



Introduction to C

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Introduction

- Originally designed for and implemented on the UNIX OS DEC PDP-11 by Dennis Ritchie
- Not tied to any hardware or system
- Easy to compile and run in other systems
- General-purpose programming language
- Not strongly typed but strong type-checking
- Variety of data types (characters, integers and float point numbers)
- Derived data types created with pointers, arrays, structures and unions

Introduction

- Fundamental control-flow (if-else, switch, while, for, do, break...)
- Functions may return basic types, structures, unions or pointers
- Supports recursive function calls
- Preprocessing performs macro substitution
- Relatively low level, C deals with same objects that most computers would use (assembly)
- High level mechanisms need to be provided by explicitly-called functions
- Book: *C Programming Language (2nd Edition)* by Brian W. Kernighan, Dennis M. Ritchie, 1988. (Pearson)
- <https://github.com/vncprado/intro-to-c>

Environment

- VSCode + SSH plugins, Brightspace instructions (Links and Resources)
- Others
 - Ubuntu

```
$ sudo apt install build-essential
```

- Windows

VSCode + Windows Subsystem for Linux (WSL), Brightspace instructions (Links and Resources)

- Mac

Xcode, brew (package manager), gcc, clang (native)

What are we covering?

- A little of *The Book: C Programming Language (2nd Edition)* by Brian W. Kernighan, Dennis M. Ritchie, 1988. (Pearson)
 - Tutorial (ch1)
 - Functions and program structure (ch4)
 - Pointers (ch5)
 - Structures and unions (ch6)

1.1 Hello World!

- Environment test
 - Windows, Mac, Linux, VS Code
 - Text editor and shell (terminal)
 - # include <stdio.h>
 - int main()

- To compile

```
gcc hello_world.c
```

- To run

```
./a.out
```

hello.c

```
#include <stdio.h>

int main () {
    printf("hello, world!\n");
}
```

```
vinicius@laptop:intro-to-c$ gcc hello.c
vinicius@laptop:intro-to-c$ ./a.out
hello, world!
```

Back to the basics

- basics.c
 - Variables
 - if else
 - while
 - for
 - printf
 - Comments
 - //
 - /**/

basics.c

```
#include <stdio.h>

int main() {
    int number = 5;

    if (number > 10)
        printf("Larger than 10\n");
    else
        printf("Smaller than 10\n");

    while (number < 10) {
        printf("Still smaller\n");
        number++;
    }
    printf("Not anymore: %d\n", number);

    for (int i=0; i<10; i++) {
        printf("Now i=%d\n", i);
    }
    return 0;
}
```

1.2, 1.3 Fahrenheits to Celsius

- $C = (5/9) * (F - 32)$
- 0, 20, 40, 60...300 F ---> C?
- While loop version
- Truncated integers
 - float - float point
 - char - character, single byte
 - short - short integer
 - long - long integer
 - double - double-precision float point

1.2Farhenheit-to-Celsius.c

```
#include <stdio.h>

int main() {

    //int F, C;
    float F, C;
    int min_value = 0;
    int max_value = 300;
    int step = 20;

    F = min_value;
    while (F <= max_value) {
        C = (5.0/9.0)*(F-32.0);
        //printf("%d\t%d\n", F, C);
        printf("%8.2f\t%8.2f\n", F, C);
        F = F + step;
    }
}
```


1.2, 1.3 Fahrenheits to Celsius

- $C = (5/9) * (F - 32)$
- 0, 20, 40, 60...300 F ---> C?
- C and F are now floats
 - printf float "%f"

1.2Farhenheit-to-Celsius.c

```
#include <stdio.h>

int main() {

    //int F, C;
    float F, C;
    int min_value = 0;
    int max_value = 300;
    int step = 20;

    F = min_value;
    while (F <= max_value) {
        C = (5.0/9.0)*(F-32.0);
        //printf("%d\t%d\n", F, C);
        printf("%8.2f\t%8.2f\n", F, C);
        F = F + step;
    }
}
```

1.2, 1.3 Fahrenheits to Celsius

- For loop version
- Symbolic constants

1.3Celsius-to-Fahrenheit-FOR.c

```
#include <stdio.h>

#define name replacement_text
#define LOWER 0
#define UPPER 100
#define STEP 5

int main() {
    int celsius;

    printf("Celsius-Fahrenheit table\n");
    /* for (<initialisation>; <expression>; <expression>) */
    for (celsius = LOWER; celsius <= UPPER; celsius += STEP) {
        printf("%3.0f %6.1f\n", (float)celsius, (celsius * 9.0 / 5.0) + 32.0);
    }
}
```

1.5 Character input/output

- One character at a time
 - `c = getchar()`
 - `printf()`
 - `putchar(c)`
- `./a.out`
 - type something + enter
- `./a.out < some_file`

basic_inout.c

```
#include <stdio.h>

int main () {
    int c;

    c = getchar();
    putchar(c);
    printf("\n");
    printf("Your input: %d\n", c);
    printf("Your input: %c\n", c);

    return 0;
}
```

```
vpradodafons@garfield ~/workspace/COMP2004/intro-to-c/examples $ ./a.out
a
Your input: 97
Your input: a
```

ASCII TABLE

Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char
0	0	[NULL]	32	20	[SPACE]	64	40	@	96	60	`
1	1	[START OF HEADING]	33	21	!	65	41	A	97	61	a
2	2	[START OF TEXT]	34	22	"	66	42	B	98	62	b
3	3	[END OF TEXT]	35	23	#	67	43	C	99	63	c
4	4	[END OF TRANSMISSION]	36	24	\$	68	44	D	100	64	d
5	5	[ENQUIRY]	37	25	%	69	45	E	101	65	e
6	6	[ACKNOWLEDGE]	38	26	&	70	46	F	102	66	f
7	7	[BELL]	39	27	'	71	47	G	103	67	g
8	8	[BACKSPACE]	40	28	(	72	48	H	104	68	h
9	9	[HORIZONTAL TAB]	41	29	)	73	49	I	105	69	i
10	A	[LINE FEED]	42	2A	*	74	4A	J	106	6A	j
11	B	[VERTICAL TAB]	43	2B	+	75	4B	K	107	6B	k
12	C	[FORM FEED]	44	2C	,	76	4C	L	108	6C	l
13	D	[CARRIAGE RETURN]	45	2D	-	77	4D	M	109	6D	m
14	E	[SHIFT OUT]	46	2E	.	78	4E	N	110	6E	n
15	F	[SHIFT IN]	47	2F	/	79	4F	O	111	6F	o
16	10	[DATA LINK ESCAPE]	48	30	0	80	50	P	112	70	p
17	11	[DEVICE CONTROL 1]	49	31	1	81	51	Q	113	71	q
18	12	[DEVICE CONTROL 2]	50	32	2	82	52	R	114	72	r
19	13	[DEVICE CONTROL 3]	51	33	3	83	53	S	115	73	s
20	14	[DEVICE CONTROL 4]	52	34	4	84	54	T	116	74	t
21	15	[NEGATIVE ACKNOWLEDGE]	53	35	5	85	55	U	117	75	u
22	16	[SYNCHRONOUS IDLE]	54	36	6	86	56	V	118	76	v
23	17	[ENG OF TRANS. BLOCK]	55	37	7	87	57	W	119	77	w
24	18	[CANCEL]	56	38	8	88	58	X	120	78	x
25	19	[END OF MEDIUM]	57	39	9	89	59	Y	121	79	y
26	1A	[SUBSTITUTE]	58	3A	:	90	5A	Z	122	7A	z
27	1B	[ESCAPE]	59	3B	;	91	5B	[	123	7B	{
28	1C	[FILE SEPARATOR]	60	3C	<	92	5C	\	124	7C	|
29	1D	[GROUP SEPARATOR]	61	3D	=	93	5D	]	125	7D	}
30	1E	[RECORD SEPARATOR]	62	3E	>	94	5E	^	126	7E	~
31	1F	[UNIT SEPARATOR]	63	3F	?	95	5F	_	127	7F	[DEL]

1.5 Character input/output

- One character at a time
 - `c = getchar()`
 - `putchar(c)`
- `./a.out`
 - type something
 - `ctrl+d`
- `./a.out < some_file`

```
vinicius@laptop:book-examples$ ./a.out
test 123 test
test 123 test
```

1.5.1getchar-putchar.c

```
#include <stdio.h>

int main() {
    int c;

    c = getchar();
    while (c != EOF) {
        //printf("%d\n", c);
        putchar(c);
        c = getchar();
    }
}
```

Input using scanf

- String example
- Scanf
 - Accept input from
 - String with format
 - Address of variable
 - Arrays variable name is a pointer

```
vinicius@laptop:intro-to-c$ gcc input_scanf_srt.c
vinicius@laptop:intro-to-c$ ./a.out
Insert a string
Test 123
you entered: Test
```

input_scanf_srt.c

```
#include <stdio.h>

int main() {
    char my_var[10]; // variable to store the input

    printf("Insert a string\n");
    scanf("%s", my_var); // scanf reading string

    printf("you entered: %s\n", my_var);
}
```

Input using scanf

- Integer example
- Scanf
 - Accept input from
 - String with format
 - Address of variable
 - Arrays variable name is a pointer

```
vinicius@laptop:intro-to-c$ gcc input_scanf_int.c
vinicius@laptop:intro-to-c$ ./a.out
Insert an integer
12323
you entered: 12323
```

input_scanf_int.c

```
#include <stdio.h>

int main() {
    int my_int; // variable to store the input

    printf("Insert an integer\n");
    // scanf need the variable address "&"
    scanf("%d", &my_int); // scanf reading integer

    printf("you entered: %d\n", my_int);
}
```


Input using formatted strings

- Scanf
 - Formatted input
 - Simple example
 - More Complex/Regex expressions
 - Accepts address of variable (&)

input_scanf_frm.c

```
#include <stdio.h>

int main() {
    int a; // variable to store the input
    int b; // variable to store the input

    printf("Insert two integers a,b\n");
    scanf("%d,%d", &a, &b); // scanf reading two values

    printf("you entered: %d and %d\n", a, b);
}
```

```
vinicius@laptop:intro-to-c$ gcc input_scanf_frm.c
vinicius@laptop:intro-to-c$ ./a.out
Insert two numbers a,b
123,457
you entered: 123 and 457
```

1.6 Arrays (mod)

- Arrays declaration
 - int ndigit[10]
- Array indexing starts with zero
- Counts
 - each digit
 - white spaces
 - other characters
- Uses the representation of numbers to index the array
 - chars = 1 byte integers

Command line ctrl+D sends EOF

```
#include <stdio.h>

int main() {
    int c, i, nwhite, nother;
    int ndigit[10];

    nwhite = nother = 0;
    for (i = 0; i < 10; ++i)
        ndigit[i] = 0; // ndigit = [0,0,0,0,0,0,0,0,0,0]

    while ((c = getchar()) != EOF) // Command line ctrl+D sends EOF
        if (c >= '0' && c <= '9') {
            int index = c - '0';
            printf("Digit %d identified\n", index);
            ndigit[index] = ndigit[index] + 1;
        }
        else if (c == ' ' || c == '\n' || c == '\t') {
            printf("Empty char identified.\n");
            nwhite++;
        }
        else {
            printf("Other char identified.\n");
            nother++;
        }

    printf("digits =");
    for (i = 0; i < 10; ++i)
        printf(" %d", ndigit[i]);
    printf(", white space = %d, other = %d\n", nwhite, nother);
}
```

1.6 Arrays

- Arrays declaration
 - `int ndigit[10]`
- Array indexing starts with zero
- Counts
 - each digit
 - white spaces
 - other characters
- Uses the representation of numbers to index the array
 - chars = 1 byte integers

Command line ctrl+D sends EOF

```
vinicius@laptop:book-examples$ gcc 1.6arrays.c
vinicius@laptop:book-examples$ ./a.out
teste 123 comp 2003
```

```
test
digits = 2 1 2 2 0 0 0 0 0 0, white space = 7, other = 13
```

```
Test 123
Other char identified.
Other char identified.
Other char identified.
Other char identified.
White space identified.
Digit 1 identified
Digit 2 identified
Digit 3 identified
White space identified.
COMP2004
Other char identified.
Other char identified.
Other char identified.
Other char identified.
Digit 2 identified
Digit 0 identified
Digit 0 identified
Digit 4 identified
White space identified.
digits = 2 1 2 1 1 0 0 0 0 0, white space = 3, other = 8
```

1.7 Functions (mod)

- Subroutine, procedure
- Encapsulate some computation
 - Ignore how is done
 - know what is done
- printf, getchar
- C has no power operator
 - Function power()
 - print 2^i and $(-3)^i$
 - Not practical
 - Only positive powers, small integers
- $\text{power}(x, y) \rightarrow x^y$
- Arguments, variable copy, local

```
#include <stdio.h>

int power(int base, int expo);

int main() {

    int my_base = 2; // base
    int my_expo = 10; // exponent
    int result = power(my_base, my_expo);
    printf("%d^%d = %d\n", my_base, my_expo, result);

    return 0;
}

int power(int base, int expo) {
    int i, pow;

    pow = 1;
    for (i = 1; i <= expo; ++i) {
        pow = pow * base;
    }

    return pow;
}
```

fileinput.c

- File descriptor/pointer
- FILE* fd
- Cursor that walks the files each fscanf/fgets call

```
FILE* fd = fopen("points.csv", "rw");  
fscanf(fd, "%s", mystring) != EOF  
fscanf(fd, "%s", mystring) != EOF  
fgets (mystring, 10, fd) != NULL
```

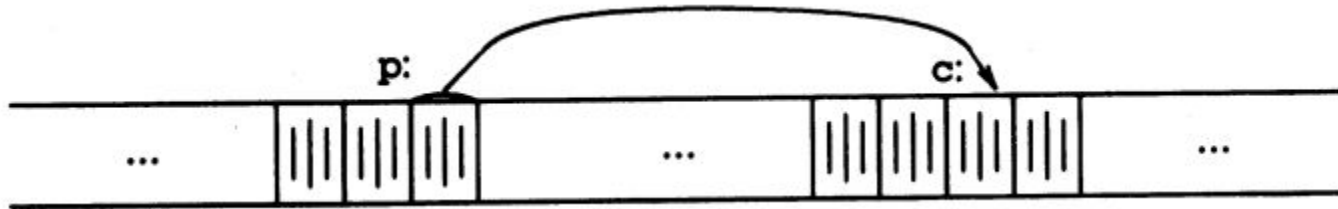
5.1 Pointers

- Memory is an consecutive numbered memory cells
- Pointer is a group of those cells that holds an address
- Operator & gives the address of something `p = &c;`
- Operator * access the object that pointer is pointing to



5.1 Pointers

```
int x = 1, y = 2;
int *ip;           // It reads "pointer to an integer"
                   // The expression "*ip" is an int
ip = &x;           // ip receives the address of x
y = *ip;           // copy the content of whatever ip points to y
*ip = *ip + 10;    // *ip affects x
```

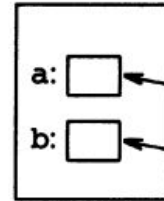


5.2 Pointers and function arguments

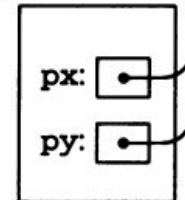
- C passes arguments to functions by value
- No direct way to alter the variable in the calling function (scope)

```
int swap(int x, int y) {  
    int temp;  
  
    temp = x;  
    x = y;  
    y = temp;  
}  
  
int pswap(int *px, int *py) {  
    int temp;  
  
    temp = *px;  
    *px = *py;  
    *py = temp;  
}
```

in caller:



in swap:



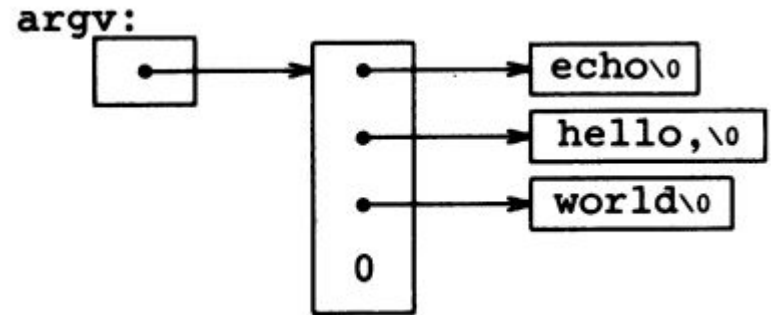
Command-line Arguments

```
gcc echo.c -o echo
```

```
./echo hello, world!
```

- argc
 - Argument counter
- argv
 - Argument vector

```
vinicius@desktop:sandbox$ gcc echo.c -o echo
vinicius@desktop:sandbox$ ./echo hello, world!
argc: 3
./echo
hello,
world!
```



Command-line Arguments

gcc cmdline_params.c

./a.out 123

- argc
 - Argument counter
- argv
 - Argument vector
- atoi()
 - To integer

```
vinicius@desktop:sandbox$ gcc cmdline_params.c
vinicius@desktop:sandbox$ ./a.out
We need at least one parameter
vinicius@desktop:sandbox$ ./a.out 34
./a.out
34
34 + 1 = 35
```

6.1 Basic of Structures

- Collection of one or more variables
 - Possibly different types
 - Grouped together
 - Treated as a unit
- Ex. Employee record
 - Name
 - Age
 - Job title
- Typedef
 - struct coord is a tag, we can use that later
 - Has to use struct <tag> <var>; everywhere
 - Typedef Coord is a type (e.g. int)
 - Can be used Coord <var>;

```
struct coord {  
    int x;  
    int y;  
};  
  
struct coord my_coord;
```

```
typedef struct coord {  
    int x;  
    int y;  
} Coord;  
  
Coord my_coord;
```

6.2 Structures and Functions

- Manipulate structures
- Pass components separately
- Pass the entire structure
- Pass a pointer

```
struct coord init_coord(int x, int y) {  
    struct coord temp_coord;  
    temp_coord.x = x;  
    temp_coord.y = y;  
  
    return temp_coord;  
}  
  
struct coord my_coord = init_coord(2, 3);
```

coord-list.c

- Structure with a pointer to the next node

Coord.next = previous

- typedef
- coordnode is a tag
 - make the struct not unknown, reference after
- typedef define **CoordNode** as a type, like int
 - More common

```
typedef struct coordnode {  
    struct coordnode *nextcoord;  
    int x;  
    int y;  
} CoordNode;
```

coord-list.c

- Dynamic allocation
 - malloc
- sizeof(CoordNode)
 - Size in bytes
- (CoordNode *)
 - Cast for the type we need

```
CoordNode *coord_alloc(void) {  
    return (CoordNode *) malloc(sizeof(CoordNode));  
}
```

coord-list.c

- Printing example
- Follow the nextpoint
- Chained/linked list

```
int print_list(){
    CoordNode* current = headcoord;
    int count=0;
    while (current != NULL) {
        count += 1;
        printf("(%d, %d)", current->x, current->y);
        current = current->nextcoord;

        printf(" -> ");
    }

    return count;
}
```



Questions?

First assignment (intro to C) available today
Try examples and code yourself

Really type the examples

Do not copy and paste

All examples are in the repo:

<https://github.com/vncprado/intro-to-c>

More examples and extra material in the next slides

4.1 Grep

- Split the problem in small parts
- Print the lines that contains a “pattern”
- `getline (chapter 1); printf()`
- `strindex(s, t)`
 - Return the index in the string `s` where `t` begins
 - `-1` if `s` does not contain `t`

```
while (there's another line)
    if (the line contains the pattern)
        print it
```

4.1 Grep

- mygetline
 - Change var s[] to the line read
 - '\0' == End of string
 - While
 - Not limit
 - Not EOF
 - Not "\n"
 - Read next char
 - Return the size of my string
 - Useful later

```
int mygetline(char s[], int lim) {  
    int c, i;  
  
    i = 0;  
    while (--lim > 0 && (c=getchar()) != EOF && c!= '\n')  
        s[i++] = c;  
    if (c == '\n')  
        s[i++] = c;  
    s[i] = '\0'; // End of string  
    return i;  
}
```

4.1 Grep

- Print the lines that contains a “pattern”
- Split the problem in small parts
- getline (chapter 1); printf()
- strindex(s, t)
 - Return the index in the string s where t begins
 - -1 if s does not contain t

```
int strindex(char s [], char t []) {  
    int i, j, k;  
  
    for (i=0; s[i] != '\0'; i++) {  
        for (j=i, k=0; t[k] != '\0' && s[j] == t[k]; j++, k++)  
            ; // do nothing  
        if (k > 0 && t[k] == '\0')  
            return i;  
    }  
    return -1;  
}
```

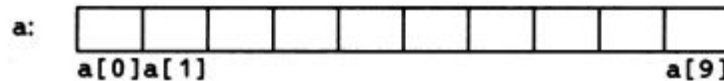
4.1 Grep

- Print the lines that contains a “substring”
- Split the problem in small parts
- getline (chapter 1); printf()
- strindex(s, t)
 - Return the index in the string s where t begins
 - -1 if s does not contain t
- cat loren.txt
- ./a.out < loren.txt

```
int main() {  
    char line[MAXLINE];  
    int found = 0;  
  
    while (mygetline(line, MAXLINE) > 0)  
        if (strindex(line, substring) >= 0) {  
            printf("%s", line);  
            found++;  
        }  
    return found;  
}
```

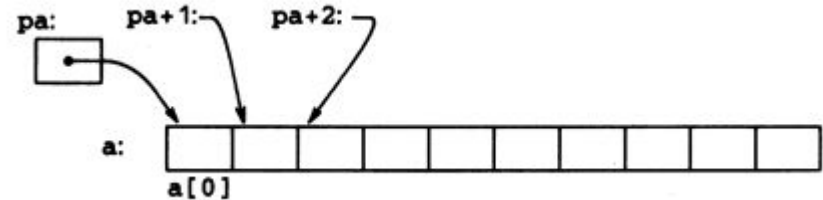
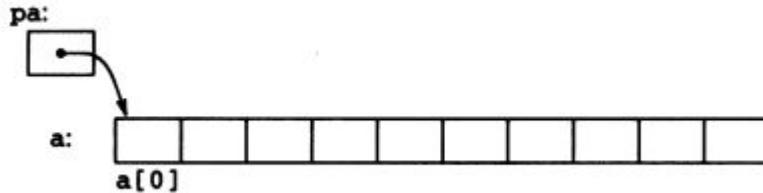
5.3 Pointers and arrays

- Strong relationship between pointers and arrays
- Any operation that can be achieved indexing (`arr[i]`) can also be done with pointers;
- In general it will be faster with pointers



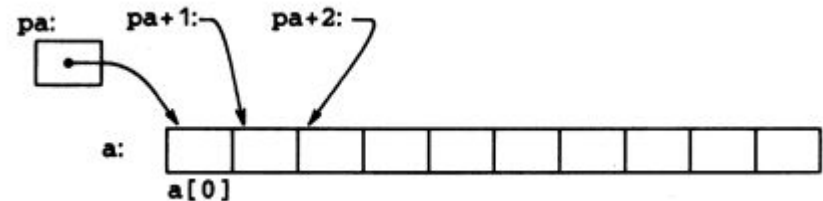
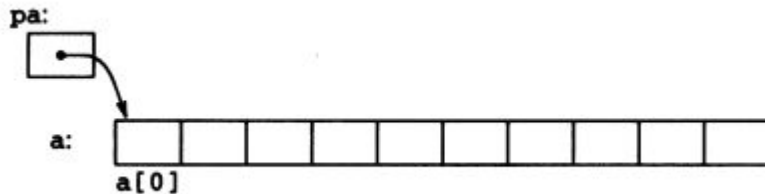
5.3 Pointers and arrays

- Strong relationship between pointers and arrays
- Any operation that can be achieved indexing (`arr[i]`) can also be done with pointers;
- In general it will be faster with pointers



5.3 Pointers and arrays

- Compilation time allocation (e.g. `char line[MAXLINE]`)
 - Scope allocation/deallocation
- Static allocation, fixed size
 - Ex: Truncate smaller string with `"\0"`
- Request memory size during run time
- Dynamic allocation moving pointers

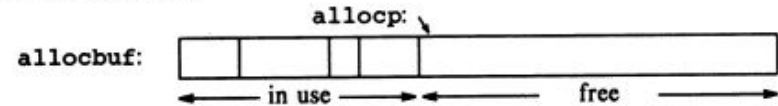


5.4 Address Arithmetic

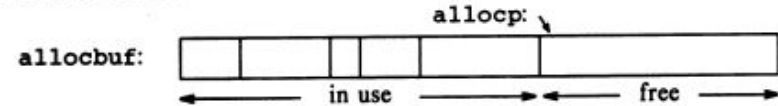
Runtime allocation

- Stack-like allocation
- `char allocbuff[ALLOCSIZE]`
- `char *allocp = allocbuff`
- `alloc(n)`
 - Pointer `p = allocp`
 - `allocp` can be only visible by `alloc` and `free`
 - Move `allocp` requested size `n`
 - `allocp + n` positions
 - Return a pointer `p`
- `afree(p)`
 - Move the `allocp` to position `p`
 - Stack, last in first out.
- Correct call order

before call to `alloc`:



after call to `alloc`:



5.4 Address Arithmetic

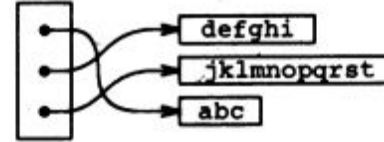
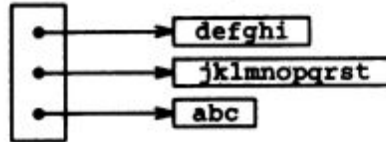
Runtime allocation

- `allocbuff[ALLOCSIZE]`
- `alloc(n)`
 - Pointer `p = allocp`
 - `allocbuff` and `allocp` can be only visible by `alloc` and `free`
 - Move `allocp` requested size `n`
 - `allocp + n` positions
 - Return a pointer `p`
- `afree(p)`
 - Move the `allocp` to position `p`
 - Stack, last in first out.
- Call `alloc/afree` correct order

```
char *alloc(int n) {  
    // will it fit?  
    if (allocbuf + ALLOCSIZE - allocp >= n) {  
        allocp += n;  
        return allocp - n;  
    } else  
        return 0;  
}
```

5.6 Array of Pointers; Pointers to Pointers

- Pointers are variables themselves
 - Can be stored in arrays, like other variables
- Points to the first letter of the text
- Sorting is faster, just swap pointers
 - 5.6pointerarrays_swap.c
- Complete sort example in the book



5.9 Pointers vs Multi-dimensional arrays

- Multi-dimensional arrays
 `int a[10][20];`
 200 int-sized locations
- Pointers
 `int *b[10]`
 Using 20-element arrays
 200 ints + 10 pointers
- Advantage is rows may have different lengths

```
char aname[][15] = { "Illegal month", "Jan", "Feb", "Mar" };
```

aname:

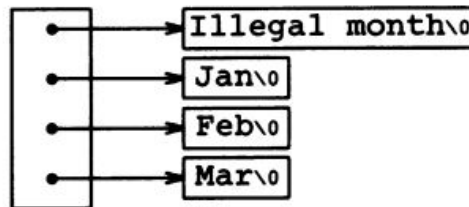
Illegal month\0	Jan\0	Feb\0	Mar\0
0	15	30	45

5.9 Pointers vs Multi-dimensional arrays

- Multi-dimensional arrays
 `int a[10][20];`
 200 int-sized locations
- Pointers
 `int *b[10]`
 Using 20-element arrays
 200 ints + 10 pointers
- Advantage is rows may have different lengths

```
char *name[] = { "Illegal month", "Jan", "Feb", "Mar" };
```

name:



1.7 Functions

- Subroutine, procedure
- Encapsulate some computation
 - Ignore how is done
 - know what is done
- printf, getchar
- C has no power operator
 - Function power()
 - print 2^i and $(-3)^i$
 - Not practical
 - Only positive powers, small integers
- $\text{power}(x, y) \rightarrow x^y$
- Arguments, variable copy, local

```
#include <stdio.h>

int power(int base, int n);

int main() {
    int i;

    for (i=0; i<=10; i++)
        printf("2^%d = %d\n", i, power(2,i));
    // printf("%d %d %d\n", i, power(2,i), power(-3, i));
    return 0;
}

int power(int base, int n) {
    int i, pow;

    pow = 1;
    for (i = 1; i<= n; ++i) {
        pow = pow * base;
    }

    return pow;
}
```

1.7 Functions

- Subroutine, procedure
- Encapsulate some computation
 - Ignore how is done
 - know what is done
- `printf`, `getchar`
- C has no power operator
 - Function `power()`
 - print 2^i and $(-3)^i$
 - Not practical
 - Only positive powers, small integers
- `power(x, y) -> x^y`
- Arguments, variable copy, local

```
vinicius@laptop:book-examples$ gcc 1.7functions.c
vinicius@laptop:book-examples$ ./a.out
2^0 = 1
2^1 = 2
2^2 = 4
2^3 = 8
2^4 = 16
2^5 = 32
2^6 = 64
2^7 = 128
2^8 = 256
2^9 = 512
2^10 = 1024
```