CS 2211
Systems Programming

Part Ten – A

Structures and Memory

POINTERS

Passing Values TO and FROM a Function

pass-by-value
verus
pass-by-reference

```
void swap_value(int va, int vb) {
  int vTmp = va;
  va = vb;
  vb = vTmp;
}

void swap_reference(int *ra, int *rb) {
  int rTmp = *ra;
  *ra = *rb;
  *rb = rTmp;
}

int main()
{
    int a = 1;
    int b = 2;
    printf("before swaps: a = %d\n", a);
    printf("before swaps: b = %d\n", b);
    swap_value(a, b);
    printf("after swap_value: a = %d\n", a);
    printf("after swap_value: b = %d\n", b);

    swap_reference(&a, &b);
    printf("after swap_reference: a = %d\n", a);
    printf("after swap_reference: b = %d\n", b);
}
```

POINTERS

(1, 2)

Passing Values TO and FROM a Function

```
void swap_value(int va, int vb) {
  int vTmp = va;
  va = vb;
  vb = vTmp;
}

void swap_reference(int *ra, int *rb) {
  int rTmp = *ra;
  *ra = *rb;
  *rb = rTmp;
}

int main()
{
    int a = 1;
    int b = 2;
    printf("before swaps: a = %d\n", a);
    printf("before swaps: b = %d\n", b);
    swap_value(a, b);
    printf("after swap_value: a = %d\n", a);
    printf("after swap_value: b = %d\n", b);

    swap_reference(&a, &b);
    printf("after swap_reference: a = %d\n", a);
    printf("after swap_reference: b = %d\n", b);
}
```

call frame (main)

Label	Address	Value
a	400 - 403	1
b	404 - 407	2
va	512 - 515	1
vb	516 -519	2

POINTERS

Passing Values TO and FROM a Function

```
void swap_value(int va, int vb) {
  int vTmp = va;
  va = vb;
  vb = vTmp;
}

void swap_reference(int *ra, int *rb) {
  int rTmp = *ra;
  *ra = *rb;
  *rb = rTmp;
}

int main()
{
    int a = 1;
    int b = 2;
    printf("before swaps: a = %d\n", a);
    printf("before swaps: b = %d\n", b);
    swap_value(a, b);
    printf("after swap_value: a = %d\n", a);
    printf("after swap_value: b = %d\n", b);

    swap_reference(&a, &b);
    printf("after swap_reference: a = %d\n", a);
    printf("after swap_reference: b = %d\n", b);
}
```

(400, 404)

call frame (main)

Label	Address	Value
a	400 - 403	1
b	404 - 407	2
ra	512 - 515	400
rb	516 -519	404

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{

   person  teacher;

   teacher.year=2025;
   strcpy(teacher.first,"Sam");
   strcpy(teacher.last,"Maggs");

   DisplayStats(teacher);
   printf("%s\n",teacher.first);


   return 0;
}
```

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char     first[32];      /* 1st field is array of char */
         char     last[32];       /* 2nd field is array of char */
         int      year;
         } person;

int main()
{

   person  teacher;

   teacher.year=2025;
   strcpy(teacher.firs
   strcpy(teacher.last

   DisplayStats(teache
   printf("%s\n",teach


   return 0;
}
```

Address Label	Label	Address	Value
teacher teacher.first	teacher.first[0]	400 -	S
	teacher.first[1]	401 -	a
	teacher.first[2]	402 -	m
	teacher.first[3]	403 -	\0
	teacher.first[5]	404 -	
	teacher.first[6] – [31]	405 - 431	
teacher.last	teacher.last[0]	432 -	M
	teacher.last[1]	433 -	a
	teacher.last[2]	434 -	g
	teacher.last[3]	435 -	g
	teacher.last[4]	436 -	s
	teacher.last[5]	437 -	\0
	teacher.last[5]	438 -	
	teacher.last[6] – [31]	439 - 463	
	teacher.year	464 - 467	2025

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{

   person  teacher;

   teacher.year=2025;
   strcpy(teacher.first,"Sam");
   strcpy(teacher.last,"Maggs");

   DisplayStats(teacher);
   printf("%s\n",teacher.first);


   return 0;
}
```

Address Label	Label	Address	Value
teacher teacher.first	teacher.first	400 - 431	Sam
teacher.last	teacher.last	432 - 463	Maggs
	teacher.year	464 - 467	2025

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{
   person  teacher, student;

   teacher.year=2025;
   strcpy(teacher.first,"Sam");
   strcpy(teacher.last,"Maggs");

   student = teacher;
   PrintStructure(student);

   UnChangeStruct(teacher);
   ChangeStruct(&teacher);
   PrintStructure(teacher);

   return 0;
}
```

Address Label	Label	Address	Value
teacher teacher.first	teacher.first	400 - 431	
teacher.last	teacher.last	432 - 463	
	teacher.year	464 - 467	
student student.first	student.first	468 - 499	
student.last	student.last	500 - 531	
	student.year	532 - 535	

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{

   person  teacher, student;

   teacher.year=2025;
   strcpy(teacher.first,"Sam");
   strcpy(teacher.last,"Maggs");

   student = teacher;
   PrintStructure(student);

   UnChangeStruct(teacher);
   ChangeStruct(&teacher);
   PrintStructure(teacher);

   return 0;
}
```

Address Label	Label	Address	Value
teacher teacher.first	teacher.first	400 - 431	Sam
teacher.last	teacher.last	432 - 463	Maggs
	teacher.year	464 - 467	2025
student student.first	student.first	468 - 499	
student.last	student.last	500 - 531	
	student.year	532 - 535	

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{

   person  teacher, student;

   teacher.year=2025;
   strcpy(teacher.first,"Sam");
   strcpy(teacher.last,"Maggs");

   student = teacher;
   PrintStructure(student);

   UnChangeStruct(teacher);
   ChangeStruct(&teacher);
   PrintStructure(teacher);

   return 0;
}
```

Address Label	Label	Address	Value
teacher teacher.first	teacher.first	400 - 431	Sam
teacher.last	teacher.last	432 - 463	Maggs
	teacher.year	464 - 467	2025
student student.first	student.first	468 - 499	Sam
student.last	student.last	500 - 531	Maggs
	student.year	532 - 535	2025

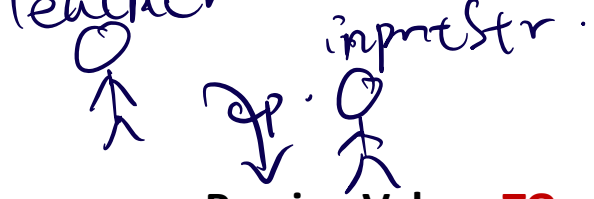
POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{

   person  teacher;

   teacher.year=2025;
   strcpy(teacher.first,"Sam");
   strcpy(teacher.last,"Maggs");

   UnChangeStruct(teacher);
   ChangeStruct(&teacher);
   PrintStructure(teacher);

   return 0;
}
```

Address Label	Label	Address	Value
teacher teacher.first	teacher.first	400 - 431	Sam
teacher.last	teacher.last	432 - 463	Maggs
	teacher.year	464 - 467	2025

Teacher



POINTERS

Passing Values TO and FROM a Function

```
void UnChangeStruct( person inputStr)
{
   strcpy(Input.first,"Ima");
   strcpy(Input.last,"Dunsl");
   PrintStructure(inputStr);
}
```

a copy of input person.

```
ty                                          char */
                                            char */

                                            */

int main()
{

   person  teacher;

   teacher.year=2025;
   strcpy(teacher.first,"Sam");
   strcpy(teacher.last,"Maggs");

   UnChangeStruct(teacher);
   ChangeStruct(&teacher);
   PrintStructure(teacher);

   return 0;
}
```

call frame (main)

Address Label	Label	Address	Value
teacher teacher.first	teacher.first	400 - 431	Sam
teacher.last	teacher.last	432 - 463	Maggs
	teacher.year	464 - 467	2025
inputStr inputStr.first	inputStr.first	620 - 651	Ima
inputStr.last	inputStr.last	652 - 683	Dunsl
	inputStr.year	684 - 687	

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{

   person  teacher;

   teacher.year=2025;
   strcpy(teacher.first,"Sam");
   strcpy(teacher.last,"Maggs");

   UnChangeStruct(teacher);
   ChangeStruct(&teacher);
   PrintStructure(teacher);

   // student = teacher;
   // PrintStructure(student);

   return 0;
}
```

Address Label	Label	Address	Value
teacher teacher.first	teacher.first	400 - 431	Sam
teacher.last	teacher.last	432 - 463	Maggs
	teacher.year	464 - 467	2025

address of structure teacher.

POINTERS

Passing Values TO and FROM a Function

```
void ChangeStruct( person *refInputStr)
{
   strcpy(refInputStr.first,"Ima");
   strcpy(refInputStr.last,"Dunsl");
   refInputStr.year = 2042;
   PrintStructure(refInputStr);
}
```

```
ty                                          char */
                                            char */

                                            */
in
{
   person  teacher;

   teacher.year=2025;
   strcpy(teacher.first,"Sam");
   strcpy(teacher.last,"Maggs");

   UnChangeStruct(teacher);
   ChangeStruct(&teacher);
   PrintStructure(teacher);

   // student = teacher;
   // PrintStructure(student);

   return 0;
}
```

call frame (main)

Address Label	Label	Address	Value
teacher teacher.first	teacher.first	400 - 431	Sam
teacher.last	teacher.last	432 - 463	Maggs
	teacher.year	464 - 467	2025
	refInputStr	640 - 643	400

Structures and Memory in C

END OF PART 1

POINTERS

DYNAMIC MEMORY ALLOCATION

- **static memory allocation** (non-changing)
  - the size (in bytes) is known BEFORE a program starts to execute
  - when the program is loaded into memory, allocation of declared variables is performed

- sometimes a program does not know exactly how much memory it may need

i.e. reading a line of text – could be a character array of any size
- always declaring a humongous array very wasteful

- so: use **dynamic memory allocation**
  ask the O/S to set aside **x** amount of memory during execution

POINTERS

DYNAMIC MEMORY ALLOCATION

variations on the malloc() function

notice **malloc()** requests exact number of bytes
- programmer must know how many based on how to be used

calloc() - sets aside cells (memory) and initializes all to zero

```
double *a;

a = (double *) calloc (70, 8);
```

70 x 8 bytes
70 double variables
560 byes

```
// could have used
a = (double *) calloc ( 70, sizeof(double) );
```

- same thing -> sizeof(?) returns size of variable type based on O/S.

POINTERS

```
double *a;      /* a pointer variable */
a = ( double *) malloc (40);
```

requesting O/S to set aside 40 bytes configured to handle values of type **double** and assign the address of this memory block in the pointer variable **a**

NOTE: {DM} – is not a label

- just something to put in temporary symbol for **allocated dynamic memory** (reserved memory for use later….)

Label	Address	Value
a	400 - 403	10000
{DM}	10000 - 10039	

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{

   person  *pTeacher;

   pTeacher = (person *)calloc(1, sizeof(person));

   pTeacher->year=2025;
   strcpy(pTeacher->first,"Sam");
   strcpy(pTeacher->last,"Maggs");

   UnChangeStruct(*teacher);
   ChangeStruct(teacher);
   PrintStructure(teacher);


   return 0;
}
```

Label	Address	Value
pTeacher	400 - 403	10000
{DM}	10000 - 10067	

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{

   person  *pTeacher;

   pTeacher = (person *)calloc(1, sizeof(person));

   pTeacher->year=2025;
   strcpy(pTeacher->first,"Sam");
   strcpy(pTeacher->last,"Maggs");

   UnChangeStruct(*teacher);
   ChangeStruct(teacher);
   PrintStructure(teacher);


   return 0;
}
```

Label	Address	Value
pTeacher	400 - 403	10000
pTeacher->first	10000 - 10031	Sam
pTeacher->last	10032 - 10063	Maggs
pTeacher->year	10064 - 10067	2025

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
    char *first;
    char *last;
    int year;
} person;

void UnChangeStruct( person inputStr)
{
    strcpy(inputstr.first,"Ima");
    strcpy(inputstr.last,"Dunsl");
    inputstr.year = 2022;
    PrintStructure(inputStr);
}

int
{
    person  *pTeacher;

    pTeacher = (person *)calloc(1, size

    pTeacher->year=2025;
    strcpy(pTeacher->first,"Sam");
    strcpy(pTeacher->last,"Maggs");

    UnChangeStruct(*pTeacher);
    ChangeStruct(pTeacher);
    PrintStructure(pTeacher);


    return 0;
}
```

Label	Address	Value
pTeacher	400 - 403	10000
inputStr.first	640 - 671	Ima
inputStr.last	672 - 703	Dunsl
inputStr.year	704 - 707	2022
pTeacher->first	10000 - 10031	Sam
pTeacher->last	10032 - 10063	Maggs
pTeacher->year	10064 - 10067	2025

POINTERS

Passing Values TO and FROM a Function

```
void ChangeStruct( person *refInputStr)
{
   strcpy(refInputStr->first,"Ima");
   strcpy(refInputStr->last,"Dunsl");
   // refInputStr->year = 2042;
   PrintStructure(refInputStr);
}
```

```
ty
                                                    char */
                                                    char */

                                                    */
in
{

   person  *pTeacher;

   pTeacher = (person *)calloc(1, size

   pTeacher->year=2025;
   strcpy(pTeacher->first,"Sam");
   strcpy(pTeacher->last,"Maggs");

   UnChangeStruct(*pTeacher);
   ChangeStruct(pTeacher);
   PrintStructure(pTeacher);


   return 0;
}
```

Label	Address	Value
pTeacher	400 - 403	10000
refInputStr	500 - 503	10000
pTeacher->first	10000 - 10031	Sam
pTeacher->last	10032 - 10063	Maggs
pTeacher->year	10064 - 10067	2025

POINTERS

Passing Values TO and FROM a Function

```
void ChangeStruct( person *refInputStr)
{
   strcpy(refInputStr->first,"Ima");
   strcpy(refInputStr->last,"Dunsl");
   // refInputStr->year = 2042;
   PrintStructure(refInputStr);
}
```

```
ty
                                                    char */
                                                    char */

                                                    */
in
{

   person  *pTeacher;

   pTeacher = (person *)calloc(1, size

   pTeacher->year=2025;
   strcpy(pTeacher->first,"Sam");
   strcpy(pTeacher->last,"Maggs");

   UnChangeStruct(*pTeacher);
   ChangeStruct(pTeacher);
   PrintStructure(pTeacher);


   return 0;
}
```

Label	Address	Value
pTeacher	400 - 403	10000
refInputStr	500 - 503	10000
pTeacher->first	10000 - 10031	Ima
pTeacher->last	10032 - 10063	Dunsl
pTeacher->year	10064 - 10067	2025

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{

   person  *pTeacher;

   pTeacher = (person *)calloc(1, size

   pTeacher->year=2025;
   strcpy(pTeacher->first,"Sam");
   strcpy(pTeacher->last,"Maggs");

   UnChangeStruct(*pTeacher);
   ChangeStruct(pTeacher);
   PrintStructure(pTeacher);


   return 0;
}
```

Label	Address	Value
pTeacher	400 - 403	10000
pTeacher->first	10000 - 10031	Ima
pTeacher->last	10032 - 10063	Dunsl
pTeacher->year	10064 - 10067	2025

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{

   person  *pTeacher;

   pTeacher = (person *)calloc(4, sizeof(person));

   pTeacher[2].year=2025;
   strcpy(pTeacher[2].first,"Sam");
   strcpy(pTeacher[2].last,"Maggs");

   UnChangeStruct(pTeacher[2]);
   ChangeStruct(&pTeacher[2]);
   PrintStructure(pTeacher[2]););


   return 0;
}
```

Label	Address	Value
pTeacher	400 - 403	10000
{DM}	10000 - 10271	

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{

   person  *pTeacher;

   pTeacher = (person *)calloc(4, si

   pTeacher[2].year=2025;
   strcpy(pTeacher[2].first,"Sam");
   strcpy(pTeacher[2].last,"Maggs");

   UnChangeStruct(pTeacher[2]);
   ChangeStruct(&pTeacher[2]);
   PrintStructure(pTeacher[2]););


   return 0;
}
```

Label	Address	Value
pTeacher	400 - 403	10000
{DM}	10000 - 10135	
pTeacher[2].first	10136 - 10167	Sam
pTeacher[2].last	10168 - 10199	Maggs
pTeacher[2].year	10200 - 10203	2025
{DM}	10204 - 10271	

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
                                                    har */
                                                    har */

                                                    /

int
{

    person  *pTeacher;

    pTeacher = (person *)calloc(4, si

    pTeacher[2].year=2025;
    strcpy(pTeacher[2].first,"Sam");
    strcpy(pTeacher[2].last,"Maggs");

    UnChangeStruct(pTeacher[2]);
    ChangeStruct(&pTeacher[2]);
    PrintStructure(pTeacher[2]););


    return 0;
}
```

```
void UnChangeStruct( person inputStr)
{
    strcpy(inputstr.first,"Ima");
    strcpy(inputstr.last,"Dunsl");
    inputstr.year = 2022;
    PrintStructure(inputStr);
}
```

Label	Address	Value
pTeacher	400 - 403	10000
inputStr.first	640 - 671	Ima
inputStr.last	672 - 703	Dunsl
inputStr.year	704 - 707	2022
{DM}	10000 - 10135	
pTeacher[2].first	10136 - 10167	Sam
pTeacher[2].last	10168 - 10199	Maggs
pTeacher[2].year	10200 - 10203	2025
{DM}	10204 - 10271	

POINTERS

Passing Values TO and FROM a Function

```
void ChangeStruct( person *refInputStr)
{
   strcpy(refInputStr->first,"Ima");
   strcpy(refInputStr->last,"Dunsl");
   // refInputStr->year = 2042;
   PrintStructure(refInputStr);
}
```

```
ty                                                    char */
                                                      char */

                                                      */
in
{

   person  *pTeacher;

   pTeacher = (person *)calloc(4, si

   pTeacher[2].year=2025;
   strcpy(pTeacher[2].first,"Sam");
   strcpy(pTeacher[2].last,"Maggs");

   UnChangeStruct(pTeacher[2]);
   ChangeStruct(&pTeacher[2]);
   PrintStructure(pTeacher[2]););


   return 0;
}
```

Label	Address	Value
pTeacher	400 - 403	10000
refInputStr	500 - 503	10136
{DM}	10000 - 10135	
pTeacher[2].first	10136 - 10167	Sam
pTeacher[2].last	10168 - 10199	Maggs
pTeacher[2].year	10200 - 10203	2025
{DM}	10204 - 10271	

POINTERS

Passing Values TO and FROM a Function

```
void ChangeStruct( person *refInputStr)
{
   strcpy(refInputStr->first,"Ima");
   strcpy(refInputStr->last,"Dunsl");
   // refInputStr->year = 2042;
   PrintStructure(refInputStr);
}
```

```
ty
                                                    char */
                                                    char */

                                                    */
in
{

   person  *pTeacher;

   pTeacher = (person *)calloc(4, si

   pTeacher[2].year=2025;
   strcpy(pTeacher[2].first,"Sam");
   strcpy(pTeacher[2].last,"Maggs");

   UnChangeStruct(pTeacher[2]);
   ChangeStruct(&pTeacher[2]);
   PrintStructure(pTeacher[2]););


   return 0;
}
```

Label	Address	Value
pTeacher	400 - 403	10000
refInputStr	500 - 503	10136
{DM}	10000 - 10135	
pTeacher[2].first	10136 - 10167	Ima
pTeacher[2].last	10168 - 10199	Dunsl
pTeacher[2].year	10200 - 10203	2025
{DM}	10204 - 10271	

Structures and Memory in C

END OF PART 2

POINTERS

```
double *a;      /* a pointer variable */
a = ( double *) malloc (40);

/* can just assume the malloc(40) call set aside
   an area in the heap to accommodate 5 double variables
   (40 bytes is:
      8 bytes (size of a double variable) x 5 )
   so, the virtual labels immediately available for use )
```

Label		Address	Value
	a	400 - 403	10000
*(a+0)	a[0]	10000 - 10007	
*(a+1)	a[1]	10008 - 10015	
*(a+2)	a[2]	10016 - 10023	
*(a+3)	a[3]	10024 - 10031	
*(a+4)	a[4]	10032 - 10039	

POINTERS

```
double *a;      /* a pointer variable */
a = ( double *) malloc (40);
A[0] = 37;
A[2] = 64;
...
// BUT! What if five elements was not enough !
```

Label		Address	Value
	a	400 - 403	10000
*(a+0)	a[0]	10000 - 10007	37
*(a+1)	a[1]	10008 - 10015	
*(a+2)	a[2]	10016 - 10023	64
*(a+3)	a[3]	10024 - 10031	
*(a+4)	a[4]	10032 - 10039	

POINTERS

DYNAMIC MEMORY ALLOCATION

variations on the malloc() function

notice **malloc()** requests exact number of bytes
- programmer must know how many based on how to be used

realloc() - is used to resize allocated memory without losing existing data

```
double *a;
a = (double *)malloc(5 *sizeof(double));

a = (double *) realloc (a, 9*sizeof(double));
```

9 x 8 bytes
increase to 9 double variables
72 byes

```
// could have used
a = (double *) realloc (a, 3*sizeof(double));
```

- decrease to 3 double variables
24 bytes.

POINTERS

```
double *a;      /* a pointer variable */
a = ( double *) malloc (40);
A[0] = 37;
A[2] = 64;
...
// BUT! What if five elements was not enough !
```

Label	Address	Value
a	400 - 403	10000
{DM}	10000 - 10039	

POINTERS

```
double *a;      /* a pointer variable */
a = ( double *) malloc (40);
A[0] = 37;
A[2] = 64;
...
// BUT! What if five elements was not enough !
```

Label		Address	Value
	a	400 - 403	10000
*(a+0)	a[0]	10000 - 10007	37
*(a+1)	a[1]	10008 - 10015	
*(a+2)	a[2]	10016 - 10023	64
*(a+3)	a[3]	10024 - 10031	
*(a+4)	a[4]	10032 - 10039	

POINTERS

```
double *a;      /* a pointer variable */
a = ( double *) malloc (40);
A[0] = 37;
A[2] = 64;
...
// BUT! What if five elements was not enough !
a = realloc ( a, 7 * sizeof(double) );
```

Label	Address	Value
a	400 - 403	10000
{DM}	10000 - 10039	

POINTERS

```
double *a;      /* a pointer variable */
a = ( double *) malloc (40);
A[0] = 37;
A[2] = 64;
...
// BUT! What if five elements was not enough !
a = realloc ( a, 7 * sizeof(double) );
```

Label	Address	Value
a	400 - 403	10000
{DM}	10000 - 10055	

POINTERS

```
double *a;      /* a pointer variable */
a = ( double *) malloc (40);
A[0] = 37;
A[2] = 64;
...
// BUT! What if five elements was not enough !
a = realloc ( a, 7 * sizeof(double) );
```

Label		Address	Value
	a	400 - 403	10000
*(a+0)	a[0]	10000 - 10007	37
*(a+1)	a[1]	10008 - 10015	
*(a+2)	a[2]	10016 - 10023	64
*(a+3)	a[3]	10024 - 10031	
*(a+4)	a[4]	10032 - 10039	
*(a+5)	a[5]	10040 - 10047	
*(a+6)	a[6]	10048 - 10055	

POINTERS

```
dou
a = ( double *) malloc (40);
A[0] =
A[2] =
...
// BUT!
a = rea
```

1st case: If sufficient memory is available after address 10039, then the address of **a** doesn't change.

2nd case: If sufficient memory is not available after address 10039, then the realloc() function allocates memory somewhere else in the heap and copies the all content from old memory block to the new memory block.
In this case the address of **a** changes.

Label		Address	Value
	a	400 - 403	10000
*(a+0)	a[0]	10000 - 10007	37
*(a+1)	a[1]	10008 - 10015	
*(a+2)	a[2]	10016 - 10023	64
*(a+3)	a[3]	10024 - 10031	
*(a+4)	a[4]	10032 - 10039	
*(a+5)	a[5]	10040 - 10047	
*(a+6)	a[6]	10048 - 10055	

Structures and Memory in C

END OF PART 3

POINTERS (double pointers)

```
int i;          /* an integer variable */
int *ptr1_i;    /* a pointer variable that points to i */
int **ptr2_i;   /* a pointer variable that points to i */
int x;          /* another integer variable */

i = 37;
ptr1_i = &i;
ptr2_i = &ptr1_i;
x = **ptr2_i;
```

Label	Address	Value
i	400 - 403	37
ptr1_i	404 - 407	400
ptr2_i	408 - 411	404
x	412 - 415	37

```
#include <stdio.h>

int twoDimArray(int **passedArray)
{
    printf("address of passedArray[0]: %u\n", &passedArray[0]);
    printf("address of passedArray[1]: %u\n", &passedArray[1]);
    passedArray [0][1] = 56;
    *(*(passedArray+1)+0) = -31;    /* same as passedArray [1][0] */
}


int main(int argc, char *argv[])
{
    int **m;                    /* 4 bytes (just an address) */
    m = (int **) calloc (2, sizeof(int *) ); /* 2 x 4 bytes */
    m[0] = (int *) calloc ( 3, sizeof(int)); /* 3 x 4 bytes */
    m[1] = (int *) calloc ( 2, sizeof(int)); /* 2 x 4 bytes */
    printf("address of m[0]: %u\n", &m[0]);
    printf("address of m[1]: %u\n", &m[1]);

    twoDimArray(m);

    printf("value of m[0][1]: %d \n",m[0][1]);
    printf("value of m[1][0]: %d \n",m[1][0]);

}
```

POINTERS (double pointers)

```
int **m;                          /* 4 bytes (just an address) */
m = (int **) calloc (2, sizeof(int *) ); /* 2 x 4 bytes */
m[0] = (int *) calloc ( 3, sizeof(int)); /* 3 x 4 bytes */
m[1] = (int *) calloc ( 2, sizeof(int)); /* 2 x 4 bytes */
m[0][1] = 56;
*(*(m+1)+0) = -31;      /* same as m[1][0] - either okay */
```

Label	Address	Value
m	400 - 404	10100
{DM}	10100 - 10107	
{DM}	10108 - 10119	
{DM}	10120 - 10127	

Label	Address	Value
m	400 - 404	10100
*(m+0) m[0]	10100 - 10103	10108
*(m+1) m[1]	10104 - 10107	10120
((m+0)+0) m[0][0]	10108 - 10111	
((m+0)+1) m[0][1]	10112 - 10115	56
((m+0)+2) m[0][2]	10116 - 10119	
((m+1)+0) m[1][0]	10120 - 10123	-31
((m+1)+1) m[1][1]	10124 - 10127	

POINTERS

Passing Values TO and FROM a Function

```
#include <stdio.h>

int twoDimArray(int **passedArray)
{
    printf("address of passedArray[0]: %u\n", &passedArray[0]);
    printf("address of passedArray[1]: %u\n", &passedArray[1]);
    passedArray [0][1] = 56;
    *(*(passedArray+1)+0) = -31;    /* same as passedArray [1][0] */
}


int main(int argc, char *argv[])
{
    int **m;
    m = (int **) calloc (2,
    m[0] = (int *) calloc (
    m[1] = (int *) calloc (
    printf("address of m[0]:
    printf("address of m[1]:

    twoDimArray(m);

    printf("value of m[0][1]
    printf("value of m[1][0]

}
```

Label		Address	Value
m		400 - 404	10100
*(m+0)	m[0]	10100 - 10103	10108
*(m+1)	m[1]	10104 - 10107	10120
((m+0)+0)	m[0][0]	10108 - 10111	
((m+0)+1)	m[0][1]	10112 - 10115	56
((m+0)+2)	m[0][2]	10116 - 10119	
((m+1)+0)	m[1][0]	10120 - 10123	-31
((m+1)+1)	m[1][1]	10124 - 10127	

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{
   person  **dpTeacher;

   dpTeacher = (person **)calloc(1, sizeof(person *));

   addTeacher(dpTeacher);
   printTeacher(dpTeacher);

    strcpy(dpTeacher[0][0].first,"Bob");
    strcpy( (*dpTeacher)[0].first,"Ted");

    (*(dpTeacher+0)+2)->year = 5;

   return 0;
}
```

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{
   person  **dpTeacher;

   dpTeacher = (person **)calloc(1, sizeof(person *));

   addTeacher(dpTeacher);
   printTeacher(dpTeacher);

    strcpy(dpTeacher[0][0].first,"Bob
    strcpy( (*dpTeacher)[0].first,"Te

    (*(dpTeacher+0)+2)->year = 5;

   return 0;
}
```

Label	Address	Value
dpTeacher	400 - 403	

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{
   person  **dpTeacher;

   dpTeacher = (person **)calloc(1, sizeof(person *));

   addTeacher(dpTeacher);
   printTeacher(dpTeacher);

    strcpy(dpTeacher[0][0].first,"Bob
    strcpy( (*dpTeacher)[0].first,"Te

    (*(dpTeacher+0)+2)->year = 5;

   return 0;
}
```

Label	Address	Value
dpTeacher	400 - 403	10000
{DM}	10000 – 10003	

POINTERS

Passing Values TO and FROM a Function

```
void addTeacher(person **dpT){

  dpT[0] = (person *) calloc ( 5, sizeof(person)); /* 5 x 68 bytes */
  for (int i=0; i<5; i++){
        strcpy( (*dpT)[i].first,"Sam");
        strcpy( (*dpT)[i].last,"Maggs");
        (*dpT)[i].year = 2042;
  }
}
```

```
ty
in
{
   dpTeacher = (person **)calloc(1, sizeof(person *));

   addTeacher(dpTeacher);
   printTeacher(dpTeacher);

    strcpy(dpTeacher[0][0].first,"Bob
    strcpy( (*dpTeacher)[0].first,"Te

    (*(dpTeacher+0)+2)->year = 5;

   return 0;
}
```

Label	Address	Value
dpTeacher	400 - 403	10000
dpT	510 - 413	10000
{DM}	10000 - 10003	

POINTERS

Passing Values TO and FROM a Function

```
void addTeacher(person **dpT){

  *dpT = (person *) calloc ( 5, sizeof(person)); /* 5 x 68 bytes */
  // dpT[0] = (person *) calloc ( 5, sizeof(person));
  for (int i=0; i<5; i++){
        strcpy( (*dpT)[i].first,"Sam");
        strcpy( (*dpT)[i].last,"Maggs");
        (*dpT)[i].year = 2042;
   }
}
```

```
ty

in
{
    dpTeacher = (person **)calloc(1, sizeof(person *));

    addTeacher(dpTeacher);
    printTeacher(dpTeacher);

     strcpy(dpTeacher[0][0].first,"Bob
     strcpy( (*dpTeacher)[0].first,"Te

     (*(dpTeacher+0)+2)->year = 5;

    return 0;
}
```

Label	Address	Value
dpTeacher	400 - 403	10000
dpT	510 - 413	10000
{DM}	10000 - 10003	10140
{DM}	10140 - 10479	

POINTERS

Passing Values TO and FROM a Function

```
void addTeacher(person **dpT){

  dpT[0] = (person *) calloc ( 5, sizeof(person)); /* 5 x 68 bytes */
   for (int i=0; i<5; i++){
         strcpy( (*dpT)[i].first,"Sam");
         strcpy( (*dpT)[i].last,"Maggs");
         (*dpT)[i].year = 2042;
   }
}
```

```
ty

in
{

   dpTeacher = (person **)calloc(1, sizeof(person *));

   addTeacher(dpTeacher);
   printTeacher(dpTeacher);

    strcpy(dpTeacher[0][0].first,"Bob
    strcpy( (*dpTeacher)[0].first,"Te

    (*(dpTeacher+0)+2)->year = 5;

   return 0;
}
```

Label	Address	Value
dpTeacher	400 - 403	10000
dpT	510 - 413	10000
dpT[0]	10000 - 10003	10140
{DM}	10140 - 10479	

POINTERS

Passing Values TO and FROM a Function

```
void addTeacher(person **dpT){

  dpT[0] = (person *) calloc ( 5, sizeof(person)); /* 5 x 68 bytes */
  for (int i=0; i<5; i++){
        strcpy( (*dpT)[i].first,"Sam");
        strcpy( (*dpT)[i].last, "Maggs");
        (*dpT)[i].year = 2042;
  }
}
```

```
ty

in
{

    dpTeacher = (person **)calloc(1, sizeof(person *));

    addTeacher(dpTeacher);
    printTeacher(dpTeacher);

     strcpy(dpTeacher[0][0].first,"Bob
     strcpy( (*dpTeacher)[0].first,"Te

     (*(dpTeacher+0)+2)->year = 5;

    return 0;
}
```

Label	Address	Value
dpTeacher	400 - 403	10000
dpT	510 - 413	10000
dpt[0]	10000 - 10003	10140
dpt[0][0].first	10140 - 10171	Sam
dpt [0][0].last	10172 - 10203	Maggs
dpt[0][0].year	10204 - 10207	2042
dpt[0][1].first	10208 - 10239	Sam
{DM}	10240 - 10271	

POINTERS

Passing Values TO and FROM a Function

```
void addTeacher(person **dpT){

  dpT[0] = (person *) calloc ( 5, sizeof(person)); /* 5 x 68 bytes */
  for (int i=0; i<5; i++){
        strcpy( (*dpT)[i].first,"Sam");
        strcpy( (*dpT)[i].last, "Maggs");
        (*dpT)[i].year = 2042;
  }
}
```

```
ty

in
{

    dpTeacher = (person **)calloc(1, sizeof(person *));

    addTeacher(dpTeacher);
    printTeacher(dpTeacher);

     strcpy(dpTeacher[0][0].first,"Bob
     strcpy( (*dpTeacher)[0].first,"Te

     (*(dpTeacher+0)+2)->year = 5;

    return 0;
}
```

Label	Address	Value
dpTeacher	400 - 403	10000
dpT	510 - 413	10000
*dpt	10000 - 10003	10140
*dpt[0].first	10140 - 10171	Sam
*dpt [0].last	10172 - 10203	Maggs
*dpt[0].year	10204 - 10207	2042
*dpt[1].first	10208 - 10239	Sam
{DM}	10240 - 10271	

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{
   person  **dpTeacher;

   dpTeacher = (person **)calloc(1, sizeof(person *));

   addTeacher(dpTeacher);
   printTeacher(dpTeacher);

    strcpy(dpTeacher[0][0].first,"Bob
    strcpy( (*dpTeacher)[0].first,"Te

    (*(dpTeacher+0)+2)->year = 5;

   return 0;
}
```

Label	Address	Value
dpTeacher	400 - 403	10000
*dpt	10000 - 10003	10140
*dpt[0].first	10140 - 10171	Sam
*dpt [0].last	10172 - 10203	Maggs
*dpt[0].year	10204 - 10207	2042
*dpt[1].first	10208 - 10239	Sam
{DM}	10240 - 10271	

POINTERS

Passing Values TO and FROM a Function

```
void printTeacher(person **dpT){

   printf("\nThis is the contents of the dynamically allocated:\n");
   for (int i=1;i<=3;i++){
     printf("Teacher %s ",(*dpT)[i].first);
     printf("%s ",dpT[0][i].last);
     printf("%d\n\n",(*(dpT+0)+i)->year);
   }
}
```

```
ty
in
{
   dpTeacher = (person **)calloc(1, sizeof(person *));

   addTeacher(dpTeacher);
   printTeacher(dpTeacher);

    strcpy(dpTeacher[0][0].first,"Bob
    strcpy( (*dpTeacher)[0].first,"Te

    (*(dpTeacher+0)+2)->year = 5;

   return 0;
}
```

Label	Address	Value
dpTeacher	400 - 403	10000
dpT	620 - 623	10000
*dpt	10000 - 10003	10140
*dpt[0].first	10140 - 10171	Sam
*dpt [0].last	10172 - 10203	Maggs
*dpt[0].year	10204 - 10207	2042
*dpt[1].first	10208 - 10239	Sam
{DM}	10240 - 10271	

POINTERS

Passing Values TO and FROM a Function

```
void printTeacher(person **dpT){

   printf("\nThis is the contents of the dynamically allocated:\n");
   for (int i=1;i<=3;i++){
     printf("Teacher %s ",(*dpT)[i].first);
     printf("%s ",dpT[0][i].last);
     printf("%d\n\n",(*(dpT+0)+i)->year);
   }
}
```

```
ty

in
{

   dpTeacher = (person **)calloc(1, sizeof(person *));

   addTeacher(dpTeacher);
   printTeacher(dpTeacher);

    strcpy(dpTeacher[0][0].first,"Bob
    strcpy( (*dpTeacher)[0].first,"Te

    (*(dpTeacher+0)+2)->year = 5;

   return 0;
}
```

Label	Address	Value
dpTeacher	400 - 403	10000
dpT	620 - 623	10000
*dpt	10000 - 10003	10140
*dpt[0].first	10140 - 10171	Sam
*dpt [0].last	10172 - 10203	Maggs
*dpt[0].year	10204 - 10207	2042
*dpt[1].first	10208 - 10239	Sam
{DM}	10240 - 10271	

POINTERS

Passing Values TO and FROM a Function

```
void printTeacher(person **dpT){

   printf("\nThis is the contents of the dynamically allocated:\n");
   for (int i=1;i<=3;i++){
     printf("Teacher %s ",(*dpT)[i].first);
     printf("%s ",dpT[0][i].last);
     printf("%d\n\n",(*(dpT+0)+i)->year);
   }
}
```

```
ty

in
{

   dpTeacher = (person **)calloc(1, sizeof(person *));

   addTeacher(dpTeacher);
   printTeacher(dpTeacher);

    strcpy(dpTeacher[0][0].first,"Bob
    strcpy( (*dpTeacher)[0].first,"Te

    (*(dpTeacher+0)+2)->year = 5;

   return 0;
}
```

Label	Address	Value
dpTeacher	400 - 403	10000
dpT	620 - 623	10000
*dpt	10000 - 10003	10140
*dpt[0].first	10140 - 10171	Sam
dpt [0][1].last	10172 - 10203	Maggs
*dpt[0].year	10204 - 10207	2042
*dpt[1].first	10208 - 10239	Sam
{DM}	10240 - 10271	

POINTERS

Passing Values TO and FROM a Function

```
void printTeacher(person **dpT){

   printf("\nThis is the contents of the dynamically allocated:\n");
   for (int i=1;i<=3;i++){
     printf("Teacher %s ",(*dpT)[i].first);
     printf("%s ",dpT[0][i].last);
     printf("%d\n\n",(*(dpT+0)+i)->year);
   }
}
```

```
ty

in
{

   dpTeacher = (person **)calloc(1, sizeof(person *));

   addTeacher(dpTeacher);
   printTeacher(dpTeacher);

    strcpy(dpTeacher[0][0].first,"Bob
    strcpy( (*dpTeacher)[0].first,"Te

    (*(dpTeacher+0)+2)->year = 5;

   return 0;
}
```

Label	Address	Value
dpTeacher	400 - 403	10000
dpT	620 - 623	10000
*dpt	10000 - 10003	10140
*dpt[0].first	10140 - 10171	Sam
*dpt [0].last	10172 - 10203	Maggs
(*(dpT+0)+1)year	10204 - 10207	2042
*dpt[1].first	10208 - 10239	Sam
{DM}	10240 - 10271	

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{
   person  **dpTeacher;

   dpTeacher = (person **)calloc(1, sizeof(person *));

   addTeacher(dpTeacher);
   printTeacher(dpTeacher);

    strcpy(dpTeacher[0][0].first,"Bob
    strcpy( (*dpTeacher)[0].first,"Te

    (*(dpTeacher+0)+2)->year = 5;

   return 0;
}
```

Label	Address	Value
dpTeacher	400 - 403	10000
*dpt	10000 - 10003	10140
*dpt[0].first	10140 - 10171	Sam
*dpt [0].last	10172 - 10203	Maggs
*dpt[0].year	10204 - 10207	2042
*dpt[1].first	10208 - 10239	Sam
{DM}	10240 - 10271	

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{
   person  **dpTeacher;

   dpTeacher = (person **)calloc(1, sizeof(person *));

   addTeacher(dpTeacher);
   printTeacher(dpTeacher);

    strcpy(dpTeacher[0][0].first,"Bob
    strcpy( (*dpTeacher)[0].first,"Te

    (*(dpTeacher+0)+2)->year = 5;

   return 0;
}
```

Label	Address	Value
dpTeacher	400 - 403	10000
{DM}	10000 - 10003	10140
{DM}	10140 - 10271	*****

POINTERS

```
typedef struct human {
          char     first[32];
          char     last[32];
          int      year;
          } person;

int main()
{
   person  **dpTeacher;

   dpTeacher = (person **)calloc

   addTeacher(dpTeacher);
   printTeacher(dpTeacher);

    strcpy(dpTeacher[0][0].first,"Bob");
     strcpy( (*dpTeacher)[0].first,"Ted");

     (*(dpTeacher+0)+2)->year = 5;

   return 0;
}
```

Label	Address	Value
dpTeacher	400 - 403	10000
dpTeacher[0]	10000 - 10003	10140
dpTeacher[0][0].first	10140 - 10171	Bob
dpTeacher[0][0].last	10172 - 10203	Maggs
dpTeacher[0][0].year	10204 - 10207	2042
dpTeacher[0][1].first	10208 - 10239	Sam
{DM}	10240 - 10271	

POINTERS

```
typedef struct human {
          char     first[32];
          char     last[32];
          int      year;
          } person;

int main()
{
   person  **dpTeacher;

   dpTeacher = (person **)calloc

   addTeacher(dpTeacher);
   printTeacher(dpTeacher);

    strcpy(dpTeacher[0][0].first,"Bob");
    strcpy( (*dpTeacher)[0].first,"Ted");

    (*(dpTeacher+0)+2)->year = 5;

   return 0;
}
```

Label	Address	Value
dpTeacher	400 - 403	10000
*dpTeacher	10000 - 10003	10140
*dpTeacher[0].first	10140 - 10171	Bob
*dpTeacher[0].last	10172 - 10203	Maggs
*dpTeacher[0].year	10204 - 10207	2042
*dpTeacher[1].first	10208 - 10239	Sam
{DM}	10240 - 10271	

POINTERS

```
typedef struct human {
          char     first
          char     last[
          int      year;
          } person;

int main()
{
    person  **dpTeacher

    dpTeacher = (person

    addTeacher(dpTeache
    printTeacher(dpTeac

     strcpy(dpTeacher[0][0].first,"Bob");
     strcpy( (*dpTeacher)[0].first,"Ted");

    (*(dpTeacher+0)+2)->year = 5;

    return 0;
}
```

Label	Address	Value
dpTeacher	400 - 403	10000
*(dpTeacher+0)	10000 - 10003	10140
(*(dpTeacher+0)+0) ->first	10140 - 10171	Bob
(*(dpTeacher+0)+1)->last	10172 - 10203	Maggs
(*(dpTeacher+0)+2)->year	10204 - 10207	2042
(*(dpTeacher+1)+0)->first	10208 - 10239	Sam
{DM}	10240 - 10271	

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{
   person  **dpTeacher;

   dpTeacher = (person **)calloc(1, sizeof(person *));

   addTeacher(dpTeacher);
   printTeacher(dpTeacher);

    strcpy(dpTeacher[0][0].first,"Bob");
    strcpy( (*dpTeacher)[0].first,"Ted");

    (*(dpTeacher+0)+2)->year = 5;

   return 0;
}
```

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{
   person  **dpTeacher;

   dpTeacher = (person **)calloc(3, sizeof(person *));
   dpTeacher[0] = (person *) calloc ( 5, sizeof(person)); /* 5 x 68 bytes */
   dpTeacher[1] = (person *) calloc ( 5, sizeof(person)); /* 5 x 68 bytes */
   dpTeacher[2] = (person *) calloc ( 5, sizeof(person)); /* 5 x 68 bytes */

   addTeacher(dpTeacher);        /* print a part or the whole matrix */
   printTeacher(dpTeacher[1]);   /* print an entire row */

    strcpy(dpTeacher[2][3].first,"Bob");
    strcpy( (*dpTeacher+2)[0].first,"Ted");

    (*(dpTeacher+1)+2)->year = 5;

   return 0;
}
```

POINTERS

Passing Values TO and FROM a Function

```
typedef struct human {
         char    first[32];      /* 1st field is array of char */
         char    last[32];       /* 2nd field is array of char */
         int     year;           /* 3rd field is int */
         } person;               /* alias for human UDT ; */

int main()
{
   person  **dpTeacher;

   dpTeacher = (person **)calloc(3, sizeof(person *));
   dpTeacher[0] = (person *) calloc ( 5, sizeof(person)); /* 5 x 68 bytes */
   dpTeacher[1] = (person *) calloc (
   dpTeacher[2] = (person *) calloc (

   addTeacher(dpTeacher);          /* pr
   printTeacher(dpTeacher[1]);     /* pr

    strcpy(dpTeacher[2][3].first,"Bob
    strcpy( (*dpTeacher+2)[0].first,"

    (*(dpTeacher+1)+2)->year = 5;

   return 0;
}
```

Label	Address	Value
dpTeacher	400 - 403	10000
{DM}	10000 - 10011	10140
{DM}	10140 - 10479	*****
{DM}	10200 - 10539	*****
{DM}	10540 - 10879	*****

Double Pointers

END OF PART 4