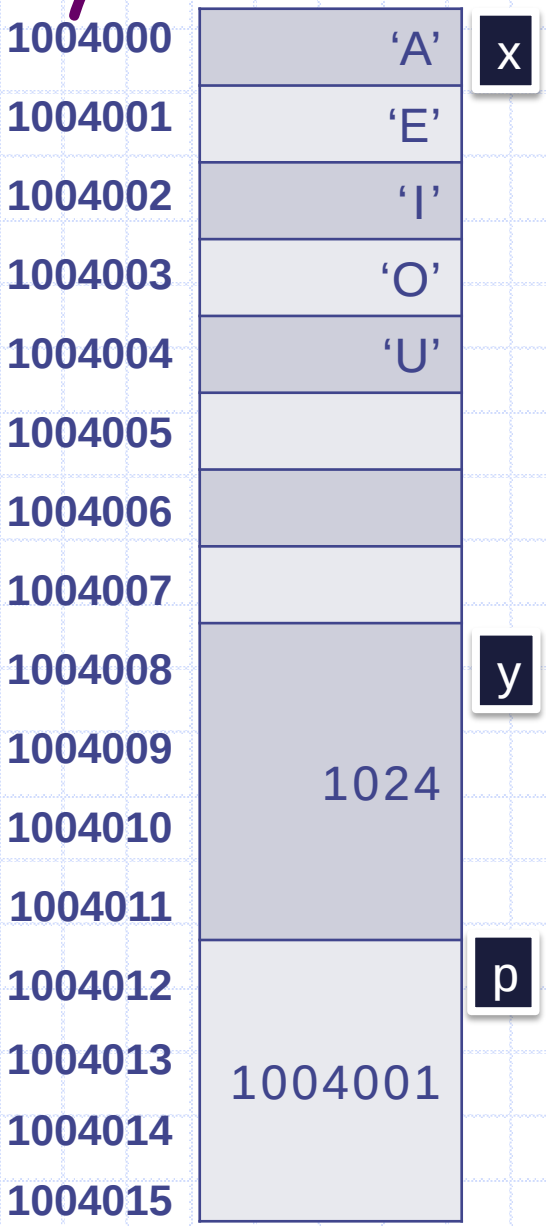
Simplified View of Memory

- In programming also, "Type" helps us decide whether 1004001 is an integer or a pointer to block containing 'E' (or something else)

```
#include<stdio.h>
int main() {
        char x[5] = {'A', 'E', 'I', 'O', 'U'};
        int y = 1024;
        char *p = x+1;
        ...
}
```

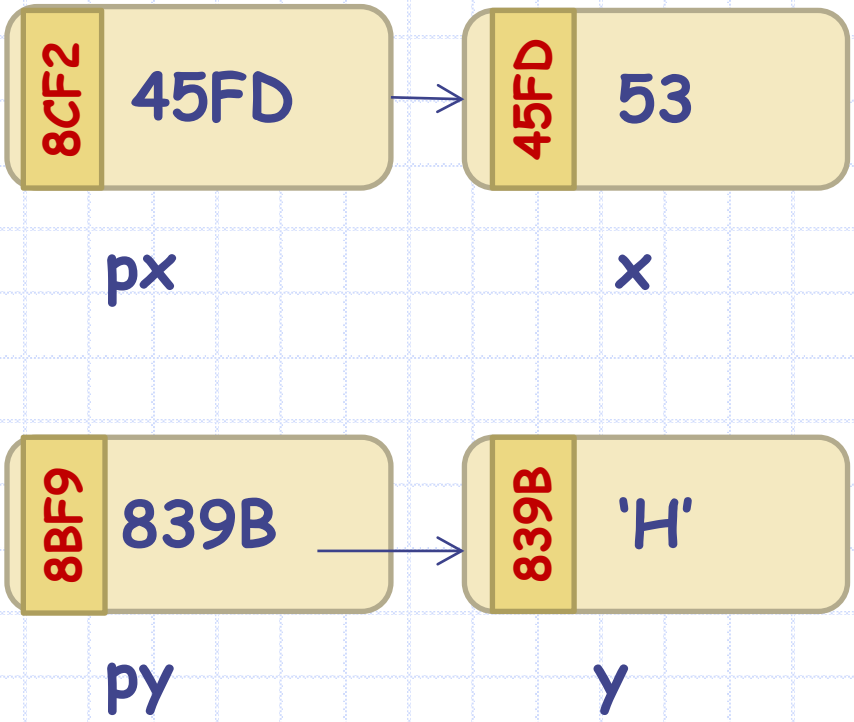
```
#include<stdio.h>
int main() {
        char x[5] = {'A', 'E', 'I', 'O', 'U'};
        int y = 1024;
        int p = 1004001;
        ...
}
```

Declaration of a pointer to char box



Pointers: Visual Representation

- Typically represented by box and arrow diagram



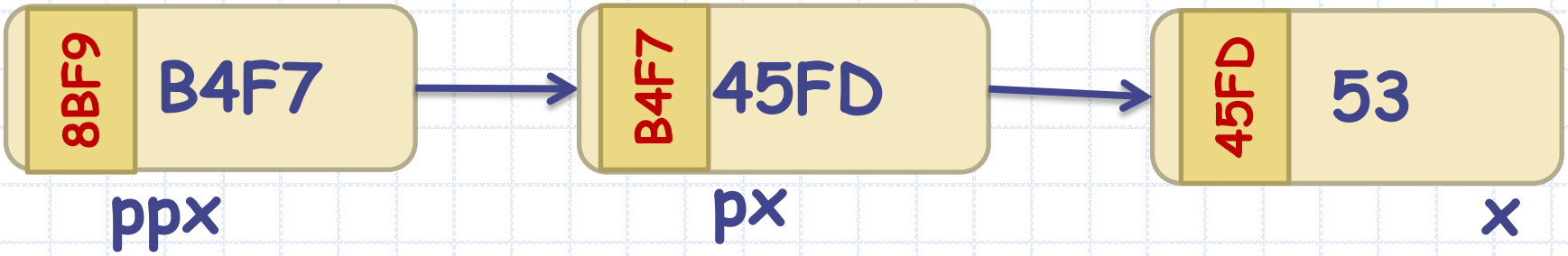
- x is an int variable that contains the value 53.
- Address of x is 45FD.
- px is a pointer to int that contains address of x.

- y is an char variable that contains the character 'H'.
- Address of y is 839B.
- py is a pointer to char that contains address of y.

We are showing addresses for explanation only.
Ideally, the program should not depend on actual addresses.

Pointer to a pointer

- If we have a pointer P to some memory cell, P is also stored somewhere in the memory.
- So, we can also talk about address of block that stores P.



We are showing addresses for explanation only.
Ideally, the program should not depend on actual addresses.

```
int x = 53;
int *px = &x;
int **ppx = &px;
```

Size of Datatypes

- The smallest unit of data in your computer's memory is one bit. A bit is either 0 or 1.
- 8 bits make up a byte.
- 2^{10} bytes is 1 kilobyte (KB). 2^{10} KB is 1 megabyte (MB). 2^{10} MB is 1 gigabyte (GB). 2^{10} GB is 1 terabyte (TB)
- Every data type occupies a fixed amount of space in your computer's memory.

Size of Datatypes

- There is an operator in C that takes as argument the name of a data type and returns the number of bytes the data type takes
  - the sizeof operator.
- For example, sizeof(int) return the number of bytes a variable of type int uses up in your computer's memory.

sizeof Examples

```
printf("int: %d\n", sizeof(int));                  int: 4
printf("float: %d\n", sizeof(float));              float: 4
printf("long int: %d\n", sizeof(long int));        long int: 8
printf("double: %d\n", sizeof(double));            double: 8
printf("char: %d\n", sizeof(char));                char: 1
printf("int ptr: %d\n", sizeof(int *));            int ptr: 8
printf("double ptr: %d\n", sizeof(double*));       double ptr: 8
printf("char ptr: %d\n", sizeof(char *));          char ptr: 8
```

- The values can vary from computer to computer.
- Note that all pointer types occupy the same number of bytes (8 bytes in this case).
  - Depends only on total # of memory blocks (RAM/Virtual Memory) and not on data type

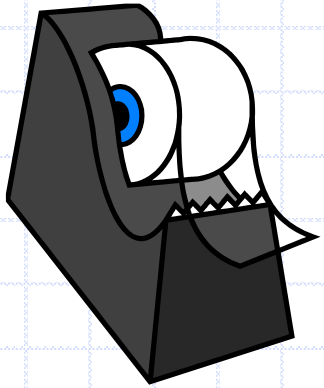
Static Memory Allocation

- When we declare an array, size has to be specified before hand.
- During compilation, the C compiler knows how much space to allocate to the program
  - Space for each variable.
  - Space for an array depending on the size.
- This memory is allocated in a part of the memory known as the stack.
- Need to assume worst case scenario
  - May result in wastage of Memory

Dynamic Memory Allocation

- There is a way of allocating memory to a program during runtime.
- This is known as dynamic memory allocation.
- Dynamic allocation is done in a part of the memory called the heap.
- You can control the memory allocated depending on the actual input(s)
  - Less wastage

Memory allocation: malloc



- The malloc function is declared in

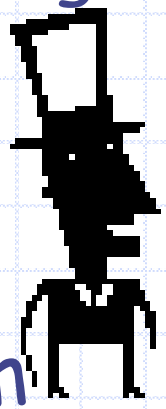
  stdlib.h

- Takes as argument an integer (say **n**, typically > 0),
- Allocates **n** consecutive bytes of memory space, and
- returns the address of t rst cell of this memory space
- The return type is void*

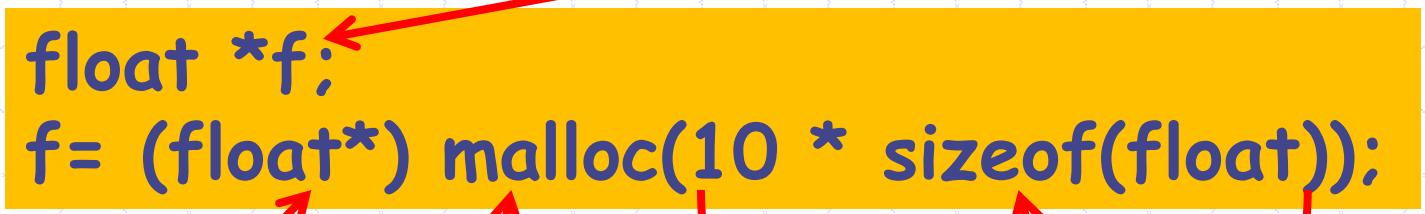
WAIT! Doesn't void means "nothing" in C? What is the meaning of void*? Pointer to nothing!

void* is NOT pointer to nothing!

- malloc knows *nothing* about the use of the memory blocks it has allocated
- void* is used to convey this message
  - Does not mean pointer to nothing, but means pointer to *something* about which *nothing is known*
- The blocks allocated by malloc can be used to store "anything" provided we allocate enough of them



malloc: Example



Size big enough to hold 10 floats.

Explicit type casting to convey users intent

Note the use of **sizeof** to keep it machine independent

malloc evaluates its arguments at *runtime* to allocate (reserve) space. Returns a **void***, pointer to first address of allocated space.

malloc: Example

Key Point: The size argument can be a variable or non-constant expression!

After memory is allocated, pointer variable behaves as if it is an **array**!

```
float *f; int n;
scanf("%d", &n);
f= (float*) malloc(n * sizeof(float));

f[0] = 0.52;
scanf("%f", &f[3]); //Overflow if n<=3
printf("%f", *f + f[0]);
```

This is because, in C, f[i] simply means *(f+i).

Exercise

- Write a program that reads two integers, n and m, and stores powers of n from 0 up to m (n^0, n^1, …, n^m)

```
#include<stdio.h>
#include<stdlib.h>
int main(){
    int *pow, i, n, m;
    scanf("%d %d", &n, &m); // m>= 0
    pow = (int *) malloc ((m+1) * sizeof(int));
    pow[0] = 1;
    for (i=1; i<=m; i++)
        pow[i] = pow[i-1]*n;
    for (i=0; i<=m; i++)
        printf("%d\n",pow[i]);
    return 0;
}
```

Note that instead of writing **pow[i]**, we can also write ***(pow + i)**