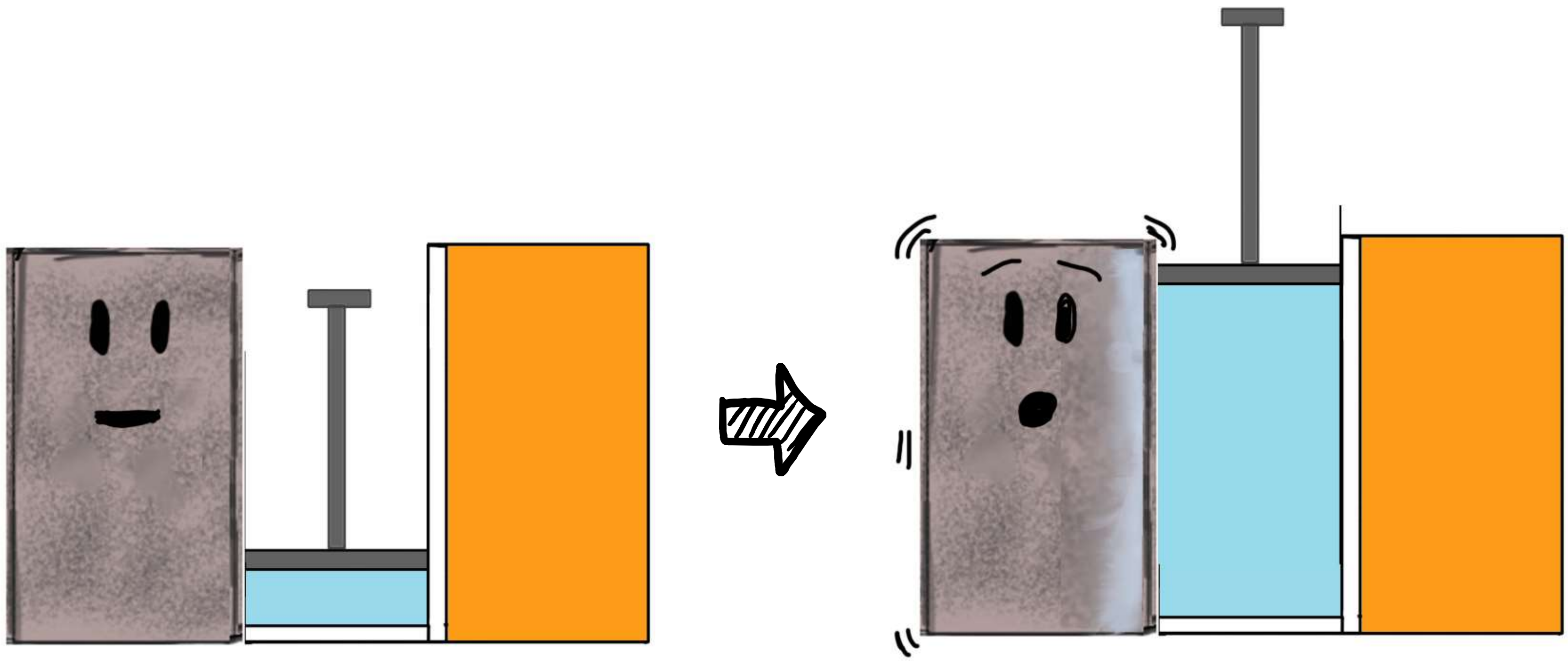
Office hours today: after class (Remo)
4-5pm, 8-9pm (Zoom)

Homework sessions:
5-8pm Monday and Tuesday in Remo

Learning goals for today:
To explain the basic gas processes that are used in refrigeration
To explain why heat always flows from hotter objects to colder objects
To describe the microscopic meaning of entropy and explain how this governs the direction of heat flow

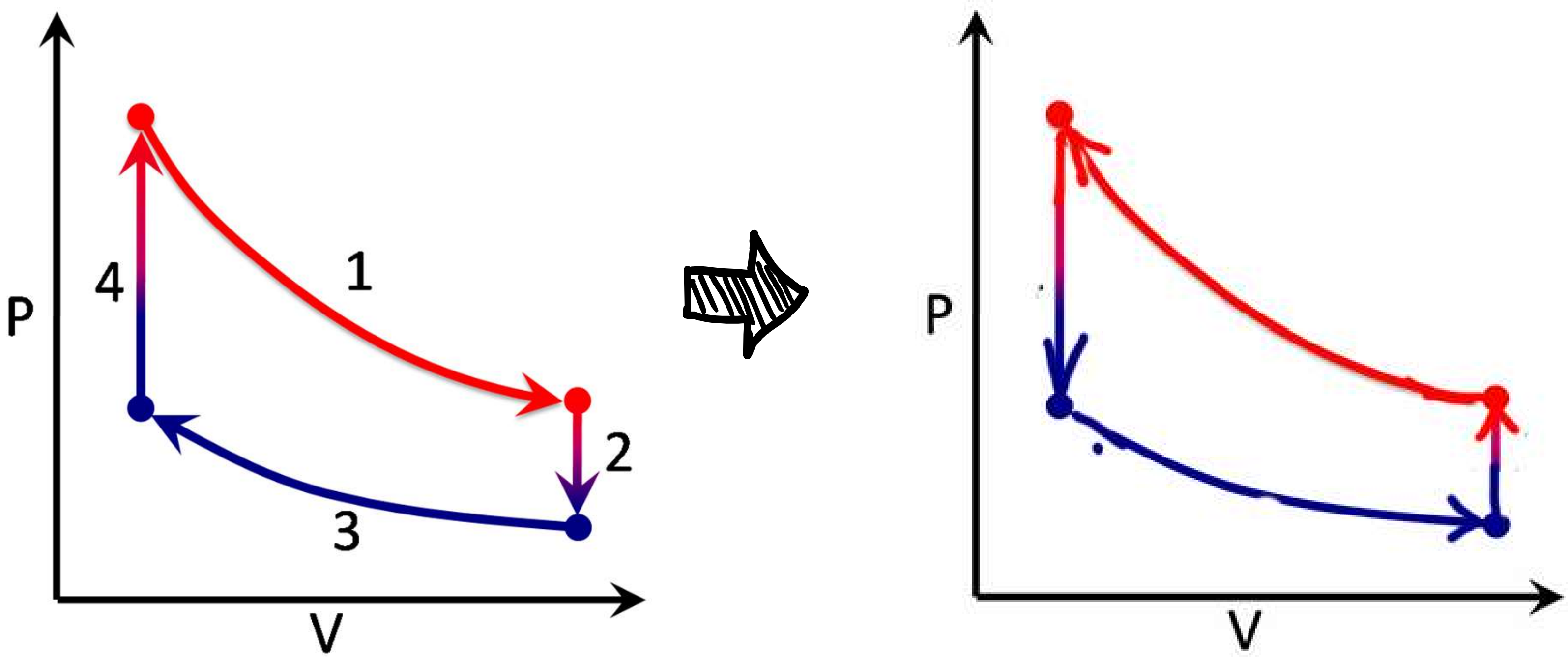
Last time in Phys 157...

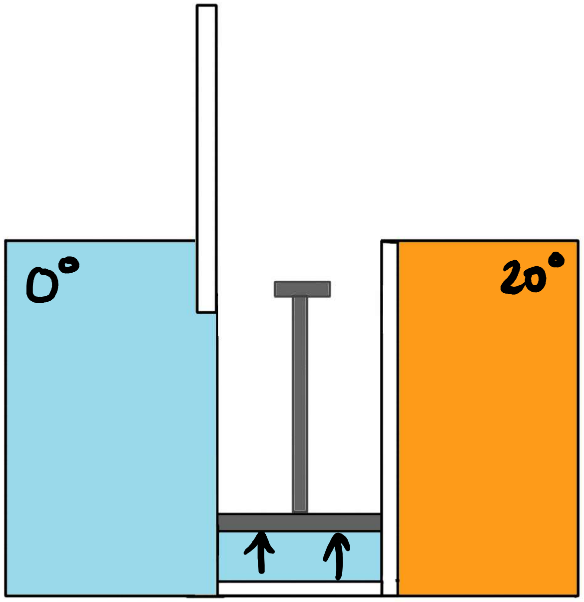


REFRIGERATORS: Can transfer heat from colder system to warmer system by doing work.

★ e.g. Stirling cycle in reverse ★

e.g.

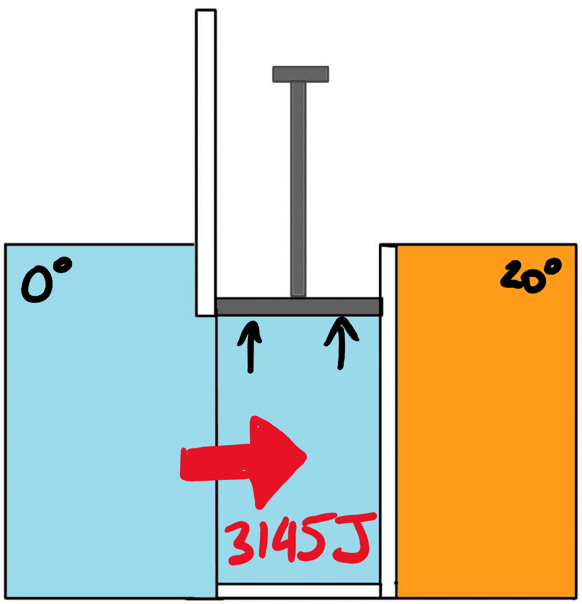




Crucial step:

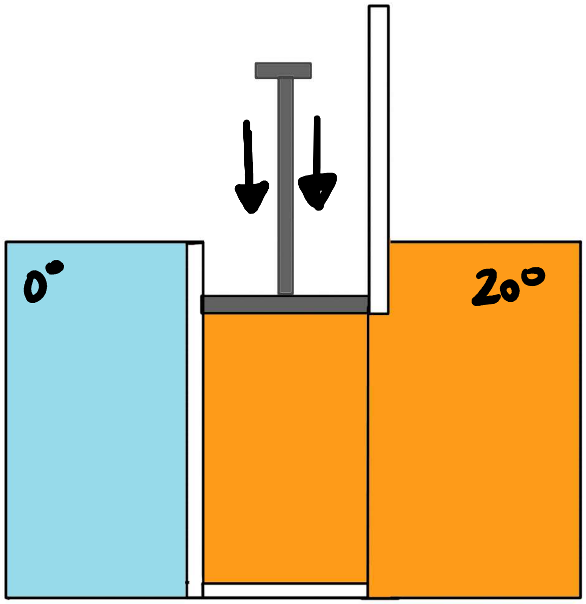
Constant temperature expansion

(1 mole, 5L → 20L)



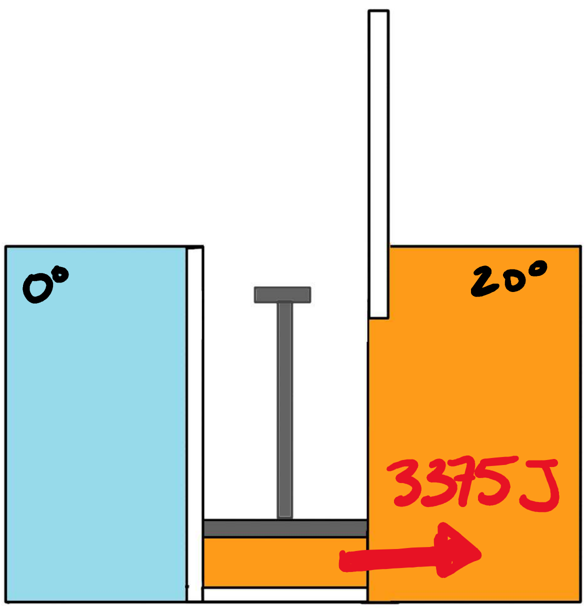
(or: Adiabatic expansion + subsequent warming)

* gas is doing work + absorbs heat to replace lost energy*

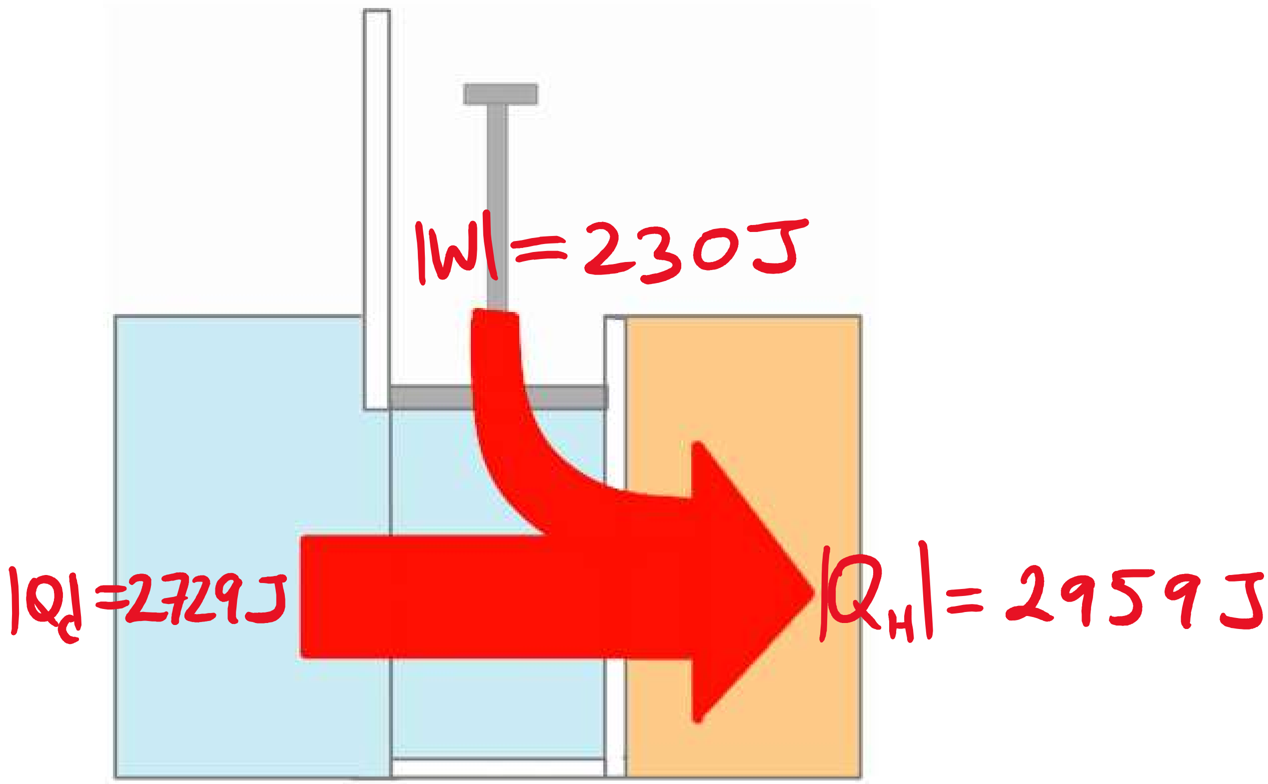


Later: gas compressed & energy sent to hot reservoir.

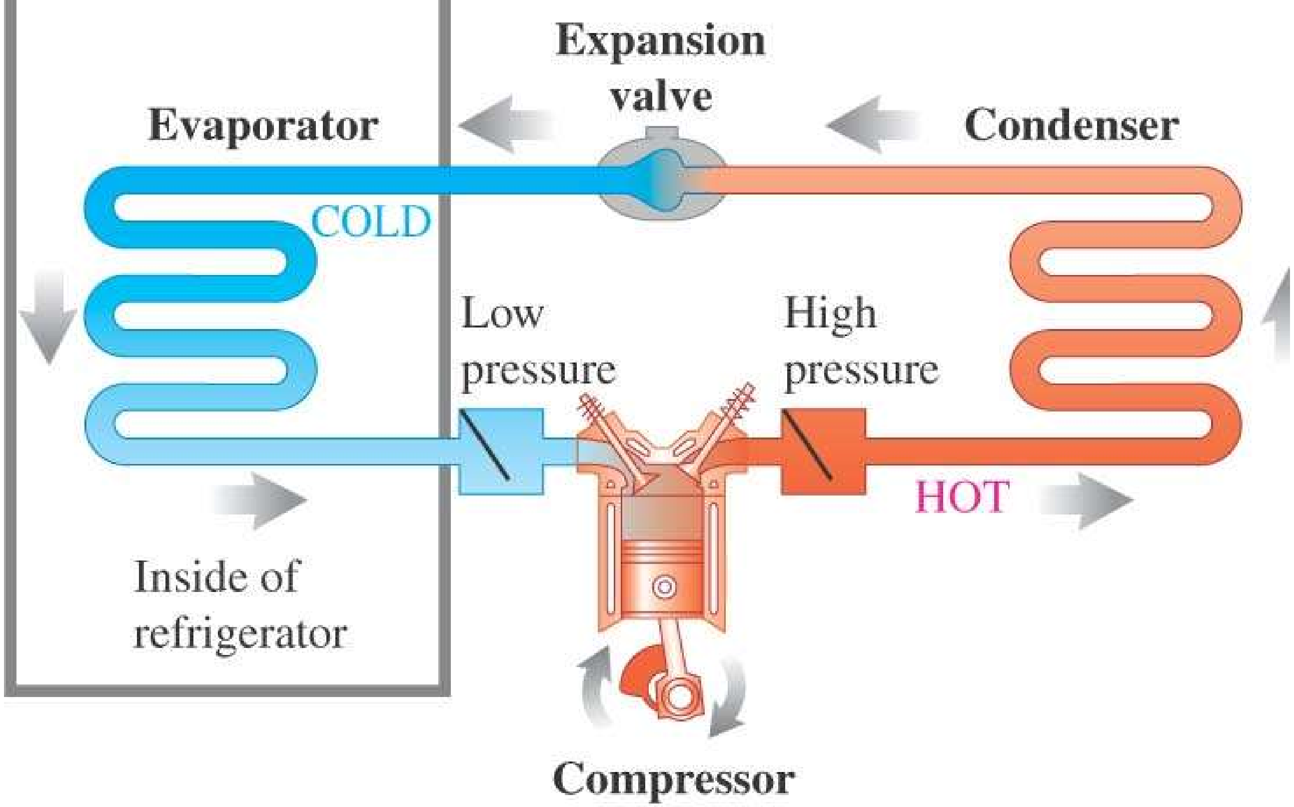
(or: adiabatic compression followed by heat flow)



Net result of cycle:



(a) Typical home refrigerator:



It’s a hot day and your house doesn’t have air conditioning. Your friend Sam suggests leaving the refrigerator door open in order to cool down the kitchen. What is an appropriate response here?

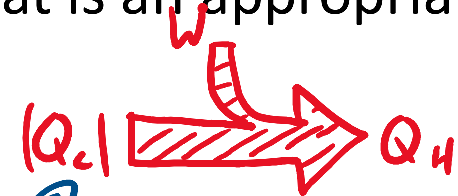
A) That’s a great idea, let’s do it!

B) Yes it will cool down the kitchen, but it’s a total waste of energy.

C) That won’t have any effect at all on the temperature of the room, but the food will go bad.

D) Hey Sam, that’s great that you’re thinking creatively, but it will actually make the room warmer than leaving the fridge door closed.

It's a hot day and your house doesn't have air conditioning. Your friend Sam suggests leaving the refrigerator door open in order to cool down the kitchen. What is an appropriate response here?



expelled heat = heat taken + work done

- energy to do work comes from power we supply
- overall, we're converting electrical energy to heat.
- compressor runs more often when door is open.

A) That's a great idea, let's do it!

B) Yes it will cool down the kitchen, but it's a total waste of energy.

C) That won't have any effect at all on the temperature of the room, but the food will go bad.

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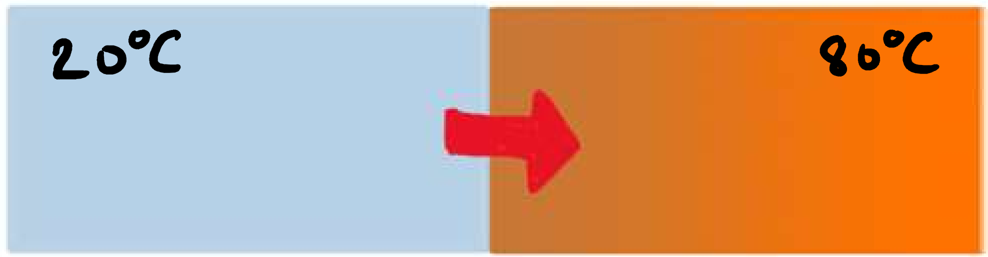
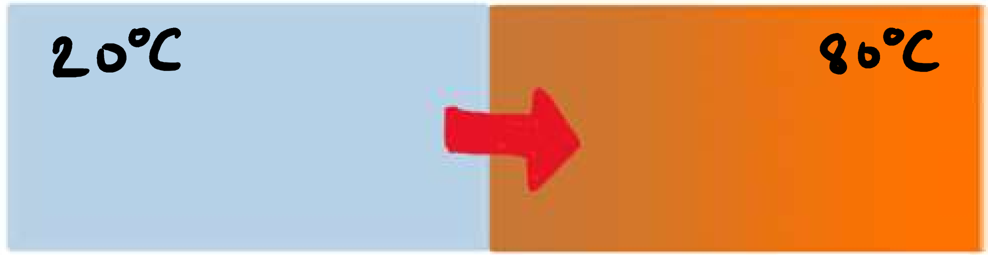


A flow of heat from a cold object to a hot object (without any associated work) would violate conservation of energy.

A) True

B) False



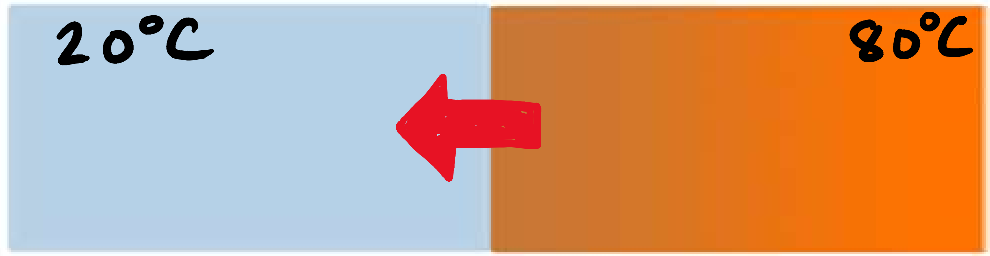
A flow of heat from a cold object to a hot object (without any associated work) would violate conservation of energy.

A) True

B) False

If we moved 100 J from the cold object to the hot object, total energy would be conserved. The cold object would get colder & the hot object would get hotter.

BUT this never happens spontaneously



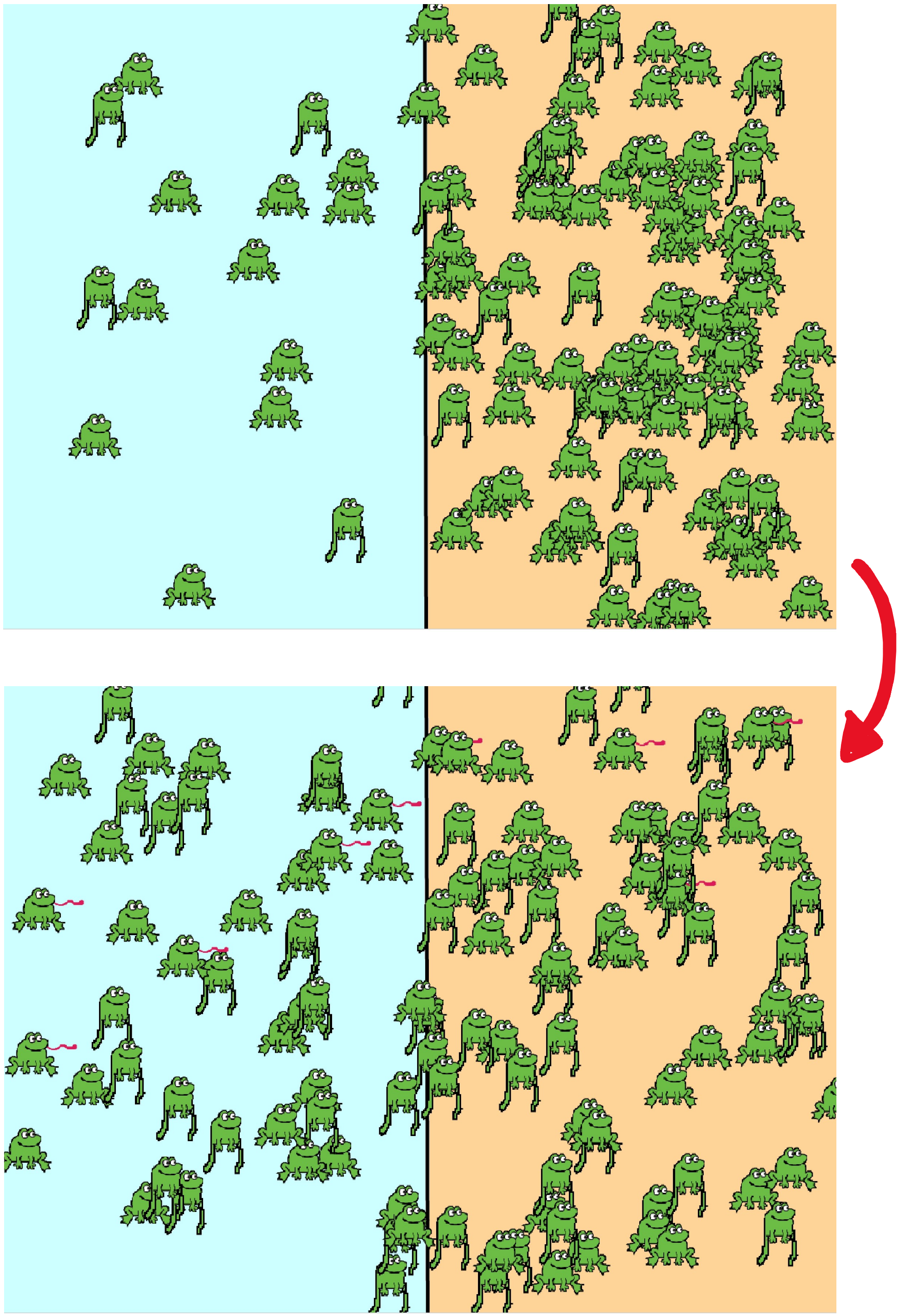
Discussion Question:

Why does heat always flow from hot objects to colder objects?

Demo!

https://youtu.be/-Ddigbvwpk8

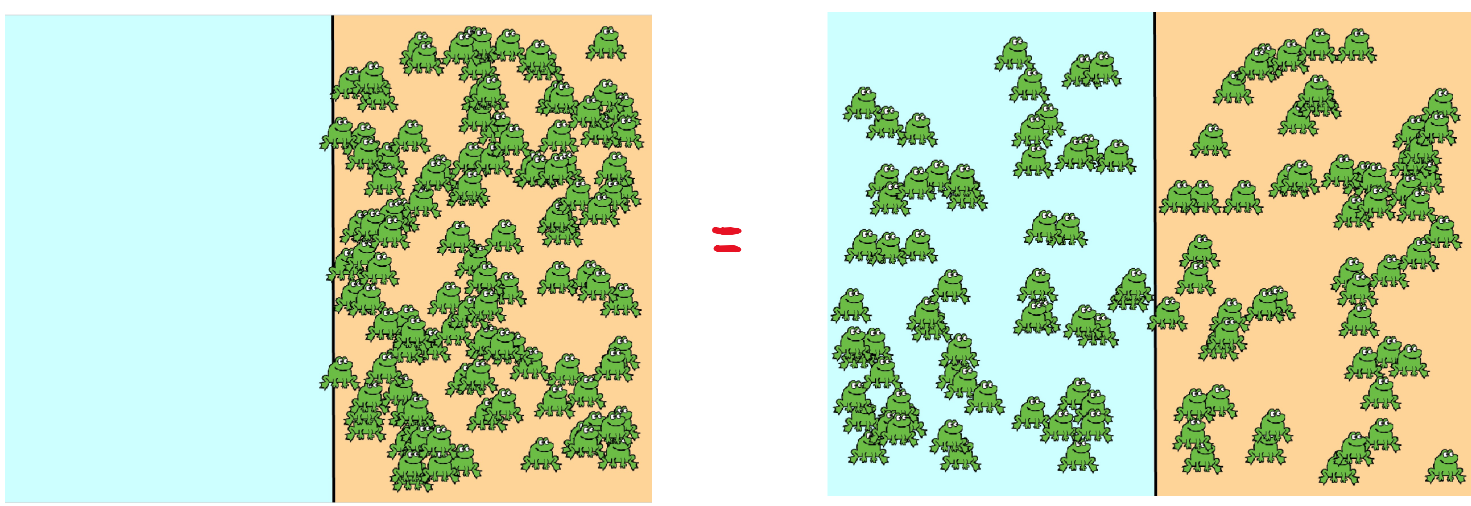
Let's use an analogy:



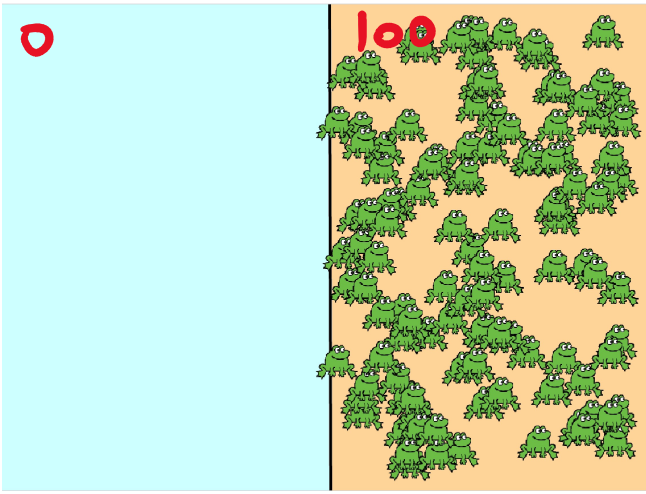
If the frogs move around randomly, why is there always a net movement of frogs from an area of high average frog density to an area of low average frog density?

As time passes, we move between possible configurations of frogs.

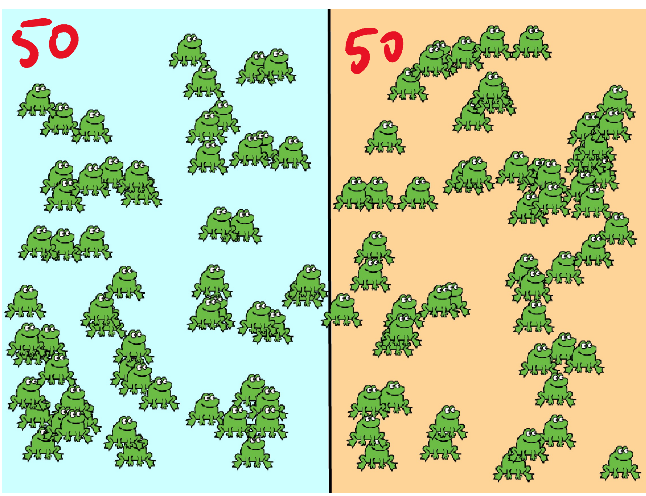
All specific configurations are equally likely



BUT...



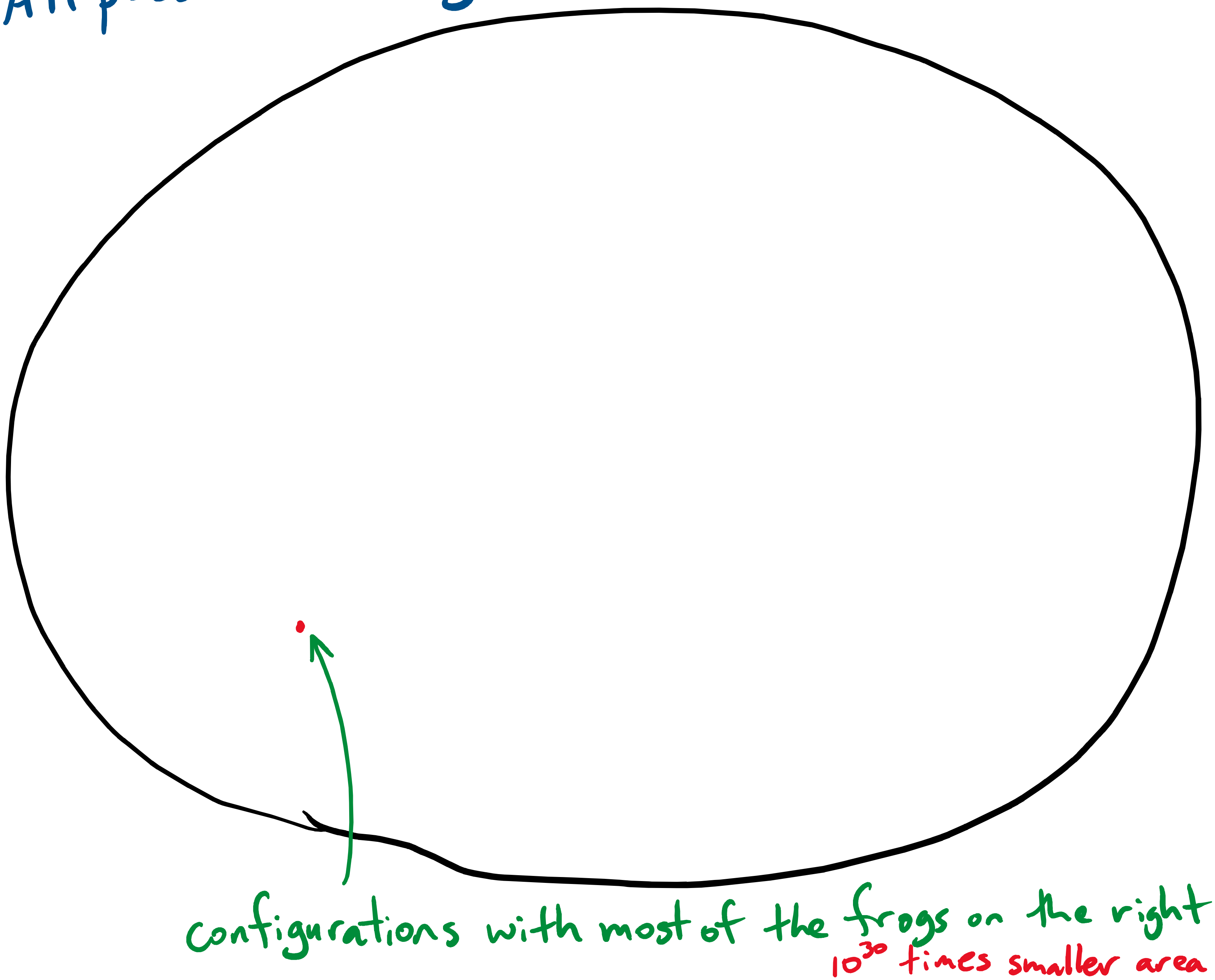
10^{500} configurations like this

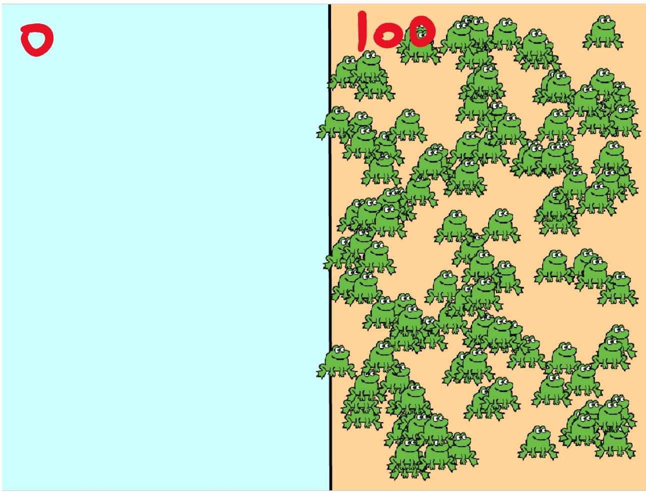


10^{530} configurations like this

(10^5 possible pixel locations for each frog)

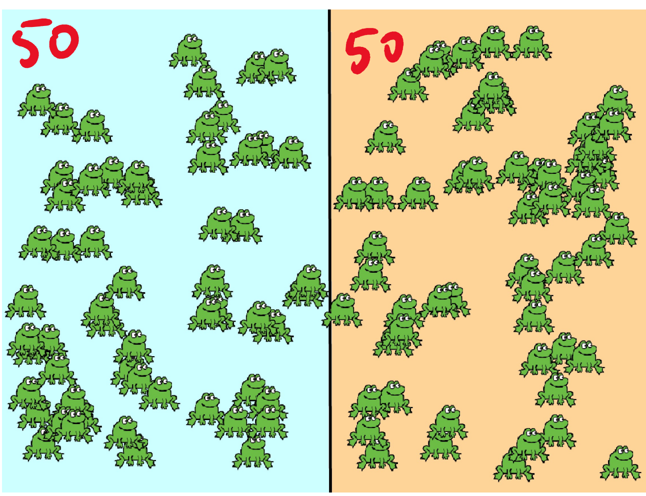
All possible configurations of frogs:

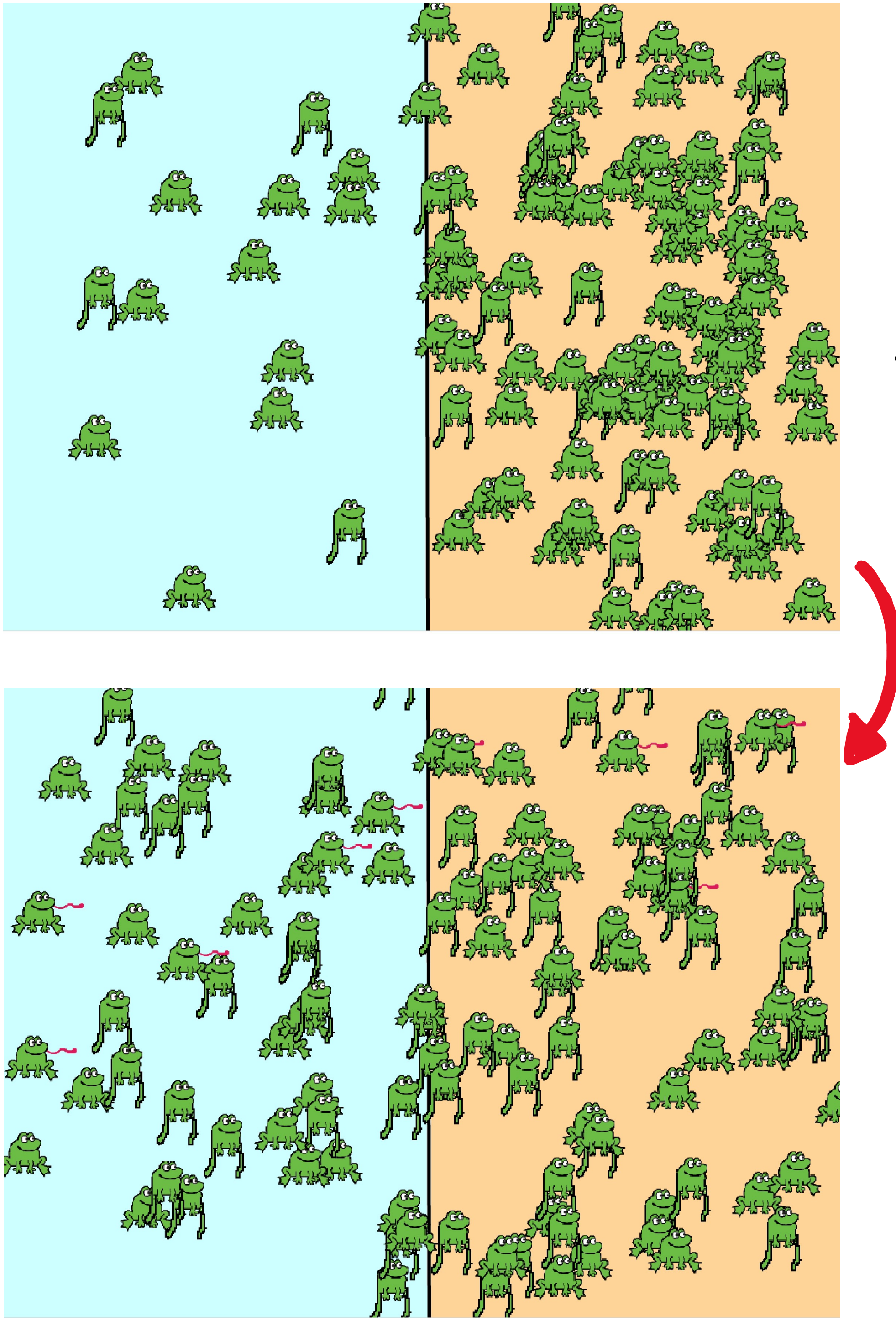




If we start here

After a while, we are 10^{30} times more likely to end up in a (50,50) configuration than a (0,100) configuration.





If the frogs move around randomly, why is there always a net movement of frogs from an area of high average frog density to an area of low average frog density?

* all configurations of frogs are possible *

* vastly more configurations with a more balanc d number of frogs *

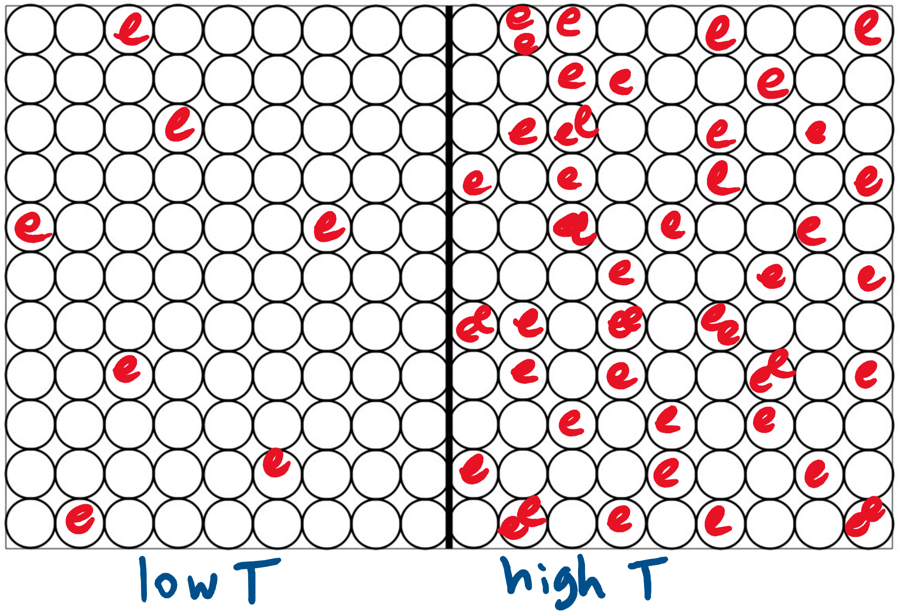
* almost certain to end up with a more balanced number than a less balanced number *

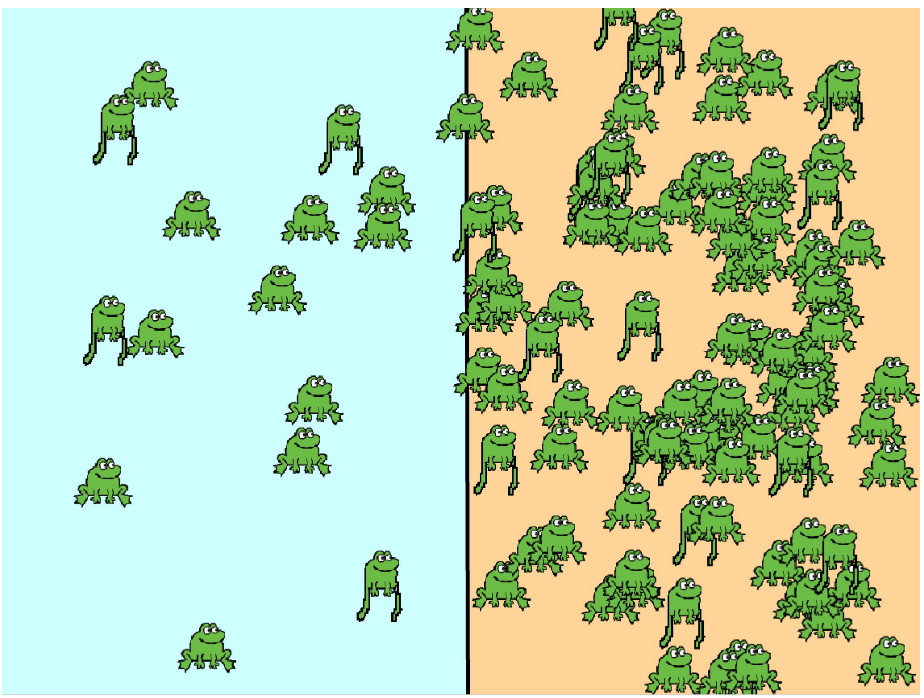
In the analogy with a thermodynamic system, the individual frogs represent

A) Molecules

B) Units of energy

C) Temperature





Analogy:

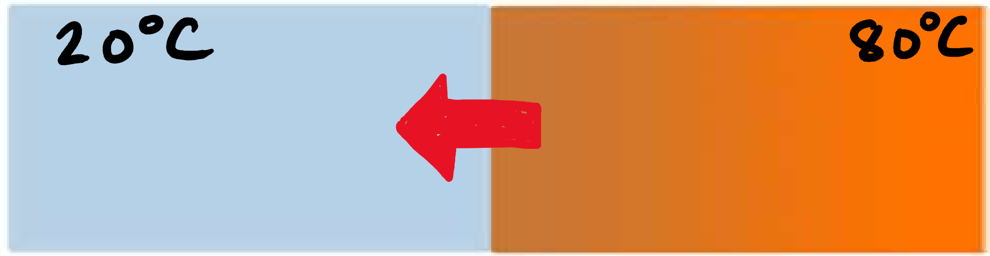
Frogs = energy

Conserved + move randomly

density of frogs = temperature

↑ proportional to energy per molecule

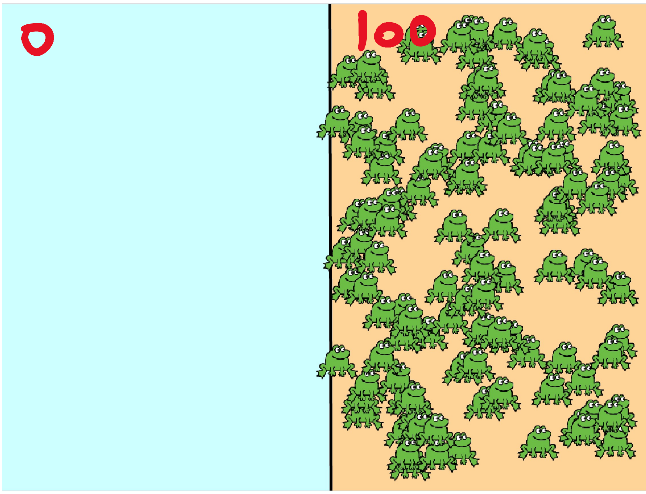
energy ~ total # frogs



temperature ~ density of frogs.

* Energy is exchanged between nearby molecules via random processes (like hopping frog) *
* vastly more configurations where energy is distributed more evenly between 2 sides *
* heat will almost certainly flow from higher temp. side to lower temp. side *

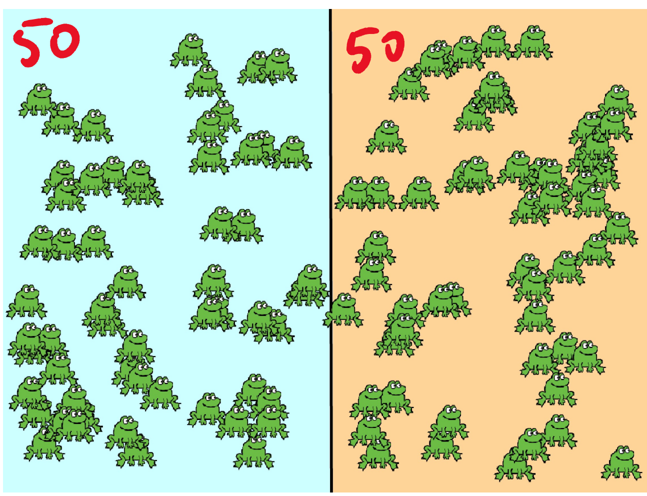
Quantitatively:



frog distribution : (0, 100)

~ 10^{500} such configurations

(10^5 possible pixel locations for each frog)



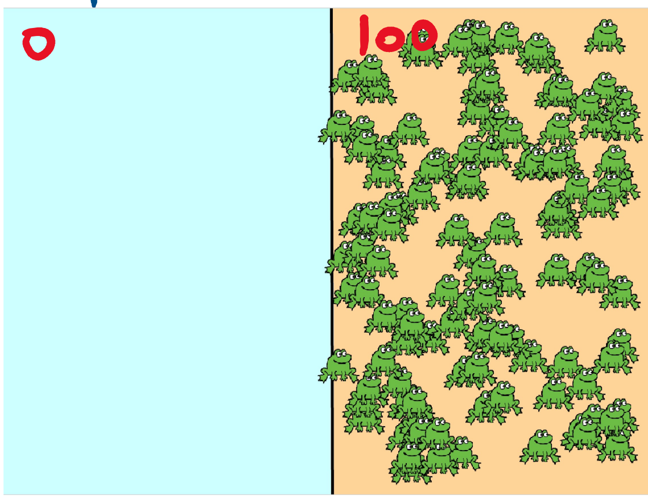
frog distribution: (50, 50)

~ 10^{530} configurations

after a long time, a (50,50) distribution is
1,000,000,000,000,000,000,000,000,000,000 times more likely

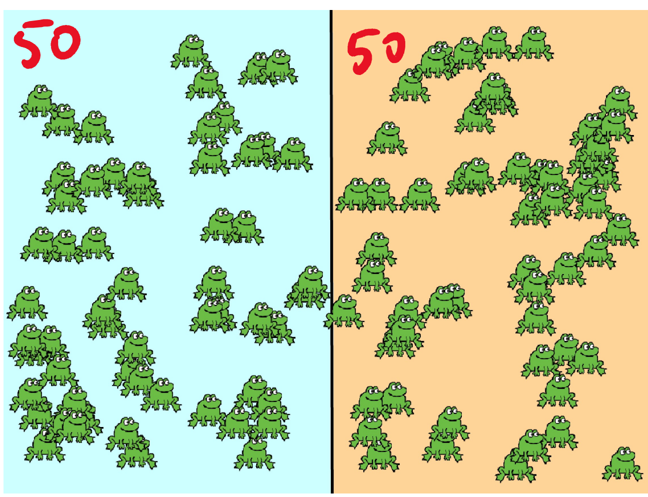
ENTROPY is a measure of how many possible microscopic configurations there are for a specified set of macroscopic variables

e.g.:



$\sim 10^{500}$ such configurations

entropy is $\log(N) \sim 500$



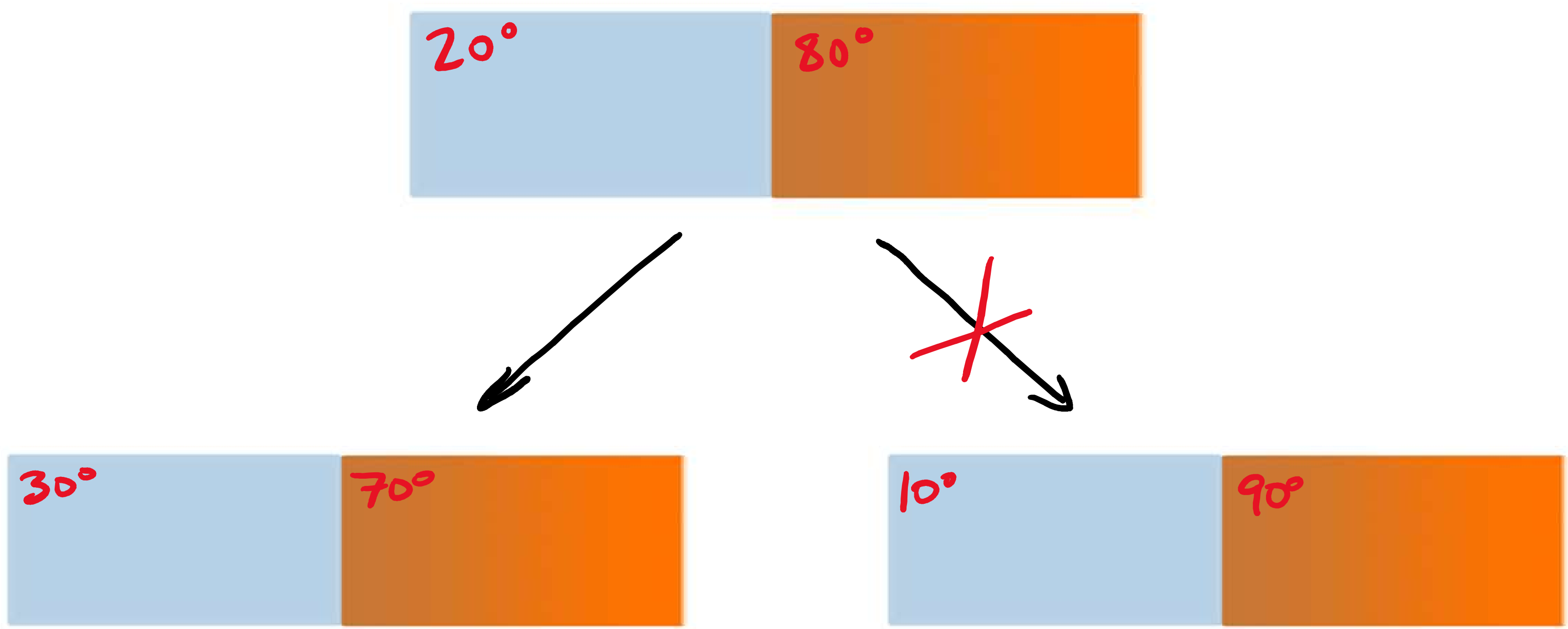
$\sim 10^{530}$ configurations

entropy is $\log(N) \sim 530$

2ND LAW OF THERMODYNAMICS:

Total entropy never decreases.

→ probability of decrease is too small to comprehend



$10^{1\,000\,000\,000\,000\,000\,000\,000}$ times more likely