# C

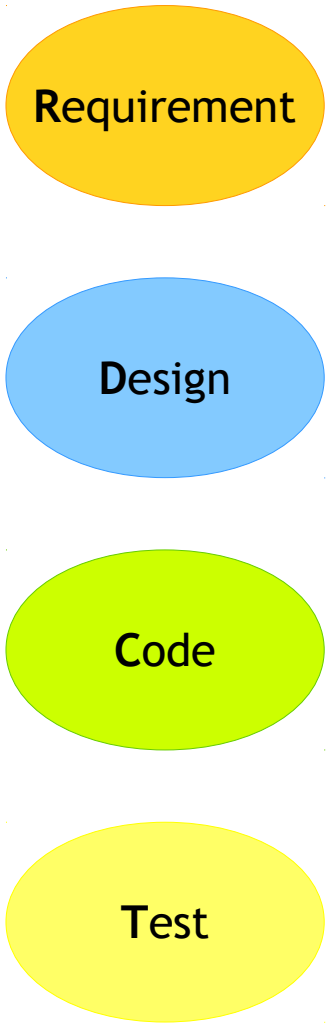
Come let's see how deep it is!!

Team Emertxe

# Introduction

# Advanced C

## SDLC - A Quick Introduction




- Understand the requirement properly
- Consider all the possible cases like inputs and outputs
- Know the boundary conditions
- Get it verified

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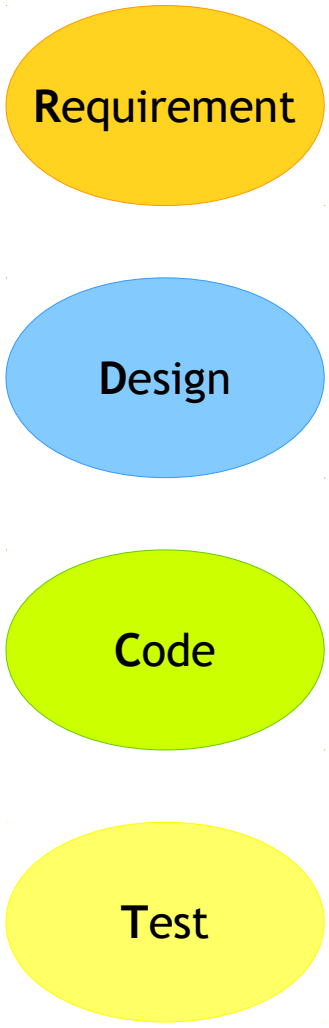
## SDLC - A Quick Introduction




- Have a proper design plan
- Use some algorithm for the requirement
  - Use paper and pen method
- Use a flow chart if required
- Make sure all the case are considered

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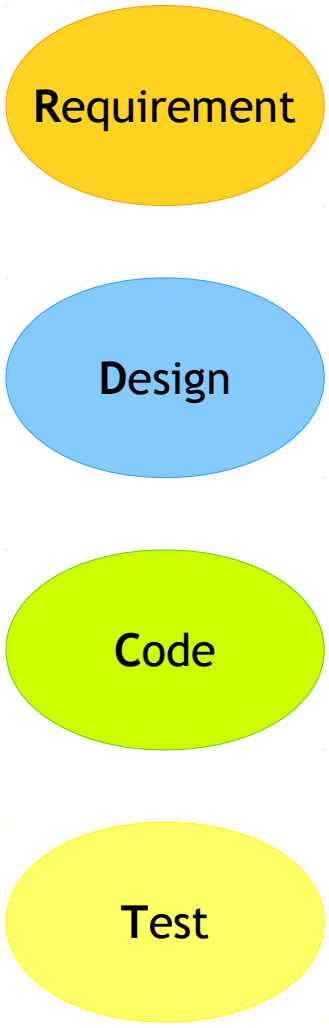
## SDLC - A Quick Introduction




- Implement the code based on the derived algorithm
- Try to have modular structure where ever possible
- Practice neat implementation habits like
  - Indentation
  - Commenting
  - Good variable and function naming's
  - Neat file and function headers

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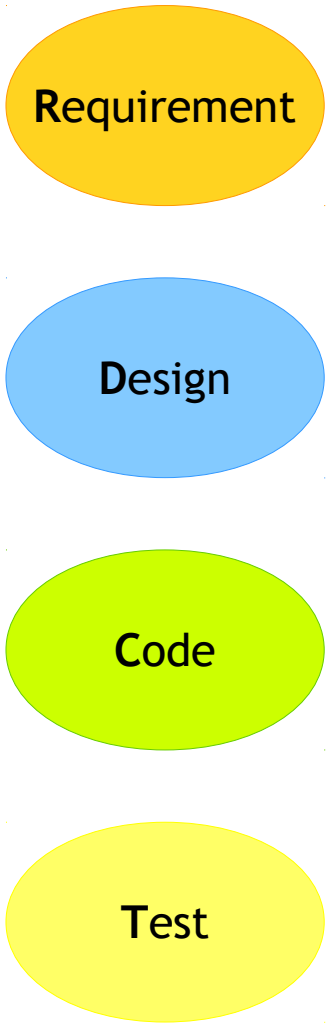
## SDLC – A Quick Introduction




- Test the implementation thoroughly
- Capture all possible cases like
  - Negative and Positive case
- Have neat output presentation
- Let the output be as per the user requirement

# Advanced C

## Problem Solving – What?

- An approach which could be taken to reach to a solution
- The approach could be ad hoc or generic with a proper order
- Sometimes it requires a creative and out of the box thinking to reach to perfect solution

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## Problem Solving - How?

- Polya's rule
  - Understand the problem
  - Devise a plan
  - Carryout the Plan
  - Look back

# Advanced C

## How should I proceed with my Application?

- Never jump to implementation. Why?
  - You might not have the clarity of the application
  - You might have some loose ends in the requirements
  - Complete picture of the application could be missing

  and many more...

# Advanced C

## Algorithm – What?

- A procedure or formula for solving a problem
- A sequence of unambiguous instructions for solving a problem, i.e., for obtaining a required output for any legitimate input in a finite amount of time.

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## Algorithm – Need?

- Algorithms is needed to generate correct output in finite time in a given constrained environment
  - Correctness of output
  - Finite time
  - Better Prediction

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## Algorithm – How?

- Natural Language
- Pseudo Codes
- Flowcharts etc.,

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## Algorithm - Daily Life Example

- Let's consider a problem of reaching this room
- The different possible approach could be thought of
  - Take a Walk
  - Take a Bus
  - Take a Car
  - Let's Pool
- Lets discuss the above approaches in bit detail

# Advanced C

## Algorithm – Reaching this Room – Take a Walk

The steps could be like

1. Start a 8 AM
2. Walk through street X for 500 Mts
3. Take a left on main road and walk for 2 KM
4. Take a left again and walk 200 Mts to reach

# Advanced C

## Algorithm – Reaching this Room – Take a Walk

- Pros
  - You might say walking is a good exercise :)
  - Might have good time prediction
  - Save some penny
- Cons
    - Depends on where you stay (you would choose if you stay closer)
    - Should start early
    - Would get tired
    - Freshness would have gone

# Advanced C

## Algorithm – Reaching this Room – Take a Bus

The steps could be like

1. Start a 8 .30 AM
2. Walk through street X for 500 Mts
3. Take a left on main road and walk for 100 Mts to bus stop
4. Take Bus No 111 and get down at stop X and walk for 100 Mts
5. Take a left again and walk 200 Mts to reach

# Advanced C

## Algorithm - Reaching this Room - Take a Bus

- Pros
  - You might save some time
  - Less tiredness comparatively
- Cons
  - Have to wait walk to the bus stop
  - Have to wait for the right bus (No prediction of time)
  - Might not be comfortable on rush hours

# Advanced C

## Algorithm – Reaching this Room – Take a Car

The steps could be like

1. Start a 9 AM
2. Drive through street X for 500 Mts
3. Take a left on main road and drive 2 KM
4. Take a left again and drive 200 Mts to reach

# Advanced C

## Algorithm – Reaching this Room – Take a Car

- Pros
  - Proper control of time and most comfortable
  - Less tiresome
- Cons
  - Could have issues on traffic congestions
  - Will be costly

# Advanced C

## Algorithm – Reaching this Room – Let's Pool

The steps could be like

1. Start a 8.45 AM
2. Walk through street X for 500 Mts
3. Reach the main road wait for you partner
4. Drive for 2 KM on the main road
5. Take a left again and drive 200 Mts to reach

# Advanced C

## Algorithm - Reaching this Room - Let's Pool

- Pros
  - You might save some time
  - Less costly comparatively
- Cons
  - Have to wait for partner to reach
  - Could have issues on traffic congestions

# Advanced C

## Algorithm – Daily Life Example - Conclusion

- All the above solution eventually will lead you to this room
- Every approach some pros and cons
- It would our duty as designer to take the best approach for the given problem

# Advanced C

## Algorithm – A Computer Example1

- Let's consider a problem of adding two numbers
- The steps involved :

  Start

  Read the value of A and B

  Add A and B and store in SUM

  Display SUM

  Stop

- The above 5 steps would eventually will give us the expected result

# Advanced C

## Algorithm – A Computer Example1 – Pseudo Code

- Let's consider a problem of adding two numbers
- The steps involved :

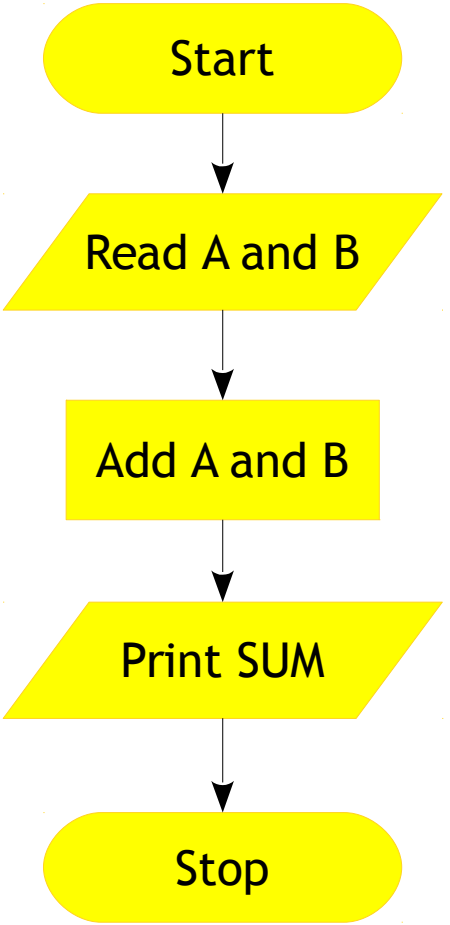
```
BEGIN

Read A, B

SUM = A + B

Print SUM

END
```

- The above 5 steps would eventually will give us the expected result

# Advanced C

## Algorithm – A Computer Example1 – A Flow Chart

- Let's consider a problem of adding two numbers



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## Algorithm – DIY

- Find the largest of given 2 numbers
- Find the average of given set of numbers
- Find out the given letter is vowel or not
- Find the sum of N natural numbers
- Find out the given number is odd or even
- Find out the given number is prime or not
- Find the largest of given 3 numbers
- Print the digits of a given number

# Advanced C

## Algorithm – DIY – H.W.

- Write an algorithm to find Armstrong numbers between 0 and 999
  - An Armstrong number of three digits is an integer such that the sum of the cubes of its digits is equal to the number itself
  - For example, 371 is an Armstrong number since 3^3 + 7^3 + 1^3 = 371
- Generate all prime numbers <= N (given)
  - Example : if N = 98 then prime numbers 2,3,5,7 … 97 shall be printed on the screen

# Advanced C

## Algorithm – DIY – Pattern

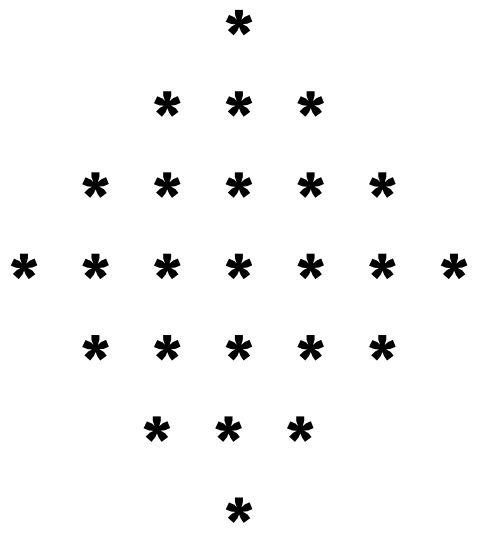
- Write an algorithm to print number pyramid

```
123454321
1234___4321
123_____321
12_______21
1_________1
```

# Advanced C

## Algorithm – DIY – Pattern (challenge)

- Print rhombus



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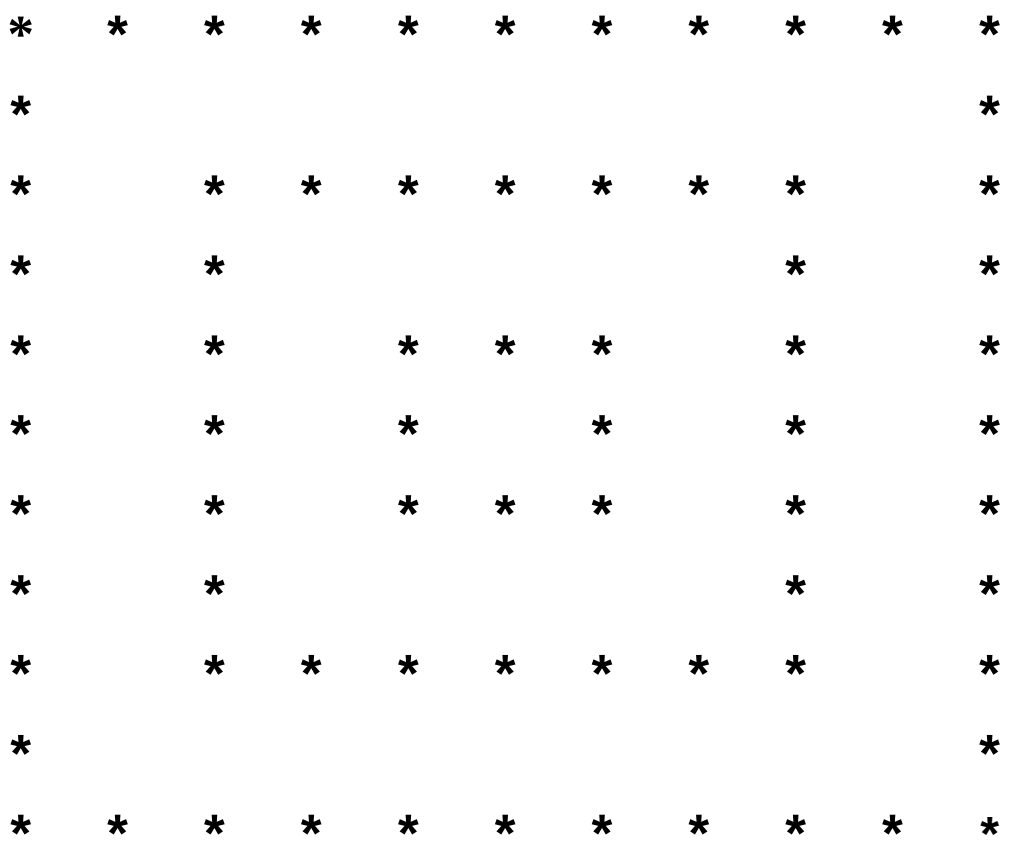
## Algorithm – DIY – Pattern (challenge)

- Print nested squares



# Advanced C

Have you ever pondered how
- powerful it is?
- efficient it is?
- flexible it is?
- deep you can explore your system?

if [ NO ]
    Wait!! get some concepts right before you dive into it
else
    You shouldn't be here!!

# Advanced C

## Where is it used?

- System Software Development
- Embedded Software Development
- OS Kernel Development
- Firmware, Middle-ware and Driver Development
- File System Development

  And many more!!

# Advanced C

## Language - What?

- A stylized communication technique
- Language has collection of words called "Vocabulary"
  - Rich vocabulary helps us to be more expressive
- Language has finite rules called "Grammar"
  - Grammar helps us to form infinite number of sentences
- The components of grammar :
  - The ***syntax*** governs the structure of sentences
  - The ***semantics*** governs the meanings of words and sentences

# Advanced C

## Language - What?

- A stylized communication technique
- It has set of words called “keywords”
- Finite rules (Grammar) to form sentences (often called expressions)
  - Expressions govern the behavior of machine (often a computer)
- Like natural languages, programming languages too have :
  - Syntactic rules (to form expressions)
  - Semantic rules (to govern meaning of expressions)

# Advanced C

## Brief History

- Prior to C, most of the computer languages (such as Algol) were academic oriented, unrealistic and were generally defined by committees.
- Since such languages were designed having application domain in mind, they could not take the advantages of the underlying hardware and if done, were not portable or efficient under other systems.
- It was thought that a high-level language could never achieve the efficiency of assembly language

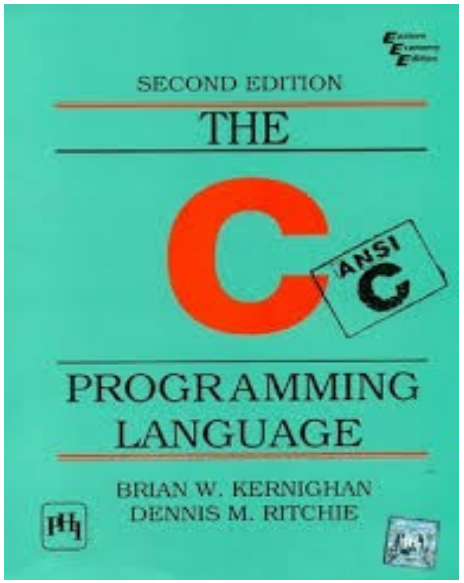
Portable, efficient and easy to use language was a dream.

# Advanced C

## Brief History

- It was a revolutionary language and shook the computer world with its might. With just 32 keywords, C established itself in a very wide base of applications.
- It has lineage starting from CPL, (Combined Programming Language) a never implemented language
- Martin Richards implemented BCPL as a modified version of CPL. Ken Thompson further refined BCPL to a language named as B
- Later Dennis M. Ritchie added types to B and created a language, what we have as C, for rewriting the UNIX operating system

# Advanced C
## Standard




- “The C programming language” book served as a primary reference for C programmers and implementers alike for nearly a decade
- However it didn’t define C perfectly and there were many ambiguous parts in the language
- As far as the library was concerned, only the C implementation in UNIX was close to the ’standard’

- So many dialects existed for C and it was the time the language has to be standardized and it was done in 1989 with ANSI C standard
- Nearly after a decade another standard, C9X, for C is available that provides many significant improvements over the previous 1989 ANSI C standard

# Advanced C

## Important Characteristics

- Considered as a middle level language
- Can be considered as a pragmatic language.
- It is indented to be used by advanced programmers, for serious use, and not for novices and thus qualify less as an academic language for learning
- Gives importance to curt code.
- It is widely available in various platforms from mainframes to palmtops and is known for its wide availability

# Advanced C

## Important Characteristics

- It is a general-purpose language, even though it is applied and used effectively in various specific domains
- It is a free-formatted language (and not a strongly-typed language)
- Efficiency and portability are the important considerations
- Library facilities play an important role

# Chapter 1

# Advanced C

## Keywords

- In programming, a keyword is a word that is reserved by a program because the word has a special meaning
- Keywords can be commands or parameters
- Every programming language has a set of keywords that cannot be used as variable names
- Keywords are sometimes called reserved names

# Advanced C

## Keywords - Categories

- Data Types
- Qualifiers
- Loop
- Storage Class
- Decision
- Jump
- Derived
- User Defined
- Others

# Advanced C

## Keywords – Data Types

| | |
|---|---|
| char | • The basic data type supported for storing characters of one byte size |
| int | • A variable would hold a integer type value<br>• A simple and efficient type for arithmetic operations<br>• Usually a word size of the processor although the compiler is free to choose the size<br>• ANSI C does not permit an integer, which is less than 16 bits |
| float | • A variable would hold a single precision value<br>• ANSI C does not specify any representation |
| double | • A variable would hold a double precision value<br>• The implementations may follow IEEE formats to represent floats and doubles, and double occupies 8-bytes in memory, Supports 0, ∞ (-/+) and NaN |

# Advanced C

## Keywords – Data Types Modifiers

| | |
|---|---|
| signed | • A variable can hold both positive and negative value<br>• Most Significant Bit (MSB) of the variable decides the sign |
| unsigned | • A variable can hold only positive value<br>• Larger range of positive values within the same available space |
| short | • Fairly small integer type of value |
| long | • Fairly large integer type of value |

- ANSI C says that the size of short and long implementation defined, but ensures that the non-decreasing order of char, short, int, and long is preserved i.e.,

  **char ≤ short ≤ int ≤ long**

# Advanced C

## Keywords – Qualifiers

| | |
|---|---|
| const | • It specifies the value of a field or a local variable that cannot be modified |
| volatile | • Instructs the complier not to optimize the variable qualified with it<br>• Indicates that the variable is asynchronous, and system or external sources may change its value |

# Advanced C

## Keywords – Loops

| | |
|---|---|
| for | • Could be used when the number of passes is known in advance (but not necessarily) |
| while | • Could be used when the number of passes is not known in advance (but not necessarily)<br>• Entry controlled looping mechanism |
| do | • Could be used when the number of passes is not known in advance (but not necessarily)<br>• Exit controlled looping mechanism |

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# Advanced C

## Keywords – Storage Class

| | | |
|---|---|---|
| auto | • Storage: | Memory |
| | • Default Initial value: | Unpredictable |
| | • Scope: | Local |
| | • Life: | Within the block |
| register | • Storage: | CPU Registers (if available) |
| | • Default Initial value: | Garbage |
| | • Scope: | Local |
| | • Life: | Within the block |
| static | • Storage: | Memory |
| | • Default Initial value: | Zero |
| | • Scope: | Local |
| | • Life: | Across function calls |
| | • Others | Limits the function's scope to the current file |
| extern | • Storage: | Memory |
| | • Default Initial value: | Zero |
| | • Scope: | Global |
| | • Life: | Program Life |

# Advanced C

## Keywords – Decision

| | |
|---|---|
| if | • Simple conditional branching statement<br>• Any non-zero value is treated as a true value and will lead to execution of this statement |
| else | • Used with if statements<br>• Else part is executed when the condition in if becomes false |
| switch | • A specialized version of an if-else cascade<br>• Equality checks only with integral type constants<br>• Simplified control-flow by generating much faster code<br>• Break keyword is must to end the current case |
| case | • Used in switch statements for selecting a particular case<br>• The case should be followed by a constant integral expression. |
| default | • This label is used in switch statements<br>• The statements after this label will be executed only when there is no match found in the case labels. |

# Advanced C

## Keywords – Jump

| | |
|---|---|
| goto | • Take the control to required place in the program |
| break | • Force immediate termination of a loop, bypassing the conditional expression and any remaining code in the body of the loop |
| continue | • Take the control to the beginning of the loop bypassing the statements inside the loop |

# Advanced C

## Keywords – Derived types

struct

- struct keyword provides support for aggregate types

unions

- Can be considered a special case of structures
- The syntax for both is mostly the same and only the semantics differ
- Memory is allocated such that it can accommodate the biggest member
- There is no in-built mechanism to know which union member is currently used to store the value

# Advanced C

## Keywords – User Defined

| | |
|---|---|
| typedef | • Do not create new types - they just add new type names<br>• Helpful in managing complex declarations<br>• Increase portability of the code<br>• Obey scoping rules and are not textual replacements (as opposed to #defines) |
| enum | • A set of named constants that are internally represented as integers<br>• Makes the code more readable and self-documenting |

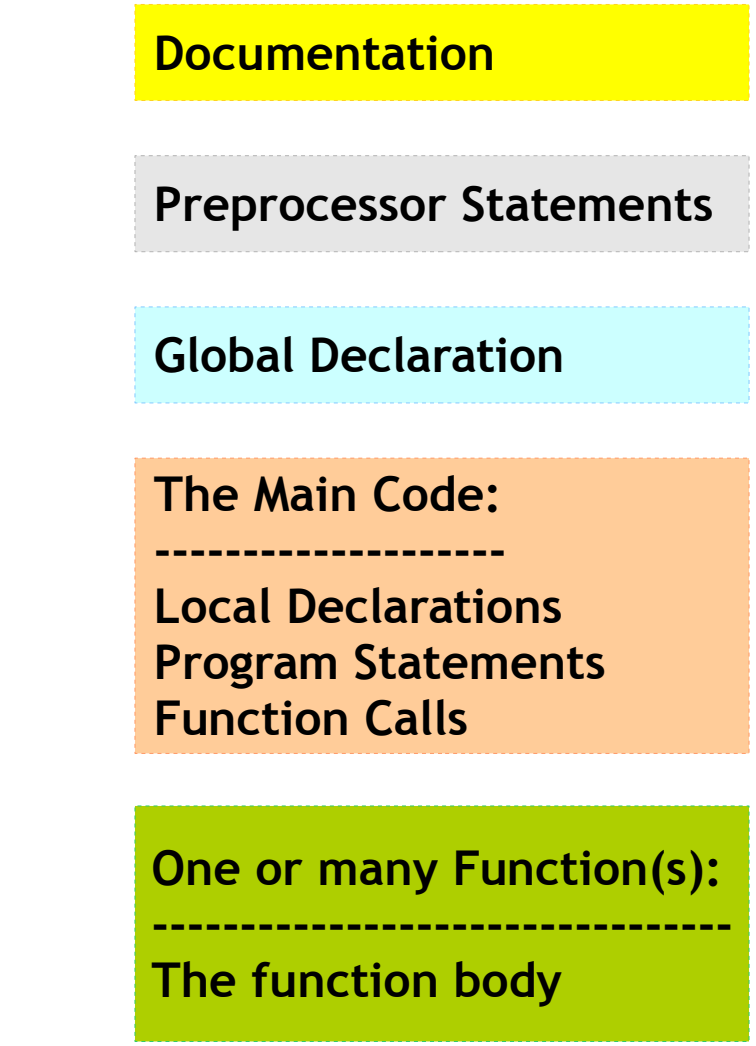
# Advanced C

## Keywords – Others

| | |
|---|---|
| void | • Non-existent or empty set of values<br>• It is used in the case of void pointers as a generic pointer type in C<br>• Return type of a function to specify that the function returns nothing<br>• You cannot have objects of type void, and hence this type is sometimes called a pseudo-type. |
| return | • To return control back from the called method |
| sizeof | • Used to obtain the size of a type or an object<br>• Can be used for portable code, since the size of a data type may differ depending on the implementation. |

# Advanced C

## Typical C Code Contents




- A typical code might contain the blocks shown on left side
- It is generally recommended to practice writing codes with all the blocks

# Advanced C

## Anatomy of a Simple C Code

```
/* My first C code */
#include <stdio.h>
int main()
{
    /* To display Hello world */
    printf("Hello world\n");
    return 0;
}
```

File Header

Preprocessor Directive

The start of program

Comment

Statement

Program Termination

# Advanced C

## Compilation

- Assuming your code is ready, use the following commands to compile the code
- On command prompt, type

  $ gcc <file_name>.c

- This will generate a executable named a.out
- But it is recommended that you follow proper conversion even while generating your code, so you could use

  $ gcc <file_name>.c -o <file_name>

- This will generate a executable named <file_name>

# Advanced C

## Execution

- To execute your code you shall try

  ```
  $ ./a.out
  ```

- If you have named you output file as your <file_name> then

  ```
  $ ./<file_name>
  ```

- This should the expected result on your system

# Chapter 2
## Basic Refreshers

# Advanced C

## Number Systems

- A number is generally represented as
  - Decimal
  - Octal
  - Hexadecimal
  - Binary

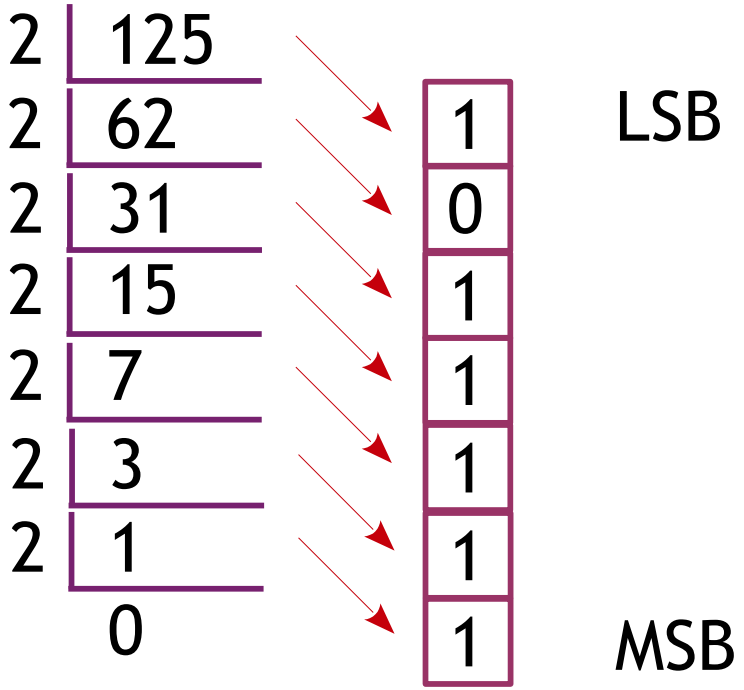
| Type | Range (8 Bits) |
|---|---|
| Decimal | 0 - 255 |
| Octal | 000 - 0377 |
| Hexadecimal | 0x00 - 0xFF |
| Binary | 0b00000000 - 0b11111111 |

| Type | Dec | Oct | Hex | Bin |
|---|---|---|---|---|
| Base | 10 | 8 | 16 | 2 |
| | 0 | 0 | 0 | 0 0 0 0 |
| | 1 | 1 | 1 | 0 0 0 1 |
| | 2 | 2 | 2 | 0 0 1 0 |
| | 3 | 3 | 3 | 0 0 1 1 |
| | 4 | 4 | 4 | 0 1 0 0 |
| | 5 | 5 | 5 | 0 1 0 1 |
| | 6 | 6 | 6 | 0 1 1 0 |
| | 7 | 7 | 7 | 0 1 1 1 |
| | 8 | 10 | 8 | 1 0 0 0 |
| | 9 | 11 | 9 | 1 0 0 1 |
| | 10 | 12 | A | 1 0 1 0 |
| | 11 | 13 | B | 1 0 1 1 |
| | 12 | 14 | C | 1 1 0 0 |
| | 13 | 15 | D | 1 1 0 1 |
| | 14 | 16 | E | 1 1 1 0 |
| | 15 | 17 | F | 1 1 1 1 |

# Advanced C

## Number Systems – Decimal to Binary

- $125_{10}$ to Binary

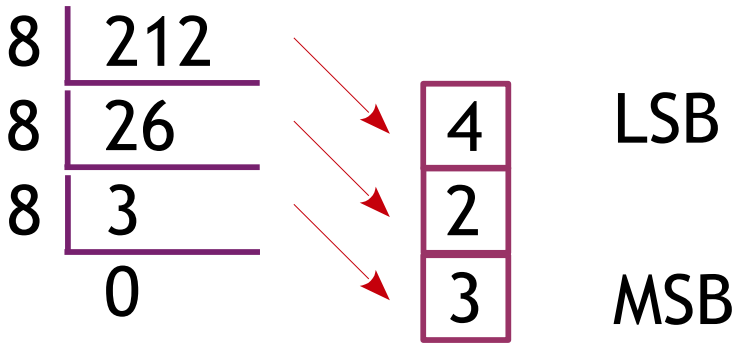



- So $125_{10}$ is $1111101_2$

# Advanced C

## Number Systems – Decimal to Octal

- $212_{10}$ to Octal

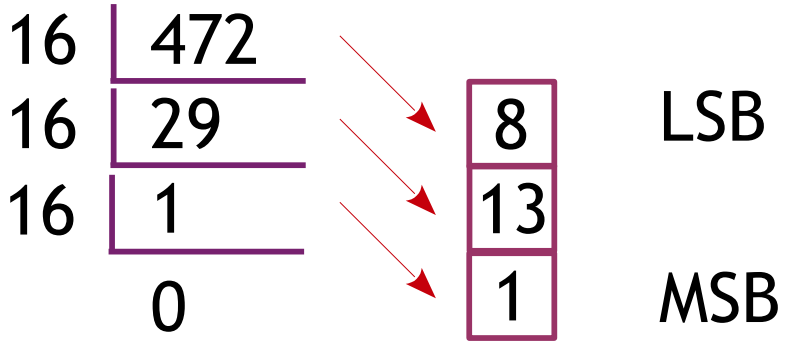



- So $212_{10}$ is $324_8$

# Advanced C

## Number Systems – Decimal to Hexadecimal

- $472_{10}$ to Hexadecimal



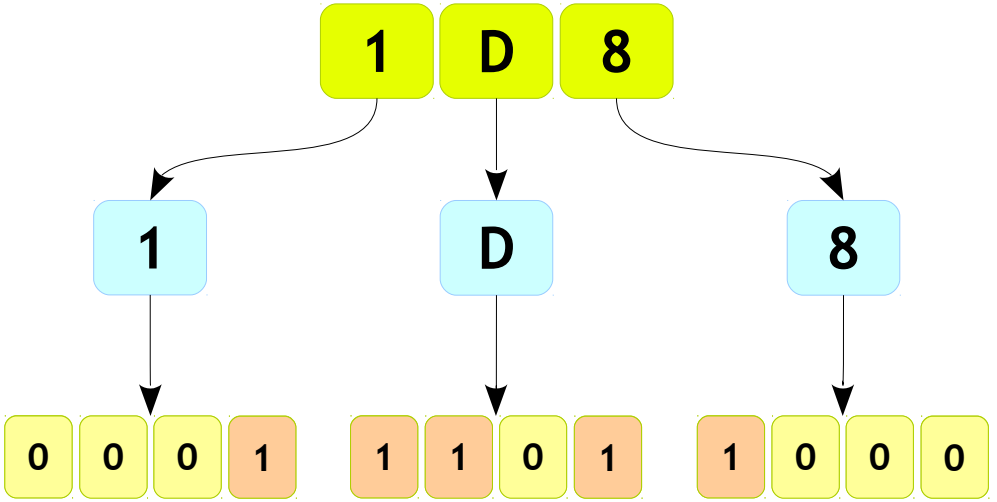

| Representation | Substitutes | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dec | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Hex | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | A | B | C | D | E | F |

- So $472_{10}$ is $1D8_{16}$

# Advanced C

## Number Systems – Hexadecimal to Binary

- $1D8_{16}$ to Binary

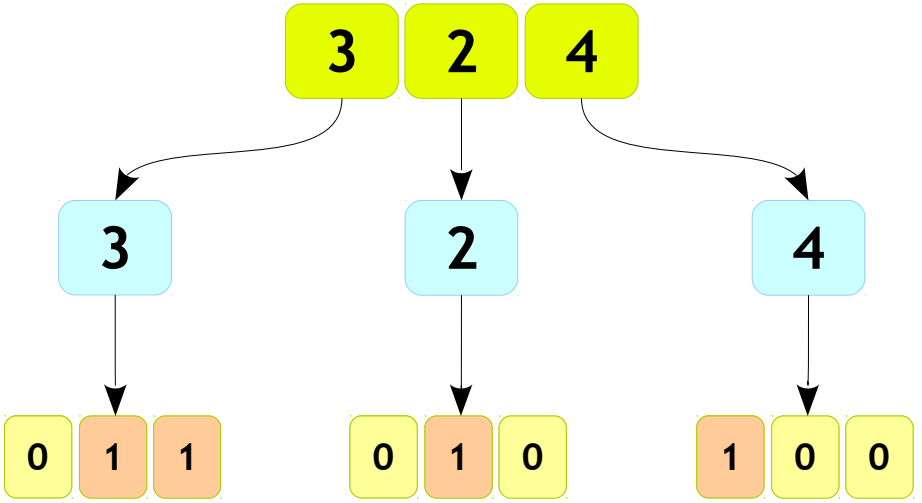



- So $1D8_{16}$ is $000111011000_2$ which is nothing but $111011000_2$

# Advanced C

## Number Systems – Octal to Binary

- $324_8$ to Binary

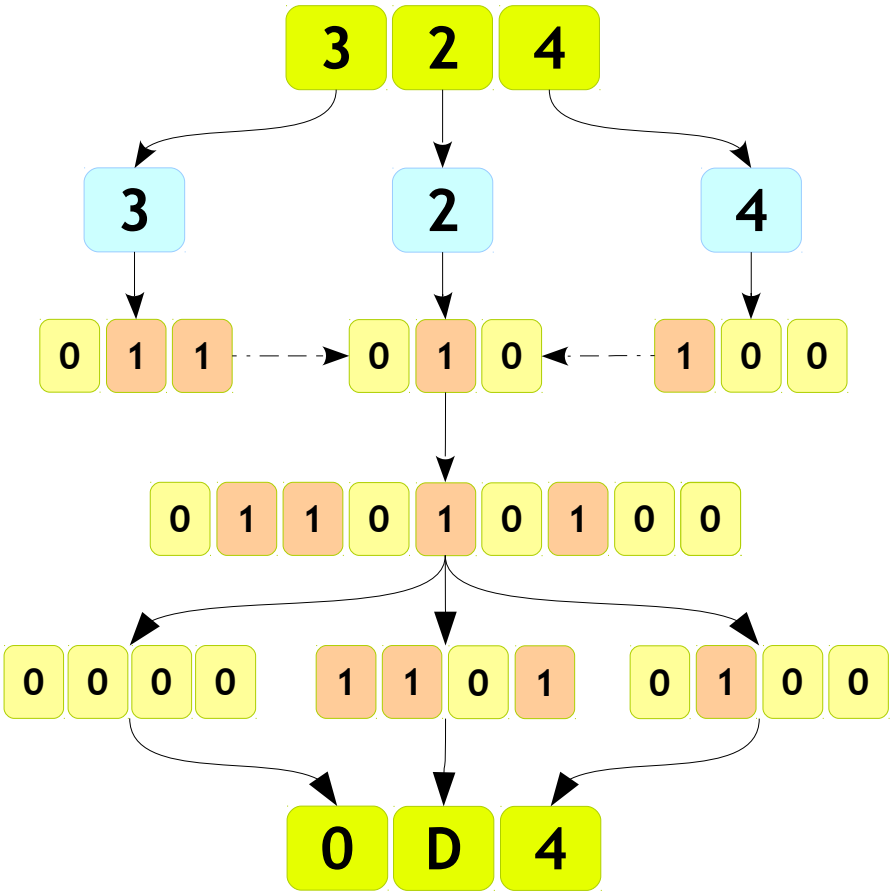



- So $324_8$ is $011010100_2$ which is nothing but $11010100_2$

# Advanced C

## Number Systems – Octal to Hexadecimal

- $324_8$ to Hexadecimal

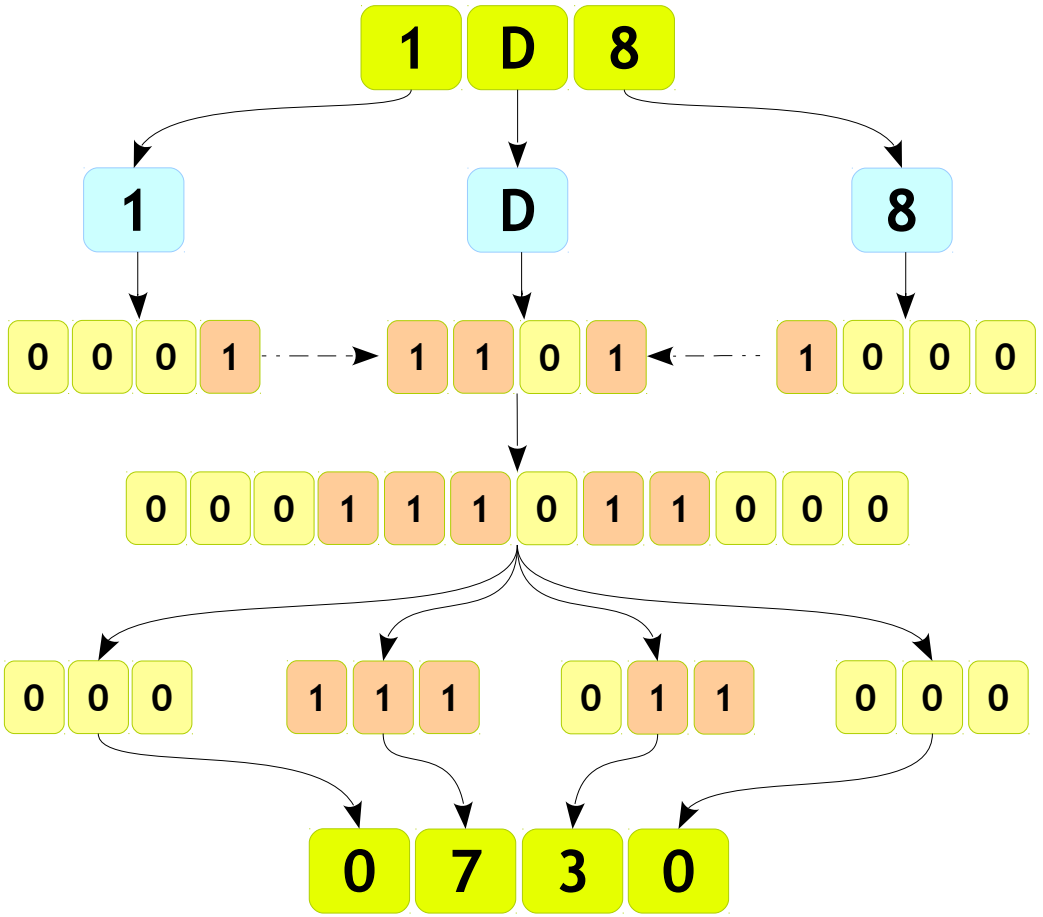



- So $324_8$ is $0D4_{16}$ which is nothing but $D4_{16}$

# Advanced C

## Number Systems – Hexadecimal to Octal

- $1D8_{16}$ to Octal

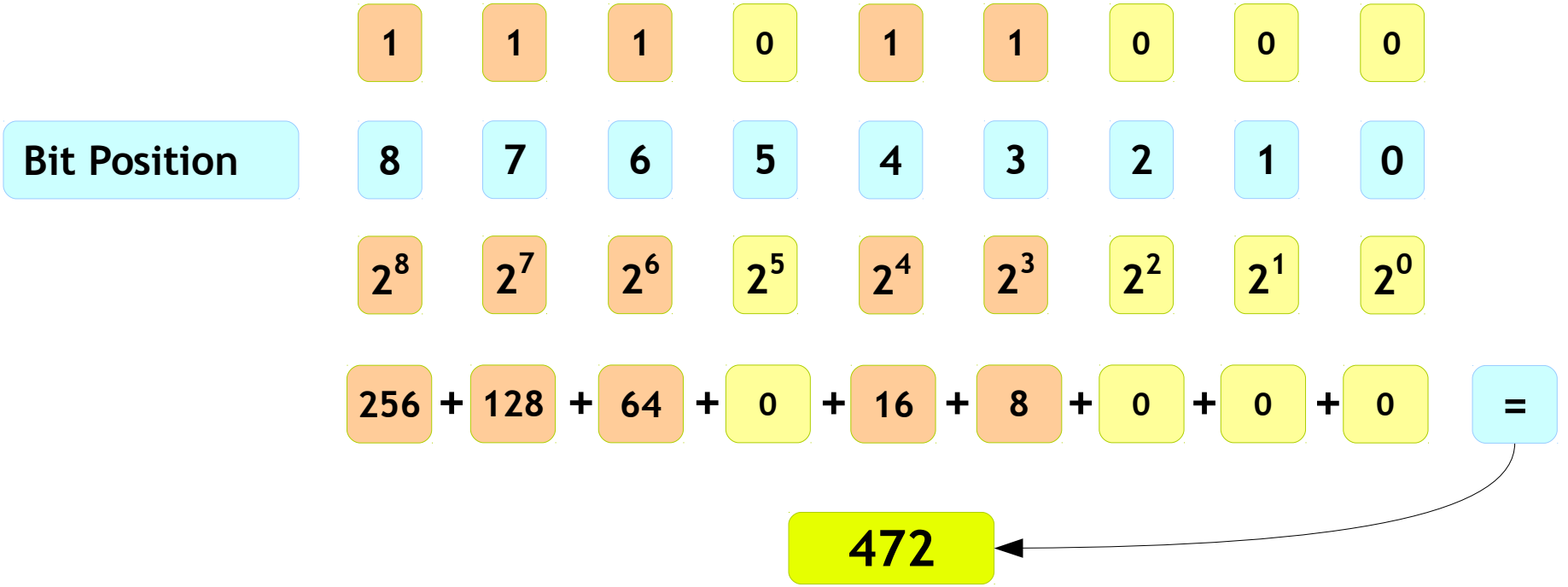



- So $1D8_{16}$ is $0730_8$ which is nothing but $730_8$

# Advanced C

## Number Systems – Binary to Decimal

- $111011000_2$ to Decimal




- So $111011000_2$ is $472_{10}$

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# Advanced C

## Data Representation - Bit

- Literally computer understand only two states HIGH and LOW making it a binary system
- These states are coded as 1 or 0 called binary digits
- “**Bi**nary Digi**t**” gave birth to the word “**Bit**”
- Bit is known a basic unit of information in computer and digital communication

| Value | No of Bits |
| --- | --- |
| 0 | 0 |
| 1 | 1 |

# Advanced C

## Data Representation - Byte

- A unit of digital information
- Commonly consist of 8 bits
- Considered smallest addressable unit of memory in computer

| Value | No of Bits |
| --- | --- |
| 0 | 0 0 0 0 0 0 0 0 |
| 1 | 0 0 0 0 0 0 0 1 |

# Advanced C

## Data Representation - Character

- One byte represents one unique character like 'A', 'b', '1', '$' ...
- Its possible to have 256 different combinations of 0s and 1s to form a individual character
- There are different types of character code representation like
  - ASCII → American Standard Code for Information Interchange – 7 Bits (Extended - 8 Bits)
  - EBCDIC → Extended BCD Interchange Code – 8 Bits
  - Unicode → Universal Code - 16 Bits and more

# Advanced C

## Data Representation - Character

- ASCII is the oldest representation
- Please try the following on command prompt to know the available codes

  $ man ascii

- Can be represented by char datatype

| Value | No of Bits |
| --- | --- |
| 0 | 0 1 1 0 0 0 0 0 |
| A | 0 1 0 0 0 0 0 1 |

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# Advanced C

## Data Representation - word

- Amount of data that a machine can fetch and process at one time
- An integer number of bytes, for example, one, two, four, or eight
- General discussion on the bitness of the system is references to the word size of a system, i.e., a 32 bit chip has a 32 bit (4 Bytes) word size

| Value | No of Bits |
|---|---|
| 0 | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 |
| 1 | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 |

# Advanced C

## Integer Number - Positive

- Integers are like whole numbers, but allow negative numbers and no fraction
- An example of $13_{10}$ in 32 bit system would be

| Bit | No of Bits | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Position | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |

# Advanced C

## Integer Number - Negative

- Negative Integers represented with the 2's complement of the positive number
- An example of $-13_{10}$ in 32 bit system would be

| Bit | No of Bits | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Position | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Value | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| 1's Compli | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| Add 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 2's Compli | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 |

- Mathematically : $-k \equiv 2^n - k$

# Advanced C

## Float Point Number

- A formulaic representation which approximates a real number
- Computers are integer machines and are capable of representing real numbers only by using complex codes
- The most popular code for representing real numbers is called the IEEE Floating-Point Standard

| | Sign | Exponent | Mantissa |
|---|---|---|---|
| **Float (32 bits) Single Precision** | 1 bit | 8 bits | 23 bits |
| **Double (64 bits) Double Precision** | 1 bit | 11 bits | 52 bits |

# Advanced C

## Float Point Number – Conversion Procedure

- STEP 1: Convert the absolute value of the number to binary, perhaps with a fractional part after the binary point. This can be done by -
  - Converting the integral part into binary format.
  - Converting the fractional part into binary format.

  The integral part is converted with the techniques examined previously.

  The fractional part can be converted by multiplying it with 2.
- STEP 2: Normalize the number. Move the binary point so that it is one bit from the left. Adjust the exponent of two so that the value does not change.

$$\text{Float} : V = (-1)^S * 2^{(E-127)} * 1.F$$

$$\text{Double} : V = (-1)^S * 2^{(E-1023)} * 1.F$$

# Advanced C

## Float Point Number – Conversion - Example 1

**Convert 2.5 to IEEE 32-bit floating point format**

### Step 1:

| | | | |
|---|---|---|---|
| 0.5 | × 2 | 1.0 | 1 |

$2.5_{10} = 10.1_2$

### Step 2:

**Normalize:** $10.1_2 = 1.01_2 \times 2^1$

**Mantissa is** 01000000000000000000000
**Exponent is** $1 + 127 = 128 = 1000\ 0000_2$
**Sign bit is** 0

| Bit | S | Exponent | | | | | | | | Mantissa | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Position | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Value | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

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# Advanced C

## Float Point Number – Conversion - Example 2

**Convert 0.625 to IEEE 32-bit floating point format**

### Step 1:

| | | | |
|---|---|---|---|
| 0.625 | × 2 | 1.25 | 1 |
| 0.25 | × 2 | 0.5 | 0 |
| 0.5 | × 2 | 1.0 | 1 |

$0.625_{10} = 0.101_2$

### Step 2:

Normalize: $0.101_2 = 1.01_2 \times 2^{-1}$

Mantissa is 01000000000000000000000
Exponent is -1 + 127 = 126 = $01111110_2$
Sign bit is 0

| Bit | S | Exponent | | | | | | | | Mantissa | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Position | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Value | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

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# Advanced C

## Float Point Number – Conversion - Example 3

**Convert 39887.5625 to IEEE 32-bit floating point format**

### Step 1:

| | | | |
|---|---|---|---|
| 0.5625 | × 2 = | 1.125 | 1 |
| 0.125 | × 2 = | 0.25 | 0 |
| 0.25 | × 2 = | 0.5 | 0 |
| 0.5 | × 2 = | 1.0 | 1 |

$39887.5625_{10} = 1001101111001111.1001_2$

### Step 2:

Normalize:
$1001101111001111.1001_2 =$
$1.0011011110011111001_2 \times 2^{15}$

Mantissa is 00110111100111110010000
Exponent is 15 + 127 = 142 = $10001110_2$
Sign bit is 0

| Bit | S | Exponent | | | | | | | | Mantissa | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Position | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Value | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |

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# Advanced C

## Float Point Number – Conversion - Example 5

**Convert -13.3125 to IEEE 32-bit floating point format**

### Step 1:

| | | | |
|---|---|---|---|
| 0.3125 | × 2 = | 0.625 | 0 |
| 0.625 | × 2 = | 1.25 | 1 |
| 0.25 | × 2 = | 0.5 | 0 |
| 0.5 | × 2 = | 1.0 | 1 |

$13.3125_{10} = 1101.0101_2$

### Step 2:

**Normalize:**

$1101.0101_2 = 1.1010101_2 \times 2^3$

**Mantissa is 10101010000000000000000**

**Exponent is 3 + 127 = 130 = 1000 0010$_2$**

**Sign bit is 1**

| Bit | S | Exponent | | | | | | | | Mantissa | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Position | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Value | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

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# Advanced C

## Float Point Number – Conversion - Example 6

**Convert 1.7 to IEEE 32-bit floating point format**

### Step 1:

| | | | |
|---|---|---|---|
| 0.7 | × 2 = | 1.4 | 1 |
| 0.4 | × 2 = | 0.8 | 0 |
| 0.8 | × 2 = | 1.6 | 1 |
| 0.6 | × 2 = | 1.2 | 1 |
| 0.2 | x 2 = | 0.4 | 0 |
| 0.4 | × 2 = | 0.8 | 0 |
| 0.8 | × 2 = | 1.6 | 1 |
| 0.6 | × 2 = | 1.2 | 1 |

### Step 2:

**Normalize:**
$1.10110011001100110011001_2 =$
$1.10110011001100110011001_2 \times 2^0$

**Mantissa is 10110011001100110011001**
**Exponent is 0 + 127 = 127 = $01111111_2$**
**Sign bit is 1**

$1.7_{10} = 1.10110011001100110011001_2$

| Bit | S | Exponent | | | | | | | | Mantissa | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Position | 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Value | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |

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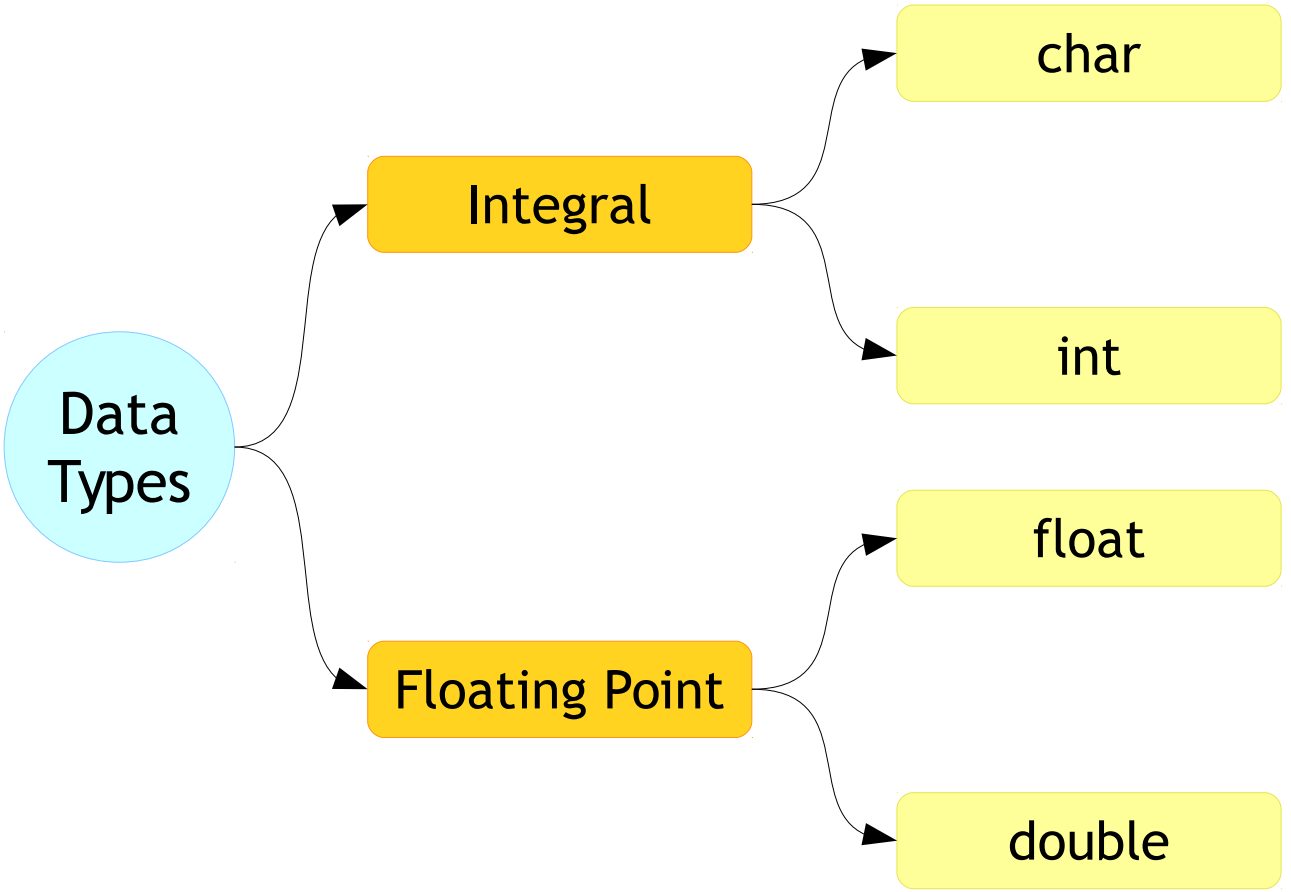
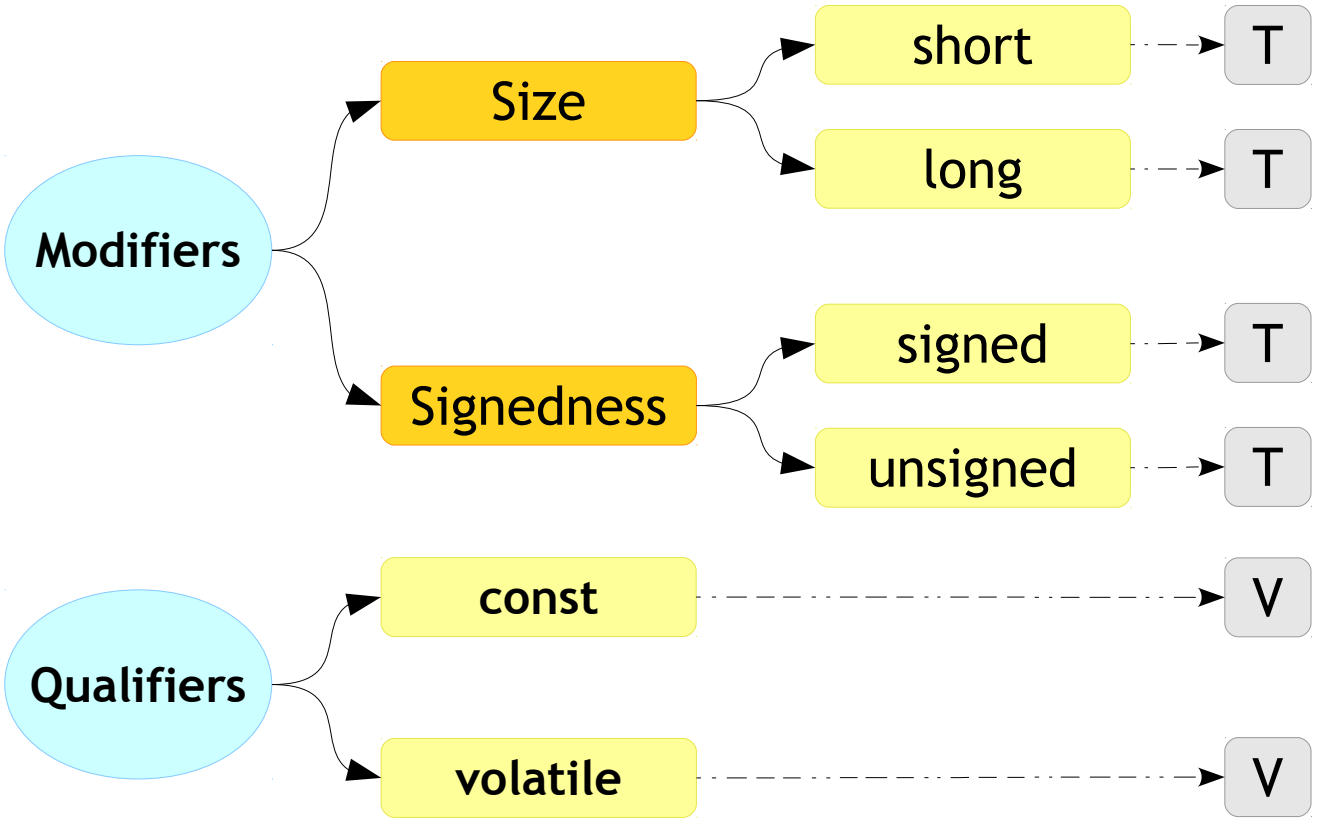
# Advanced C

## Basic Data Types



# Advanced C

## Data Type Modifiers and Qualifiers

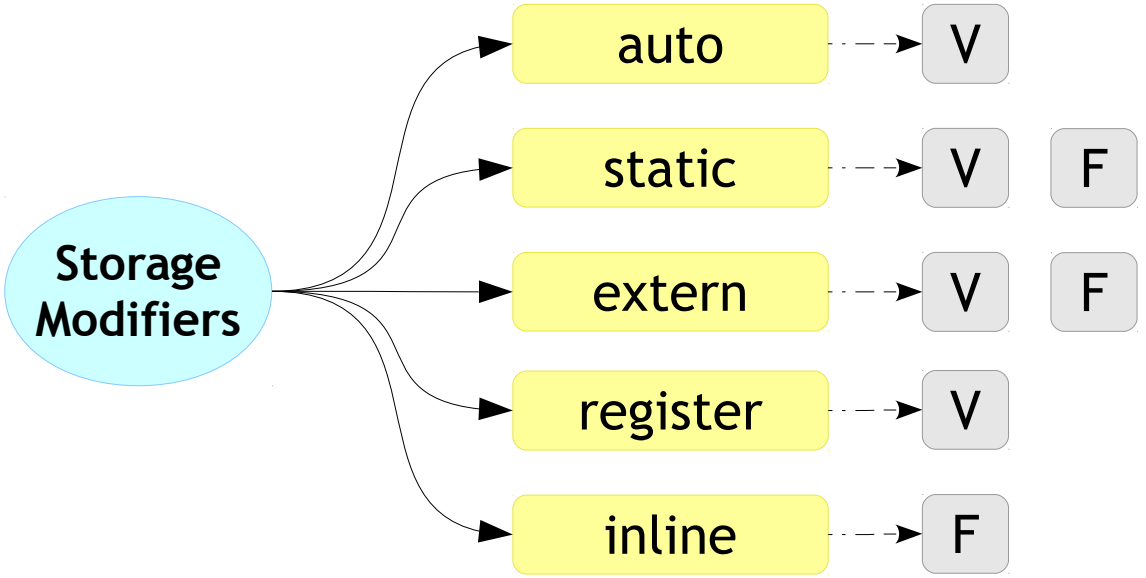



| | |
|---|---|
| V | Variables |
| T | Data Types |
| F | Functions |

Note: Unsigned float in not supported

# Advanced C

## Data Type and Function storage modification




| | |
|---|---|
| V | Variables |
| T | Data Types |
| F | Functions |

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# Advanced C

## Code Statements - Simple

```c
int main()
{
    number = 5;
    3; +5;
    sum = number + 5;
    4 + 5;
    ;
}
```

Assignment statement

Valid statement, But smart compilers might remove it

Assignment statement. Result of the number + 5 will be assigned to sum

Valid statement, But smart compilers might remove it

This valid too!!

# Advanced C

## Code Statements - Compound

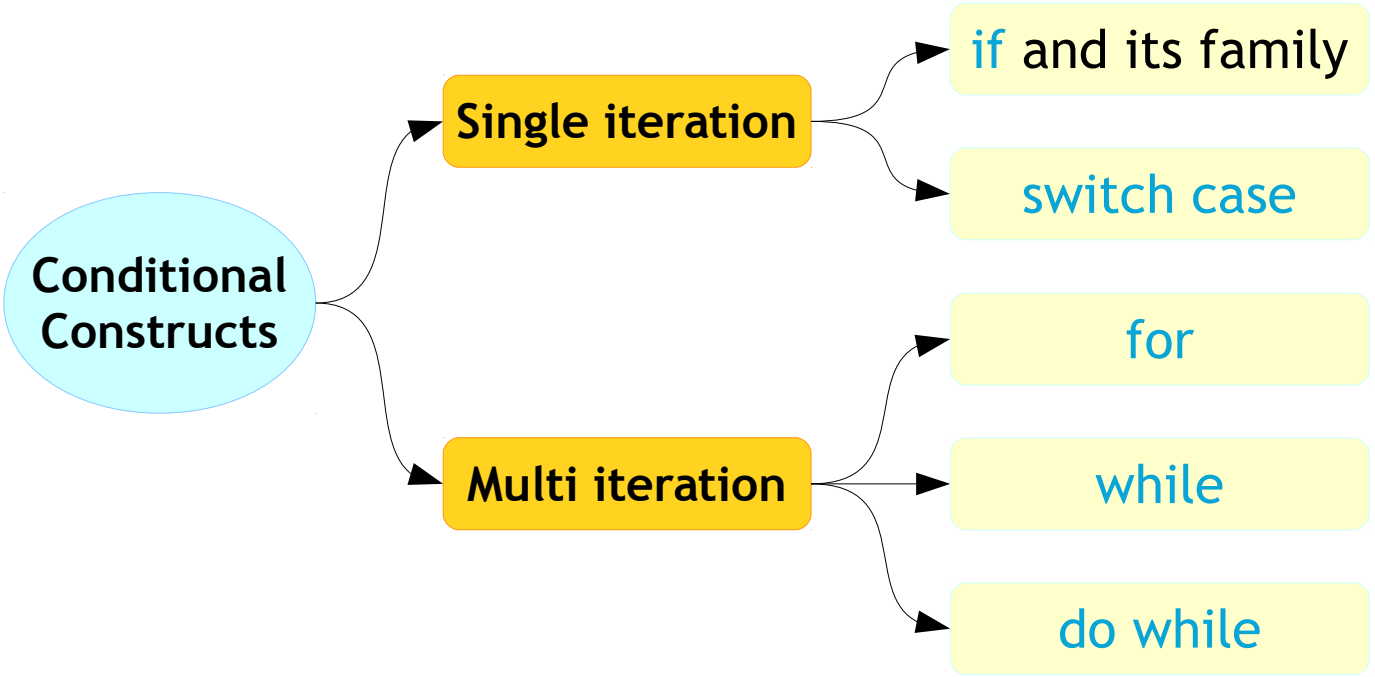
```
int main()
{
    ...
    if (num1 > num2)
    {
        if (num1 > num3)
        {
            printf("Hello");
        }
        else
        {
            printf("World");
        }
    }
    ...
}
```

If conditional statement

Nested if statement

# Advanced C

## Conditional Constructs

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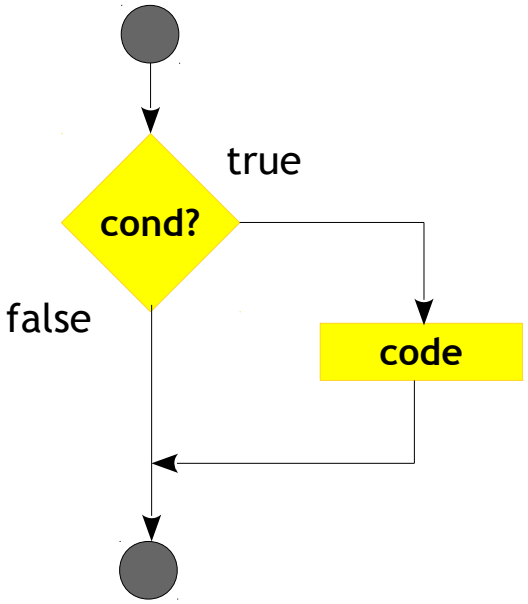
# Advanced C

## Conditional Constructs - if

### Syntax

```
if (condition)
{
    statement(s);
}
```

### Flow




### Example

```
#include <stdio.h>

int main()
{
    int num = 2;

    if (num < 5)
    {
        printf("num < 5\n");
    }
    printf("num is %d\n", num);

    return 0;
}
```

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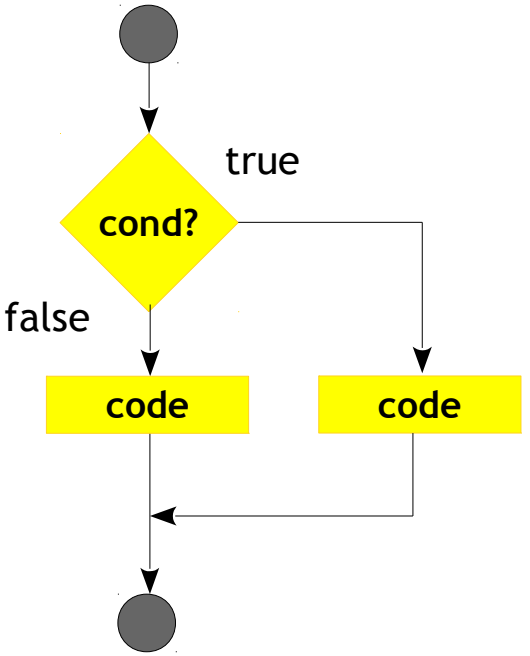
# Advanced C

## Conditional Constructs - if else

### Syntax

```
if (condition)
{
    statement(s);
}
else
{
    statement(s);
}
```

### Flow

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# Advanced C

## Conditional Constructs - if else

**Example**

```c
#include <stdio.h>

int main()
{
    int num = 10;

    if (num < 5)
    {
        printf("num is smaller than 5\n");
    }
    else
    {
        printf("num is greater than 5\n");
    }

    return 0;
}
```

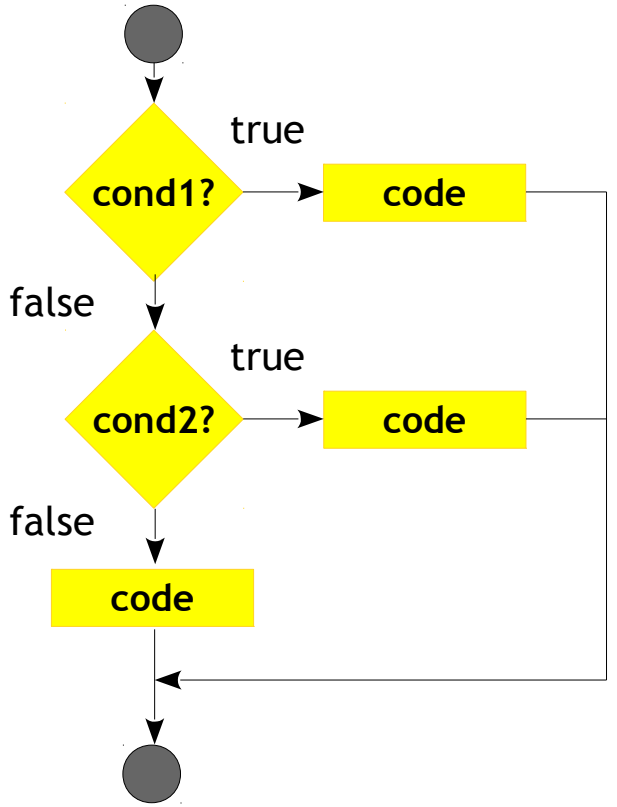
# Advanced C

## Conditional Constructs - if else if

### Syntax

```
if (condition1)
{
    statement(s);
}
else if (condition2)
{
    statement(s);
}
else
{
    statement(s);
}
```

### Flow



# Advanced C

## Conditional Constructs - if else if

**Example**

```c
#include <stdio.h>

int main()
{
    int num = 10;

    if (num < 5)
    {
        printf("num is smaller than 5\n");
    }
    else if (num > 5)
    {
        printf("num is greater than 5\n");
    }
    else
    {
        printf("num is equal to 5\n");
    }


    return 0;
}
```

# Advanced C

## Conditional Constructs – Exercise

- WAP to find the max of two numbers
- WAP to find the greatest of given 3 numbers
- WAP to check whether character is
  - Upper case
  - Lower case
  - Digit
  - No of the above
- WAP to find the middle number (by value) of given 3 numbers

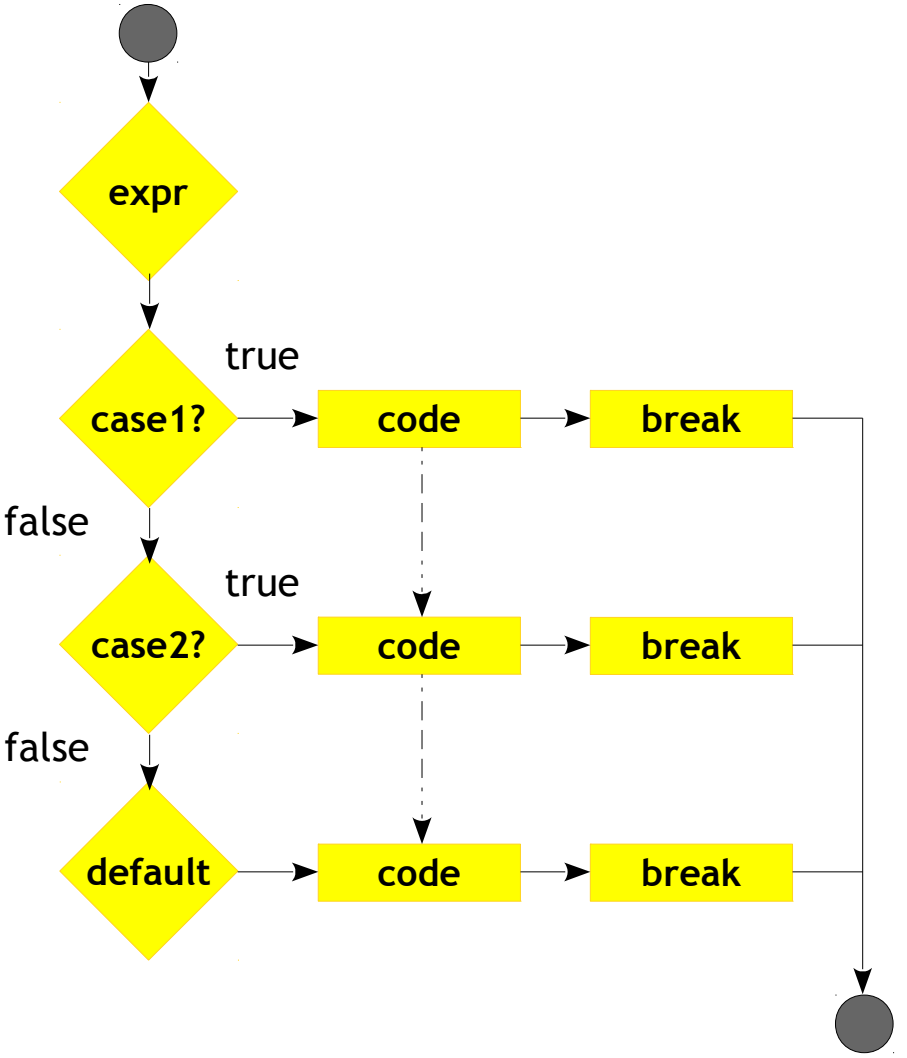
# Advanced C

## Conditional Constructs - switch

### Syntax

```
switch (expression)
{
    case constant:
        statement(s);
        break;
    case constant:
        statement(s);
        break;
    case constant:
        statement(s);
        break;
    default:
        statement(s);
}
```

### Flow

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# Advanced C

## Conditional Constructs - switch

**Example**

```c
#include <stdio.h>

int main()
{
    int option;
    printf("Enter the value\n");
    scanf("%d", &option);

    switch (option)
    {
        case 10:
            printf("You entered 10\n");
            break;
        case 20:
            printf("You entered 20\n");
            break;
        default:
            printf("Try again\n");
    }

    return 0;
}
```

# Advanced C

## Conditional Constructs – switch - DIY

- W.A.P to check whether character is
  - Upper case
  - Lower case
  - Digit
  - None of the above
- W.A.P for simple calculator

# Advanced C

## Conditional Constructs - while

### Syntax

```
while (condition)
{
    statement(s);
}
```

- **Controls** the loop.
- Evaluated **before** each execution of loop body

### Example

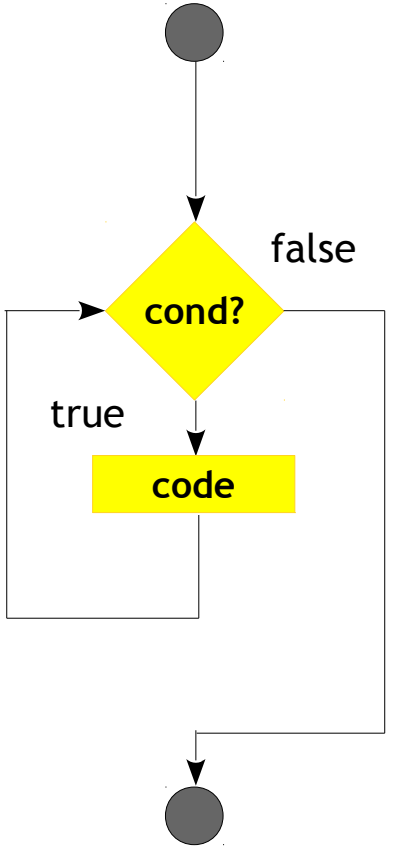
```
#include <stdio.h>

int main()
{
    int iter;

    iter = 0;
    while (iter < 5)
    {
        printf("Looped %d times\n", iter);
        iter++;
    }

    return 0;
}
```

### Flow



# Advanced C

## Conditional Constructs - do while

### Syntax

```
do
{
    statement(s);
} while (condition);
```

- **Controls** the loop.
- Evaluated **after** each execution of loop body

### Example

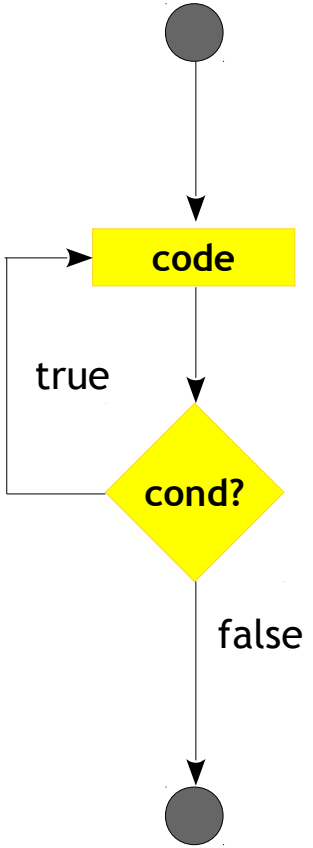
```
#include <stdio.h>

int main()
{
    int iter;

    iter = 0;
    do
    {
        printf("Looped %d times\n", iter);
        iter++;
    } while (iter < 10);

    return 0;
}
```

### Flow

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# Advanced C

## Conditional Constructs - for

### Syntax

```
for (init; condition; post evaluation expr)
{
    statement(s);
}
```

- **Controls** the loop.
- Evaluated **before** each execution of loop body

### Example

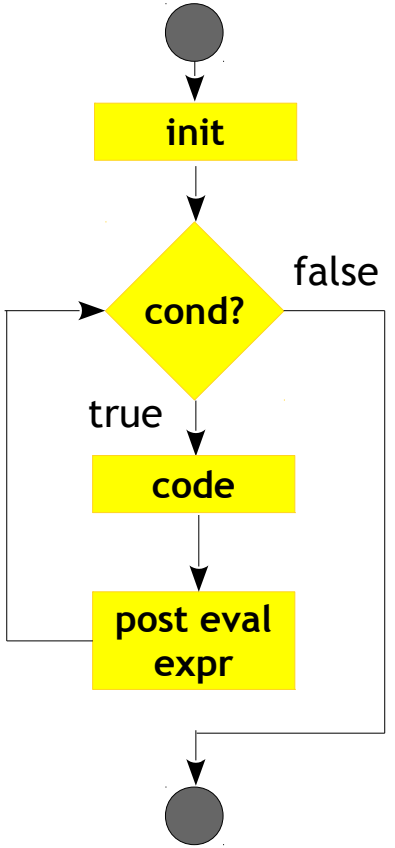
```
#include <stdio.h>

int main()
{
    int iter;

    for (iter = 0; iter < 10; iter++)
    {
        printf("Looped %d times\n", iter);
    }

    return 0;
}
```

### Flow



# Advanced C

## Conditional Constructs - Classwork

- W.A.P to print the power of two series using for loop
  - $2^1$, $2^2$, $2^3$, $2^4$, $2^5$ ...
- W.A.P to print the power of N series using Loops
  - $N^1$, $N^2$, $N^3$, $N^4$, $N^5$ ...
- W.A.P to multiply 2 nos without multiplication operator
- W.A.P to check whether a number is palindrome or not

# Advanced C

## Conditional Constructs – for – DIY

- WAP to print line pattern
  - Read total (n) number of pattern chars in a line (number should be “odd”)
  - Read number (m) of pattern char to be printed in the middle of line (“odd” number)
  - Print the line with two different pattern chars
  - Example – Let's say two types of pattern chars '$' and '*' to be printed in a line. Total number of chars to be printed in a line are 9. Three '*' to be printed in middle of line.
    - Output ==> $$$* * *$$$

# Advanced C

## Conditional Constructs – for – DIY

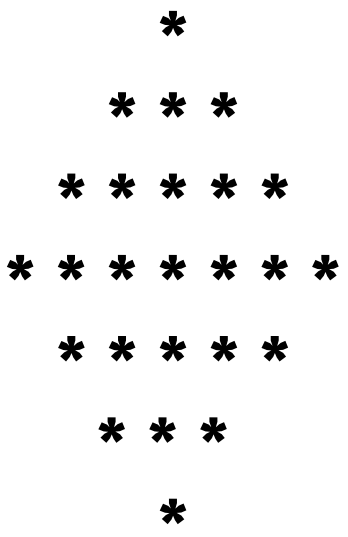
- Based on previous example print following pyramid

```
   *
  * * *
 * * * * *
* * * * * * *
```

# Advanced C

## Conditional Constructs – for – DIY

- Print rhombus using for loops



# Advanced C

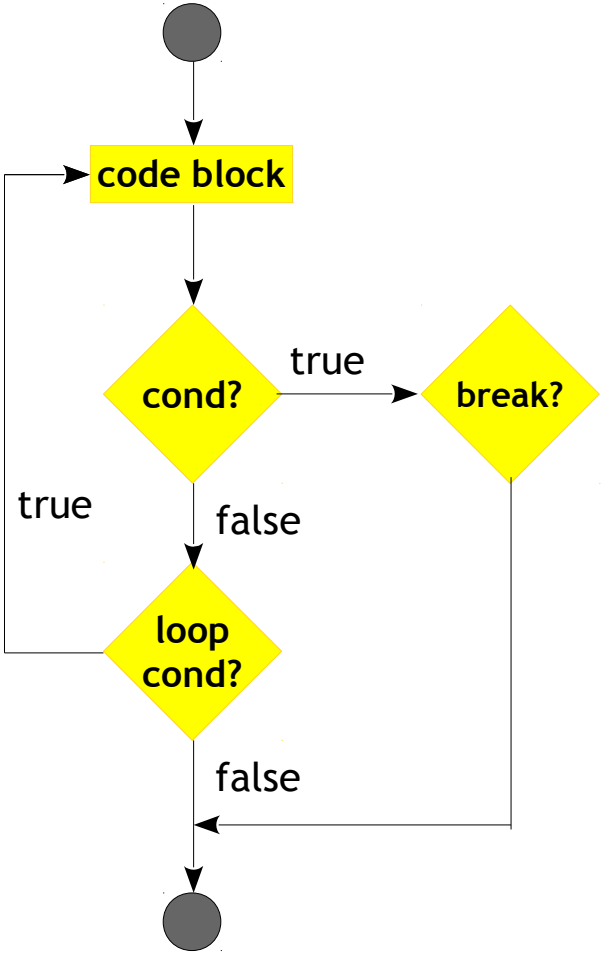
## Conditional Constructs - break

- A break statement shall appear only in “switch body” or “loop body”
- *“break”* is used to exit the loop, the statements appearing after break in the loop will be skipped

**Syntax**

```
do
{
    conditional statement
        break;
} while (condition);
```

**Flow**

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# Advanced C

## Conditional Constructs - break

**Example**

```c
#include <stdio.h>

int main()
{
    int iter;

    for (iter = 0; iter < 10; iter++)
    {
        if (iter == 5)
        {
            break;
        }
        printf("%d\n", iter);
    }

    return 0;
}
```

# Advanced C

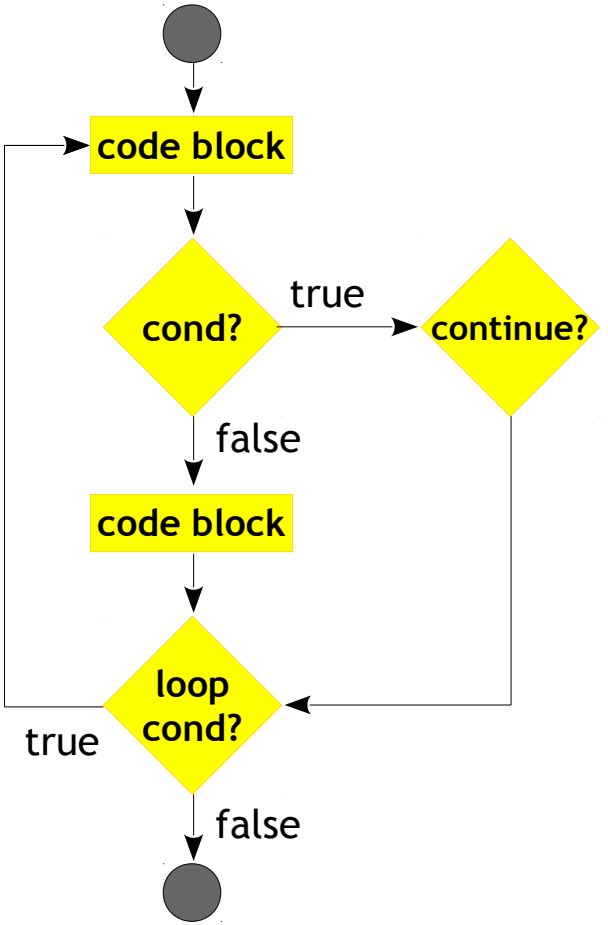
## Conditional Constructs - continue

- A *continue* statement causes a jump to the loop-continuation portion, that is, to the end of the loop body
- The execution of code appearing after the continue will be skipped
- Can be used in any type of multi iteration loop

**Syntax**

```
do
{
    conditional statement
        continue;
} while (condition);
```

**Flow**



# Advanced C

## Conditional Constructs - continue

**Example**

```c
#include <stdio.h>

int main()
{
    int iter;

    for (iter = 0; iter < 10; iter++)
    {
        if (iter == 5)
        {
            continue;
        }
        printf("%d\n", iter);
    }

    return 0;
}
```

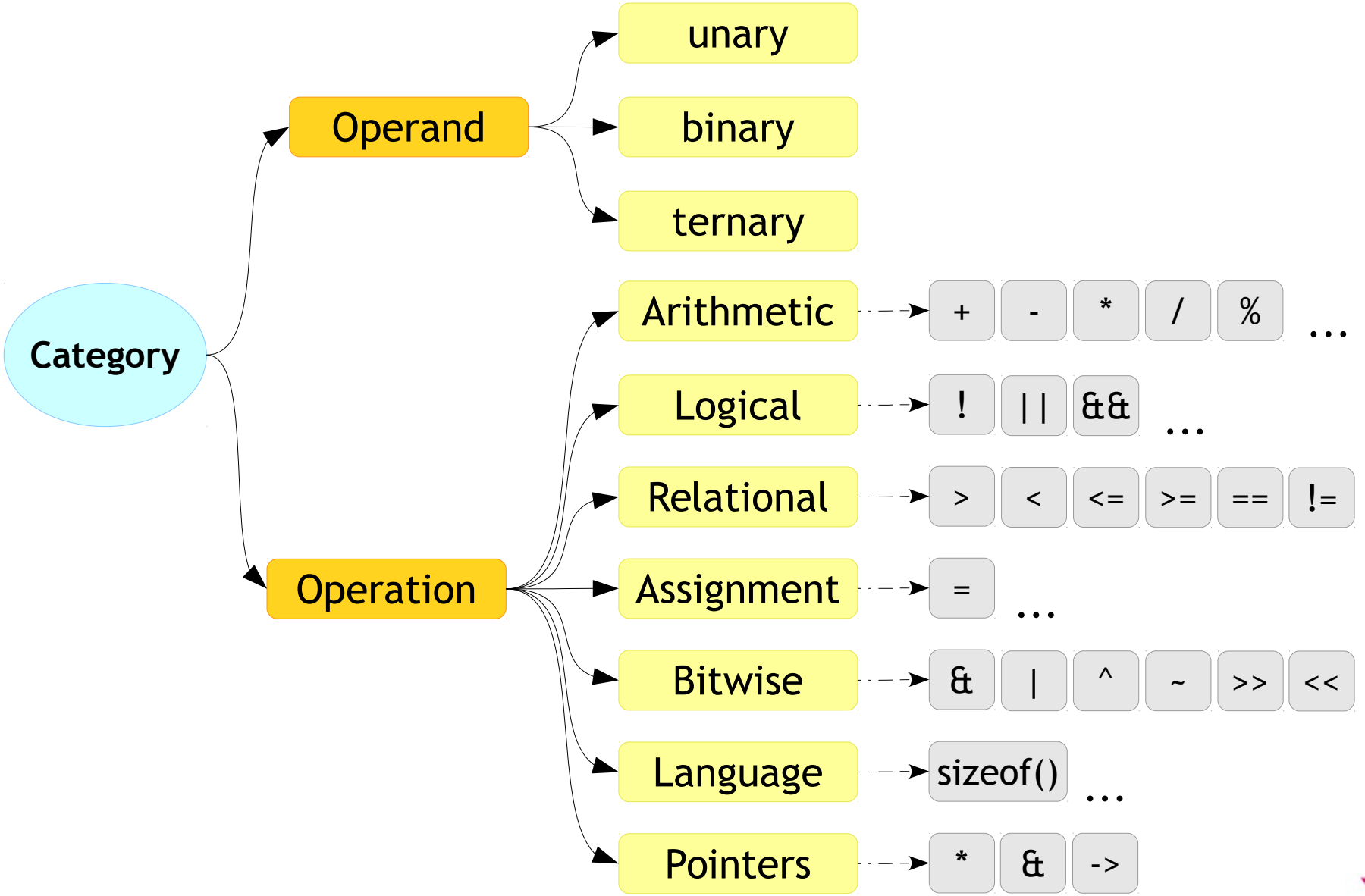
# Advanced C

## Operators

- Symbols that instructs the compiler to perform specific arithmetic or logical operation on operands
- All C operators do 2 things
  - Operates on its operands
  - Returns a value

# Advanced C

## Operators



# Advanced C

## Operators – Precedence and Associativity

| Operators | Associativity | Precedence |
|---|---|---|
| () [] -> . | L - R | HIGH |
| ! ~ ++ -- - + * & (type) sizeof | R - L | |
| / % * | L - R | |
| + - | L - R | |
| << >> | L - R | |
| < <= > >= | L - R | |
| == != | L - R | |
| & | L - R | |
| ^ | L - R | |
| \| | L - R | |
| && | L - R | |
| \|\| | L - R | |
| ?: | R - L | |
| = += -= *= /= %= &= ^= \|= <<= >>= | R - L | |
| , | L - R | LOW |

**Note:**

post ++ and -- operators have higher precedence than pre ++ and -- operators

(Rel-99 spec)

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# Advanced C

## Operators - Arithmetic

| Operator | Description | Associativity |
|---|---|---|
| *<br>/<br>% | Multiplication<br>Division<br>Modulo | L to R |
| +<br>- | Addition<br>Subtraction | R to L |

**Example**

```
#include <stdio.h>

int main()
{
    int num;

    Num = 7 - 4 * 3 / 2 + 5;

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

    return 0;
}
```

What will be the output?

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# Advanced C

## Operators - Language - sizeof()

### Example

```c
#include <stdio.h>

int main()
{
    int num = 5;

    printf("%u:%u:%u\n", sizeof(int), sizeof num, sizeof 5);

    return 0;
}
```

### Example

```c
#include <stdio.h>

int main()
{
    int num1 = 5;
    int num2 = sizeof(++num1);

    printf("num1 is %d and num2 is %d\n", num1, num2);

    return 0;
}
```

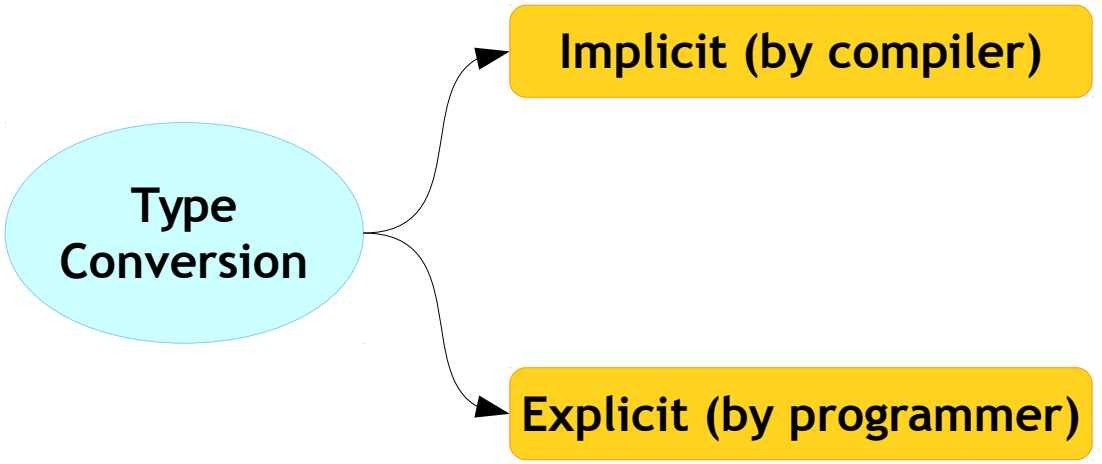
# Advanced C

## Operators – Language - sizeof()

- 3 reasons for why sizeof is not a function
  - Any type of operands
  - Type as an operand
  - No brackets needed across operands

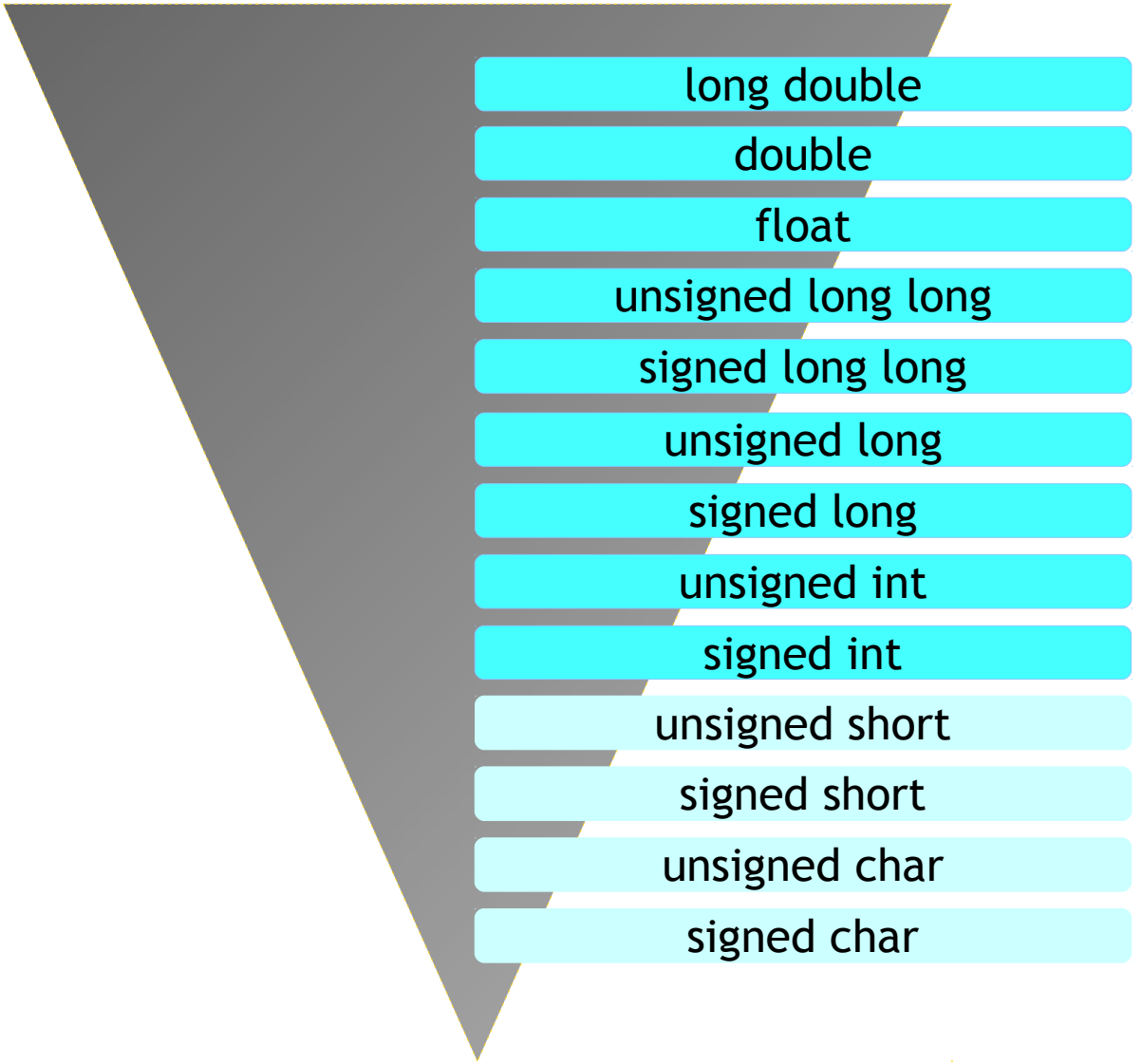
# Advanced C

## Type Conversion



# Advanced C

## Type Conversion Hierarchy



# Advanced C

## Type Conversion - Implicit

- Automatic Unary conversions
  - The result of + and - are promoted to int if operands are char and short
  - The result of ~ and ! is integer
- Automatic Binary conversions
  - If one operand is of LOWER RANK data type & other is of HIGHER RANK data type then LOWER RANK will be converted to HIGHER RANK while evaluating the expression.
  - Example : If one operand is int & other is float then, int is converted to float.

# Advanced C

## Type Conversion - Implicit

- Type conversions in assignments
  - The type of right hand side operand is converted to type of left hand side operand in assignment statements.
  - If type of operand on right hand side is LOWER RANK data type & left hand side is of HIGHER RANK data type then LOWER RANK will be promoted to HIGHER RANK while assigning the value.
- If type of operand on right hand side is HIGHER RANK data type & left hand side is of LOWER RANK data type then HIGHER RANK will be demoted to LOWER RANK while assigning the value.
- Example
  - Fractional part will be truncated during conversion of float to int.

# Advanced C

## Type Conversion - Explicit (Type Casting)

### Syntax

```
(data type) expression
```

### Example

```
#include <stdio.h>

int main()
{
    int num1 = 5, num2 = 3;

    float num3 = (float) num1 / num2;

    printf("nun3 is %f\n", num3);

    return 0;
}
```

# Advanced C

## Operators - Logical

| Operator | Description | Associativity |
|---|---|---|
| ! | Logical NOT | R to L |
| && | Logical AND | L to R |
| \|\| | Logical OR | L to R |

**Example**

```
#include <stdio.h>

int main()
{
     int num1 = 1, num2 = 0;

     if (++num1 || num2++)
     {
          printf("num1 is %d num2 is %d\n", num1, num2);
     }
     num1 = 1, num2 = 0;
     if (num1++ && ++num2)
     {
          printf("num1 is %d num2 is %d\n", num1, num2);
     }
     else
     {
          printf("num1 is %d num2 is %d\n", num1, num2);
     }
     return 0;
}
```

What will be the output?

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# Advanced C

## Operators – Circuit Logical

- Have the ability to “short circuit” a calculation if the result is definitely known, this can improve efficiency
  - Logical AND operator ( `&&` )
    - If one operand is false, the result is false.
  - Logical OR operator ( `||` )
    - If one operand is true, the result is true.

# Advanced C

## Operators - Relational

| Operator | Description | Associativity |
|---|---|---|
| > | Greater than | L to R |
| < | Lesser than | |
| >= | Greater than or equal | |
| <= | Lesser than or equal | |
| == | Equal to | |
| != | Not Equal to | |

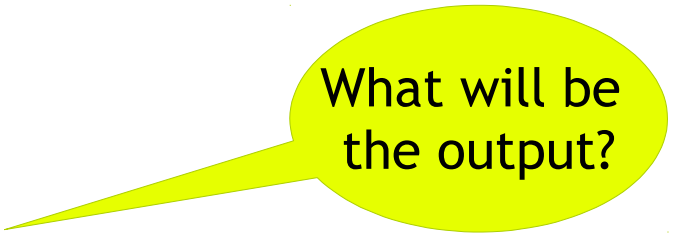
**Example**

```
#include <stdio.h>

int main()
{
     float num1 = 0.7;

     if (num1 == 0.7)
     {
          printf("Yes, it is equal\n");
     }
     else
     {
          printf("No, it is not equal\n");
     }

     return 0;
}
```



# Advanced C

## Operators - Assignment

### Example

```c
#include <stdio.h>

int main()
{
    int num1 = 1, num2 = 1;
    float num3 = 1.7, num4 = 1.5;

    num1 += num2 += num3 += num4;

    printf("num1 is %d\n", num1);

    return 0;
}
```

### Example

```c
#include <stdio.h>

int main()
{
    float num1 = 1;

    if (num1 = 1)
    {
        printf("Yes, it is equal!!\n");
    }
    else
    {
        printf("No, it is not equal\n");
    }

    return 0;
}
```

# Advanced C

## Operators - Bitwise

- Bitwise operators perform operations on bits
- The operand type shall be integral
- Return type is integral value

# Advanced C

## Operators - Bitwise

| | | |
|---|---|---|
| & | **Bitwise AND** | Bitwise ANDing of all the bits in two operands |

| Operand | Value | |
|---|---|---|
| A | 0x61 | 0 1 1 0 0 0 0 1 |
| B | 0x13 | 0 0 0 1 0 0 1 1 |
| A & B | 0x01 | 0 0 0 0 0 0 0 1 |

| | | |
|---|---|---|
| \| | **Bitwise OR** | Bitwise ORing of all the bits in two operands |

| Operand | Value | |
|---|---|---|
| A | 0x61 | 0 1 1 0 0 0 0 1 |
| B | 0x13 | 0 0 0 1 0 0 1 1 |
| A \| B | 0x73 | 0 1 1 1 0 0 1 1 |

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# Advanced C

## Operators - Bitwise

| | | |
|---|---|---|
| ^ | **Bitwise XOR** | Bitwise XORing of all the bits in two operands |

| Operand | Value | |
|---|---|---|
| A | 0x61 | 0 1 1 0 0 0 0 1 |
| B | 0x13 | 0 0 0 1 0 0 1 1 |
| A ^ B | 0x72 | 0 1 1 1 0 0 1 0 |

| | | |
|---|---|---|
| ~ | **Compliment** | Complimenting all the bits of the operand |

| Operand | Value | |
|---|---|---|
| A | 0x61 | 0 1 1 0 0 0 0 1 |
| ~A | 0x9E | 1 0 0 1 1 1 1 0 |

# Advanced C

## Operators - Bitwise - Shift

**Syntax**

**Left Shift : shift-expression << additive-expression**

**(left operand) (right operand)**

**Right Shift : shift-expression >> additive-expression**

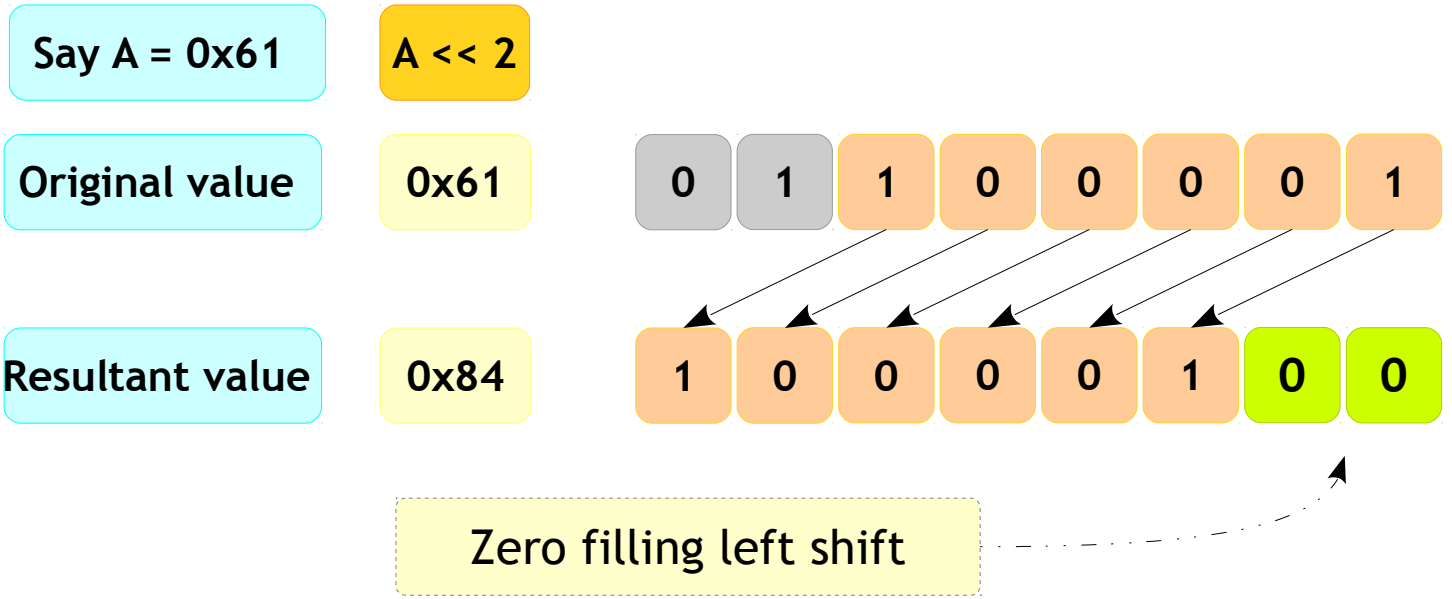
**(left operand) (right operand)**

# Advanced C

## Operators – Bitwise – Left Shift

**'Value' << 'Bits Count'**

- **Value** : Is shift-expression on which bit shifting effect to be applied
- **Bits count** : Is additive-expression, by how many bit(s) the given "Value" to be shifted

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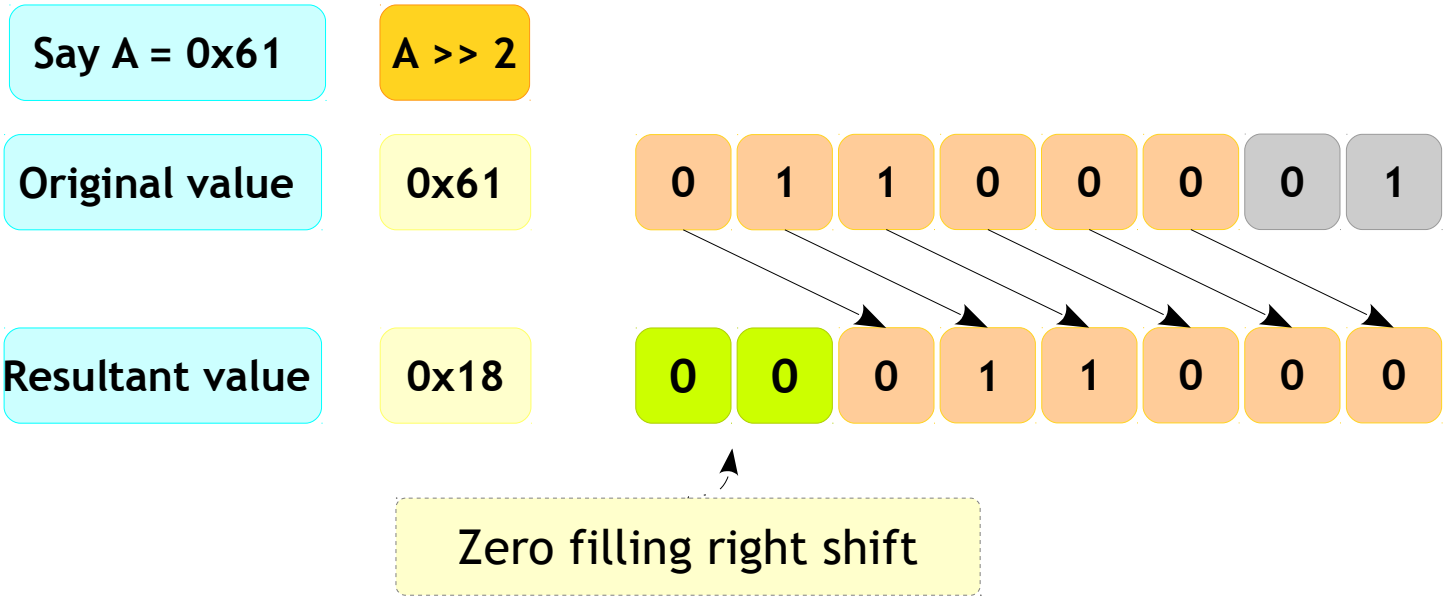
# Advanced C

## Operators – Bitwise – Right Shift

**'Value' >> 'Bits Count'**

- **Value** : Is shift-expression on which bit shifting effect to be applied
- **Bits count** : Is additive-expression, by how many bit(s) the given "Value" to be shifted

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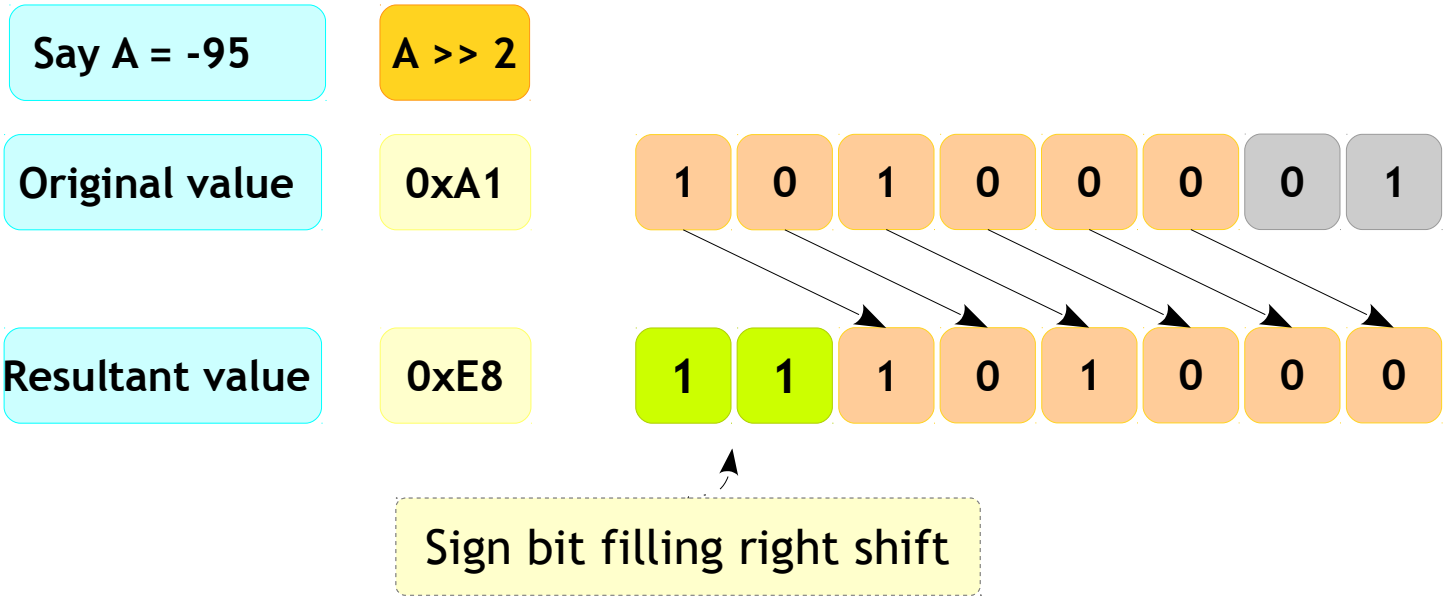
# Advanced C

## Operators - Bitwise - Right Shift - Signed Valued

**“Signed Value' >> 'Bits Count'**

- Same operation as mentioned in previous slide.
- But the sign bits gets propagated.

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# Advanced C

## Operators - Bitwise

### Example

```
#include <stdio.h>

int main()
{
     int count;
     unsigned char iter = 0xFF;

     for (count = 0; iter != 0; iter >>= 1)
     {
          if (iter & 01)
          {
               count++;
          }
     }

     printf("count is %d\n", count);

     return 0;
}
```

# Advanced C

## Operators - Bitwise - Shift

- Each of the operands shall have integer type
- The integer promotions are performed on each of the operands
- If the value of the right operand is negative or is greater than or equal to the width of the promoted left operand, the behavior is undefined
- Left shift (<<) operator : If left operand has a signed type and nonnegative value, and (left_operand * (2^n)) is representable in the result type, then that is the resulting value; otherwise, the behavior is undefined

# Advanced C

## Operators - Bitwise - Shift

- The below example has undefined behaviour

**Example**

```
#include <stdio.h>

int main()
{
    int x = 7, y = 7;

    x = 7 << 32;
    printf("x is %x\n", x);

    x = y << 32;
    printf("x is %x\n", x);

    return 0;
}
```

# Advanced C

## Operators – Bitwise - Shift

- W.A.P to count set bits in a given number
- W.A.P to print bits of given number
- W.A.P to swap nibbles of given number

# Advanced C

## Operators – Bitwise

- Set bit
- Get bit
- Clear bit

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# Advanced C

## Operators - Ternary

### Syntax

```
Condition ? Expression 1 : Expression 2;
```

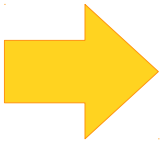
### Example

```c
#include <stdio.h>

int main()
{
    int num1 = 10;
    int num2 = 20;
    int num3;

    if (num1 > num2)
    {
        num3 = num1;
    }
    else
    {
        num3 = num2;
    }
    printf("%d\n", num3);

    return 0;
}
```



```c
#include <stdio.h>

int main()
{
    int num1 = 10;
    int num2 = 20;
    int num3;

    num3 = num1 > num2 ? num1 : num2;
    printf("Greater num is %d\n", num3);

    return 0;
}
```

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# Advanced C

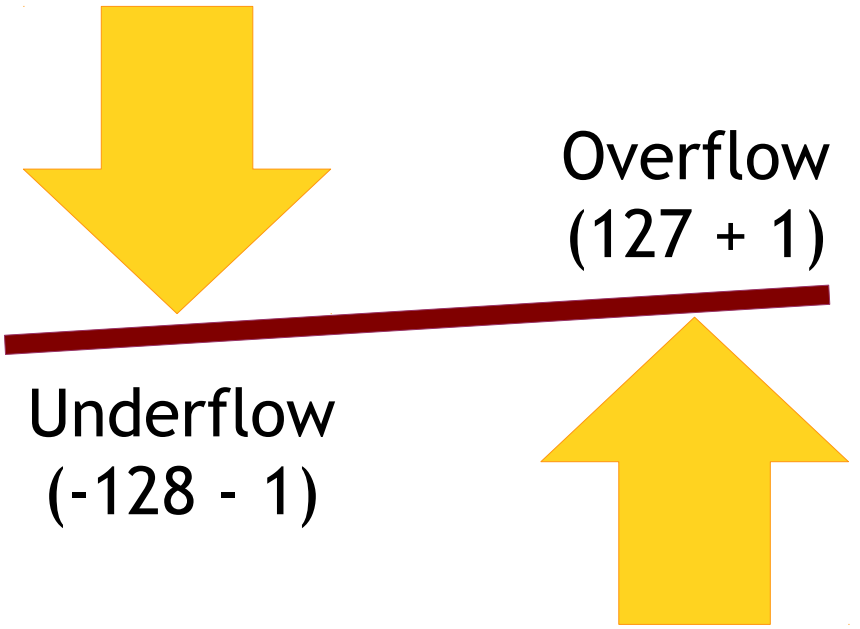
## Operators – Comma

- The left operand of a comma operator is evaluated as a void expression (result discarded)
- Then the right operand is evaluated; the result has its type and value
- Comma acts as separator (not an operator) in following cases -
  - Arguments to function
  - Lists of initializers (variable declarations)
- But, can be used with parentheses as function arguments such as -
  - foo ((x = 2, x + 3)); // final value of argument is 5

# Advanced C

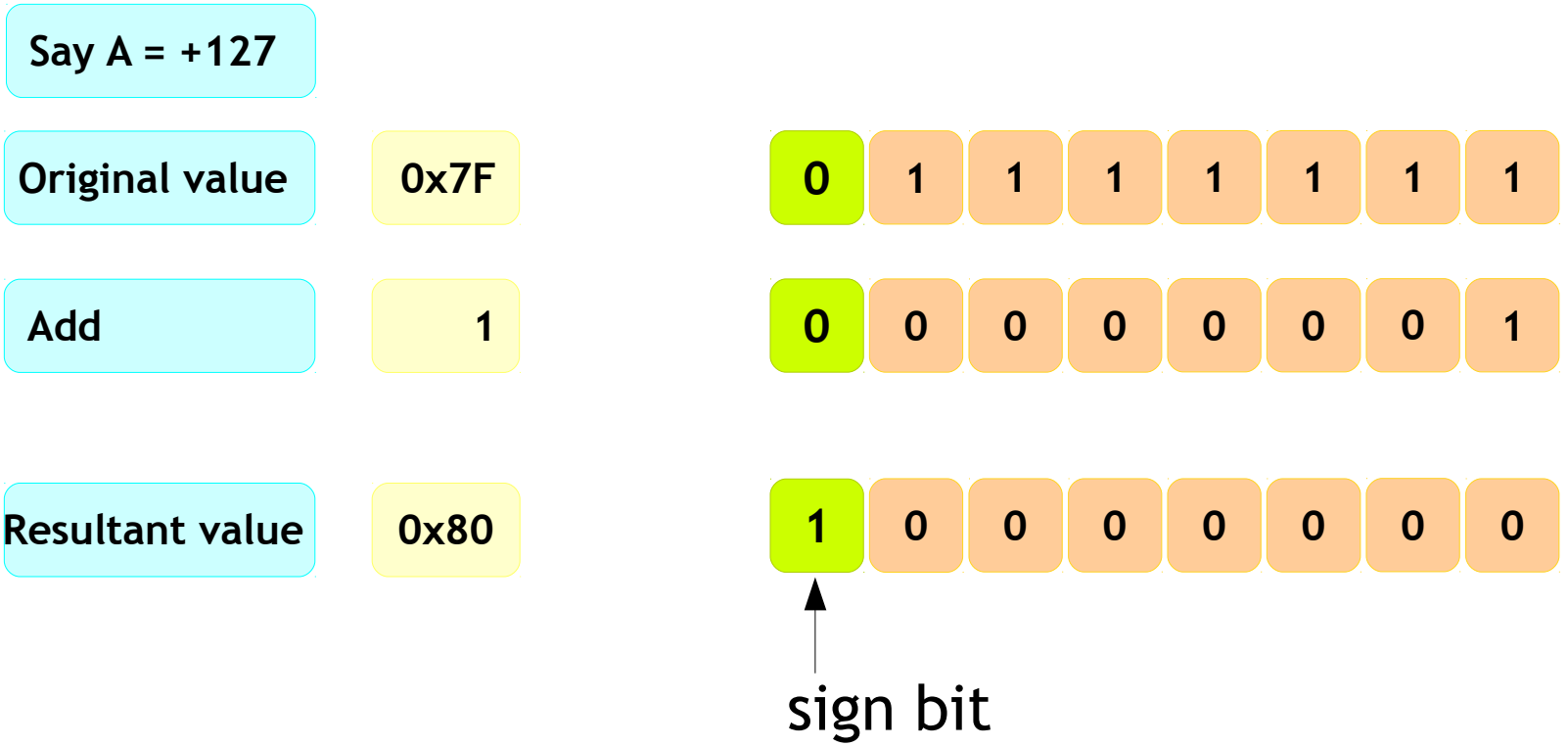
## Over and Underflow

- 8-bit Integral types can hold certain ranges of values
- So what happens when we try to traverse this boundary?



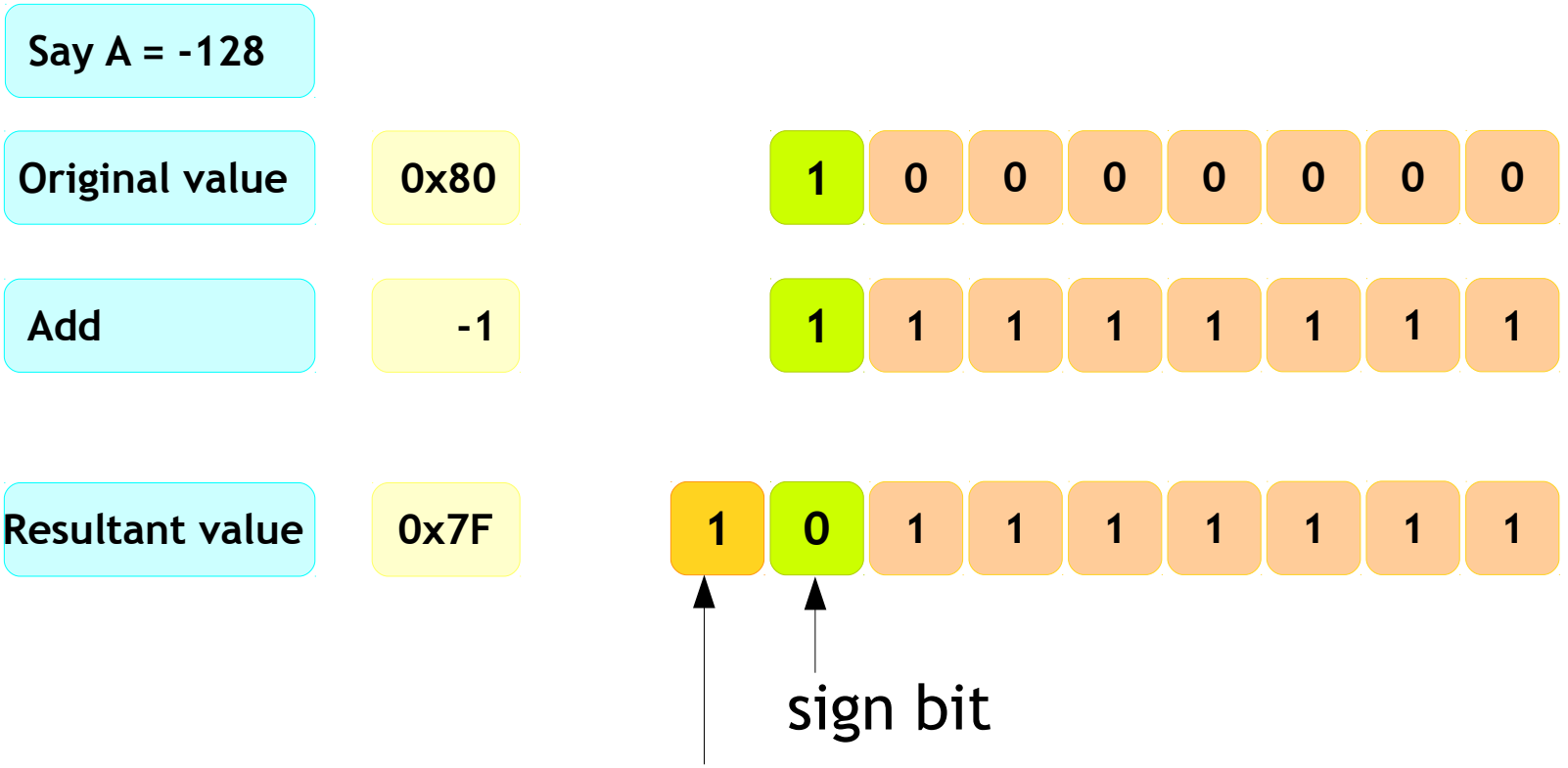
# Advanced C

## Overflow – Signed Numbers



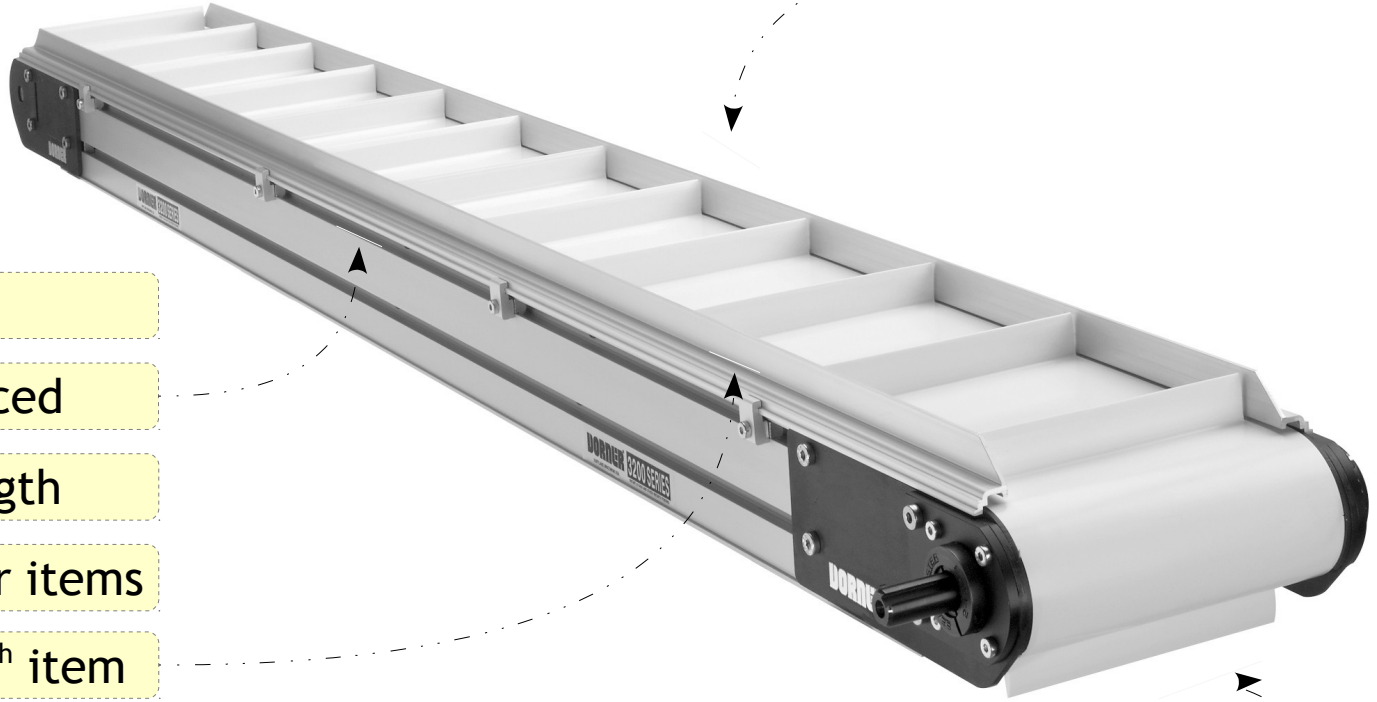
# Advanced C

## Underflow – Signed Numbers



# Advanced C

## Arrays – Know the Concept




A conveyor belt

Starts here

Equally spaced

Defined length

Carry similar items

Index as 10th item

Ends here

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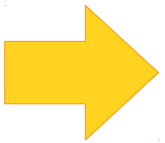
# Advanced C

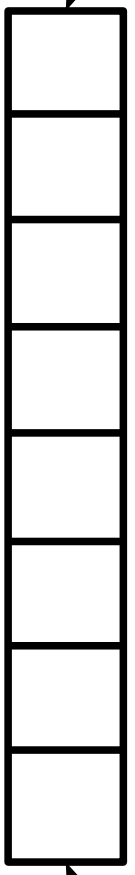
## Arrays - Know the Concept

**Conveyor Belt**
**Top view**



**An Array**





First Element
Start (Base) address

- Total Elements
- Fixed size
- Contiguous Address
- Elements are accessed by indexing
- Legal access region

Last Element
End address

**What is the type of conveyor belt?**

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# Advanced C

## Arrays

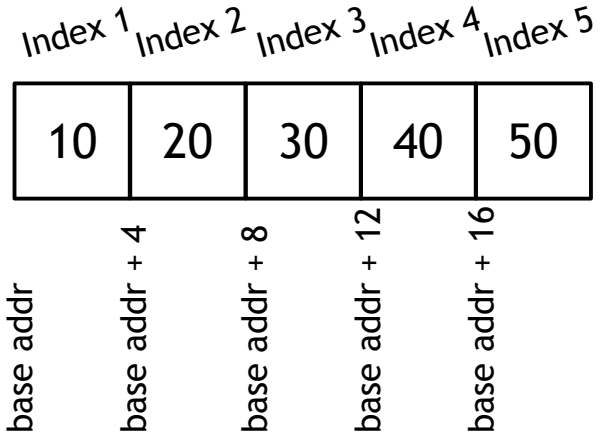
### Syntax

```
data_type name[SIZE];

Where SIZE represents number of elements
Memory occupied by array = (number of elements * size of an element)
    = SIZE * <size of data_type>
```

### Example

```
int age[5] = {10, 20, 30, 40, 50};
```

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# Advanced C

## Arrays – Points to be noted

- An array is a collection of similar data type
- Elements occupy consecutive memory locations (addresses)
- First element with lowest address and the last element with highest address
- Elements are indexed from 0 to SIZE – 1. Example : 5 elements array (say array[5]) will be indexed from 0 to 4
- Accessing out of range array elements would be “illegal access”
  - Example : Do not access elements array[-1] and array[SIZE]
- Array size can't be altered at run time

# Advanced C

## Arrays - Why?

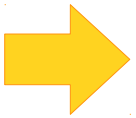
**Example**

```c
#include <stdio.h>

int main()
{
    int num1 = 10;
    int num2 = 20;
    int num3 = 30;
    int num4 = 40;
    int num5 = 50;

    printf("%d\n", num1);
    printf("%d\n", num2);
    printf("%d\n", num3);
    printf("%d\n", num4);
    printf("%d\n", num5);

    return 0;
}
```



```c
#include <stdio.h>

int main()
{
    int num_array[5] = {10, 20, 30, 40, 50};
    int index;

    for (index = 0; index < 5; index++)
    {
        printf("%d\n", num_array[index]);
    }

    return 0;
}
```

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# Advanced C

## Arrays - Reading

**Example**

```c
#include <stdio.h>

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

    index = 0;
    do
    {
        printf("Index %d has Element %d\n", index, array[index]);
        index++;
    } while (index < 5);

    return 0;
}
```

# Advanced C

## Arrays - Storing

**Example**

```
#include <stdio.h>

int main()
{
    int array[5];
    int index;

    for (index = 0; index < 5; index++)
    {
        scanf("%d", &num_array[index]);
    }

    return 0;
}
```

# Advanced C

## Arrays - Initializing

**Example**

```c
#include <stdio.h>

int main()
{
    int array1[5] = {1, 2, 3, 4, 5};
    int array2[5] = {1, 2};
    int array3[] = {1, 2};
    int array4[]; /* Invalid */

    printf("%u\n", sizeof(array1));
    printf("%u\n", sizeof(array2));
    printf("%u\n", sizeof(array3));

    return 0;
}
```

# Advanced C

## Arrays - Copying

- Can we copy 2 arrays? If yes how?

**Example**

```c
#include <stdio.h>

int main()
{
    int array_org[5] = {1, 2, 3, 4, 5};
    int array_bak[5];
    int index;

    array_bak = array_org;

    if (array_bak == array_org)
    {
        printf("Copied\n");
    }

    return 0;
}
```

# Advanced C

## Arrays – Copying

- No!! its not so simple to copy two arrays as put in the previous slide. C doesn't support it!
- Then how to copy an array?
- It has to be copied element by element

# Advanced C

## Arrays - DIY

- W.A.P to find the average of elements stored in a array.
  - Read value of elements from user
  - For given set of values : { 13, 5, -1, 8, 17 }
  - Average Result = 8.4
- W.A.P to find the largest array element
  - Example 100 is the largest in {5, 100, -2, 75, 42}

# Advanced C

## Arrays – DIY

- W.A.P to compare two arrays (element by element).
  - Take equal size arrays
  - Arrays shall have unique values stored in random order
  - Array elements shall be entered by user
  - Arrays are compared “EQUAL” if there is one to one mapping of array elements value
  - Print final result “EQUAL” or “NOT EQUAL”

Example of Equal Arrays :

- A[3] = {2, -50, 17}
- B[3] = {17, 2, -50}

# Advanced C

## Arrays – Oops!! what is this now?

# Chapter 3
## Functions

# Advanced C

## Functions – What?

An activity that is natural to or the purpose of a person or thing.

"bridges perform the function of providing access across water"

A relation or expression involving one or more variables.

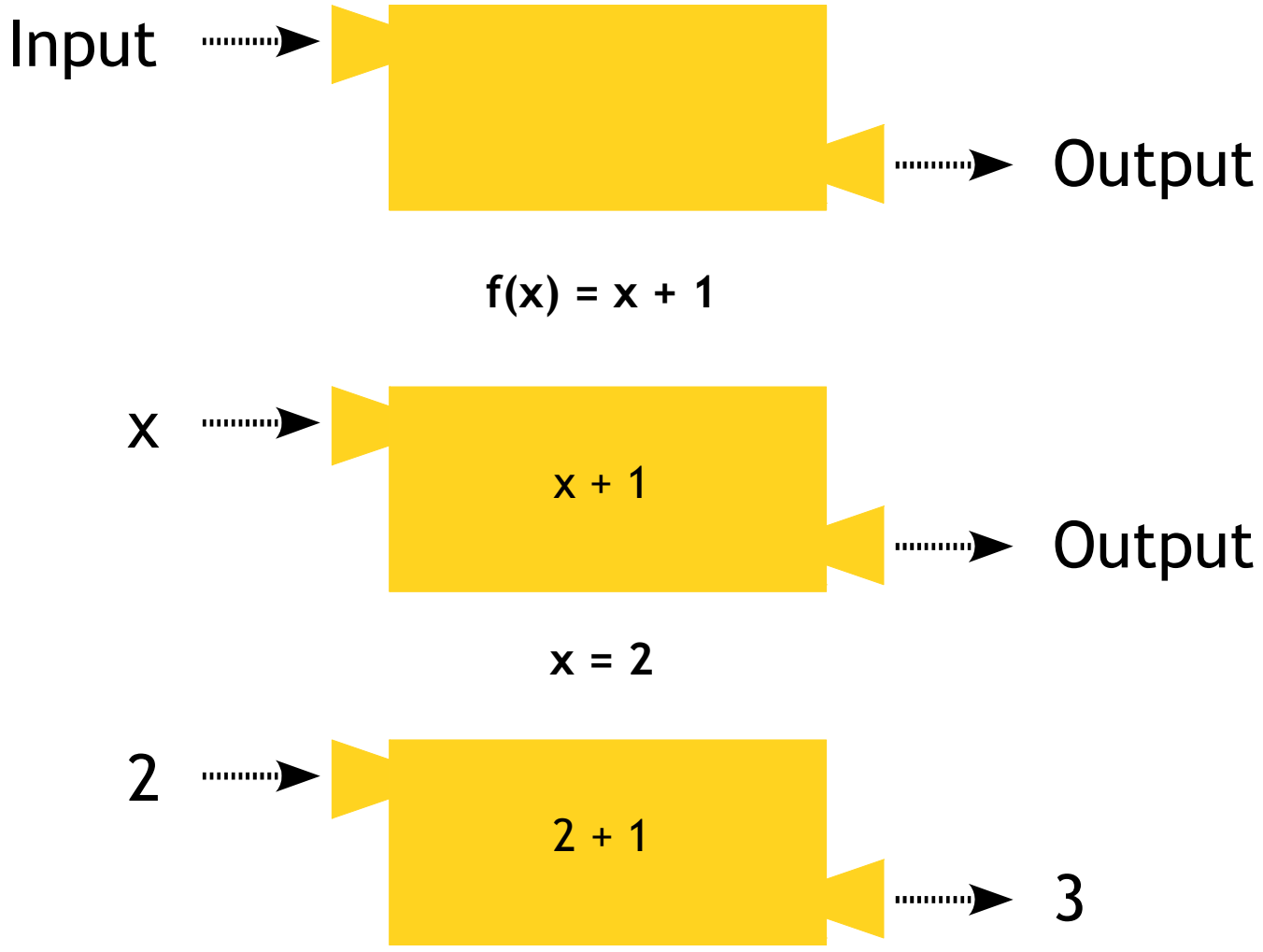
"the function (bx + c)"

Source: Google

- In programing languages it can be something which performs a specific service
- Generally a function has 3 properties
  - Takes Input
  - Perform Operation
  - Generate Output

# Advanced C

## Functions – What?

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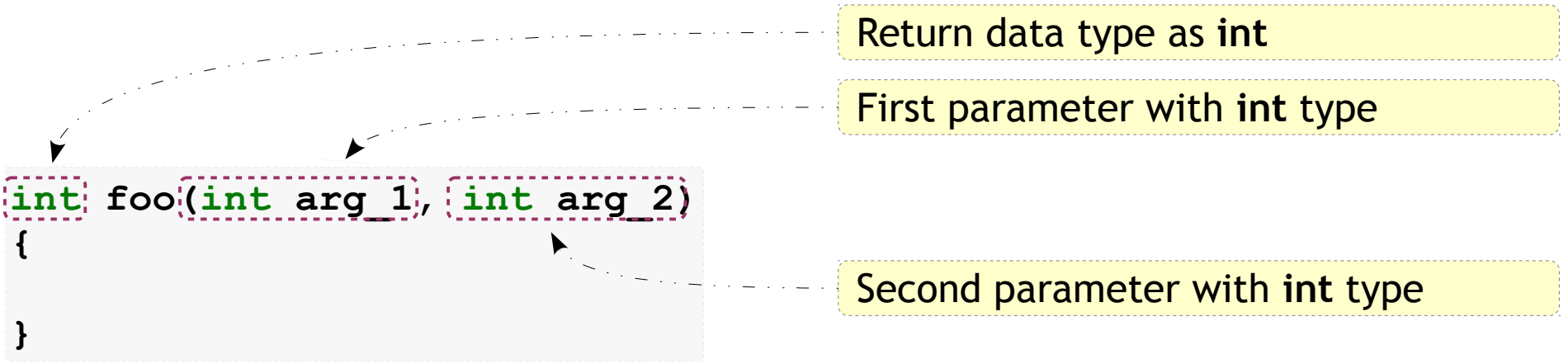
# Advanced C

## Functions - How to write

### Syntax

```
return_data_type function_name(arg_1, arg_2, ..., arg_n)
{
    /* Function Body */
}
```

### Example

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# Advanced C

## Functions - How to write

$$y = x + 1$$

**Example**

```
int foo(int x)
{
    int ret = 0;

    ret = x + 1;

    return ret;
}
```

Return from function

# Advanced C

## Functions - How to call

**Example**

```c
#include <stdio.h>

int main()
{
    int x, y;

    x = 2;

    y = foo(x);
    printf("y is %d\n", y);

    return 0;
}
```

The function call

```c
int foo(int x)
{
    int ret = 0;

    ret = x + 1;

    return ret;
}
```

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# Advanced C

## Functions – Why?

- Re usability
  - Functions can be stored in library & re-used
  - When some specific code is to be used more than once, at different places, functions avoids repetition of the code.
- Divide & Conquer
  - A big & difficult problem can be divided into smaller sub-problems and solved using divide & conquer technique
- Modularity can be achieved.
- Code can be easily understandable & modifiable.
- Functions are easy to debug & test.
- One can suppress, how the task is done inside the function, which is called Abstraction

# Advanced C

## Functions - A complete look

**Example**

```c
#include <stdio.h>

int main()
{
    int num1 = 10, num2 = 20;
    int sum = 0;

    sum = add_numbers(num1, num2);
    printf("Sum is %d\n", sum);

    return 0;
}

int add_numbers(int num1, int num2)
{
    int sum = 0;

    sum = num1 + num2;

    return sum;
}
```

The main function

The function call

Actual arguments

Return type

Formal arguments

Function

Return from function

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# Advanced C

## Functions - Ignoring return value

**Example**

```c
#include <stdio.h>

int main()
{
    int num1 = 10, num2 = 20;
    int sum = 0;

    add_numbers(num1, num2);
    printf("Sum is %d\n", sum);

    return 0;
}
```

Ignored the return from function
In C, it is up to the programmer to capture or ignore the return value

```c
int add_numbers(int num1, int num2)
{
    int sum = 0;

    sum = num1 + num2;

    return sum;
}
```

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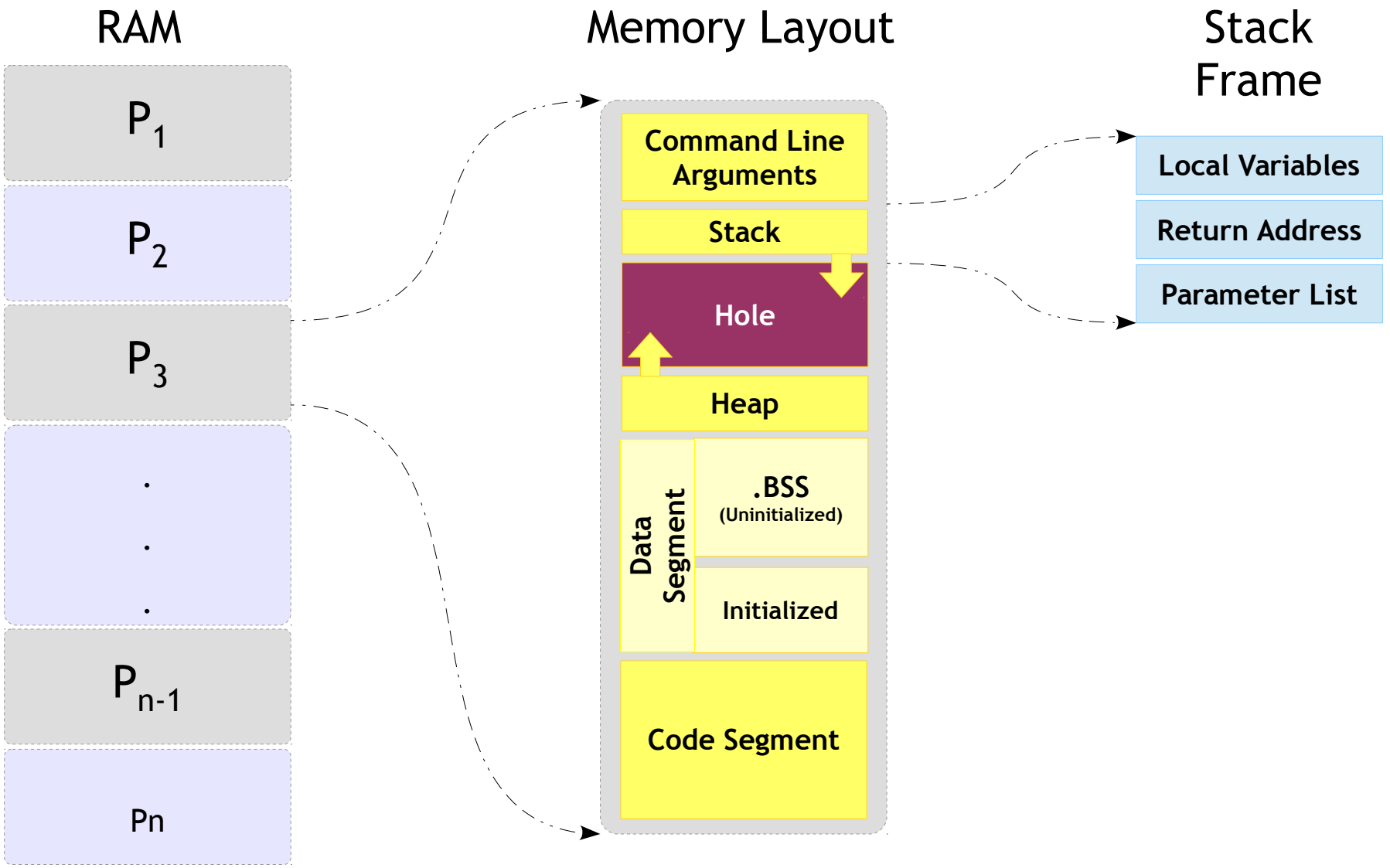
# Advanced C

## Functions – DIY

- Write a function to calculate square a number
  - y = x * x
- Write a function to convert temperature given in degree Fahrenheit to degree Celsius
  - C = 5/9 * (F - 32)
- Write a program to check if a given number is even or odd. Function should return TRUE or FALSE

# Advanced C

## Function and the Stack



# Advanced C

## Functions – Parameter Passing Types

| Pass by Value | Pass by reference |
| --- | --- |
| • This method copies the actual value of an argument into the formal parameter of the function. | • This method copies the address of an argument into the formal parameter. |
| • In this case, changes made to the parameter inside the function have no effect on the actual argument. | • Inside the function, the address is used to access the actual argument used in the call. This means that changes made to the parameter affect the argument. |

# Advanced C

## Functions - Pass by Value

**Example**

```c
#include <stdio.h>

int add_numbers(int num1, int num2);

int main()
{
    int num1 = 10, num2 = 20, sum;

    sum = add_numbers(num1, num2);
    printf("Sum is %d\n", sum);

    return 0;
}
```

```c
int add_numbers(int num1, int num2)
{
    int sum = 0;

    sum = num1 + num2;

    return sum;
}
```

# Advanced C

## Functions - Pass by Value

**Example**

```c
#include <stdio.h>

void modify(int num1)
{
    num1 = num1 + 1;
}

int main()
{
    int num1 = 10;

    printf("Before Modification\n");
    printf("num1 is %d\n", num1);

    modify(num1);

    printf("After Modification\n");
    printf("num1 is %d\n", num1);

    return 0;
}
```

# Advanced C

## Functions - Pass by Value


Are you sure you understood the previous problem?

Are you sure you are ready to proceed further?

Do you know the prerequisite to proceed further?

If no let's get it cleared

# Advanced C

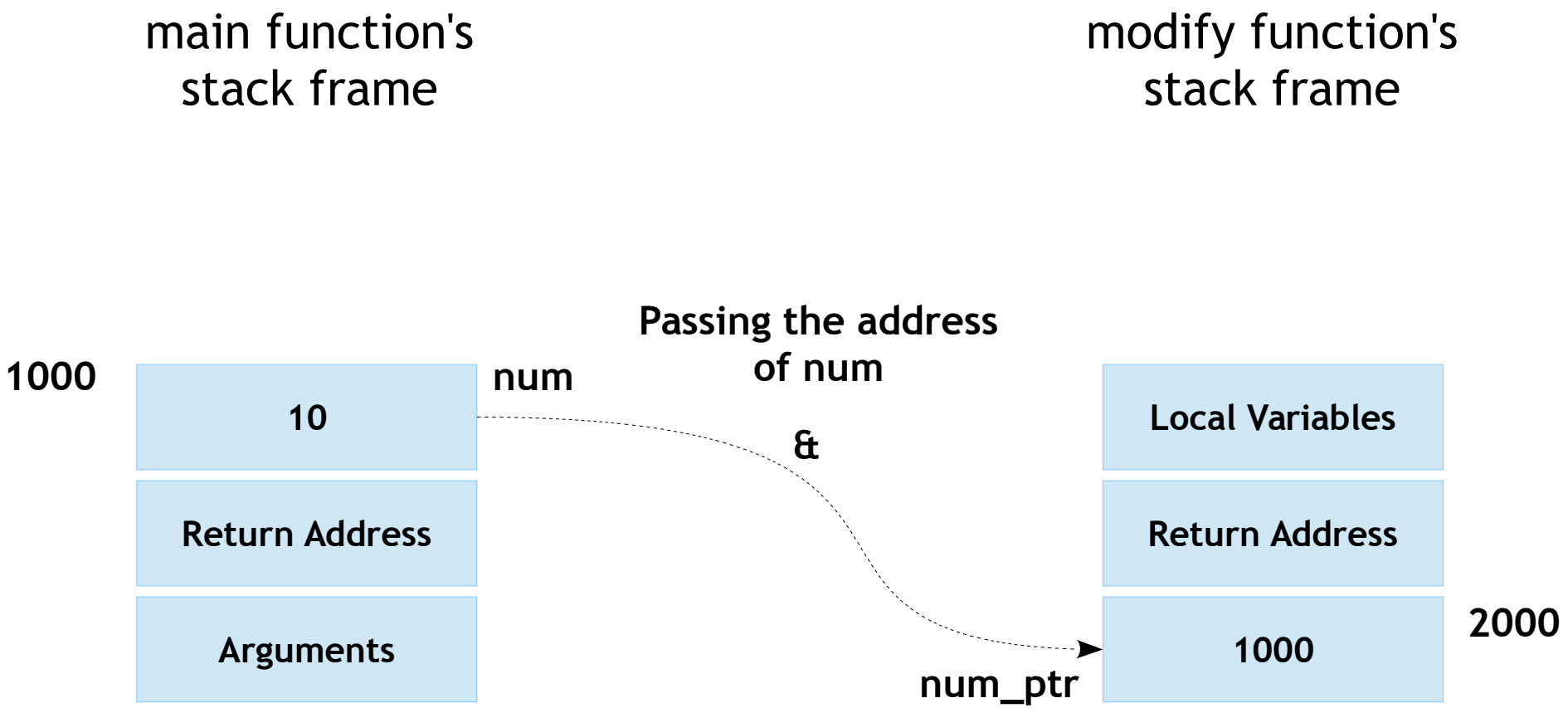
## Functions - Pass by Reference

**Example**

```c
#include <stdio.h>

void modify(int *num_ptr)
{
    *num_ptr = *num_ptr + 1;
}

int main()
{
    int num = 10;

    printf("Before Modification\n");
    printf("num1 is %d\n", num);

    modify(&num);

    printf("After Modification\n");
    printf("num1 is %d\n", num);

    return 0;
}
```

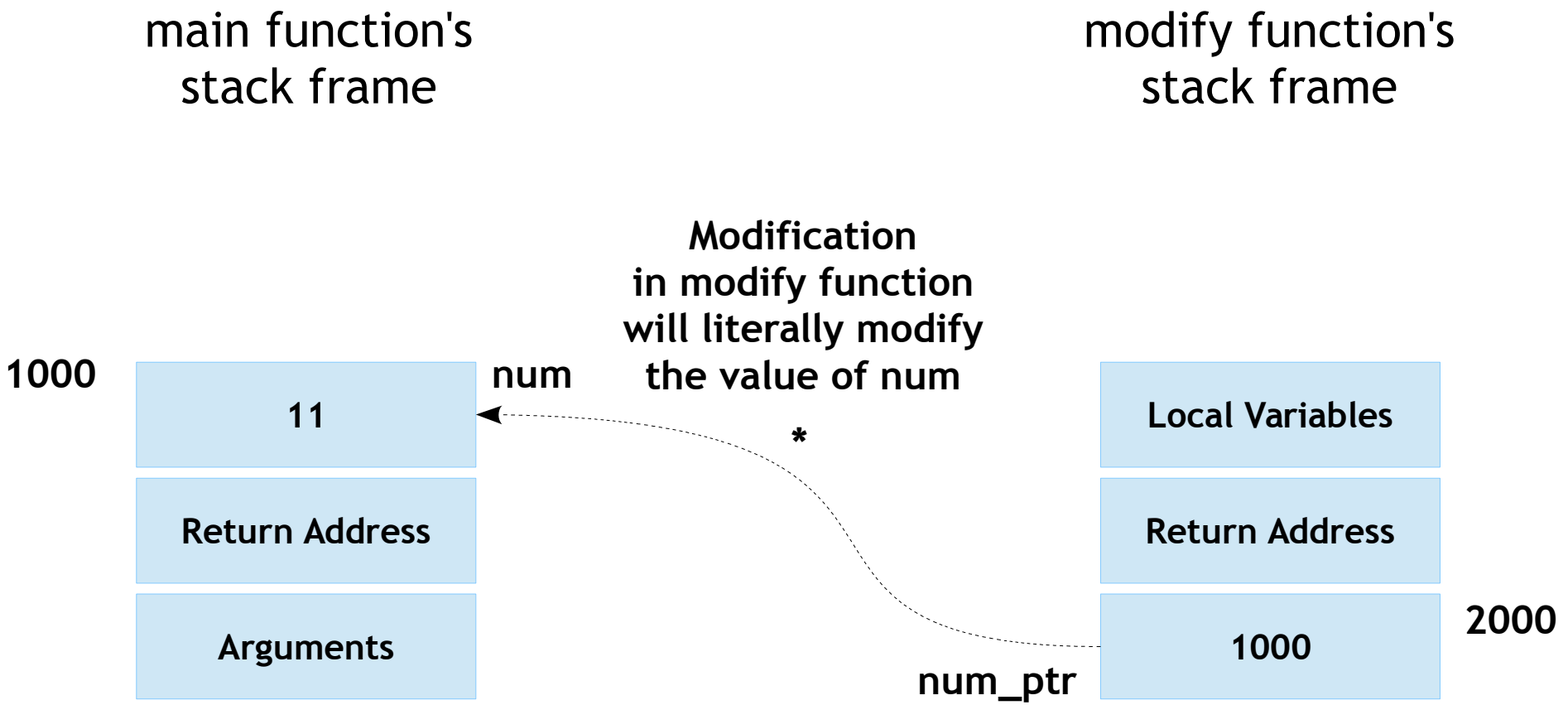
# Advanced C

## Functions - Pass by Reference



# Advanced C

## Functions - Pass by Reference



# Advanced C

## Functions – Pass by Reference - Advantages

- Return more than one value from a function
- Copy of the argument is not made, making it fast, even when used with large variables like arrays etc.
- Saving stack space if argument variables are larger (example – user defined data types)

# Advanced C

## Functions – DIY

- Write a program to find the square of a number
- Write a program to find the square and cube of a number
- Write a program to swap two numbers
- Write a program to find the sum and product of 2 numbers

# Advanced C

## Functions – Passing Array

- As mentioned in previous slide passing an array to function can be faster
- But before you proceed further it is expected you are familiar with some pointer rules
- If you are OK with your concepts proceed further, else please know the rules first

# Advanced C

## Functions - Passing Array

**Example**

```
#include <stdio.h>

void print_array(int array[]);

int main()
{
     int array[5] = {10, 20, 30, 40, 50};

     print_array(array);

     return 0;
}
```

```
void print_array(int array[])
{
     int iter;

     for (iter = 0; iter < 5; iter++)
     {
          printf("Index %d has Element %d\n", iter, array[iter]);
     }
}
```

# Advanced C

## Functions - Passing Array

**Example**

```c
#include <stdio.h>

void print_array(int *array);

int main()
{
    int array[5] = {10, 20, 30, 40, 50};

    print_array(array);

    return 0;
}
```

```c
void print_array(int *array)
{
    int iter;

    for (iter = 0; iter < 5; iter++)
    {
        printf("Index %d has Element %d\n", iter, *array);
        array++;
    }
}
```

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# Advanced C

## Functions - Passing Array

**Example**

```
#include <stdio.h>

void print_array(int *array, int size);

int main()
{
     int array[5] = {10, 20, 30, 40, 50};

     print_array(array, 5);

     return 0;
}
```

```
void print_array(int *array, int size)
{
     int iter;

     for (iter = 0; iter < size; iter++)
     {
          printf("Index %d has Element %d\n", iter, *array++);
     }
}
```

# Advanced C

## Functions - Returning Array

### Example

```c
#include <stdio.h>

int *modify_array(int *array, int size);
void print_array(int array[], int size);

int main()
{
     int array[5] = {10, 20, 30, 40, 50};
     int *new_array_val;

     new_array_val = modify_array(array, 5);
     print_array(new_array_val, 5);

     return 0;
}
```

```c
int *modify_array(int *array, int size)
{
     int  iter;

     for (iter = 0; iter < size; iter++)
     {
          *(array + iter) += 10;
     }

     return array;
}
```

```c
void print_array(int array[], int size)
{
     int  iter;

     for (iter = 0; iter < size; iter++)
     {
          printf("Index %d has Element %d\n", iter, array[iter]);
     }
}
```

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# Advanced C

## Functions - Returning Array

### Example

```c
#include <stdio.h>

int *return_array(void);
void print_array(int *array, int size);

int main()
{
     int *array_val;

     array_val = return_array();
     print_array(array_val, 5);

     return 0;
}
```

```c
int *return_array(void)
{
     static int array[5] = {10, 20, 30, 40, 50};

     return array;
}
```

```c
void print_array(int *array, int size)
{
     int  iter;

     for (iter = 0; iter < size; iter++)
     {
          printf("Index %d has Element %d\n", iter, array[iter]);
     }
}
```

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# Advanced C

## Functions – DIY

- Write a program to find the average of 5 array elements using function
- Write a program to square each element of array which has 5 elements

# Advanced C

## Functions – Prototype

- Need of function prototype
- Implicit int rule

# Advanced C

## Functions – return type

- Local return
- Void return

# Advanced C

## Functions

# Advanced C

## Functions – Recursive

- Recursion is the process of repeating items in a self-similar way
- In programming a function calling itself is called as recursive function
- Two steps

  Step 1: Identification of base case

  Step 2: Writing a recursive case

# Advanced C

## Functions - Recursive - Example

**Example**

```c
#include <stdio.h>

/* Factorial of 3 numbers */

int factorial(int number)
{
    if (number <= 1)
    {
        return 1;
    }
    else
    {
        return number * factorial(number - 1);
    }
}

int main()
{
    int ret;

    ret = factorial(3);
    printf("Factorial of 3 is %d\n", ret);

    return 0;
}
```

| n | !n |
|---|---|
| 0 | 1 |
| 1 | 1 |
| 2 | 2 |
| 3 | 6 |
| 4 | 24 |

# Advanced C

## Functions – Function Pointers

- A variable that stores the pointer to a function.

**Syntax**

```
datatype (*foo)(datatype, ...);
```

# Advanced C

## Functions - Variadic

- Variadic functions can be called with any number of trailing arguments
- For example,

  printf(), scanf() are common variadic funtions
- Variadic functions can be called in the usual way with individual arguments

**Syntax**

```
return data_type function_name(parameter list, ...);
```

# Advanced C

## Functions - Variadic - Definition & Usage

- Defining and using a variadic function involves three steps:

  Step 1: Variadic functions are defined using an ellipsis ('...') in the argument list, and using special macros to access the variable arguments.

  Example

```
int foo(int a, ...)
{
    /* Function Body */

}
```

  Step 2: Declare the function as variadic, using a prototype with an ellipsis ('...'), in all the files which call it.

  Step 3: Call the function by writing the fixed arguments followed by the additional variable arguments.

# Advanced C

## Functions – Variadic – Argument access macros

- Descriptions of the macros used to retrieve variable arguments
- These macros are defined in the header file stdarg.h

| Type/Macros | Description |
|---|---|
| va_list | The type va_list is used for argument pointer variables |
| va_start | This macro initializes the argument pointer variable ap to point to the first of the optional arguments of the current function; last-required must be the last required argument to the function |
| va_arg | The va_arg macro returns the value of the next optional argument, and modifies the value of ap to point to the subsequent argument. Thus, successive uses of va_arg return successive optional arguments |
| va_end | This ends the use of ap |

# Advanced C

## Functions - Variadic - Example

**Example**

```c
#include <stdio.h>

int main()
{
    int ret;

    ret = add(3, 2, 4, 4);
    printf("Sum is %d\n", ret);

    ret = add(5, 3, 3, 4, 5, 10);
    printf("Sum is %d\n", ret);

    return 0;
}
```

```c
int add(int count, ...)
{
    va_list ap;
    int iter, sum;

    /* Initilize the arg list */
    va_start(ap, count);

    sum = 0;
    for (iter = 0; iter < count; iter++)
    {
        /* Extract args */
        sum += va_arg(ap, int);
    }

    /* Cleanup */
    va_end(ap);

    return sum;
}
```

# Chapter 6
## Pointers and Strings

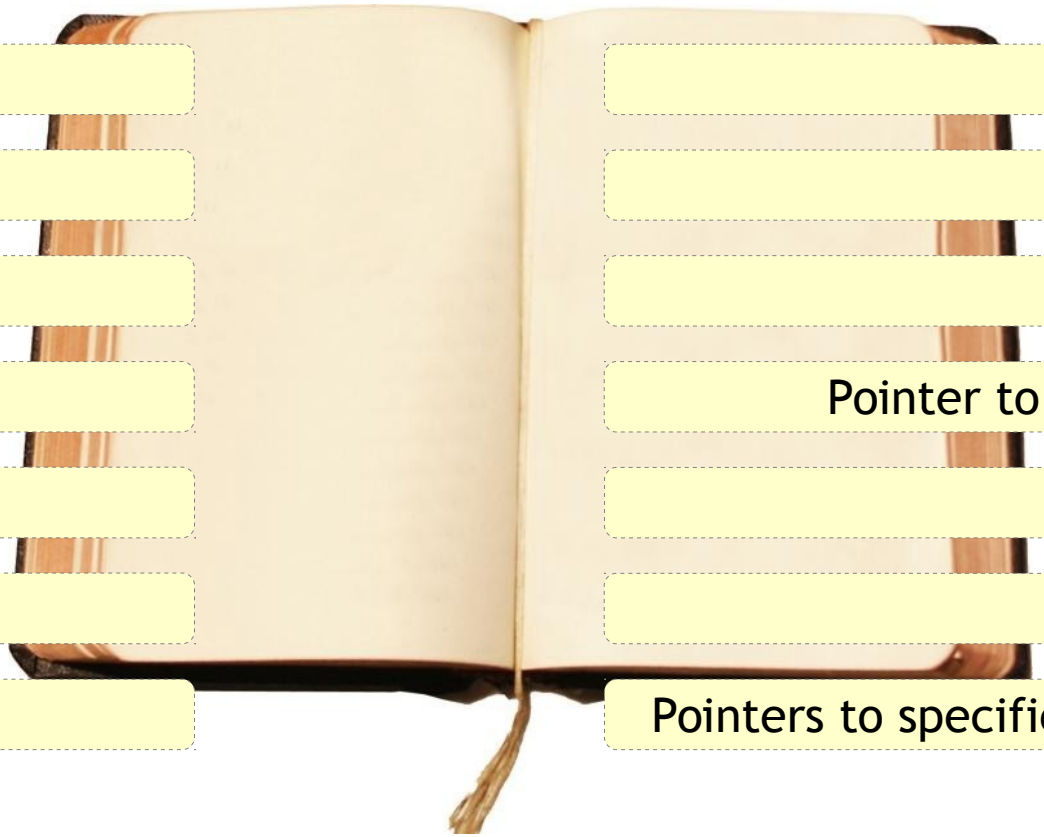
# Advanced C

## 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

# Advanced C

## 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 |

# Advanced C

## 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 a address!!
- So the pointer concept plays a big role here

# Advanced C

## 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 variable”
- parameter passing mechanism in function, by passing the reference
- To have the dynamic allocation mechanism

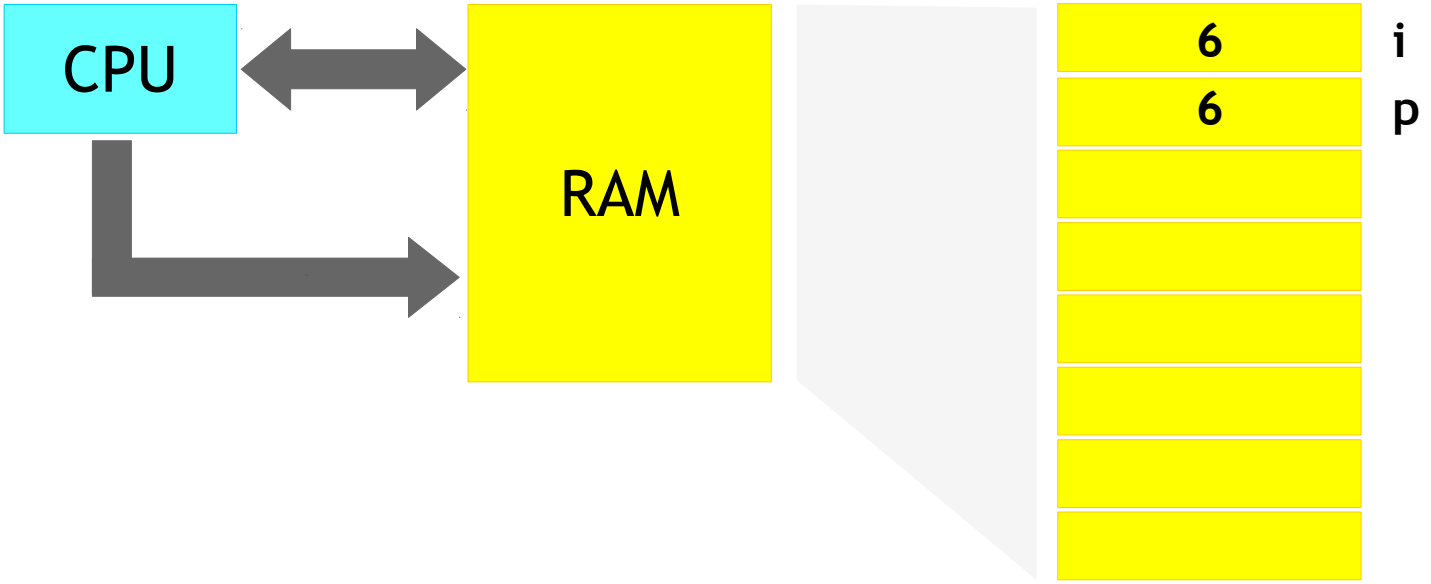
# Advanced C

## 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

# Advanced C

## Pointers - The 7 Rules - Rule 1




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

# Advanced C

## 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)

# Advanced C

## Pointers - Rule 1 in detail

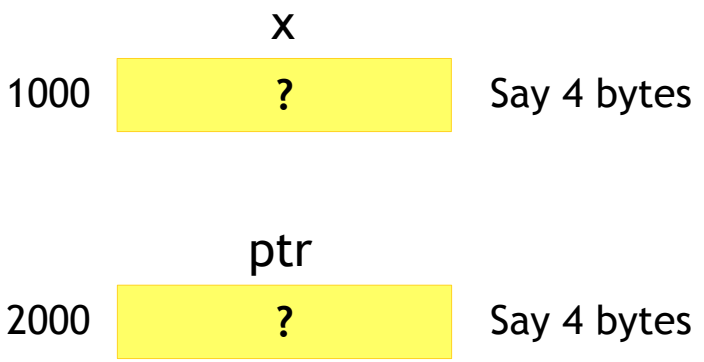
**Example**

```c
#include <stdio.h>

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

    x = 5;
    ptr = 5;

    return 0;
}
```

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# Advanced C

## Pointers - Rule 1 in detail

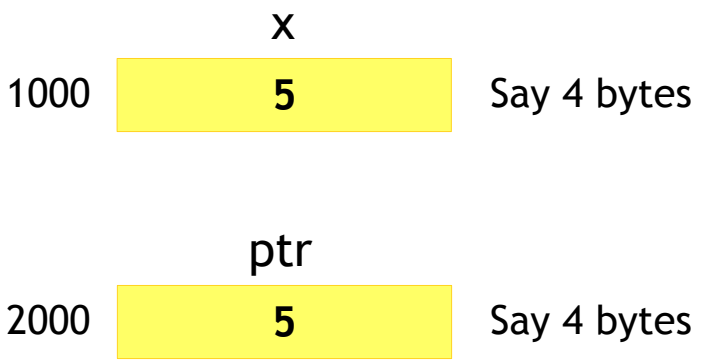
**Example**

```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”

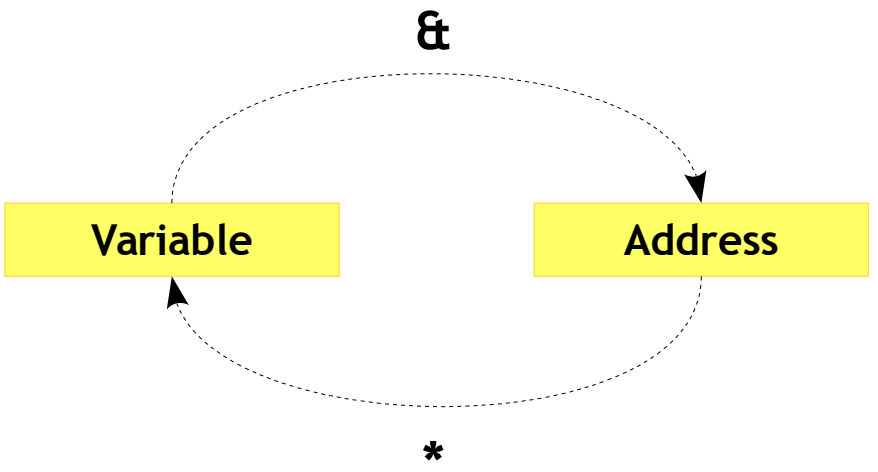
  32 bit system = 4 Bytes

  64 bit system = 8 Bytes

# Advanced C

## Pointers - The 7 Rules - Rule 2

- Rule : “Referencing and Dereferencing”



# Advanced C

## Pointers - Rule 2 in detail

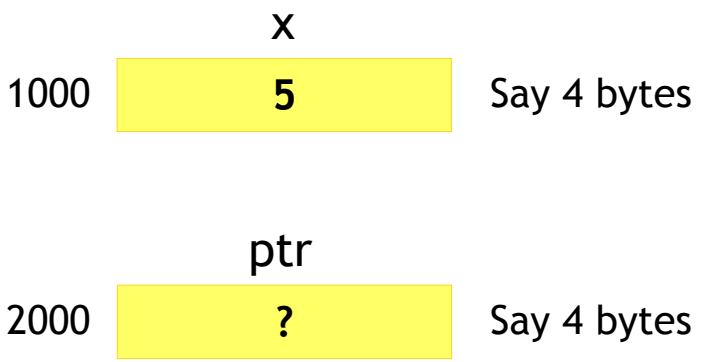
**Example**

```c
#include <stdio.h>

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

    x = 5;

    return 0;
}
```




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

  * 1000

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# Advanced C

## Pointers - Rule 2 in detail

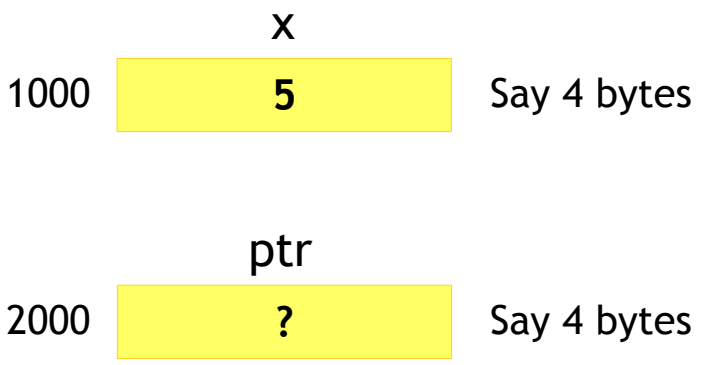
**Example**

```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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# Advanced C

## Pointers - Rule 2 in detail

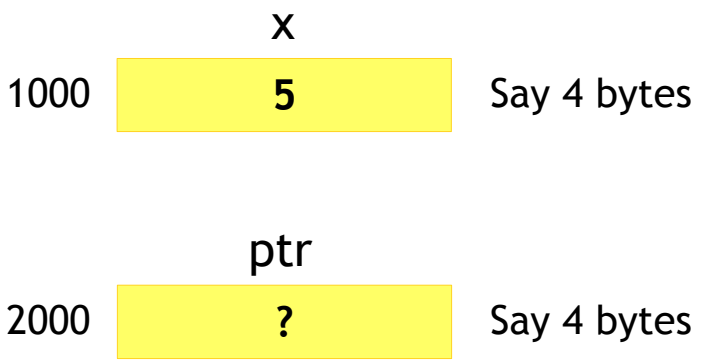
**Example**

```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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# Advanced C

## Pointers - Rule 2 in detail

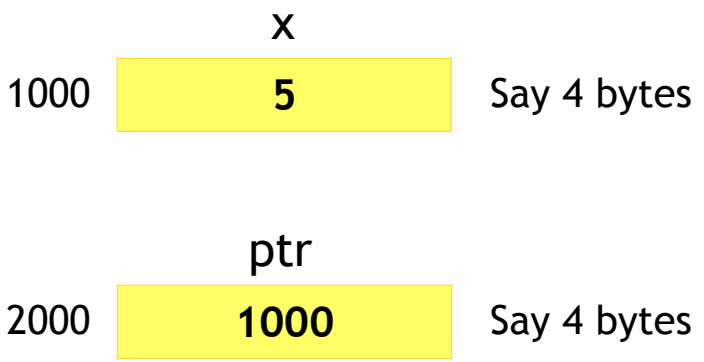
**Example**

```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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# Advanced C

## Pointers - Rule 2 in detail

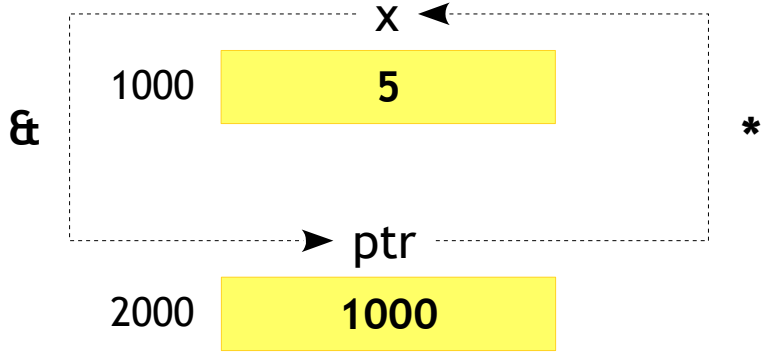
**Example**

```c
#include <stdio.h>

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

    x = 5;
    ptr = &x

    return 0;
}
```




"Add a & on variable to store its address in a pointer"

"Add a * on the pointer to extract the value of variable it is pointing to"

# Advanced C

## Pointers - Rule 2 in detail

**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;
}
```

# Advanced C

## Pointers - Rule 2 in detail

**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

**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;
}
```

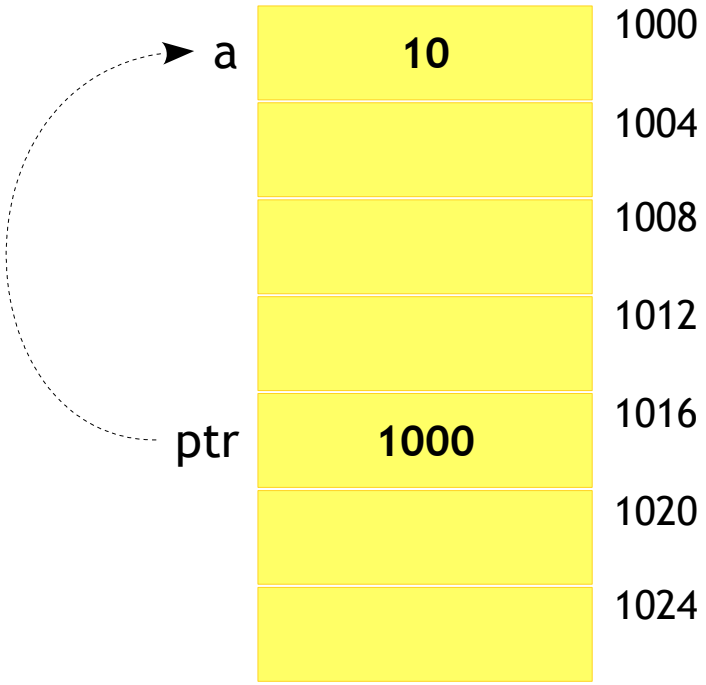
- By compiling and executing the above code we can conclude

"*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”
- int *ptr; int a = 5; ptr = &a;

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# Advanced C

## Pointers - The 7 Rules - Rule 4

- So, why do we need types attached to pointers?
  - Only for 'De-referencing'
  - Pointer arithmetic
- Summarized as the following rule:

  Rule: “Pointer of type t = t Pointer = (t *) = A variable, which contains an address, which when dereferenced returns a variable of type t, starting from that address”

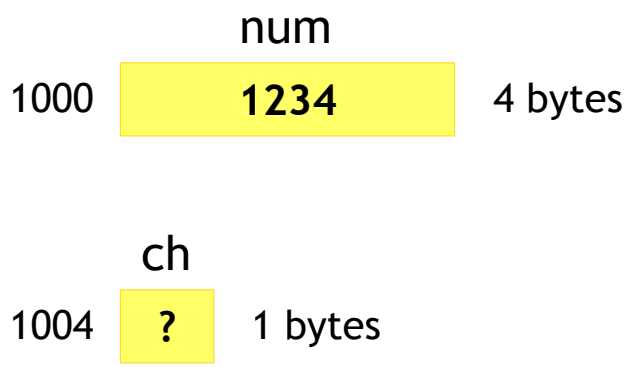
# Advanced C

## Pointers - Rule 4 in detail

- Does address has a type?

**Example**

```c
#include <stdio.h>

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

    return 0;
}
```



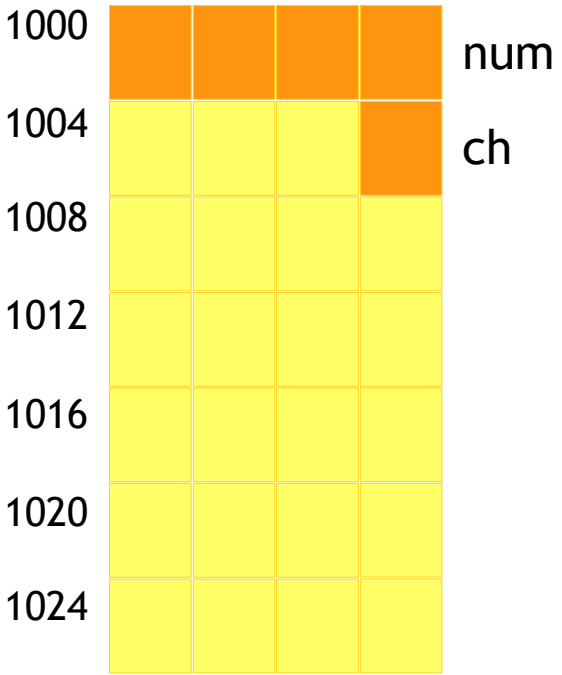

- So, from the above above diagram can we say &num → 4 bytes and &ch → 1 byte?

EMERTXE

# Advanced C

## Pointers – Rule 4 in detail

- The answer is no!!, it does not depend on the type of the variable
- The size of address remains the same, and it depends on the system we use
- Then a simple questions arises is why types to pointers?

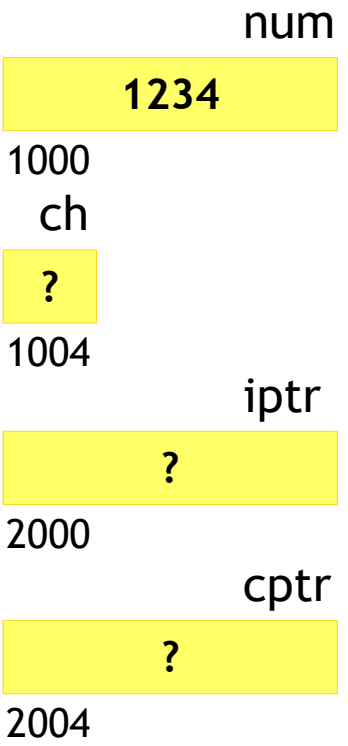


# Advanced C

## Pointers - Rule 4 in detail

**Example**

```c
#include <stdio.h>

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

    int *iptr;
    char *cptr;

    return 0;
}
```



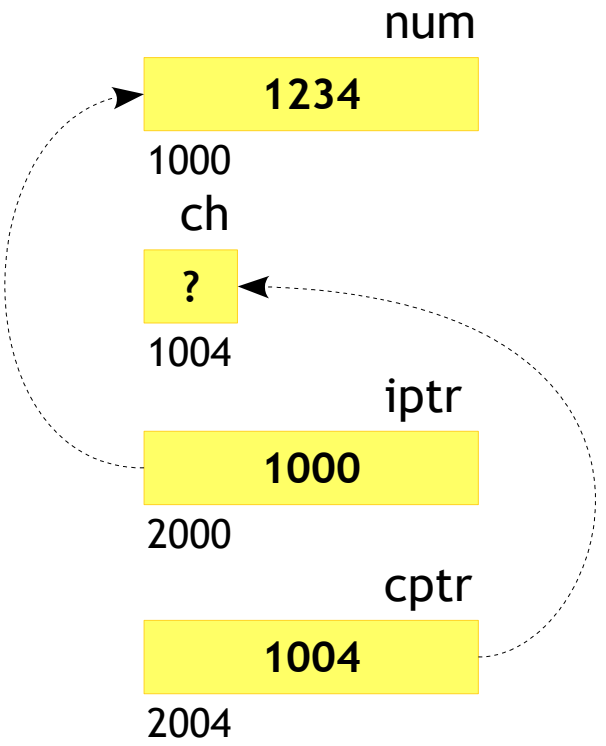

- Lets consider the above examples to understand it
- Say we have an integer and a character pointer

# Advanced C

## Pointers - Rule 4 in detail

**Example**

```c
#include <stdio.h>

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

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

    return 0;
}
```

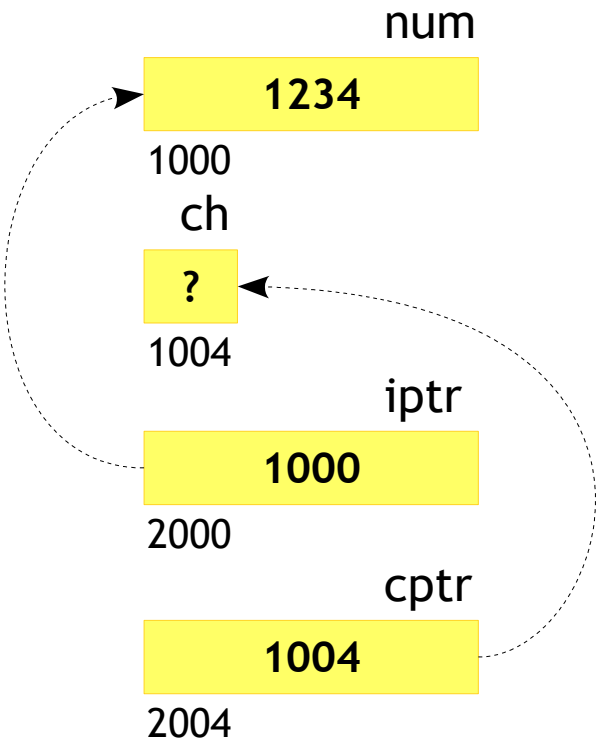



- Lets consider the above examples to understand it
- Say we have an integer and a character pointer

# Advanced C

## Pointers – Rule 4 in detail

- With just the address, can 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!!
- So the type of the pointer is required while
  - Dereferencing it
  - Doing pointer arithmetic



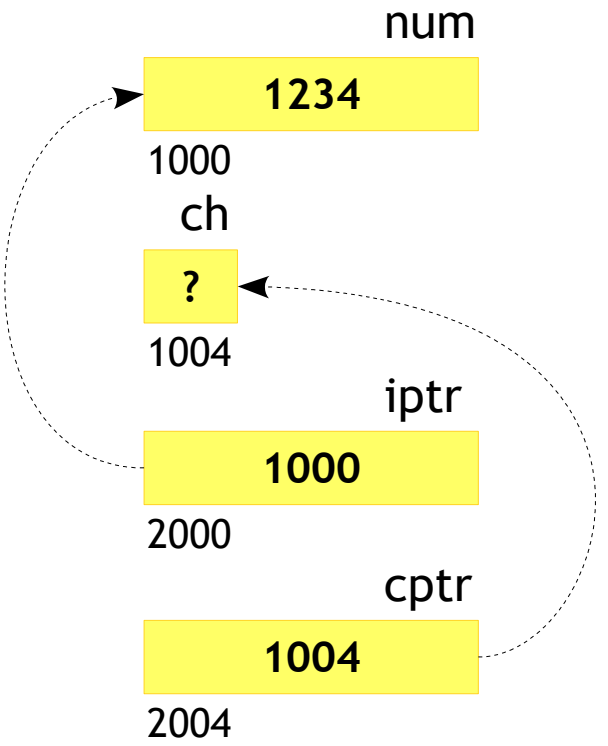
# Advanced C

## Pointers – Rule 4 in detail

- When we say while dereferencing, how does the pointer know how much data it should fetch at a time
- From the diagram right side we can say

  *cptr fetches a single byte

  *iptr fetches 4 consecutive bytes
- So as conclusion we can say




type * → fetch sizeof(type) bytes

# Advanced C

## 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 order Memory Address
  - Big Endian – MSB in Lower Memory Address

# Advanced C

## Pointers – Rule 4 in detail - Endianness

- LSB
  - The byte of a multi byte number with the least importance
  - The change in it would have least effect on complete number
- MSB
  - The byte of a multi byte number with the most importance
  - The change in it would have more effect on complete change number

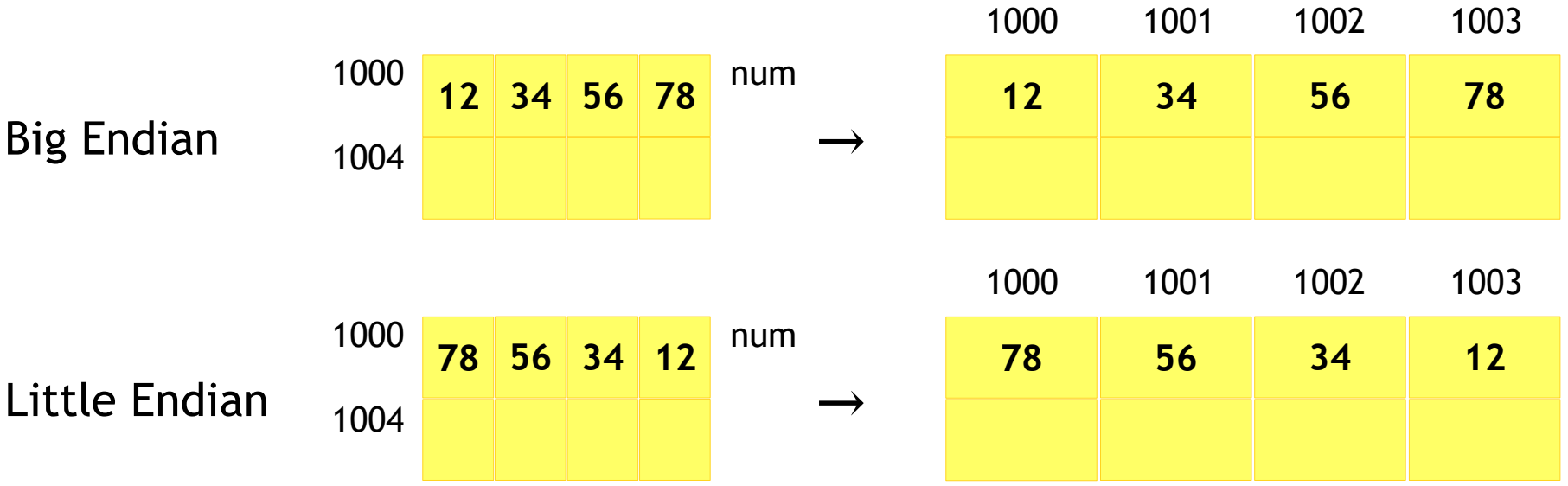
# Advanced C

## 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




*Little Endian - Lower order byte at Lower address

# Advanced C

## Pointers – Rule 4 in detail - Endianness

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

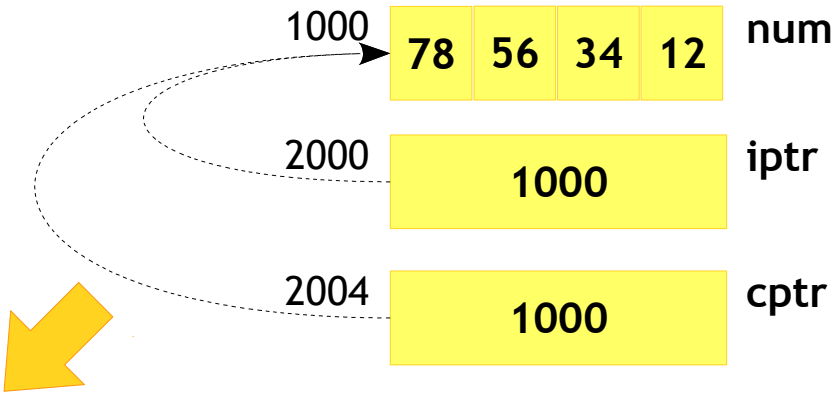
**Example**

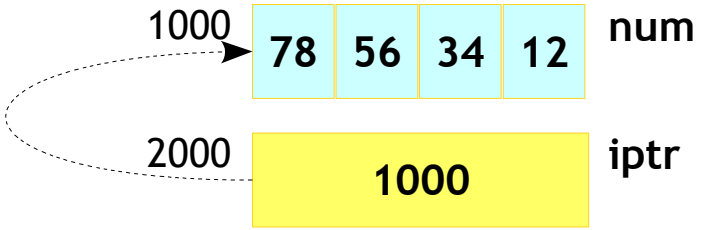
```c
#include <stdio.h>

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

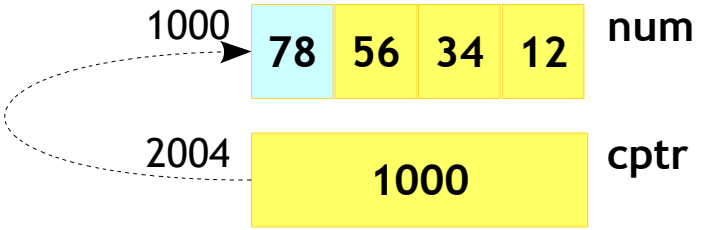
# Advanced C

## Pointers – Rule 4 in detail - Endianness




*iptr = 0x12345678




*cptr = 0x78

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

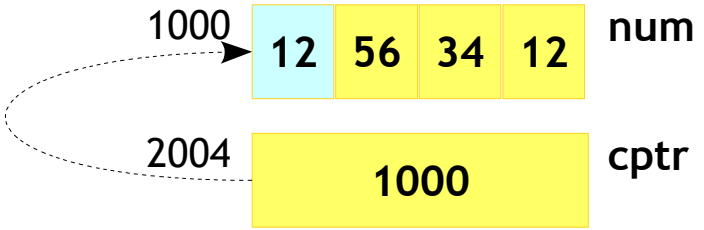
# Advanced C

## Pointers - The 7 Rules - Rule 5

**Example**

```
#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!!

# Advanced C

## Pointers - The 7 Rules - Rule 5

- In conclusion, the type of a pointer represents it's ability to perform read or write operations on number of bytes (data) its pointing to
- So the size of the pointer for different types remains the same

**Example**

```
#include <stdio.h>

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

    return 0;
}
```

# Advanced C

## Pointers – The 7 Rules – Rule 5

- 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

  (1) Original Big Variable (bunch of variables, whole array)

  (2) 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

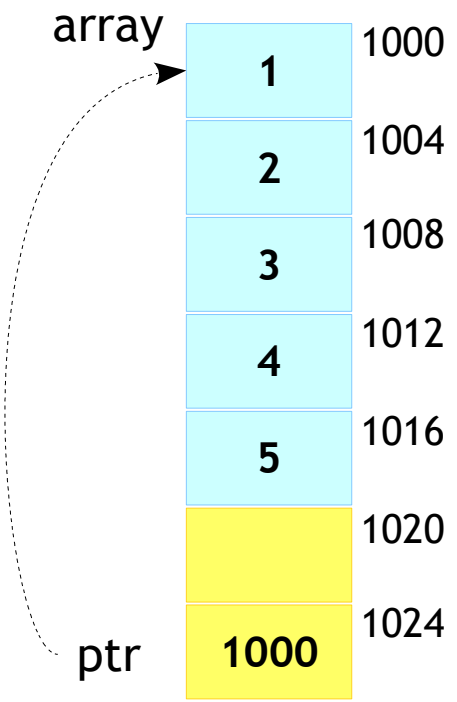
- Cases when first interpretation applies
  - When name of array is operand to sizeof operator
  - When “address of operator (&)” is used the with name of array while performing pointer arithmetic
- The following are the case when first interpretation fails:
  - When we pass array name as function argument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

# Advanced C

## Pointers - The Rule 5 in detail

**Example**

```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

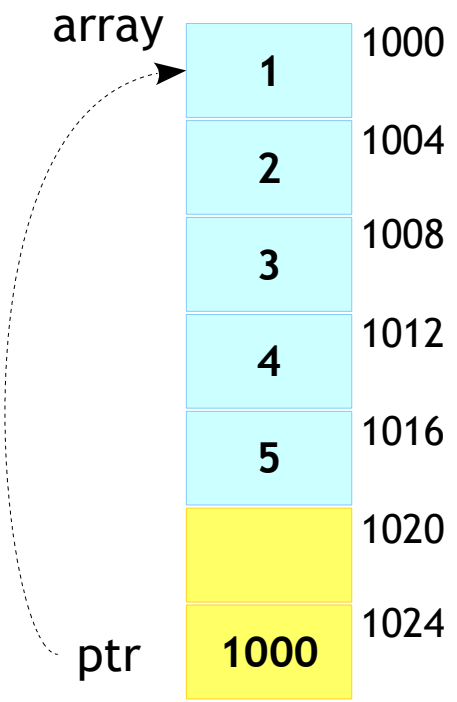
  &array[1] = 2 → 1004

# Advanced C

## Pointers - The Rule 5 in detail

**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

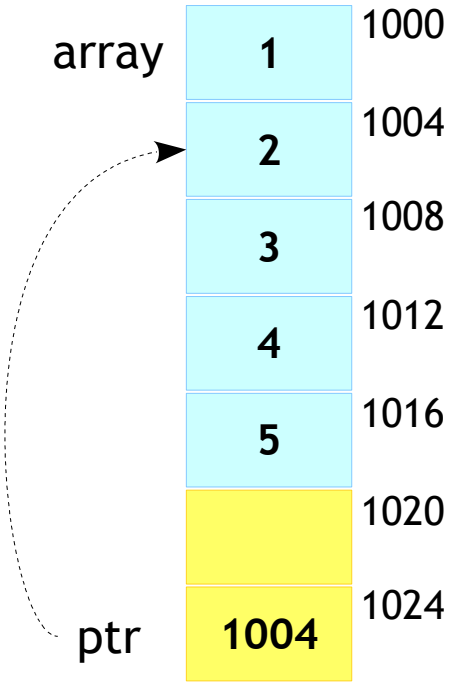
- ptr = ptr + 1;
- The above line can be described as follows
- ptr = ptr + 1 * sizeof(data type)
- In this example we have an integer array, so
- ptr = ptr + 1 * sizeof(int)

  = ptr + 1 * 4

  = ptr + 4
- Here ptr = 1000 so

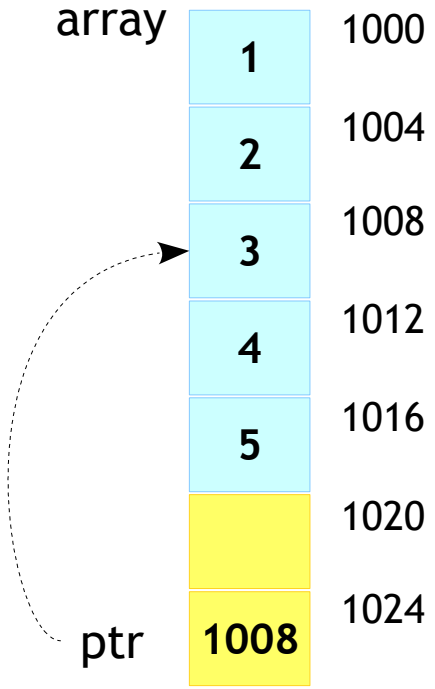
  = 1000 + 4

  = 1004

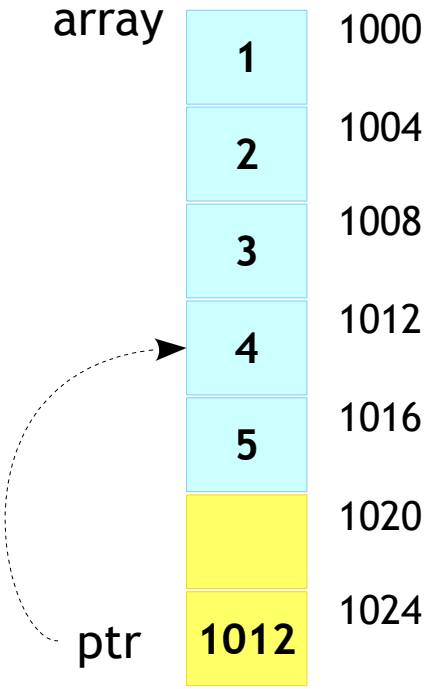


# Advanced C

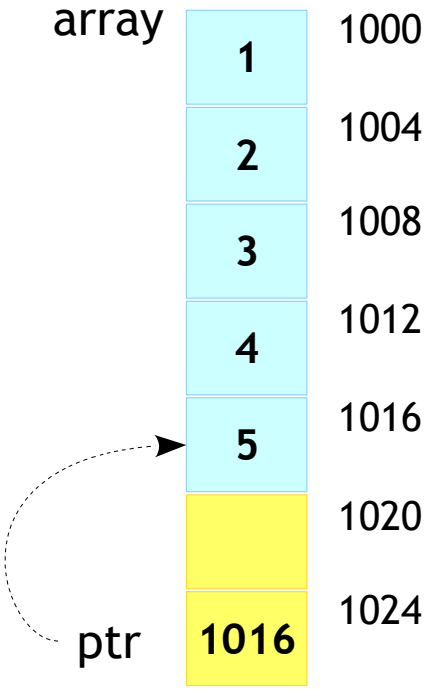
## Pointers - The Rule 5 in detail




ptr = ptr + 2;




ptr = ptr + 3;

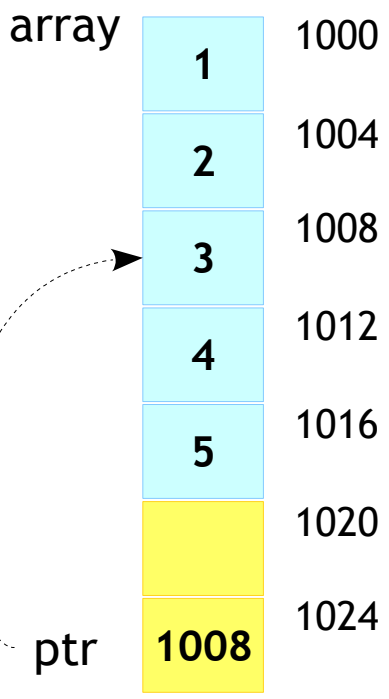



ptr = ptr + 4;

- Why does the compiler does this?. Just for convenience

# Advanced C

## Pointers – The Rule 5 in detail




ptr = ptr + 2;

- Relation with array 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 as 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

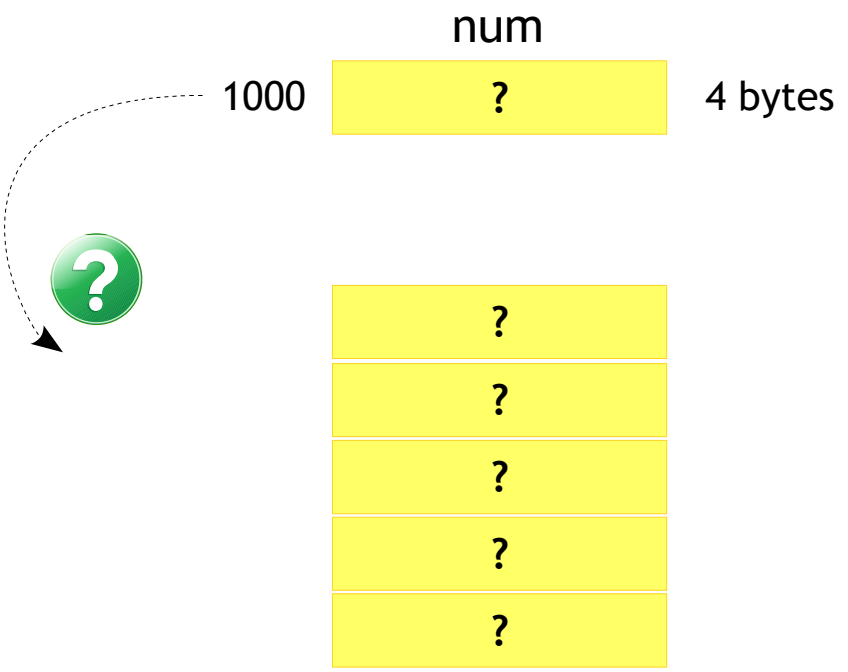
- Rule: “Pointer value of NULL or Zero = Null Addr = Null Pointer = Pointing to Nothing”

# Advanced C

## 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?**

EMERTXE

# 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!!

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# Advanced C

## Pointers – Rule 6 in detail – NULL Pointer

- Now, what is “Pointing 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

- So by convention if a pointer is initialized to zero value, it is logically understood to be “pointing to nothing”.
- And now, in the pointer context, 0 is called as **NULL**
- So a pointer that is assigned NULL is called a Null Pointer which is **Pointing to Nothing**
- So dereferencing a NULL pointer is illegal and will always lead to segment violation, 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, ...and string functions
- 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 slides 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;
}
```

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# Advanced C

## Pointers – Void Pointer

- A pointer with incomplete type
- Void pointer can't be dereferenced. You MUST use type cast operator (type) to dereference.
- Exercise -
  - W.A.P to swap any given data type

# Advanced C

## void Pointers – Size of void

- The void type comprises an empty set of values; it is an incomplete type that cannot be completed
- Hence pointer arithmetic can NOT be performed on void pointer

Note: To make standard compliant, compile using
- gcc -pedantic-errors or -Werror-pointer-arith

# Advanced C

## void Pointers – Size of void – compiler dependency

**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

# 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;
}
```

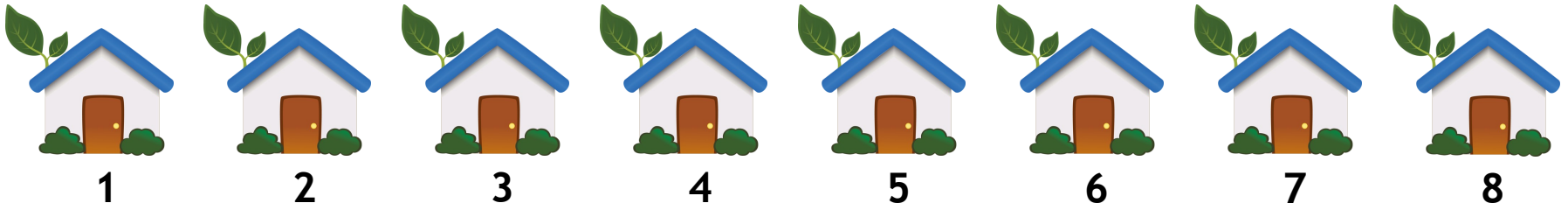
**Example**

```c
#include <stdio.h>

int main()
{
    char *str;

    str = malloc(5);

    return 0;
}
```

# Advanced C

## Pointers – Rule 7 in detail

- Named vs Unnamed Allocation = Named/Unnamed Houses




**Ok, House 1, I should go that side ←**

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

# Advanced C

## Pointers - Rule 7 in detail

- Managed by Compiler vs User
- Compiler
  - The compiler will allocate the required memory
  - Required memory is computed at compile time
  - Memory is allocated in data segment or stack
- User
  - The user has to allocate the memory whenever required and deallocate whenever required
  - This is done by using malloc and free functions
  - Memory is allocated in heap

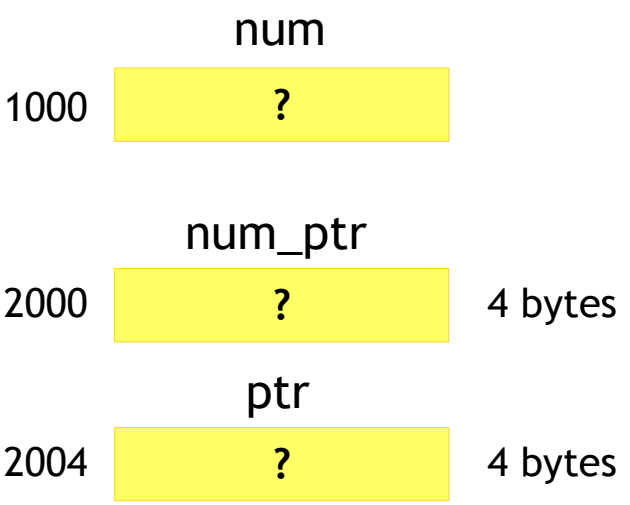
# Advanced C

## 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**

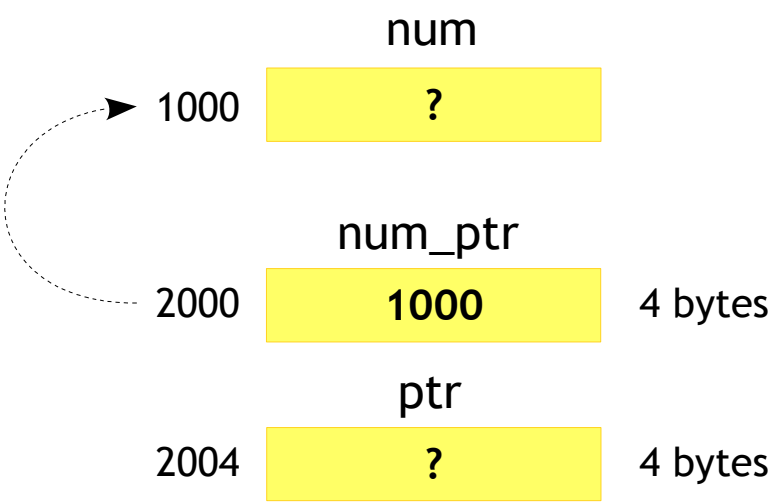
```c
#include <stdio.h>

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

    num_ptr = &num;

    ptr = malloc(4);

    return 0;
}
```

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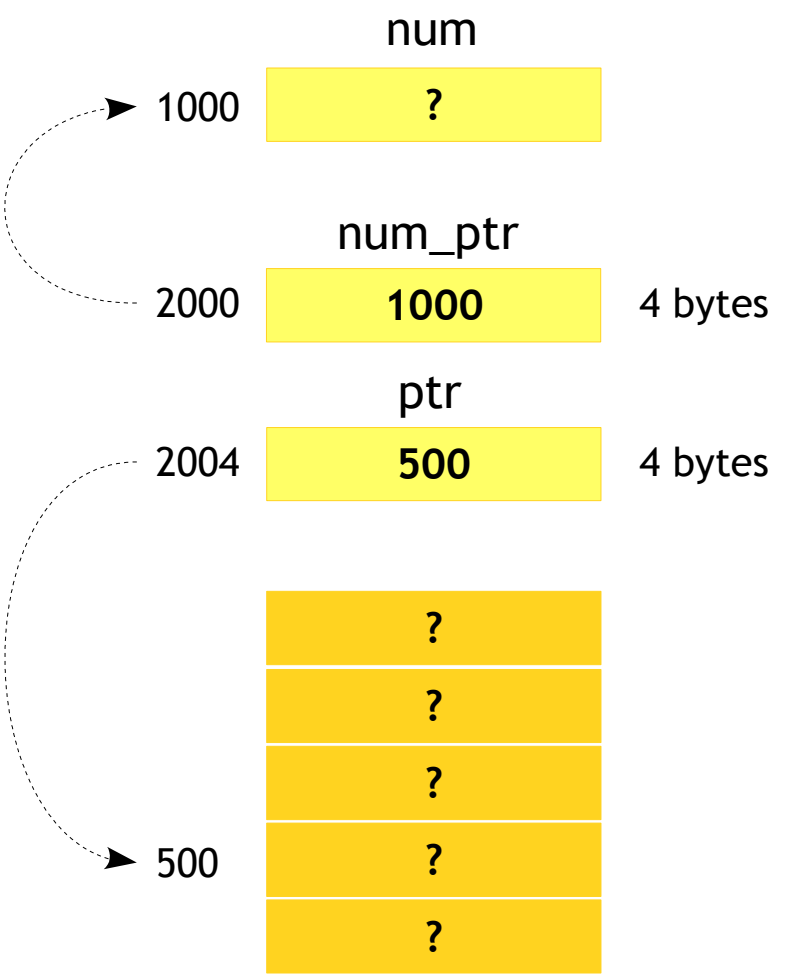
# Advanced C

## Pointers - Rule 7 in detail

- Static vs Dynamic

**Example**

```c
#include <stdio.h>

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

    num_ptr = &num;

    ptr = malloc(4);

    return 0;
}
```




EMERTXE

# 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

# Advanced C

## Pointers - Rule 7 - Dynamic Allocation - malloc

**Prototype**

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

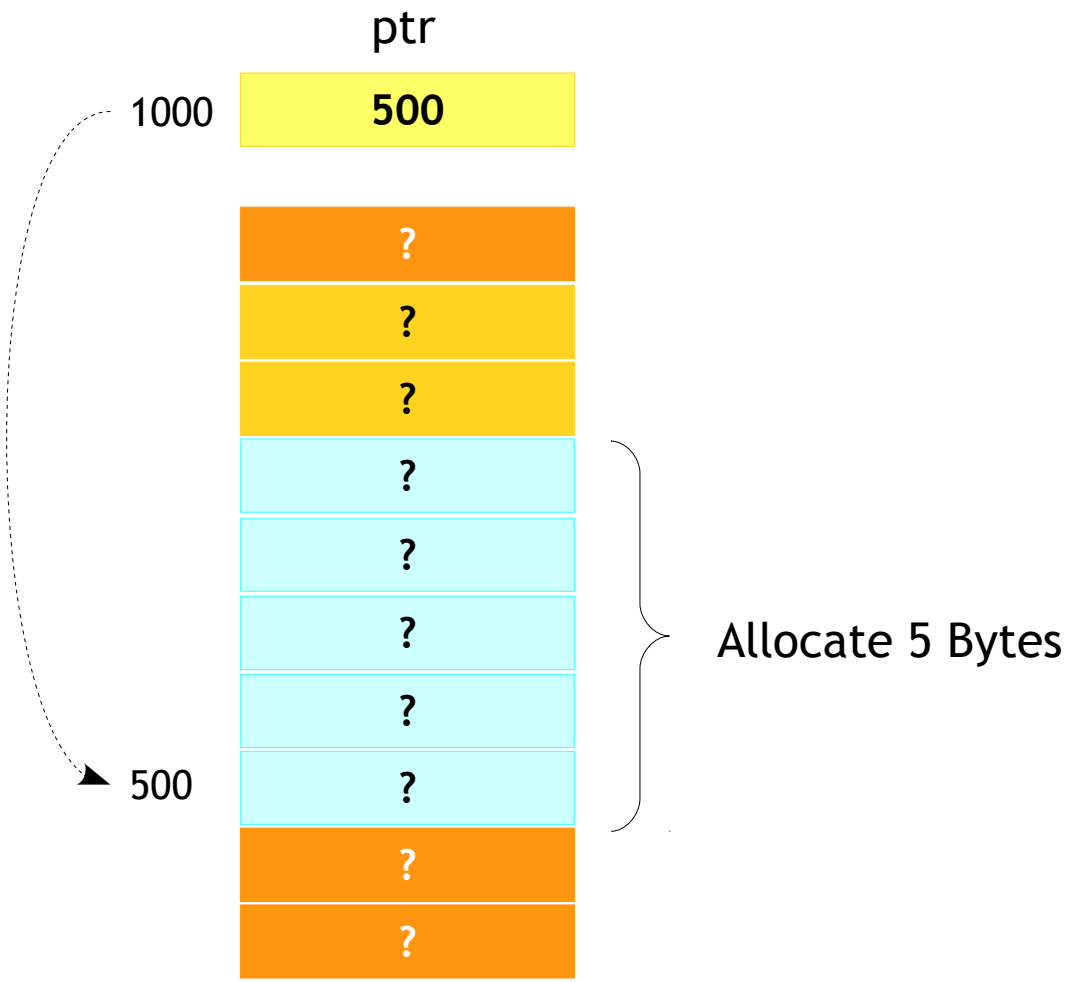
- Allocates the requested size of memory from the heap
- The size is in bytes
- Returns the pointer of the allocated memory on success, else returns NULL pointer

# Advanced C

## Pointers - Rule 7 - Dynamic Allocation - malloc

**Example**

```c
#include <stdio.h>

int main()
{
    char *str;

    str = malloc(5);

    return 0;
}
```



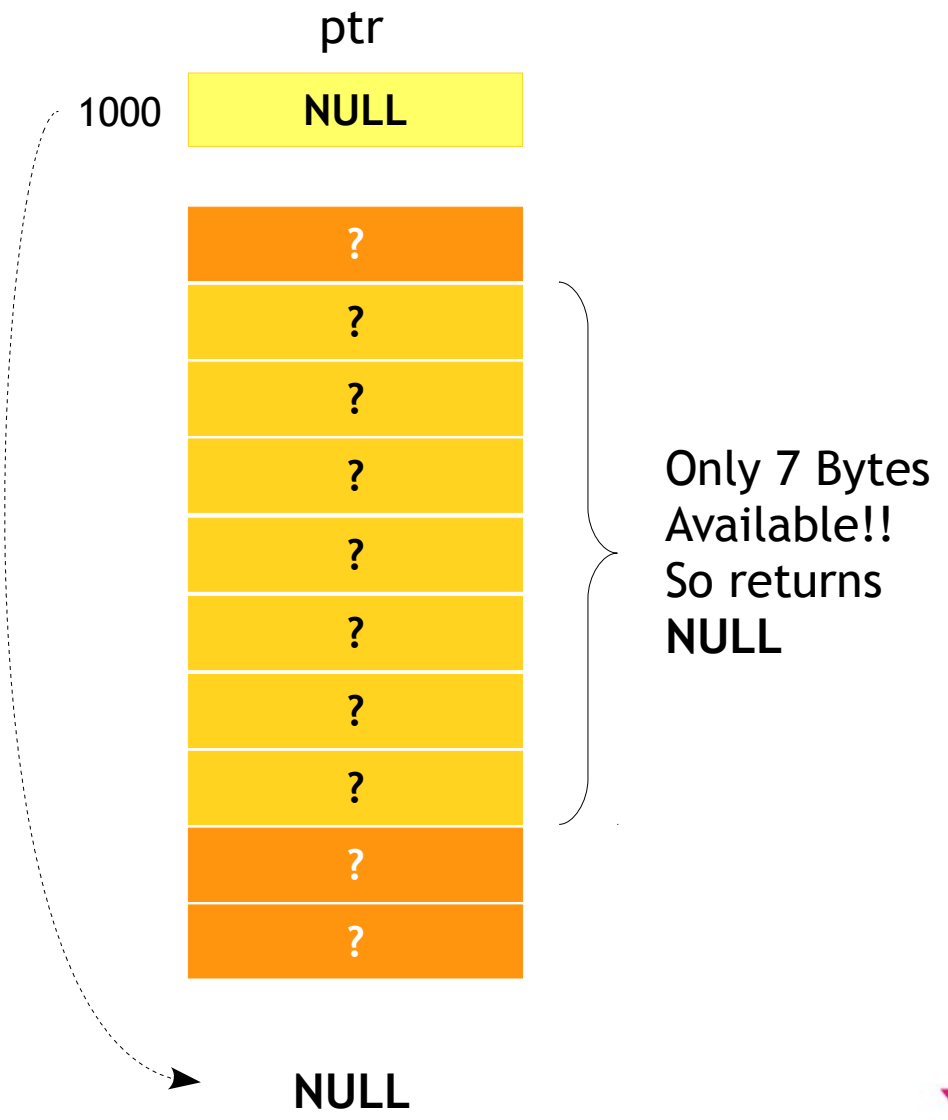

EMERTXE

# Advanced C

## Pointers - Rule 7 - Dynamic Allocation - malloc

**Example**

```c
#include <stdio.h>

int main()
{
    char *str;

    str = malloc(10);

    return 0;
}
```



# Advanced C

## Pointers - Rule 7 - Dynamic Allocation - calloc

**Prototype**

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

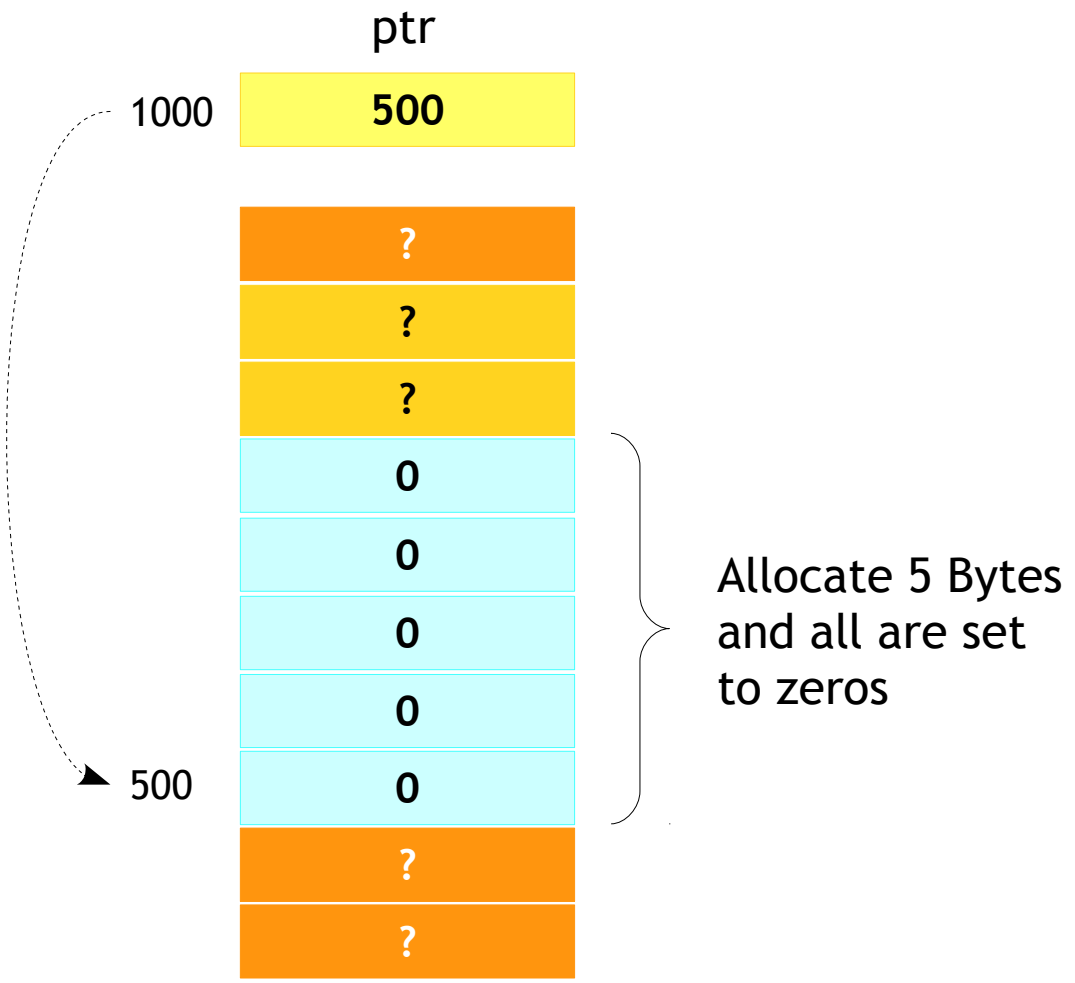
- Allocates memory blocks large enough to hold "n elements" of "size" bytes each, from the heap
- The allocated memory is set with 0's
- Returns the pointer of the allocated memory on success, else returns NULL pointer

# Advanced C

## Pointers - Rule 7 - Dynamic Allocation - calloc

**Example**

```c
#include <stdio.h>

int main()
{
    char *str;

    str = calloc(5, 1);

    return 0;
}
```




EMERTXE

# Advanced C

## Pointers - Rule 7 - Dynamic Allocation - realloc

**Prototype**

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

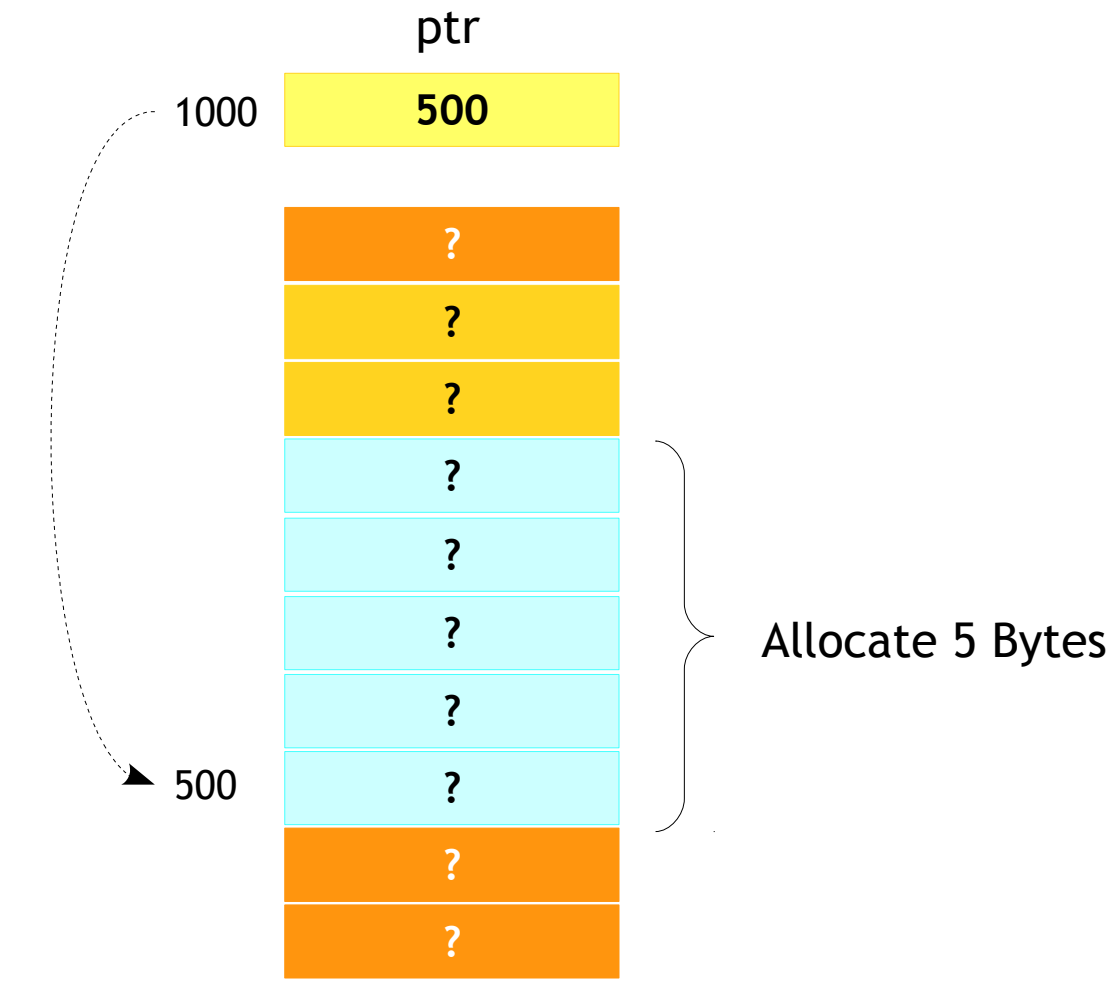
- Changes the size of the already allocated memory by malloc or calloc
- Returns the pointer of the allocated memory on success, else returns NULL pointer

# Advanced C

## Pointers - Rule 7 - Dynamic Allocation - realloc

**Example**

```c
#include <stdio.h>

int main()
{
    char *str;

    str = malloc(5);

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

    return 0;
}
```

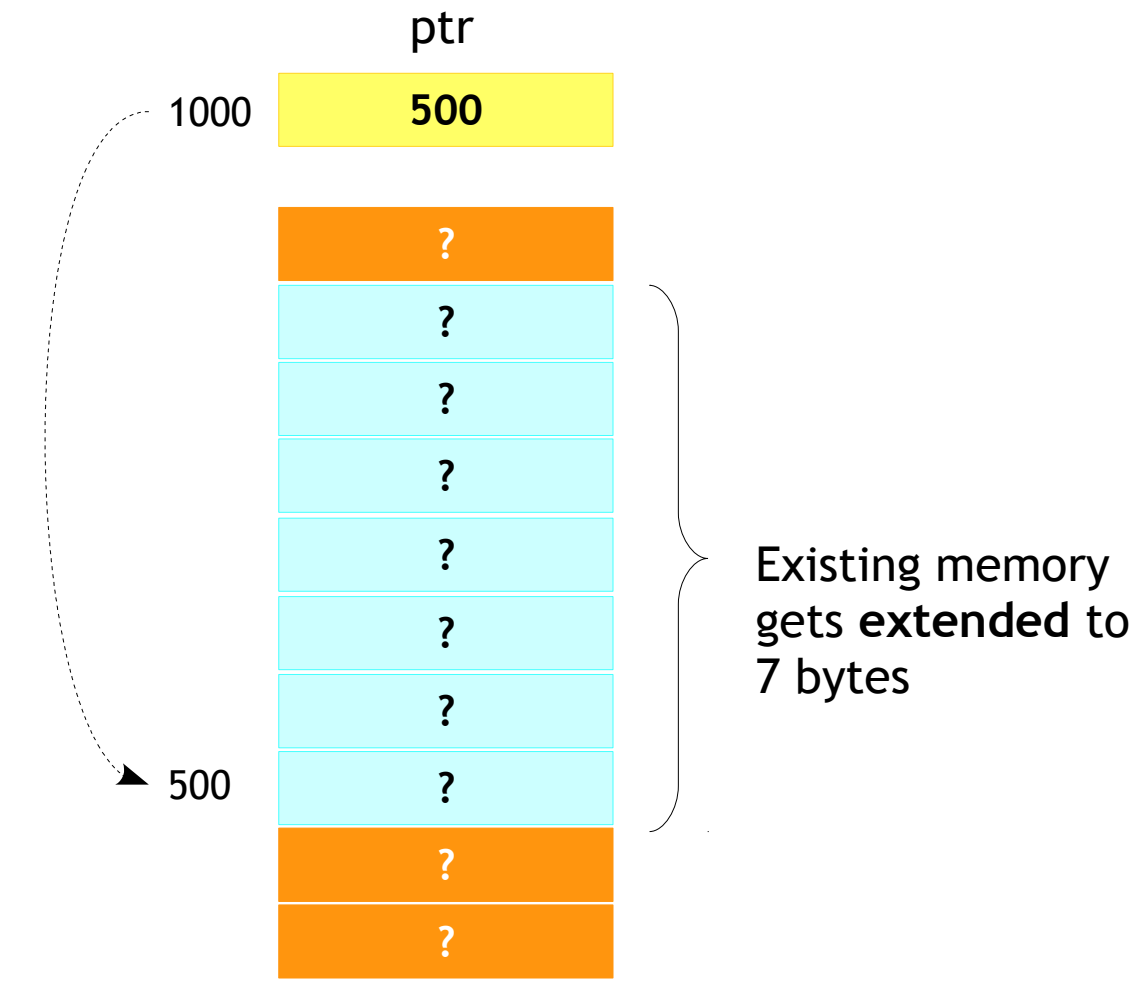


# Advanced C

## Pointers - Rule 7 - Dynamic Allocation - realloc

**Example**

```c
#include <stdio.h>

int main()
{
    char *str;

    str = malloc(5);

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

    return 0;
}
```



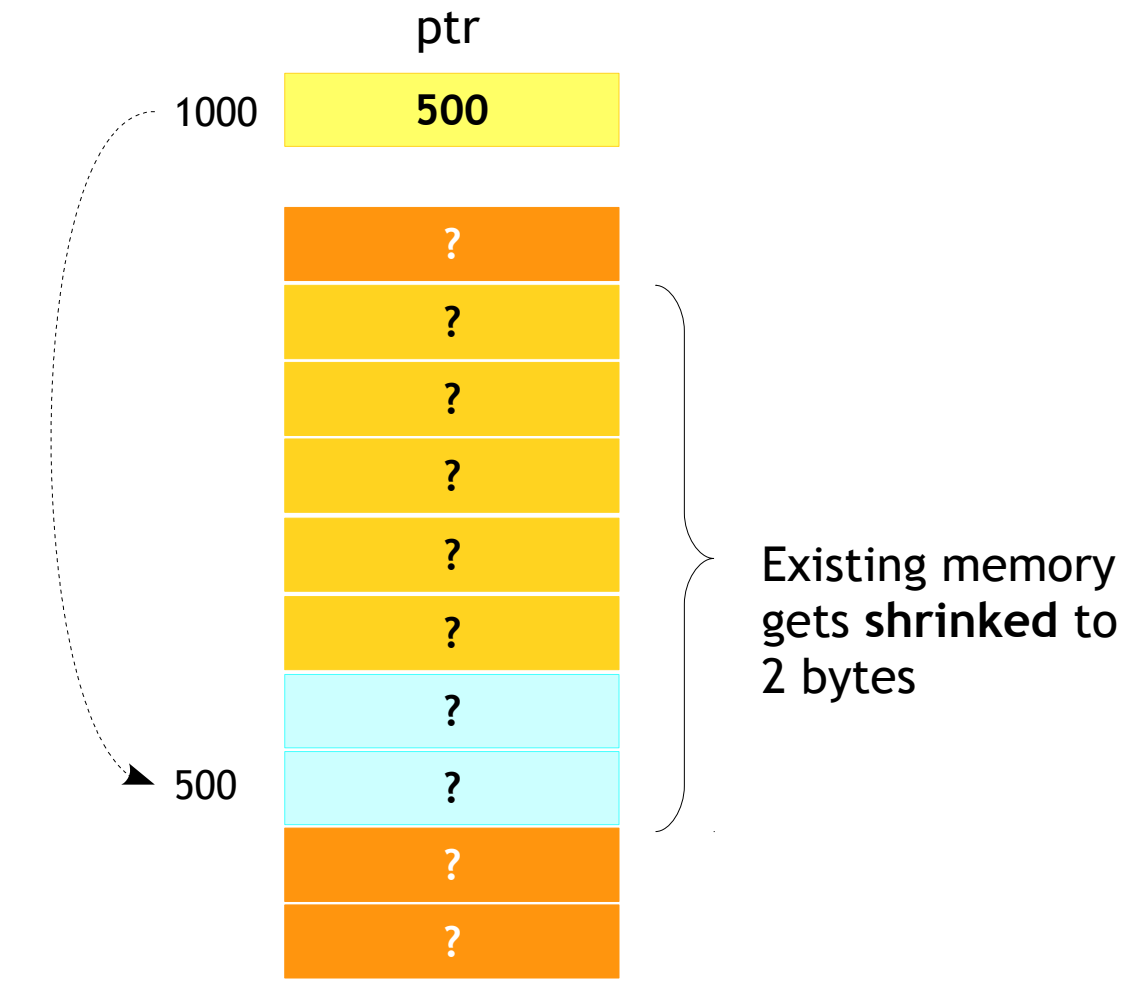

EMERTXE

# Advanced C

## Pointers - Rule 7 - Dynamic Allocation - realloc

**Example**

```c
#include <stdio.h>

int main()
{
    char *str;

    str = malloc(5);

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

    return 0;
}
```



# 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);
```

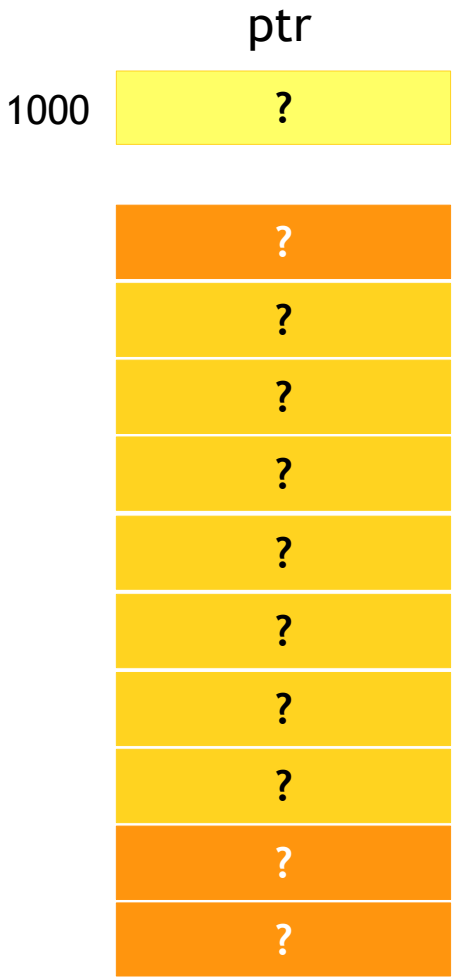
- Frees the allocated memory, which must have been returned by a previous call to malloc(), calloc() or realloc()
- Freeing an already freed block or any other block, would lead to undefined behavior
- Freeing NULL pointer has no abnormal effect.
- If free() is called with invalid argument, might collapse 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**

```c
#include <stdio.h>

int main()
{
    char *ptr;

    ptr = malloc(5);

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

    free(ptr);

    return 0;
}
```

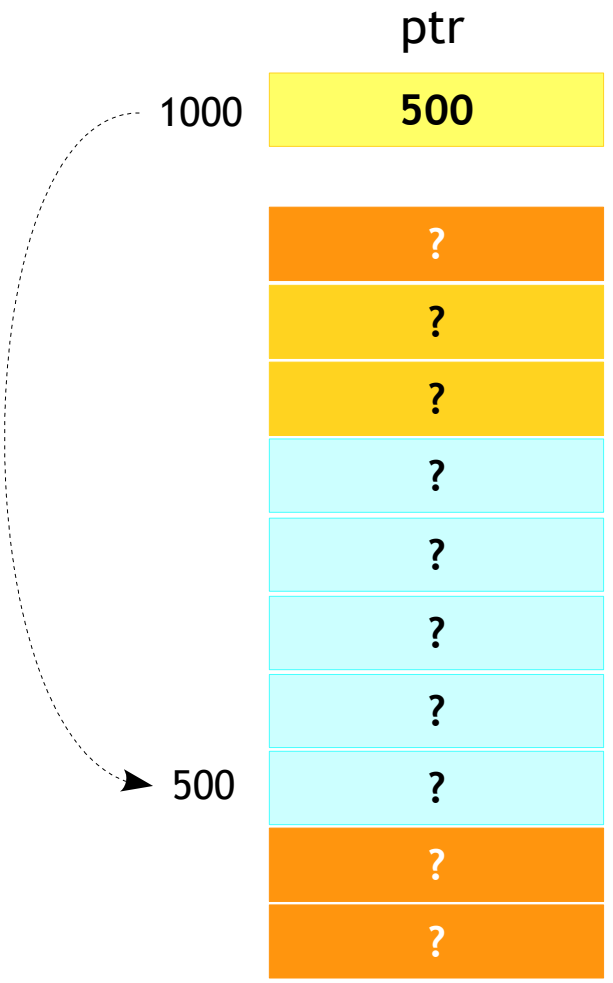


# Advanced C

## Pointers - Rule 7 - Dynamic Deallocation - free

**Example**

```c
#include <stdio.h>

int main()
{
    char *ptr;

    ptr = malloc(5);

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

    free(ptr);

    return 0;
}
```

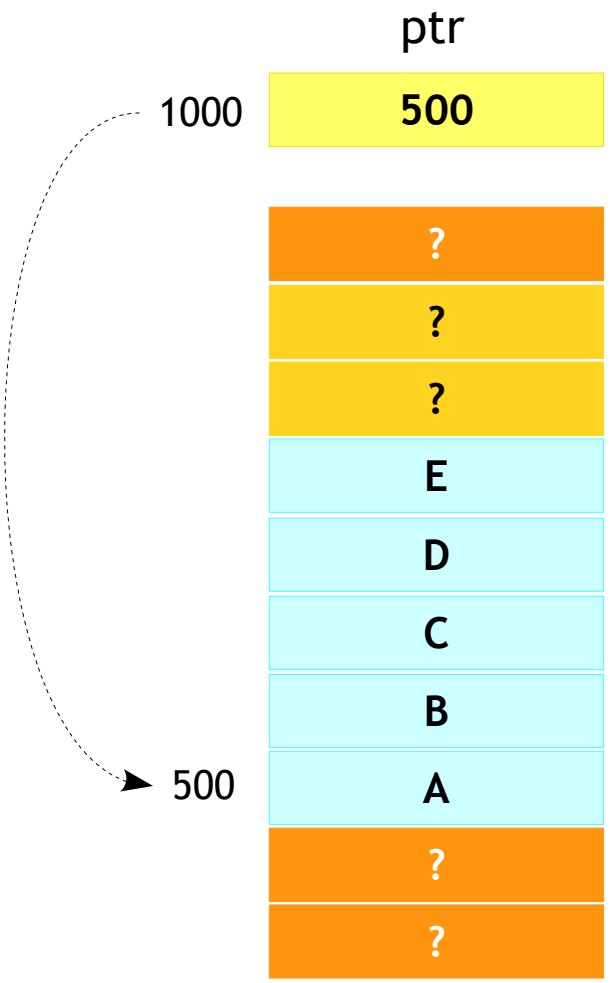


# Advanced C

## Pointers - Rule 7 - Dynamic Deallocation - free

**Example**

```c
#include <stdio.h>

int main()
{
    char *ptr;

    ptr = malloc(5);

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

    free(ptr);

    return 0;
}
```

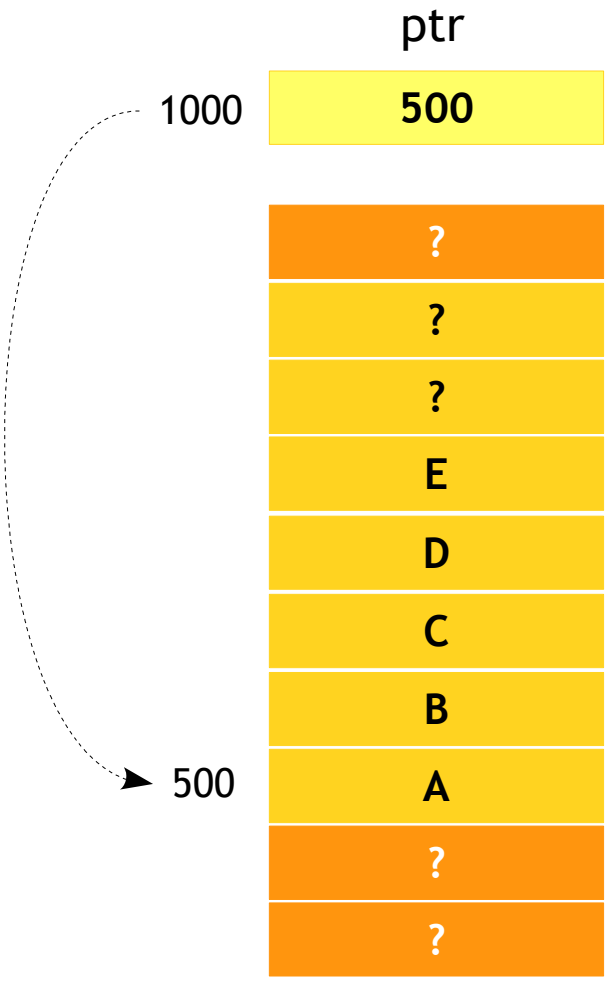


# Advanced C

## Pointers - Rule 7 - Dynamic Deallocation - free

**Example**

```c
#include <stdio.h>

int main()
{
    char *ptr;

    ptr = malloc(5);

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

    free(ptr);

    return 0;
}
```



# Advanced C

## Pointers – Rule 7 – Dynamic Deallocation - free

- 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 behavior
  - 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 – Multilevel

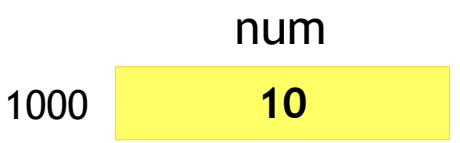
- A pointer, pointing to another pointer which can be pointing to others pointers and so on is know as multilevel pointers.
- We can have any level of pointers.
- As the depth of the level increase we have to bit careful while dealing with it.

# Advanced C

## Pointers - Multilevel

**Example**

```c
#include <stdio.h>

int main()
{
    int num = 10;
    int *ptr1 = &num;
    int **ptr2 = &ptr1;
    int ***ptr3 = &ptr2;

    printf("%d", ptr3);
    printf("%d", *ptr3);
    printf("%d", **ptr3);
    printf("%d", ***ptr3);

    return 0;
}
```

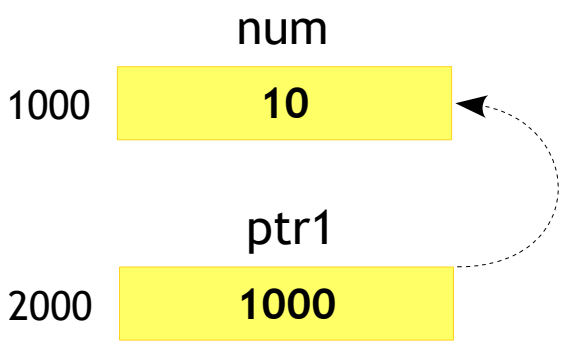


# Advanced C

## Pointers - Multilevel

**Example**

```c
#include <stdio.h>

int main()
{
    int num = 10;
    int *ptr1 = &num;
    int **ptr2 = &ptr1;
    int ***ptr3 = &ptr2;

    printf("%d", ptr3);
    printf("%d", *ptr3);
    printf("%d", **ptr3);
    printf("%d", ***ptr3);

    return 0;
}
```



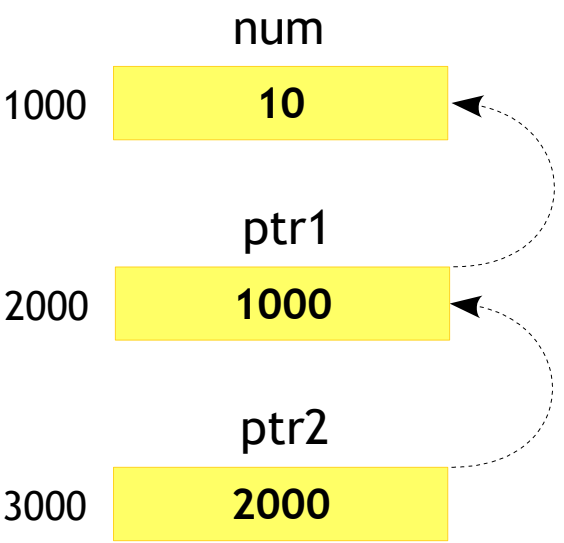

EMERTXE

# Advanced C

## Pointers - Multilevel

**Example**

```c
#include <stdio.h>

int main()
{
    int num = 10;
    int *ptr1 = &num;
    int **ptr2 = &ptr1;
    int ***ptr3 = &ptr2;

    printf("%d", ptr3);
    printf("%d", *ptr3);
    printf("%d", **ptr3);
    printf("%d", ***ptr3);

    return 0;
}
```



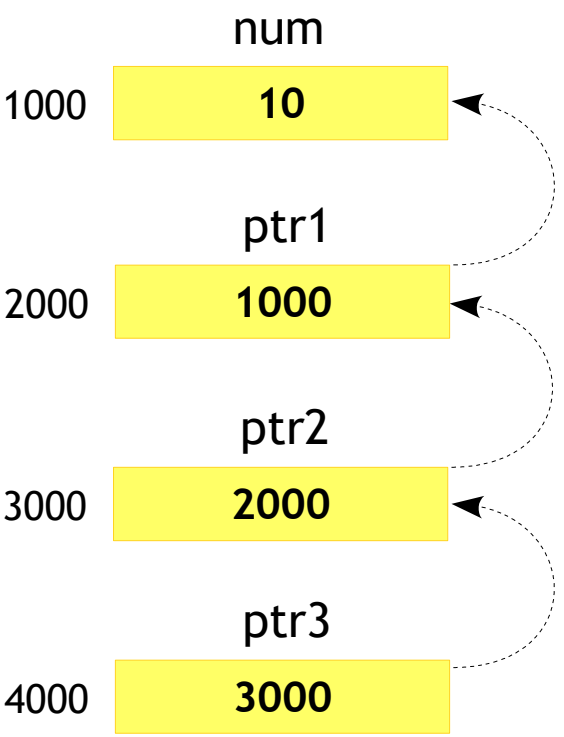

EMERTXE

# Advanced C

## Pointers - Multilevel

**Example**

```c
#include <stdio.h>

int main()
{
    int num = 10;
    int *ptr1 = &num;
    int **ptr2 = &ptr1;
    int ***ptr3 = &ptr2;

    printf("%p", ptr3);
    printf("%p", *ptr3);
    printf("%p", **ptr3);
    printf("%d", ***ptr3);

    return 0;
}
```

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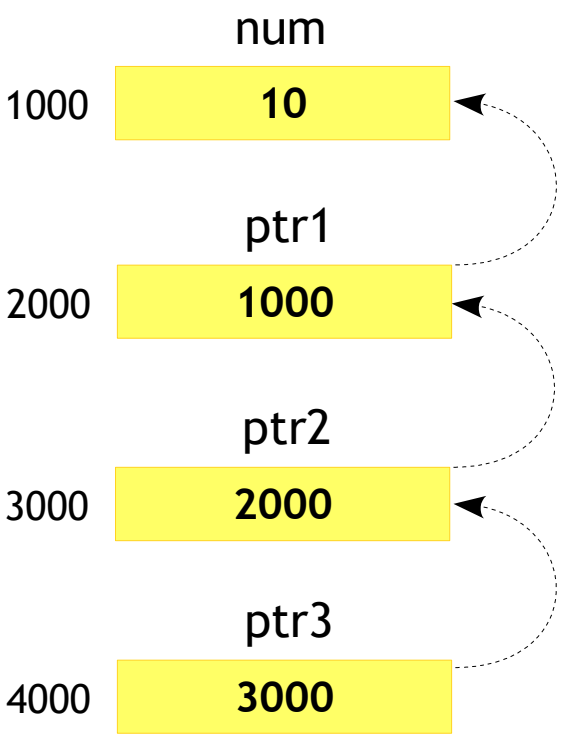
# Advanced C

## Pointers - Multilevel

**Example**

```c
#include <stdio.h>

int main()
{
    int num = 10;
    int *ptr1 = &num;
    int **ptr2 = &ptr1;
    int ***ptr3 = &ptr2;

    printf("%p", ptr3);
    printf("%p", *ptr3);
    printf("%p", **ptr3);
    printf("%d", ***ptr3);

    return 0;
}
```



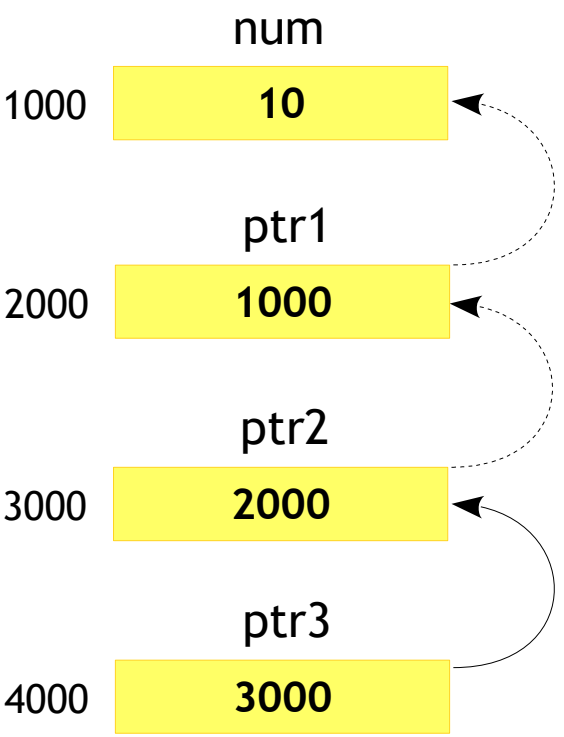

**Output → 3000**

# Advanced C

## Pointers - Multilevel

**Example**

```c
#include <stdio.h>

int main()
{
    int num = 10;
    int *ptr1 = &num;
    int **ptr2 = &ptr1;
    int ***ptr3 = &ptr2;

    printf("%d", ptr3);
    printf("%d", *ptr3);
    printf("%d", **ptr3);
    printf("%d", ***ptr3);

    return 0;
}
```



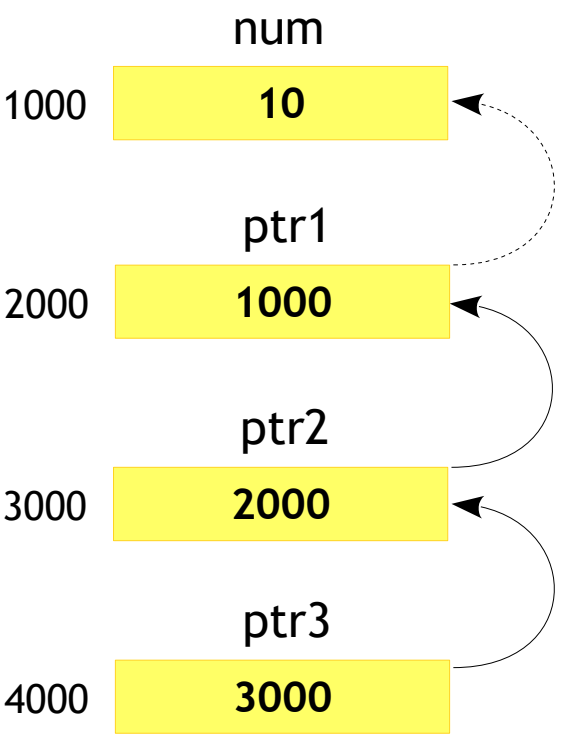

**Output → 2000**

# Advanced C

## Pointers - Multilevel

**Example**

```c
#include <stdio.h>

int main()
{
    int num = 10;
    int *ptr1 = &num;
    int **ptr2 = &ptr1;
    int ***ptr3 = &ptr2;

    printf("%d", ptr3);
    printf("%d", *ptr3);
    printf("%d", **ptr3);
    printf("%d", ***ptr3);

    return 0;
}
```



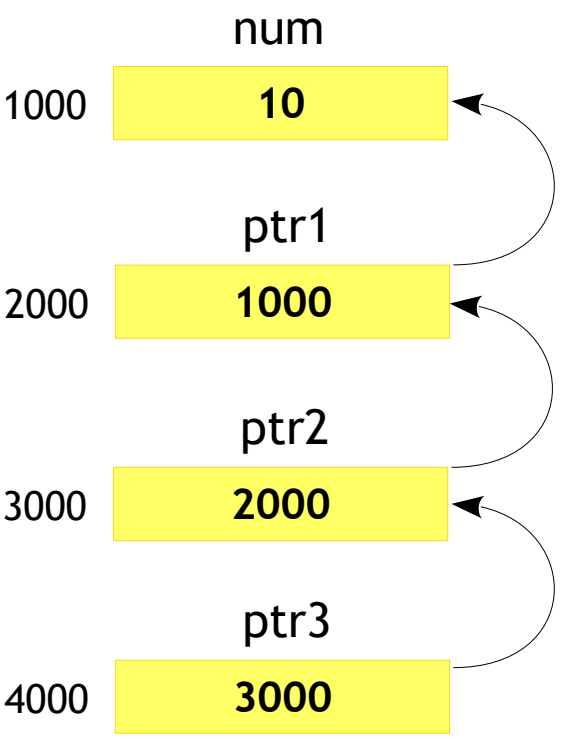

**Output → 1000**

# Advanced C

## Pointers - Multilevel

**Example**

```c
#include <stdio.h>

int main()
{
    int num = 10;
    int *ptr1 = &num;
    int **ptr2 = &ptr1;
    int ***ptr3 = &ptr2;

    printf("%d", ptr3);
    printf("%d", *ptr3);
    printf("%d", **ptr3);
    printf("%d", ***ptr3);

    return 0;
}
```




**Output → 10**

# Advanced C

## Pointers – Constant Pointer

- A read only pointer
- Valid address MUST be assigned while defining constant pointer
- Once address assigned, it can't be changed

# Advanced C

## revising few points - Quiz

int arr[5];

- What is the interpretation of arr?
  - Whole array or Base address
- What is (arr + i) ?
  - Address of ith element
- What is *(arr + i)
  - Content of ith element

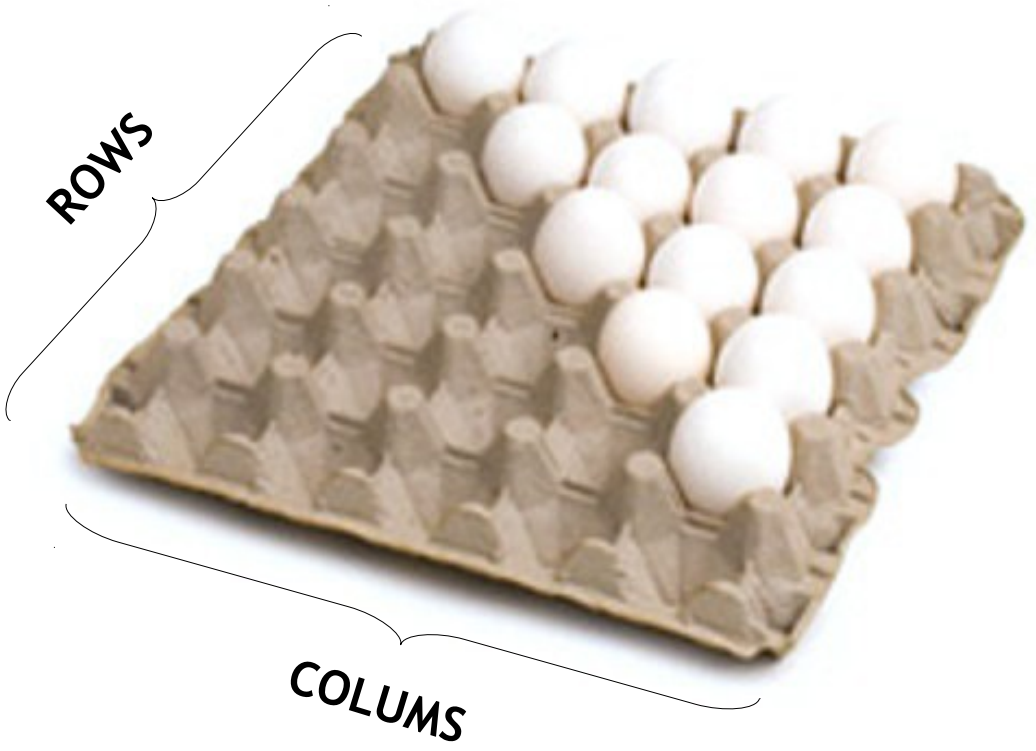
# Advanced C

## revising few points - Quiz

- What is the type of array?
  - Type of array is derived from it's elements
- What *(arr + i) would return?
  - It would depend on dimension of arr.
  - Dereferencing n-dimension array returns n-1 dimension array
  - 1 D array would return primitive data value
- What is *(arr + i) equivalent to?
  - arr[i]

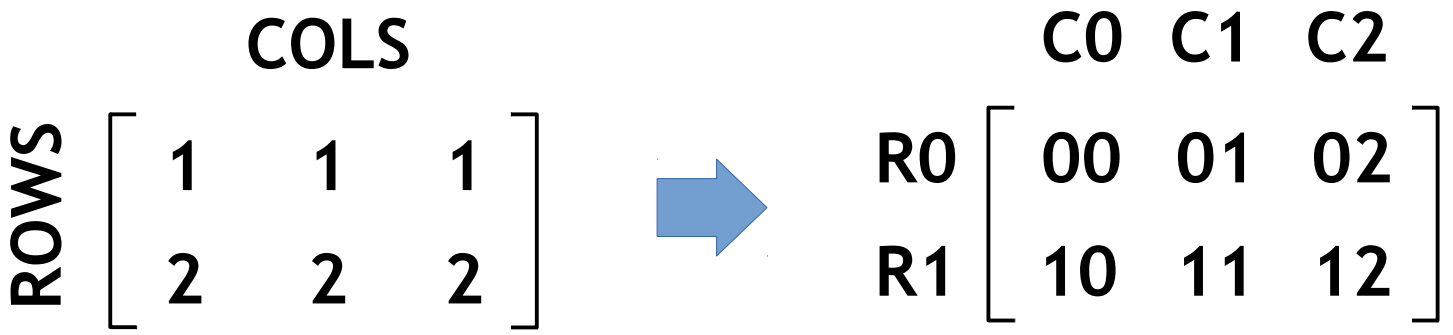
# Advanced C

## Pointers - 2D Array



# Advanced C

## Pointers – 2D Array



# Advanced C

## Pointers - 2D Array

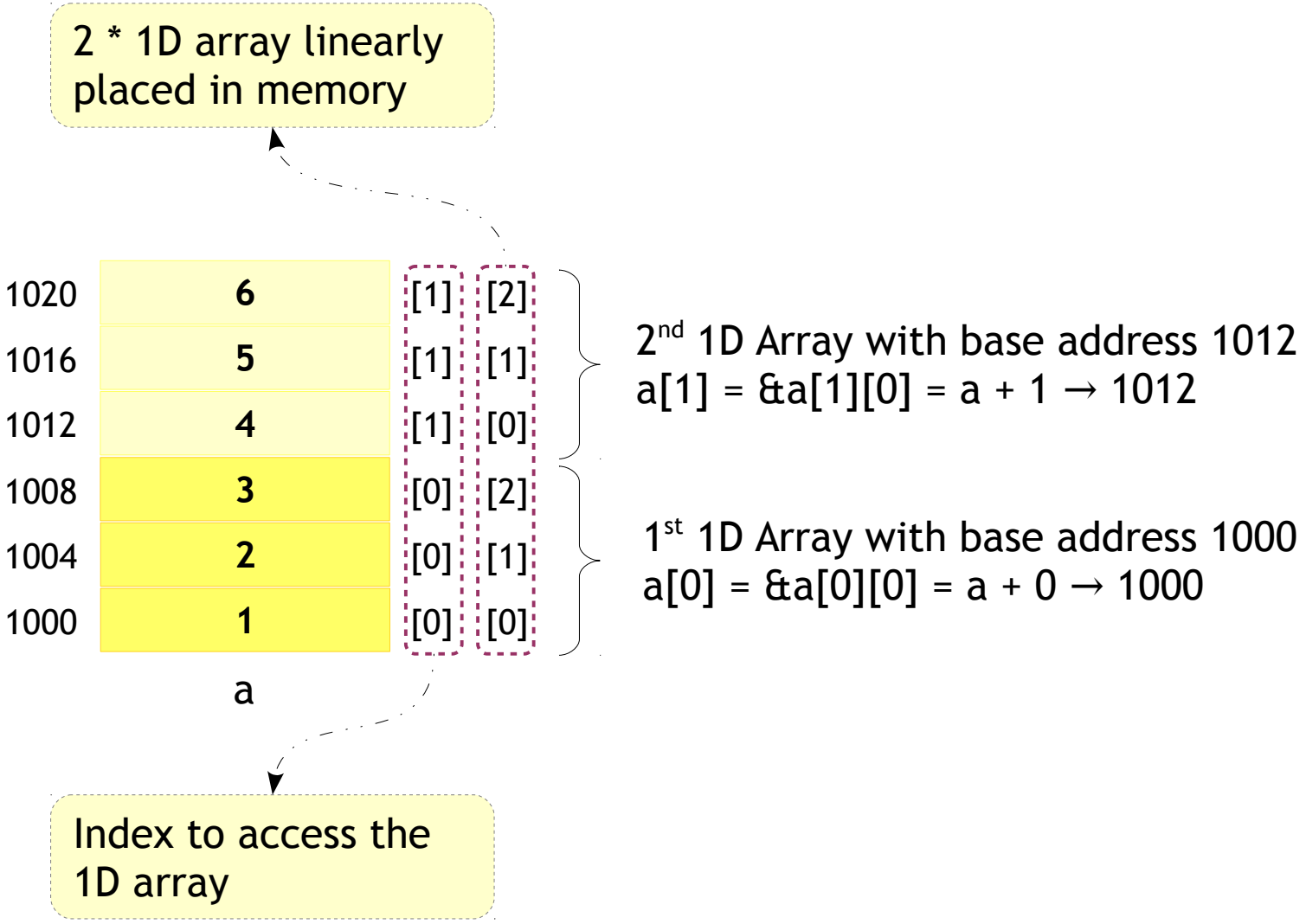
**Example**

```c
#include <stdio.h>

int main()
{
    int a[2][3] = {1, 2, 3, 4, 5, 6};

    return 0;
}
```

```
Total Memory: ROWS * COLS * sizeof(datatype) Bytes
```

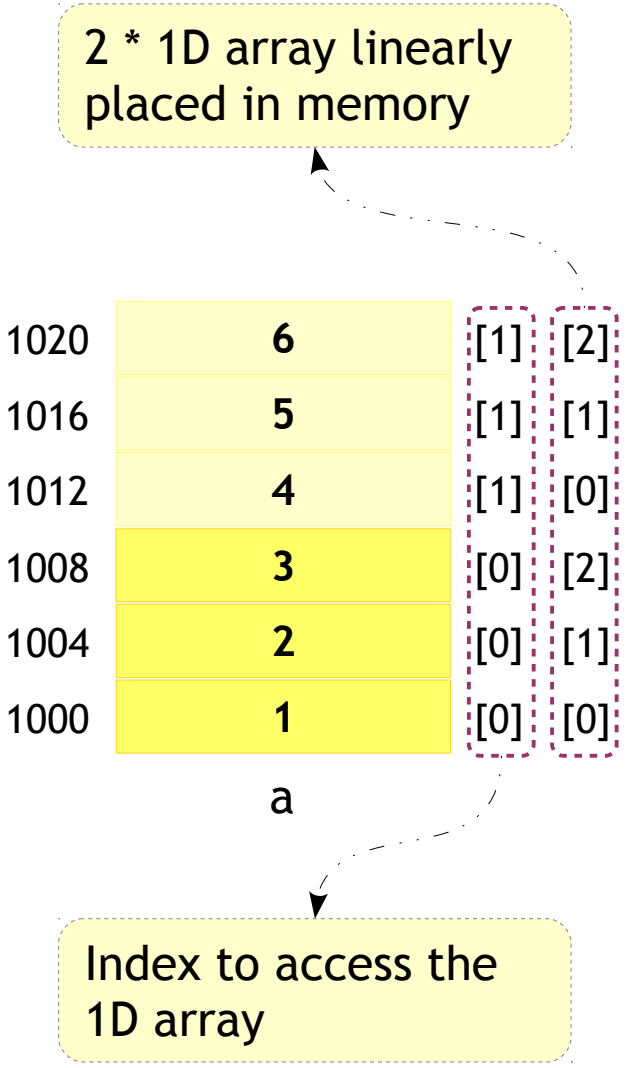
# Advanced C

## Pointers – 2D Array - Referencing



# Advanced C

## Pointers – 2D Array - Dereferencing




**Example 1:** Say **a[0][1]** is to be accessed, then decomposition happens like,

**a[0][1]** = *(a[0] + 1 * sizeof(type))
= *(*(a + 0 * sizeof(1D array)) + 1 * sizeof(type))
= *(*(1000 + 0 * 12) + 1 * 4)
= *(*(1000 + 0) + 4)
= *(*(1004))
= 2

**Example 2:** Say **a[1][2]** is to be accessed, then decomposition happens like,

**a[1][2]** = *(a[1] + 2 * sizeof(type))
= *(*(a + 1 * sizeof(1D array)) + 2 * sizeof(type))
= *(*(1000 + 1 * 12) + 2 * 4)
= *(*(1000 + 12) + 8)
= *(*(1020))
= 6

# Advanced C

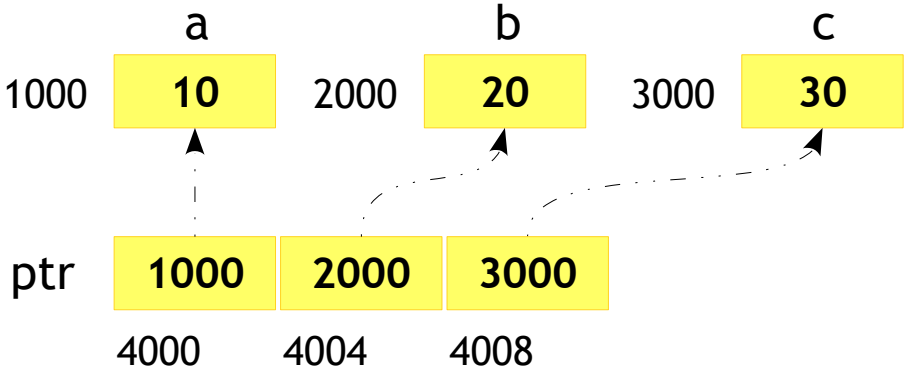
## Pointers - Array of pointers

### Syntax

```
datatype *ptr_name[SIZE]
```

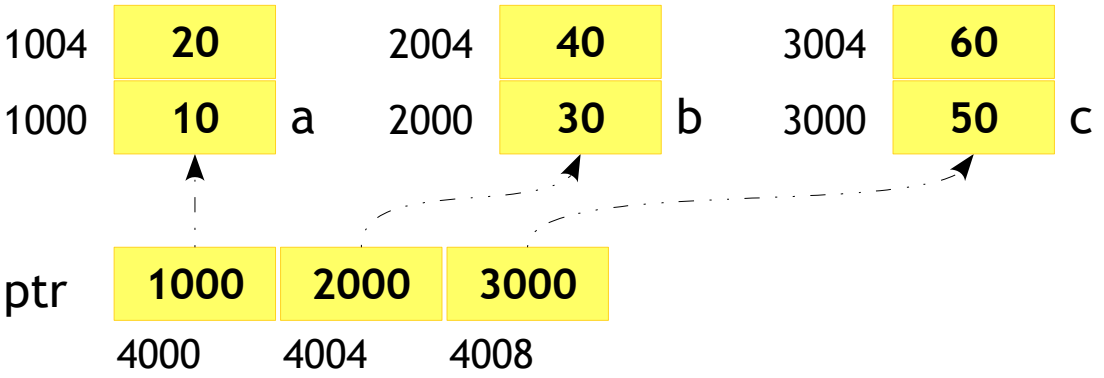
### Example

```
int a = 10;
int b = 20;
int c = 30;

int *ptr[3] = {&a, &b, &c};
```




### Example

```
int a[2] = {10, 20};
int b[2] = {30, 40};
int c[2] = {50, 60};

int *ptr[3] = {a, b, c};
```

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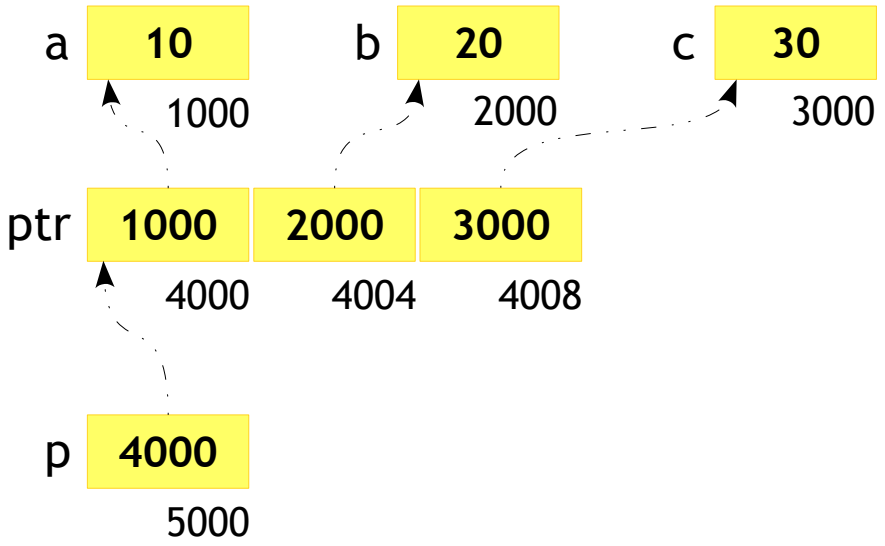
# Advanced C

## Pointers - Array of pointers

**Example**

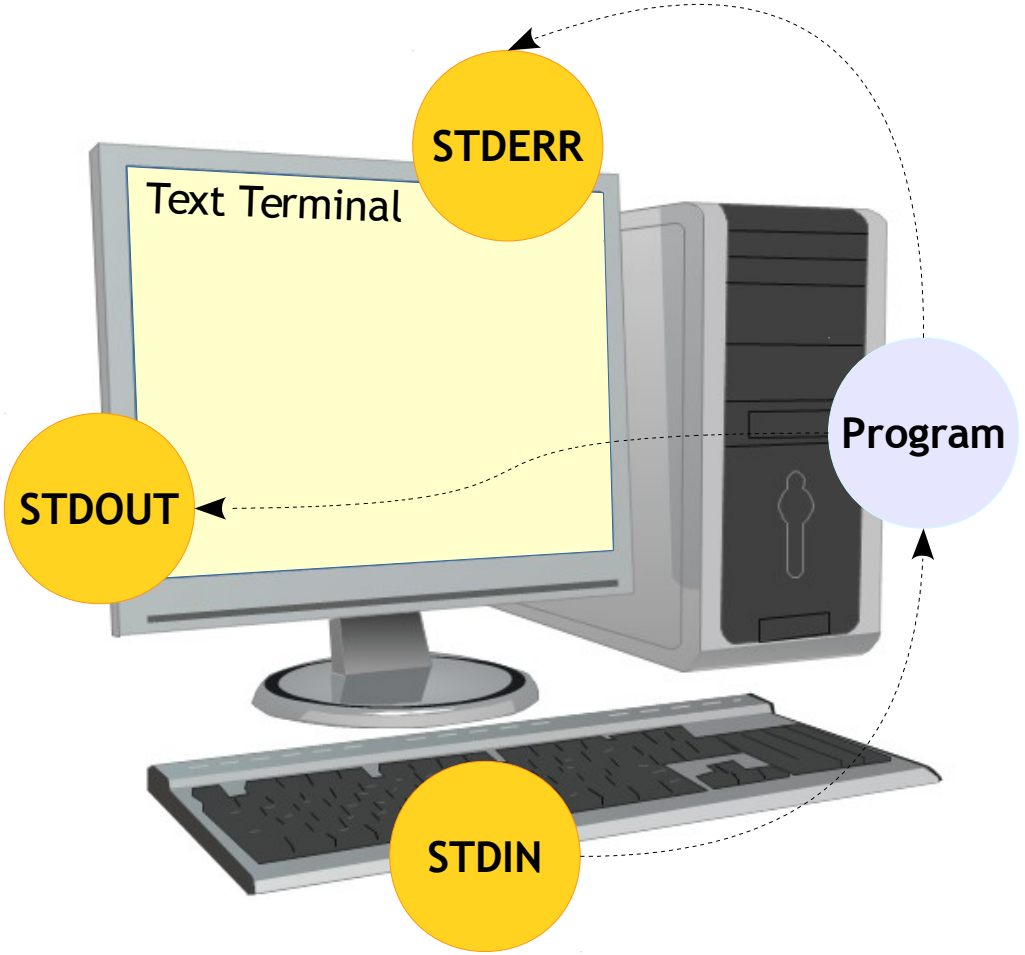
```c
#include <stdio.h>

void print_array(int **p)
{
     int i;

     for (i = 0; i < 3; i++)
     {
          printf("%d ", *p[i]);
          printf("at %p\n", p[i]);
     }
}

int main()
{
     int a = 10;
     int b = 20;
     int c = 30;
     int *ptr[3] = {&a, &b, &c};

     print_array(ptr);

     return 0;
}
```



# Chapter 4
## Standard Input / Output

# Advanced C

## Standard I/O

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# Advanced C

## Standard I/O - The File Descriptors

- OS uses 3 file descriptors to provide standard input output functionalities
  - 0 → stdin
  - 1 → stdout
  - 2 → stderr
- These are sometimes referred as “The Standard Streams”
- The IO access example could be
  - stdin → Keyboard, pipes
  - stdout → Console, Files, Pipes
  - stderr → Console, Files, Pipes

# Advanced C

## Standard I/O – The File Descriptors

- Wait!!, did we see something wrong in previous slide? Both stdout and stderr are similar ?
- If yes why should we have 2 different streams?
- The answer is convenience and urgency.
  - Convenience : the stderr could be used while doing diagnostics. Example - we can separate error messages from low priority informatory messages
  - Urgency : serious error messages shall be displayed on the screen immediately
- So how the C language help us in the standard IO?.

# Advanced C

## Standard I/O – The header file

- You need to refer input/output library function

  ```
  #include <stdio.h>
  ```

- When the reference is made with "<*name*>" the search for the files happen in standard path

# Advanced C

## Standard I/O – Unformatted (Basic)

- Internal binary representation of the data directly between memory and the file
- Basic form of I/O, simple, efficient and compact
- Unformatted I/O is not directly human readable, so you cannot type it out on a terminal screen or edit it with a text editor
- getchar() and putchar() are two functions part of standard C library
- Some functions like getch(), getche(), putch() are defined in conio.h, which is not a standard C library header and is not supported by the compilers targeting Linux / Unix systems

# Advanced C

## Standard I/O - Unformatted (Basic)

**Example**

```
#include <stdio.h>
#include <ctype.h>

int main()
{
    int ch;

    for ( ; (ch = getchar()) != EOF; )
    {
        putchar(toupper(ch));
    }

    puts("EOF Received");

    return 0;
}
```

# Advanced C

## Standard I/O - Formatted

- Data is formatted or transformed
- Converts the internal binary representation of the data to ASCII before being stored, manipulated or output
- Portable and human readable, but expensive because of the conversions to be done in between input and output
- The printf() and scanf() functions are examples of formatted output and input

# Advanced C

## Standard I/O - printf()

**Example**

```
#include <stdio.h>

int main()
{
    char *a = "Emertxe";

    printf(a);

    return 0;
}
```

- What will be the output of the code on left side?
- Is that syntactically OK?
- Lets understand the printf() prototype
- Please type

  man printf

  on your terminal

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# Advanced C

## Standard I/O - printf()

**Prototype**

```
int printf(char *format, arg1, arg2, ...);
or
int printf("format string", [variables]);

where format string arguments can be
%[flags][width][.precision][length]specifier

%format_specifier is mandatory and others are optional
```

- Converts, formats, and prints its arguments on the standard output under control of the format
- Returns the number of characters printed

# Advanced C

## Standard I/O - printf()

**Prototype**

```
int printf(char *format, arg1, arg2, ...);
```

What is this!?

# Advanced C

## Standard I/O - printf()

**Prototype**

```
int printf(char *format, arg1, arg2, ...);
```

What is this!?

- Is called as ellipses
- Means, can pass any number of arguments of any type

  i.e 0 or more
- So how to complete the below example?

What should be wrriten here and how many?

**Example**

```
int printf("%c %d %f",  );
```

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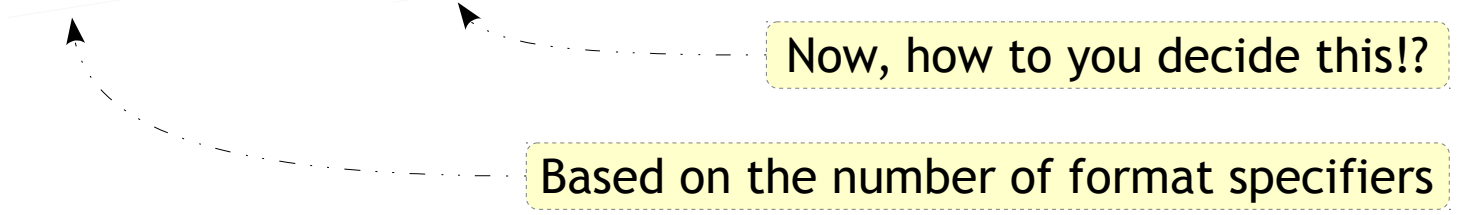
# Advanced C

## Standard I/O - printf()

**Example**

```
int printf("%c %d %f", arg1, arg2, arg3);
```




- So the number of arguments passed to the printf function should exactly match the number of format specifiers
- So lets go back the code again

# Advanced C

## Standard I/O - printf()

**Example**

```
#include <stdio.h>

int main()
{
    char *a = "Emertxe";

    printf(a);

    return 0;
}
```

Isn't this a string?

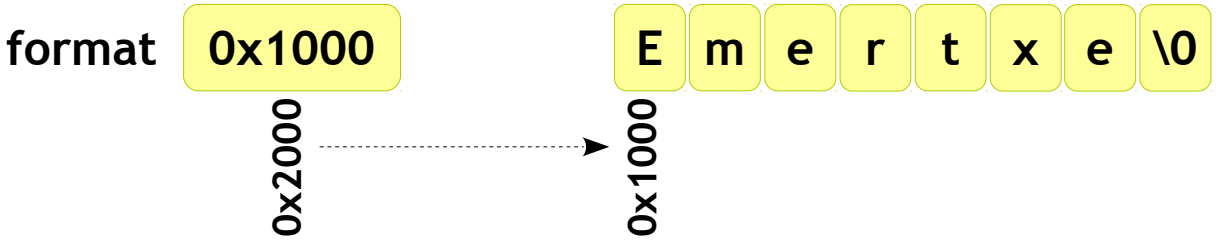
And strings are nothing but array of characters terminated by **null**

So what get passed, while passing a array to function?

```
int printf(char *format, arg1, arg2, ...);
```

Isn't this a pointer?

So a pointer hold a address, can be drawn as




So the base address of the array gets passed to the pointer, Hence the output

**Note: You will get a warning while compiling the above code. So this method of passing is not recommended**

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# Advanced C

## Standard I/O – printf() - Type Specifiers

| Specifiers | Example | Expected Output |
|---|---|---|
| %c | **printf("%c", 'A')** | A |
| %d %i | **printf("%d %i", 10, 10)** | 10 10 |
| %o | **printf("%o", 8)** | 10 |
| %x %X | **printf("%x %X %x", 0xA, 0xA, 10)** | a A a |
| %u | **printf("%u", 255)** | 255 |
| %f %F | **printf("%f %F", 2.0, 2.0)** | 2.000000 2.000000 |
| %e %E | **printf("%e %E", 1.2, 1.2)** | 1.200000e+00 1.200000E+00 |
| %a %A | **printf("%a", 123.4)**<br>**printf("%A", 123.4)** | 0x1.ed9999999ap+6<br>0X1.ED9999999AP+6 |
| %g %G | **printf("%g %G", 1.21, 1.0)** | 1.21 1 |
| %s | **printf("%s", "Hello")** | Hello |

# Advanced C

## Standard I/O – printf() - Type Length Specifiers

| Length specifier | Example | Expected Output |
|---|---|---|
| %[h]X | **printf("%hX", 0xFFFFFFFF)** | FFFF |
| **%[l]**X | **printf("%lX", 0xFFFFFFFFl)** | FFFFFFFF |
| **%[ll]**X | **printf("%llX", 0xFFFFFFFFFFFFFFFF)** | FFFFFFFFFFFFFFFF |
| **%[L]**f | **printf("%Lf",1.23456789L)** | 1.234568 |

# Advanced C

## Standard I/O – printf() - Width

| Width | Example | Expected Output |
|---|---|---|
| %**[x]**d | **printf("%3d %3d", 1, 1)**<br>**printf("%3d %3d", 10, 10)**<br>**printf("%3d %3d", 100, 100)** | 1 1<br>10 10<br>100 100 |
| %**[x]**s | **printf("%10s", "Hello")**<br>**printf("%20s", "Hello")** | Hello<br>Hello |
| %*[specifier] | **printf("%*d", 1, 1)**<br>**printf("%*d", 2, 1)**<br>**printf("%*d", 3, 1)** | 1<br>1<br>1 |

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# Advanced C

## Standard I/O – printf() - Precision

| Precision | Example | Expected Output |
|---|---|---|
| %**[x].[x]**d | **printf("%3.1d", 1)**<br>**printf("%3.2d", 1)**<br>**printf("%3.3d", 1)** | 1<br>01<br>001 |
| %0.**[x]**f | **printf("%0.3f", 1)**<br>**printf("%0.10f", 1)** | 1.000<br>1.0000000000 |
| %**[x].[x]**s | **Printf("%12.8", "Hello World")** | Hello Wo |

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# Advanced C

## Standard I/O – printf() - Flags

| Flag | Example | Expected Output |
|---|---|---|
| %[#]x | **printf("%#x %#X %#x", 0xA, 0xA, 10)**<br>**printf("%#o", 8)** | 0xa 0XA 0xa<br>010 |
| %[-x]d | **printf("%-3d %-3d", 1, 1)**<br>**printf("%-3d %-3d", 10, 10)**<br>**printf("%-3d %-3d", 100, 100)** | 1 1<br>10 10<br>100 100 |
| %[ ]3d | **printf("% 3d", 100)**<br>**printf("% 3d", -100)** | 100<br>-100 |

# Advanced C

## Standard I/O – printf() - Escape Sequence

| Escape Sequence | Meaning | Example | Expected Output |
|---|---|---|---|
| **\n** | New Line | **printf(**“Hello World**\n”)** | Hello World (With a new line) |
| **\r** | Carriage Return | **printf(**“Hello**\r**World”**)** | World |
| **\t** | Tab | **printf(**“Hello**\t**World”**)** | Hello World |
| **\b** | Backspace | **printf(**“Hello**\b**World”**)** | HellWorld |
| **\v** | Vertical Tab | **printf(**“Hello**\v**World”**)** | Hello<br>World |
| **\f** | Form Feed | **printf(**“Hello World**\f**”**)** | Might get few extra new line(s) |
| **\e** | Escape | **printf(**“Hello**\e**World”**)** | Helloorld |
| **** | | **printf**(“A\\B\\C”) | A\B\C |
| **\”** | | **printf(**“\“Hello World\””**)** | “Hello World” |

# Advanced C

## Standard I/O - printf()

- So in the previous slides we saw some 80% of printf's format string usage.

  What?? Ooh man!!. Now how to print **80%**??

# Advanced C

## Standard I/O - printf() - Example

**Example**

```
#include <stdio.h>

int main()
{
    int num1 = 123;
    char ch = 'A';
    float num2 = 12.345;
    char string[] = "Hello World";

    printf("%d %c %f %s\n",num1 , ch, num2, string);
    printf("%+05d\n", num1);
    printf("%.2f %.5s\n", num2, string);

    return 0;
}
```

# Advanced C

## Standard I/O - printf() - Return

**Example**

```
#include <stdio.h>

int main()
{
    int ret;
    char string[] = "Hello World";

    ret = printf("%s", string);

    printf("The previous printf() printed %d chars\n", ret);

    return 0;
}
```

# Advanced C

## Standard I/O - sprintf() - Printing to string

**Prototype**

```
int sprintf(char *string, char *format, arg1, arg2, ...);
```

- Similar to printf() but prints to the buffer instead of stdout
- Formats the arguments in arg1, arg2, etc., according to format specifier
- buffer must be big enough to receive the result

# Advanced C

## Standard I/O - sprintf() - Example

**Example**

```
#include <stdio.h>

int main()
{
    int num1 = 123;
    char ch = 'A';
    float num2 = 12.345;
    char string1[] = "sprintf() Test";
    char string2[100];

    sprintf(string2, "%d %c %f %s\n",num1 , ch, num2, string1);
    printf("%s", string2);

    return 0;
}
```

# Advanced C

## Standard I/O - Formatted Input - scanf()

**Prototype**

```
int scanf(char *format, ...);
or
int scanf("string", [variables]);
```

- Reads characters from the standard input, interprets them according to the format specifier, and stores the results through the remaining arguments.
- All most all the format specifiers are similar to printf() except changes in few
- Each of the other argument must be a **pointer**

# Advanced C

## Standard I/O – Formatted Input - scanf()

- It returns as its value the number of successfully matched and assigned input items.
- On the end of file, EOF is returned. Note that this is different from 0, which means that the next input character does not match the first specification in the format string.
- The next call to scanf() resumes searching immediately after the last character already converted.

# Advanced C

## Standard I/O - scanf() - Example

**Example**

```
#include <stdio.h>

int main()
{
    int num1;
    char ch;
    float num2;
    char string[10];

    scanf("%d %c %f %s", &num1 , &ch, &num2, string);
    printf("%d %c %f %s\n", num1 , ch, num2, string);

    return 0;
}
```

# Advanced C

## Standard I/O – scanf() - Format Specifier

| Flag | Examples | Expected Output |
|---|---|---|
| %*[specifier] | **scanf("%d%*c%d%*c%d", &h, &m, &s)** | User Input → HH:MM:SS<br>Scanned Input → HHMMSS<br><br>User Input → 5+4+3<br>Scanned Input → 543 |
| %[] | **scanf("%[a-z A-Z]", name)** | User Input → Emertxe<br>Scanned Input → Emertxe<br><br>User Input → Emx123<br>Scanned Input → Emx |
| | **scanf("%[0-9]", &id)** | User Input → 123<br>Scanned Input → 123<br><br>User Input → 123XYZ<br>Scanned Input →123 |

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# Advanced C

## Standard I/O - scanf() - Return

**Example**

```c
#include <stdio.h>

int main()
{
    int num, int ret;

    printf("The enter a number [is 100 now]: ");
    ret = scanf("%d", &num);

    if (ret != 1)
    {
        printf("Invalid input. The number is still %d\n", num);
        return 1;
    }
    else
    {
        printf("Number is modified with %d\n", num);
    }

    return 0;
}
```

# Advanced C

## Standard I/O – sscanf() - Reading from string

**Prototype**

```
int sscanf(char *string, char *format, ...);
```

- Similar to sscanf() but read from string instead of stdin
- Formats the arguments in arg1, arg2, etc., according to format

# Advanced C

## Standard I/O - sscanf() - Example

**Example**

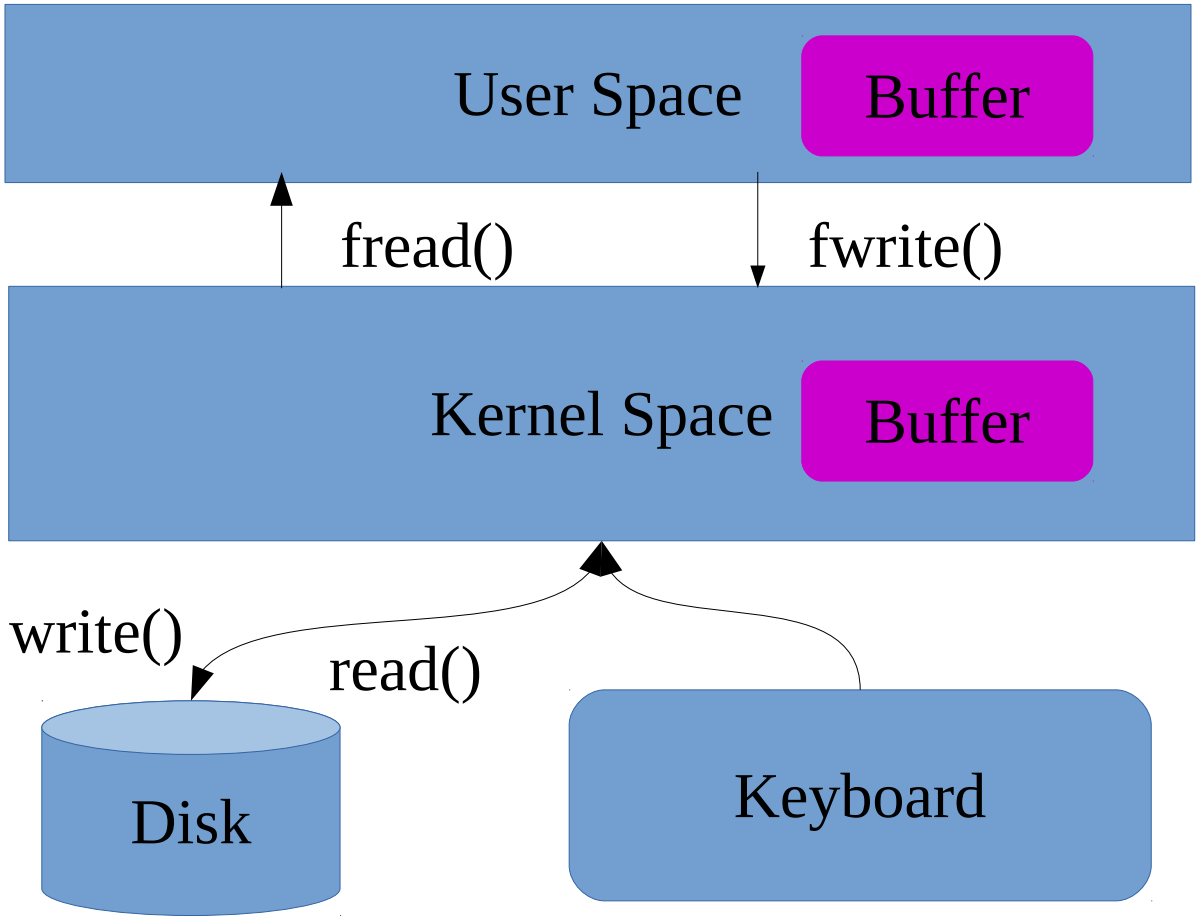
```
#include <stdio.h>

int main()
{
    int age;
    char array_1[10];
    char array_2[10];

//  sscanf("I am 30 years old", "%s %s %d", array_1, array2, &age);
    sscanf("I am 30 years old", "%*s %*s %d", &age);
    printf("OK you are %d years old\n", age);

    return 0;
}
```

# Advanced C

## Standard I/O - Buffering

# Advanced C

## Standard I/O - Buffering



# Advanced C

## Standard I/O - Buffering

- Buffer is a consecutive memory block used for temporary storage
- The standard I/O, except stderr, uses the buffer to store the data
- The input would be stored in the user space before providing it to your process
- The main idea is to reduce the context switching between user and kernel space which leads to better I/O efficiency

# Advanced C

## Standard I/O - User Space Buffering

- Refers to the technique of temporarily storing the results of an I/O operation in user-space before transmitting it to the kernel (in the case of writes) or before providing it to your process (in the case of reads)
- This technique minimizes the number of system calls (between user and kernel space) which may improve the performance of your application

# Advanced C

## Standard I/O – User Space Buffering

- For example, consider a process that writes one character at a time to a file. This is obviously inefficient: Each write operation corresponds to a write() system call
- Similarly, imagine a process that reads one character at a time from a file into memory!! This leads to read() system call
- I/O buffers are temporary memory area(s) to moderate the number of transfers in/out of memory by assembling data into batches

# Advanced C

## Standard I/O - Buffering

- The output buffer get flushed out due to the following reasons
  - Normal Program Termination
  - '\n' in a printf
  - Read
  - fflush call
  - Buffer Full

# Chapter 6
## Program Segments & Storage Classes

# Advanced C

## Memory Segments


The Linux OS is divided into two major sections

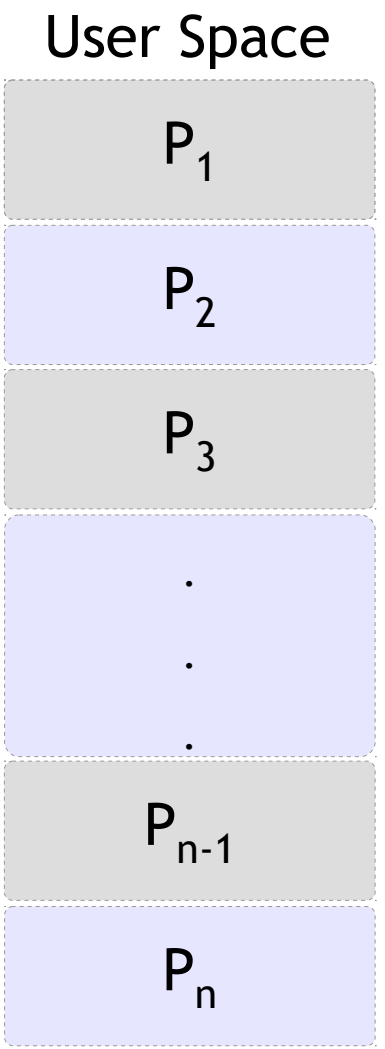
- User Space
- Kernel Space

The user programs cannot access the kernel space. If done will lead to segmentation violation

Let us concentrate on the user space section here

# Advanced C

## Memory Segments

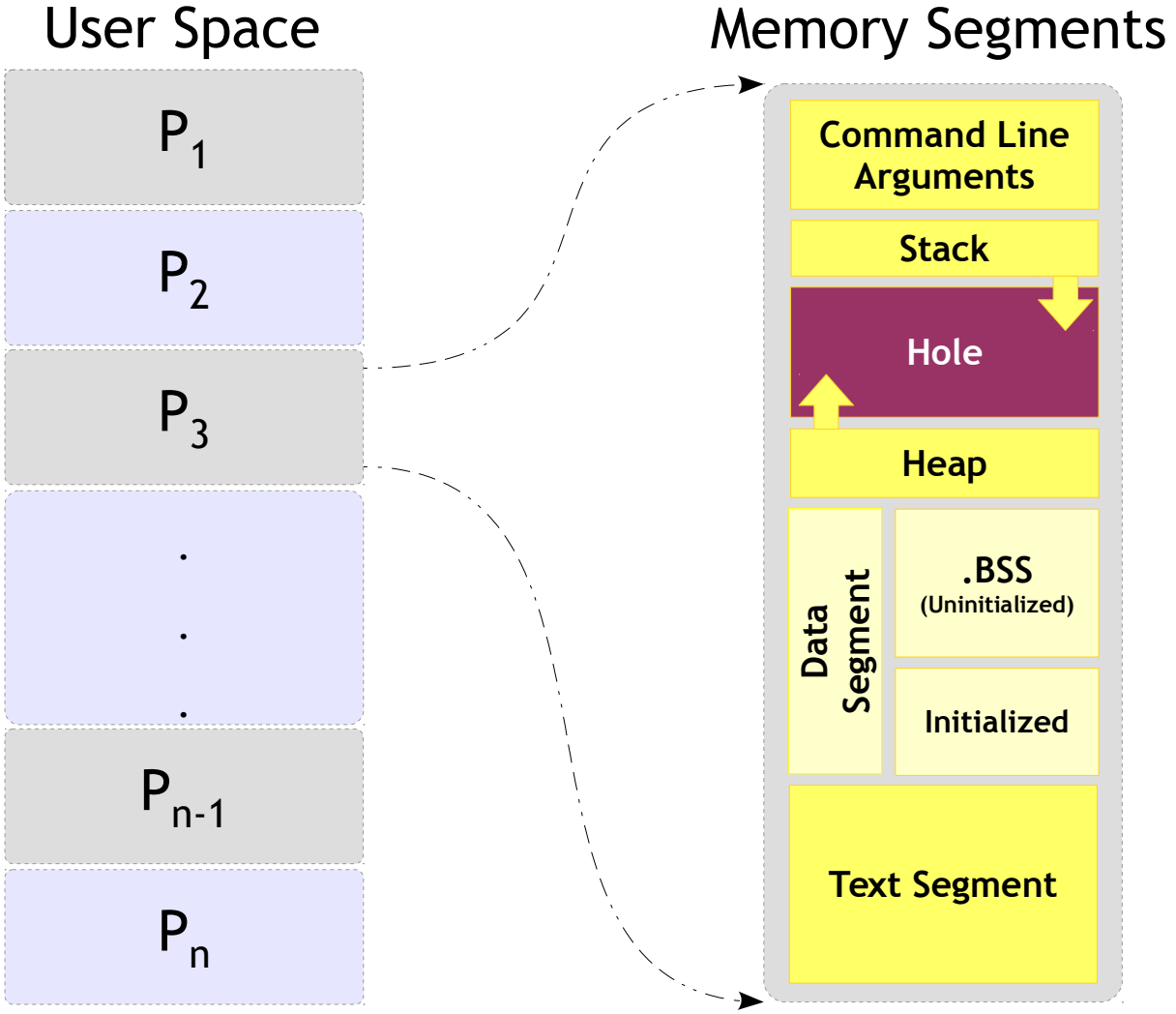

The User space contains many processes

Every process will be scheduled by the kernel

Each process will have its memory layout discussed in next slide

# Advanced C

## Memory Segments




The memory segment of a program contains four major areas.

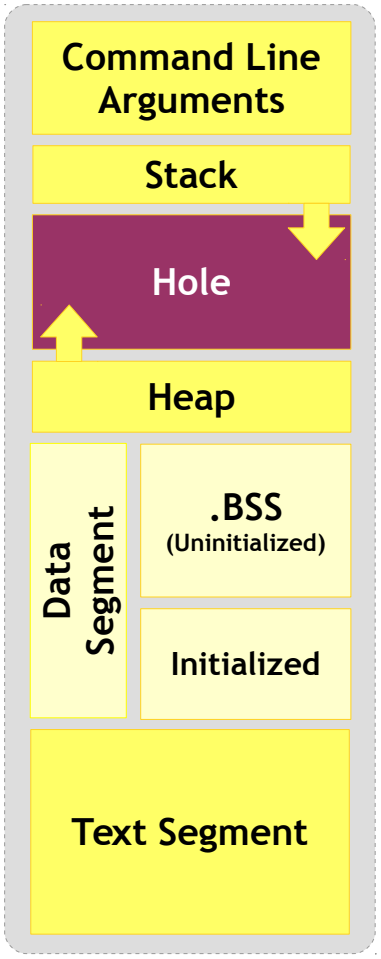
- Text Segment
- Stack
- Data Segment
- Heap

.BSS – Block Started by Symbol

# Advanced C

## Memory Segments - Text Segment

### Memory Segments




- Also referred as Code Segment
- Holds one of the section of program in object file or memory
- In memory, this is place below the heap or stack to prevent getting over written
- Is a read only section and size is fixed

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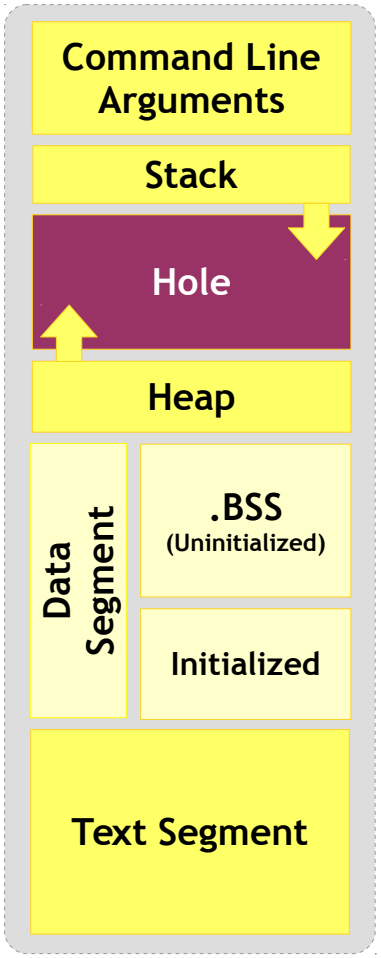
# Advanced C

## Memory Segments - Data Segment

### Memory Segments

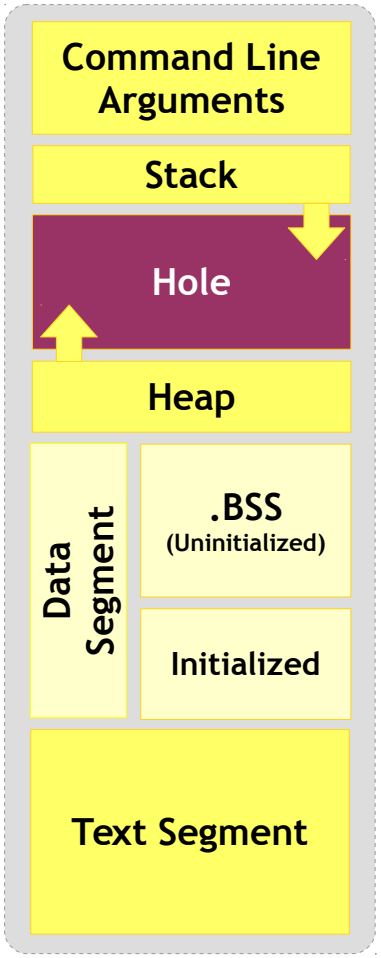



- Contains 2 sections as initialized and uninitialized data segments
- Initialized section is generally called as Data Segment
- Uninitialized section is referred as BSS (Block Started by Symbol) usually filled with 0s

# Advanced C

## Memory Segments – Data Segment

### Memory Segments



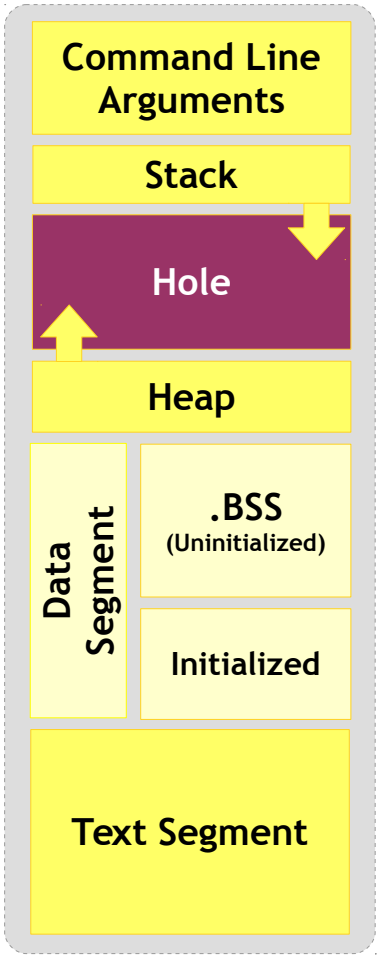

Dynamic memory allocation takes place here

Begins at the end of BSS and grows upward from there

# Advanced C

## Memory Segments – Stack Segment

### Memory Segments

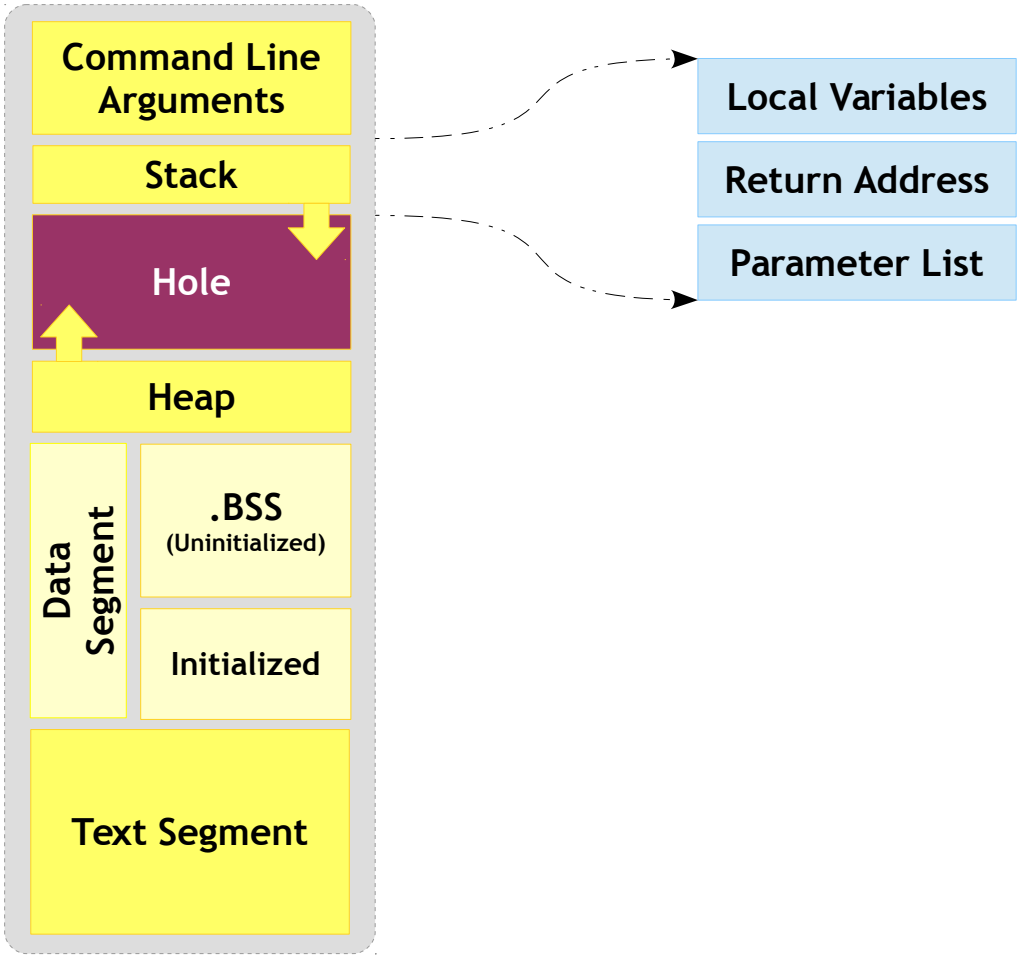



- Adjoins the heap area and grow in opposite area of heap when stack and heap pointer meet (Memory Exhausted)
- Typically loaded at the higher part of memory
- A “stack pointer” register tracks the top of the stack; it is adjusted each time a value is “pushed” onto the stack
- The set of values pushed for one function call is termed a “stack frame”

# Advanced C

## Memory Segments - Stack Segment

### Memory Segments




### Stack Frame




A stack frame contain at least of a return address

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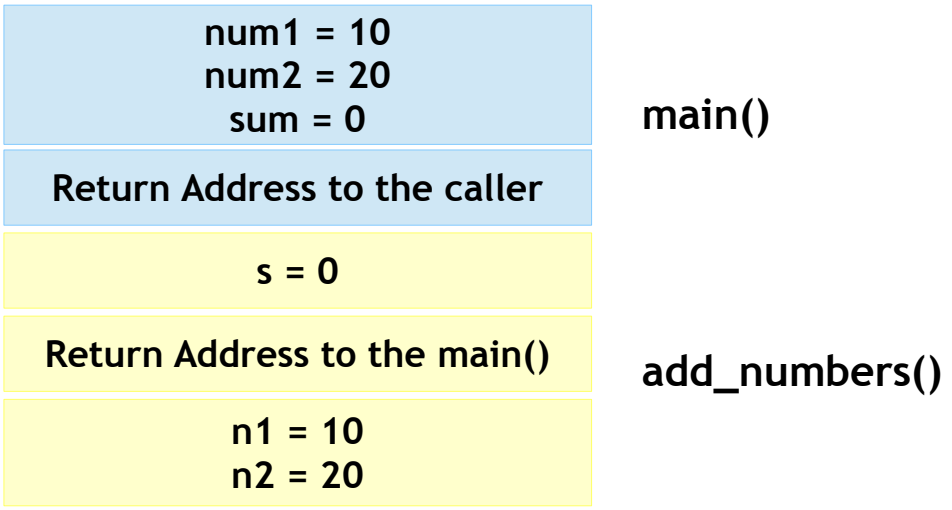
# Advanced C

## Memory Segments - Stack Frame

```c
#include <stdio.h>

int main()
{
    int num1 = 10, num2 = 20;
    int sum = 0;

    sum = add_numbers(num1, num2);
    printf("Sum is %d\n", sum);

    return 0;
}
```

```c
int add_numbers(int n1, int n2)
{
    int s = 0;

    s = n1 + n2;

    return s;
}
```

### Stack Frame



# Advanced C

## Memory Segments - Runtime

- Run-time memory includes four (or more) segments
  - Text area: program text
  - Global data area: global & static variables
  - Allocated during whole run-time
- Stack: local variables & parameters
  - A stack entry for a functions
  - Allocated (pushed) - When entering a function
  - De-allocated (popped) - When the function returns
- Heap
  - Dynamic memory
  - Allocated by malloc()
  - De-allocated by free()

# Advanced C

## Memory Segments - Runtime

- Text Segment: The text segment contains the actual code to be executed. It's usually sharable, so multiple instances of a program can share the text segment to lower memory requirements. This segment is usually marked read-only so a program can't modify its own instructions
- Initialized Data Segment: This segment contains global variables which are initialized by the programmer
- Uninitialized Data Segment: Also named “BSS" (block started by symbol) which was an operator used by an old assembler. This segment contains uninitialized global variables. All variables in this segment are initialized to 0 or NULL (for pointers) before the program begins to execute

# Advanced C

## Memory Segments - Runtime

- The Stack: The stack is a collection of stack frames. When a new frame needs to be added (as a result of a newly called function), the stack grows downward
- The Heap: Most dynamic memory, whether requested via C's malloc() . The C library also gets dynamic memory for its own personal workspace from the heap as well. As more memory is requested "on the fly", the heap grows upward

# Advanced C

## Storage Classes

| Storage Class | Scope | Lifetime | Memory Allocation |
|---|---|---|---|
| auto | Within the block / Function | Till the end of the block / function | Stack |
| register | Within the block / Function | Till the end of the block / function | Register |
| static local | Within the block / Function | Till the end of the program | Data Segment |
| static global | File | Till the end of the program | Data segment |
| extern | Program | Till the end of the program | Data segment |

# Advanced C

## Storage Classes

**Example**

```c
#include <stdio.h>

int global_1;
int global_2 = 10;

static int global_3;
static int global_4 = 10;

int main()
{
    int local_1;
    static int local_1;
    static int local_2 = 20;

    register int iter;
    for (iter = 0; iter < 0; iter++)
    {
        /* Do Something */
    }

    return 0;
}
```

| Variable | Storage Class | Memory Allocation |
|---|---|---|
| global_1 | No | .BSS |
| global_2 | No | Initialized data segment |
| global_3 | Static global | .BSS |
| global_4 | Static global | Initialized data segment |
| local_1 | auto | stack |
| local_2 | Static local | .BSS |
| local_3 | Static local | Initialized data segment |
| iter | Register | Registers |

# Advanced C

## Declaration

```
extern int num1;
extern int num1;

int main();

int main()
{
    int num1, num2;
    char short_opt;

    ...
}
```

Declaration specifies type to the variables

Its like an announcement and hence can be made 1 or more times

Declaration about num1

Declaration about num1 yet again!!

Declaration about main function

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# Advanced C

## Storage Classes - extern

file1.c

```c
#include <stdio.h>

int num;

int main()
{
    while (1)
    {
        num++;
        func_1();
        sleep(1);
        func_2();
    }

    return 0;
}
```

file2.c

```c
#include <stdio.h>

extern int num;

int func_1()
{
    printf("num is %d from file2\n", num);

    return 0;
}
```

file3.c

```c
#include <stdio.h>

extern int num;

int func_2()
{
    printf("num is %d from file3\n", num);

    return 0;
}
```

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# Chapter 6
## Strings

# Advanced C

S_____s - Fill in the blanks please ;)

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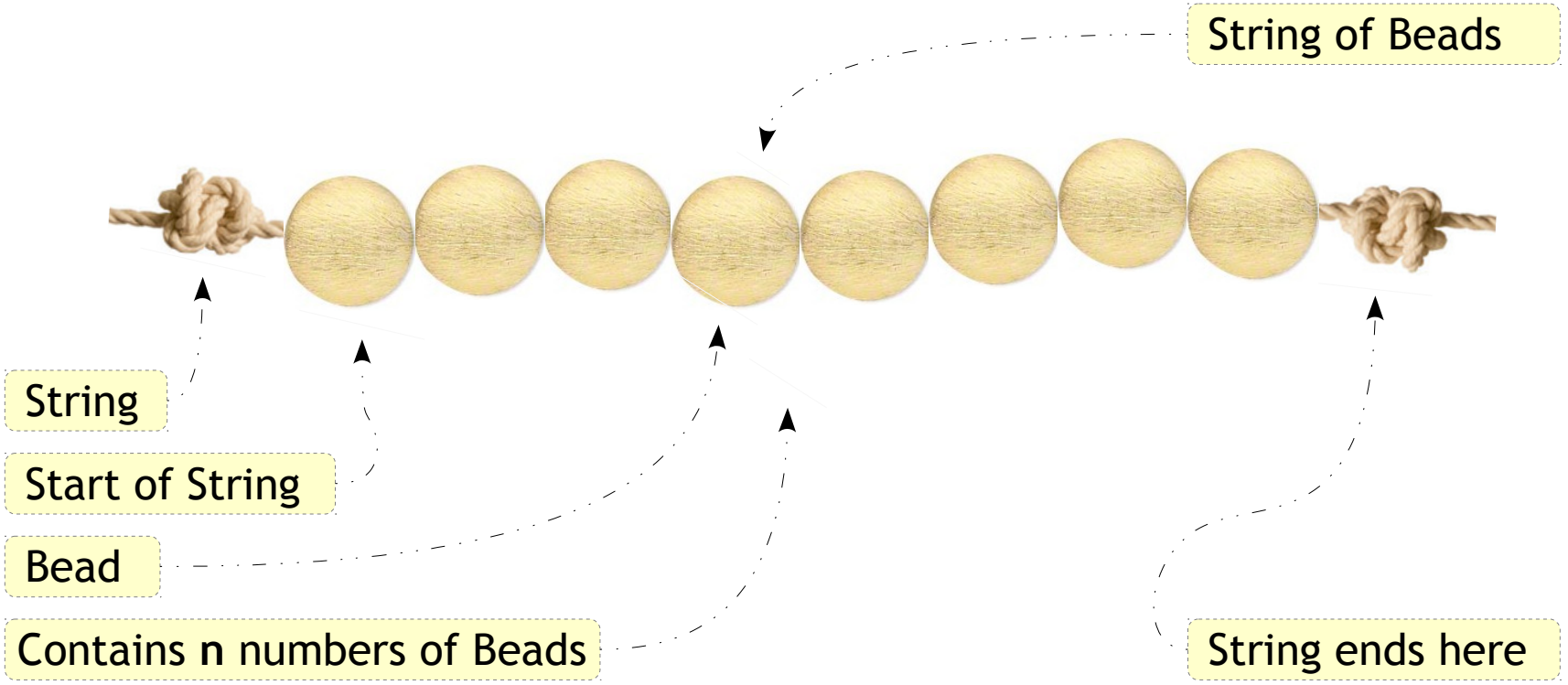
# Advanced C

## Strings

A set of things tied or threaded together on a thin cord

Source: Google

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# Advanced C

## Strings

- Contiguous sequence of characters
- Stores printable ASCII characters and its extensions
- End of the string is marked with a special character, the null character '\0'
- '\0' is implicit in strings enclosed with “”
- Example

“You know, now this is what a string is!”

# Advanced C

## Strings - Initializations

**Examples**

```
char char_array[5] = {'H', 'E', 'L', 'L', 'O'};
```
Character Array

```
char str[6] = {'H', 'E', 'L', 'L', 'O', '\0'};
```
String

```
char str[] = {'H', 'E', 'L', 'L', 'O', '\0'};
```
Valid

```
char str[6] = {"H", "E", "L", "L", "O"};
```
Invalid

```
char str[6] = {"H" "E" "L" "L" "O"};
```
Valid

```
char str[6] = {"HELLO"};
```
Valid

```
char str[6] = "HELLO";
```
Valid

```
char str[] = "HELLO";
```
Valid

```
char *str = "HELLO";
```
Valid

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# Advanced C

## Strings - Size

### Examples

```c
#include <stdio.h>

int main()
{
    char char_array_1[5] = {'H', 'E', 'L', 'L', O'};
    char char_array_2[] = "Hello";

    sizeof(char_array_1);
    sizeof(char_array_2);

    return 0;
}
```

The size of the array Is calculated So,

5, 6

```c
int main()
{
    char *str = "Hello";

    sizeof(str);

    return 0;
}
```

The size of pointer is always constant so,

4 (32 Bit Sys)

# Advanced C

## Strings - Size

**Example**

```c
#include <stdio.h>

int main()
{
    if (sizeof("Hello" "World") == sizeof("Hello") + sizeof("World")
    {
        printf("WoW\n");
    }
    else
    {
        printf("HuH\n");
    }


    return 0;
}
```

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# Advanced C

## Strings - Manipulations

**Examples**

```
char str1[6] = "Hello";
char str2[6];

str2 = "World";
```

Not possible to assign a string to a array since its a constant pointer

```
char *str3 = "Hello";
char *str4;

str4 = "World";
```

Possible to assign a string to a pointer since its variable

```
Str1[0] = 'h';
```

Valid. str1 contains "hello"

```
Str3[0] = 'w';
```

Invalid. str3 might be stored in read only section. Undefined behaviour

# Advanced C

## Strings - Sharing

**Example**

```
#include <stdio.h>

int main()
{
    char *str1 = "Hello";
    char *str2 = "Hello";

    if (str1 == str2)
    {
        printf("Hoo. They share same space\n");
    }
    else
    {
        printf("No. They are in different space\n");
    }

    return 0;
}
```

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# Advanced C

## Strings – Library Functions

| Purpose | Prototype | Return Values |
|---|---|---|
| Length | **size_t strlen(const char *str)** | String Length |
| Compare | **int strcmp(const char *str1, const char *str2)** | str1 < str2 → < 0<br>str1 > str2 → > 0<br>str1 = str2 → = 0 |
| Copy | **char *strcpy(char *dest, const char *src)** | Pointer to dest |
| Check String | **char *strstr(const char *haystack, const char *needle)** | Pointer to the beginning of substring |
| Check Character | **char *strchr(const char *s, int c)** | Pointer to the matched char else NULL |
| Merge | **char *strcat(char *dest, const char *src)** | Pointer to dest |

# Advanced C

## Strings – Quiz

- Can we copy 2 strings like, str1 = str2?
- Why don't we pass the size of the string to string functions?
- What will happen if you overwrite the '\0' of string? Will you still call it a string?
- What is the difference between char *s and char s[]?

# Advanced C

## Strings – DIY

- WAP to calculate length of the string
- WAP to reverse a string
- WAP to check a given string is palindrome or not
- WAP to compare two strings
- WAP to compare string2 with string1 up to n characters
- WAP to copy a strings
- WAP to concatenate two strings

# Advanced C

## Strings – DIY- usage of std functions

"strlen, strcpy, strcmp, strcat, strstr, strtok"

- WAP to print user information –
  - Read : Name, Age, ID, Mobile number
  - Print the information on monitor
  - Print error "Invalid Mobile Number" if length of mobile number is not 10
- WAP to read user name and password and compare with stored fields. Present a puzzle to fill in the banks
- Use strtok to separate words from string "www.emertxe.com/bangalore"

# Chapter 7
## Preprocessor

# Advanced C

## Preprocessor

- One of the step performed before compilation
- Is a text substitution tool and it instructs the compiler to do required pre-processing before the actual compilation
- Instructions given to preprocessor are called preprocessor directives and they begin with “#” symbol
- Few advantages of using preprocessor directives would be,
  - Easy Development
  - Readability
  - Portability

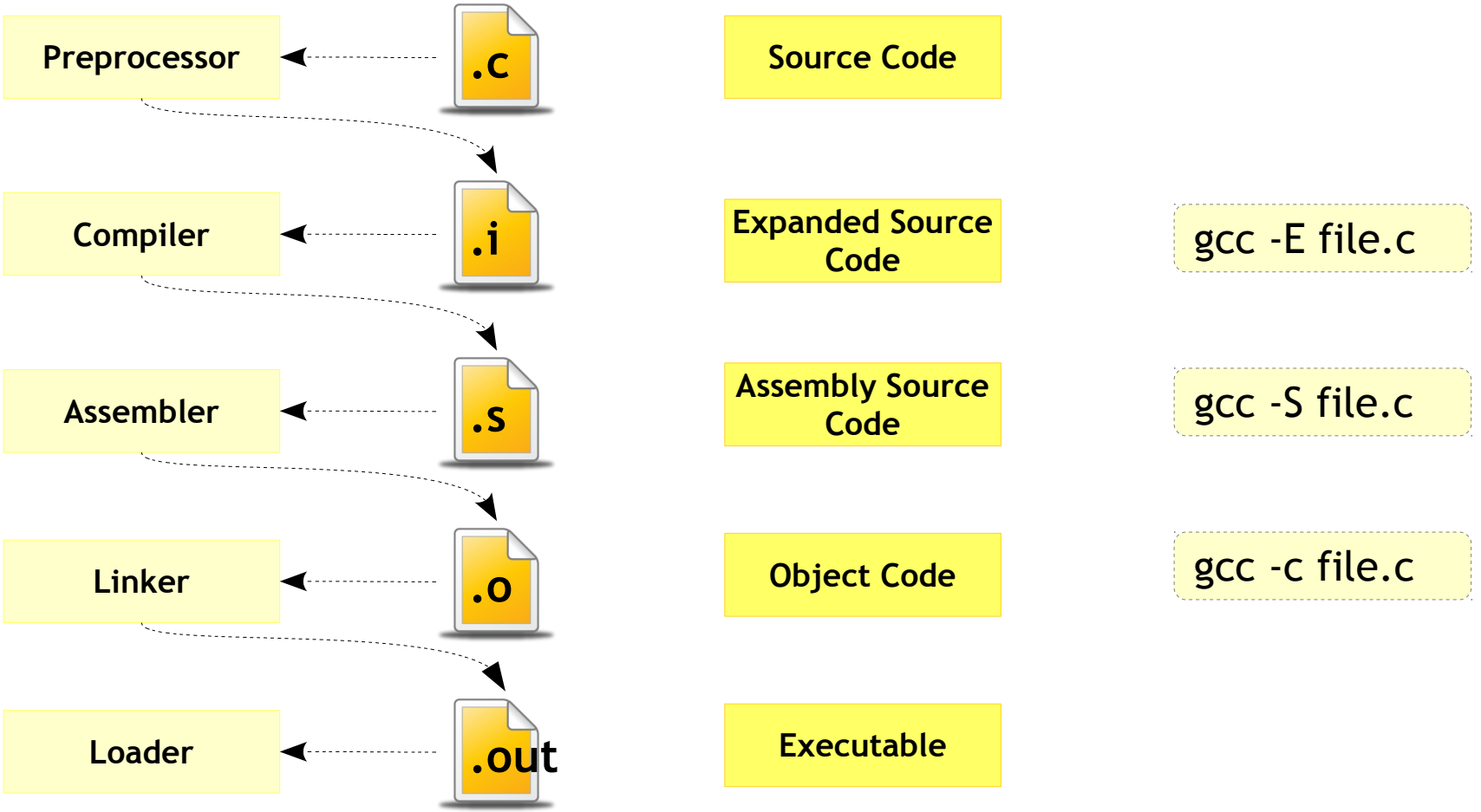
# Advanced C

## Preprocessor - Compilation Stages

- Before we proceed with preprocessor directive let's try to understand the stages involved in compilation
- Some major steps involved in compilation are
  - Preprocessing (Textual replacement)
  - Compilation (Syntax and Semantic rules checking)
  - Assembly (Generate object file(s))
  - Linking (Resolve linkages)
- The next slide provide the flow of these stages

# Advanced C

## Preprocessor - Compilation Stages




**gcc -save-temps file.c** would generate all intermediate files

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# Advanced C

## Preprocessor – Directives

#include
#define
#undef
#ifdef
#ifndef
#else
#endif
#if
#else
#elif
#error
#warning
#line
#pragma
#
##

# Advanced C

## Preprocessor - Header Files

- A header file is a file containing C declarations and macro definitions to be shared between several source files.
- Has to be included using C preprocessing directive '**#include**'
- Header files serve two purposes.
  - Declare the interfaces to parts of the operating system by supplying the definitions and declarations you need to invoke system calls and libraries.
  - Your own header files contain declarations for interfaces between the source files of your program.

# Advanced C

## Preprocessor – Header Files vs Source Files


VS


- Declarations
- Sharable/reusable
  - #defines
  - Datatypes
- Used by more than 1 file

- Function and variable definitions
- Non sharable/reusable
  - #defines
  - Datatypes

# Advanced C

## Preprocessor – Header Files - Syntax

**Syntax**

```
#include <file.h>
```

- System header files
- It searches for a file named ***file*** in a standard list of system directories

**Syntax**

```
#include "file.h"
```

- Local (your) header files
- It searches for a file named ***file*** first in the directory containing the current file, then in the quote directories and then the same directories used for <file>

# Advanced C

## Preprocessor - Header Files - Operation

**file2.c**

```
char *test(void)
{
    static char *str = "Hello";

    return str;
}
```

**file2.h**

```
char *test(void);
```

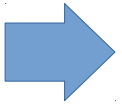
**file1.c**

```
int num;

#include "file2.h"

int main()
{
    puts(test());

    return 0;
}
```



```
int num;

char *test(void);

int main()
{
    puts(test());

    return 0;
}
```

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# Advanced C

## Preprocessor - Header Files - Search Path

- On a normal Unix system GCC by default will look for headers requested with #include <file> in:
  - /usr/local/include
  - libdir/gcc/target/version/include
  - /usr/target/include
  - /usr/include
- You can add to this list with the -I <*dir*> command-line option

**"gcc -print-prog-name=cc1 -v"** would search the path info

# Advanced C

## Preprocessor - Header Files - Once-Only

- If a header file happens to be included twice, the compiler will process its contents twice causing an error
- E.g. when the compiler sees the same structure definition twice
- This can be avoided like

**Example**

```
#ifndef NAME
#define NAME

/* The entire file is protected */

#endif
```

# Advanced C

## Preprocessor - Macro - Object-Like

- An object-like macro is a simple identifier which will be replaced by a code fragment
- It is called object-like because it looks like a data object in code that uses it.
- They are most commonly used to give symbolic names to numeric constants

**Syntax**

```
#define SYMBOLIC_NAME      CONSTANTS
```

**Example**

```
#define BUFFER_SIZE        1024
```

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# Advanced C

## Preprocessor - Macro - Arguments

- Function-like macros can take arguments, just like true functions
- To define a macro that uses arguments, you insert parameters between the pair of parentheses in the macro definition that make the macro function-like

**Example**

```
#include <stdio.h>

#define SET_BIT(num, pos)      (num | (1 << pos))

int main()
{
    SET_BIT(0, 2);

    return 0;
}
```

# Advanced C

## Preprocessor - Macro - Multiple Lines

- You may continue the definition onto multiple lines, if necessary, using backslash-newline.
- When the macro is expanded, however, it will all come out on one line

**Example**

```
#include <stdio.h>

#define SWAP(a, b)                  \
{                                   \
    int temp = a;                   \
    a = b;                          \
    b = temp;                       \
}

int main()
{
    int num1 = 10, num1= 20;

    SWAP(num1, num2);

    printf("%d %d\n", num1, num2);

    return 0;
}
```

# Advanced C

## Preprocessor - Macro - Stringification

**Example**

```c
#include <stdio.h>

#define WARM_IF(EXP)                                    \
do                                                      \
{                                                       \
    x--;                                                \
    if (EXP)                                            \
    {                                                   \
        fprintf(stderr, "Warning: " #EXP "\n");         \
    }                                                   \
} while (x);

int main()
{
    int x = 5;

    WARN_IF(x == 0);

    return 0;
}
```

- You can convert a macro argument into a string constant by adding #

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# Advanced C

## Preprocessor - Macro - Standard Predefined

- Several object-like macros are predefined; you use them without supplying their definitions.
- Standard are specified by the relevant language standards, so they are available with all compilers that implement those standards

**Example**

```
#include <stdio.h>

int main()
{

    printf("Program: \"%s\" ", __FILE__);
    printf("was compiled on %s at %s. ", __DATE__, __TIME__);
    printf("This print is from Function: \"%s\" at line %d\n", __func__, __LINE__);

    return 0;
}
```

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# Advanced C

## Preprocessor – Conditional Compilation

- A conditional is a directive that instructs the preprocessor to select whether or not to include a chunk of code in the final token stream passed to the compiler
- Preprocessor conditionals can test arithmetic expressions, or whether a name is defined as a macro, or both simultaneously using the special defined operator
- A conditional in the C preprocessor resembles in some ways an if statement in C with the only diffrence being it happens in compile time
- Its purpose is to allow different code to be included in the program depending on the situation at the time of compilation.

# Advanced C

## Preprocessor – Conditional Compilation

- There are three general reasons to use a conditional.
  - A program may need to use different code depending on the machine or operating system it is to run on
  - You may want to be able to compile the same source file into two different programs, like one for debug and other as final
  - A conditional whose condition is always false is one way to exclude code from the program but keep it as a sort of comment for future reference

# Advanced C

## Preprocessor - Conditional Compilation - ifdef

**Syntax**

```
#ifdef MACRO

/* Controlled Text */

#endif
```

# Advanced C

## Preprocessor - Conditional Compilation - defined

**Syntax**

```
#if defined (ERROR) && (WARNING)

/* Controlled Text */

#endif
```

# Advanced C

## Preprocessor - Conditional Compilation - if

**Syntax**

```
#if expression

/* Controlled Text */

#endif
```

# Advanced C

## Preprocessor - Conditional Compilation - else

**Syntax**

```
#if expression

/* Controlled Text if true */

#else

/* Controlled Text if false */

#endif
```

# Advanced C

## Preprocessor - Conditional Compilation - elif

**Syntax**

```
#if DEBUG_LEVEL == 1

/* Controlled Text*/

#elif  DEBUG_LEVEL == 2

/* Controlled Text */

#else

/* Controlled Text */

#endif
```

# Advanced C

## Preprocessor - Conditional Com... - Deleted Code

**Syntax**

```
#if 0

/* Deleted code while compiling */
/* Can be used for nested code comments */
/* Avoid for general comments */

#endif
```

# Advanced C

## Preprocessor – Diagnostic

- The directive ‘#error’ causes the preprocessor to report a fatal error. The tokens forming the rest of the line following ‘#error’ are used as the error message
- The directive ‘#warning’ is like ‘#error’, but causes the preprocessor to issue a warning and continue preprocessing. The tokens following ‘#warning’ are used as the warning message

# Chapter 8
## User Defined Datatype

# Advanced C

## UDDs – Structures (Composite data types)

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# Advanced C

## UDDs - Structures (Composite data types)

- Sometimes it becomes tough to build a whole software that works only with integers, floating values, and characters.
- In circumstances such as these, you can create your own data types which are based on the standard ones
- There are some mechanisms for doing this in C:
  - Structures
  - Unions
  - Typedef
  - Enums
- Hoo!!, let's not forget our old friend _r_a_ which a user defined data type too!!.

# Advanced C

## UDDs – Structures (Composite data types)

Composite (or compound) data type :

- Any data type which can be constructed from primitive data types and other composite types
- It is sometimes called a structure or aggregate data type
- Primitives types – int, char, float, double

# Advanced C

## UDDs - Structures

**Syntax**

```
struct StructureName
{
    /* Group of data types */
};
```

- If we consider the Student as an example, The admin should have at least some important data like name, ID and address.
- So if we create a structure of the above requirement, it would look like,

**Example**

```
struct Student
{
    int id;
    char name[30];
    char address[150]
};
```

# Advanced C

## UDDs - Structures - Declaration and definition

**Example**

```
struct Student
{
    int id;
    char name[30];
    char address[150];
};

int main()
{
    struct Student s1;

    return 0;
}
```

- Name of the **datatype**. Note it's **struct Student** and not Student
- Are called as **fields** or **members** of of the structure
- Declaration **ends** here
- The memory is not yet allocated!!
- **s1** is a **variable** of **type struct Student**
- The memory is allocated now

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# Advanced C

## UDDs - Structures - Memory Layout

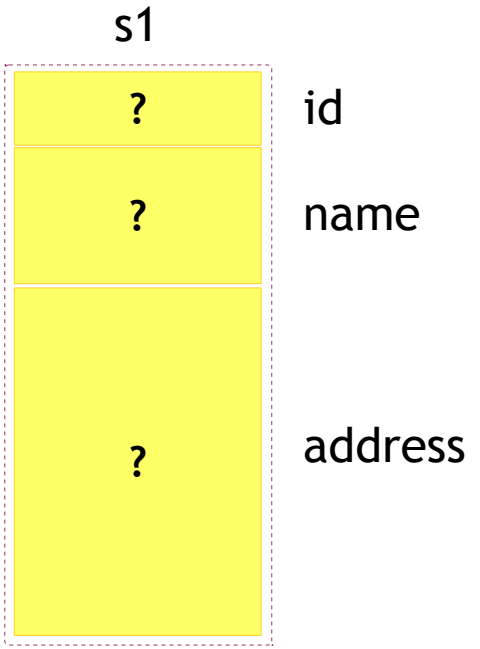
**Example**

```
struct Student
{
    int id;
    char name[30];
    char address[150];
};

int main()
{
    struct Student s1;

    return 0;
}
```

- What does s1 contain?
- How can we draw it's memory layout?

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# Advanced C

## UDDs - Structures - Access

**Example**

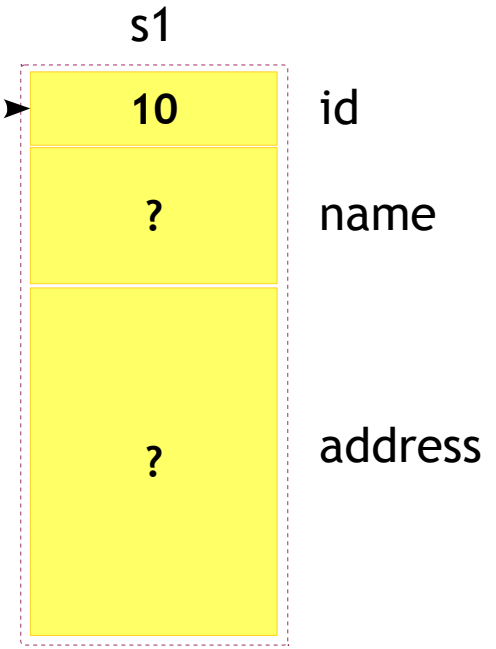
```
struct Student
{
    int id;
    char name[30];
    char address[150];
};

int main()
{
    struct Student s1;

    s1.id = 10;

    return 0;
}
```

- How to write into id now?
- It's by using “.” (Dot) operator (member access operator)




- Now please assign the name for s1

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# Advanced C

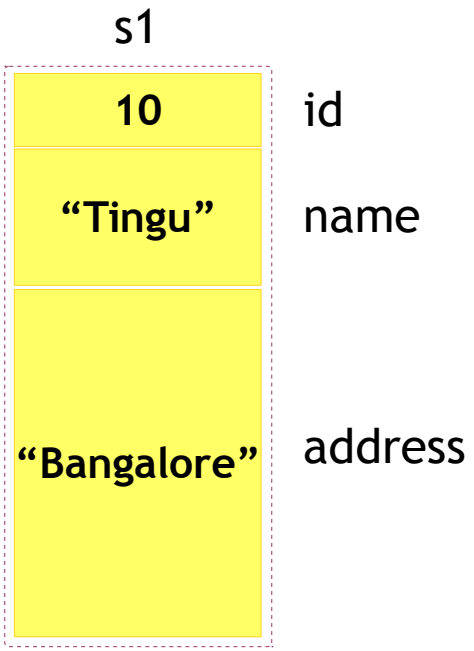
## UDDs – Structures - Initialization

**Example**

```
struct Student
{
    int id;
    char name[30];
    char address[150];
};

int main()
{
    struct Student s1 = {10, "Tingu", "Bangalore"};

    return 0;
}
```



# Advanced C

## UDDs – Structures - Copy

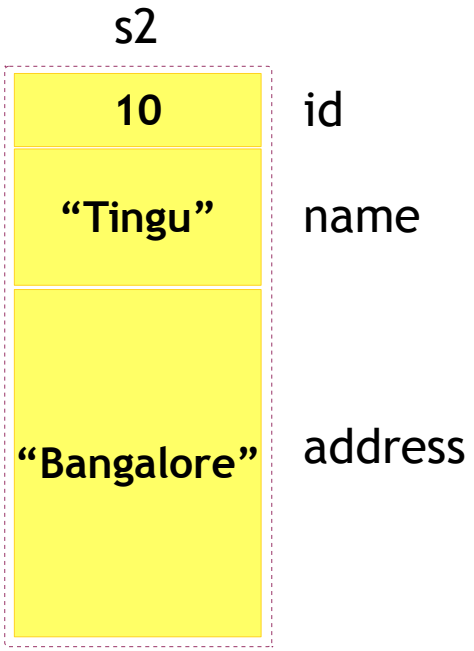
**Example**

```
struct Student
{
    int id;
    char name[30];
    char address[150];
};

int main()
{
    struct Student s1 = {10, "Tingu", "Bangalore"};
    struct Student s2;

    s2 = s1;

    return 0;
}
```




Structure name does not represent its address. (No correlation with arrays)

# Advanced C

## UDDs - Structures - Address

**Example**

```
struct Student
{
    int id;
    char name[30];
    char address[150];
};

int main()
{
    struct Student s1 = {10, "Tingu", "Bangalore"};

    printf("Struture starts at %p\n", &s1);
    printf("Member id is at %p\n", &s1.id);
    printf("Member name is at %p\n", s1.name);
    printf("Member address is at %p\n", s1.address);

    return 0;
}
```

# Advanced C

## UDDs – Structures - Pointers

- Pointers!!!. Not again ;). Fine don't worry, not a big deal
- But do you any idea how to create it?
- Will it be different from defining them like in other data types?

# Advanced C

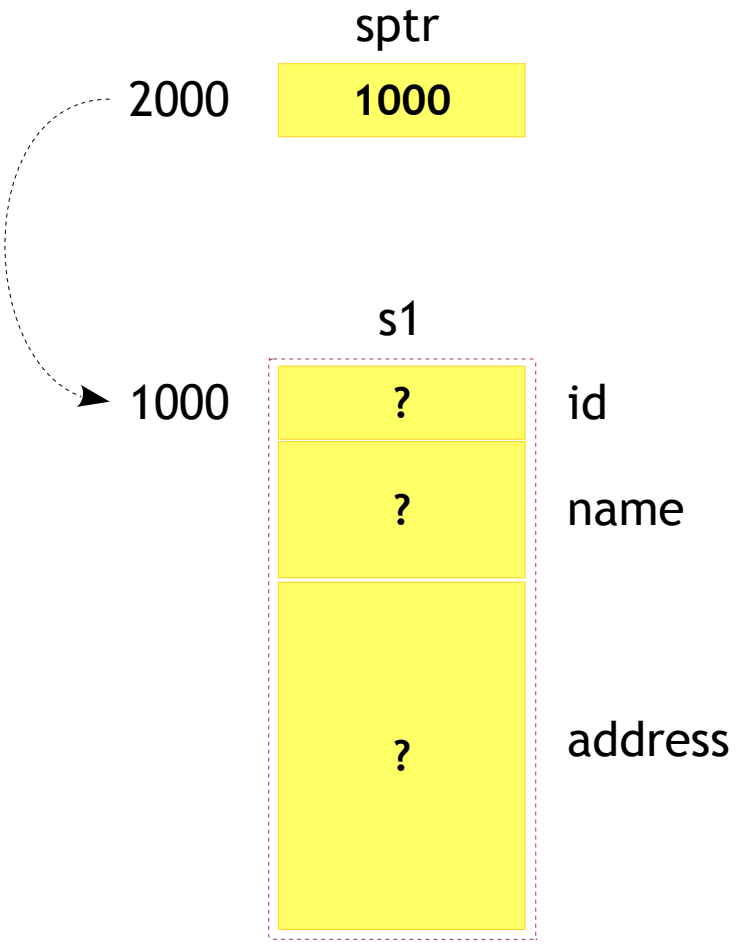
## UDDs - Structures - Pointer

**Example**

```
struct Student
{
    int id;
    char name[30];
    char address[150];
};

int main()
{
    struct Student s1;
    struct Student *sptr = &s1;

    return 0;
}
```

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# Advanced C

## UDDs - Structures - Pointer - Access

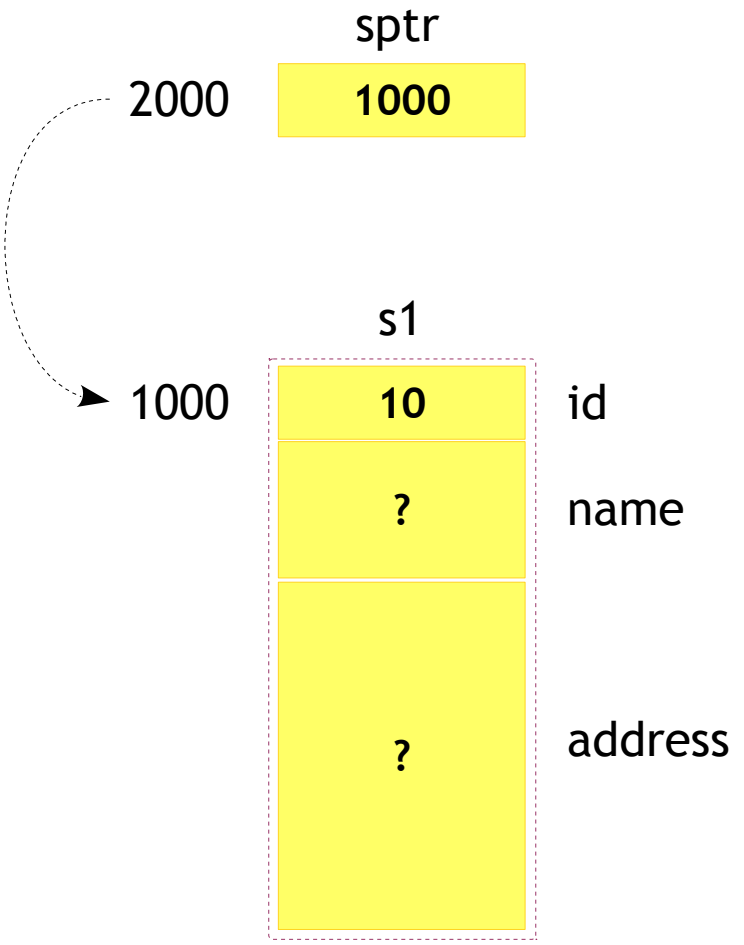
**Example**

```
struct Student
{
    int id;
    char name[30];
    char address[150];
};

int main()
{
    struct Student s1;
    struct Student *sptr = &s1;

    (*sptr).id = 10;

    return 0;
}
```



# Advanced C

## UDDs - Structures - Pointer - Access - Arrow

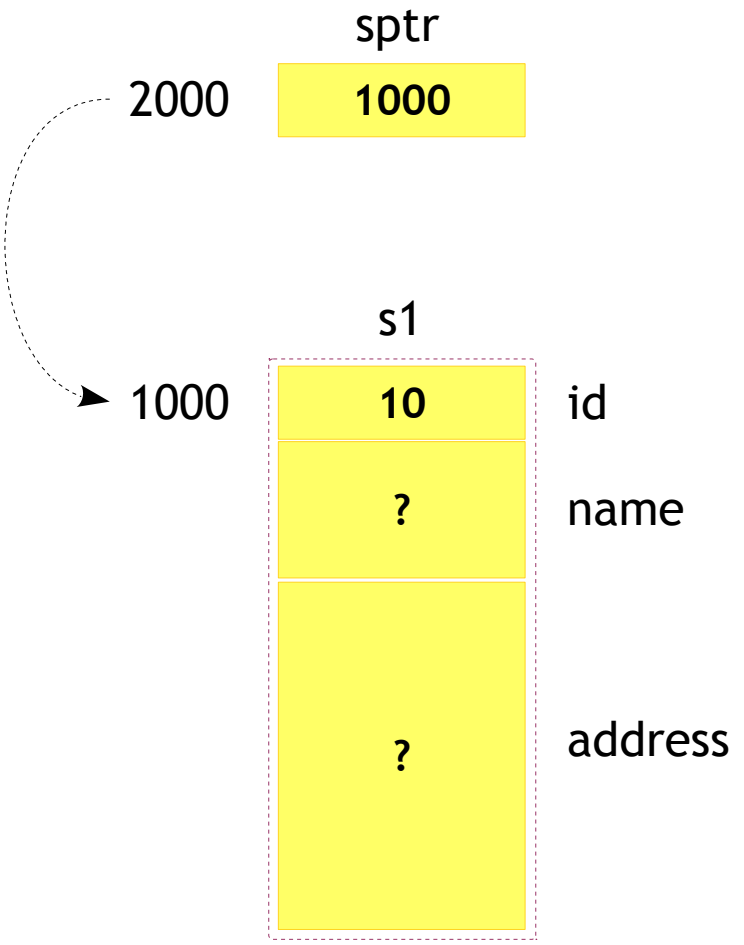
**Example**

```
struct Student
{
    int id;
    char name[30];
    char address[150];
};

int main()
{
    struct Student s1;
    struct Student *sptr = &s1;

    sptr->id = 10;

    return 0;
}
```




Note: we can access the structure pointer as seen in the previous slide. The Arrow operator is just convinence and frequently used

# Advanced C

## UDDs – Structures - Functions

- The structures can be passed as parameter and can be returned from a function
- This happens just like normal datatypes.
- The parameter passing can have two methods again as normal
  - Pass by value
  - Pass by reference

# Advanced C

## UDDs - Structures - Functions - Pass by Value

**Example**

```
struct Student
{
    int id;
    char name[30];
    char address[150];
};

void data(struct Student s)
{
    s.id = 10;
}

int main()
{
    struct Student s1;

    data(s1);

    return 0;
}
```

Not recommended on larger structures

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# Advanced C

## UDDs - Structures - Functions - Pass by Reference

**Example**

```
struct Student
{
    int id;
    char name[30];
    char address[150]
};

void data(struct Student *s)
{
    s->id = 10;
}

int main()
{
    struct Student s1;

    data(&s1);

    return 0;
}
```

Recommended on larger structures

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# Advanced C

## UDDs - Structures - Functions - Return

**Example**

```c
struct Student
{
    int id;
    char name[30];
    char address[150]
};

struct Student data(struct Student s)
{
    s.id = 10;

    return s;
}

int main()
{
    struct Student s1;

    s1 = data(s1);

    return 0;
}
```

# Advanced C

## UDTs – Structures – Padding

- Adding of few extra useless bytes (in fact skip address) in between the address of the members are called structure padding.
- What!!?, wasting extra bytes!!, Why?
- This is done for Data Alignment.
- Now!, what is data alignment and why did this issue suddenly arise?
- No its is not sudden, it is something the compiler would internally while allocating memory.
- So let's understand data alignment in next few slides

# Advanced C

## Data Alignment

- A way the data is arranged and accessed in computer memory.
- When a modern computer reads from or writes to a memory address, it will do this in word sized chunks (4 bytes in 32 bit system) or larger.
- The main idea is to increase the efficiency of the CPU, while handling the data, by arranging at a memory address equal to some multiple of the word size
- So, Data alignment is an important issue for all programmers who directly use memory.

# Advanced C

## Data Alignment

- If you don't understand data and its address alignment issues in your software, the following scenarios, in increasing order of severity, are all possible:
  - Your software will run slower.
  - Your application will lock up.
  - Your operating system will crash.
  - Your software will silently fail, yielding incorrect results.

# Advanced C

## Data Alignment

**Example**

```
int main()
{
    char ch = 'A';
    int num = 0x12345678;
}
```

| | |
|---|---|
| 0 | ch |
| 1 | 78 |
| 2 | 56 |
| 3 | 34 |
| 4 | 12 |
| 5 | ? |
| 6 | ? |
| 7 | ? |

- Lets consider the code as given
- The memory allocation we expect would be like shown in figure
- So lets see how the CPU tries to access these data in next slides

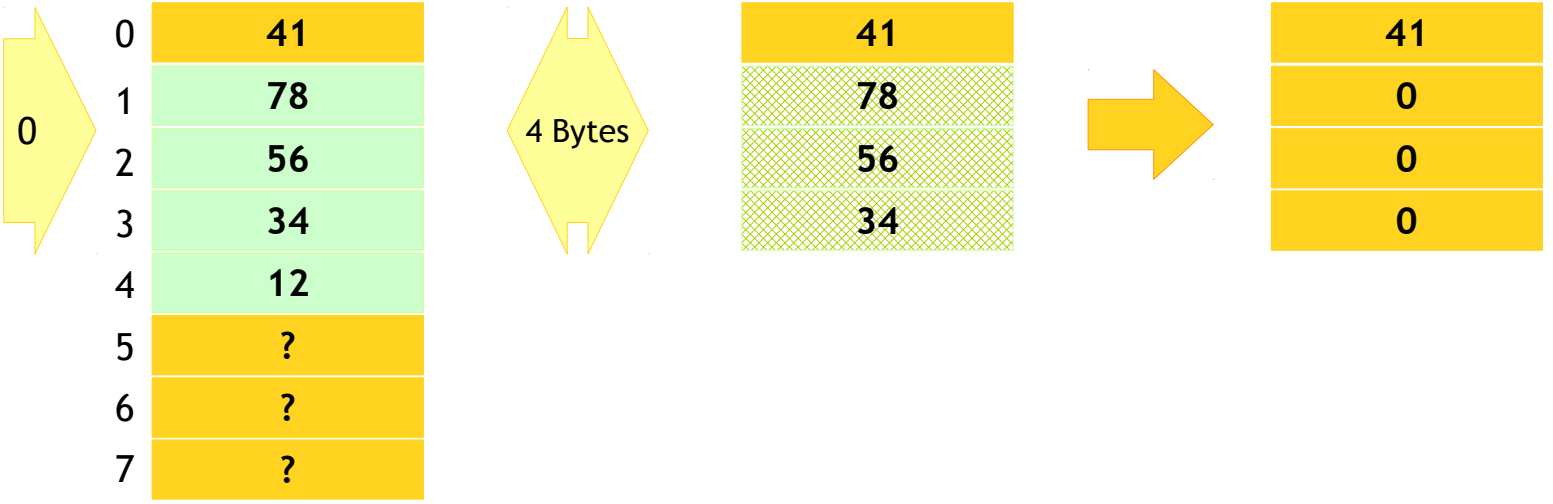
# Advanced C

## Data Alignment

**Example**

```
int main()
{
    char ch = 'A';
    int num = 0x12345678;
}
```

- Fetching the character by the CPU will be like shown below



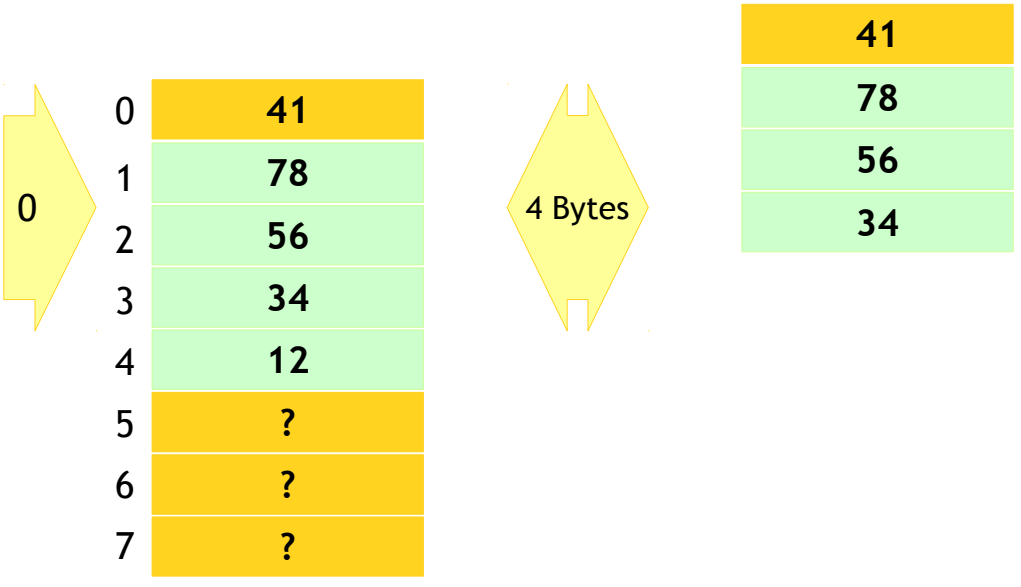
# Advanced C

## Data Alignment

**Example**

```
int main()
{
    char ch = 'A';
    int num = 0x12345678;
}
```

- Fetching the integer by the CPU will be like shown below

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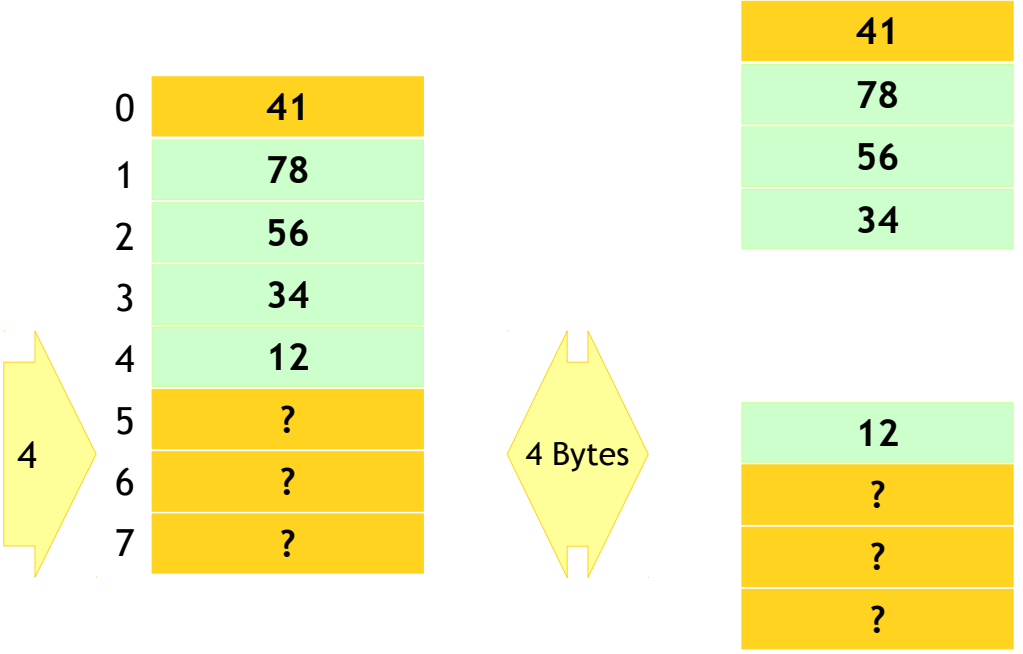
# Advanced C

## Data Alignment

**Example**

```
int main()
{
    char ch = 'A';
    int num = 0x12345678;
}
```

- Fetching the integer by the CPU will be like shown below



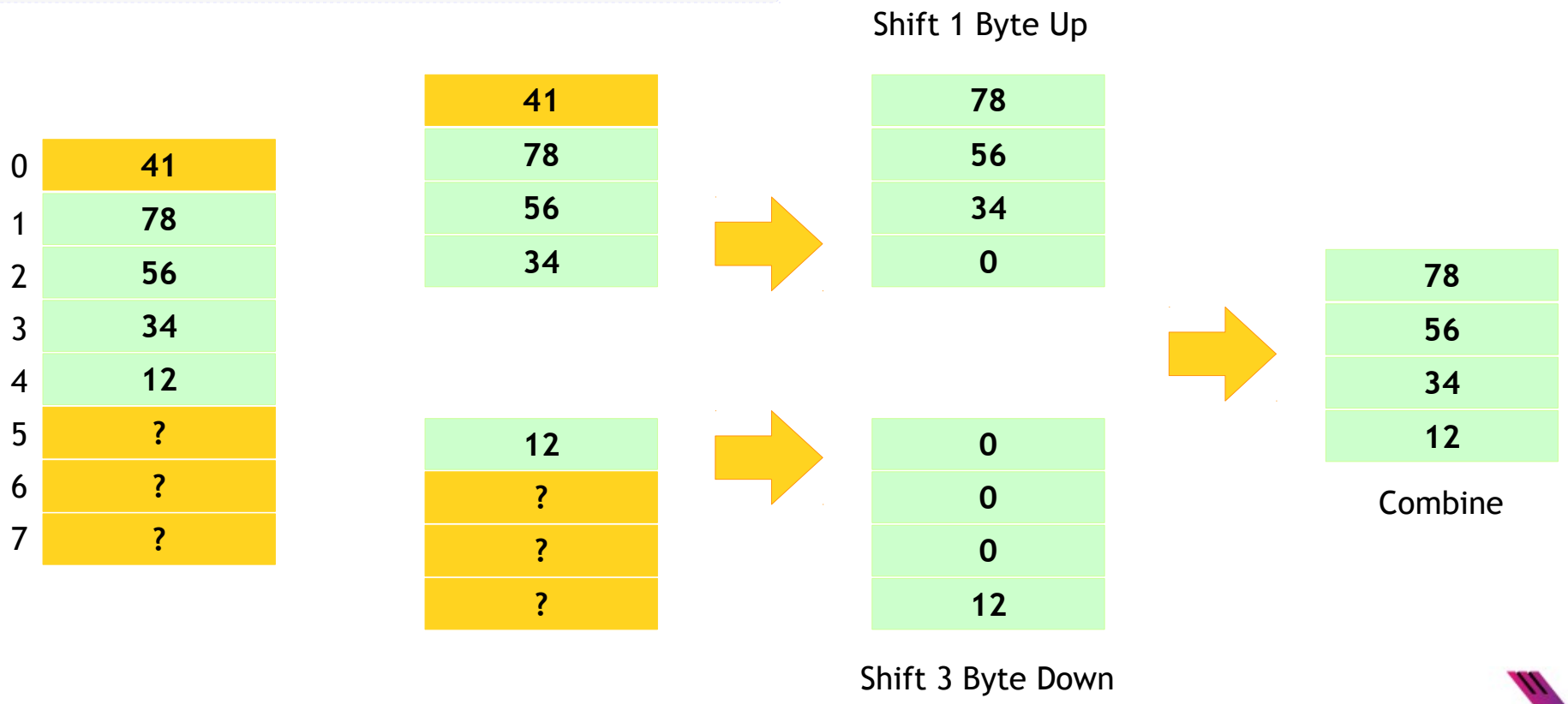
# Advanced C

## Data Alignment

**Example**

```
int main()
{
    char ch = 'A';
    int num = 0x12345678;
}
```

- Fetching the integer by the CPU will be like shown below



# Advanced C

## UDTs – Structures – Data Alignment - Padding

- Because of the data alignment issue, structures uses padding between its members if the don't fall under even address.
- So if we consider the following structure the memory allocation will be like shown in below figure

**Example**

```
struct Test
{
    char ch1;
    int num;
    char ch2;
}
```

| | |
|---|---|
| 0 | ch1 |
| 1 | pad |
| 2 | pad |
| 3 | pad |
| 4 | num |
| 5 | num |
| 6 | num |
| 7 | num |
| 8 | ch2 |
| 9 | pad |
| A | pad |
| B | pad |

# Advanced C

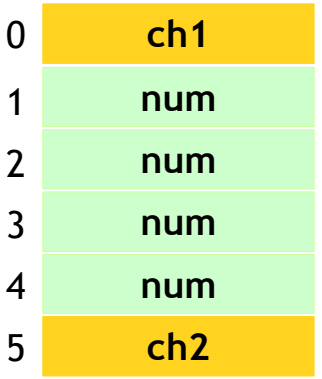
## UDTs - Structures - Data Alignment - Padding

- You can instruct the compiler to modify the default padding behavior using #pragma pack directive

**Example**

```
#pragma pack(1)

struct main()
{
    char ch1;
    int num;
    char ch2;
}
```

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# Advanced C

## UDTs – Structures – Bit Fields

- The compiler generally gives the memory allocation in multiples of bytes, like 1, 2, 4 etc.,
- What if we want to have freedom of having getting allocations in bits?!.
- This can be achieved with bit fields.
- But not that
  - The minimum memory allocation for a bit field member would be a byte that can be broken in max of 8 bits
  - The maximum number of bits assigned to a member would depend on the length modifier
  - The default size is equal to word size

# Advanced C

## UDTs - Structures - Bit Fields

**Example**

```
struct Nibble
{
    unsigned char upper    : 4;
    unsigned char lower    : 4;
};
```

- The above structure divides a char into two nibbles
- We can access these nibbles independently

# Advanced C

## UDDs – Unions

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# Advanced C

## UDTs – Unions

- Like structures, unions may have different members with different data types.
- The major difference is, the structure members get different memory allocation, and in case of unions there will be single memory allocation for the biggest data type

# Advanced C

## UDTs – Unions

**Example**

```
union DummyVar
{
    char option;
    int id;
    double height;
};
```

- The above union will get the size allocated for the type double
- The size of the union will be 8 bytes.
- All members will be using the same space when accessed
- The value the union contain would be the latest update
- So as summary a single varible can store different type of data as required

# Advanced C

## UDTs - Typedefs

- Typedef is used to create a new name to the existing types.
- K&R states that there are two reasons for using a typedef.
  - First, it provides a means to make a program more portable. Instead of having to change a type everywhere it appears throughout the program's source files, only a single typedef statement needs to be changed.
  - Second, a typedef can make a complex definition or declaration easier to understand.

# Advanced C

## UDTs – Enums

- Set of named integral values

**Examples**

```
enum Boolean
{
    e_false,
    e_true
};
```

```
typedef enum
{
    e_red = 1,
    e_blue = 4,
    e_green
} Color;
```

```
typedef enum
{
    red,
    blue
} Color;

int blue;
```

- The above example has two members with its values starting from 0. i.e, e_false = 0 and e_true = 1.
- The member values can be explicitly initialized
- The is no constraint in values, it can be in any order and same values can be repeated
- Enums does not have name space of its own, so we cannot have same name used again in the same scope.

# Chapter 5
## File Input / Output

# Advanced C

## File Input / Output

- Sequence of bytes
- Could be regular or binary file
- Why?
  - Persistent storage
  - Theoretically unlimited size
  - Flexibility of storing any type data

# Advanced C

## File Input / Output – Via Redirection

- General way for feeding and getting the output is using standard input (keyboard) and output (screen)
- By using redirection we can achieve it with files i.e

  ```
  ./a.out < input_file > output_file
  ```

- The above line feed the input from input_file and output to output_file
- The above might look useful, but its the part of the OS and the C doesn't work this way
- C has a general mechanism for reading and writing files, which is more flexible than redirection

# Advanced C

## File Input / Output

- C abstracts all file operations into operations on streams of bytes, which may be "input streams" or "output streams"
- No direct support for random-access data files
- To read from a record in the middle of a file, the programmer must create a stream, seek to the middle of the file, and then read bytes in sequence from the stream
- Let's discuss some commonly used file I/O functions

# Advanced C

## File Input / Output - File Pointer

- stdio.h is used for file I/O library functions
- The data type for file operation generally is

Type

```
FILE *fp;
```

- FILE pointer, which will let the program keep track of the file being accessed
- Operations on the files can be
  - Open
  - File operations
  - Close

# Advanced C

## File Input / Output - Functions

### Prototype

```
FILE *fopen(const char *filename, const char *mode);
int fclose(FILE *filename);

Where mode are:
r   - open for reading
w   - open for writing (file need not exist)
a   - open for appending (file need not exist)
r+  - open for reading and writing, start at beginning
w+  - open for reading and writing (overwrite file)
a+  - open for reading and writing (append if file exists)
```

### Example

```
#include <stdio.h>

int main()
{
    FILE *fp;

    fp = fopen("test.txt", "r");
    fclose(fp);

    return 0;
}
```

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# Advanced C

## File Input / Output - Functions

### Example

```c
#include <stdio.h>
#include <stdlib.h>

int main()
{
    FILE *input_fp;

    input_fp = fopen("text.txt", "r");

    if (input_fp == NULL)
    {
        exit(1);
    }

    fclose(input_fp);

    return 0;
}
```

# Advanced C

## File Input / Output - Functions

### Prototype

```
int *fgetc(FILE *fp);
int fputc(int c, FILE *fp);
```

### Example

```
#include <stdio.h>
#include <stdlib.h>

int main()
{
    FILE *input_fp;
    char ch;

    input_fp = fopen("text.txt", "r");

    if (input_fp == NULL)
    {
        exit(1);
    }

    while ((ch = fgetc(input_fp)) != EOF)
    {
        fputc(ch, stdout);
    }

    fclose(input_fp);

    return 0;
}
```

# Advanced C

## File Input / Output - Functions

### Prototype

```
int fprintf(char *string, char *format, ...);
```

### Example

```
#include <stdio.h>
#include <stdlib.h>

int main()
{
    FILE *input_fp;

    input_fp = fopen("text.txt", "r");

    if (input_fp == NULL)
    {
        fprintf(stderr, "Can't open input file text.txt!\n");
        exit(1);
    }

    fclose(input_fp);

    return 0;
}
```

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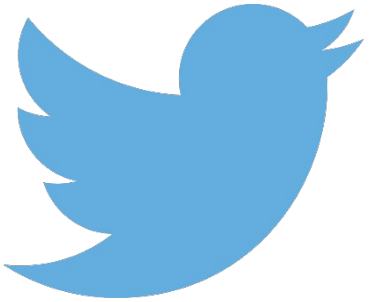

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