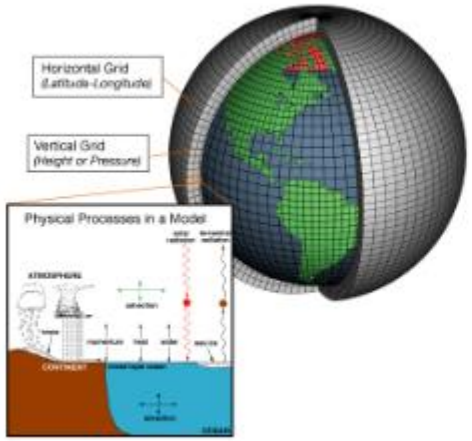
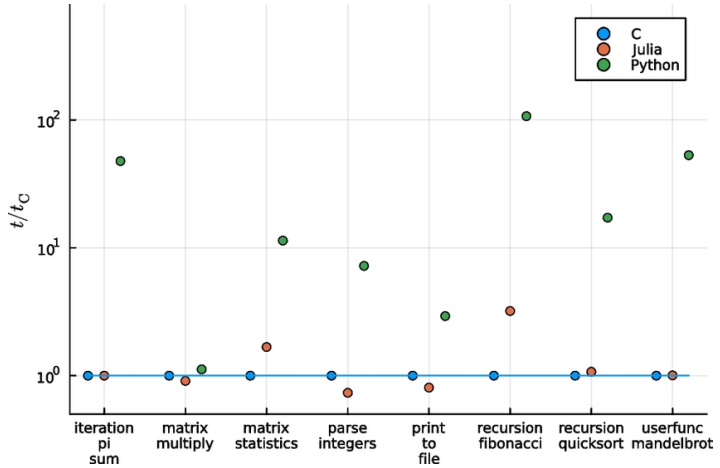
C introduction part 1

ENG-270

Why C?

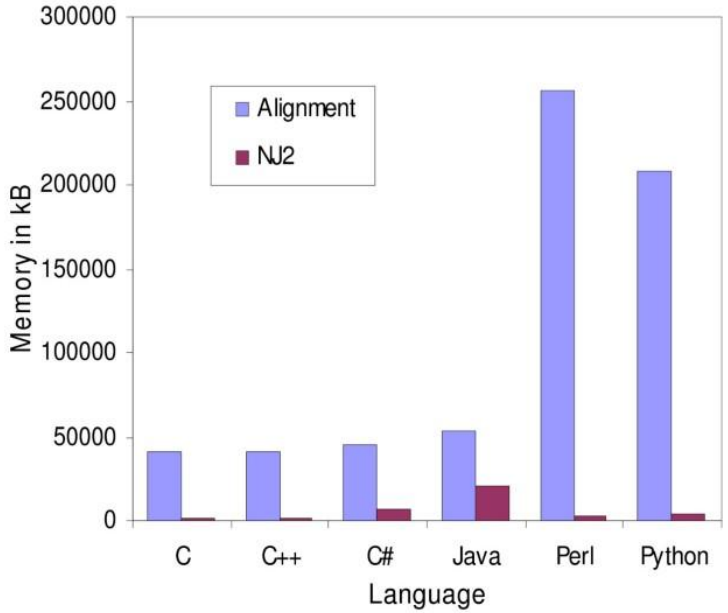
Blazing fast speed





https://www.climatehubs.usda.gov/hubs/northwest/topic/basics-global-climate-models
https://www.nzz.ch/technologie/die-schweiz-bekommt-einen-der-besten-ki-supercomputer-der-welt-ld.1770303
Eshel et al., https://doi.org/10.1007/s41781-023-00104-x, 2023

Low memory footprint



Topping et al., https://doi.org/10.3389/frsc.2021.786563, 2021
https://learn.epfl.ch/wwd_learn/e-puck/
Fourment et al., https://doi.org/10.1186/1471-2105-9-82, 2008

Why is C more efficient / faster?

- Explicit allocation of resources (memory)
- Type declarations lets compiler know what will be computed
- Compiler can optimize computation

- Dynamic, interpreted languages (e.g, Python) cannot optimize because they don't know what data will be fed to the program until runtime

Language	Type	Compiled/Interpreted
C	statically typed	compiled
Python	dynamically typed	interpreted
MATLAB	dynamically typed	JIT (compiled piecewise)

Steps for code execution

Compiled language

- Write code
- Compile in terminal
- Fix compilation errors
- Execute
- Check results
- Debug

Interpreted language

- Write code
- Execute parts of your code in REPL
- Check results
- Write more code
- Execute more parts of your code in REPL
- Check results
- Debug

Anatomy of a C program

Sum of natural numbers up to 10

```
sum = 1 + 2 + 3 + ... + 10
```

C code

```c
#include <stdio.h>
int main() {
    int n, i, sum = 0;

    printf("Enter a positive integer: ");
    scanf("%d", &n);

    for (i = 1; i <= n; ++i) {
        sum += i;
    }

    printf("Sum = %d", sum);
    return 0;
}
```

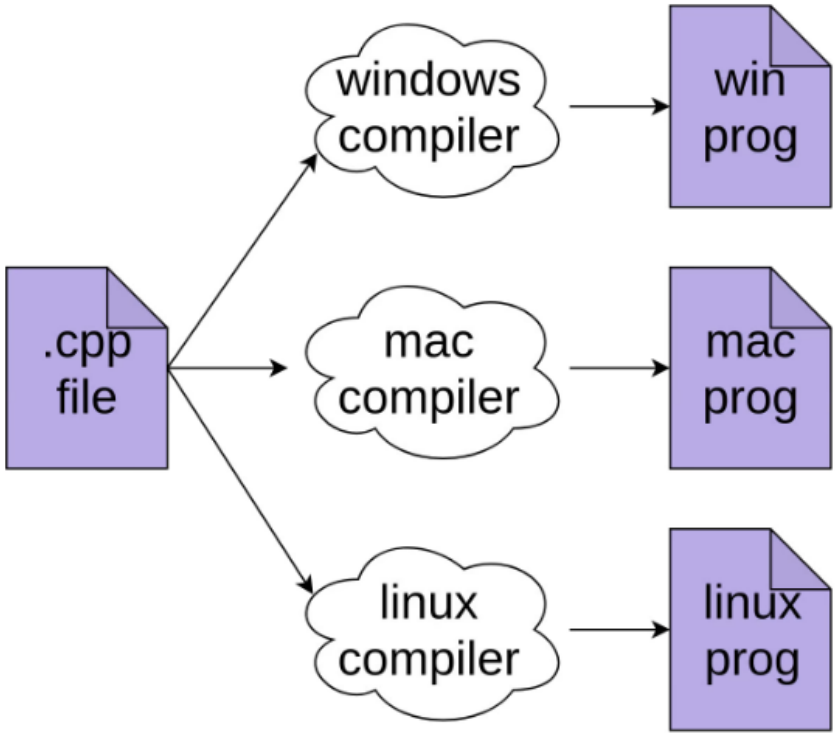
Basic elements

- #include statement to import libraries
- main() function with return value of 0
- required type annotations everywhere
- semicolon is *required* at the end of each statement

Compiler vs. Interpreter

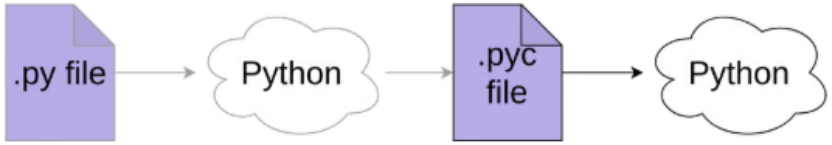
C compiler

once program is compiled, can run on machine it was compiled for without user having to install C



Python interpreter

user needs to install Python to run Python scripts

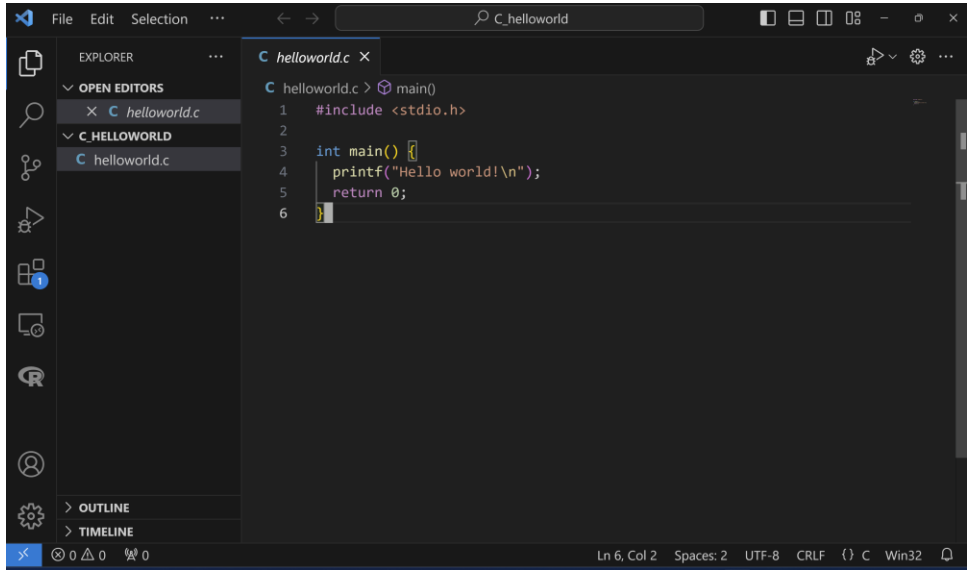


https://realpython.com/python-vs-cpp/

First program

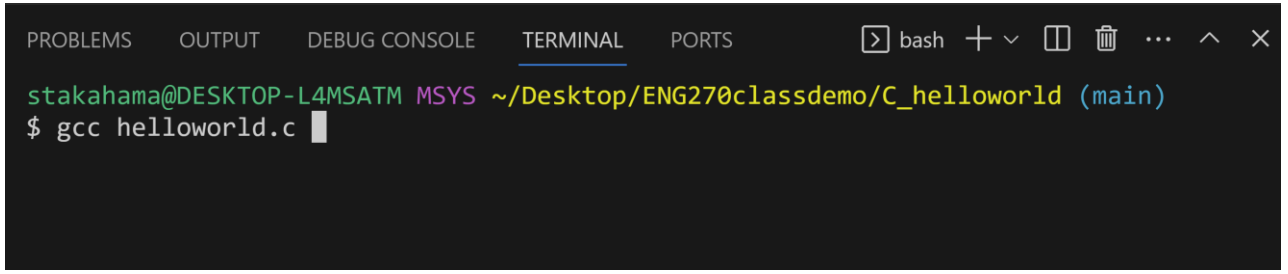
VSCode script window

1. Write the program and save it to a file (“helloworld.c”)

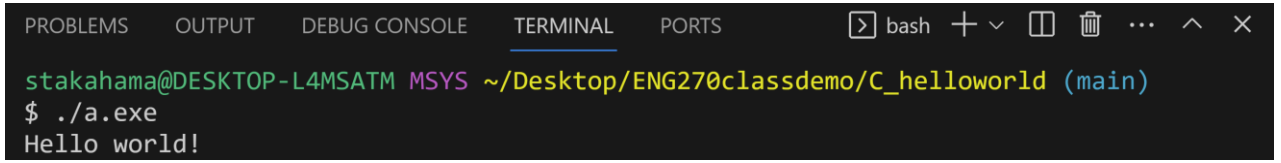


VSCode terminal

2. Compile the program to generate an executable



3. Run the program



```c
int main() {
```

or

```c
int main( int argc, char *argv[] ) {
```

?

see https://stakahama.gitlab.io/sie-eng270/intro_C.html#hello-world

Terminal

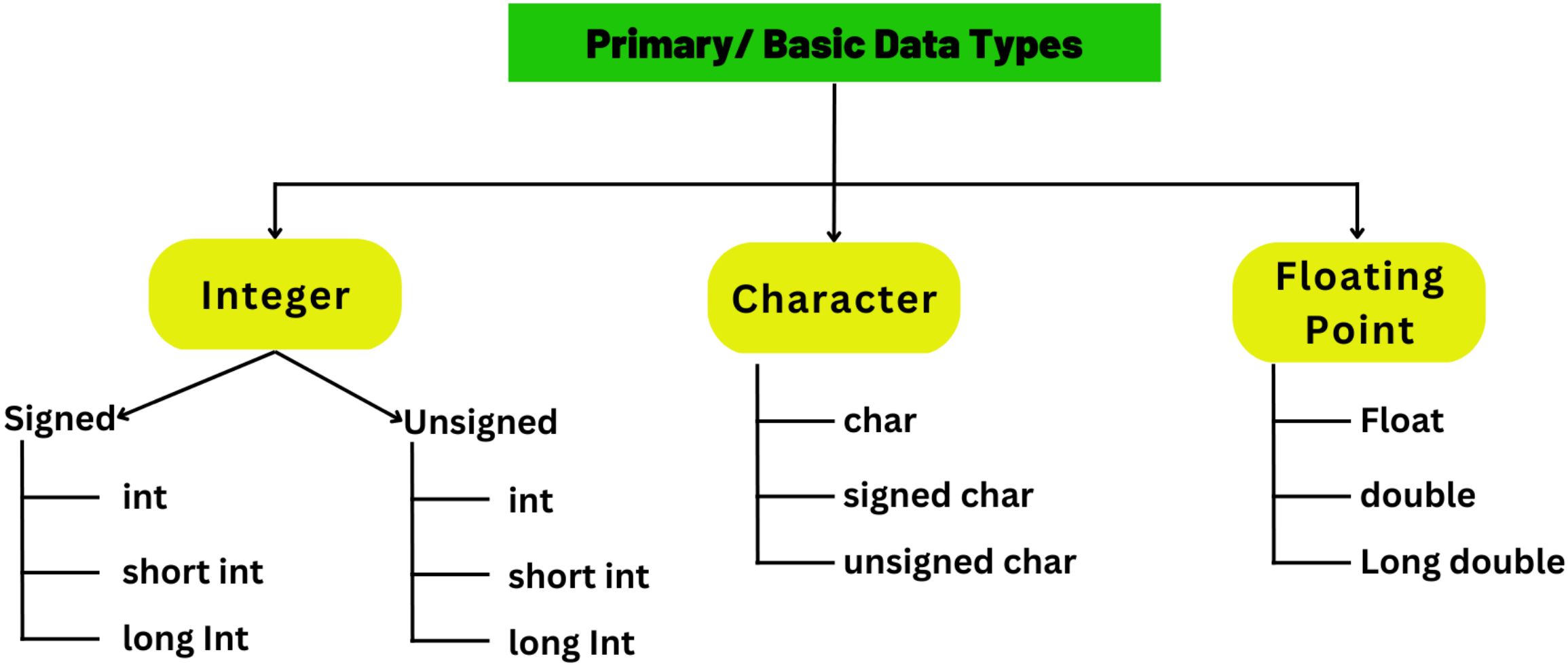
- Interact with the operating system. Typical commands (non-exhaustive!): https://sieprog.ch/#terminal
  - cd: change directory (“./” current directory, “../” up one directory)
  - pwd: check current working directory
  - gcc: compile program with gcc (run compiled file “*program*” with “./*program*”)
  - gdb: run gdb
  - echo: print
  - ls: list contents of directory
- POSIX-compliant shell
  - macOS, Linux – default
  - Windows – MSYS2 / Git Bash. Note path separator “/” for POSIX-compliant, “\” for Windows cmd
- USE TAB COMPLETION!!! (to save yourself keystrokes)

Back to C: Data types

- You must declare data types for all variables and functions.
  - https://sieprog.ch/#c/variables
  - https://sieprog.ch/#c/fonctions

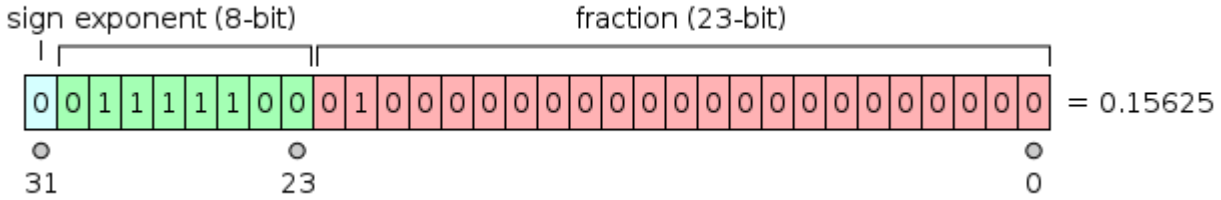
- Where?
  - Close to where it is used
  - At the beginning of the function
  - Within a loop (if used only in the loop)

- Do not forget to initialize variables when you declare them.



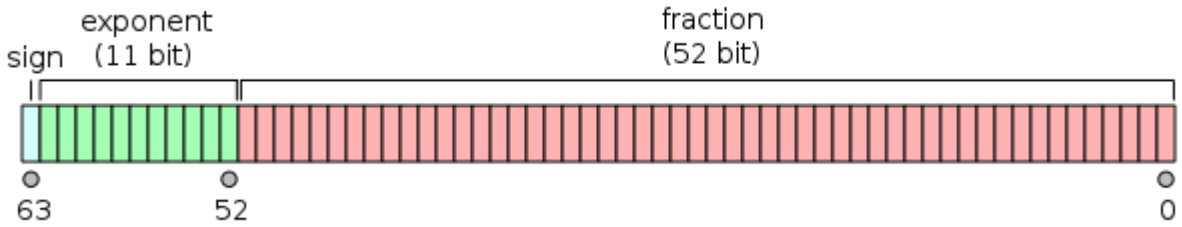
Floating point representation

32-bit
(32 binary digits)



float
single precision

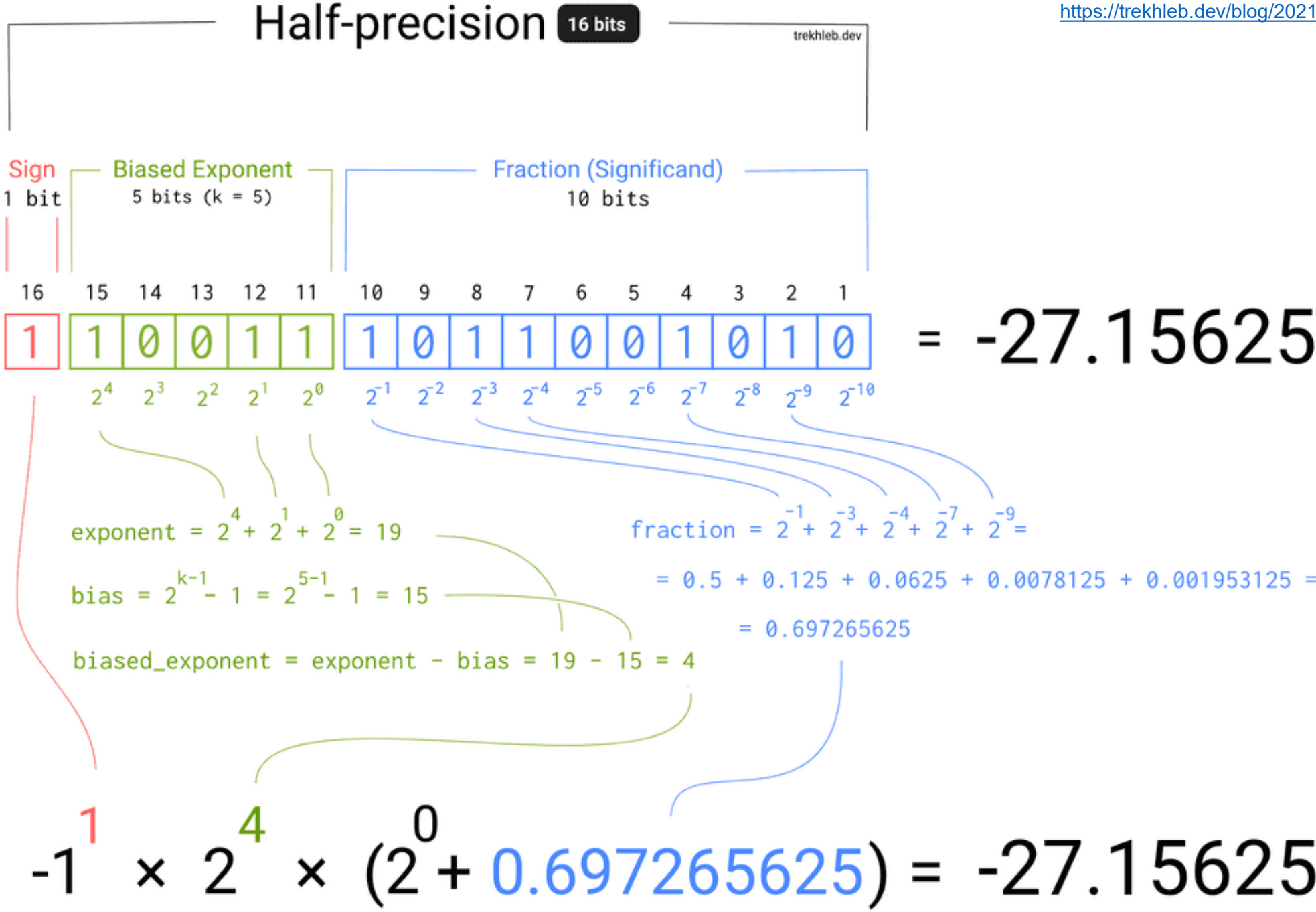
64-bit
(64 binary digits)



double
double precision

https://en.wikipedia.org/wiki/IEEE_754-1985

https://trekhleb.dev/blog/2021/binary-floating-point/



Size and range of values

For reference – your computer typically has 8-16 GB (10^9 bytes) of memory (*RAM: Random Acces Memory*)

Data Type	Range	Bytes	Format
signed char	-128 to + 127	1	%c
unsigned char	0 to 255	1	%c
short signed int	-32768 to +32767	2	%d
short unsigned int	0 to 65535	2	%u
signed int	-32768 to +32767	2	%d
unsigned int	0 to 65535	2	%u
long signed int	-2147483648 to +2147483647	4	%ld
long unsigned int	0 to 4294967295	4	%lu
float	-3.4e38 to +3.4e38	4	%f
double	-1.7e308 to +1.7e308	8	%lf
long double	-1.7e4932 to +1.7e4932	10	%Lf

Note: The sizes and ranges of int, short and long are compiler dependent. Sizes in this figure are for 16-bit compiler.

1 byte = 8 bits

https://c-programmingbooks.blogspot.com

Pointer data types

- Essential for programming in C

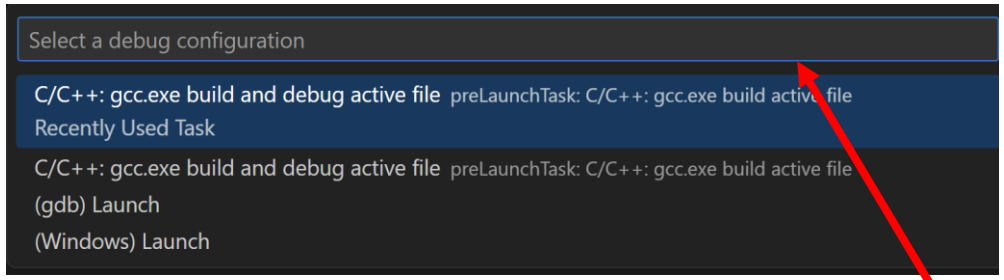
- Covered in future lesson

Debugging

- Use print statements or debugger
- gdb (GNU debugger)
  - from command line
    - https://sieprog.ch/#gdb
    - https://www.tutorialspoint.com/gnu_debugger/gdb_commands.htm
  - through VS Code
    - https://code.visualstudio.com/docs/cpp/cpp-debug
    - https://code.visualstudio.com/docs/cpp/config-mingw (Windows)
- lldb is also available, but gdb is recommended. lldb is part of the clang compiler suite and gdb is part of the gcc compiler suite, but, in principle, the two can be used with either compiler.
- Note that C++ is a superset of C; many tutorials on C++ (e.g., installation, debugging) will apply to C.

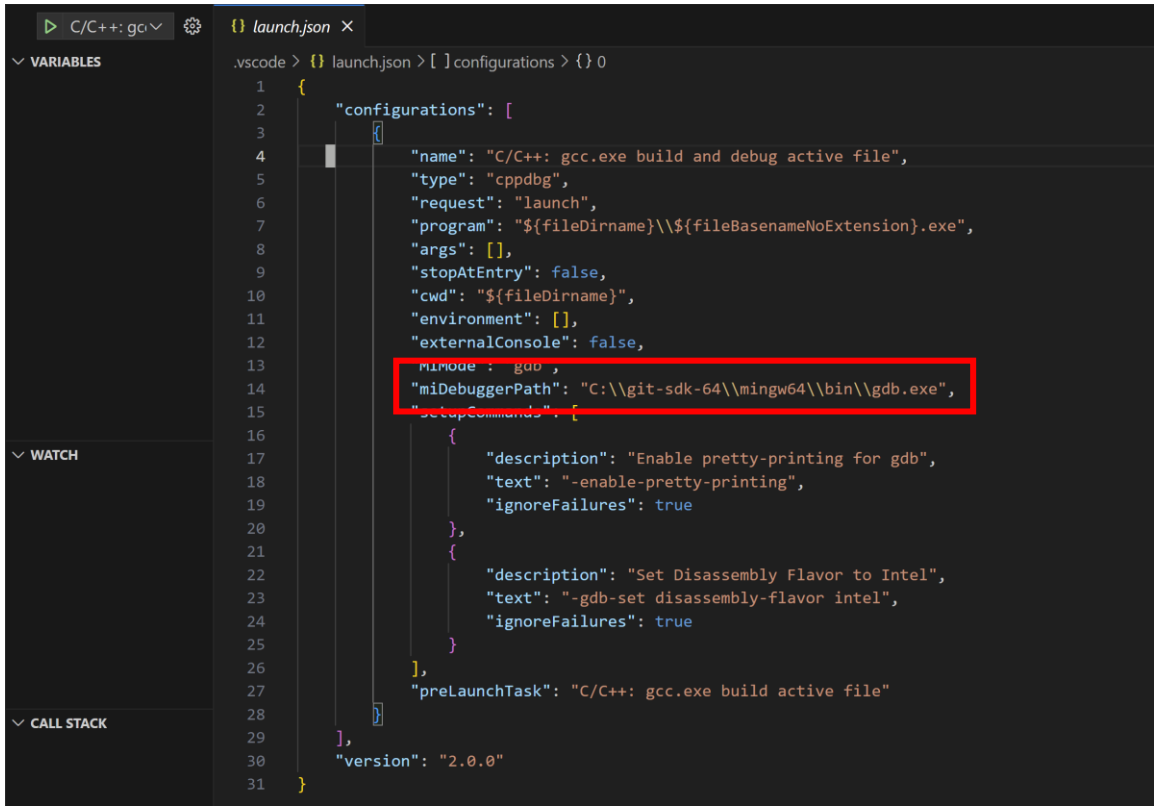
GDB in VS Code

step 0 click where you want your program to stop to inspect variables – you should see a red dot appear



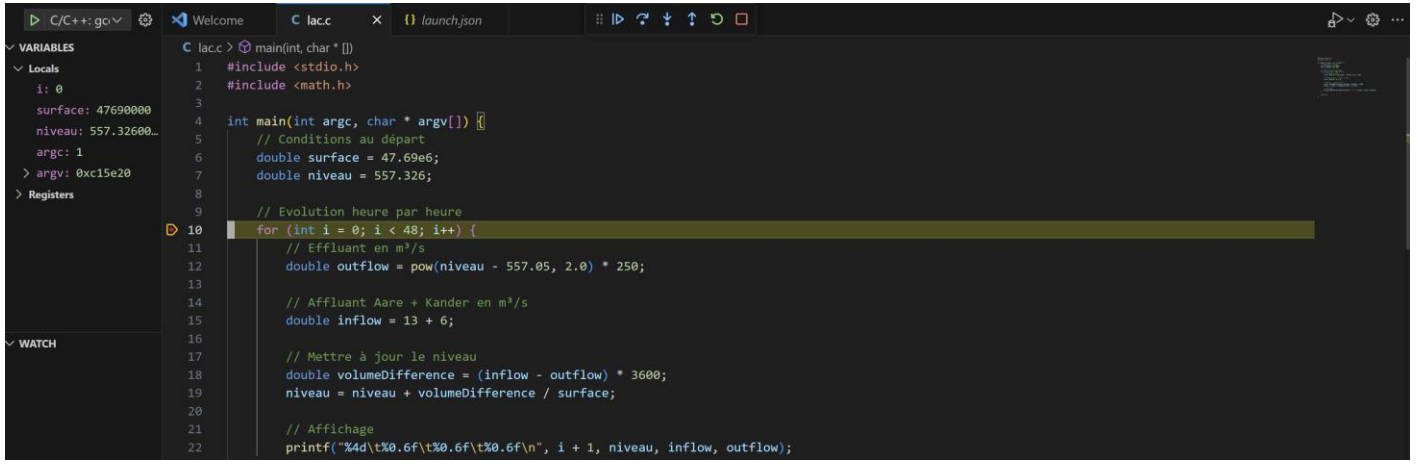
step 1 click on the gear box

step 2 check that the debugger is set to right path (save)



step 3 select debug C/C++ file

step 4 enjoy!



Testing installation

Is the problem with the compiler, or with VS Code calling the compiler?

→ USE THE TERMINAL

Is the right compiler being used?

→ type which gcc without quotes

Am I in the right directory?

→ type pwd, and then ls to see what's in the directory