Chapter 8
Networks:
A Sketchy Portrait of an Emergent Paradigm

Alessandro Giuliani
Istituto Superiore di Sanita, Italy

ABSTRACT

The term 'network' is more and more widespread in all the fields of human investigation from physics to sociology. It evokes a systemic approach to problems able to overcome the limitations reductionist approaches evidenced since some decades. Network based approaches gave brilliant results in fields like biochemistry where the consideration of the whole set of metabolic reactions of an organism allowed us to understand some very important properties of the organisms that cannot be appreciated by the simple enumeration of the single biochemical reactions. Nevertheless, the lack of appreciation networks are modelling tools and not real entities could be detrimental to the exploitation of the full potential of this paradigm. On a separate but related note, not discovering the model-like nature of networks severely limits the recognition of the substantial identity between networks and other mathematical models so hampering the power of network-like thought.

Some applications of network based modelling are presented so to introduce the basic terminology of the emergent network paradigm to highlight strengths and limitations of the method and to sketch the strong relation linking network based approach to other modelling tools.

INTRODUCTION

The network paradigm is the prevailing metaphor in nowadays natural sciences. We can read about gene networks (De Jong 2002, Gardner & Faith 2005), protein networks (Bork et al. (2004)), metabolic networks (Nielsen 1998, Palumbo et al. 2005), ecological networks (Lassig et al. 2001) and so forth. This metaphor went well outside the realm of natural science so to invade most 'humanistic' and less formalized fields like sociology or psychology (McMahon et al. 2001).

The network paradigm is an horizontal construct (Palumbo et al. 2006), basically different

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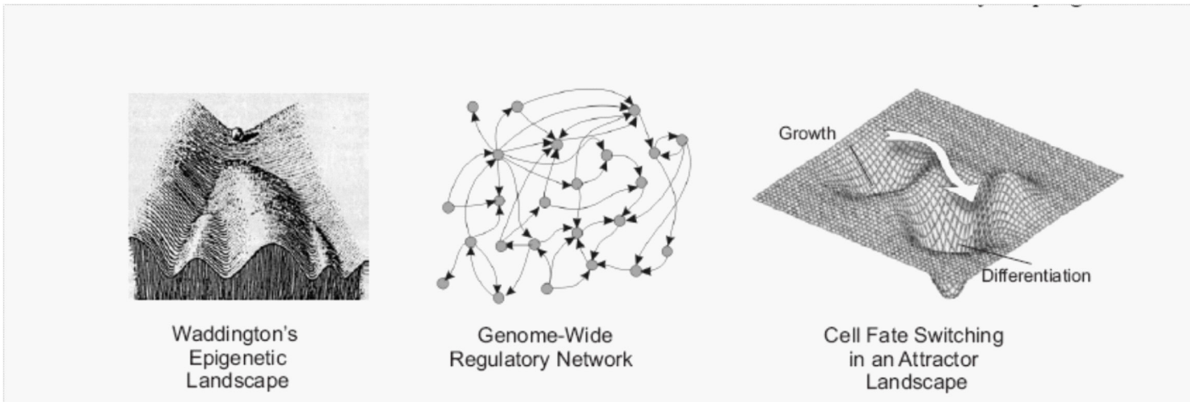
Figure 1. Waddington's epigenetic landscape, genome-wide regulatory network, and cell fate switching in an attractor landscape



from the classical top-down paradigms of modern science, dominating the theoretical scene until not so many years ago (and still more or less unconsciously shaping the way of thinking of the large majority of scientists), in which there was a privileged flux of information (and a consequent hierarchy of explanation power) from more basic atomisms (fundamental forces in physics, DNA in biology) down to the less fundamental phenomenology (condensed matter organization, physiology).

The general concept of network as a collection of elements (nodes) and the relationships among those (arcs), cannot be separated by the definition of a "system" in dynamical systems theory, where the basic elements (nodes) are time varying functions and relationships are differential or difference equations. In this respect, the two definitions are very similar, while the emphasis of the term 'network' is on topology (i.e. the static wiring diagram of the modelled reality), the term 'dynamical system' refers to the dynamics emerging from the interaction of components, i.e. to the actual behaviour of the network when observed in time. This analogy is at the root of the recently renewed interest for systems biology (Klipp et al. 2005). The following sketch (Figure 1) comes (with permission) from a recent paper by Donald Ingber (Ingber D.E. (2006)).

On the left of Figure 1 the Conrad Waddington's cartoon of epigenetic landscape is depicted: it is a very famous and effective model of embryological development in which the differentiation trajectories of cell populations are depicted as a marble rolling across a rugged landscape of peaks and valleys following a 'least-action' trajectory driving the cell from an unstable undifferentiated stem state (top of the landscape, first embryonic development phases) to the definitive cell fates (bottom of the landscape, correspondent to mature, definitive tissues) following the 'valleys' generated by the regulation of genes expression (epigenetic control) (Waddington CH (1956)). In the fifties the Waddington's model was nothing more than a genial metaphor, in the XXI century this metaphor was filled by 'reality' by the discovery the epigenetic landscape was nothing more nothing less than the image of the stable states of a very connected network of interacting genes giving rise to an energy field in which the different cell kinds correspond to the potential minima. Even if we are still very far to understand the 'nature' of this differentiation 'energy, nevertheless we are able to sketch the phenomenological features of such landscapes (Felli et al 2010). It is worth considering how the network model was in this case a sort of 'transit paradigm' from a metaphorical to a fully dynamical and measurable way to model complex systems.

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