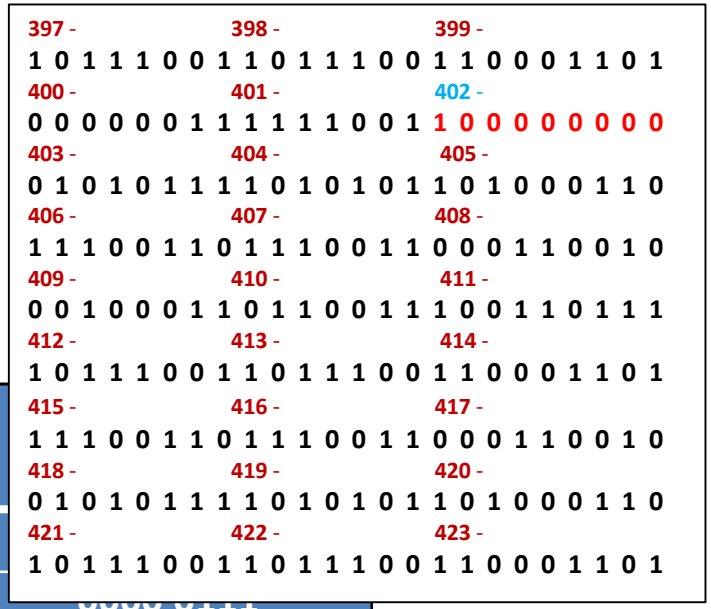
CS 1037
Computer Science Fundamentals II

Part Six:

Pointers

POINTERS

… nothing more than a mechanism to manipulate and utilize computer memory



Label	Address	Value	
	399		
a	400	7	[illegible]
b	401	-13	1111 0011
c	402	0	0000 0000
	403		
	404		
	405		
	406		
	…		

POINTERS

… nothing more than a mechanism to
manipulate and utilize computer memory

- nothing more than just another variable
  - BUT instead of a value – it stores an **address** to another variable

* (asterisk) – declare a pointer variable of a type
* (asterisk) – what the address points to [indirection]
(go to the value 'box' of the address stored in this value)

& (ampersand) – return the address of the variable.

POINTERS

… nothing more than a mechanism to
manipulate and utilize computer memory

- **Declaration**
  variable type (asterisk) pointer variable name
  - all pointer variables are same size (same number of bits)

    conventional memory (DOS) (2.5 bytes – 20 bits)
    (what is the limit in size of available memory?)
    2^{20} = 1,048,576 (~ 1 MB) [640 kb of usable memory]

    based on OS and architecture (assume 4 bytes – 32 bits)
    (what is the limit in size of available memory?)
    2^{32} = 4,294,967,295 (~ 4 Gigs)

    based on OS and architecture (assume 8 bytes – 64 bits)
    (what is the limit in size of available memory?)
    2^{64} = 18,446,744,073,709,551,616 (~ 16 EiB [exabytes])

POINTERS

… nothing more than a mechanism to
manipulate and utilize computer memory

- for the remainder of this class: Assume 32 bits

When a pointer variable is declared
- the variable name must be preceded by an asterisk:

```
int *p;
```

`p` in this incarnation is a pointer variable capable of pointing to **objects** of type **int**.

- why not a "pointer" variable type instead ?
- **pointer arithmetic** –the computer must know what the data type is

POINTERS

… nothing more than a mechanism to
manipulate and utilize computer memory

- **Declaration**

Pointer variables can appear in declarations along with other variables:

```
int i, j, a[10], b[20], *p, *q;
```

C requires that every pointer variable point only to:
objects of a particular type (the **referenced** type):

```
int *p;      /* points only to integers   */
double *q;   /* points only to doubles    */
char *r;     /* points only to characters */
```

There are no restrictions on what the referenced type may be.

POINTERS

… nothing more than a mechanism to
manipulate and utilize computer memory

* (asterisk) – indirection:
go to the **memory location** stored in this variable and return the value from that location.

& (ampersand) – return the **address** of the variable.

POINTERS

```
char c;    /* 1 byte */
```

Label	Address	Value
c	400 -	

POINTERS

```
char c;    /* 1 byte */
char *cp   /* a pointer of type char 4 bytes */
```

Label	Address	Value
c	400 -	
cp	401 - 404	

POINTERS

```
char c;    /* 1 byte */
char *cp   /* a pointer of type char 4 bytes */
```

WARNING:
Declaring a pointer variable sets aside space for a pointer
but doesn't make it point to an object:

```
char *cp;  /* points nowhere */
```

It's crucial to define **cp** before we use it.

Label	Address	Value
c	400 -	
cp	401 - 404	

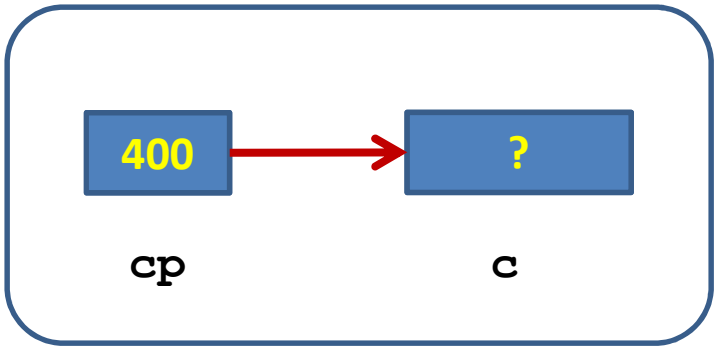
POINTERS

```
char c;    /* 1 byte */
char *cp   /* a pointer of type char 4 bytes */

cp = &c;   /* cp is assigned the ADDRESS of c */
```

Label	Address	Value
c	400 -	
cp	401 - 404	400

POINTERS

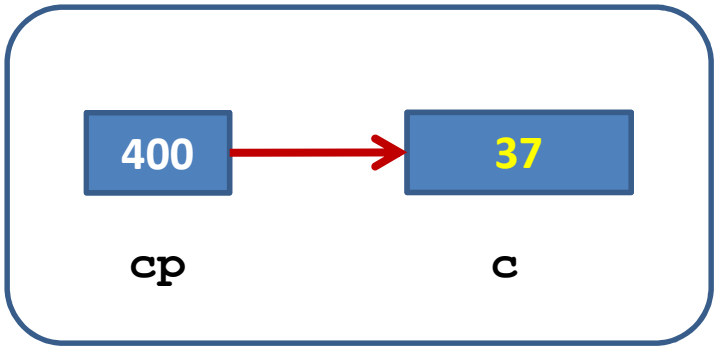
```
char c;    /* 1 byte */
char *cp   /* a pointer of type char 4 bytes */

cp = &c;   /* cp is assigned the ADDRESS of c */
```



Label	Address	Value
c	400 -	
cp	401 - 404	400

POINTERS

```
char c;    /* 1 byte */
char *cp   /* a pointer of type char 4 bytes */

cp = &c;   /* cp is assigned the ADDRESS of c */
*cp = 37; /* in the location stored in cp */
```



Label	Address	Value
c	400 -	37
cp	401 - 404	400

POINTERS

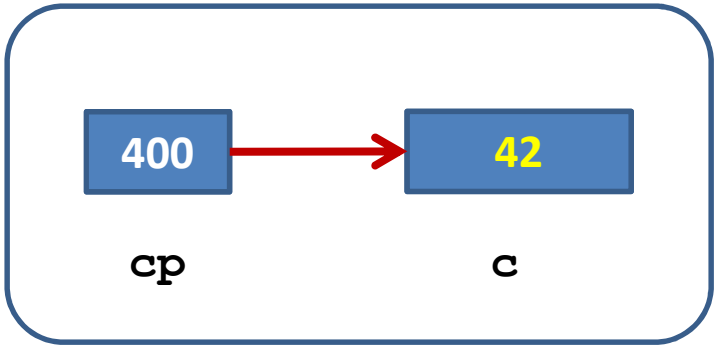
```
char c;    /* 1 byte */
char *cp   /* a pointer of type char 4 bytes */

cp = &c;   /* cp is assigned the ADDRESS of c */
*cp = 37; /* in the location stored in cp */
printf("c = %d and *cp = %d and %u\n", c, *cp, cp);
```

output:
37 and 37 and 400

Label	Address	Value
c	400 -	37
cp	401 - 404	400

POINTERS

```
char c;    /* 1 byte */
char *cp   /* a pointer of type char 4 bytes */

cp = &c;   /* cp is assigned the ADDRESS of c */
*cp = 37; /* in the location stored in cp */
printf("c = %d and *cp = %d and %u\n", c, *cp, cp);
c = 42;
```



Label	Address	Value
c	400 -	42
cp	401 - 404	400

POINTERS

```
char c;    /* 1 byte */
char *cp   /* a pointer of type char 4 bytes */

cp = &c;   /* cp is assigned the ADDRESS of c */
*cp = 37; /* in the location stored in cp */
printf("c = %d and *cp = %d and %u\n", c, *cp, cp);
c = 42;
printf("c = %d and *cp = %d and %u\n", c, *cp, cp);
```

output:
37 and 37 and 400
42 and 42 and 400

Label	Address	Value
c	400 -	42
cp	401 - 404	400

POINTERS

```
char c,*cp;        /* 1 byte  – 4 bytes */
```

Label	Address	Value
c	400 -	
cp	401 - 404	

POINTERS

```
char c,*cp;        /* 1 byte  - 4 bytes */
int i,*ip;         /* 4 bytes - 4 bytes */
```

Label	Address	Value
c	400 -	
cp	401 - 404	
i	405 - 408	
ip	409 - 412	

POINTERS

```
char c,*cp;        /* 1 byte  - 4 bytes */
int i,*ip;         /* 4 bytes - 4 bytes */
float f,*fp;       /* 4 bytes - 4 bytes */
```

Label	Address	Value
c	400 -	
cp	401 - 404	
i	405 - 408	
ip	409 - 412	
f	413 – 416	
fp	417 – 420	

POINTERS

```
char c,*cp;        /* 1 byte  - 4 bytes */
int i,*ip;         /* 4 bytes - 4 bytes */
float f,*fp;       /* 4 bytes - 4 bytes */
double d,*dp;      /* 8 bytes - 4 bytes */
```

Label	Address	Value
c	400 -	
cp	401 - 404	
i	405 - 408	
ip	409 - 412	
f	413 – 416	
fp	417 – 420	
d	421 – 428	
dp	429 - 432	

POINTERS

```
char c,*cp;        /* 1 byte  - 4 bytes */
int i,*ip;         /* 4 bytes - 4 bytes */
float f,*fp;       /* 4 bytes - 4 bytes */
double d,*dp;      /* 8 bytes - 4 bytes */

cp = &c;
```

Label	Address	Value
c	400 -	
cp	401 - 404	400
i	405 - 408	
ip	409 - 412	
f	413 – 416	
fp	417 – 420	
d	421 – 428	
dp	429 - 432	

POINTERS

```
char c,*cp;        /* 1 byte  - 4 bytes */
int i,*ip;         /* 4 bytes - 4 bytes */
float f,*fp;       /* 4 bytes - 4 bytes */
double d,*dp;      /* 8 bytes - 4 bytes */

cp = &c;
ip = &i;
```

Label	Address	Value
c	400 -	
cp	401 - 404	400
i	405 - 408	
ip	409 - 412	405
f	413 – 416	
fp	417 – 420	
d	421 – 428	
dp	429 - 432	

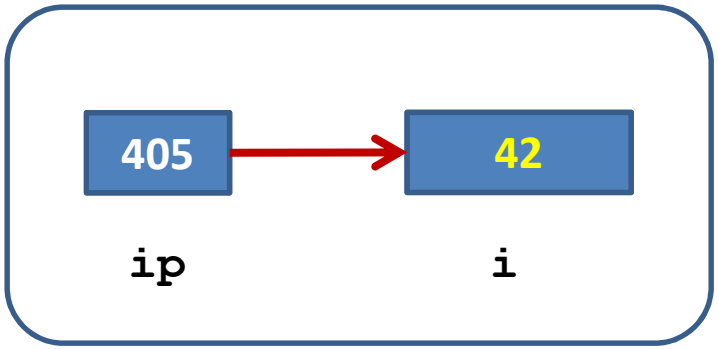
POINTERS

```
char c,*cp;        /* 1 byte  - 4 bytes */
int i,*ip;         /* 4 bytes - 4 bytes */
float f,*fp;       /* 4 bytes - 4 bytes */
double d,*dp;      /* 8 bytes - 4 bytes */

cp = &c;
ip = &i;
*ip = 42;
```

Label	Address	Value
c	400 -	
cp	401 - 404	400
i	405 - 408	42
ip	409 - 412	405
f	413 – 416	
fp	417 – 420	
d	421 – 428	
dp	429 - 432	

POINTERS

```
char c,*cp;        /* 1 byte  - 4 bytes */
int i,*ip;         /* 4 bytes - 4 bytes */
float f,*fp;       /* 4 bytes - 4 bytes */
double d,*dp;      /* 8 bytes - 4 bytes */

cp = &c;
ip = &i;
*ip = 42;
```



Label	Address	Value
c	400 -	
cp	401 - 404	400
i	405 - 408	42
ip	409 - 412	405
f	413 – 416	
fp	417 – 420	
d	421 – 428	
dp	429 - 432	

POINTERS

```
char c,*cp;        /* 1 byte  - 4 bytes */
int i,*ip;         /* 4 bytes - 4 bytes */
float f,*fp;       /* 4 bytes - 4 bytes */
double d,*dp;      /* 8 bytes - 4 bytes */

cp = &c;
ip = &i;
*ip = 42;
```

NOTE:
As long as **`ip`** points to **`i`**, **`*ip`** is an ***alias*** for **`i`**.

`*ip` has the same value as **`i`.**

Changing the value of **`*ip`**
changes the value of **`i`**.

Label	Address	Value
c	400 -	
cp	401 - 404	400
i	405 - 408	42
ip	409 - 412	405
f	413 – 416	
fp	417 – 420	
d	421 – 428	
dp	429 - 432	

POINTERS

```
char c,*cp;        /* 1 byte  - 4 bytes */
int i,*ip;         /* 4 bytes - 4 bytes */
float f,*fp;       /* 4 bytes - 4 bytes */
double d,*dp;      /* 8 bytes - 4 bytes */

cp = &c;
ip = &i;
*ip = 42;
```

NOTE:
Applying **&** to a variable produces a pointer to the variable.
Applying ***** to the pointer takes us back to the original variable:

```
int j = *&i;    /* same as j = i; */
```

Label	Address	Value
c	400 -	
cp	401 - 404	400
i	405 - 408	42
ip	409 - 412	405
f	413 – 416	
fp	417 – 420	
d	421 – 428	
dp	429 - 432	
j	433 - 436	42

POINTERS

```
char c,*cp;        /* 1 byte  - 4 bytes */
int i,*ip;         /* 4 bytes - 4 bytes */
float f,*fp;       /* 4 bytes - 4 bytes */
double d,*dp;      /* 8 bytes - 4 bytes */

cp = &c;
ip = &i;
*ip = 42;
```

WARNING:
Applying the indirection operator to an uninitialized pointer variable causes undefined behavior:

```
int *i;
printf("%d", *i);    /* WRONG */
printf("%d", i);     /* CORRECT */
```

Label	Address	Value
c	400 -	
cp	401 - 404	400
i	405 - 408	42
ip	409 - 412	405
f	413 – 416	
fp	417 – 420	
d	421 – 428	
dp	429 - 432	

POINTERS

```
char c,*cp;        /* 1 byte  - 4 bytes */
int i,*ip;         /* 4 bytes - 4 bytes */
float f,*fp;       /* 4 bytes - 4 bytes */
double d,*dp;      /* 8 bytes - 4 bytes */

cp = &c;
ip = &i;
*ip = 42;
```

WARNING:
never assign a value to a pointer variable!

```
ip = 137;
/* assumes 137 is an address */
```

pointer variables must only contain addresses.

Label	Address	Value
c	400 -	
cp	401 - 404	400
i	405 - 408	42
ip	409 - 412	405
f	413 – 416	
fp	417 – 420	
d	421 – 428	
dp	429 - 432	

POINTERS

```
char c;    /* 1 byte */
char *cp   /* a pointer of type char 4 bytes */

c = 7;
cp = &c;
printf("%d  %u  %p  value = %d\n", b, b, b, *b);
/*
    %d -> int
    %u -> unsigned int
    %p -> pointer address
          (in hex)
*/
```

Label	Address	Value
c	400 -	7
cp	401 - 404	400

output:
-1073764873 3221202423 0xbfffa5f7 value = 7

POINTERS

```
char ca[3],*cap;        /* 3 x 1 byte  – 4 bytes */
```

- a pointer varaible can hold the **address of any variable**, including a cell in an array

- a pointer variable is **NEVER** used to hold anything BUT an **address**.

- a pointer variable is **NEVER** used to hold **actual data**.

Label	Address	Value
ca[0]	400 -	
ca[1]	401 -	
ca[2]	402 -	
cap	403 - 406	

POINTERS

```
char ca[3],*cap;        /* 3 x 1 byte  - 4 bytes */
cap = &(ca[1]);
```

note:

`&(ca[1])` is preferred over `&ca[1]`

(order of precedent is shown using this)

Label	Address	Value
ca[0]	400 -	
ca[1]	401 -	
ca[2]	402 -	
cap	403 - 406	401

POINTERS

```
char ca[3],*cap;        /* 3 x 1 byte  - 4 bytes */
cap = &(ca[1]);
*cap = 7;
```

note:

`&(ca[1])` is preferred over `&ca[1]`

(order of precedent is shown using this)

Label	Address	Value
ca[0]	400 -	
ca[1]	401 -	7
ca[2]	402 -	
cap	403 - 406	401

POINTERS

```
char ca[3]        /* 3 x 1 bytes */
char *pc;         /* 4 bytes */
int ia[3],        /* 3 x 4 bytes */
int *ip;          /* 4 bytes */
```

Pointer Arithmetic

- address plus (+) an integer n

- advance to the nth
  memory location
  (based on the variable type)

Label	Address	Value
ca[0]	400 -	
ca[1]	401 -	
ca[2]	402 -	
cp	403 - 406	
ia[0]	407 - 410	
ia[1]	411 - 414	
ia[2]	415 - 418	
ip	419 - 422	

POINTERS

```
char ca[3]        /* 3 x 1 bytes */
char *pc;         /* 4 bytes */
int ia[3],        /* 3 x 4 bytes */
int *ip;          /* 4 bytes */

cp = &(ca[0]);
ip = &(ia[0]);
```

Pointer Arithmetic

- address plus (+) an integer n

- advance to the nth
  memory location
  (based on the variable type)

Label	Address	Value
ca[0]	400 -	
ca[1]	401 -	
ca[2]	402 -	
cp	403 - 406	400
ia[0]	407 - 410	
ia[1]	411 - 414	
ia[2]	415 - 418	
ip	419 - 422	407

POINTERS

```
char *pc;          /* 4 bytes */
int *ip;           /* 4 bytes */

cp = &(ca[0]);
ip = &(ia[0]);

*(cp+2) = 8;       // cp + 2 of what?
*(ip+2) = 33;      // ip + 2 of what?
```

Pointer Arithmetic

- plus two UNITS of the variable type

cp+2 // plus two characters (2 x 1 bytes)

ip+2 // plus two integers (2 x 4 bytes)

```
*(cp+2) = 8;      // 400 + 2 = 402
*(ip+2) = 33;     // 407 + 8 = 415
```

Label	Address	Value
ca[0]	400 -	
ca[1]	401 -	
ca[2]	402 -	8
cp	403 - 406	400
ia[0]	407 - 410	
ia[1]	411 - 414	
ia[2]	415 - 418	33
ip	419 - 422	407

POINTERS - special case: VOID POINTER

```
char c              /* 1 byte */
char *pc;           /* 4 bytes */
double db,          /* 8 bytes */
double *pdb;        /* 4 bytes */
void *pV ;          /* 4 bytes */

pc = &c;
pdb = &db;
```

Label	Address	Value
c	400 -	
pc	403 - 406	400
db	407 - 414	
pdb	415 - 418	407
pV	419 - 422	

VOID POINTER

A void pointer in c is called a **generic pointer**, it has no associated data type.

It can store the address of **any type** of object and it can be **type-casted** to any types.

POINTERS - special case: VOID POINTER

```
char c              /* 1 byte */
char *pc;           /* 4 bytes */
double db,          /* 8 bytes */
double *pdb;        /* 4 bytes */
void *pV ;          /* 4 bytes */

pc = &c;
pdb = &db;

//Assigning address of character
pV = &c;

//dereferencing void pointer with character typecasting
printf("c = %c\n\n",*((char*)pV));
```

Label	Address	Value
c	400 -	
pc	403 - 406	400
db	407 - 414	
pdb	415 - 418	407
pV	419 - 422	400

POINTERS - special case: VOID POINTER

```
char c              /* 1 byte */
char *pc;           /* 4 bytes */
double db,          /* 8 bytes */
double *pdb;        /* 4 bytes */
void *pV ;          /* 4 bytes */

pc = &c;
pdb = &db;
```

Label	Address	Value
c	400 -	
pc	403 - 406	400
db	407 - 414	
pdb	415 - 418	407
pV	419 - 422	407

```
//Assigning address of character
pV = &c;

//dereferencing void pointer with character typecasting
printf("c = %c\n\n",*((char*)pV));

//Assigning address of double
pvD = &db;

//dereferencing void pointer with integer typecasting
printf("db = %d\n\n",*((double *)pV));
```

POINTERS

Referencing (&) in scanf()

```
int main( int argc, char* argv[] )
  {
     int a;
     float y;

     printf( "Enter an integer value:");
     scanf( "%d", &a );
     printf( "a = %d\n", a);

     printf( "Enter a floating point value:");
     scanf( "%f", &y );
     printf( "y = %f\n", y);

     return (0);
  }
```

POINTERS

Referencing (&) in scanf()

```
int main( int argc, char* argv[] )
  {
     int a;
     float y;

     printf( "Enter an integer value
     scanf( "%d", &a );
     printf( "a = %d\n", a);

     printf( "Enter a floating point
     scanf( "%f", &y );
     printf( "y = %f\n", y);

     return (0);
  }
```

Label	Address	Value	Binary
	399		
a	400	37	0000 0000
	401		0000 0000
	402		0000 0000
	403		001 0001
y	404	3.14159	0000 0100
	405		1100 1011
	406		0010 1111
	407		000 00000
	408		0000 0000
	409		0000 0000
	410		0000 0000
	411		0000 0000
	412		
	413		
	414		
	415		
	416		
	417		
	418		
	…		

detail:

```
scanf( "%d", &a );
```

read in a decimal value **(%d)** and place that value in the memory location **(&)** delineated by the variable labeled '**a**'.

POINTERS

… nothing more than a mechanism to
manipulate and utilize computer memory

POINTERS ARE A VERY DIFFICULT TOOL TO MASTER

- big headache for beginning programmers

- so: why use them

big reason: passing values to/from functions

```
int division(int numerator, int denominator,
             int *dividend, int *remainder)
```

Passing Values TO and FROM a Function

```
#include <stdio.h>

int division(int numerator, int denominator,
             int *dividend, int *remainder)
{
    printf("address stored in dividend: %u\n",dividend);
    printf("address stored in remainder: %u\n",remainder);
    if (denominator < 1)
        return(0);
    *dividend=numerator/denominator;
    *remainder=numerator%denominator;
}


int main(int argc, char *argv[])
{
     int x,y,d,r;

     x=9;
     y=2;
     printf("address of d: %u\n",&d);
     printf("address of r: %u\n",&r);
     division(x,y,&d,&r);
     printf("%d/%d = %d with %d remainder\n",x,y,d,r);
     printf("x=%d\n",x);
}
```

```
#include <stdio.h>

int division(int numerator, int denominator,
             int *dividend, int *remainder)
{
    printf("address stored in dividend: %u\n",dividend);
    printf("address stored in remainder: %u\n",remainder);
    if (denominator < 1)
        return(0);
    *dividend=numerator/denominator;
    *remainder=numerator%denominator;
}


int main(int argc, char argv[])
{
     int x,y,d,r;

     x=9;
     y=2;
     printf("address of d: %u\n",&d);
     printf("address of r: %u\n",&r);
     division(x,y,&d,&r);
     printf("%d/%d = %d with %d remainder\n",x,y,d,r);
     printf("x=%d\n",x);
}
```

but we will return to this later ….
for now, back to basic C