Test your i>clicker! Turn it on and enter a response to the question below:

A mercury thermometer sits in a glass of water. If the thermometer reads 20ºC, we can conclude that

.

A) The temperature of the water is 20ºC.
B) The temperature of the mercury in the thermometer is 20ºC.
C) Both A and B
D) Neither A nor B

You should see a green light if everything worked.

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The thermometer reading depends on the volume of the mercury, which is determined by its temperature.

We are not told how long the thermometer has been in the water, so we don't know if it is in equilibrium with (and thus the same temp. as) the water

Office hours

I am available after each class. Also: which times would work for you?

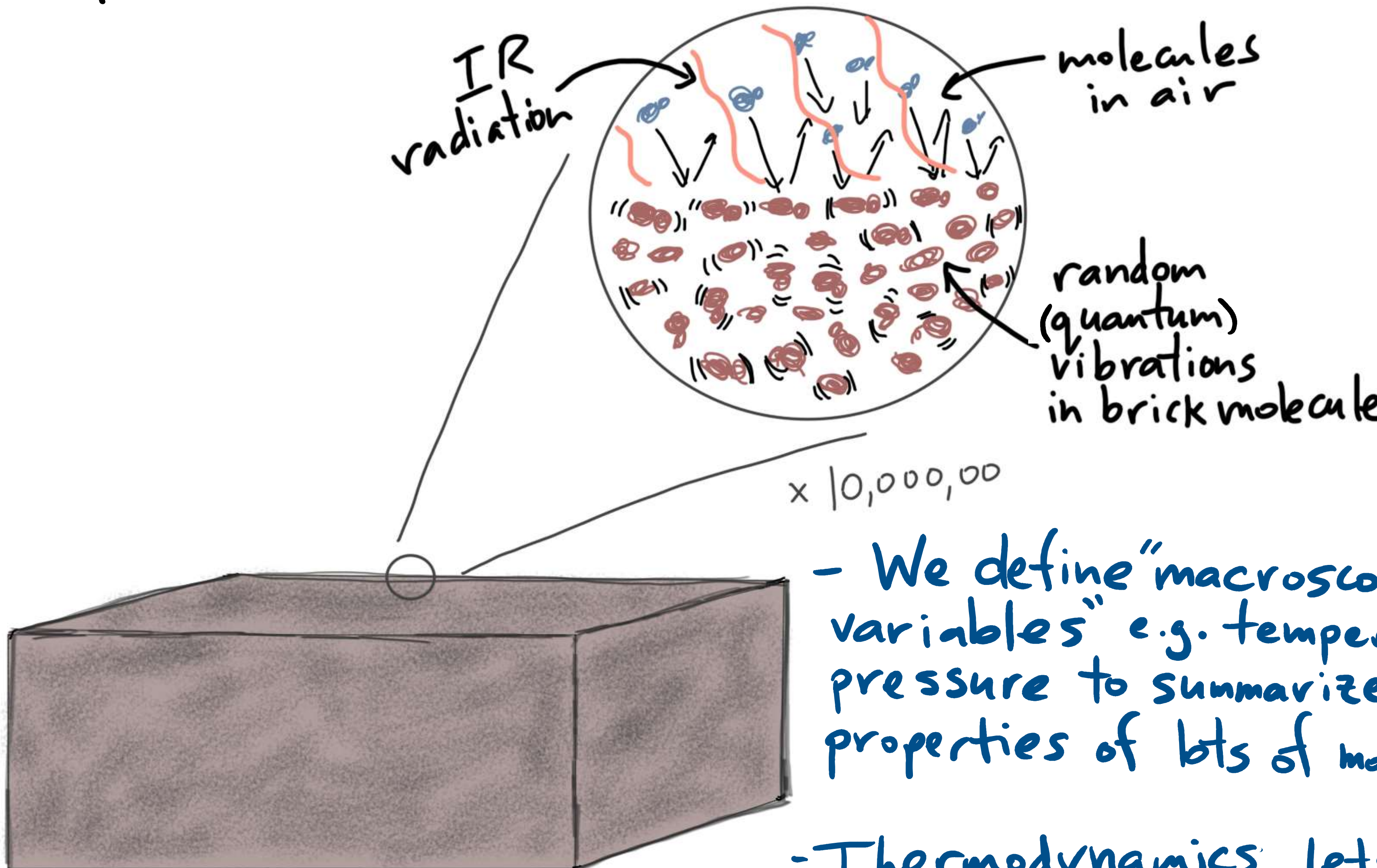
A) Monday 3-4

B) Monday 4-5

C) Both A and B

D) Neither A nor B

Thermodynamics: how to summarize microscopic physics of 10^{23}+ things.



- We define "macroscopic variables" e.g. temperature, pressure to summarize average properties of lots of molecules.

- Thermodynamics lets us understand behavior of these

Our starting point:

Conservation of Energy

ASIDE:

First understood fully by one of the greatest physicists of all time...

Emmy Noether 1882-1935

Proved "Noether's Theorem" that explains how conserved quantities are related to "symmetries" in nature

(ask me later!)

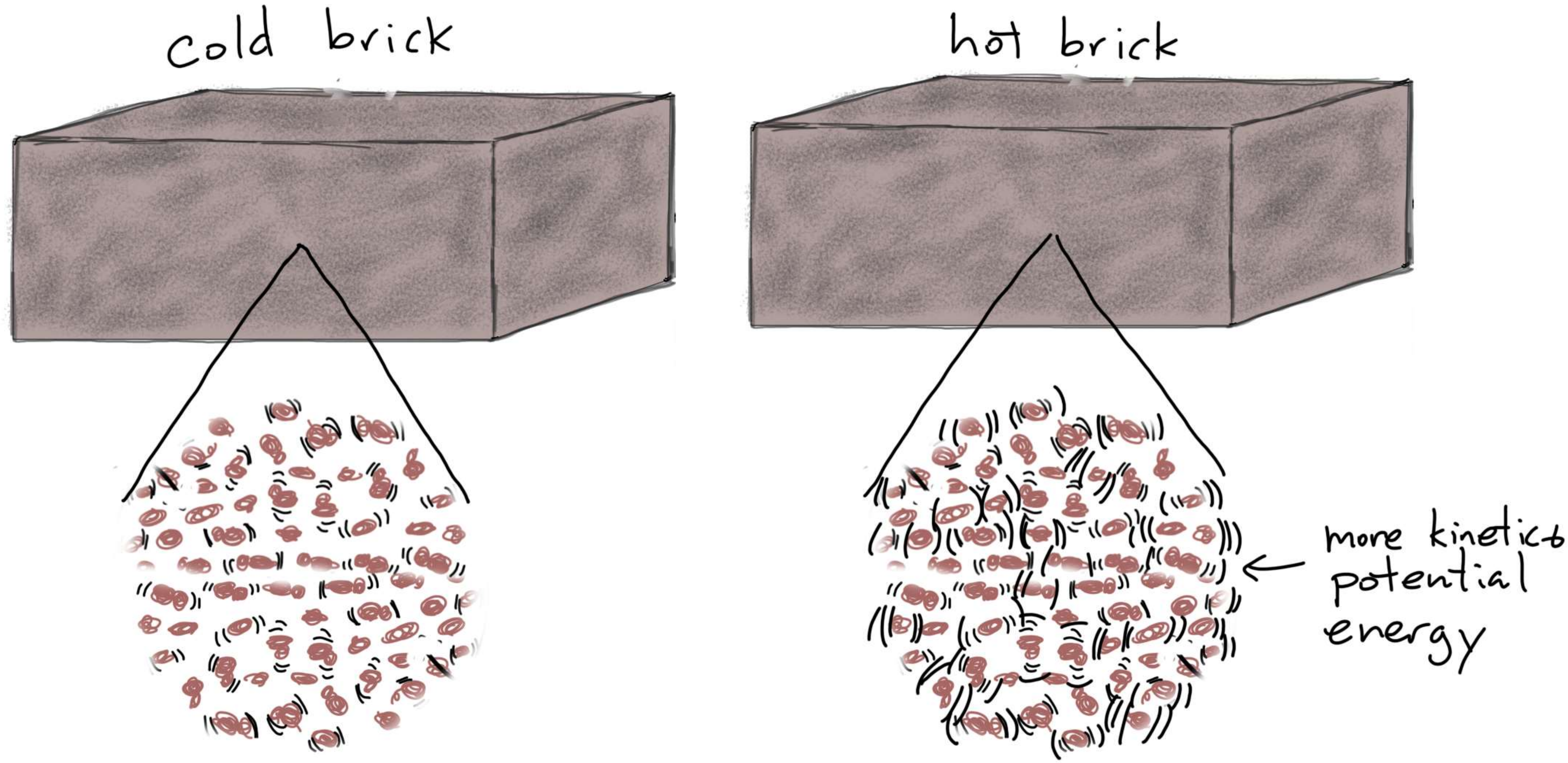
In practice:

- each part of a physical system has a certain amount of energy
- the total energy of an isolated system doesn't change with time

BUT: energy can move between different parts and take different forms

In thermodynamics we care about the microscopic kinetic & potential energy of atoms & molecules

When we heat/cool an object, we are adding/removing energy at the molecular level:



Which macroscopic properties of objects change when they are heated/cooled?

Which macroscopic properties of objects change when they are heated/cooled?

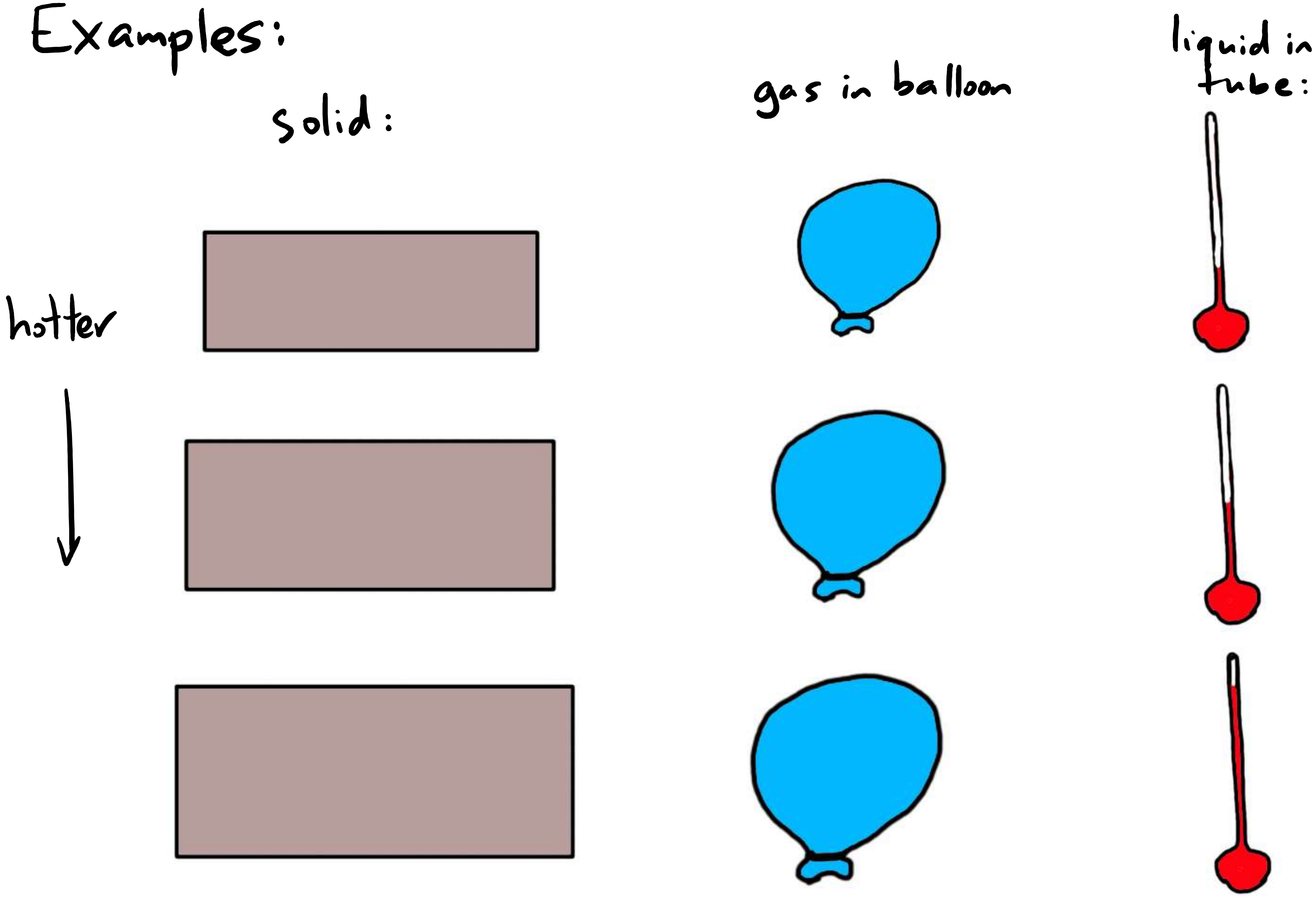
* Most of them (but often only slightly)

↓ size/volume/density

↓ amount of light/IR radiation emitted at differant frequencies

(and many others e.g. electrical conductivity)

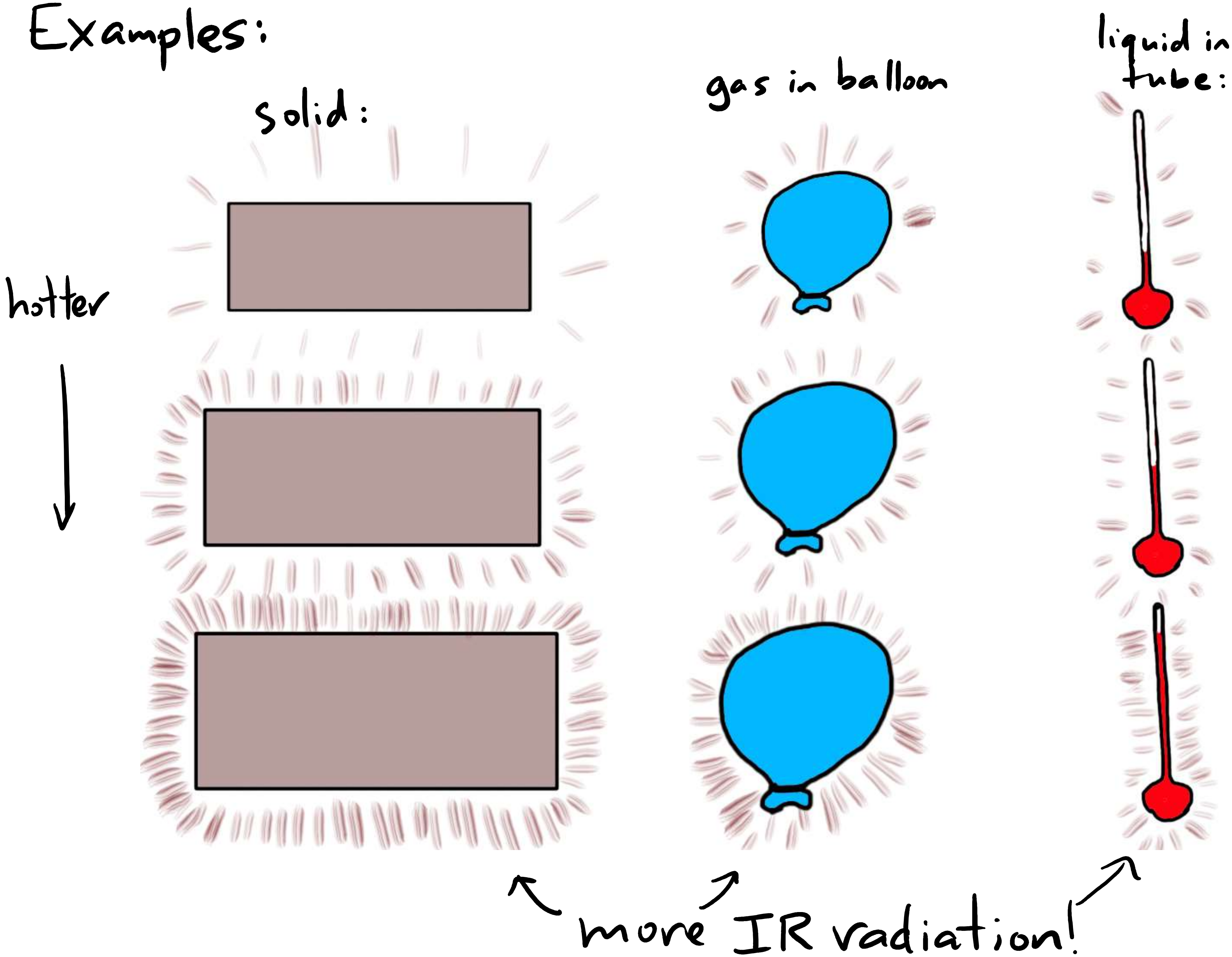
Examples:



(size changes greatly exaggerated)

★ there are exceptions! ★

Examples:

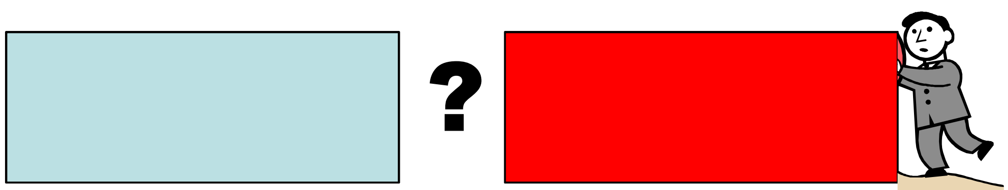


solid:
gas in balloon
liquid in tube:
hotter
more IR radiation!

Hot block + room temperature block

What happens if we put a hot block in contact with a room temperature block?

A. Nothing
B. Heat flows until they are the same temperature
C. The hot block will cool down to room temperature
D. The room temperature block will heat up to the temperature of the hot block
E. None of the above



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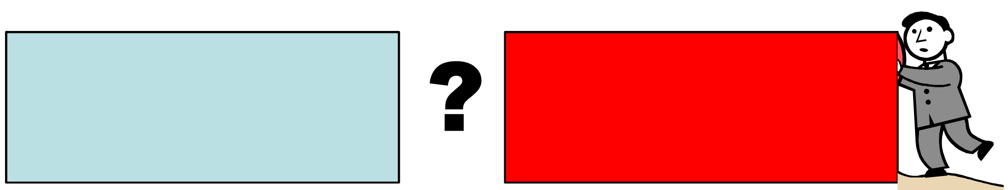
final temperature depends on how hot the hot block was



Demo: IR camera

Make a prediction:

We put together two blocks of aluminum, one heated on the hot plate and the other left in the room for a long time. We observe this on an infrared (IR) camera. It shows hotter objects as brighter.

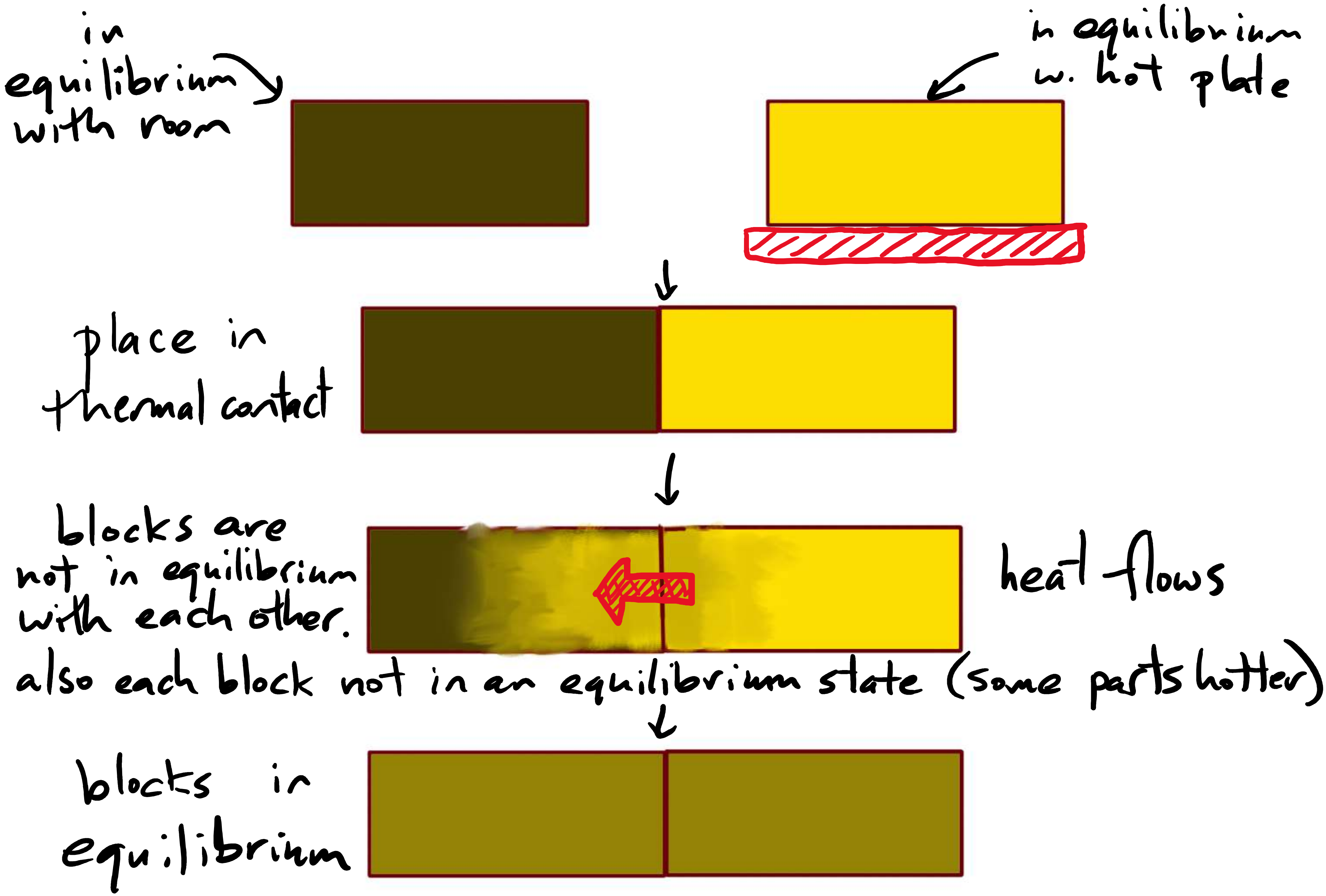
Make a sketch of what you think we will see

a) just as we bring the blocks together

b) after a short amount of time

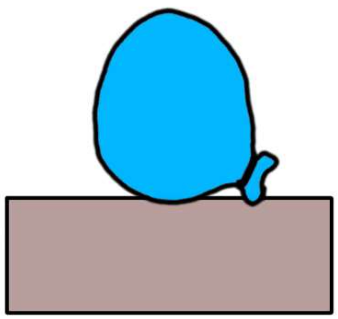
c) after a long amount of time

(shade in regions that are brighter on the IR camera)


in equilibrium with room
in equilibrium w. hot plate
place in thermal contact
blocks are not in equilibrium with each other.
heat flows
also each block not in an equilibrium state (some parts hotter)
blocks in equilibrium

If we bring two objects in contact:

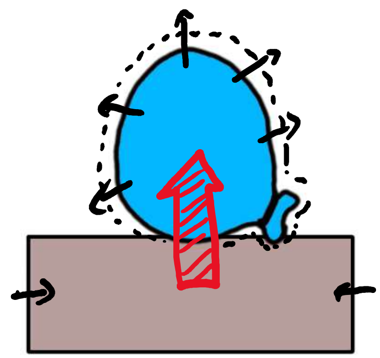
3 options:



nothing changes

we say the systems are EQUILIBRIUM

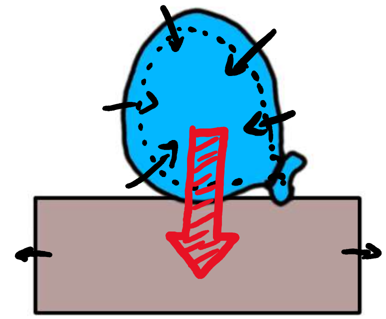
same TEMPERATURE



energy from brick→balloon

= flow of HEAT

brick has higher temperature

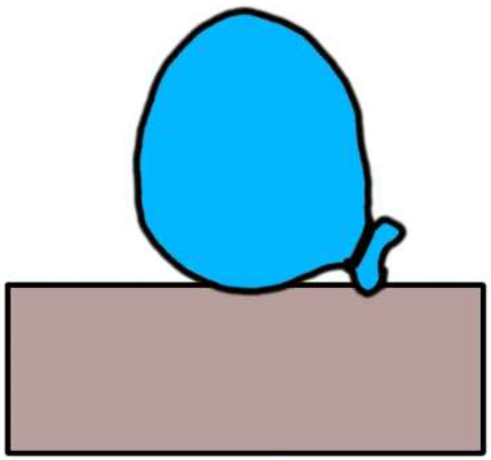


energy from balloon to brick

balloon has higher temperature

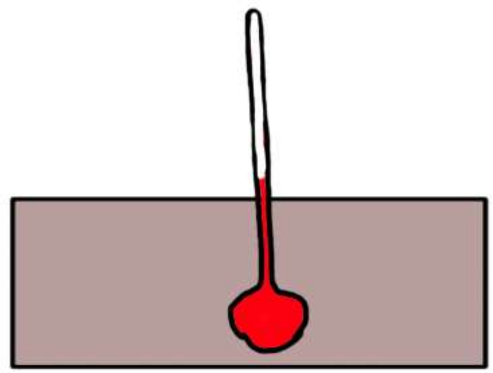
Zeroth Law of Thermodynamics:

If



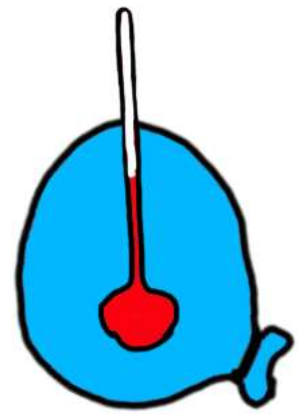
in equilibrium

and



in equilibrium

then:



in equilibrium

otherwise, temperature wouldn't make sense!

We can assign a numerical value for different temperatures by using some temperature-dependent macroscopic property of a standard object (e.g. volume of liquid in a tube)