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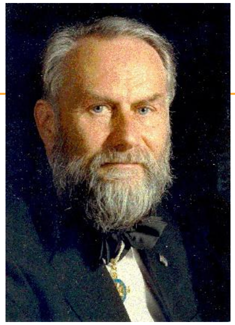
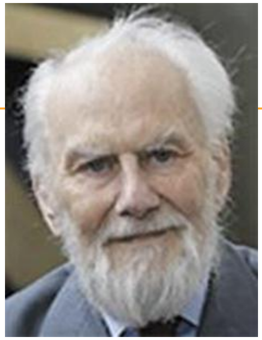
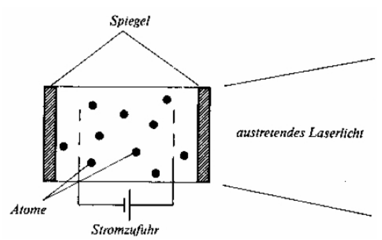
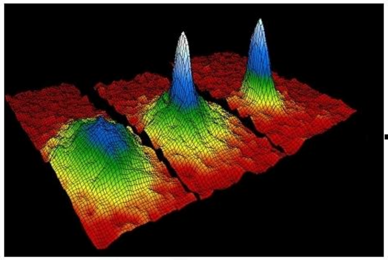
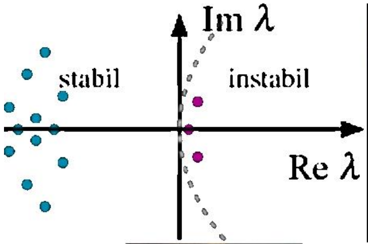



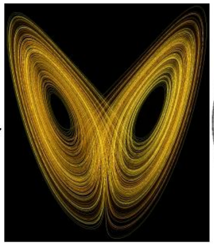
# Hermann Haken
# His roadmap to synergetics

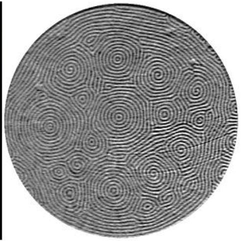
**Laser**



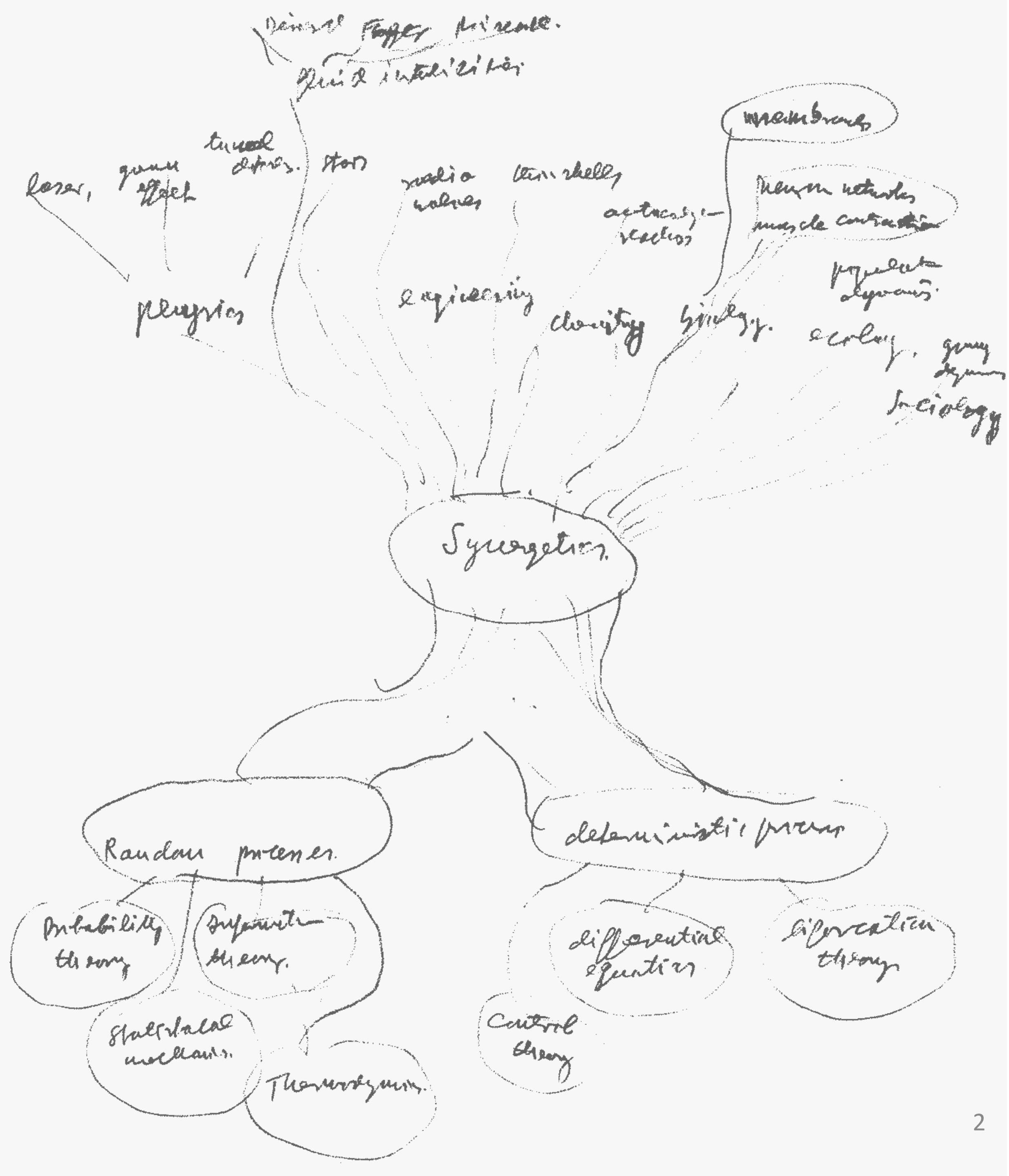


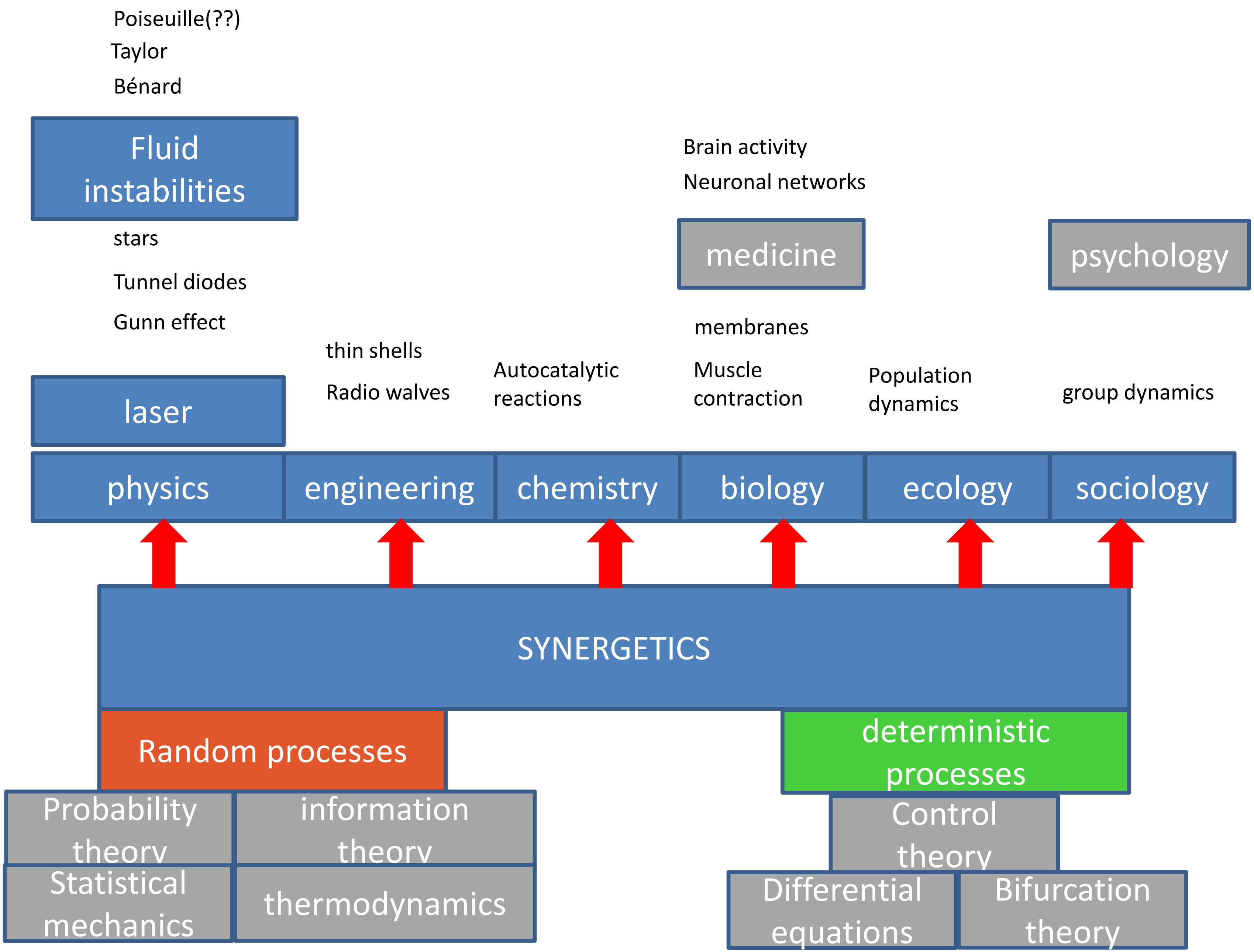





Bernd Kröger
Tübingen (and: Institute for the History of Science and Technology (GNT)
at the University of Stuttgart)

# The „Synergetics Tree“ according to Hermann Haken (ca. 1985)




Poiseuille(??)
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Bénard
Fluid instabilities
stars
Tunnel diodes
Gunn effect
laser
thin shells
Radio walves
Autocatalytic reactions
Brain activity
Neuronal networks
medicine
membranes
Muscle contraction
Population dynamics
psychology
group dynamics
physics
engineering
chemistry
biology
ecology
sociology
SYNERGETICS
Random processes
Probability theory
information theory
Statistical mechanics
thermodynamics
deterministic processes
Control theory
Differential equations
Bifurcation theory

# The historical development from 1953 - 1983

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**Solid state physics** (quantum mechanics, statistical physics, exciton theory, quantum field theory, superconductivity)

**Laser physics** (nonlinear optics, noise, theory of dissipative systems far from thermodynamic equilibrium, order parameter, slaving principle)

**Phase transition theory** (symmetry breaking, critical slowing down, big fluctuations)

**SYNERGETICS (Theory of Self-Organization)**

**Deterministic Chaos** (Bifurcation Theory)

**Pattern formation and pattern recognition** in nature and by computer

**Information theory**

**Neural activity and brain function**

Synergetic Applications to **Psychology**

# The Erlangen Years

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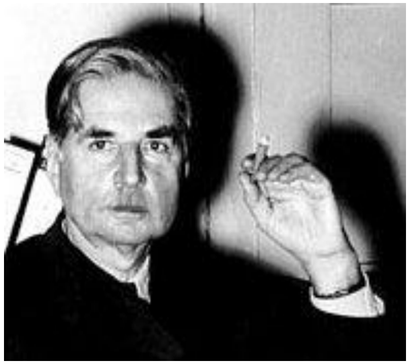

Walter Schottky (*1886 – †1976) ca. 1954

Eberhard Spenke (*1905 – †1992) 1954

Hermann Haken ca. 1957

Wilhelm Specht (*1907 - †1985)

Helmut Volz (*1911 – †1978)

Learning the Second Quantization
and Quantum Field Theory
by helping Spenke to write a book

# Hermann Haken and his connection to Herbert Fröhlich

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Zeitschrift für Physik, Bd. 146, S. 527—554 (1956)

Aus dem Institut für Theoretische Physik der Universität Erlangen

**Zur Quantentheorie des Mehrelektronensystems im schwingenden Gitter. I**

Von

HERMANN HAKEN

*(Eingegangen am 2. August 1956)*

Zeitschrift für Physik, Bd. 146, S. 555—570 (1956)

Aus dem Institut für Theoretische Physik der Universität Erlangen

**Zur Quantentheorie des Mehrelektronensystems im schwingenden Gitter**

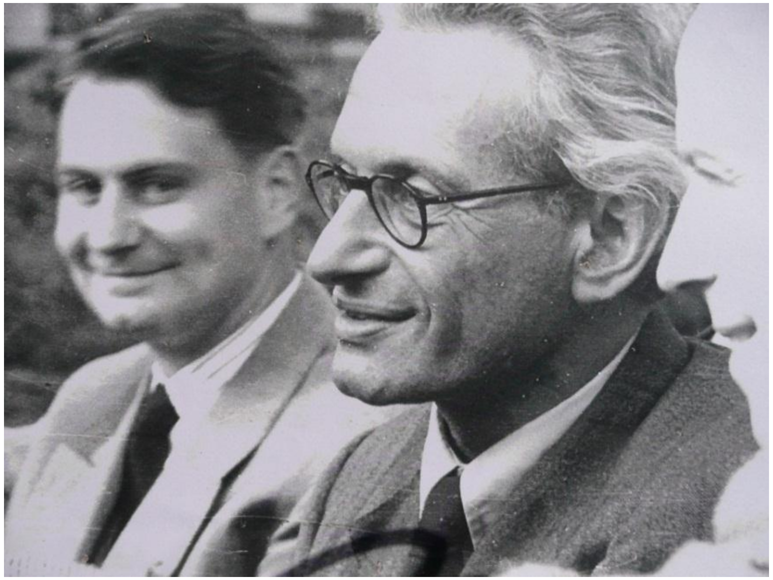
**II. Zu FRÖHLICHs eindimensionalem Supraleitungsmodell***

Von

HERMANN HAKEN

*(Eingegangen am 2. August 1956)*

Paper introducing the „Haken-Potential“ for excitons (electron-hole pairs in semiconductors)



Hermann Haken and Herbert Fröhlich (early 60‘)

# Referee quotes on Hermann Haken (1960)

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„Dr. Haken gehört sicher in die erste Reihe der auf dem Gebiet der Festkörperphysik arbeitenden jungen theoretischen Physiker, insbesondere hat er sich durch seine Arbeiten über Excitonen in nichtmetallischen Kristallen ein internationales Ansehen erworben.

(Dr. Haken is one of the leading young theoretical physicists working in the field of solid state physics. He has achieved international recognition for his work on excitons in nonmetallic cristals.)

Cited from Personalakte Hermann Haken: Vorlage der Berufungskommission an den Großen Senat der TH Stuttgart vom 12.1.1960, Seite 2.

Er ist der einzige deutsche Theoretiker, der die allgemeinen Methoden der quantenmechanischen Feldtheorie erfolgreich auf Festkörperprobleme anwendet.“

(He is the only german theoretician who in problems of solid state physics successfully applies the general methods of quantum-mechanical field theory.)

H. Haken: *A Nonlinear Theory of Laser Noise and Coherence.*
Zeitschrift für Physik **181** (1964), 96 - 124

**„In contrast to linear theories there exists a marked threshold.**
**Below it the amplitude decreases after each excitation exponentially and the linewidth turns out to be identical with those of previous authors […]**
**Above the threshold the light amplitude converges towards a stable value, whereas the phase undergoes some kind of undamped diffusion process".**

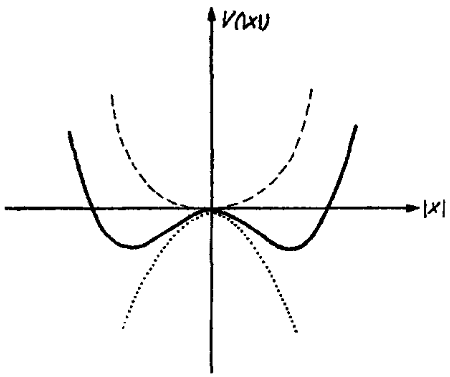
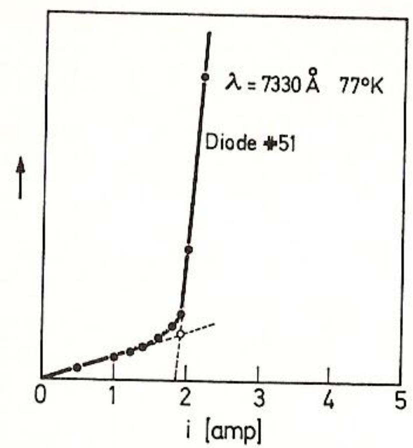



**Fig. 2.** Plot of "potential energy" versus light amplitude. – – – below threshold (*linear and nonlinear* theory); ········ above threshold, *linear* theory leads to instability; ——— above threshold, *nonlinear* theory




Start of laser-action at the threshold
(later experimental data)

In 1964 H. Haken showed that laser light above threshold differs completely from the light emitted below threshold.

# The Laser years 1962 – 1970 (and beyond)

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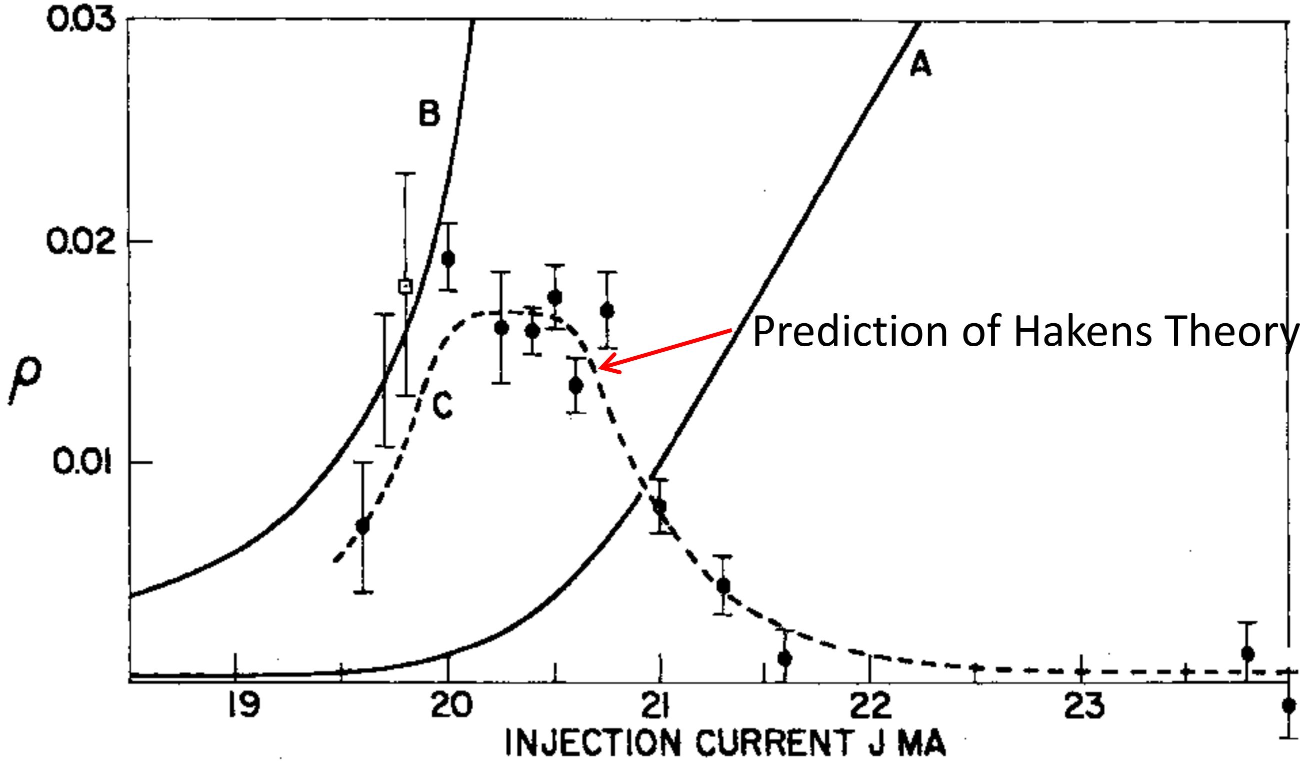
**In this paper Haken also predicts the decline of the Laser-Amplitude-Fluctuations with increasing pump-strength. This was confirmed by experiments in the following year 1965.**




from: J. Armstrong; A. Smith: Intensity Fluctuations in a Gaas Laser, Phys. Rev. Lett. 14 (1965), 68

# The 1964 Laser article

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H. Haken: *A Nonlinear Theory of Laser Noise and Coherence.* Zeitschrift für Physik **181** (1964), 96 - 124

"in this paper I introduced noise. Before, noise has only been calculated for the [electromagnetic] field, but noise for the atoms occured for the first time. The other novelty has been the operator method according to Heisenbergs second quantisation formalism. First of all the elimination procedure: the adiabatic method was known, but it was new that you are able to do it with quantum mechanical operators. And so was the Ansatz for the field operator. To split the operator into a classical and a quantum mechanical part, that was also new."

H. Haken: Interview October 2012

# Pioneers and creators of QM-Lasertheory

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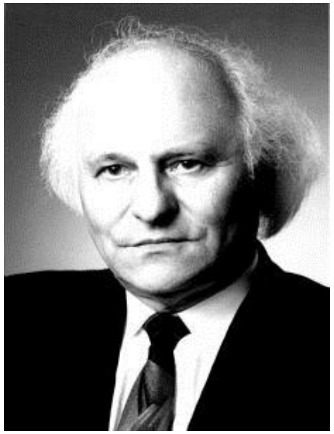
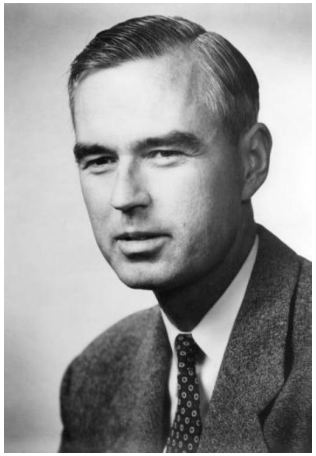
Hermann Haken



Wolfgang Weidlich

Hannes Risken



Willis Lamb jr.

Melvin Lax

# Distribution of papers concerning QM-Lasertheory (different „schools“)

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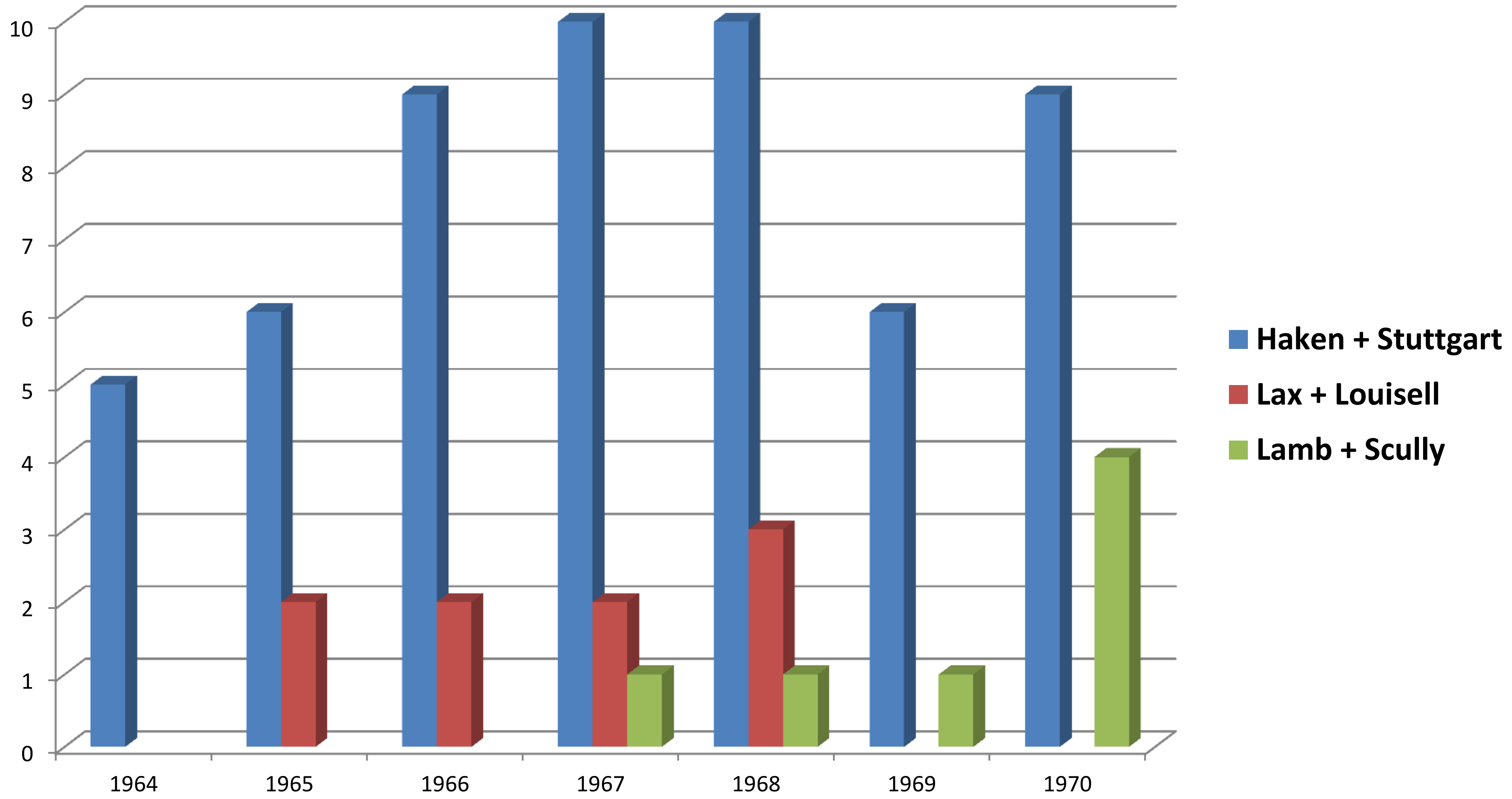

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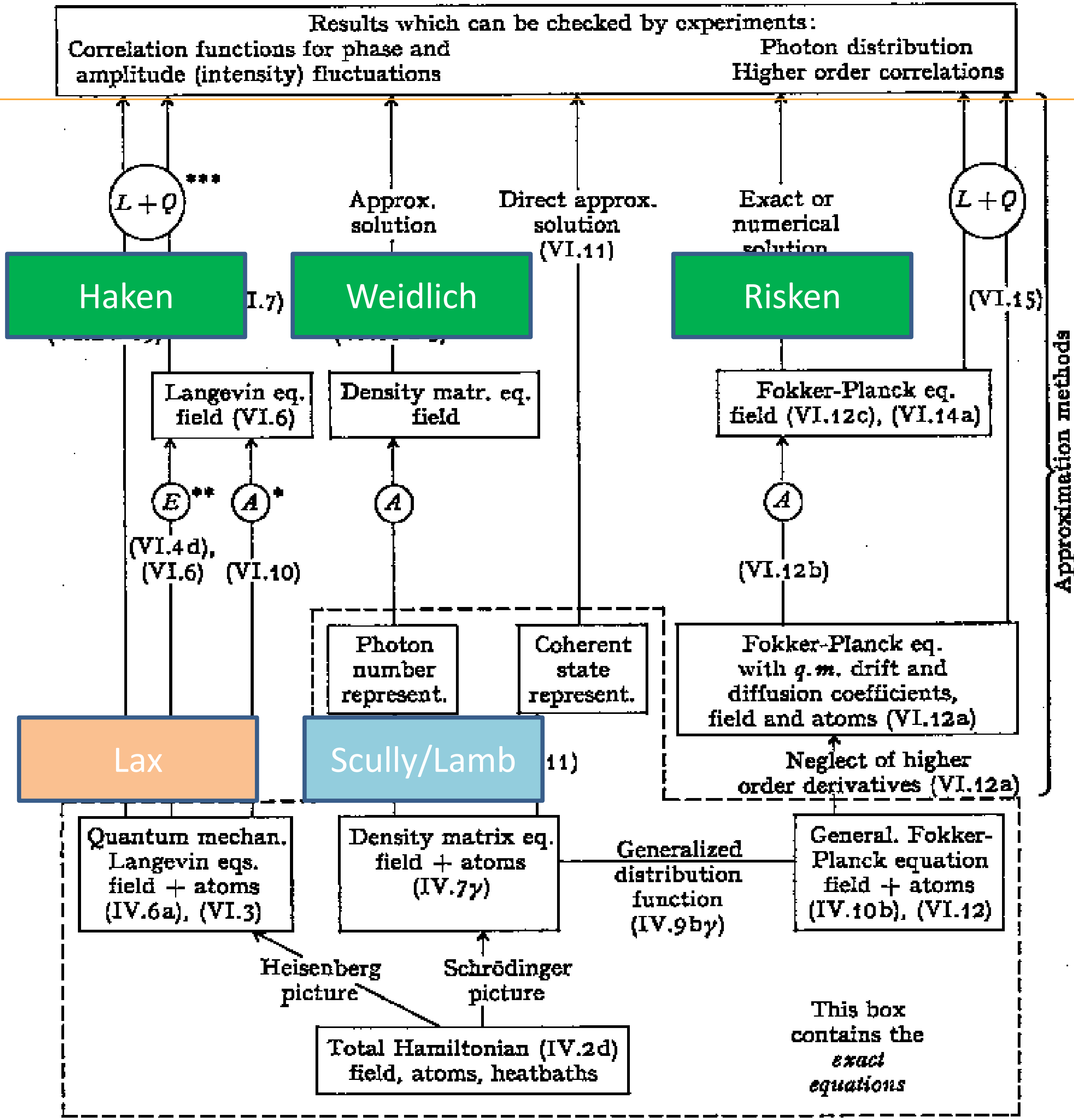

# The Stuttgart School of Laser Theory

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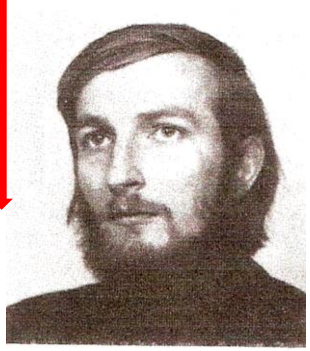
Haken ca. 1970

Risken1969

Weidlich 1967

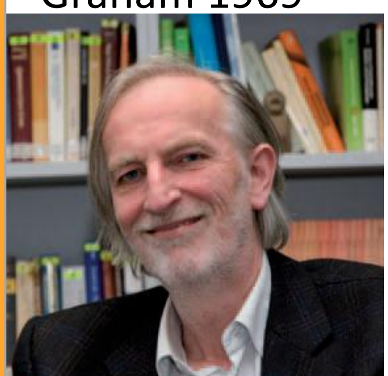


Graham 1969

Haug 1967

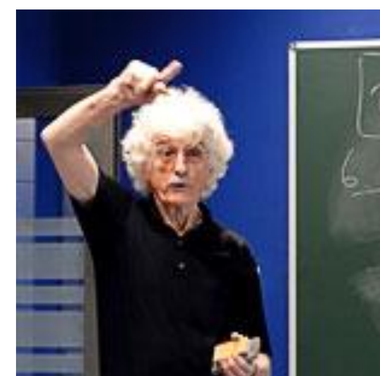
Sauermann 1963

Haake 1967



Graham 2008

Haug 2008



Haake ca. 200?

# The Question for life

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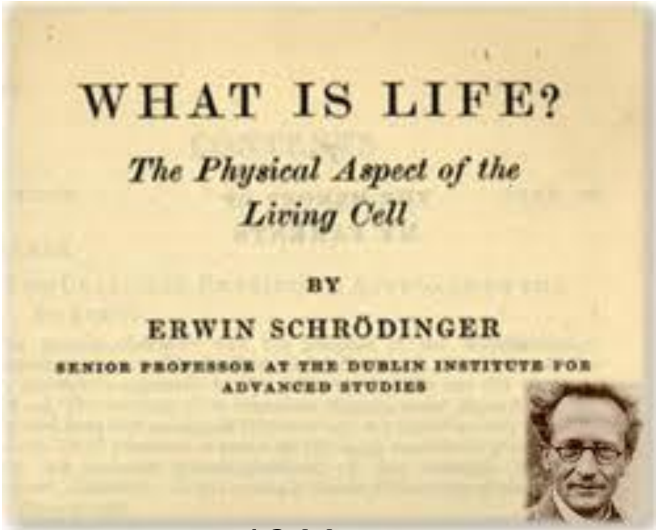
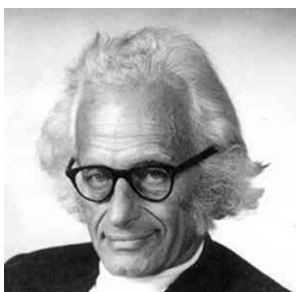



1944

E. Wigner (1961)(Nobel prize 1963):
„On the probability of the Existence of a Self-Reproducing Unit"

… the present laws and concepts of quantum mechanics will have to undergo modifications before they can be applied to the problem of life."



…"eventually Fröhlich agreed to help organize what was to be the first of many successfull international Conferences on theoretical physics and biology that were to be held, under the auspices of l'Institut de la Vie, at the Trianon Palace Hotel in Versailles. These conferences which continued, biennially, until 1988, were attended by highly eminent physicists and biologists, including such people as Onsager, Prigogine, Crick, Edelman, Cooper and Wigner himself."

Maurice Marois

# The „Versailles“ Conferences of the „Institut de la Vie“

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*INSTITUT DE LA VIE*

## THEORETICAL PHYSICS AND BIOLOGY

*Proceedings of The First International Conference on Theoretical Physics and Biology,*
*Palais des Congrès, Versailles, 26–30 June 1967*

*Edited by*
M. MAROIS

ORGANIZING COMMITTEE

P. AUGER (Paris) – A. FESSARD (Paris) – H. FRÖHLICH (Liverpool) – P. P. GRASSÉ (Paris) – A. LICHNEROWICZ (Paris) – I. PRIGOGINE (Bruxelles) – L. ROSENFELD (Copenhagen) – M. MAROIS, Conference General Secretary

SPONSORS

*M. le Ministre d'Etat Chargé de la Recherche Scientifique et des Questions Atomiques et Spatiales (France)*

*International Union of Pure and Applied Physics*

1969
NORTH-HOLLAND PUBLISHING COMPANY
AMSTERDAM • LONDON

Conferences on ***Theoretical Physics and Biology***

Participation of

| | |
|---|---|
| 1967: Versailles: | Haken, Prigogine, Eigen |
| 1969: Versailles: | Haken, Prigogine, Eigen |
| 1971: Versailles: | Haken, Prigogine, Eigen |
| 1973: Versailles: | Haken, Prigogine, Eigen |
| 1975: Versailles: | Haken |
| 1977: Versailles: | Haken, Prigogine |
| 1979: Wien: | Haken, Prigogine, Eigen |
| 1981: Versailles: | Haken |
| 1984: Lille: | Haken |
| 1988: Versailles | |

# Conferences „From Theoretical Physics to Biology“: Topics

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**Versailles 1967:**

- statistical mechanics,
- dissipative structures,
- neurocybernetics,
- physical chemistry of life,
- Non-equilibrium thermodynamics;
- Information in biology;
- Mechanism in Physiology

**Versailles 1969:**

- Order in systems;
- structures and the maintenance of life;
- Self-Organization;
- Dissipative Structures in Biology;
- Mutations and Evolution;
- Information and biological Systems;
- Information Storage in the central nerveous System.

# Analogy Laser - Superconductivity

In 1969 Graham and Haken found a laser-expression that showed a nearly perfect analogy to the Ginzburg-Landau expression of superconductivity

**Laser equation**

$$f = N \exp\left(-\frac{B}{Q}\right)$$

$$B = \int \left\{ \alpha |E(x)|^2 + \beta |E(x)|^4 + \gamma \left| \left( \frac{d}{dx} - i \frac{\omega_0}{c} \right) E(x) \right|^2 \right\} dx$$

<u>Ginzburg-Landau theory of superconductivity</u>

$$f = N \exp\left(-\frac{F}{kT}\right)$$

$$F = \int \left\{ \alpha |\psi(x)|^2 + \beta |\psi(x)|^4 + \frac{1}{2m} \left| \left( \nabla - \frac{2ei}{c} A \right) \psi(x) \right|^2 \right\} d^3x$$

# The Laser Phase-Transition Analogy

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Hermann Haken:
„as Graham and I looked at this expression, we were highly reminded of the Ginzburg-Landau Theory. A comparison of the laser-expression and the expression auf Ginzburg-Landau showed a perfect analogy. […] So we concluded that the laser must have the same statistical properties at the phase-boundary as it is shown by superconductors.“

Hermann Haken: Talk given at the spring meeting of the german physical society in Freudenstadt (April 1970)

R. Graham, H. Haken: Laserlight – first example of a second order phase-transition far away from thermal equilibrium, Zs. f. Physik 237 (April 1970), 31 – 46

M. Scully, V. deGiorgio: Analogy between the Laser Threshold Region and a Second-Order Phase Transition. Physical Review A2 (October 1970), 1170

# The Concept of flux equilibria

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Volume 32A, number 2 PHYSICS LETTERS 15 June 1970

The concept of flux equilibria ("Fliessgleichgewichte") was originally coined by a biologist [1]. Recently it was applied by Weidlich to nuclear reactions [2]. This concept applies to the following situations: A system, in particular a quantum system, is coupled to reservoirs at different temperatures, so that there is a flux of energy through it. This energy flux may cause new stable configurations of the system, which are not present in complete thermal equilibrium.

RMAL

We expect further applications not only to active devices in solid state physics (e.g. the Gunn oscillator), but also in astrophysics and biology.

# Finding „Detailed Balance“

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Z. Physik 243, 289–302 (1971)


## Generalized Thermodynamic Potential for Markoff Systems in Detailed Balance and far from Thermal Equilibrium

R. Graham and H. Haken
Institut für Theoretische Physik der Universität Stuttgart

Received January 6, 1971

We analyze the question why there exist systems far from thermal equilibrium, e.g. lasers, whose stationary state may be described by a potential function, which has all the properties of a thermodynamic potential. It is argued, that the physical property, common to thermal equilibrium states and to these more general stationary states is detailed balance.

**!**

This shows that detailed balance can provide a basis for a unified description of both the thermal equilibrium systems and some more general stationary states far from thermal equilibrium. Our potential function appears as a natural generalization of thermodynamic potentials to more general stationary states with detailed balance.

# The „Umschau“ paper on Synergetics

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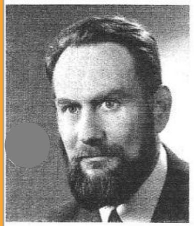
Hermann Haken, Robert Graham

## Synergetik — die Lehre vom Zusammenwirken

**Was verbindet die Physik, Chemie und Biologie?**



*In der letzten Zeit hat sich eine neue Forschungsrichtung entwickelt, die es gestattet, Erscheinungen in ganz verschiedenen Gebieten, wie Physik, Chemie, Biologie und sogar Soziologie, unter einem gemeinsamen Gesichtspunkt zu behandeln. In der Tat gelingt es hier, überraschende gemeinsame Gesetzmäßigkeiten etwa zwischen folgenden Problemen aufzudecken: Welchen Regeln gehorcht das Laserlicht, die Struktur eines Waldes, die Bildung eines Enzyms, die Entstehung des Lebens, die Entwicklung der Sprache? Das gemeinsame Problem, um das es sich hierbei handelt, ist folgendes: Obwohl die Untersuchungsobjekte, z. B. in der Physik ein Körper oder in der Biologie eine Zelle, aus sehr vielen Untersystemen bestehen, so wirken sie doch nach außen hin als ein charakteristisches Ganzes, dessen Eigenschaften meist nicht einfach durch eine zufällige Überlagerung der Untersysteme zustande kommen. Vielmehr scheint es gewisse, zunächst geheimnisvoll anmutende Ordnungsprinzipien zu geben, die ein konstruktives Zusammenwirken der Untersysteme hervorrufen. Nach welchen Gesetzen gelingt es nun der Natur oder auch dem Menschen, derartige Ordnungen zu erzeugen? Da eine Reihe von Ordnungen oder Ordnungszuständen in der Physik am besten erforscht sind, liegt es nahe, mit diesen zu beginnen. Wir betonen aber, daß wir in keiner Weise versuchen, die Biologie oder gar die Soziologie auf die Physik zurückzuführen. Es ist lediglich so, daß die relativ einfachen Erscheinungen der Physik uns inspirieren können, Begriffe und Methoden zu entwickeln, die auch in anderen Gebieten wesentlich neue Einblicke gewähren.*

Uns allen sind die Aggregatzustände („Phasen“) der Materie, fest, flüssig und gasförmig, geläufig. Im gasförmigen Zustand fliegen die Bestandteile der Materie, die Atome oder Moleküle, völlig ungeordnet durcheinander. Im flüssigen Zustand halten die Atome einen mittleren gegenseitigen Abstand ein, sind aber noch gegeneinander verschieblich. Beim Idealfall des festen Körpers, dem Kristall, sind die einzelnen Atome schließlich räumlich streng periodisch angeordnet. Die verschiedenen Phasen unterscheiden sich aber nicht nur durch die geometrische Anordnung der Atome oder Moleküle, sondern auch durch physikalische Eigenschaften. So können sich der elektrische Widerstand,

bei dem Ferromagnetismus werden, ebenfalls beim Abkühlen, gewisse Stoffe magnetisch. Ähnlich wie vorher die geometrische Anordnung der Atome Anlaß zum Kristallgitter gaben, sind es nun Ordnungsbeziehungen zwischen den Elektronen, die als Ursache für diese neuen Erscheinungen angesehen werden können. So ordnen sich z. B. in Supraleitern die Elektronen jeweils zu Paaren an. Beläßt man die Stoffe auf der tiefen Temperatur im thermischen Gleichgewicht mit ihrer Umgebung (wobei „tief“ relativ zu verstehen ist), so bleiben die neuen ungewöhnlichen Eigenschaften erhalten; andererseits werden sie durch Energiezufuhr z. B. in Form von Wärme, wieder zer-

*Prof. Dr. H. Haken,*
*Institut für Theoretische Physik der Universität Stuttgart.*
*Geb. 1927; Arbeitsgebiete: Festkörperphysik, Quantenoptik, Quantenstatistik.*

*Dr. R. Graham,*
*Institut für Theoretische Physik der Universität Stuttgart.*
*Geb. 1942; Arbeitsgebiete: Quantenstatistik Quantenoptik.*

*Der vorliegende Artikel basiert auf eine… von den Autoren a… gart im Sommersemester 1970 gehaltenen Vorlesung.*

UMSCHAU 1971, Heft 6

March 1971

**Handwritten plan of the first course in Synergetics (1969/1970)**

*(Transcript of original paper in Haken‘s Archiv)*

§ 1. Voraussetzungen und Plan (H)
§ 2. Klassisch: Langevin – Fokker-Planck (H)
§ 3. Quantenmechanisch: Dichtematrixgleichung (G)
elementar, Agyres u. Kelley
§ 4. Quasiverteilungsfunktion (H)
§ 5. Q.[uanten]M.[echanisch] Fokker-Planck: Bose (G)
§ 6. Q.[uanten]M.[echanisch] „ „ : beliebige (G)
§ 7. Fliessgleichgewichte, Definition (H)
§ 8. Bedingungen für Fliessgleichgewichte (H)
§ 9. Phasenübergänge und deren Klassifizierung (G)
§ 10. Laser, Parametrische Prozesse (H,G)
§ 11. Biologische Prozesse (G,H)
§ 12. Ordnungshierarchien (H,G)

*Der vorliegende Artikel basiert auf einer von den Autoren an der Universität Stuttgart im Sommersemester 1970 gehaltenen Vorlesung.*

(The article is based on a lecture given by the authors during the summer term 1970 at the university of Stuttgart)

# The „Umschau“ paper on Synergetics



„Zusammenfassend können wir also sagen, daß eine Vielzahl von völlig verschiedenen Erscheinungen mit Hilfe einiger weniger Begriffe von einem einheitlichen Gesichtspunkt aus betrachtet werden kann. Die geheimnisvollen Ordnungsprinzipien, die das Zusammenwirken der einzelnen Teile eines großen Systems regieren, erweisen sich als von den Untersystemen geschaffene Regelkreise. Überraschend abrupte Änderungen in diesen Ordnungsprinzipien werden hervorgerufen durch Phasenübergänge. Ein Weg zu einer mathematischen Erfassung dieser Vorgänge erscheint damit geöffnet.“

„In summary we can say that a great number of quite different phenomena can be looked at with the help of only a few concepts from an unified point of view. The mysterious order principles that govern the cooperation of the different parts of a large system manifest themselves as feedback-systems created by the sub-systems. Unexpected sudden changes of these order principles are initiated by phase-transitions. This opens a perspective to deal with these processes in a mathematical way.“

# 3rd Versailles Conference 1971

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In June 1971 Hermann Haken was invited Speaker at the 3rd Versailles Conference, speaking about
„Cooperative Phenomena far from thermal equilibrium“.

Manfred Eigen also delivered a talk. He rembers

„I met Haken for the first time in Paris. [...] I had to give talk following the presentation of Haken and was a little bit late. [...] then I spoke about my new findings and wanted to write down the formulas on the blackboard. But, I wondered „they are already there! How did they got here?“ [Interviewer: the rate equations...] Yes, still the ones from Haken, but very similar, the autocatalytic term.“*

*Interview Manfred Eigen 24.05.2011

# Analogy Laser – Hypercycle – Ansatz (rate equation)

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## Autokatalytische Reaktion („Hyperzyklusansatz“) Manfred Eigen 1971

$$n_j = k_j \cdot n_A \cdot n_j - \gamma_j \cdot n_j$$

$$n_A = n_o - \sum_{l=1}^{N} n_j$$

$\gamma_j$ = loss-coefficient ; $k_j$ = gain-coefficient ; $n_A$= number of molecules of type A ;
$n_j$ = number of molecules in state j ; $n_0$ = start concentration of molecules A

## Singlemode-Laser-Ansatz H. Haken 1964

$$\dot{n}_\lambda = n_\lambda \cdot \omega_\lambda \cdot \mathrm{D} - 2\,\kappa_\lambda \cdot n_\lambda$$

$$\mathrm{D} \equiv \sum_\mu \sigma_\mu \approx D_0 - (2\,D_c/\gamma_{||}) \sum \omega_\lambda\, n_\lambda$$

$n_\lambda$= number of photons of mode λ ; $D_c$= critical inversion number of all atoms at threshold

# 1971: annus mirabilis 1 (☺) for Self-Organization

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Hermann Haken, Robert Graham

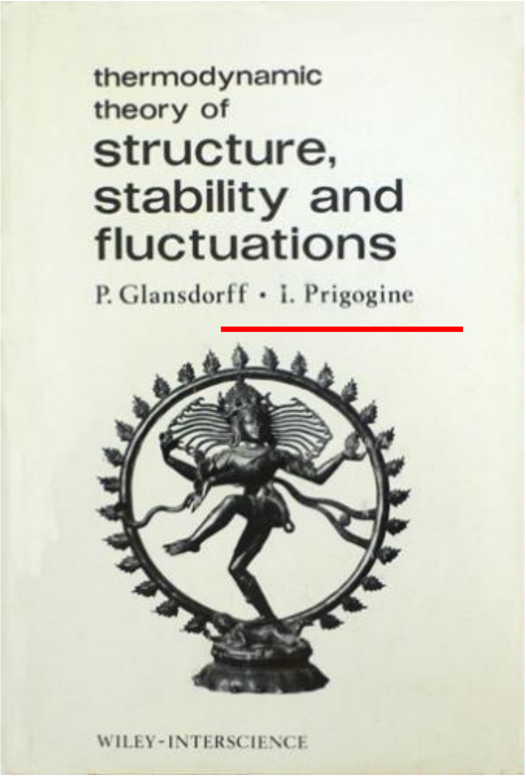
**Synergetik —**
**die Lehre vom Zusammenwirken**

Was verbindet die Physik, Chemie und Biologie?

**Selforganization of Matter and the Evolution of Biological Macromolecules**

MANFRED EIGEN*

Max-Planck-Institut für Biophysikalische Chemie,
Karl-Friedrich-Bonhoeffer-Institut, Göttingen-Nikolausberg



# The first ELMAU- Conference in 1972

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**Elmau 1972:**

- Mathematical and physical concepts of cooperative phenomena;
- Instabilities and phase-transition-like phaenomena in systems far from thermal equilibrium;
- Biochemical kinetics and population-dynamics;
- biological structures;
- general structures.

**Versailles 1967 and Versailles 1969:**

- statistical mechanics,
- dissipative structures,
- neurocybernetics,
- physical chemistry of life,
- Non-equilibrium thermodynamics;
- Information in biology;
- Mechanism in Physiology

- Order in systems;
- structures and the maintenance of life;
- Self-Organization;
- Dissipative Structures in Biology;
- Mutations and Evolution;
- Information and biological Systems;
- Information Storage in the central nerveous System.

1972 Elmau conference speakers include 9 Versailles participants!

# The first ELMAU- Conference in 1972

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**Rolf Landauer**:

„Hermann Haken in 1972 had the first interdisciplinary meeting [...] all of it was serious and represented real intellectual depth and effort. Participation was a breath-taking experience for me; for the first time I found myself among people with comparable interests and a comparable sense of values. I was no longer an orphan! And the meeting had another earmark of a good conference: The conference had broad representation in its selection of speakers; it was not dominated by the organizer and his close associates."

# Theory of the Bénard convection

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Volume 46A, number 3 PHYSICS LETTERS 17 December 1973

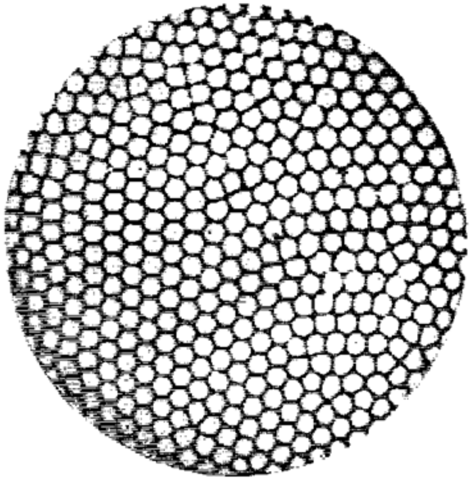
## STABILITY AND FLUCTUATIONS OF MULTI-MODE CONFIGURATIONS NEAR THE CONVECTION INSTABILITY

H. HAKEN

*Institut für theoretische Physik der Universität Stuttgart, Germany*

Received 4 October 1973

The exact solution of a Fokker-Planck equation yields a distribution function which governs the stability and fluctuations of various mode configurations (e.g. hexagons and roles) of the Bénard convection of fluids and related problems.



# 1975: Entering the „transition region“

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1975 was another important year for Hermann Haken and the development of Synergetics:

- **January:** *Cooperative phenomena in systems far from thermal equilibrium and in nonphysical systems*. Review Mod. Physics 47 (1975), 67 – 121 (not mentioning the word Synergetics (!)
- **February:** Solves the Brusselator (experimental and theoretical work of Prigogine, Lefever and Nicolis). *Statistical Physics of Bifurcation, Spatial Structures and Fluctuations of Chemical Reactions*. Zs. f. Physik B 20 (1975), 413 - 420
- **March:** Develops time dependent Ginzburg-Landau equations with fluctuating forces (the mathematical basis for Synergetics). *Generalized Ginzburg-Landau equations for Phase-Transition Phenomena in Lasers, Nonlinear Optics, Hydrodynamics and Chemical Reactions.* Zs. f. Physik B 21 (1975), 105 - 114
- **April:** Shows the analogy between the laser and the Lorenz-equations. *Analogy between higher instabilities in fluids and lasers*. Phys. Letters 53A (1975), 77 - 78

# 1975: Analogy Laser – Lorenz equations

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| **Lorenz - Functions** | **Laser -Functions** |
|---|---|
| $\xi = \sigma\eta - \sigma\xi$ | $E = \kappa P - \kappa E$ |
| $\dot{\eta} = \xi\zeta - \eta$ | $\dot{P} = \gamma E D - \gamma P$ |
| $\dot{\zeta} = b(r - \zeta) - \xi\eta$ | $\dot{D} = \gamma(\Lambda + 1) - \gamma D - \gamma \Lambda E P$ |

**Identitätsbedingungen**

$t \rightarrow t'\sigma/\kappa$ , $E \rightarrow \alpha\xi$ , wobei $\alpha = [b(r-1)]^{-1/2}$ , $r > 1$

$P \rightarrow \alpha\eta$ , $D \rightarrow \zeta$ , $\gamma = \kappa b/\sigma$ , $\gamma = \kappa/\sigma$, $\Lambda = r - 1$

"The Laser when pumped high enough is the first realistic system obeying the Lorenz' equations."

H. Haken June 1977 at the 4th Rochester Conference

# 1975: Entering the „transition region“

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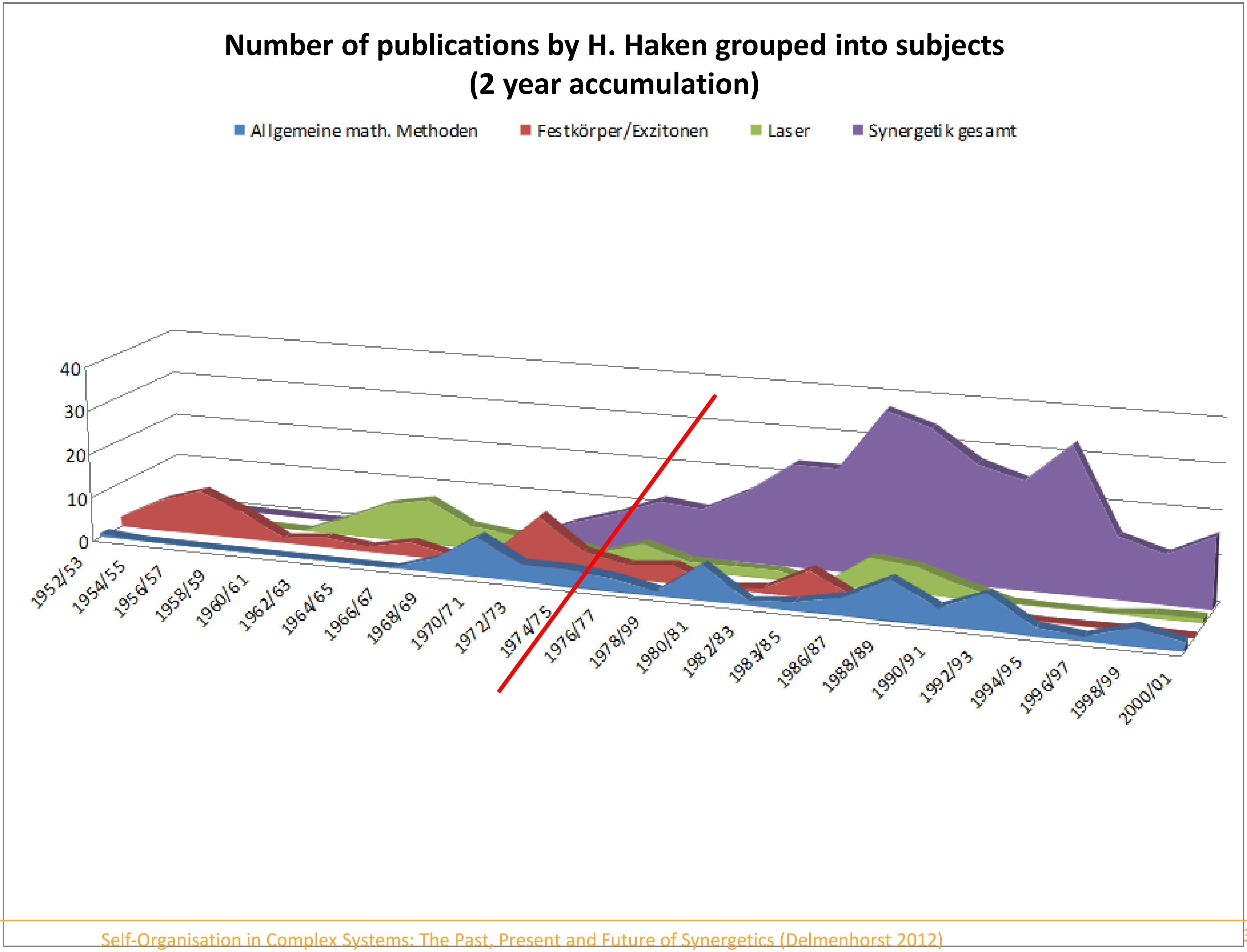

# 1977: Das Buch Synergetics

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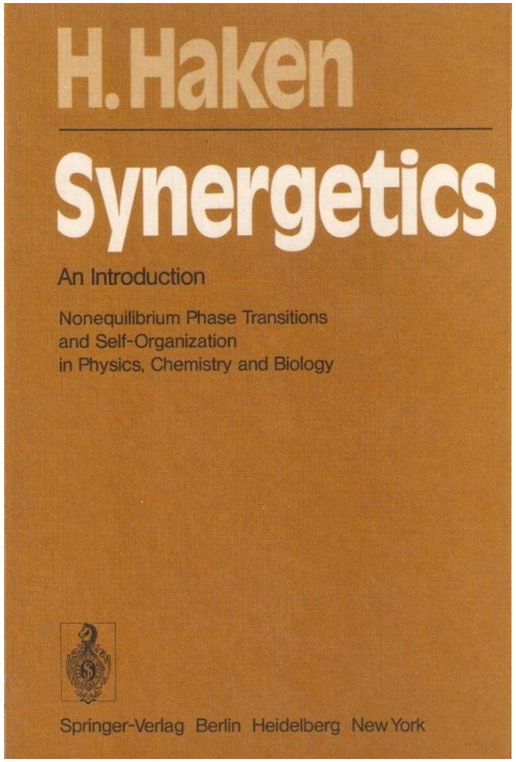


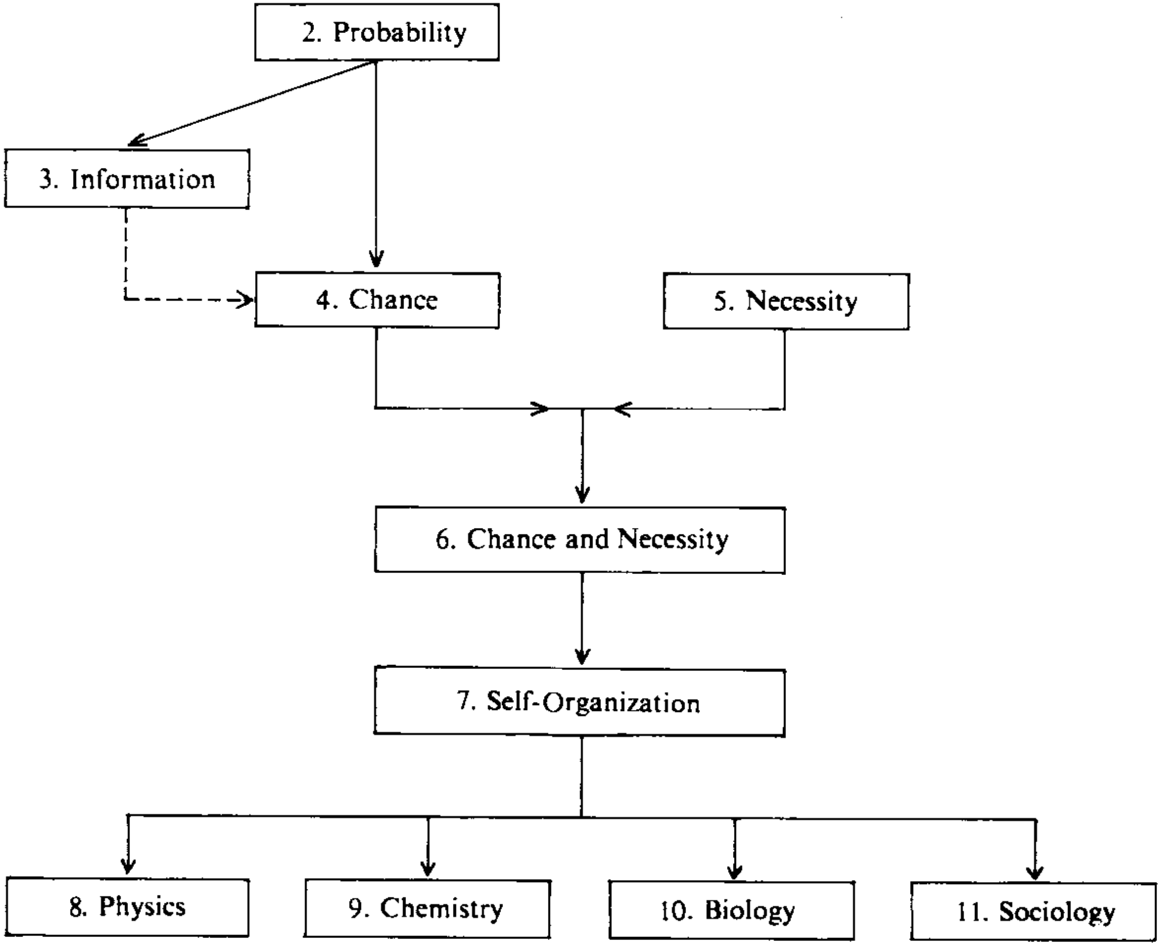

# 1977: Das Buch Synergetics

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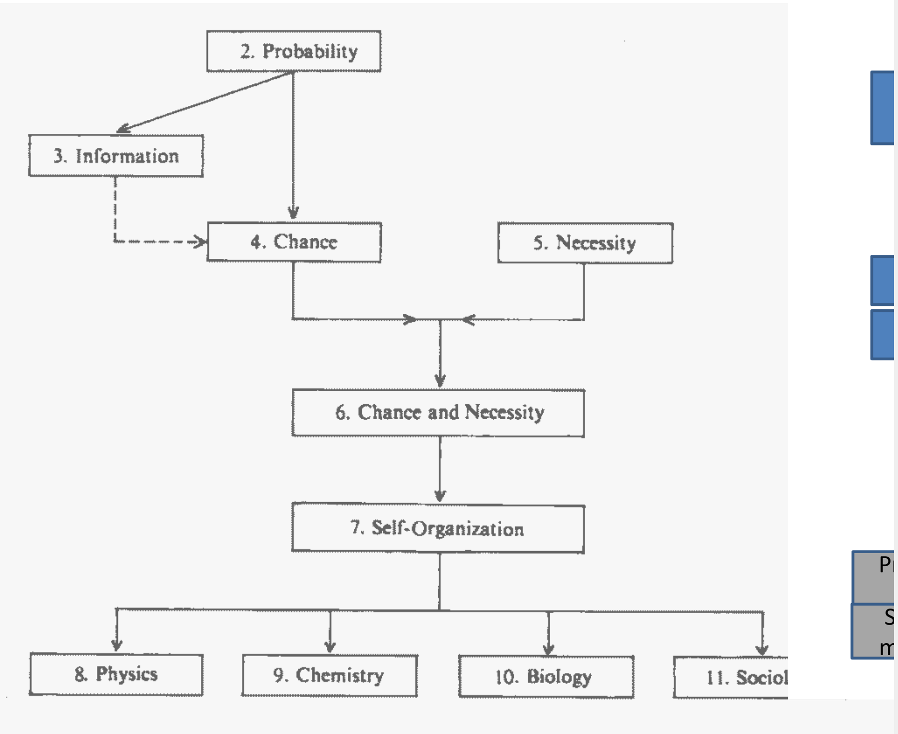


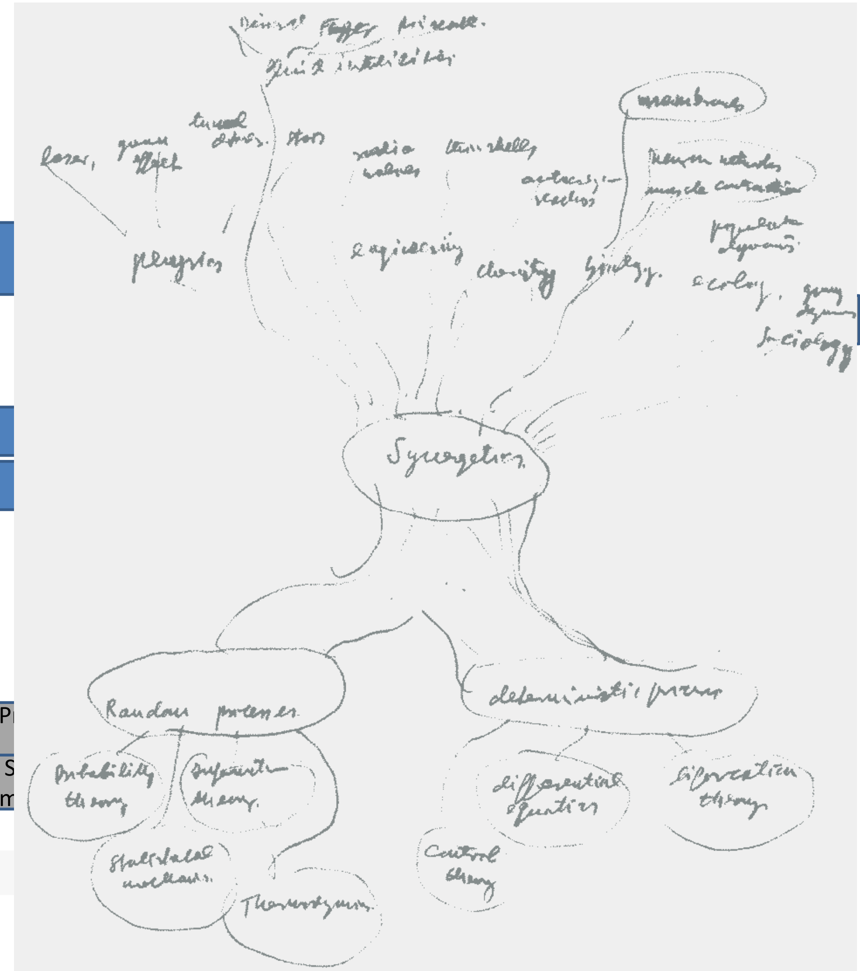

# 1977: annus mirabilis 2 (☺) for Self-Organization

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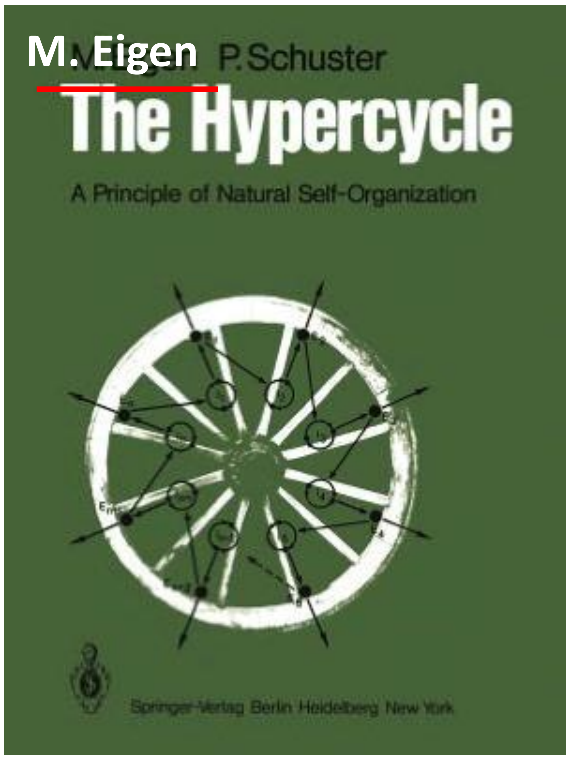


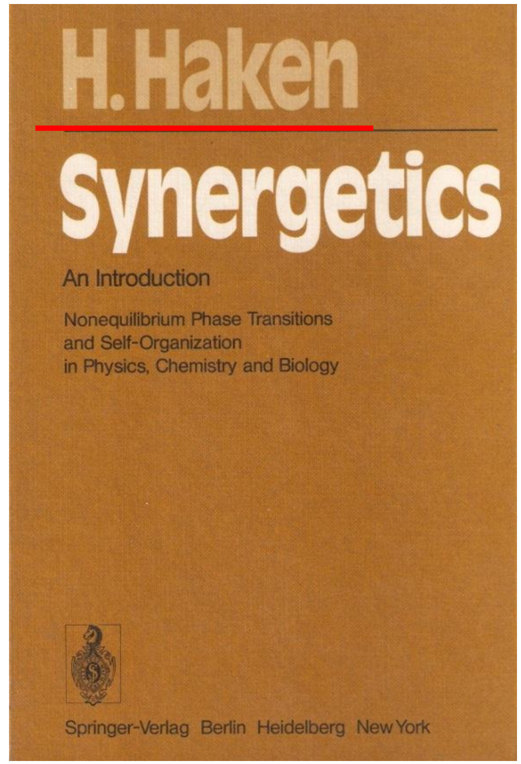


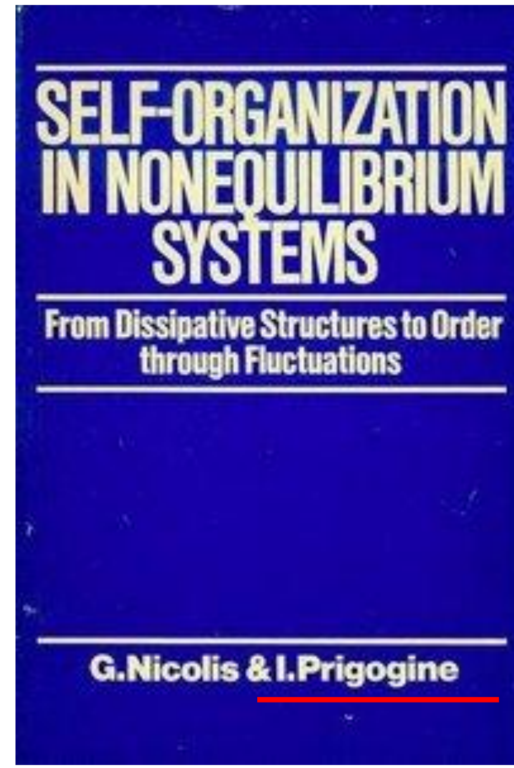

# 1977: The second ELMAU- conference

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**Second Elmau-Conference 1977:**

- General concepts (including catastrophe theory)
- Bifurcation Theory
- Instabilities in Hydrodynamics
- Biological structures;
- Solitons
- Non-equilibrium phase-transitions in chemical reactions
- Chemical waves and turbulence (including a talk about chaos by O. Rössler)
- Morphogenesis
- General structures (including oeconomy, sociology and linguistics)

**First Elmau-Conference 1972:**

- Mathematical and physical concepts of cooperative phenomena;
- Instabilities and phase-transition-like phänomena in Systems far from thermodynamical equilibrium;
- Biochemical kinetics and population-dynamics;
- biological structures;
- general structures.

# 1977: Synergetics – Spreading the Word

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November 1977: New York — H.H.: *„Synergetics and Bifurcation Theory“*. In: Gurel, Ö.; Rössler, O. Bifurcation Theory and its Applications in Scientific Disciplines. Annals of the New York Academy of Sciences **316** (1979).

May 1978: Tübingen — H.H.: *„Synergetics and a new approach to bifurcation theory.* In: W. Güttinger & H. Eikemeier (Eds.), *Structural Stability in Physics* (pp. 31 - 40). Berlin: Springer.

June 1978: Sitges (Spain) — H.H.: *„Synergetics - a field beyond irreversible thermodynamics“.* In: L. Garrido (Ed.), Stochastic Processes in Nonequilibrium Systems (pp. 139 - 167). Berlin: Springer.

July 1978: Tokyo — H.H.: *„Synergetics - Some Recent Trends and Developments”* . Supplement of the Progress of Theoretical Physics **64** (1978), 21-34.

September 1978: Bordeaux — H.H.: *„Nonequilibrium Phase Transitions and Instability Hierarchy of the Laser, an example from Synergetics“.* In: A. Pacault & C. Vidal (Eds.),Synergetics far from Equilibrium (pp. 22 - 33). Berlin: Springer.

November 1978: Brussels — Graham, R. *„Onset of Cooperative Behavior in Nonequilibrium Steady States.“* In: G. Nicolis, G. Dewel & J. W. H. Turner (Eds.), Order and Fluctuations in Equilibrium and Non-Equilibrium Statistical Mechanics (pp. 235 - 288). 1981. Dordrecht: Reidel. (Haken conference participant)

# Synergetics being „Focus“-Program of VW-Foundation

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„Angeregt durch ein als „unkonventionelles Vorhaben“ gefördertes Forschungsprojekt von Professor Dr. H. Haken am I. Institut für Theoretische Physik der Universität Stuttgart, hat die Stiftung die Möglichkeit einer Förderung dieses neuen Gebietes geprüft und im Frühjahr 1980 seine Aufnahme in die Schwerpunktliste beschlossen. Das Förderungs-Programm ist auch im Zusammenhang mit Arbeiten über „Dissipative Strukturen“ zu sehen, für die Professor I. Prigogine, Brüssel, 1977 den Nobelpreis für Chemie erhielt.*

*Bericht der Stiftung Volkswagenwerk 1980, S. 124

Synergetics: „Initiated by a research project of Professor Dr. H. Haken from the I. Theoretical Physics Institute at the University of Stuttgart that was sponsored as an „unconventionell task“, the foundation has decided in spring 1980 to include [synergetics] into its list of thematic priorities.
The sponsorship is also to be viewed in context with the work on „dissipative structures“, work, for which Professor I. Prigogine, Brusselles, was honored the Nobel Prize in chemistry“ in 1977.

# Synergetics being „Focus"-Program of VW-Foundation

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„Synergetics is multidisciplinary. It deals with aspects of the following sciences:

**Mathematics:** Bifurcation-Theory, Theory of Singularities, Stochastic Processes

**Physics:** Laser, nonlinear optics, Theory of Hydrodynamics, Turbulence, Current Instabilities;

**Chemistry:** Chemical Oscillators, Dissipative Structures;

**Biology:** [...] Population Dynamics, Morphogenesis, Neuronal Networks

**Engineering:** nonlinear continuum Mechanics, especially problems of Shell-deformation,

**Informatics:** Self-Organization of computers in networks

# Synergetics Conferences in ELMAU 1972 - 1990

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| 30.4.-6.5. 1972 | Synergetics:<br>Cooperative Phenomena in Multi-Component Systems |
| 2.5.-7.5. 1977 | Synergetics - A Workshop |
| 30.4.-5.5. 1979 | Pattern Formation by Dynamic Systems and<br>Pattern Recognition |
| 27.4. - 2.5. 1981 | Chaos and Order in Nature |
| 26.4. - 1.5. 1982 | Evolution of Order and Chaos |
| 2.5. - 7.5. 1983 | Synergetics of the Brain |
| 6.5. - 11.5. 1985 | Complex Systems - Operational Approaches in Neurobiology, Physics and Computers |
| 4.5. - 9.5. 1987 | Computational Systems - Natural and Artificial |
| 13.6. - 17.6. 1988 | Neural and Synergetic Computers |
| 4.6. - 8.6. 1989 | Synergetics of Cognition |
| 22.10. – 25.10. 1990 | Rhythms in Physiological Systems |

# 1983: Advanced Synergetics

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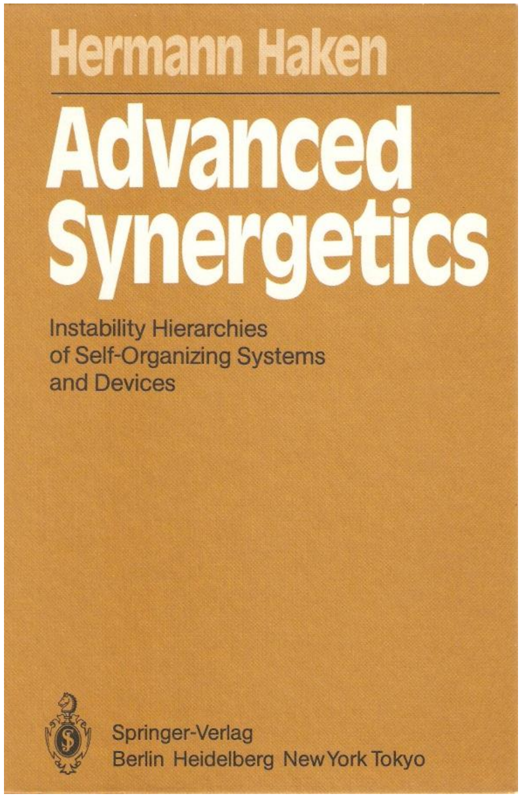


The start-up phase of Synergetics was finished with the book „Advanced Synergetics in 1983.

It contains the major mathematical tools of Synergetics
(generalized Ginzburg-Landau Theory, order parameter concept and slaving mechanism).

# The Development of Analogies and Topics of Synergetics

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| (1973) Synergetics – Cooperative Phenomena | (1983) Advanced Synergetics |
|---|---|
| Physics:<br>▪ Laser<br>▪ Superconduction<br>▪ Ferromagnetism | Physics:<br>▪ Laser<br>▪ Bénard-Effect<br>▪ Hydrodynamics<br>▪ Plasmaphysics<br>▪ Solid State Physics |
| Chemistry:<br>▪ Bénard-Effect | Chemistry:<br>▪ Belousov-Zhabotinsky<br>▪ Brusselator<br>▪ Oregenator |
| Biology:<br>▪ Hypercycle (Eigen) | Biology:<br>▪ Biological Clocks<br>▪ coordinated muscle operation<br>▪ Morphogenesis<br>▪ Evolution<br>▪ Immunsystem |
| | Computer:<br>▪ Pattern recognition<br>▪ Selft-Organization (parallel computing)<br>▪ Reliable systems from unreliable components |
| | Economy |
| | Engineering Sciences |
| | Ecology: Phasen-Transitions |
| Sociology:<br>▪ Opinion formation | Sociology:<br>▪ Opinion formation |

# 1983: Advanced Synergetics

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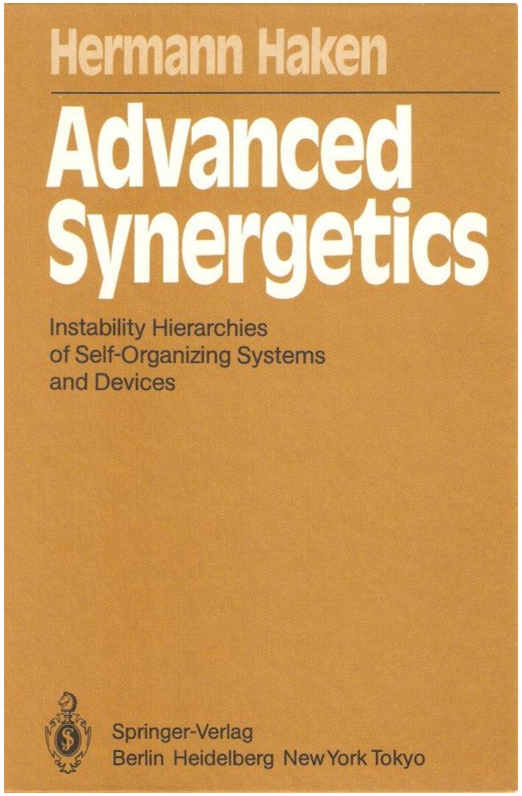


Hermann Haken:
„the basic concepts of synergetics can be explained rather simply,
but
the application of these concepts to real systems call for considerable technical (i.e. mathematical) know-how.”

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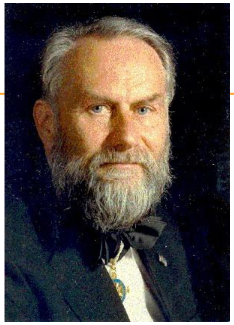
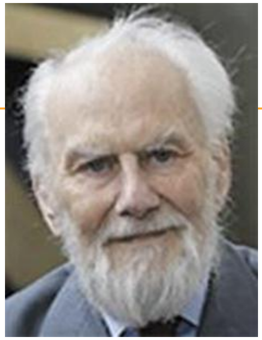

# Thank you very much for your attention.

**Laser**