ECM3412/ECMM409
Nature Inspired Computation
Lecture 9

Swarm Intelligence I:
Ant Colony Optimisation

Swarm Intelligence

Swarms, flocks, etc… often exhibit the following rather interesting properties:

- Individuals of the swarm are incapable of X, or could do X with only low probability.
- However, the *swarm* as a unit is able to do X, with high probability.

The ability to do X is an *emergent property* of the swarm.

Swarm Intelligence II

- Each element of the swarm has its own simple behaviour, and a set of rules for interacting with its fellows, and with the environment.
- Every element is the same – there is no central controller.
- However, X emerges as a result of these local interactions.
- E.g. ants finding food, termites building mounds, jellyfish.

Swarm Algorithms

Inspiration from swarm intelligence has led to some highly successful optimisation algorithms. We will look at:

- Ant Colony (-based) Optimisation – a way to solve optimisation problems based on … well, you work it out!
- Particle Swarm Optimisation — a different way to solve optimisation problems, based on the swarming behaviour of several kinds of organisms.

Ant Colony Optimization

My starting point for these slides was some excellent ppt by Tony White (tony@sce.carleton.ca)

With some input from David Corne

Emergent Problem Solving in *Lasius Niger* ants,

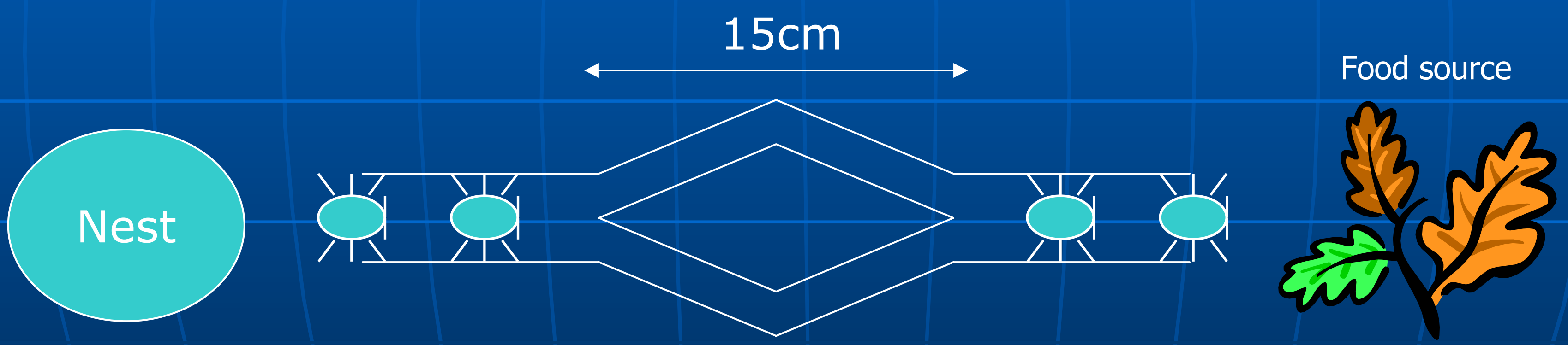
For *Lasius Niger* ants, [Franks, 89] observed:

- regulation of nest temperature within 1 degree celsius range;
- forming bridges;
- raiding specific areas for food;
- building and protecting nest;
- sorting brood and food items;
- cooperating in carrying large items;
- emigration of a colony;
- finding shortest route from nest to food source;
- preferentially exploiting the richest food source available.

These are swarm behaviours – beyond what any individual can do.

Real Ant Experiments

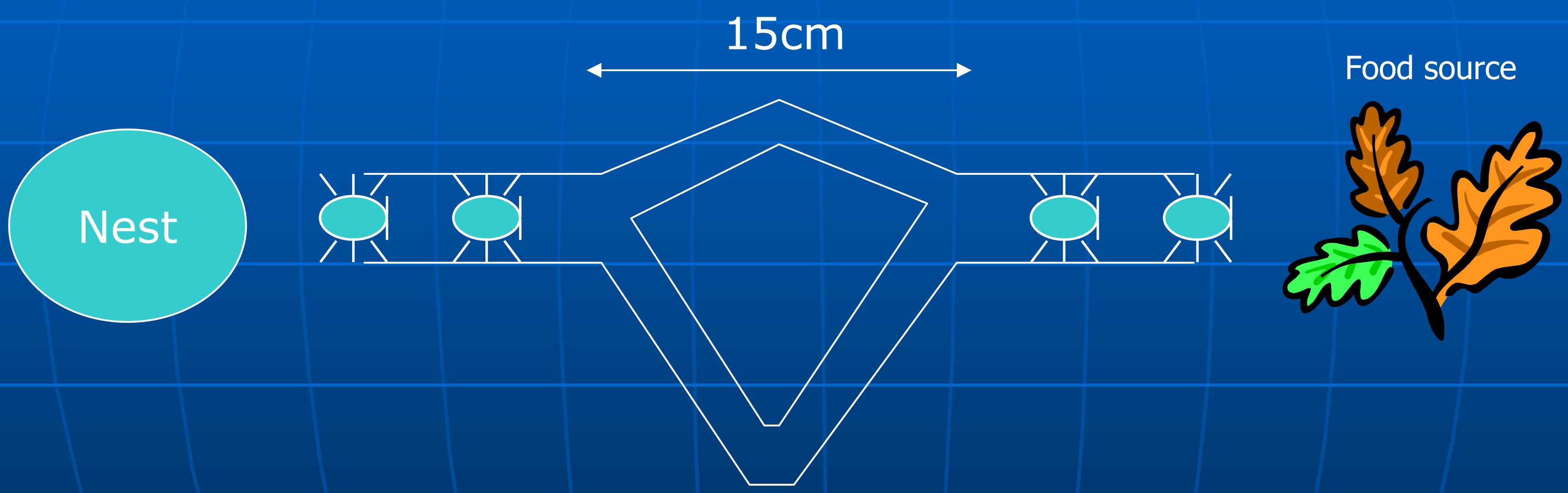
- Experiments conducted on real ants and found very interesting results.
- Deneubourg et al (1989) Double Bridge Experiment



- Ants observed over time
- To begin with - random choices of path
- Later, one path taken by most ants

Real Ant Experiments

- Deneubourg et al (1989) Double Bridge Experiment – 2nd Experiment



- To begin with - random choices of path
- Soon, shortest path selected by most ants
- How?

A key player: Stigmergy

Stigmergy is: indirect communication via interaction with the environment [Gassé, 59]

- Sematonic stigmergy
  - action of agent directly related to problem solving and affects behaviour of other agents.(e.g. an individual may position itself in the environment in such a way to influence others)
- Sign-based stigmergy
  - action of agent affects environment not directly related to problem solving activity.

I.e. swarm behaviour emerges from the way individuals .communicate through and affect their environment

Ants

Ants are behaviorally unsophisticated, but collectively they can perform complex tasks.

Ants have *highly developed sophisticated sign-based stigmergy*

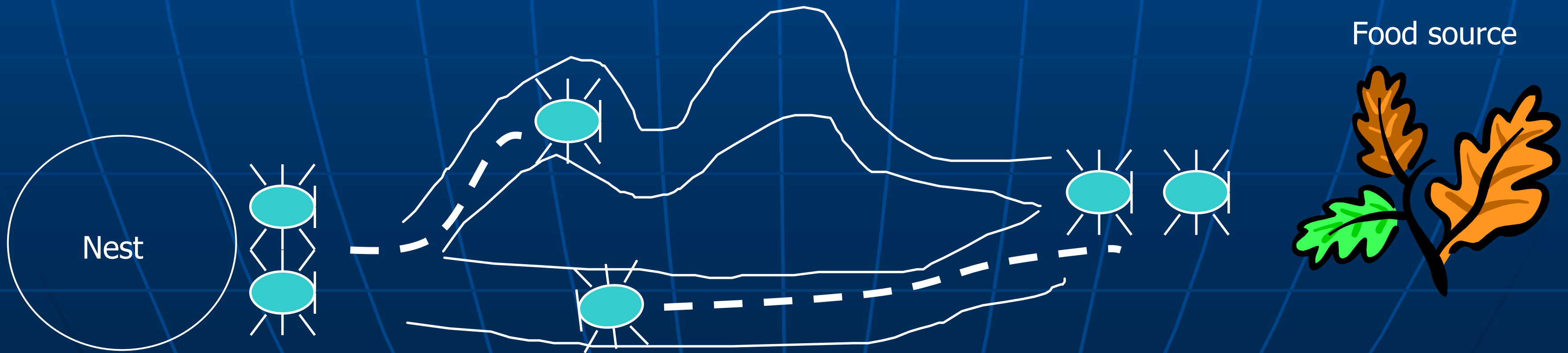
- They communicate using pheromones;
- They lay trails of pheromone that can be followed by other ants.

Pheromone Trails

Individual ants lay pheromone trails while travelling from the nest, to the nest or possibly in both directions.

The pheromone trail gradually evaporates over time.

But pheromone trail strength accumulate with multiple ants using path.



Ant Colony Optimisation Algoirithms: Basic Ideas

Ants are *agents* that:

Move along between nodes in a graph.

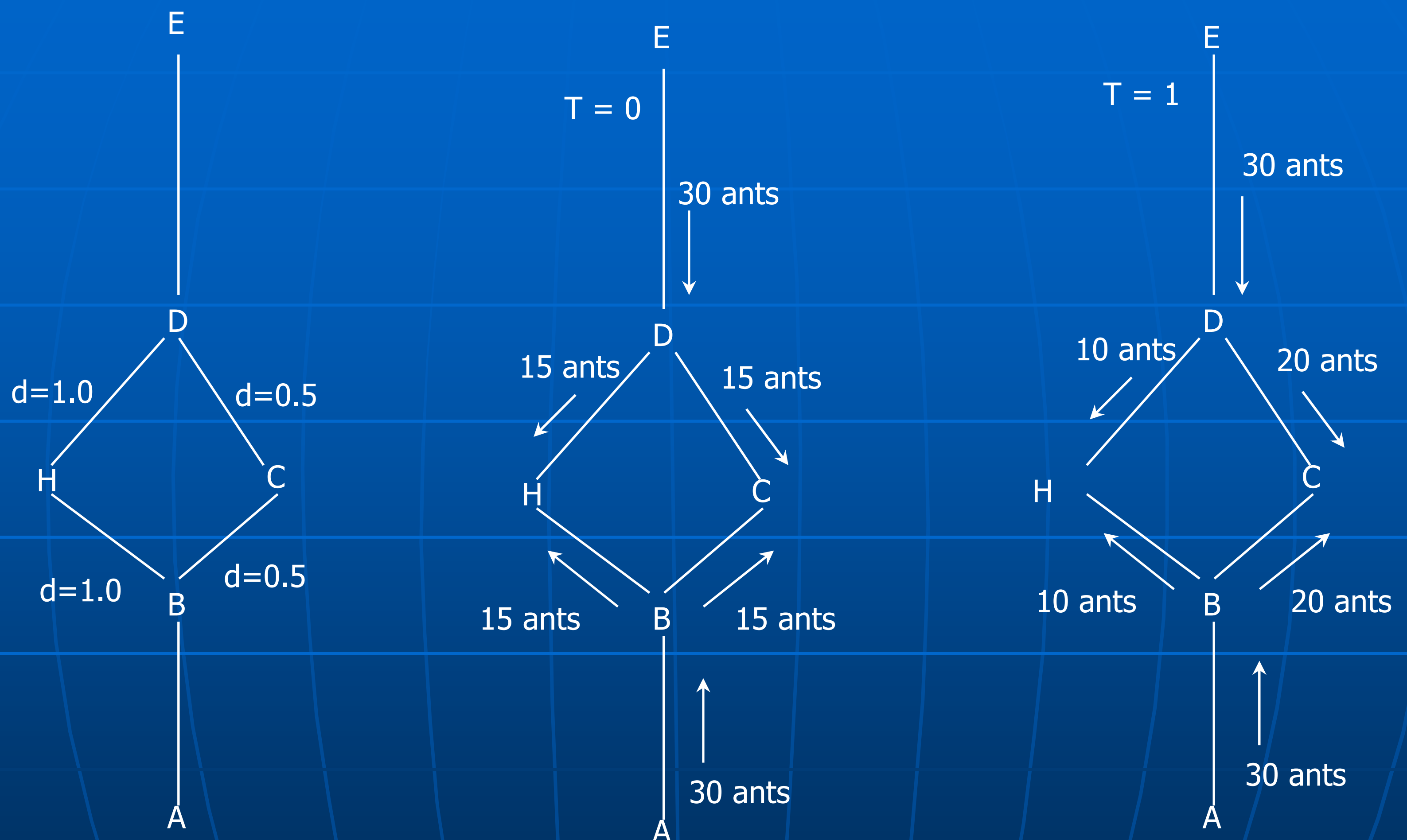
They choose where to go based on pheromone strength (and maybe other things)

An ant’s path represents a specific candidate solution.

When an ant has finished a solution, pheromone is laid on its path, according to quality of solution.

This affects behaviour of other ants by `stigmergy’ …

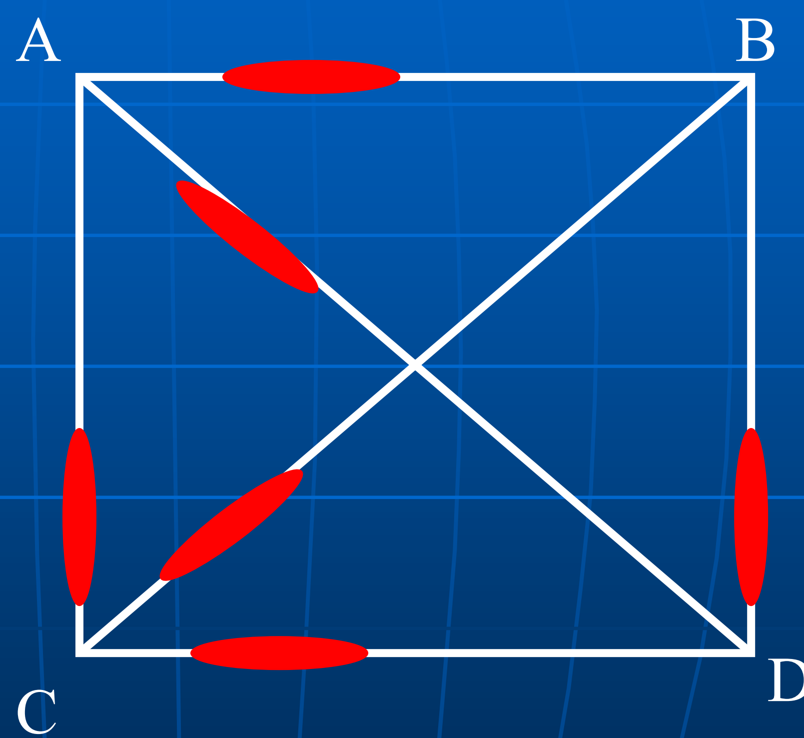
Basic Operation



- Time is discrete
- Ants move at 1 unit per timestep
- Example of an autocatalytic process

E.g. A 4-city TSP

Initially, random levels of pheromone are scattered on the edges



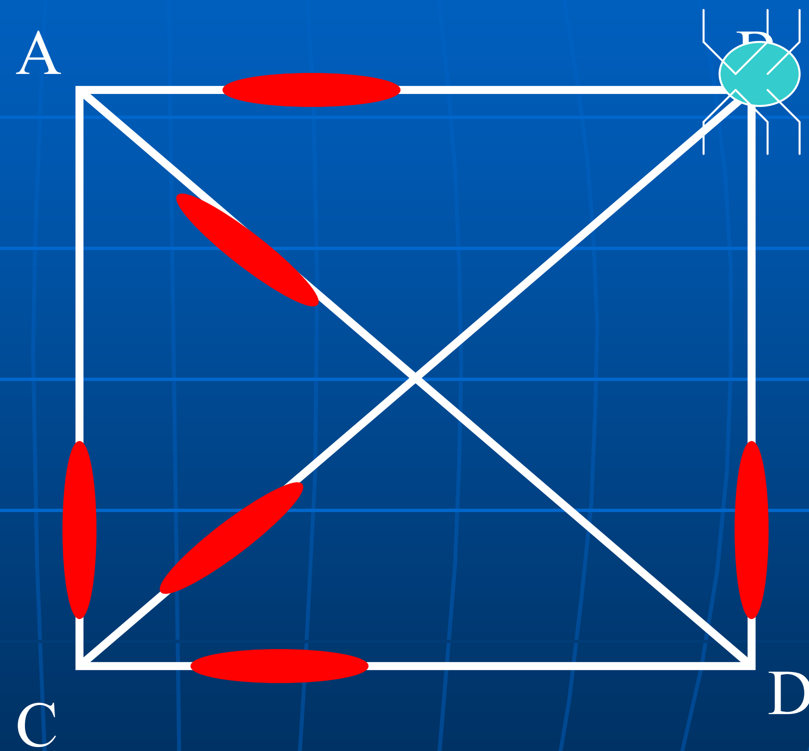

Pheromone


Ant

AB: 10, AC: 10, AD, 30, BC, 40, CD 20

E.g. A 4-city TSP

An ant is placed at a random node



Pheromone

Ant

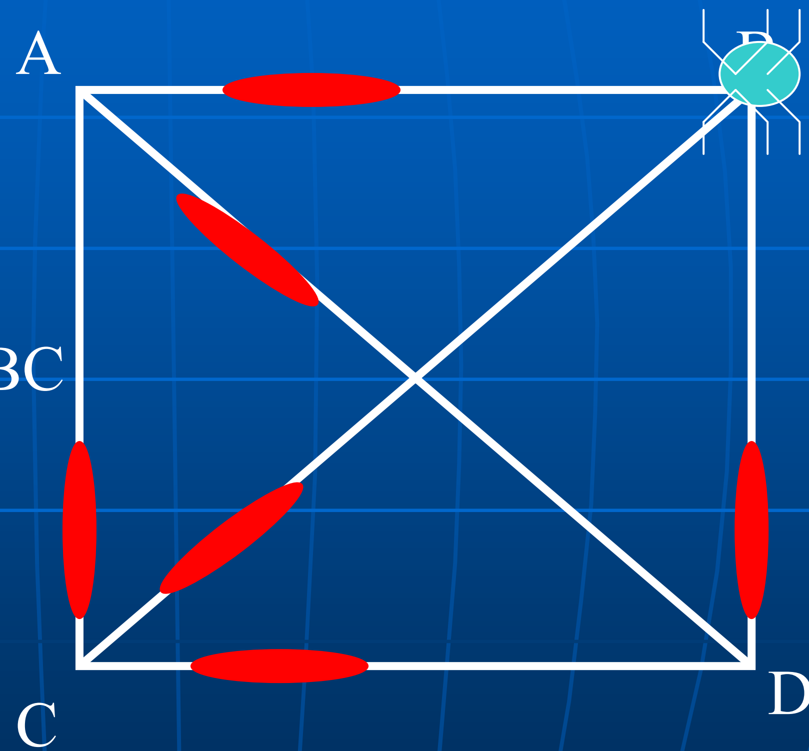
AB: 10, AC: 10, AD, 30, BC, 40, CD 20

E.g. A 4-city TSP

The ant decides where to go from that node, based on probabilities calculated from:

- pheromone strengths,
- next-hop distances.

Suppose this one chooses BC



Pheromone

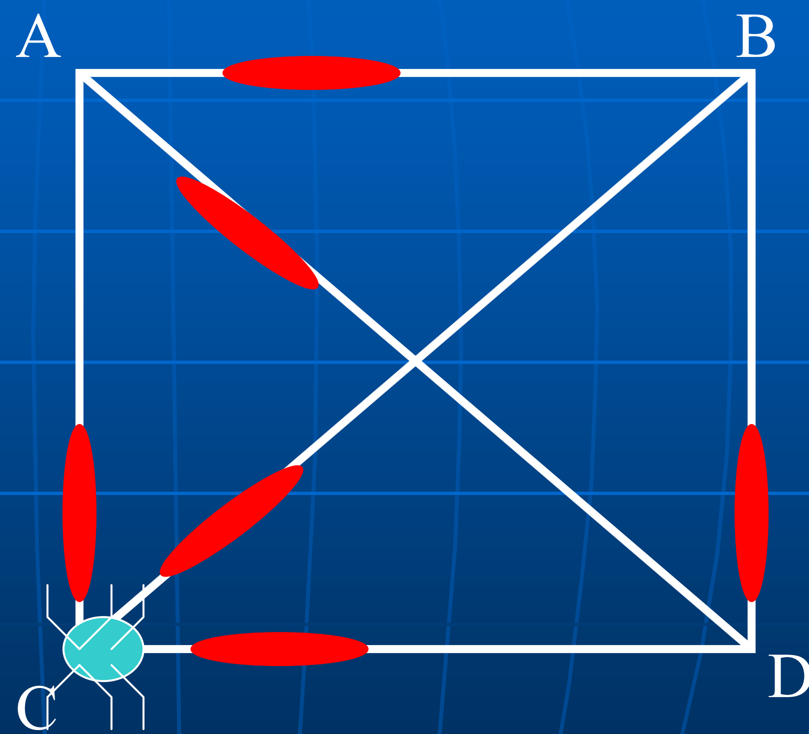
Ant

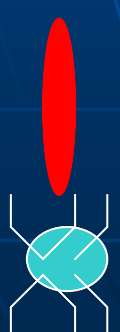
AB: 10, AC: 10, AD, 30, BC, 40, CD 20

E.g. A 4-city TSP

The ant is now at AC, and has a `tour memory' = {B, C} – so he cannot visit B or C again.

Again, he decides next hop (from those allowed) based on pheromone strength and distance; suppose he chooses CD





Pheromone

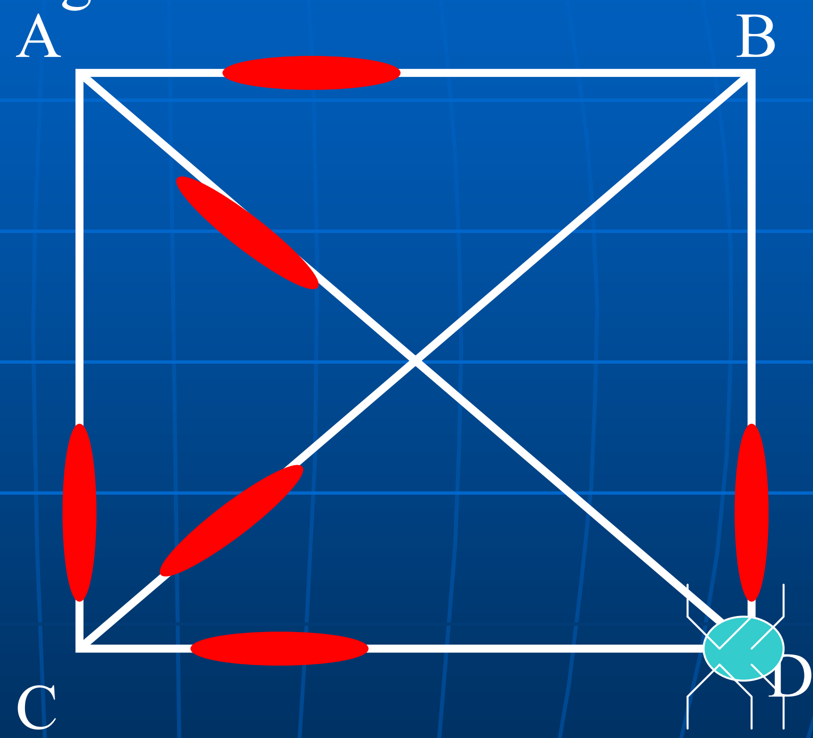
Ant

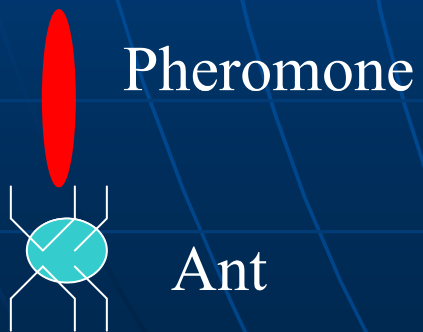
AB: 10, AC: 10, AD, 30, BC, 40, CD 20

E.g. A 4-city TSP

The ant is now at D, and has a `tour memory’ = {B, C, D}

There is only one place he can go now:





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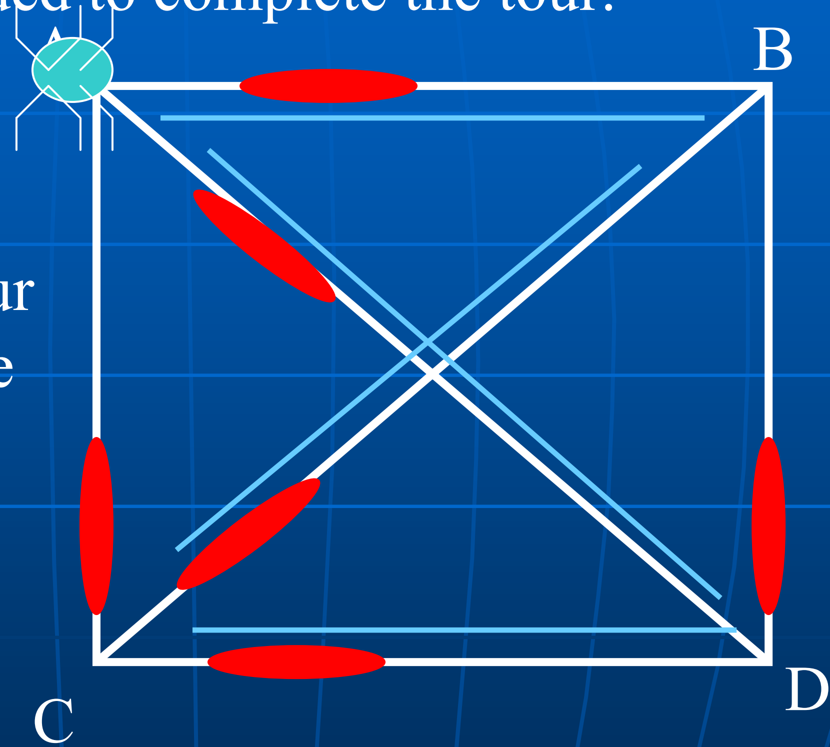
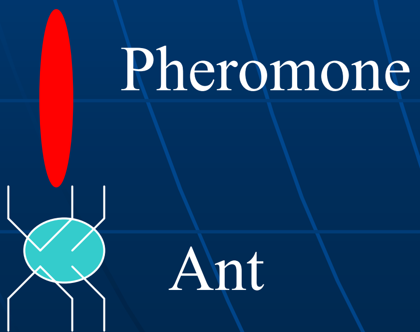
E.g. A 4-city TSP

So, he finished his tour, having gone over the links: BC, CD, and DA. AB is added to complete the tour.



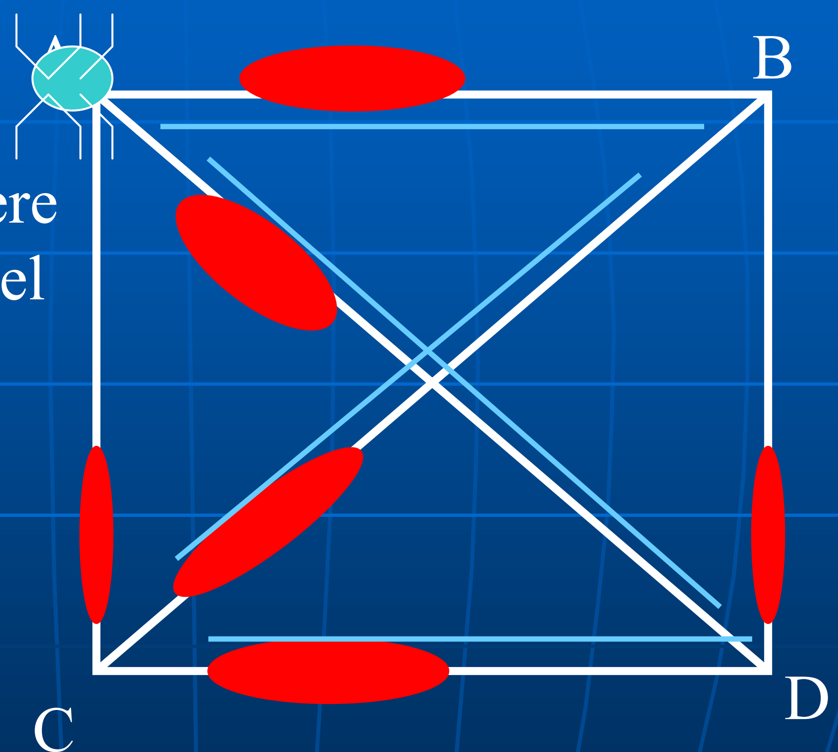
Now, pheromone on the tour is increased, in line with the fitness of that tour.



AB: 10, AC: 10, AD, 30, BC, 40, CD 20

E.g. A 4-city TSP

Next, pheromone everywhere is decreased a little, to model decay of trail strength over time



Pheromone

Ant

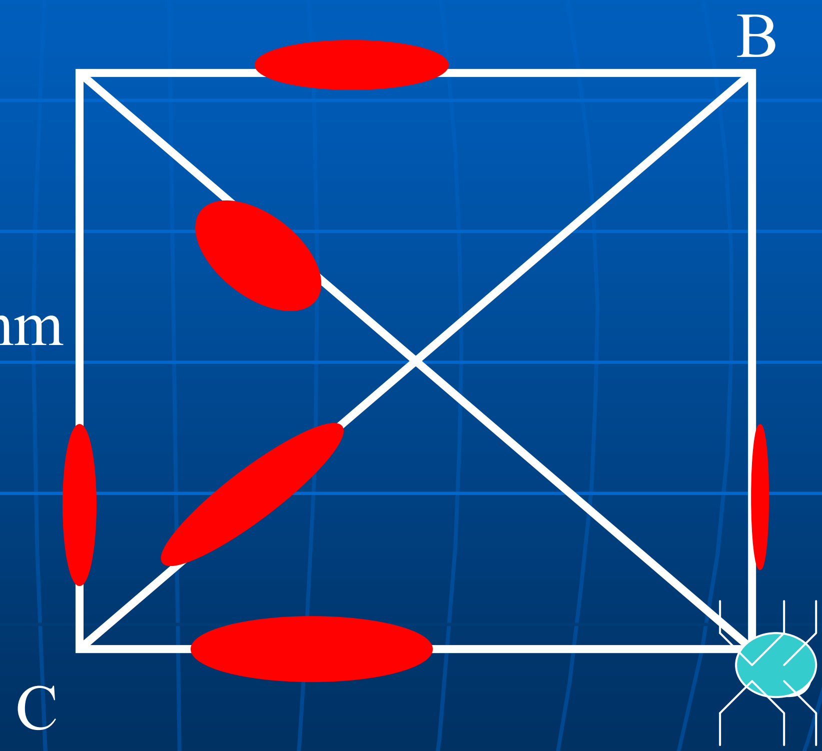
AB: 10, AC: 10, AD, 30, BC, 40, CD 20

E.g. A 4-city TSP

We start again, with another ant in a random position.

Where will he go?

Next time, the actual algorithm and variants.




Pheromone


Ant

AB: 10, AC: 10, AD, 30, BC, 40, CD 20

Ant Colony WWW references

- http://iridia.ulb.ac.be/~mdorigo/ACO/ACO.html

Examinable Reading

Specific papers that:

- Will be posted on the Study Resources
- Relate fairly closely in lectures
- Not (in fact, far from) fully covered in lectures
- For you to read, hopefully enjoy, and try to understand
- May turn up in the exam
- May not turn up in the exam

General Notes on examinable reading

- If you revise a paper so throughly that you can reproduce it in the exam word for word, you are wasting your revision time!
- If you read it, understanding the general gist, but have trouble with lots of the detail, then that’s what I expect.
- If some of your trouble with the detail hampers your overall understanding of the main points, then I would expect you to work harder at understanding those bits – via a bit of personal research (e.g. google, or emailling me a clear question).