Lecture P1: Introduction to C

```
#include <stdio.h>
int main(void) {
   printf("This is a C program.\n");
   return 0;
}
```

Learning to Program

Programming is learned with practice and patience.

- Don't expect to learn solely from these lectures.
- Do exercises.
- Experiment and write lots of code.

Do reading.

- Finish King Chapters 1-6 today!

Aspects of learning to program.

- Language syntax.
- Algorithms.
- Libraries.
- These are different skills and learning processes.

C Background

Born along with Unix in the early 1970s.

- One of most popular languages today.

C Features.

- Concise.
- Widespread usage.
- Exposes low-level details of machine.

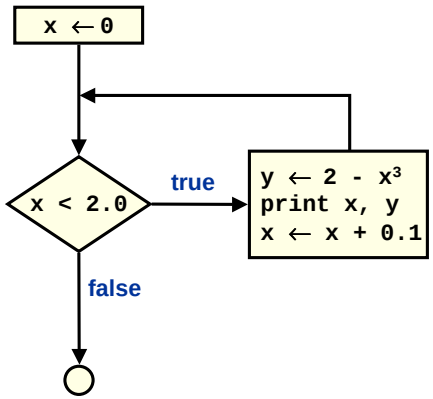
Consequences.

- Positive: you can do whatever you want.
  →
- Negative: you can do whatever you want.
  →

Language Syntax: Loops

Print a table of values of function $f(x) = 2 - x^3$.

```
x    f(x)
0.0  2.000
0.1  1.999
0.2  1.992
0.3  1.973
0.4  1.936
0.5  1.875
0.6  1.784
0.7  1.657
0.8  1.488
0.9  1.271
1.0  1.000
1.1  0.669
1.2  0.272
1.3 -0.197
1.4 -0.744
1.5 -1.375
1.6 -2.096
1.7 -2.913
1.8 -3.832
1.9 -4.859
```



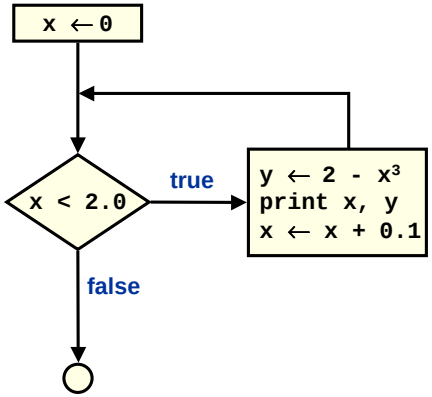
Anatomy of a While Loop

Print a table of values of function f(x) = 2 - x^3 .

- Use `while` loop to perform repetitive tasks.

```
x = 0.0;
while (x < 2.0) {
   y = 2 - x*x*x;
   printf("%f %f\n", x, y);
   x = x + 0.1;
}
```

C code



Language Syntax: Loops

Print a table of values of function f(x) = 2 - x^3 .

- Use `while` loop to perform repetitive tasks.

input/output library functions

computer starts

declare real-valued variables x and y

printf used to print characters to screen

repeat as long as x is less than 2.0

print new values of y

reassign variable x with the x + 0.1

print x < 2.0

end of code

table2.c

```
#include <stdio.h>

int main(void) {
   double x, y;

   printf(" x     f(x)\n");
   x = 0.0;
   while (x < 2.0) {
      y = 2.0 - x*x*x;
      printf("%4.1f %6.3f\n", x, y);
      x = x + 0.1;
   }

   return 0;
}
```


Debugging a Program

When you type commands, you are controlling an abstract machine called the "Unix shell."

- Compile: convert the program from human's language (C) to machine's language.
- Syntax error: illegal C program.
- Semantic error: legal but wrong C program.
- Debugging: cyclic process of editing, compiling, and fixing errors.
  - always a logical explanation
  - enjoy the satisfaction of a working program!

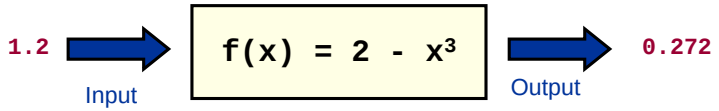
Unix

```
% gcc table.c
% a.out
```

Language Syntax: Functions

Convenient to break up programs into smaller modules or functions.

- Layers of abstraction.
- Makes code easier to understand.
- Makes code easier to debug.
- Makes code easier to change later on.




```
double f(double x) {
   return 2 - x*x*x;
}
```

C function

Anatomy of a Function

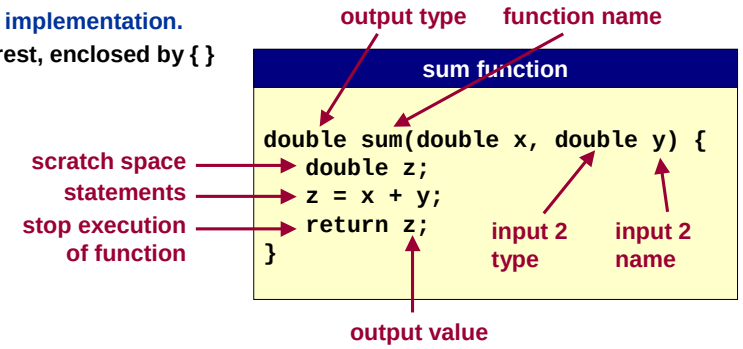
C function similar to mathematical function.

Prototype or interface is first line of C function.

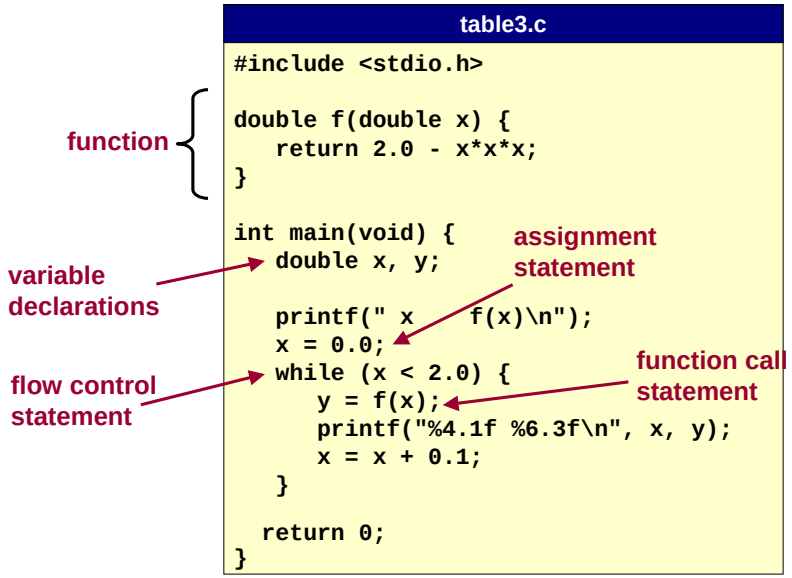
- specifies input argument(s) and their types
  - can be integers, real numbers, strings, vectors, user-defined
- specifies return value

Body or implementation.

- The rest, enclosed by { }



Anatomy of a C Program



Library Functions: `printf()`

Library functions.

- Functions provided as part of C implementation.

Example: `printf()`.

- Contact between your C program and outside world.
- Puts characters on "standard output."
- By default, stdout is the "terminal" that you're typing at.

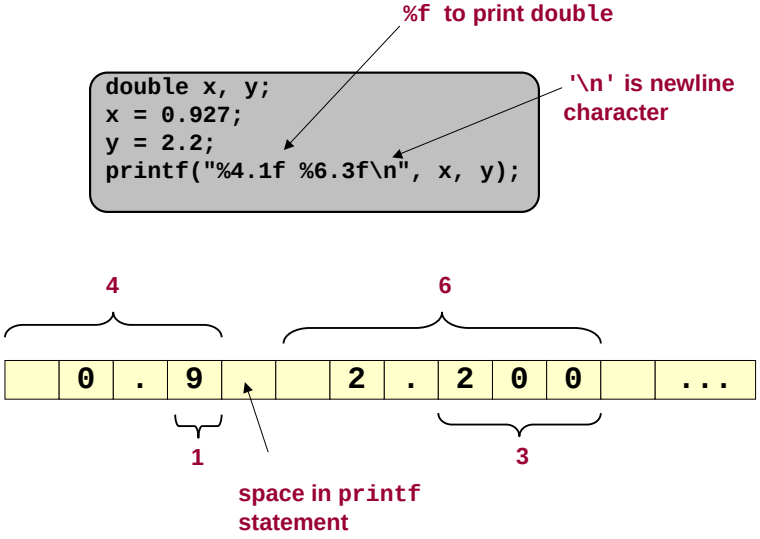
Internally, all numbers represented in BINARY (0's and 1's).

- `printf()` displays more useful representation (`int`, `double`).

Formatted output.

- How do you want the numbers to look?
  - integers, how many digits?
  - real numbers, how many digits after decimal place?
- Very flexible.

Library Functions: `printf()`



Library Functions: `printf()`

How is library function `printf()` implemented?

- User doesn't need to know details. (see COS 217)
- User doesn't want to know details. (abstraction)

Library Functions: `rand()`

Print 10 "random" integers.

- Library function `rand()` in `stdlib.h` returns integer between 0 and `RAND_MAX` (32,767 = 2^{16} - 1 on arizona).

int.c

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

int main(void) {
   int i = 0;
   while (i < 10) {
      printf("%d\n", rand());
      i = i + 1;
   }
   return 0;
}
```

i++;

Unix

```
% gcc int.c
% a.out
16838
5758
10113
17515
31051
5627
23010
7419
16212
4086
```


Library Functions: `rand()`

Print 10 "random" integers between 0 and 599.

- No precise match in library.
- Try to leverage what's there to accomplish what you want.

int600.c

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

int randomInteger(int n) {
   return rand() % n;
}

int main(void) {
   int i = 0;
   while (I < 10) {
      printf("%d\n", randomInteger(600));
      i++;
   }
   return 0;
}
```

p % q gives remainder of p divided by q

Unix

```
% gcc int600.c
% a.out
168
5
1
175
310
562
230
341
16
386
```


Library Functions: `rand()`

How is library function `rand()` implemented?

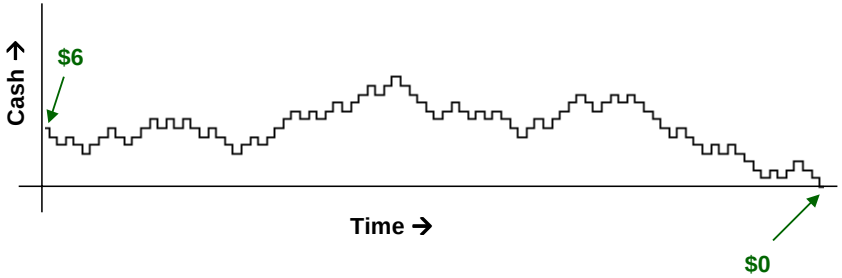
- Linear feedback shift register? Cosmic rays?
- Depends on compiler and operating system.
- Caveat 1: "random" numbers are not really random.
  →
- Caveat 2: on many systems, `randomInteger()`is very poor.
  →

Moral: check assumptions about library function.

Gambler's Ruin

Simulate gambler placing $1 even bets.

- **Will gambler always go broke.**
- **If so, how long will it take if gambler starts with $c?**



Gambler's Ruin

gambler.c

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

int randomInteger(int n) { ... }

int main(void) {
  int cash, seed;
  scanf("%d %d", &cash, &seed);
  srand(seed);

  while (cash > 0) {
     if (randomInteger(2) == 1)
        cash++;
     else
        cash--;
     printf("%d\n", cash);
  }
  return 0;
}
```

scanf() takes input from terminal

srand() sets random seed

while I still have money left, repeat

make a bet

print money left

Gambler's Ruin

Simulate gambler placing $1 even bets.
Q. How long does the game last if we start with $c ?

Unix

```
% gcc gambler.c

% a.out          % a.out
4 543            4 1234
3                3
4                2
5                3
4                4
3                3
4                4
3                5
2                6
1                7
0                6
                 7
                 8
                 9
```

Hmmm.

Gambler's Ruin

Simulate gambler placing $1 even bets.
Q. How long does the game last if we start with $c ?

Unix

```
% gcc gambler.c

% a.out          % a.out
4 543            4 1234
***              ***
****             **
*****            ***
****             ****
***              ***
****             ****
***              *****
**               ******
*                *******
                 ******
                 *******
                 ********
                 *********
```

To print plot, replace:

```
printf("%d\n", cash);
```

with

```
i = cash;
while (i > 0) {
   printf("*");
   i--;
}
printf("\n");
```

Gambler's Ruin Numerical Experiment

Goal: run experiment to see how long it takes to go broke.

- Do for different values of starting cash values c.

Unix

```
% gcc gexperiment.c
% a.out
```

bets

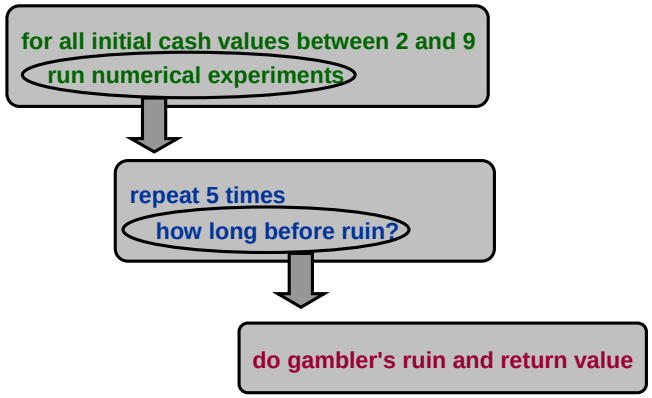
initial cash

2	2	6	304	2	2
3	33	17	15	53	29
4	22	1024	7820	22	54
5	243	25	41	7	249
6	494	14	124	152	14
7	299	33	531	49	93
8	218	10650	36	42048	248
9	174090315	83579	299	759	69

Top-Down Design of Numerical Experiment

Goal: run experiment to see how long it takes to go broke.

- Do for different values of starting cash values c.



Gambler's Ruin Numerical Experiment

single experiment (code as before)

return # of times instead of printing each trial

gexperiment.c

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

int randomInteger(int n) { ... }

int doit(int cash) {
   int count = 0;
   while (cash > 0) {
      if (randomInteger(2) == 1) cash++;
      else cash--;
      count++;
   }
   return count;
}
```


Gambler's Ruin Numerical Experiment

repeat for all initial cash values 2 to 9

repeat 5 times

gexperiment.c (cont)

```
int main(void) {
   int cash, t;
   cash = 2;
   while (cash <= 9) {
      printf("%d ", cash);
      t = 0;
      while (t < 5) {
         printf("%d ", doit(cash));
         t++;
      }
      printf("\n");
      cash++;
   }
   return 0;
}
```

Do one experiment

Gambler's Ruin Numerical Experiment

Unix

```
% gcc gexperiment.c
% a.out
```

initial cash	# bets				
2	2	6	304	2	2
3	33	17	15	53	29
4	22	1024	7820	22	54
5	243	25	41	7	249
6	494	14	124	152	14
7	299	33	531	49	93
8	218	10650	36	42048	248
9	174090315	83579	299	759	69

How long will it take to go broke?

→

Layers of abstraction.

- Random bit → gambler's ruin sequence → experiment.

Programming Style

Concise programs are the norm in C.

Your goal: write READABLE and EFFICIENT programs.

- Use consistent indenting.
  - automatic indenting in program editors (Icc for Windows, emacs for Unix)
- Choose descriptive variable names.
- Use comments as needed.

"Pick a style that suits you, then use it consistently."

-Kernighan and Ritchie

Programming Advice

Understand your program.

- What would the machine do?

Read, understand, and borrow from similar code.

" Good artists borrow. Great artists steal. "

Develop programs incrementally.

- Test each piece separately before continuing.
- Plan multiple lab sessions.

Summary

Lots of material.

C is a structured programming language.

- Functions, loops.
- Simple, but powerful tools.

Programming maturity comes with practice.

- Everything seems simpler in lecture and textbooks.
- Always more difficult when you do it yourself!
- Learn main ideas from lecture, learn to program by writing code.

You will create many bugs without any practice whatever.

"As soon as we started programming, we found out to our surprise that it wasn't as easy to get programs right as we had thought. I can remember the exact instant when I realized that a large part of my life from then on was going to spent in finding mistakes in my own programs."

--Maurice Wilkes, 1949

Lecture P1: Supplemental Notes

For Loop Example

Print a table of values of function f(x) = 2 - x^3. A final attempt.

use a for loop

table4.c

```
#include <stdio.h>

double f (double x) {
   return 2.0 - x*x*x;
}

int main(void) {
   double x, y;

   printf(" x     f(x)\n");
   for (x = 0.0; x < 2.0; x += 0.1) {
     y = f(x);
     printf("%4.1f %6.3f\n", x, y);
   }

   return 0;
}
```

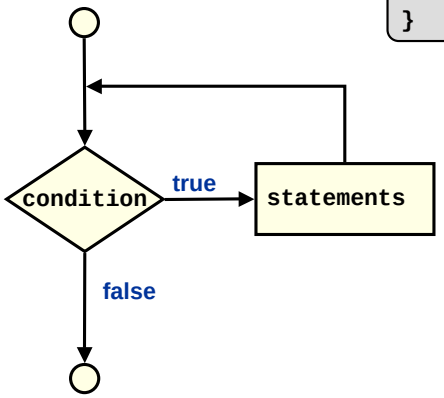
x += 0.1 is shorthand in C for x = x+ 0.1

Anatomy of a While Loop

The while loop is a common repetition structure.

```
while (condition) {
   statements;
}
```

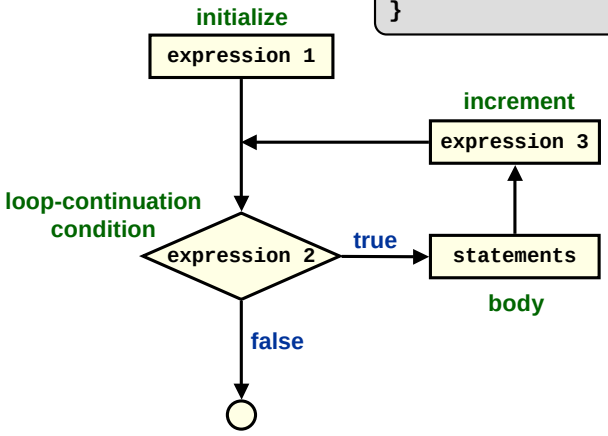
while loop



Anatomy of a For Loop

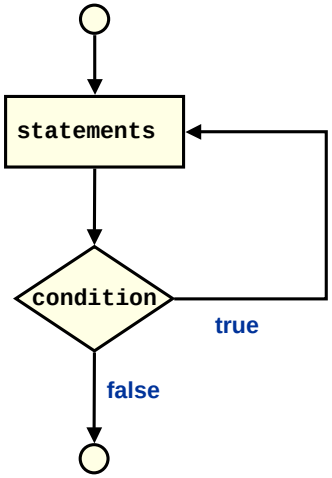
The for loop is another common repetition structure.

```
for (expr1; expr2; expr3) {
   statements;
}
```



Anatomy of a Do-While Loop

The do-while loop is not-so-common repetition structure.




```
do {
   statements;
} while (condition)
```

do-while loop

What is a C Program?

C PROGRAM: a sequence of FUNCTIONS that manipulate data.

- `main()` function executed first.

A FUNCTION consists of a sequence of DECLARATIONS followed by a sequence of STATEMENTS.

- Can be built-in like `printf(...)`.
- Or user-defined like `f(x)` or `sum(x, y)`.

A DECLARATION names variables and defines type.

- double `double x;`
- integer `int i;`

A STATEMENT manipulate data or controls execution.

- assignment: `x = 0.0;`
- control: `while (x < 2.0) {...}`
- function call: `printf(...);`