Review

Brown established the **universality** of the motion: Brownian motion. 9.1-3

**Why didn’t the founders** of stat thermodynamics pay any attention to Brownian motion? 9.1

**LLN** kills naive noise effects.

   Noises are not at all simple; fluids are complicated.
Einstein’s ‘mesoscopic’ theory: 9.6-7, 9.10

Macro input: \( \mathbf{v} = -\mathbf{F}/\zeta \),

Micro input: \( n\mathbf{F} = -k_B T \text{grad} n \).

\[ \Rightarrow D = k_B T/\zeta \]

with \( \langle r(t)^2 \rangle = 2D Dt \) (9.9) cf. Perrin.

Top down mesoscopic approach: Simple Langevin 10.9-10

\[ \frac{d\mathbf{r}}{dt} = -\frac{1}{\zeta} \nabla U + \mathbf{v}, \]

with \( \langle \mathbf{v}(t)\mathbf{v}^T(s) \rangle = 2D I \delta(t - s) \).

**Fluctuation-Dissipation relation**: Steady distribution consistent with the Boltzmann factor. 10.2, 10.6
Lecture 7. Macrosystems, thermodynamics

rather philosophical today.

Macrophenomena simplify thanks to LLN.

What is ‘macroscopic’? 12.1 f4

For LLN to hold, uniformity is needed.
⇒ calm and stationary

Description by Mechanics

see the last appendix
Review of QM.
Can we rely on mechanics?

Let us be critical.

Mechanics is not empirical enough.

**Well, BUT... Really?**

Three limits are non-commutative: 12.3

(1) External influence $\rightarrow 0$ ($R \rightarrow 0$)

(2) Long time limit ($t \rightarrow \infty$)

(3) Thermodynamic or large size limit ($N \rightarrow \infty$).

$\exists$ **Fundamental difference** between Mechanics & Thermodynamics
According to pure mechanics, what can we say?

(1) Energy is additive.\textbf{11.2-4 proof}

If the interaction $\sim 1/r^{d+\epsilon}$: very difficult

Extensive quantities, intensive quantities

(2) \textbf{Irreversibility 11.8-11 Toy model}
Loschmidt: Rückerkehreinwandt (Reversibility paradox)
Mechanics is reversible; why irreversible?

Zermelo: Recurrence paradox (cf Poincare) Planck
Translator of Gibbs’ famous book
Axiomatic Set Theory, Axiom of Choice
Phenomenology

What is phenomenology? 12.1

Thermodynamics =

    Macroscopic phenomenology of equilibrium systems.

* Choose right states
* Choose right variables

Equilibrium states

What is it? 12.2

Devise your characterization
Basic structure of thermodynamics

What are the fundamental variables required to specify states? 12.4

Thermodynamic space/thermodynamic coordinates

Privileged set

We trust macroscopic mechanics/electromagnetism.

Quasistatic process 12.6, fn 9

Pay due attention to Warning

State function

usefulness of thermodynamics

Zeroth law: what is it? 12.13
Partitioning-rejoining invariance

This makes extensivity operational.