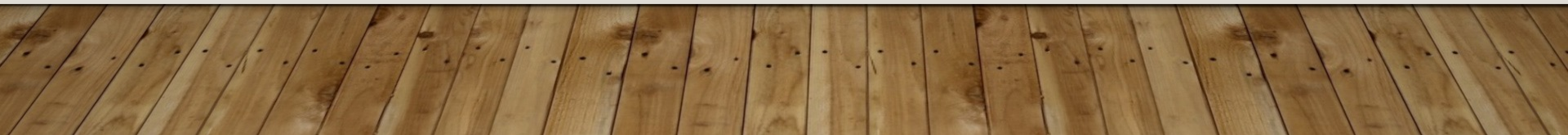


# ISIT307 - WEB SERVER PROGRAMMING

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LECTURE 7.2 – RECURSION AND DATA STRUCTURES IN PHP



# LECTURE PLAN

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- Recursion
- Data structures

Sources:

Rahman, M., 2017. *PHP 7 Data Structures and Algorithms*. Packt Publishing Ltd.

Gilberg R., Forouzan B, 2004, *Data Structures : A Pseudocode Approach with C*. Cengage Learning

# RECURSION

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- Recursion occurs when something contains, or uses, a similar version of itself
  - That similar version then contains or uses another similar version of itself, and so on...
- The number of repetitions, or "depth" of the recursion, is limited by some sort of end condition
- In programming recursion occurs when a function calls itself
  - end condition - base case
  - reduction step – function call itself

# RECURSION

---

- A good recursive method :
  - begins with a conditional statement with a return – without base case the recursion will run indefinitely
  - recursive calls to sub-problems converge to the base case
  - called sub-problems should not overlap
- **\*every call creates a new instance of the function**

```
function myRecursiveFunction() {  
    // (do the required processing...)  
    if ( baseCaseReached ) {  
        // end the recursion  
        return;  
    } else {  
        // continue the recursion  
        myRecursiveFunction();  
    }  
}
```

# RECURSION

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- Some cases when is useful to use recursion:
  - When processing recursively defined data
  - When you have nested structures

# RECURSION – EXAMPLE (I)

## FACTORIAL

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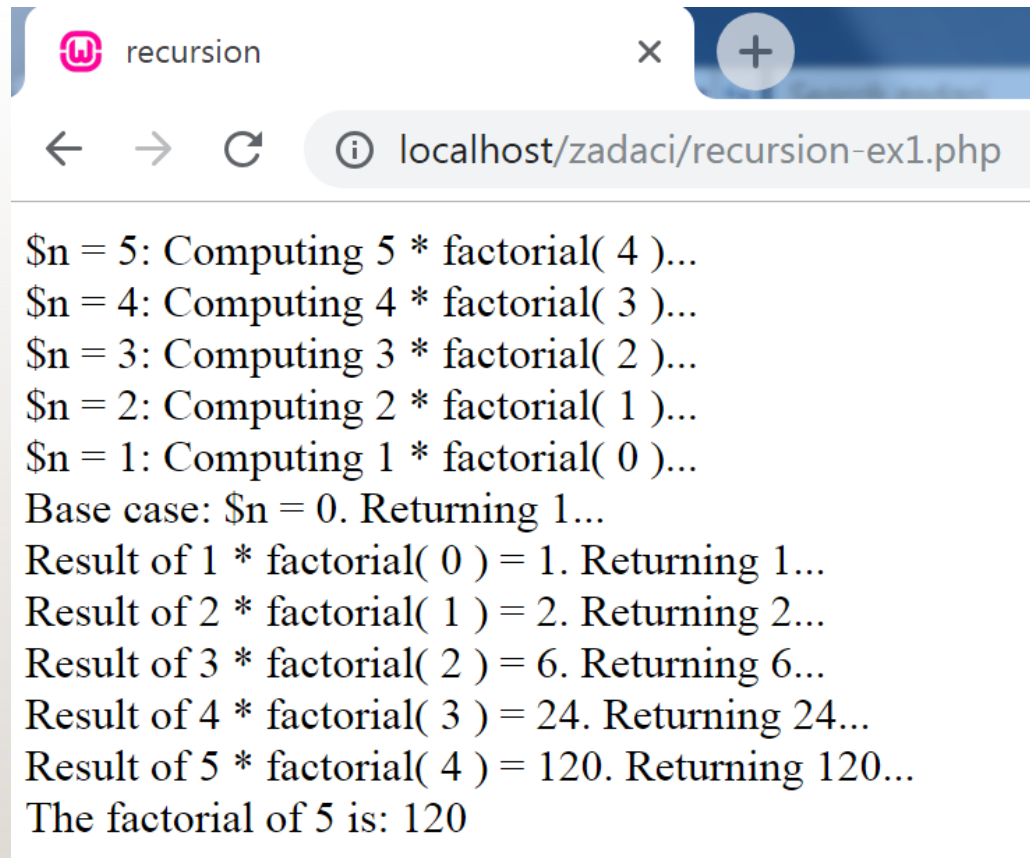
```
<?php
function factorial( $n ) {
    if ( $n == 0 ) {
        echo "Base case: \$n = 0. Returning 1...<br>";
        return 1;
    } else {
        echo "\$n = $n: Computing $n * factorial( " .
                                                    ($n-1) . " ) ...<br>";

        $result = ( $n * factorial( $n-1 ) );
        echo "Result of $n * factorial( " . ($n-1) .
                                                    " ) = $result. Returning $result...<br>";
        return $result;
    }
}

echo "The factorial of 5 is: " . factorial( 5 );
?>
```

# RECURSION – EXAMPLE (I) OUTPUT

## FACTORIAL



The screenshot shows a web browser window with the title 'recursion'. The address bar displays 'localhost/zadaci/recursion-ex1.php'. The main content area shows the output of a recursive factorial function for n=5. The output is as follows:

```
$n = 5: Computing 5 * factorial( 4 )...  
$n = 4: Computing 4 * factorial( 3 )...  
$n = 3: Computing 3 * factorial( 2 )...  
$n = 2: Computing 2 * factorial( 1 )...  
$n = 1: Computing 1 * factorial( 0 )...  
Base case: $n = 0. Returning 1...  
Result of 1 * factorial( 0 ) = 1. Returning 1...  
Result of 2 * factorial( 1 ) = 2. Returning 2...  
Result of 3 * factorial( 2 ) = 6. Returning 6...  
Result of 4 * factorial( 3 ) = 24. Returning 24...  
Result of 5 * factorial( 4 ) = 120. Returning 120...  
The factorial of 5 is: 120
```



# RECURSION – EXAMPLE (2)

## DISPLAYING TREE OF FILES AND FOLDERS

---

```
<?php
$folderPath = "C://wamp64/www";
function readFolder( $path ) {
    if ( !( $dir = opendir( $path ) ) )
        die( "Can't open $path" );
    $filenames = array();
    while ( $filename = readdir( $dir ) ) {
        if ( $filename != '.' && $filename != '..' ) {
            if ( is_dir( "$path/$filename" ) )
                $filename .= '/';
            $filenames[] = $filename;
        }
    }
}
closedir ( $dir );
```



# RECURSION – EXAMPLE (2)

## DISPLAYING TREE OF FILES AND FOLDERS

---

```
// Display the filenames, and process any subfolders
echo "<ul>";
foreach ( $filenames as $filename ) {
    echo "<li>$filename";

    if ( substr( $filename, -1 ) == '/' )
        readFolder( "$path/" . substr( $filename, 0, -1 ) );
    echo "</li>";
}
echo "</ul>";
}
echo "<h2>Contents of '$folderPath':</h2>";
readFolder( $folderPath );
?>
```

# RECURSION – EXAMPLE (2) OUTPUT

## DISPLAYING TREE OF FILES AND FOLDERS

---

- FileDownloader.php
- PHPCodeBlocks.php
- ViewFiles.php
- backup/
  - Comment.1545915450.4533.txt
  - Comment.1545915465.3897.txt
  - Comment.1545915491.6001.txt
  - Comment.1545954019.5635.txt
  - Comment.1545954031.5897.txt
  - Comment.1545954091.3807.txt
  - Comment.1545954098.7962.txt
  - Comment.1545954276.091.txt
  - Comment.1545955214.9985.txt
  - Comment.1545955221.8813.txt
- comments/
  - Comment.1545915450.4533.txt
  - Comment.1545915465.3897.txt
  - Comment.1545915491.6001.txt
  - Comment.1545954019.5635.txt
  - Comment.1545954031.5897.txt
  - Comment.1545954091.3807.txt
  - Comment.1545954098.7962.txt
  - Comment.1545954276.091.txt
  - Comment.1545955214.9985.txt
  - Comment.1545955221.8813.txt
- createDatabase.php
- createTable.php
- example-ch10/
  - ElectronicsBoutique.css

# RECURSION AND STATIC VARIABLES

---

- A static variable exists only in a local function scope, but it does not lose its value when program execution leaves this scope
- Static variables provide one way to deal with recursive functions

# RECURSION AND STATIC VARIABLES (EXAMPLE)

---

```
<?php
function test()
{
    static $step = 0;
    if ($step < 10) {
        $step++;
        echo "<p>into function step = $step </p>";
        test();
    }
    else {
        echo "finish";
    }
}
test();
echo "<p>out of function";
?>
```

into function step = 1

into function step = 2

into function step = 3

into function step = 4

into function step = 5

into function step = 6

into function step = 7

into function step = 8

into function step = 9

into function step = 10

finish

out of function

# DATA STRUCTURES

---

- Data structures are very important components for computers and programming languages
- Majority of the data structures are inspired from real life, so can be used to solve a real-life problems or find a solutions
- For example: find the shortest way; diet charting; preparing a family tree; or organization hierarchy

# DATA STRUCTURES

---

- PHP is a weakly typed language and has eight primitive data types (boolean, integer, float, string, array, object, resource, and null)
- The primitive data types have one particular objective - storing data
- In order to achieve some flexibility in performing operations on those data, the data types can be used to represent particular model and perform some operations



# DATA STRUCTURES

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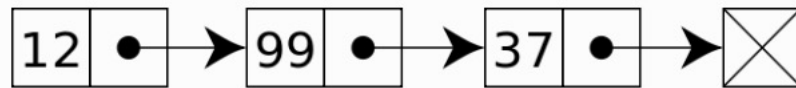
- This particular way of handling data through a conceptual model is known as Abstract Data Type (ADT)
- Data structures are concrete representations
- Some common ADT:
  - List
  - Map
  - Set
  - Stack
  - Queue
  - Priority queue
  - Graph
  - Tree



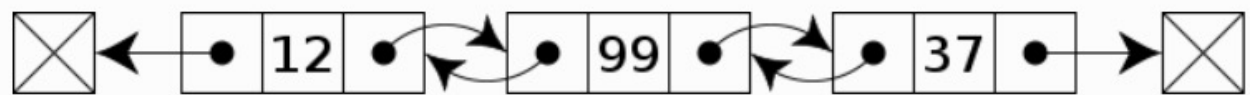
# DATA STRUCTURES

---

- A linked list is a linear data structure which is a collection of data elements also known as nodes
- Listed items are connected through a pointer which is known as a link - linked list



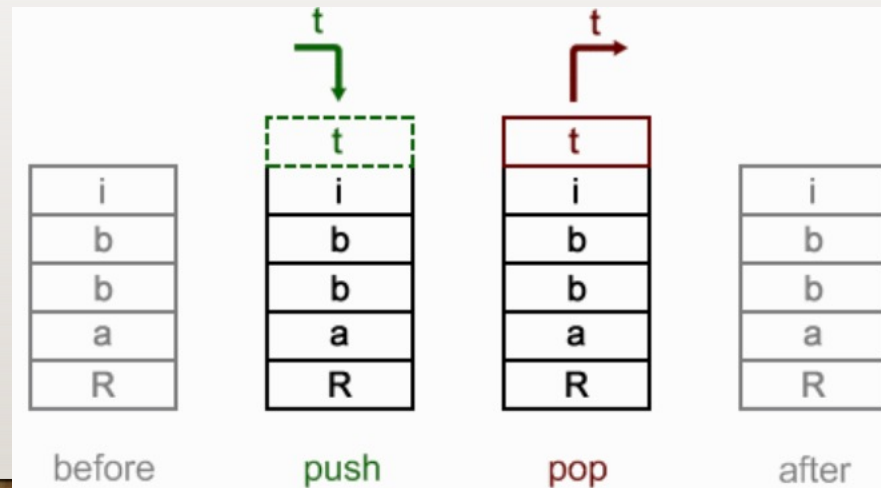
- A doubly linked list is a special type of linked list where not only previous node is connected to the next node, but reverse link apply as well
- As a result, it can move forward and backward within the list



# DATA STRUCTURES

---

- A stack is a linear data structure with the LIFO principle
- Stacks have only one end to add a new item or remove an item
- It is one of the oldest and most used data structures in computer technology



# STACK - SAMPLE IMPLEMENTATION

---

```
class Stack
{
    protected $stack;
    protected $top;

    public function __construct() {
        $this->stack = array();
        $this->top = -1;
    }

    public function push($item) { . . . }

    public function pop() { . . . }

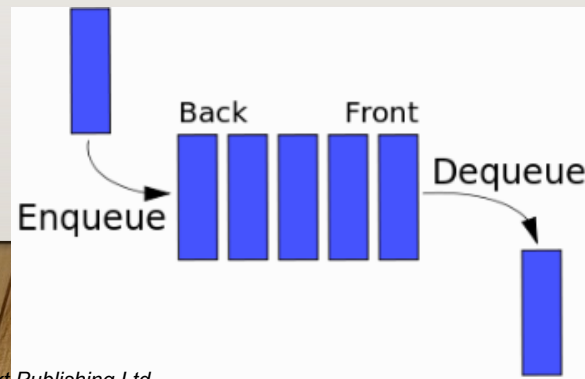
    public function top() { . . . }

    public function isEmpty() { . . . }
}
```

# DATA STRUCTURES

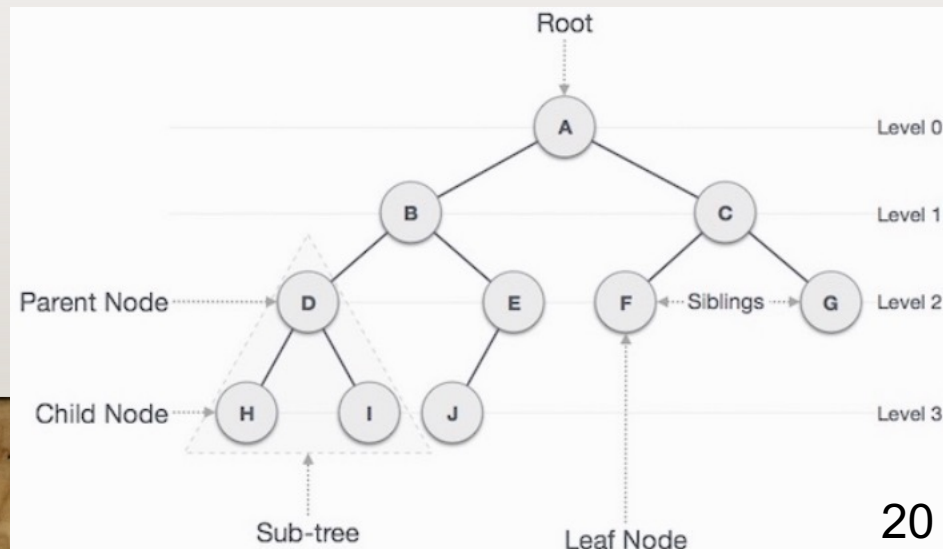
---

- A queue is another linear data structure which follows the FIFO principle
- A queue allows two basic operations on the collection
  - **enqueue** - allows us to add an item to the back of the queue
  - **dequeue** - allows us to remove an item from the front of the queue
- A queue is another of the most used data structures in computer technology



# DATA STRUCTURES

- A tree is the most widely used nonlinear data structure in the computing world
  - It is highly used for hierarchical data structures
- A tree consists of nodes and there is a special node which is known as the root of the tree which starts the tree structure
  - Other nodes descend from the root node
- Tree data structure is recursive which means a tree can contain many subtrees
- Nodes are connected with each other through edges



# BINARY TREE – SAMPLE IMPLEMENTATION

---

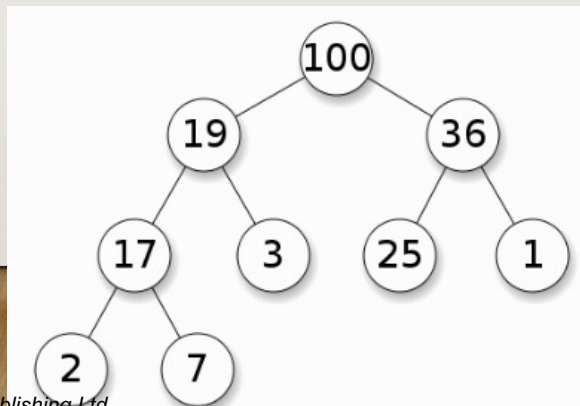
```
class BinaryNode
{
    public $value;
    public $left;
    public $right;

    public function __construct($item) {
        $this->value = $item;
        $this->left = null; // new nodes are leaf nodes
        $this->right = null;
    }

    public function addChildren($left, $right) {
        $this->left = $left;
        $this->right = $right;
    }
}
- - -
class BinaryTree
{
    . . .
}
```

# DATA STRUCTURES

- A heap is a special tree-based data structure which satisfies the heap properties
  - If the largest key is the root and smaller keys are leaves – it is known as max heap
  - If the smallest key is the root and larger keys are leaves – it is known as min heap
- Though the root of a heap structure is either the largest or smallest key of the tree, it is not necessarily a sorted structure

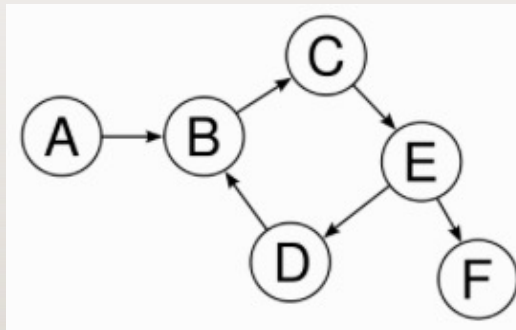




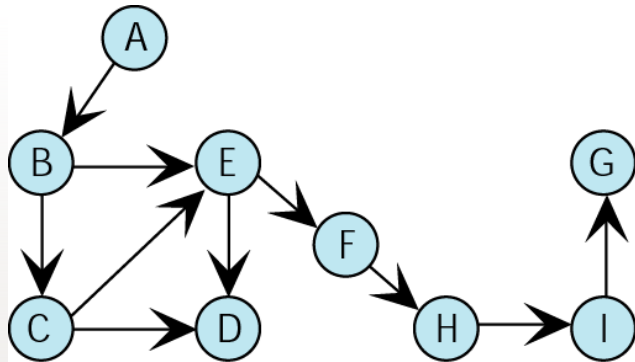
# DATA STRUCTURES

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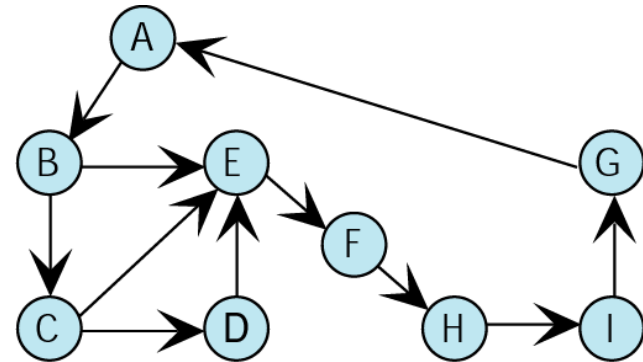
- A graph data structure is a special type of nonlinear data structure which consists of a finite number of vertices or nodes, and edges or arcs
- A graph can be directed or undirected
  - a directed graph clearly indicates the direction of the edges
  - an undirected graph mentions the edges, not the direction



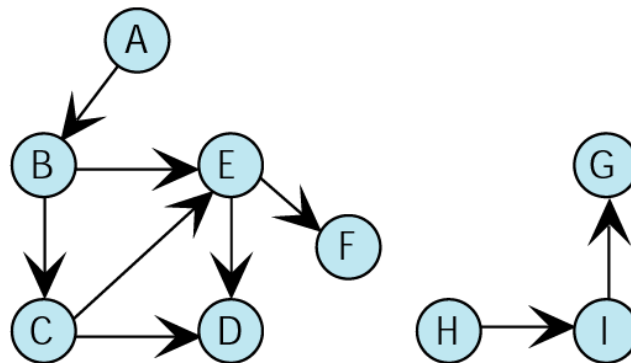
# DATA STRUCTURES - GRAPH



**(a) Weakly connected**



**(b) Strongly connected**



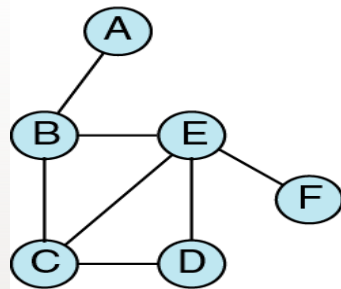
**(c) Disjoint graph**

# DATA STRUCTURES - GRAPH

---

- To represent a graph, we need to store two sets
  - the first set represents the vertices (nodes) of the graph and
  - the second set represents the edges (arcs)
- Two methods can be used:
  - Adjacency matrix
  - Adjacency list

# DATA STRUCTURES - GRAPH



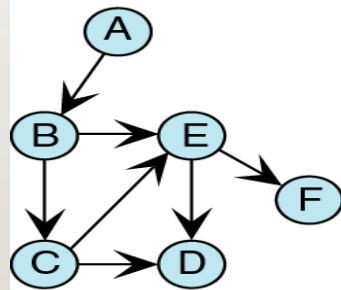
A
B
C
D
E
F

Vertex vector

	A	B	C	D	E	F
A	0	1	0	0	0	0
B	1	0	1	0	1	0
C	0	1	0	1	1	0
D	0	0	1	0	1	0
E	0	1	1	1	0	1
F	0	0	0	0	1	0

Adjacency matrix

## Adjacency matrix for non-directed graph



A
B
C
D
E
F

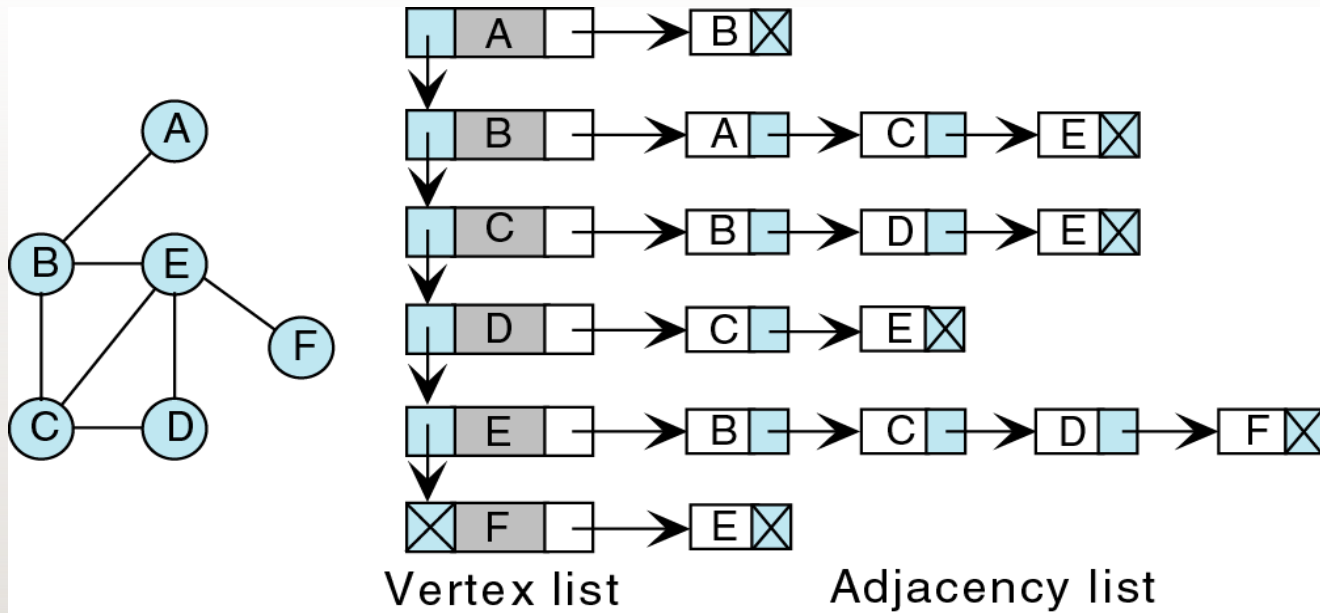
Vertex vector

	A	B	C	D	E	F
A	0	1	0	0	0	0
B	0	0	1	0	1	0
C	0	0	0	1	1	0
D	0	0	0	0	0	0
E	0	0	0	1	0	1
F	0	0	0	0	0	0

Adjacency matrix

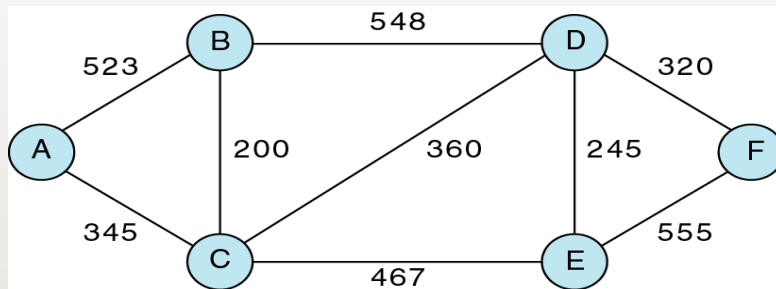
## Adjacency matrix for directed graph

# DATA STRUCTURES - GRAPH



# DATA STRUCTURES

- A network is a graph whose lines are weighted - weighted graph
- The meaning of the weights depends on the application

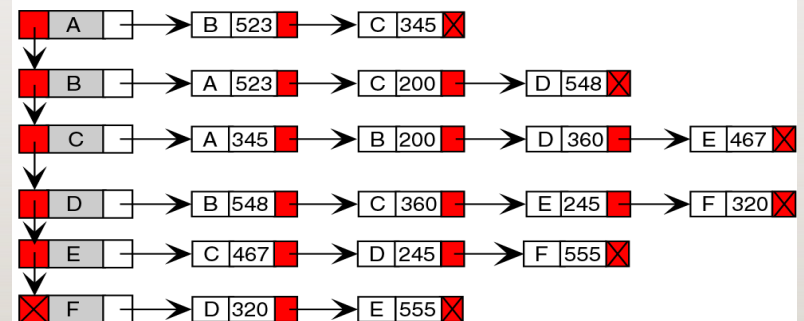
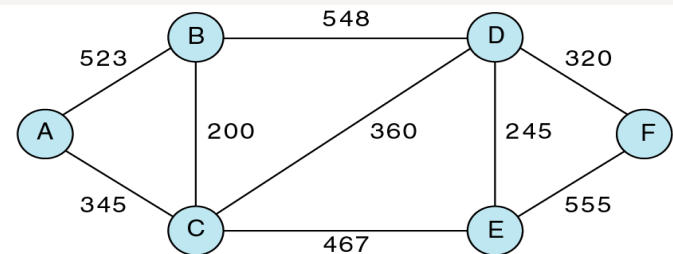


A
B
C
D
E
F

Vertex vector

	A	B	C	D	E	F
A	0	523	345	0	0	0
B	523	0	200	548	0	0
C	345	200	0	360	467	0
D	0	548	360	0	245	320
E	0	0	467	245	0	555
F	0	0	0	320	555	0

Adjacency matrix



Vertex list

Adjacency list

# STANDARD PHP LIBRARY (SPL) AND DATA STRUCTURES

---

- SPL was created to solve common problems which were lacking in PHP as its support of data structures
- SPL comes with core PHP installations and does not require any extension or change in configurations to enable it



# STANDARD PHP LIBRARY (SPL) AND DATA STRUCTURES

---

- SPL provides a set of standard data structures through Object-Oriented Programming in PHP
- The supported data structures are:
  - Doubly linked lists: It is implemented in `SplDoublyLinkedList`
  - Stack: It is implemented in `SplStack` by using `SplDoublyLinkedList`
  - Queue: It is implemented in `SplQueue` by using `SplDoublyLinkedList`
  - Heaps: It is implemented in `SplHeap`; it also supports max heap in `SplMaxHeap` and min heap in `SplMinHeap`
  - Priority queue: It is implemented in `SplPriorityQueue` by using `SplHeap`
  - Arrays: It is implemented in `SplFixedArray` for a fixed size array
  - Map: It is implemented in `SplObjectStorage`