# Nanoscale Thin Films

STEM ED

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# Today's Agenda

- Ben Franklin's Observation
- Interactions between Oleic Acid and Water
- Create a thin film of oleic acid
- Calculate the thickness of the thin film of oleic acid

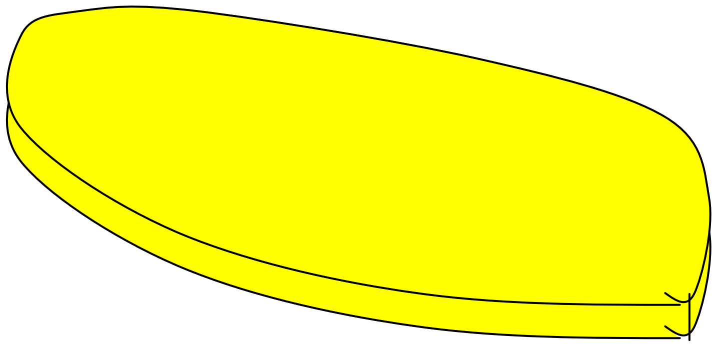
# Was Ben Franklin an Early Nanoscientist?

Excerpt from Letter of Benjamin Franklin to William Brownrigg (*Nov. 7, 1773)*

*...At length being at Clapham, where there is, on the Common, a large Pond ... I fetched out a Cruet of Oil, and dropt a little of it on the Water. I saw it spread itself with surprising Swiftness upon the Surface ... the Oil tho' not more than a Tea Spoonful ... which spread amazingly, and extended itself gradually till it reached the Lee Side, making all that Quarter of the Pond, perhaps half an Acre, as smooth as a Looking Glass....*

... ***the Oil tho' not more than a Tea Spoonful*** ...
... ***perhaps half an Acre***

CHALLENGE: **How thick was the film of Ben Franklin's oil?**



Volume = (Area)(Thickness)

V = A T

T = V/A

$$T = \frac{2\ cm^3}{20{,}000{,}000\ cm^2}$$

V = 1 teaspoonful ~ 2 $cm^3$

A = 0.5 acre ~ 2,000 $m^2$

20,000,000 $cm^2$

T = 0.0000001 cm

T = 1 x $10^{-7}$ cm

T = 1 x $10^{-9}$ m

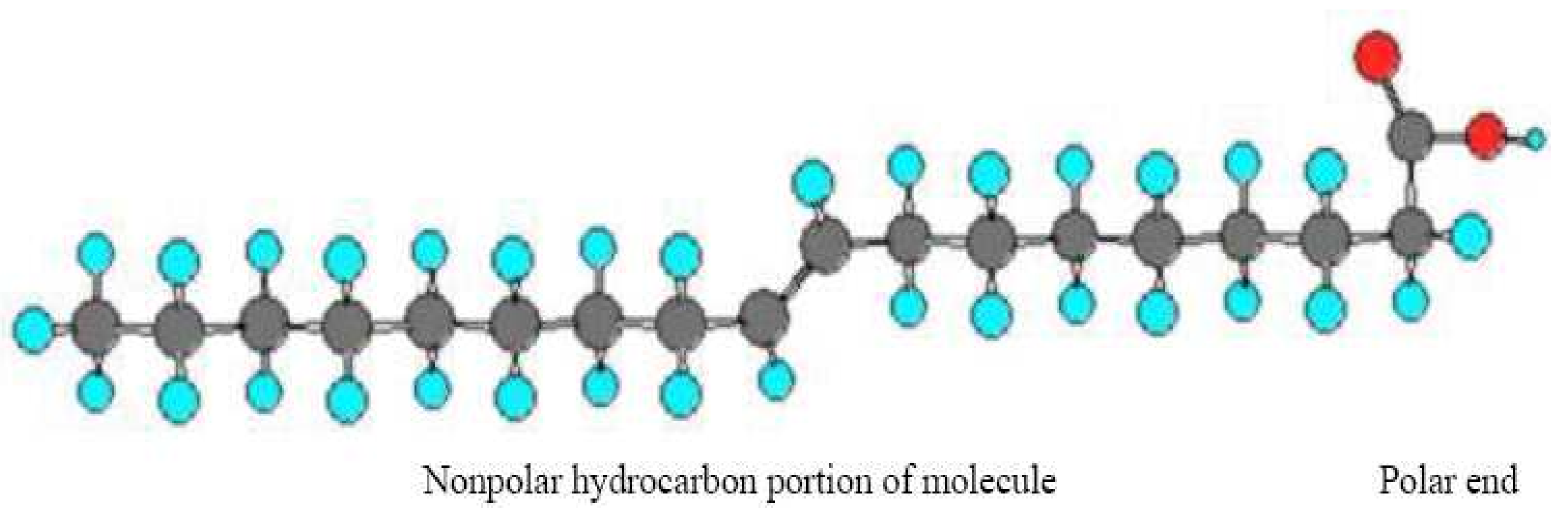
T = **1 nanometer**

# It would be difficult to conduct a thin film experiment on the UMass Amherst campus pond.

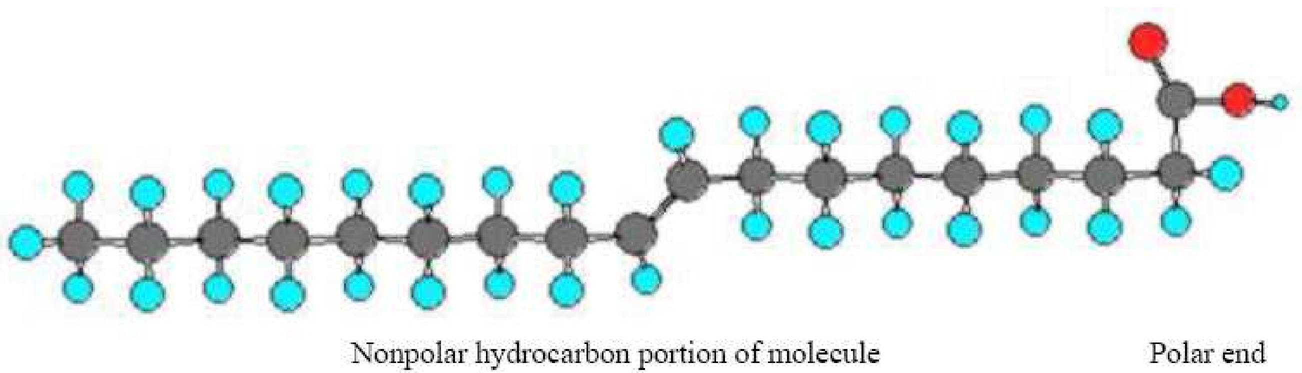
A plastic tray can be used to experiment with thin films. However, you need to use much less than a teaspoon of oil.

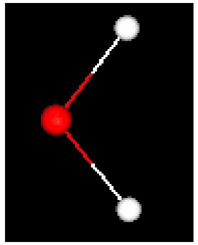
You will form a thin film on the surface of water using a small amount of one of olive oil's ingredients.

# That ingredient is oleic acid.

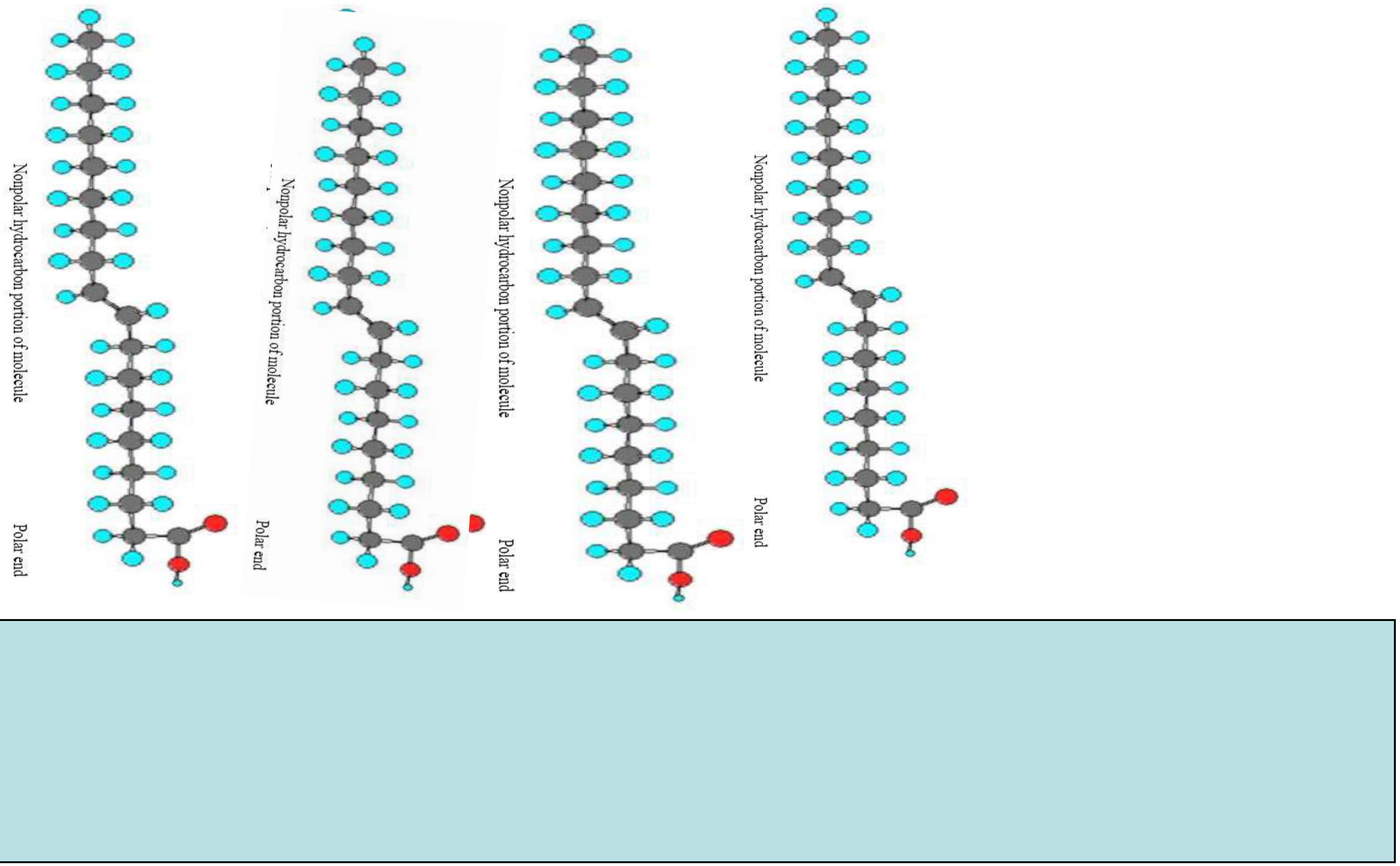


There is an attraction between the polar end of oleic acid molecules and polar water molecules.

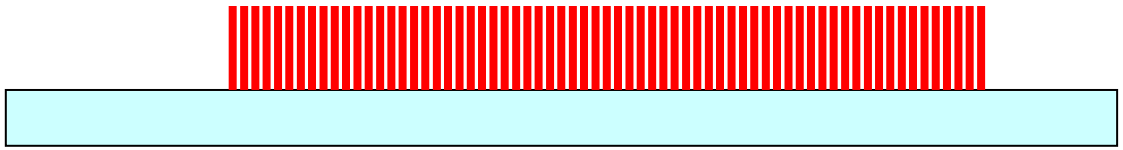


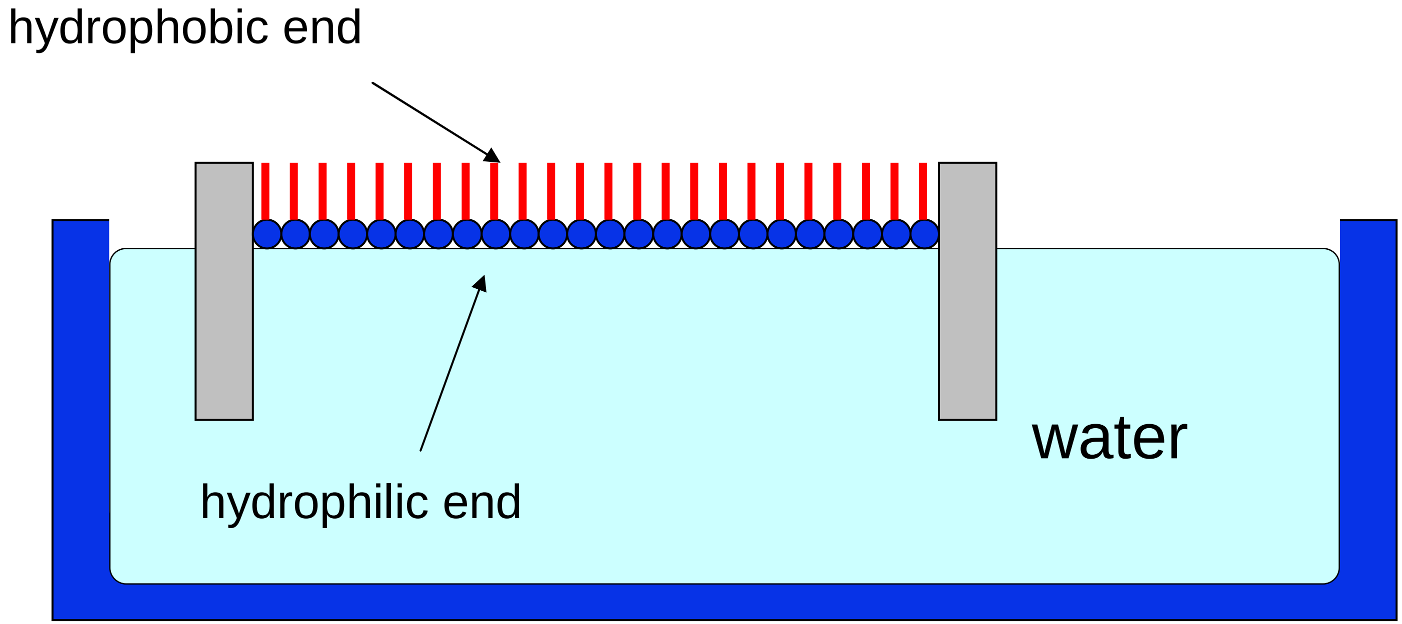
**When you pour a very small amount of oleic acid onto the surface of water, the oleic acid molecules can “self-assemble” into a thin layer.**



**In a small drop of oleic acid there are billions of oleic acid molecules that will stand up like blades of grass on the surface of water.**



**The thin film of oleic acid forms a Langmuir Film. The thin film can be confined to a specific area with a barrier. You will use small particles as a confining barrier.**



# Now its your turn to create a thin layer on the surface of water.

- Water is in each plastic tray.
- Make a very dilute solution of oleic acid in alcohol.
- Determine how many drops of a very dilute solution are in one $cm^3$ of the very dilute solution.
- Evenly sprinkle a layer of baby powder across the surface of the water.
- Let one drop of the very dilute solution of oleic acid spread across the surface of the water.
- The alcohol solvent will dissolve in water leaving a thin film of oleic acid solute on the surface
- Measure the average diameter of the circular layer of oleic acid.

# Nanoscale Calculations

- The procedure and calculation worksheets are provided.
- One side of the worksheet includes hints for calculations.
- Calculators need to be shared.

# A Sample Calculation of the volume of oleic acid in just one drop of the second dilute solution

The following steps correspond to the sequence of calculations on your calculation worksheet.

Step 1: The volume fraction = 1 / 25

Step 2: 0.04 $cm^3$

Step 3: 0.04 $cm^3$ / 25 = 0.0016 $cm^3$

Step 4: A group determined that 40 drops of the second dilute solution = 1.0 $cm^3$.

Step 5: If a group determined that 40 drops of the second solution of oleic acid had a volume of 1.0 $cm^3$; Then 0.0016 $cm^3$ / 40 = 0.00004 $cm^3$.

# A sample calculation of the thickness of the oleic acid film

Step 6: If a group estimated that average diameter their thin film of oleic acid was 14.50 cm, then the average radius is 7.25 cm.

Step 7: Area = 3.14 x $R^2$   For example: The area of that thin film was 165.05 $cm^2$

Step 8:

- ✓ If Volume = Area x Depth;
- ✓ Then: Depth = Volume / Area and the thickness of the example group's film would be 2.42 x $10^{-7}$ cm.

Step 9: 2.42 x $10^{-7}$ cm = 2.42 x $10^{-9}$ m = 2.42 nanometers

# Big Ideas in Self-Assembly

- Mobile structural components
- Target is low energy equilibrium state
- Ordered structures
- Assembly through attraction or repulsion forces between the components
- Environment selected to induce designed interaction
- Components retain physical identity through and after
- Reversible by controlling the environment

Whitesides & Boncheva (2002)

# A Few Questions

**What might be some sources of error when calculating the thickness of a layer of oleic acid?**

**How could the sources of error be minimized?**

**How might you integrate this activity into a STEM curriculum?**