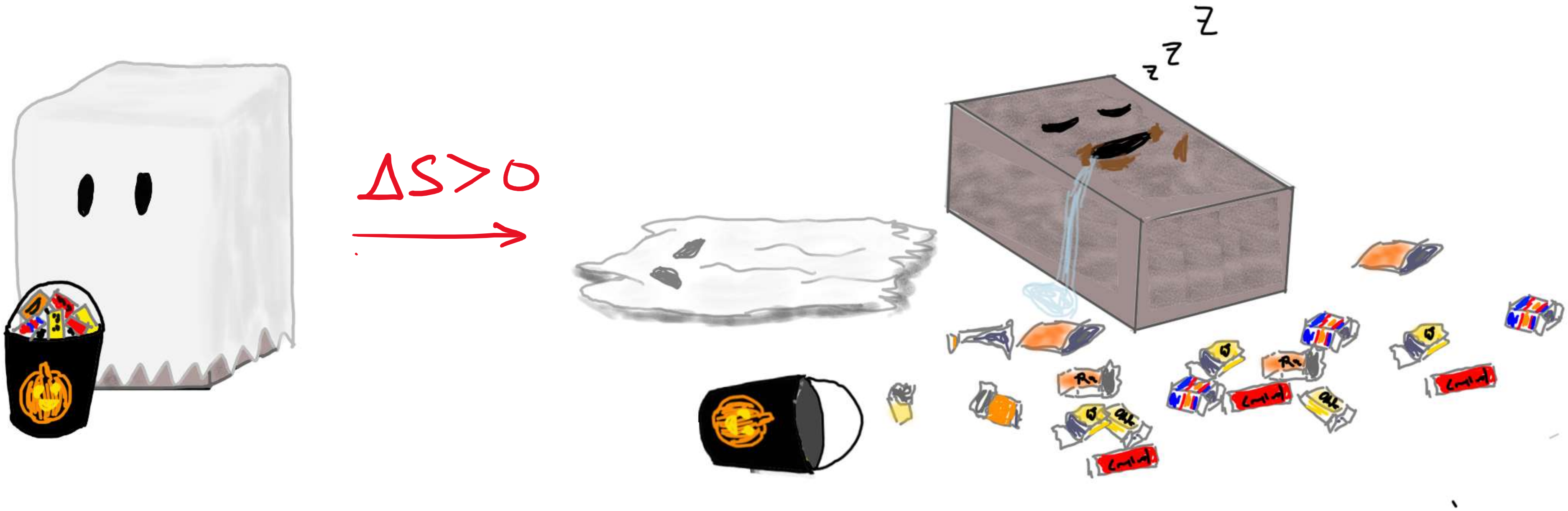
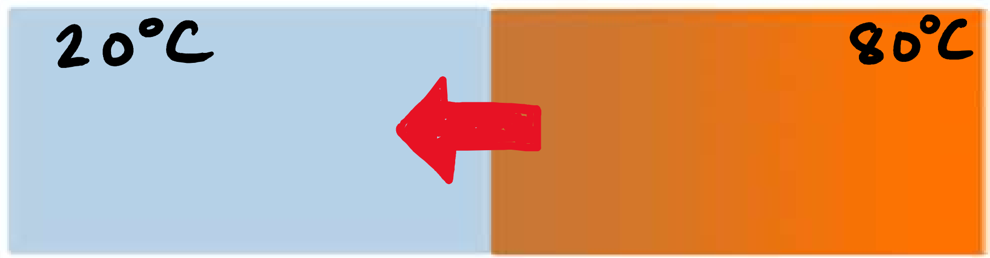
Last time in Physics 157...

(and last weekend at Mark's house)



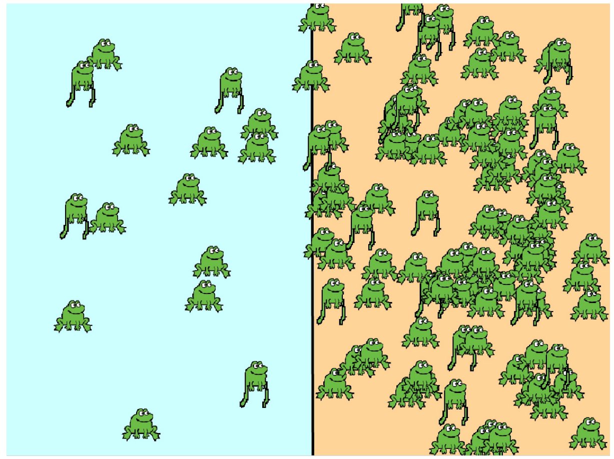


Why does heat always flow from hot objects to colder objects?

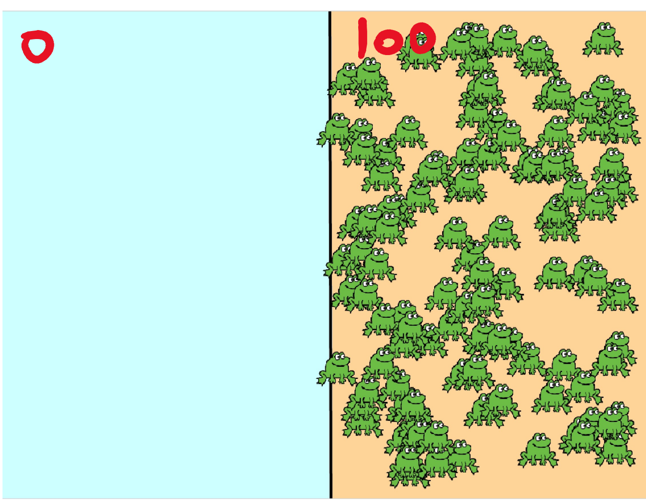
Why can’t we make a refrigerator that requires no work done?

Why can’t we make an engine that converts heat completely into work?

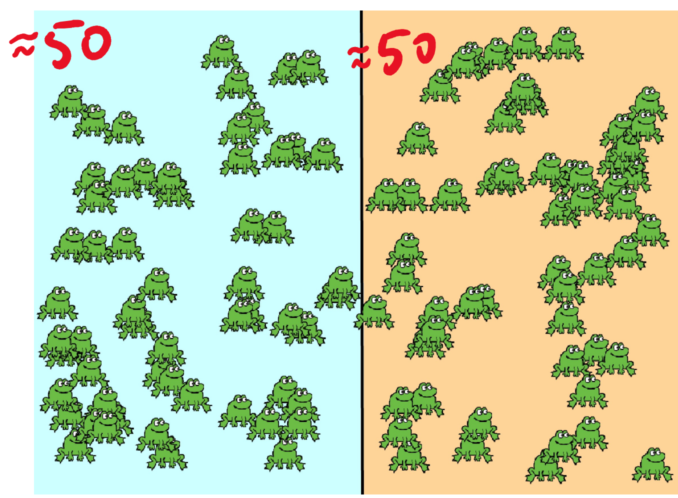
If we start here and wait ....



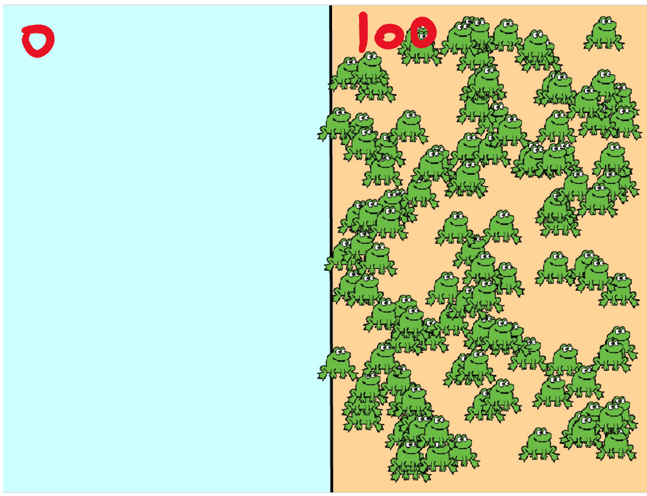
we never see this



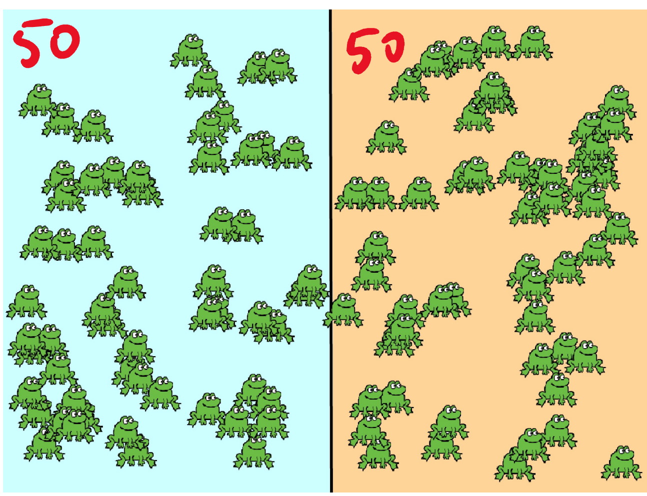
we always move toward a configuration like this:



Why?



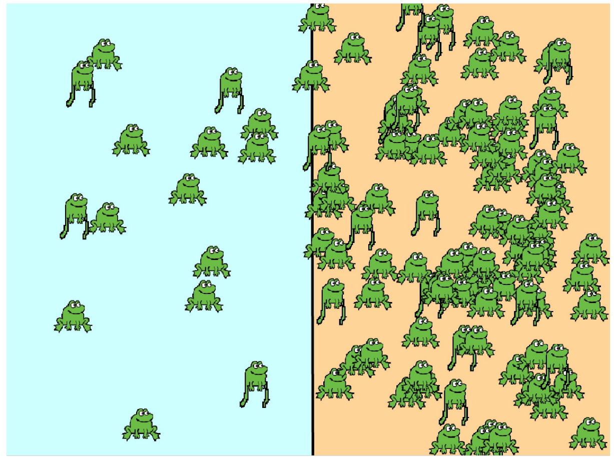
10^{500} configurations like this



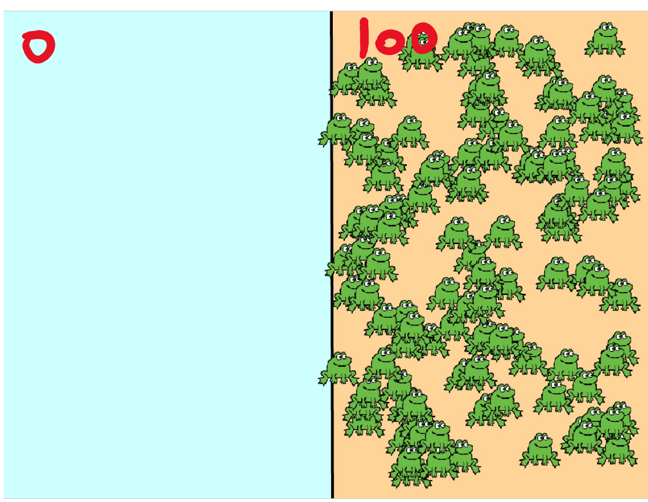
10^{530} configurations like this

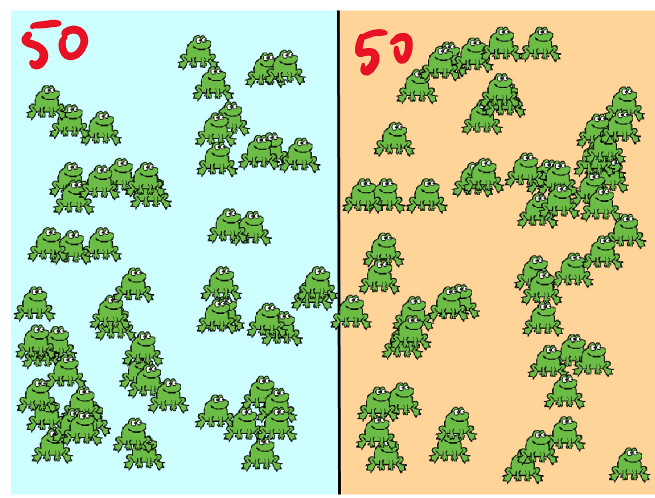
(10^5 possible pixel locations for each frog)

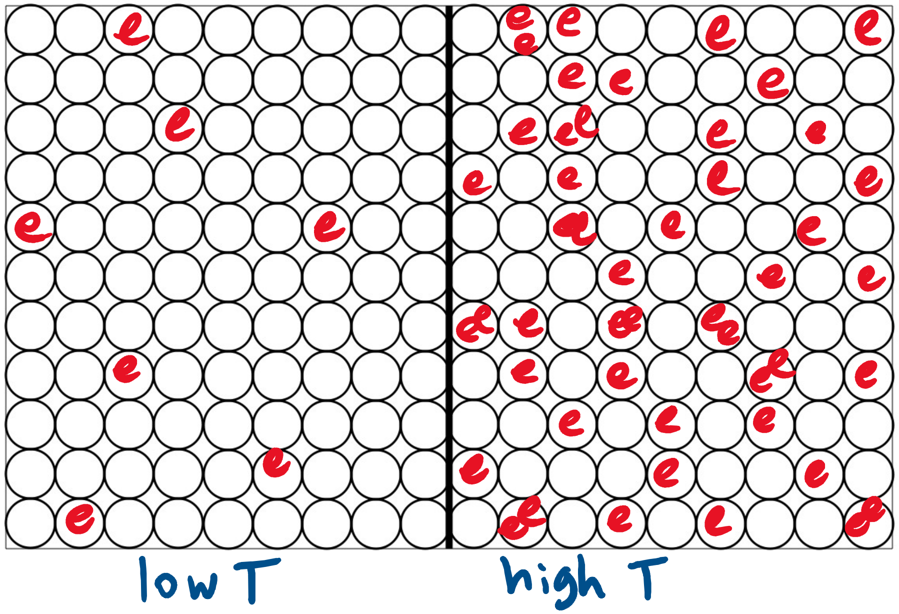
If we start here and wait ....

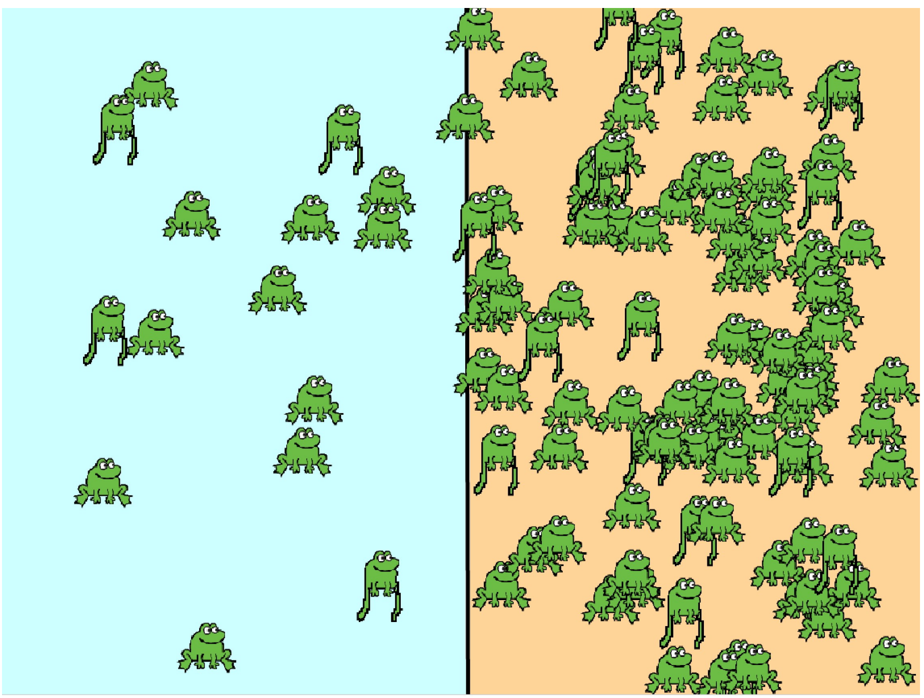


10^{30} times more likely to end up in configuration like this:









Analogy:

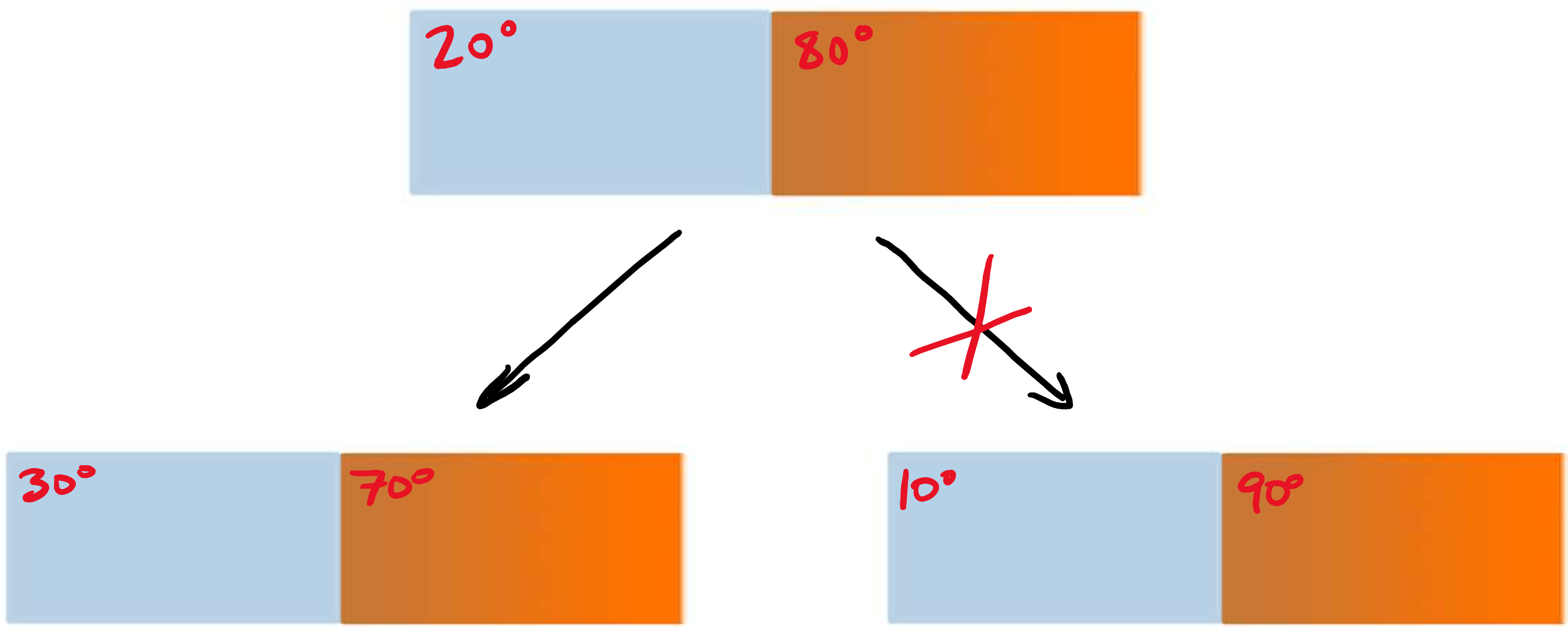
Frogs = energy

Conserved + move randomly

density of frogs = temperature

proportional to energy per molecule

If we start here:



$10^{1000\,000\,000\,000\,000\,000\,000000}$

times more likely to end up here.

Define ENTROPY of a macroscopic configuration

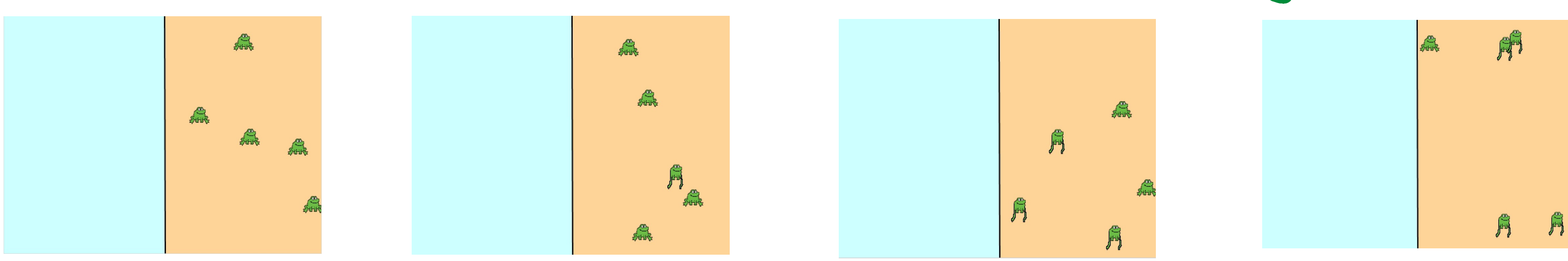
e.g. (30, 70) distribution of frogs

e.g.2: gas with pressure P, volume V, temperature T

$$S = \text{const} \times \log[N]$$

number of microscopic configurations of this type

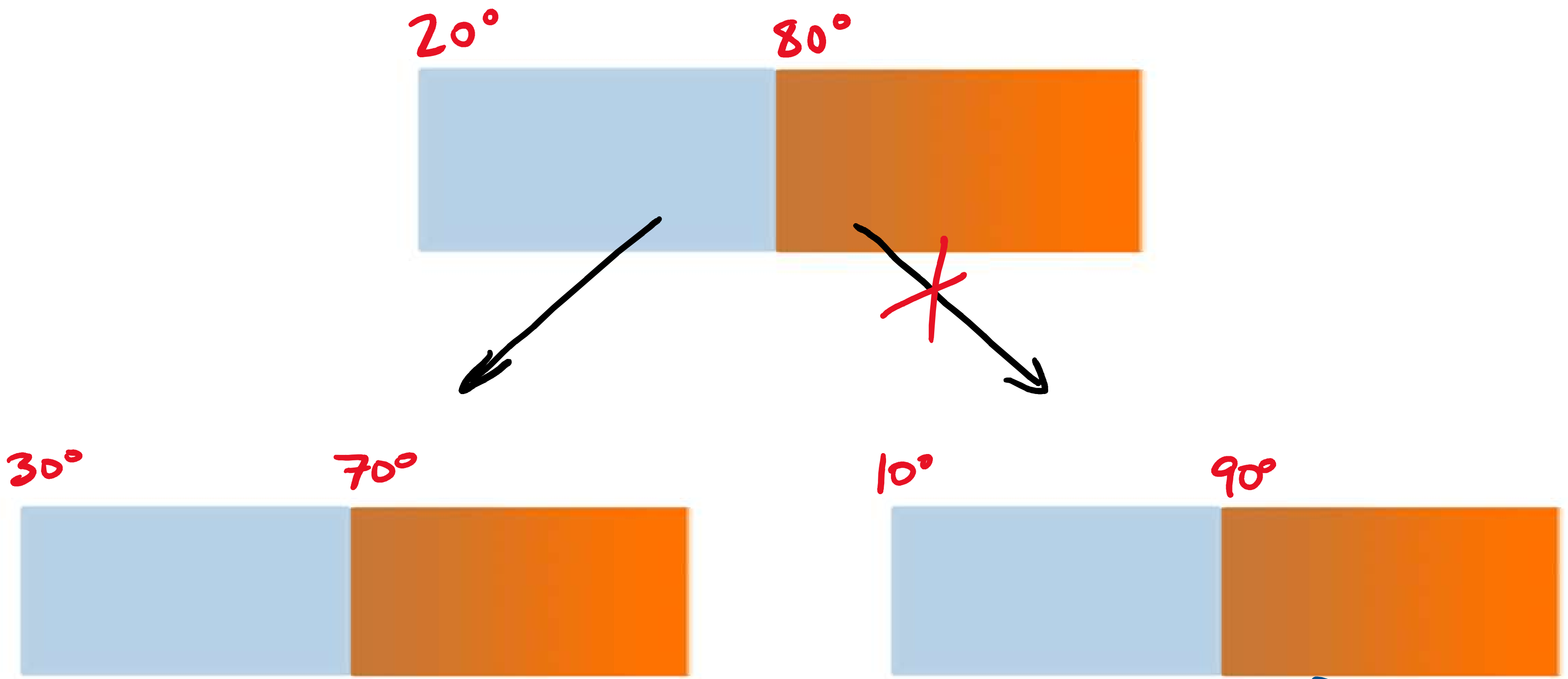
examples of (0,5) frog configurations:



2ND LAW OF THERMODYNAMICS:

Total entropy never decreases.

↳ probability of decrease is unimaginably small

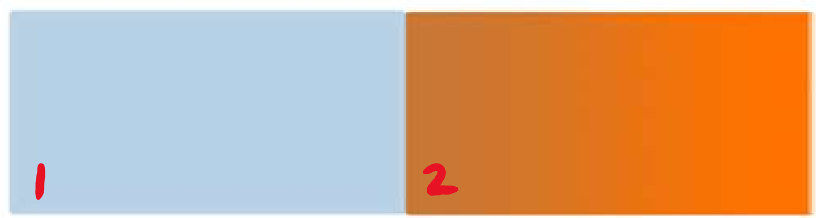


higher entropy: far more states with these Ts.

lower entropy: far less states with these Ts.

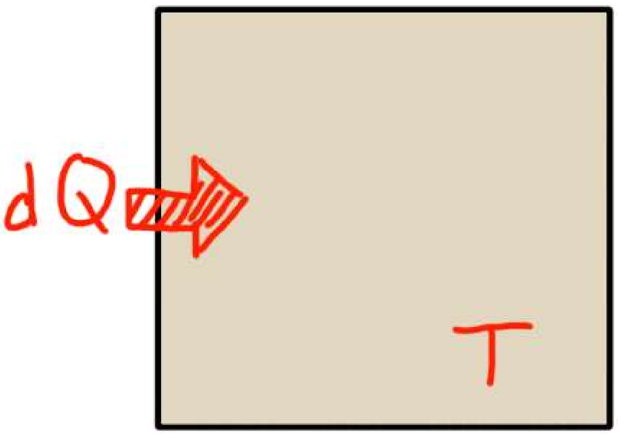
Entropy is additive (= "extensive")

$$S_{TOTAL} = S_1 + S_2$$



(because
$\log(N_1 \times N_2)$
$= \log(N_1) + \log(N_2)$)

ENTROPY: macroscopic definition



$$dS = \frac{dQ}{T}$$

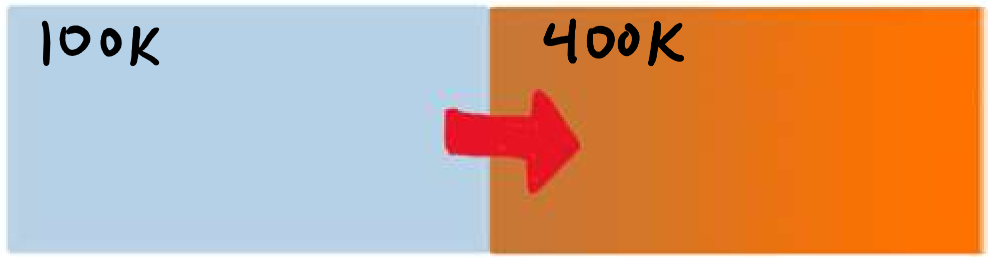
heat added

change in entropy

Amazing result:

we can prove this from the microscopic definition of S.

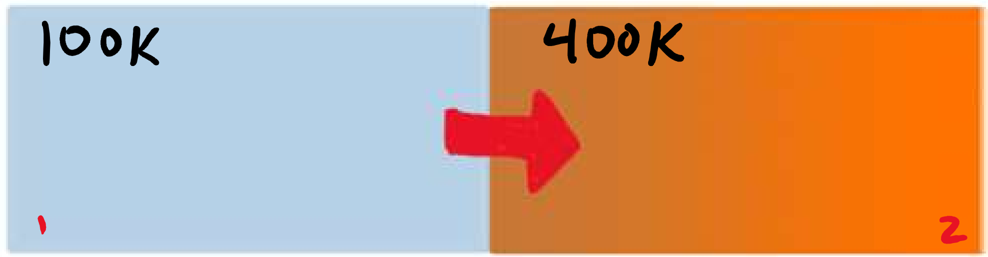
* see bonus video * https://www.youtube.com/watch?v=t7gyi8NhgYg



Suppose that we had 1J of energy flow from the cold object to the hotter object. What would be the change in entropy of the whole system?

A) -0.0125 J/K
B) -0.0075 J/K
C) 0
D) 0.0075 J/K
E) 0.0125 J/K

$$dS = \frac{dQ}{T}$$



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D) 0.0075 J/K
E) 0.0125 J/K

Have $dS = dS_1 + dS_2$

$$= \frac{dQ_1}{T_1} + \frac{dQ_2}{T_2}$$

$$= \frac{-1J}{100K} + \frac{1J}{400K}$$

$$= -0.0075 \, J/K$$

BAD

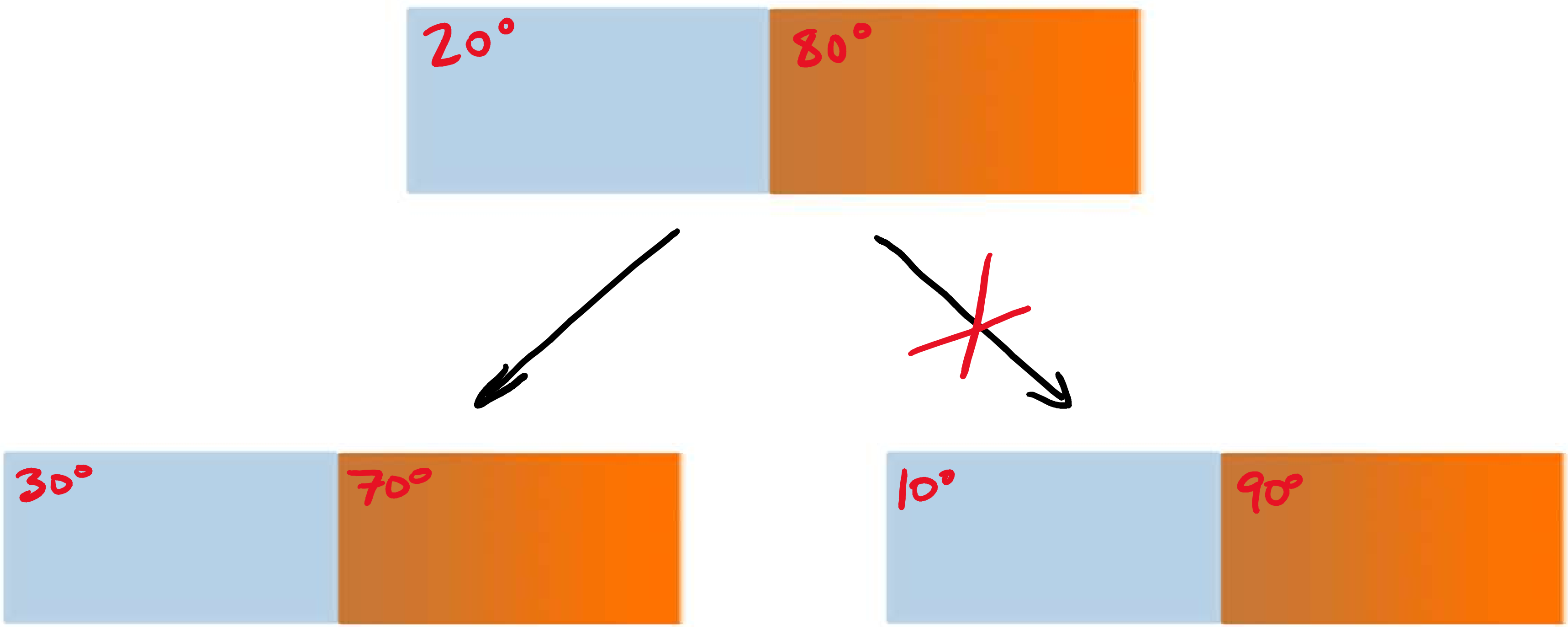
$$dS = \frac{dQ}{T}$$

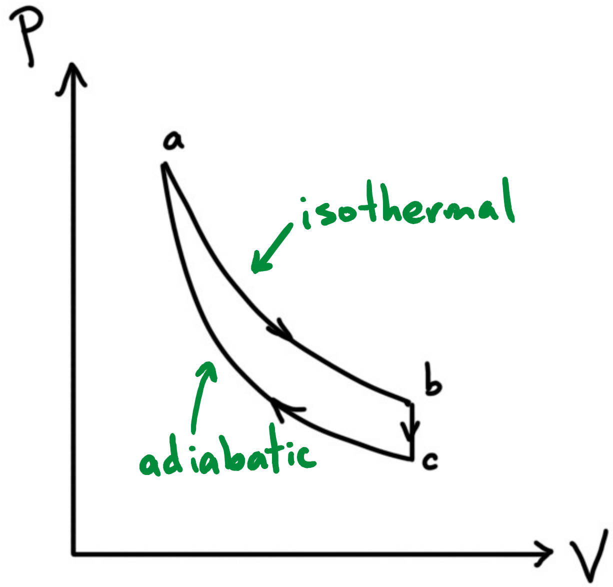
Violates 2nd Law so won't happen

2ND LAW OF THERMODYNAMICS:

Total entropy never decreases.

→ probability of decrease is too small to comprehend





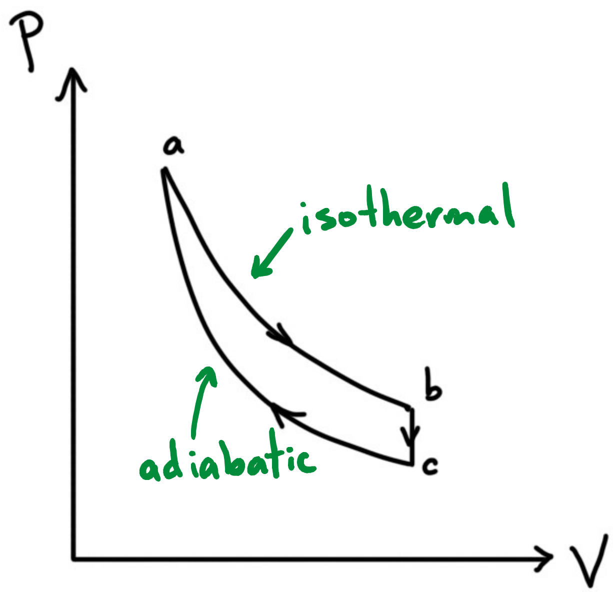
In the cycle shown, we can say that from c -> a,

A) The entropy increases

B) The entropy is constant

C) The entropy decreases

$$ds = \frac{dQ}{T}$$



In the cycle shown, we can say that from c -> a,

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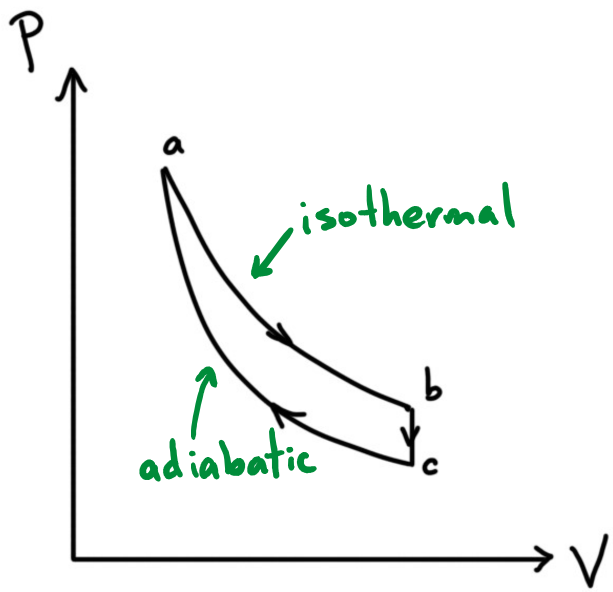
C) The entropy decreases

$c \rightarrow a$ adiabatic so $Q = 0$

$dQ = 0$ for each part so

$dS = 0$

$$dS = \frac{dQ}{T}$$



In the cycle shown, heat Q enters the gas in the isothermal step a -> b at temperature T. The entropy change during this step

A) is equal to Q/T.

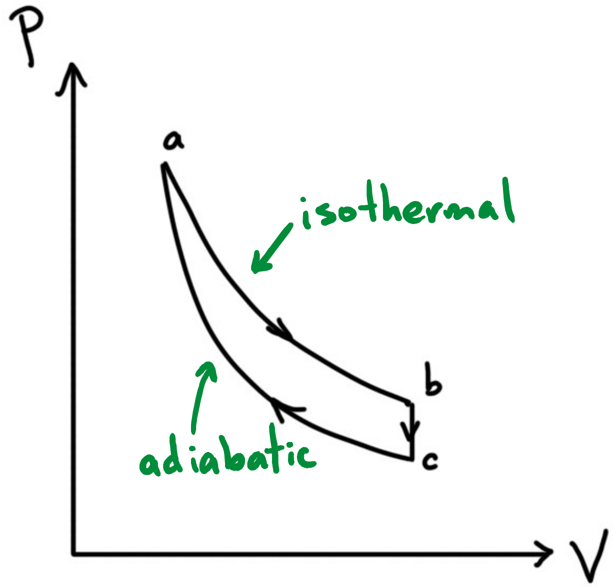
B) is equal to $Q^2/(2T)$.

C) Is equal to 0.

D) is equal to -Q/T.

E) cannot be determined from the information provided.

$dS = \frac{dQ}{T}$



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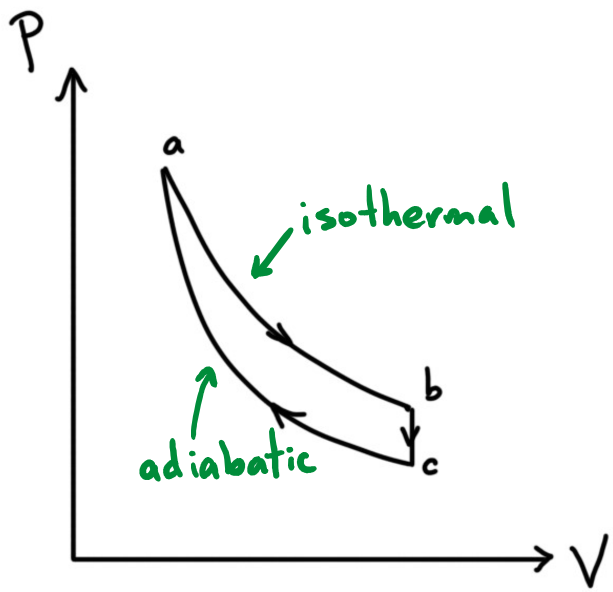
T const. so

$$\Delta S = \frac{Q}{T}$$

$$dS = \frac{dQ}{T}$$



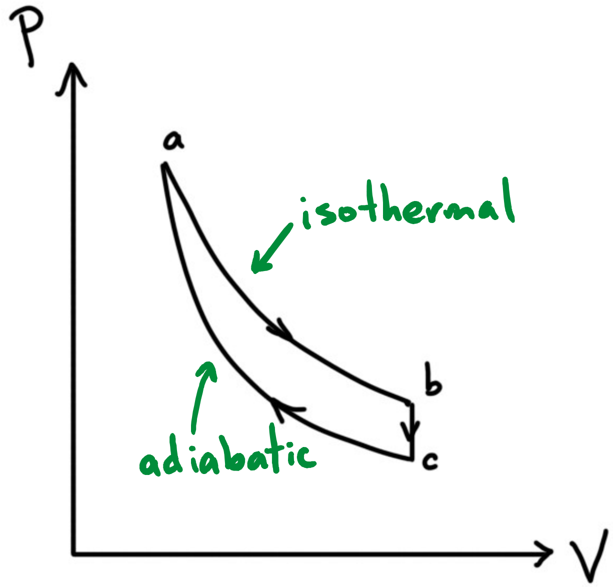
In the cycle shown, the change in entropy for the system around a complete cycle is

A) Positive

B) Zero

C) Negative

$$dS = \frac{dQ}{T}$$



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A) Positive

B) Zero

C) Negative

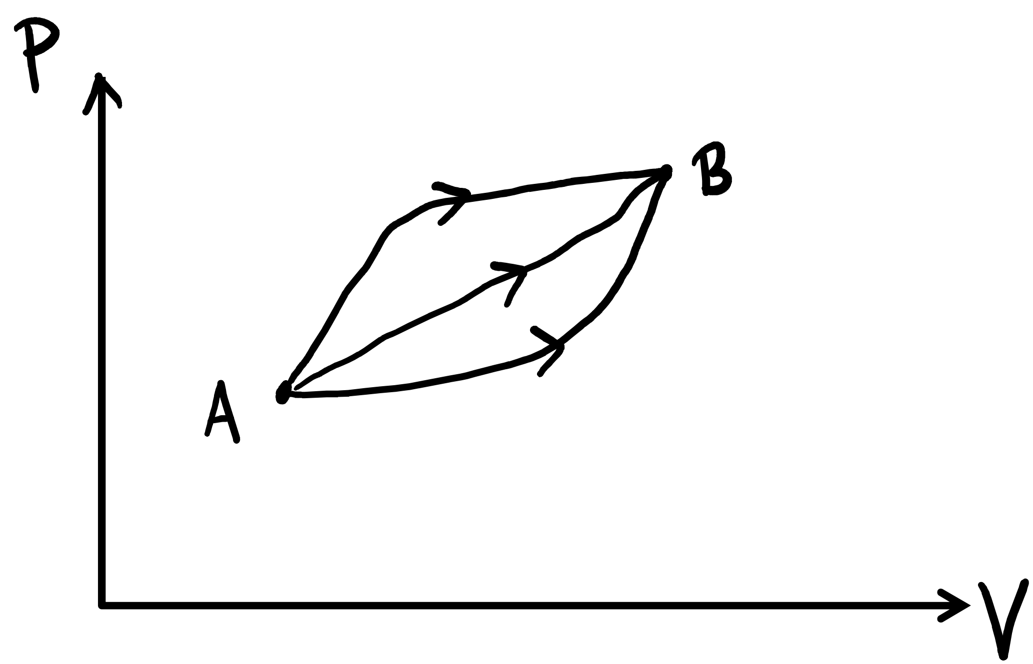
S is a state variable.

Around a whole cycle, we come back to the same state.

So $\Delta S = 0$.

$dS = \frac{dQ}{T}$

Entropy is a state variable - like P, V, T, U



ΔS same for all paths, zero for cycle.

But: S for environment usually increases!

EXTRA PROBLEM: 1 moles of ideal monatomic gas is cooled at constant volume from 300K to 200K. What is the change in entropy?

Hint: this is something like calculating work when pressure is changing.

$$dS = \frac{dQ}{T}$$

1 moles of ideal monatomic gas is cooled at constant volume from 300K to 200K. What is the change in entropy?

Hint: this is something like calculating work when pressure is changing.

Have: constant volume $\Rightarrow W = 0$

$\Rightarrow dQ = dU = n C_v \, dT$

$\Rightarrow dS = n C_v \frac{dT}{T}$ for each infinitesimal part.

Now we add the parts: $\Delta S = n C_v \int_{T_i}^{T_f} \frac{dT}{T}$

$$= n C_v \ln\left(\frac{T_f}{T_i}\right)$$

$$= \frac{3}{2} n R \ln\left(\frac{T_f}{T_i}\right)$$