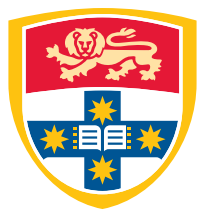
COMP2017 & COMP9017: Systems Programming

School of Computer Science, University of Sydney



Copyright Warning

Lecture 1: About this course

Lightest intro

COMP2017 & COMP9017

This unit is *Systems Programming*

These slides and more here:

Figure 1: `https://edstem.org`

COMP2017 & COMP9017

Our time is short!

Lecture 0 & Induction slides available on Ed[1]

Lecture 0 & Induction recording available on Canvas[2]

- Structure of this course: `https://sydney.edu.au/units/COMP2017` [3]
- Lecture & Seminar recording: Canvas
- More resources: `https://edstem.org` and Canvas
- More programming: YOU!

Coronavirus (Covid-19) infection: University of Sydney advice

---

[1] all students are expected to read these

[2] all students are expected to watch these

[3] 40/50/50 pass condition. Late penalty → 25% per day. Absence → 0. Weekly lecture, lab, task & eval.

Assessment components

Assessment	Due Date	Weighting
Task Set 1	11:59 PM, 20 March 2020 (Friday Week 4)	2%
Quiz 1	Week 5 Tutorial	5%
Assignment 1	11:59 PM, 27 March 2020 (Friday Week 5)	6%
Task Set 2	11:59 PM, 10 April 2020 (Friday Week 7)	2%
Assignment 2	11:59 PM, 24 April 2020 (Friday Week 8)	8%
Quiz 2	Week 10 Tutorial	5%
Task Set 3	11:59 PM, 8 May 2020 (Friday Week 10)	2%
Computer Exam	Week 12 Tutorial	10%
Assignment 3	11:59 PM, 29 May 2020 (Friday Week 13)	10%
Final Exam	Formal Exam Period	50%

Note: the due date for Assignment 1 on Sydney Curriculum is incorrect

Note: all due dates are Sydney local time

About The Coordinator/Lecturer

The unit coordinator and lecturer is
Dr. John Stavrakakis

PhD in Computer Science
Specialises in 3D computer graphics

Overall course administration and design

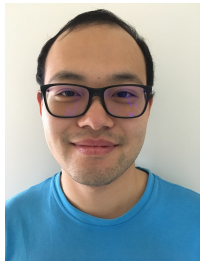
Coordinator/Lecturer for over **1800** students over many courses this semester.

Please be considerate of his time.

About the Teaching Assistants (TA)

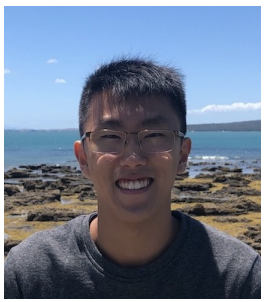
Tyson Thomas

tinkerer, sketcher and trekkie



William Wang

anatomical pathology, miscellaneous tech things, cooking



Byung Hoon (BH) Cho

camping, road trips, Kerbal Space Program

The teaching assistants help with the preparation and delivery of the course contents. Seminars, labs, tutorials, quizzes, assignments, challenges, computer examinations. They

About our teaching team

We have a fantastic team of tutors. Each are talented in their own regard.

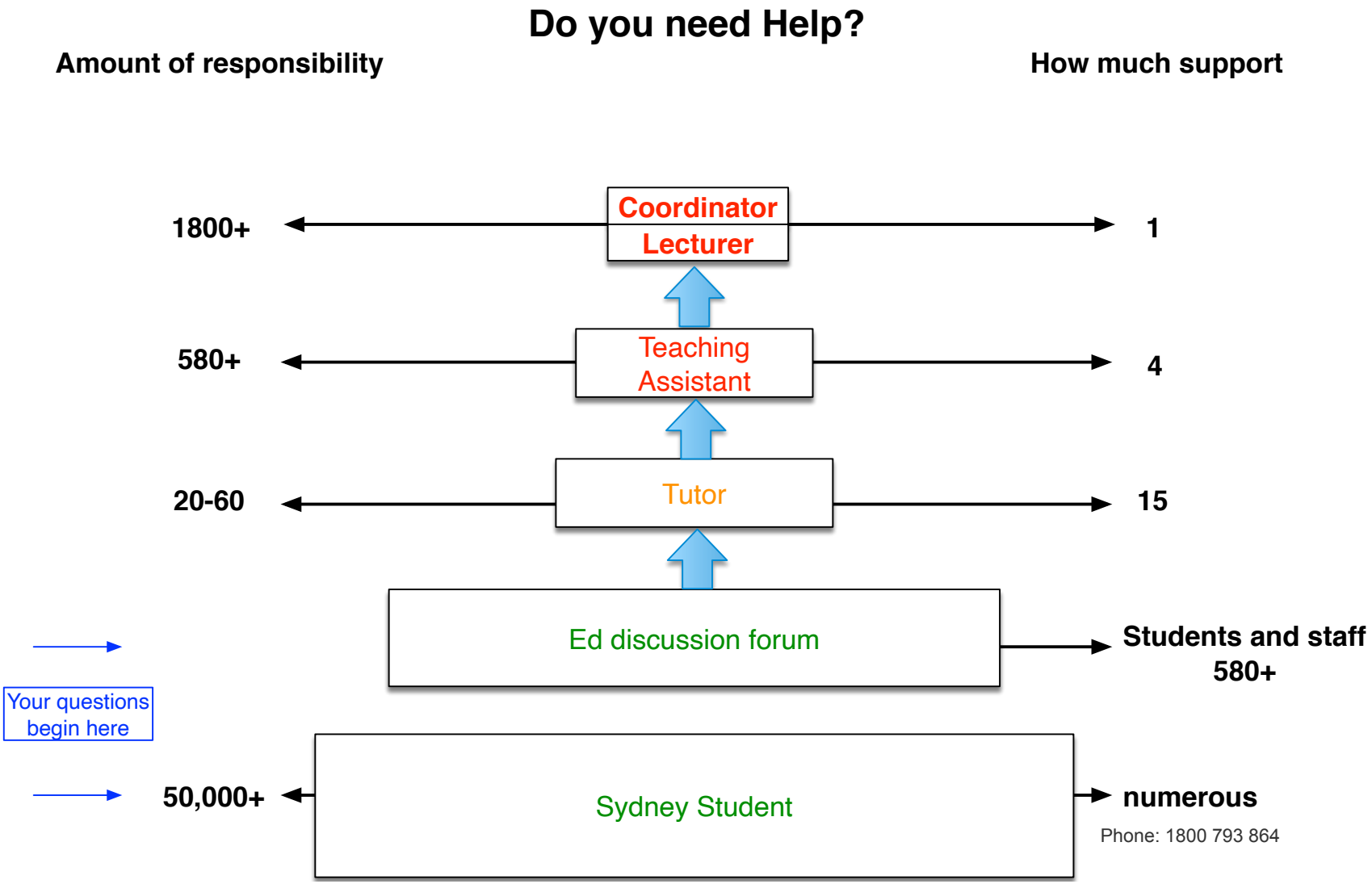
- Anuj Dhavalikar
- Michael Zammit
- Dennis Chen
- Mai Le
- Mathew Magee
- Zijun Hui
- Yun Li
- Gregory McLellan
- Shumin Kong
- Alan Robertson
- Sam Arch
- Matthew Strasiotto
- Darius Zhu

If you encounter any problems with our tutors, please contact the TA or the coordinator directly.

Where to get help?

1. Student admin → `https://sydneystudent.sydney.edu.au` or contact the Student Centre. Please check these first. E.g. timetable, passwords, payments, enrolments etc.
2. Ed discussion forum → Ed
3. Your tutor in your designated laboratory
4. Contact a TA for administration → Ed (private thread)
5. Your tutor in your designated laboratory
6. The teaching assistants email:
   Tyson Thomas, William Wang,
   Byung Hoon Cho (BH), Yun Li (Distance Learning Only),
7. Consultation with Dr. John Stavrakakis:
   16:15 - 17:15 Monday, Meeting room 302, Level 3, School of Computer Science, Building J12

The hierarchy of help



Expected questions

Seminar is optional, and it is recorded. Week 1 already available.

Lab begin in week 2

Submission instructions for assessments on Ed

Our distance learning students. Please check your unikey email, and refer to this Ed thread for updates: Info for DL students

Do you have another question? See lecture 0 slides, the week 0 recordings which explain a lot, the unit of study website...if it is not explained in these, feel free to ask!

Slides: `https://edstem.org/courses/3996/resources`

Memory

Memory of a computer: The addressing system

We have memory: How much do we have?

We want to retrieve a value: Where is it?

We want to store a new value: Where does it go?

We want to refer to an area of memory for someone else: How can we do that?

Memory of a computer: The addressing system (cont.)

Memory is all about addresses and values

Address is the location in memory of the value

Values are an *arbitrary* number of the bits

The first bit of a value is stored at the address

Memory of a computer: The addressing system (cont.)

Computers: 1) calculate and 2) copy memory

Computers are constantly copying values from one address to another address.[4]

copy `64` bits from address `0x0123` to address `0x0480`

All calculations rely on the memory being organised:

- The correct values were copied into the area of memory,
- using the correct addresses,
- at the right time!

[4] A simplification for modern von neumann architecture

Introduction to C

FACULTY OF
ENGINEERING

John Stavrakakis

COMP2017/COMP9017

Acknowledgement

Some material in these slides was based on lectures by A/Prof Bernhard Scholz, A/Prof Bob Kummerfeld and Prof Judy Kay

History of C

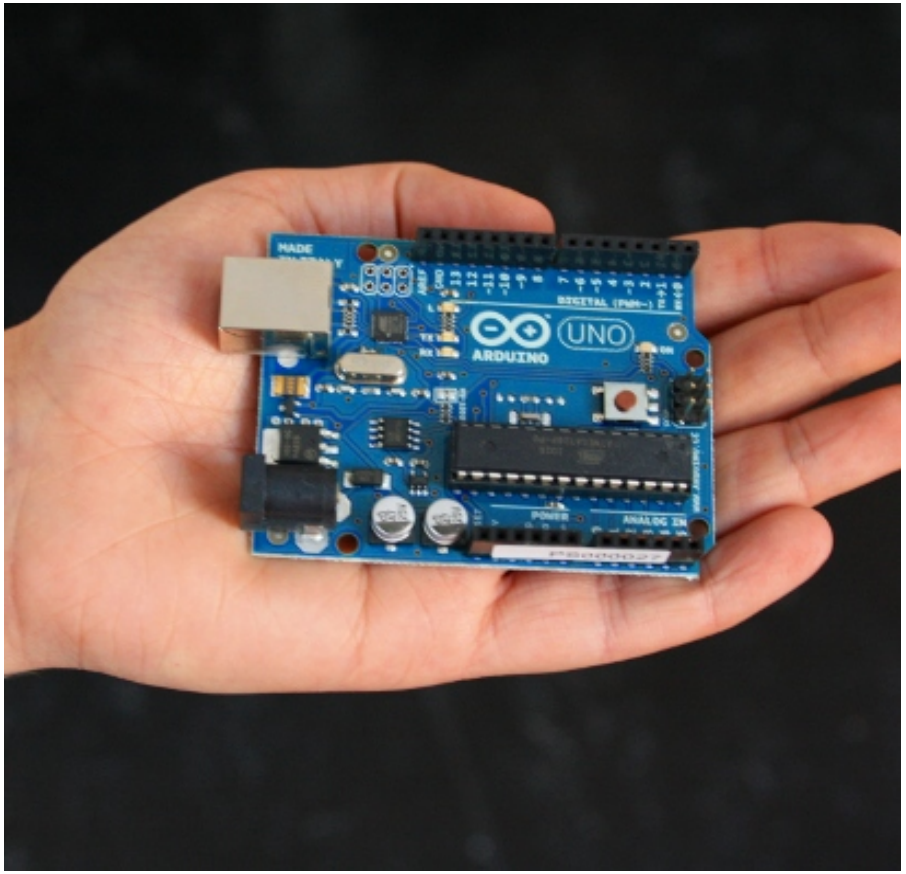
- Initially UNIX was written in low-level PDP-7 assembly
- Ken Thompson invented B based on BCPL to overcome issues of PDP-7 assembly.
- Dennis Ritchie built on B and called his language C.
- Unix on PDP-11 was rewritten in C
  - First Unix kernel in C in the year 1973
- Kernighan and Ritchie published book in 1978
  - “The C Programming Language”
- Later C was standardized
  - C89 standard (or ANSI-C) introduced better parameter handling and library standards.
  - C90 standard few minor modifications
  - C99 latest standard (we use this for this class)
  - C1X -> new standard will come up soon
- C-compilers employ two languages:
  - Preprocessing Language: text-macro language
  - Actual C-language: high-level programming language

PDP-11

C-Language (cont'd)

- Mainly used for
  - Systems software (OS, embedded systems, etc.)
  - Software that needs hardware interaction
- Also..
  - Application programming, science/engineering, etc.
- C-Compilers exist for nearly all computer architectures
- A very popular language
- C does not have features such as
  - Objects and Classes
  - Templates
  - Operator/Function overloading
- C++ overcomes this and is a successor of C
- Writing a non-optimizing C-Compiler is straightforward
  - Reason for the success story of C

Example: µC platform using C/C++



› Arduino Platform

› Project started in 2005

› Open-source electronics prototyping platform

› IDE: Arduino development environment

› ATMEL processor

› Cheap to purchase: $35

› Programmed in C (C++)

- Better than assembly
- Full control of µC
- No operating system

› More than 1M devices sold!

THE UNIVERSITY OF SYDNEY

Example: Operating System Linux in C

- Started in 1991 by Linux Torvalds
- Linus' UNIX -> Linux
- Kernel, i.e., core of the operating system.
- To complete distribution, GNU tools were used.
- In 1992 the first distributions emerged.
- Now we have numerous devices running Linux
  - Smartphones, routers, …
- C is the language of choice
  - HW Indepdence & Performance

Example: Python written in C

- Python is a scripting language.
- Was released in 2000; has been spreading rapidly because ease of use.
- Comprises several programming paradigms
  - Imperative
  - Object-oriented
  - Functional
- Easy to learn
- Standard reference implementation is written in C.

Guido van Rossum

Example: Apache Web-Server

- Apache Web-server is back-bone of the internet
- Initially released 1995
- surpass the 100 million website milestone in 2009
- Runs widely on Windows, Unix, Mac, …
- Written in C

C-Language (cont')

- C-Programs consists of two language components
  - Preprocessing Language
  - C-Language
- Preprocessing Language
  - Text-macro language
  - Definition of macros
  - Include files
  - Conditional compilation

Java to C

- Differences
  - Control flow structures are the same
    - esp. before Java 1.4
  - References are called “pointers” in C
  - No garbage collection
    - Programmer is responsible for allocating and freeing memory
  - No classes or objects
- A C-program consists of a set of files containing:
  - global variables
  - function definitions
    - “main” is the first function invoked
  - functions have local variables

```
/* This program prints "Hello world." on a line and exits
 */
public class HelloWorld
{
  public static void main (String args[])
  {
        System.out.println ("Hello world.");
  }
}
```

The most known C-Program

```
#include <stdio.h>

int main (int argc, char **argv)
{
      printf("Hello World!\n");
      return 0;
}
```

- Prints “Hello world!” on standard output
- Does not read from standard input
- Variable argc stores number of arguments
- Variable argv pointers to arguments


```
int main(int argc, char **argv)
{
 int      ftemp;  /* the fahrenheit temperature */

 printf("Please enter a fahrenheit temperature");
 scanf("%d", &ftemp);
 printf("%d fahrenheit is %d centigrade", ftemp,
                          (ftemp - 32) * 5 /  9);
 return 0;
}
```

THE UNIVERSITY OF SYDNEY

Running C Code

- Create a program text in a file whose name has the suffix ".c"
- Compile the program using the command gcc
  - gcc hello.c –o hello
  - gcc hello.c
- Use all those compiler flags
- Run the program by typing the name of the object file produced by the compiler. (The default is a.out.)
  - ./hello
  - ./a.out

Java v C
Philosophical differences

- C closer to underlying machine
- C has simple memory model
  - pointers, bit-level operators
  - arrays very close to memory model
- C assume programmer knows best
- Java object-oriented v C procedural
  - No object
  - No polymorphism
  - No inheritance

Strong similarities

- Block structured
- Most control structures
  - if, else, while, do ... while, switch, for (mostly),
  - break, continue (no labels in C)
- Arrays
- Operators (mainly the same)
- Basic data types (mainly similar)

THE UNIVERSITY OF SYDNEY

More differences - preprocessor

- C macros (#define)
- Call-by-name
- C has declaration for variables and functions, often in header files that are included
- conditional compilation

- Arrays can be handled with pointers
- Arrays can be created and initialised in declaration
- C strings are just arrays (with termination character)
- sizeof operator
- create dynamic data structures with malloc()
- C allows declarations only at block start

Summary

- C and Java have some similarities
  - syntax, control structures
- but some deep differences
  - Java is OO, C much closer to the hardware
- C is higher performance than Java
- C is widely used for embedded systems, operating systems etc
- C has evolved into OO forms (Objective C, C++)

Functions in C

A function consists of

- A function declaration:
  - Name of function,
  - Return type of function,
  - Parameter list and their types

```
int foo(float f1, char c2)
.....
```

- Followed by a function body:
  - Local variables & control flow

```
int foo(float f1, char c2)
{
    int x = 0;
    …
    return x;
}
```

Functions in C

- External or forward function declarations do not have a function body, just a semicolon
  - parameter types are specified without variable names

```
int foo(float, char);
```

```
extern int foo(float, char);
```

- A function with a given name can only be defined once
- If no return value exists for a function, use the type **void**

```
void foo(….) { ….}
```

- If no parameters exist use, use type **void**

```
void foo(void) { ….}
```

Functions in C

- Functions with arbitrary numbers of parameters are possible

```
int printf(const char *format, …)
```

- In this case, a special interface is required for querying values of parameters
  - Lookup the **va_args** interface
  - At least one fixed parameter in the function is necessary
  - Function call is simple

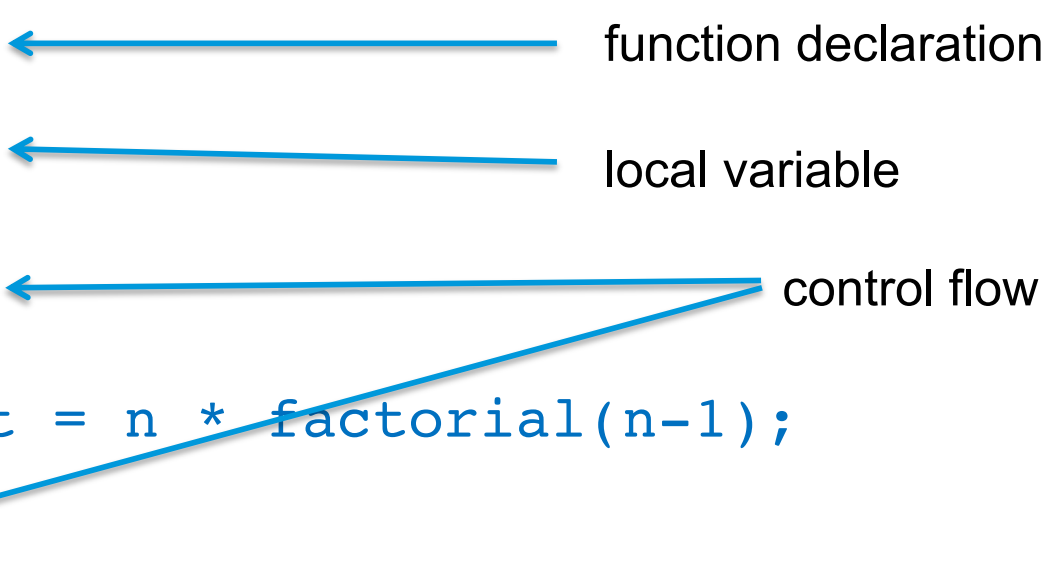
```
printf("%d, %f", 10, 10.5);
```

Example: Function

› Compute factorial n!

```
int factorial (int n)
{
        int result;

        if (n > 1 )
        {
              result = n * factorial(n-1);
        }
        else
        {
              result = 1;
        }
        return result;
}
```



Control-structures in C

- Mostly the same as in Java
- statements are terminated by a semicolon; the null statement is allowed.

```
<stmnt>;….; <stmnt>;
```

- A statement can be a sequence of statements inside a ***block***

```
{
    <stmnt>;
    <stmnt>;
}
```

Control-structures in C

› if statements:

```
if ( <expr> )
    <stmnt>
```

```
if ( <expr> )
    <stmnt>
else
    <stmnt>
```

› while statements:

```
while ( <expr> )
    <stmnt>
```

```
do <stmnt>
while ( <expr> )
```

Control-structures in C

› for statement:

```
for ( <initial-expr>; <boolean-expr>; <continuation-expr> )
    <stmnt>
```

Control-structures in C

› for statement example:

```
for ( x = 0; x < 100; x++)
    counter[x] = x;
```

Control-structures in C

› return, break and continue statements:

```
return <optional expression>;

break;

continue;
```

› **return** will return to the calling function, optionally returning a value.

› **break** will jump out of the smallest enclosing loop or switch

› **continue** will jump to the next iteration of the smallest enclosing loop

Control-structures in C

› switch statement:

```
switch(…)
{
case <const-expr>: <statement-sequence>;
case …: …
default: …
}
```

C modules

- Programs consist of “modules”
  - **A module is a file**, i.e., hello.c
- Modules consist of
  - Function declarations
  - Function definitions
  - Global variables
- Modules are translated to object files
- Object files are linked by linker with other object files and standard libraries

C file or module

- A module can refer to global variables and functions of other modules
  - use the **extern** qualifier for global variables
- Symbols can only be *defined* in one module
- Data structures definitions and declarations, macro definitions and external function declarations are found in modules
  - These are commonly found in header files

```
#include <stdio.h>
#include <stdlib.h>

int global1;

int foo(int x,int y)
{
    return x + y;
}
```

```
#include <stdio.h>
#include <stdlib.h>

extern int global1;

extern int foo(int x,int y);

int foo2(int x,int y)
{
    return foo(x,y)+global1;
}
```

Module example

foo.c

```
int foo()
{
        printf ("hello from foo\n");
        return 0;
}
```

foo.h

```
extern int foo();
```

Module example

foo.c

```
int foo()
{
        printf ("hello from foo\n");
        return 0;
}
```

foo.h

```
extern int foo();
```

sample.c

```
#include “foo.h”

int main(int argc, char **argv)
{
        foo();
        return 0;
}
```

Input/Output functions

- Basic Input: int getchar(void);
  - reads from standard input next character
  - returns -1 (defined as the symbol EOF) if end of input reached
- Basic Output: void putchar(int c);
  - Write a character (represented as an integer) to standard output
- getchar/putchar are very simple

THE UNIVERSITY OF SYDNEY

printf()-function

- printf()-function writes to standard output:
  - Strings
  - variables of primitive a data-type

```
int printf(const char *format, …);
```

- Return value:
  - Number of printed characters
- Arguments
  - First argument is a format string
  - Followed my an arbitrary number of parameters depending on format string
- Example:

  printf("%d %f\n", 10, 10.5);
  - Output: 10 10.5
  - %d print an integer followed later as a parameter
  - %f print a float followed later as a parameter
  - \n means print new line

THE UNIVERSITY OF SYDNEY

Format string codes for printf

Code	Description
%c	Character
%d	Integer
%u	Unsigned integer
%f, %g, %e	Double floating point number
%x	Hexadecimal
%ld	long
%.2f	Print floating point numbers with two decimal points
%s	String
%p	Pointer
%%	Print %

THE UNIVERSITY OF SYDNEY

scanf()-function

- scanf()-function reads from standard input:
  - Values of primitive data-type and strings
- Return value:
  - Number of successfully read items

```
int scanf(const char *format, …);
```

- Argument
  - First argument is a format string
  - Followed my an arbitrary number of parameters depending on format string
  - ***Parameters must be pointers*** – not values
- Example:
  - Read an integer and store it in x
  - Read a float and store it in f
  - Same format string as in scanf

```
int x;
float f;
scanf("%d %f", &x, &f);
```

End of Section