

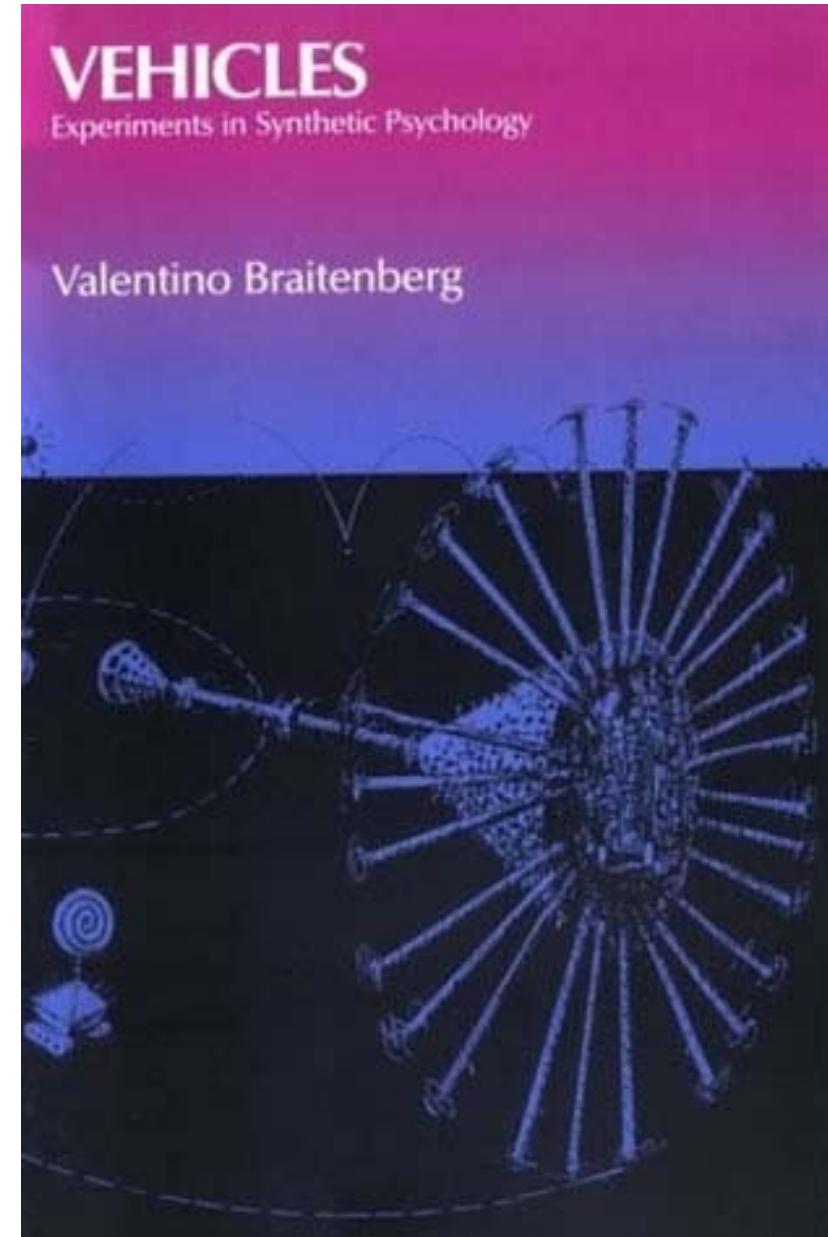
# **Braitenberg's Vehicles and Cybernetic Robotics**

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Bristol Robotics Lab, UWE

# Vehicles

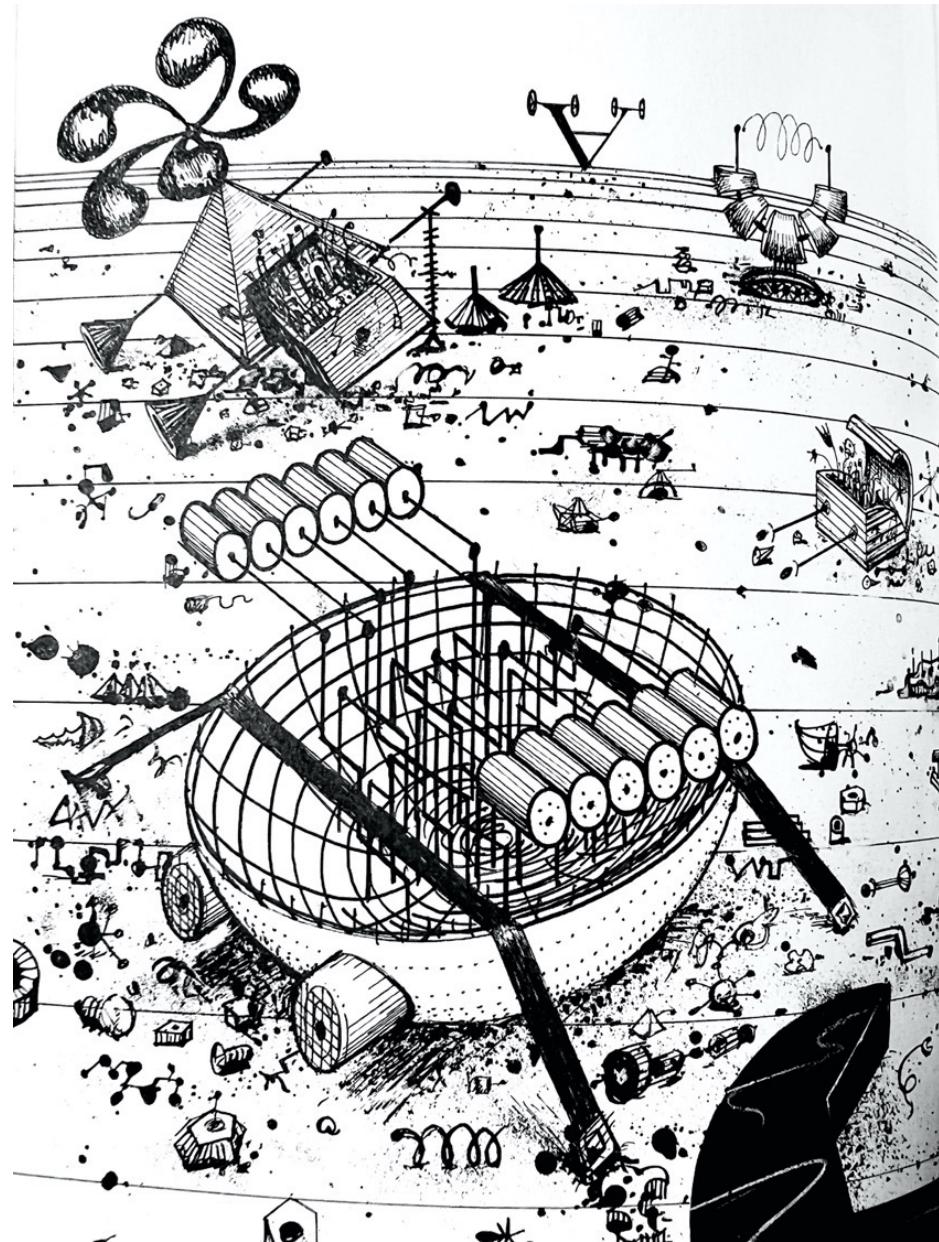
Experiments in Synthetic Psychology  
by Valentino Braitenberg (1984)

*“Get used to a way of thinking in which the hardware of the realization of an idea is much less important than the idea itself. Norbert Wiener was emphatic about this when he formulated the title of his famous book: Cybernetics, or Control and Communication in Animals and Machines.” – Braitenberg*

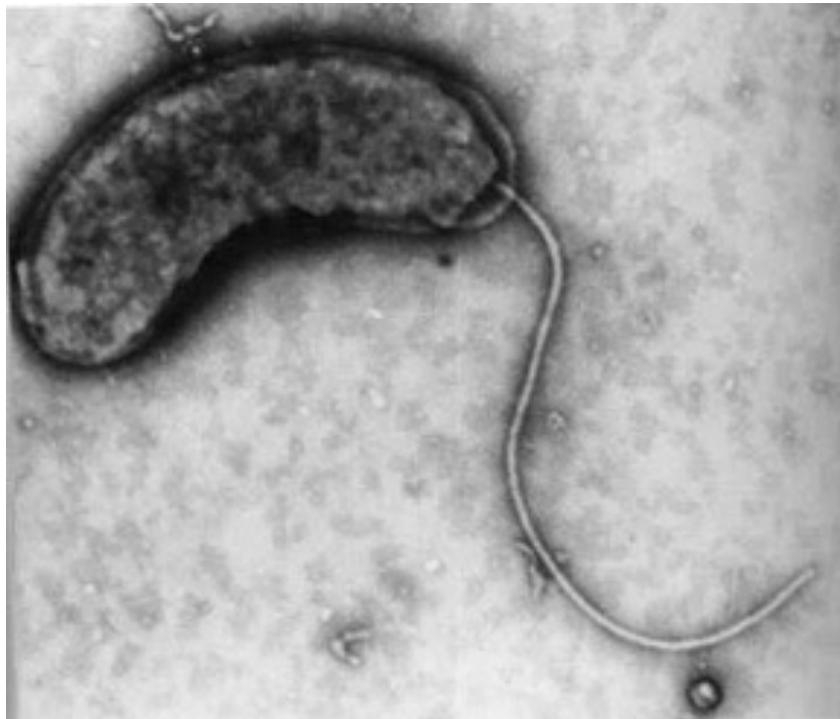


# Vehicles of Thought

*“This is an exercise in fictional science, or science fiction, if you like that better. Not for amusement: science fiction in the service of science.” –  
Braitenberg*



# Nature's Vehicles: E Coli



- The flagellum is a long hollow filament
- At the base, a flagellar motor rotates at 100 revolutions per second.
- The direction of rotation determines the kind of movement.

This trilobite is called *Erbenochile*. It had incredibly tall, tower-like eyes that provided 360-degree vision!



Fortey and Chatterton. 2003. A Devonian Trilobite with an Eyeshade. Science.



# Connect the BBC micro:bit

- The BBC micro:bit is a small ARM based computer.
- Open [python.microbit.org](https://python.microbit.org) in Chrome.
- Connect the micro:bit to your laptop using a USB cable.
- Click **Connect** – Chrome uses web USB to connect to the micro:bit
- Select BBC micro:bit then **Connect**



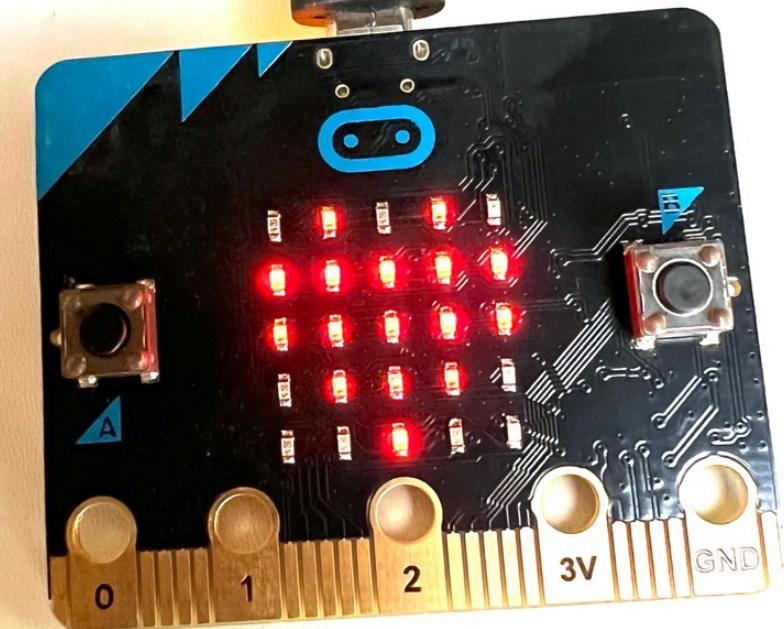


# Flash code to the micro:bit

- Program the micro:bit in microPython
- The editor opens with the default code:

```
1 from microbit import *
2
3 while True:
4     display.scroll('Hello, World!')
5     display.show(Image.HEART)
6     sleep(2000)
```

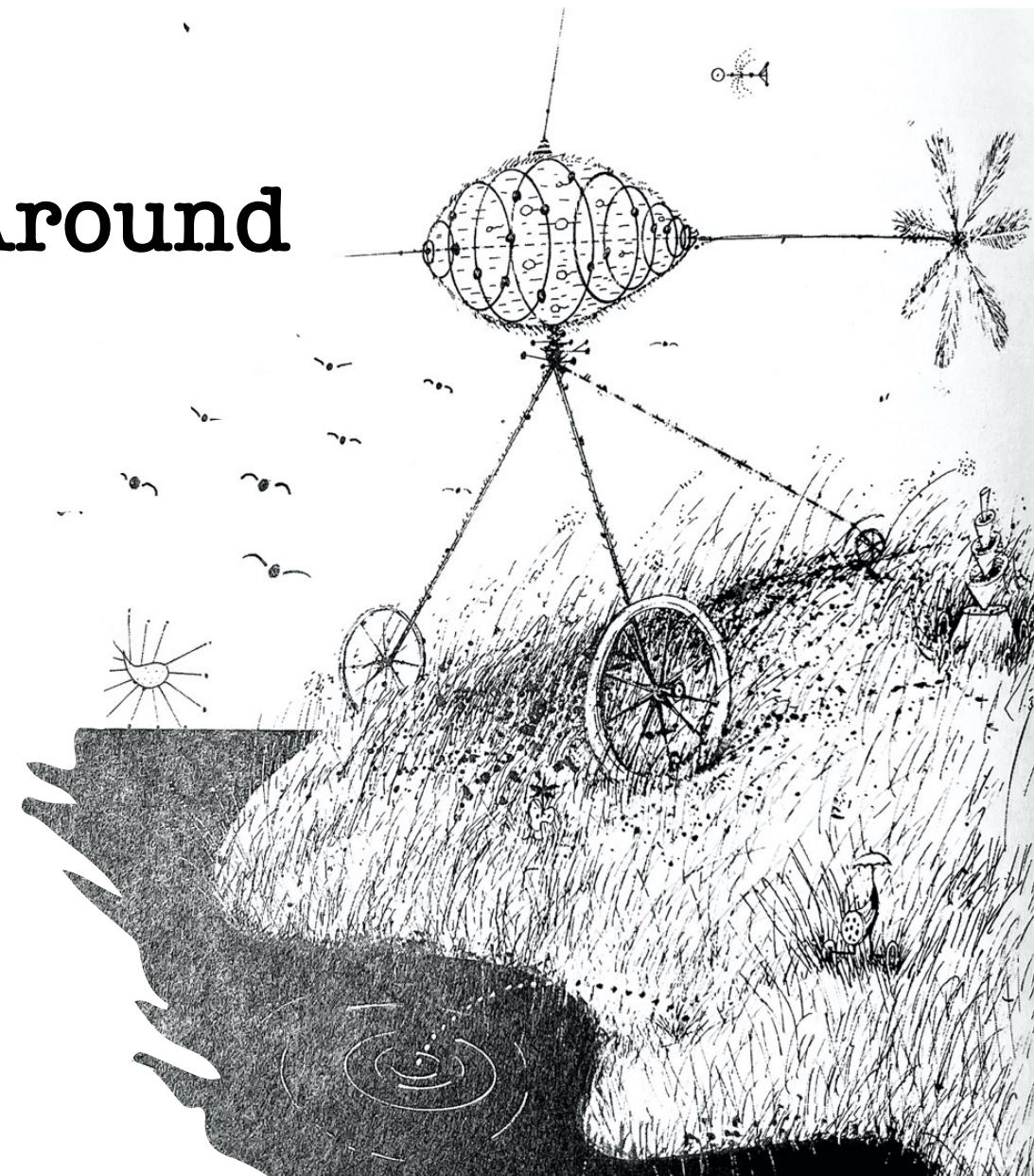
- **Flash** to the micro:bit
- Wait for the light to stop blinking...



# Vehicle 1: Getting Around

Vehicle 1 has one sensor and one motor.

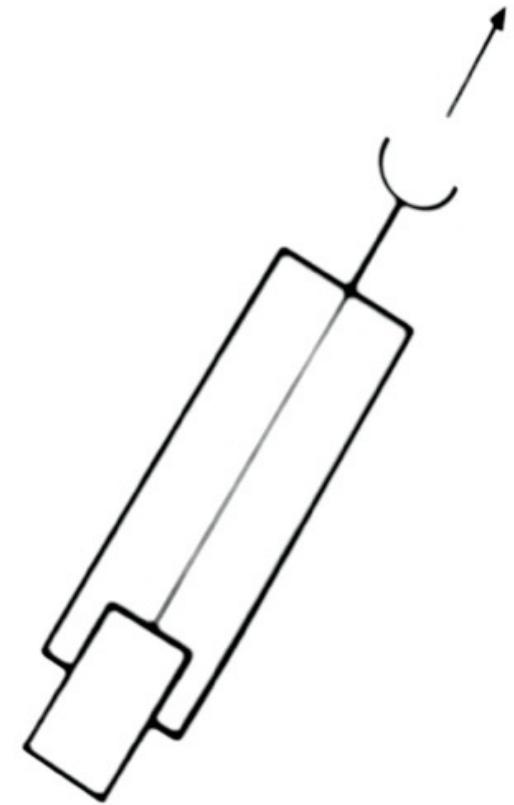
- The **motor** is anything that can provide a propulsive force, not just electric motors.
- The **sensor** can be of any kind of analogue detector.



# Vehicle 1

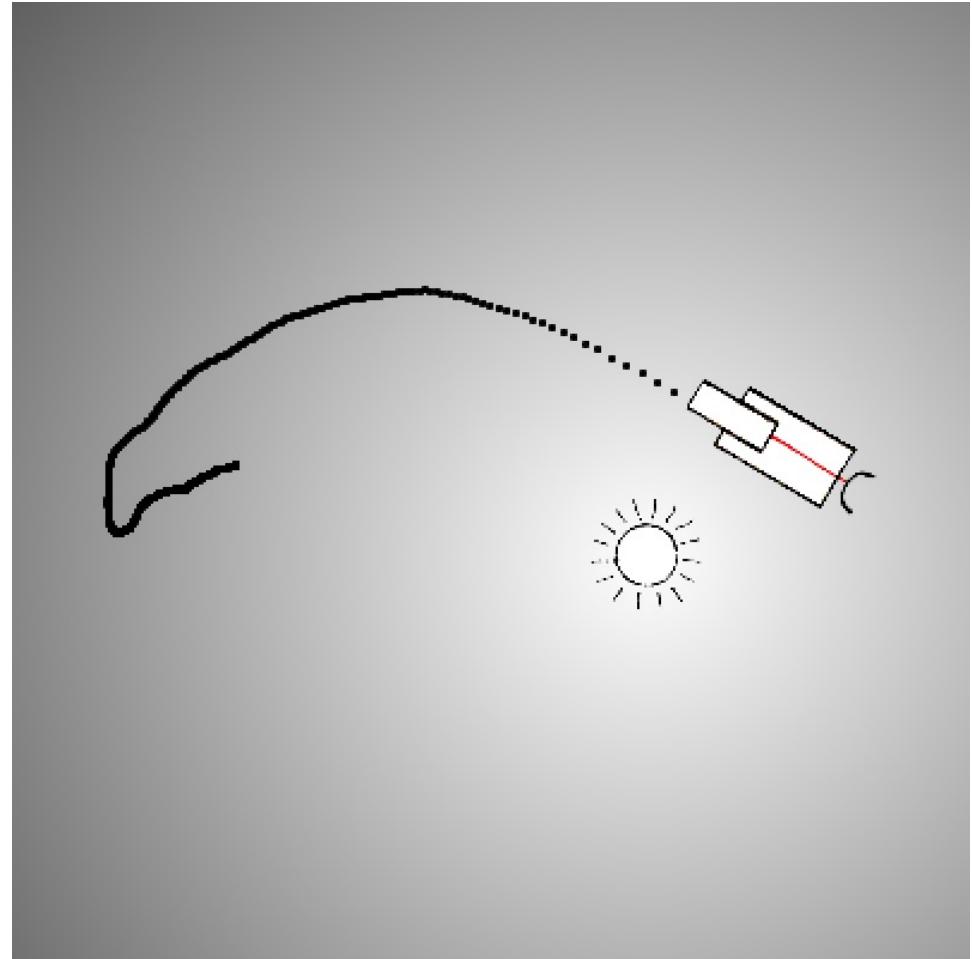
The signal is conveyed from the sensor to the motor by a **nerve fibre**, causing the motor to vary continuously in its output.

*“The more there is of the quality to which the sensor is tuned, the faster the motor goes”* - Braitenberg.



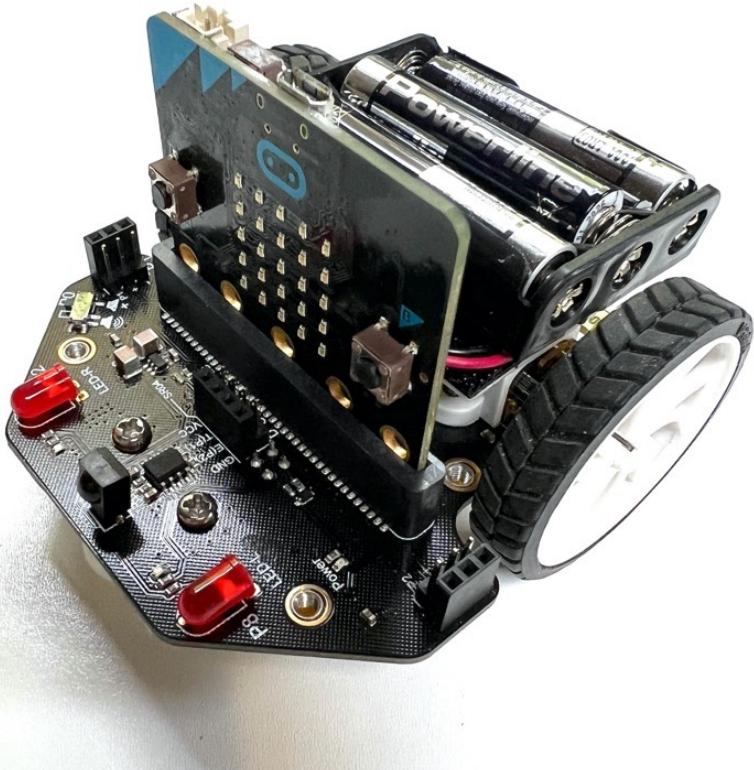
# Vehicle 1 Simulator

Using a light sensor, the brighter the light, the faster it goes.



<https://go.uwe.ac.uk/v1>

# Maqueen robot



- Plug the micro:bit into the robot.
- Light Emitting Diodes (LEDs) can be used in reverse as a **light sensor**.
- Get the **vehicle.py** code at:  
<https://go.uwe.ac.uk/cybsoc1>
- Select the **raw** view, and copy all
- Copy into the microPython editor

# Vehicle.py

- Map sensor values from 0 (inactive) to 1 (active)
- The sensor inputs positively excite the motor ‘neurons’
- Condition the inputs into output range 0 – 225

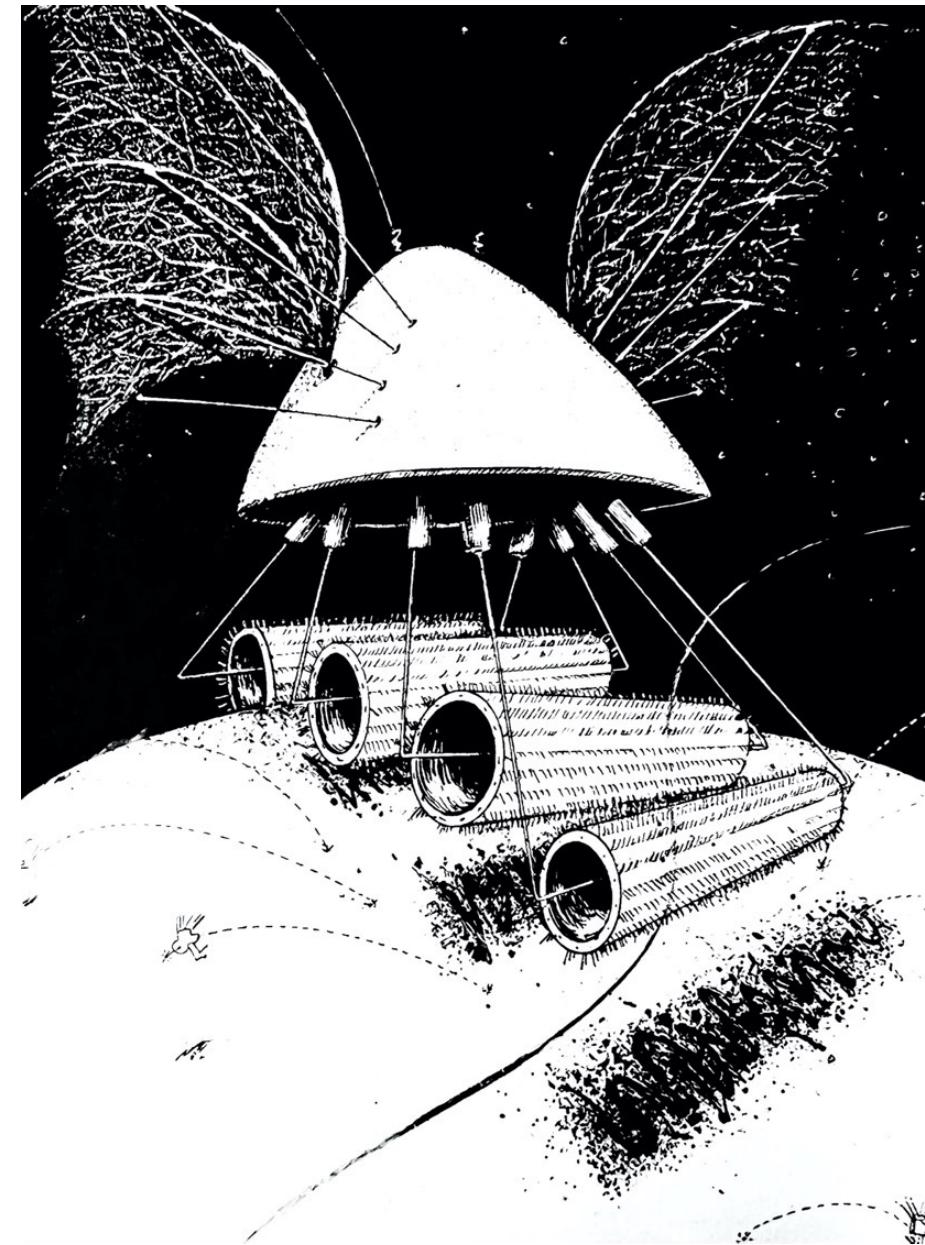
```
23     while True:  
24         a = mapValue(display.read_light_level(), 0, 100, 0, 1)  
25         motor(LEFT_MOTOR, 0, condition(a))  
26         motor(RIGHT_MOTOR, 0, condition(a))  
27         print("{:.2f}".format(a))
```



# Open Serial connection

- Flash the code to the robot
- Switch the robot ON  
(switch at the back)
- **Open the serial connection**  
to see the sensor values
- **Open the serial connection**  
to see error messages
- Can you use the torch to  
make the robot go?





## Vehicle 2: Fear & Aggression

Vehicle 2 equips our robot with  
**a fight or flight response to light.**

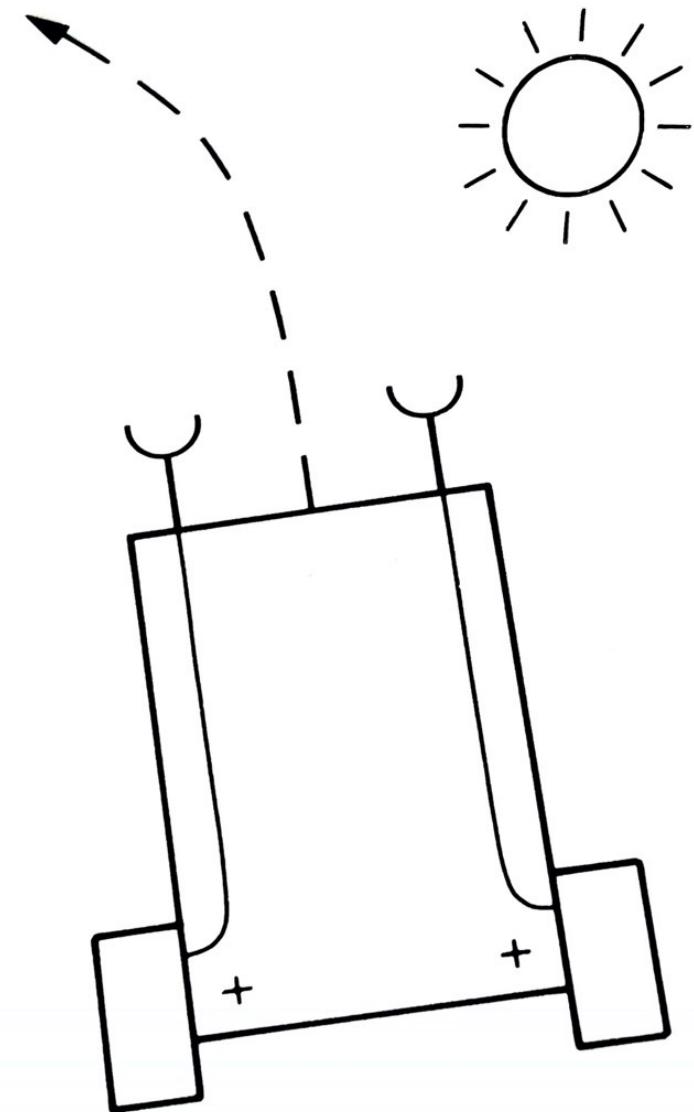
*“It flees from light in fear, or  
heads towards it in a way that  
might be considered aggressive.”*

– Braitenberg

## Vehicle 2a: Fear

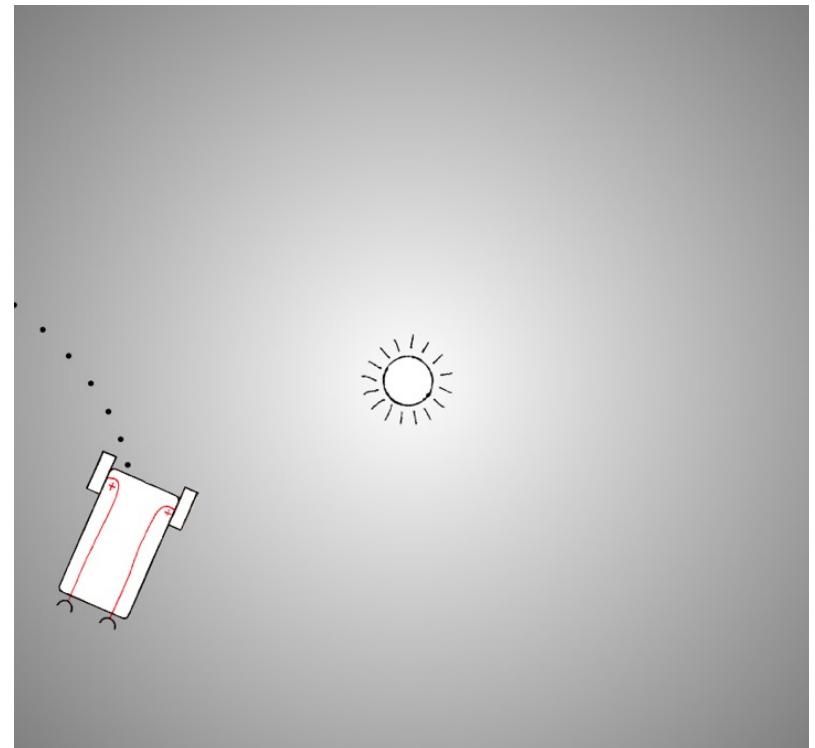
- Two eyes, and two motors.
- '+' indicates an **excitatory** connection.

Vehicle 2a is averse to light, veering away from it, “*escaping until it safely reaches a place where the influence of the source is scarcely felt. Vehicle 2a is a coward, you would say.*” – Braitenberg



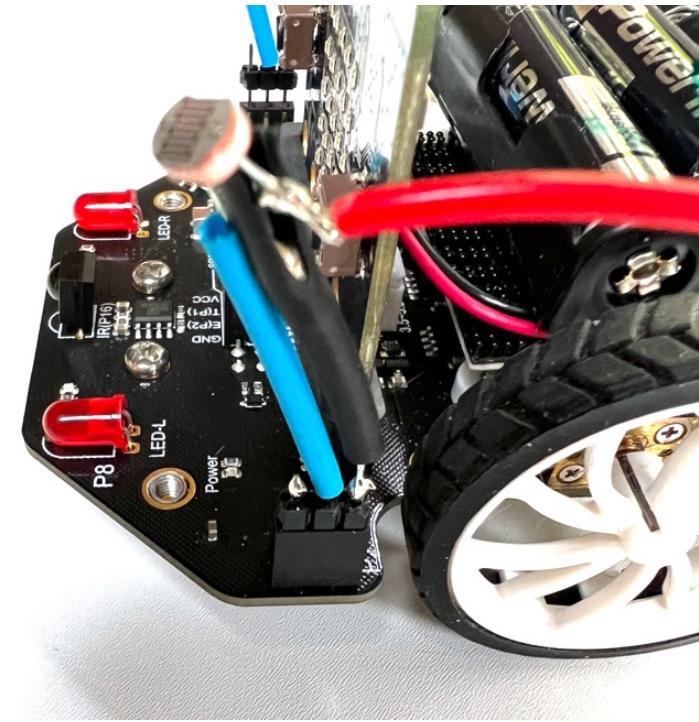
# Vehicle 2a Simulator

- Vehicle **2a** connects each sensor to the motor on the same side.
- If the light is brighter on one side of the vehicle, the motor on that side runs faster causing it to turn away from it.



<https://go.uwe.ac.uk/v2>

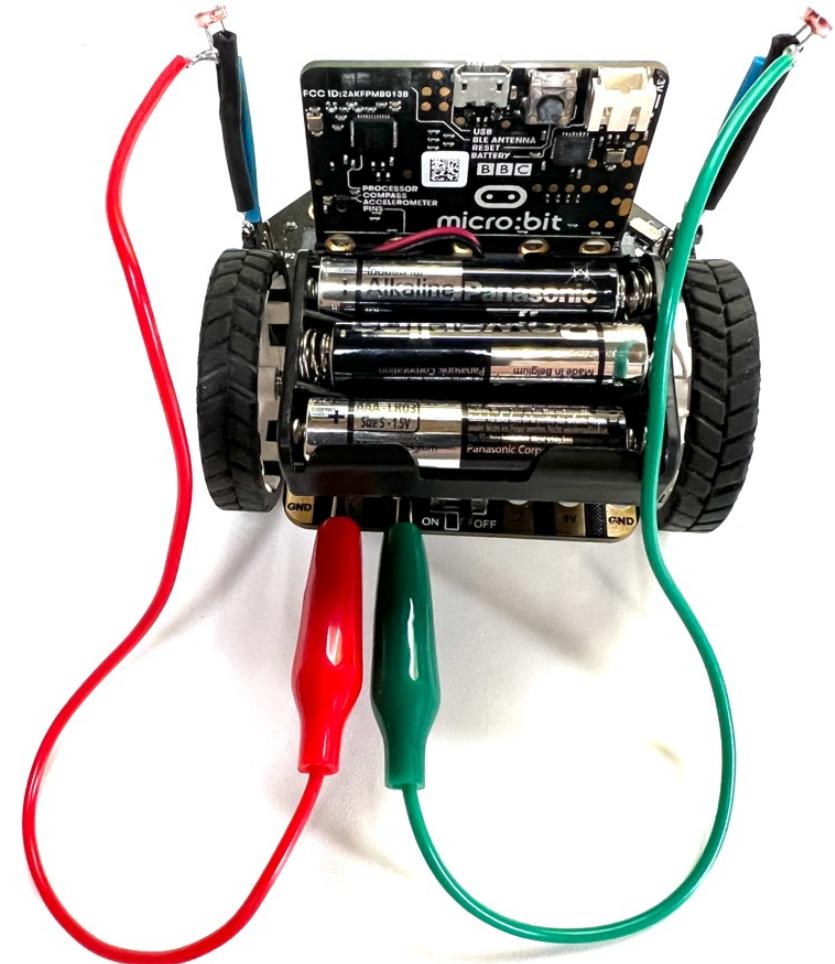
# Photocells for Eyes



- Grab a pair of photocell ‘eyes’
- The colours don’t matter
- Insert them into the sockets with the blue wire frontmost (but in the middle).

# Wires for Brains

- When light falls on the cell, its resistance drops and the signal is pulled high.
- Connect the left eye to pin 0, and the right eye to pin 1 to control the left and right motors.
- Get the **vehicle2.py** code from <https://go.uwe.ac.uk/cybsoc1>
- Flash the code
- Shade its eyes or use the torch to steer it



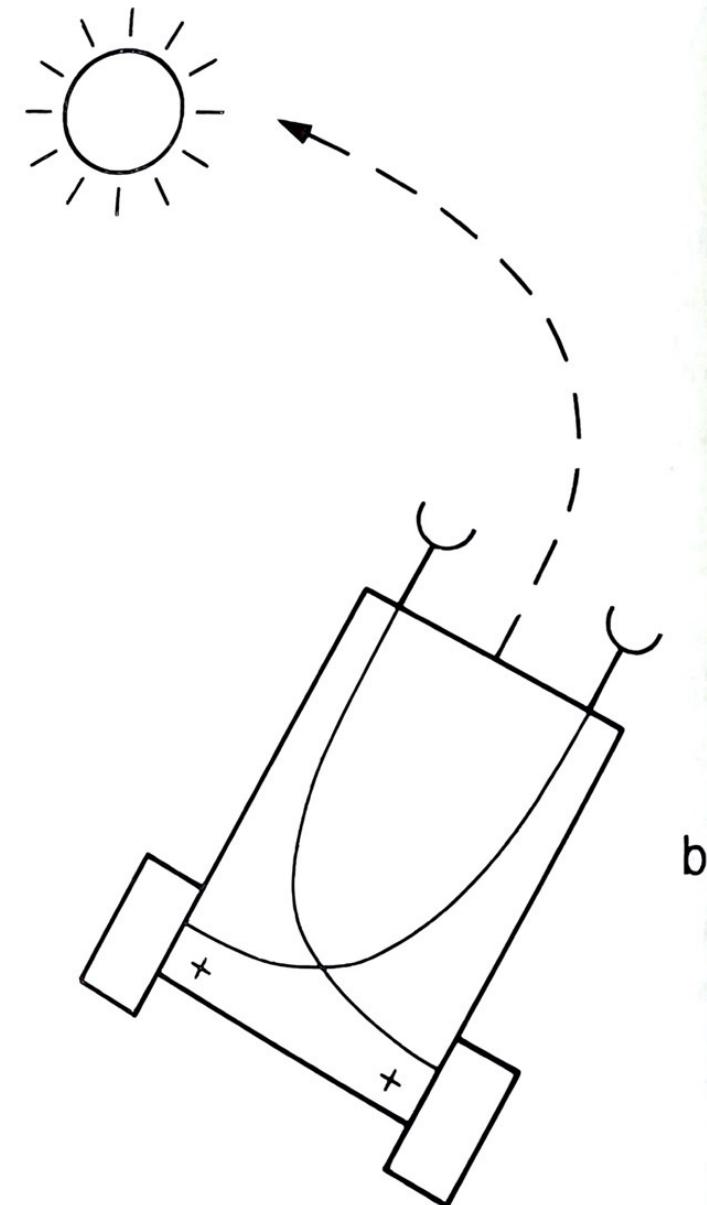
# Vehicle2.py

- Reads data from pin0 into variable a (mapped to 0-1)
- Reads data from pin1 into variable b (mapped to 0-1)
- Conditioned values a, b sent to left, right motors

```
23 while True:  
24     a = mapValue(pin0.read_analog(),200,1000,0,1)  
25     b = mapValue(pin1.read_analog(),200,1000,0,1)  
26     motor(LEFT_MOTOR,0,condition(a))  
27     motor(RIGHT_MOTOR,0,condition(b))  
28     print("{:.2f} {:.2f}".format(a,b))
```

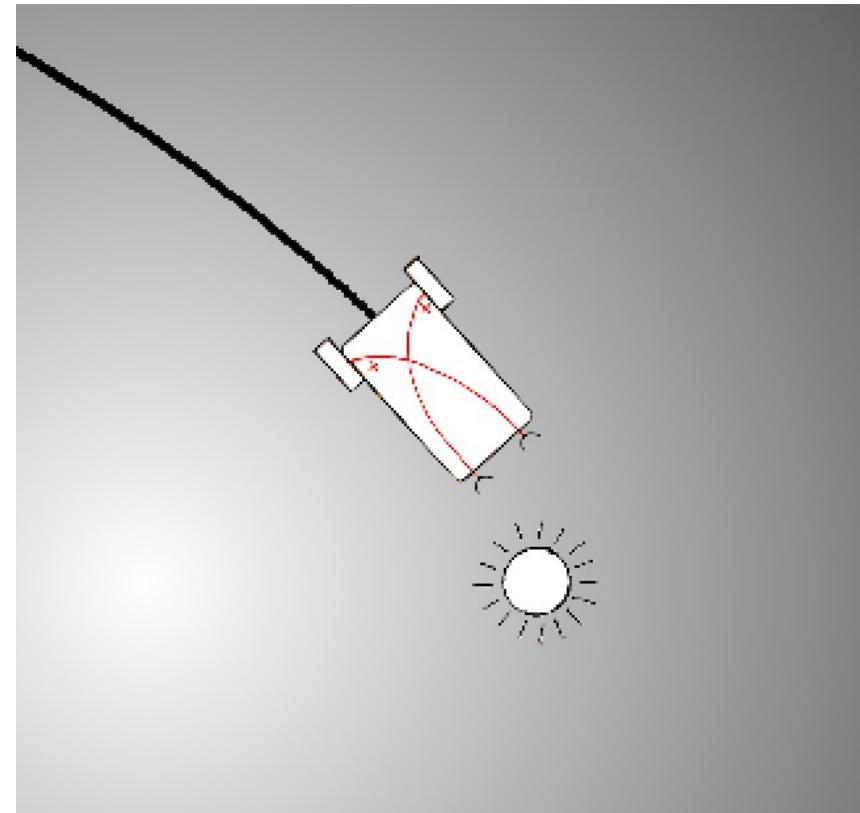
## Vehicle 2b: Aggression

*“Vehicle 2b. It, too, is excited by the presence of sources, but resolutely turns toward them and hits them with high velocity, as if it wanted to destroy them. Vehicle 2b is **aggressive**, obviously.” – Braitenberg*

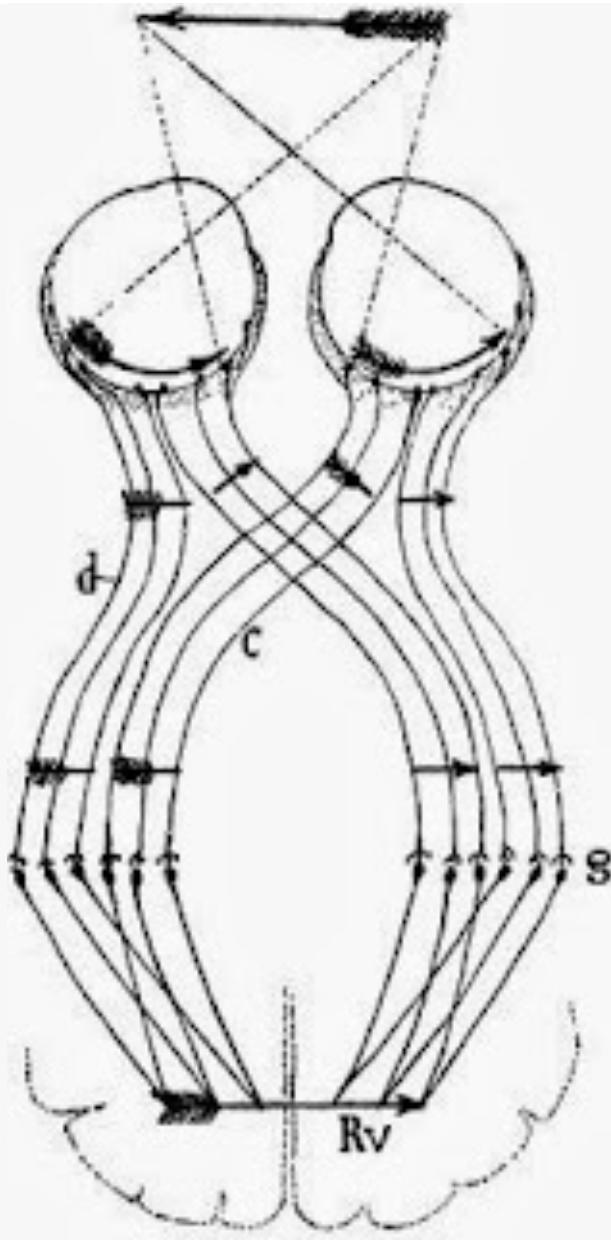


# Vehicle 2b Simulator

- Vehicle **2b** connects each sensor to the motor on the opposite side.
- If the light is brighter on one side of the vehicle, the motor on that side runs faster causing it to head towards the light.



<https://go.uwe.ac.uk/v2>

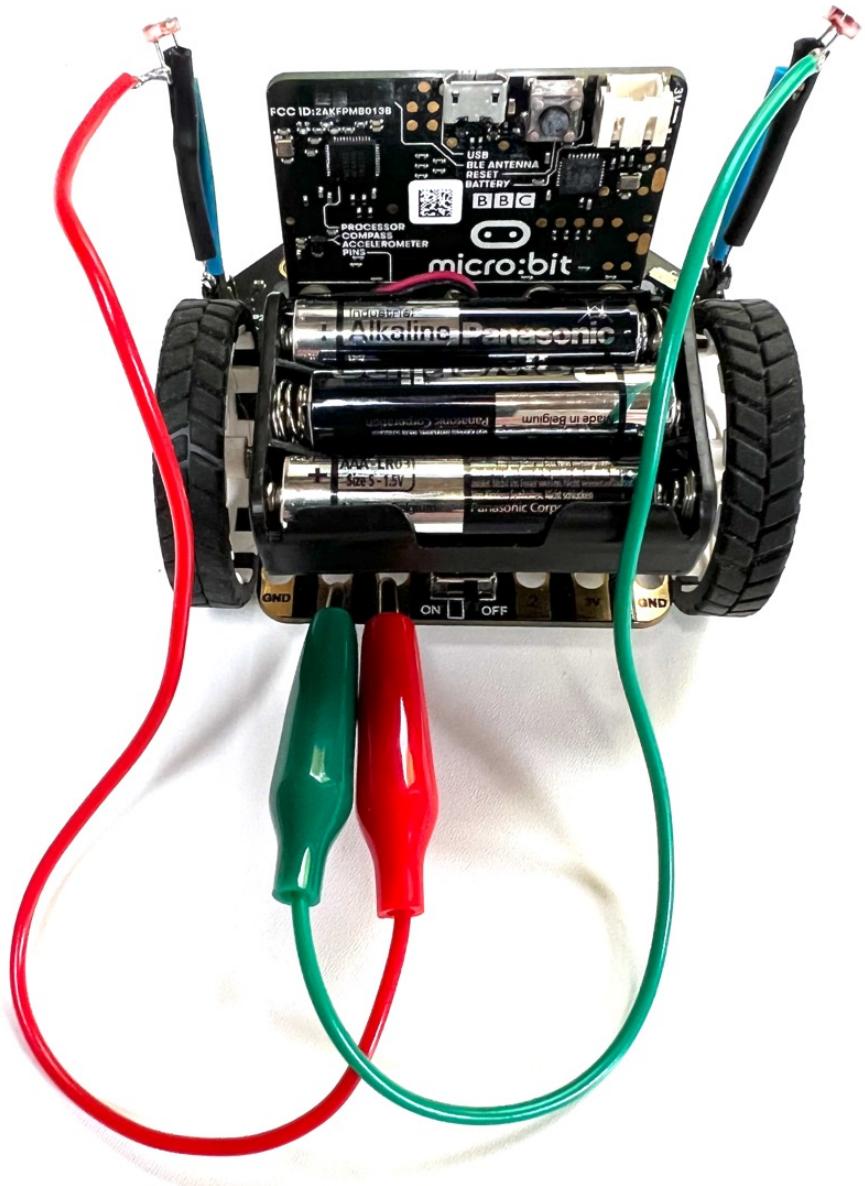


## Crossing Connections

- In 1899, Spanish neuroanatomist *Ramón y Cajal* observed optic nerve fibres from the half of the eye closest to the nose cross over to the opposite side of the brain.
- Crossed connections are common in vertebrates, including us.
- Nobody knows why.

# Vehicle 2b

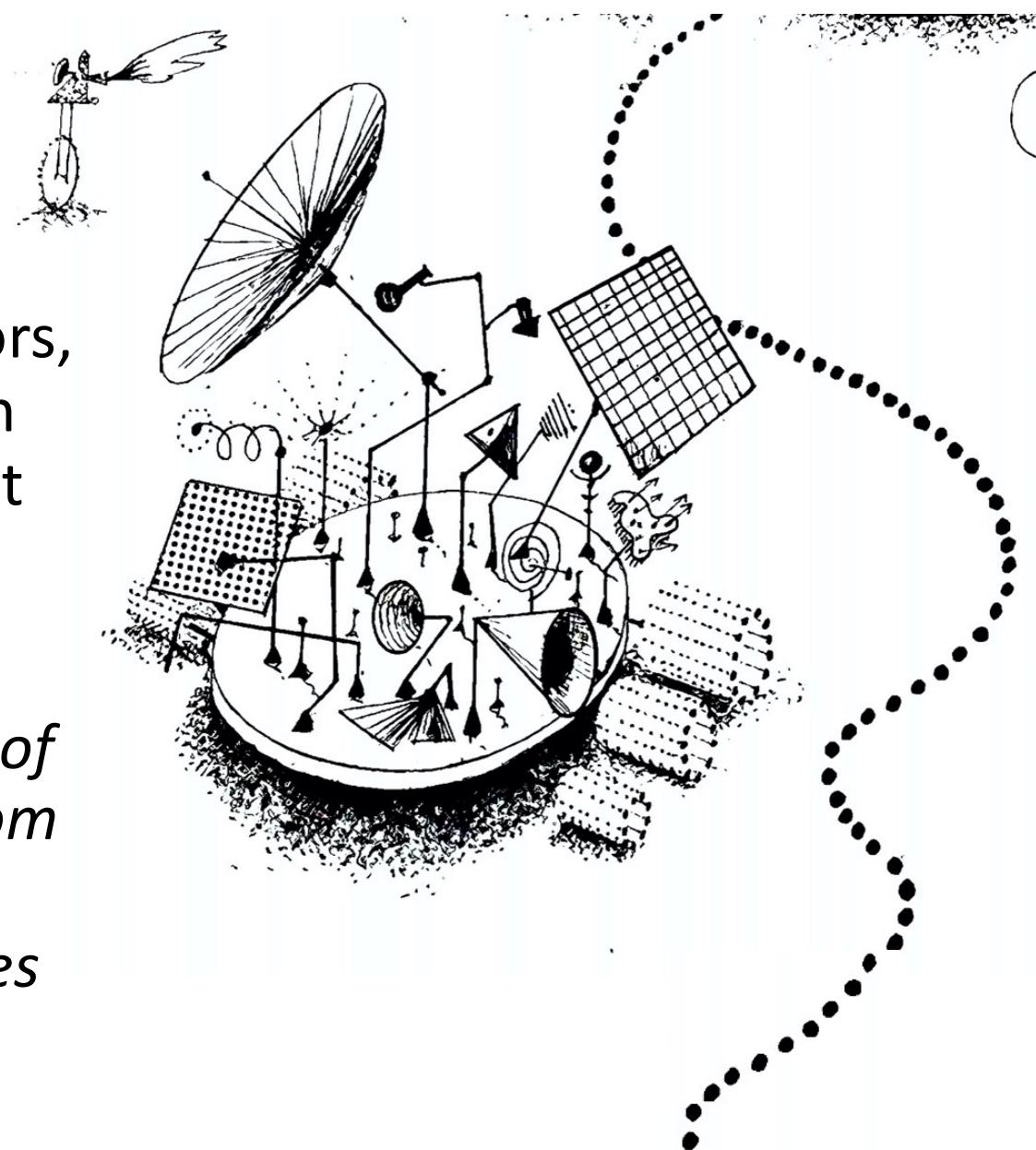
- No need to change the code
- Just cross the connections to pin0 and pin1
- Can you guide it with the torch?



## Vehicle 3: Love

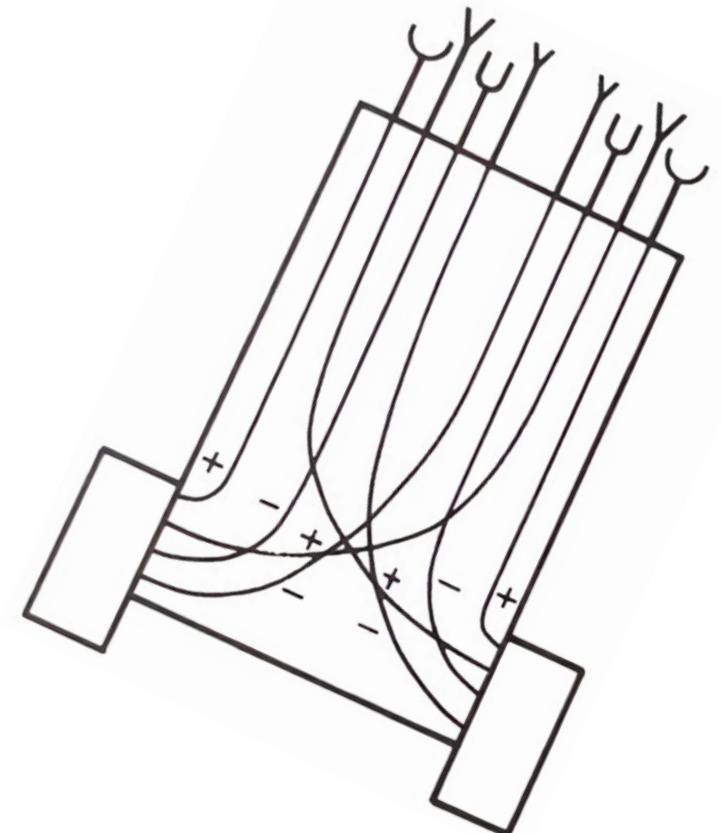
Some sensors **inhibit** the motors, causing Vehicle 3 to slow down and bask in the sunshine that it loves.

*“If you consider the possibility of strong and weak influences from the sensors to the motors, you realize that the variety becomes even greater.” – Braitenberg*



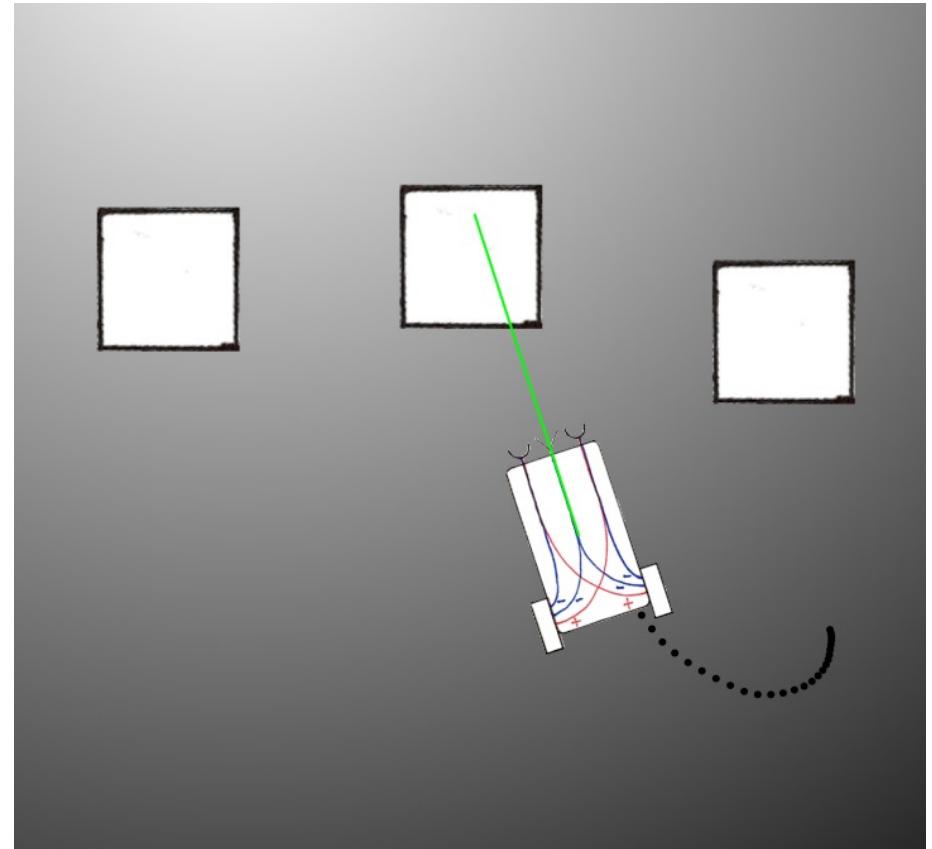
# Vehicle 3

- Multi-sensorial
- '-' indicates an **inhibitory** connection.
- Inputs arriving at the same time are *summed* together.
- Bernard Katz observed the summation of signals in nerve cells in the 1950s in the squid giant synapse (not the same thing as a giant squid synapse).



# Vehicle 3 Simulator

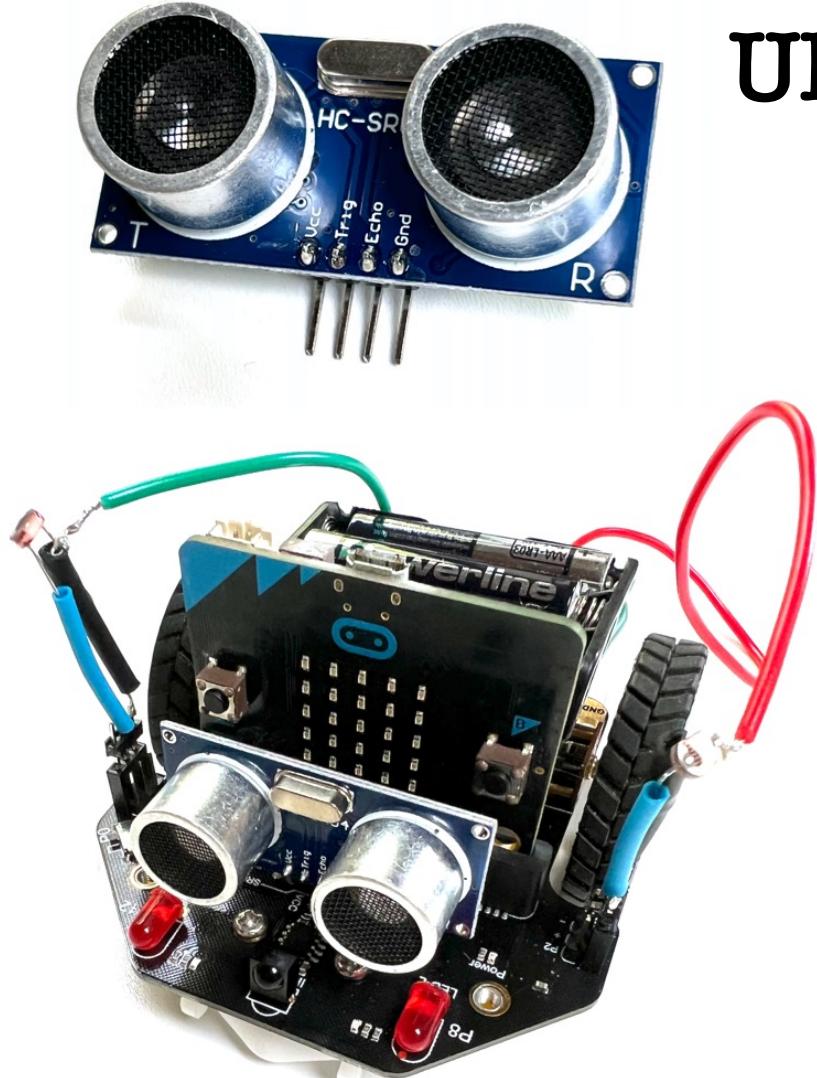
A new proximity sensor **inhibits** the motors, causing Vehicle 3 to slow down.



<https://go.uwe.ac.uk/v3>

# Ultrasonic Proximity Sensor

- Grab an ultrasonic proximity sensor.
- Plug it into the 4-way socket near the front of the robot.
- Get the **vehicle3.py** code from <https://go.uwe.ac.uk/cybsoc1>
- It transmits a 10us pulse and times the echo received.
- Flash the code to the robot.

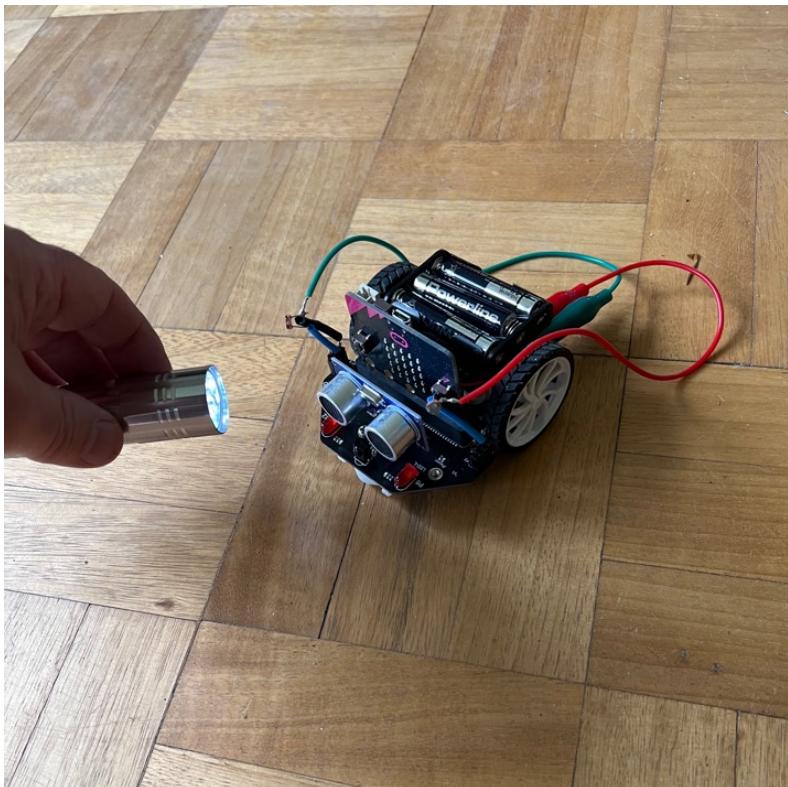


# Vehicle3.py

- New sensor data is read into variable c
- This is subtracted from both motors (inhibitory)

```
37  while True:  
38      a = mapValue(pin0.read_analog(),200,1000,0,1)  
39      b = mapValue(pin1.read_analog(),200,1000,0,1)  
40      c = mapValue(sonar(),0,50,1,0)  
41      motor(LEFT_MOTOR,0,condition(a-c))  
42      motor(RIGHT_MOTOR,0,condition(b-c))  
43      print("{:.2f} {:.2f} {:.2f}".format(a,b,c))
```

# Purposeful behaviour



- Vehicle 3 is now positively phototactic
- The bat-like sonar gives it obstacle avoidance behaviour.
- We can see vehicles as *purposeful*



“The Triumph of Cybernetics”, Glushkov Institute of Cybernetics, Kyiv