TUTORIAL 1

DATE: 12th January 2015

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1. Consider the programs shown in the class, with some modifications:

```
#include <stdio.h> /* included system
                      header files */
/*main.c*/
void swap (); /* declaration */
int buf [2] = {34,56}; /* initialised global */
int main ()  /* definition main */
{
  swap ();
  printf("buf[0]= %d buf[1]= %d\n", buf[0], buf[1]);
  return 0;
}
-----------------------------------------------
/*swap.c*/

extern int buf []; /*declaration buf*/
#define one 1
int *bufp0 = &buf[0]; /* initialized global */
int *bufp1;   /* uninitialized global */

void swap ()   /* definition swap */
{
  int temp;    /* local */
  f();
  bufp1 = &buf[one];
  temp = *bufp0;
  *bufp0 = *bufp1;
  *bufp1 = temp;
}
-----------------------------------------------
/*other.c*/
int buf[2];
void f()
{
   buf[0] = 3;
   buf[1] = 4;
}
```

Now use the `objdump` switches once again to find out how the relocatable symbols have been relocated in the executable `a.out`. Produce the excutable twice – once with and once without the switch `-static`.

2. Study the following programs and their corresponding code generated. For each do the following:

   (a) Annotate fragments of target code with the source statemets that they correspond to.

   (b) Annotate each local variable and parameter with its (relative address)

   Compile your programs as:

   `gcc -static -fno-asynchronous-unwind-tables programname.c`

   (a) A program with a while loop in a file test1.c:

```
int main()
{
  int a=1,b=1;
  while(a<=10)
    {
      b=b*a;
      a++;
    }
  return b;
 }

main:
        pushq   %rbp
        movq    %rsp, %rbp
        movl    $1, -8(%rbp)
        movl    $1, -4(%rbp)
        jmp     .L2
.L3:
        movl    -4(%rbp), %eax
        imull   -8(%rbp), %eax
        movl    %eax, -4(%rbp)
        addl    $1, -8(%rbp)
.L2:
        cmpl    $10, -8(%rbp)
        jle     .L3
        movl    -4(%rbp), %eax
        popq    %rbp
        ret
```

   (b) C Program using structures in a file test2.c

```
struct data{
        int sum;
        int b[5];
        };

int main()
{
  struct data rec1;
  rec1.sum=0;
  rec1.b[0]=2;
  rec1.sum=rec1.sum+rec1.b[0];
  return rec1.sum;
}
```

```
main:
        pushq   %rbp
        movq    %rsp, %rbp
        movl    $0, -32(%rbp)
        movl    $2, -28(%rbp)
        movl    -32(%rbp), %edx
        movl    -28(%rbp), %eax
        addl    %edx, %eax
        movl    %eax, -32(%rbp)
        movl    -32(%rbp), %eax
        popq    %rbp
        ret
```

3. This question assumes static linking. In each of the pairs of modules shown below, indicate how the multiply defined symbol `main` would be resolved. Your answer should be of the form "The use of the symbol `main` in module X will resolve to the declaration of `main` in module Y". You may also mention if the linker will give an error or will arbitrarily choose a declaration. Verify your answer by using `objdump` and `readelf` on the `.o` and the `a.out files`.

Module 1:

```
#include <stdio.h>
int main()
{
  printf("%p\n", &main);
  p();
}
```

Module 2:

```
#include <stdio.h>
int main;
int p ()
{
  printf("%p\n", &main);
}
```

Module 1:

```
#include <stdio.h>
int main()
{
  printf("%p\n", &main);
  p();
}
```

Module 2:

```
#include <stdio.h>
int main=1;
int p ()
{
  printf("%p\n", &main);
}
```

Module 1:

```
#include <stdio.h>
int main()
{
  printf("%p\n", &main);
  p();
}
```

Module 2:

```
#include <stdio.h>
static int main=1;
int p ()
{
  printf("%p\n", &main);
}
```

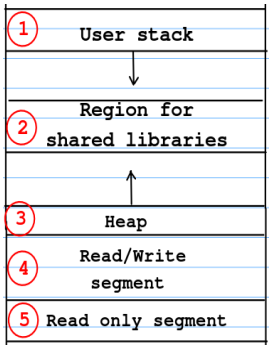
4. Consider the following modules and the memory image of a program in Linux. The regions in the memory image have been numbered. Also given are two modules in which symbols (variables and function names) have been declared. Consider the executable formed after the two modules are compiled and statically linked under the linux environment that was discussed in the class. For each symbol mention the region number in which it will be stored.

Module 1:

```
int x = 10;
static int y = 5;
main ()
{
  int* p;
  p = (int *) malloc(4);
  printf("%d\n", f());
  printf("%d\n", f());
}
```

Module 2:

```
int a[10];
int f ()
{
  static int k = 0;
  return k++;
}
```



5. Assume that two files `test1.c` and `test2.c` contain the programs shown below:

test1.c:

```
#include<stdio.h>
struct {
  int x;
  int y;
} rec = {13,5};

main ()
{
  f1 ();
  printf(" %d %d\n", rec.x,
         rec.y);
}
```

test2.c:

```
#include<stdio.h>

struct {
  int y;
  int x;
} rec;

f1 ()
{
  printf(" %d %d\n",
           rec.x, rec.y);
}
```

What is the output of the program when the files are compiled and linked with the gcc compiler? Explain your answer.

6. This question assumes static linking. Consider the two modules shown below stored in the files `f1.c` and `f2.c`.

Module 1: `f1.c`

```
#include<stdio.h>
int a[5] = {0,1,2,3,4};
extern int b [];
double c;
int *x = &(a[3]);
int *y = b;
extern int f();
main ()
{
 c = 100.0;
 printf("%d", 5==fn());
}
```

Module 2: `f2.c`

```
int c = 58; int d = 5;
extern int a[];
int b []= {1,2,3};
int z = a[5];
fn ()
{
 int e = d;
 return(e);
}
```

Now answer the following questions assuming that an address takes 4 bytes, an `int` takes 4 bytes and a `double` takes 8 bytes.

(a) There is a compilation error in the program involving a single line. Point out the line and explain the error. For the rest of the question assume that the line is not there.

(b) The program outputs the value 0. Assuming the symbol resolution policy discussed in the class explain the output.

(c) Consider the symbol references (underlined) in the program. Which of these symbol references are relocatable? For each relocatable symbol reference mention whether the relocation is PC-relative or Absolute.

(d) In the table below, I have given you the final addresses of *symbol definitions*. Fill in the values of references after relocation.

Symbol Name	Address in `a.out`
`a`	080ef068– the address of a
`b`	080ef08c
`c`	080ef084
`x`	080ef07c
`y`	080ef080
`main`	08048f14– the address of the function main
`call printf(...)`	08048f4d—the address of the 4-byte offset in the instruction
`call fn(...)`	08048f29—the address of the 4-byte offset in the instruction
`stdio::printf`	080499d0—the address of the function printf
`d`	080ef088
`z`	080ef091
`fn`	08048f54– the address of the function fn