Emergence lec 17 2011

simple rules → v. complex results.

physical systems → chaos

→ abstract space behind the obvious motion → fractal structure.

→ NONLINEAR. solutions do not just add up.

$F(S_1)$ $F(S_2)$ $S_1 + S_2 \neq$ solution.

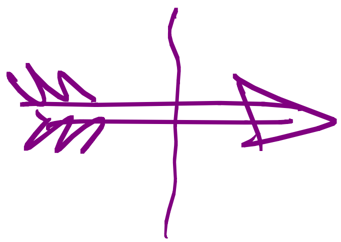
Mandelbrot z_n^2 Logistic $x_n(1-x_n)$

→ emergence of chaotic beh. fractals.

Systems with many parts (atoms).

"Arrow of time" — A.S. Eddington

why?



past "now" future

— Microscopic systems (single particles).
don't have an arrow!

t = just a variable.

$t \to -t$

$F = ma \to$ doesn't care about $t \to -t$

why does the arrow exist?:

time reversal symmetry

⟺ Energy Conservation

Macroscopic systems (many particle).

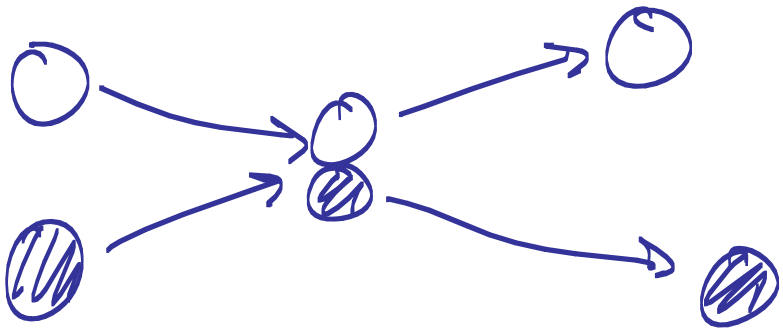
Macro Energy can dissipated

→ Heat.

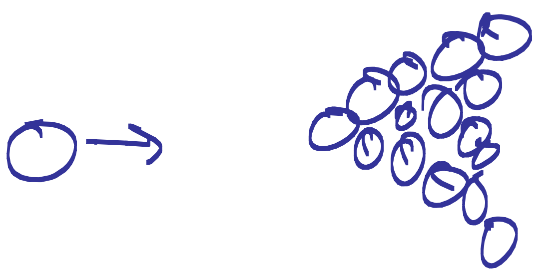
(microscopic Motion)

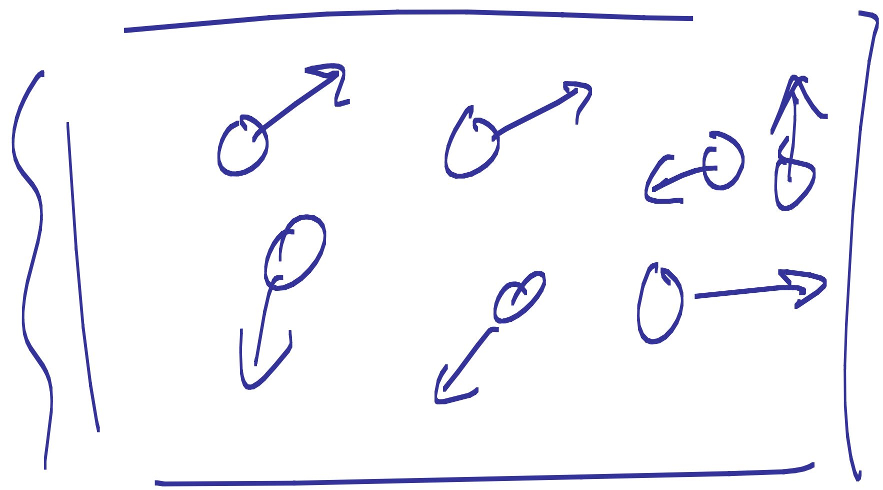
— total Energy still conserved.

"fundamental" interactions



looks same if
$t \to -t$
(no friction [



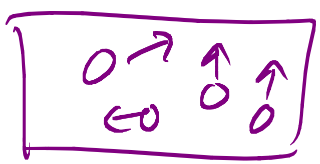
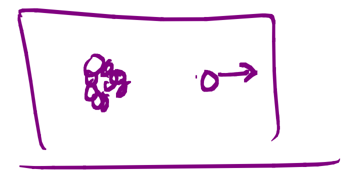


reversible in principle

but astronomically unlikely
in practice

— sensitive dependence on initial conditions

a random choice of initial conditions

like  → never find 

← easy

"effectively" irreversible ⟷ chaos is effectively random.

"random" evolved from "special states"

$\Delta \leftarrow 0$

macroscopically indistinguishable
(plates of spaghetti).

→ effectively time irreversible.

J. C. Maxwell
J. W. Gibbs
Ludwig Boltzmann

Thermodynamics
– 19th c of
steam engines
work ⟷ heat.

↪ "statistical Mechanics"

— stat Mech.

connects mechanics ⟷ thermodyn.

Lord Kelvin "the kind of motion we call heat".

macroscopic quantities

— pressure! temperature.

Microscopic

— don't exist. (emergent)

3 laws of thermodynamics.

1. Energy is conserved.
2. Entropy must increase (in a closed system).
3. ... not important.