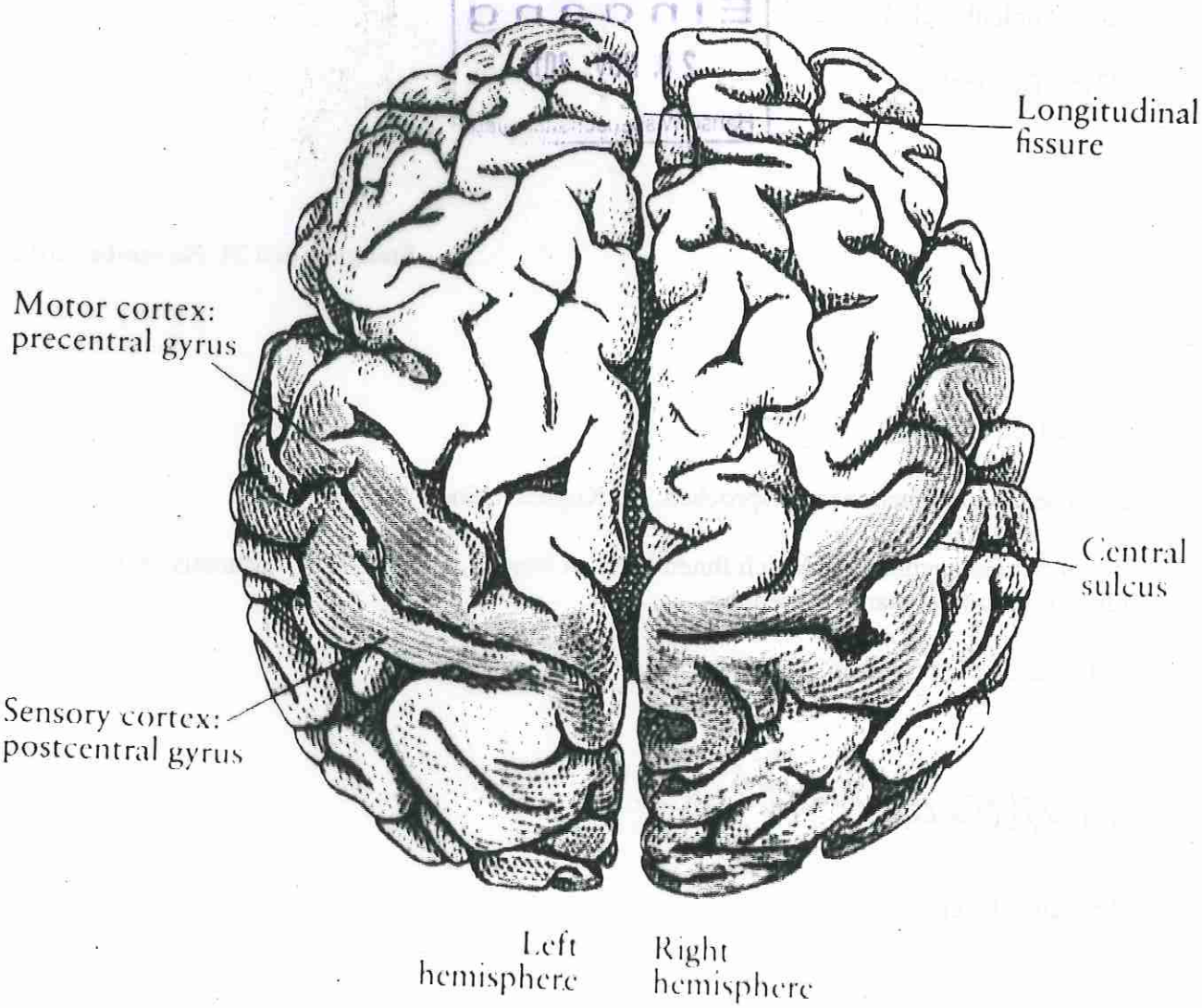
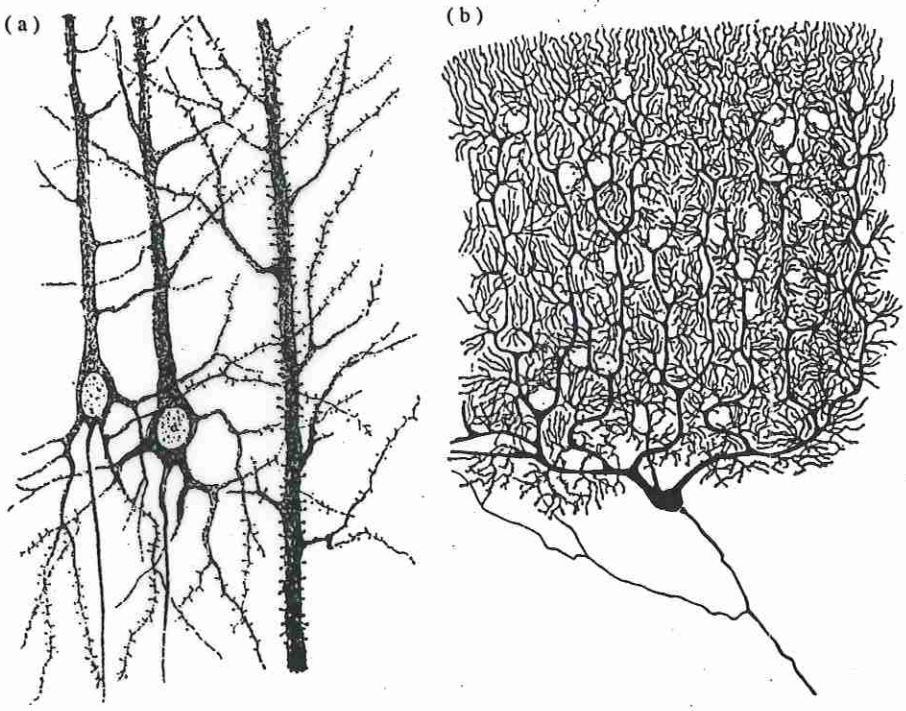

Longitudinal fissure
Motor cortex: precentral gyrus
Central sulcus
Sensory cortex: postcentral gyrus
Left hemisphere
Right hemisphere



2.3
a, b

Neuron

Brain

≈ 100 billion neurons
up to 10 000 connections
the most complex system

recognition: faces, objects, ...
movement control: arms, legs, ...
speech
thinking
feelings

who or what steers the neurons ?

Sir John Eccles ? ("computer")

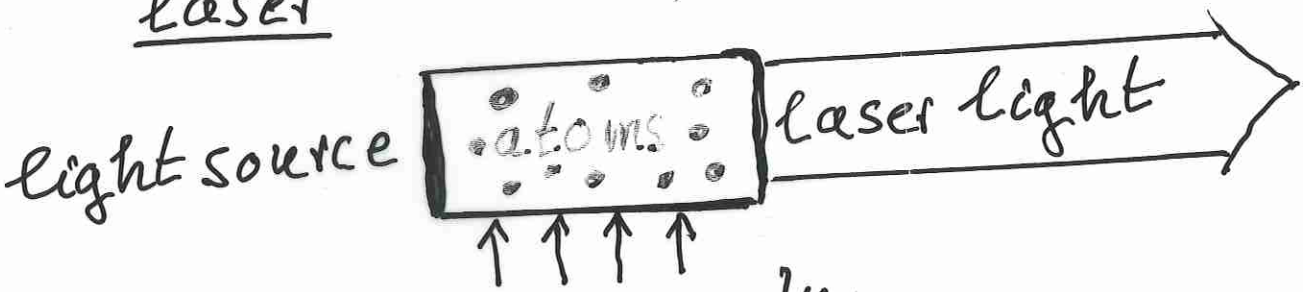
selforganization: synergetics

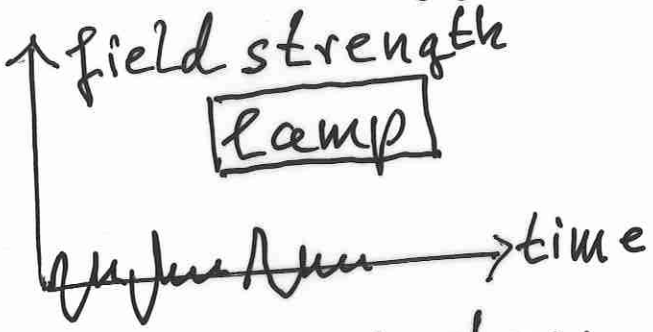
The brain as a synergetic and physical system

Synergetics

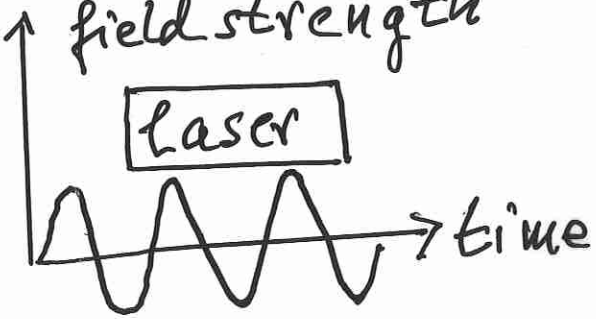
2 examples from physics

laser



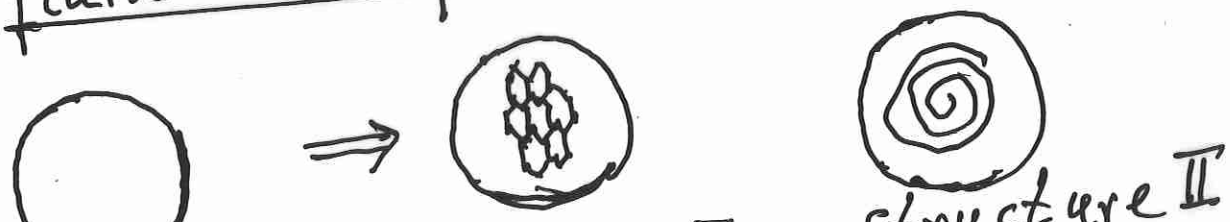


microscopic chaos



order

fluid heated from below

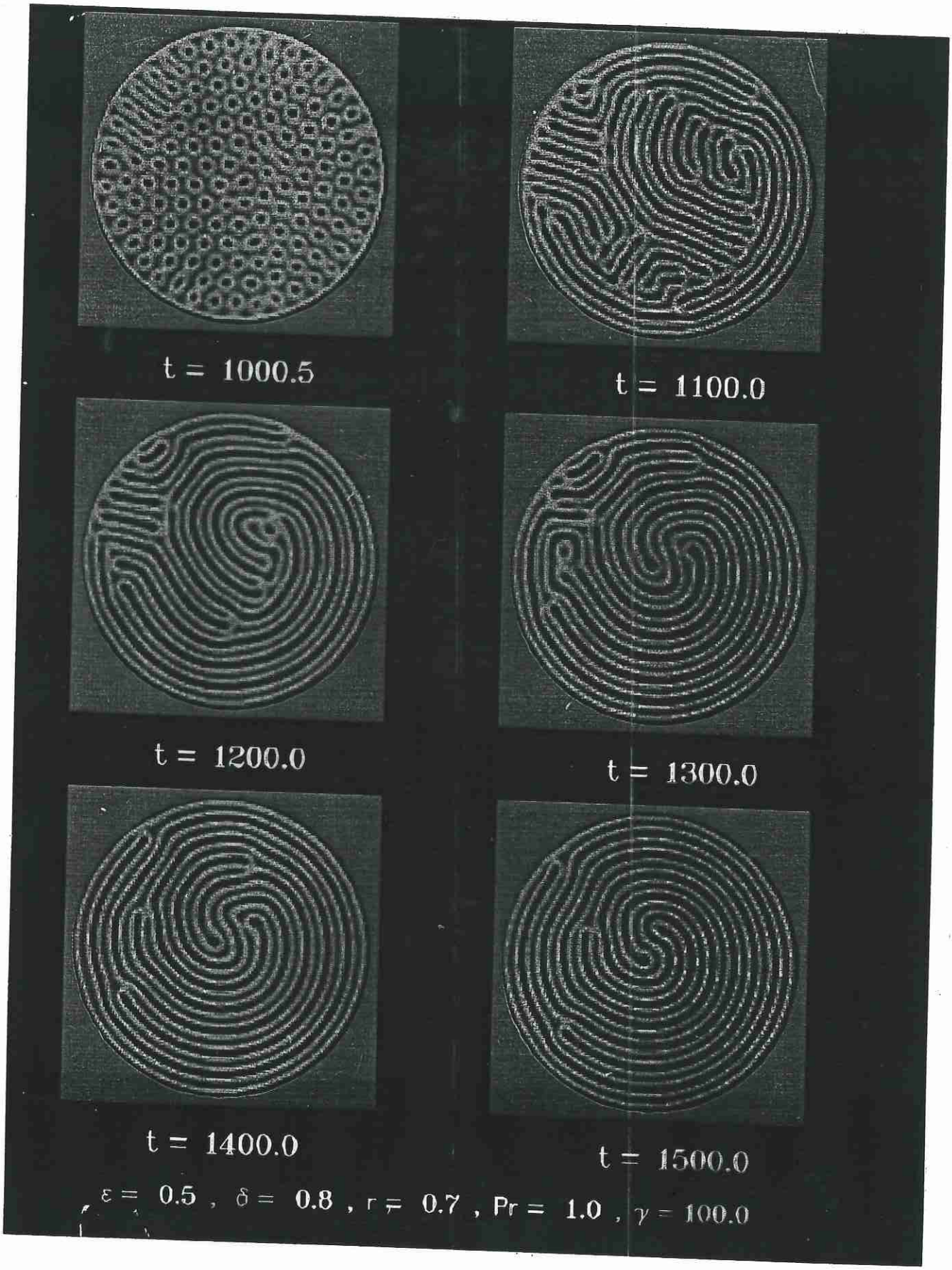


no structure

temporal, spatial, functional structures

emergence of new qualities

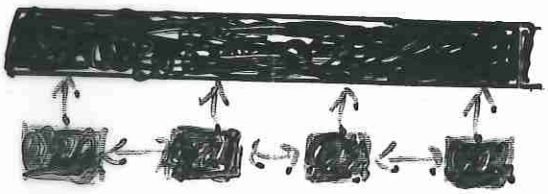
via self-organization


t = 1000.5
t = 1100.0
t = 1200.0
t = 1300.0
t = 1400.0
t = 1500.0
ε = 0.5 , δ = 0.8 , r = 0.7 , Pr = 1.0 , γ = 100.0

Basic concepts of Synergetics

system

macro



structures

micro

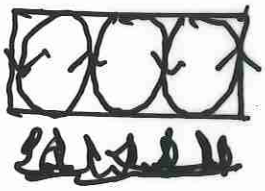
parts

control parameters

input of
energy, matter
information

⟹ [system]

fluid



T_2

T_1

temperature difference

$\Delta = T_1 - T_2$

brain coffein — blocks serotonin receptors

haldol — blocks dopamin$_2$ receptors

neurotransmitters
neuromodulators
hormones
internal control parameters

Instability

old state tends to disappear
critical fluctuations

order parameters

new collective variables
macroscopic descriptors
in general few, low dimensional dynamics

enslavement

order parameters, few

parts, many.

circular causality

order parameters

parts

"consensualization"

micro

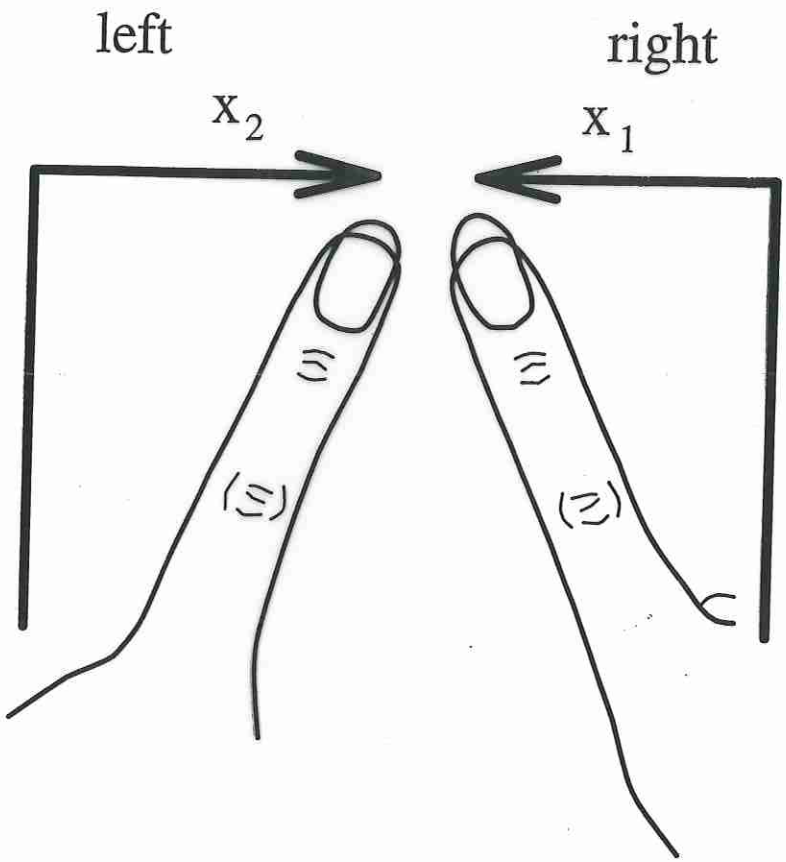
information compression
phenomenological

macro

The phenomenological level I

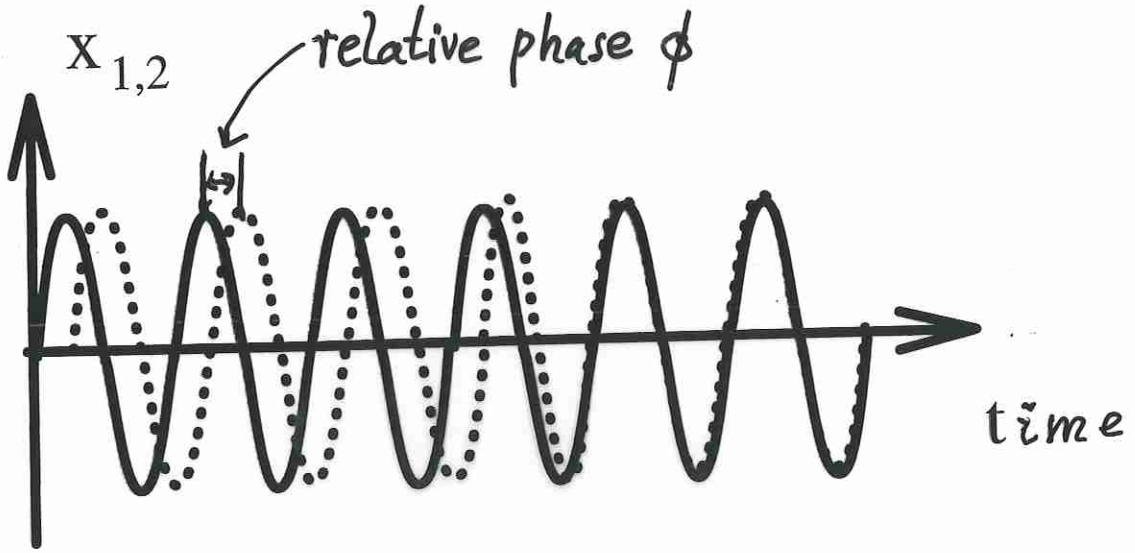
order parameters and movement coordination

Kelso experiment, HKB model


left
right
x_2
x_1

parallel

antiparallel

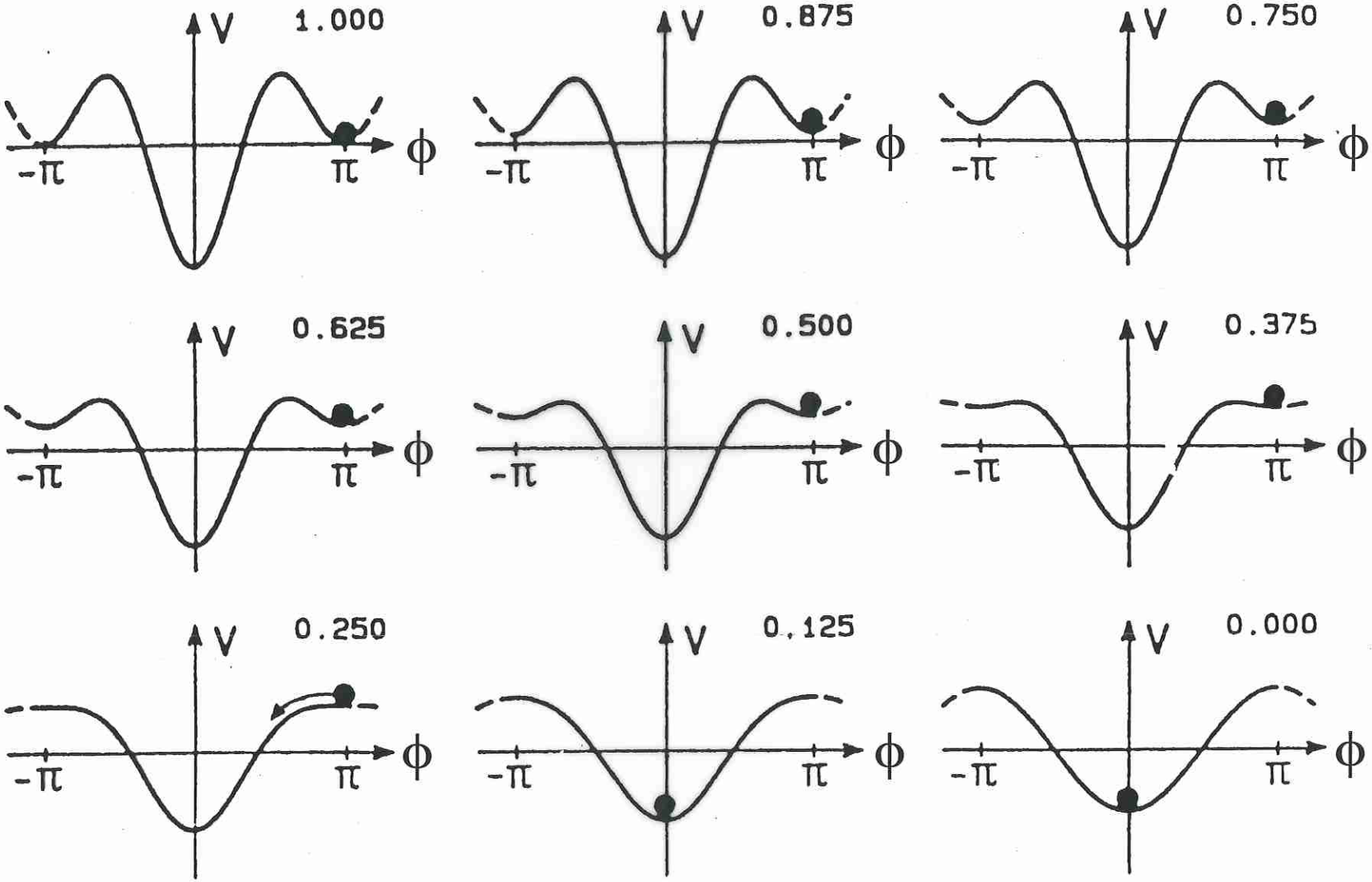

$x_{1,2}$
relative phase ϕ
time

control parameter: frequency ω

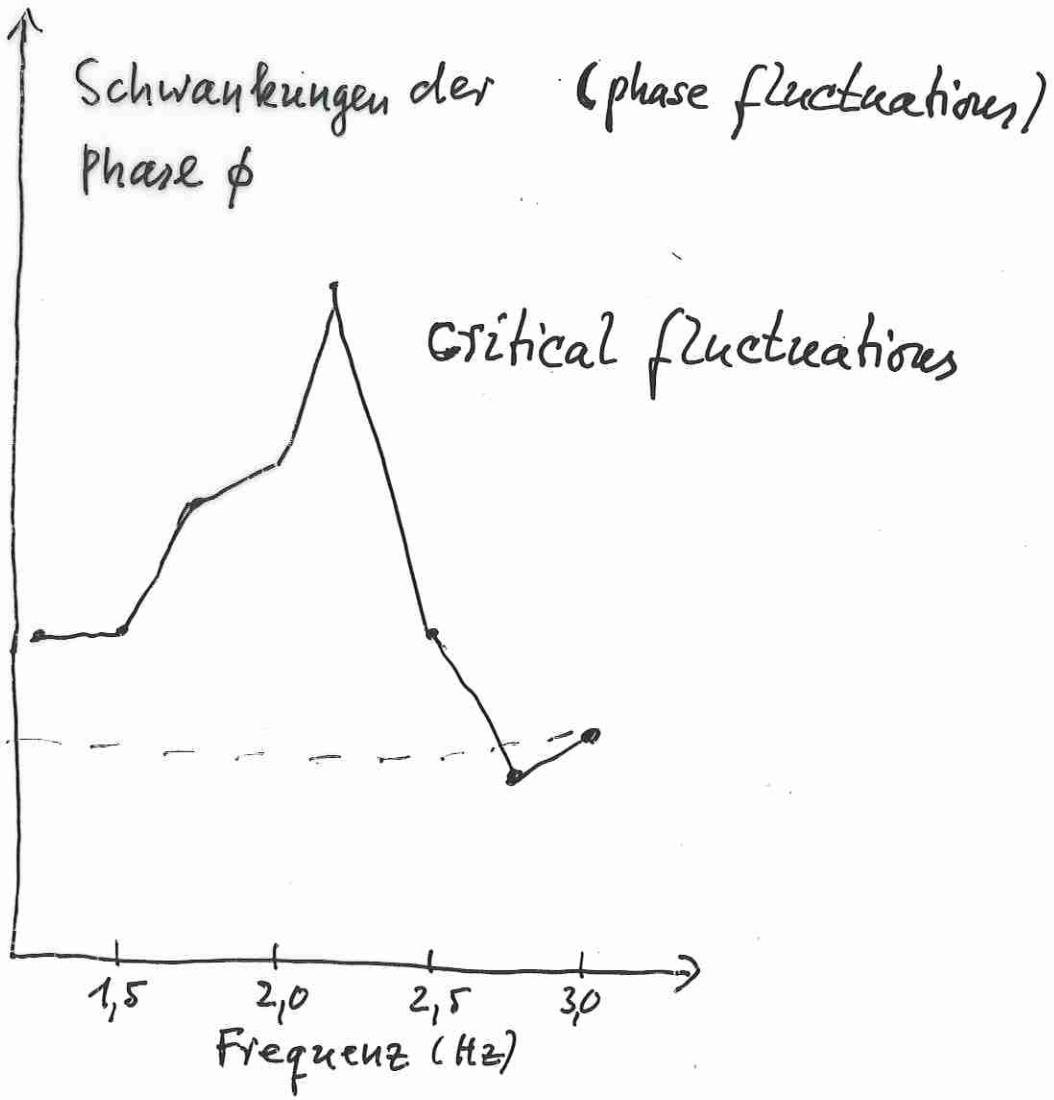
order parameter: relative phase ϕ

$$\frac{d\phi}{dt} = -\frac{\partial V(\phi)}{\partial \phi} + F(t)$$

V: "potential"


V
1.000
-π
π
ϕ
V
0.875
-π
π
ϕ
V
0.750
-π
π
ϕ
V
0.625
-π
π
ϕ
V
0.500
-π
π
ϕ
V
0.375
-π
π
ϕ
V
0.250
-π
π
ϕ
V
0.125
-π
π
ϕ
V
0.000
-π
π
ϕ

HKB-model.


Schwankungen der Phase φ
(phase fluctuations)
critical fluctuations
1,5
2,0
2,5
3,0
Frequenz (Hz)

conclusions

hysteresis

critical fluctuations

critical slowing down

no motorprogram

but

self-organization of the brain

⇒ synergetics

further work

experiment Kelso & his group

theory L. Borland, A. Daffertshofer, T. Frank, A. Fuchs, G. Schöner ...

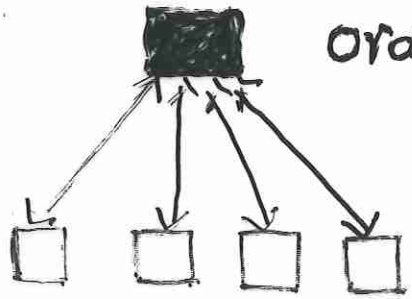
a general conclusion

only specific movement patterns

realization under specific conditions

The phenomenological level II

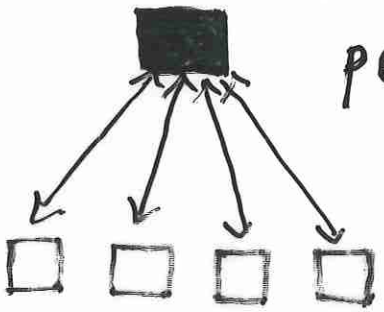
order parameters and psychophysics



order parameters slow

parts fast

brain



percepts 1/10 sec

neurons 1/1000 sec

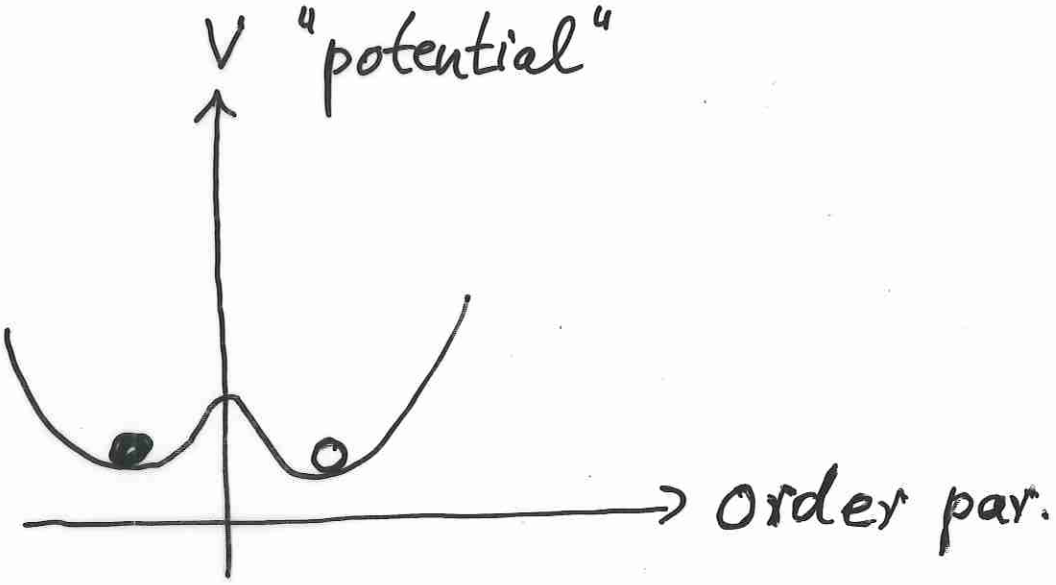
order parameter dynamics

in the brain

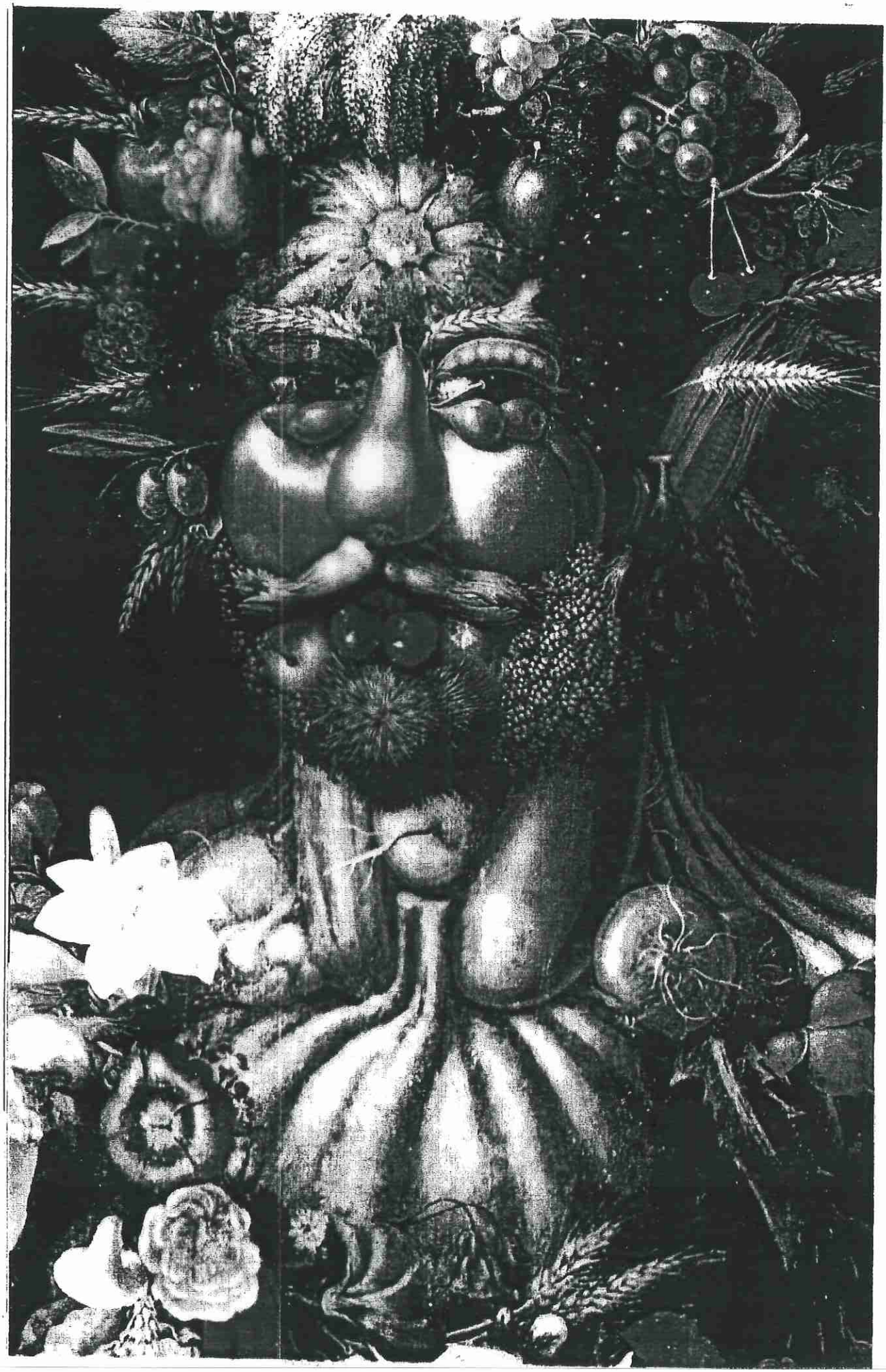
⇕

psychophysics

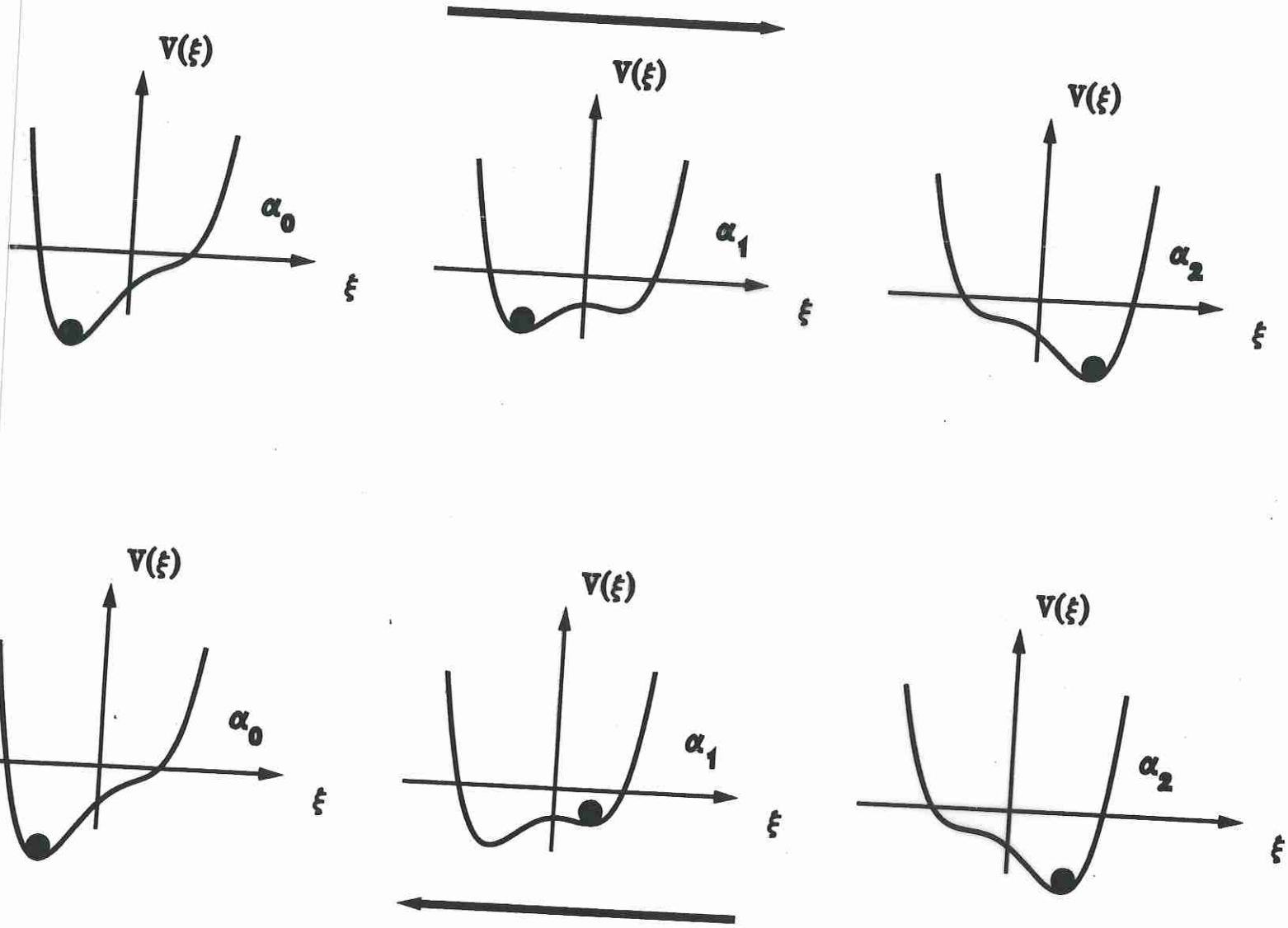
1 order parameter

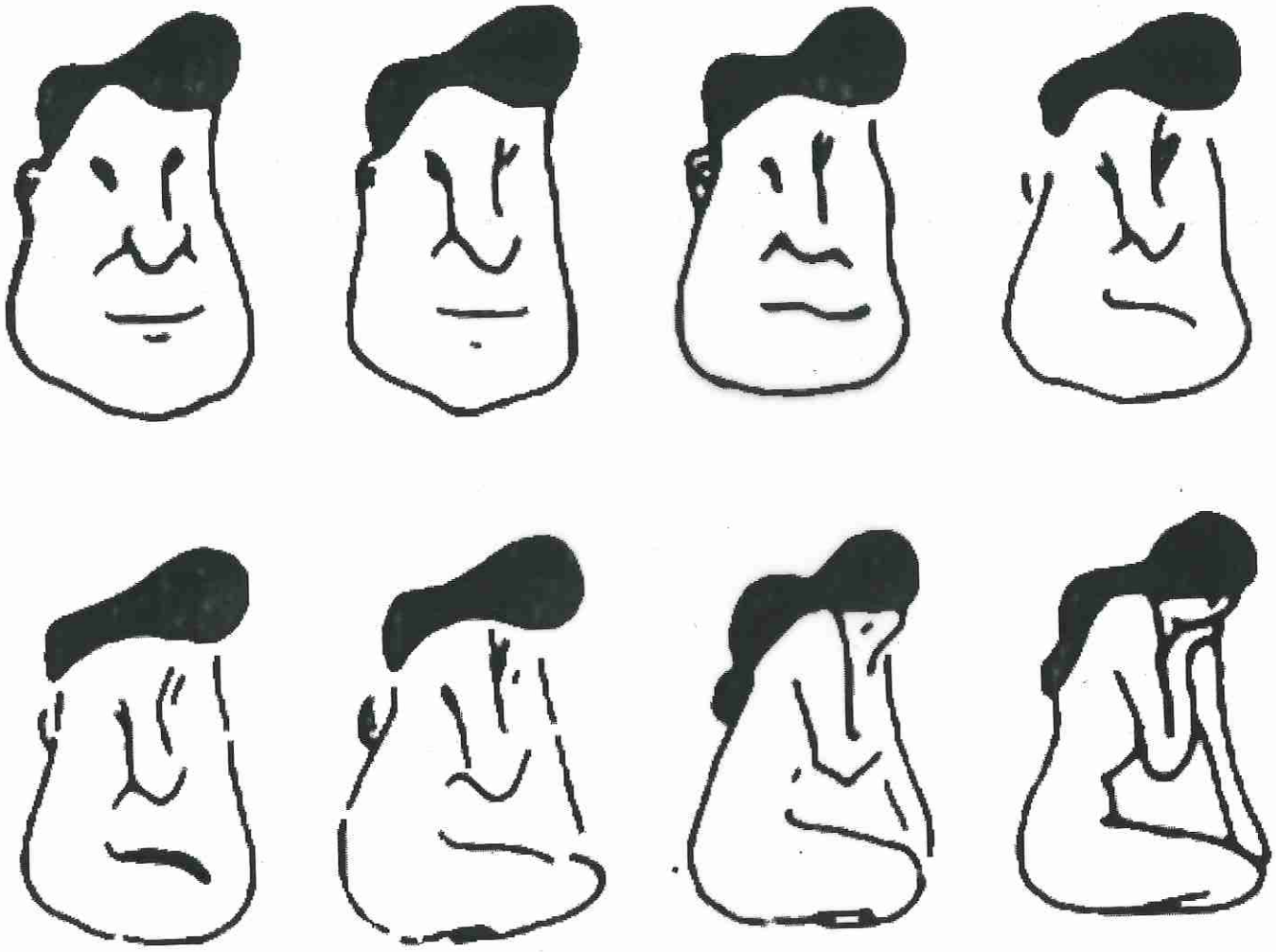


bistability

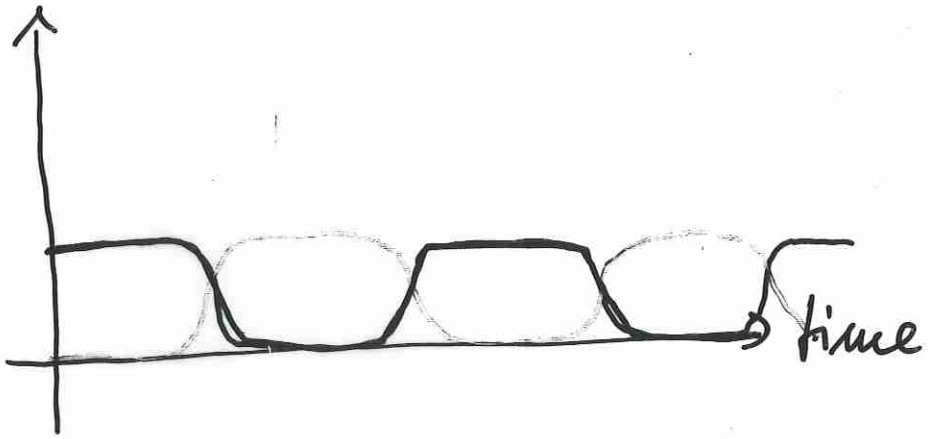


Hysteresis

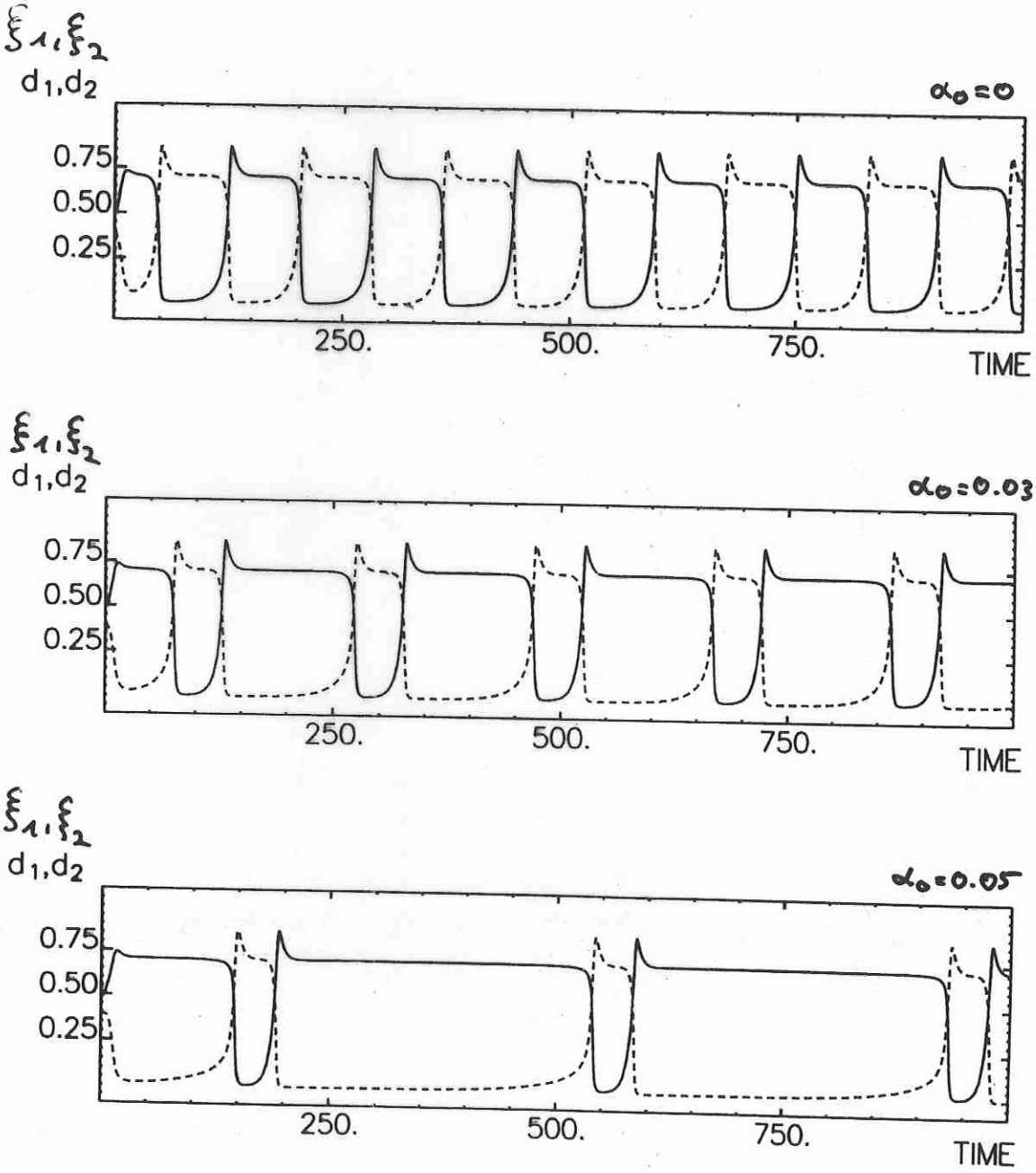




2 order parameters



oscillations



no bias

↓

zunehmendes α_0 bias

↓

large bias

$\gamma = 0.1,\ \beta = 0.8,\ c = 1$

H. & T. Ditzinger

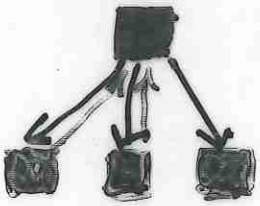
Down to the microscopic level: models

pattern recognition by the
synergetic computer

based on order parameter dynamics

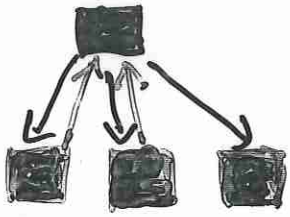
analogy

pattern formation pattern recognition



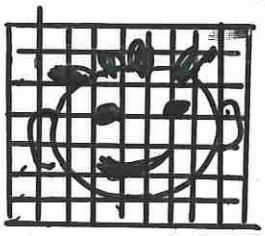
parts

order param.



features
e.g. grey values of pixels

H.: algorithm
Armin Fuchs: implementation
invariance



$$\underbrace{q(t)}_{\uparrow} = \sum_k \xi_k(t) \underbrace{v_k}_{\uparrow} + \text{rest}$$

pixel vector ord. par. prototypes

$$\frac{d\xi_k}{dt} = \xi_k\left(\underbrace{\lambda_k}_{\uparrow} + a\xi_k^2 - b\sum_{l}\xi_l^2\right)$$

attention parameters

A
B
C
D
E
F
G
H
I

I
I
D
D

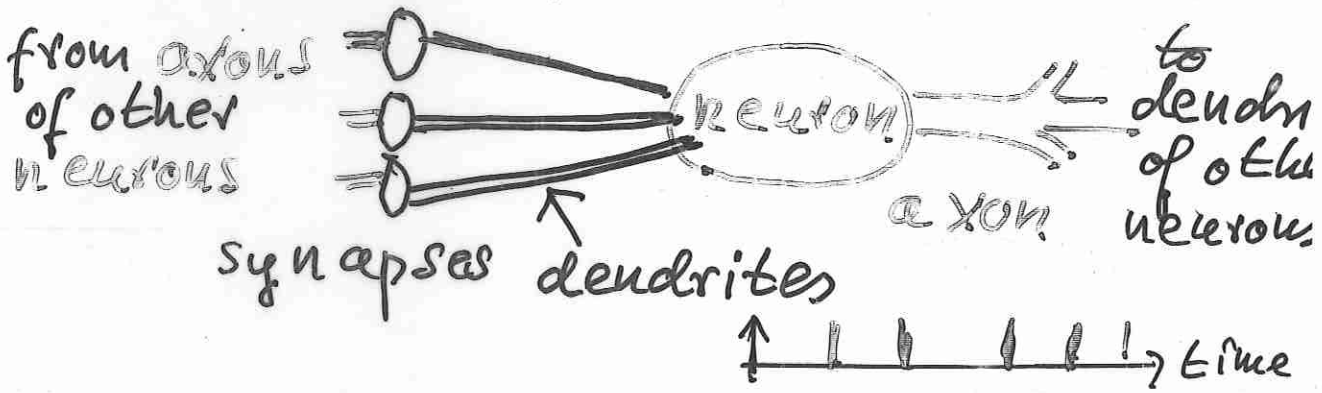
Down to the physical level of the brain

The dynamics of "real" neurons

A. Daffertshofer, T. Frank, V. Jirsa, P. Tass,

H.: "Eight house" model

Brain dynamics, Springer Verlag, 2002, 2007



neuron emits spike trains into axon

synapses convert spikes into el. currents

dendrites carry el. currents

neuron: sums up, "fires" beyond threshold

axon: transports spikes

The basic equations

1) electric current of dendrite m

ψ_m is generated by

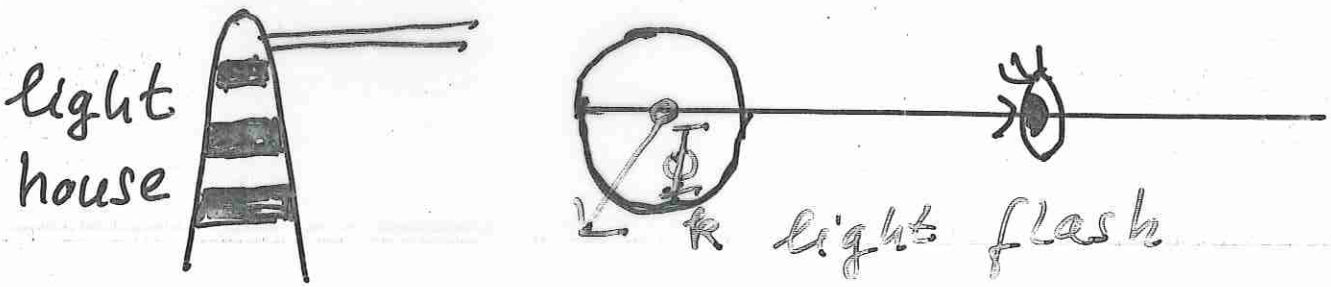
axonal pulse P_k from neuron k

$$\left(\frac{d}{dt}+\gamma\right)^{\alpha}\psi_m = a_{mk}\,\dot{P}_k$$

γ: damping, $1<\alpha<2$

a_{mk}: transformation rate, experimt. determined

2) pulse production by neuron k



$$\Phi_k(t_n) = 2\pi n, \quad n = 1, 2, 3, \ldots$$

rotation speed determined by dendritic curr.

$$\frac{d}{dt}\Phi_k(t) + \Gamma\Phi_k(t) \bmod 2\pi = \sum_m c_{km}\psi_m + \sum_{ml} d_{kml}\psi_m\psi_l + P_k$$

P_k: external signal

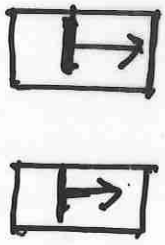
from basic equations to

→ synergetic computer:
pattern recognition

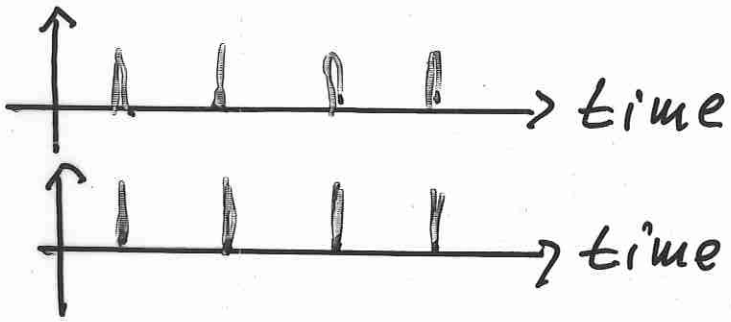
→ pulse train synchronization

experiments: Gray, Singer, Eckhorn
(local field potentials)

moving bars



visual fields



spike trains synchronized !

Down to the molecular level

axon

transport / quantum theory !

Haken / Levi

Synergetic Agents

Wiley 2012 (September)

Outlook

Back to the phenomenological level

Psychology and psychotherapy

order parameters ↔ behavioral patterns
phase transitions:
Günter Schiepek: critical fluctations
qualitative changes

the principle of indirect steering

interventions: verbal, drugs

body-mind: two sides of the same coin (Spinoza)

parts ↔ order parameters (ontology!)

the problem of qualia:

an eternal enigma ?!