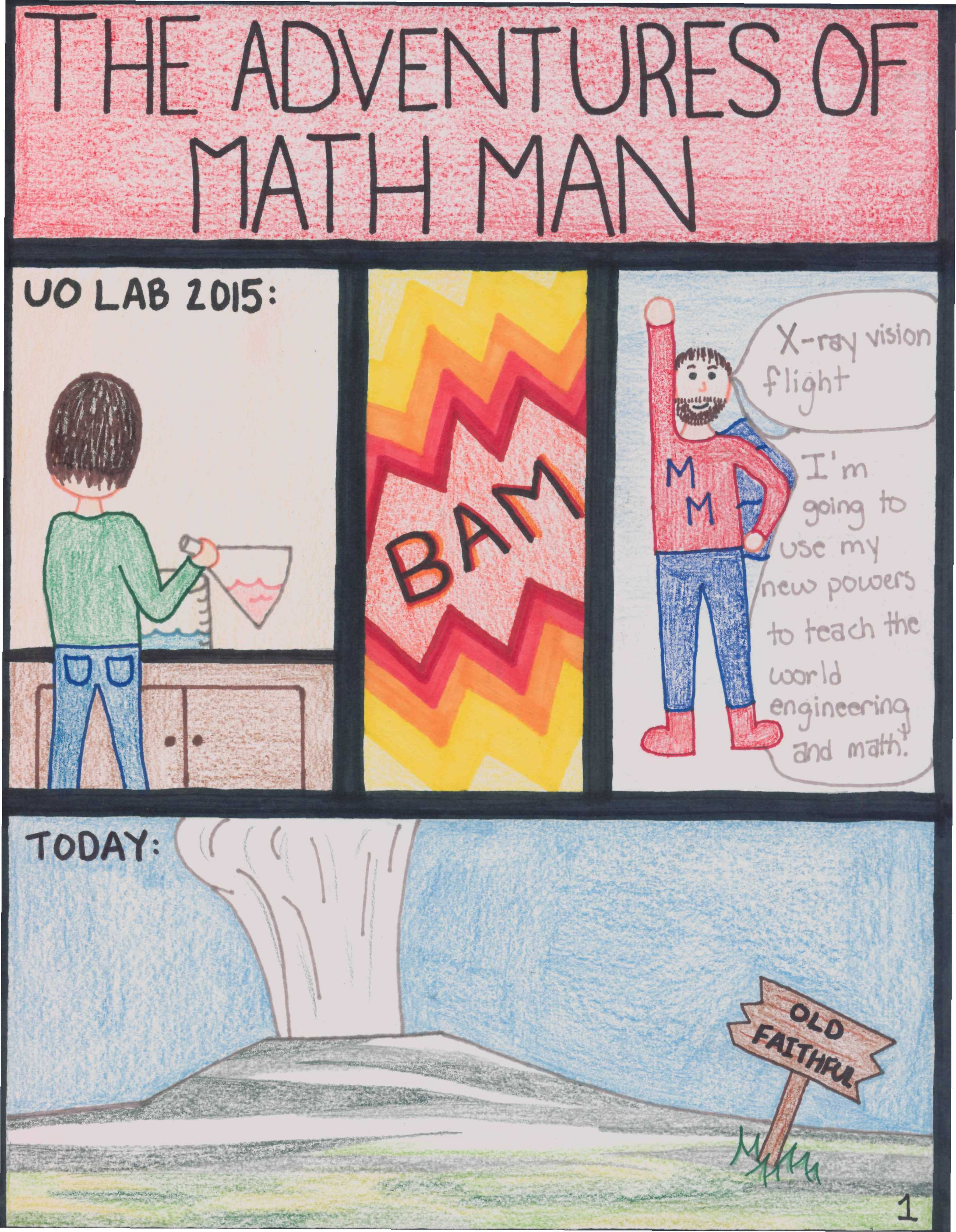
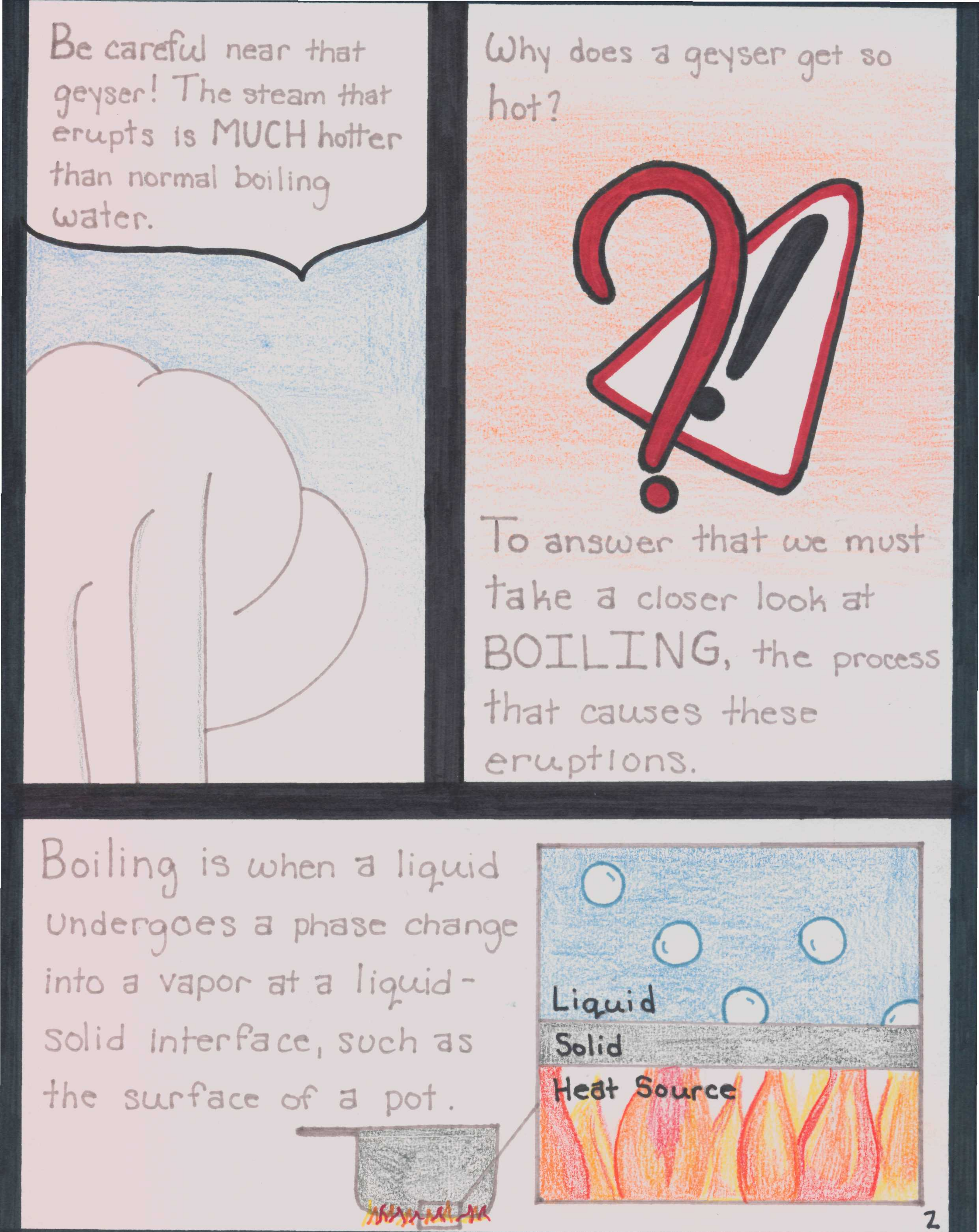
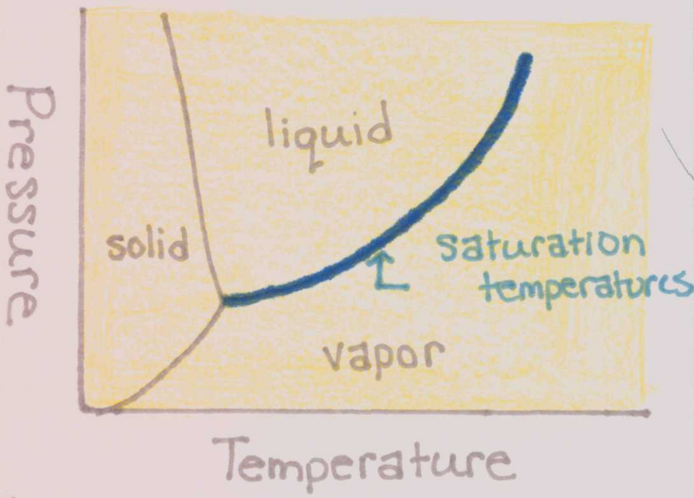

THE ADVENTURES OF MATH MAN
UO LAB 2015:
BAM
X-ray vision
flight
I'm going to use my new powers to teach the world engineering and math!
TODAY:
OLD FAITHFUL

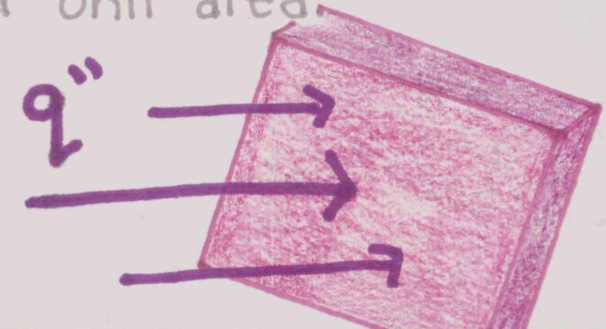

Be careful near that geyser! The steam that erupts is MUCH hotter than normal boiling water.
Why does a geyser get so hot?
To answer that we must take a closer look at BOILING, the process that causes these eruptions.
Boiling is when a liquid undergoes a phase change into a vapor at a liquid-solid interface, such as the surface of a pot.
Liquid
Solid
Heat Source

Boiling occurs when a liquid reaches its saturation temperature.

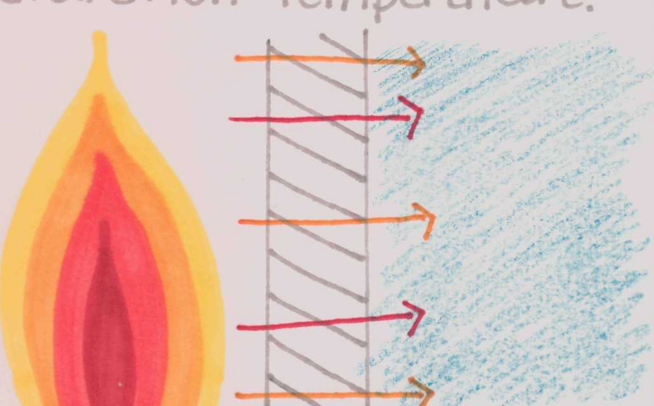


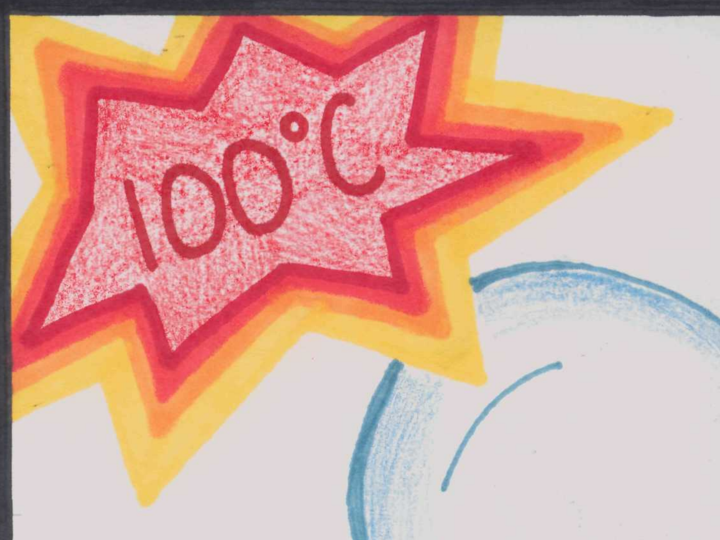
The saturation temperature of water is 100°C (@ 1 atm).

Heat transfer is the process of moving heat or energy from one material to another. It is often measured in heat flux, the amount of heat transfer per unit area.



During boiling, an energy source, like a flame, transfers thermal energy into a liquid until the liquid reaches its saturation temperature.

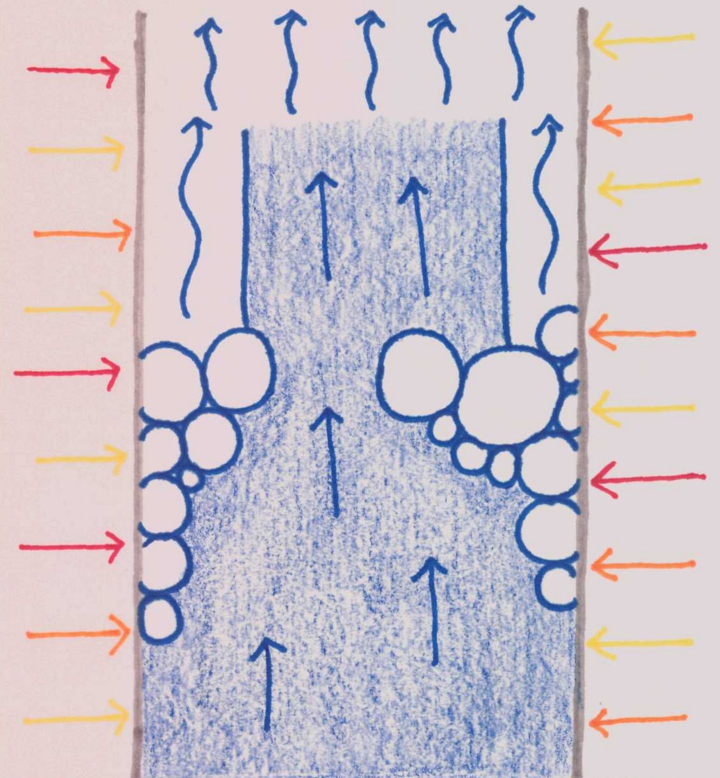




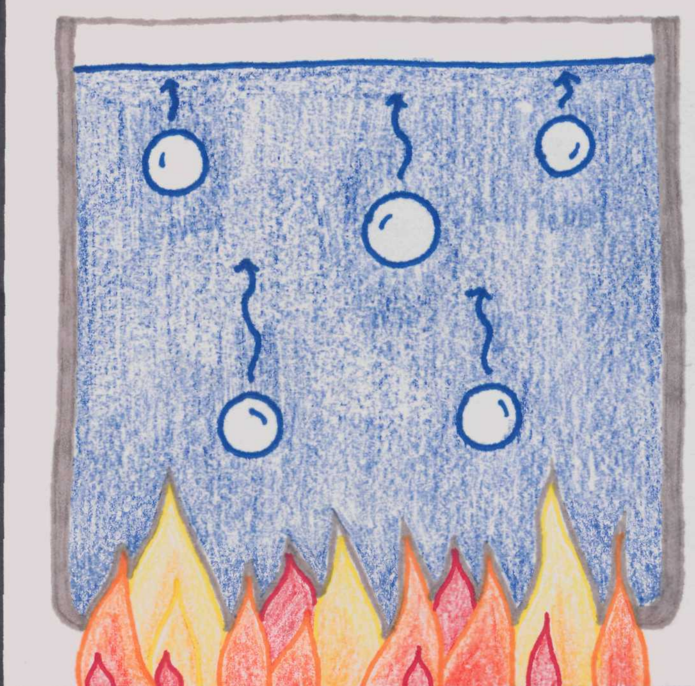
At the saturation temperature, the flame energy causes the liquid to vaporize.

There are two types of boiling...

FORCED CONVECTION



POOL BOILING



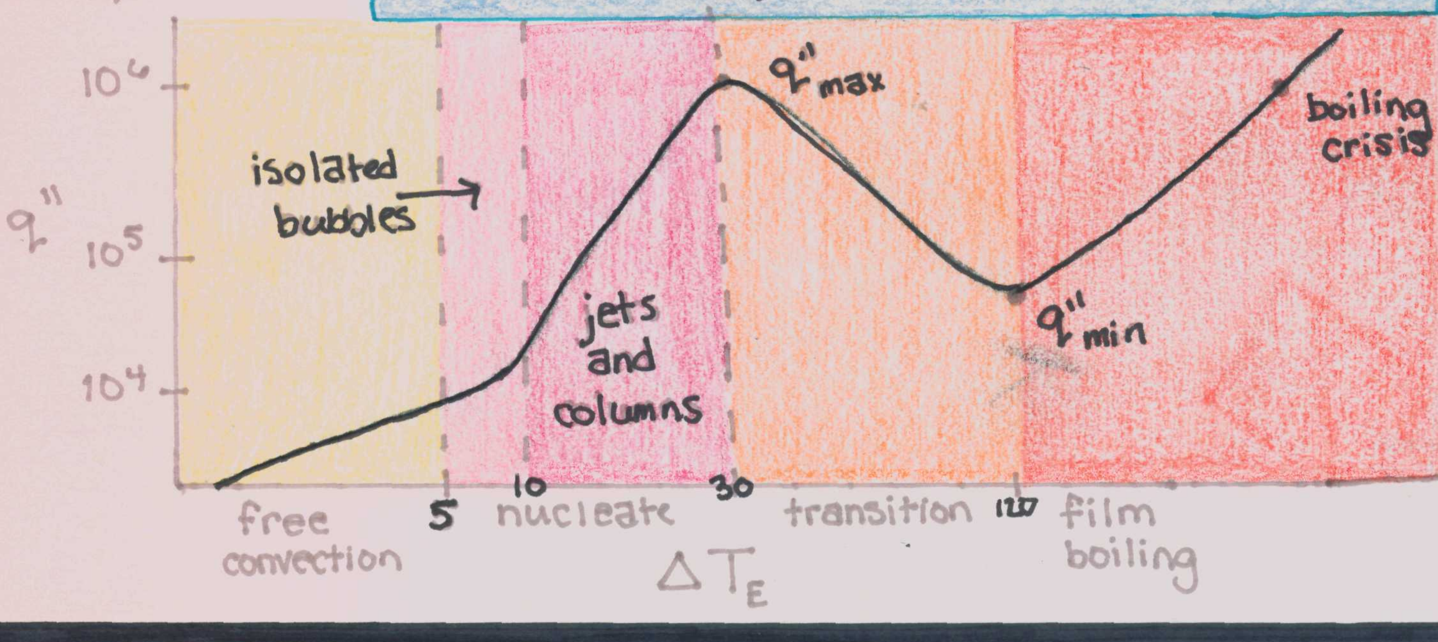
We are going to focus on pool boiling:

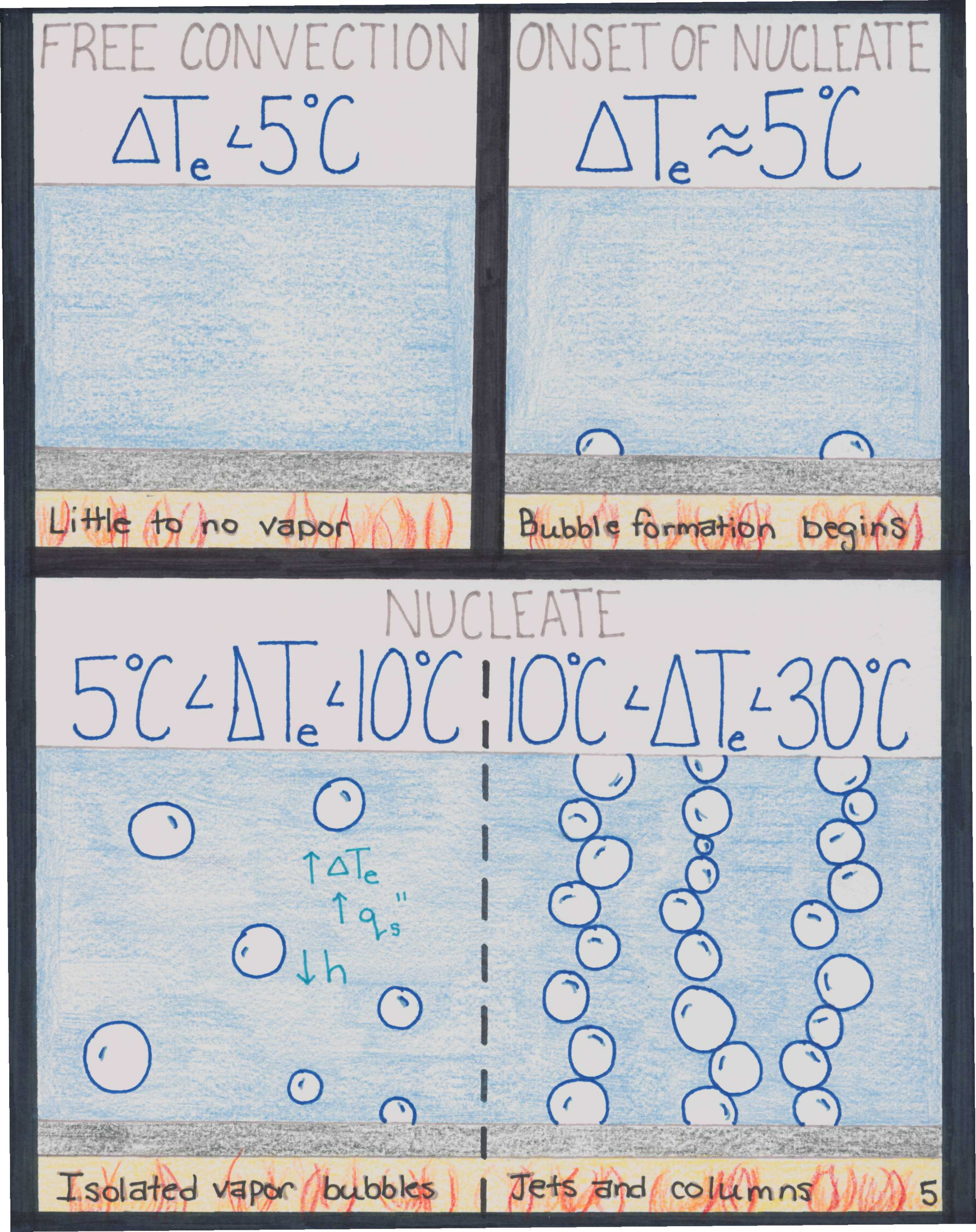
Pool boiling has several stages defined by excess temperature

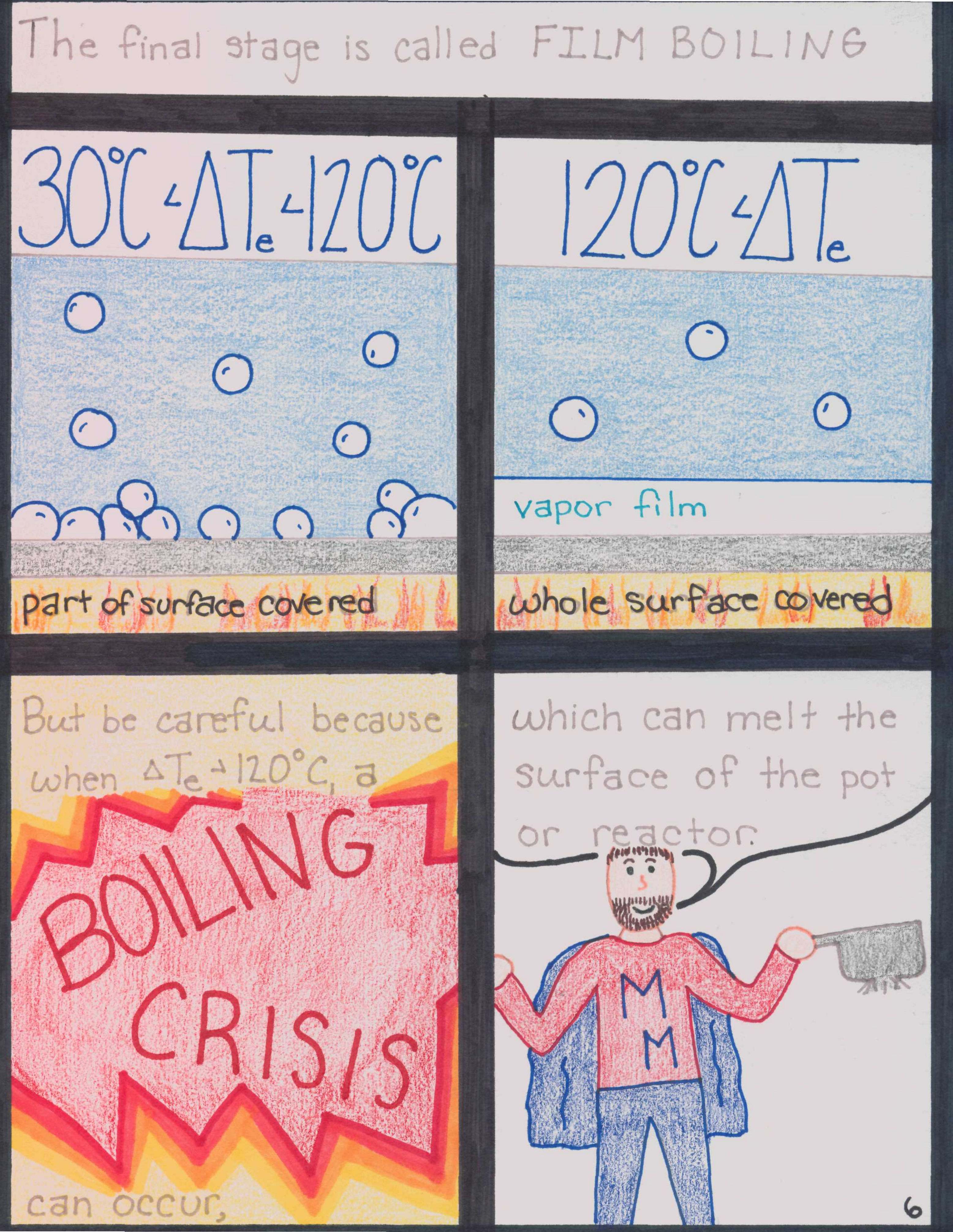
$$\Delta T_E = T_S - T_{SAT}$$

T_S : temperature of surface

T_{SAT} : saturation temperature




FREE CONVECTION
$\Delta T_e < 5°C$
Little to no vapor
ONSET OF NUCLEATE
$\Delta T_e \approx 5°C$
Bubble formation begins
NUCLEATE
$5°C < \Delta T_e < 10°C$
$\uparrow \Delta T_e$
$\uparrow q_s''$
$\downarrow h$
Isolated vapor bubbles
$10°C < \Delta T_e < 30°C$
Jets and columns


The final stage is called FILM BOILING
$30°C < \Delta T_e < 120°C$
part of surface covered
$120°C < \Delta T_e$
vapor film
whole surface covered
But be careful because when $\Delta T_e > 120°C$, a
BOILING CRISIS
can occur,
which can melt the surface of the pot or reactor.
M
M

The heat flux due to boiling can be calculated using the ROHSENOW CORRELATION

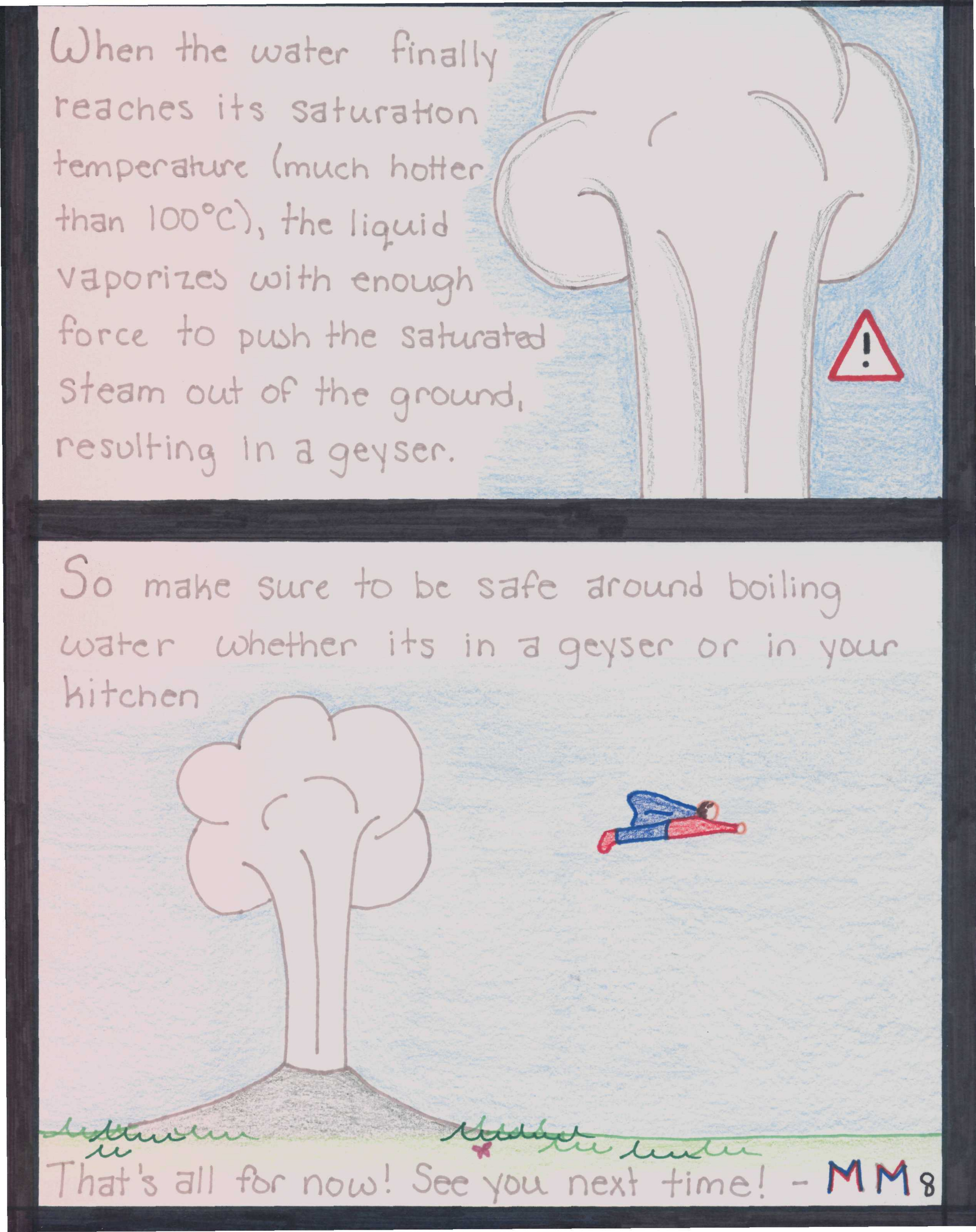
$$q''_s = \mu_l h_{fg} \left[\frac{g(\rho_l - \rho_v)}{\sigma} \right]^{\frac{1}{2}} \left[\frac{c_{p,l} \cdot \Delta T_e}{C_{sf} \cdot h_{fg} \cdot Pr_l^n} \right]^3$$

The maximum heat flux can be found by:

$$q''_{max} = C \cdot h_{fg} \rho_v \left[\frac{\sigma g (\rho_l - \rho_v)}{\rho_v^2} \right]^{\frac{1}{4}}$$

This always occurs in the nucleate boiling range, where most boiling processes should be operated.

But what does this have to do with geysers? In geysers, magma in the earth's crust heats up pockets of water. This water is under immense pressure, which raises the saturation temperature of the water.


When the water finally reaches its saturation temperature (much hotter than 100°C), the liquid vaporizes with enough force to push the saturated steam out of the ground, resulting in a geyser.
!
So make sure to be safe around boiling water whether its in a geyser or in your kitchen
That's all for now! See you next time! - MM