

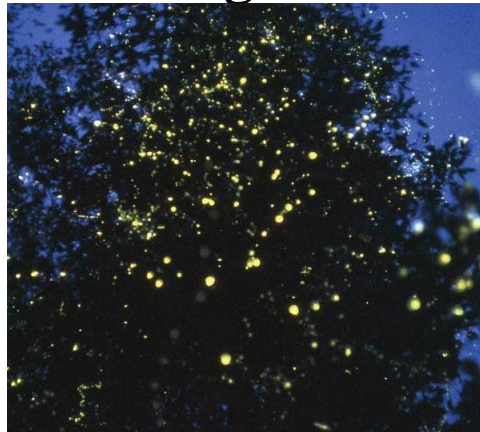
Scientific Investigation

To discover the rules behind a given phenomenon

- **Observe and analyze** relevant data
- **Develop** hypotheses (your own guessed rules)
- **Test** hypotheses through more experiments, analysis, simulation
- **Compare** the results from the tests to the observed phenomenon
 - If they are consistent, great
 - If not, go back to **make more observations, revise hypotheses, do more tests** ... until discovering rules or concluding the problem to be very hard...

Emergence

- **global, unexpected** patterns emerged out of **local, simple interactions**
 - e.g. the synchronization of hundreds or thousands of fireflies: First they flash randomly but after some time and influencing each other, they flash in sync.
 - No leader control
 - Simple rules behind this: all fireflies have nearly the same frequency for their flashing, but their phase is shifted. If a firefly receives a flash of a neighbor firefly, it flashes slightly earlier.



Emergence Examples

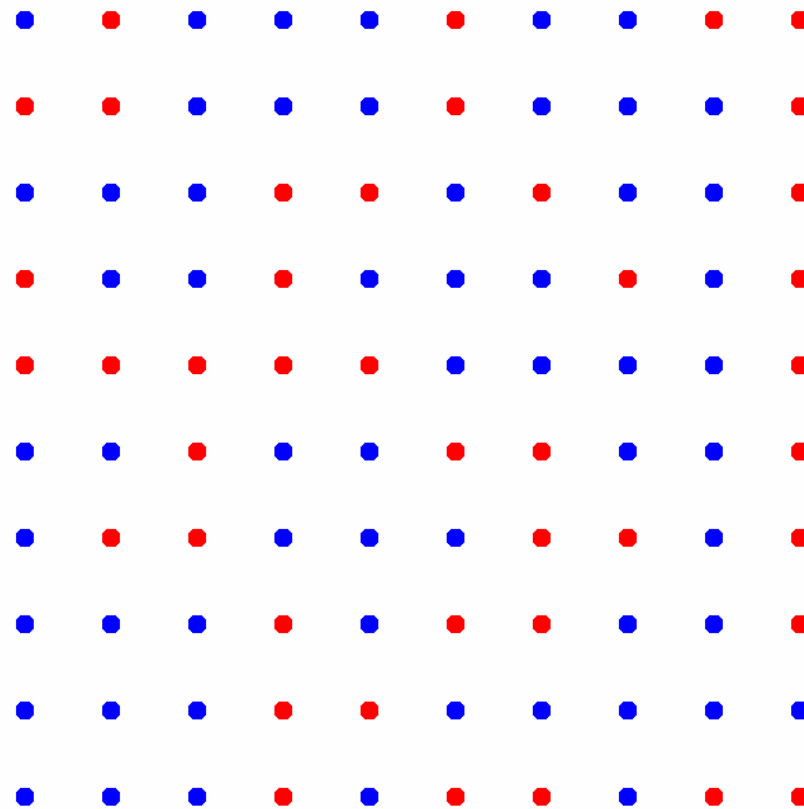
(<http://en.wikipedia.org/wiki/Emergence>)

- Emergence in Nature
 - living, biological systems:
 - a school of fish, a flock of bird: Rules -- go in the same direction as neighbors, don't get too close, and flee any predators
 - Non-living, physical systems
- Emergence in humanity
 - economics, internet, cities
- Emergence in political philosophy
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Our Emergence Example

- 2D array of dots, initially with a random distribution of red and blue colors, e.g.



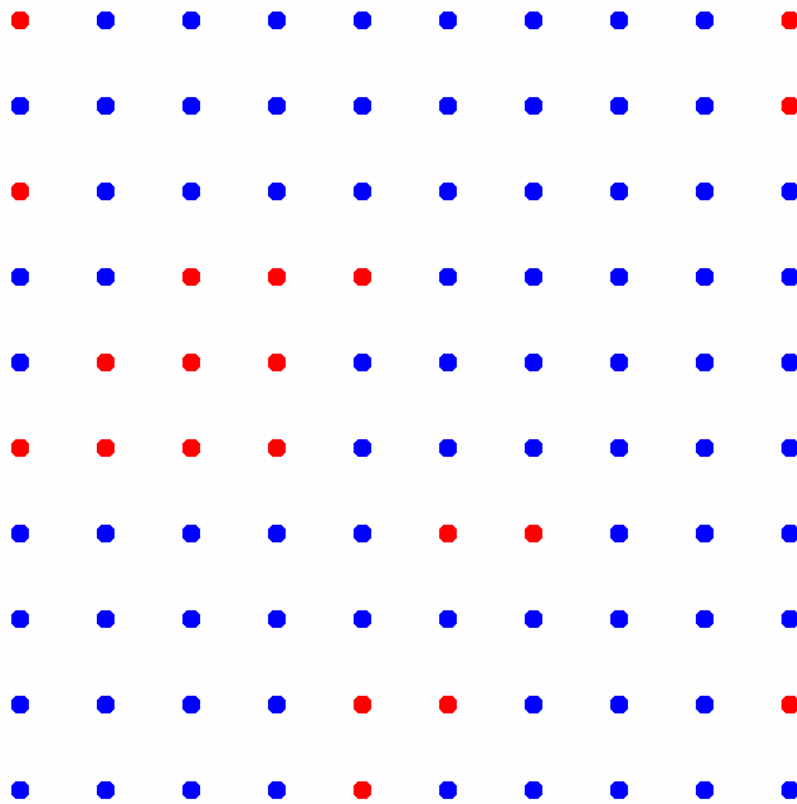
Initial setup

Our Emergence Example (cont.)

- At each step
 - Each dot checks its neighbors' colors and determines what'll be its own color
- Challenge: we don't tell you the color update rules
 - What are a dot's neighbors?
 - How does a dot decide its own color at the next step based on its neighbors' current colors?
- You need to use the scientific investigation process to try to discover the rules
 - First, observe some example data
 - Develop your hypotheses
 - Test your hypotheses through programming
 - Refine your hypotheses if needed

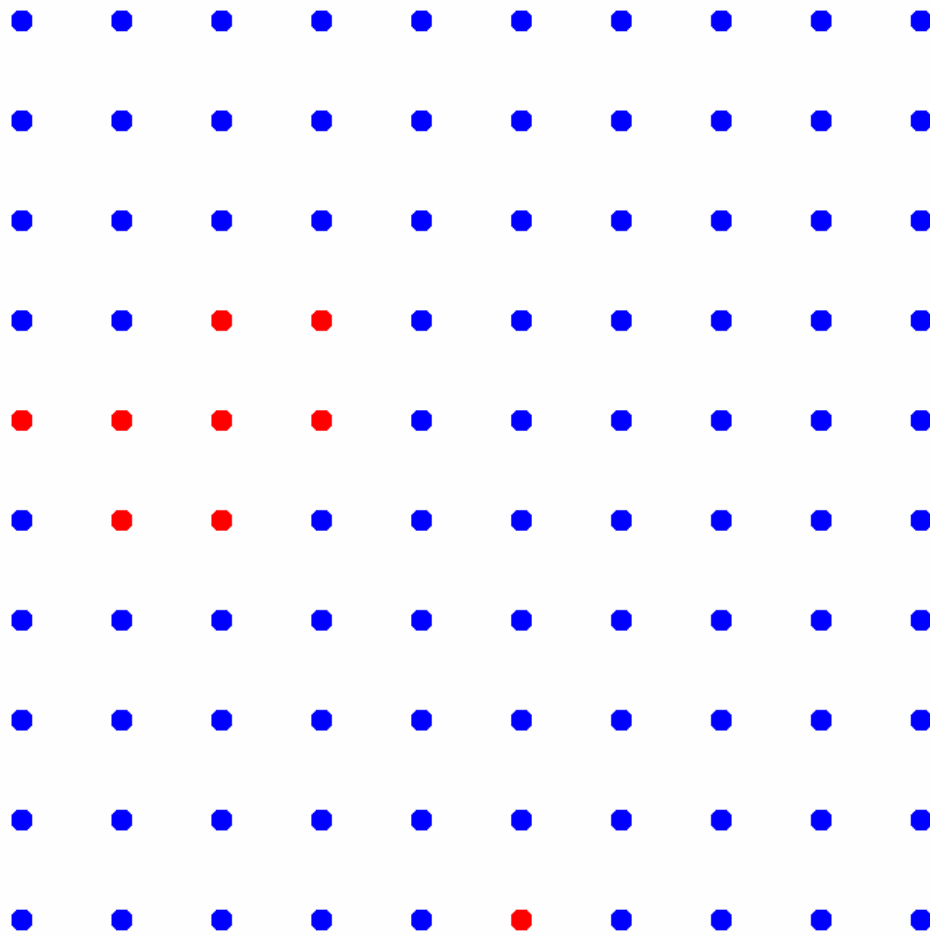
Our Emergence Example (cont.)

The dot colors at subsequent steps, for the initial setup given 2 slides earlier:



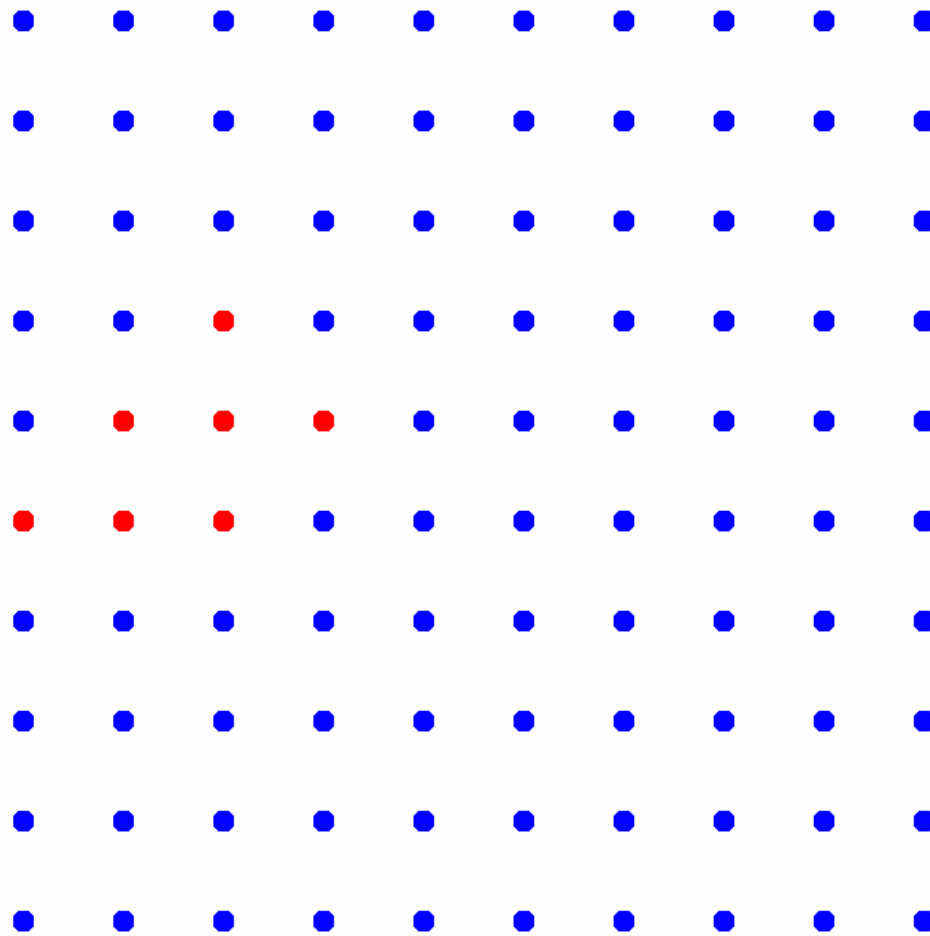
Step 1

Our Emergence Example (cont.)



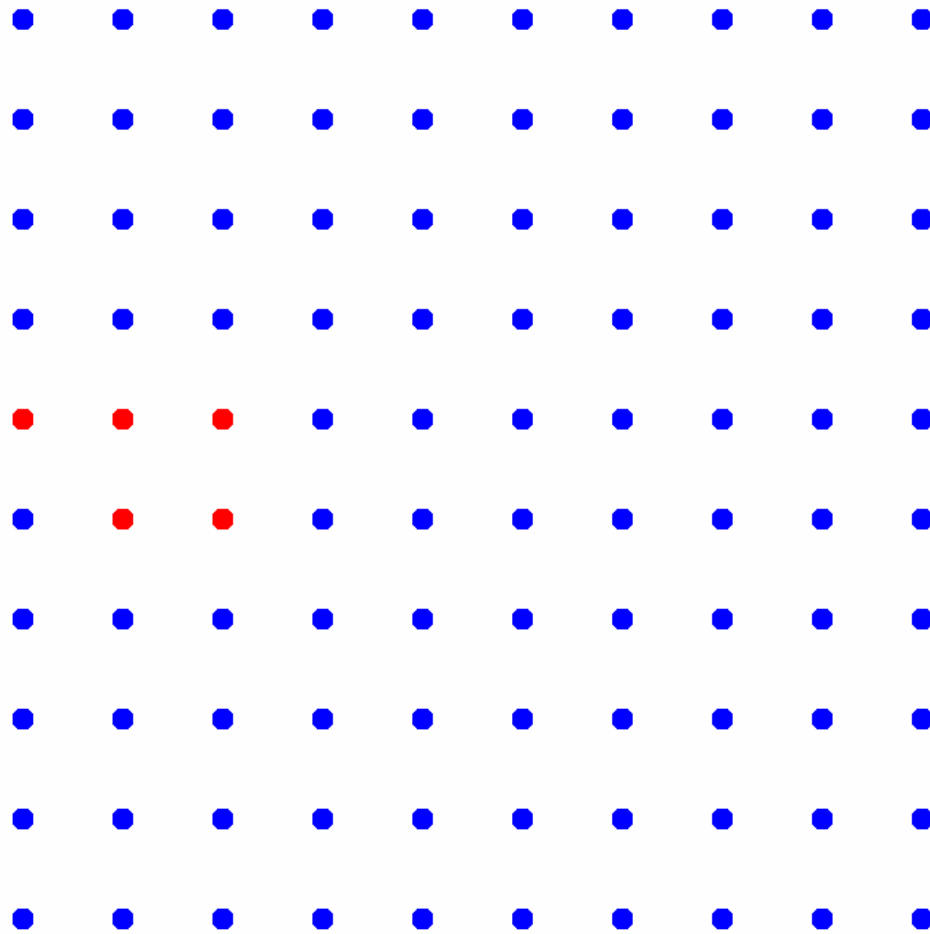
Step 2

Our Emergence Example (cont.)



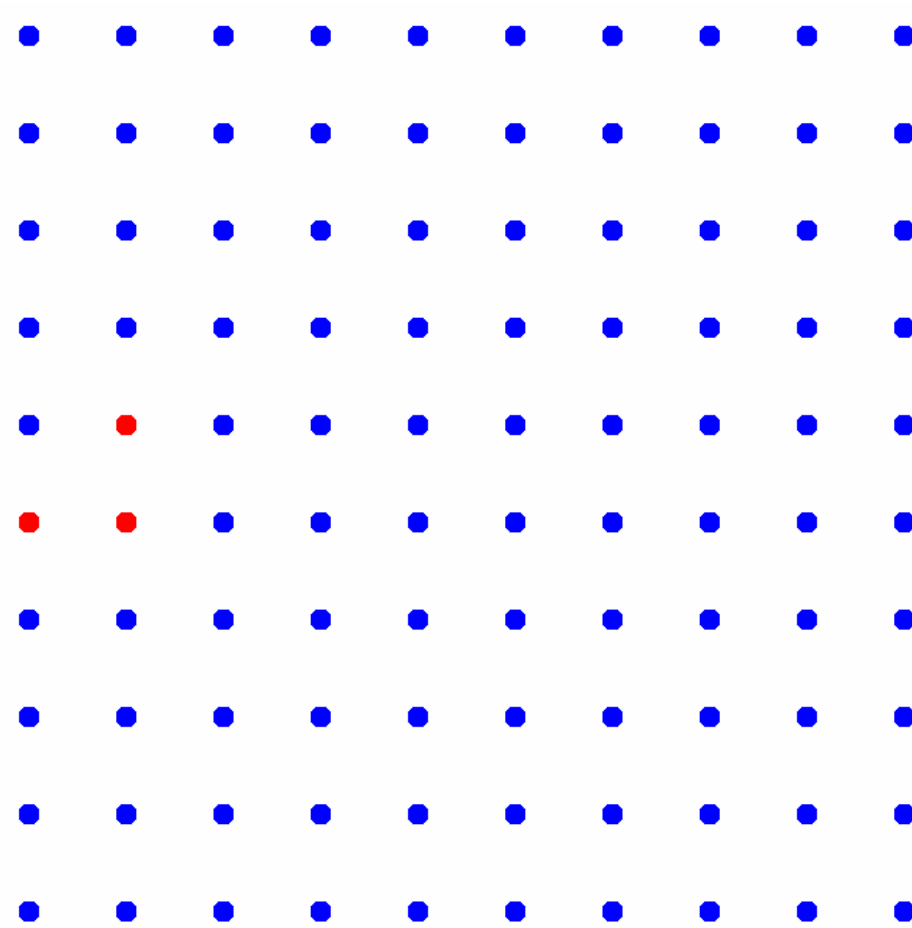
Step 3

Our Emergence Example (cont.)



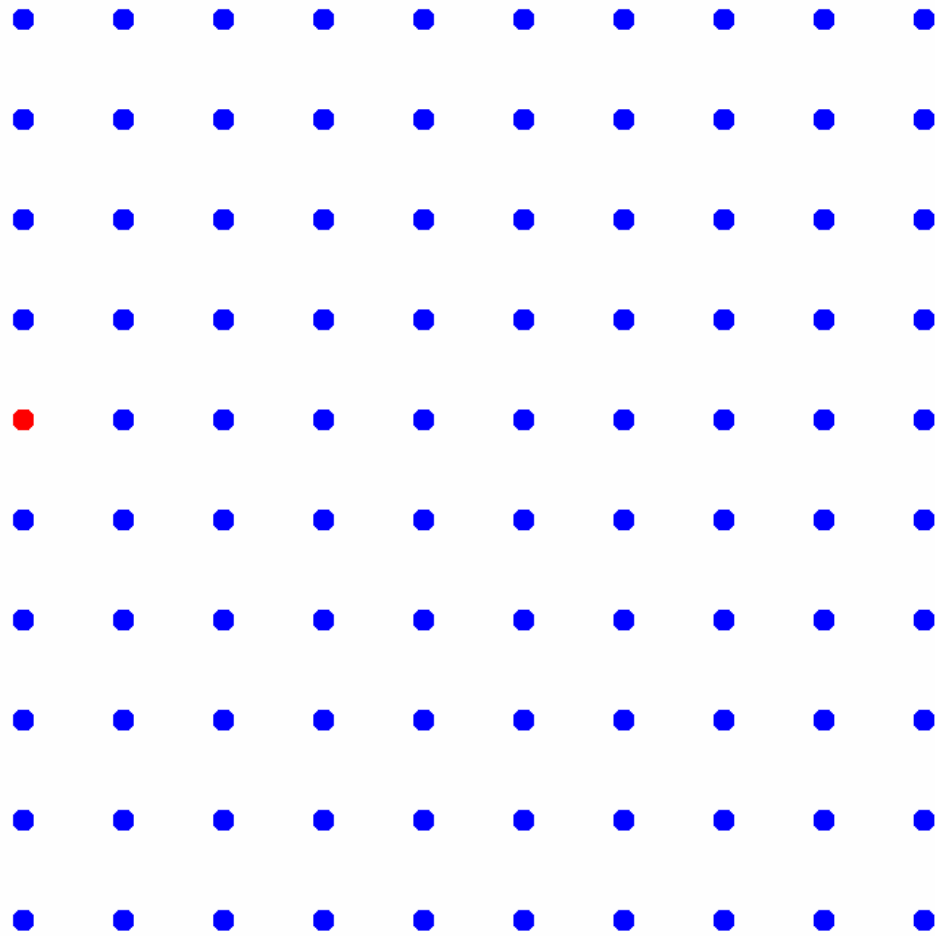
Step 4

Our Emergence Example (cont.)



Step 5

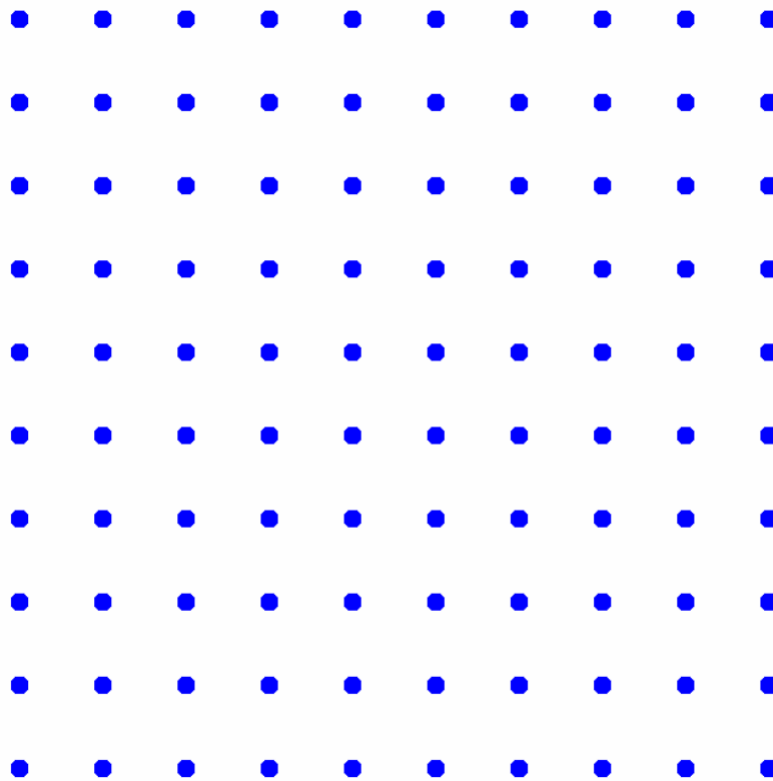
Our Emergence Example (cont.)



Step 6

Our Emergence Example (cont.)

- All dots have the same blue color at step 7
no more change after step 7



Step 7