6.1 Addresses and Pointers

Recall memory concepts from Ch2

```
int x1=1, x2=7;

double distance;

int *p;

int q=8;

p = &q;
```

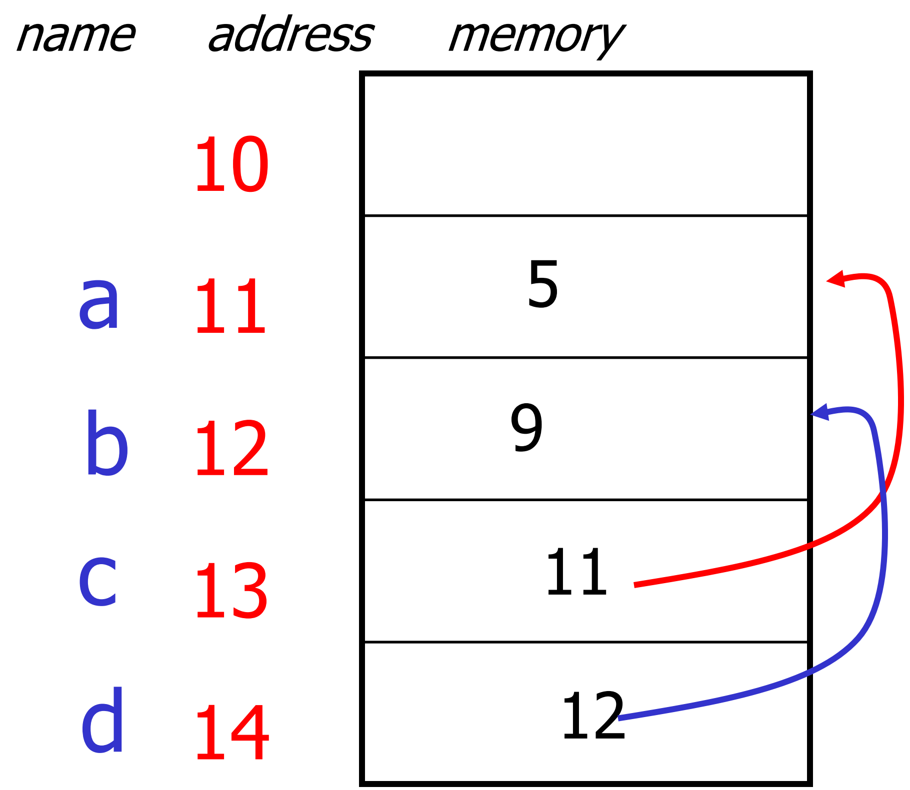
name	*address*	*Memory - content*
	10	
	11	
x1	12	1 = 00000001
x2	13	7 = 00000111
distance	14	? = arbitrary 1's and 0's
p	15	16
q	16	8
	...	

* has different meanings in different contexts

- `a = x * y;` → multiplication
- `int *ptr;` → declare a pointer
- * is also used as **indirection** or **de-referencing** operator in C statements.
- `ptr = &y;`
- `a = x * *ptr;`

Example: Pointers, address, indirection

```
int a, b;
int *c, *d;
a = 5;
c = &a;
d = &b;
*d = 9;
print c, *c, &c
print a, b
```




```
c=11   *c=5    &c=13

a=5  b=9
```

Exercise:
Trace the following code

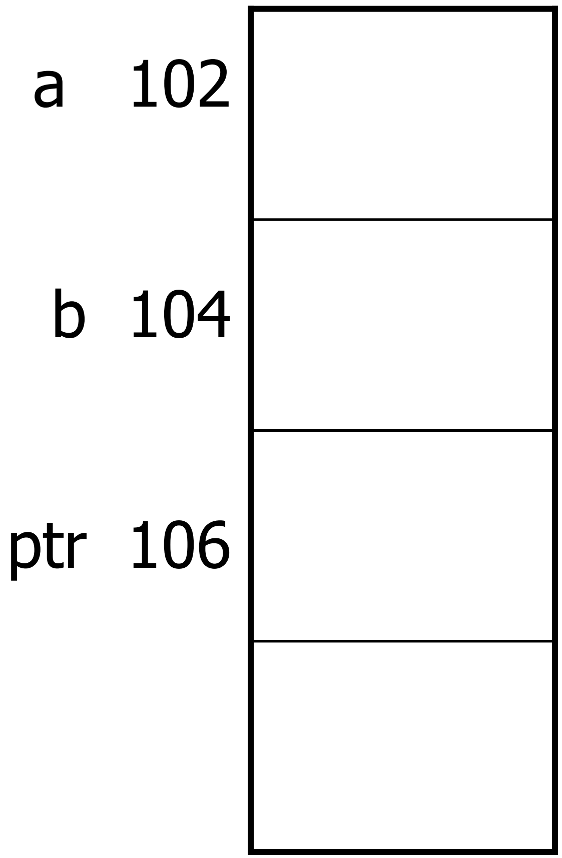
```
int x, y;
int *p1, *p2;
x = 3 + 4;
Y = x / 2 + 5;
p1 = &y;
p2 = &x;
*p1 = x + *p2;
*p2 = *p1 + y;
print p1, *p1, &p1
print x, &x, y, &y
```

name	*address*	*memory*
	510	
x	511	?
y	512	?
p1	513	?
p2	514	?

Exercise

Give a memory snapshot after each set of assignment statements

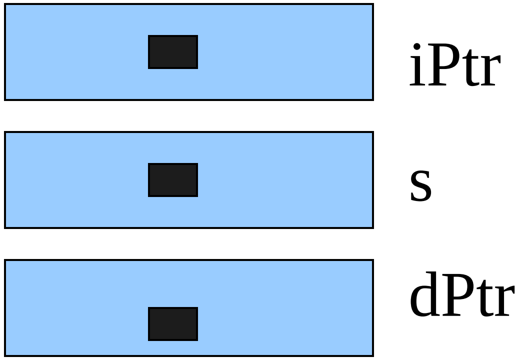
```
int a=1, b=2, *ptr;
ptr  = &b;
a    = *ptr;
*ptr = 5;
```



NULL pointer

- A pointer can be assigned or compared to the integer zero, or, equivalently, to the symbolic constant **NULL**, which is defined in **<stdio.h>**.
- A pointer variable whose value is NULL is not pointing to anything that can be accessed

Pointer Initialization




```
int *iPtr=0;
char *s=0;
double *dPtr=NULL;
```

!!! When we assign a value to a pointer during it is declaration, we mean to put that value into pointer variable (no indirection)!!!

`int *iPtr=0;` is same as

```
int *iPtr;
iPtr=0; /* not like *iPtr = 0; */
```

Many-to-One Pointing

A pointer can point to only one location at a time, but several pointers can point to the same location.

```
/* Declare and
   initialize variables. */
int x=-5, y = 8;
int *ptr1, *ptr2;

/*  Assign both pointers
    to point to x.  */
ptr1 = &x;
ptr2 = ptr1;
```

The memory snapshot after these statements are executed

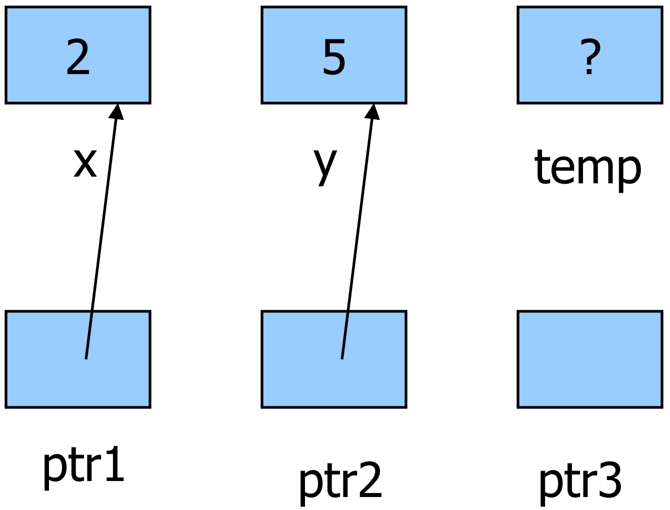
Exercise

Show the memory snapshot after the following operations

```
int x=2, y=5, temp;
int *ptr1, *ptr2, *ptr3;

// make ptr1 point to x
  ptr1 = &x;

// make ptr2 point to y
  ptr2 = &y;
```

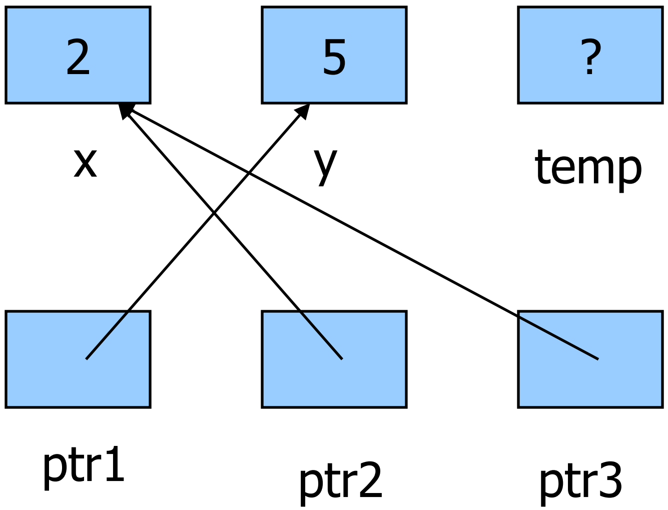


Exercise

Show the memory snapshot after the following operations

```
// swap the contents of
// ptr1 and ptr2

  ptr3 = ptr1;
  ptr1 = ptr2;
  ptr2 = ptr3;
```

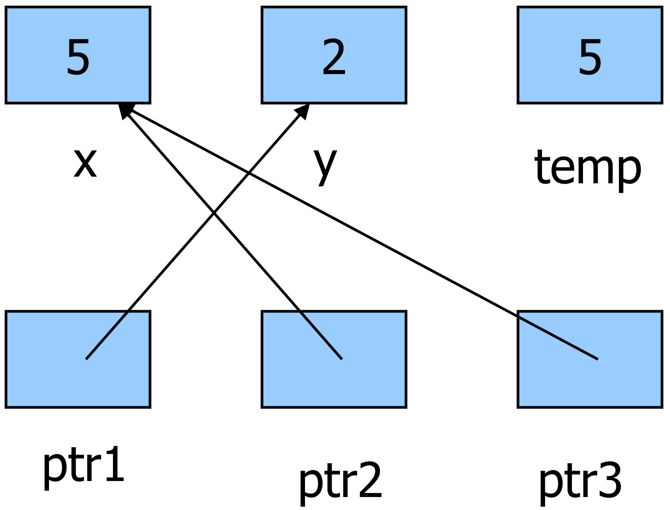


Exercise

Show the memory snapshot after the following operations

```
// swap the values pointed
// by ptr1 and ptr2

  temp = *ptr1;
  *ptr1 = *ptr2;
  *ptr2 = temp;
```



Comparing Pointers

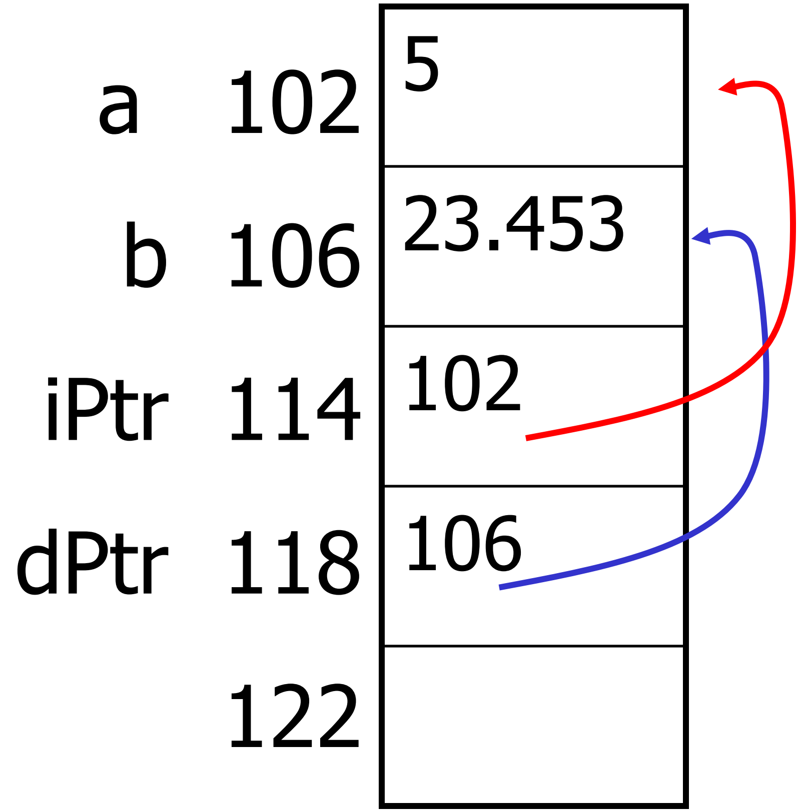
- You may compare pointers using >,<,== etc.
- Common comparisons are:
  - check for null pointer `if (p == NULL)` …
  - check if two pointers are pointing to the same location
    - `if (p == q)` … Is this equivalent to
    - `if (*p == *q)` …
  - Then what is `if (*p == *q)` …
    - compare two values pointed by p and q

Pointer types

- Declaring a pointer creates a variable that is capable of holding an address
- And addresses are integers!
- But, the type we specify in the declaration of a pointer is the type of variable to which this pointer points
  - *!!! a pointer defined to point to an integer variable cannot also point to a float/double variable even though both holds integer address values !!!*

Example: pointers with different types

```
int a=5;
double b=23.452;
int *iPtr;
double *dPtr;
iPtr = &a;
dPtr = &b;
```



- the variable iPtr is declared to point to an int
- the variable dPtr is declared to point to a double

6.4 Pointers in Function References (!IMPORTANT!)

- In C, function references are call-by-value except when an array name is used as an argument.
  - An array name is the address of the first element
  - Values in an array can be modified by statements within a function
- To modify a function argument, a pointer to the argument must be passed
  - `scanf("%f", &X);` This statement specifies that the value read is to be stored at the address of X
- The actual parameter that corresponds to a pointer argument must be an address or pointer.

Call by Value

```
void swap(int a,int b)
{
   int temp;

   temp = a;
   a = b;
   b = temp;

   return;
}
```

```
main()
{
  int x = 2, y = 3;

  printf("%d %d\n",x,y);
   swap(x,y);
  printf("%d %d\n",x,y);
}
```

Changes made in function swap are lost when the function execution is over

Call by reference

```
void swap2(int *aptr,
           int *bptr)
{
  int temp;

  temp = *aptr;
  *aptr = *bptr;
  *bptr = temp;

  return;
}
```

```
main()
{
 int x = 2, y = 3;

 printf("%d %d\n",x,y);
  swap2(&x, &y);
 printf("%d %d\n",x,y);
}
```

Changes made in function swap are done on original x and y and.
So they do not get lost when the function execution is over

Trace a program

```
main()
{
  int x0=5, x1=2, x2=3;
  int *p1=&x1, *p2;

  p2 = &x2;

  swap2(&x0, &x1);

  swap2(p1, p2);

  printf("%d %d %d\n", x0, x1, x2);
}
void swap2(int *a, int *b)
{
   int tmp;

   tmp = *a;
   *a = *b;
   *b = tmp;
   return;
}
```

Name	Addr	Value
x0	1	
x1	2	
x2	3	
p1	4	
p2	5	
	6	
a	7	
b	8	
tmp	9	

Now we can get more than one value from a function

- Write a function to compute the roots of quadratic equation ax^2+bx+c=0. How to return two roots?

```
void comproots(int a,int b,int c,
          double *dptr1, double *dptr2)
{
 *dptr1 = (-b - sqrt(b*b-4*a*c))/(2.0*a);
 *dptr2 = (-b + sqrt(b*b-4*a*c))/(2.0*a);
 return;
}
```

Exercise cont'd

```
main()
{
   int a,b,c;
   double root1,root2;

   printf("Enter Coefficients:\n");
   scanf("%d %d %d",&a,&b,&c);

   computeroots(a,b,c,&root1,&root2);

   printf("First Root = %lf\n",root1);
   printf("Second Root = %lf\n",root2);
}
```

Trace a program

```
main()
{
  int x, y;
  max_min(4, 3, 5, &x, &y);
  printf(" First: %d  %d", x, y);
  max_min(x, y, 2, &x, &y);
  printf("Second: %d  %d", x, y);
}
void max_min(int a, int b, int c,
             int *max, int *min)
{
   *max = a;
   *min = a;
   if (b > *max) *max = b;
   if (c > *max) *max = c;
   if (b < *min) *min = b;
   if (c < *min) *min = c;
   printf("F: %d  %d\n", max, *max);
}
```

name	Addr	Value
x	1	
y	2	
	3	
	4	
	5	
a	6	
b	7	
c	8	
max	9	
min	10	

Pointer Arithmetic

- Four arithmetic operations are supported
  - +, -, ++, --
  - only integers may be used in these operations
  - Arithmetic is performed relative to the variable type being pointed to
  - MOSTLY USED WITH ARRAYS (see next section)

Example: p++;

  - if p is defined as int *p, p will be incremented by 4 (system dependent)
  - if p is defined as double *p, p will be incremented by 8(system dependent
  - when applied to pointers, ++ means increment pointer to point to next value in memory

6.2 Pointers and Arrays

- The name of an array is the address of the first elements (i.e. a pointer to the first element)
- The array name is a *constant* that always points to the first element of the array and its value can not be changed.
- Array names and pointers may often be used interchangeably.

Example

```
int num[4] = {1,2,3,4}, *p, q[];
p = num;
q = p; // or q = num;
/* above assignment is the same as p = &num[0]; */
printf("%i", *p);     // print num[0]
p++;
printf("%i", *p);     // print num[1]
printf("%i",  *q); // print num[0]
printf("%i", *(p+2));     // print num[2]
```

Pointers and Arrays (cont'd)

- You can also index a pointer using array notation

```
char string[] = “This is a string”;
char *str;
int i;
str = string;
for(i =0; str[i]!=NULL; i++)
  printf(“%c”, str[i]);
```

Two Dimensional Arrays

A two-dimensional array is stored in sequential memory locations, in row order.

```
int s[2][3] = {{2,4,6}, {1,5,3}};

int *sptr = &s[0][0];

Memory allocation:

s[0][0]    2
s[0][1]    4
s[0][2]    6
s[1][0]    1
s[1][1]    5
s[1][2]    3

A pointer reference to s[0][1] would be *(sptr+1)
A pointer reference to s[1][1] would be *(sptr+4)
```

row offset * number of columns + column offset

6.7 Dynamic Memory Allocation

- Dynamically allocated memory is determined at *runtime*
- A program may create as many or as few variables as required, offering greater flexibility
- Dynamic allocation is often used to support data structures such as stacks, queues, linked lists and binary trees.
- Dynamic memory is finite
- Dynamically allocated memory may be freed during execution

Dynamic Memory Allocation

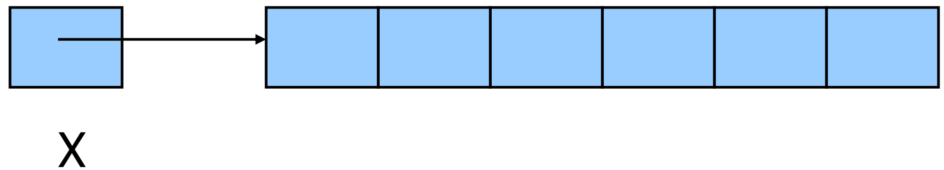
- Memory is allocated using the:
  - malloc function (memory allocation)
  - calloc function (cleared memory allocation)
- Memory is released using the:
  - free function
- The size of memory requested by malloc or calloc can be changed using the:
  - realloc function

malloc and calloc

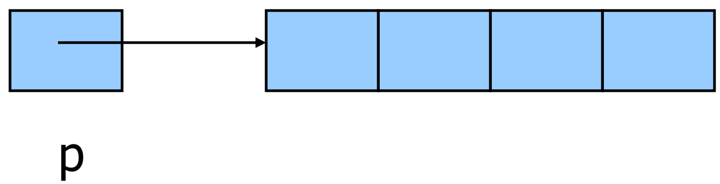
- Both functions return a pointer to the newly allocated memory
- If memory can not be allocated, the value returned will be a **NULL** value
- The pointer returned by these functions is declared to be a **void pointer**
- A cast operator should be used with the returned pointer value to coerce it to the proper pointer type

Example of malloc and calloc

```
int n = 6, m = 4;
double *x;
int *p;
```




```
/*  Allocate memory for 6 doubles.  */
x = (double *)malloc(n*sizeof(double));
```




```
/*  Allocate memory for 4 integers.  */
p = (int *)calloc(m,sizeof(int));
```