Pointers

Advanced C

Pointers – Jargon

- What's a Jargon?
  - Jargon may refer to terminology used in a certain profession, such as computer jargon, or it may refer to any nonsensical language that is not understood by most people.
  - Speech or writing having unusual or pretentious vocabulary, convoluted phrasing, and vague meaning.
- Pointer are perceived difficult
  - Because of “jargonification”
- So, let's “dejargonify” & understand them

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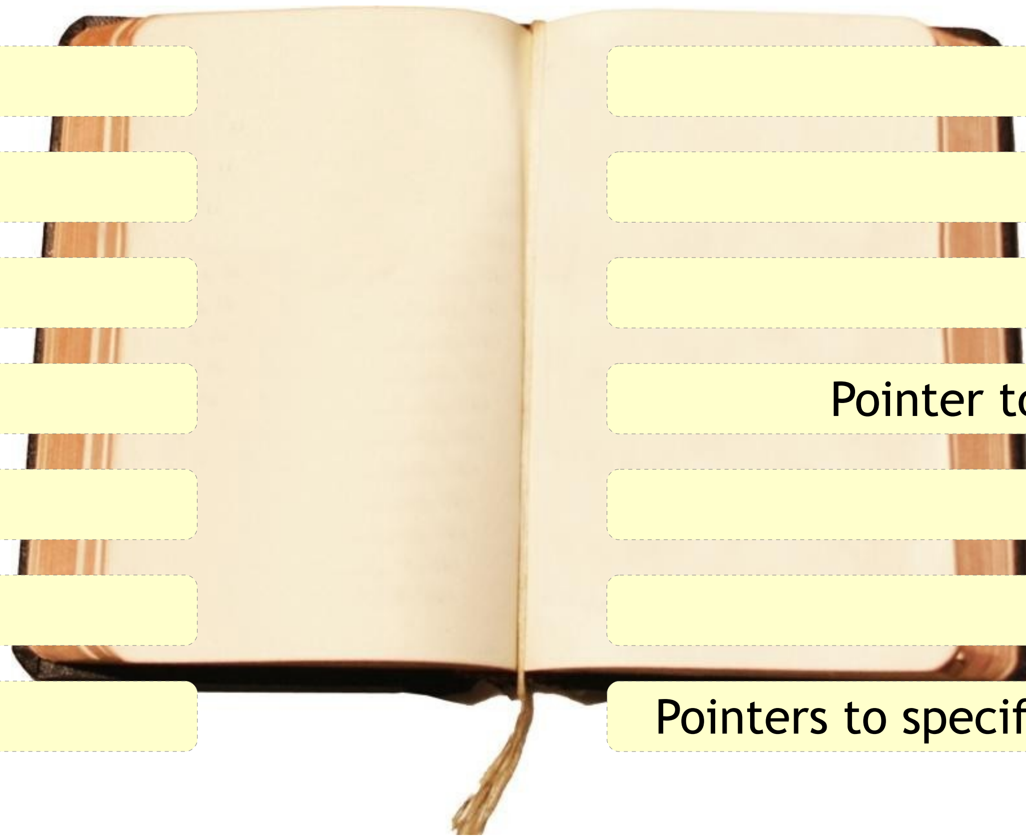
Pointers – Analogy with Book



A Book	System Memory
Contains pages	Memory Pages
Front matter	Boot Code
Table of Contents	Pointer to different programs
Chapters	Code Segments
Notes Section	Data & Stack
Indexes	Pointers to specific memory locations

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Pointers – Computers

- Just like a book analogy, Computers contains different different sections (Code) in the memory
- All sections have different purposes
- Every section has a address and we need to point to them whenever required
- In fact everything (Instructions and Data) in a particular section has an address!!
- So the pointer concept plays a big role here

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Pointers – Why?

- To have C as a low level language being a high level language
- Returning more than one value from a function
- To achieve the similar results as of ”pass by value”
- parameter passing mechanism in function, by passing the reference
- To have the dynamic allocation mechanism

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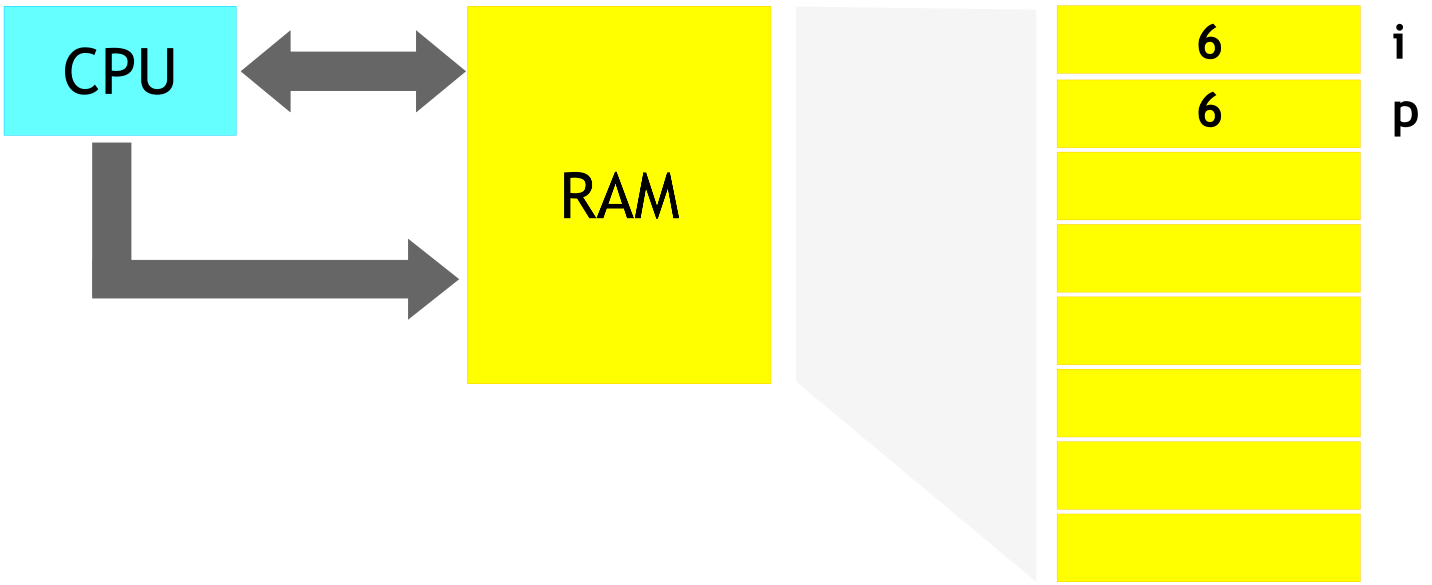
Pointers – The 7 Rules

- Rule 1 - Pointer is an Integer
- Rule 2 - Referencing and De-referencing
- Rule 3 - Pointing means Containing
- Rule 4 - Pointer Type
- Rule 5 - Pointer Arithmetic
- Rule 6 - Pointing to Nothing
- Rule 7 - Static vs Dynamic Allocation



Integer i;
Pointer p;
Say:
    i = 6;
    p = 6;

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Pointers – The 7 Rules – Rule 1

- Whatever we put in data bus is Integer
- Whatever we put in address bus is Pointer
- So, at concept level both are just numbers. May be of different sized buses
- Rule: “Pointer is an Integer”
- Exceptions:
  - May not be address and data bus of same size
  - Rule 2 (Will see why? while discussing it)

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Pointers - Rule 1 in detail

001_example.c

```c
#include <stdio.h>

int main()
{
    int x;
    int *ptr;

    x = 5;
    ptr = 5;

    return 0;
}
```

Address	Variable	Value	Size
1000	x	?	Say 4 bytes
2000	ptr	?	Say 4 bytes

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Pointers – Rule 1 in detail

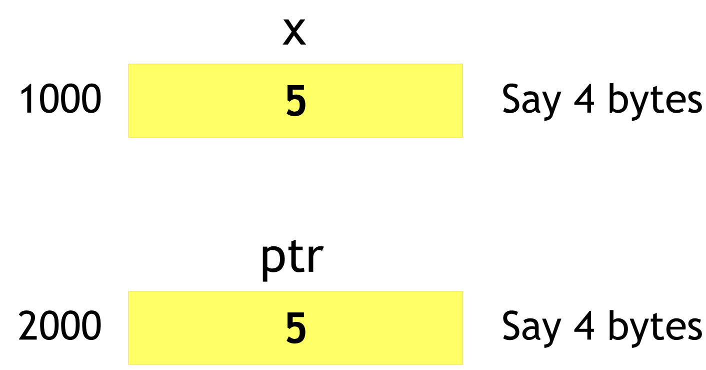
001_example.c

```c
#include <stdio.h>

int main()
{
    int x;
    int *ptr;

    x = 5;
    ptr = 5;

    return 0;
}
```



- So pointer is an integer
- But remember the “They may not be of same size”

  32 bit system = 4 Bytes

  64 bit system = 8 Bytes

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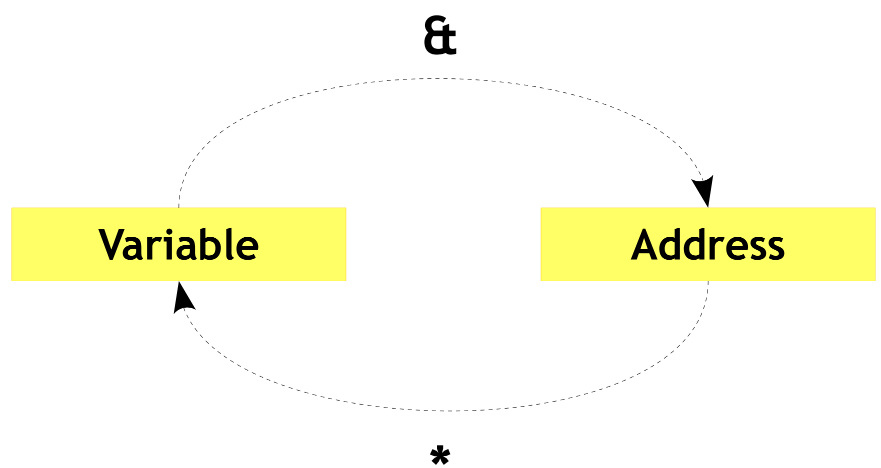
Pointers – The 7 Rules – Rule 2

- Rule : “Referencing and Dereferencing”



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Pointers – Rule 2 in detail

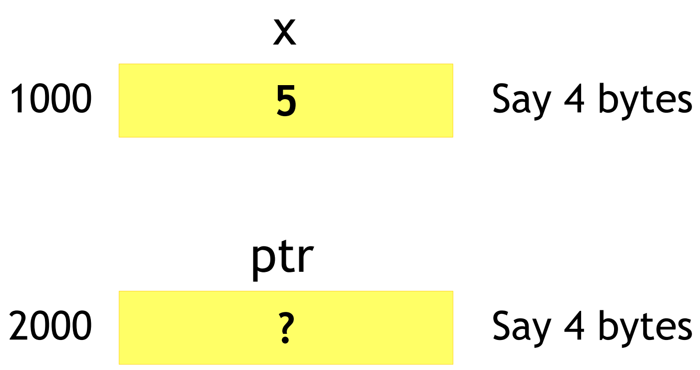
002_example.c

```c
#include <stdio.h>

int main()
{
    int x;
    int *ptr;

    x = 5;

    return 0;
}
```



- Considering the image, What would the below line mean?

  * 1000

Advanced C

Pointers – Rule 2 in detail

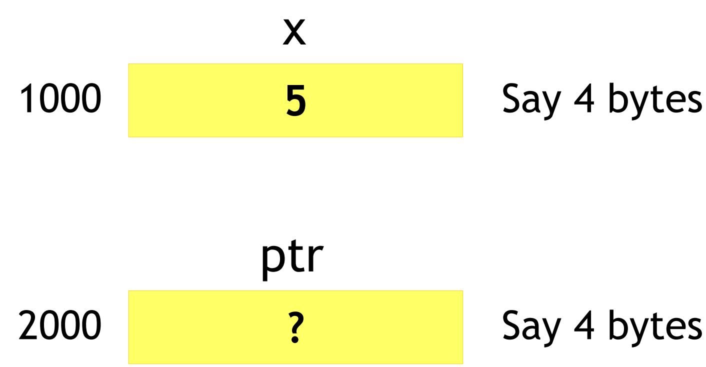
002_example.c

```c
#include <stdio.h>

int main()
{
    int x;
    int *ptr;

    x = 5;

    return 0;
}
```



- Considering the image, What would the below line mean?

  * 1000

- Goto to the location 1000 and fetch its value, so

  * 1000 → 5

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Pointers – Rule 2 in detail

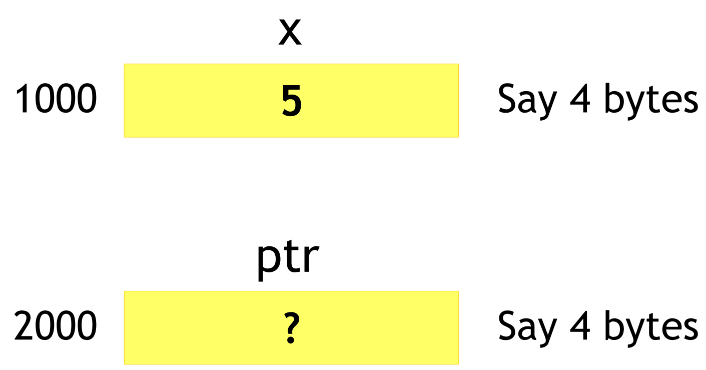
002_example.c

```c
#include <stdio.h>

int main()
{
    int x;
    int *ptr;

    x = 5;
    ptr = &x;

    return 0;
}
```



- What should be the change in the above diagram for the above code?

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Pointers – Rule 2 in detail

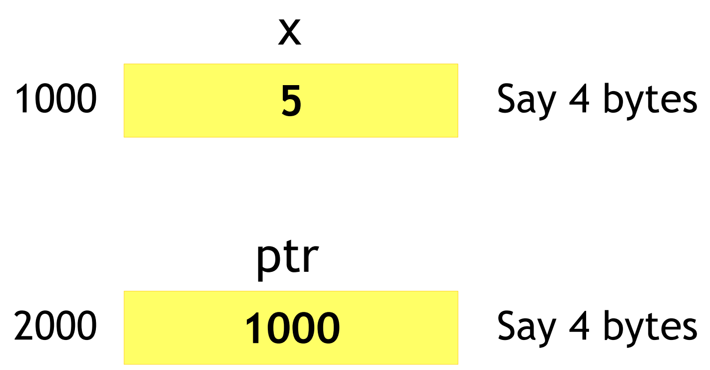
002_example.c

```c
#include <stdio.h>

int main()
{
    int x;
    int *ptr;

    x = 5;
    ptr = &x;

    return 0;
}
```



- So pointer should contain the address of a variable
- It should be a valid address

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Pointers - Rule 2 in detail

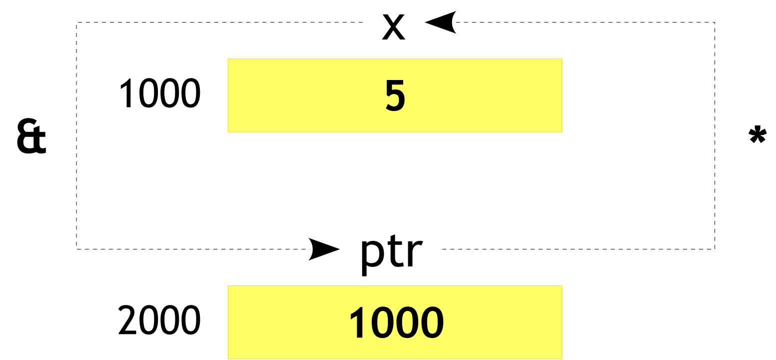
002_example.c

```
#include <stdio.h>

int main()
{
    int x;
    int *ptr;

    x = 5;
    ptr = &x;

    return 0;
}
```



“Prefix 'address of operator' (&) with variable (x) to get its address and store in the pointer”

“Prefix 'indirection operator' (*) with pointer to get the value of variable (x) it is pointing to”

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Pointers – Rule 2 in detail

003_example.c

```
#include <stdio.h>

int main()
{
    int number = 10;
    int *ptr;

    ptr = &number;

    printf("Address of number is %p\n", &number);
    printf("ptr contains %p\n", ptr);

    return 0;
}
```

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Pointers – Rule 2 in detail

004_example.c

```
#include <stdio.h>

int main()
{
    int number = 10;
    int *ptr;

    ptr = &number;

    printf("number contains %d\n", number);
    printf("*ptr contains %d\n", *ptr);

    return 0;
}
```

Advanced C

Pointers – Rule 2 in detail

005_example.c

```
#include <stdio.h>

int main()
{
    int number = 10;
    int *ptr;

    ptr = &number;
    *ptr = 100;

    printf("number contains %d\n", number);
    printf("*ptr contains %d\n", *ptr);

    return 0;
}
```

- So, from the above code we can conclude

“*ptr <=> number”

Advanced C

Pointers – The 7 Rules – Rule 3

- Pointer pointing to a Variable = Pointer contains the Address of the Variable
- Rule: “Pointing means Containing”

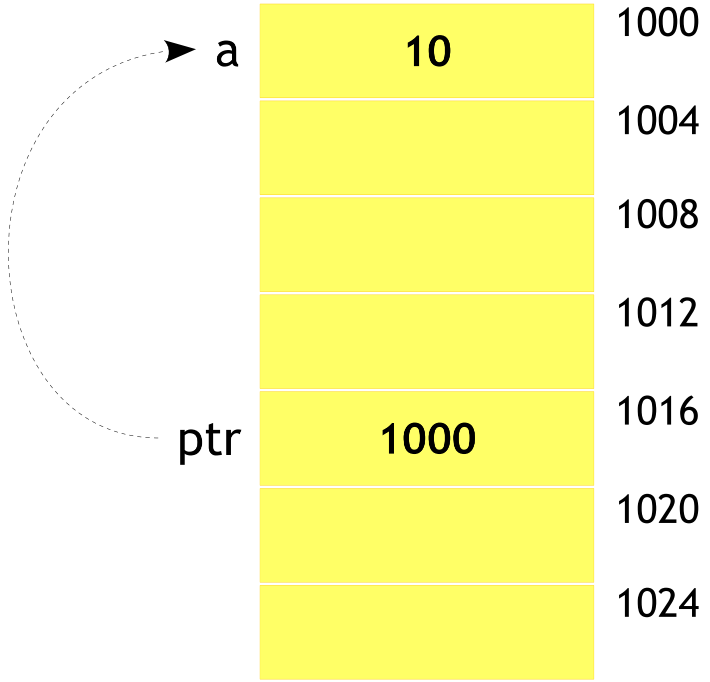
Example

```
#include <stdio.h>

int main()
{
    int a = 10;
    int *ptr;

    ptr = &a;

    return 0;
}
```



- Types to the pointers
- What??, why do we need types attached to pointers?

Advanced C

Pointers – Rule 4 in detail

- Does address has a type?

Example

```c
#include <stdio.h>

int main()
{
    int num = 1234;
    char ch;

    return 0;
}
```

	num	
1000	1234	4 bytes

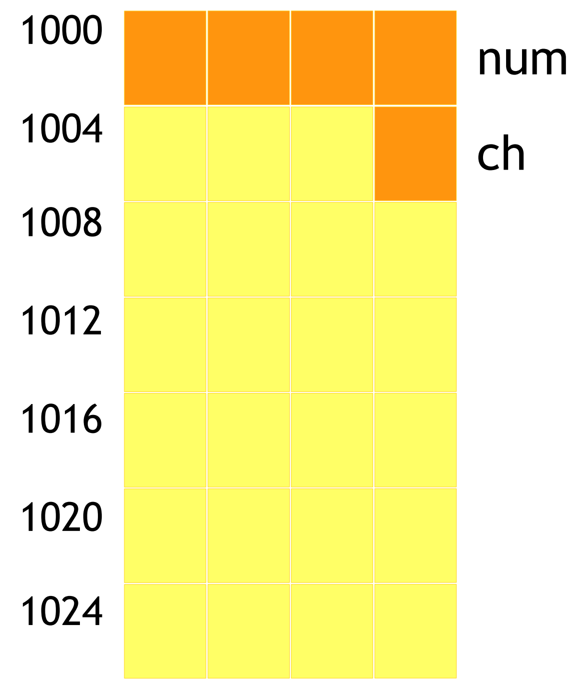
	ch	
1004	?	1 bytes

- So from the above diagram can we say &num → 4 bytes and &ch → 1 byte?

Advanced C

Pointers – Rule 4 in detail

- The answer is no!!
- Address size does not depend on type of the variable
- It depends on the system we use and remains same across all pointers
- Then a simple questions arises “why type is used with pointers?”



Advanced C

Pointers – Rule 4 in detail

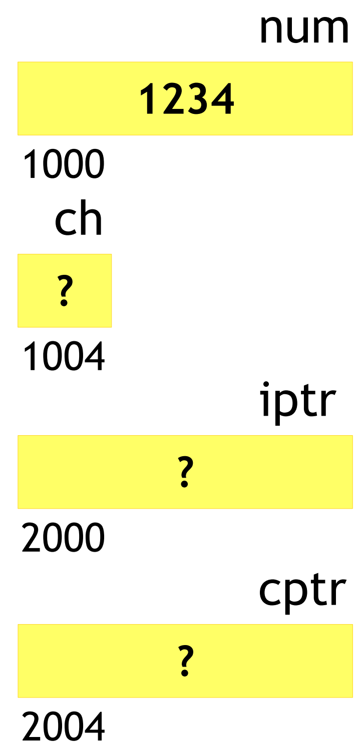
Example

```c
#include <stdio.h>

int main()
{
    int num = 1234;
    char ch;

    int *iptr;
    char *cptr;

    return 0;
}
```



- Lets consider above example to understand it
- Say we have an integer and a character pointer

Advanced C

Pointers – Rule 4 in detail

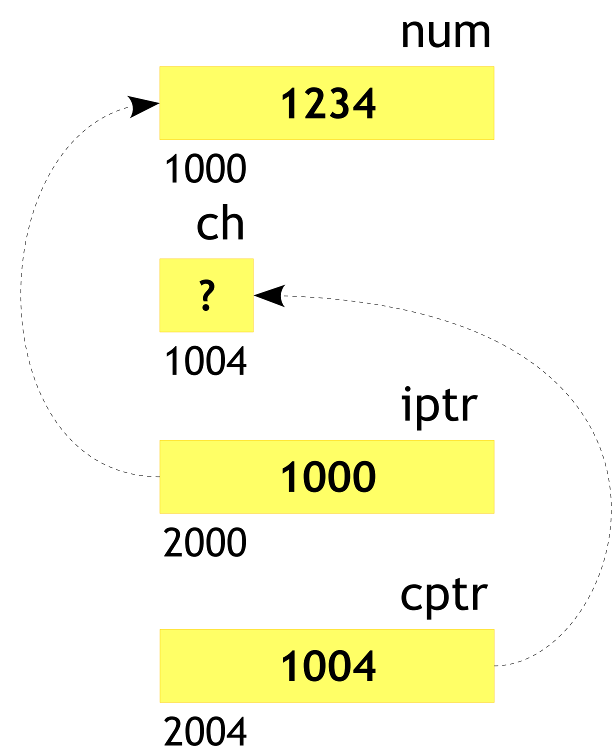
Example

```
#include <stdio.h>

int main()
{
    int num = 1234;
    char ch;

    int *iptr = &num;
    char *cptr = &ch;

    return 0;
}
```



- Lets consider the above examples to understand it
- Say we have a integer and a character pointer

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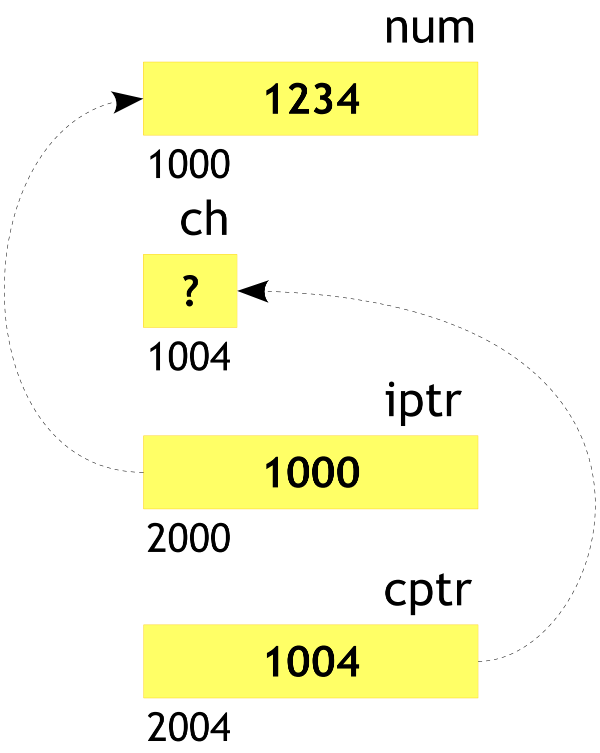
Pointers – Rule 4 in detail

- With just the address, can we know what data is stored?
- How would we know how much data to fetch for the address it is pointing to?
- Eventually the answer would be NO!!



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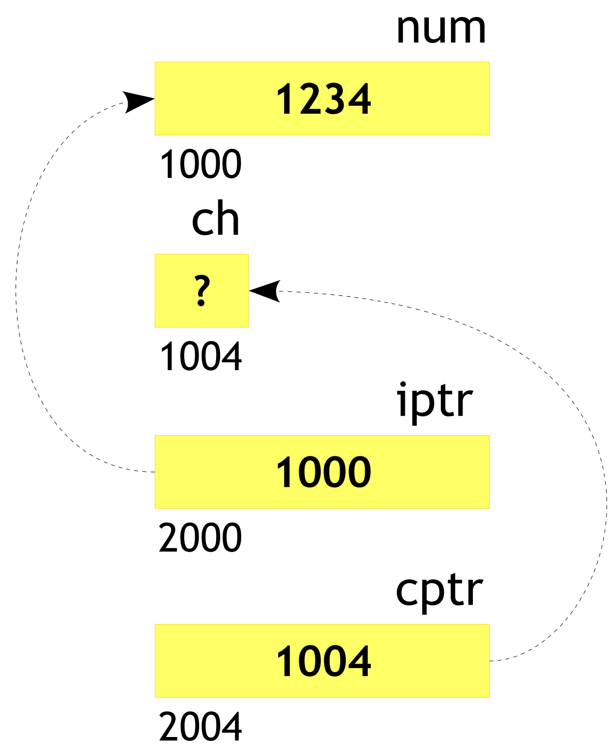
Pointers – Rule 4 in detail

- From the diagram right side we can say

  *cptr fetches a single byte

  *iptr fetches 4 consecutive bytes

- So, in conclusion we can say



(type *) → fetch sizeof(type) bytes

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Pointers – Rule 4 in detail - Endianness

- Since the discussion is on the data fetching, its better we have knowledge of storage concept of machines
- The Endianness of the machine
- What is this now!!?
  - Its nothing but the byte ordering in a word of the machine
- There are two types
  - Little Endian – LSB in Lower Memory Address
  - Big Endian – MSB in Lower Memory Address

Advanced C

Pointers – Rule 4 in detail - Endianness

- LSB (Least Significant Byte)
  - The byte of a multi byte number with the least importance
  - The change in it would have least effect on number's value change
- MSB (Most Significant Byte)
  - The byte of a multi byte number with the most importance
  - The change in it would have larger effect on number's value change

Advanced C

Pointers – Rule 4 in detail - Endianness

Example

```c
#include <stdio.h>

int main()
{
    int num = 0x12345678;

    return 0;
}
```

- Let us consider the following example and how it would be stored in both machine types

Big Endian

1000	12	34	56	78	num
1004					

→

1000	1001	1002	1003
12	34	56	78

Little Endian

1000	78	56	34	12	num
1004					

→

1000	1001	1002	1003
78	56	34	12

Advanced C

Pointers – Rule 4 in detail - Endianness

- OK Fine. What now? How is it going to affect the fetch and modification?
- Let us consider the same example put in the previous slide

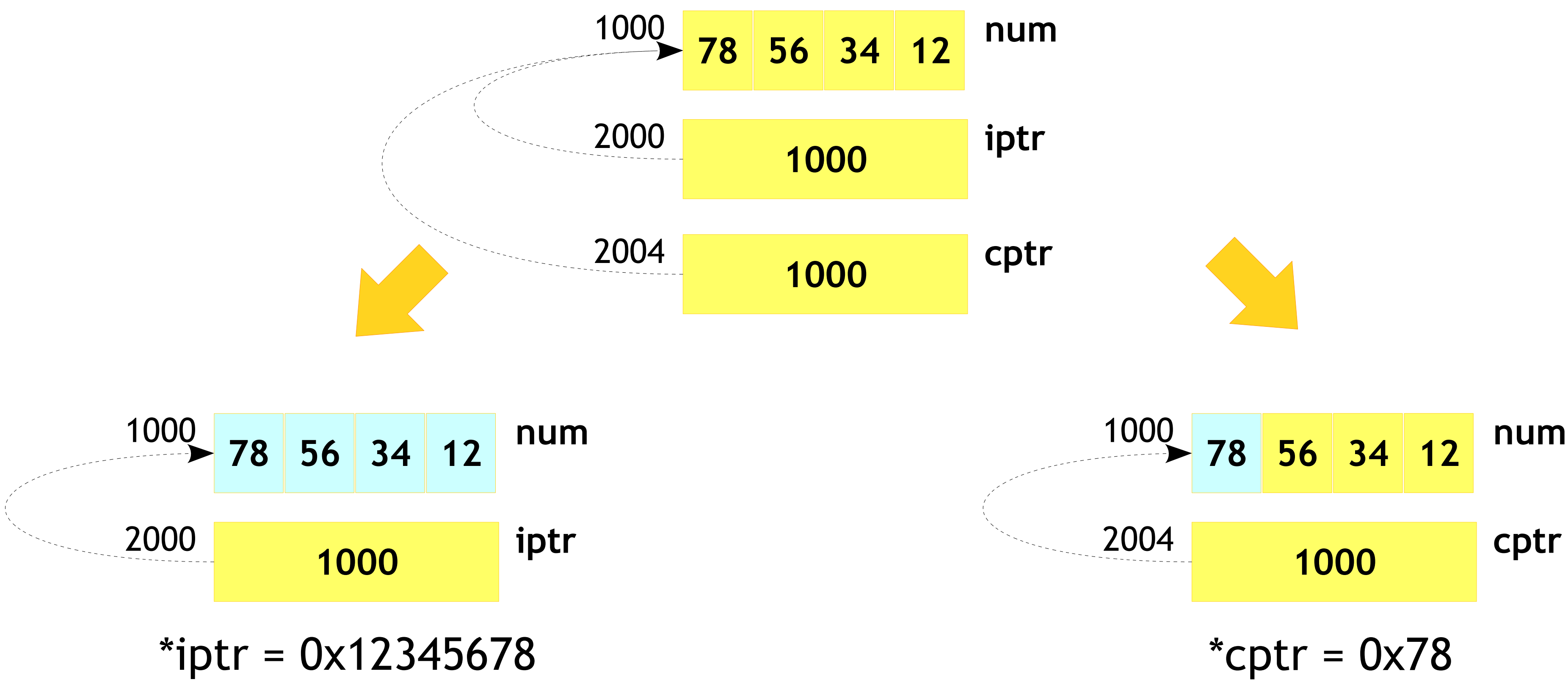
Example

```
#include <stdio.h>

int main()
{
    int num = 0x12345678;
    int *iptr, char *cptr;

    iptr = &num;
    cptr = &num;

    return 0;
}
```

- First of all is it possible to access a integer with character pointer?
- If yes, what should be the effect on access?
- Let us assume a Litte Endian system

Advanced C

Pointers – Rule 4 in detail - Endianness

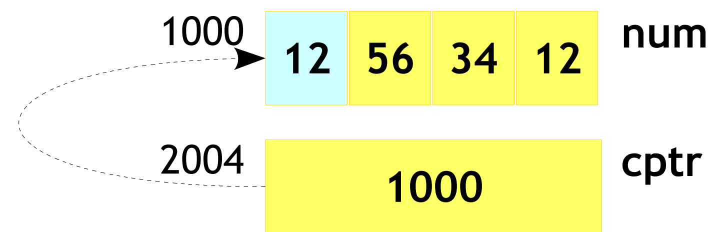


- So from the above diagram it should be clear that when we do cross type accessing, the endianness should be considered

Example

```c
#include <stdio.h>

int main()
{
    int num = 0x12345678;
    char ch;

    int *iptr = &num;
    char *cptr = &num;

    *cptr = 0x12;

    return 0;
}
```

- So changing *cptr will change only the byte its pointing to



*cptr = 0x12

- So *iptr would contain 0x12345612 now!!

- In conclusion,
  - The type of a pointer represents it's ability to perform read or write operations on number of bytes (data) starting from address its pointing to
  - Size of all different type pointers remains same

006_example.c

```
#include <stdio.h>

int main()
{
    if (sizeof(char *) == sizeof(long long *))
    {
        printf("Yes its Equal\n");
    }

    return 0;
}
```

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Pointers – The 7 Rules – Rule 4 - DIY

- WAP to check whether a machine is Little or Big Endian

- Pointer Arithmetic

  Rule: "Value(p + i) = Value(p) + i * sizeof(*p)"

Advanced C

Pointers – The Rule 5 in detail

- Before proceeding further let us understand an array interpretation
  - Original Big Variable (bunch of variables, whole array)
  - Constant Pointer to the 1st Small Variable in the bunch (base address)
- When first interpretation fails than second interpretation applies

Advanced C

Pointers – The Rule 5 in detail

- Cases when first interpretation applies
  - When name of array is operand to sizeof operator
  - When “address of operator (&)” is used with name of array while performing pointer arithmetic
- Following are the cases when first interpretation fails
  - When we pass array name as function argument
  - When we assign an array variable to pointer variable

Advanced C

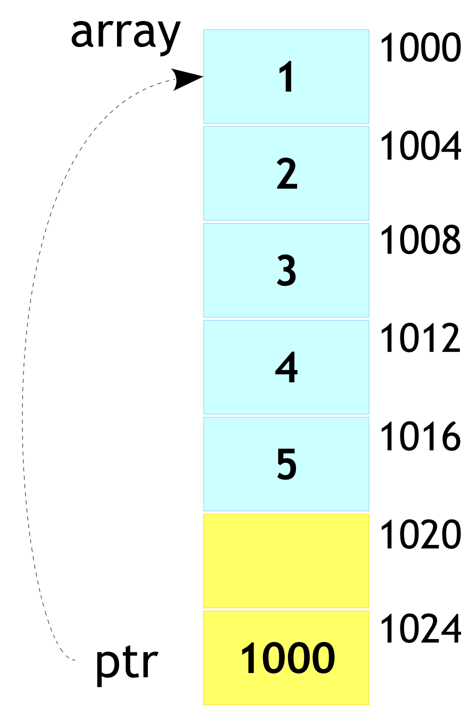
Pointers – The Rule 5 in detail

007_example.c

```c
#include <stdio.h>

int main()
{
    int array[5] = {1, 2, 3, 4, 5};
    int *ptr = array;

    return 0;
}
```



- So,

  Address of array = 1000

  Base address = 1000

  &array[0] = 1 → 1000

  &array[1] = 2 → 1004

Advanced C

Pointers – The Rule 5 in detail

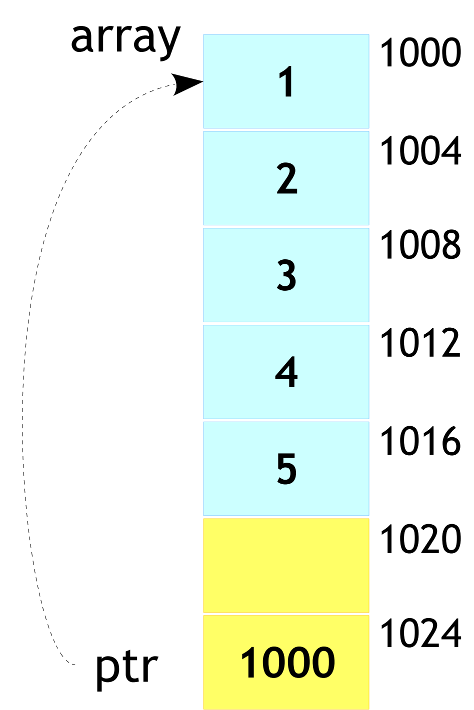
007_example.c

```
#include <stdio.h>

int main()
{
    int array[5] = {1, 2, 3, 4, 5};
    int *ptr = array;

    printf("%d\n", *ptr);

    return 0;
}
```



- This code should print 1 as output since its points to the base address
- Now, what should happen if we do

  ptr = ptr + 1;

Advanced C

Pointers – The Rule 5 in detail

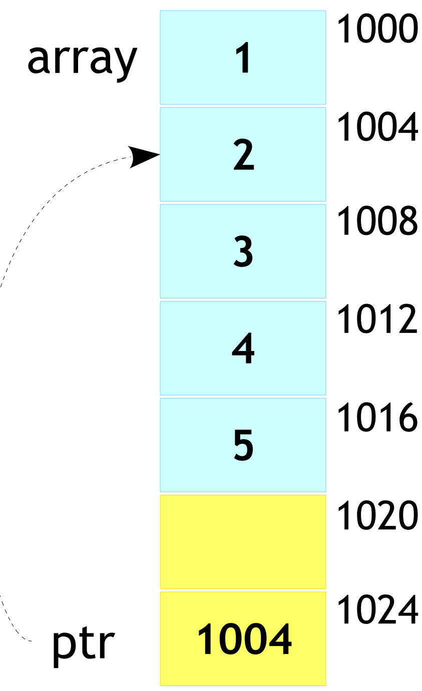
- ptr = ptr + 1;
- The above line can be described as follows
- ptr = ptr + 1 * sizeof(data type)
- In this example we have a integer array, so
- ptr = ptr + 1 * sizeof(int)

  = ptr + 1 * 4

  = ptr + 4
- Here ptr = 1000 so

  = 1000 + 4

  = 1004



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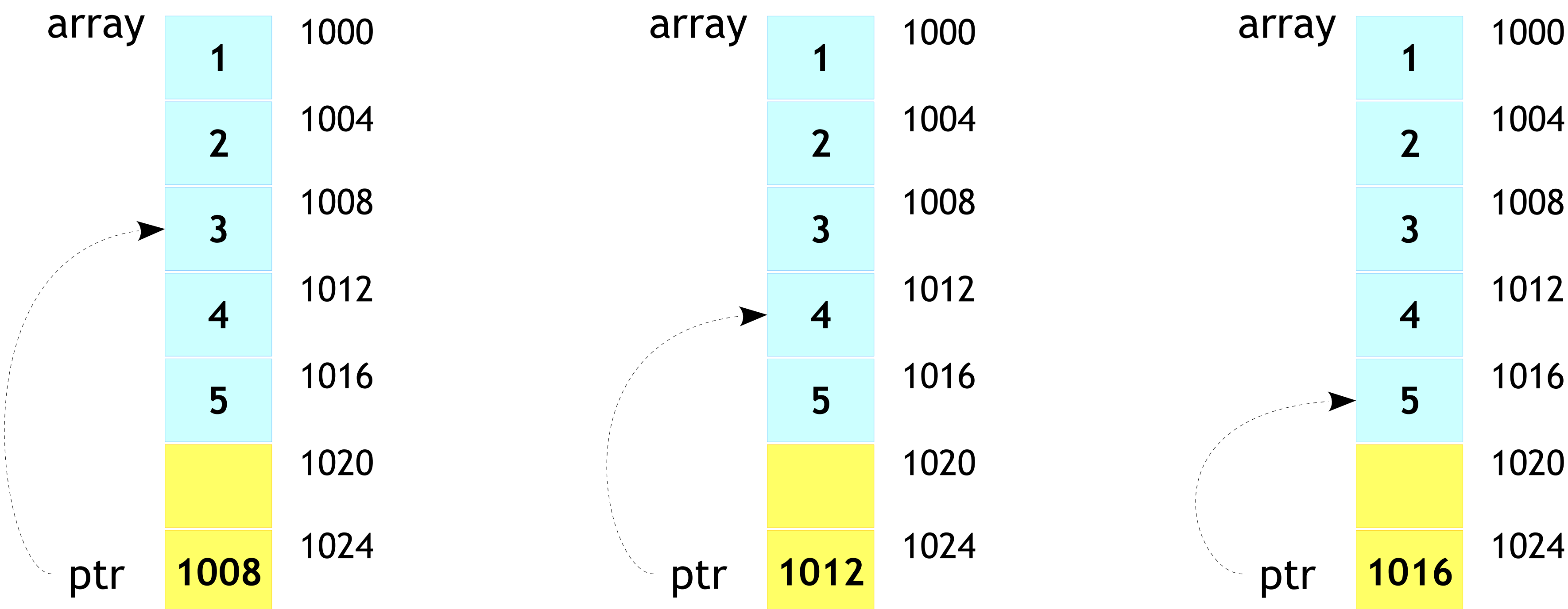
Pointers – The Rule 5 in detail




```
ptr = ptr + 2;          ptr = ptr + 3;          ptr = ptr + 4;
```

- Why does the compiler does this? Just for convenience

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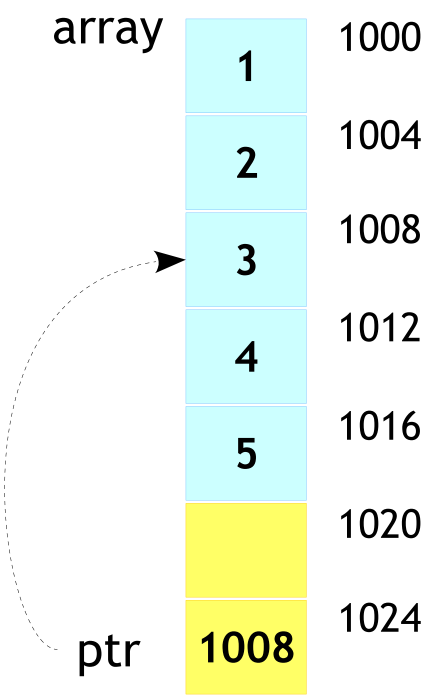
Pointers – The Rule 5 in detail



ptr = ptr + 2;

- For array, it can be explained as

  ptr + 2

  ptr + 2 * sizeof(int)

  1000 + 2 * 4

  1008 → &array[2]

- So,

  ptr + 2 → 1008 → &array[2]

  *(ptr + 2) → *(1008) → array[2]

Advanced C

Pointers – The Rule 5 in detail

- So to access an array element using a pointer would be

  *(ptr + i) → array[i]

- This can be written as following too!!

  array[i] → *(array + i)

- Which results to

  ptr = array

- So, in summary, the below line also becomes valid because of second array interpretation

```
int *ptr = array;
```

Advanced C

Pointers – The Rule 5 in detail

- Wait can I write

*(ptr + i) → *(i + ptr)

- Yes. So than can I write

array[i] → i[array]

- Yes. You can index the element in both the ways

Advanced C

Pointers – The 7 Rules – Rule 6

- Rule: “Pointer value of NULL or Zero = Null Addr = Null Pointer = Pointing to Nothing”

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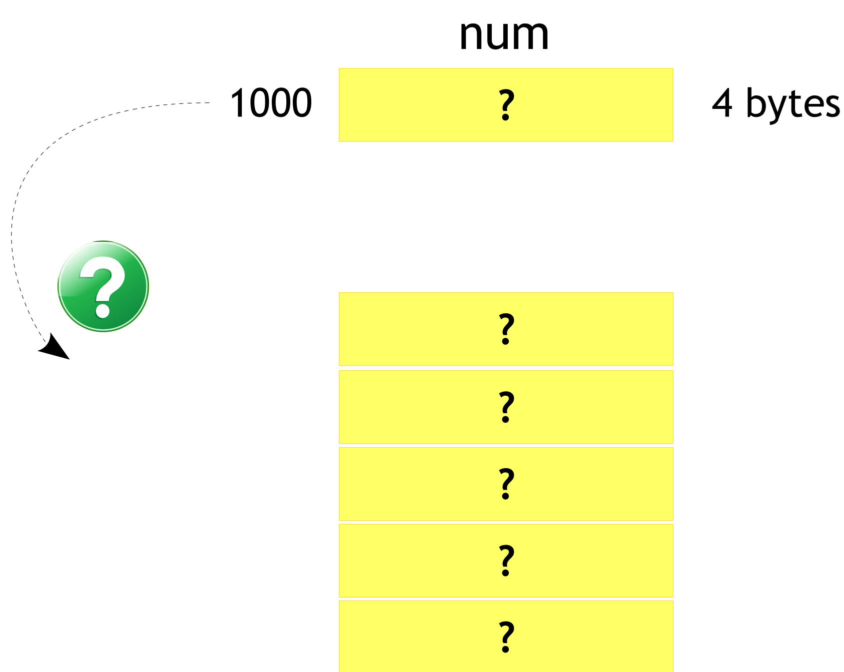
Pointers – Rule 6 in detail – NULL Pointer

Example

```c
#include <stdio.h>

int main()
{
    int *num;

    return 0;
}
```



Where am I pointing to?

What does it Contain?

Can I read or write wherever I am pointing?

Advanced C

Pointers – Rule 6 in detail – NULL Pointer

- Is it pointing to the valid address?
- If yes can we read or write in the location where its pointing?
- If no what will happen if we access that location?
- So in summary where should we point to avoid all this questions if we don't have a valid address yet?
- The answer is Point to Nothing!!

Advanced C

Pointers – Rule 6 in detail – NULL Pointer

- Now what is Point to Nothing?
- A permitted location in the system will always give predictable result!
- It is possible that we are pointing to some memory location within our program limit, which might fail any time! Thus making it bit difficult to debug.
- An act of initializing pointers to 0 (generally, implementation dependent) at definition.
- 0??, Is it a value zero? So a pointer contain a value 0?
- Yes. On most of the operating systems, programs are not permitted to access memory at address 0 because that memory is reserved by the operating system

Advanced C

Pointers – Rule 6 in detail – NULL Pointer

- In pointer context, an integer constant expression with value zero or such an expression typecast to void * is called **null pointer constant** or NULL
  - [defined as 0 or (void *)0]
- If a pointer is initialized with null pointer constant, it is called **null pointer**
- A Null Pointer is logically understood to be **Pointing to Nothing**
- De-referencing a NULL pointer is illegal and will lead to crash (segment violation on Linux or reboot on custom board), which is better than pointing to some unknown location and failing randomly!

Advanced C

Pointers – Rule 6 in detail – NULL Pointer

- Need for Pointing to 'Nothing'
  - Terminating Linked Lists
  - Indicating Failure by malloc, ...
- Solution
  - Need to reserve one valid value
  - Which valid value could be most useless?
  - In wake of OSes sitting from the start of memory, 0 is a good choice
  - As discussed in previous sides it is implementation dependent

Advanced C

Pointers – Rule 6 in detail – NULL Pointer

Example

```c
#include <stdio.h>

int main()
{
    int *num;

    num = NULL;

    return 0;
}
```

Example

```c
#include <stdio.h>

int main()
{
    int *num = NULL;

    return 0;
}
```

Advanced C

Pointers – Void Pointer

- A pointer with incomplete type
- Due to incomplete type
  - Pointer arithmetic can’t be performed
  - Void pointer can't be dereferenced. You MUST use type cast operator “(type)” to dereference

:GCC Extension:

6.22 Arithmetic on void- and Function-Pointers

In GNU C, addition and subtraction operations are supported on “pointers to void” and on “pointers to functions”. This is done by treating the size of a void or of a function as 1.

A consequence of this is that sizeof is also allowed on void and on function types, and returns 1.

The option **-Wpointer-arith** requests a warning if these extensions are used

- Due to gcc extension, size of void is 1
- Hence, gcc allows pointer arithmetic on void pointer
- Don’t forget! Its compiler dependent!

Note: To make standard compliant, compile using gcc -pedantic-errors

Advanced C

Pointers – Void Pointer

- A generic pointer which can point to data in memory
- The data type has to be mentioned while accessing the memory which has to be done by type casting

Example

```
#include <stdio.h>

int main()
{
    void *vptr;

    return 0;
}
```

vptr

2000 ?

Advanced C

Pointers – Void Pointer

008_example.c

```c
#include <stdio.h>

int main()
{
    double x = 7.2;
    void *vptr = &x;

    return 0;
}
```

- vptr is a void pointer pointing to address of x which holds floating point data with double type
- These eights bytes are the legal region to the vptr
- We can access any byte(s) within this region by type casting

	vptr
1000	2000

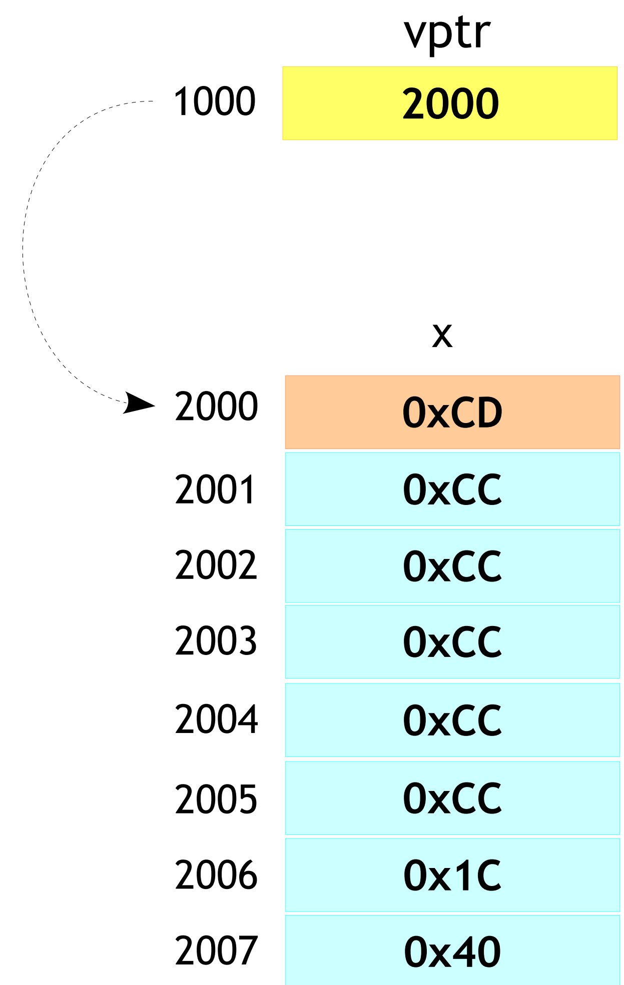
	x
2000	0xCD
2001	0xCC
2002	0xCC
2003	0xCC
2004	0xCC
2005	0xCC
2006	0x1C
2007	0x40

Advanced C

Pointers – Void Pointer

008_example.c

```
#include <stdio.h>

int main()
{
    double x = 7.2;
    void *vptr = &x;

    printf(“%hhx\n”, *(char *)vptr);
    printf(“%hhx\n”, *(char *)(vptr + 7));
    printf(“%hu\n”, *(short *)(vptr + 3));
    printf(“%x\n”, *(int *)(vptr + 0));

    return 0;
}
```



Advanced C

Pointers – Void Pointer

008_example.c

```c
#include <stdio.h>

int main()
{
    double x = 7.2;
    void *vptr = &x;

    printf(“%hhx\n”, *(char *)vptr);
    printf(“%hhx\n”, *(char *)(vptr + 7));
    printf(“%hu\n”, *(short *)(vptr + 3));
    printf(“%x\n”, *(int *)(vptr + 0));

    return 0;
}
```

	vptr
1000	2000

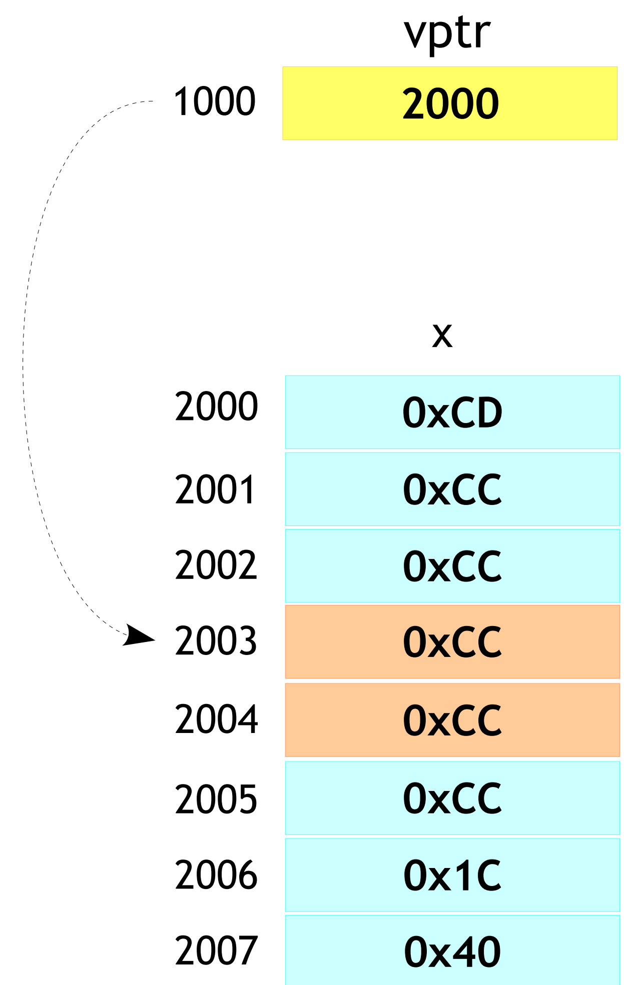
	x
2000	0xCD
2001	0xCC
2002	0xCC
2003	0xCC
2004	0xCC
2005	0xCC
2006	0x1C
2007	0x40

Advanced C

Pointers – Void Pointer

008_example.c

```
#include <stdio.h>

int main()
{
    double x = 7.2;
    void *vptr = &x;

    printf(“%hhx\n”, *(char *)vptr);
    printf(“%hhx\n”, *(char *)(vptr + 7));
    printf(“%hu\n”, *(short *)(vptr + 3));
    printf(“%x\n”, *(int *)(vptr + 0));

    return 0;
}
```

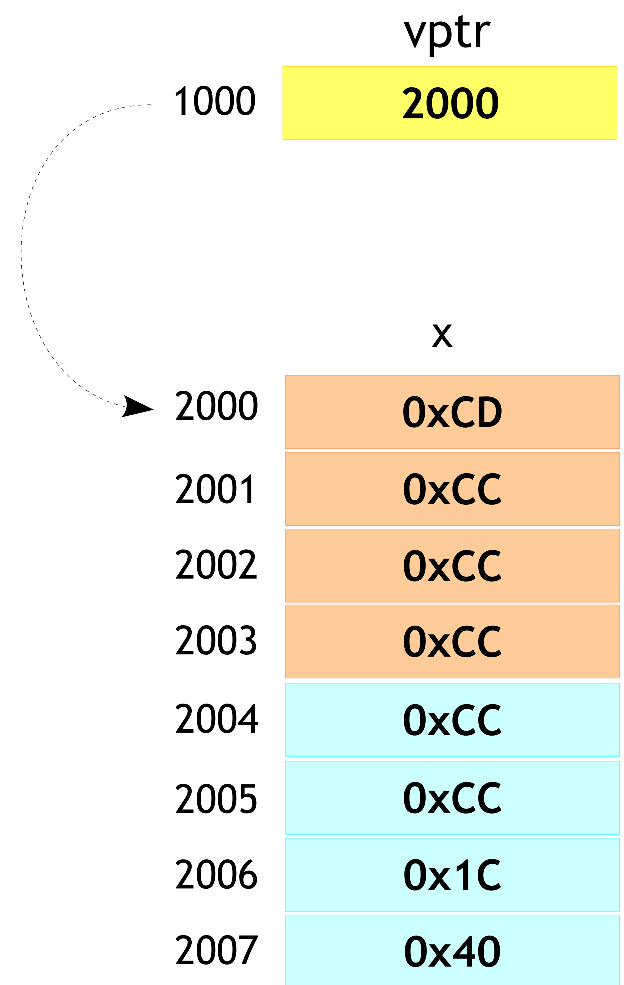


Advanced C

Pointers – Void Pointer

008_example.c

```c
#include <stdio.h>

int main()
{
    double x = 7.2;
    void *vptr = &x;

    printf("%hhx\n", *(char *)vptr);
    printf("%hhx\n", *(char *)(vptr + 7));
    printf("%hu\n", *(short *)(vptr + 3));
    printf("%x\n", *(int *)(vptr + 0));

    return 0;
}
```



Advanced C
Pointers – Void Pointer

- W.A.P to swap any given data type

Advanced C

Pointers – The 7 Rules – Rule 7

- Rule: "Static Allocation vs Dynamic Allocation"

Example

```c
#include <stdio.h>

int main()
{
    char array[5];

    return 0;
}
```

Example

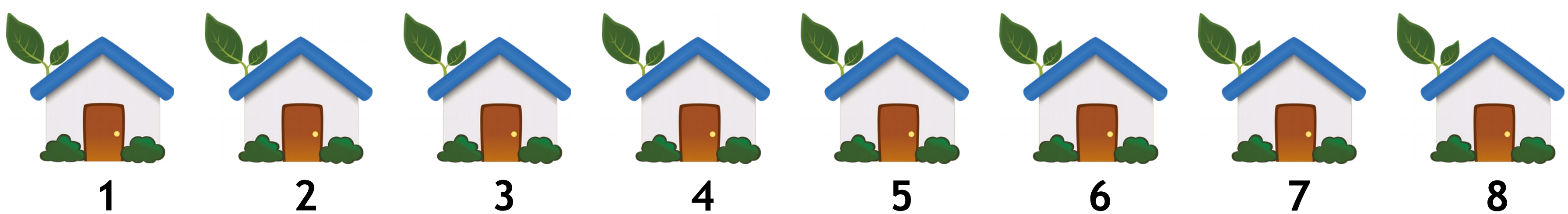
```c
#include <stdio.h>

int main()
{
    char *ptr;

    ptr = malloc(5);

    return 0;
}
```

Advanced C

Pointers – Rule 7 in detail

- Named vs Unnamed Allocation = Named vs Unnamed Houses

Ok, House 1, I should go??? Oops



Ok, House 1, I should go that side ←

Pointers – Rule 7 in detail

- Managed by Compiler vs User
- Compiler
  - The compiler will allocate the required memory internally
  - This is done at the time of definition of variables
- User
  - The user has to allocate the memory whenever required and deallocate whenever required
  - This done by using malloc and free

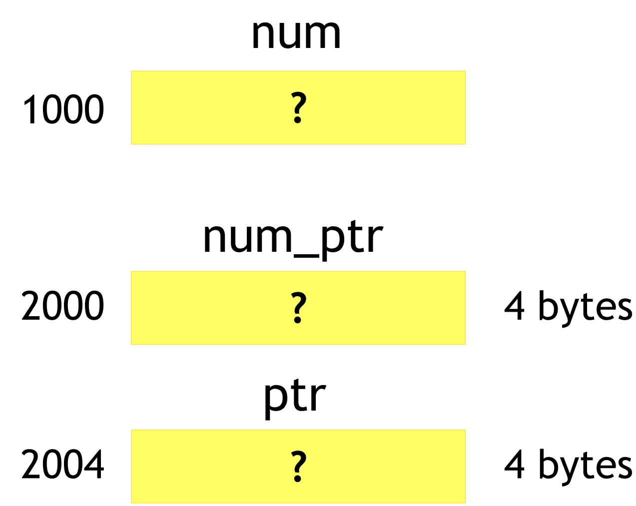
Advanced C

Pointers – Rule 7 in detail

- Static vs Dynamic

Example

```
#include <stdio.h>

int main()
{
    int num, *num_ptr, *ptr;

    num_ptr = &num;

    ptr = malloc(4);

    return 0;
}
```



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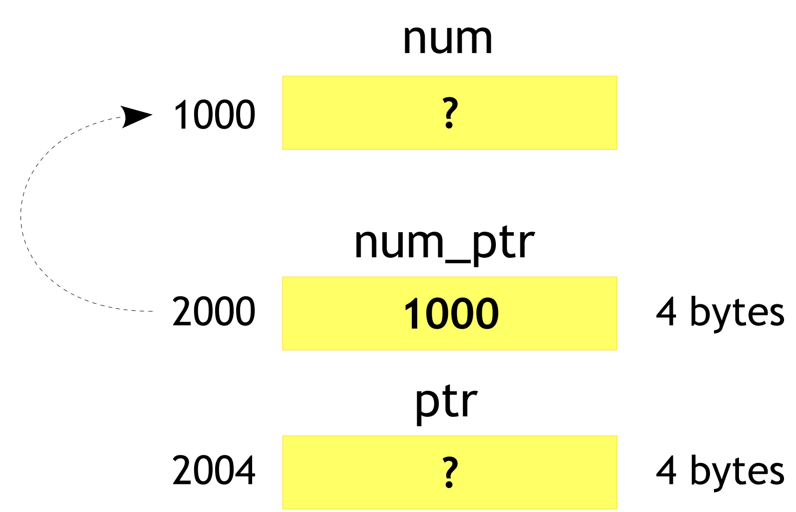
Advanced C

Pointers – Rule 7 in detail

- Static vs Dynamic

Example

```
#include <stdio.h>

int main()
{
    int num, *num_ptr, *ptr;

    num_ptr = &num;

    ptr = malloc(4);

    return 0;
}
```



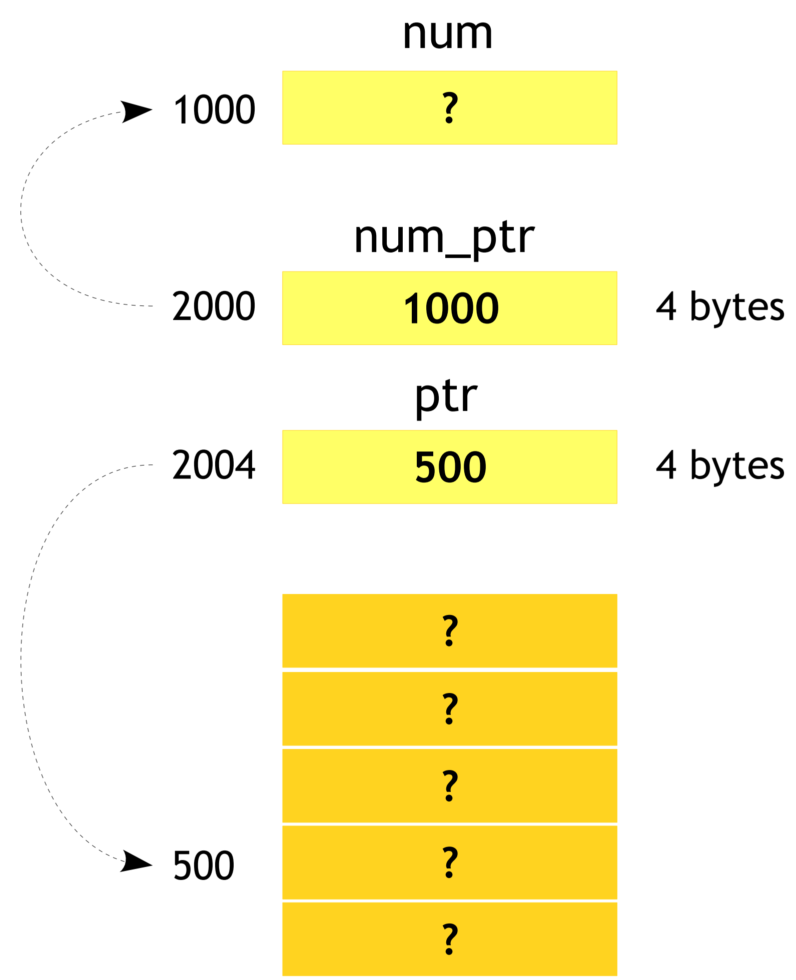
Advanced C

Pointers – Rule 7 in detail

- Static vs Dynamic

Example

```
#include <stdio.h>

int main()
{
    int num, *num_ptr, *ptr;

    num_ptr = &num;

    ptr = malloc(4);

    return 0;
}
```



Advanced C

Pointers – Rule 7 in detail - Dynamic Allocation

- The need
  - You can decide size of the memory at run time
  - You can resize it whenever required
  - You can decide when to create and destroy it

Prototype

```
void *malloc(size_t size);
```

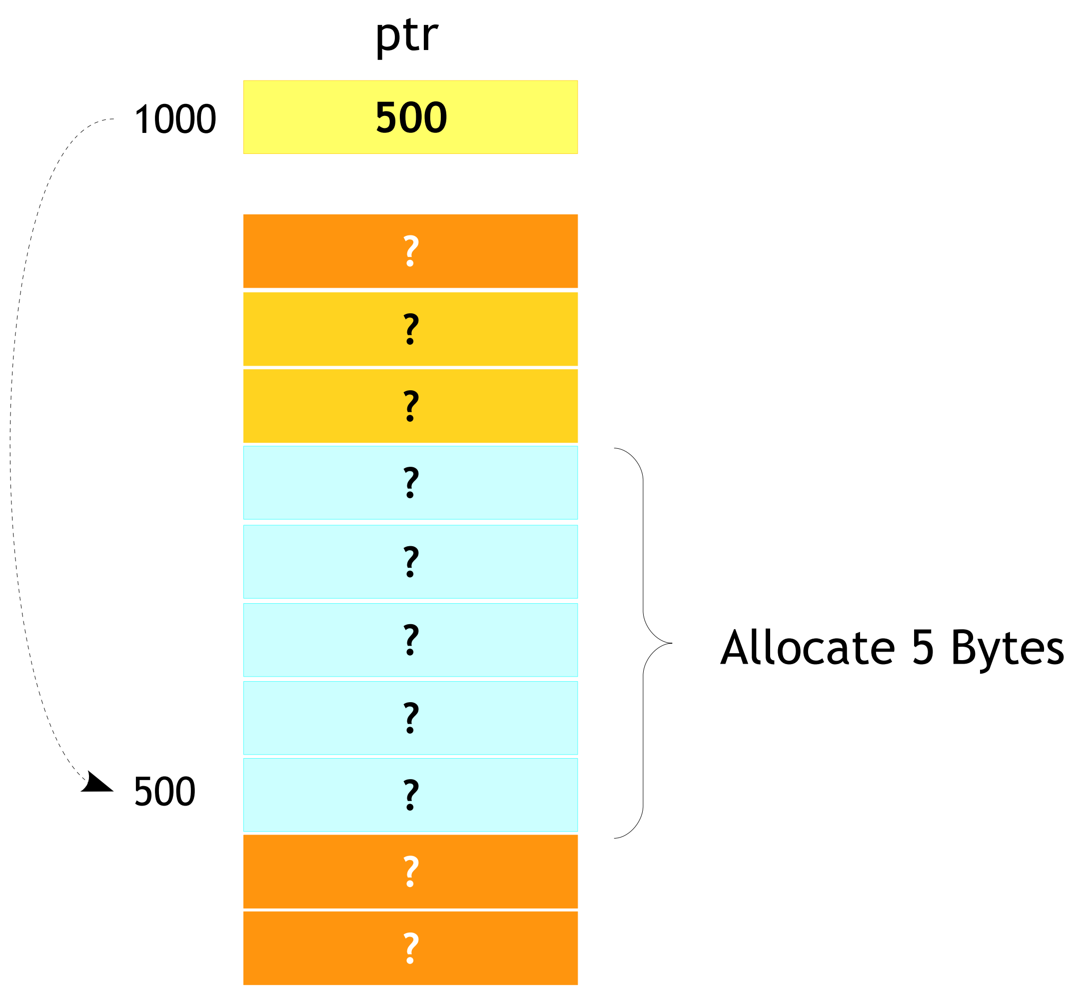
- Allocates the requested size of memory from the heap
- The size is in bytes
- Returns the pointer of the allocated memory on success, else returns NULL pointer

Advanced C

Pointers – Rule 7 – Dynamic Allocation - malloc

Example

```
#include <stdio.h>

int main()
{
    char *ptr;

    ptr = malloc(5);

    return 0;
}
```

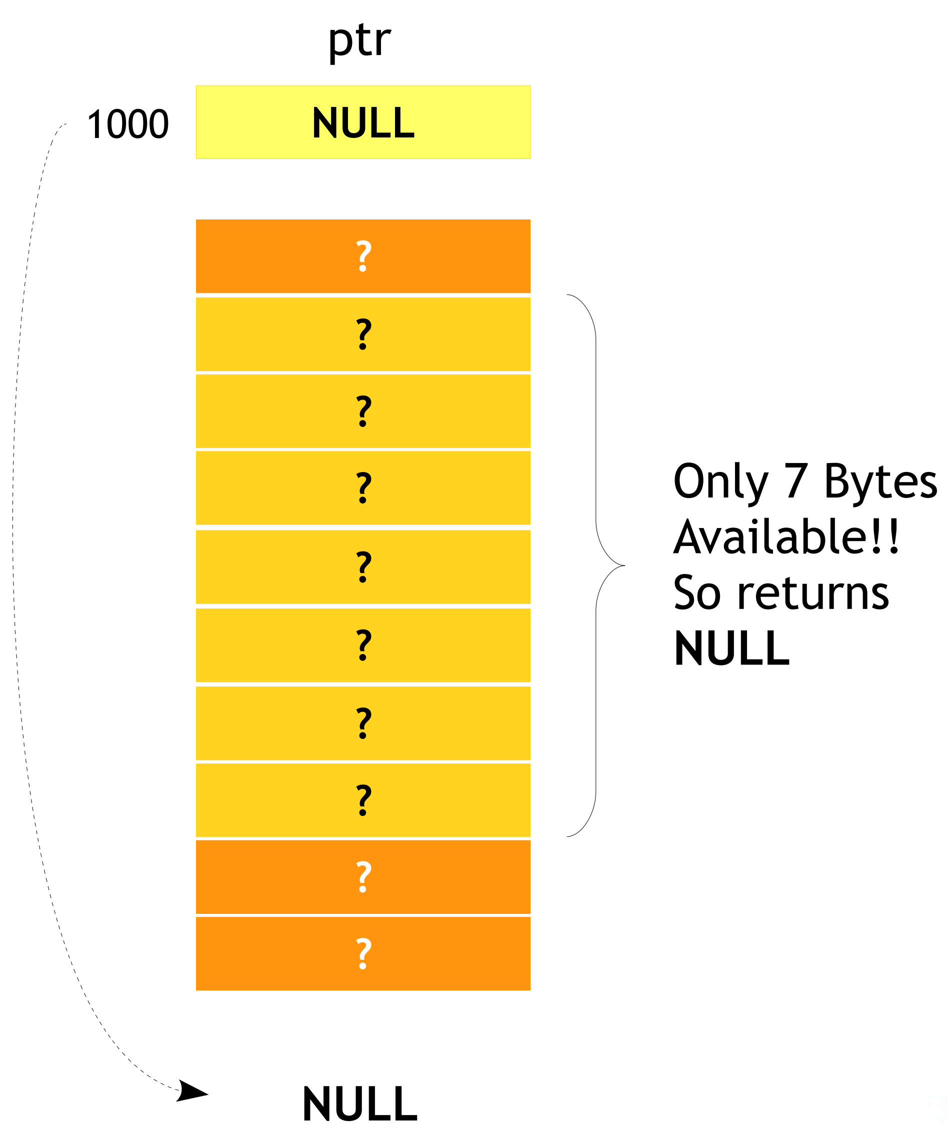


Advanced C

Pointers – Rule 7 – Dynamic Allocation - malloc

Example

```
#include <stdio.h>

int main()
{
    char *ptr;

    ptr = malloc(10);

    return 0;
}
```



Prototype

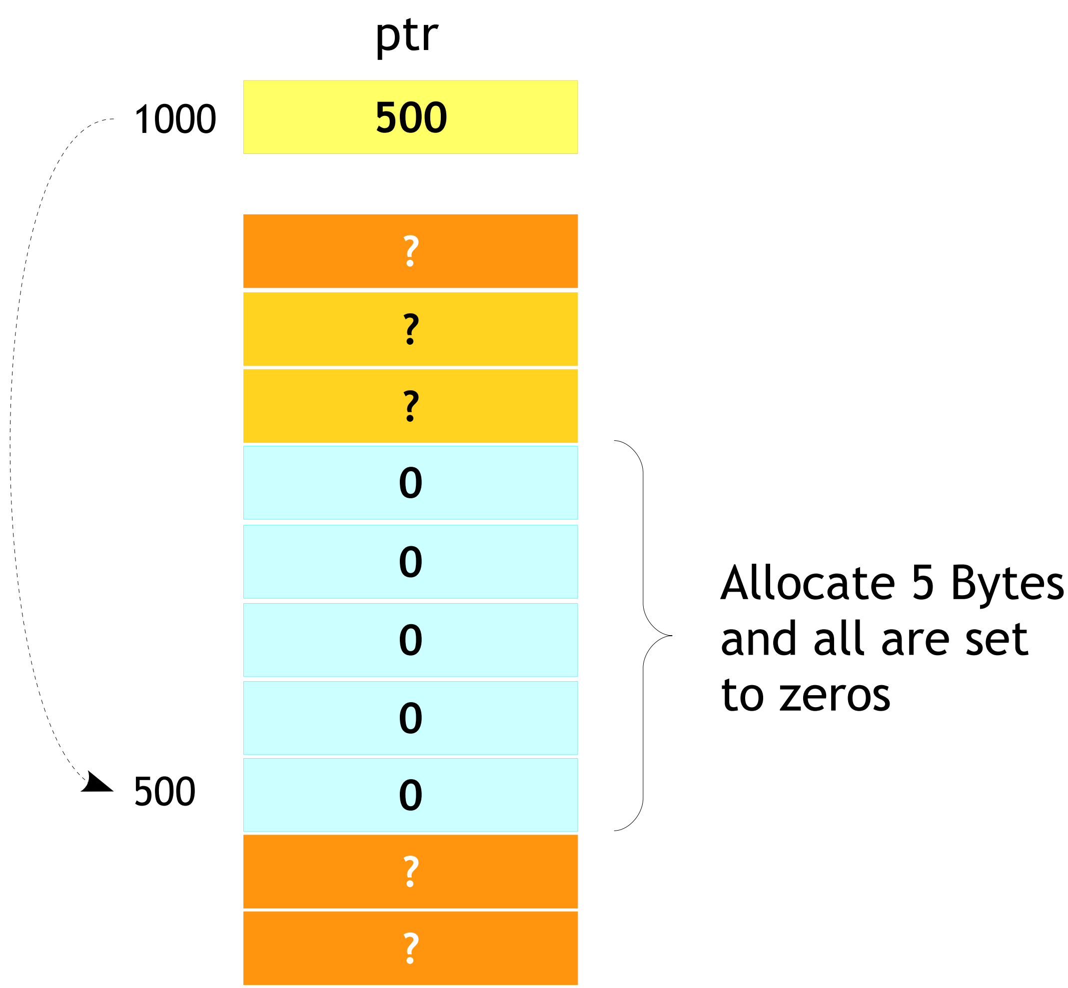
```
void *calloc(size_t nmemb, size_t size);
```

- Allocates memory blocks large enough to hold "n elements" of "size" bytes each, from the heap
- The allocated memory is set with 0's
- Returns the pointer of the allocated memory on success, else returns NULL pointer

Pointers – Rule 7 – Dynamic Allocation - calloc

Example

```c
#include <stdio.h>

int main()
{
    char *ptr;

    ptr = calloc(5, 1);

    return 0;
}
```



Advanced C

Pointers – Rule 7 – Dynamic Allocation - realloc

Prototype

```
void *realloc(void *ptr, size_t size);
```

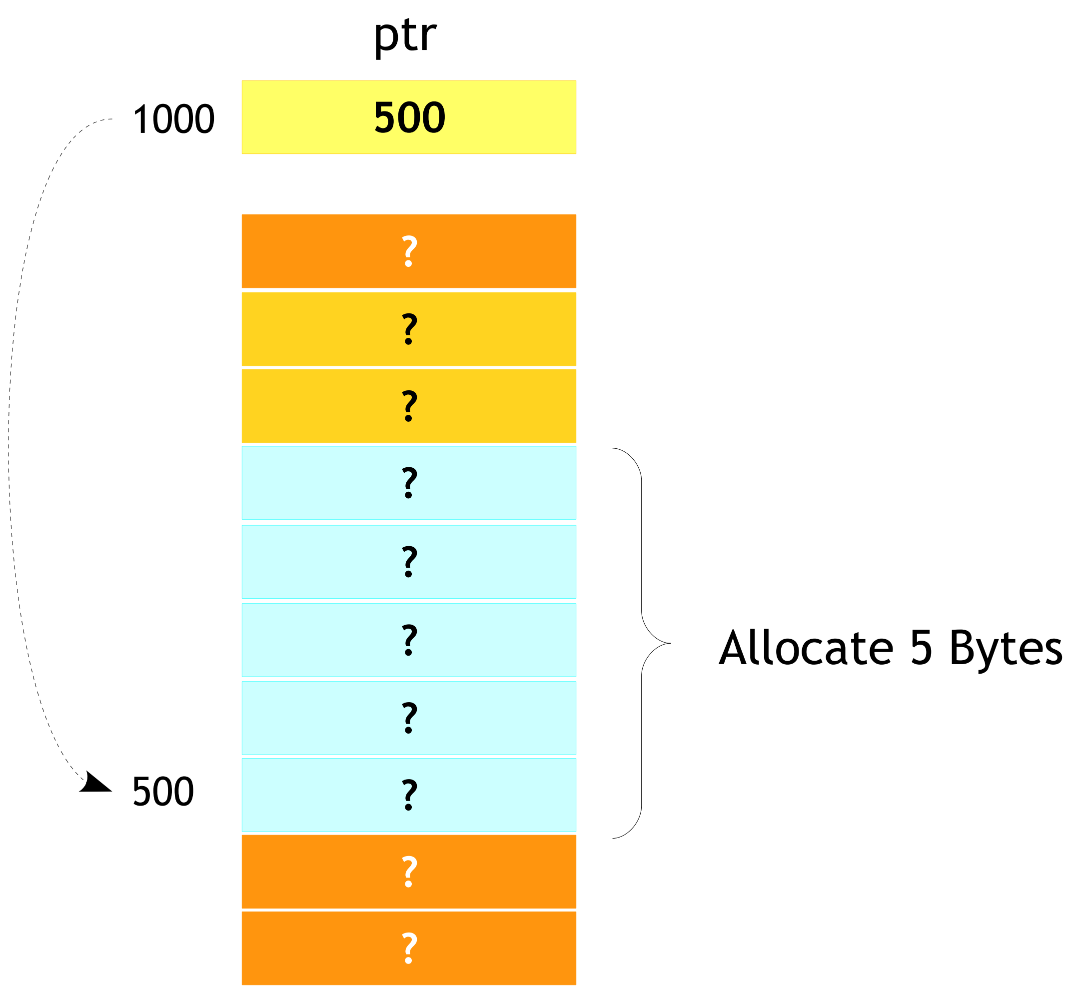
- Changes the size of the already allocated memory by malloc or calloc.
- Returns the pointer of the allocated memory on success, else returns NULL pointer

Advanced C

Pointers – Rule 7 – Dynamic Allocation - realloc

Example

```c
#include <stdio.h>

int main()
{
    char *ptr;

    ptr = malloc(5);

    ptr = realloc(ptr, 7);
    ptr = realloc(ptr, 2);

    return 0;
}
```

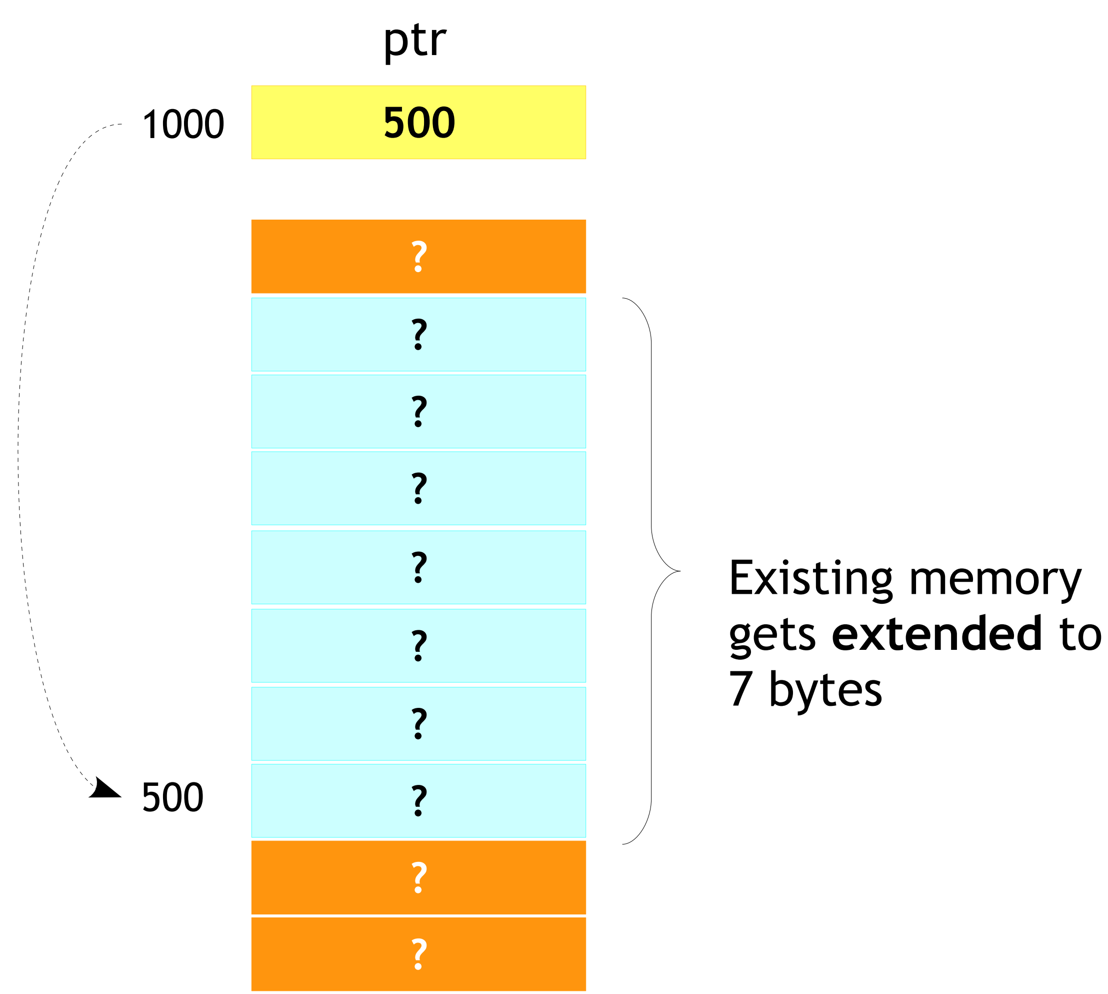


Advanced C

Pointers – Rule 7 – Dynamic Allocation - realloc

Example

```c
#include <stdio.h>

int main()
{
    char *ptr;

    ptr = malloc(5);

    ptr = realloc(ptr, 7);
    ptr = realloc(ptr, 2);

    return 0;
}
```

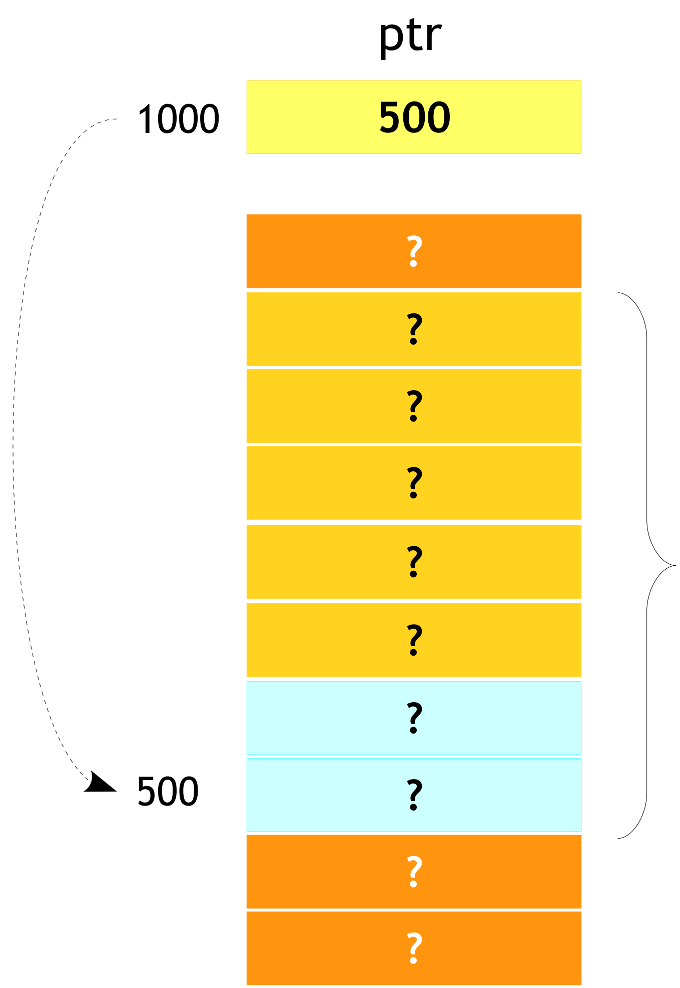


Advanced C

Pointers – Rule 7 – Dynamic Allocation - realloc

Example

```c
#include <stdio.h>

int main()
{
    char *ptr;

    ptr = malloc(5);

    ptr = realloc(ptr, 7);
    ptr = realloc(ptr, 2);

    return 0;
}
```



Existing memory gets **shrinked** to 2 bytes

Advanced C

Pointers – Rule 7 – Dynamic Allocation - realloc

- Points to be noted
  - Reallocating existing memory will be like deallocating the allocated memory
  - If the requested chunk of memory cannot be extended in the existing block, it would allocate in a new free block starting from different memory!
  - If new memory block is allocated then old memory block is automatically freed by realloc function

Advanced C

Pointers – Rule 7 – Dynamic Deallocation - free

Prototype

```
void free(void *ptr);
```

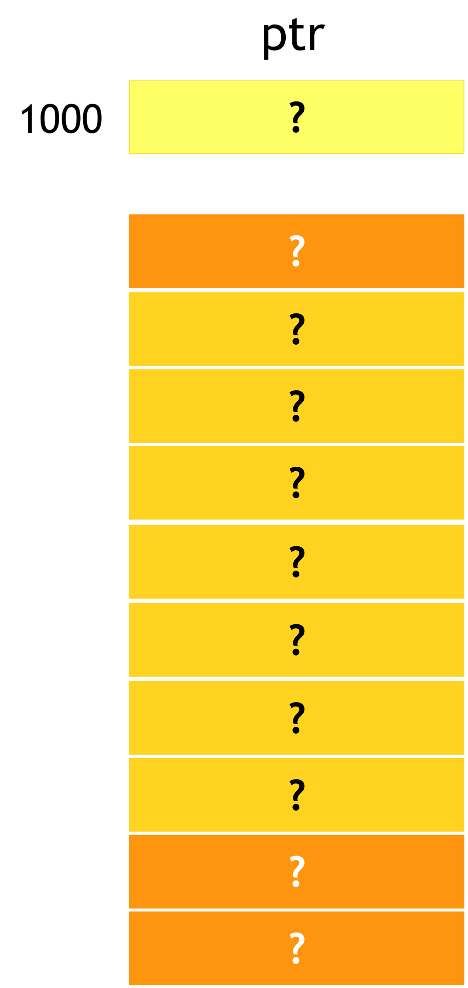
- Frees the allocated memory, which must have been returned by a previous call to malloc(), calloc() or realloc()
- Freeing an already freed block or any other block, would lead to undefined behaviour
- Freeing NULL pointer has no effect.
- If free() is called with invalid argument, might collapse the memory management mechanism
- If free is not called after dynamic memory allocation, will lead to memory leak

Advanced C

Pointers – Rule 7 – Dynamic Deallocation - free

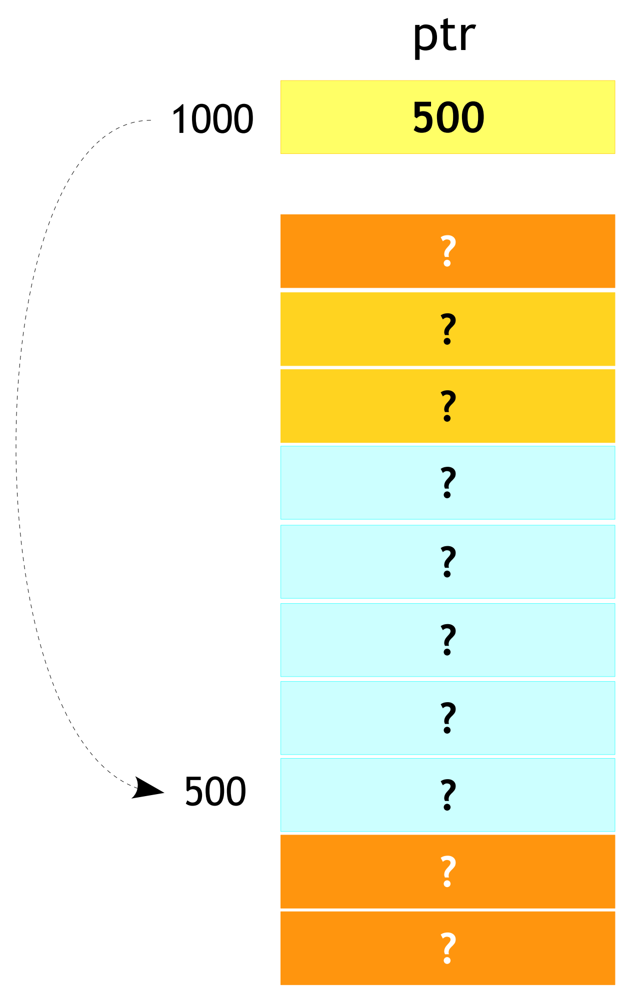
Example

```
#include <stdio.h>

int main()
{
    char *ptr;
    int iter;

    ptr = malloc(5);

    for (iter = 0; iter < 5; iter++)
    {
        ptr[iter] = 'A' + iter;
    }

    free(ptr);

    return 0;
}
```



Example

```c
#include <stdio.h>

int main()
{
    char *ptr;
    int iter;

    ptr = malloc(5);

    for (iter = 0; iter < 5; iter++)
    {
        ptr[iter] = 'A' + iter;
    }

    free(ptr);

    return 0;
}
```

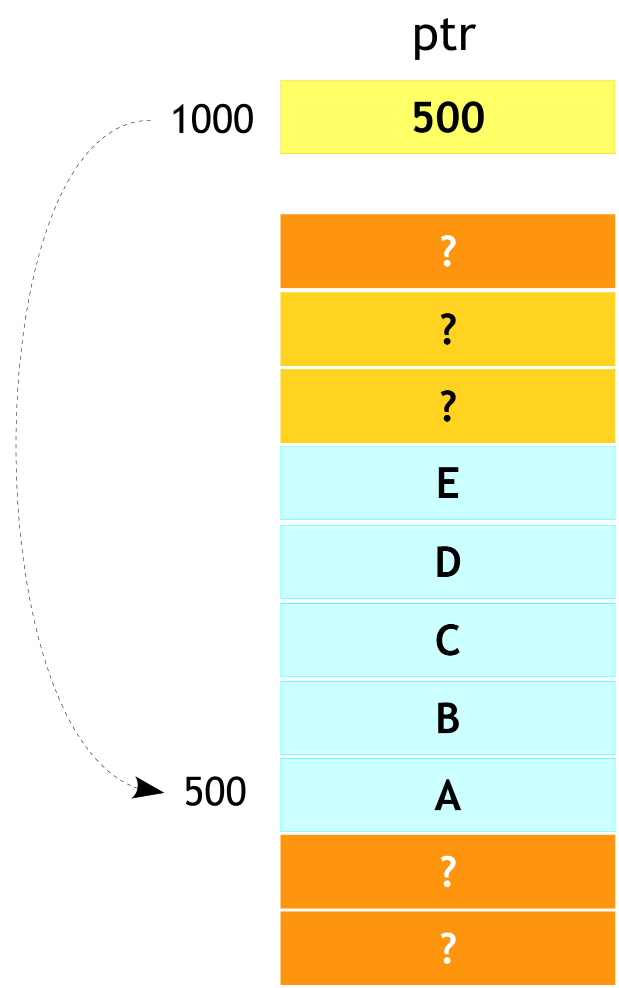


Advanced C

Pointers – Rule 7 – Dynamic Deallocation - free

Example

```c
#include <stdio.h>

int main()
{
    char *ptr;
    int iter;

    ptr = malloc(5);

    for (iter = 0; iter < 5; iter++)
    {
        ptr[iter] = 'A' + iter;
    }

    free(ptr);

    return 0;
}
```

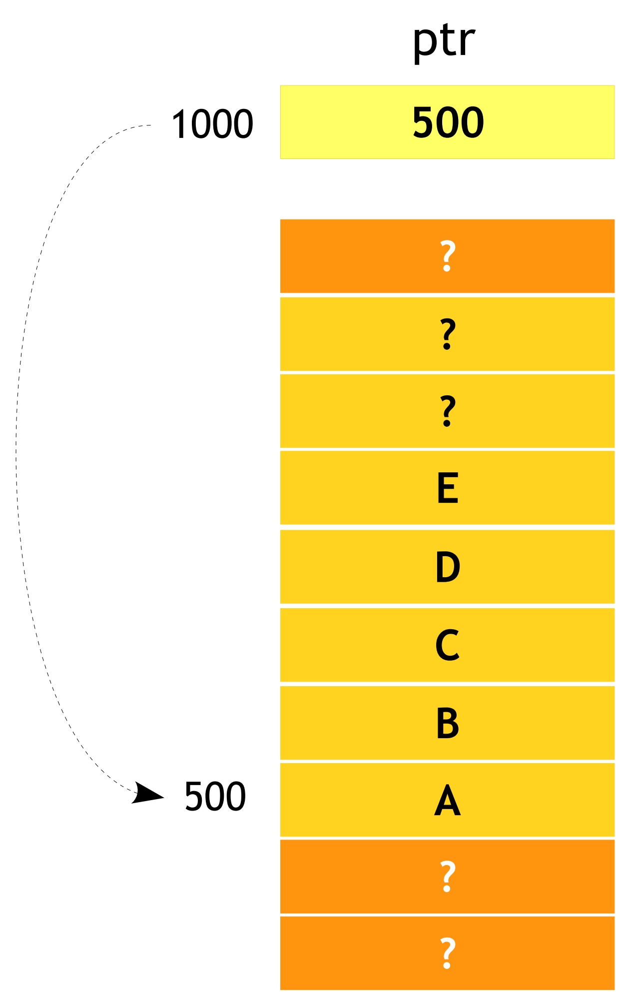


Advanced C

Pointers – Rule 7 – Dynamic Deallocation - free

Example

```c
#include <stdio.h>

int main()
{
    char *ptr;
    int iter;

    ptr = malloc(5);

    for (iter = 0; iter < 5; iter++)
    {
        ptr[iter] = 'A' + iter;
    }

    free(ptr);

    return 0;
}
```



- Points to be noted
  - Free releases the allocated block, but the pointer would still be pointing to the same block!!, So accessing the freed block will have undefined behaviour.
  - This type of pointer which are pointing to freed locations are called as **Dangling Pointers**
  - Doesn't clear the memory after freeing

Advanced C

Pointers – Rule 7 – DIY

- Implement my_strdup function

Advanced C

Pointers – Const Pointer

Example

```
#include <stdio.h>

int main()
{
    int const *num = NULL;

    return 0;
}
```

The location, its pointing to is constant

Example

```
#include <stdio.h>

int main()
{
    int *const num = NULL;

    return 0;
}
```

The pointer is constant

Advanced C

Pointers – Const Pointer

Example

```c
#include <stdio.h>

int main()
{
    const int *const num = NULL;

    return 0;
}
```

Both constants

Advanced C

Pointers – Const Pointer

Example

```
#include <stdio.h>

int main()
{
    const int num = 100;
    int *iptr = &num;

    printf("Number is %d\n", *iptr);

    *iptr = 200;

    printf("Number is %d\n", num);

    return 0;
}
```

Advanced C

Pointers – Const Pointer

Example

```
#include <stdio.h>

int main()
{
    int num = 100;
    const int *iptr = &num;

    printf("Number is %d\n", num);

    num = 200;

    printf("Number is %d\n", *iptr);

    return 0;
}
```

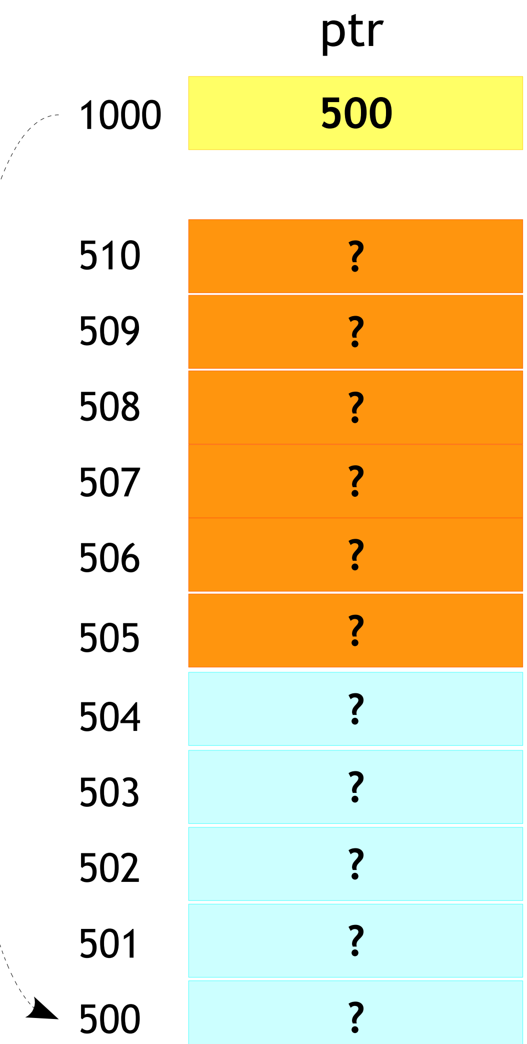
Advanced C

Pointers – Do's and Dont's

Example

```c
#include <stdio.h>

int main()
{
    char *ptr = malloc(5);

    ptr = ptr + 10; /* Yes */
    ptr = ptr - 10; /* Yes */

    return 0;
}
```

- malloc(5) allocates a block of 5 bytes as shown



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Advanced C

Pointers – Do's and Dont's

Example

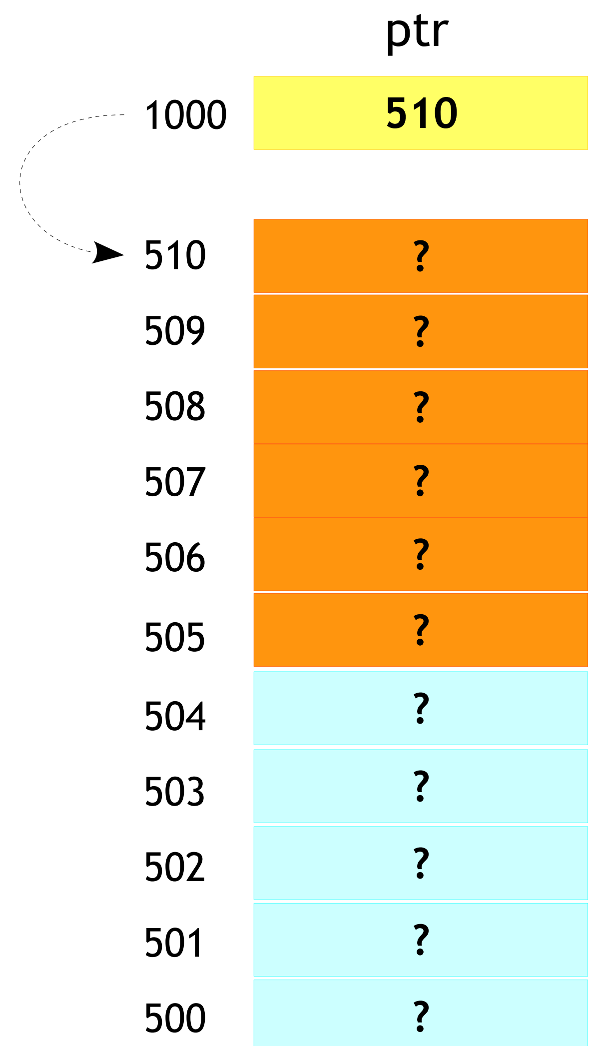
```
#include <stdio.h>

int main()
{
    char *ptr = malloc(5);

    ptr = ptr + 10; /* Yes */
    ptr = ptr - 10; /* Yes */

    return 0;
}
```

- Adding 10 to ptr we will advance 10 bytes from the base address which is illegal but no issue in compilation!!



Advanced C

Pointers – Do's and Dont's

Example

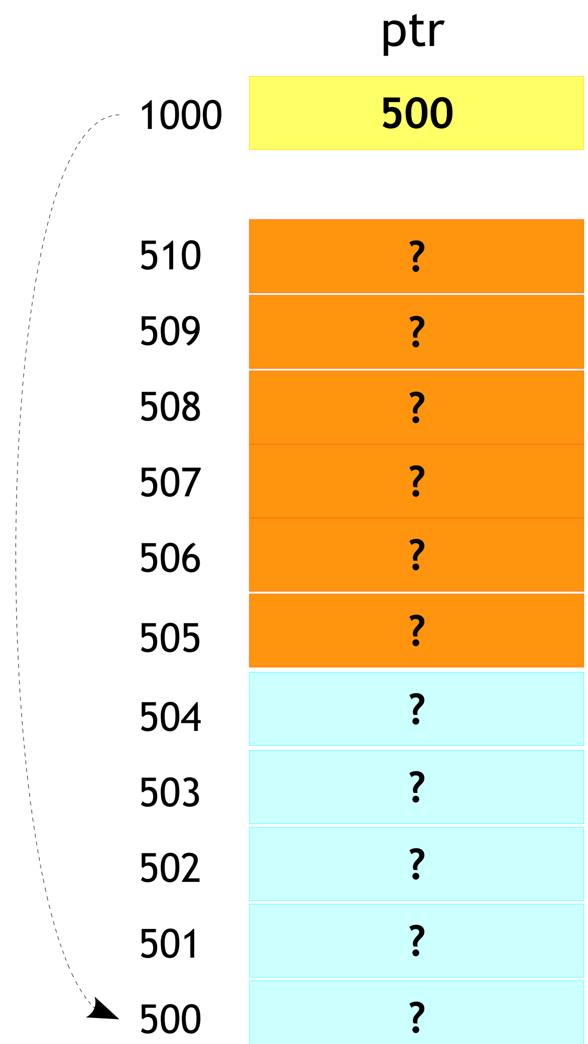
```
#include <stdio.h>

int main()
{
    char *ptr = malloc(5);

    ptr = ptr + 10; /* Yes */
    ptr = ptr - 10; /* Yes */

    return 0;
}
```

- Subtracting 10 from ptr we will retract 10 bytes to the base address which is perfectly fine



Advanced C

Pointers – Do's and Dont's

Example

```c
#include <stdio.h>

int main()
{
    char *ptr = malloc(5);

    ptr = ptr * 1; /* No */
    ptr = ptr / 1; /* No */

    return 0;
}
```

- All these operation on the ptr will be illegal and would lead to compiler error!!
- In fact most of the binary operator would lead to compilation error

Advanced C

Pointers – Do's and Dont's

Example

```c
#include <stdio.h>

int main()
{
    char *ptr = malloc(5);

    ptr = ptr + ptr; /* No */
    ptr = ptr * ptr; /* No */
    ptr = ptr / ptr; /* No */

    return 0;
}
```

- All these operation on the ptr will be illegal and would lead to compiler error!!
- In fact most of the binary operator would lead to compilation error

Advanced C

Pointers – Do's and Dont's

Example

```
#include <stdio.h>

int main()
{
    char *ptr = malloc(5);

    ptr = ptr - ptr;

    return 0;
}
```

- What is happening here!?
- Well the value of ptr would be 0, which is nothing but NULL (Most of the architectures) so it is perfectly fine
- The compiler would compile the code with a warning though

Advanced C

Pointers – Pitfalls – Segmentation Fault

- A segmentation fault occurs when a program attempts to access a memory location that it is not allowed to access, or attempts to access a memory location in a way that is not allowed.

Example

```
#include <stdio.h>

int main()
{
    int num = 0;

    printf("Enter the number\n");
    scanf("%d", num);

    return 0;
}
```

Example

```
#include <stdio.h>

int main()
{
    int *num = 0;

    printf("The number is %d\n", *num);

    return 0;
}
```

Advanced C

Pointers – Pitfalls – Dangling Pointer

- A dangling pointer is something which does not point to a valid location any more.

Example

```c
#include <stdio.h>

int main()
{
    int *num_ptr;

    num_ptr = malloc(4);
    free(num_ptr);

    *num_ptr = 100;

    return 0;
}
```

Example

```c
#include <stdio.h>

int *foo()
{
    int num_ptr;

    return &num_ptr;
}

int main()
{
    int *num_ptr;

    num_ptr = foo();

    return 0;
}
```

Advanced C

Pointers – Pitfalls – Wild Pointer

- An uninitialized pointer pointing to a invalid location can be called as an wild pointer.

Example

```
#include <stdio.h>

int main()
{
    int *num_ptr_1; /* Wild Pointer */
    static int *num_ptr_2; / Not a wild pointer */


    return 0;
}
```

- Improper usage of the memory allocation will lead to memory leaks
- Failing to deallocating memory which is no longer needed is one of most common issue.
- Can exhaust available system memory as an application runs longer.

Advanced C

Pointers – Pitfall - Memory Leak

Example

```
#include <stdio.h>

int main()
{
     int *num_array, sum = 0, no_of_elements, iter;

     while (1)
     {
          printf("Enter the number of elements: \n");
          scanf("%d", &no_of_elements);
          num_array = malloc(no_of_elements * sizeof(int));

          sum = 0;
          for (iter = 0; iter < no_of_elements; iter++)
          {
               scanf("%d", &num_array[iter]);
               sum += num_array[iter];
          }

          printf("The sum of array elements are %d\n", sum);
          /* Forgot to free!! */
     }
     return 0;
}
```

Advanced C

Pointers – Pitfalls – Bus Error

- A bus error is a fault raised by hardware, notifying an operating system (OS) that, a process is trying to access memory that the CPU cannot physically address: an invalid address for the address bus, hence the name.

Example

```
#include <stdio.h>

int main()
{
    char array[sizeof(int) + 1];
    int *ptr1, *ptr2;

    ptr1 = &array[0];
    ptr2 = &array[1];

    scanf("%d %d", ptr1, ptr2);

    return 0;
}
```