  = nullptr;     // Error! cannot change the pointer
}
```

# Pointers

## Pointers to constant and constant pointer

```
int k;              // int that can be modified
int const c = 100;// constant int
int const * pc;   // pointer to constant int
int *pi;            // pointer to modifiable int

pc = &c;   // OK
pc = &k;   // OK, but k cannot be changed through *pc
pi = &c;   // Error! pi may not point to a constant
*pc = 0;   // Error! pc is a pointer to const int

int* const cp = &k; // Constant pointer
cp = nullptr;        // Error! The pointer cannot be reseated
*cp = 123;           // OK! Changes k to 123
```

# Suggested reading

References to sections in Lippman

| | |
|---|---|
| Literals | 2.1.3 |
| Pointers and references | 2.3 |
| std::string | 3.2 |
| std::vector | 3.3 |
| Arrays and pointers | 3.5 |
| Classes | 2.6, 7.1.4, 7.1.5, 13.1.3 |
| Scope and lifetimes | 2.2.4, 6.1.1 |
| I/O | 1.2, 8.1–8.2, 17.5.2 |

# Next lecture
## Classes

References to sections in Lippman

Variable initialization 2.2.1

Classes 2.6, 7.1.4, 7.1.5

Constructors 7.5–7.5.4

(Aggregate classes) ("C structs" without constructors) 7.5.5

Operator overloading 14.1 – 14.3, 14.5 – 14.6

const, constexpr 2.4

this and const p 257–258

inline 6.5.2, p 273

friend 7.2.1

static members 7.6