

Weak Links

The Universal Key to the Stability of Networks and Complex Systems

Peter Csermely

(September 2005

weaklink@puskin.sote.hu

www.weaklinks.sote.hu)

Synopsis

The author is a professor of biochemistry, who studied the weak links between proteins for 15 years, and was intrigued by the unexplained, stress protein-induced stabilization of cells and animal development. When he started to look for an explanation, a strikingly general statement emerged from sporadic data published in various disciplines: weak links stabilize complex systems. This book is to show the exciting consequences of this concept in all areas of science providing a universal key to understand the stability and diversity of networks ranging from the atomic to the planetary level. The author builds on recent advances showing an astonishing identity in the topology of various networks, and shows that weak links play a major role to stabilize most, if not all of them. The initial part of the book gives a concise summary of the structure, dynamics and perturbations of networks. Further chapters raise lots of exciting examples from the role of weak bonds developing macromolecular structures, through the role of weak protein-protein interactions in genetic stability, evolution, aging and cancer, as well as the stabilization of neural networks, social nets, the human language, software systems, town architecture, business organizations, the world-trade web and the whole ecosystem around us by weak links. The book is written to a general audience having a high school science education. Besides a panel of eminent scientists from a broad range of various disciplines and a number of high school student researchers will be asked to read the text and suggest modifications to increase its clarity. However, despite its popular tone, the book will use a sharp logic throughout, and will cite all the key original references proving the concept. The book will synthesize the network-, holistic and dynamism-oriented approaches of the books published recently in the field, and use them to prove and elucidate its take home message: weak links stabilize complex systems.

Copyright © 2005 by Springer Verlag

Table of contents

1. Introduction: How the LINK-s were formed	5
2. A principle is born: the Granovetter-study	13
3. Why do we like networks?	16
3.1. Small-worldness	19
3.2. Scale-freeness	22
3.3. Nestedness	36
3.4. Weak-linkness	43
4. Network stability	45
4.1. Perturbations, bad and good noise	45
4.2. Life as a relaxation phenomenon: dissipate locally, connect globally	52
4.3. Network failures	60
4.4. Topological phase transitions of networks	64
4.5. Nestedness and stability: Sync	68
4.6. How can we stabilize networks? Engineers or tinkerers	76
5. Weak links as stabilizers of complex systems	79
5.1. Weak links stabilize complex systems: an emerging synthesis	79
5.2. Weak links: a starting definition	83
5.3. Stability: a starting definition	85
5.4. Complex systems	87
5.5. Weak links and system-degeneracy	88
6. Atoms, molecules, macromolecules	92
6.1. The problems of protein folding	92
6.2. Energy landscapes	95
6.3. Weak bonds in protein and RNA folding	98
7. Weak links and cellular stability	102
7.1. Cellular networks	102
7.2. Stability of the cellular net	104
7.3. Stress, diversity and jumps in evolution	112
7.4. Cancer, diseases, aging	119
8. Weak links and the stability of organisms	125
8.1. Immunological networks	125
8.2. Transport systems	128
8.3. Muscle-net	129
8.4. The neuro-glial network	131
8.5. Psycho-net	134

9. Social nets	141
9.1. Animal communities	141
9.2. A novel explanation of menopause	143
9.3. Stability of human societies	145
9.4. Firms and human organizations	155
9.5. Dark networks, terror-nets	161
9.6. Pseudo-grooming	162
10. Networks of human culture	168
10.1. The language-net	168
10.2. Novels, dramas and films as networks	172
10.3. Our engineered space	177
10.4. Software-nets	181
10.5. Engineers and tinkerers: an emerging synthesis	183
11. The global-web	185
11.1. The world trade web	185
11.2. Turning points in history	188
11.3. Weak links: a part of social capital	195
12. The eco-web	199
12.1. Weak links and the stability of ecosystems	199
12.2. Omnivory	202
12.3. The weak links of Gaia	204
13. Conclusions and perspectives	208
13.1. The unity of the weakly-linked world: a summary	208
13.2. Return to the definitions: a synthesis	213
13.3. Limitations and extensions	229
13.4. Weak links and our life	231
14. Appendix	236
14.1. References	236
14.2. Useful links	262
14.3. Glossary	264
14.4. Index	269