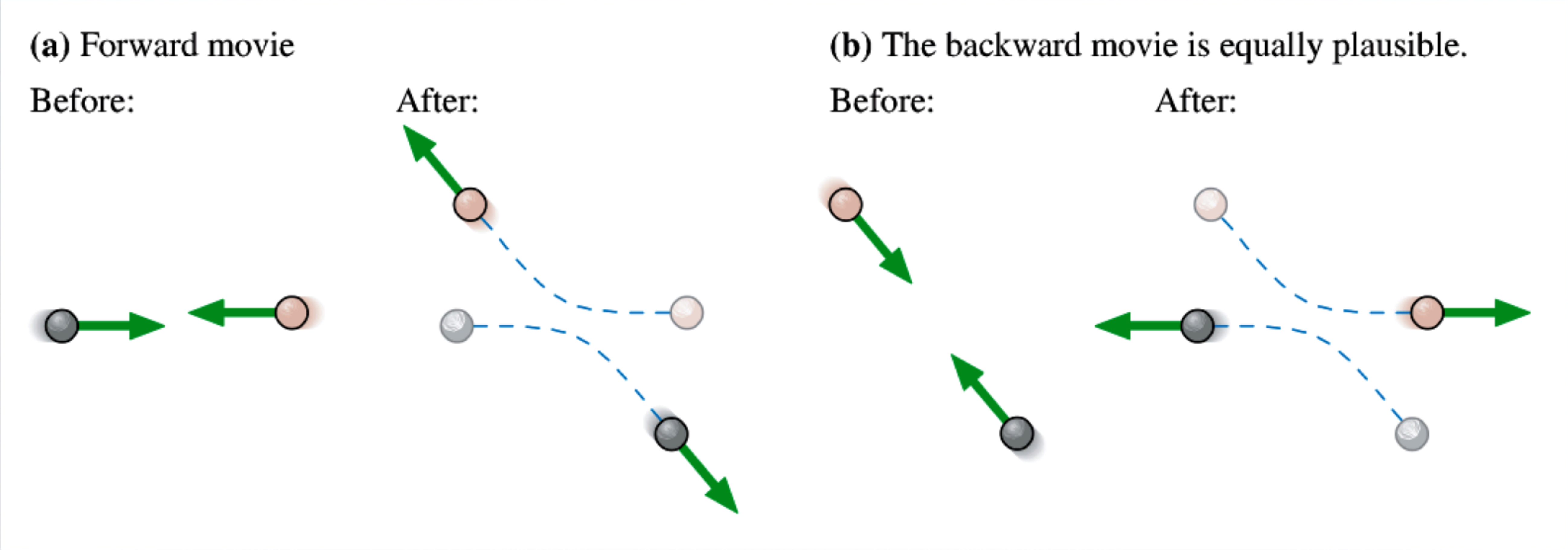
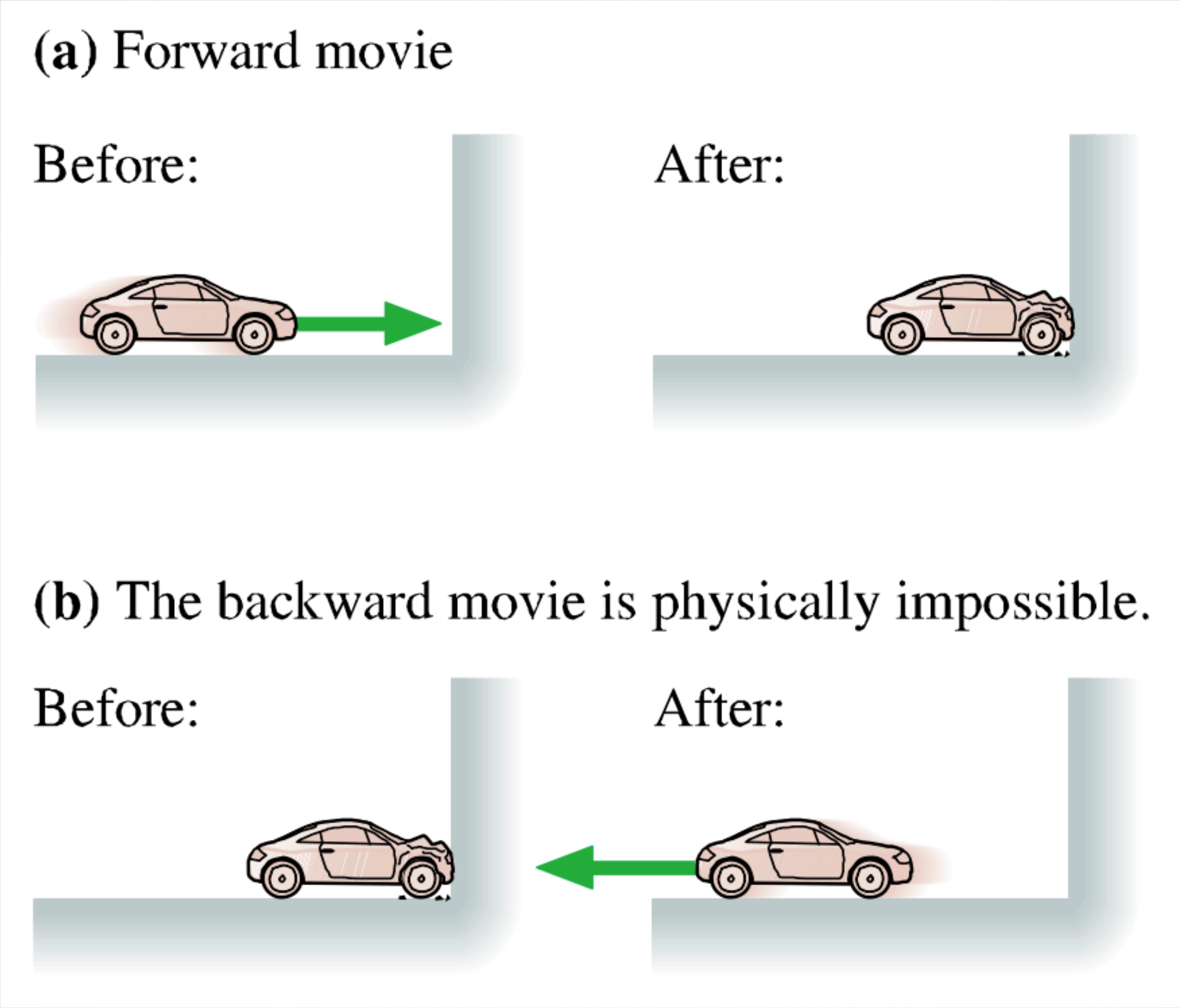
# IRREVERSIBLE PROCESSES AND THE SECOND LAW OF THERMODYNAMICS

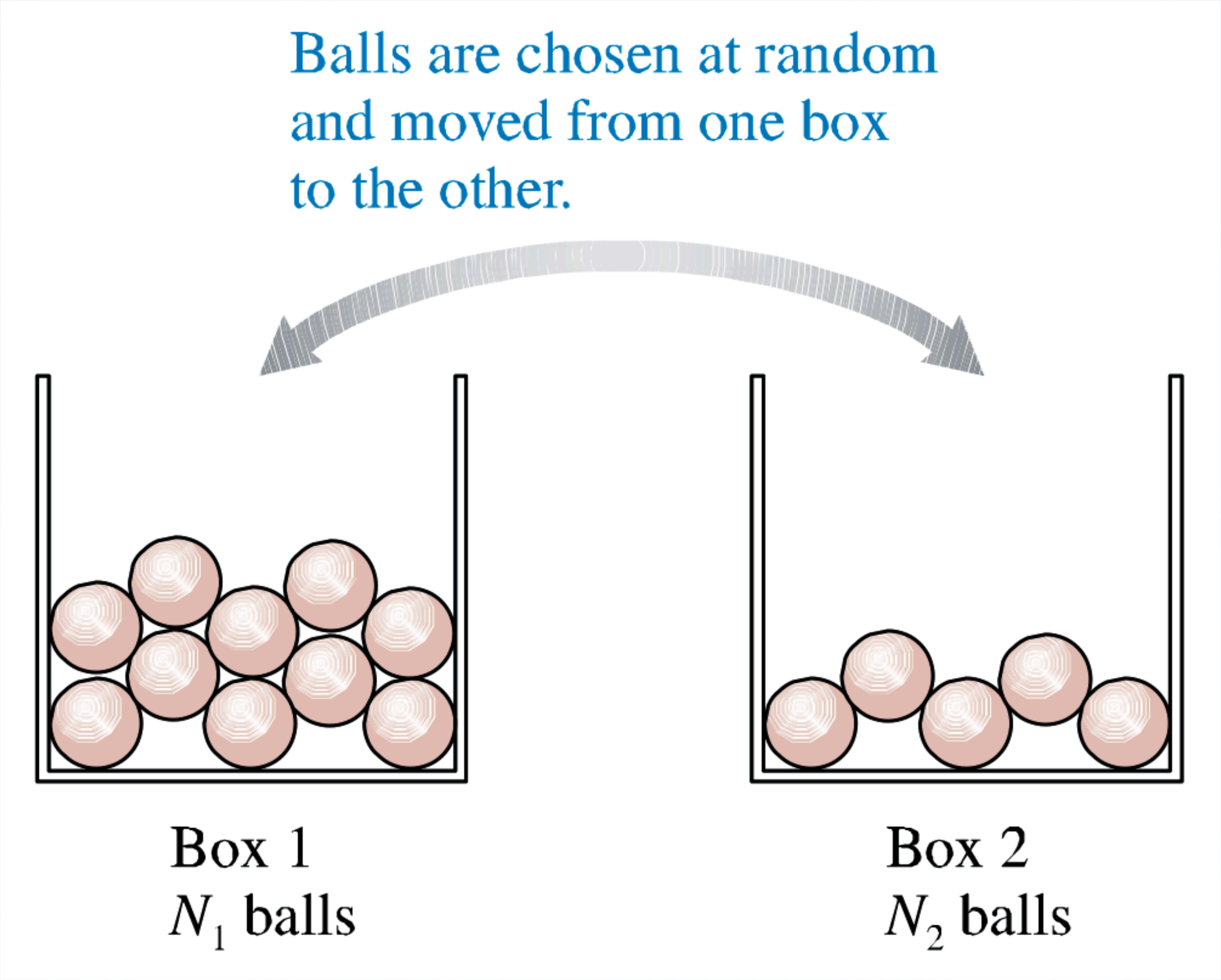



Molecular collisions are reversible.



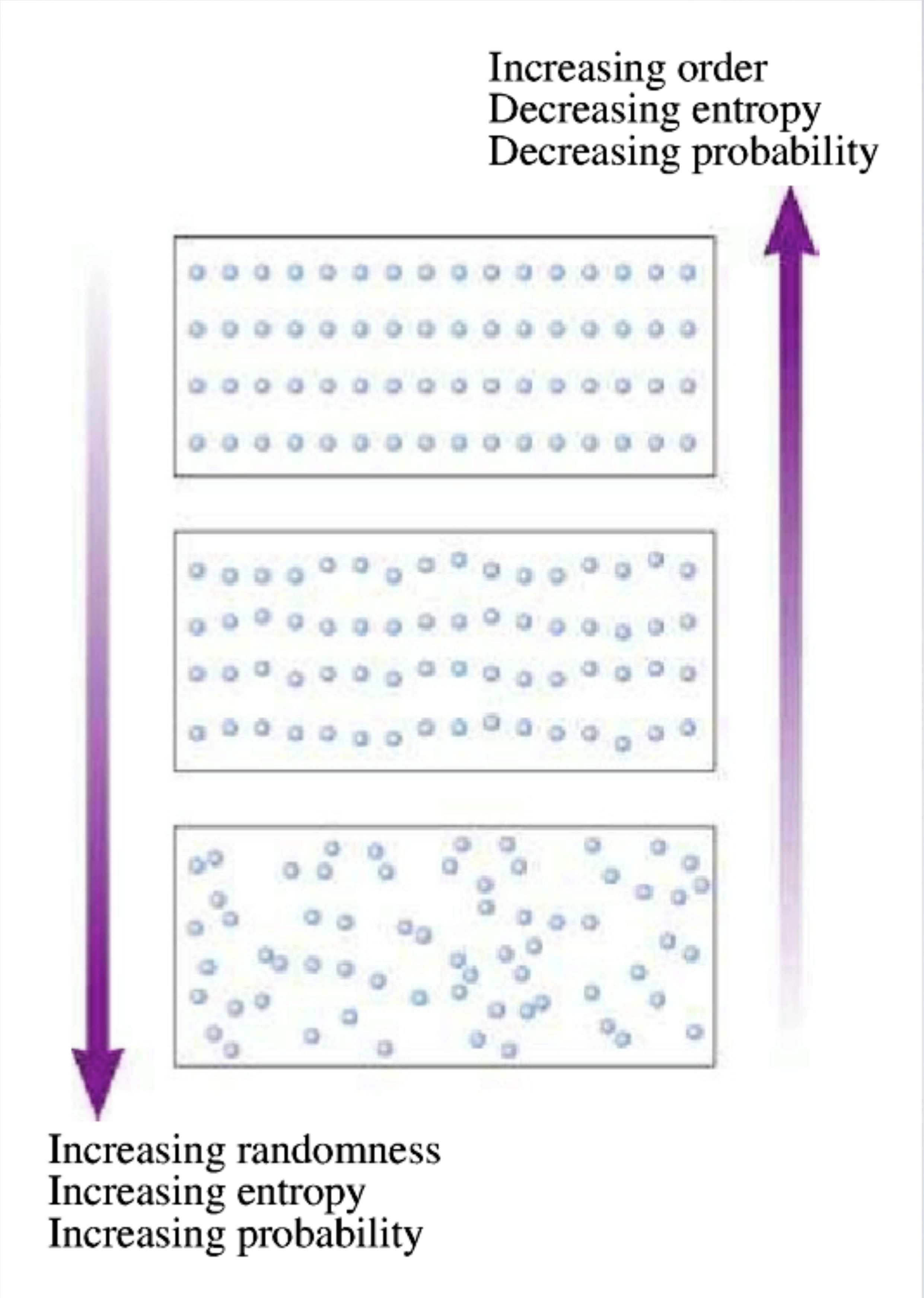

A car crash is irreversible.

# Which way to equilibrium?




Two interacting systems. Balls are chosen at random and moved to the other box.

# Order, Disorder, and Entropy




Ordered and disordered systems.

Tossing all heads, while not impossible, is extremely unlikely, and the probability of doing so rapidly decreases as the number of coins increases.

entropy |ˈentrəpē|

noun Physics

a thermodynamic quantity representing the unavailability of a system's thermal energy for conversion into mechanical work, often interpreted as the degree of disorder or randomness in the system. (Symbol: **S**)

- figurative lack of order or predictability; gradual decline into disorder : *a marketplace where entropy reigns supreme*.

# The Second Law of Thermodynamics

The entropy of an isolated system (or group of systems) never decreases. The entropy either increases, until the system reaches equilibrium, or, if the system began in equilibrium, stays the same.

The second law of thermodynamics tells us that an isolated system evolves such that

- Order turns into disorder and randomness.
- Information is lost rather than gained.
- The system "runs down."

**Second law, informal statement #1** When two systems at different temperatures interact, heat energy is transferred spontaneously from the hotter to the colder system, never from the colder to the hotter.

**Second law, informal statement #2** The time direction in which the entropy of an isolated macroscopic system increases is "the future."

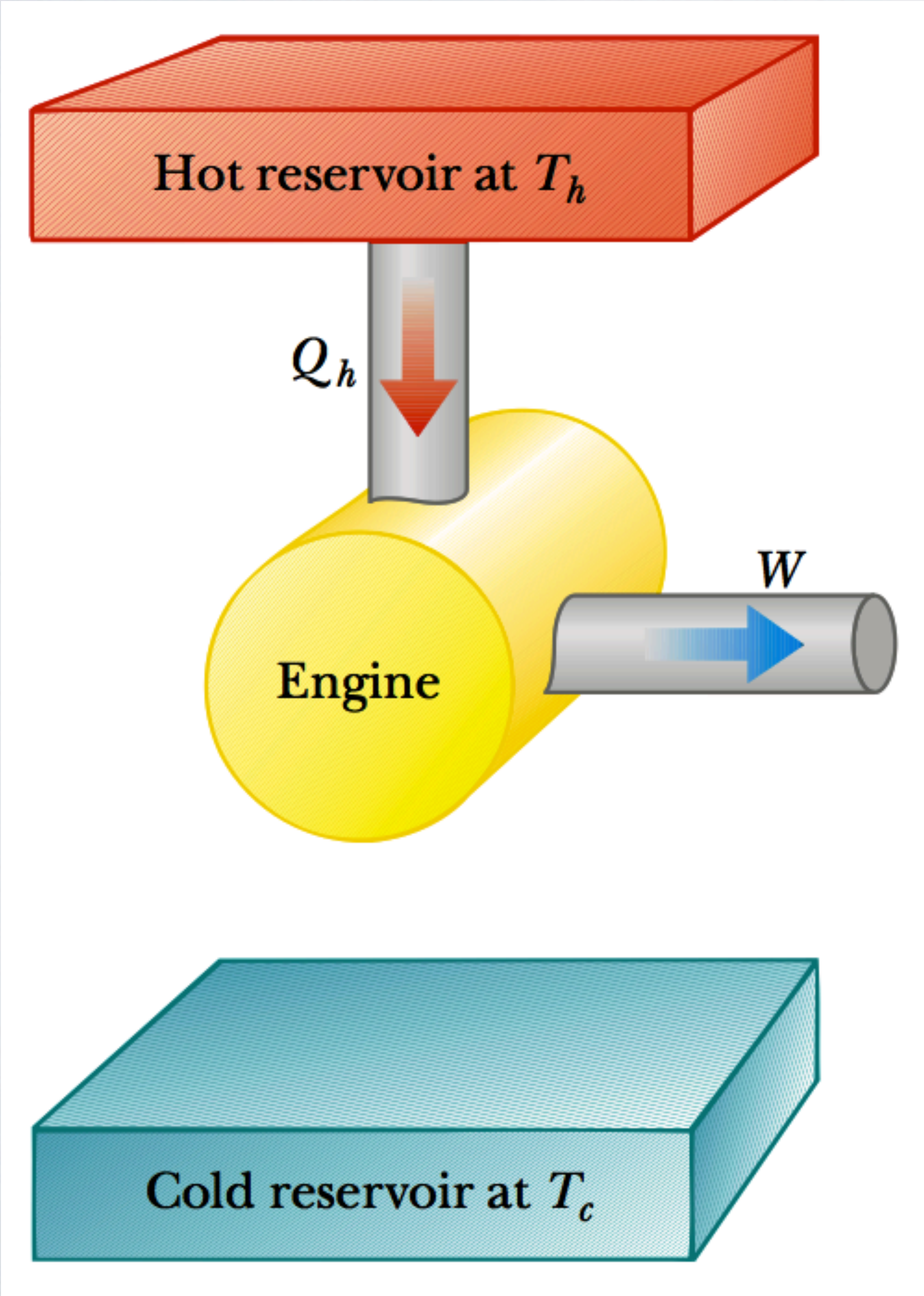
**Exercise**

Two identical boxes each contain 1,000,000 molecules. In box A, 750,000 molecules happen to be in the left half of the box while 250,000 are in the right half. In box B, 499,900 molecules happen to be in the left half of the box while 500,100 are in the right half. At this instant of time,

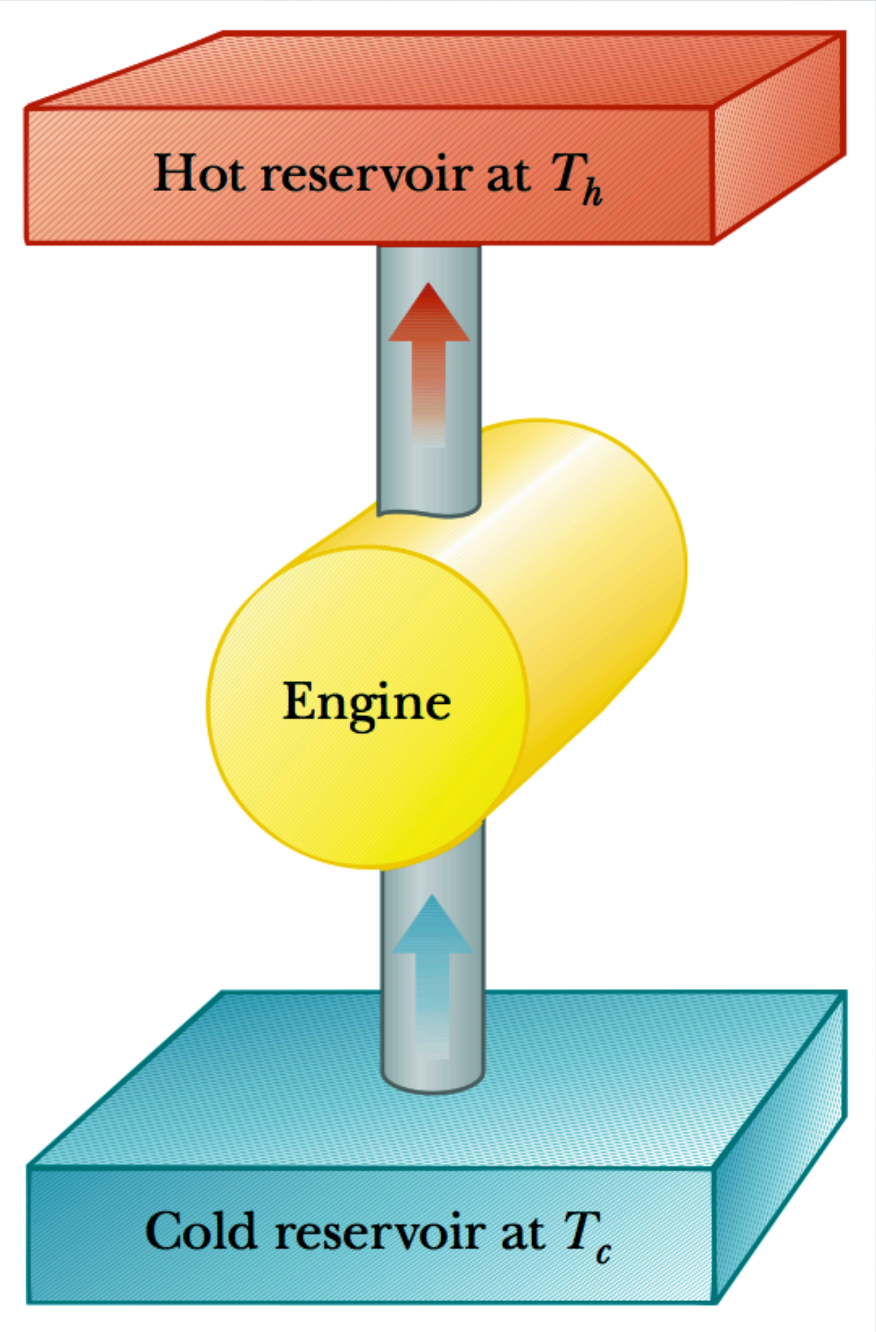
a. The entropy of box A is larger than the entropy of box B.
b. The entropy of box A is equal to the entropy of box B.
c. The entropy of box A is smaller than the entropy of box B.

## Kelvin–Planck statement of the second law of thermodynamics

It is impossible to construct a heat engine that, operating in a cycle, produces no effect other than the absorption of energy from a reservoir and the performance of an equal amount of work.

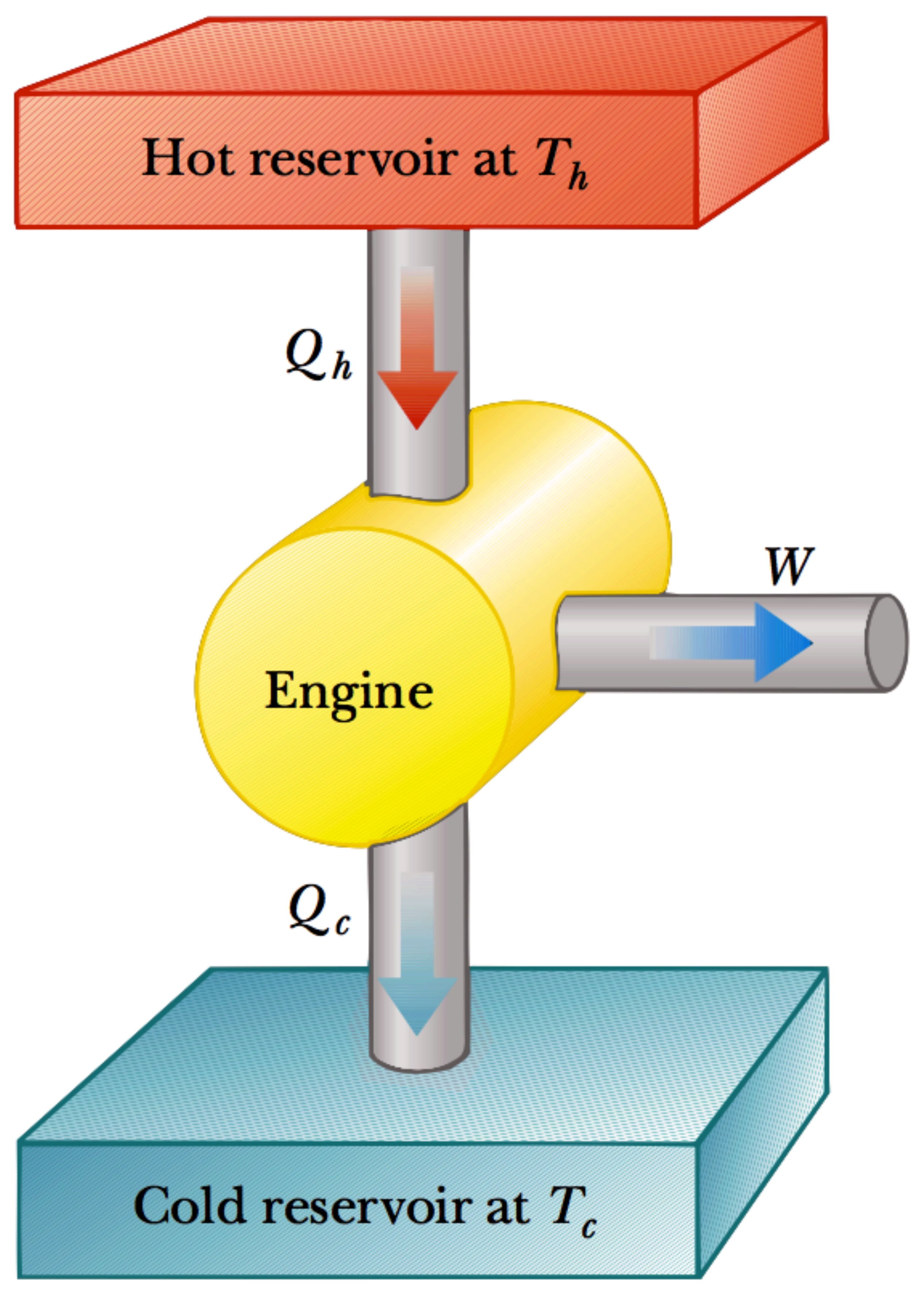


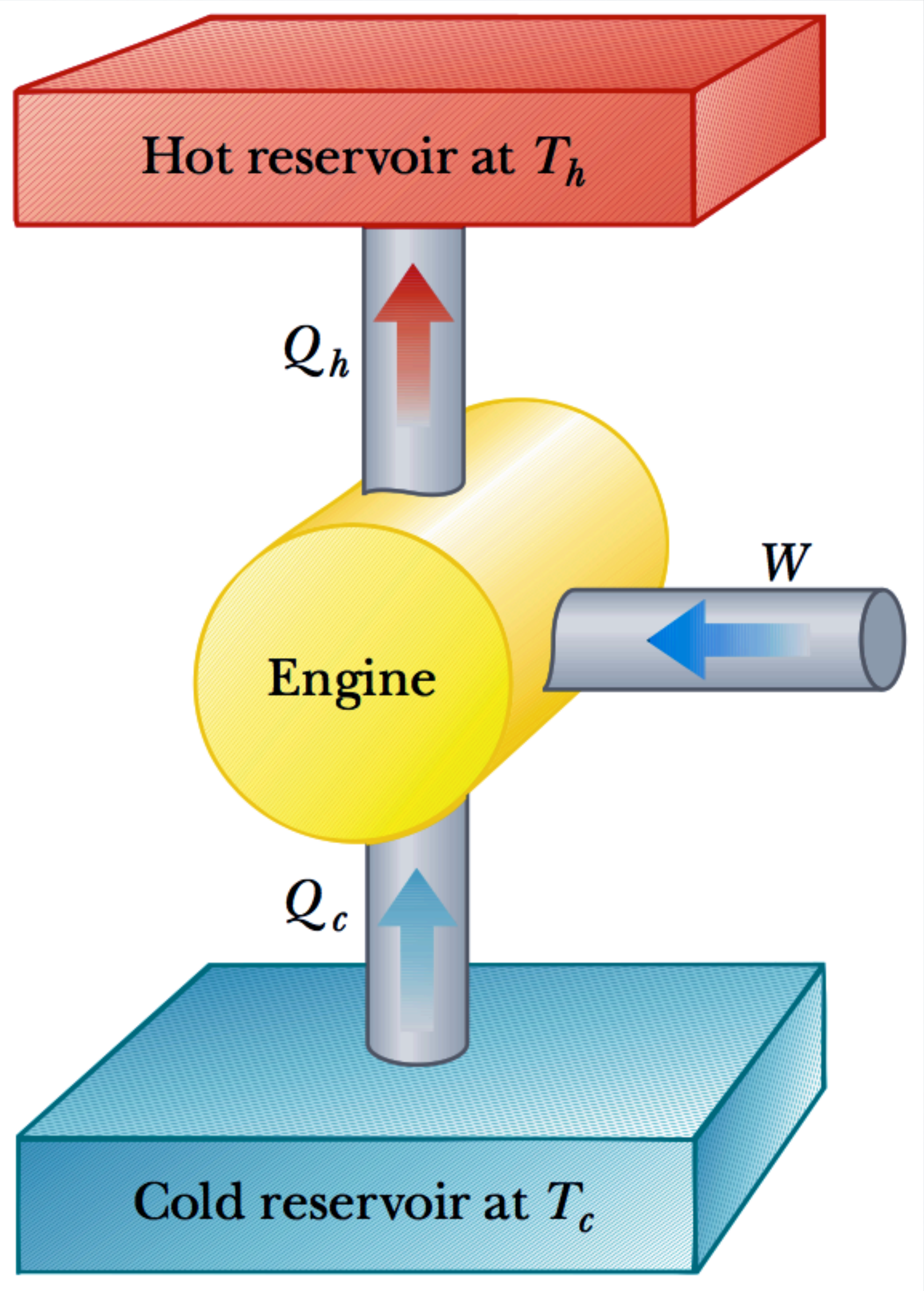

Impossible engine




Impossible refrigerator

# Heat engines and refrigerators



**Kelvin–Planck statement of the second law of thermodynamics**

It is impossible to construct a heat engine that, operating in a cycle, produces no effect other than the absorption of energy from a reservoir and the performance of an equal amount of work.

**Clausius statement of the second law of thermodynamics**

It is impossible to construct a cyclical machine whose sole effect is the continuous transfer of energy from one object to another object at a higher temperature without the input of energy by work.

# Clausius definition of change in entropy

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

Change in entropy for a finite process

$$\Delta S = \int_i^f dS = \int_i^f \frac{dQ_r}{T}$$