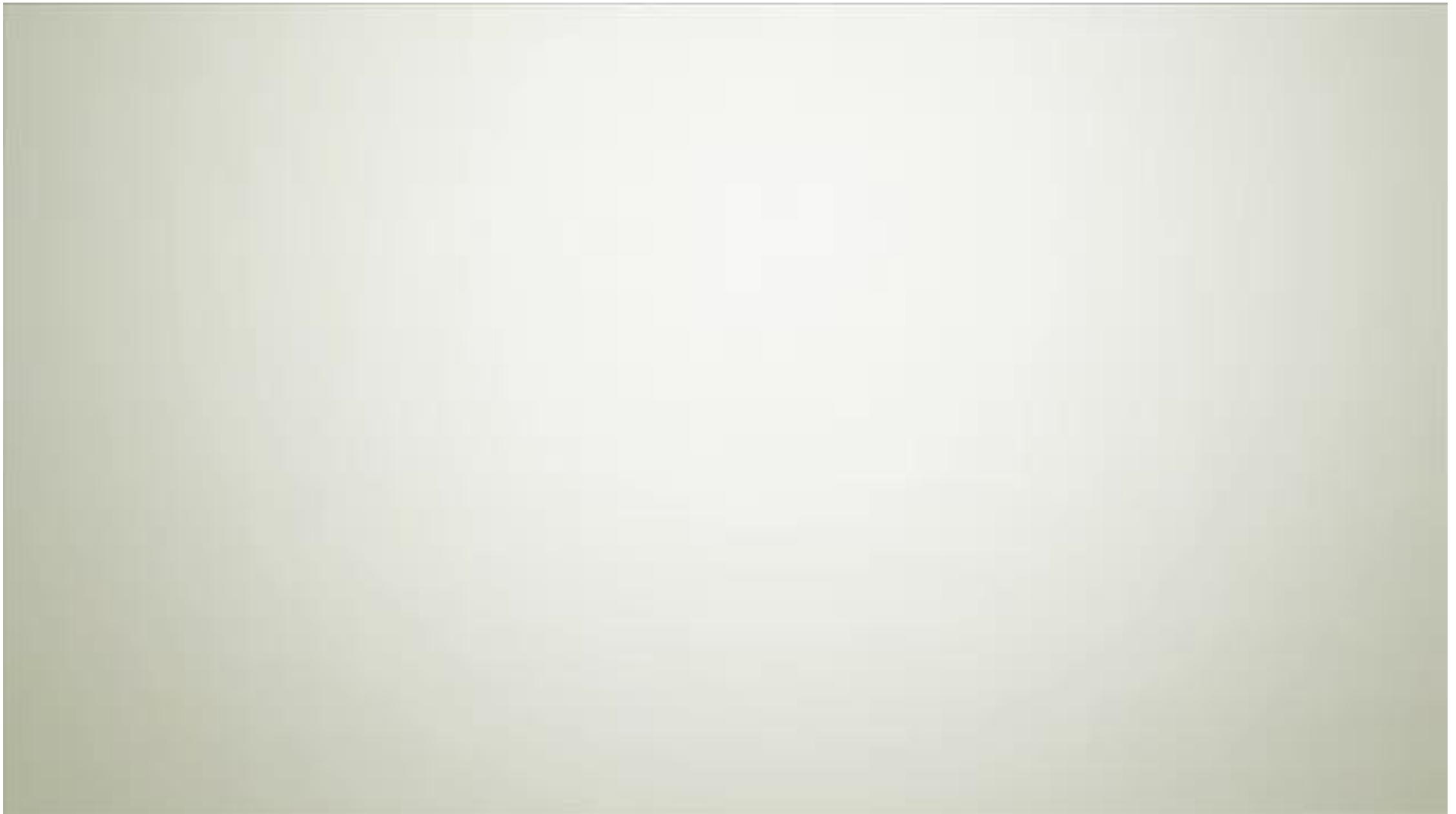
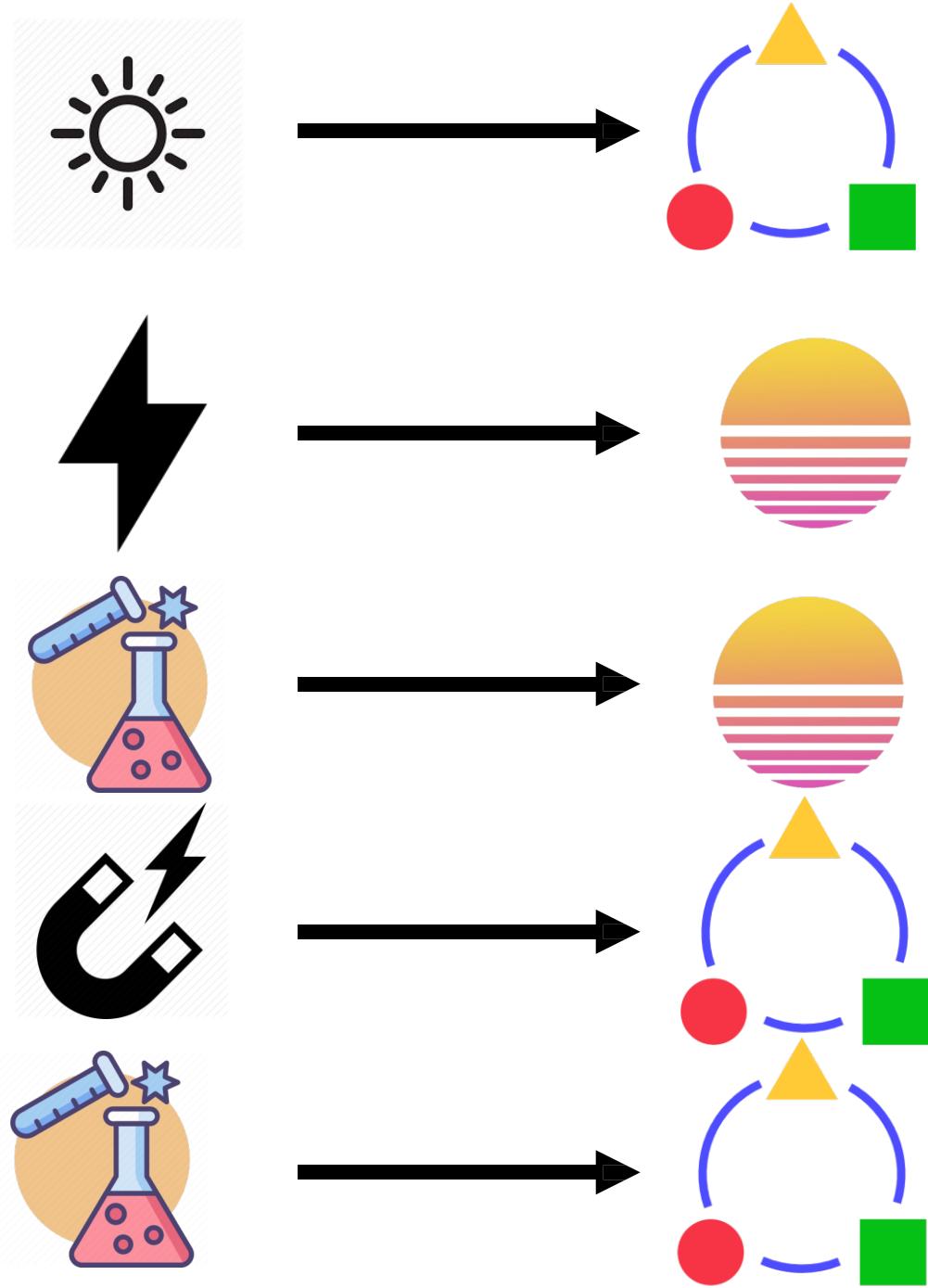
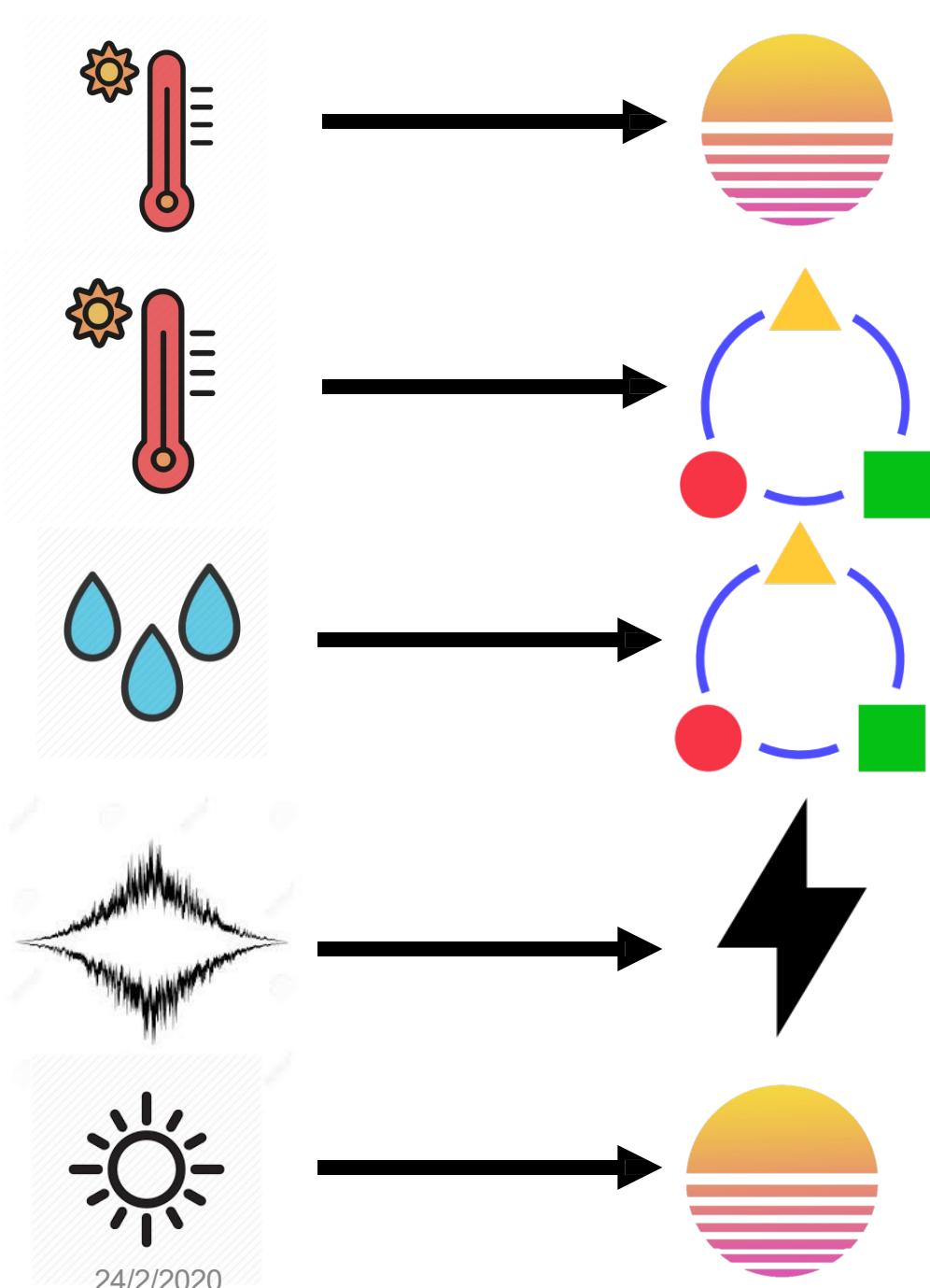


Smart Material III: Color-changing Materials

Smart? Responsive/Reactive

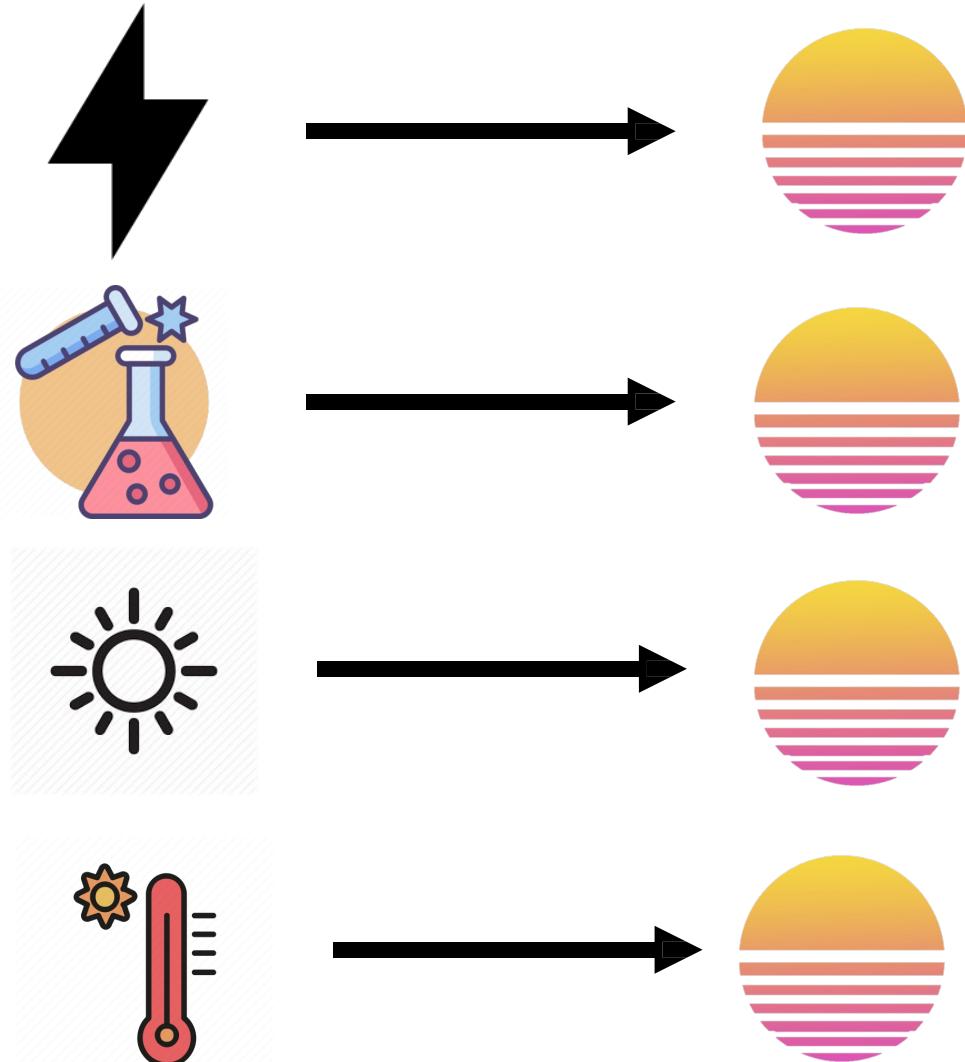
- Smart materials are the materials that can significantly alter one or more of their inherent properties due to the external stimuli.
 - Stress/Force/Pressure
 - Temperature
 - Moisture
 - Electric Fields
 - Magnetic Fields
 - Etc.
- Usually, the smart material can return to the original status after the stimulus is removed.



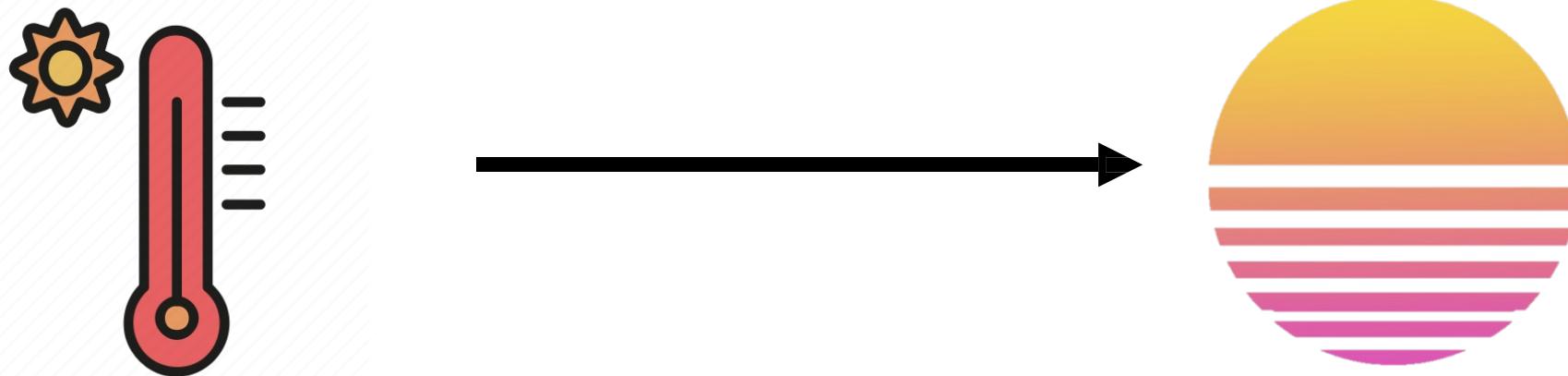


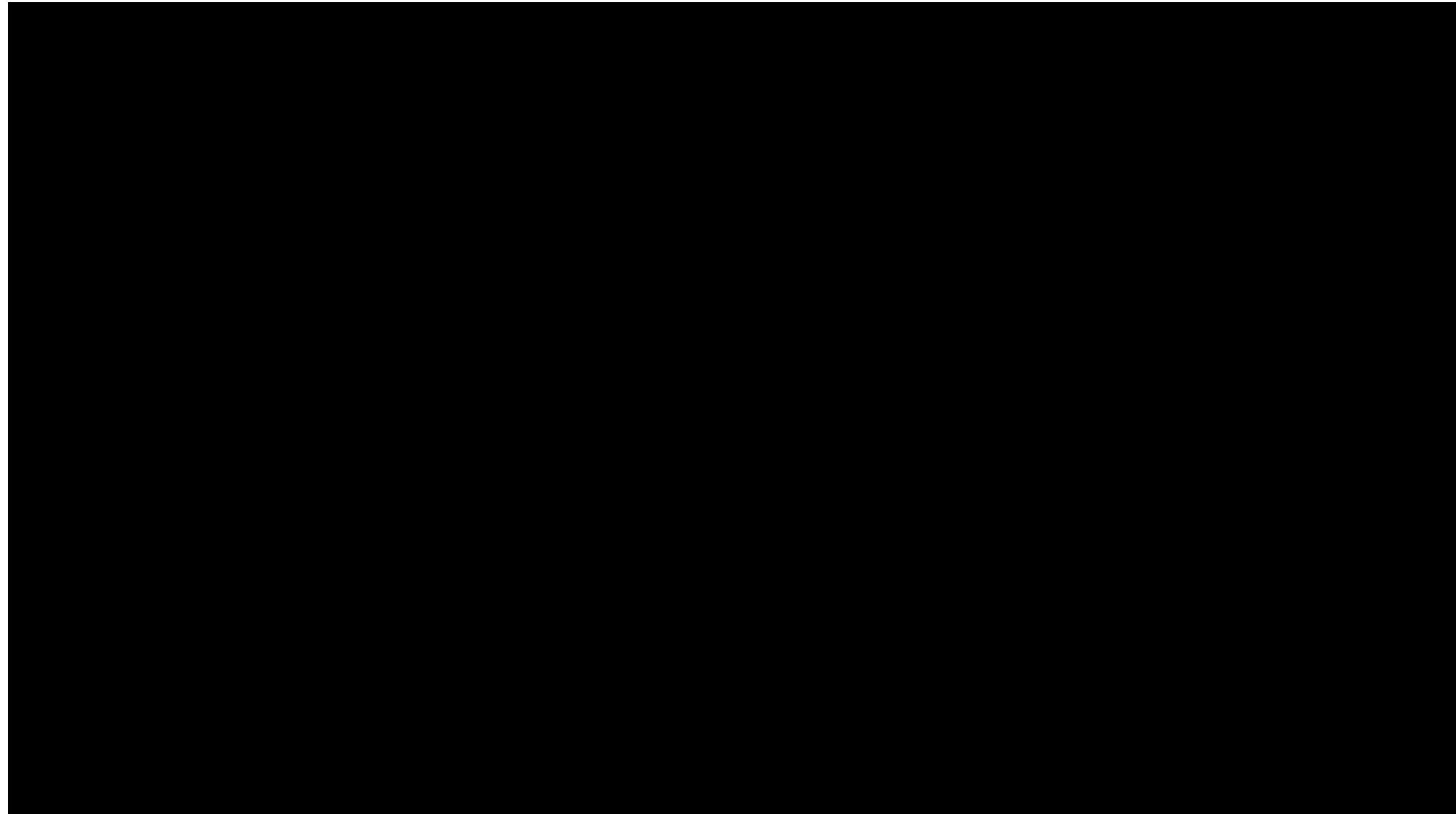
Chromism: Thermo-, Photo-, Electro-, etc.

- In chemistry, **chromism** is a process that induces a change, often reversible, in the colors of compounds.
- In most cases, **chromism** is based on a change in the electron states of molecules.
- It is known that there are many natural compounds that have chromism, and many artificial compounds with specific chromism have been synthesized to date.



Thermochromism 热致變色





<http://youtube.com/watch?v=7jled7OHPsE>

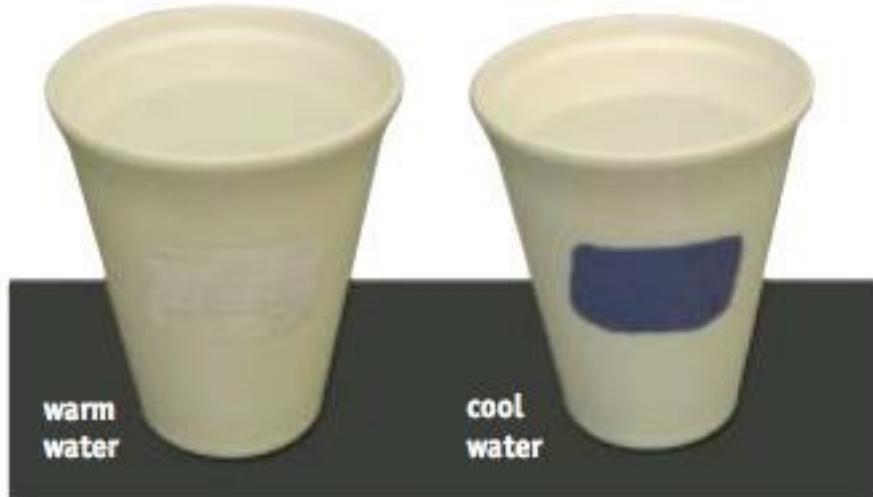
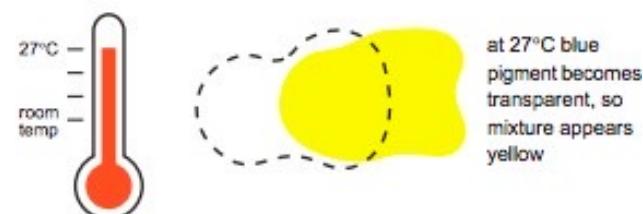
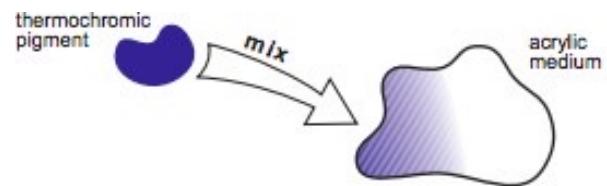
Thermochromic Leuco Dying (Pigment)





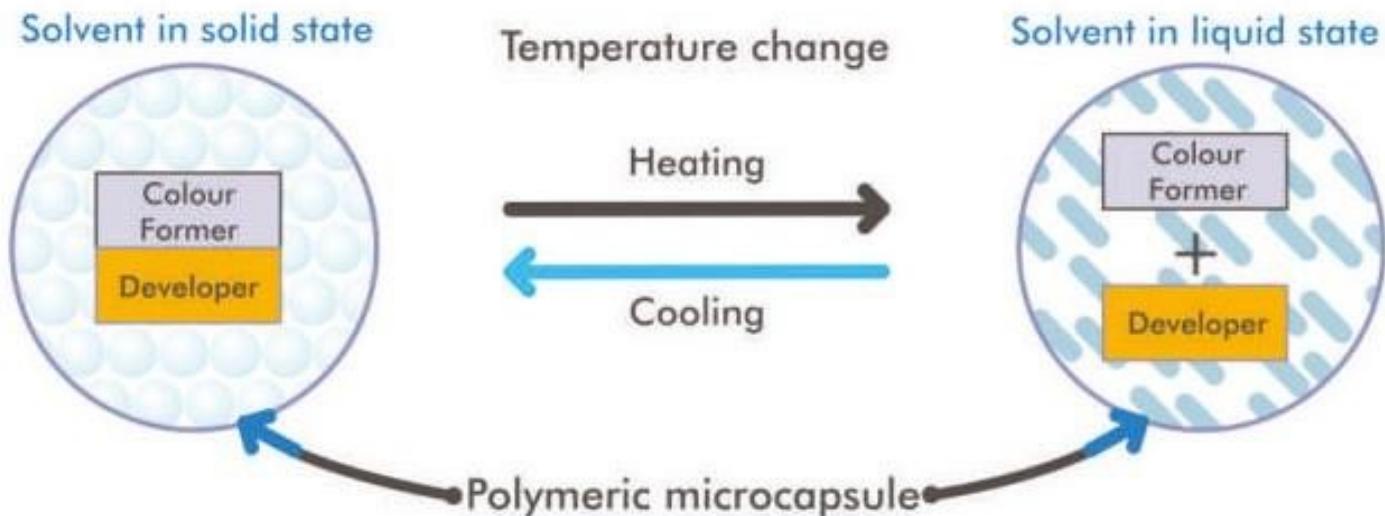
24/2/2020

http://youtube.com/watch?v=rV_-cw-P2EM



The Science Behind...

Principle of Thermochromism



Coloured state

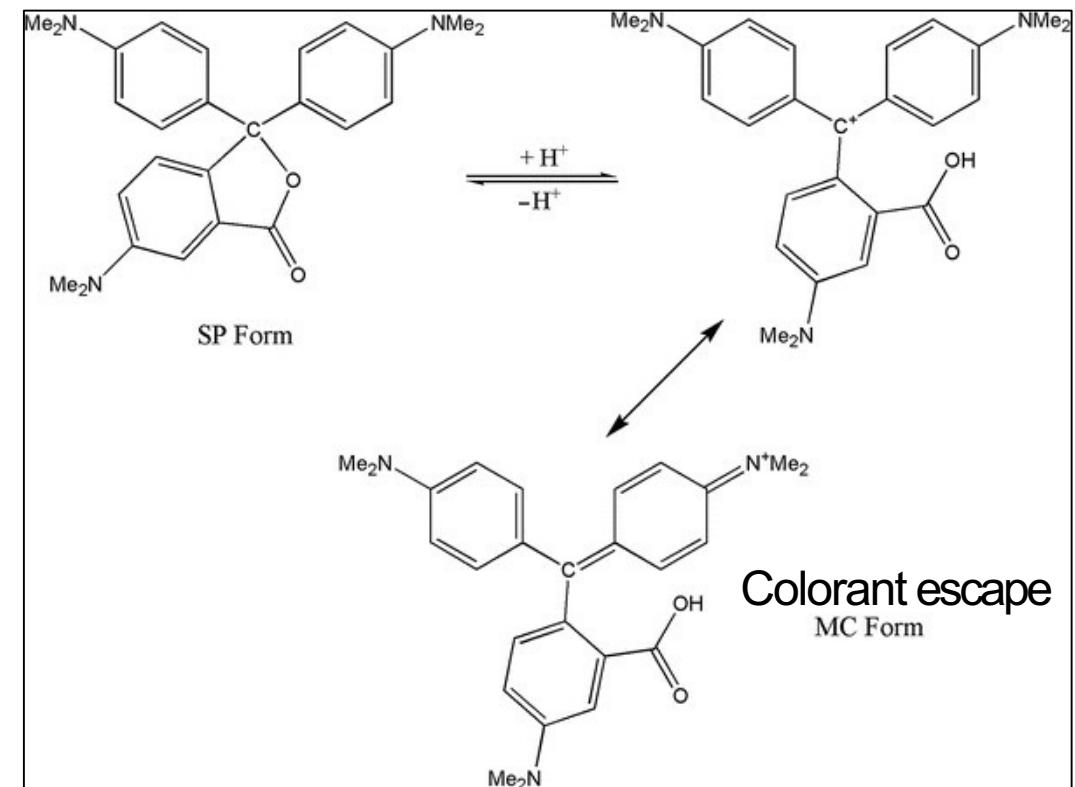
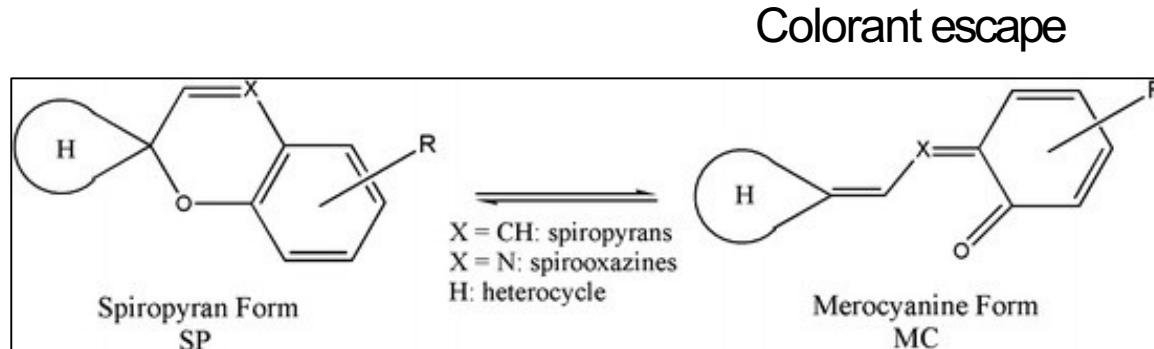
If the temperature is below the melting point of the solvent, the colour forming components are in contact. Due to electron interaction a visible colour occurs

Colourless state

If the temperature is above the melting point of the solvent, the colour forming components are separated. Therefore no electron interaction and no visible colour occur.

Science Behind...

- Spiro compounds: Spiropyran/Spirolactone
 - the most important class of compound used in thermochromic applications



SMOKING 2 X 1,90
GROOTE FRIET 2 X 0,45
MAYONNAISE 0,90
GROOTE FRIET 1,90
MAYONNAISE 0,45
CURRY 0,45

KROKET 1,25
KAASSOUFFLE 5,00
FRIK. SPEC. 1,45
1,70

15
18,65

KONTANT

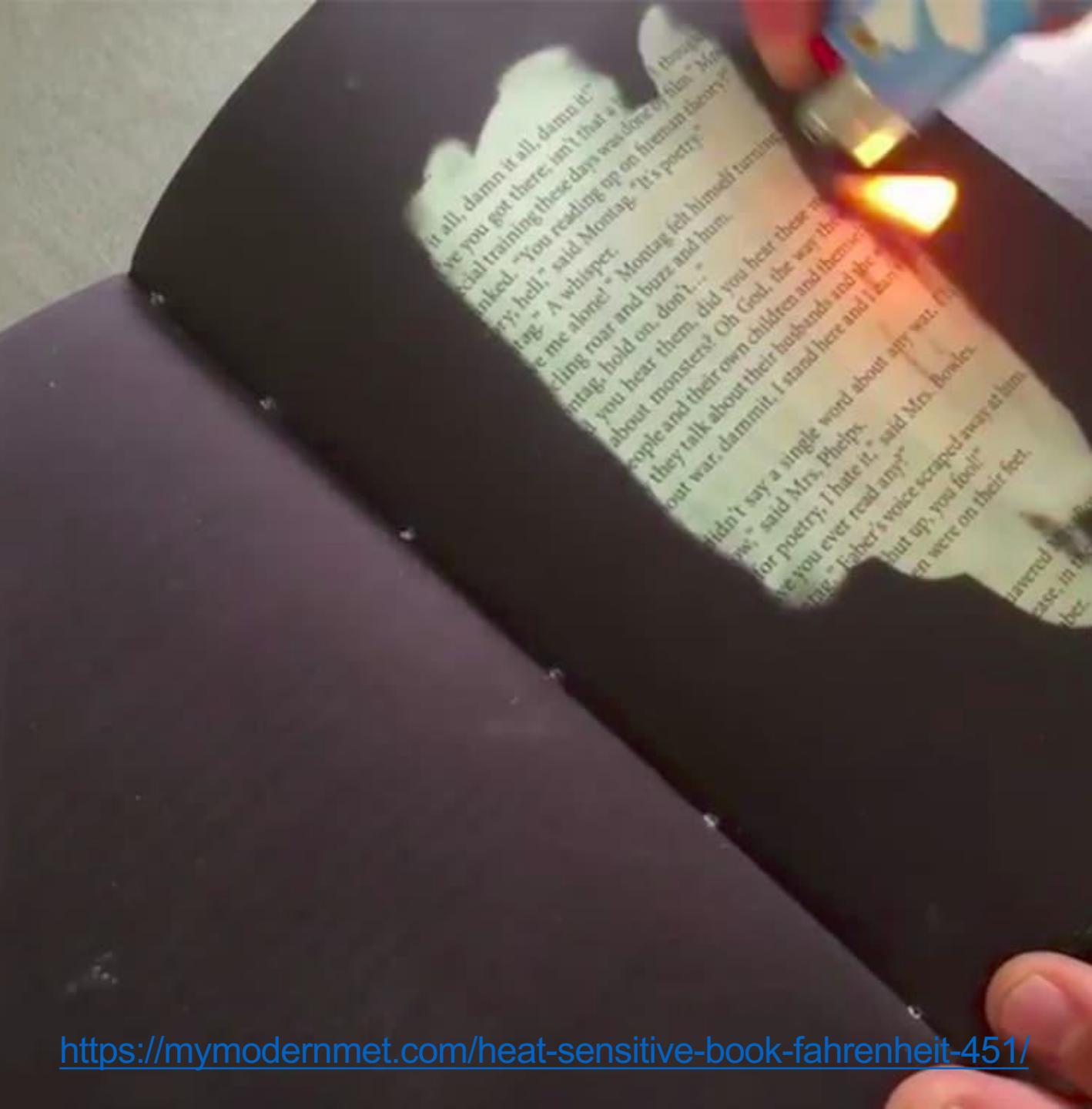


FACT

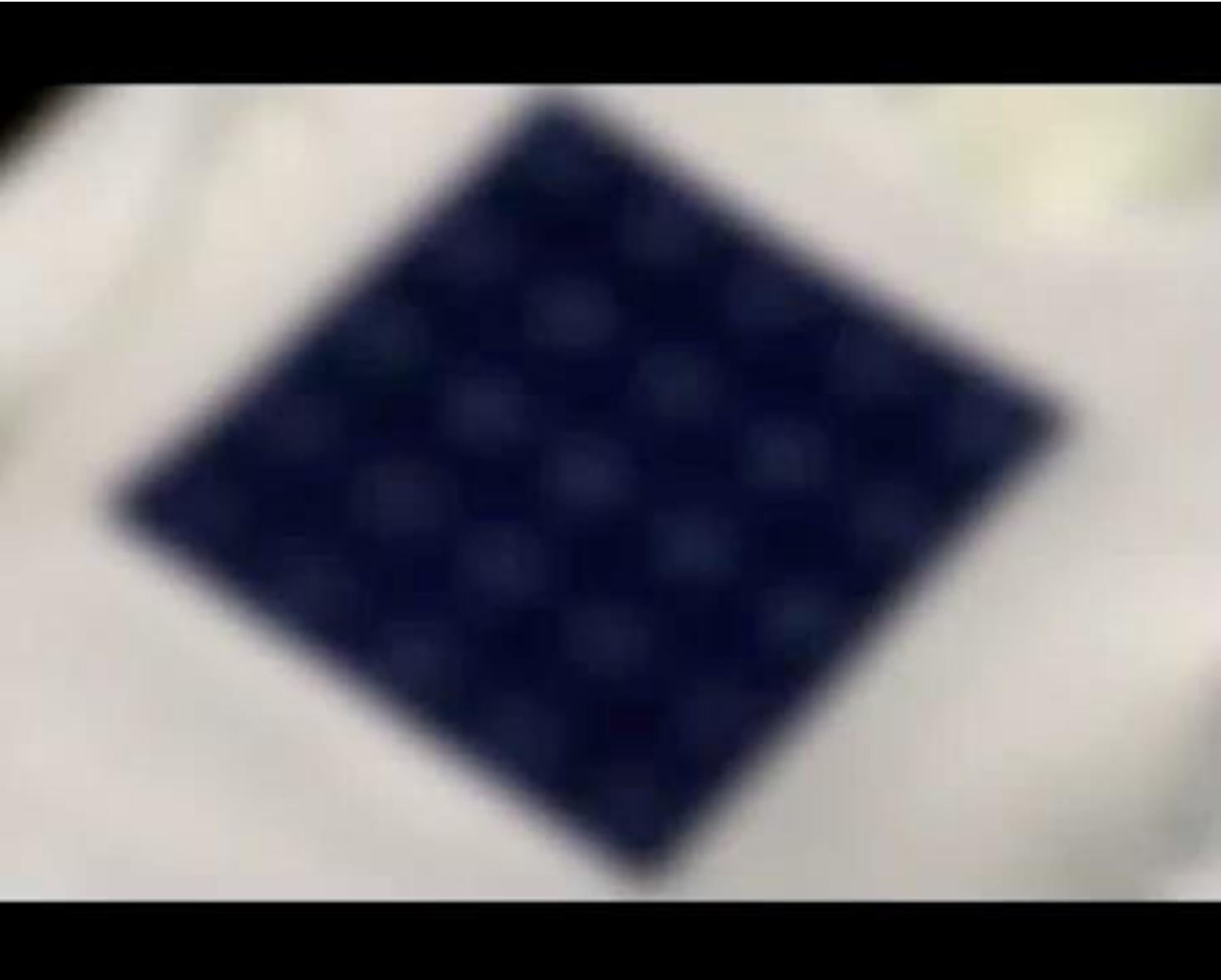
Heat sensitive fax paper
when expose to heat will
turn black.

Hair dryer is our heat
source to create a bold
stroke.



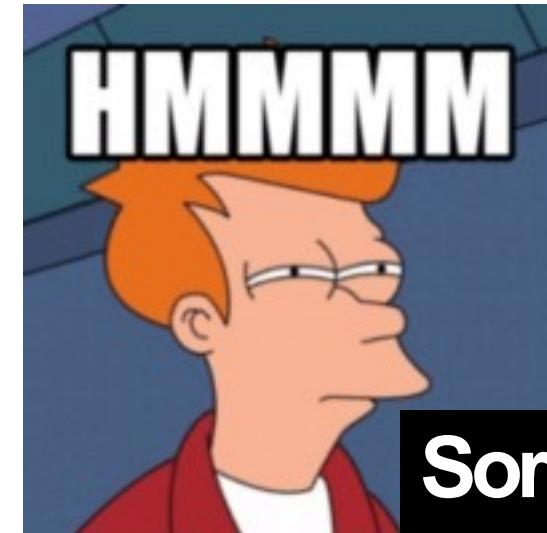
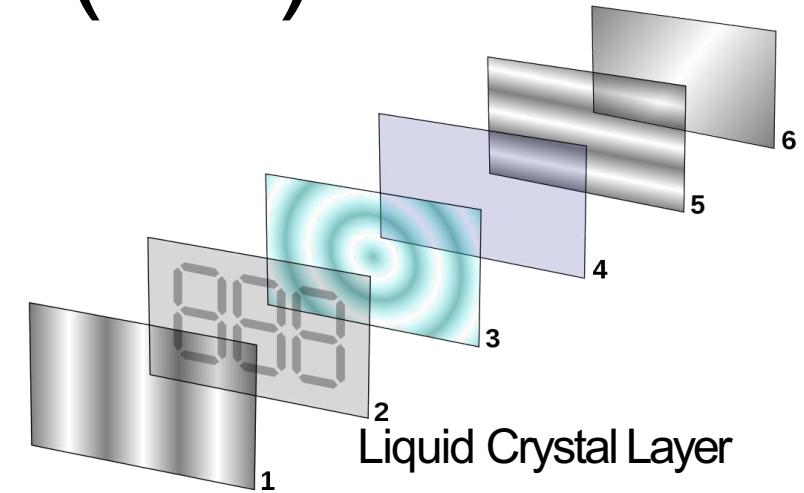






Thermochromic Liquid Crystal (TLC)

- Liquid Crystal Display?



Thermochromic Liquid Crystal (TLC)

- Thermochromic liquid crystals can be found in products as diverse as mood rings, “stress testers,” warning indicators, and thermometers.

Change through a wide spectrum of colours known as ‘colour play’ commonly red, very quickly through yellow, moving through green and blue.



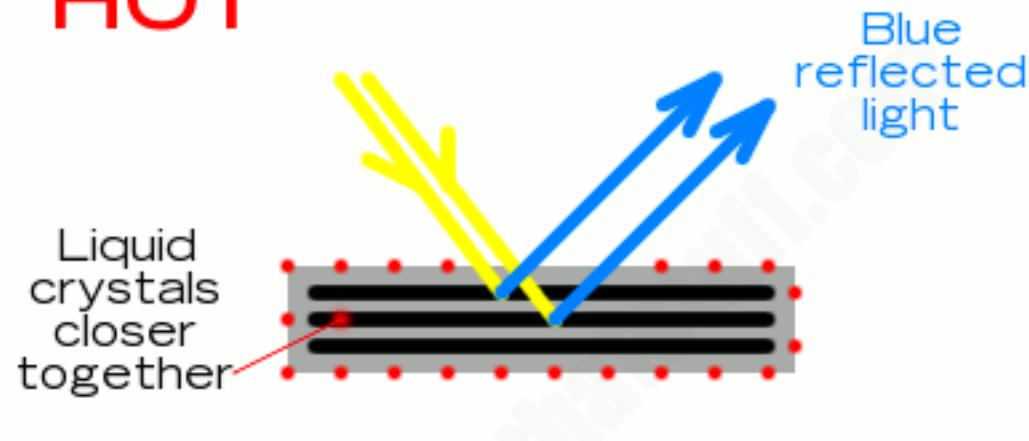


24/2/2020

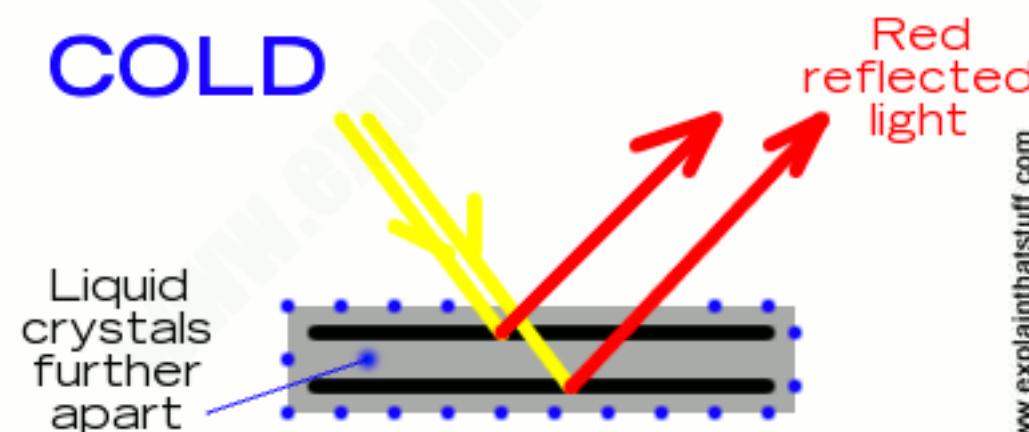
http://youtube.com/watch?v=DscgYJu_HGE

Science Behind...

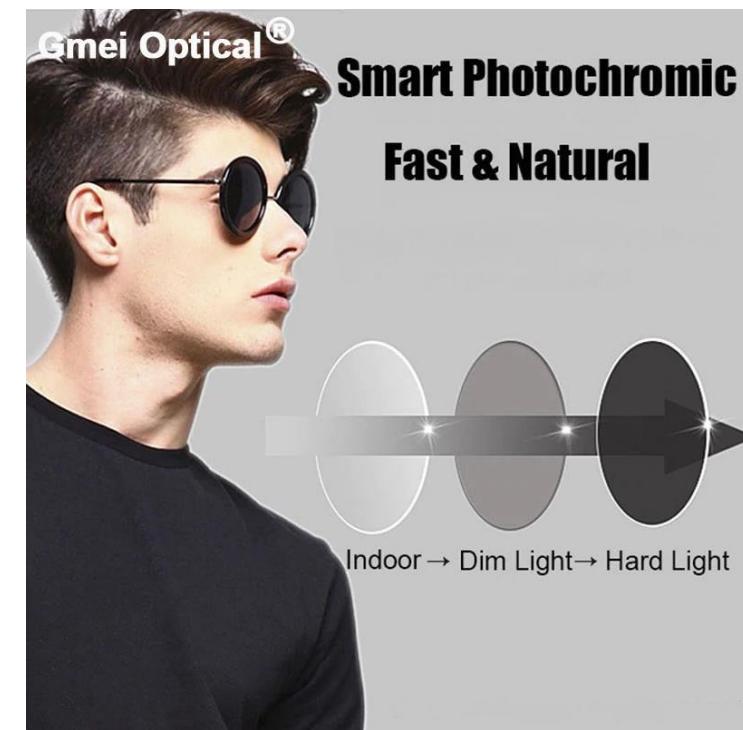
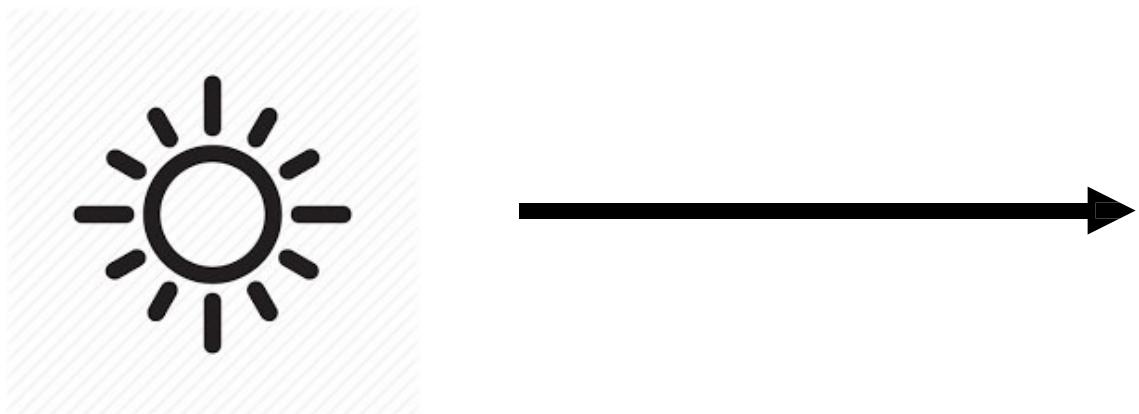
HOT



COLD



Photochromism





VISION
EASE®



24/12/2020

Slow Display

Daniel Saakes, Kevin Chiu, Tyler Hutchison, Biyeun M. Buczyk, Naoya Koizumi, Masahiko Inami, Ramesh Raskar

MIT Media Lab

ACM SIGGRAPH EMERGING TECHNOLOGIES 2010



Photo-Chameleon: Re-Programmable Multi-Color Textures Using Photochromic Dyes

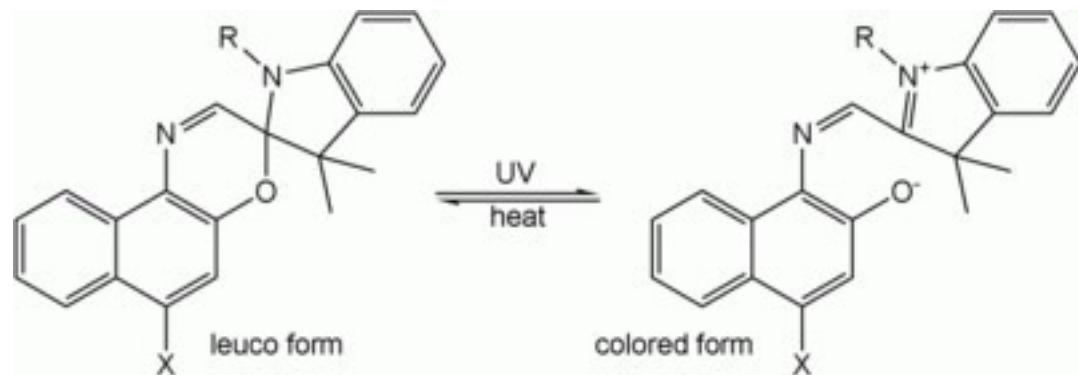
Yuhua Jin*, Isabel Qamar*, Michael Wessely*,
Aradhana Adhikari, Katarina Bulovic,
Parinya Punpongsanon, Stefanie Mueller

*equal contribution

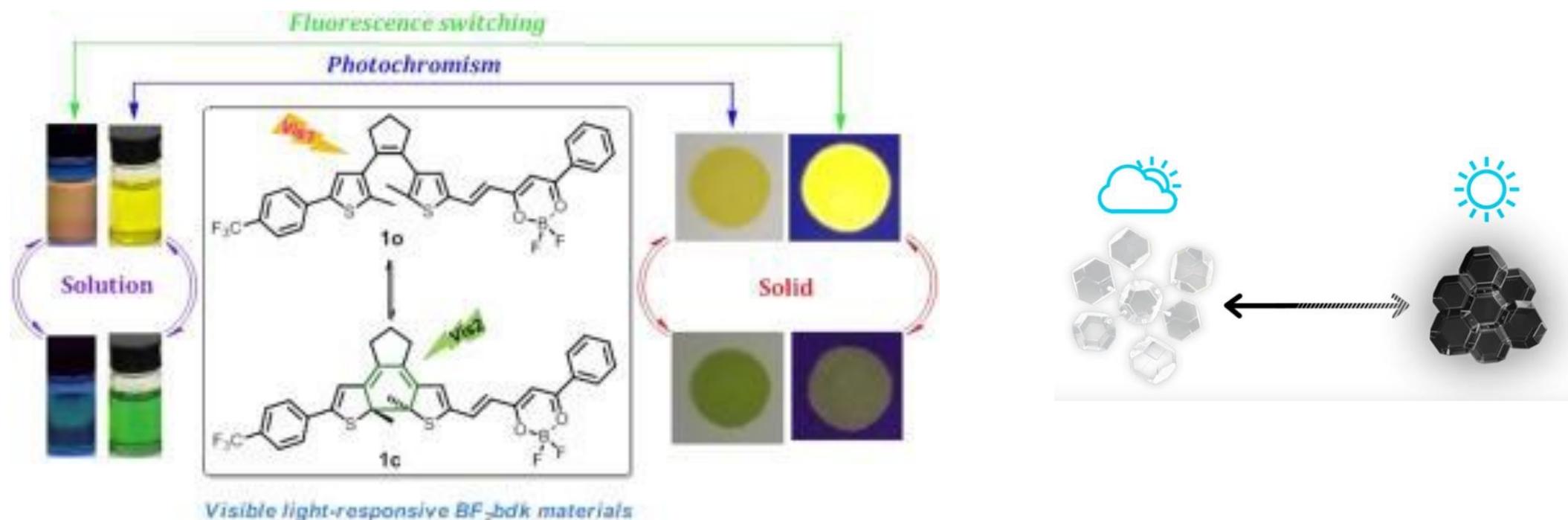
video: Tom Buehler



Science Behind...

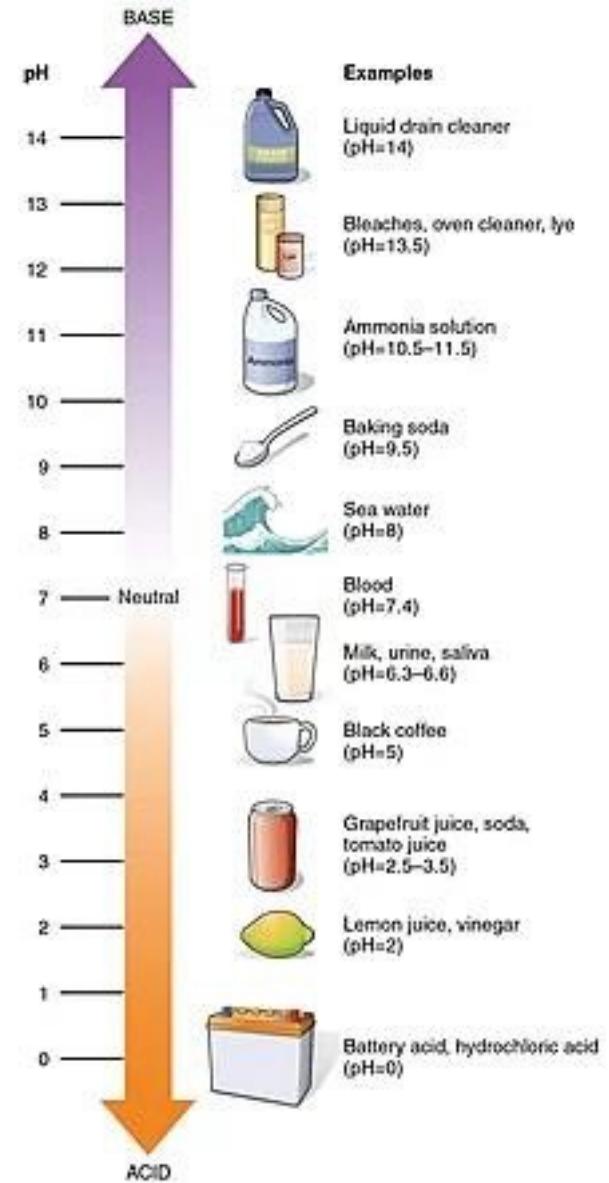


Spiro-mero photochromism.

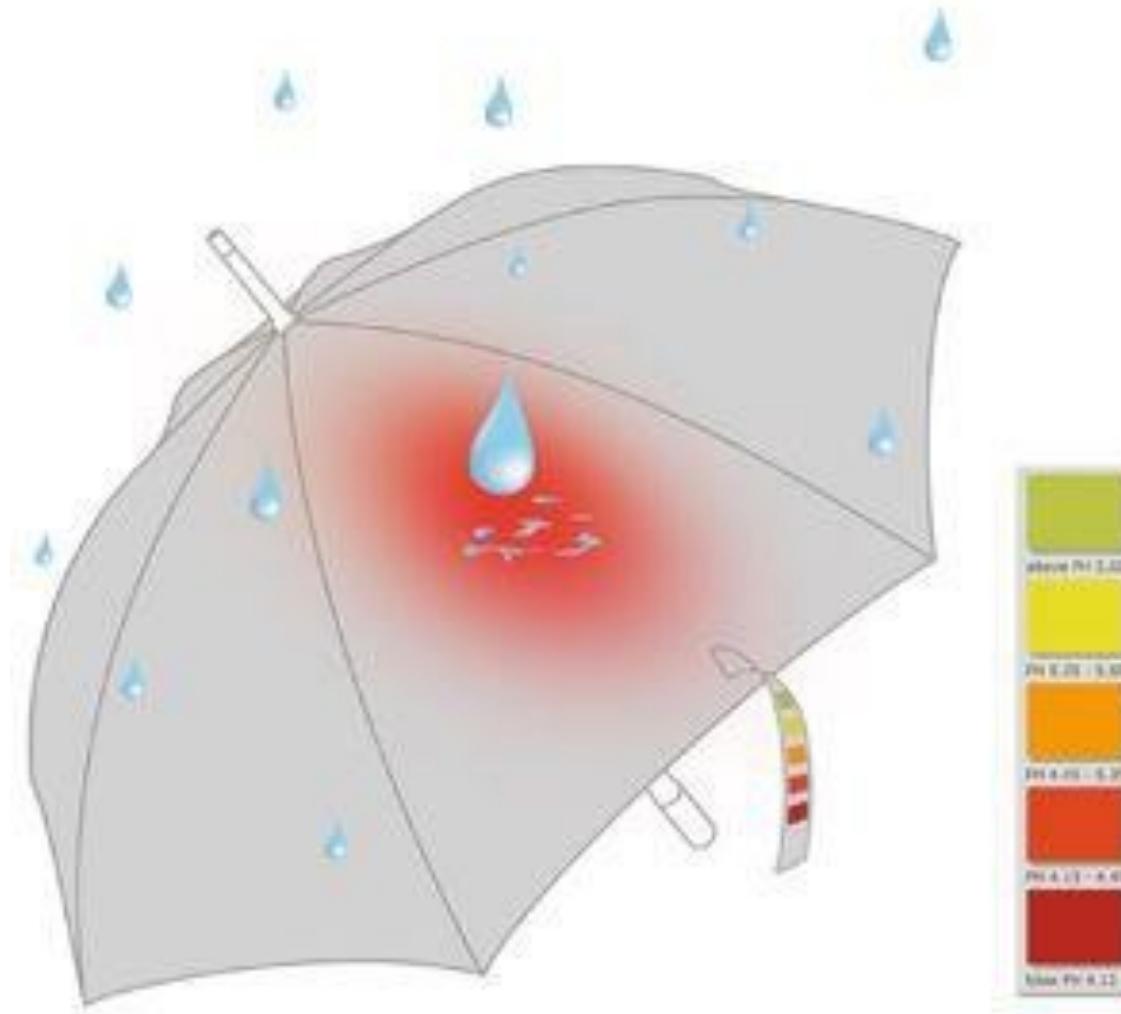


Halochromism

- Ahalochromic material is a material which changes color when **pH** changes occur.
 - pH: acid level

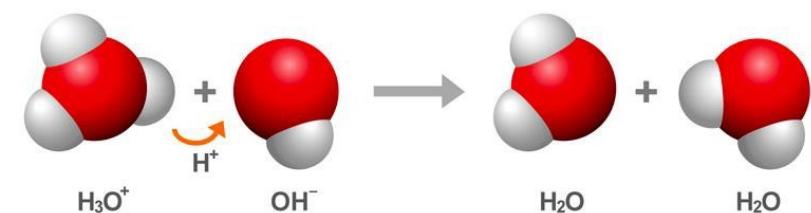
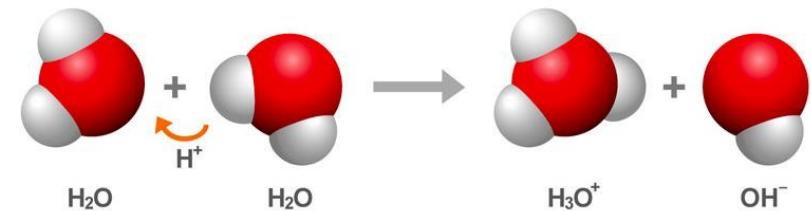
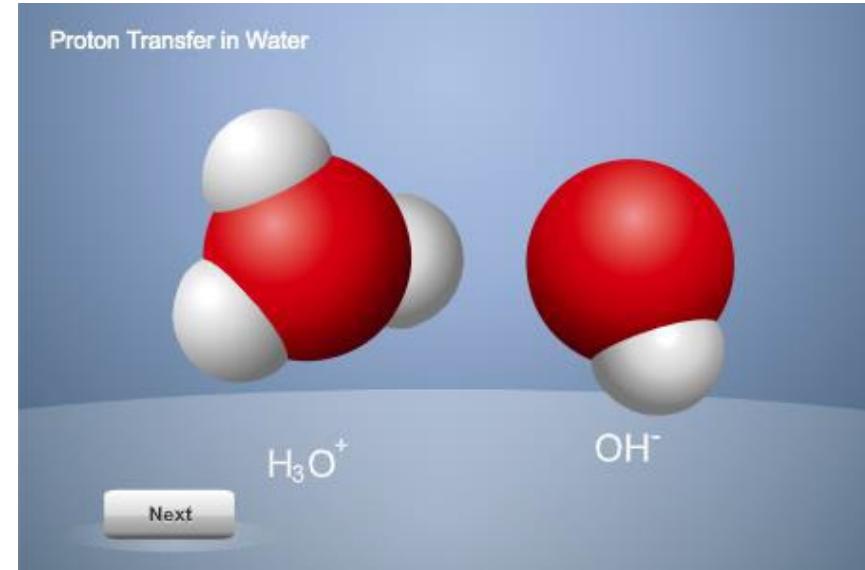


<http://youtube.com/watch?v=Ga-l9uUKnPI>



Science Behind...

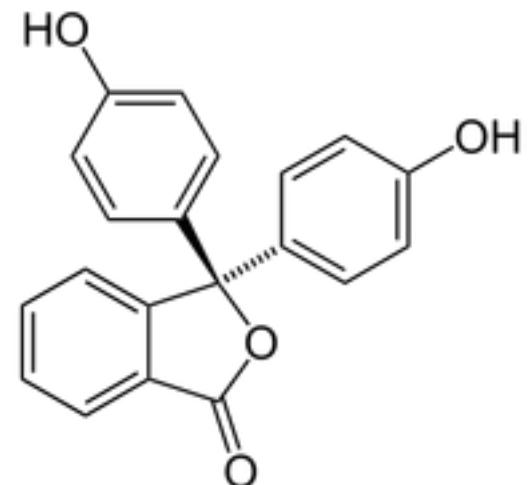
- Water molecules (H_2O) can interact with one another to form H_3O^+ ions and OH^- ions.
- At a pH of 7, there are equal numbers of H_3O^+ ions and OH^- ions in water, and this is called a neutral solution.
 - To create an indicator liquid solution, we add a kind of indicator element and react with the water molecules.
 - And the water element will not break the balance.



https://www.middleschoolchemistry.com/multimedia/chapter6/lesson8#proton_transfer_animation

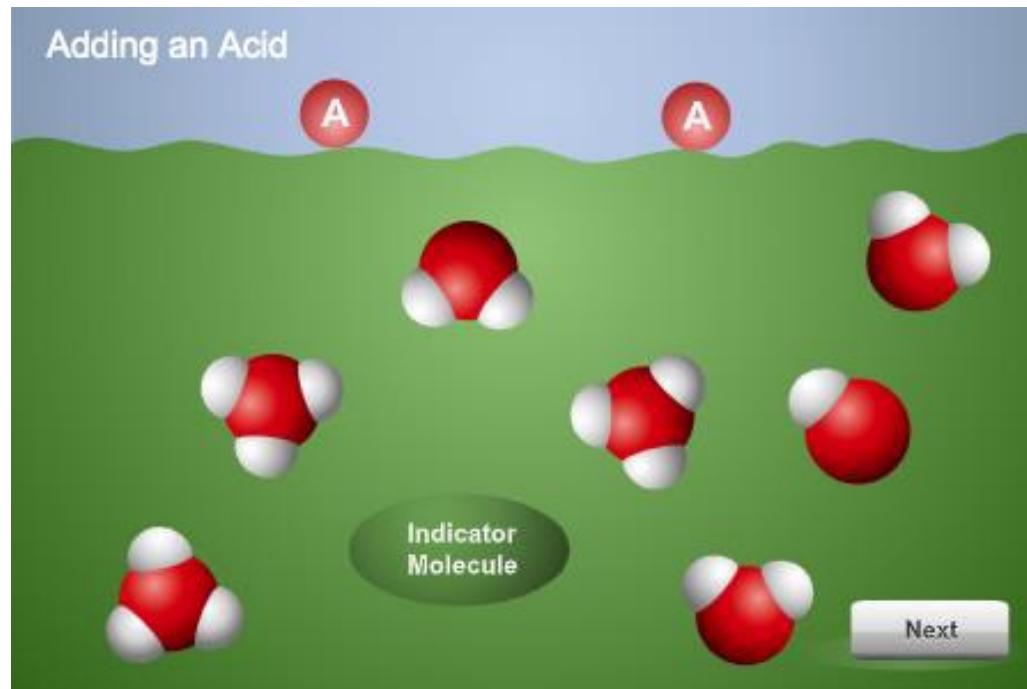
Science Behind..

- The indicators themselves are actually either weak acids or bases. When they're dissolved in water, their molecules dissociate slightly and form ions.
- Indicators tend to be molecules containing a fair number of alternating (conjugated) carbon-carbon double bonds and single bonds, such as phenolphthalein, shown below:



Science Behind...

- When we add different chemical solutions into the indicator liquid, the balance will be broken, causing the molecules to absorb different wavelengths of light and appear a different colour.



https://www.middleschoolchemistry.com/multimedia/chapter6/lesson8#proton_transfer_animation



Hydrangea in acid soil



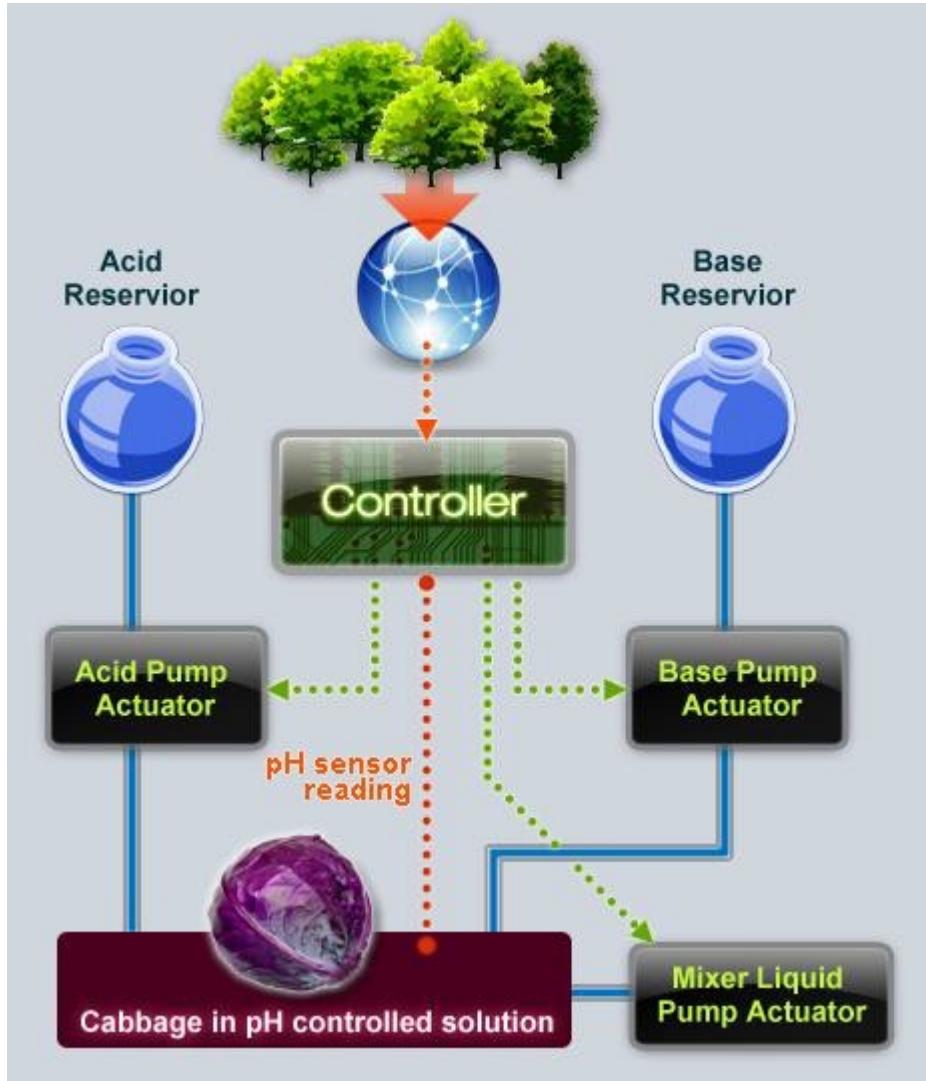
Hydrangea in
alkaline soil



A gradient of red cabbage
extract pH indicator from acidic
solution on the left to basic on
the right



Purple
cauliflower
soaked in
baking soda
(left) and
vinegar
(right).
Anthocyanin
acts as an
pH indicator.

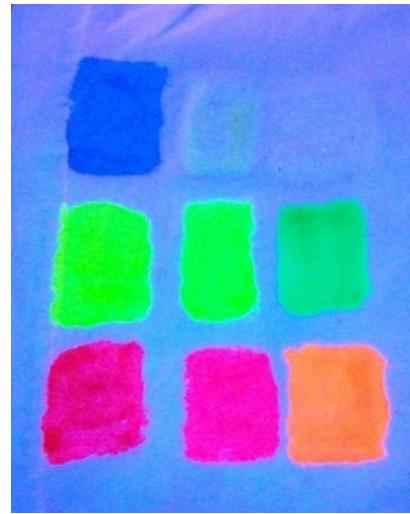
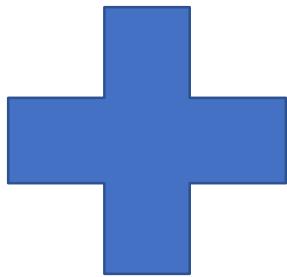
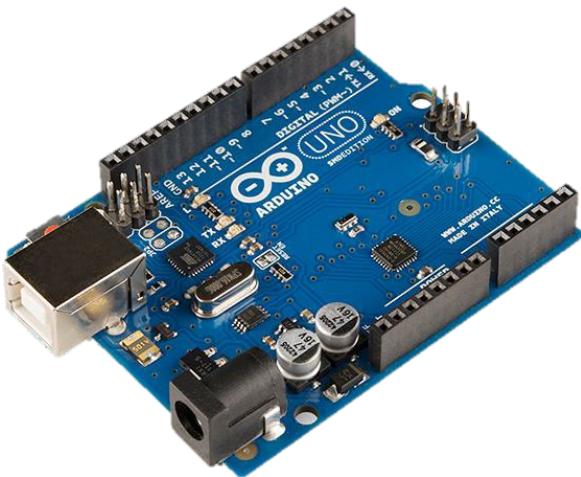


"Our present global crisis is more profound than any previous historical crises; hence our solutions must be equally drastic. I propose that we should adopt the plant as the organizational model for life in the 21st Century..."

(McKenna 1992)

Controlling the color-changing process with electronics

Control the thermochromic process with Arduino



What kind of electronic components are heat sources?

- Resistors (single direction: hot)
- Conductive Thread (single direction: hot)
- Peltier Module (two directions: hot and cool)

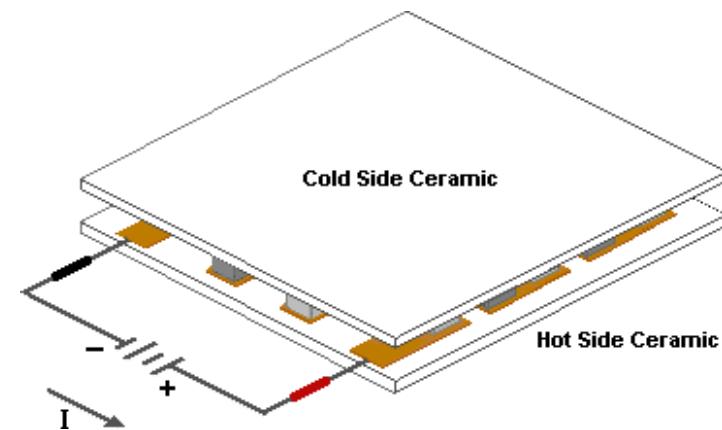
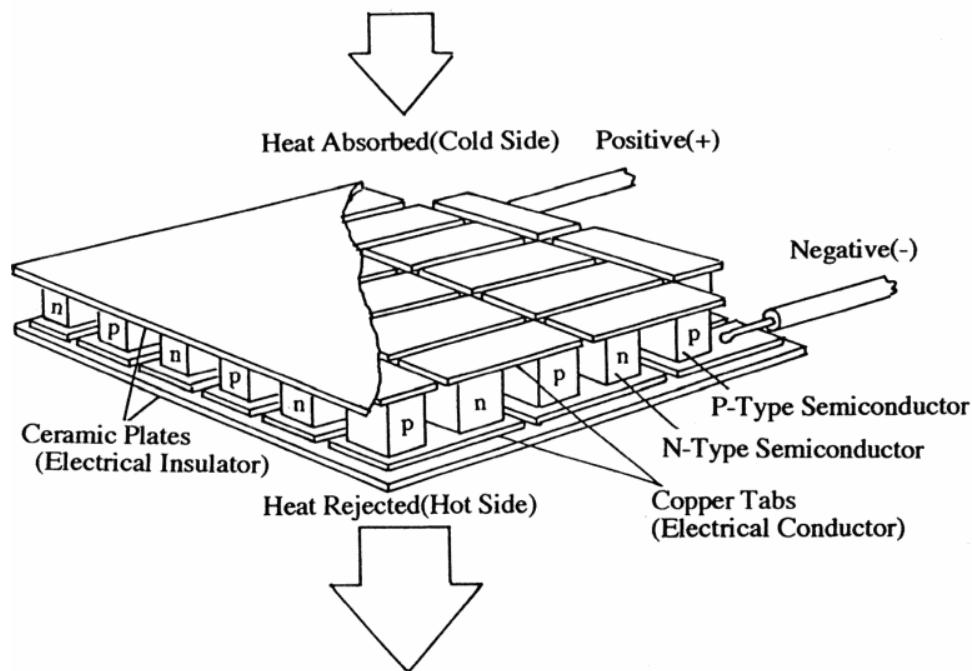
Peltier Module

- Semiconductor
- Can quickly heat and cool



How it works

- A solid-state active heat pump which transfers heat from one side of the device to the other, with consumption of electrical energy, depending on the direction of the current.



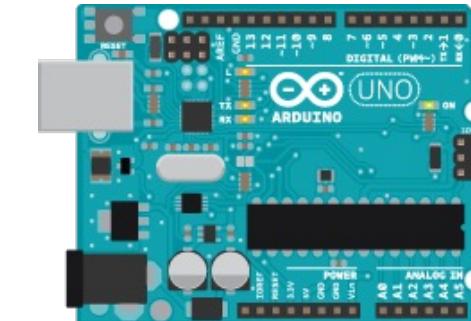
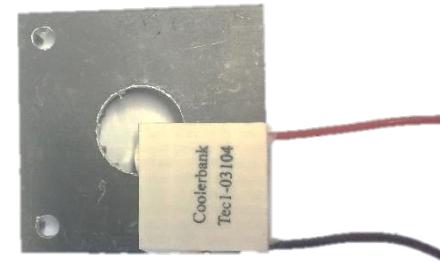
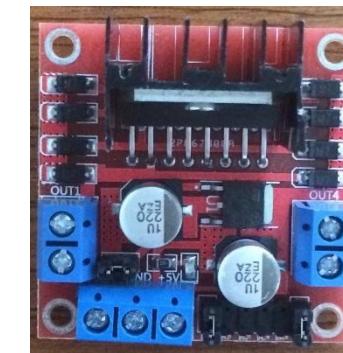
Connect it directly to the battery

- Put the hot side behind your thermochromic painting



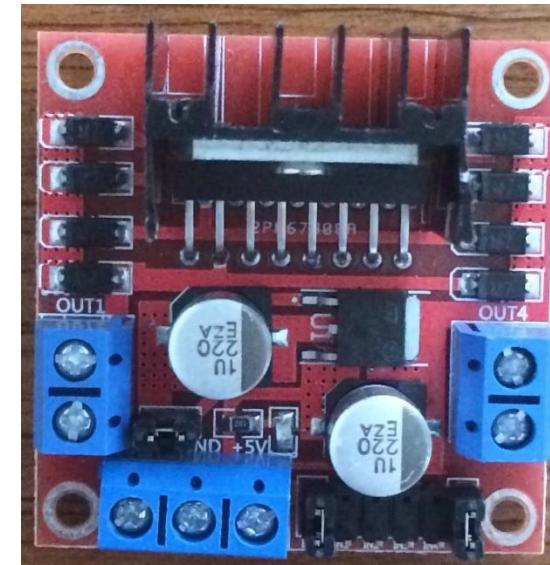
Control the color/temperature with Arduino

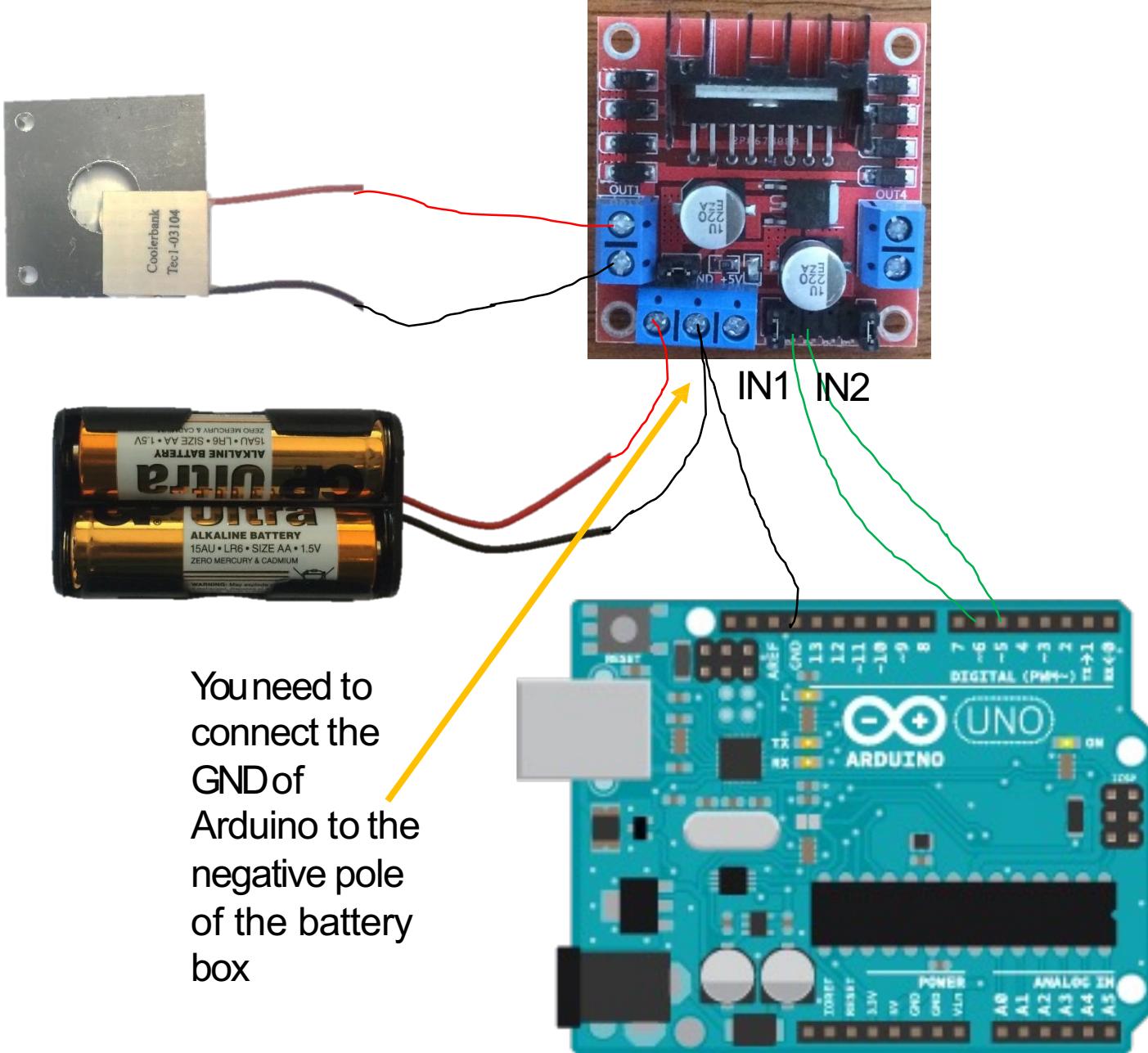
- We need
 - 1 battery box
 - 4 AA batteries
 - 1 L298N motor driver
 - 1 peltier module attached to heat sink
 - 1 Arduino
 - Of course, wires, and usb cables



L298N motor driver

- The L298N is a dual H-Bridge motor driver which allows **speed and direction control** of two DCmotors at the same time. The module can drive DCmotors that have voltages between 5 and 35V, with a peak current up to 2A.
- It is usually used for controlling motors
 - Speed
 - Direction



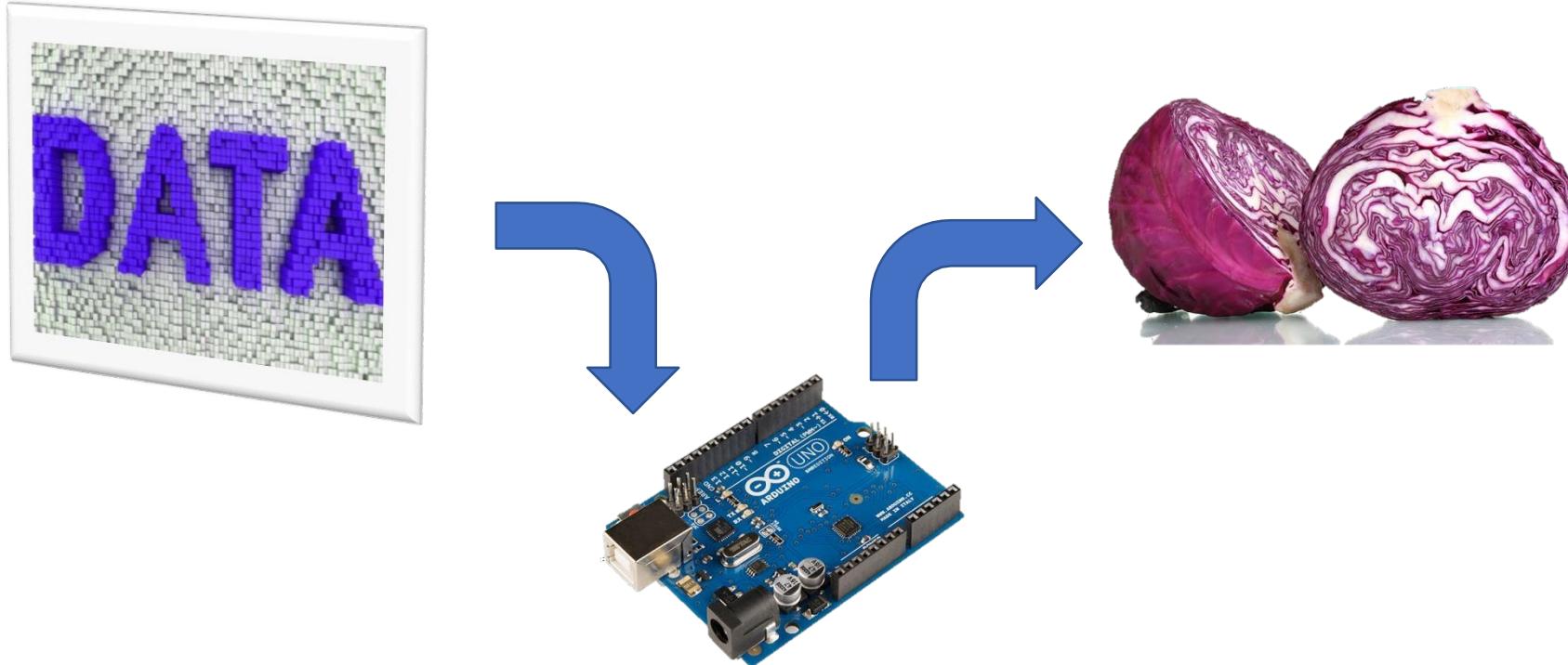


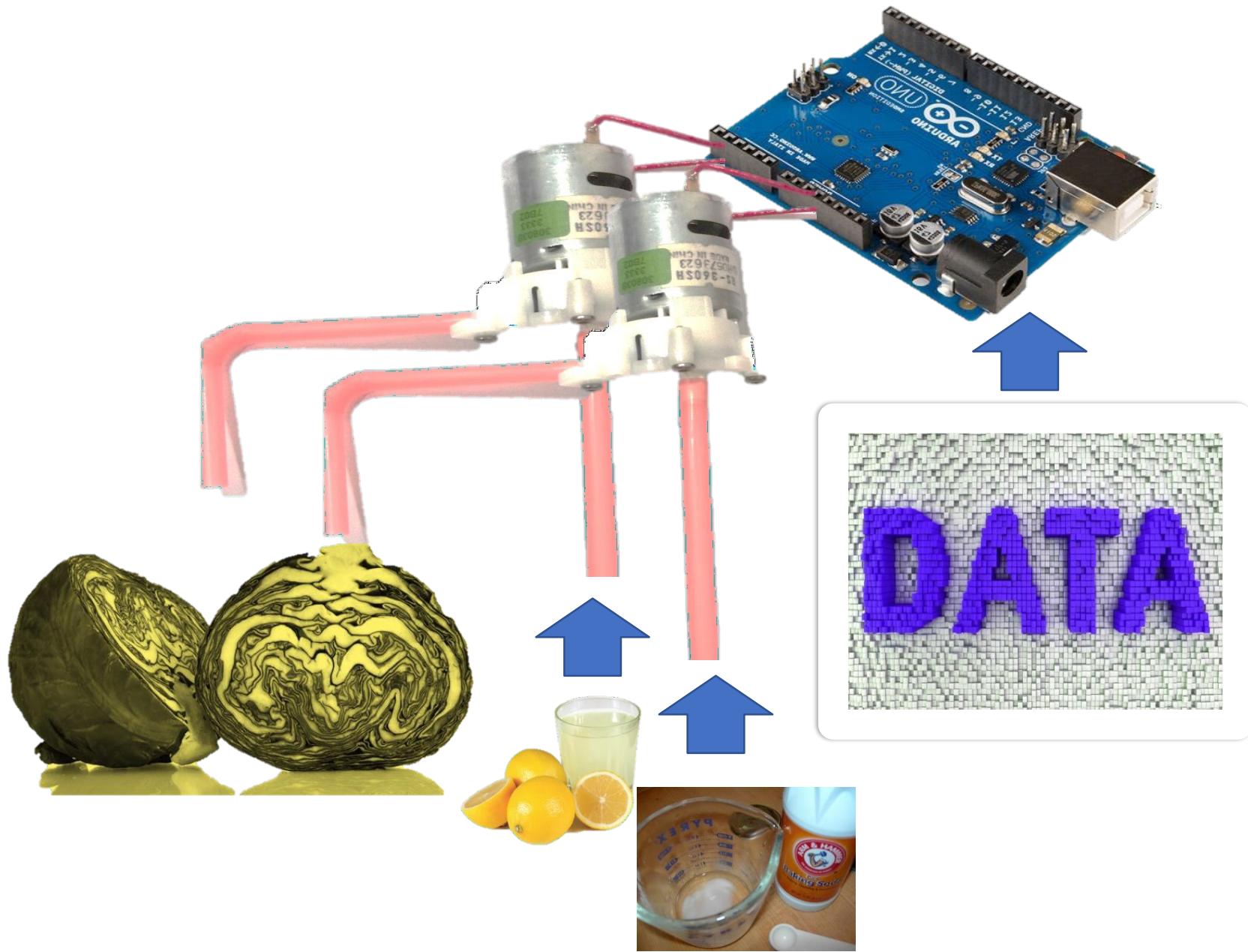
Coding Logic

- Set pin 5 and 6 to OUTPUT
- When IN1 receives a 255 analog signal and IN2 receives a 0 analog signal
 - The peltier module heats
- Delay 6s
 - For reset
- When IN1 receives a 0 analog signal and IN2 receives a 255 analog signal
 - The peltier module cools
- Delay 10s
 - For reset

Controlling the halochromic process

How to control it?

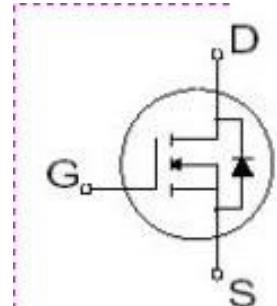




The Water Pump



IRF530 Transistor

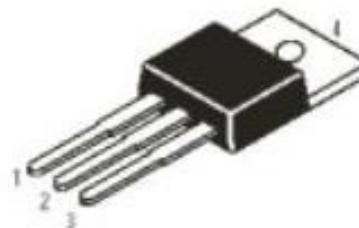


V_{DSS} = 100V

I_{D25} = 17A

R_{DSON} = 0.09Ω

Rectifier Utilize advanced
low on-resistance per silicon
switching speed and ruggedized
are well known for, provides
reliable device for use in a



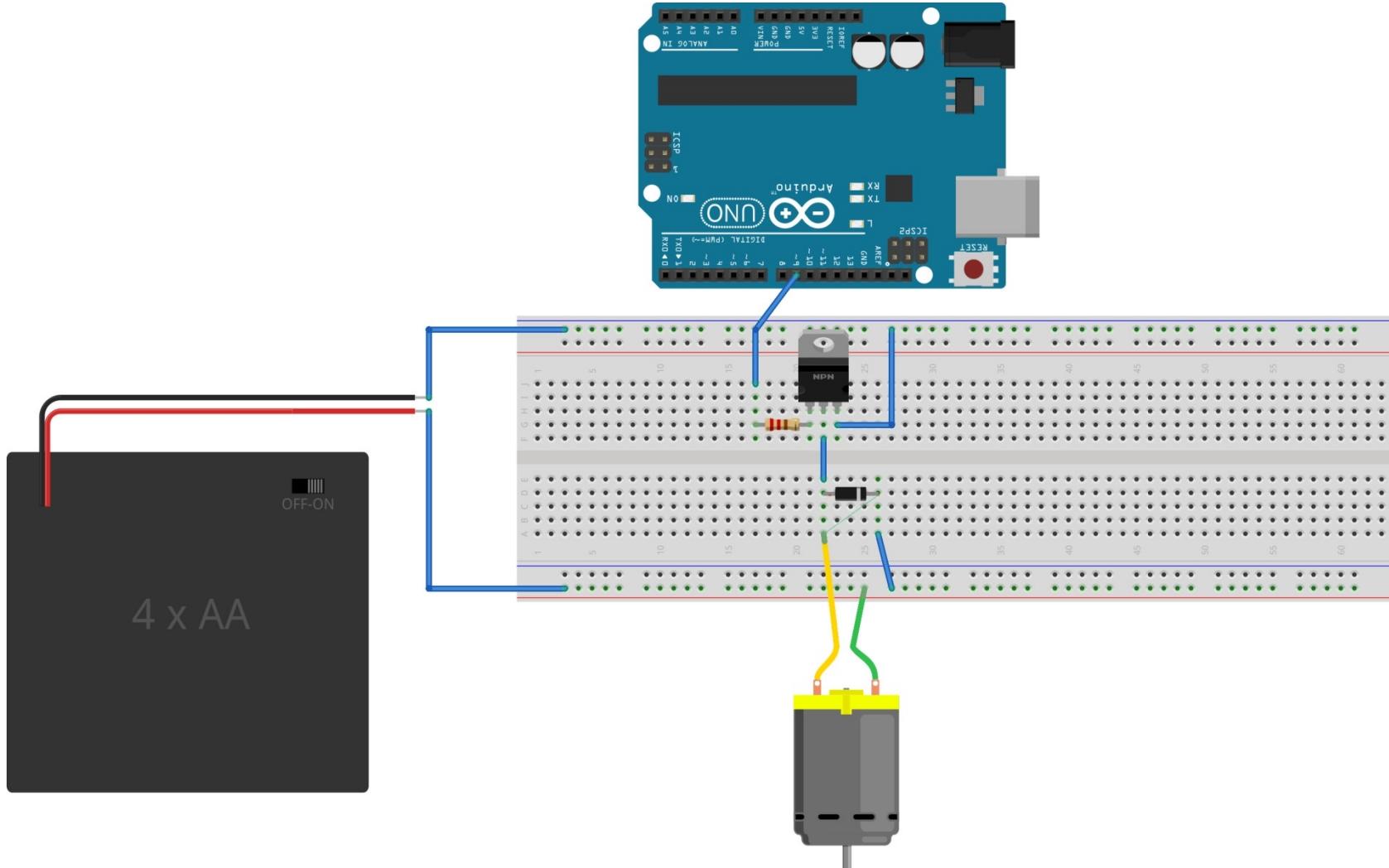
for all commercial-industrial
approximately 50watts. The low
the TO-220 contribute to its

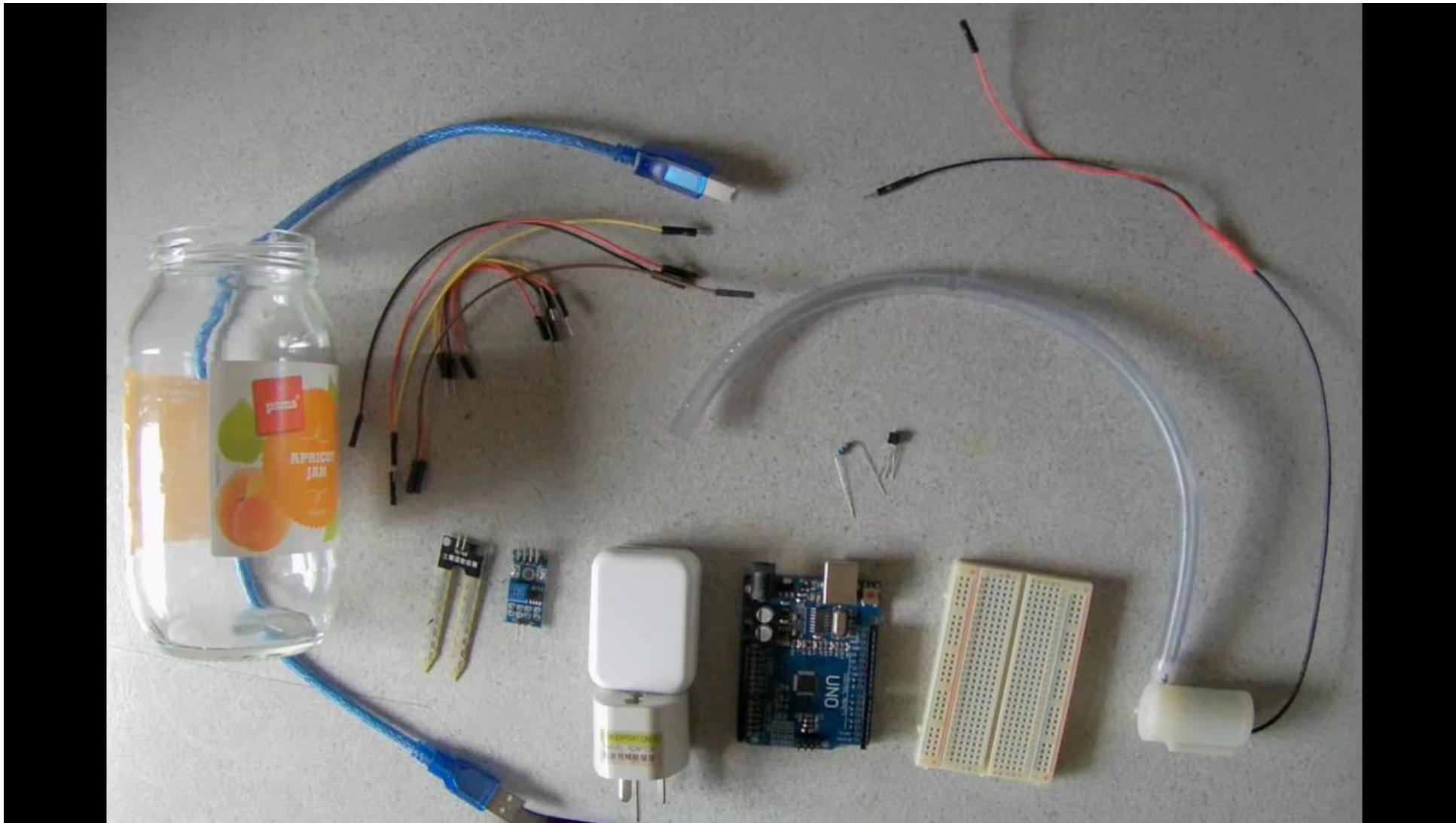
Pin1-Gate

Pin2-Drain

Pin3-Source

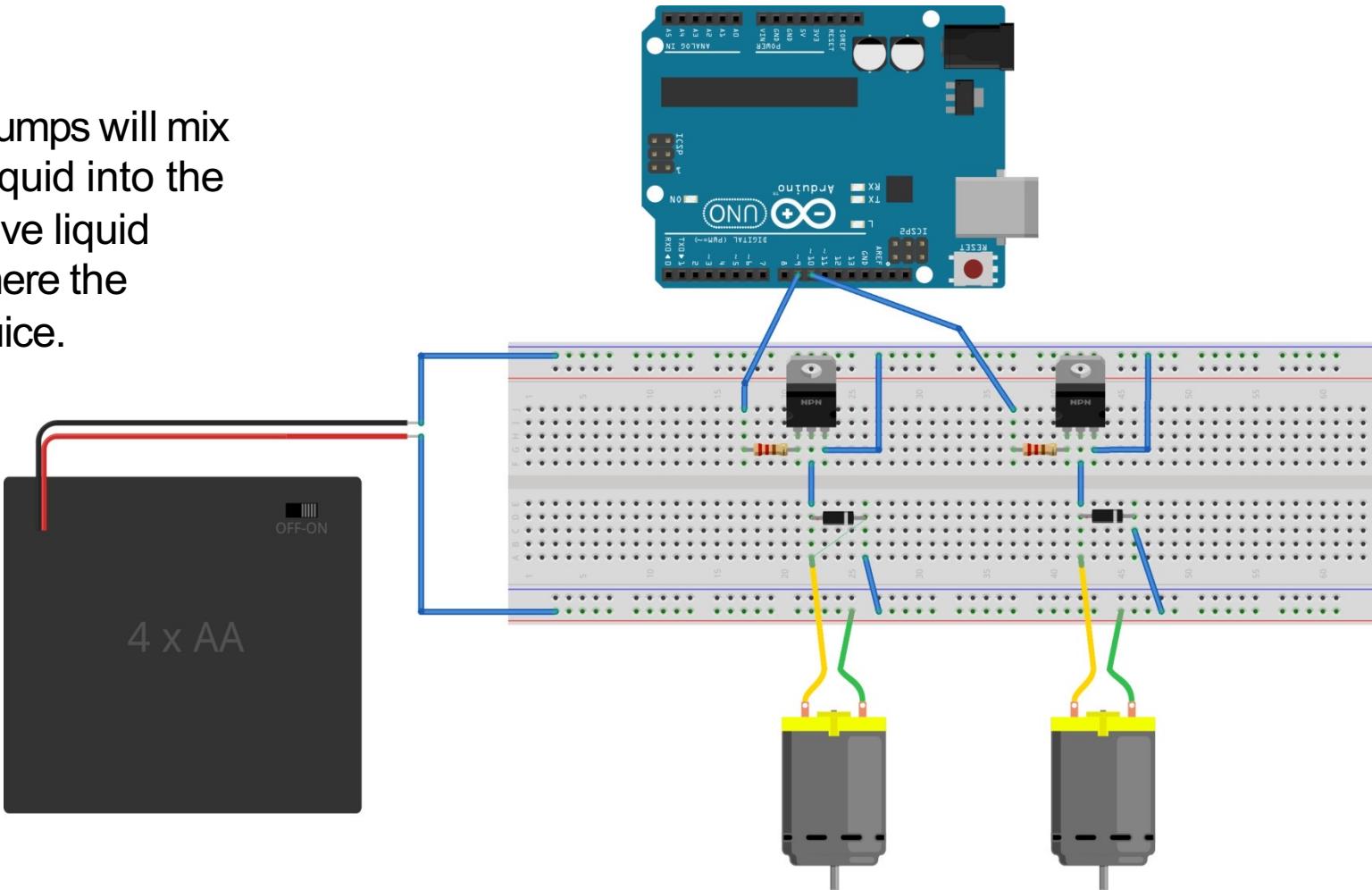
Connect the pump to Arduino





Connect Two Pumps to Arduino

The two pumps will mix different liquid into the pH indicative liquid solution, here the cabbage juice.



Of course

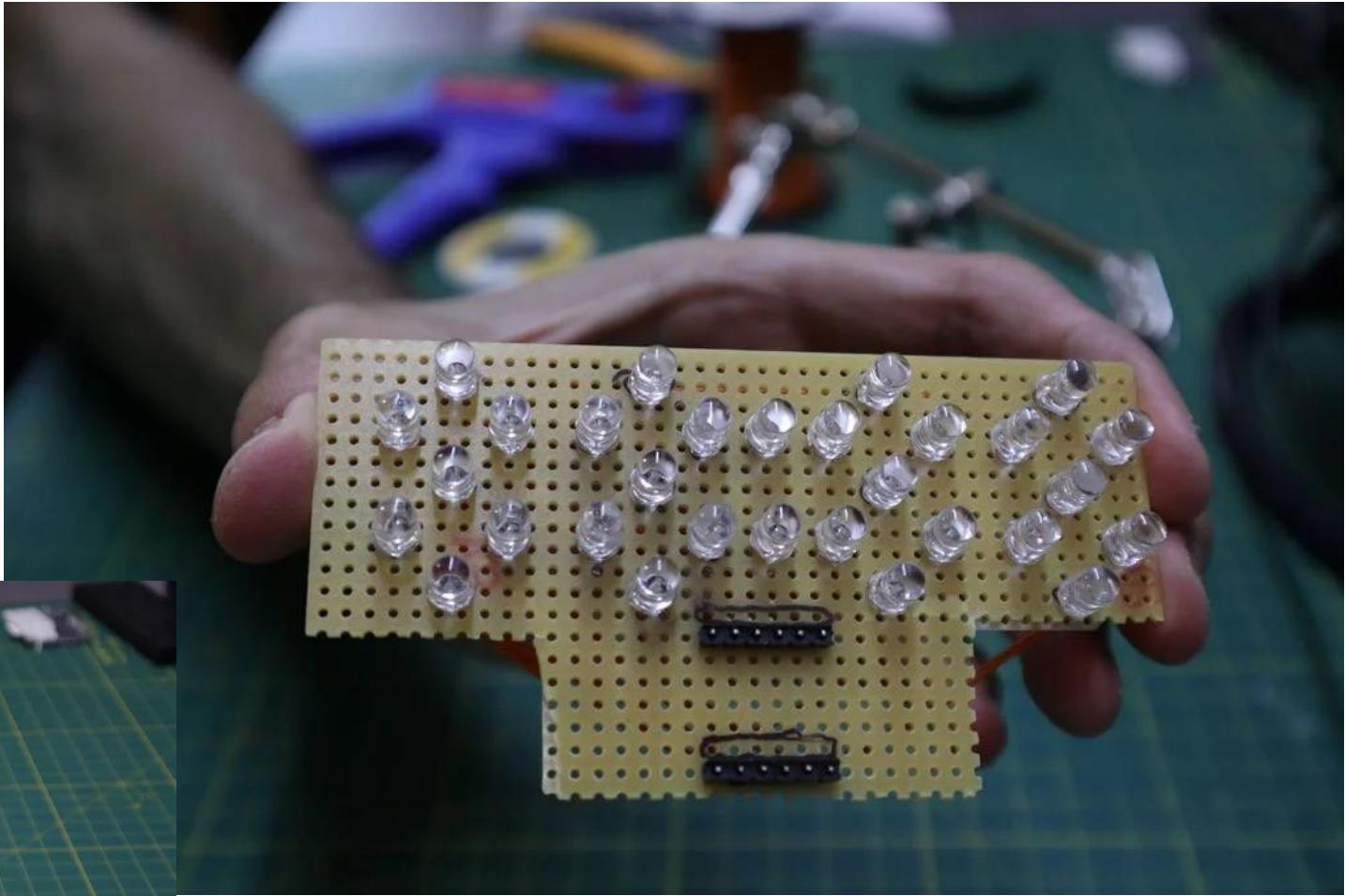
- You can dye fabrics and papers with the purple cabbage juice
 - To make halochromic fabric and paper
 - <https://brave-the-elements.com/2018/01/07/make-your-own-color-changing-paint-with-red-cabbage/>
- You can paint an object, maybe 3D printed, with the purple cabbage juice
- Let them dry in the air
- And pump/pour the different liquid on them to make color change.

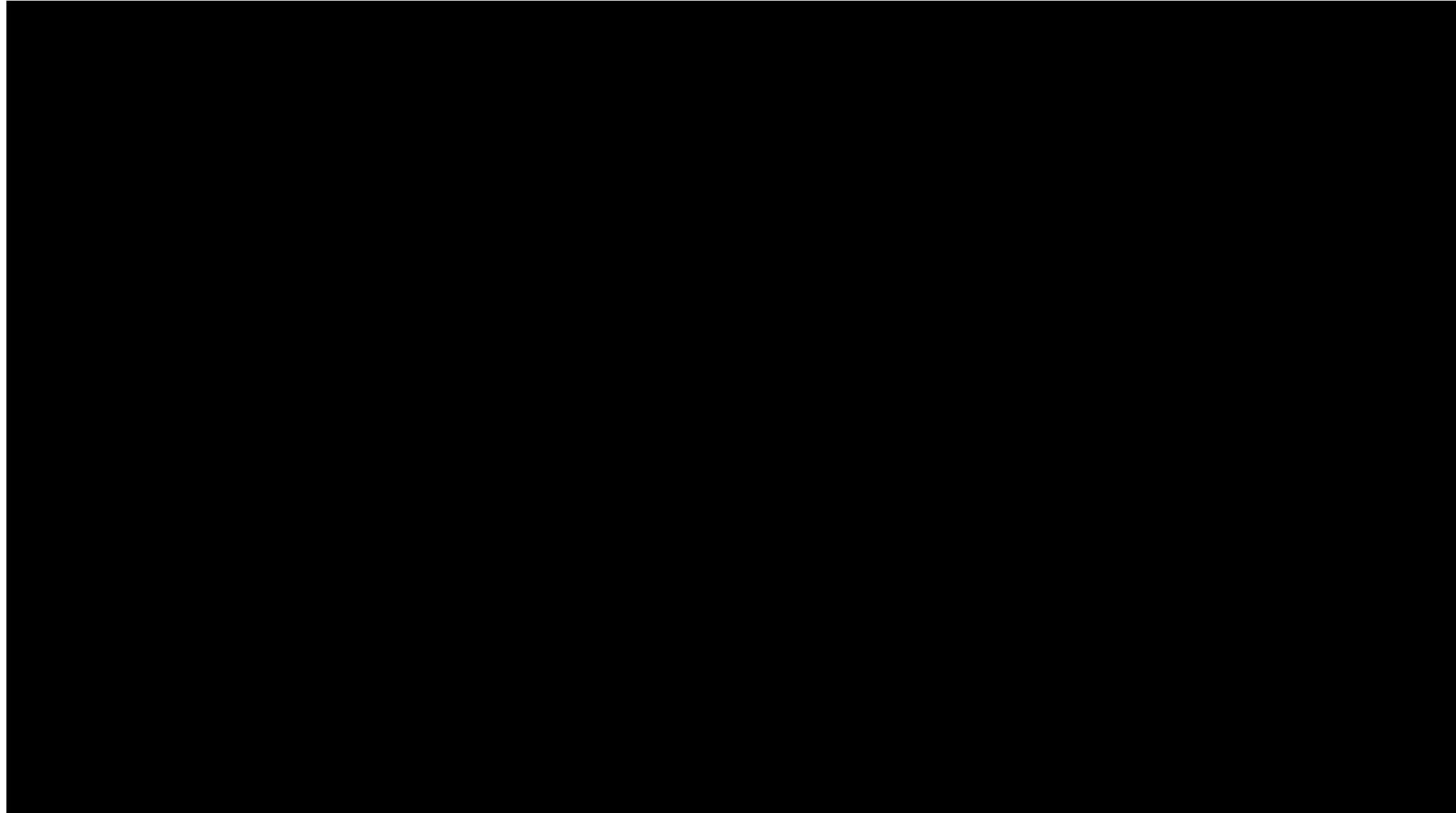
You can also pump different liquid into soil to control the color of flower



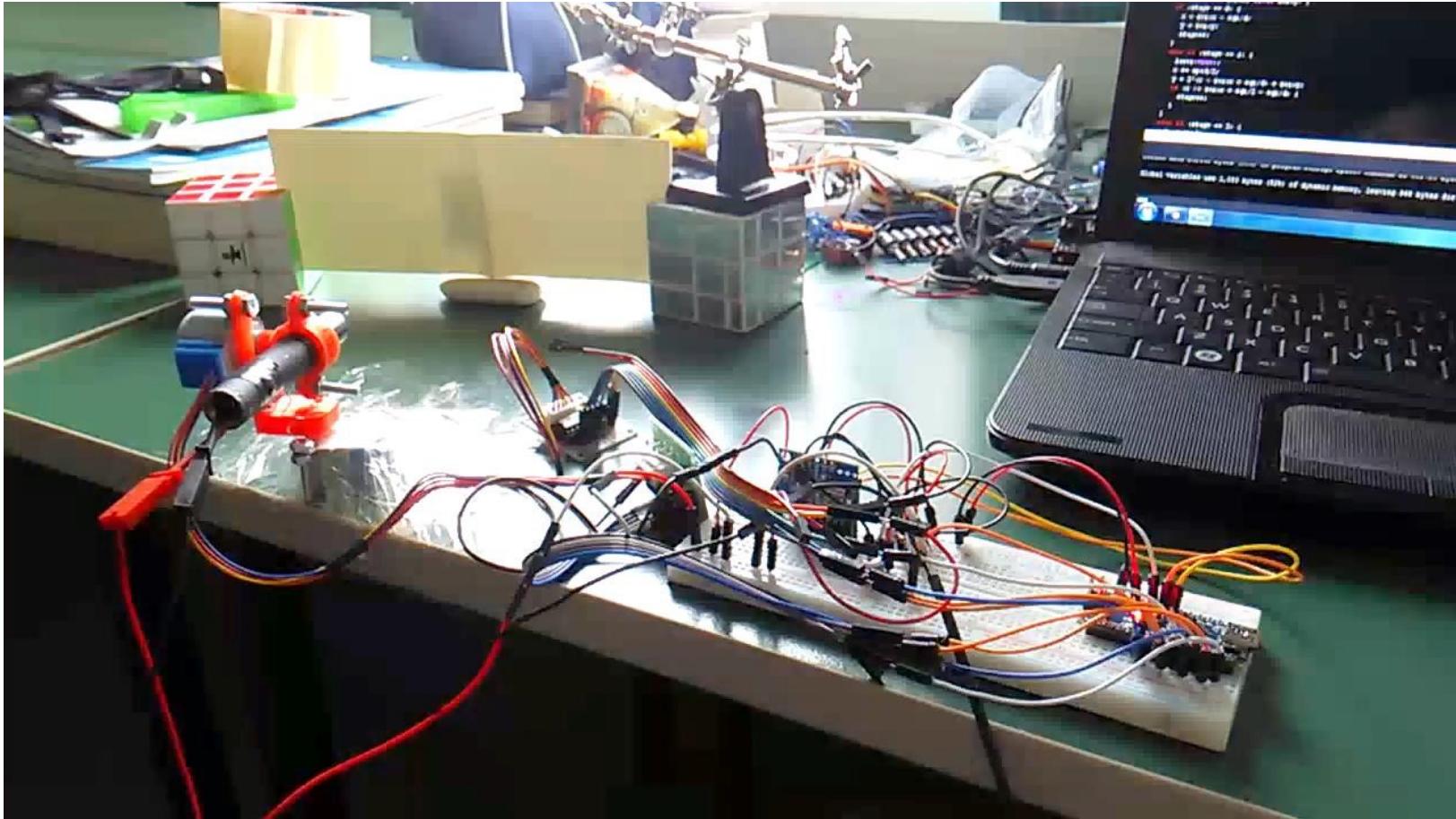
Photochromic?

- LEDs!!!
- Bright white LEDs!!!





Or...servo motor + laser pointer...



<https://hackaday.com/2016/11/04/laser-pointer-clock-makes-timekeeping-a-drawn-out-affair/>

You can also 3D Print Photochromatic Objects



MAKERBOT PLA FILAMENT

**BLUE
PHOTOCHROMATIC**

[https://www.amazon.com/
MG-Chemicals-
Thermochromic-Printer-
Filaments/dp/B01M9IEPPV](https://www.amazon.com/MG-Chemicals-Thermochromic-Printer-Filaments/dp/B01M9IEPPV)

Or 3D print thermochromic objects



Take-home Task

Please draw something using the color-changing materials (could be thermochromic or photochromic)

Please video-record the process of drawing and the demo of your drawing changing color.

The drawing should be meaningful.