

# Self-Organisation of Symbolic Information



**Rainer Feistel**

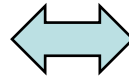
*Leibniz-Institut für Ostseeforschung  
Universität Rostock  
D-18119 Warnemünde, Germany*



**There is no general definition of what „Information“ exactly is.**

**From a physicist's perspective, distinguish between  
two kinds of information:**

**Structural Information**



**Symbolic Information**

What are their properties ?

What is their mutual relation ?

Ebeling, W., Feistel, R. (1982): Physik der Selbstorganisation und Evolution. Akademie-Verlag, Berlin.

Feistel, R. (1990): Ritualisation und die Selbstorganisation der Information. doi:10.13140/RG.2.1.2924.7526

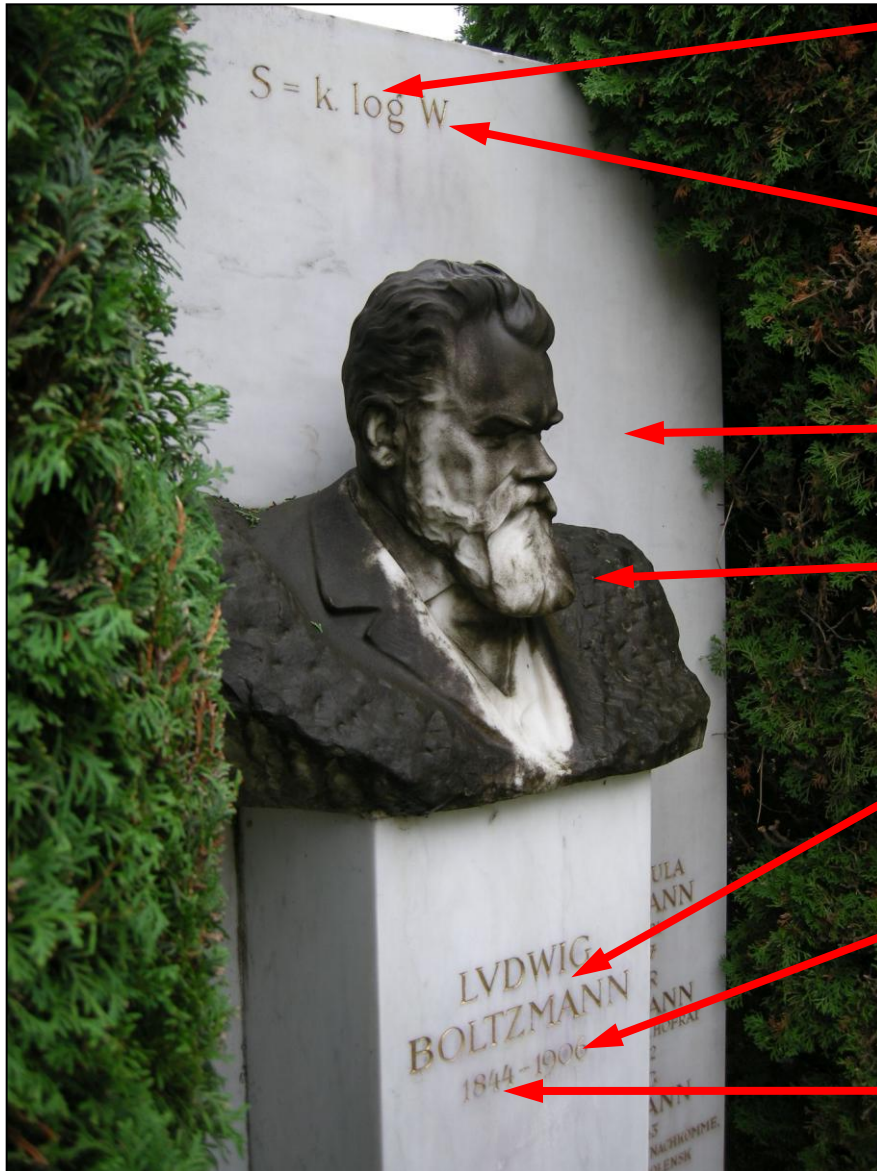


Ebeling, W., Feistel, R. (1994): Chaos und Kosmos. Spektrum, Heidelberg.

Feistel, R., Ebeling, W. (2011): Physics of Self-Organization and Evolution. Wiley-VCH, Weinheim.

Ebeling, W., Feistel, R. (2015): Selforganization of Symbols and Information. In: Chaos, Information Processing and Paradoxical Games, World Scientific, <http://www.worldscientific.com/worldscibooks/10.1142/9145>

# Vienna: Central Cemetery



Physics: **symbolic information** extracted from **structural information** of the world

**Structural residual entropy**  
= **symbolic information capacity**

**Marble entropy**

**Sculpture entropy**

**Engraved letter „A“**

**Engraved number symbols**

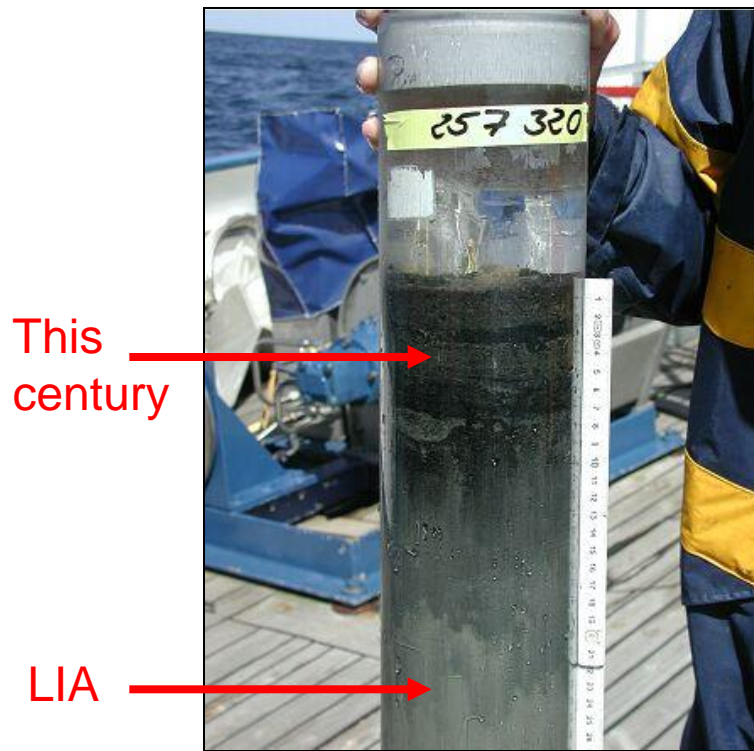
**Years = counting „summers“**  
= native kind of measurement  
= extracting **symbolic information**

Photo taken in October 2010

# Structural Information of Physical Systems

Example: History of the Baltic Sea

Baltic Sea – layered sediments



Recent 500 years



Littorina Sea  
8000 years

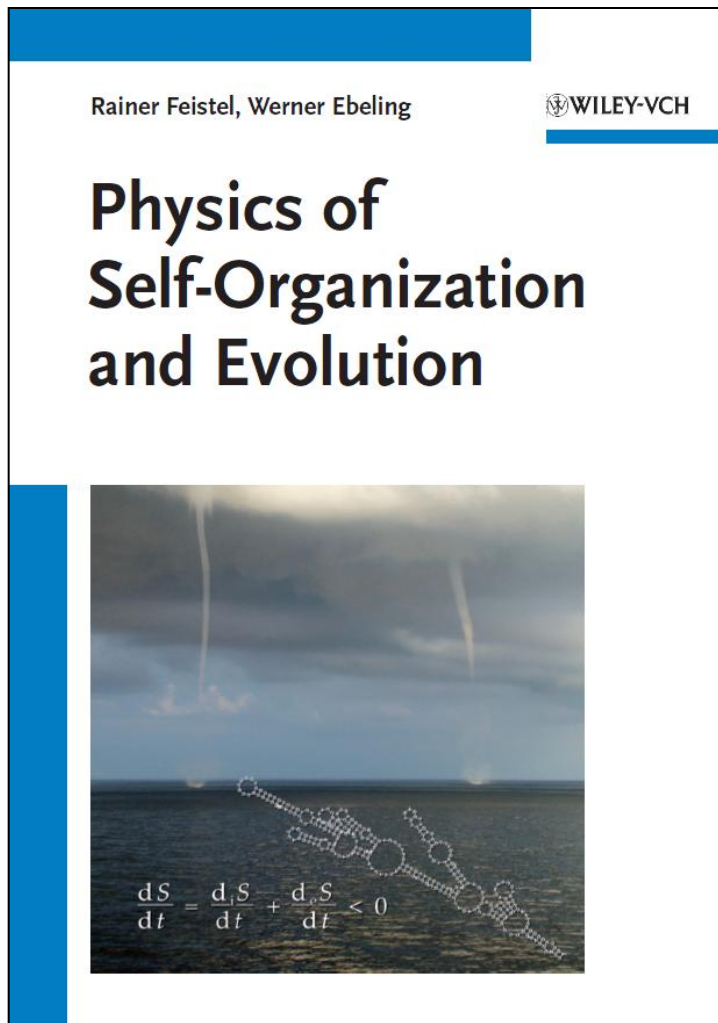
Ancylus Lake  
9500 years

Yoldia Sea  
10 300 years

Baltic Ice Lake  
14 000 years

# Symbolic Information of Physical Systems

Example: A scientific textbook



Preface

1. Introduction to the Field of Self-Organization
2. Fundamental Laws of Equilibrium and Non-equilibrium Thermodynamics
3. Evolution of Earth and the Terrestrial Climate
4. Nonlinear Dynamics, Instabilities and Fluctuations
5. Self-Reproduction, Multistability and Information Transfer as Basic Mechanisms of Evolution
6. Competition and Selection Processes
7. Models of Evolution Processes
- 8. Self-Organization of Information and Symbols**
9. On the Origin of Life
10. Conclusion and Outlook

References

Index

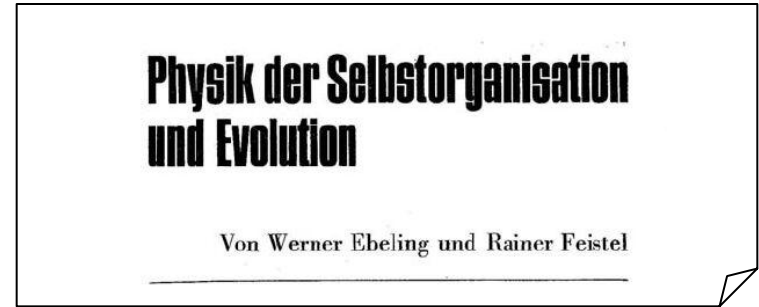
Wiley – VCH, Weinheim 2011

# Information Stored in Physical Structures



## Native, bound, analog

- Meaning is inherent to the carrier
- Cannot be copied loss-free
- Does slowly degrade
- Encoded by natural laws
- Different structure = other meaning
- Obeys physical laws

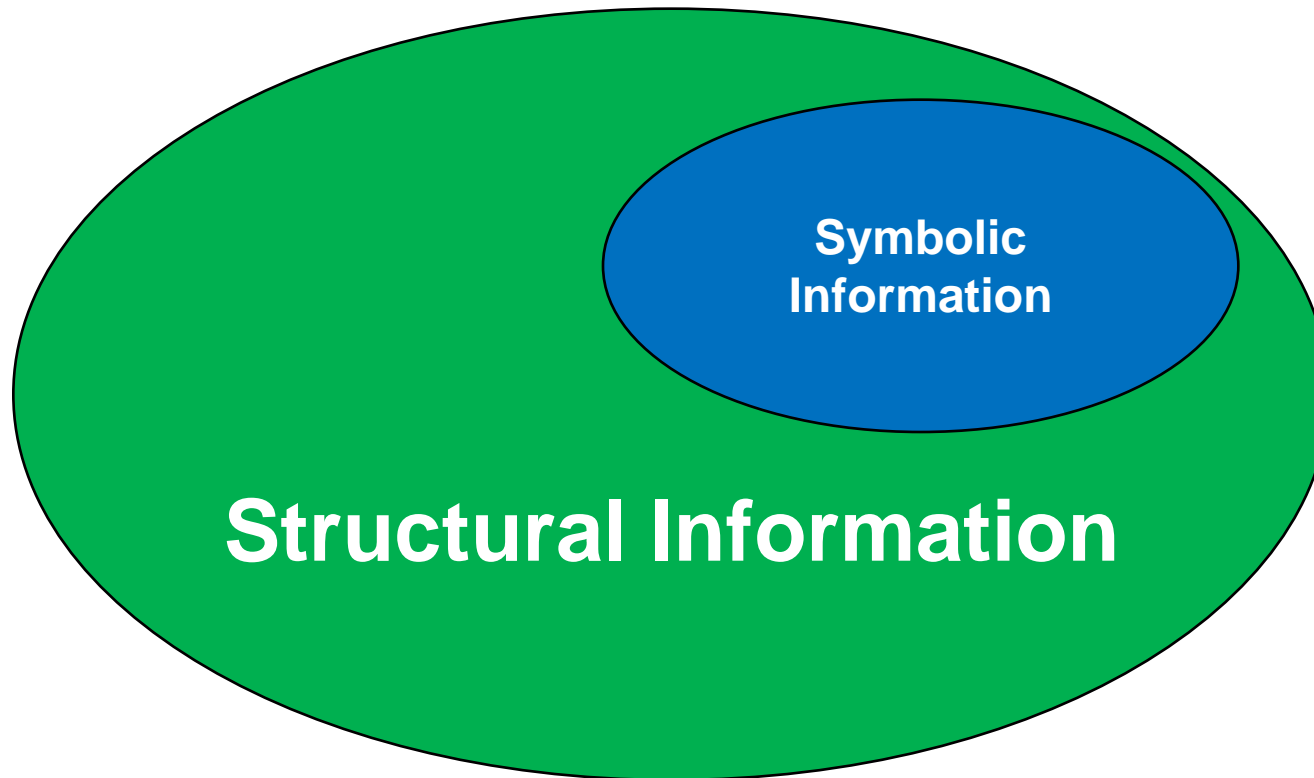


## Symbolic, free, digital

- Meaning is independent of the carrier
- Can be copied loss-free
- Does not degrade („quanta“)
- Encoded by „conjugate“ „ciphers“
- Possesses a new symmetry:  
„Code invariance“
- Obeys „higher“, „emergent“ laws

## Symbolic information:

- cannot exist outside structural information
- cannot be reduced to structural information
- is an emergent property of structural information
- emerges from structural information by the **Ritualisation Transition**



# Ritualisation

Julian Huxley (1914):

[Ritualisation is] *the gradual change of a useful action into a symbol and then into a ritual; or in other words, the change by which the same act which first subserved a definite purpose directly comes later to subserve it only indirectly (symbolically) and then not at all.*

Konrad Lorenz (1970):

*Ritualisation* is a process by which behavioural or physical forms, or both, that had originally developed to serve certain different purposes for the species' survival, turned into *symbols* that serve the communication within a population.

Günter Tembrock (1977):

Ritualisation is the development of *signal-activity* out of *use-activity*.

Feistel & Ebeling (2011):

Ritualisation is the self-organised emergence of systems capable of processing symbolic information.

Huxley, Sir J. (1914): The Courtship-Habits of the Great Crested Grebe (*Podiceps cristatus*); with an Addition to the Theory of Sexual Selection. Proceedings of the Zoological Society of London 1914, 491-562

Lorenz, K. (1970): Vorwort zu Otto Koenig, Kultur und Verhaltensforschung. Dtv, München

Tembrock, G. (1977): Grundlagen des Tierverhaltens. Akademie-Verlag Berlin



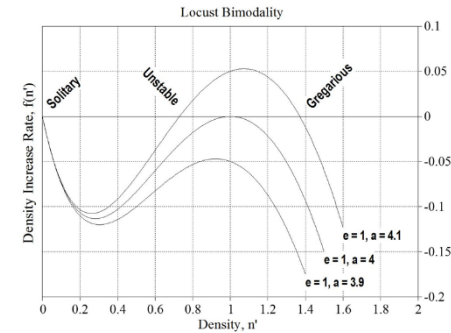


# Ritualisation Example

Locusts change from solitary to swarming behaviour as a result of tactile stress



Source: Spiegel Online 7.3.2013



Honey bees start swarming behaviour as a result of tactile stress

Honey bees derived from swarming the tactile „waggle dance“ (with dialects)



Ritualisation



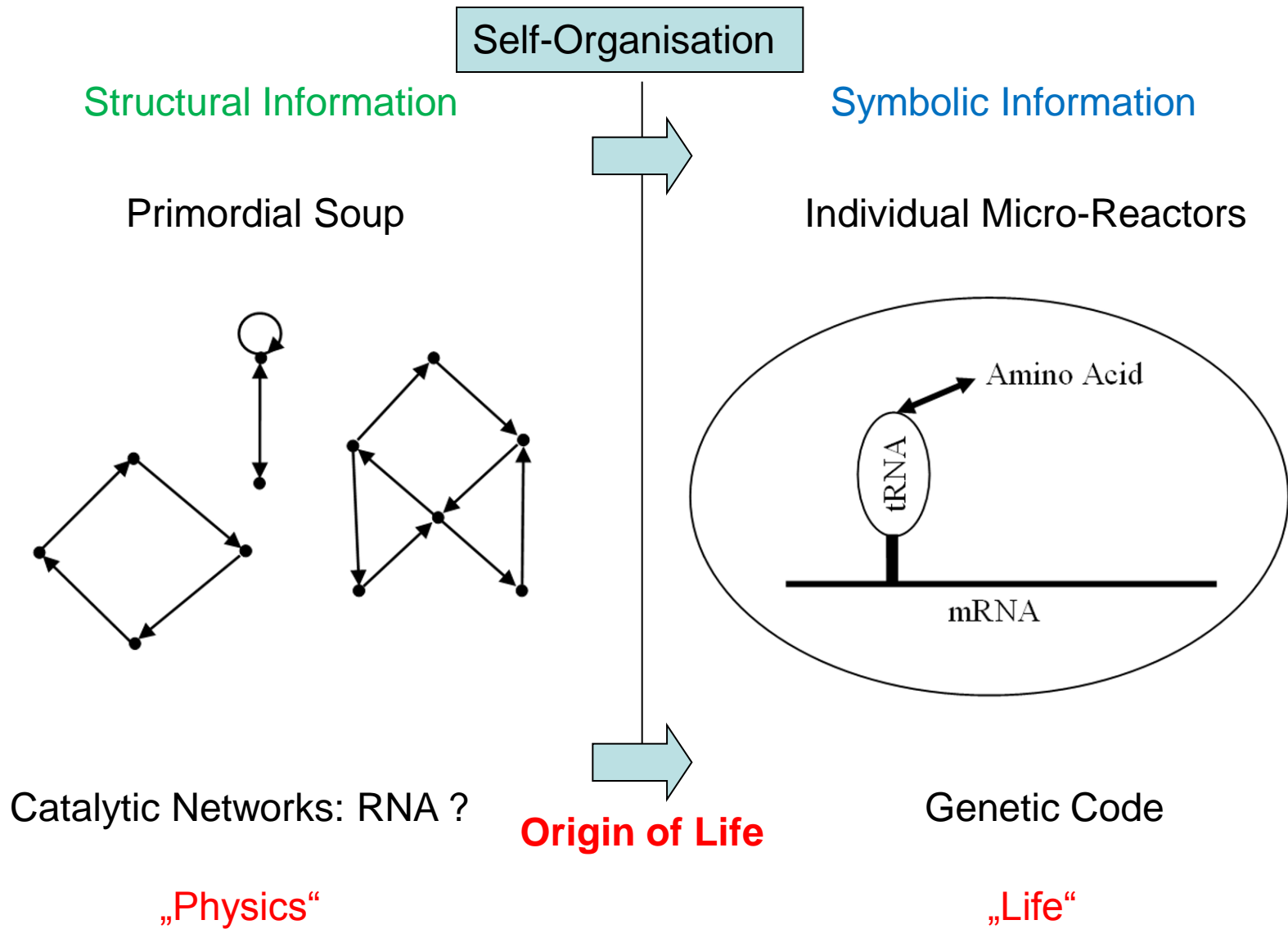
Source: www.overclockers.at



Waggle dance: [http://en.wikipedia.org/wiki/Waggle\\_dance](http://en.wikipedia.org/wiki/Waggle_dance)

Feistel, R., Feistel, S. (2012): Locust Phase Transitions. doi:10.13140/RG.2.1.2905.0407

# Emergence of Symbolic Information



# Three Evolution Stages of the Ritualisation Transition

## Precursory phase:

- Structure/process is only slowly variable (frozen) to not degrade functionality
- Successively, structures are reduced to **rudimentary “caricatures”** which represent the minimum complexity necessary to maintain the function

## Transition phase:

- Caricatures turn into mere symbols that may be modified arbitrarily (**coding invariance**) and permit divergent, macroscopic fluctuations
- Kind and pool of symbols may quickly adjust to new requirements
- **Symmetry breaking**, neutral Goldstone mode, random drift & diversification

## Final phase:

- “Standardised” code for intrinsic consistency of the information-processing system
- Fluctuations are suppressed to a necessary minimum, the code is frozen-in
- Structure preserves in its arbitrary form a **record of its own evolution history**

# Three Stages of the Evolution of Spoken Language

Precursory phase:

Sound and apparatus of breathing and drinking permit baby's crying after mother's loss of human body hair

Transition phase:

Certain sounds produced by the baby are recognised by the mother as signals, and vice versa

Final phase:

Mother-child communication is maintained among adults and develops to spoken human language

Herder 1772: Are words of onomatopoeic origin or arbitrary creations?

Jonas, D., Jonas, D. (1975): Gender Differences in Mental Functions: A Clue to the Origin of Language. *Current Anthropology* 16, 626-630



Fitch, W.T. (2010): *The evolution of language*. Cambridge University Press, Cambridge

# Three Stages of the Evolution of Numerals

## Precursory phase:

- Numbers are confined in the human's mind to multiple objects that can be recognised at a single glimpse.
- The imagination of numbers is bound to the observed reality and is not separable from the nature of the object immediately present

## Transition phase:

- Numerals are basically names for body parts used for counting, they increasingly lose their original meaning when representing amounts of certain items, this way turning into half-concrete and half-abstract constructions.
- Numerals show the tendency to gradually separate from their original meaning to be applicable to arbitrary objects, i.e., as symbolic information.

## Final phase:

- Words used for counting developed to abstract numerals, to true symbols that may be freely modified and are then well distinguished from their original concrete objects

Lévy-Bruhl, L. (1926): How Natives Think, Allen & Unwin, London

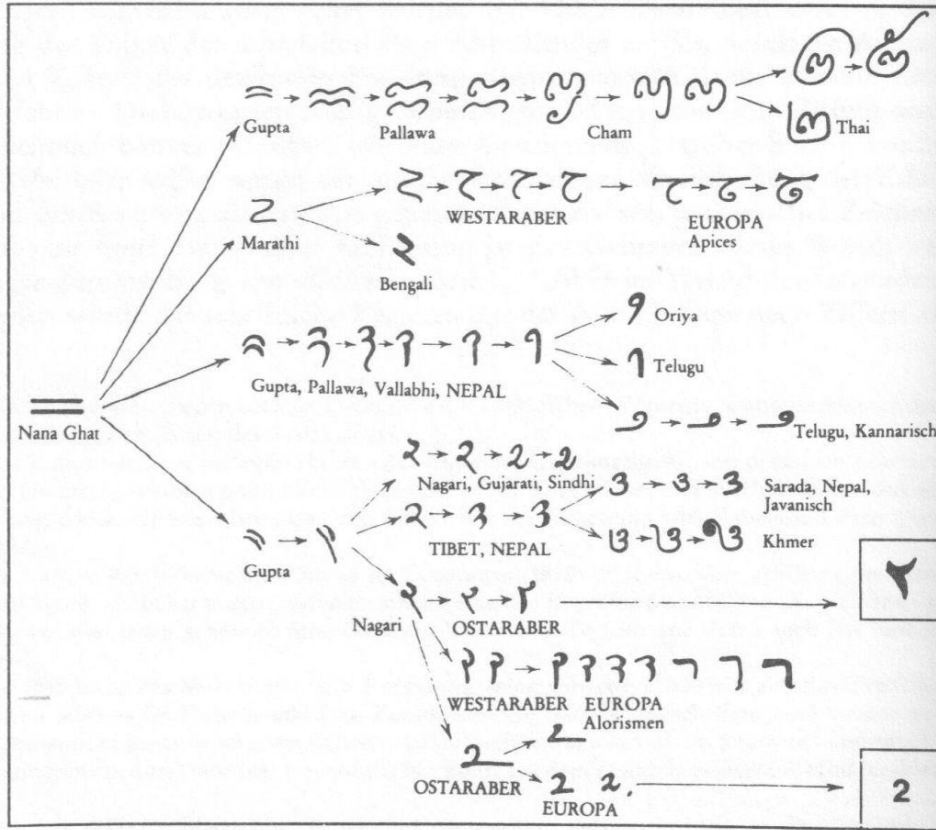


Dantzig, T. (1930): Number, the language of science. Macmillan Company, London

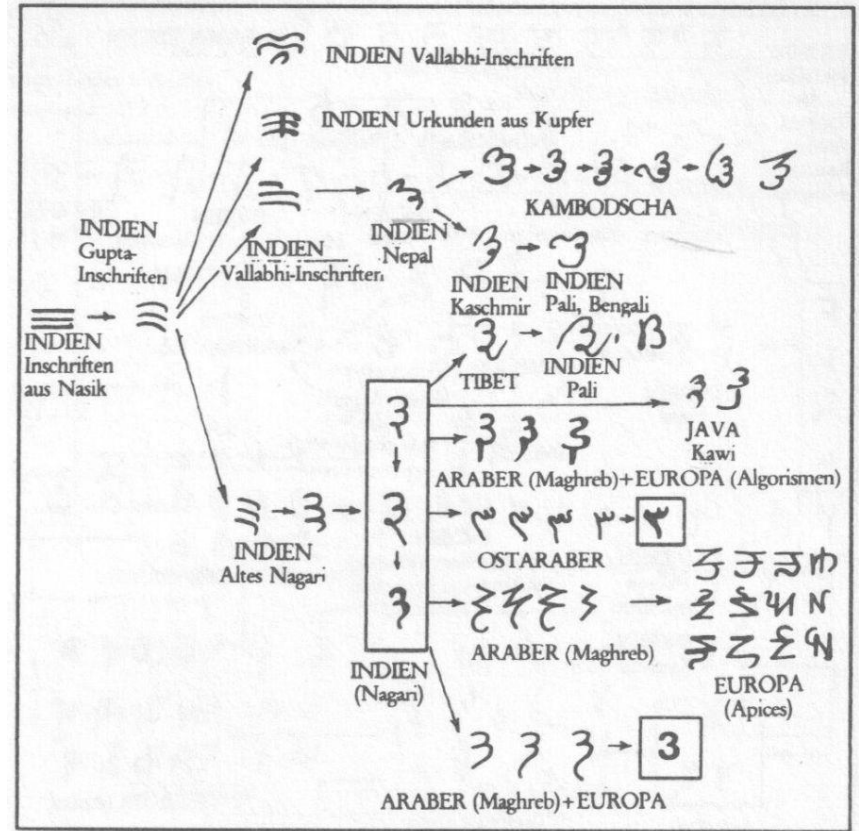
Ifrah, G. (1999): The Universal History of Numbers: From Prehistory to the Invention of the Computer. Wiley, New York

# Ritualisation of Written Numerals

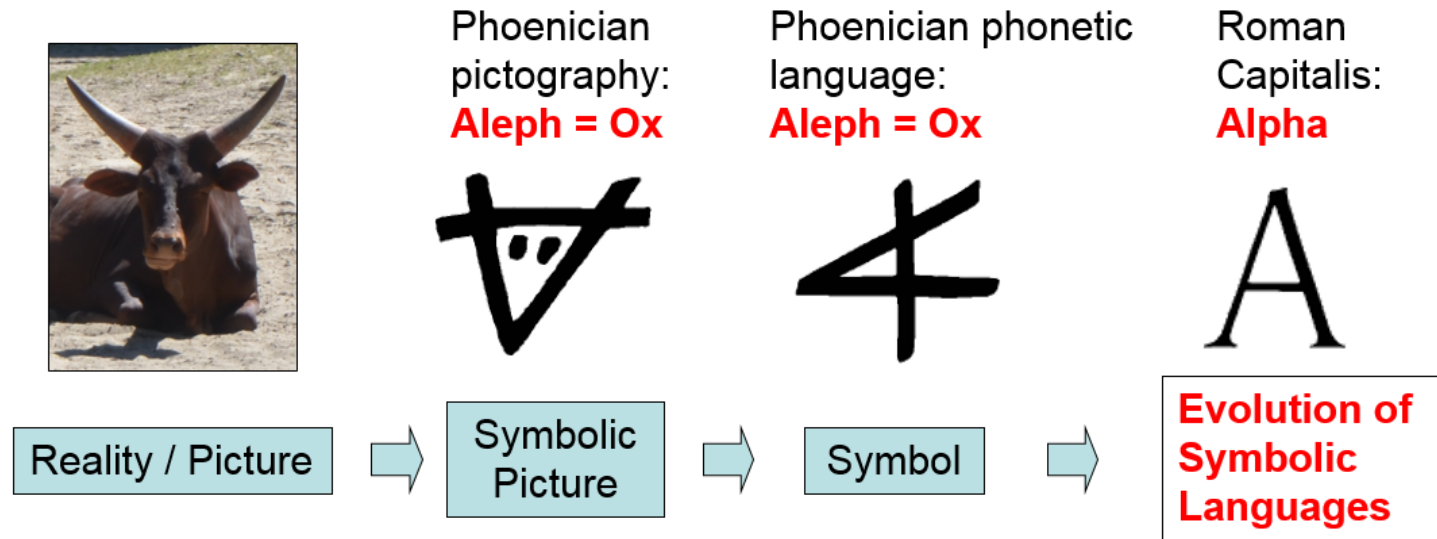
## Number Two



## Number Three



# Ritualisation of Written Letters



Sign	Name	Meaning	Greek	Latin
𐤀	aleph	ox	A: alpha	A
𐤁	beth	house	B: beta	B
𐤂	gamel	camel	Γ: gamma	C, G
𐤃	daleth	door	Δ: delta	D



## Fundamental Ritualisation Events in the History of Natural Evolution

<b>Time BP</b>	<b>Evolution stage</b>	<b>Emergence of</b>
4500 Myr	Random catalysis	Physico-chemical networks
3700 Myr	Genetic code	Biological systems
1200 Myr	Sexual reproduction	Sexual selective values
635 Myr	Morphogenesis	Multicellular organisms
518 Myr	Neuronal networks	Individual information gathering
2 Myr	Human spoken language	Human social systems
5500 yr	Written numbers	Book-keeping of personal property
2600 yr	Coined money	Market economy, exchange values
2600 yr	Greek natural science	Scientific information accumulation



**There is no symbolic information processing without life.**

**There is no life without symbolic information processing.**

(here, technology is understood as an “honorary living thing”)

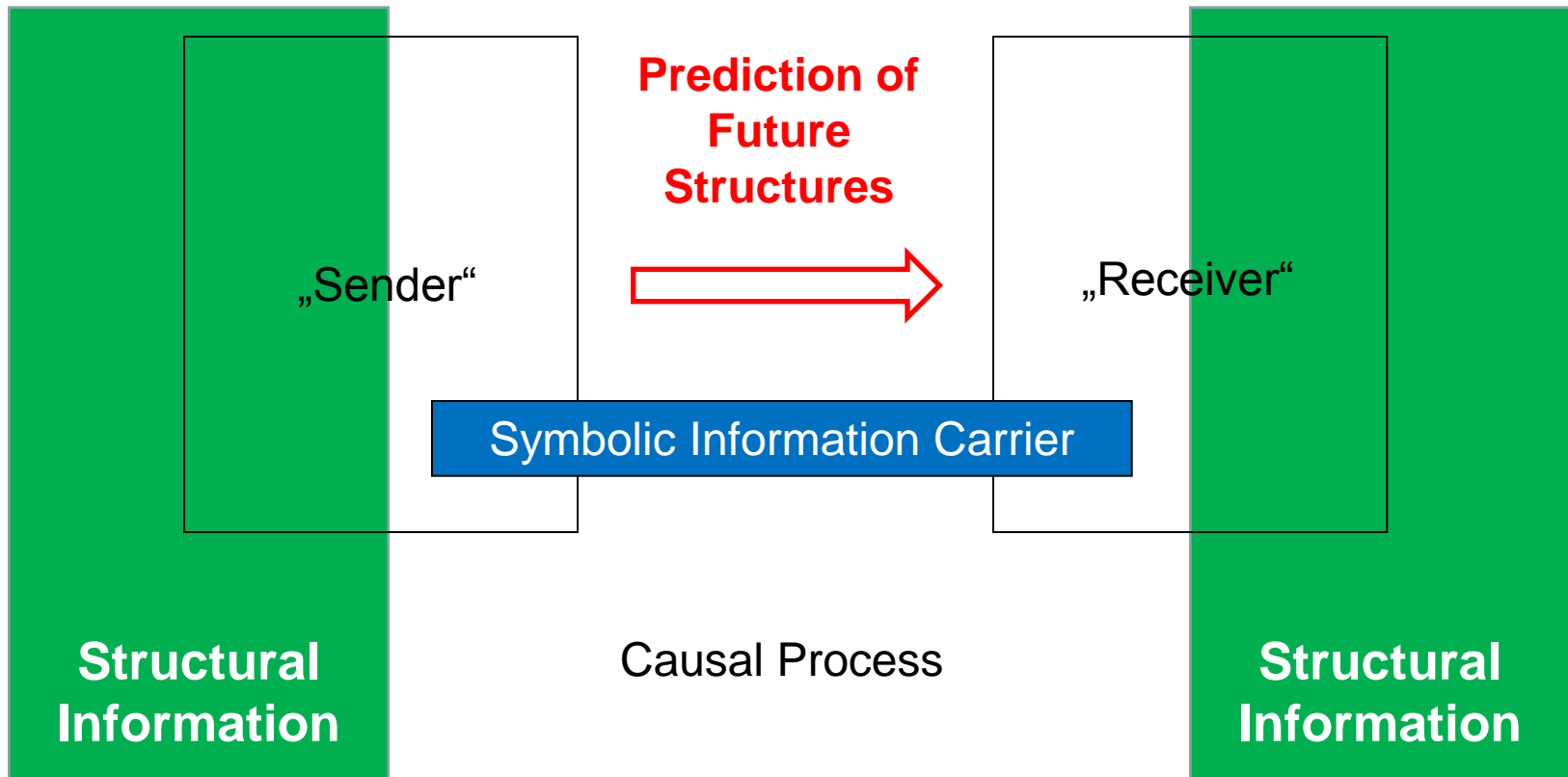
**Evolution can be seen as a process that extracts symbolic information from the structural information available in the surrounding world.**



# Ultimate „Purpose“ of Symbolic Information

Extracting Symbolic Information

Producing Structural Information



Value of symbolic information = measure of the structural information change induced

# Counting (Measurement) is a Fundamental Process of Extracting Symbolic Information

Units of time and length,  
Greenwich Observatory



Photo taken in September 2013

Counting sticks found at  
Abri Cellier, ca 28 000 BP



Source: <http://donsmaps.com/sousruth.html>

## Vienna – Central Cemetery



Photo taken in October 2010

## London – Westminster Abbey (at the feet of Isaac Newton's monument)

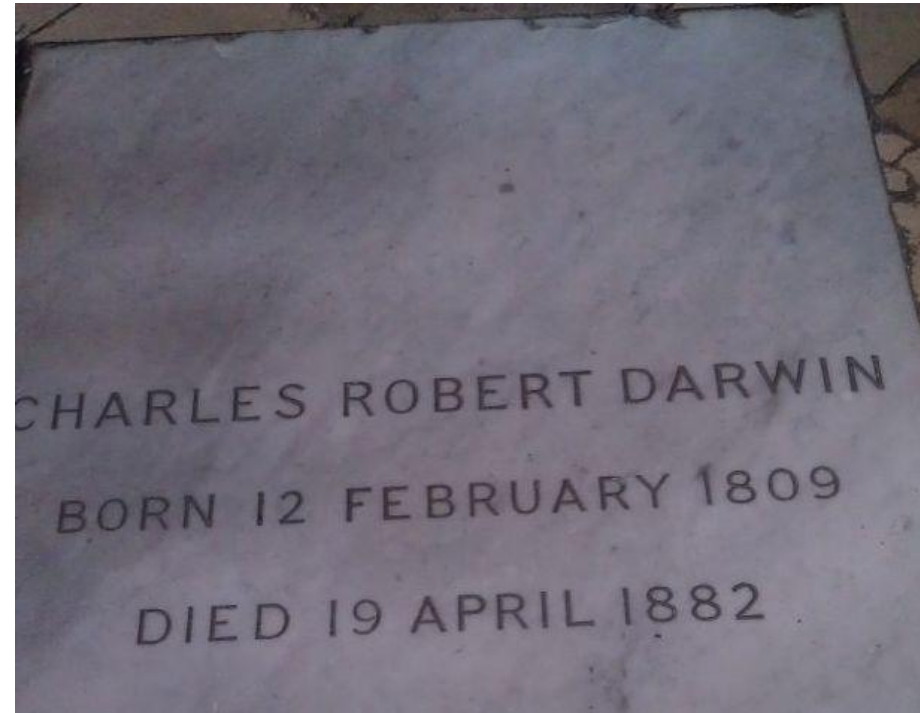


Photo taken in September 2013

Add Darwin to the Fathers of Information

*Thank you*