Pointers: Basics

What is a pointer?

- First of all, it is a variable, just like other variables you studied
  - So it has type, storage etc.
- Difference: it can only store the address (rather than the value) of a data item
- Type of a pointer variable – pointer to the type of the data whose address it will store
  - Example: int pointer, float pointer,…
  - Can be pointer to any user-defined types also like structure types

- They have a number of useful applications
  - Enables us to access a variable that is defined outside the function
  - Can be used to pass information back and forth between a function and its reference point
  - More efficient in handling data tables
  - Reduces the length and complexity of a program
  - Sometimes also increases the execution speed

Basic Concept

- As seen before, in memory, every stored data item occupies one or more contiguous memory cells
  - The number of memory cells required to store a data item depends on its type (char, int, double, etc.).
- Whenever we declare a variable, the system allocates memory location(s) to hold the value of the variable.
  - Since every byte in memory has a unique address, this location will also have its own (unique) address.

Contd.

- Consider the statement

  int xyz = 50;

  - This statement instructs the compiler to allocate a location for the integer variable xyz, and put the value 50 in that location
  - Suppose that the address location chosen is 1380

xyz	**➔**	**variable**
50	**➔**	**value**
1380	**➔**	**address**

Contd.

- During execution of the program, the system always associates the name xyz with the address 1380
  - The value 50 can be accessed by using either the name xyz or the address 1380
- Since memory addresses are simply numbers, they can be assigned to some variables which can be stored in memory
  - Such variables that hold memory addresses are called pointers
  - Since a pointer is a variable, its value is also stored in some memory location

Contd.

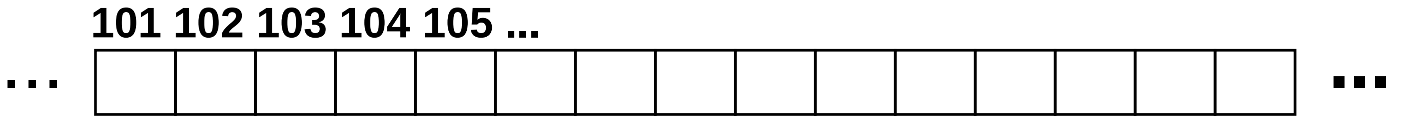
- Suppose we assign the address of xyz to a variable p
  - p is said to point to the variable xyz

Variable	Value	Address
xyz	50	1380
p	1380	2545

p = &xyz;

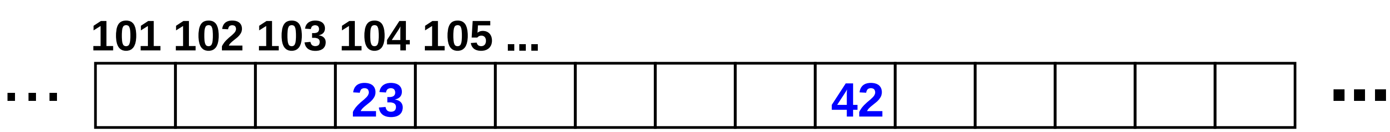
Address vs. Value

- Each memory cell has an address associated with it



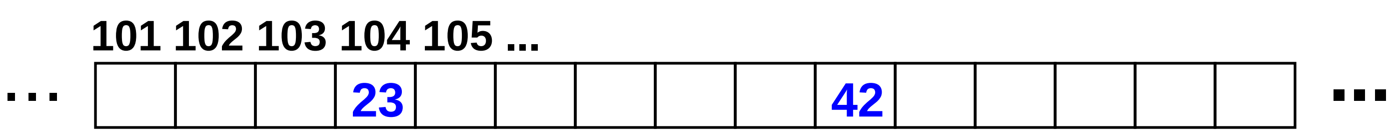
Address vs. Value

- Each memory cell has an address associated with it
- Each cell also stores some value



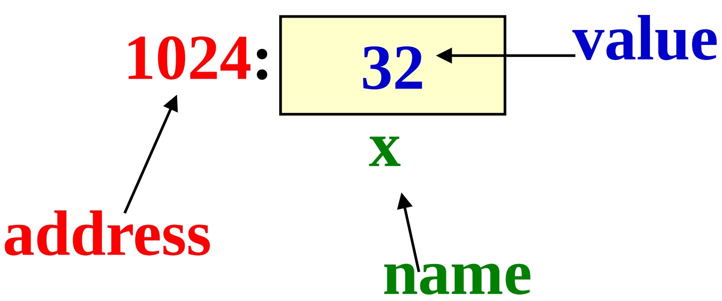
Address vs. Value

- Each memory cell has an address associated with it
- Each cell also stores some value
- Don’t confuse the address referring to a memory location with the value stored in that location



Values vs Locations

- Variables name memory locations, which hold values



Pointers

- A pointer is just a C variable whose value can contain the address of another variable
- Needs to be declared before use just like any other variable
- General form:

    data_type *pointer_name;

- Three things are specified in the above declaration:
    - The asterisk (*) tells that the variable pointer_name is a pointer variable
    - pointer_name needs a memory location
    - pointer_name points to a variable of type data_type

Example

```
int      *count;
float   *speed;
char *c;
```

- Once a pointer variable has been declared, it can be made to point to a variable using an assignment statement like

```
int *p, xyz;
    :
p = &xyz;
```

  - This is called pointer initialization

- Pointers can be defined for any type, including user defined types
- Example

```
struct name {
    char first[20];
    char last[20];
};
struct name *p;
```

  - p is a pointer which can store the address of a struct name type variable

Accessing the Address of a Variable

- The address of a variable is given by the & operator
  - The operator & immediately preceding a variable returns the address of the variable
- Example:

```
p = &xyz;
```

  - The address of xyz (1380) is assigned to p

- The & operator can be used only with a simple variable (of any type, including user-defined types) or an array element

```
&distance
&x[0]
&x[i-2]
```

Illegal Use of &

- &235
    - Pointing at constant

- int arr[20];
  :
  &arr;
    - Pointing at array name

- &(a+b)
    - Pointing at expression

In all these cases, there is no storage, so no address either

Example

```
#include  <stdio.h>
int main()
{
    int   a;
    float  b, c;
    double  d;
    char  ch;

    a = 10;   b = 2.5;  c = 12.36;  d = 12345.66;  ch = ‘A’;
    printf  (“%d is stored in location %u \n”,  a,  &a) ;
    printf  (“%f is stored in location %u \n”,  b,  &b) ;
    printf  (“%f is stored in location %u \n”,  c,  &c) ;
    printf  (“%lf is stored in location %u \n”, d,  &d) ;
    printf  (“%c is stored in location %u \n”,  ch, &ch) ;
    return 0;
}
```

Output

```
10 is stored in location 3221224908
2.500000 is stored in location 3221224904
12.360000 is stored in location 3221224900
12345.660000 is stored in location 3221224892
A is stored in location 3221224891
```

Accessing a Variable Through its Pointer

- Once a pointer has been assigned the address of a variable, the value of the variable can be accessed using the indirection operator (*).

```
int   a, b;
int   *p;
p = &a;
b = *p;
```

Equivalent to

```
b = a;
```

Example

```
#include  <stdio.h>
int main()
{
    int   a, b;
    int   c = 5;
    int   *p;

    a  =  4  *  (c  +  5) ;

    p  =  &c;
    b  =  4  *  (*p  +  5) ;
    printf  (“a=%d  b=%d \n”,  a, b);
    return 0;
}
```

Equivalent

```
a=40 b=40
```

Example

```
int main()
{
    int  x, y;
    int  *ptr;

    x = 10 ;
    ptr = &x ;
    y = *ptr ;
    printf (“%d is stored in location %u \n”,  x,  &x);
    printf (“%d is stored in location %u \n”,  *&x,  &x);
    printf (“%d is stored in location %u \n”,  *ptr,  ptr);
    printf (“%d is stored in location %u \n”,  y,  &*ptr);
    printf (“%u is stored in location %u \n”,  ptr, &ptr);
    printf (“%d is stored in location %u \n”,  y,  &y);

    *ptr = 25;
    printf (“\nNow x = %d \n”, x);
    return 0;
}
```

Suppose that

```
Address of x:      3221224908
Address of y:      3221224904
Address of ptr:    3221224900
```

Then output is

```
10 is stored in location 3221224908
10 is stored in location 3221224908
10 is stored in location 3221224908
10 is stored in location 3221224908
3221224908 is stored in location 3221224900
10 is stored in location 3221224904

Now x = 25
```

Example

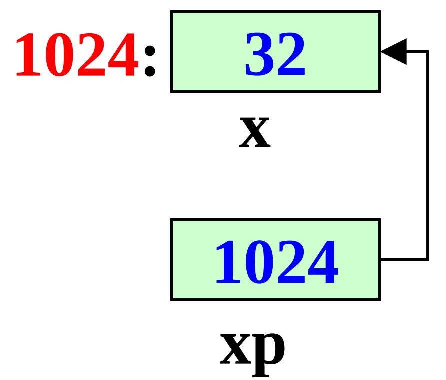
```
int x;

int * xp ;

xp = &x ;
```

pointer to int

address of x




```
*xp = 0;           /* Assign 0 to x */
*xp = *xp + 1;     /* Add 1 to x */
```

Value of the pointer

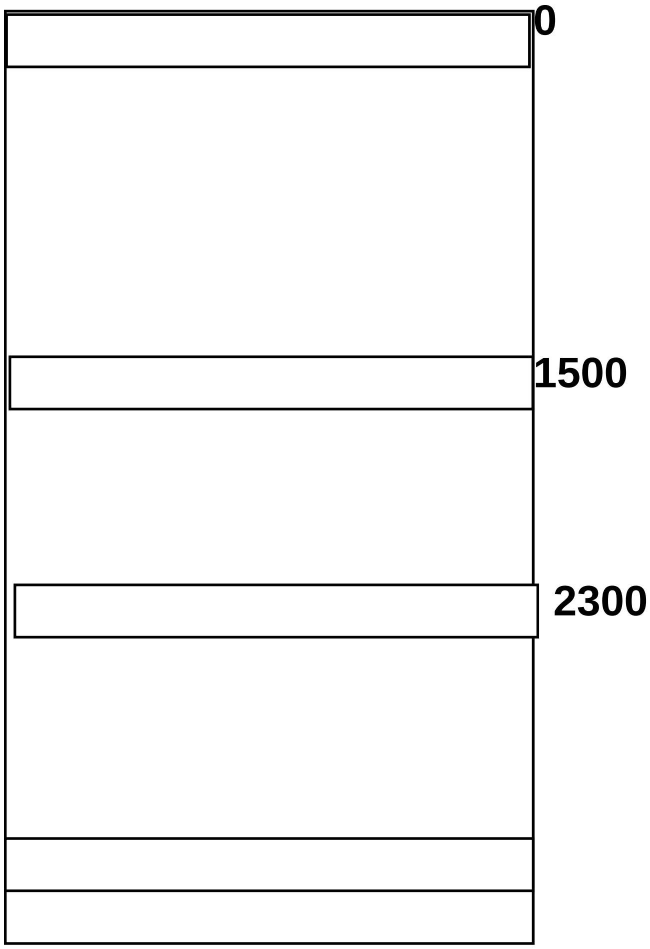
- Declaring a pointer just allocates space to hold the pointer – it does not allocate something to be pointed to!
  - Local variables in C are not initialized, they may contain anything

- After declaring a pointer:

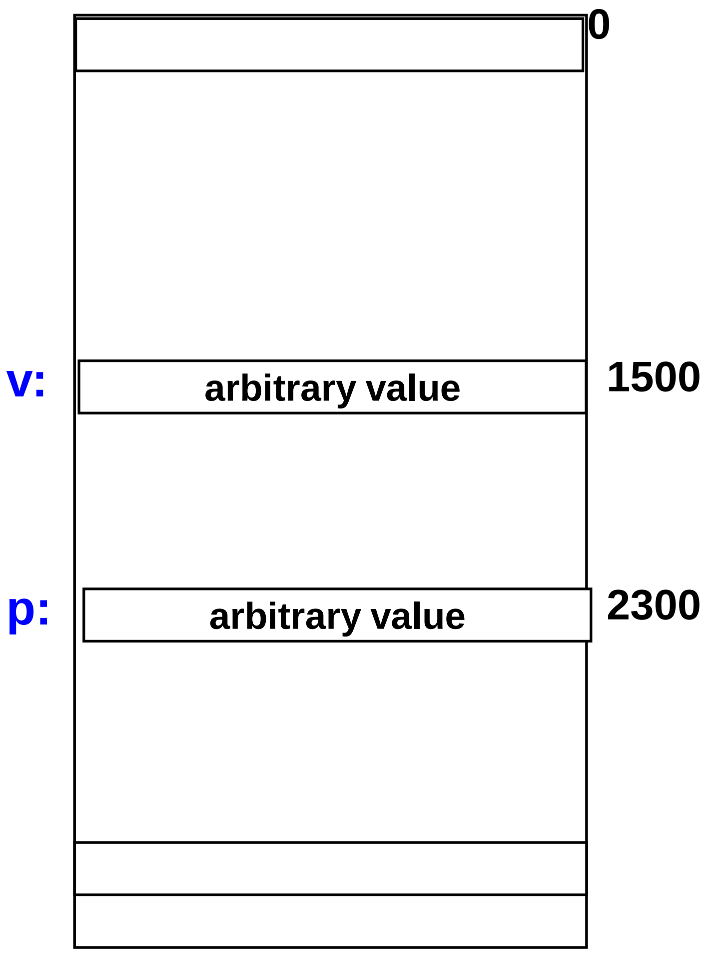
```
int *ptr;
```

  ptr doesn't actually point to anything yet. We can either:
  - make it point to something that already exists, or
  - allocate room in memory for something new that it will point to… (dynamic allocation, to be done later)

Example

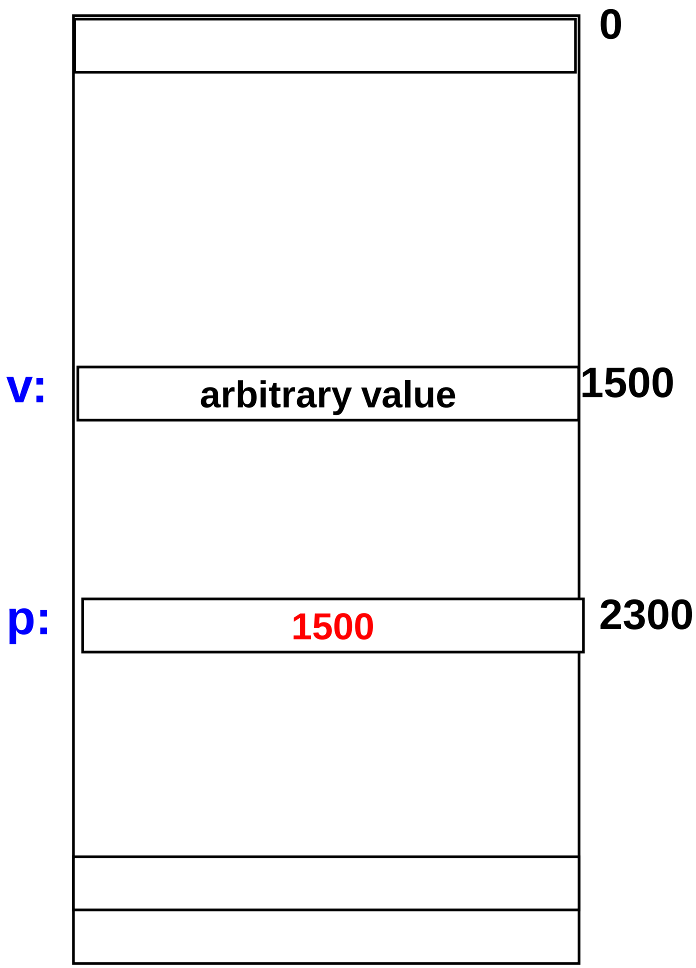


Memory and Pointers:



Memory and Pointers:

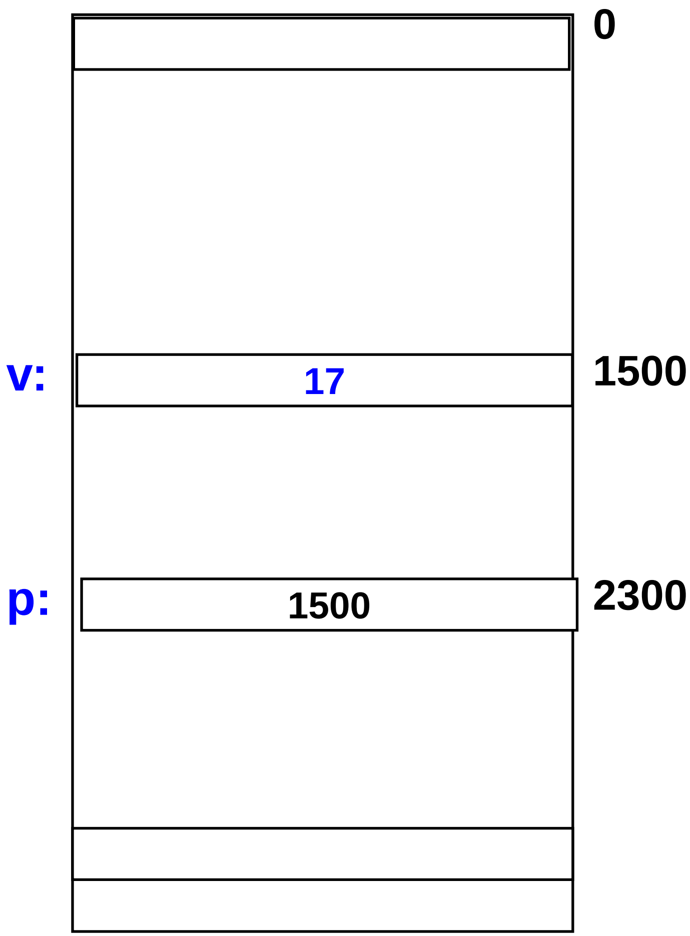
int *p, v;



Memory and Pointers:

int v, *p;

p = &v;

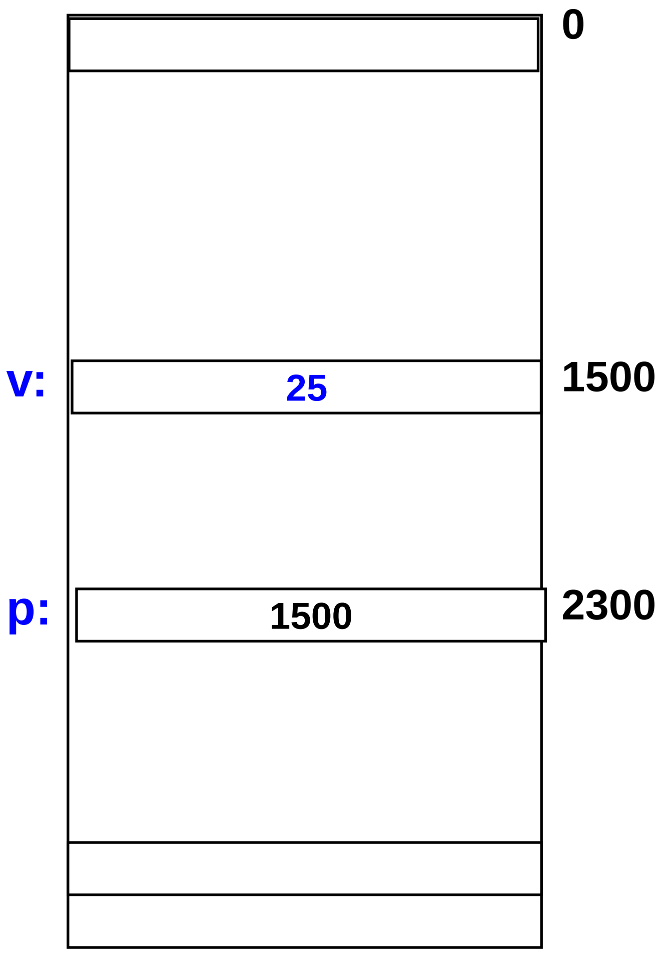


Memory and Pointers:

int v, *p;

p = &v;

v = 17;



Memory and Pointers:

int v, *p;

p = &v;

v = 17;

*p = *p + 4;

v = *p + 4

More Examples of Using Pointers in Expressions

- If p1 and p2 are two pointers, the following statements are valid:

```
sum = *p1 + *p2;
prod = *p1 * *p2;
prod = (*p1) * (*p2);
*p1 = *p1 + 2;
x = *p1 / *p2 + 5;
```

`*p1` can appear on the left hand side

- Note that this unary * has higher precedence than all arithmetic/relational/logical operators

Things to Remember

- Pointer variables must always point to a data item of the same type

```
float   x;
int     *p;
   :
p = &x;
```

will result in wrong output

- Never assign an absolute address to a pointer variable

```
int   *count;
count = 1268;
```

Pointer Expressions

- Like other variables, pointer variables can appear in expressions
- What are allowed in C?
  - Add an integer to a pointer
  - Subtract an integer from a pointer
  - Subtract one pointer from another (related)
    - If p1 and p2 are both pointers to the same array, then p2 – p1 gives the number of elements between p1 and p2

Contd.

- What are not allowed?
  - Adding two pointers.

    ```
    p1 = p1 + p2;
    ```

  - Multiply / divide a pointer in an expression

    ```
    p1 = p2 / 5;
    p1 = p1 – p2 * 10;
    ```

Scale Factor

- We have seen that an integer value can be added to or subtracted from a pointer variable

```
int  *p1, *p2;
int  i, j;
      :
p1 = p1 + 1;
p2 = p1 + j;
p2++;
p2 = p2 – (i + j);
```

  - In reality, it is not the integer value which is added/subtracted, but rather the scale factor times the value

Contd.

Data Type	Scale Factor
char	1
int	4
float	4
double	8

- If p1 is an integer pointer, then

  p1++

  will increment the value of p1 by 4

- The scale factor indicates the number of bytes used to store a value of that type
  - So the address of the next element of that type can only be at the (current pointer value + size of data)
- The exact scale factor may vary from one machine to another
- Can be found out using the sizeof function
  - Gives the size of that data type
- Syntax:

  sizeof (data_type)

Example

```
int main()
{
  printf ("No. of bytes in int is %u \n",       sizeof(int));
  printf ("No. of bytes in float is %u \n",     sizeof(float));
  printf ("No. of bytes in double is %u \n", sizeof(double));
  printf ("No. of bytes in char is %u \n",      sizeof(char));

  printf ("No. of bytes in int * is %u \n",       sizeof(int *));
  printf ("No. of bytes in float * is %u \n",     sizeof(float *));
  printf ("No. of bytes in double * is %u \n",  sizeof(double *));
  printf ("No. of bytes in char * is %u \n",      sizeof(char *));
  return 0;
}
```

Output on a PC

```
No. of bytes in int is 4
No. of bytes in float is 4
No. of bytes in double is 8
No. of bytes in char is 1
No. of bytes in int * is 4
No. of bytes in float * is 4
No. of bytes in double * is 4
No. of bytes in char * is 4
```

- Note that pointer takes 4 bytes to store, independent of the type it points to
- However, this can vary between machines
  - Output of the same program on a server

```
No. of bytes in int is 4
No. of bytes in float is 4
No. of bytes in double is 8
No. of bytes in char is 1
No. of bytes in int * is 8
No. of bytes in float * is 8
No. of bytes in double * is 8
No. of bytes in char * is 8
```

- Always use sizeof() to get the correct size`
- Should also print pointers using **%p** (instead of %u as we have used so far for easy comparison)

Example

```
int main()
{
  int A[5],  i;

  printf("The addresses of the array elements are:\n");
  for (i=0; i<5; i++)
     printf("&A[%d]: Using \%p = %p,   Using \%u = %u", i, &A[i], &A[i]);
  return 0;
}
```

Output on a server machine

```
&A[0]: Using %p = 0x7fffb2ad5930,   Using %u = 2997705008
&A[1]: Using %p = 0x7fffb2ad5934,   Using %u = 2997705012
&A[2]: Using %p = 0x7fffb2ad5938,   Using %u = 2997705016
&A[3]: Using %p = 0x7fffb2ad593c,   Using %u = 2997705020
&A[4]: Using %p = 0x7fffb2ad5940,   Using %u = 2997705024
```

0x7fffb2ad5930 = 140736191093040 in decimal (**NOT 2997705008**) so print with %u prints a wrong value (4 bytes of unsigned int cannot hold 8 bytes for the pointer value)