# Braitenberg Vehicles

- A series of thought experiments by neuroscientist Valentino Braitenberg

- *Vehicles: Experiments in Synthetic Psychology*
  MIT Press, 1984

- Helped inspire interest in "embodied" artificial intelligence

- 14 types of vehicles of increasing complexity

Vehicle 1

- Single sensor-motor coupling

- Sensor measures concentration of X (light, temperature, chemical gradient, food, noise, etc.)

- Vehicle moves forward in response to amount of X

- If X is temperature, vehicle will move fast in hot regions and slowly in cold regions

- Appears to "like" cold regions and "dislike" hot regions

- Friction or noise in environment results in more complicated behavior
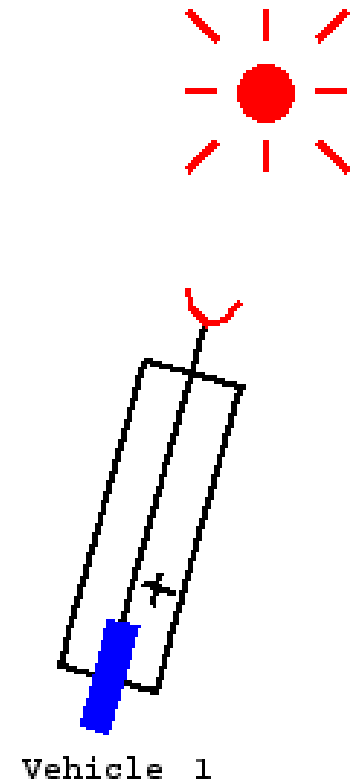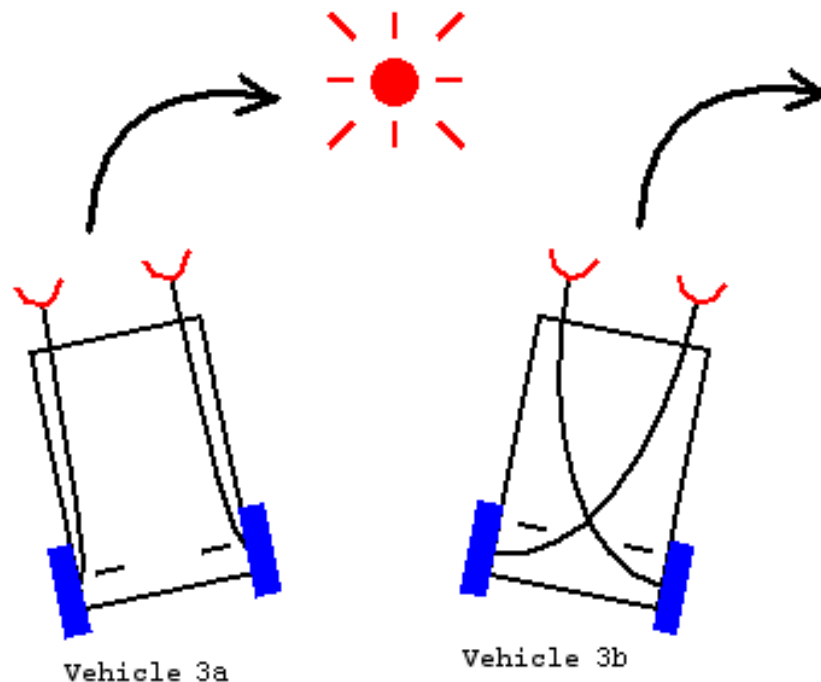
Vehicle 1

Vehicle 2a, 2b

- Two sensors, positive excitatory connections

- Each motor is stimulated by one of the sensors

- Vehicle 2a is a "coward" (it avoids X)

- Vehicle 2b is "aggressive" (it approaches X and speeds up)


Vehicle 2a   Vehicle 2b
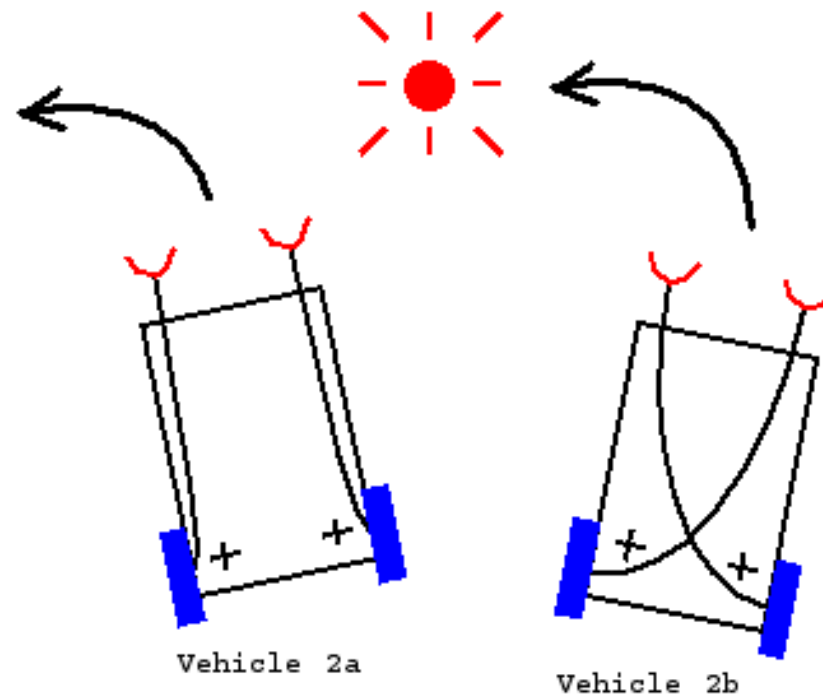
Vehicle 3a, 3b

- Two sensors, negative inhibitory connections

- Each motor is inhibited by one of the sensors

- Vehicle 3a "loves" X (it turns toward X and stays close by)

- Vehicle 3b likes X too but keeps an eye out for other sources (it gradually moves away from X)

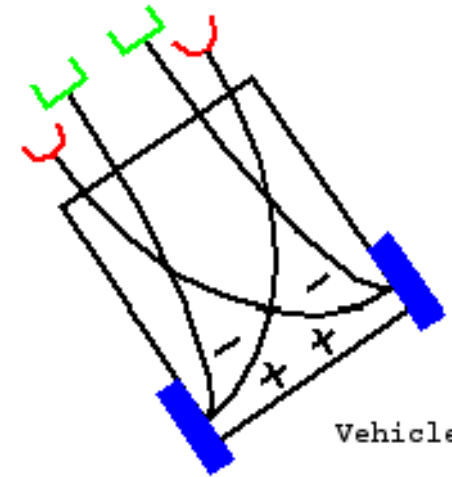Vehicle 3a   Vehicle 3b

Vehicle 3c

- Multiple sensors and connections

- Several types of sensors, tuned to different aspects of the environment

- Mixture of excitatory and inhibitory connections
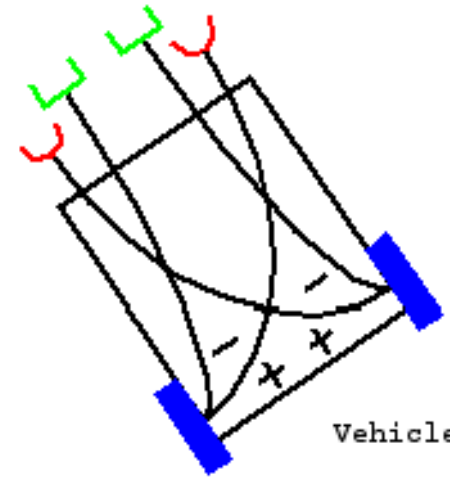
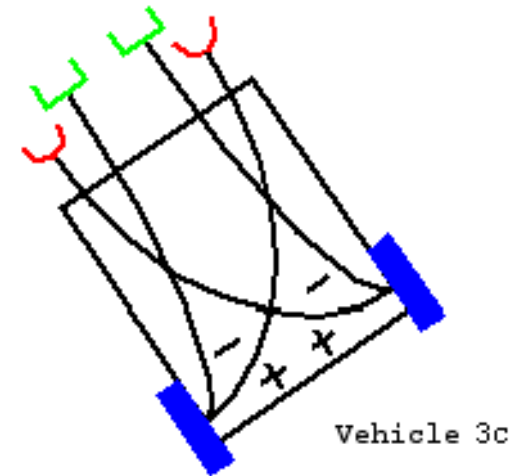Vehicle 3c

Vehicle 3c

- Now we have really interesting behavior:

  - dislikes high temperature

  - turns away from hot places

  - hates light bulbs, since it turns toward them and destroys them

  - prefers well-oxygenated regions of the environment with many organic molecules, since it spends much of its time in such places

  - may move elsewhere when supply of oxygen or organic matter is low
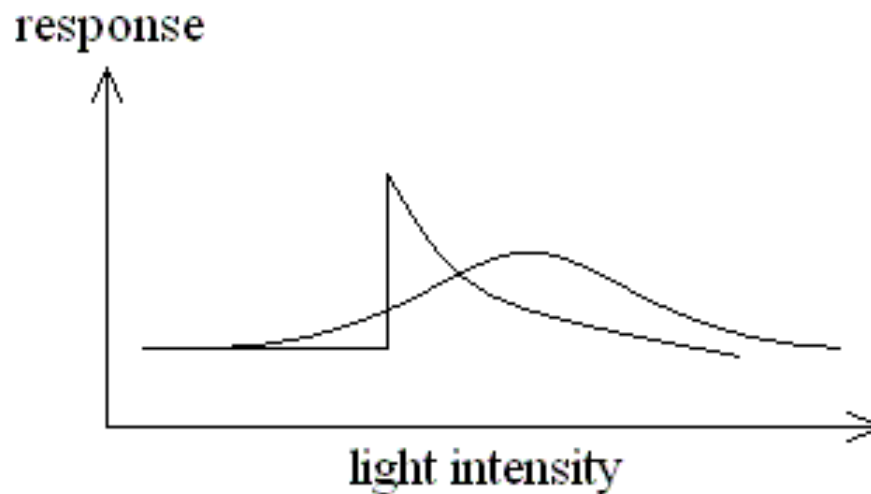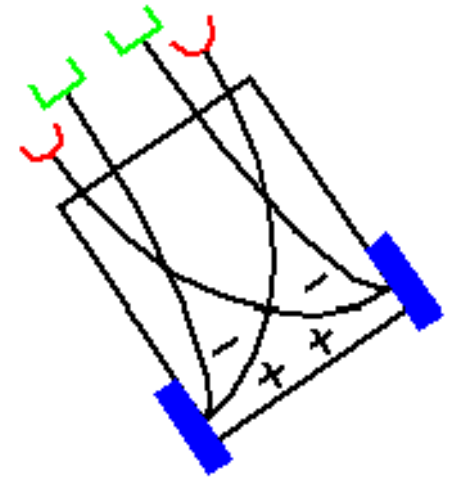
Vehicle 3c

Vehicle 3c

- Vehicle 3c has a system of "values"

- It "knows" what it likes and dislikes

Vehicle 3c

Vehicle 4

- Non-linear sensory response curves

- Responses may be continuous, discontinuous, or a combination of both

- Vehicle 4 now appears to "ponder" over its decisions
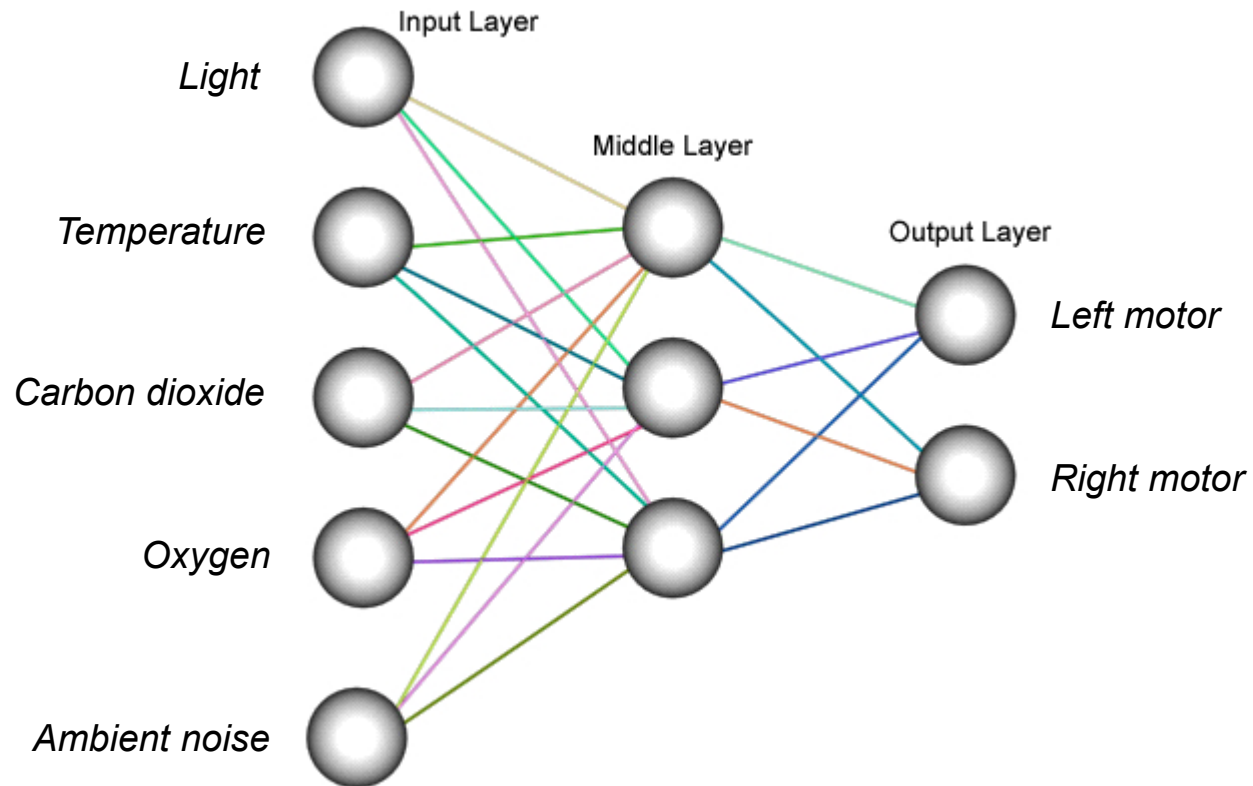

response

light intensity

Vehicle 4

- Behavior is now even more interesting:

  - likes one sort of stimulus when it is weak but not when it is too strong

  - likes another the stronger it becomes

  - turns away from a weak smell and destroys the source of a strong one

  - visits in alternation a source of smell and a source of sound

  - turns away from both with a change in temperature

  - may respond suddenly when approached with a lure

- We might be tempted to attribute **free will** to the vehicle

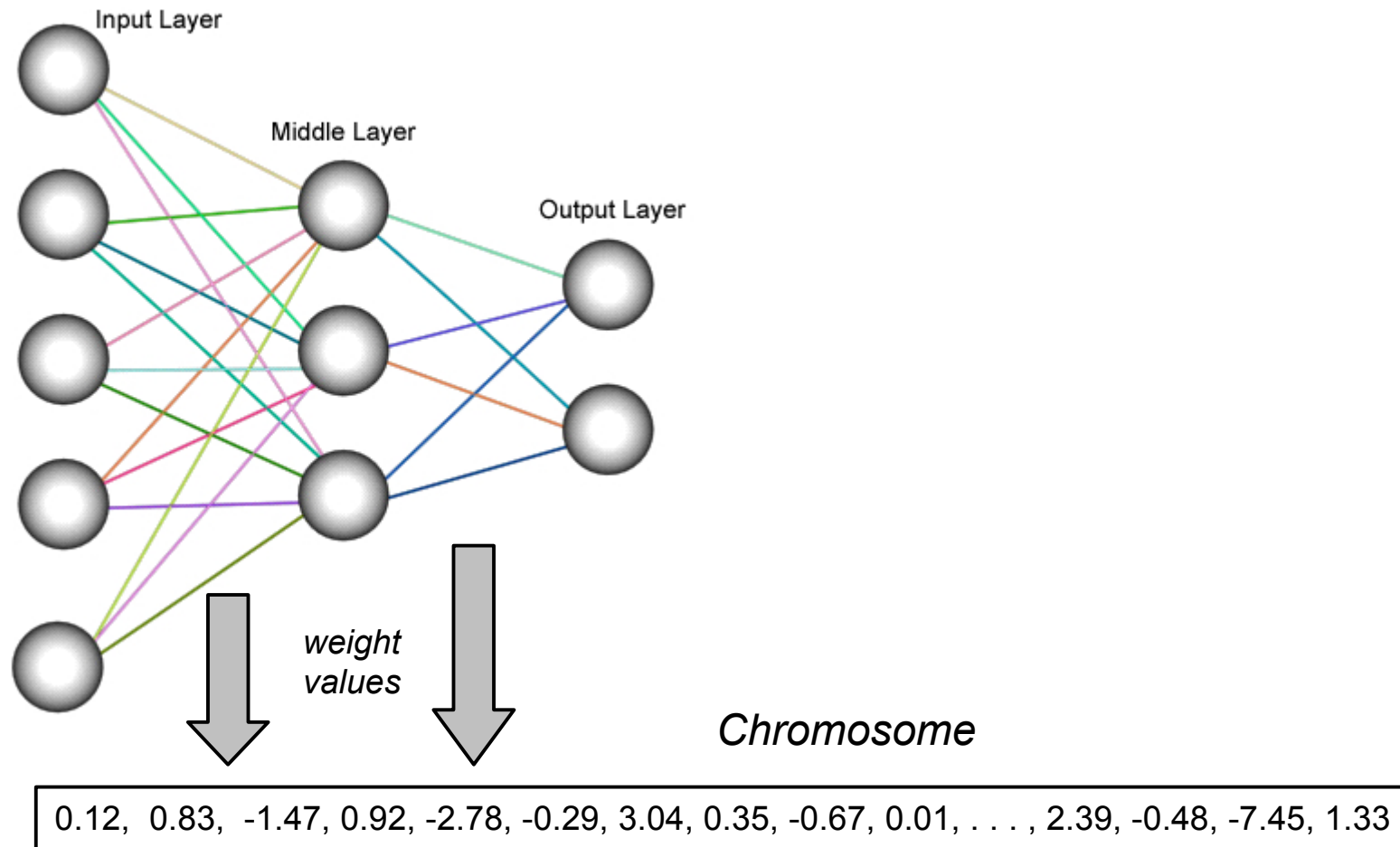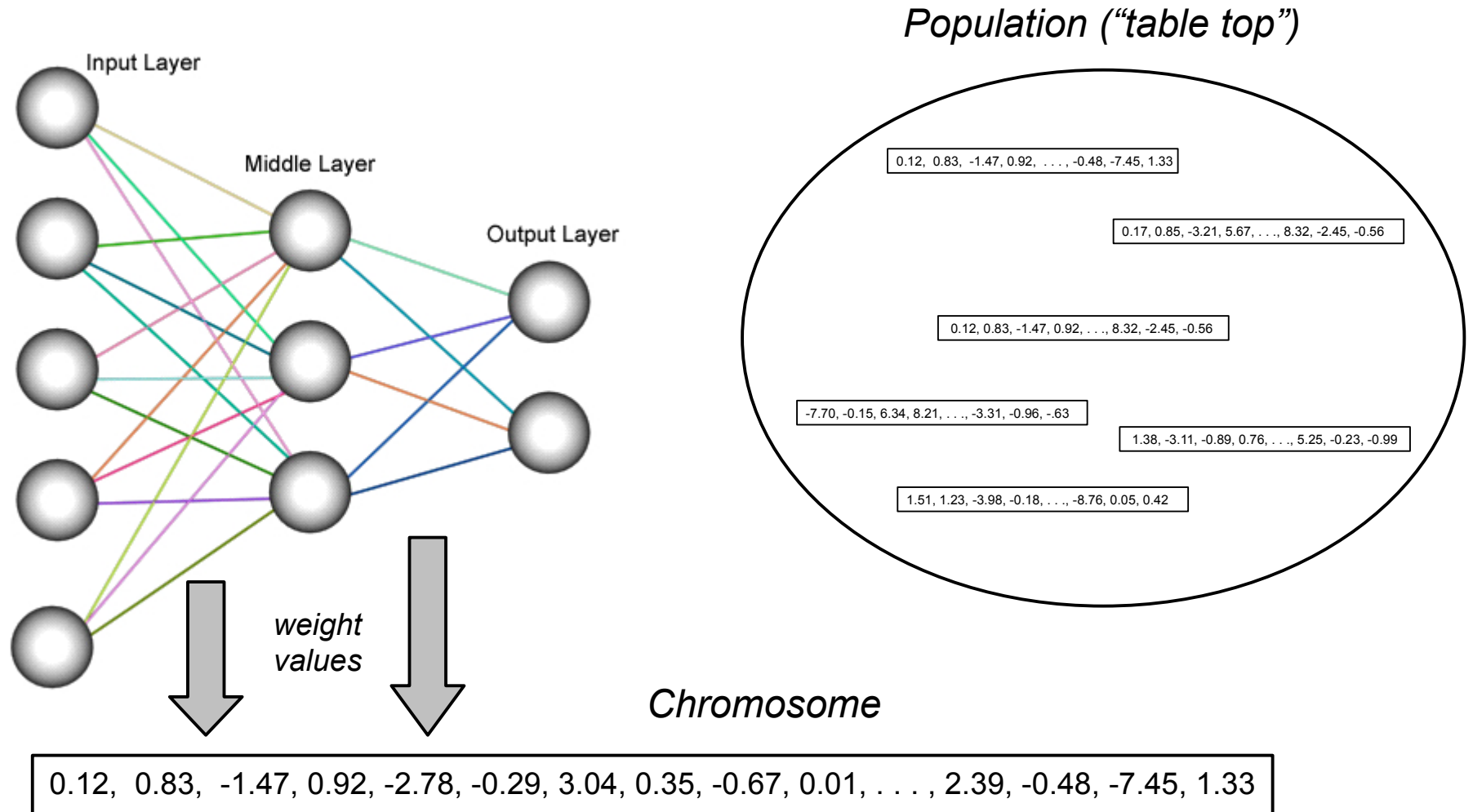# Vehicle 5

- Neural networks

Vehicle 6

- Evolution, genetic algorithms

Input Layer

Middle Layer

Output Layer

weight values

Chromosome

0.12, 0.83, -1.47, 0.92, -2.78, -0.29, 3.04, 0.35, -0.67, 0.01, . . . , 2.39, -0.48, -7.45, 1.33

Vehicle 6

- Evolution, genetic algorithms

Population ("table top")

Input Layer

Middle Layer

Output Layer

0.12, 0.83, -1.47, 0.92, . . . , -0.48, -7.45, 1.33

0.17, 0.85, -3.21, 5.67, . . ., 8.32, -2.45, -0.56

0.12, 0.83, -1.47, 0.92, . . ., 8.32, -2.45, -0.56

-7.70, -0.15, 6.34, 8.21, . . ., -3.31, -0.96, -.63

1.38, -3.11, -0.89, 0.76, . . ., 5.25, -0.23, -0.99

1.51, 1.23, -3.98, -0.18, . . ., -8.76, 0.05, 0.42

weight values

Chromosome

0.12, 0.83, -1.47, 0.92, -2.78, -0.29, 3.04, 0.35, -0.67, 0.01, . . . , 2.39, -0.48, -7.45, 1.33

More Complex Vehicles

- Vehicles 7-14
    - Concepts
    - Learning from experience
    - More sophisticated cognitive abilities

- Easy to implement Vehicles 1-6 as mobile robots

"Law of uphill analysis and downhill invention"