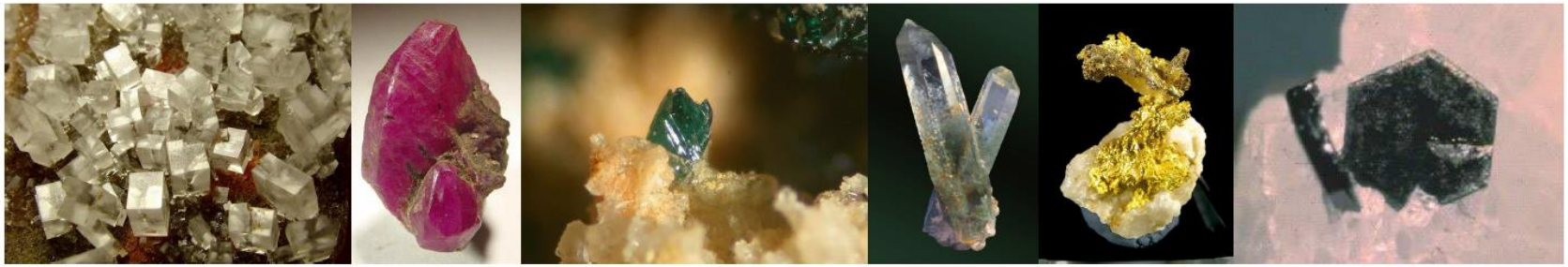
现代物理学概论

1. 还原论 vs 演生论
2. “热”究竟是什么？

How to gain a deeper understanding of our world?



对自然界(宇宙)的基本看法/研究方法：

一切归结为最基本的组成单元和决定单元行为的最基本规律。

--还原论 (Reductionism)

“最终目的”是建立一个包罗万象的 “大统一理论” – Grand Unification Theory

包罗万象的理论 (Theory of Everything)

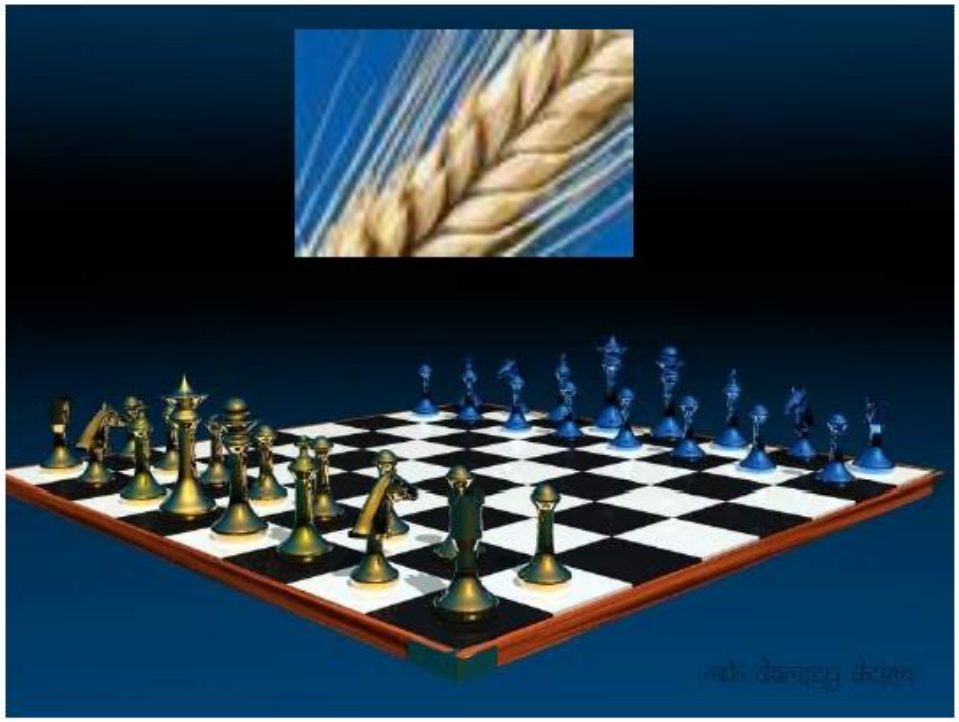
上一世纪量子力学的建立似乎提供了我们日常生活所接触的世界的包罗万象的理论:

物质的构成 – 原子核 + 电子

相互作用 – 电磁作用

运动规律 – 量子力学中的Schrodinger 方程

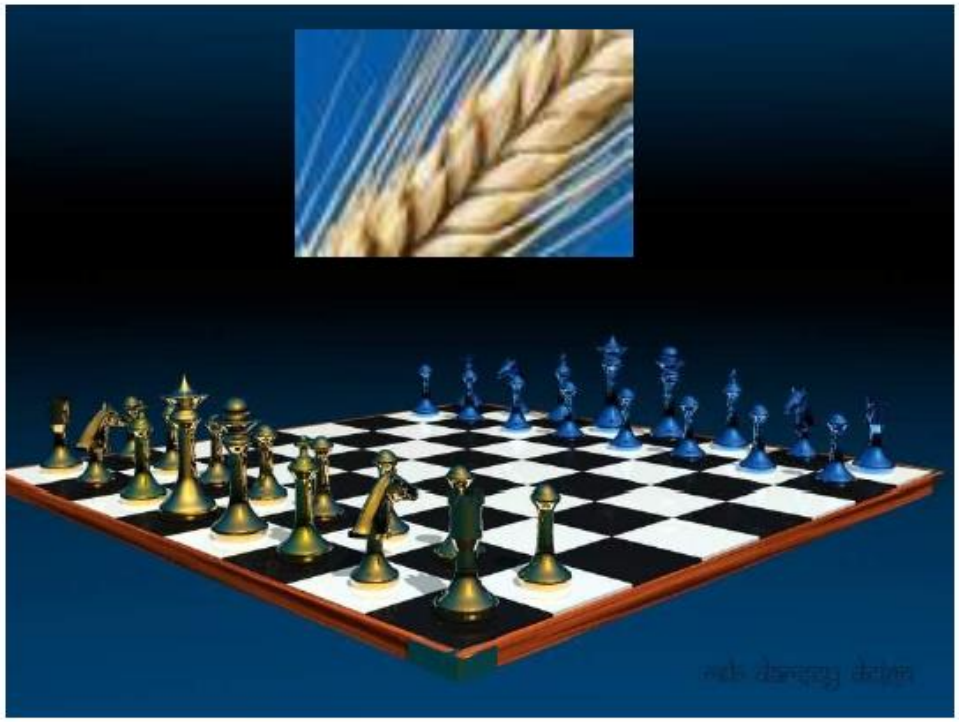
Why is the problem so difficult to study?



棋盘上的麦粒

第一个格子：1 粒麦子
第二个格子：2 粒麦子
第三个格子：4 粒麦子
……
按此比例每一格加一倍，一直放到第64格

Why is the problem so difficult to study?



棋盘上的麦粒

第一个格子：1 粒麦子
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第三个格子：4 粒麦子
……
按此比例每一格加一倍，一直放到第64格

$$1 + 2 + 4 + 8 + \cdots\cdots + 2^{63} = 2^{64} - 1$$

$$= 18446744073709551615$$

$$\approx 1\text{万}8\text{千亿吨麦子}$$

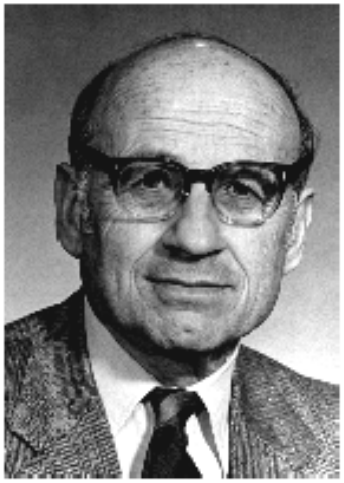
棋盘上由黄、蓝两种颜色棋子组成系统

每个格子只能放一个棋子，
系统可能的状态数是多少?

指数墙带来的困惑

由基本的相互作用力就能推出自然界的所有规律吗？

这是“大统一理论”的追求目标，但答案是否定的。



Walter Kohn
Nobel化学奖

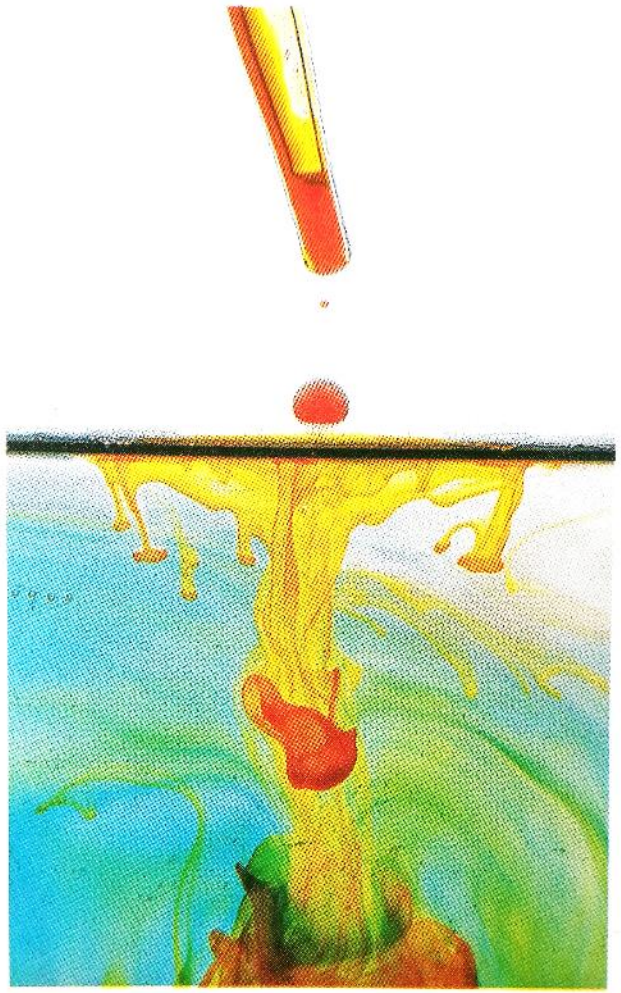
指数墙问题

实际材料中原子数 $N \sim 10^{23}$

系统总的自由度数不是每个粒子自由度数相加，而是相乘！

↓

自由度随粒子数指数增加

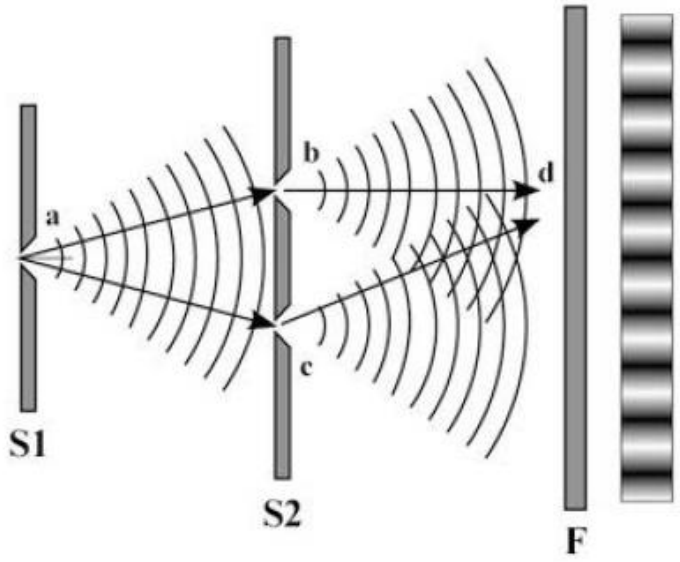


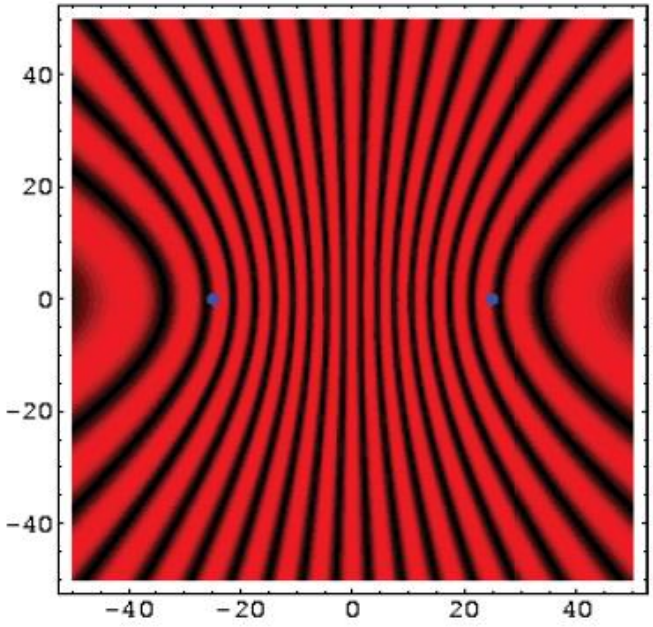
20.17 The mixing of colored ink and water starts from a state of relative order (low entropy) in which each fluid is separate and distinct from the other. The final state after mixing is more disordered (has greater entropy). Spontaneous unmixing of the ink and water, a process in which there would be a net decrease in entropy, is never observed.

热力学过程不可逆！

INTERFERENCE OF LIGHT

Because light is a wave, two light waves can interfere to produce a stronger or weaker wave:





动力学随机性
和统计的确定性

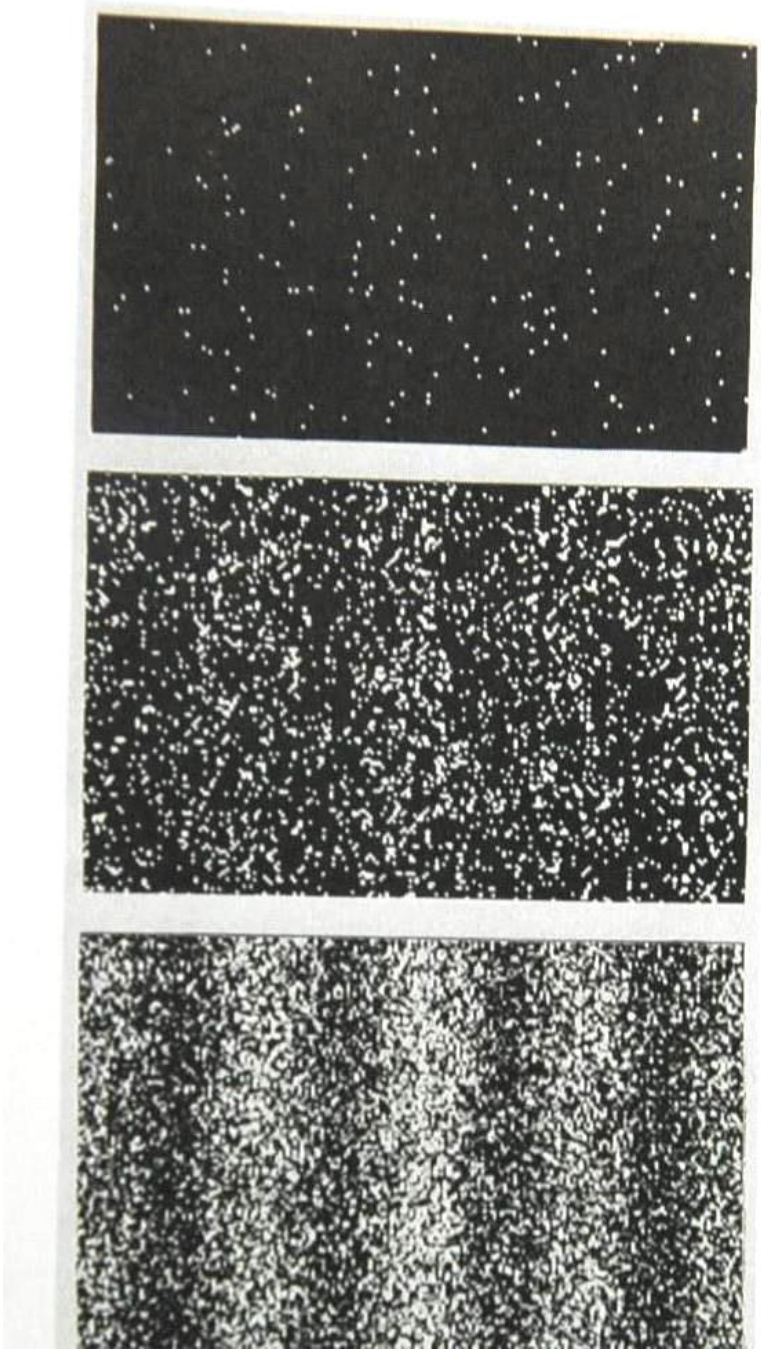


FIGURE 38–4 Young's double-slit experiment done with electrons—note that the pattern is not evident with only a few electrons (top photo), but with more and more electrons (second and third photos), the familiar double-slit interference pattern (Chapter 34) is seen.

我们能按古希腊人的理想把一切复杂的系统分解成最基本的单元，了解这些单元的行为，但对于复杂系统本身却一无所知！！

更不要说预言蛋白质的功能，人脑的行为。

J. Horgan 在1997年写了一本书：

“The End of Science: Facing the Limits of Knowledge in the Twilight of the Scientific Age”

是科学的末日，还是“绝对还原论”的末日？

对自然界(宇宙)的另一种看法/研究方法：

客观世界是分层次的，每个层次都有自己的基本规律，重要的是承认客观现实，以它为依据，找出它的基本规律，理解这些现象是如何“演生”出来的。

--演生论 (Emergence) / 整体论 (Whoism)

演生论与还原论这两者是对立的，但又是互补的！

Philip W. Anderson: More is different (1972)

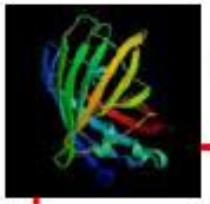
更多是不同的

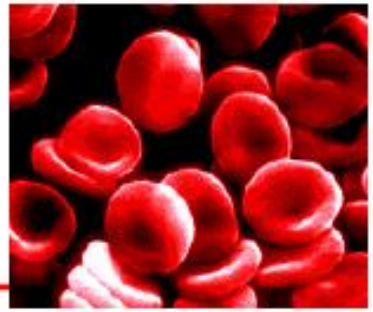
……将万事万物还原成简单的基本规律，并不蕴含着从这些规律出发重建宇宙的能力……

面对尺度与复杂性的双重困难，重建论的假定就崩溃了。不能依据少数粒子的性质作简单外推来解释由大量粒子构成的复杂集聚体的行为。正好相反，在复杂性的每一个层次会呈现全新的性质，为理解这些新行为所需要作的研究，就其基础性而言，与其他研究相比毫不逊色。

More Is Different!

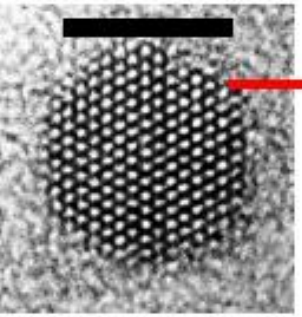
自组织、自适应、非平衡

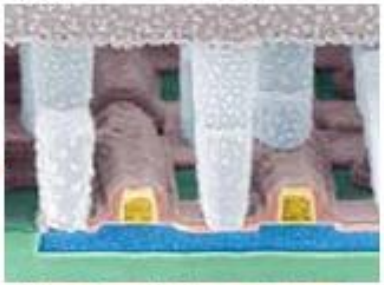
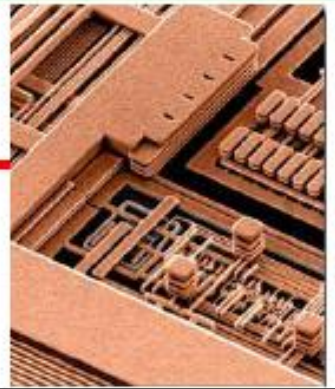
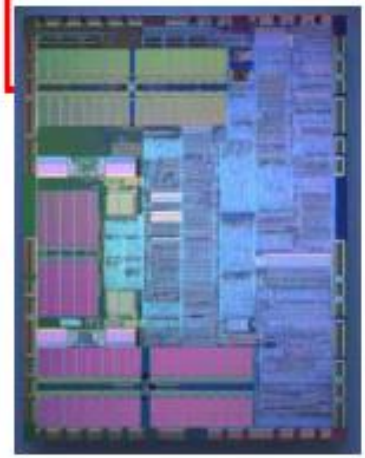




米

10^{-10} 10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2}

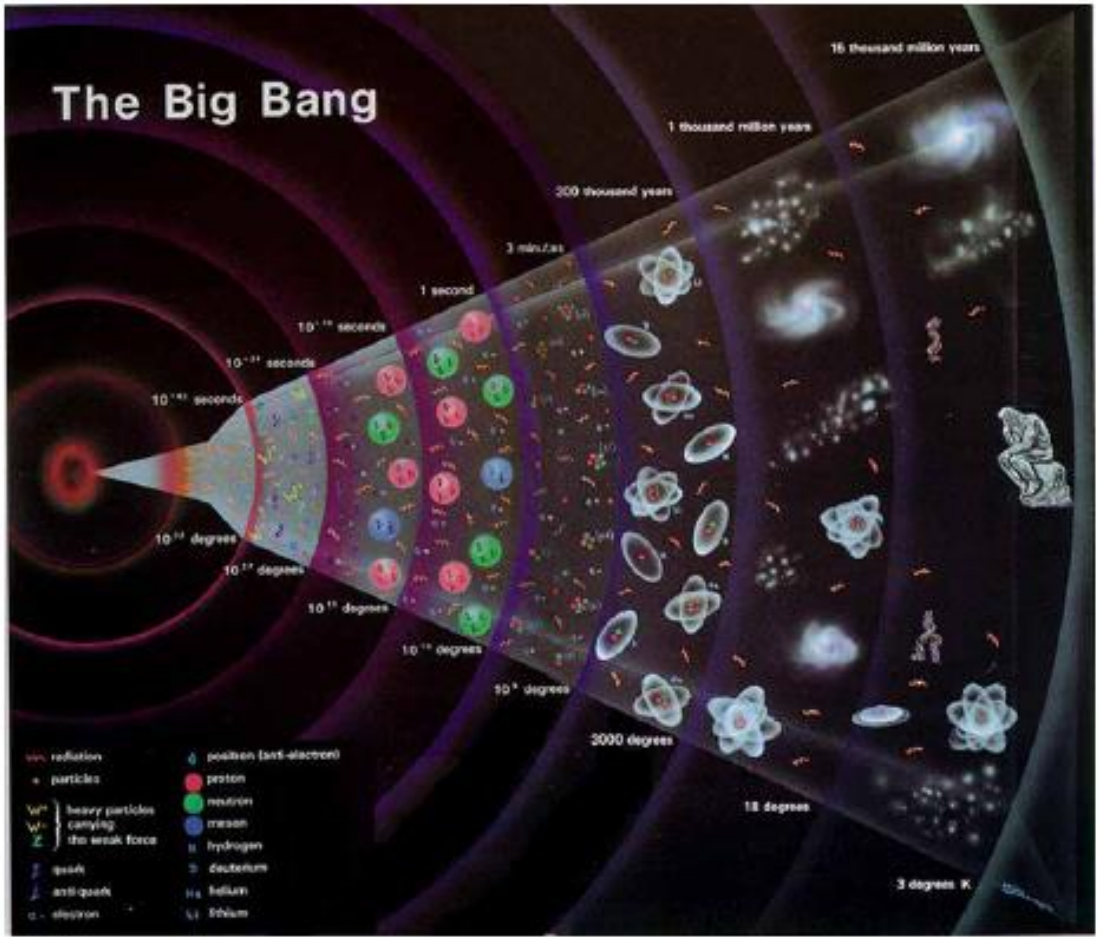


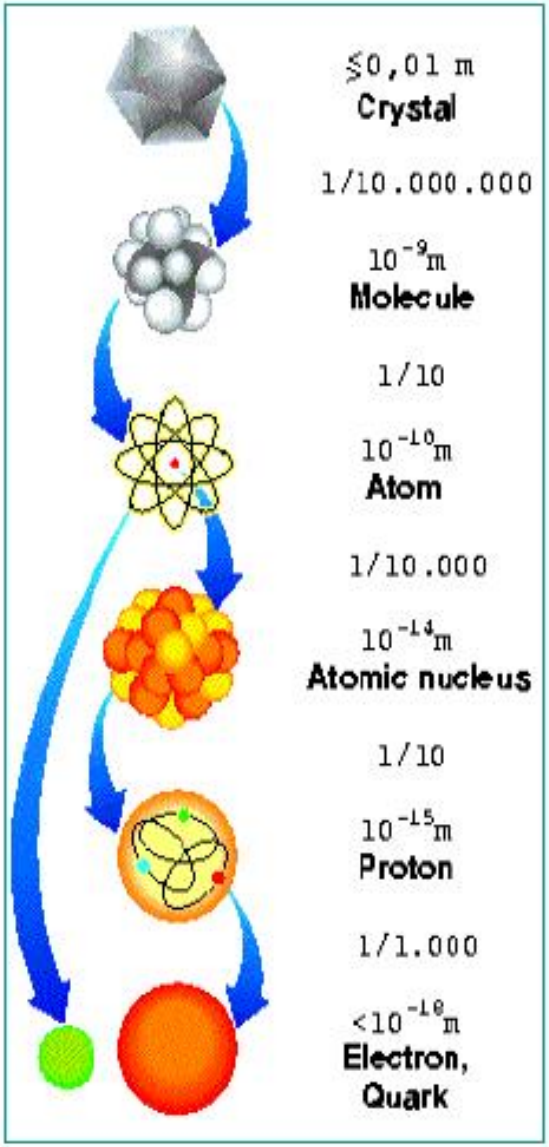




复杂性、多样性、层次性

不同层次现象脱耦合

The universe is emerged !

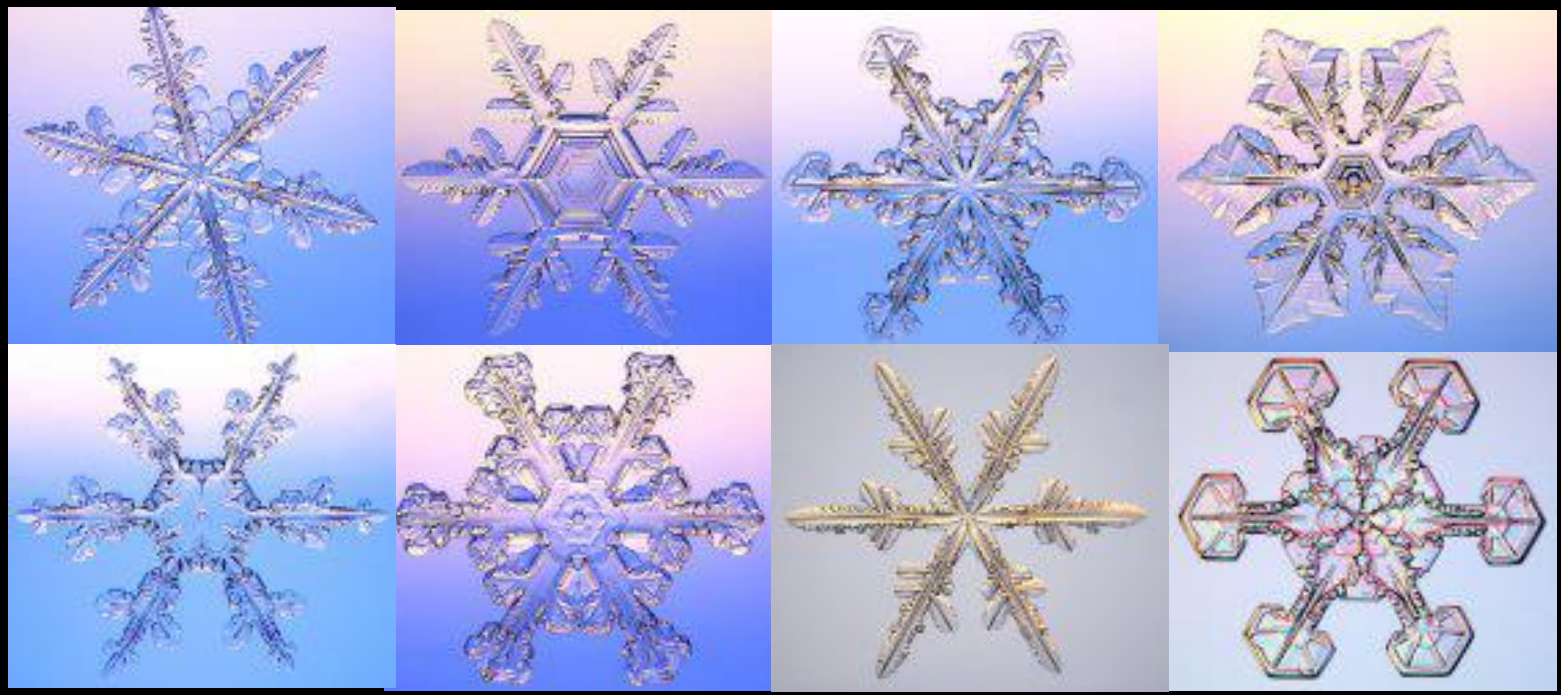




从水的三态变化

100°C 水沸腾成蒸汽　　0°C 水冻结成冰

仔细想想，为什么10^{23}个水分子，单个水分子结构不变、相互作用不变，会“集体地”、“不约而同地”从一个相“变”到另一个相呢？“新相”在“老相”中如何“孕育”、“形成”，如何“呈展”？



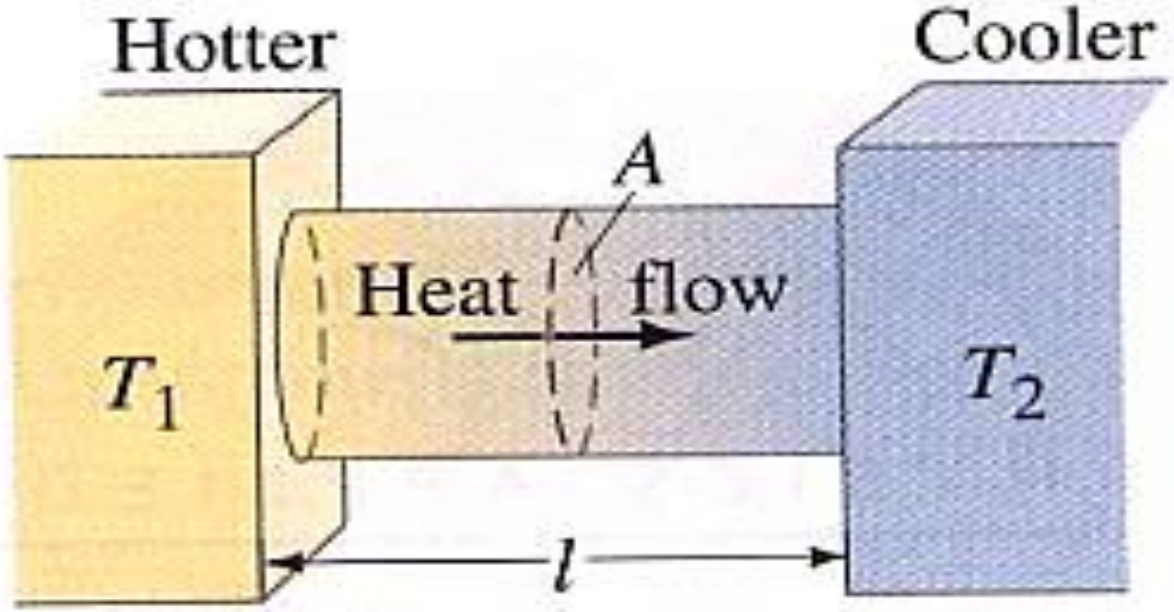
“热”究竟是什么？

与温度有何关系？

冷热的感觉

Questions ?

FIGURE 19–19 Heat conduction between areas at temperatures T_1 and T_2. If T_1 is greater than T_2, the heat flows to the right; the rate is given by Eq. 19–14a.



Questions ?

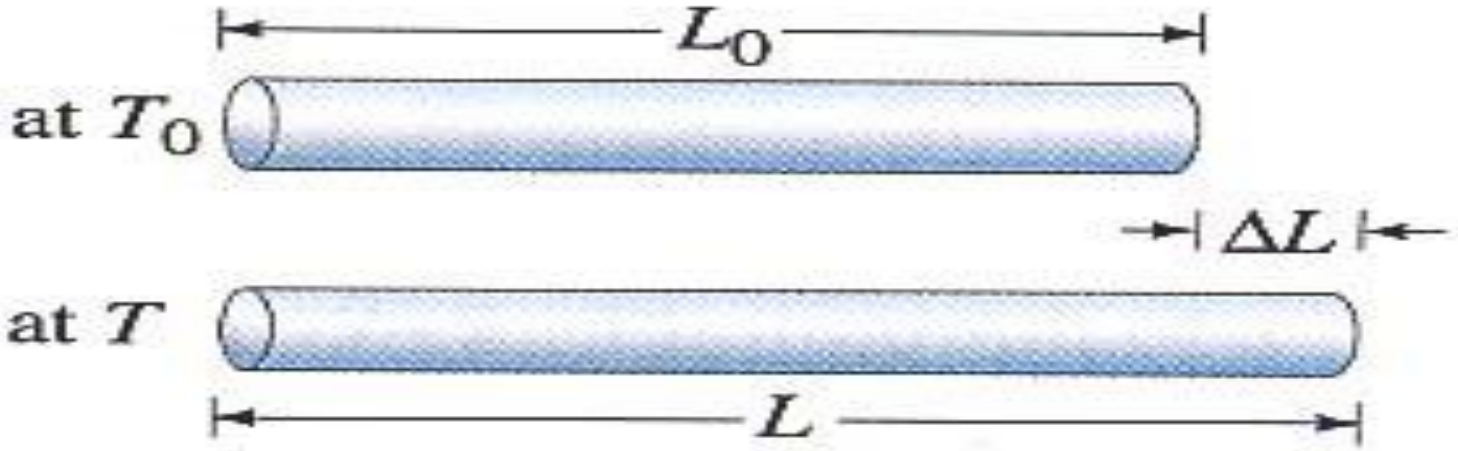
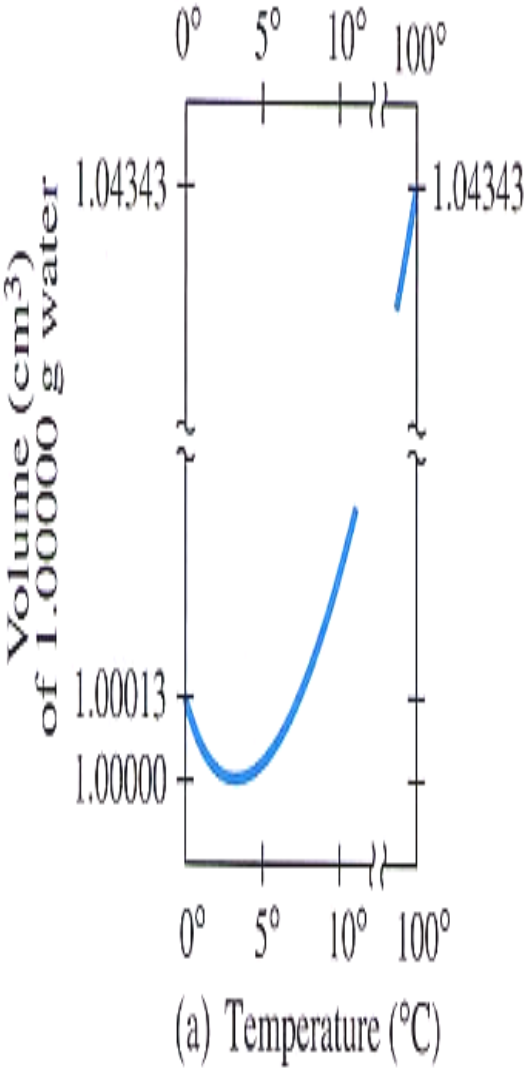


FIGURE 17–8 A thin rod of length L_0 at temperature T_0 is heated to a new uniform temperature T and acquires length L, where $L = L_0 + \Delta L$.

Linear expansion

所有物质都是热胀冷缩的吗？

反常温度效应



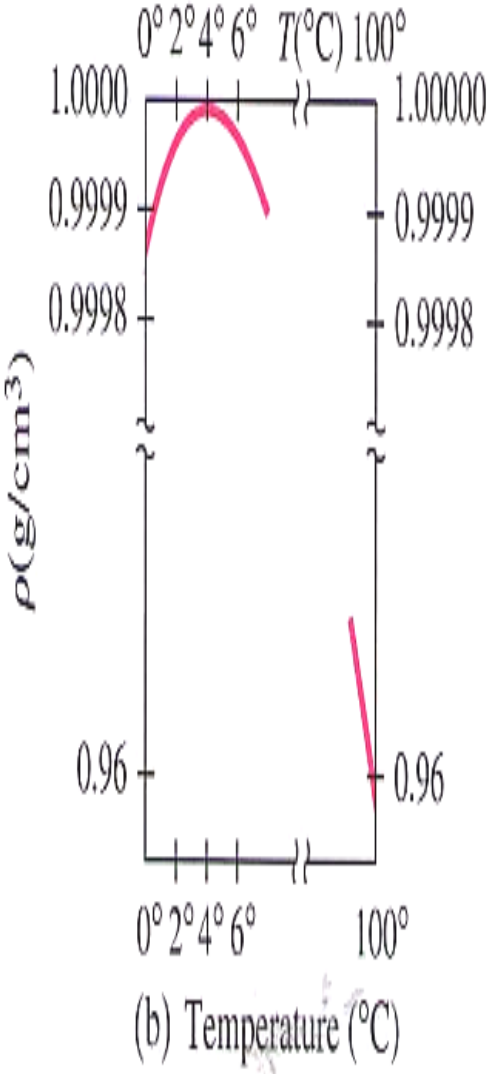
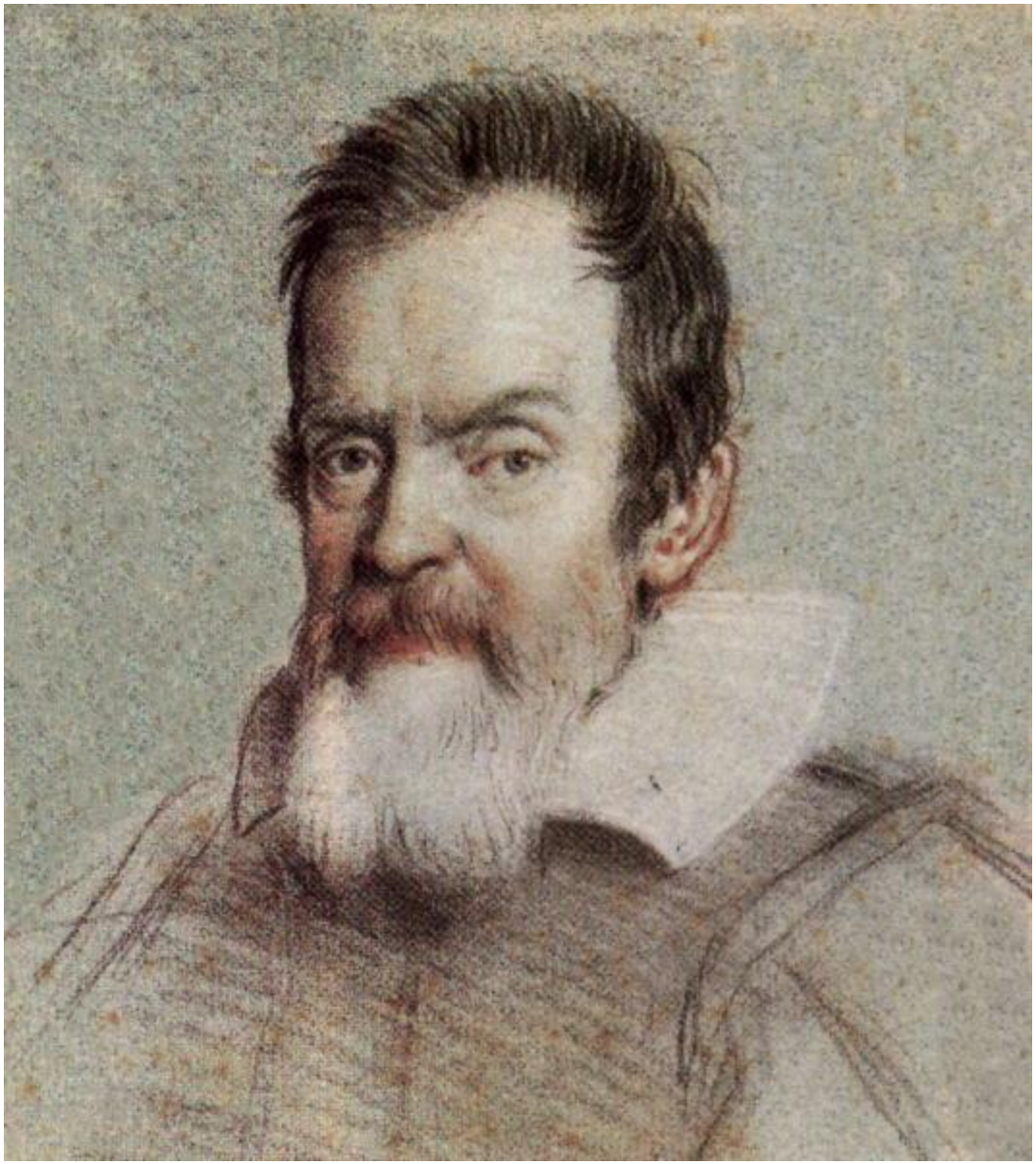


FIGURE 17–11 Behavior of water as a function of temperature near 4°C. (a) Volume, of 1.00000 gram of water, as a function of temperature. (b) Density vs. temperature. [Note the break in each axis.]

伽利略
Galileo Galilei

温度计的发明



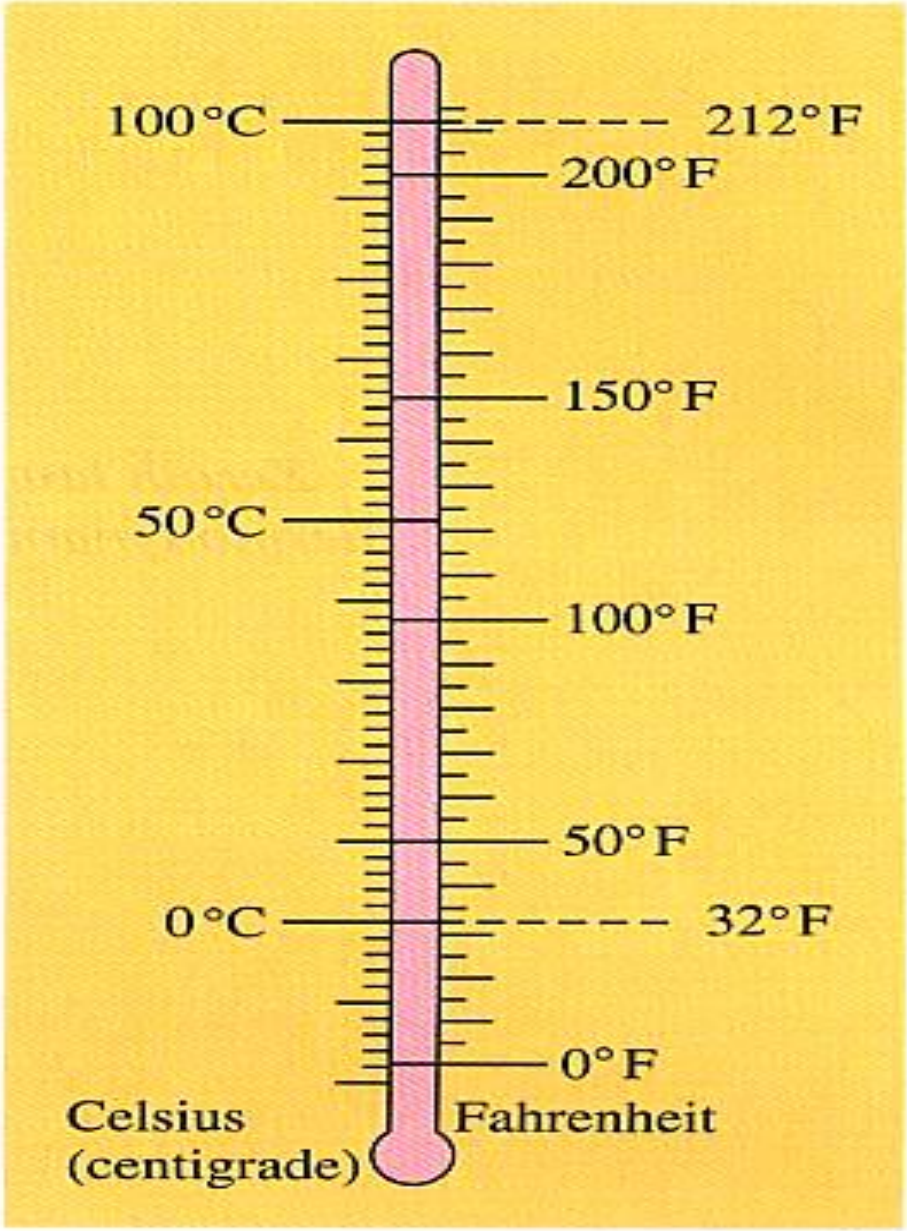
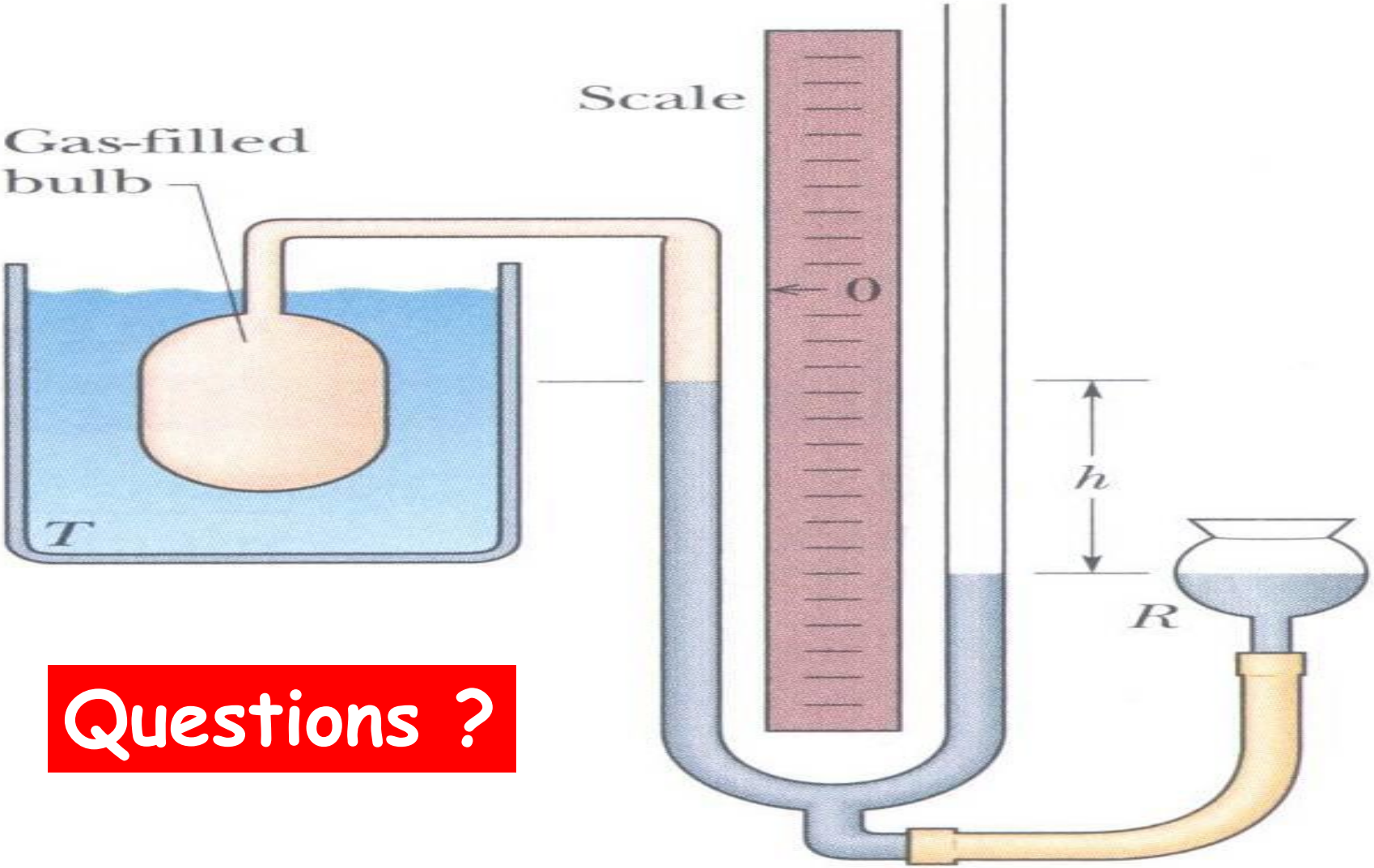


FIGURE 17–6 Celsius and Fahrenheit scales compared.

Questions ?

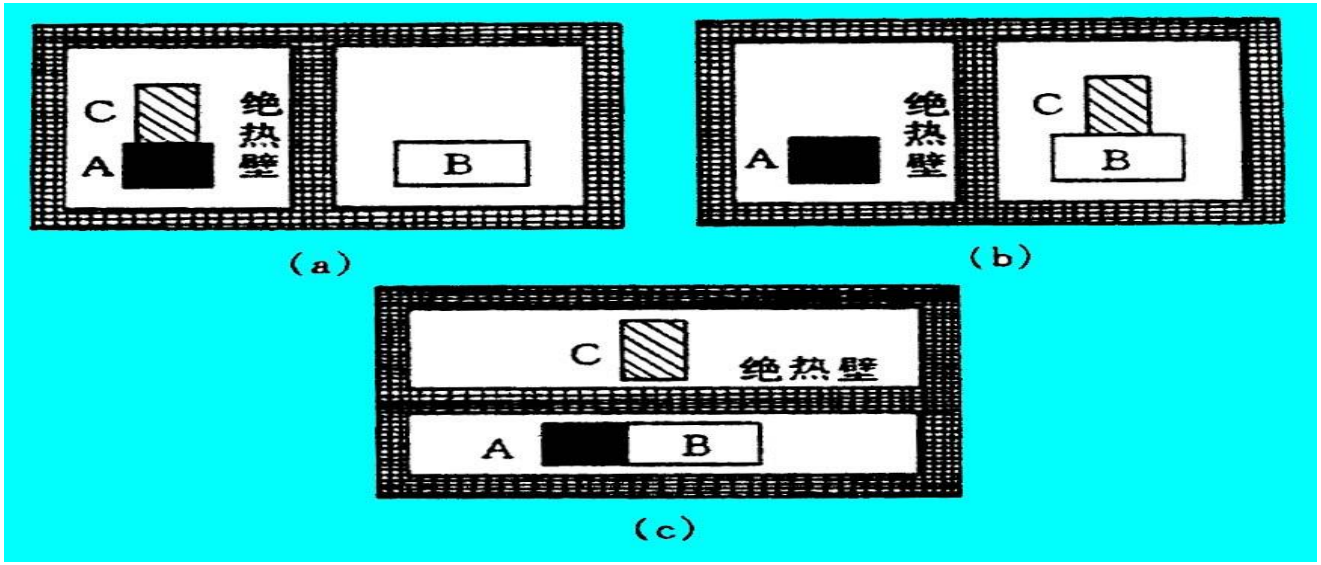
华氏温标100度为人体温度，0度为氯化铵与冰水混合物。



Questions ?

Fig. 18-5 A constant-volume gas thermometer, its bulb immersed in a liquid whose temperature T is to be measured.

热力学第零定律



- 在不受外界影响的情况下，只要A和B同时与C处于热平衡，即使A和B没有热接触，它们仍然处于热平衡状态，
- 这种规律也被称为热平衡定律。

焦 耳

James Prescott Joule

(1842)

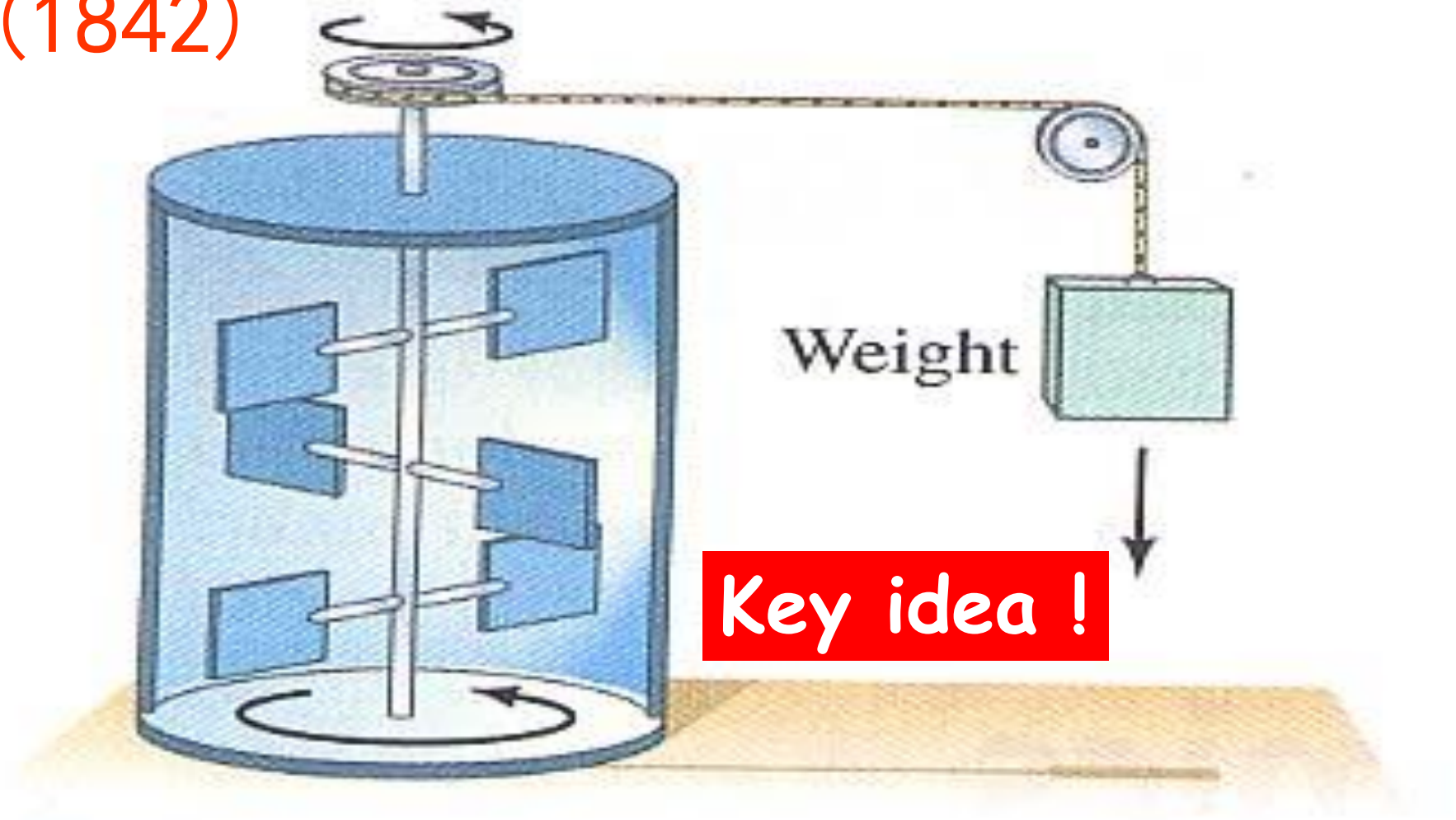


FIGURE 19–1 Joule's experiment on the mechanical equivalent of heat.

热量＝能量!

- Heat is energy that is transferred from one body to another because of a difference in temperature.

(1842)

- $dU=dQ+dW$

Einstein

"The most fundamental concepts in the description of heat phenomena are **temperature** and **heat**. It took an unbelievable long time in the history of science for these two to be distinguished, but once this distinction was made rapid progress resulted."

利用热能做功是否存在限制?

卡 诺

Sadi Carnot

卡诺循环

REFLECTIONS ON THE MOTIVE POWER OF FIRE AND ON MACHINES FITTED TO DEVELOP THAT POWER

BY SADI CARNOT

one-time pupil of the
ÉCOLE POLYTECHNIQUE
1824

Translated and edited by
R. H. THURSTON

(1824)

RÉFLEXIONS SUR LA PUISSANCE MOTRICE DU FEU ET SUR LES MACHINES PROPRES A DÉVELOPPER CETTE PUISSANCE.

PAR S. CARNOT,

ANCIEN ÉLÈVE DE L'ÉCOLE POLYTECHNIQUE.

A PARIS,
CHEZ BACHELIER, LIBRAIRE,
QUAI DES AUGUSTINS, N°. 55.

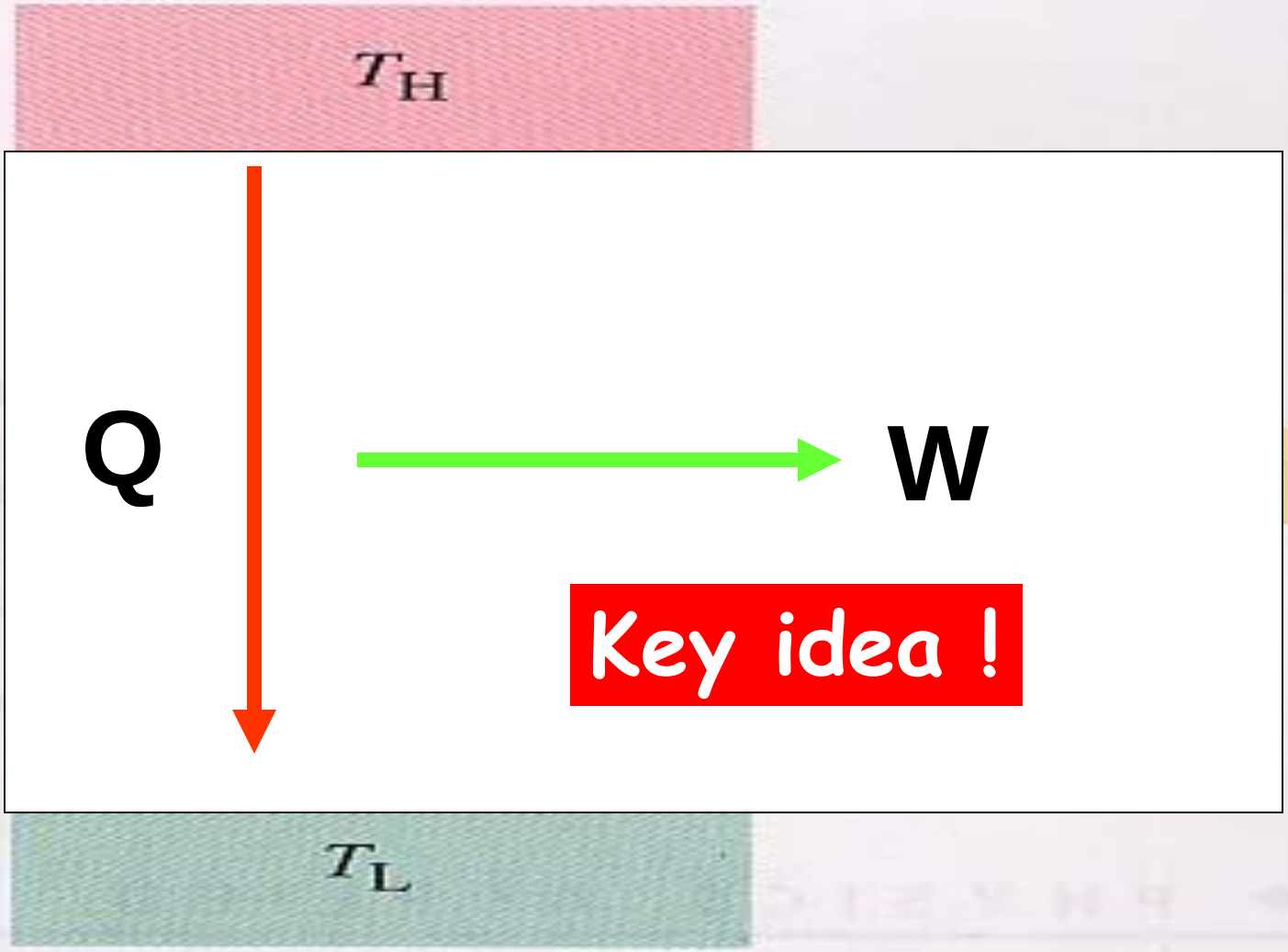
1824.

Title page of the memoir published in 1824.

Carnot's ideas

"The production of motive power is then due in steam-engines not to an actual consumption of caloric, but *to its transportation from a warm body to a cold body.*"

Carnot's ideas



Carnot's ideas

"According to this principle, the production of **heat** alone is not sufficient to give birth to the impelling power: *it is necessary that there should also be* ***cold****; without it, the* ***heat*** *would be useless.*"

Carnot's ideas

"The necessary condition of the maximum is, then, that in the bodies employed by realize the motive power of heat there should not occur any change of temperature which may not due to a change of volume."

Carnot's theorem

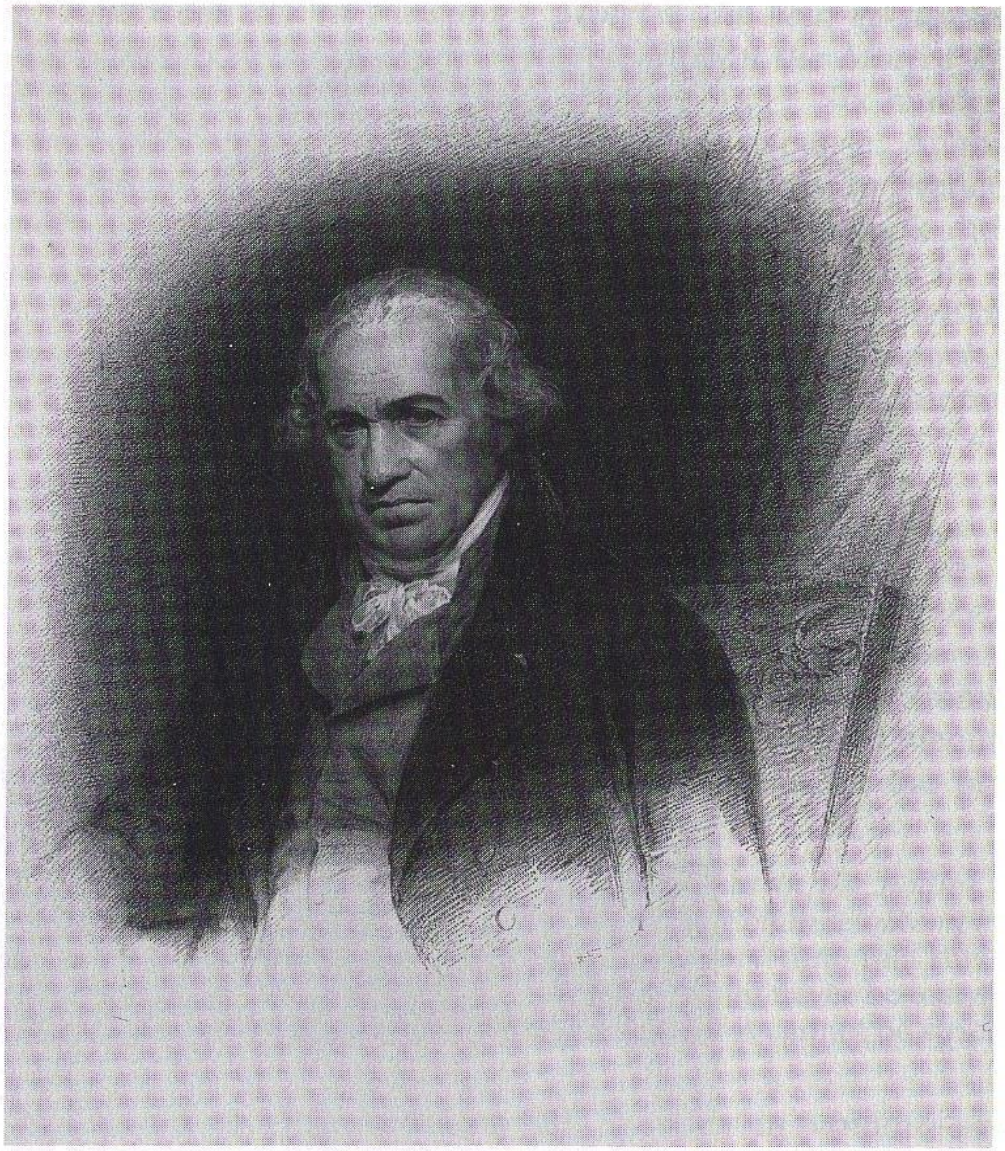
"All reversible engines operating between the same two constant temperatures T_H and T_L have the same efficiency.

$$e = W/Q_H = 1 - Q_L/Q_H = 1 - T_L/T_H$$

Any irreversible engine operating between the same two fixed temperatures will have an efficiency **less than** this."

瓦特
J. Watt

蒸汽机



James Watt (1736–1819) (Courtesy the E. F. Smith Collection, Van-Pelt-Dietrich Library, University of Pennsylvania)

Key idea !

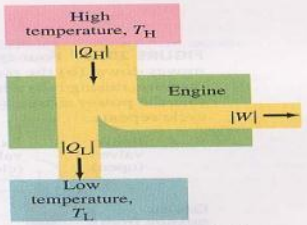


FIGURE 20–1 Schematic diagram of energy transfers for a heat engine.

FIGURE 20–5 The Carnot cycle. Heat engines work in a cycle, and the cycle for the Carnot engine begins at point a on this *PV* diagram. (1) The gas is first expanded isothermally, with the addition of heat $|Q_H|$, along the path ab at temperature T_H. (2) Next the gas expands adiabatically from b to c—no heat is exchanged, but the temperature drops to T_L. (3) The gas is then compressed at constant temperature T_L, path c to d, and heat $|Q_L|$ flows out. (4) Finally, the gas is compressed adiabatically, path da, back to its original state. No Carnot engine actually exists, but as a theoretical engine it played an important role in the development of thermodynamics.

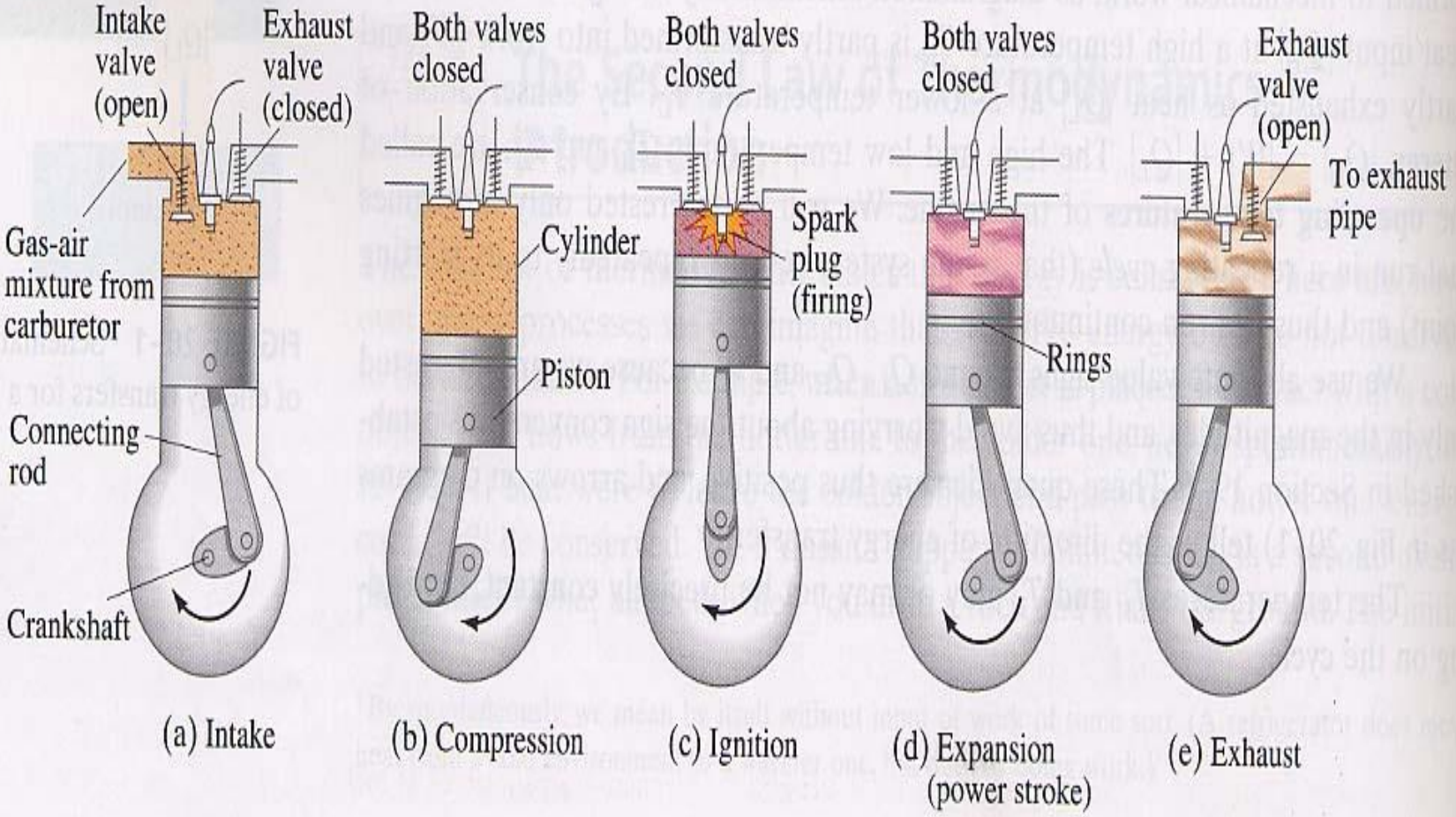
$e = W / Q_H$

$= 1 - Q_L/Q_H$

$= 1 - T_L/T_H$

$Q_L / T_L = Q_H / T_H$, $Q_H / T_H - Q_L / T_L = 0$

FIGURE 20–3 Four-cycle internal combustion engine: (a) the gasoline–air mixture flows into the cylinder as the piston moves down; (b) the piston moves upward and compresses the gas; (c) firing of the spark plug ignites the gasoline–air mixture, raising it to a high temperature; (d) the gases, now at high temperature and pressure, expand against the piston in this, the power stroke; (e) the burned gases are pushed out to the exhaust pipe; the intake valve then opens, and the whole cycle repeats.



为什么用热做功会存在限制？

课后阅读：

1. 探究热力熵本源的研究历程