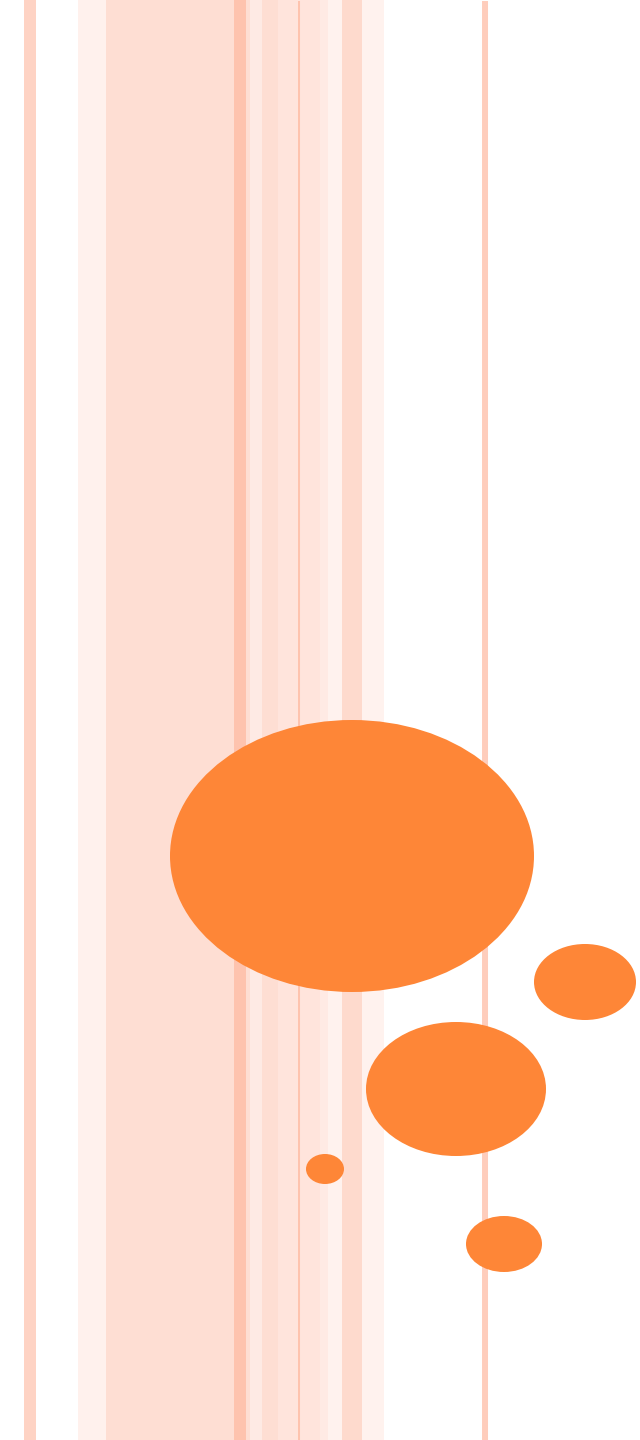




USE OF PHYSICAL MODELS IN BIOLOGY TEACHING

Victor Lau
The Chinese University of Hong Kong

WHY PHYSICAL MODELS?

Students have difficulty in understanding **3D structure** from 2D drawings of textbook, in particular students with poor spatial skills. Through manipulating a physical model, the **cognitive load** needed to convert 2D image into 3D is reduced, thus leaving more WM for understanding the structure and functions (Herman et al., 2006)

But models can also be powerful tools to teach about difficult concepts and misconceptions!





Problems

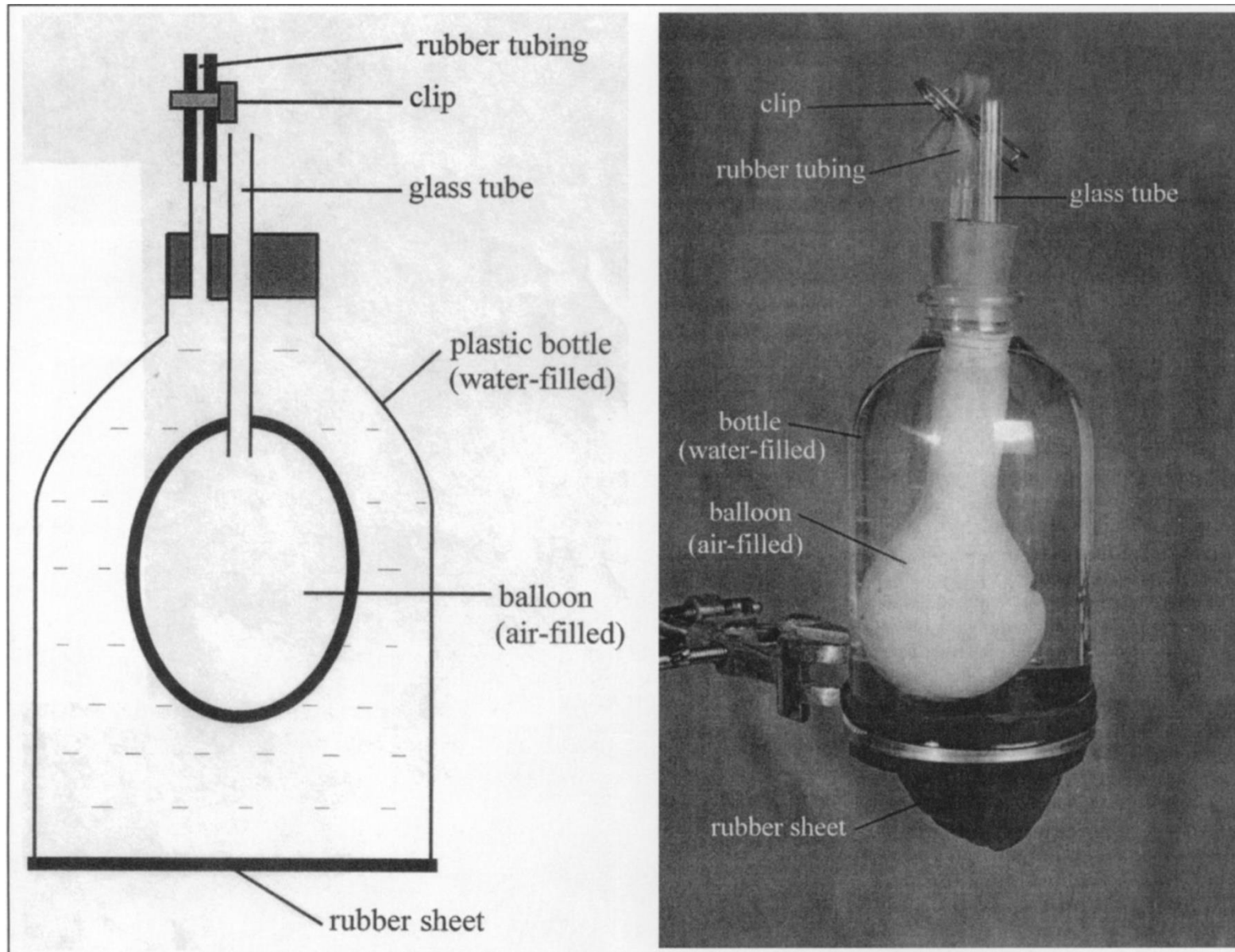
Lungs deflated after exhalation

Air inside the chest

Diaphragm flattened at rest and needs to be pulled down or pushed up to work

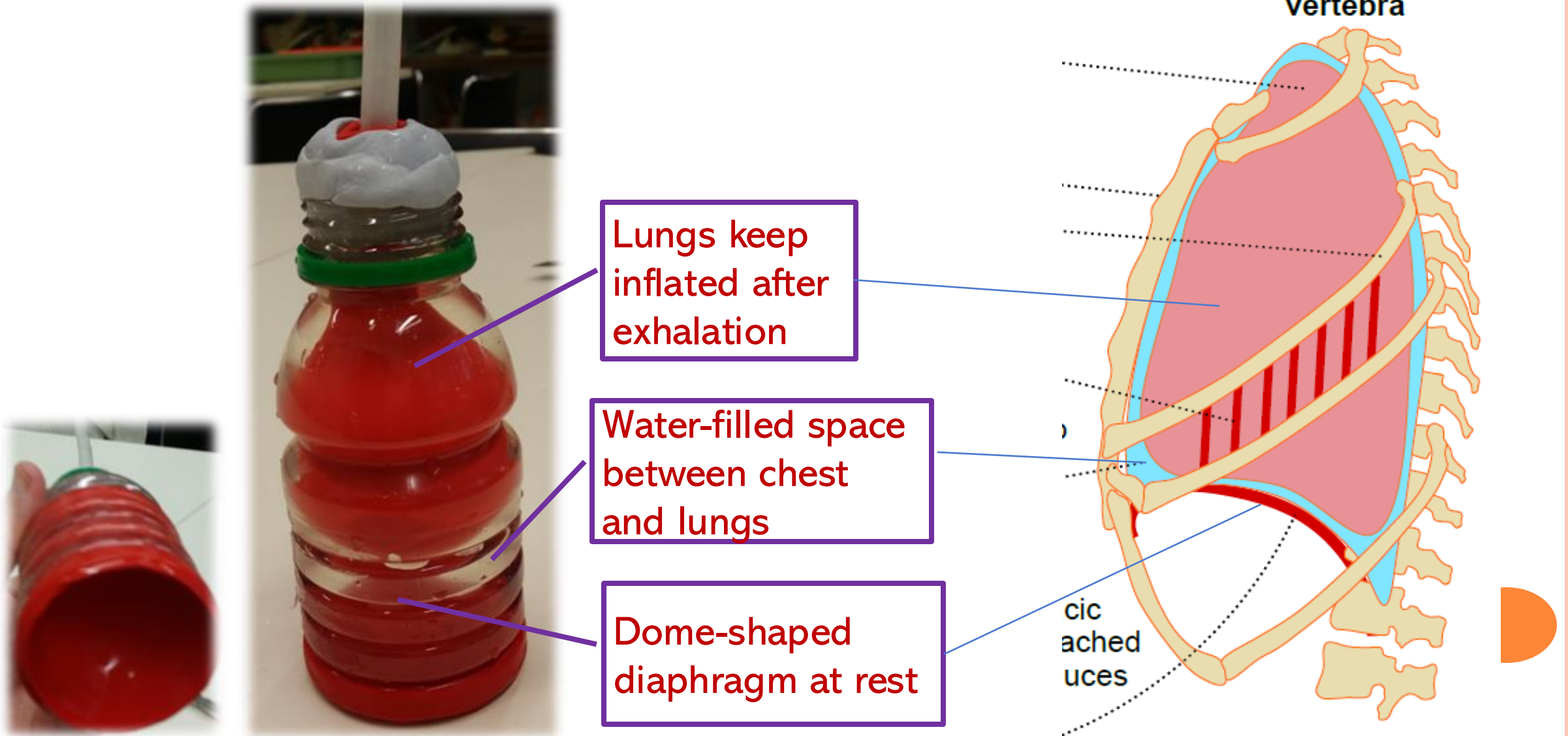
A BETTER LUNG MODEL

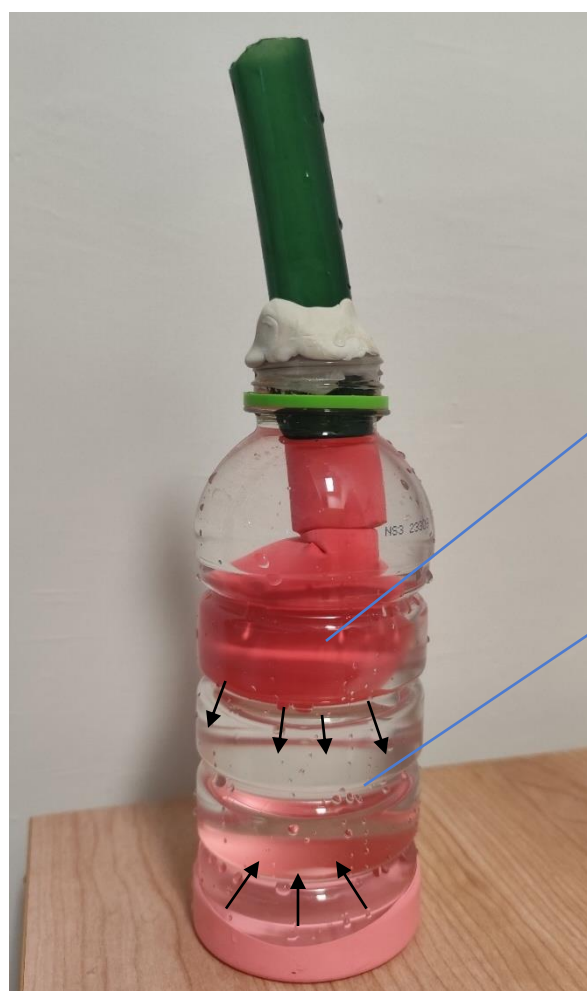
American biology teacher 60,7, 1998



MY LUNG MODEL

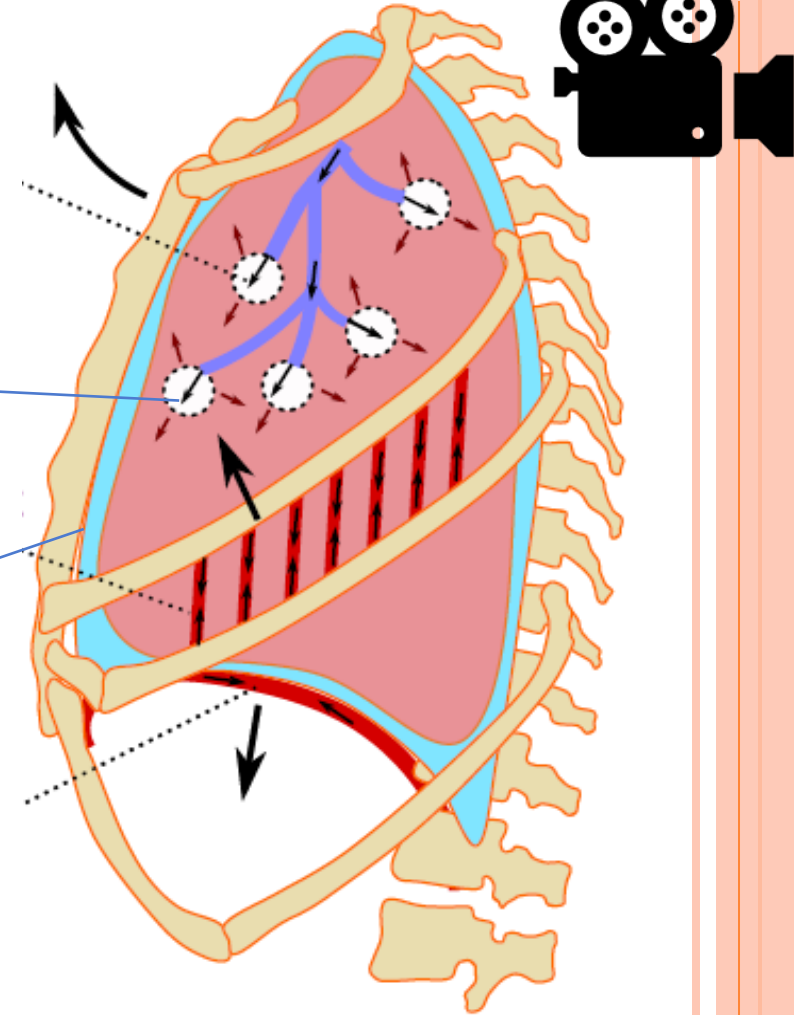
Lau, Kwok-chi. (2020). An improved physical lung model for teaching lung ventilation. *American Biology Teacher*, 82 (6)1-3.
<https://www.youtube.com/watch?v=VIM77ps50tE>





Atmospheric
pressure

Sub-atmospheric
pressure - tension

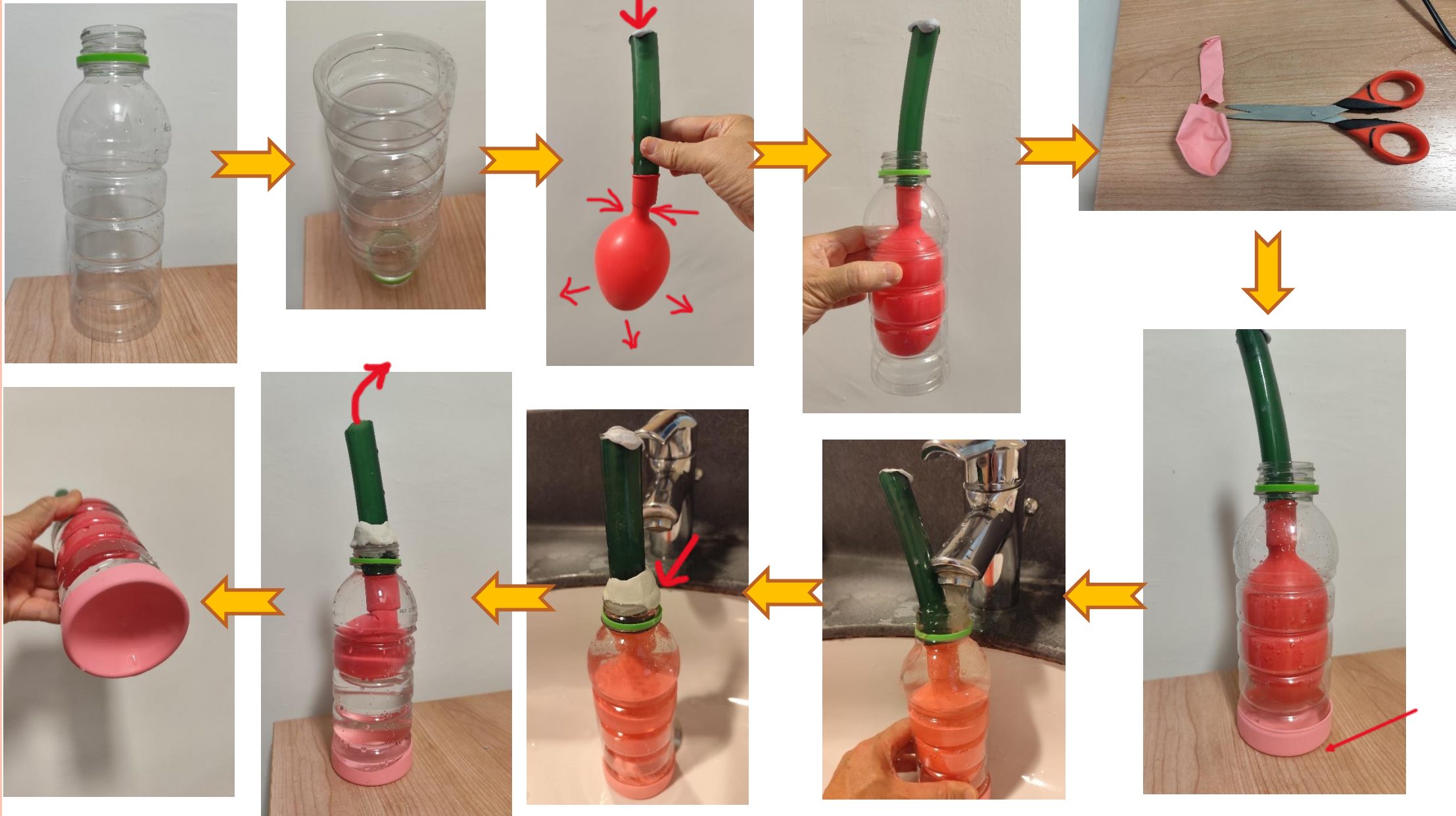


Concepts

- Lungs are inflated all the time as stretched by the tension of pleural fluid. That explains why the lungs shrink in pneumothorax.
- Exhalation at rest is mainly brought about by the elastic recoil of the lungs, rather than by the movement of the diaphragm and rib cage.

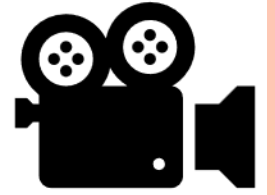


How to make it



ENZYME

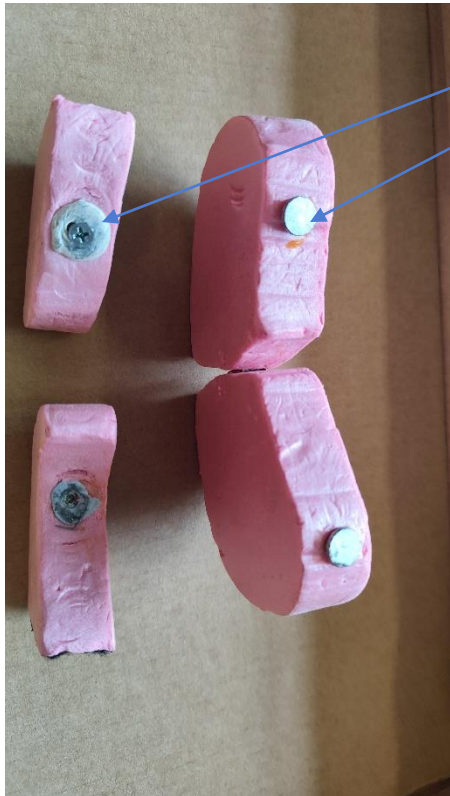
https://www.youtube.com/watch?v=wNG2uPao8BI&ab_channel=BioManBiology
1:31



Lau, Kwok-chi, 2013. American Biology Teacher, v75, no 7

Concepts

- Enzyme binds to substrate by **random collisions**. So catalysis takes **time**, depending on **frequency of collisions**, which are affected by **T, [E] and [S]**.
- Enzyme works by bringing the substrates close and in the right positions to form bonds.



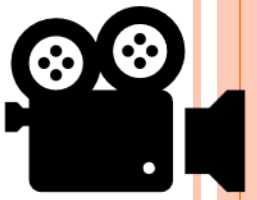
Magnet and nail
(weak bonds)

Concepts

Enzyme only forms temporary, weak bonds with substrate – they do not react.



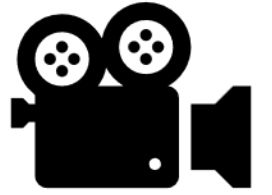
Velcro
(strong bonds)



Concepts

- Enzyme in flexible shapes rather than in fixed shape
- Induced fit model vs lock and key model
- Denaturation

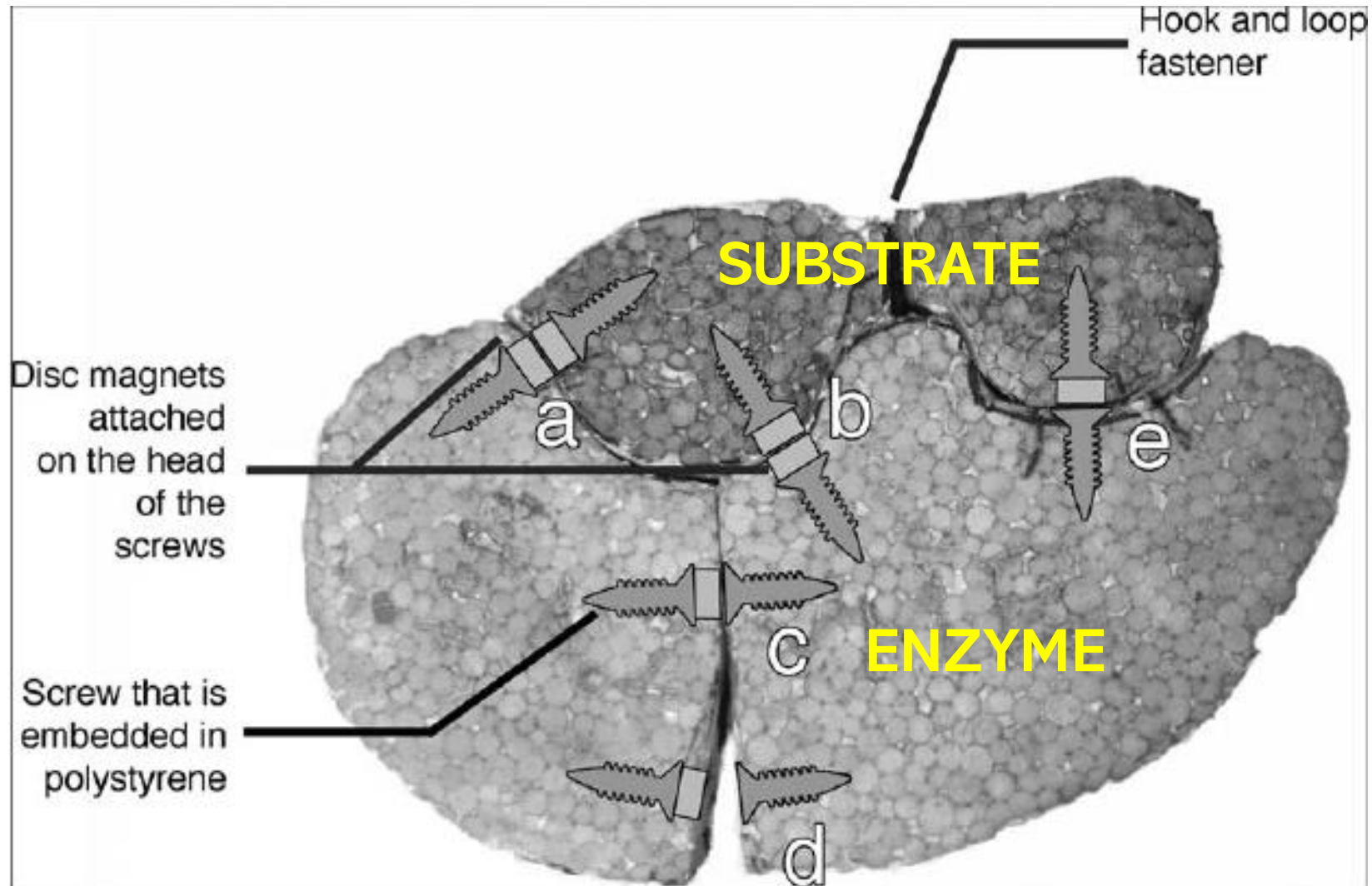




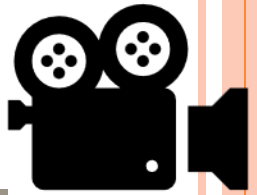
ENZYME INHIBITOR (COMPETITIVE)



HOW TO MAKE IT



CELL MEMBRANE

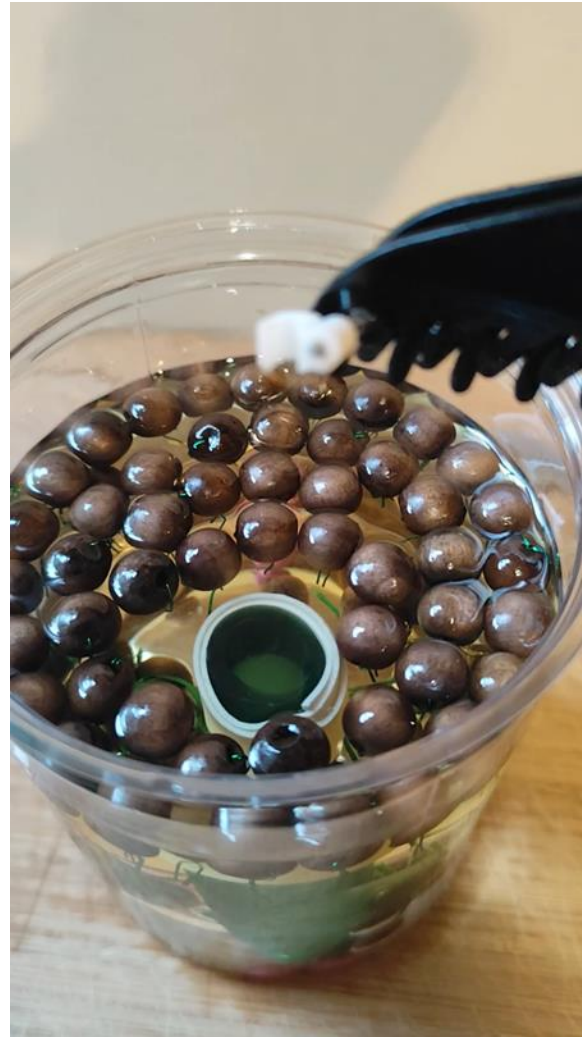
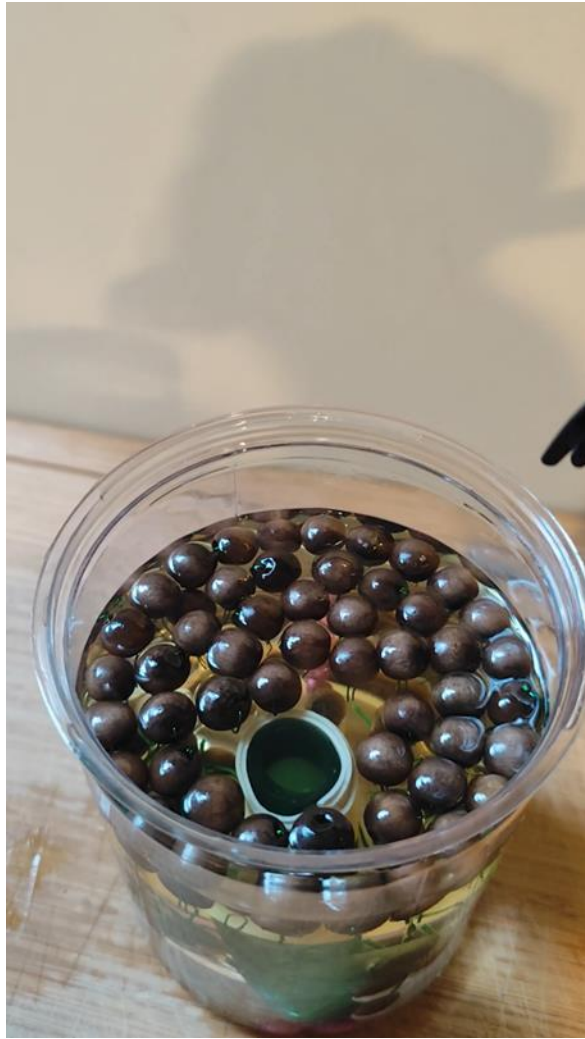
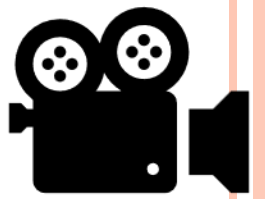


Fluidic
phospholipid
bilayers

Oil and water are
not mixed → fatty
acid tails inside the
bilayer



DIFFERENTIAL PERMEABILITY

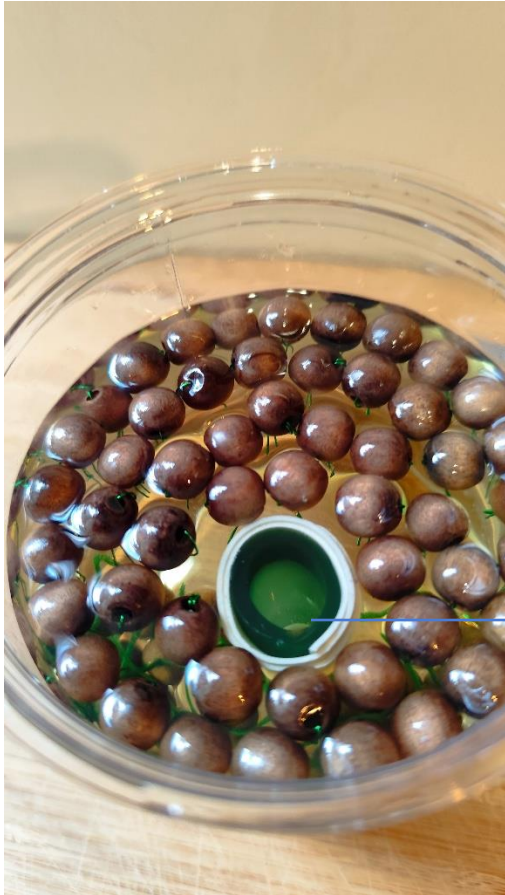
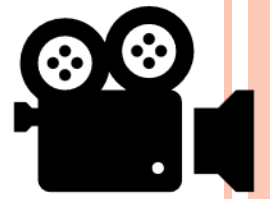


Phospholipid layers are less permeable or impermeable to ions and polar molecules, but permeable to non-polar molecules

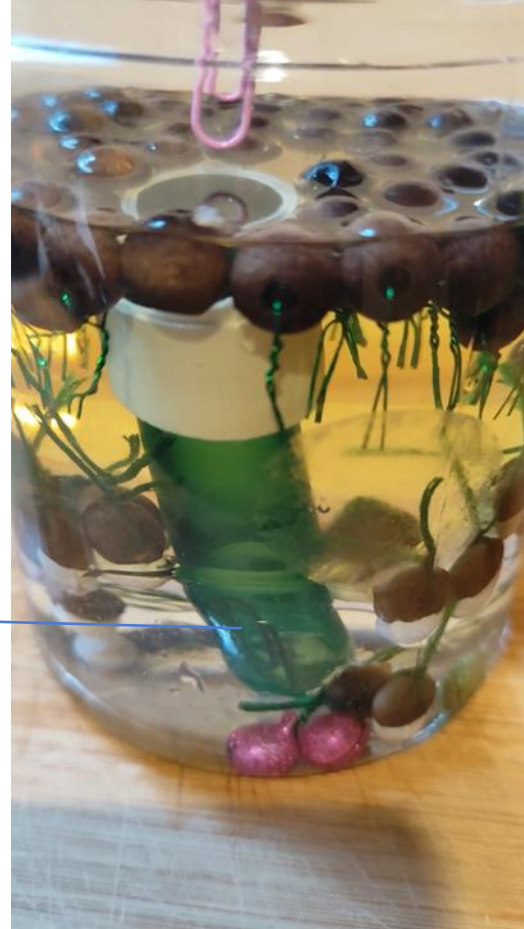


MEMBRANE PROTEINS

– FACILITATED DIFFUSION, ACTIVE TRANSPORT



Carrier
protein



Carrier proteins allow ions and polar molecules to pass through the lipid layers. The passage is specific.

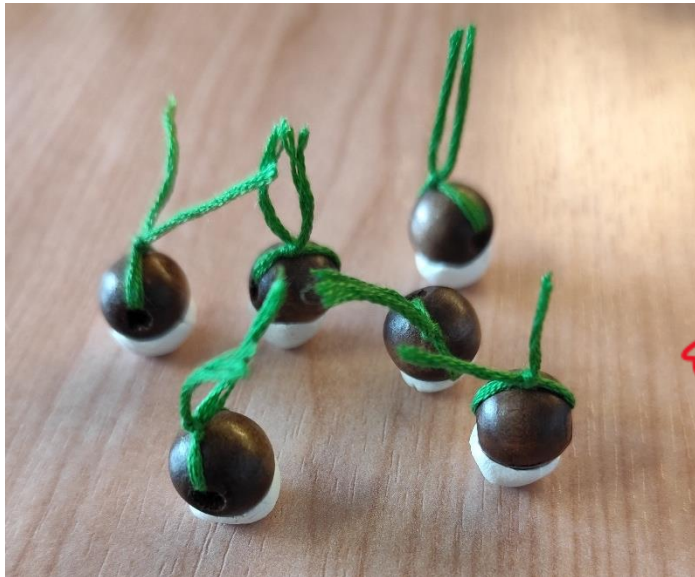


HOW TO MAKE IT

Beans and iron
wires



Beans attached
by blutack and
cotton threads



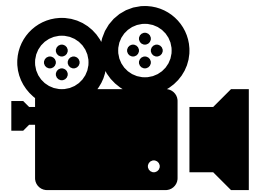
oil

water

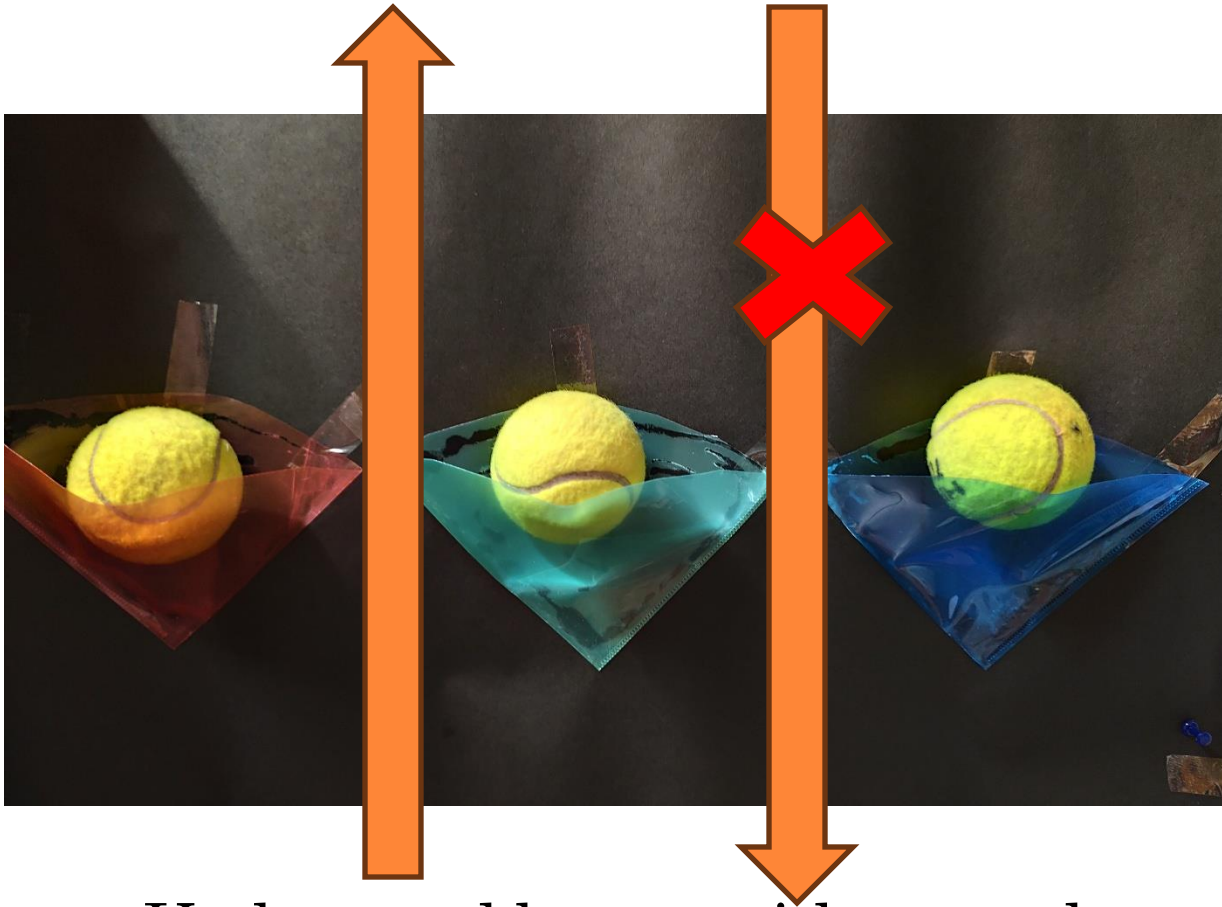


OSMOSIS



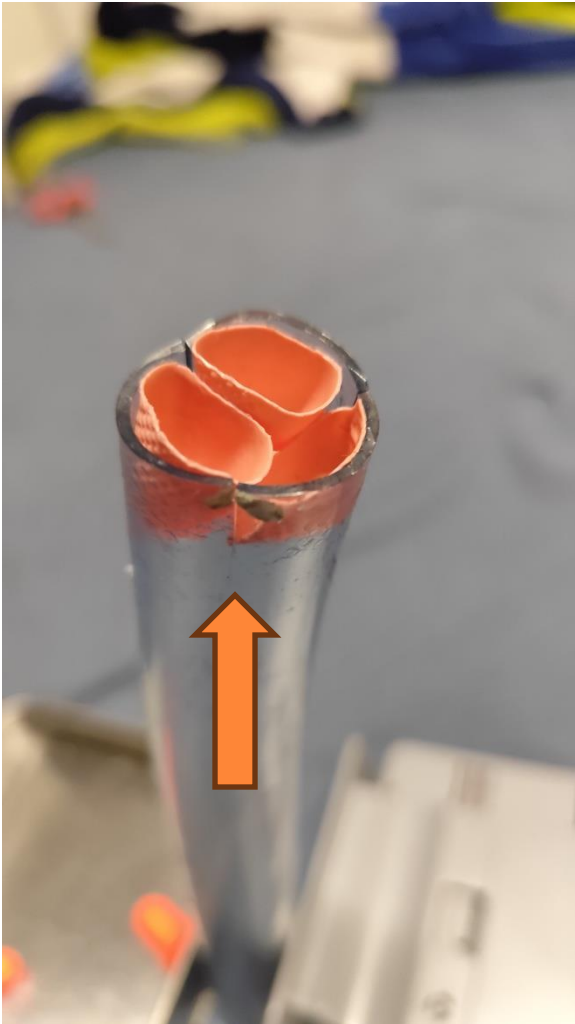


SEMI-LUNAR VALVES



- Understand how semi-lunar valves work –structure and functions.
- Valves are mechanically controlled by pressure difference, rather than by nervous control

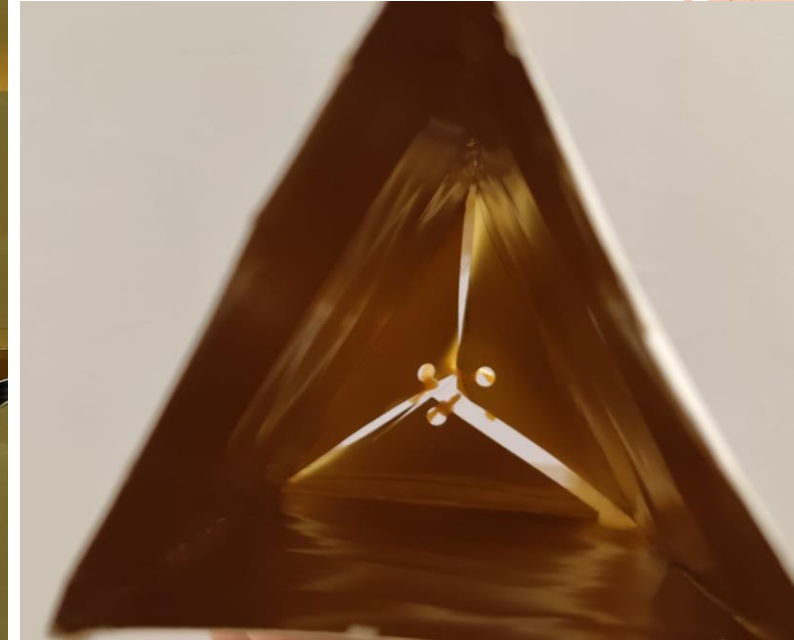
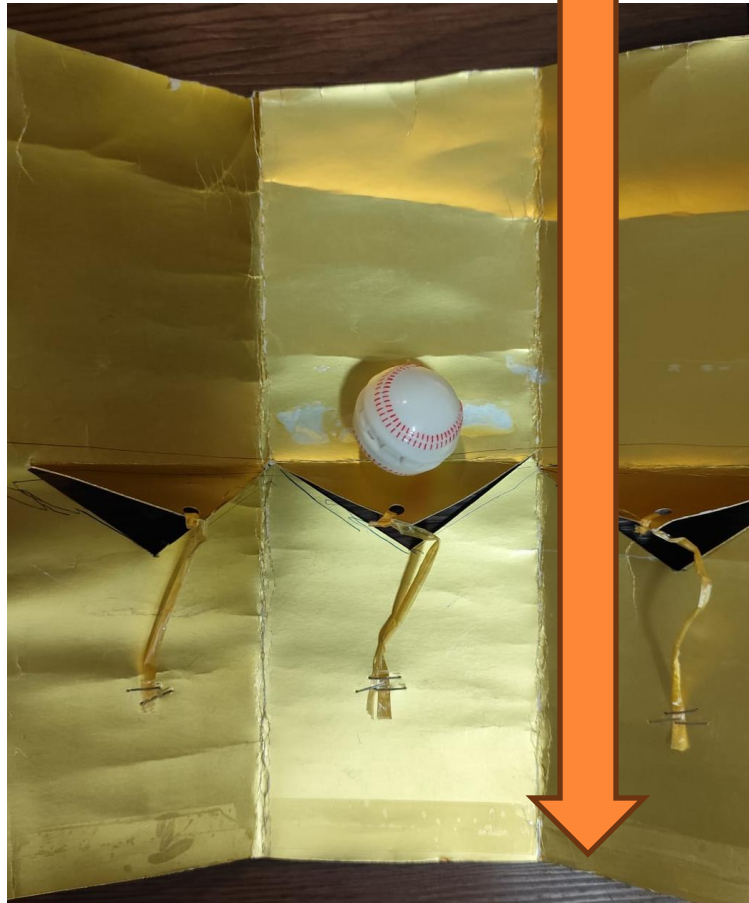
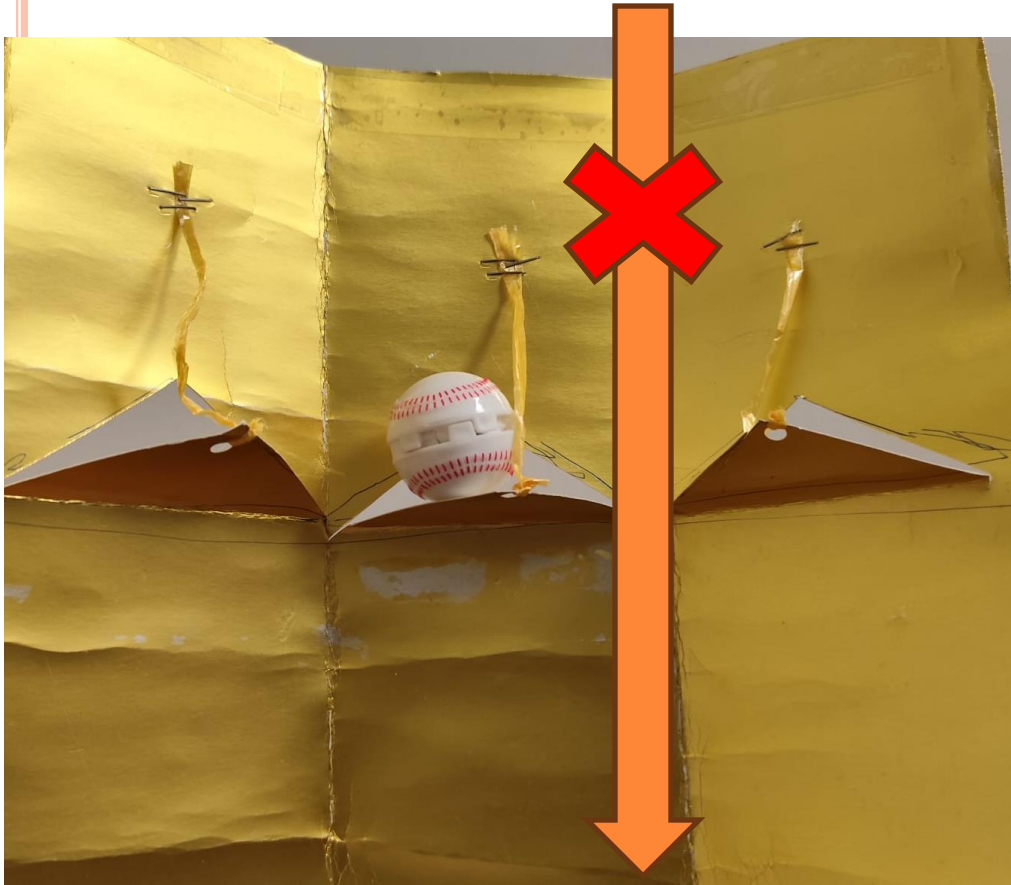
VALVES IN VEINS



Tip of rubber glove



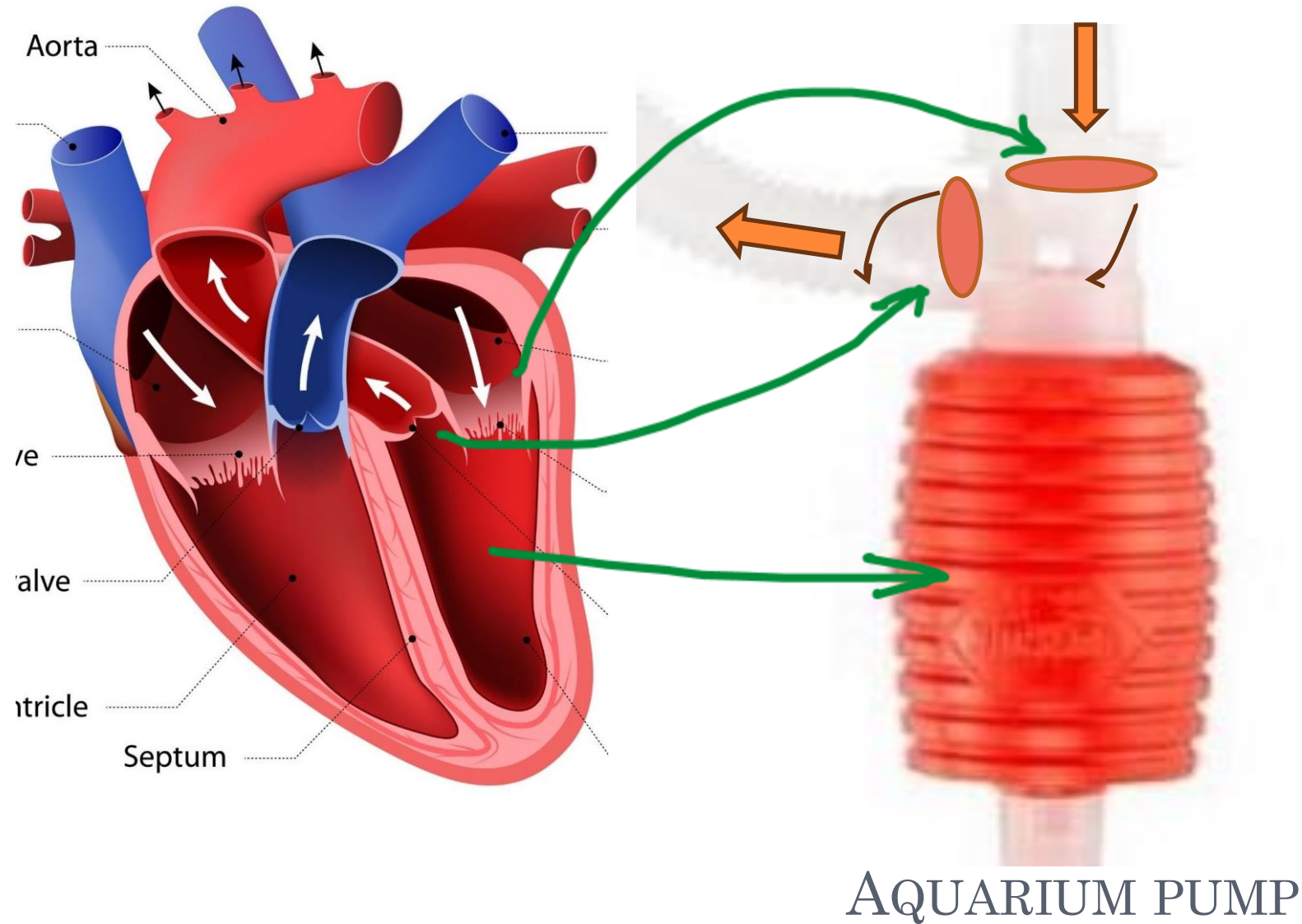
TRICUSPID VALVES



The importance of valve tendon.



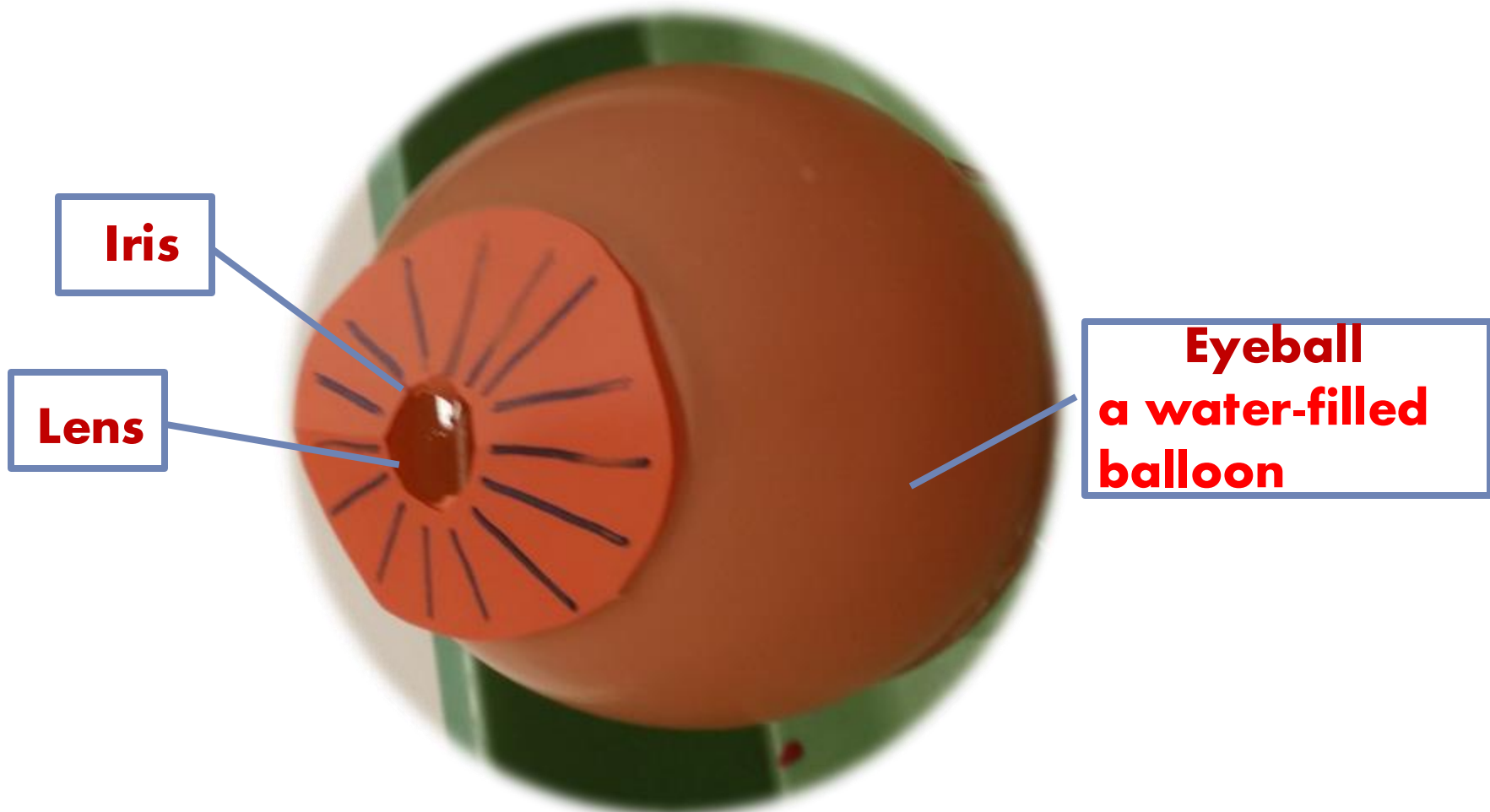
How two valves coordinate the unidirectional flow of blood in the heart.



EYES



MY EYE MODEL



Lau, Kwok-chi. (2020). A water balloon eye model for teaching about the human eye. *American Biology Teacher*, 82 (5), 341-343.

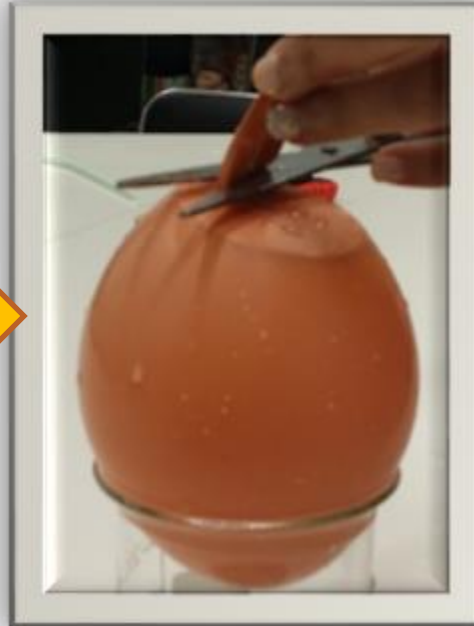




- Realize the presence of eye pressure (IOP) that helps maintain the shape of the eyeball
- Understand how focusing of images is affected by the shape of the eyeball - short/longsightedness



HOW TO MAKE IT

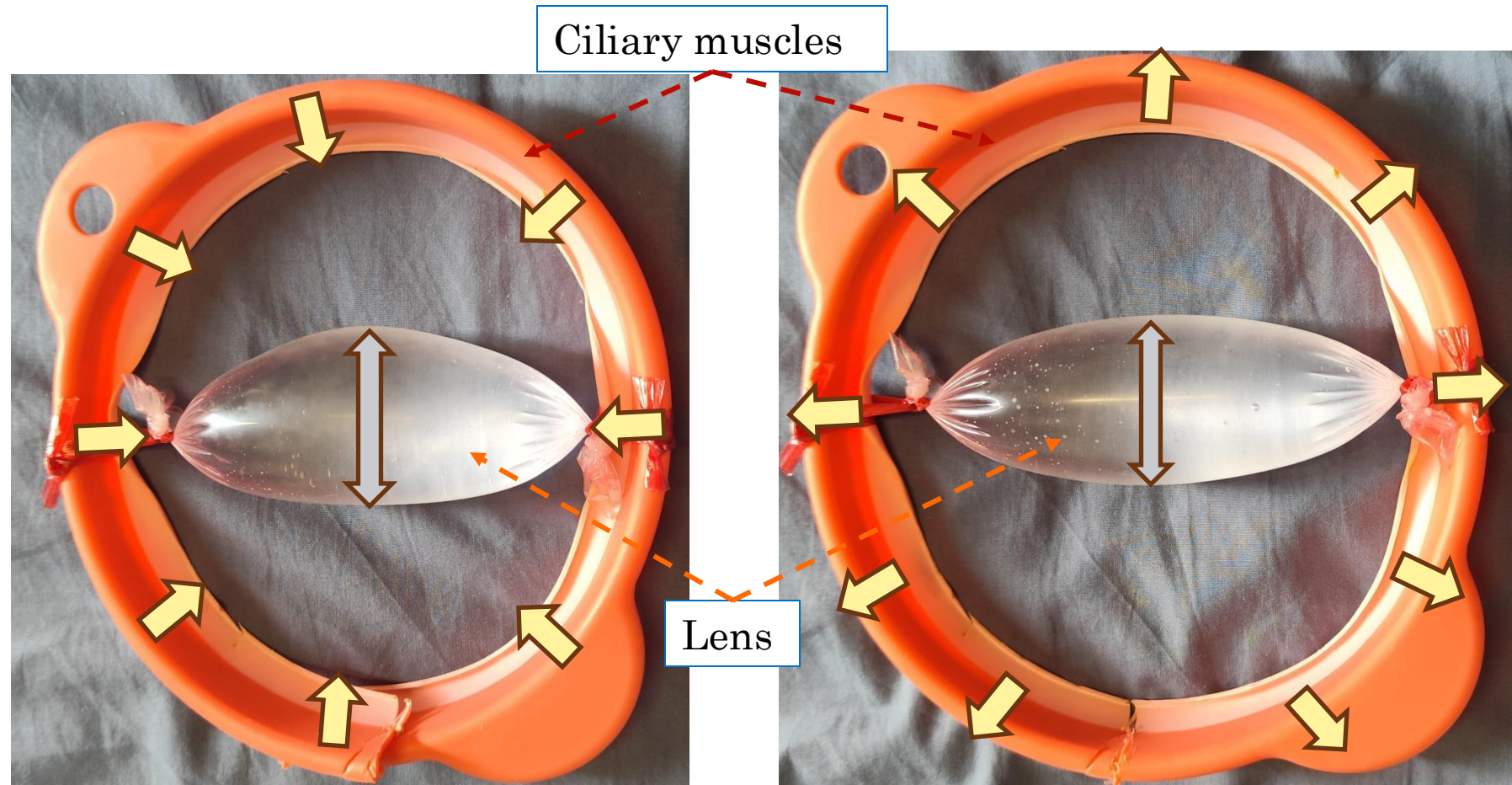
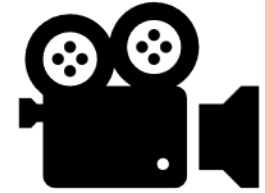


Fill the balloon with water.
Twist the neck and invert
the balloon to let the lens
sink to cover the mouth.

Cut the neck off to
make a hole (pupil) at
the centre of the lens.



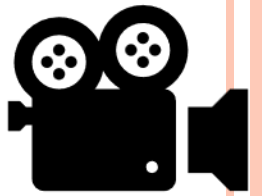
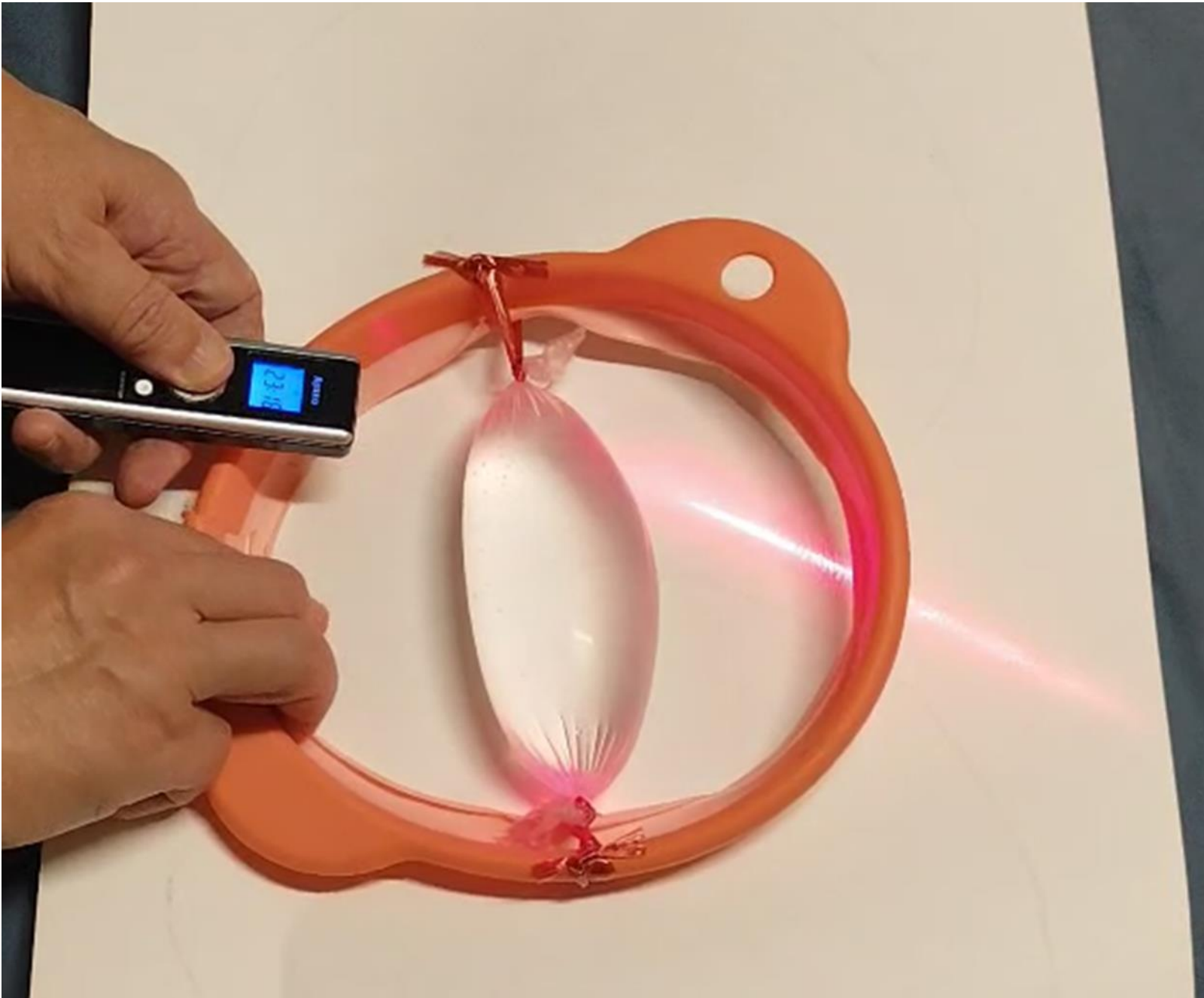
ACCOMMODATION OF EYE LENS



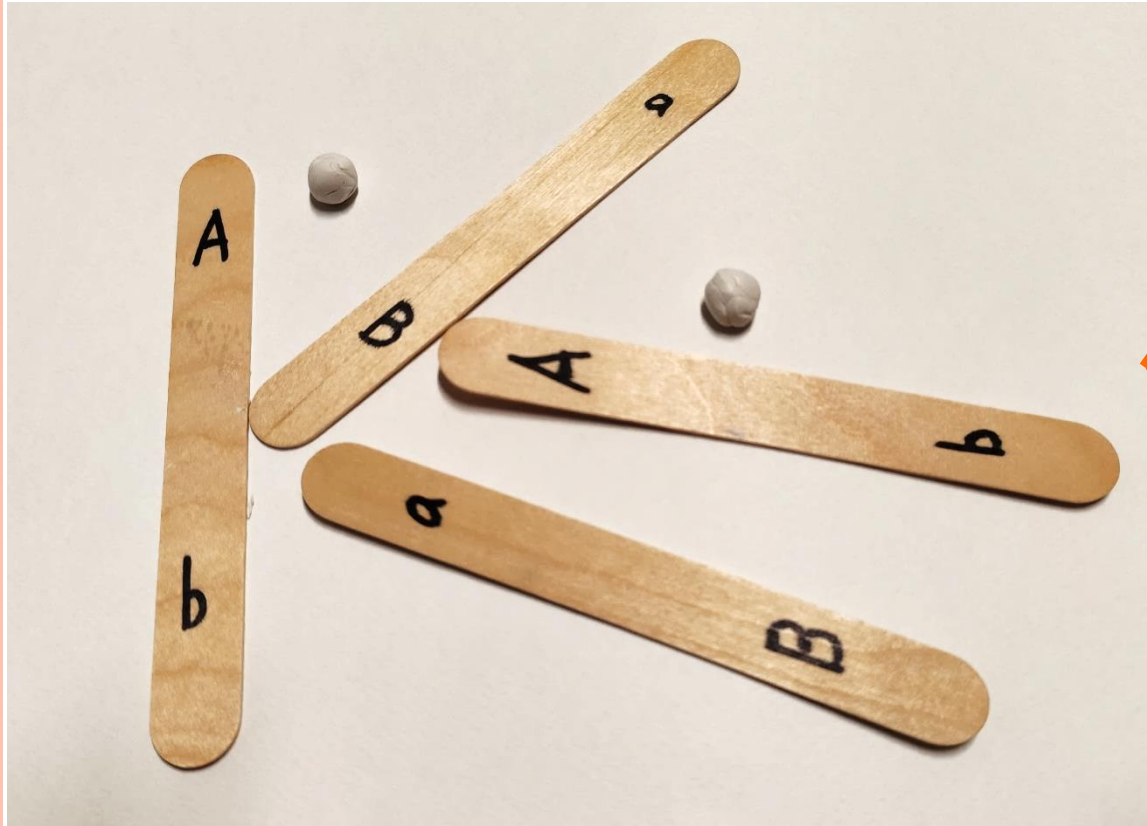
- Ciliary muscles contract
- Diameter of the ring decreases
- Lens becomes more convex by **elastic recoil**

- Ciliary muscles relax
- Diameter of the ring increases due to the **eye structure and pressure**
- Lens is pulled to becomes less convex





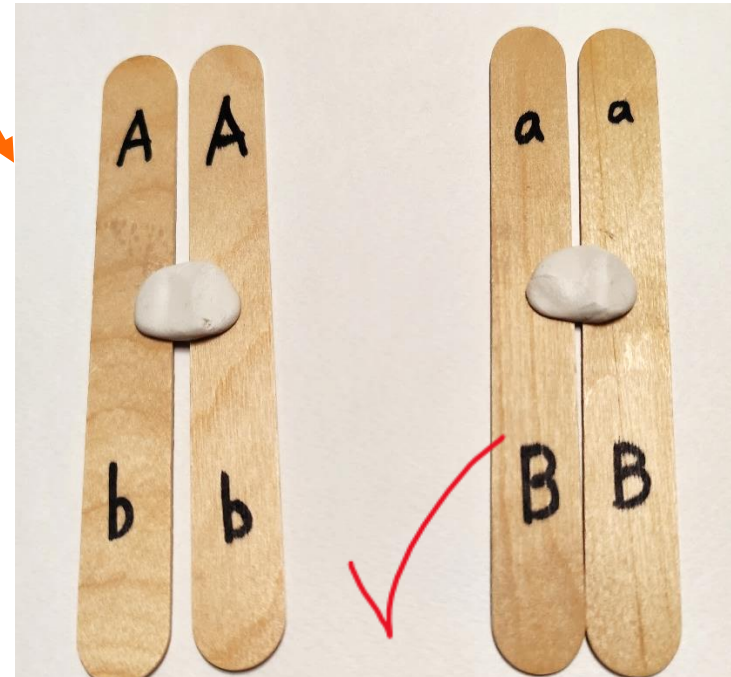
CHROMOSOMES



Make two chromosomes at the beginning of mitosis

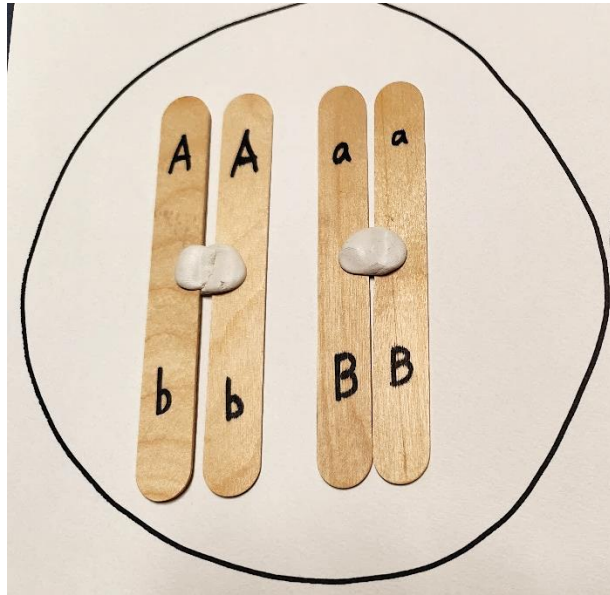


The two sister chromatids of a duplicated chromosome must have the **same gene/allele** at the same positions

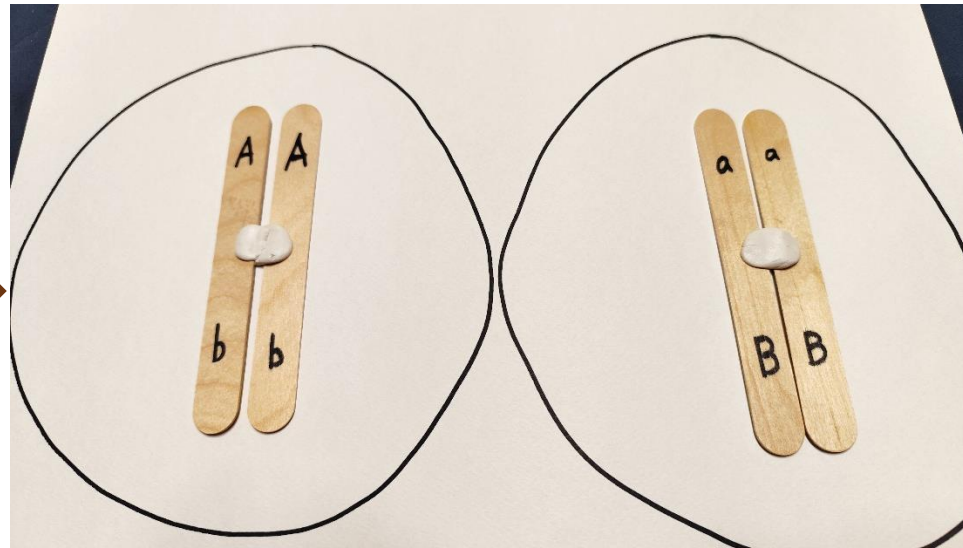


Two **duplicated chromosomes** each consisting of two sister **chromatids** connected by a **centromere**

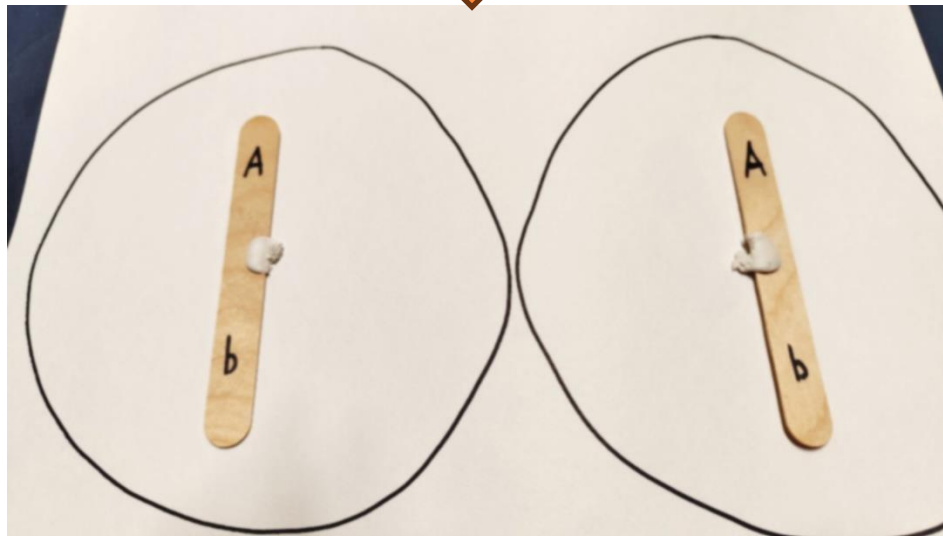
Meiosis



Two duplicated chromosomes in one homologous pair

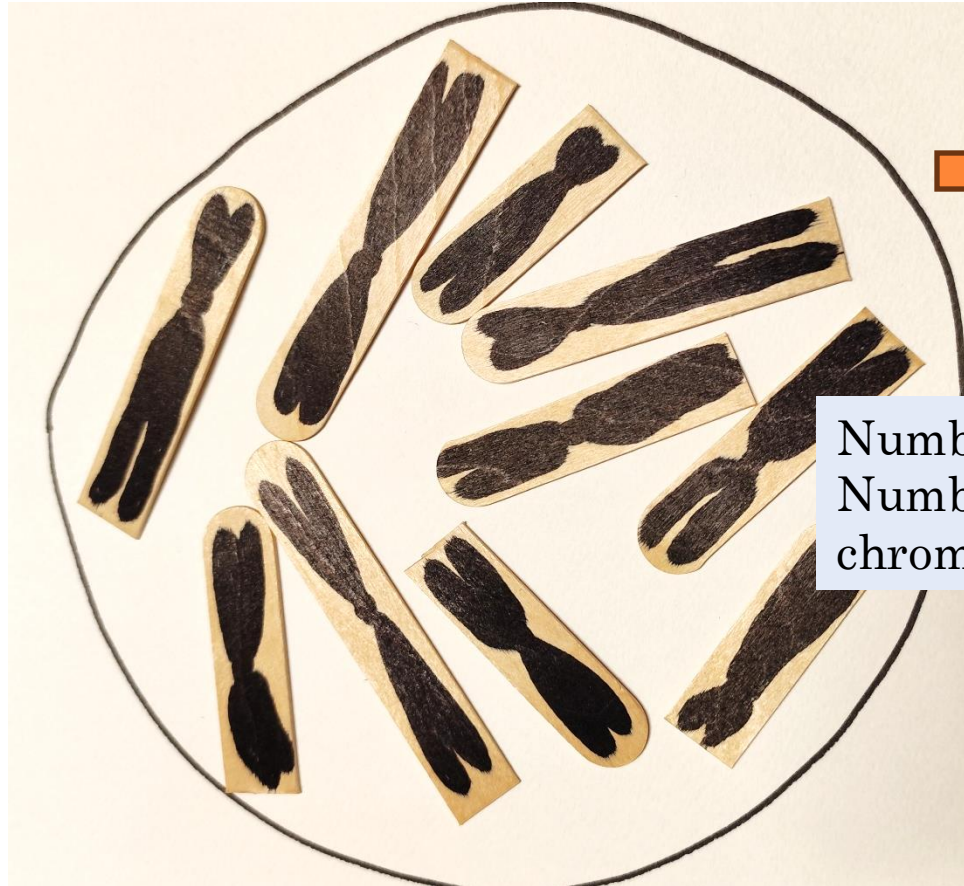


One duplicated chromosome without homologous pair in a cell



One unduplicated chromosome without homologous pair in a cell

CHROMOSOMES

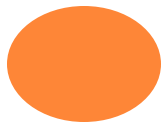


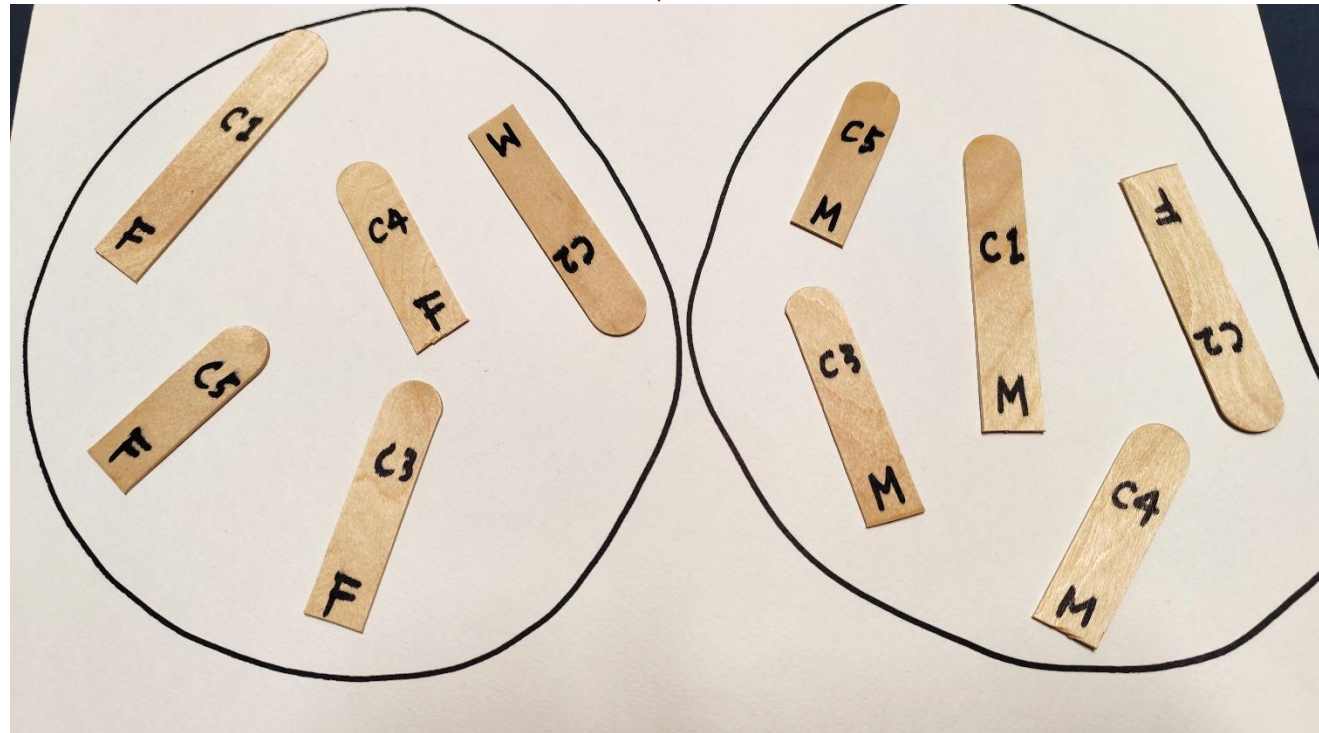
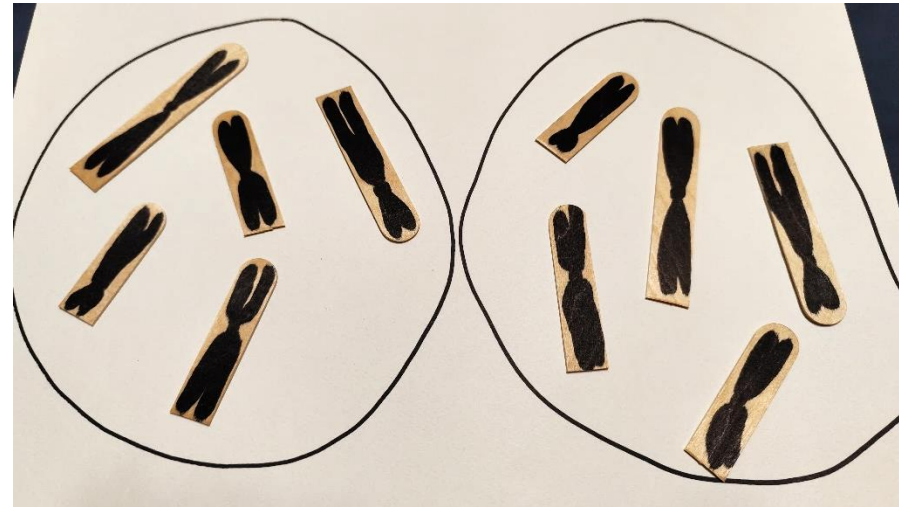
Pair up the chromosomes into homologous pairs to enter the metaphase of meiosis



Separate the homologous pairs to enter the telophase of meiosis

Number of chromosome:?
Number of pairs of chromosomes: ?





Random alignment of pairs of homologous chromosomes at metaphase of meiosis



Independent assortment of the members of a pair of homologous chromosomes into daughter cells

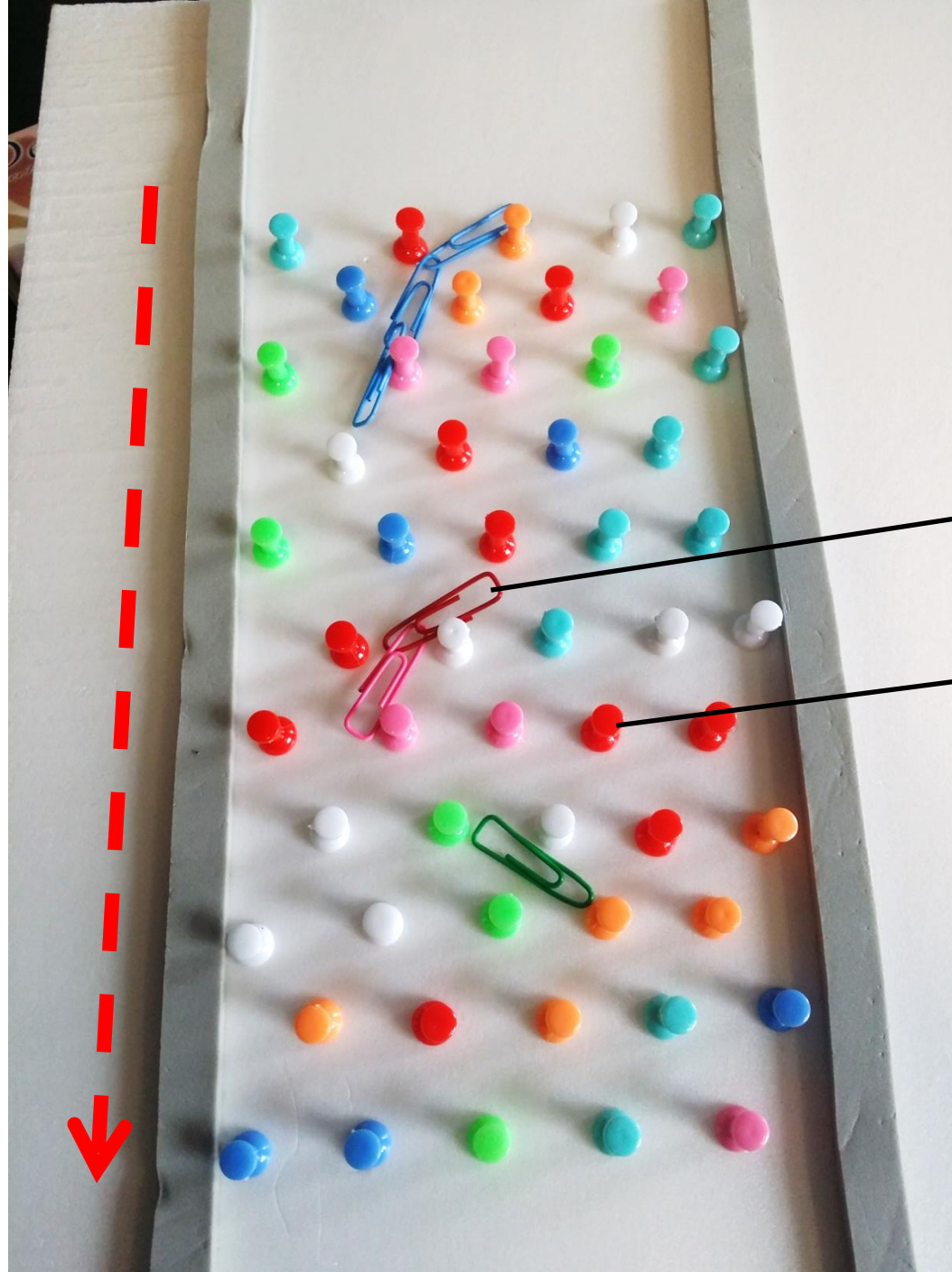


Each meiosis produces daughter cells of different combinations of chromosomes



Genetic variations





ELECTROPHORESIS

DNA fragments

Gel

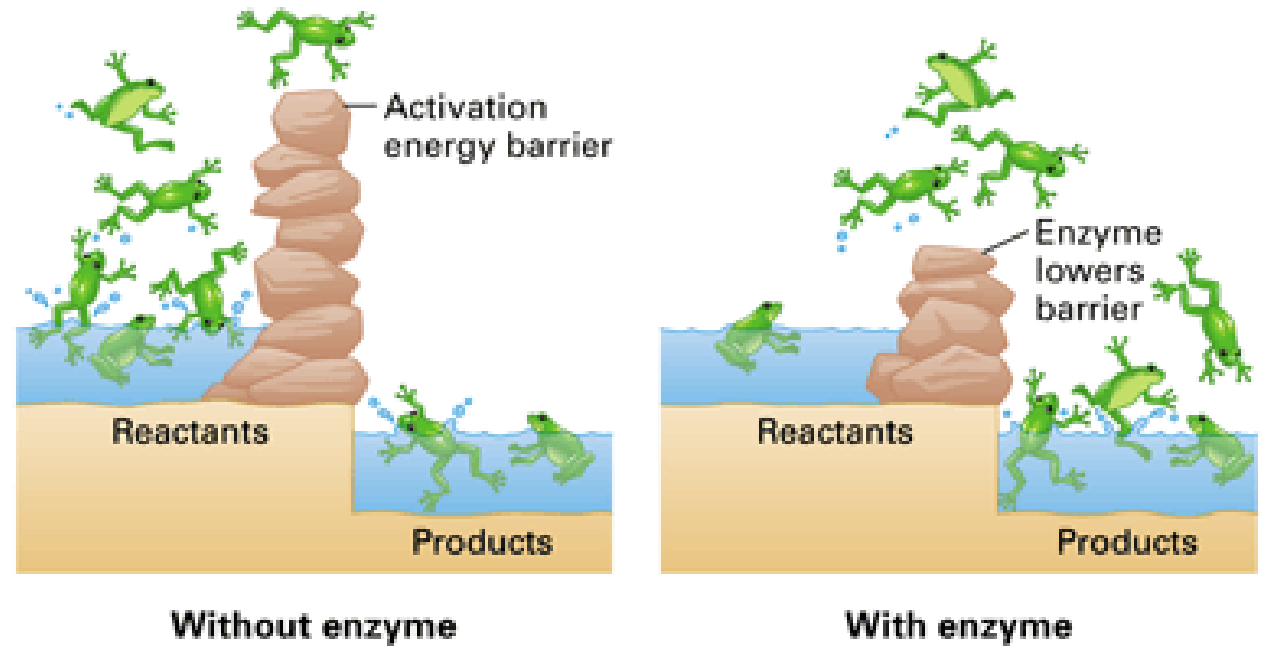


ANALOGY



dreamstime.com

Burton, E. P. (2012). The Nuts and Bolts of Enzymes, The Science Teacher



<https://bodell.mtchs.org/OnlineBio/BIOCD/text/chapter5/concept5.5.html>



HOW TO USE MODELS IN TEACHING

- All models are **approximation** of the real structures and processes. Teachers need to explain how the model **can and cannot** simulate the real structure/process.
 - Do not make models just for fun! Use models to deal with **difficult concepts and misconceptions** that are hardly comprehensible with texts and diagrams.
 - Let **students make and even design** the models.
 - Let students play the model freely rather than watch their teacher playing it!
 - Models can be used to **explore** a concept before it is taught, or **consolidate** a concept taught.
- 

THANK YOU!

