Swarm Intelligence :-

* Swarm Intelligence was introduced by "Gerardo Beni and Jing wang" in the year 1989.

* Def :- Swarm intelligence means using the knowledge of collective objects like people, insects etc together and then reaching the optimized solution for a given problem.

* Here Swarm refers to the collection or group of objects

* In swarm Intelligence, each individual in the group is independent of others, each individual is responsible for their own contribution to solve that problem regardless of what others are doing. (GFM)

Properties of Swarm Intelligence :-

* It is composed of many Individuals
* The individuals are relatively homogeneous
* The interactions among the Individuals are based on simple behaviours rules related to the local information that the individuals exchange directly via the environment

* The overall behaviour of the system results from the interactions of individuals with each other and with their environment, that is the group behaviour self-organizes.

Examples of Swarm Intelligence Algorithms:-

(i) Ant colony optimization (ACO)

(ii) ~~Swarm Bees~~ Particle Swarm optimization (PSO)

(iii) River formation dynamics

(iv) Gravitation search Algorithm.

(v) Charged system search etc...

Ant colonies:-

An ant colony is a population of ants, typically from a single species, capable of maintaining their complete life cycle.

* Ant colonies are the best example of the Swarm Intelligence.
* Ant colonies are highly organized societies where thousands of ants work collectively to
  * Find and collect food
  * Build and repair nests
  * Retrieve prey
  * cluster and remove dead bodies.
* In ant colonies - there is no leader or boss.
* Here the queen ant doesn't rule the entire colony, the only work of queen ant is to lay eggs.
* Ants follow simple signals like smell or touch to decide what to do.
* Ants releases a chemical substance named <u>pheromone</u> in order to establish communication among them.

* A single ant is not very smart, but together thousands of ants can solve big and complex problems.

* This teamwork has inspired scientists to develop computer models and robots that copy their behaviours.

* Ant colony optimization is a technique in computer science inspired by ant colonies.

Ant colony optimization :=

* Ant colony optimization is a class of optimization algorithms modeled on the actions of an Ant colony.

* Ant colony optimization is a probabilistic technique for solving computational problems which can be reduced to finding good paths through graphs.

* Aco methods are useful in problems that need to find paths to goals.

* In Aco - Artificial ants - locate optimal solution by moving through a parameter space representing all possible solutions.

* They leave virtual pheromones on good soln.

This Algorithm is inspired by forgiving behaviour of ants.

1) The first ant finds the food source (F), via a way (a), then returns to the nest (N), leaving behind a trial pheromone (b).

2) Ants indiscriminately follow ~~four~~ possible ways, but the strengthening of the runway makes it more attractive as the shortest route.

3) Ants take the shortest route, long portions of other ways lose their trail pheromones.

Pseudo code:-

Procedure [best] = Aco (max_it, N, To)

- Clustering and data mining

```
procedure [best] = ACO(max_it,N,τ0)
   initialize τij   //usually initialized with the same τ0
   initialize best
   place each ant k on a randomly selected edge
   t ← 1
   while t < max_it do,
      for i = 1 to N do,  //for each ant
         build a solution by applying a probabilistic
         transition rule (e-1) times.
         //The rule is a function of τ and η
         //e is the number of edges on the graph G
      end for
      eval the cost of every solution built
      if an improved solution is found,
         then update the best solution found
      end if
      update pheromone trails
      t ← t + 1
   end while
end procedure
```

Steps of the ACO Algorithm:

1. **Initialization**
   - Start with all edges having the same pheromone value (τ_0).
   - Set the best solution as empty.
   - Place each ant randomly on an edge of the graph.
   - Set iteration counter t = 1.

2. **Main Loop (repeat until max iterations)**
   - For each ant (N ants):
     - The ant builds a solution (like finding a path in a graph).
     - This is done by choosing edges **probabilistically** based on:
       - **τ (pheromone level)** → preference for paths with strong trails.
       - **η (heuristic information, like distance or cost)** → preference for good edges.
     - This is repeated until the ant completes its path.
3. **Evaluate Solutions**
   - After all ants build their paths, calculate the **cost/quality** of each solution.
4. **Update Best Solution**
   - If a better solution than the current best is found, update the best.
5. **Update Pheromones**
   - Increase pheromones on good paths (ants found better solutions).
   - Evaporate pheromones (reduce values over time) to avoid getting stuck in bad paths.
6. **Next Iteration**
   - Increase t and repeat until t < max_it.

Q) Swarm Robotics

Swarm Robotics:-

Swarm Robotics is a branch of autonomous robotics that takes inspiration from biological systems, especially social insects like ants, bees, wasps and termites.

* Swarm robotics refers to the application of swarm intelligence principles and methodologies to groups of simple robots that work together in a decentralized manner to accomplish complex tasks.
* swarm robotics aims to achieve tasks that are beyond the capabilities of individual robots by utilizing local communication and sensing abilities.
* Here the robots perform tasks through distributed control and self-organization, without a central leader.
* Swarm robotics follows a bottom-up approach, where each robot follows simple rules and reacts to local changes in the environment and other robots. Complex group behaviors then emerges naturally from these interactions.

Reasons why Swarm Robotics are useful:-

* Some tasks are too complex for a single robot. So multiple robots can perform tasks. Tasks
* And many simple robots are cheaper and easier to build, more flexible than a Single complex robot.
* Falling prices of small commercial robots made experiments easier.
* This swarm robotics is encouraged by some biological sectors like studies of emergent behaviour etc..
* Swarm robotics also helps understand problems in social and life sciences like psychology and biology.

Working of Swarm Robotics:-

* Each robot follows simple behaviour rules
* Robots interact with one another and the environment
* The task is achieved through emergent group-level behaviour, not individual intelligence.

challanges:-

* Sometimes groups may stagnate or deadlock due to lack of global knowledge.
* Evaluating whether the choosen rules are "best" for robots is still difficult.
* Many applications may require miniaturization for practical use.