Flows of information as the driving force behind chemical pattern formation[1]

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Pattern formation in chemical systems is a dynamical process that has been extensively studied in the litterature since the original work by Turing. Thermodynamic analysis of this type of self-organising systems is of importance in order to understand some of the constraints that self-organisation meets, primarily the need of free energy as a driving force behind formation of spatial patterns.

We have developed an information-theoretic framework that goes one step further in the analysis of physical constraints in chemical pattern formation, see Lindgren et al (2004)[2]. The formalism is based on a thermodynamic information quantity (via statistical mechanics), and this makes it possible to connect an information-theoretic characterisation of a spatial pattern with the free energy driving the system. In this way, a consistent picture of the pattern formation process in terms of free energy being transformed into information in a spatial pattern and eventually destroyed by entropy production when reactions and diffusion processes tries to bring the system towards equilibrium.

In our analysis the information in the pattern is decomposed into contributions from both different positions and different length scales. The overall picture we get is an inflow of information at large length scales, due to the inflow of chemical free energy. Information then flows down in length scale (and also across space), where accumulation at certain positions is connected with the pattern formation. Information is lost from the system at the finest length scales. The whole process is summarised in a continuity equation for information.

In the present paper we investigate the possibility to use this formalism to make predictions on how pattern formation may depend on the structure of the driving force, i.e., the inflow of free energy. Preliminary results indicate that the information flow is generally going in the direction described above – from larger to smaller length scales – which may be viewed as generalised ”second law” of information destruction. If the characteristic length scale of the free energy inflow is reduced below the length scale of the patterns in the system, the flow will not be able to support the structures built up and neither will new structure emerge unless that happends on a smaller length scale. In the same way as ambient heat has too low energy quality to drive a physical process, a chemical free energy inflow of too low length scale characteristics may be insufficient to support pattern formation.

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[2] Lindgren, K., Eriksson, A., and Eriksson, K.-E., ”Flows of information in spatially extended chemical dynamics,” in *Artificial Life IX: Proceedings of the Ninth International Conference on the Simulation and Synthesis of Living Systems*, Pollack, J., Bedau, M., Husbands, P., Ikegami, T, and Watson, R. A. (MIT Press, 2004).