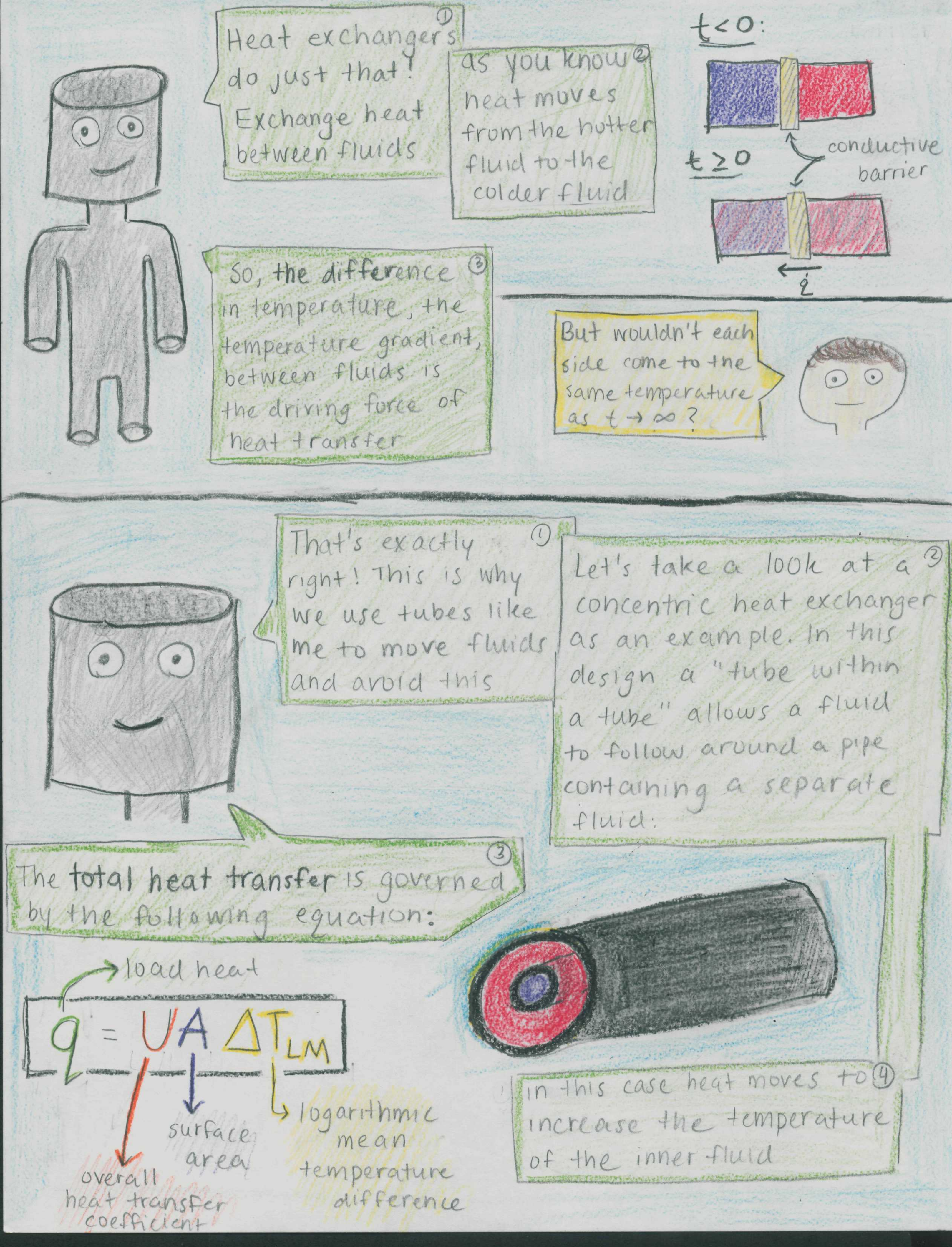
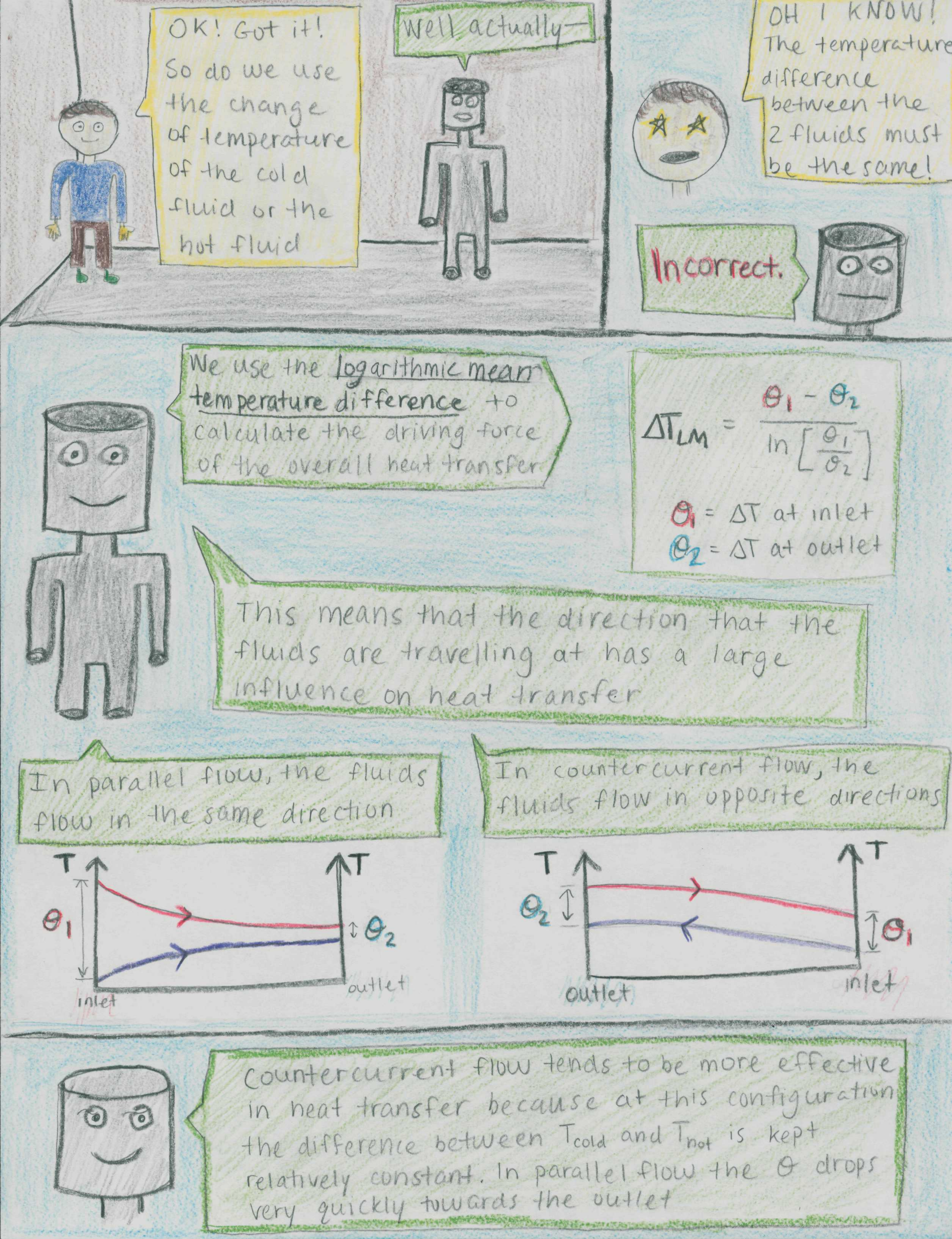
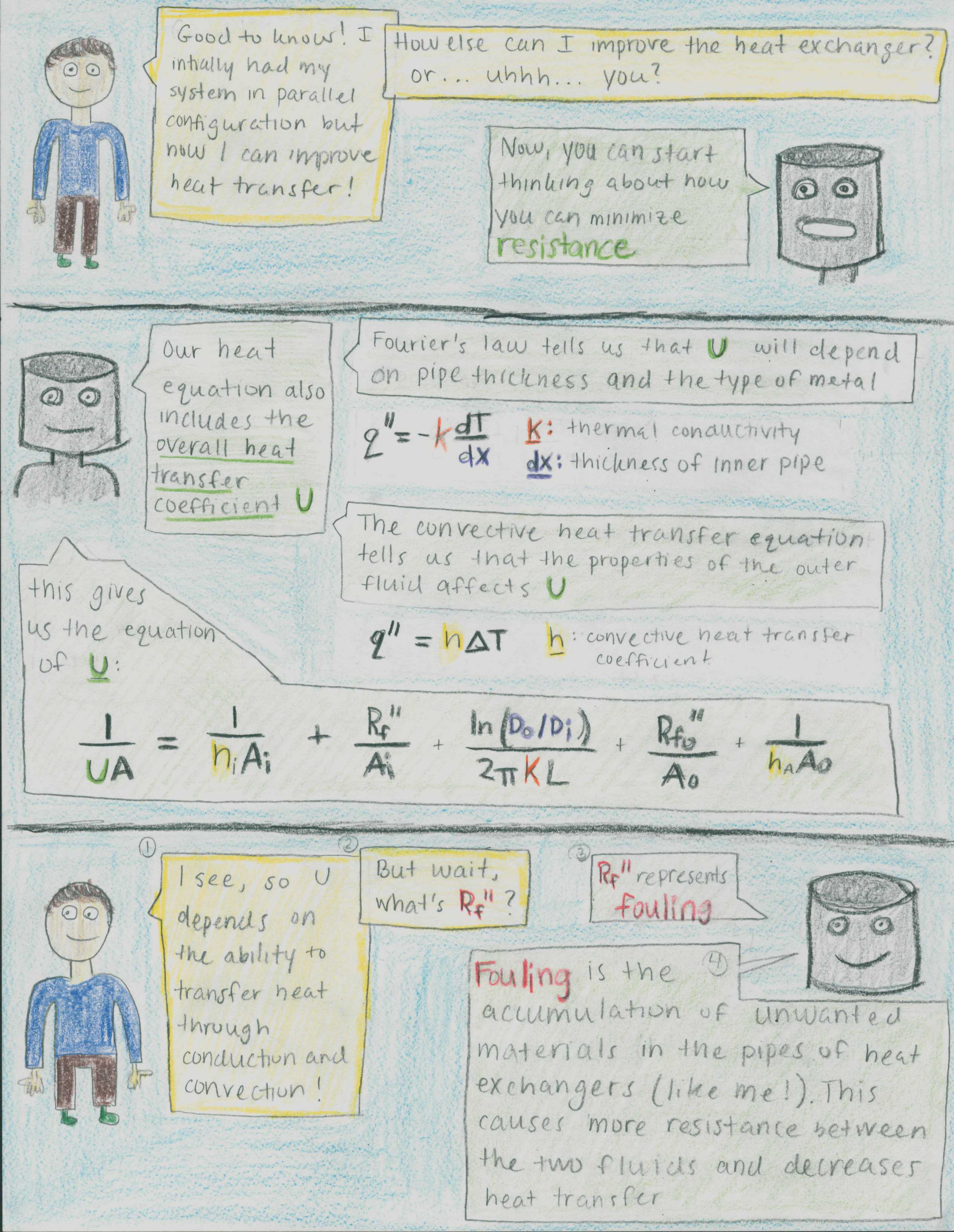
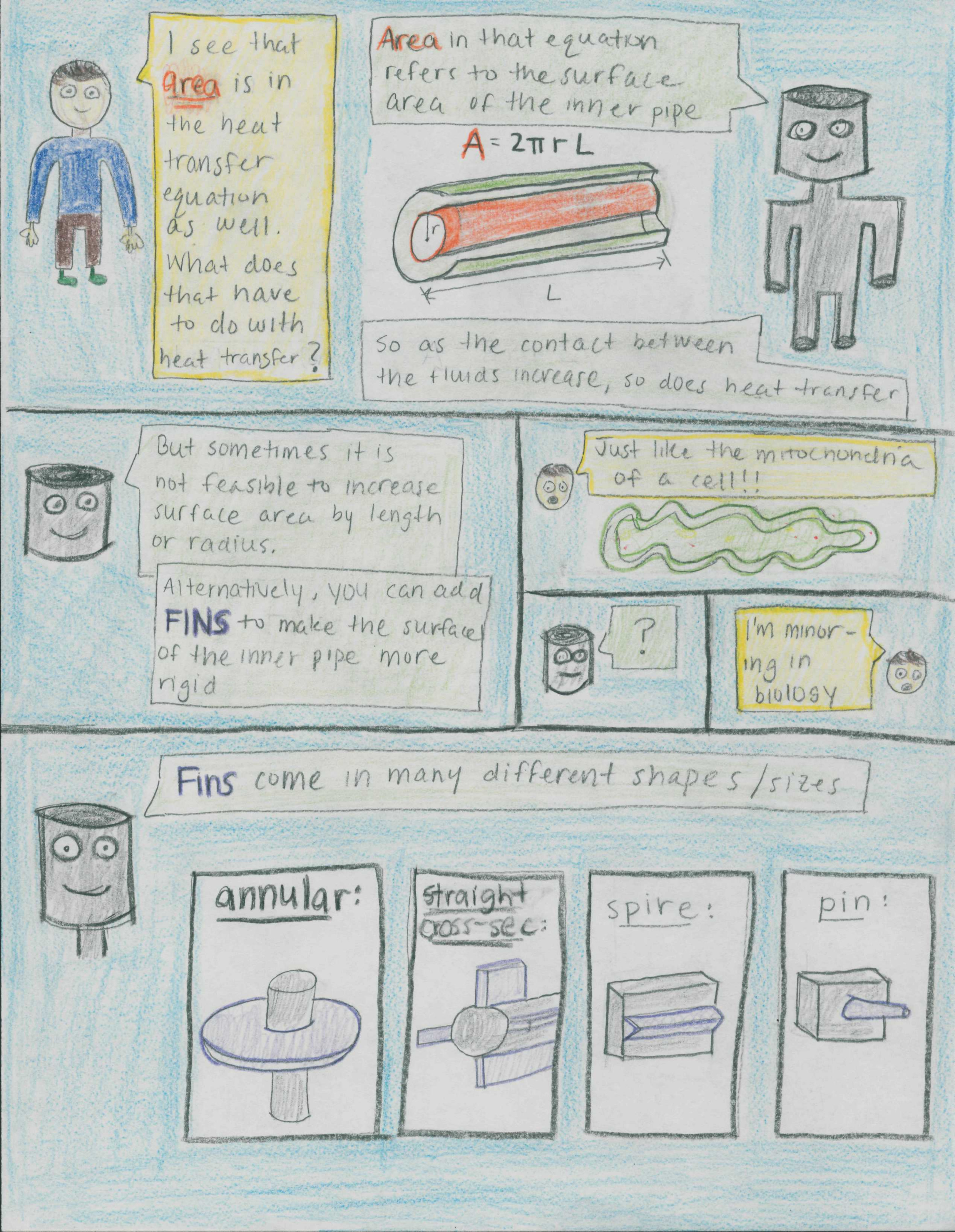

HEAT EXCHANGERS
A comic by Andi Shehu
Down in the depths of the UO lab is a Transport 2 student operating a G-fin HEx...
.05
0.05?! What is wrong with this thing?? Professor Pfluger will never pass me with fin effectiveness 0.05
It's not my fault! You're not operating me the right way!
What was that?!
It's me! The UO Lab's G-fin heat exchanger. But you can just call me BOB
Sounds legit. Can you increase your effective-ness?
Nope! I'm just hollow pipes. Only you can change my effectiveness through operating parameters
But first, you must understand the basics about Heat exchangers
I'm ready to learn BOB!

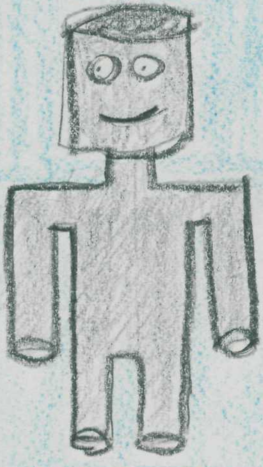

① Heat exchangers do just that! Exchange heat between fluids
② as you know heat moves from the hotter fluid to the colder fluid
t<0:
t≥0
conductive barrier
q̇
③ So, the difference in temperature, the temperature gradient, between fluids is the driving force of heat transfer
But wouldn't each side come to the same temperature as t→∞?
① That's exactly right! This is why we use tubes like me to move fluids and avoid this
② Let's take a look at a concentric heat exchanger as an example. In this design a "tube within a tube" allows a fluid to follow around a pipe containing a separate fluid:
③ The total heat transfer is governed by the following equation:
load heat
$q = UA\,\Delta T_{LM}$
overall heat transfer coefficient
surface area
logarithmic mean temperature difference
④ in this case heat moves to increase the temperature of the inner fluid


OK! Got it! So do we use the change of temperature of the cold fluid or the hot fluid
Well actually—
OH I KNOW! The temperature difference between the 2 fluids must be the same!
Incorrect.
We use the logarithmic mean temperature difference to calculate the driving force of the overall heat transfer
$\Delta T_{LM} = \frac{\theta_1 - \theta_2}{\ln\left[\frac{\theta_1}{\theta_2}\right]}$
θ_1 = ΔT at inlet
θ_2 = ΔT at outlet
This means that the direction that the fluids are travelling at has a large influence on heat transfer
In parallel flow, the fluids flow in the same direction
T
T
θ_1
θ_2
inlet
outlet
In countercurrent flow, the fluids flow in opposite directions
T
T
θ_2
θ_1
outlet
inlet
Countercurrent flow tends to be more effective in heat transfer because at this configuration the difference between T_{cold} and T_{hot} is kept relatively constant. In parallel flow the θ drops very quickly towards the outlet



Good to know! I intially had my system in parallel configuration but now I can improve heat transfer!
How else can I improve the heat exchanger? or... uhhh... you?
Now, you can start thinking about how you can minimize resistance
Our heat equation also includes the overall heat transfer coefficient U
Fourier's law tells us that U will depend on pipe thickness and the type of metal
$q'' = -k\frac{dT}{dx}$
k: thermal conductivity
dx: thickness of inner pipe
The convective heat transfer equation tells us that the properties of the outer fluid affects U
$q'' = h\Delta T$
h: convective heat transfer coefficient
this gives us the equation of U:
$\frac{1}{UA} = \frac{1}{h_i A_i} + \frac{R_f''}{A_i} + \frac{\ln(D_o/D_i)}{2\pi K L} + \frac{R_{fo}''}{A_o} + \frac{1}{h_A A_o}$
① I see, so U depends on the ability to transfer heat through conduction and convection!
② But wait, what's R_f''?
③ R_f'' represents fouling
④ Fouling is the accumulation of unwanted materials in the pipes of heat exchangers (like me!). This causes more resistance between the two fluids and decreases heat transfer


I see that Area is in the heat transfer equation as well. What does that have to do with heat transfer?
Area in that equation refers to the surface area of the inner pipe
A = 2πrL
r
L
So as the contact between the fluids increase, so does heat transfer
But sometimes it is not feasible to increase surface area by length or radius.
Alternatively, you can add FINS to make the surface of the inner pipe more rigid
Just like the mitochondria of a cell!!
?
I'm minor-ing in biology
Fins come in many different shapes/sizes
annular:
straight cross-sec:
spire:
pin:



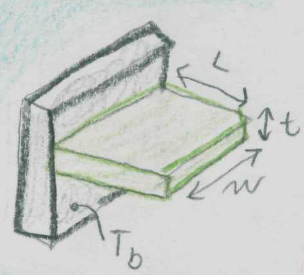
Now, you know what affects heat transfer in a heat exchanger like me!

Fin effectiveness can measure how much better the heat exchanger operates with fins vs. without fins

fin effectiveness → ε_{fin}; heat transfer with fin → $\dot{Q}_{fin}$; heat transfer without fin → $\dot{Q}_{no\ fin}$

$$\varepsilon_{fin} = \frac{\dot{Q}_{fin}}{\dot{Q}_{no\ fin}}$$

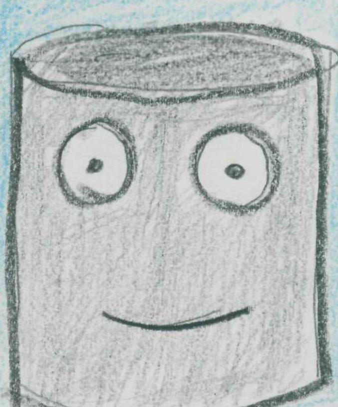
The difference between $\dot{Q}_{fin}$ and $\dot{Q}_{no\ fin}$ is the surface area of the outer side of the inner pipe



$$SA_{no\ fin} = T_b$$

$$SA_{fin} = T_b + wt + 2wL + 2Lt$$

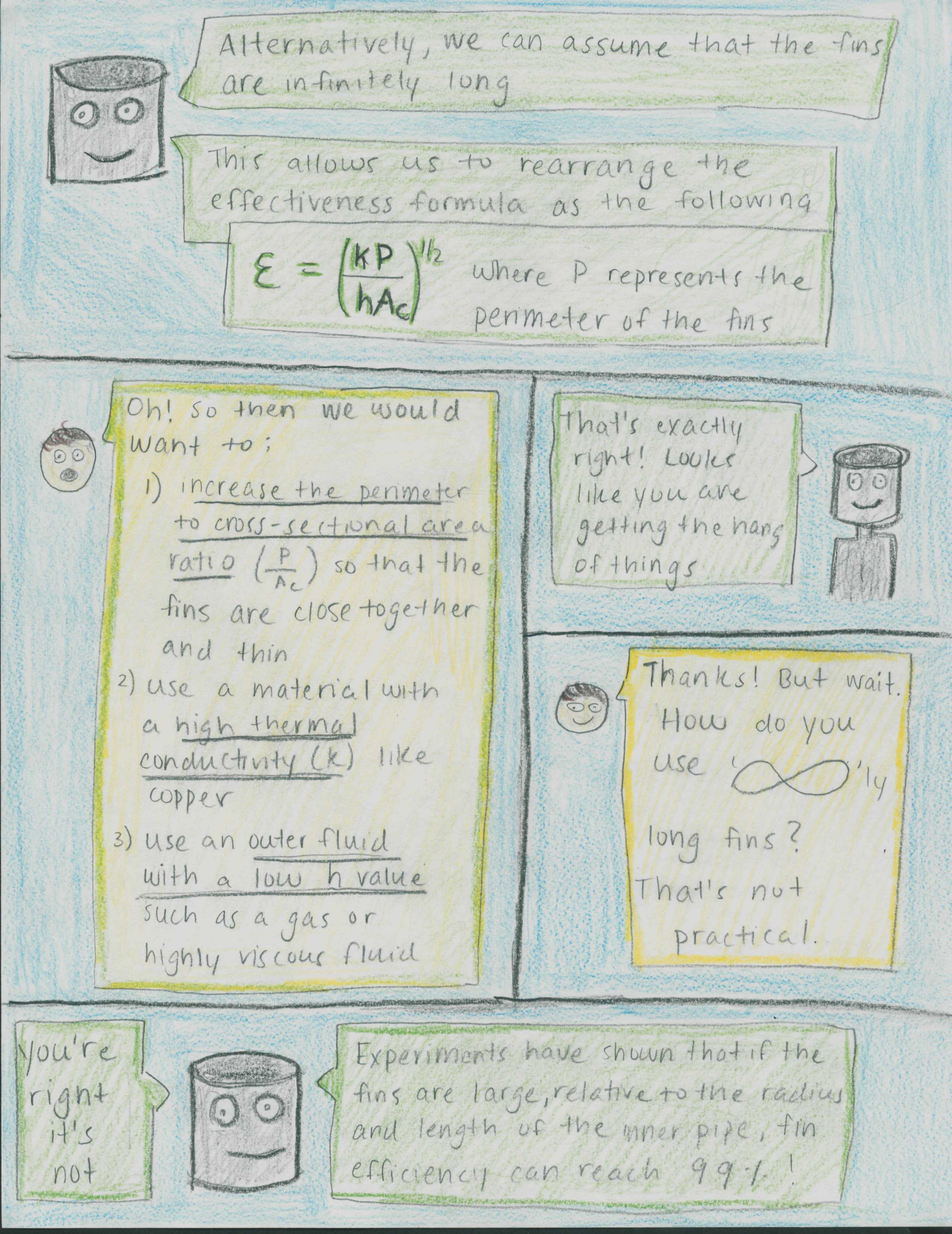
So, now you can calculate **fin effectiveness**. What does the number mean?



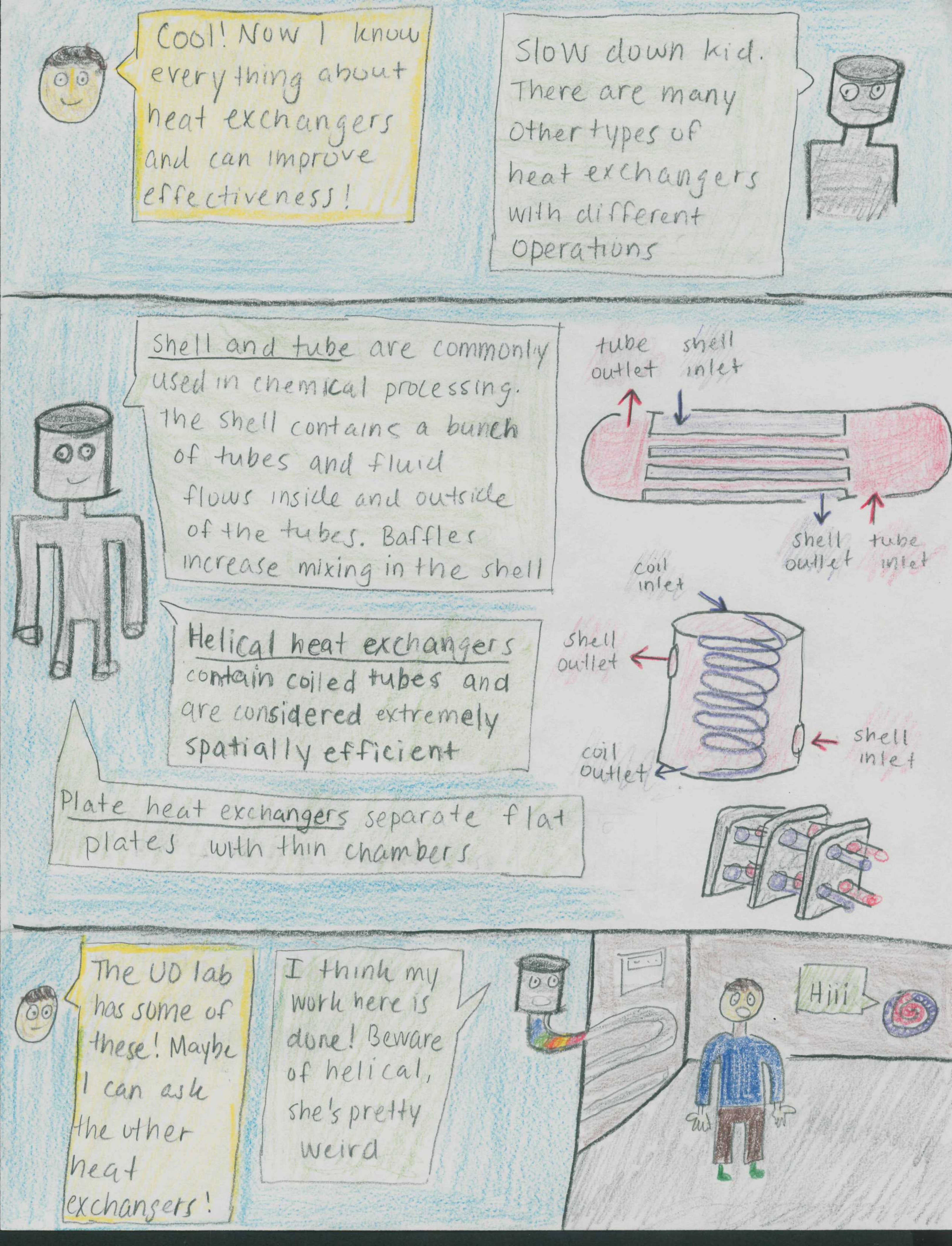
If $\varepsilon_{fin} < 1$, the fin acts as insulation since more heat is transferred without the fins

If $\varepsilon_{fin} = 1$, the fin does not affect the amount of heat exchanged.

If $\varepsilon_{fin} > 1$, the fins enhance heat transfer and if $\varepsilon_{fin} > 2$, the fins are justified



Alternatively, we can assume that the fins are infinitely long
This allows us to rearrange the effectiveness formula as the following
$\varepsilon = \left(\frac{kP}{hA_c}\right)^{1/2}$ where P represents the perimeter of the fins
Oh! So then we would want to;
1) increase the perimeter to cross-sectional area ratio ($\frac{P}{A_c}$) so that the fins are close together and thin
2) use a material with a high thermal conductivity (k) like copper
3) use an outer fluid with a low h value such as a gas or highly viscous fluid
That's exactly right! Looks like you are getting the hang of things
Thanks! But wait. How do you use '∞'ly long fins? That's not practical.
You're right it's not
Experiments have shown that if the fins are large, relative to the radius and length of the inner pipe, fin efficiency can reach 99% !


Cool! Now I know everything about heat exchangers and can improve effectiveness!
Slow down kid. There are many other types of heat exchangers with different operations
Shell and tube are commonly used in chemical processing. the shell contains a bunch of tubes and fluid flows inside and outside of the tubes. Baffles increase mixing in the shell
tube outlet
shell inlet
shell outlet
tube inlet
Helical heat exchangers contain coiled tubes and are considered extremely spatially efficient
coil inlet
shell outlet
shell inlet
coil outlet
Plate heat exchangers separate flat plates with thin chambers
The UO lab has some of these! Maybe I can ask the other heat exchangers!
I think my work here is done! Beware of helical, she's pretty weird
Hiii