C
Come let's see how deep it is!!
- Strorage Classes

Team Emertxe

Advanced C

Memory Segments

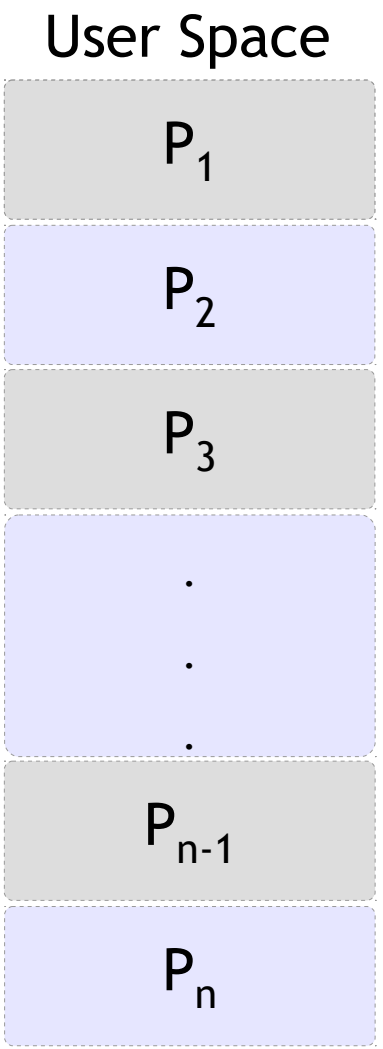
The Linux OS is divided into two major sections
- User Space
- Kernel Space

The user programs cannot access the kernel space. If done will lead to segmentation violation

Let us concentrate on the user space section here

Advanced C

Memory Segments



The User space contains many processes

Every process will be scheduled by the kernel

Each process will have its memory layout discussed in next slide

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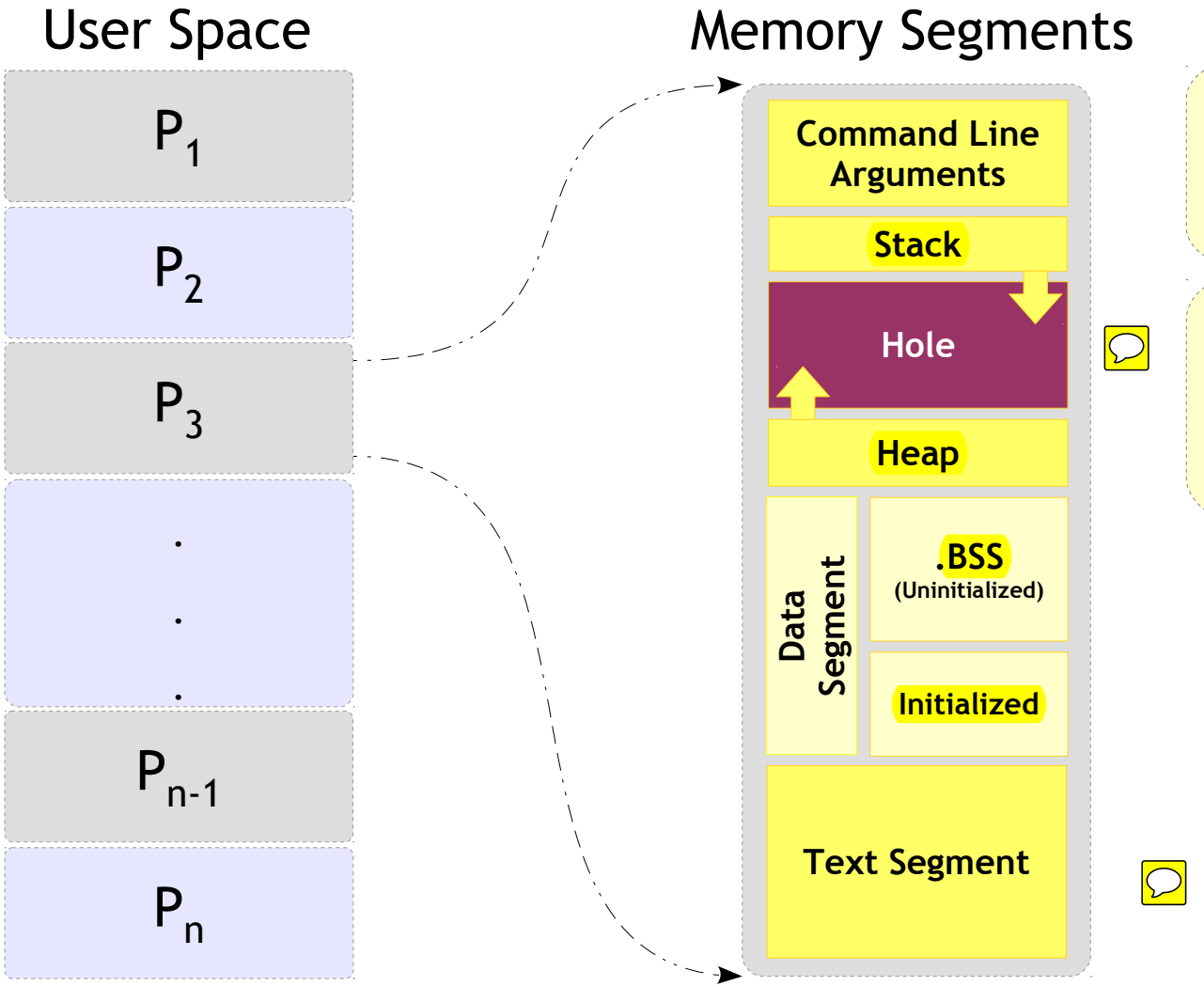
Memory Segments



The memory segment of a program contains four major areas.

- Text Segment
- Stack
- Data Segment
- Heap

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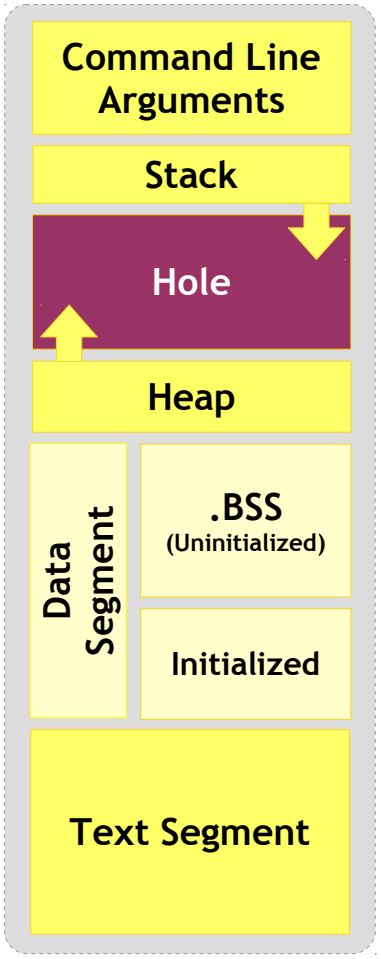
Memory Segments - Text Segment

Memory Segments



- Also referred as Code Segment
- Holds one of the section of program in object file or memory
- In memory, this is place below the heap or stack to prevent getting over written
- Is a read only section and size is fixed

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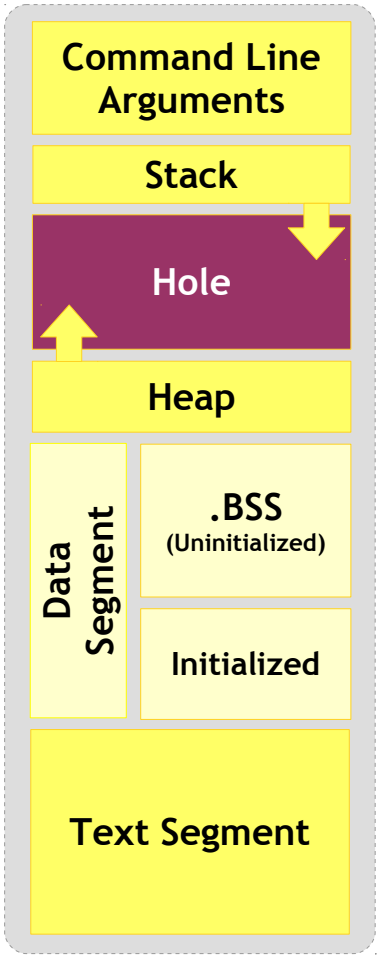
Memory Segments - Data Segment

Memory Segments



- Contains 2 sections as initialized and uninitialized data segments
- Initialized section is generally called as Data Segment
- Uninitialized section is referred as BSS (Block Started by Symbol) usually filled with 0s

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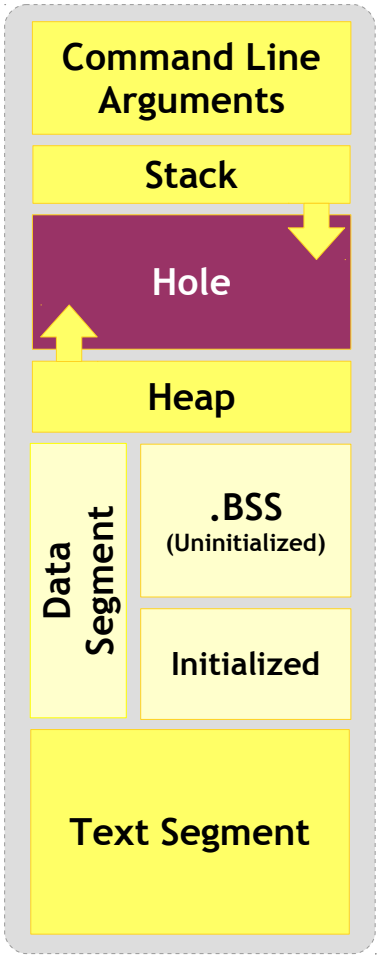
Memory Segments - Data Segment

Memory Segments



Dynamic memory allocation takes place here

Begins at the end of BSS and grows upward from there

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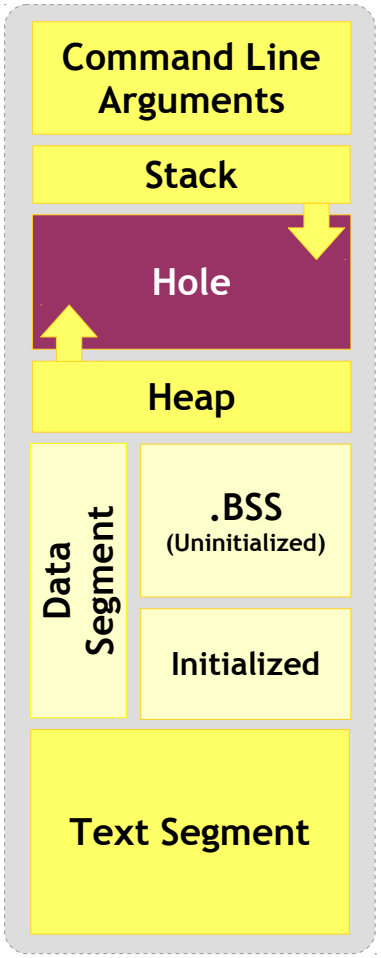
Memory Segments - Stack Segment

Memory Segments



- Adjoins the heap area and grow in opposite area of heap when stack and heap pointer meet (Memory Exhausted)
- Typically loaded at the higher part of memory
- A “stack pointer” register tracks the top of the stack; it is adjusted each time a value is “pushed” onto the stack
- The set of values pushed for one function call is termed a “stack frame”

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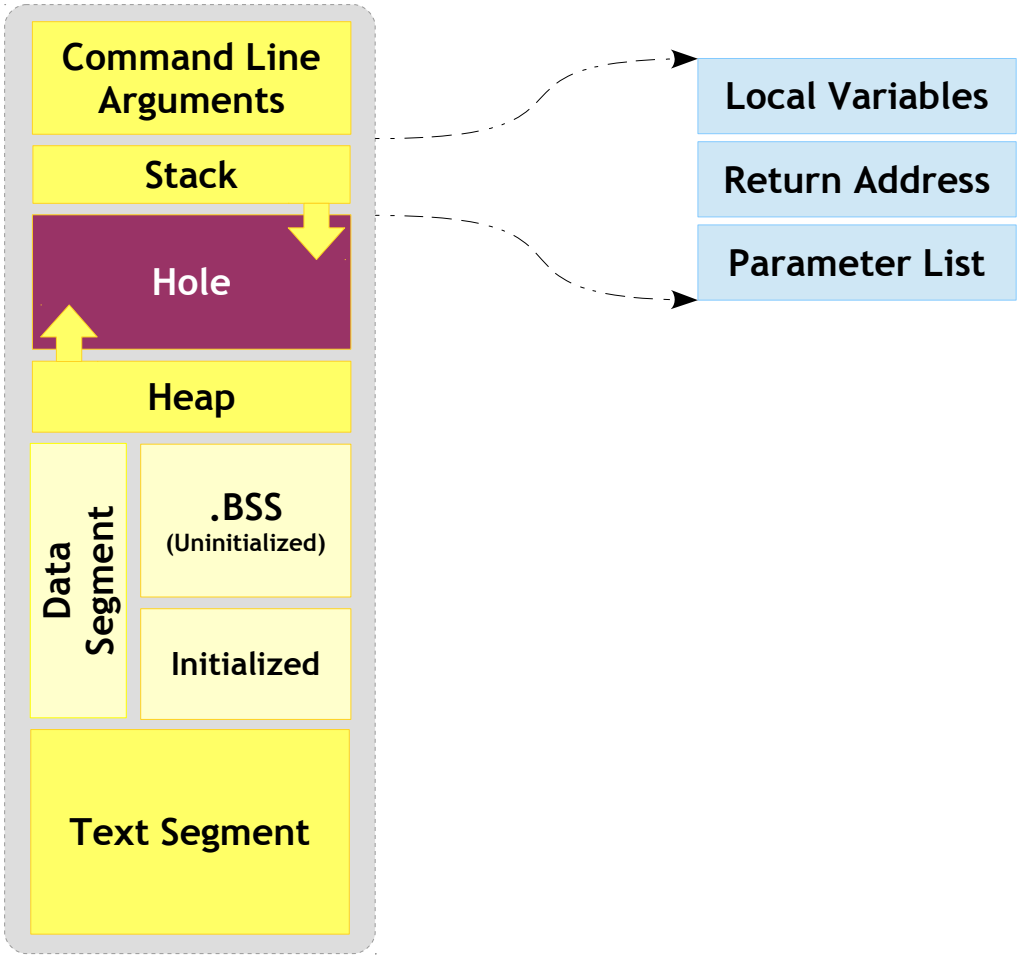
Memory Segments - Stack Segment

Memory Segments



Stack Frame

A stack frame contain at least of a return address

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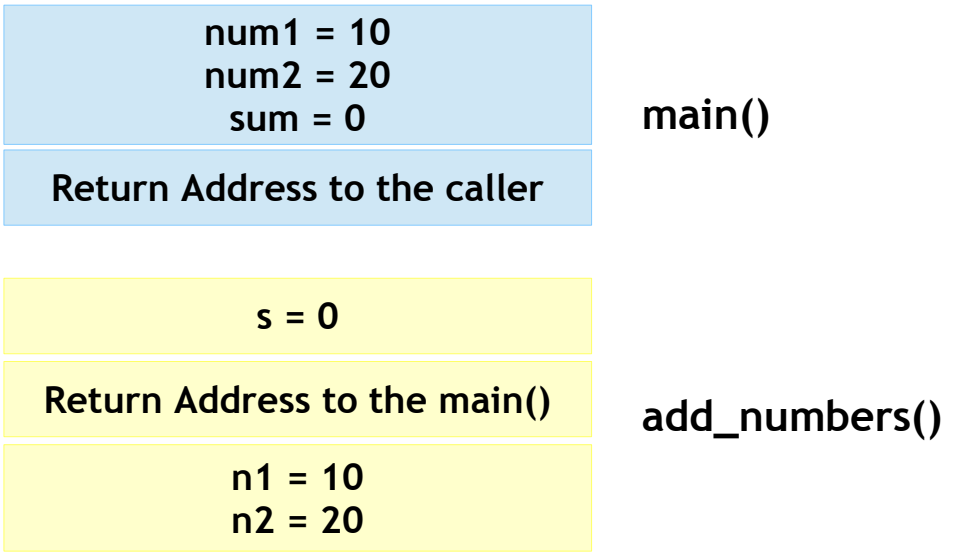
Memory Segments - Stack Frame

```c
#include <stdio.h>

int main()
{
    int num1 = 10, num2 = 20;
    int sum = 0;

    sum = add_numbers(num1, num2);
    printf("Sum is %d\n", sum);

    return 0;
}
```

```c
int add_numbers(int n1, int n2)
{
    int s = 0;

    s = n1 + n2;

    return s;
}
```

Stack Frame



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Memory Segments - Runtime

- Text Segment: The text segment contains the actual code to be executed. It's usually sharable, so multiple instances of a program can share the text segment to lower memory requirements. This segment is usually marked read-only so a program can't modify its own instructions
- Initialized Data Segment: This segment contains global variables which are initialized by the programmer
- Uninitialized Data Segment: Also named “BSS" (block started by symbol) which was an operator used by an old assembler. This segment contains uninitialized global variables. All variables in this segment are initialized to 0 or NULL (for pointers) before the program begins to execute

Advanced C

Memory Segments - Runtime

- The Stack: The stack is a collection of stack frames. When a new frame needs to be added (as a result of a newly called function), the stack grows downward
- The Heap: Most dynamic memory, whether requested via C's malloc() . The C library also gets dynamic memory for its own personal workspace from the heap as well. As more memory is requested "on the fly", the heap grows upward

Advanced C

Storage Classes

Variable	Storage Class	Scope	Lifetime	Memory Allocation	Linkage
Local	auto	Block	B/W block entry and exit	Stack	None
	register	Block	B/W block entry and exit	Register / Stack	None
	static	Block	B/W program start & end	Data Segment	None
Global	static	File	B/W program start & end	Data segment	Internal
	extern	Program	B/W program start & end	Data segment	Internal / External
Function Parameter	register	Function	Function entry and exit	Stack	None

***Block : function body or smaller block with in function**

Advanced C

Declaration

```
extern int num1;
extern int num1;

int main();

int main()
{
    int num1, num2;
    char short_opt;

    ...
}
```

Declaration specifies type to the variables

Its like an announcement and hence can be made 1 or more times

Declaration about num1

Declaration about num1 yet again!!

Declaration about main function

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Advanced C

Declaration

```
extern int num1;
extern int num1;

int main();

int main()
{
    int num1, num2;
    char short_opt;

    ...
}
```

Declaration specifies type to the variables

Its like an announcement and hence can be made 1 or more times

Declaration about num1

Declaration about num1 yet again!!

Declaration about main function

***** One Definition Rule for variables *****
“In a given scope, there can be only one definition of a variable”

Advanced C

Storage Classes - Auto

001_example.c

```c
#include <stdio.h>

int main()
{
    int i = 0;

    printf("i %d\n", i);

    return 0;
}
```

Advanced C

Storage Classes - Auto

002_example.c

```c
#include <stdio.h>

int foo()
{
    int i = 0;

    printf("i %d\n", i);

    return 0;
}

int main()
{
    foo();

    return 0;
}
```

Advanced C

Storage Classes - Auto

003_example.c

```c
#include <stdio.h>

int *foo()
{
    int i = 10;
    int *j = &i;

    return j;
}

int main()
{
    int *i;

    i = foo();
    printf("*i %d\n", *i);

    return 0;
}
```

Advanced C

Storage Classes - Auto

004_example.c

```c
#include <stdio.h>

char *foo()
{
    char ca[12] = "Hello World";

    return ca;
}

int main()
{
    char *ca;

    ca = foo();
    printf("ca is %s\n", ca);

    return 0;
}
```

Advanced C

Storage Classes - Auto

005_example.c

```c
#include <stdio.h>

int book_ticket()
{
    int ticket_sold = 0;

    ticket_sold++;

    return ticket_sold;
}

int main()
{
    int count;

    count = book_ticket();
    count = book_ticket();

    printf("Sold %d\n", count);

    return 0;
}
```

Advanced C

Storage Classes - Auto

006_example.c

```c
#include <stdio.h>

int main()
{
    int i = 0;

    {
        int j = 0;

        printf("i %d\n", i);
    }

    printf("j %d\n", j);

    return 0;
}
```

Advanced C

Storage Classes - Auto

007_example.c

```c
#include <stdio.h>

int main()
{
    int j = 10;

    {
        int j = 0;

        printf("j %d\n", j);
    }

    printf("j %d\n", j);

    return 0;
}
```

Advanced C

Storage Classes - Auto

008_example.c

```c
#include <stdio.h>

int main()
{
    int i = 10;
    int i = 20;

    {
        printf("i %d\n", i);
    }

    printf("i %d\n", i);

    return 0;
}
```

Advanced C

Storage Classes - Register

009_example.c

```c
#include <stdio.h>

int main()
{
    register int i = 0;

    scanf("%d", &i);
    printf("i %d\n", i);

    return 0;
}
```

Advanced C

Storage Classes - Register

010_example.c

```c
#include <stdio.h>

int main()
{
    register int i = 10;
    register int *j = &i;

    printf("*j %d\n", *j);

    return 0;
}
```

Advanced C

Storage Classes - Register

011_example.c

```c
#include <stdio.h>

int main()
{
    int i = 10;
    register int *j = &i;

    printf("*j %d\n", *j);

    return 0;
}
```

Advanced C

Storage Classes - Static Local

012_example.c

```c
#include <stdio.h>

int *foo()
{
    static int i = 10;
    int *j = &i;

    return j;
}

int main()
{
    int *i;

    i = foo();
    printf("*i %d\n", *i);

    return 0;
}
```

Advanced C

Storage Classes - Static Local

013_example.c

```
#include <stdio.h>

char *foo()
{
    static char ca[12] = "Hello World";

    return ca;
}

int main()
{
    char *ca;

    ca = foo();
    printf("ca is %s\n", ca);

    return 0;
}
```

Advanced C

Storage Classes - Static Local

014_example.c

```c
#include <stdio.h>

int book_ticket()
{
    static int ticket_sold = 0;

    ticket_sold++;

    return ticket_sold;
}

int main()
{
    int count;

    count = book_ticket();
    count = book_ticket();

    printf("Sold %d\n", count);

    return 0;
}
```

Advanced C

Storage Classes - Static Local

015_example.c

```c
#include <stdio.h>

int main()
{
    static int i = 5;

    if (--i)
    {
        main();
    }

    printf("i %d\n", i);

    return 0;
}
```

016_example.c

```c
#include <stdio.h>

int main()
{
    static int i = 5;

    if (--i)
    {
        return main();
    }

    printf("i %d\n", i);

    return 0;
}
```

Advanced C

Storage Classes - Static Local

017_example.c

```c
#include <stdio.h>

int foo()
{
    static int i;

    return i;
}

int main()
{
    static int x = foo();

    printf("x %d\n", x);

    return 0;
}
```

Advanced C

Storage Classes - Static Local

018_example.c

```c
#include <stdio.h>

int *foo()
{
    static int i = 10;
    int *j = &i;

    return j;
}

int main()
{
    int *i;

    i = foo();
    printf("*i %d\n", *i);

    return 0;
}
```

Advanced C

Storage Classes - Static Local

019_example.c

```c
#include <stdio.h>

int *foo()
{
    int i = 10;
    static int *j = &i;

    return j;
}

int main()
{
    int *i;

    i = foo();
    printf("*i %d\n", *i);

    return 0;
}
```

Advanced C

Storage Classes - Global

020_example.c

```c
#include <stdio.h>

int x;

int foo()
{
    printf("x %d\n", x);

    return ++x;
}

int main()
{
    foo();

    printf("x %d\n", x);

    return 0;
}
```

Advanced C

Storage Classes - Global

021_example.c

```c
#include <stdio.h>

auto int x;

int foo()
{
    printf("x %d\n", x);

    return ++x;
}

int main()
{
    foo();

    printf("x %d\n", x);

    return 0;
}
```

Advanced C

Storage Classes - Global

022_example.c

```c
#include <stdio.h>

register int x;

int foo()
{
    printf("x %d\n", x);

    return ++x;
}

int main()
{
    foo();

    printf("x %d\n", x);

    return 0;
}
```

Advanced C

Storage Classes - Global

023_example.c

```c
#include <stdio.h>

int x = 10;

int foo()
{
    printf("x %d\n", x);

    return 0;
}

int main()
{
    foo();

    return 0;
}
```

Advanced C

Storage Classes - Global

024_example.c

```c
#include <stdio.h>

int x = 10;
int x;

int foo()
{
    printf("x %d\n", x);

    return 0;
}

int main()
{
    foo();

    return 0;
}
```

- Will there be any compilation error?

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Advanced C

Storage Classes - Global

025_example.c

```c
#include <stdio.h>

int x = 10;
int x = 20;

int foo()
{
    printf("x %d\n", x);

    return 0;
}

int main()
{
    foo();

    return 0;
}
```

- Will there be any compilation error?

Advanced C

Storage Classes - Global

Example

```c
#include <stdio.h>

int x = 10;          // Definition
int x;               // Tentative definition
extern int x;        // not a definition either
extern int x = 20;   // Definition
static int x;        // Tentative definition
```

- Declaration Vs definition
  - All the above are declarations
  - Definitions as mentioned in the comment

Advanced C

Storage Classes - Global

- Complying with one definition rule
  - All the tentative definitions and extern declarations are eliminated and mapped to definition by linking method
  - If there exists only tentative definitions then all of them are eliminated except one tentative definition which is changed to definition by assigning zero to the variable

- **Compilation error if there are more then one definitions**
- **Compilation error if no definition or tentative definition exists**

Advanced C

Storage Classes – Global

- **Translation unit –** A source file + header file(s) forms a translation unit
- Compiler translates source code file written in ‘C’ language to machine language
- A program is constituted by the set of translation units and libraries
- An identifier may be declared in a scope but used in different scopes (within a translation unit or in other translation units or libraries)
- **Linkage –** An identifier declared in different scopes or in the same scope more than once can be made to refer to the same object or function by a process called linkage
- There are three type of linkages – **internal, external and none**

Advanced C

Storage Classes - Global

- **External Linkage** - A global variable declared without storage class has "external" linkage
- **Internal Linkage** - A global variable declared with static storage class has "internal" linkage
- **None Linkage** - Local variables have "none" linkage
- Variable declaration with "extern" - in such case, linkage to be determined by referring to **"previous visible declaration"**
  - If there is no "previous visible declaration" then external linkage
  - If "previous visible declaration" is local variable then external linkage
  - If "previous visible declaration" is global variable then linkage is same as of global variable

"Compilation error if there is linkage disagreement among definition and tentative definitions"

Advanced C

Storage Classes - Static Global

026_example.c

```c
#include <stdio.h>

static int x = 10;

int foo()
{
    printf("x %d\n", x);

    return 0;
}

int main()
{
    foo();

    return 0;
}
```

Advanced C

Storage Classes - Static Global

027_example.c

```c
#include <stdio.h>

static int x = 10;
int x;

int foo()
{
    printf("x %d\n", x);

    return 0;
}

int main()
{
    foo();

    return 0;
}
```

Advanced C

Storage Classes - External

028_file1.c

```c
#include <stdio.h>

int num;

int main()
{
    while (1)
    {
        num++;
        func_1();
        sleep(1);
        func_2();
        sleep(1);
    }

    return 0;
}
```

029_file2.c

```c
#include <stdio.h>

extern int num;

int func_1()
{
    printf("num is %d from file2\n", num);

    return 0;
}
```

030_file3.c

```c
#include <stdio.h>

extern int num;

int func_2()
{
    printf("num is %d from file3\n", num);

    return 0;
}
```

Advanced C

Storage Classes - External

031_file1.c

```c
#include <stdio.h>

int num;

int main()
{
    while (1)
    {
        num++;
        func_1();
        sleep(1);
    }

    return 0;
}
```

032_file2.c

```c
#include <stdio.h>

extern int num;
extern int num;

int func_1()
{
    printf("num is %d from file2\n", num);

    return 0;
}
```

Advanced C

Storage Classes - External

033_file1.c

```c
#include <stdio.h>

int num;

int main()
{
    while (1)
    {
        num++;
        func_1();
        sleep(1);
    }

    return 0;
}
```

034_file2.c

```c
#include <stdio.h>

static int num;
extern int num;

int func_1()
{
    printf("num is %d from file2\n", num);

    return 0;
}
```

Advanced C

Storage Classes - External

035_file1.c

```c
#include <stdio.h>

int num;

int main()
{
    while (1)
    {
        num++;
        func_1();
        sleep(1);
    }

    return 0;
}
```

036_file2.c

```c
#include <stdio.h>

extern char num;

int func_1()
{
    printf("num is %d from file2\n", num);

    return 0;
}
```

Advanced C

Storage Classes - External

037_file1.c

```c
#include <stdio.h>

int num;

int main()
{
    while (1)
    {
        num++;
        func_1();
        sleep(1);
    }

    return 0;
}
```

038_file2.c

```c
#include <stdio.h>

extern int num;
extern char num;

int func_1()
{
    printf("num is %d from file2\n", num);

    return 0;
}
```

Conflicting types

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Advanced C

Storage Classes - External

039_example.c

```c
#include <stdio.h>

int main()
{
    int x;

    {
        int x = 10;
        {
            extern int x;
            printf("x %d\n", x);
        }
        printf("x %d\n", x);
    }
    printf("x %d\n", x);

    return 0;
}

int x = 20;
```

Advanced C

Storage Classes - External

040_example.c

```c
#include <stdio.h>

int main()
{
    extern char x;

    printf("x %c\n", x);

    return 0;
}

int x = 0x31;
```

Advanced C

Storage Classes - External

041_example.c

```c
#include <stdio.h>

int main()
{
    int x;

    {
        int x = 10;
        {
            extern int x = 20;
            printf("x %d\n", x);
        }
        printf("x %d\n", x);
    }
    printf("x %d\n", x);

    return 0;
}

int x;
```

Invalid, extern and initializer not permitted in block scope

Advanced C

Storage Classes - Static Function

042_file1.c

```c
#include <stdio.h>

int num;

int main()
{
    while (1)
    {
        num++;
        func_1();
    }

    return 0;
}
```

043_file2.c

```c
#include <stdio.h>

extern int num;

static int func_2()
{
    printf("num is %d from file2\n", num);

    return 0;
}

int func_1()
{
    func_2();
}
```

Advanced C

Storage Classes - Static Function

044_file1.c

```c
#include <stdio.h>

int num;

int main()
{
    while (1)
    {
        num++;
        func_2();
    }

    return 0;
}
```

045_file2.c

```c
#include <stdio.h>

extern int num;

static int func_2()
{
    printf("num is %d from file2\n", num);

    return 0;
}

int func_1()
{
    func_2();
}
```

Extra Examples

Advanced C

Storage Classes - External

file1.c

```c
#include <stdio.h>

int num;

int main()
{
    while (1)
    {
        num++;
        func_1();
        sleep(1);
    }

    return 0;
}
```

file2.c

```c
#include <stdio.h>

extern int num;
static int num;

int func_1()
{
    printf("num is %d from file2\n", num);

    return 0;
}
```

- Compiler error due to linkage disagreement

Advanced C

Storage Classes - External

file1.c

```c
#include <stdio.h>

int num;

int main()
{
    while (1)
    {
        num++;
        func_1();
        sleep(1);
    }

    return 0;
}
```

file2.c

```c
#include <stdio.h>

int num;
static int num;

int func_1()
{
    printf("num is %d from file2\n", num);

    return 0;
}
```

- Compiler error due to linkage disagreement

Advanced C

Storage Classes - External

file1.c

```c
#include <stdio.h>

int num;

int main()
{
    while (1)
    {
        num++;
        func_1();
        sleep(1);
    }

    return 0;
}
```

file2.c

```c
#include <stdio.h>

static int num;
int num;

int func_1()
{
    printf("num is %d from file2\n", num);

    return 0;
}
```

- Compiler error due to linkage disagreement

Advanced C

Storage Classes - External

Example

```c
#include <stdio.h>

int main()
{
    int x;

    {
        int x = 10;
        {
            extern int x;
            printf("x %d\n", x);
        }
        printf("x %d\n", x);
    }
    printf("x %d\n", x);

    return 0;
}

static int x = 20;
```

- Compiler error due to linkage disagreement

Advanced C

Storage Classes - External

Example

```c
#include <stdio.h>

static int x = 20;

int main()
{
    int x;

    {
        int x = 10;
        {
            extern int x;
            printf("x %d\n", x);
        }
        printf("x %d\n", x);
    }
    printf("x %d\n", x);

    return 0;
}
```

- Compiler error due to linkage disagreement

Advanced C

Storage Classes - External

Example

```c
#include <stdio.h>

int x = 20;

int main()
{
    int x;

    {
        int x = 10;
        {
            extern int x;
            printf("x %d\n", x);
        }
        printf("x %d\n", x);
    }
    printf("x %d\n", x);

    return 0;
}
```

- Should be a fine since the compiler refers the same variable **x** and prints 20