GO CLASSES

Memory Layout of a program

Storage classes in C language

auto
register
static
extern

Memory Layout of a program


hello.c
hello.out
load it into MM
till Compilation
MM

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printf ("%u", &a)

logical address

Compiler assume that whole memory is available to just one program.

← Virtual memory

Contigious

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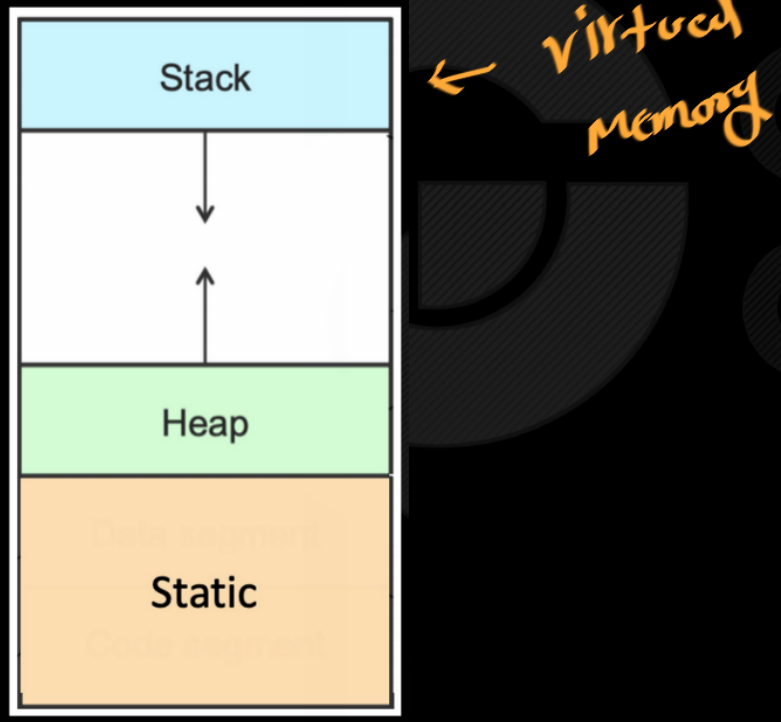
Memory Layout of a program



virtual memory

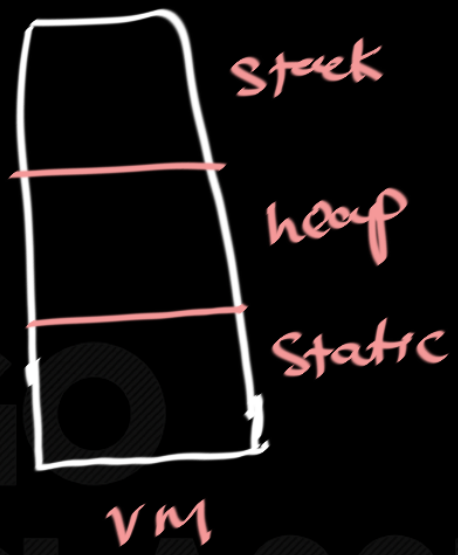
instructions

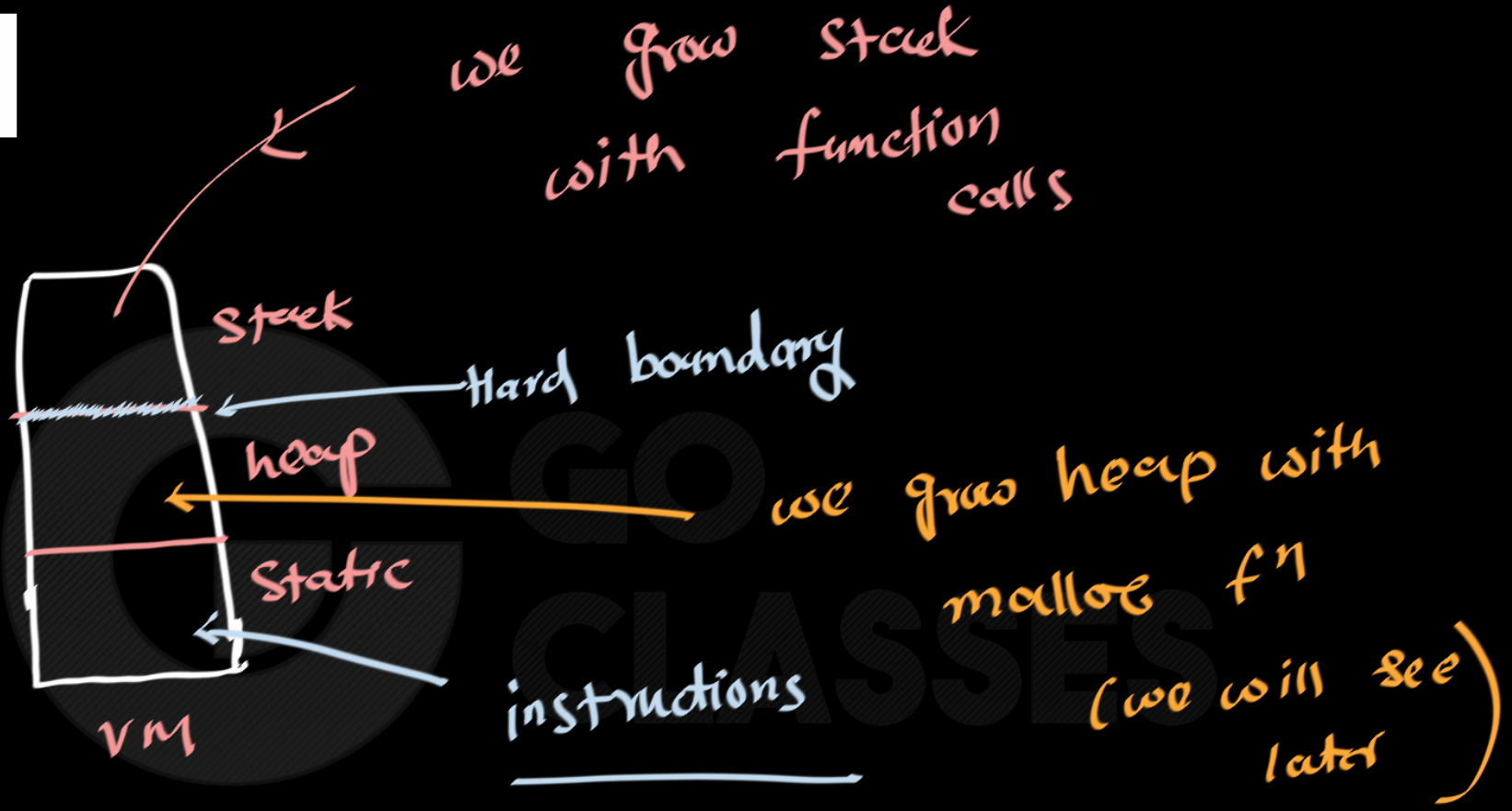
hello.out

Stack

heap

Static ~ to Store Code (instructions)




we grow stack with function calls
stack
Hard boundary
heap
we grow heap with malloc fn (we will see later)
static
instructions
VM

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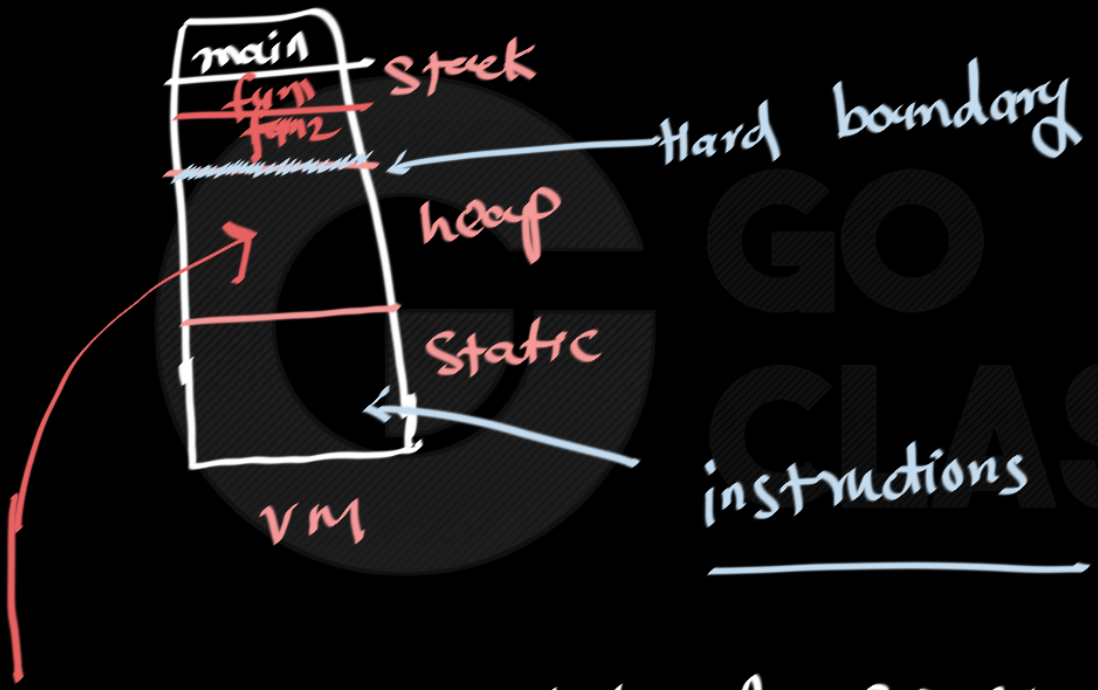
Design choice



there is a lot of space in heap, still you can not call any more function

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Design choice

fix boundary design choice is not a good idea

```
main( )
{
  fun1( );
  fun2( );
  fun3( );
}
```

Stack is full, and heap is empty

Still you can not call fun3( );

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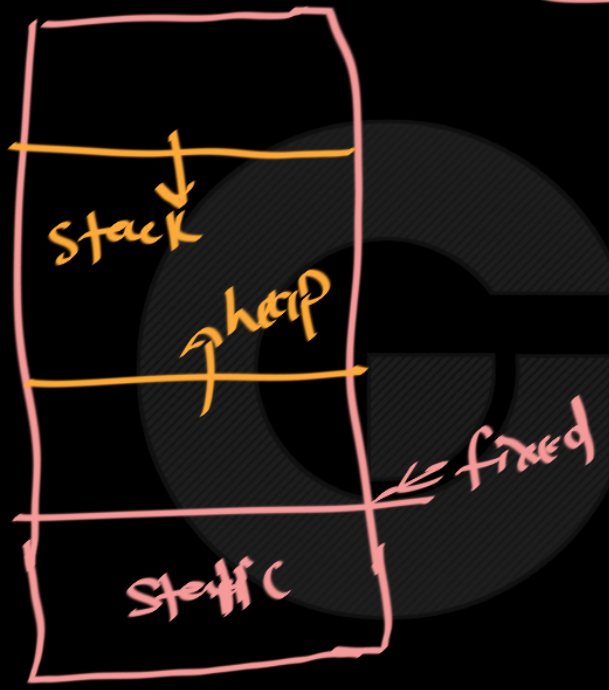
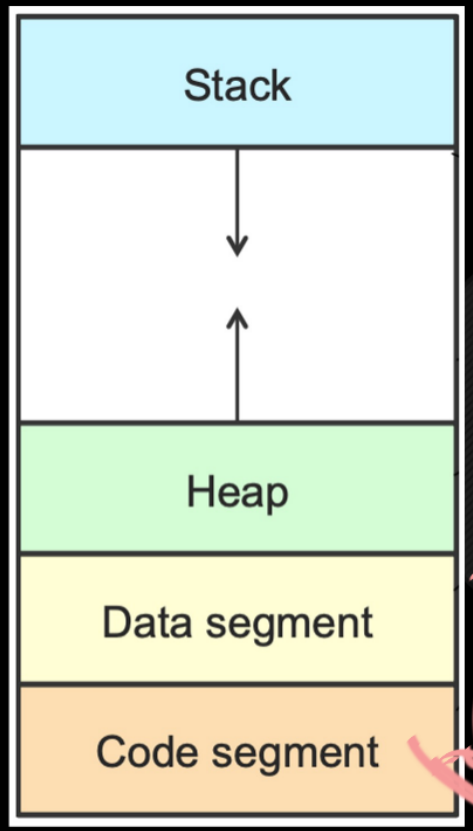
Design Choice ?



C proj (PS

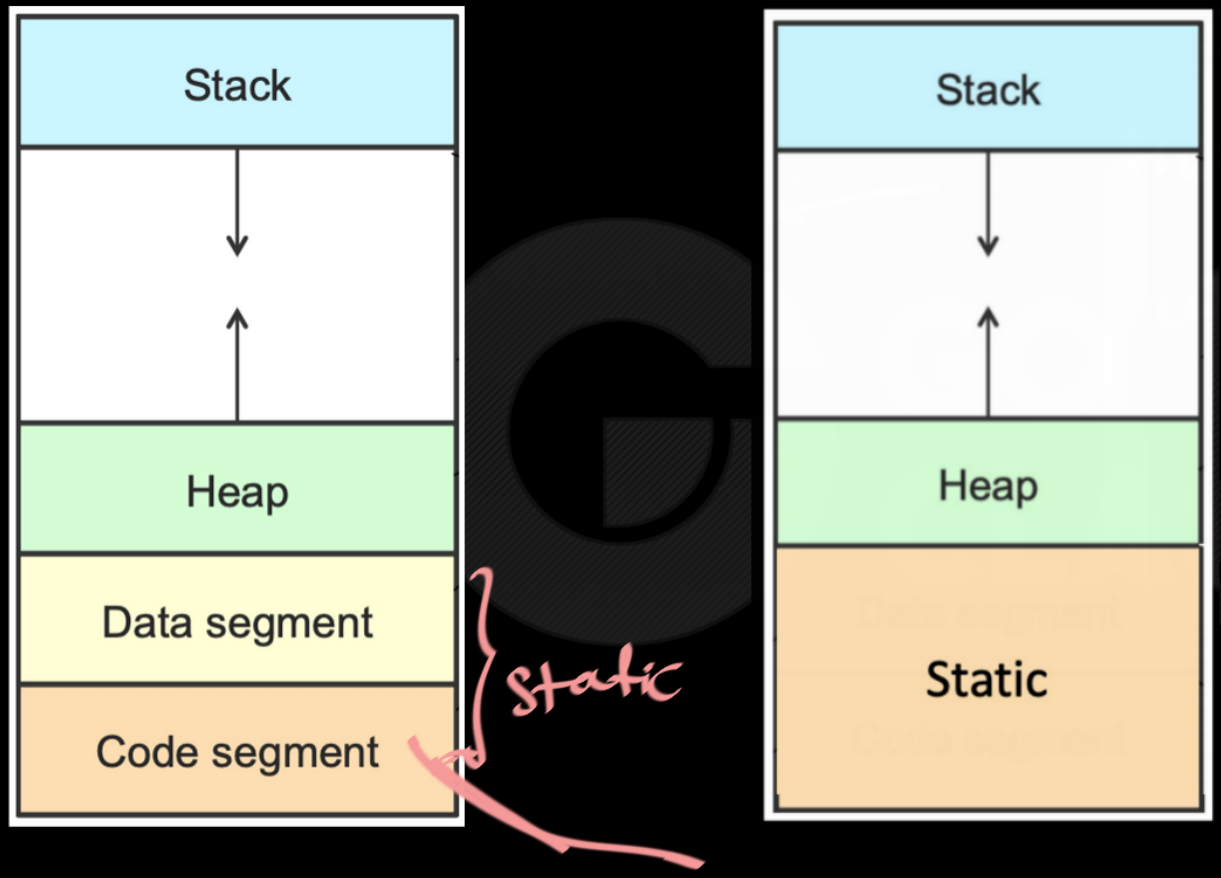
50 50

30 pages 60 pages



this is when Program (hello.out) will fit in.

static


Stack
Heap
Data segment
Code segment
Static
Stack
Heap
Static

- **The Stack -** This is where local variables and Function Activation records are stored. Size changes at runtime.

- **The Heap -** This is where dynamically allocated data is stored. Size changes at runtime.

↳ malloc ( )

- **The Static area -** This is where statically declared data (static and global variables) and code is stored. Size fixed at runtime

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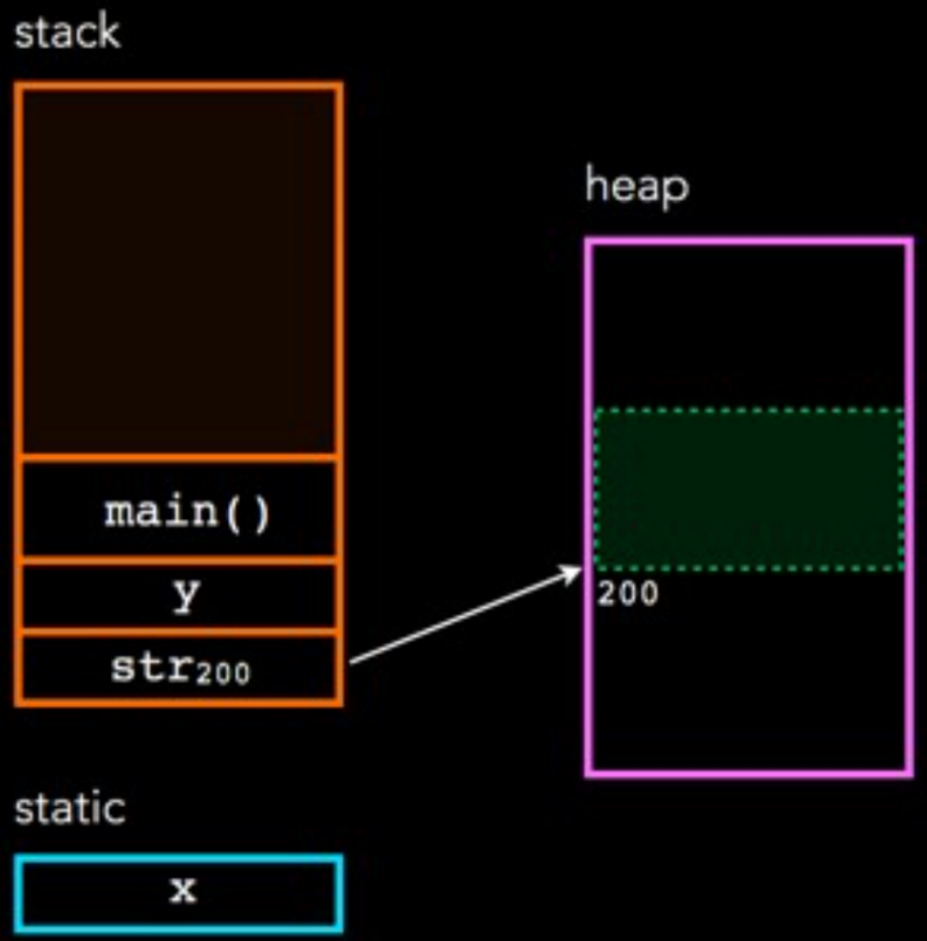
From Now on, Just know

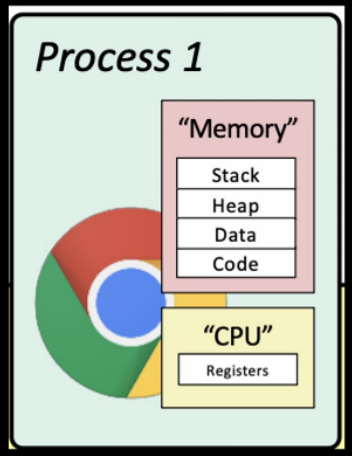
- there is some stack
- there is some heap.
- there is some static area.

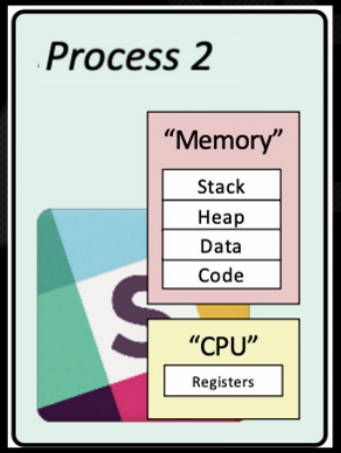
Enough for C prg. Course

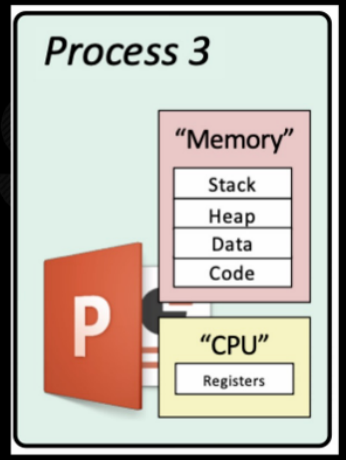
```c
#include <stdio.h>


int x;
int main(void)
{
    int y;
    char *str

    y = 4;
    printf("stack memory: %d\n", y);

    str = malloc(100*sizeof(char));
    str[0] = 'm';
    printf("heap memory: %c", str[0]);
    free(str);
    return 0;

}
```



It's an illusion!







GO CLASSES

Virtual memory is one of the great ideas in computer systems. A major reason for its success is that it works silently and automatically, without any intervention from the application programmer.

Computer Systems: A Programmer's Perspective.

```
int a = 5;
```

Storage classes in C language

auto
register
static
extern

auto
register
static
extern

} local variables

} for both global and local variables

auto Storage Class

- Storage – Stack
- Initial Value – Garbage
- Scope – within block
- Life Time – end of block

auto int a;

{ auto int a; }

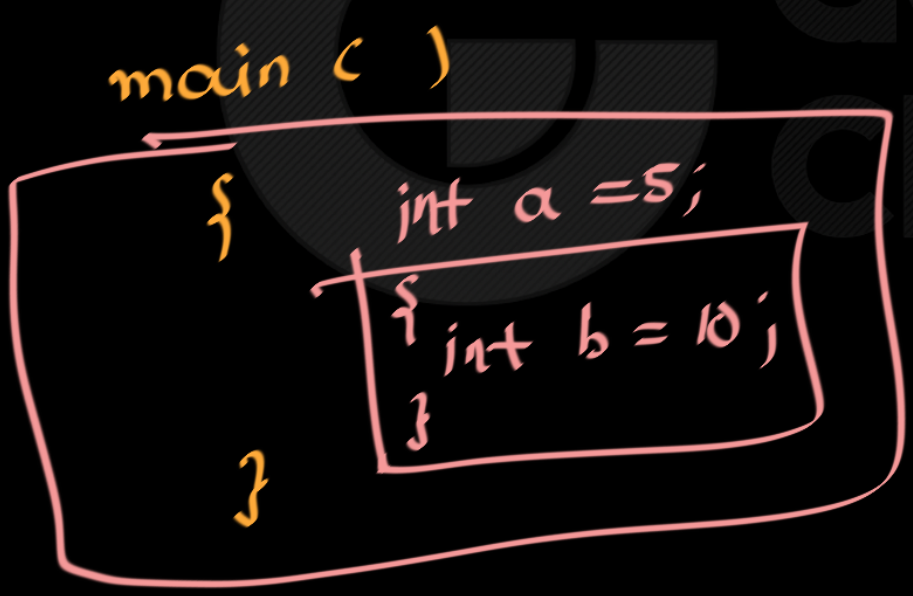
→ no scope (You can't access)
→ no lifetime (Not in memory)

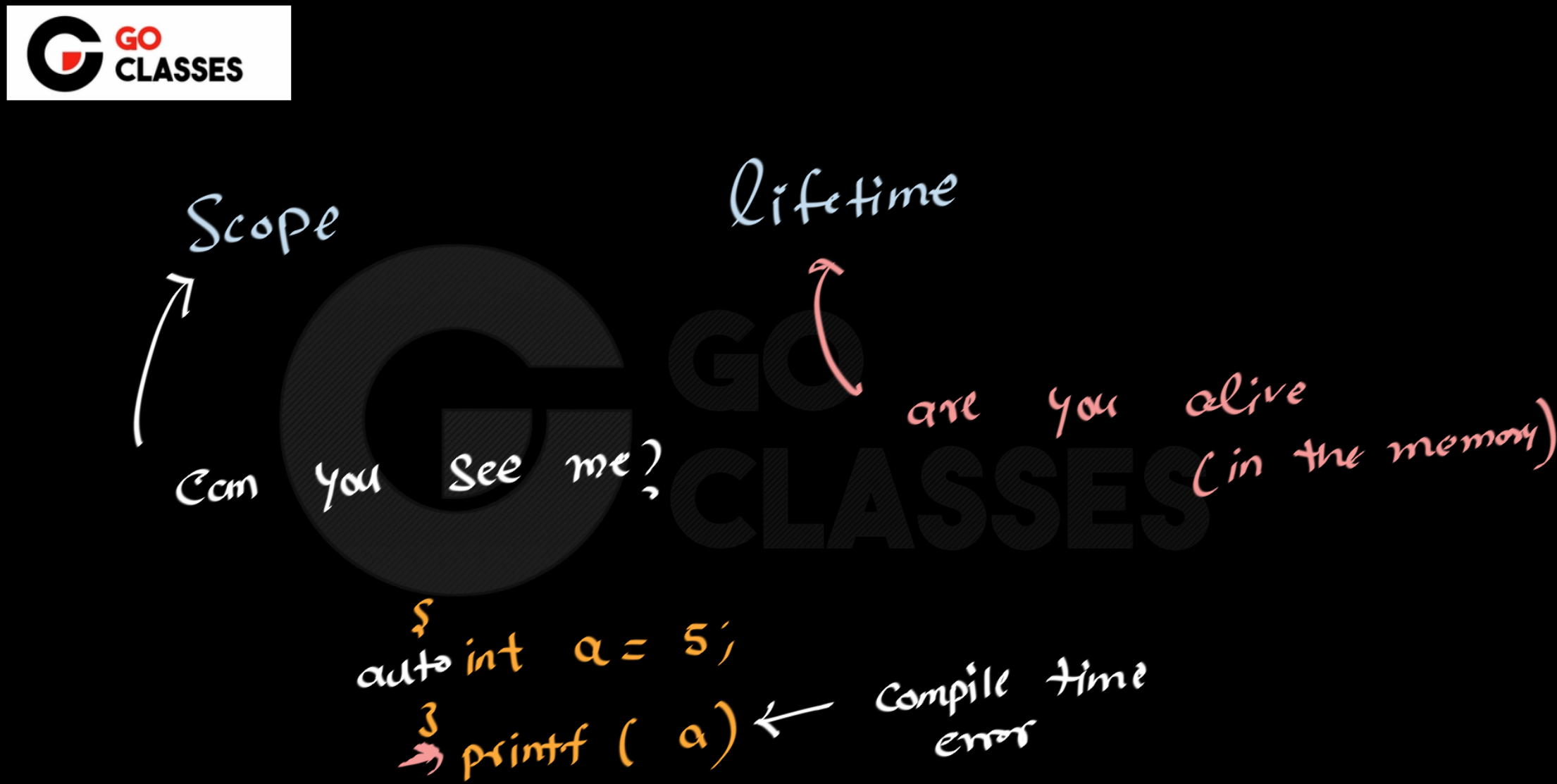
- ONLY used for local variables

GO CLASSES

Scope

lifetime



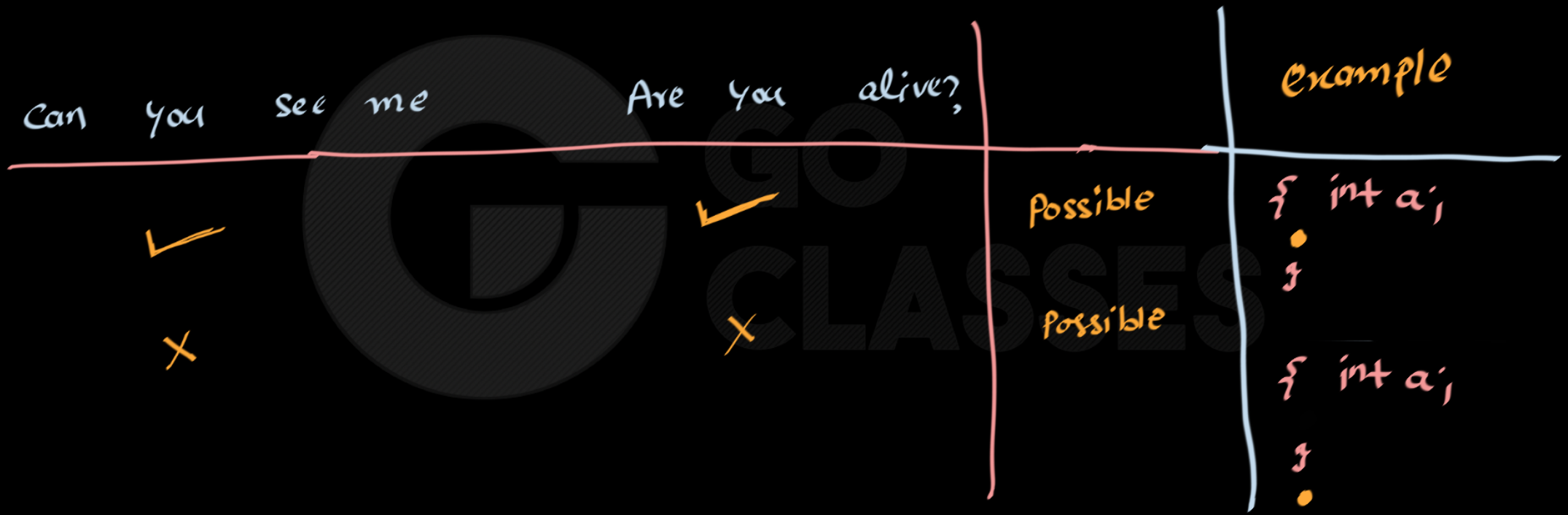

Scope
lifetime
Can you see me?
are you alive (in the memory)
{
auto int a = 5;
printf (a)
Compile time error

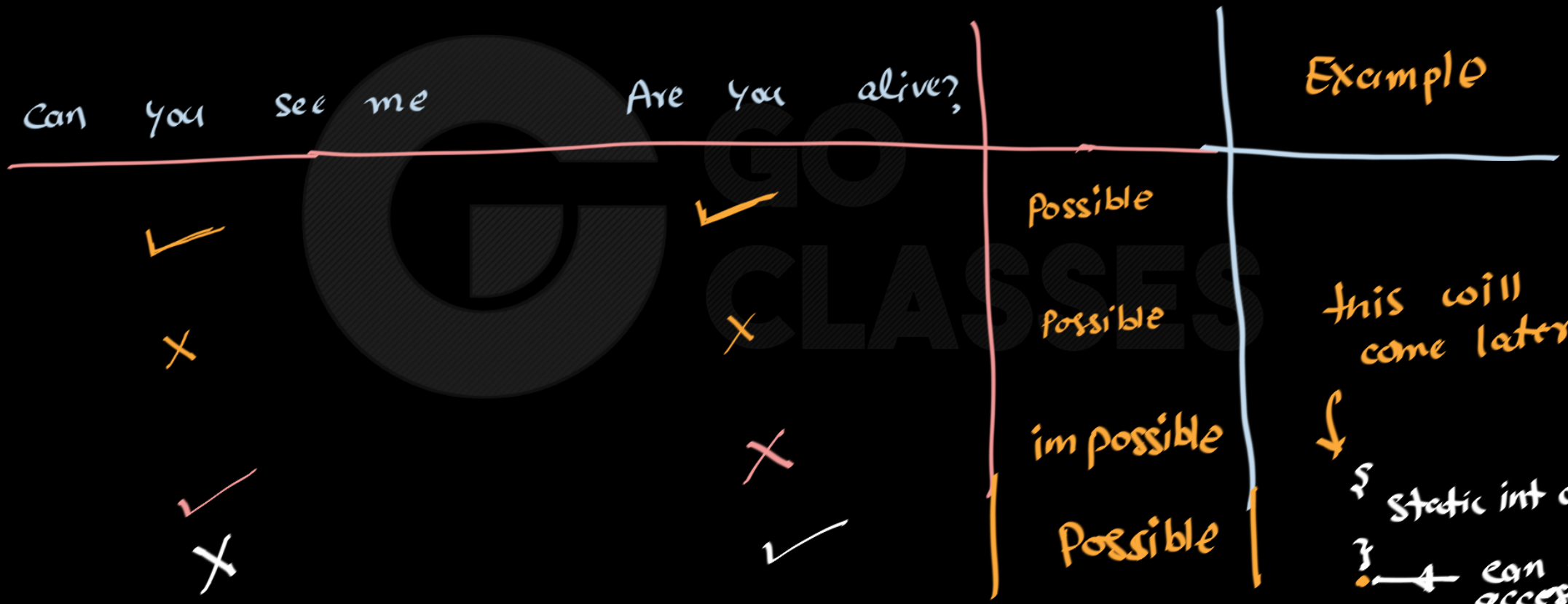
GO CLASSES

```
{
auto int a = 5;
}
```

⟹ Can you see (print) a ?

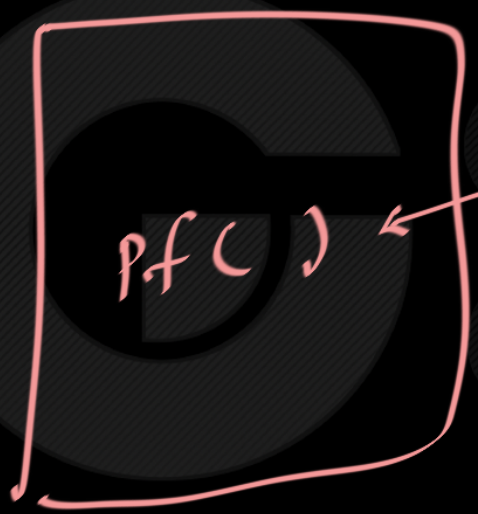
⇒ is this variable a alive ? (memory)


Can you see me
Are you alive?
Possible
Possible
Example
{ int a;
}
{ int a;
}


Can you see me
Are you alive?
Example
Possible
Possible
this will come later
impossible
Possible
static int a;
can not access

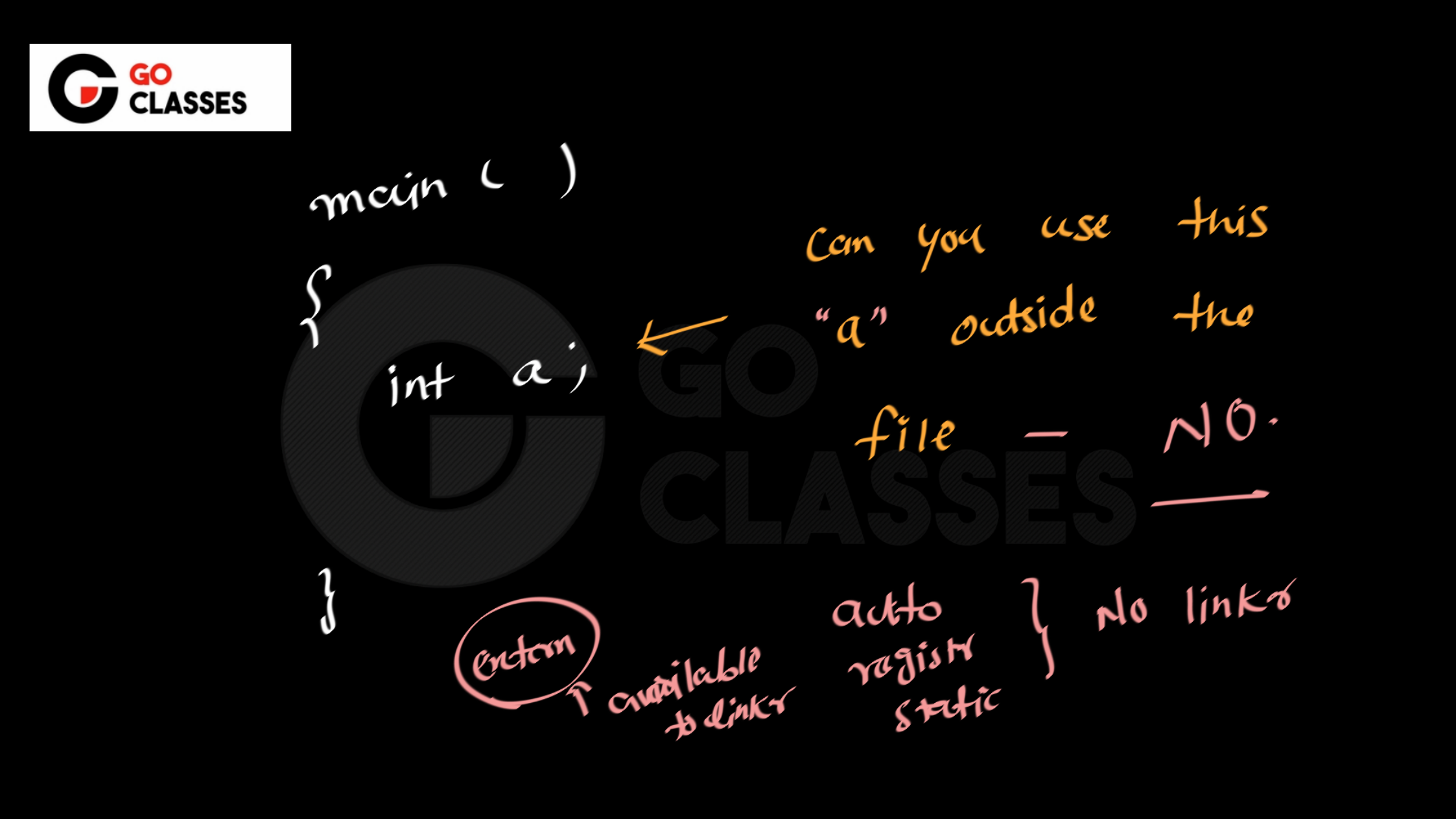
auto Storage Class (Cont..)

- The auto storage class is the default storage class for all local variables.
- Objects with the auto class are NOT available to the **linker**.
- You can't use for global variables.



defined in some other file

```
{
    auto int a;
}
```


GO CLASSES
main ( )
{
int a;
}
Can you use this "a" outside the file — NO.
extern
available to linker
auto
register
static
No linkage

auto Storage Class example -

```
main ()
{
    auto int b;                  /*  Valid auto declaration   */
    for (b = 0; b < 10; b++)
      {
        auto int a = b + a;      /*   Valid inner block declaration    */
      }
}
```

auto Storage Class example -

```
auto int a;          /*  Illegal -- auto must be within a block  */

main ()
{
    auto int b;                 /*  Valid auto declaration   */
    for (b = 0; b < 10; b++)
      {
        auto int a = b + a;     /*   Valid inner block declaration    */
      }
}
```

Register Storage Class

- Storage – CPU register (may)
- Initial Value – Garbage
- Scope – Within Block
- LifeTime – End of block

Same as auto

i is getting used again and again

```
for (register int i=0; i<5; i++)
{
    pf(i);
}
```

Register Storage Class example -

```
void main(){

    register int i =0;
    printf("%d", i);
}
```

suggestion

It's a hint to the compiler that the variable will be heavily used and that you recommend it be kept in a processor register if possible.

Most modern compilers do that automatically, and are better at picking them than us humans.

Register Storage Class example -

```
void main(){

    register int i =0;
    printf("%d", i);
}
```

No one use register keyword.

It's a hint to the compiler that the variable will be heavily used and that you recommend it be kept in a processor register if possible.

Most modern compilers do that automatically, and are better at picking them than us humans.

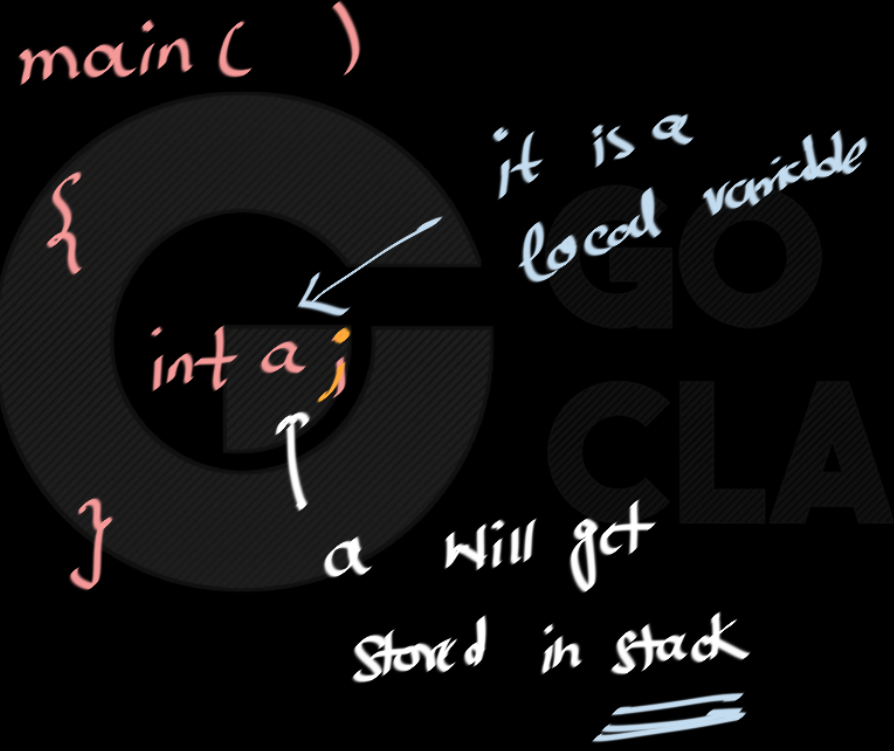
GO CLASSES

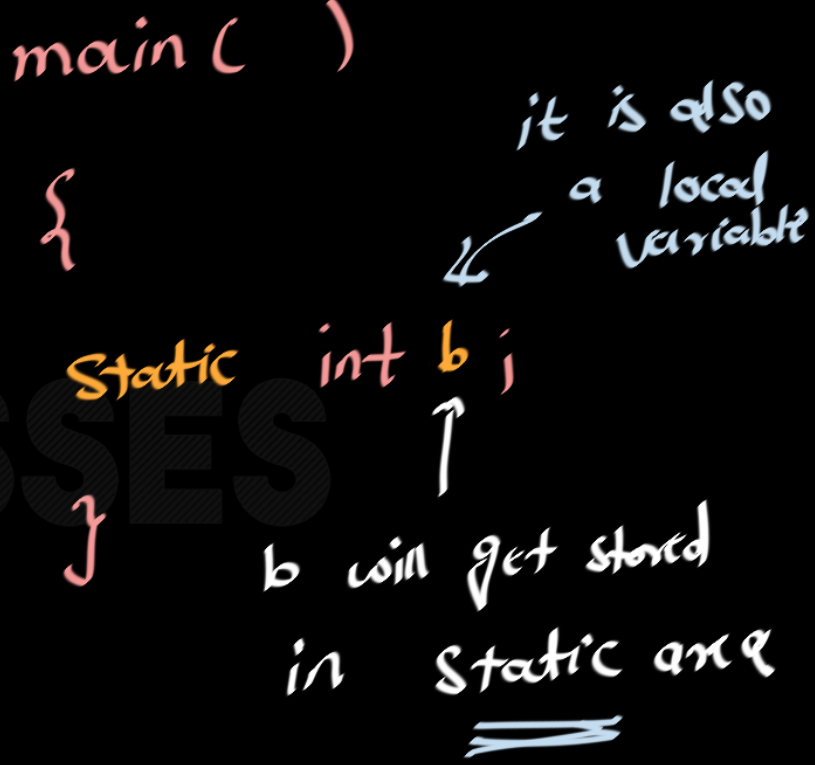
- You can't use auto or register for global variables.
- No one uses auto and register keywords.

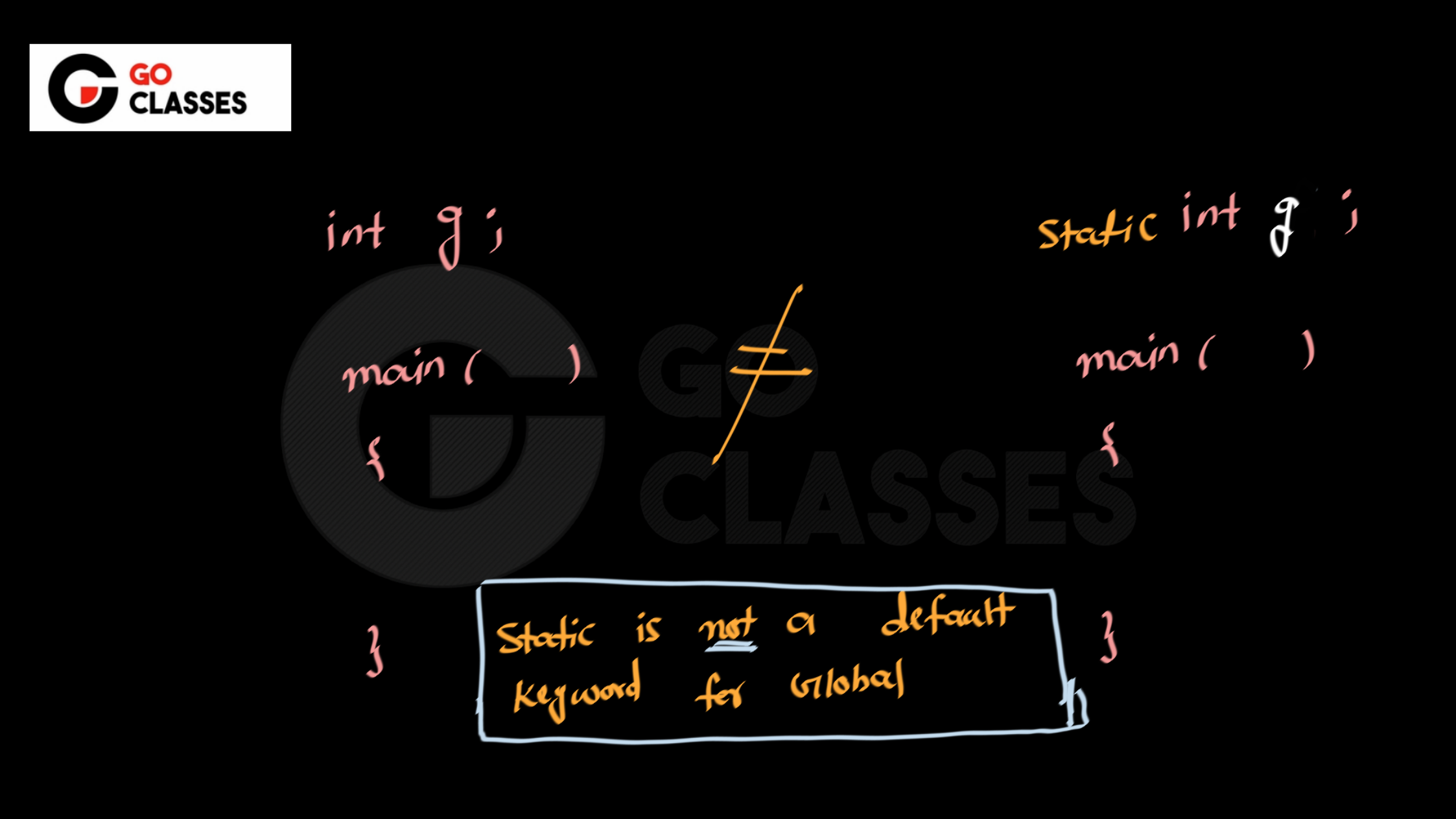
Static Storage Class

as per GATE it is very imp.

- Storage – Static Memory
- Initial Value – zero
- Scope – within block
- Life Time – Till end of program
- Objects with the Static class are also NOT available to the **linker**.


main ( )
{
int a j
}
it is a local variable
a will get stored in stack


main ( )
{
Static int b j
}
it is also a local variable
b will get stored in static area


int g;
main ( )
{
}
≠
static int g;
main ( )
{
}
Static is not a default keyword for Global

GO CLASSES

```
main ( )
{
int j;
}
```

=

```
main ( )
{
auto int j;
}
```

GO CLASSES

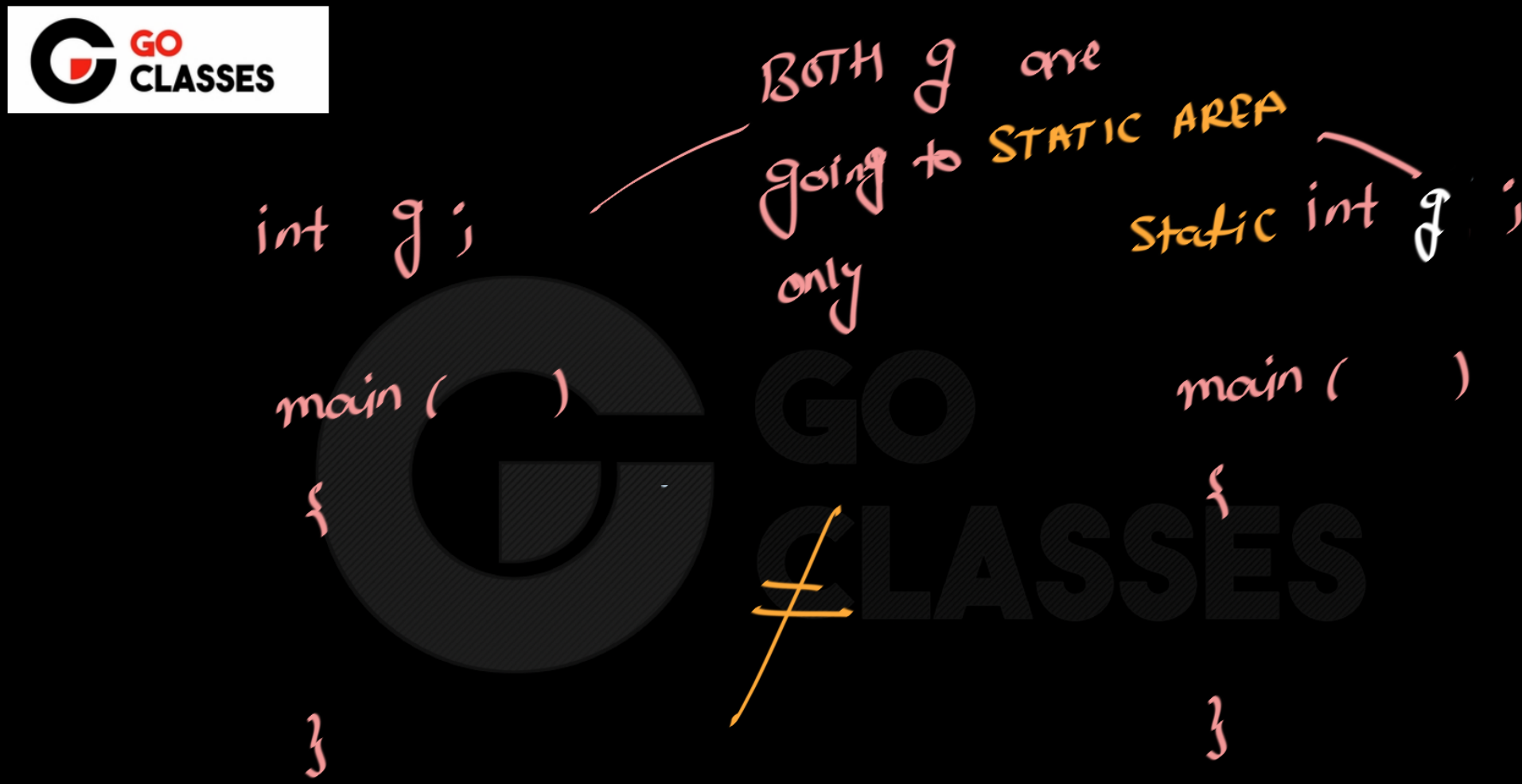
```
int g;
main ( )
{
}
```

g is a global variable and all global variables goes to static area

$\neq$

```
Static int g;
main ( )
{
}
```

a global variable and also static variable storage is static


GO CLASSES
BOTH g are going to STATIC AREA only
int g;
main ( )
{
}
≠
Static int g;
main ( )
{
}

GO CLASSES

local (auto) ⇒ stack storage

local (static) ⇒ static storage

global (static, or no static) ⇒ static storage

- Scope – within block
- Life Time – Till end of program

if local then within { }

if global then within same file (you can not access in other file)

Static variable get destroyed only if Program terminates.

GO CLASSES

```
fun ( )
{
    static int a = 5;
}
main ( )
{
    fun ( );
}
```

fun( ); ⟶ a is in memory but we cant access it.

Static Storage Class Example -

```c
#include <stdio.h>

void increment() {
    static int count = 0;
    count++;
    printf("%d ", count);
}

int main() {
    increment();
    increment();
    increment();
    return 0;
}
```

output: 1 2 3

Question: What will be the output of following program ?

```c
#include <stdio.h>

void increment() {
    static int count = 5;
    count--;
    printf("%d ", count);
}

int main() {
    increment();
    increment();
    increment();
    return 0;
}
```

What will be the output of the program?

a) 4 3 2

b) 5 4 3

c) 5 5 5

d) 4 4 4

Question: What will be the output of following program ?

```c
#include <stdio.h>

void increment() {
    static int count = 5;
    count--;
    printf("%d ", count);
}

int main() {
    increment();
    increment();
    increment();
    return 0;
}
```

4 3 2

What will be the output of the program?

a) 4 3 2

b) 5 4 3

c) 5 5 5

d) 4 4 4

5 4 3 2

```c
#include <stdio.h>

static int y = 5;

void fun() {
    static int y;
    y++;
    return;
}


int main() {

    fun();
    printf("%d", y);

    return 0;
}
```

→ 5

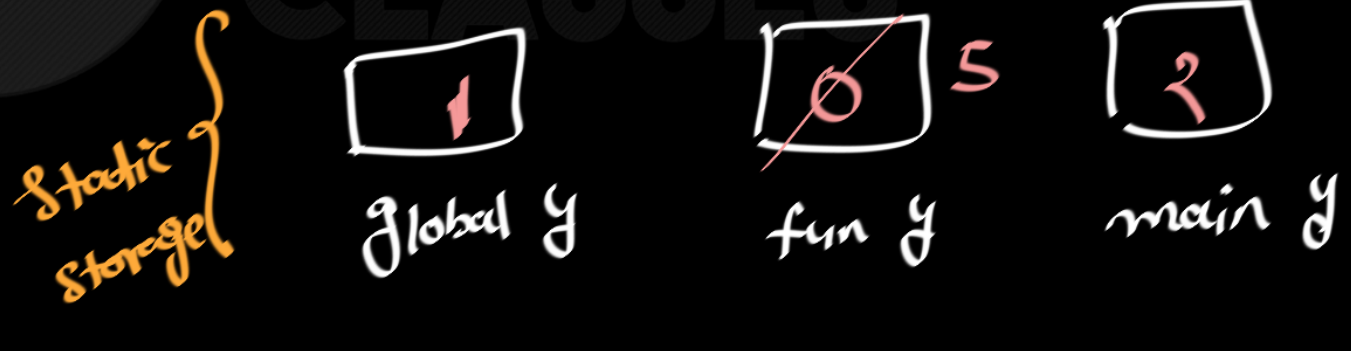
Question: What will be the output of program given?

```c
#include <stdio.h>

static int y = 1;

void fun() {
    static int y;
    y=5;
    return;
}


int main() {
    static int y = 2;

    fun();
    printf("%d", y);


    return 0;
}
```

Question: What will be the output of program given?

```c
#include <stdio.h>

static int y = 1;

void fun() {
    static int y;
    y=5;
    return;
}


int main() {
    static int y = 2;

    fun();
    printf("%d", y);


    return 0;
}
```

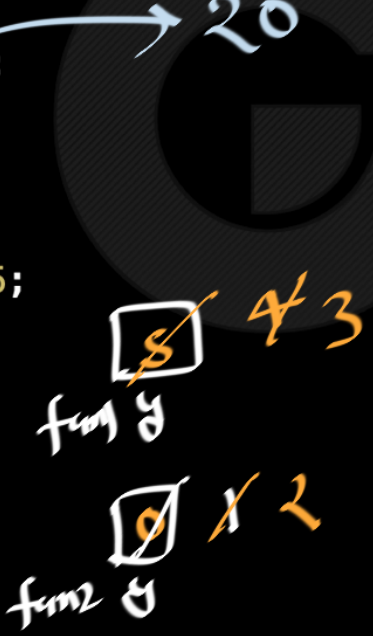
Question: What will be the output of program given?



```c
main()
{
    int x = 0;

    for (int i = 1; i<5; i++)
    {
        x += fun1()+fun2();
    }

    printf("%d", x);
}


int fun1(){
    static int y = 5;
    y--;
    return y;
}
int fun2(){
    static int y;
    y++;
    return y;
}
```

Question: What will be the output of program given?

```c
main()
{
    int x = 0;

    for (int i = 1; i<5; i++)
    {
        x += fun1()+fun2();
    }

    printf("%d", x);
}


int fun1(){
    static int y = 5;
    y--;
    return y;
}
int fun2(){
    static int y;
    y++;
    return y;
}
```



Question: What will be the output of program given?

$i=1 \quad x = 0 + \underbrace{fun1()}_{4} + \underbrace{fun2()}_{1} = 5$

$i=2 \quad x = 5 + \underbrace{fun1()}_{3} + \underbrace{fun2()}_{2} = 10$

$i=3 \quad x = 10 + 2 + 3 = 15$

$i=4 \quad x = 15 + 1 + 4 = 20$

Extern Storage Class

- Storage – Static Memory
- Initial Value – zero
- Scope – Global
- Life Time – Till end of program

extern refers to global variable

extern int a;

global variable

- Objects with the extern class are available to the **linker**.

GO CLASSES

extern int a ;

a

int a

a

Extern Storage Class example -

Example 1

```c
#include <stdio.h>

int max;

int main() {
    int len;
    extern int max;
    printf("%d", max);
    max = 5;
}
```

0

it is a way to tell compiler that there is a global variable max.

Extern Storage Class example -

```c
#include <stdio.h>

int max;

int main() {
    int len;

    extern int max;

    printf("%d", max);

    max = 5;

}
```

(Suppose we remove extern from this code)

→ 0 ← output

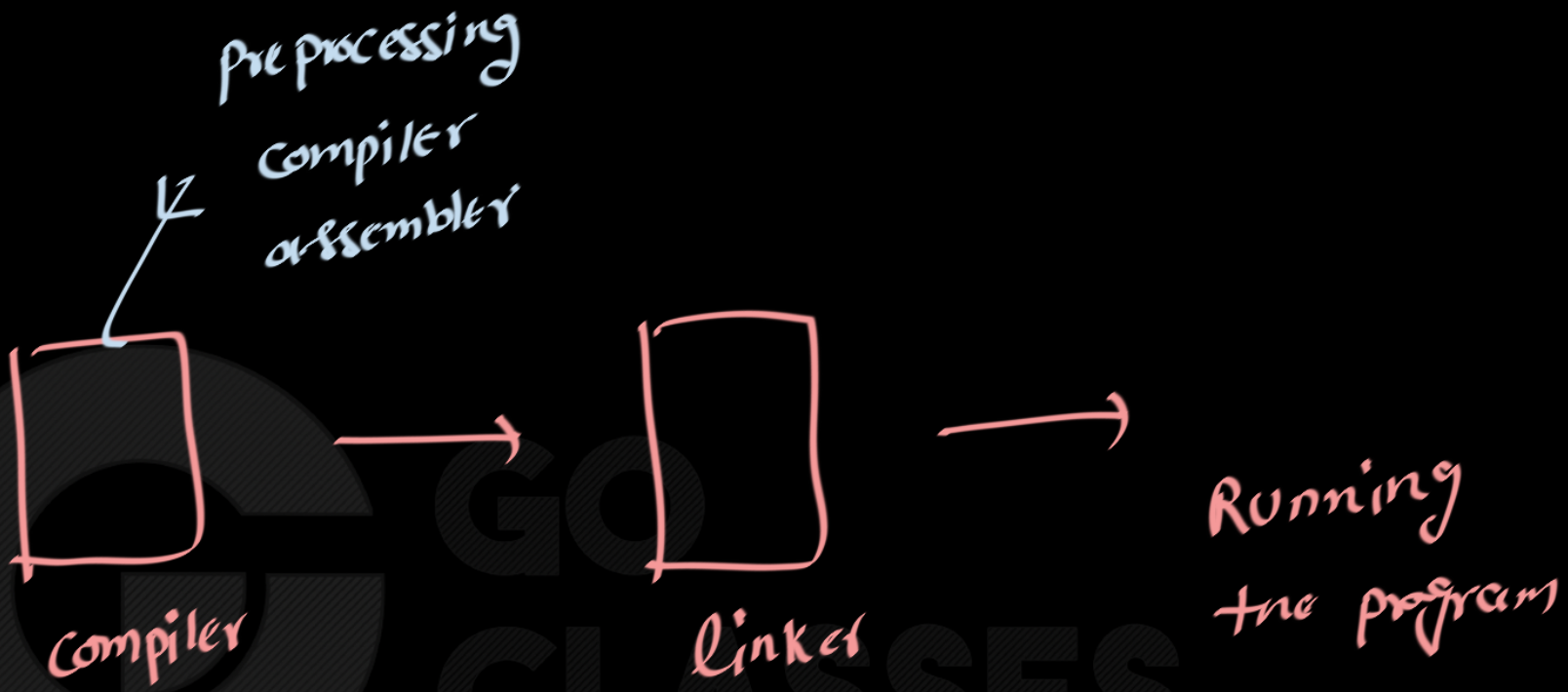
Extern Storage Class example -

Example 2

this line is telling to the compiler that - Please don't worry, there is a global variable max which is either in this file or in another file

```c
#include <stdio.h>

int main() {
    int len;
    extern int max;
    printf("%d", max);
    max = 5;
}

int max;
```

0 output


Preprocessing
Compiler
assembler
Compiler
Linker
Running
the program

Extern Storage Class example -

```c
#include <stdio.h>

int max;

int main() {
    int len;
    extern int max;
    printf("%d", max);
    max = 5;
}
```

this is useless

```c
#include <stdio.h>

int main() {
    int len;
    extern int max;
    printf("%d", max);
    max = 5;
}

int max;
```

this is useful

Extern Storage Class example -

```c
#include <stdio.h>

int max;

int main() {
    int len;
    extern int max;
    printf("%d", max);
    max = 5;
}
```

this is useless

```c
#include <stdio.h>

int main() {
    int len;
    extern int max;
    printf("%d", max);
    max = 5;
}

int max;
```

this is useful (but can be omitted)

why not shift the int max to top and remove extern?

Extern Storage Class example -

```c
#include <stdio.h>

int max;

int main() {
    int len;

    extern int max;

    printf("%d", max);

    max = 5;

}
```

```c
#include <stdio.h>

int main() {
    int len;

    extern int max;

    printf("%d", max);

    max = 5;

}

int max;
```

Extern Storage Class example -

Common practice is to place definitions of all external variables at the beginning of source file and then omit all the extern declarations.

GO CLASSES

```
extern int a;

main ( )
{
}

int a
```

Global use of extern

We can NOT refer local variable using extern

```
main ( )
{
  int a;
  extern int a;
}
```

X

here extern is reffering to local variable

```
main ( )
{
  extern int a;
}
int a;
```

use local at extern

Note -

- Extern always refer global variables but it can be used with local or global variable.

GO CLASSES

Optional

Real use of extern keyword

(with 2 files or more)

```c
/* main.c */
#include <stdio.h>

extern int gInt;

void change_extern(void);

int main()
{
    printf("main1 gInt %d\n", gInt);
    change_extern();
    gInt = 5;
    change_extern();
    printf("main2 gInt %d\n", gInt);
    return 0;
}
```

Will this program get compiled? ⇒ YES.

```c
/* main.c */
#include <stdio.h>

extern int gInt;

void change_extern(void);

int main()
{
    printf("main1 gInt %d\n", gInt);
    change_extern();
    gInt = 5;
    change_extern();
    printf("main2 gInt %d\n", gInt);
    return 0;
}
```

what kind of error it will show

⇒ linker error

```c
/* main.c */
#include <stdio.h>

extern int gInt;

void change_extern(void);

int main()
{
    printf("main1 gInt %d\n", gInt);
    change_extern();
    gInt = 5;
    change_extern();
    printf("main2 gInt %d\n", gInt);
    return 0;
}
```

```c
/* main.c */
#include <stdio.h>

extern int gInt;

void change_extern(void);

int main()
{
    printf("main1 gInt %d\n", gInt);
    change_extern();
    gInt = 5;
    change_extern();
    printf("main2 gInt %d\n", gInt);
    return 0;
}
```

```c
/* extern.c */
#include <stdio.h>

int gInt;

void change_extern(void)
{
    printf("change_extern1 gInt %d\n", gInt);
    gInt = 10;
    printf("change_extern2 gInt %d\n", gInt);
}
```

GO CLASSES

How does it look like after Linking?

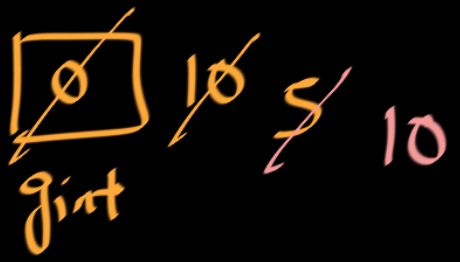
One file

```c
extern int gInt;

void change_extern(void);

int main()
{
    printf("main1 gInt %d\n", gInt);
    change_extern();
    gInt = 5;
    change_extern();
    printf("main2 gInt %d\n", gInt);
    return 0;
}
```

```c
int gInt;

void change_extern(void)
{
    printf("change_extern1 gInt %d\n", gInt);
    gInt = 10;
    printf("change_extern2 gInt %d\n", gInt);
}
```

```c
int gInt;

void change_extern(void)
{
    printf("change_extern1 gInt %d\n", gInt);
    gInt = 10;
    printf("change_extern2 gInt %d\n", gInt);
}

int main()
{
    printf("main1 gInt %d\n", gInt);
    change_extern();
    gInt = 5;
    change_extern();
    printf("main2 gInt %d\n", gInt);
    return 0;
}
```

linked file



main1 gInt 0

change_extern1 gInt 0

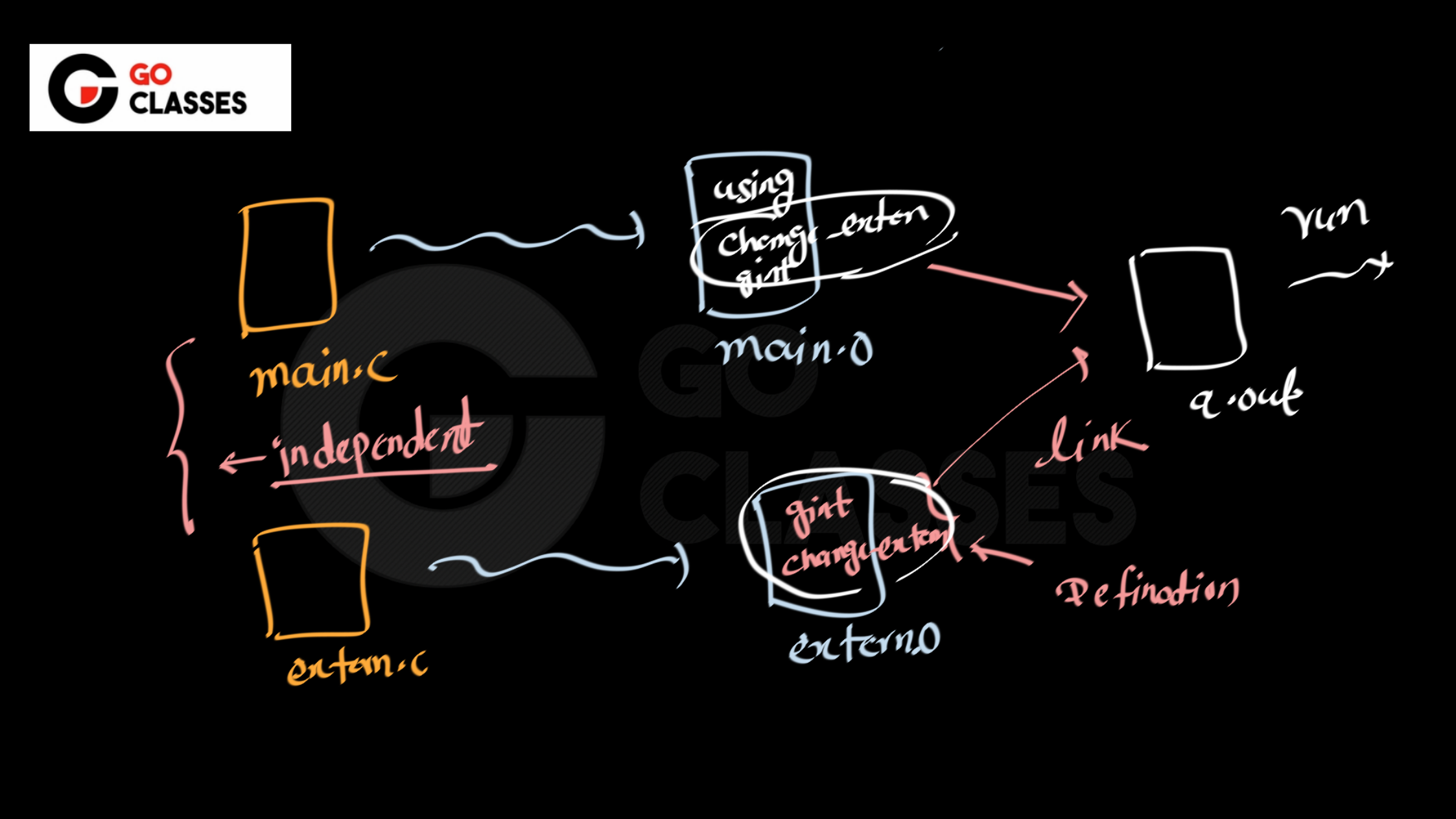
change_extern2 gInt 10

change_extern1 gInt 5

change_extern2 gInt 10

main2 gInt 10

```
main1 gInt 0
change_extern1 gInt 0
change_extern2 gInt 10
change_extern1 gInt 5
change_extern2 gInt 10
main2 gInt 10
```


GO CLASSES
main.c
'independent
extern.c
using change_extern
first
main.o
extern.o
first changeextern
Definition
link
a.out
run

GO CLASSES

Few more Questions

```c
#include<stdio.h>
main()
{
   extern int num;
   num = 20;
   printf("%d", num);
}
```

there is a global variable num either in this file or any other file (don't worry)

No compilation error

Linker error

```c
#include<stdio.h>
main()
{
   extern int num;
   num = 20;
   printf("%d", num);
}
```

there is a global variable num either in this file or any other file (don't worry)

linker error

```c
#include<stdio.h>
main()
{

   num = 20;
   printf("%d", num);
}
```

then is a compiler error.

```c
#include <stdio.h>
extern int i; //extern variable
int main(){
    i=5;
    printf("%d",i);
    return 0;
}
```

```c
#include <stdio.h>
extern int i; //extern variable
int main(){
    i=5;
    printf("%d",i);
    return 0;
}
```

No compiler error
linker error

```c
#include <stdio.h>
extern int i;  //extern variable
int main(){
    int i=5;
    printf("%d",i);
    return 0;
}
```

Not using this anywhere (No linking required)

```c
#include <stdio.h>
extern int i;  //extern variable
int main(){
    int i=5;
    printf("%d",i);
    return 0;
}
```

[No Compiler error
No linker error]

```c
#include <stdio.h>
extern int i;     //extern variable
int main(){
     printf("Hello");
     return 0;
}
```

```c
#include <stdio.h>
extern int i;     //extern variable
int main(){
    printf("Hello");
    return 0;
}
```

i am not using this i anywhere

No Compiler error

```c
#include <stdio.h>

void fun(void);

int main(){
    printf("Hello");
    return 0;
}
```

```c
#include <stdio.h>

void fun(void);

int main(){
    printf("Hello");
    return 0;
}
```

No compiler error

not using/calling this f^n anywhere

No linker error also.

```c
#include <stdio.h>

void fun(void);

int main(){
    printf("Hello");
    fun();
    return 0;
}
```

GO CLASSES

```c
#include <stdio.h>

void fun(void);

int main(){
    printf("Hello");
    fun();
    return 0;
}
```

No compiler error

Linker error

we are using/calling

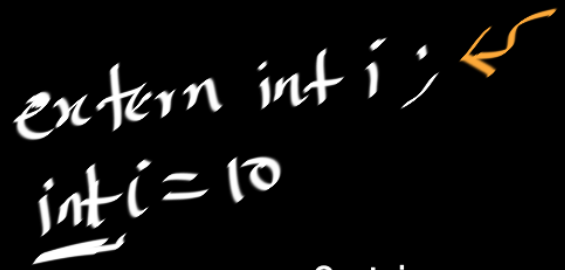
GO CLASSES

```c
#include <stdio.h>

int main(){
    printf("Hello");
    fun();
    return 0;
}
```

```c
#include <stdio.h>

int main(){
    printf("Hello");
    fun();
    return 0;
}
```

compiler will produce error here.

```c
#include<stdio.h>
int main() {

    extern int i = 10;
    printf("%d", i);
    return 0;
}
```



Options:

A. Garbage value

B. 10

C. Compiler Error

D. Linker Error

No one use '=' with extern.

```
#include<stdio.h>
int main() {

    extern int i = 10;
    printf("%d", i);
    return 0;
}
```

extern int i;
int i = 10;

Options:

A. Garbage value

B. 10

C. Compiler Error

D. Linker Error

extern int i;
int i = 10;

```c
#include<stdio.h>
extern int i = 10;
int main() {

    extern int i;
    printf("%d", i);
    return 0;
}
```

Options:

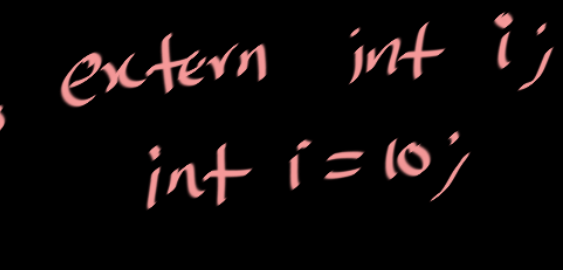
A. Garbage value

B. 10

C. Compiler Error

D. Linker Error

```c
#include<stdio.h>
extern int i = 10;
int main() {

    extern int i;
    printf("%d", i);
    return 0;
}
```



Options:

A. Garbage value

B. 10

C. Compiler Error

D. Linker Error