NATIONAL RESEARCH UNIVERSITY

Computer Architecture and Operating Systems
Lecture 2: The C Programming Language

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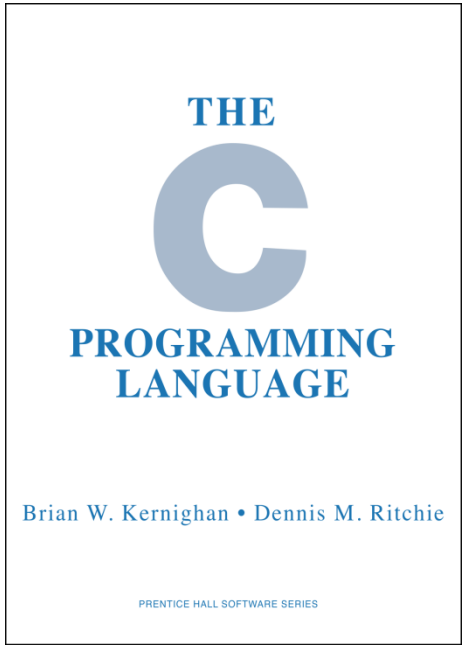
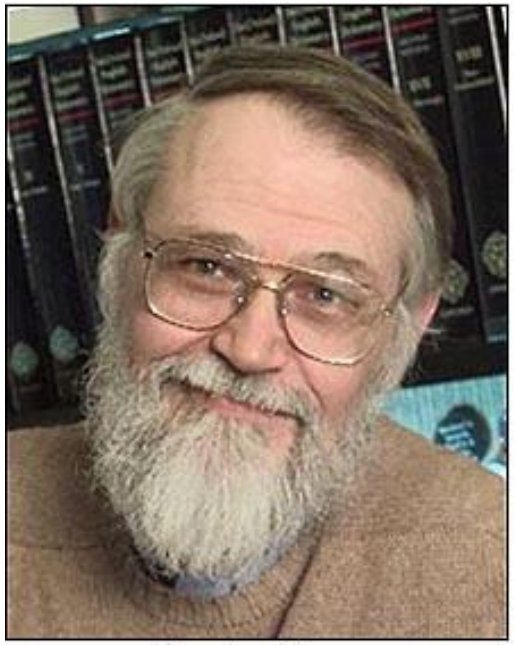
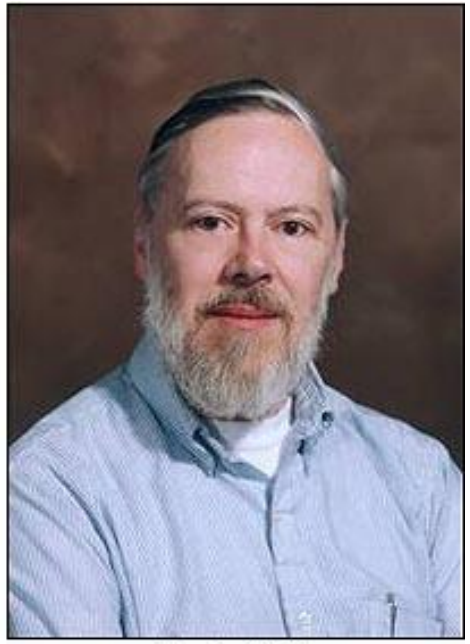
The C Programming Language

- 1972-1973: Developed at Bell Labs by Dennis Ritchie to create utilities for Unix
- 1973: Unix was re-implemented in C
- 1978: Brian Kernighan and Dennis Ritchie published The C Programming Language
- 1989/1990: ANSI C and ISO C; 1999: C99; 2011: C11; 2017: C17




Brian Kernighan


Dennis Ritchie

The Application of C Language

- C is not a “very high level” language, nor a “big” one, and is not specialized to any particular area of application. But its absence of restrictions and its generality make it more convenient and effective for many tasks than supposedly more powerful languages.

Kernighan and Ritchie

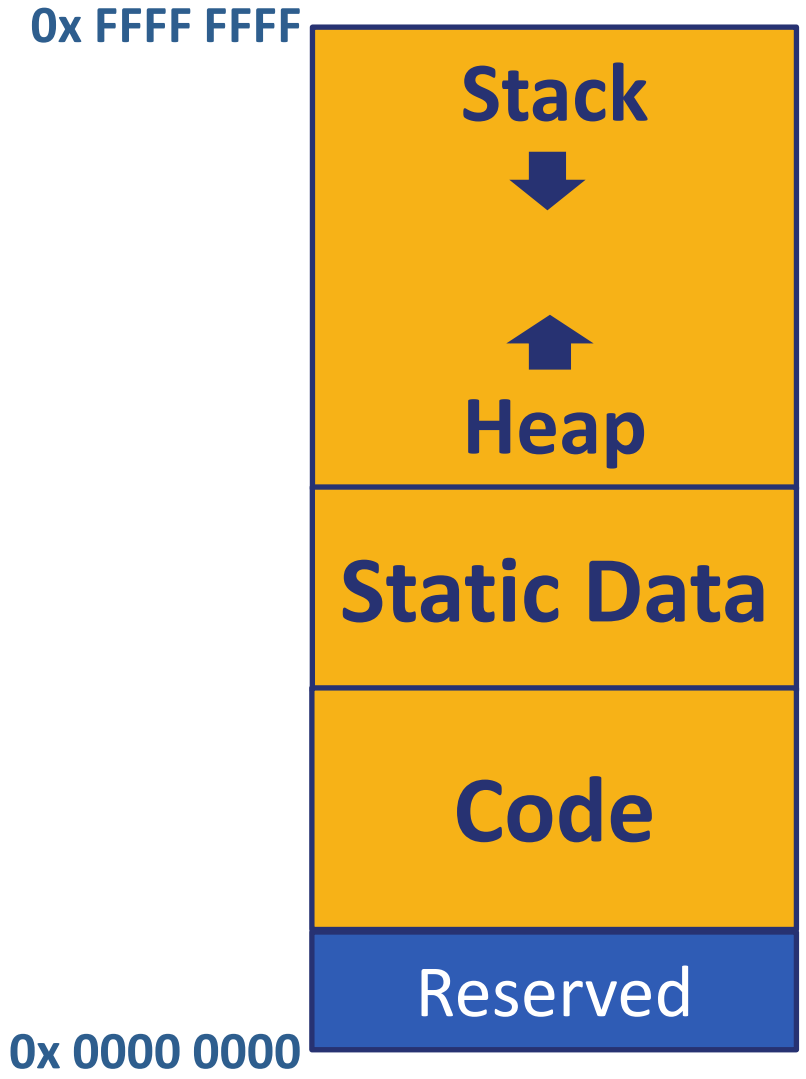
- With C we can write programs that allow us to exploit underlying features of the architecture

C Concepts

Compiler	Creates usable programs from C source code
Typed variables	Must declare the kind of data the variable will contain
Typed functions	Must declare the kind of data returned from the function
Header files (.h)	Allows declaring functions and variables in separate files
Structs	Groups of related values
Enums	Lists of predefined values
Pointers	Aliases to other variables

C Memory Layout

- Program's **address space** contains 4 regions:
  - **Stack**: local variables, grows downward
  - **Heap**: space requested via *malloc*() and used with pointers; resizes dynamically, grows upward
  - **Static Data**: global and static variables, does not grow or shrink
  - **Code**: loaded when program starts, does not change



OS prevents accesses between stack and heap (via virtual memory)

Where Do the Variables Go?

- Declared outside a function:
  - **Static Data**
- Declared inside a function:
  - **Stack**
    - main() is a function
    - freed when the function returns
- Dynamically allocated:
  - **Heap**
    - i.e. malloc (will be covered shortly)

```
#include <stdio.h>

int varGlobal;

int main() {
  int varLocal;
  int *varDyn =
    malloc(sizeof(int));
}
```

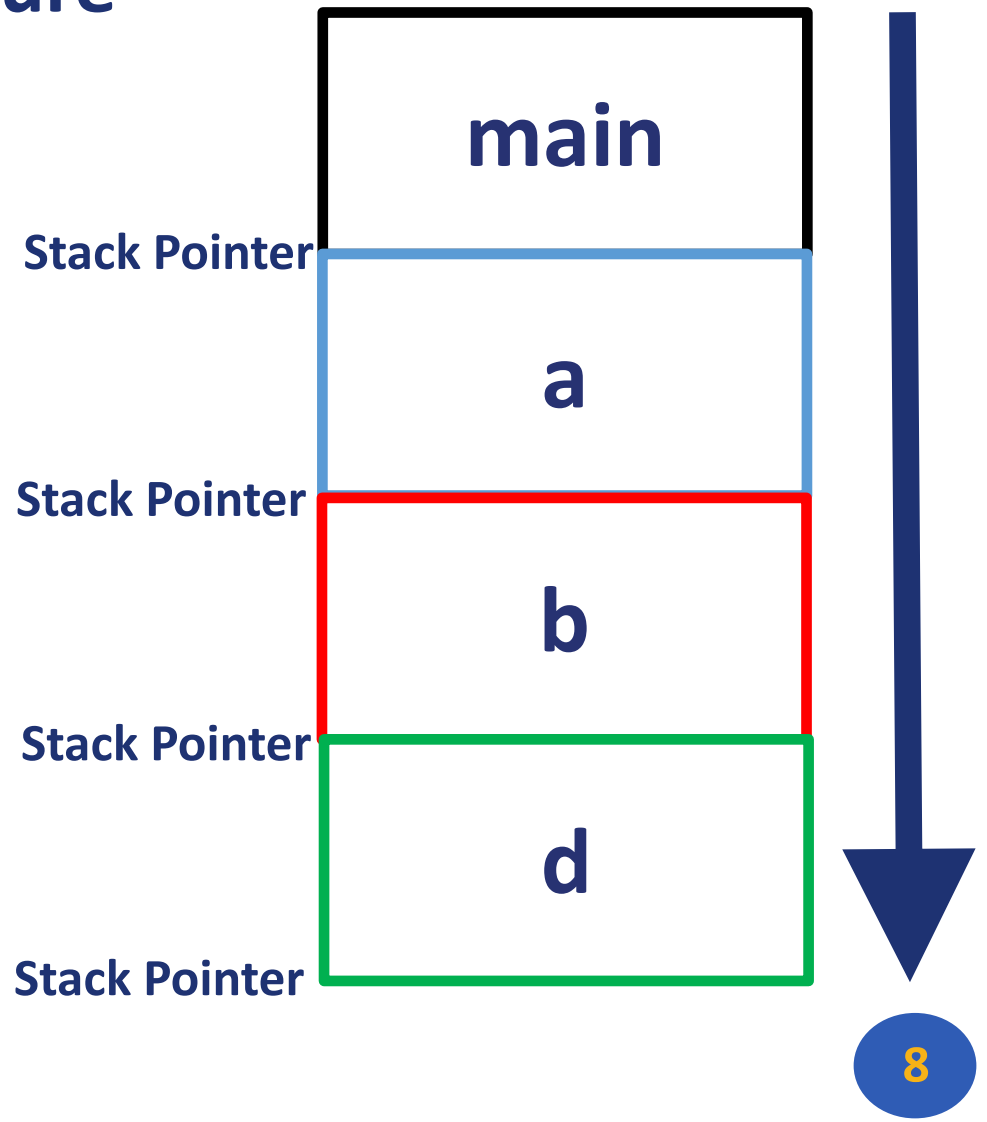
Stack

- Each stack frame is a contiguous block of memory holding the local variables of a single function
- A stack frame includes:
  - Location of caller function
  - Function arguments
  - Space for local variables
- Stack pointer (SP) tells where lowest (current) stack frame is
- When function ends, stack pointer is moved back (but data remains (garbage!)); frees memory for future stack frames

Stack

Last In, First Out (LIFO) data structure

```
int main() {
    a(0);
    return 1;
}
void a(int m) {
    b(1);
}
void b(int n) {
    c(2);
    d(4);
}
void c(int o) {
    printf("c");
}
void d(int p) {
    printf("d");
}
```



Stack Misuse

```
int *getPtr() {
    int y;
    y = 3;
    return &y;
}

int main () {
    int *stackAddr, content;
    stackAddr = getPtr();
    content = *stackAddr;
    printf("%d", content); /* 3 */
    content = *stackAddr;
    printf("%d", content); /* ? */
}
```

Never return pointers to local variable from functions!

Your compiler will warn you about this.

Do not ignore such warnings!

printf overwrites stack frames.

Any Questions?

```
            .text
__start:    addi t1, zero, 0x18
            addi t2, zero, 0x21
cycle:      beq t1, t2, done
            slt t0, t1, t2
            bne t0, zero, if_less
            nop
            sub t1, t1, t2
            j cycle
            nop
if_less:    sub t2, t2, t1
            j cycle
done:       add t3, t1, zero
```