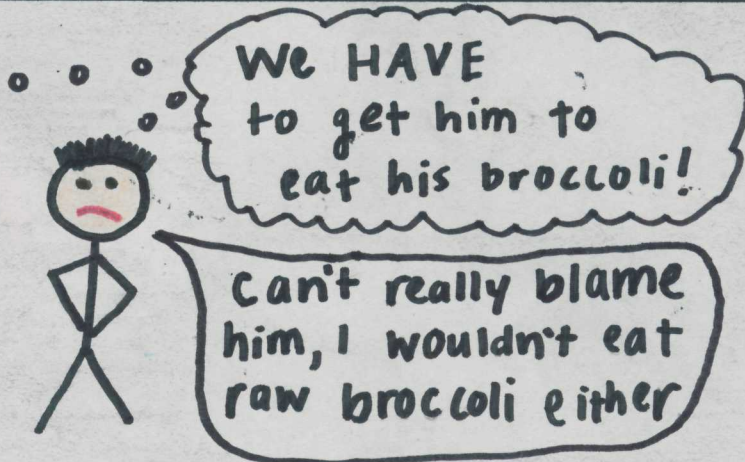
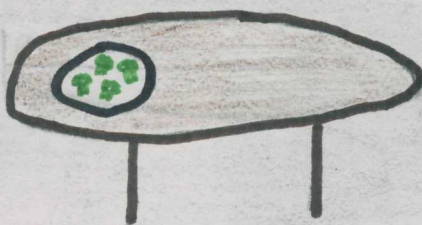


by Siobhan Powers and Alex Censullo



How can we both be brilliant chemical engineers but such awful cooks?



well if I remember correctly, neither of us had time in undergrad because we were always studying! We basically survived on ramen and cereal



You're right! How about we put that studying to use for once. How well do you understand heat transfer?



Like the back of my hand! And I think I know where you're going with this. We can use conduction, convection, AND radiation to cook!

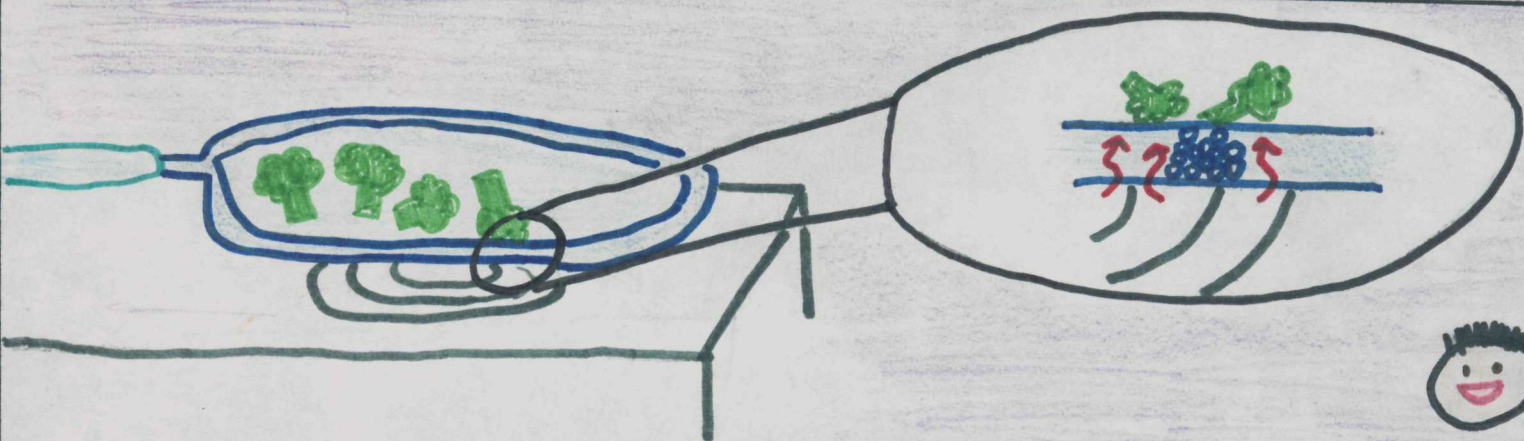




Exactly! How do you want to go about this?

Let's start with conduction, the transfer of heat through random molecular interactions of adjacent particles!

Good thinking, we can stir-fry the broccoli on the stove top using a skillet!

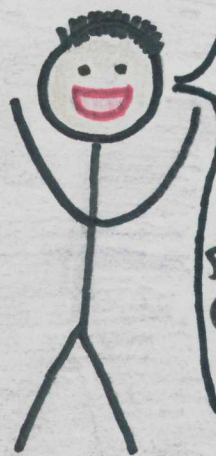
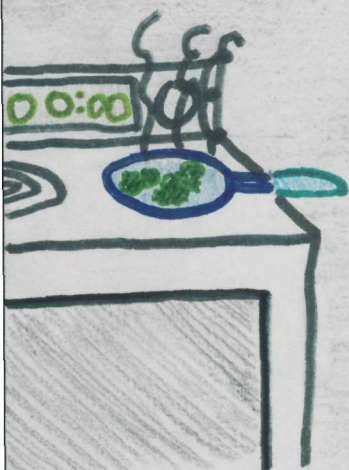


The stovetop will heat up, transferring energy into the molecules in the skillet. These molecules vibrate, causing their adjacent molecules to vibrate, eventually transferring this heat energy into the broccoli.

Oh no, the broccoli is starting to burn! Honey, how do I prevent this?

Hmmm... well let's think of the equation:  $q_x'' = -k \frac{dT}{dx}$  where  $q_x''$  is the heat flux,  $k$  is the thermal conductivity, and  $\frac{dT}{dx}$  is the temperature gradient.

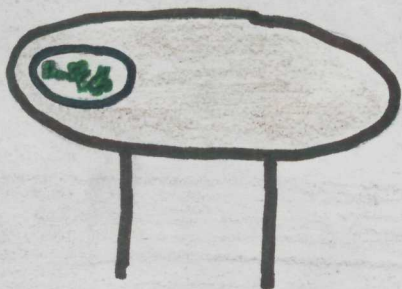




So to decrease  $q_x''$ , we should decrease  $k$ , decrease  $\Delta T$ , or increase  $\Delta x$ . We can use a less conductive material for the skillet, turn down the heat on the stove, or get a thicker skillet!

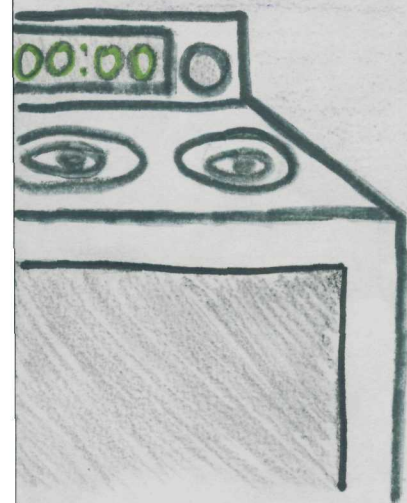


Y-yess... good job dear, but can you pay attention to the stove?



Hmm... why doesn't he like it?

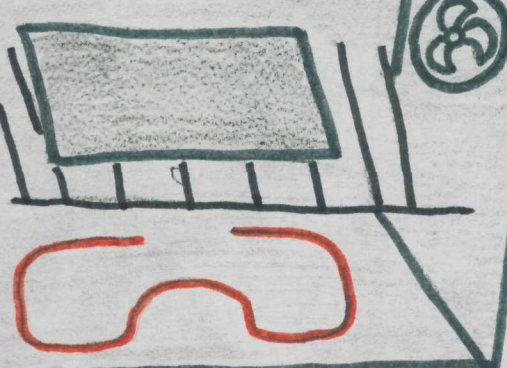
Probably because the broccoli was completely burnt, let me try to use convection.



Ovens are perfect examples of convection - heat transfer through the bulk motion of a fluid or random molecular motion

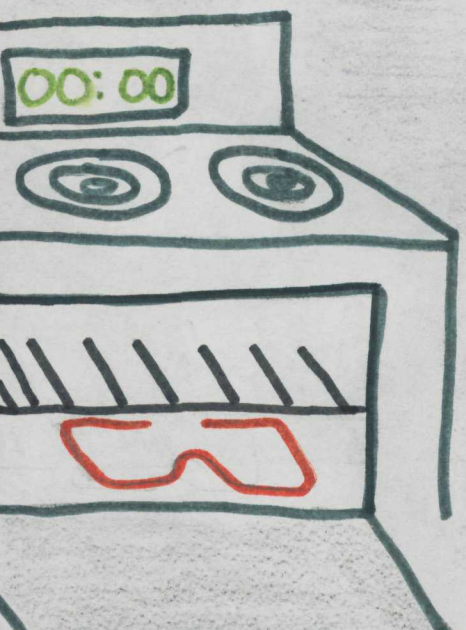






In an oven, heat is transferred to the food by both radiation and convection. There is free convection in a conventional oven and forced convection in a convection oven. In a convection oven,

the air is heated by heating coils, then an external force (a fan) circulates the air. This hot air passes over the surface of interest (the broccoli) and in turn heats it up.



The equation for convective heat transfer is  $q'' = h(T_s - T_\infty)$ .  $h$  is the convective heat transfer coefficient and  $T_s$  and  $T_\infty$  are the respective temperatures of the surface and the bulk fluid.



Our baby is getting hungry... we need to cook this broccoli as fast as possible

We need a high rate of heat transfer!



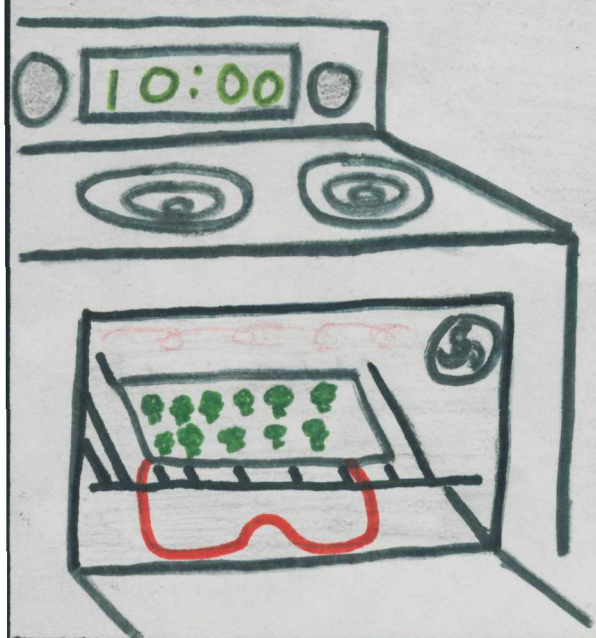


$q_b = h(T_{\infty} - T_s)A$

We can set the oven to the highest temperature possible!

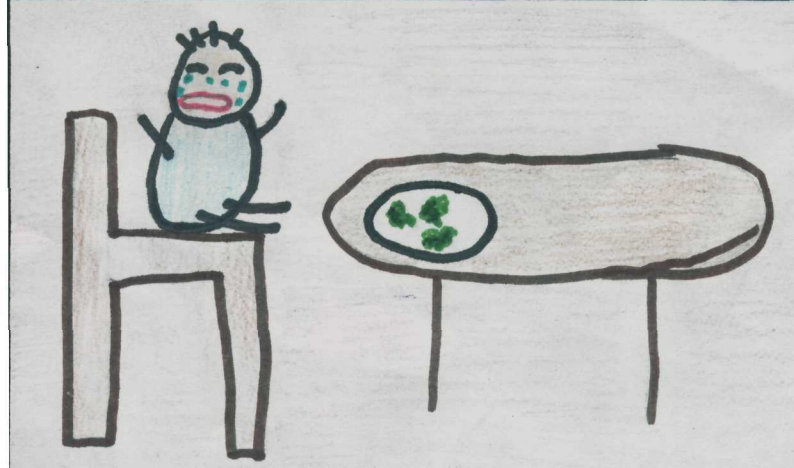
$q_b = h(T_{\infty} - T_s)A$

We can also increase the surface area of the broccoli



$q_b = h(T_{\infty} - T_s)A$

The convective heat transfer coefficient,  $h$ , is a property that has a set value depending on the velocity and viscosity of the fluid, among other variables. However, we can change our  $h$  value by using a conventional or convection oven. We need a high heat transfer rate, so we will choose the convection oven, which has a greater  $h$ .



He doesn't seem to like it

Probably because your broccoli was more burnt than mine!



The only method we haven't yet tried is cooking it entirely through radiation

Maybe he'll like that!

Good thing I'm a pro with the microwave!

That isn't actually a proper example of heat transfer through radiation.. I had other ideas

Yes it is radiation! It's literally called microwave radiation!

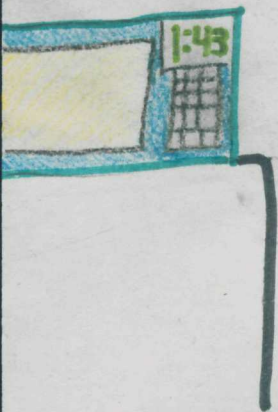
You know how there is a wavelength called 'microwaves'? Radiation does not use that wavelength. But microwaves, the physical box? Those do use radiation to heat the food. In other words, microwaves may use radiation, but radiation is not actually microwaves.

We'll just have to see whose broccoli is better then.

I'm always up for a competition! I'll be back in under 10 minutes

The Lab

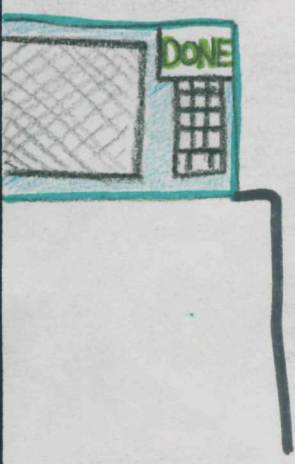




Ugh, he can be so confusing. He basically said that microwave ovens DO use radiation, which is true!

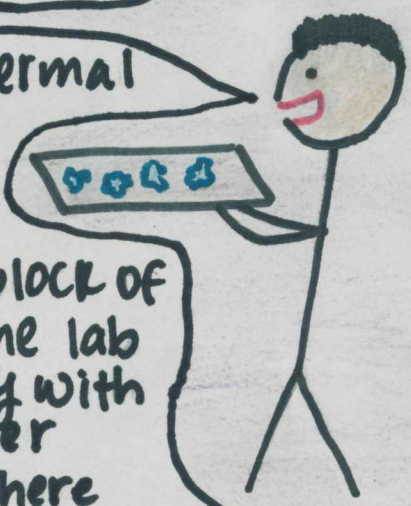


Thinking about it now, microwave ovens do use radiation, I can't let her know she was right!

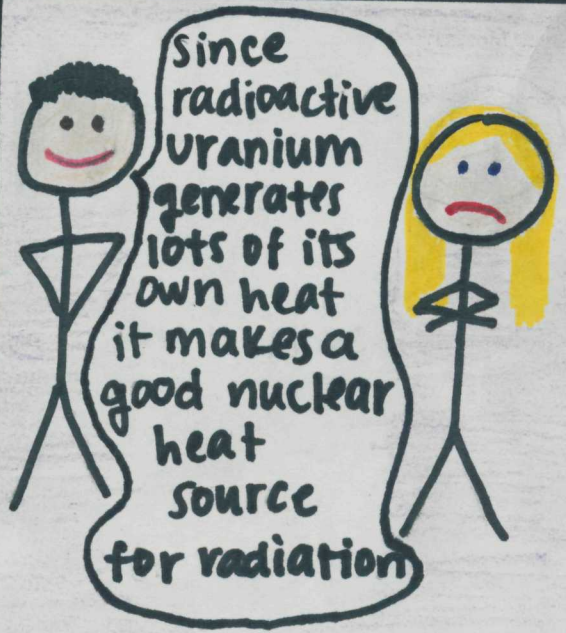


What did you do?!

I just used thermal radiation to transfer heat to the broccoll. The block of Uranium in the lab releases energy with emissive power  $E = \epsilon \sigma T_s^4$  where  $\sigma =$  Boltzmann constant  $\epsilon =$  emissivity  $T_s =$  surface temperature in Kelvin

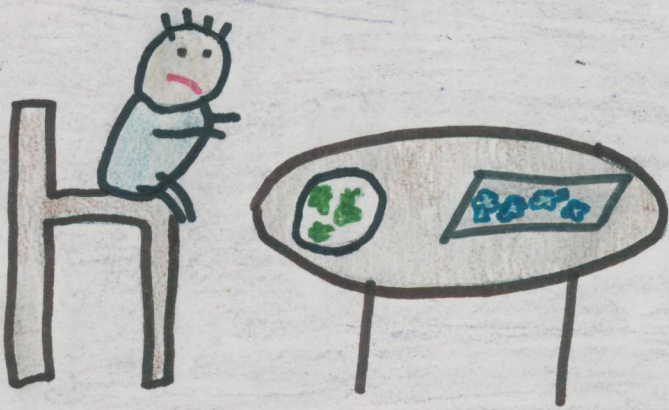


Generated heat radiates in the form of electromagnetic waves, and the broccoli absorbs the emitted photons, cooking it



Since radioactive Uranium generates lots of its own heat it makes a good nuclear heat source for radiation





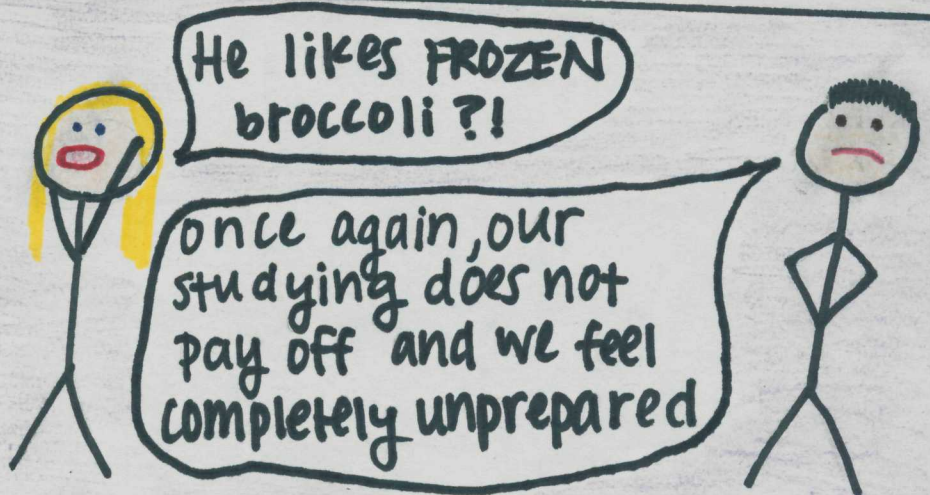
I really should be stopping you from feeding our baby radioactive broccoli. why do we even have uranium in the house?

He's totally going to like my broccoli better! microwaving is totally the inferior cooking method



What have you done to my precious child? I'm never letting you feed him again!

It seems like my broccoli was better



He likes FROZEN broccoli?!

once again, our studying does not pay off and we feel completely unprepared