Evolution, Hierarchy and Modular Organization in Complex Networks

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Thesis Defence

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University of Notre Dame

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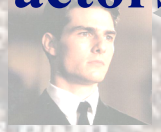
Networks in life

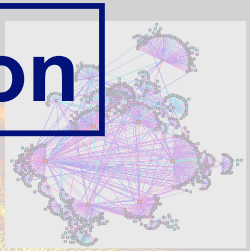
Society

→ Friendships, sexual contacts
→ Co-authorship, citations
→ Movie actors, business



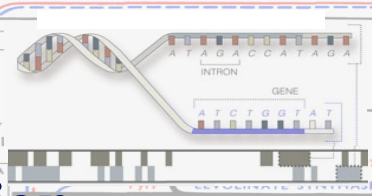
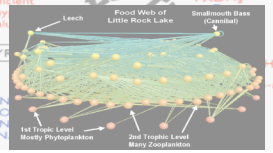

Days of Thunder
Far and Away
Eyes Wide Shut

Communication



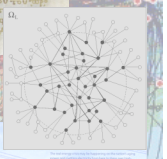
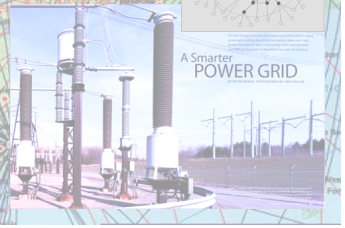
→ Internet
→ World Wide Web
→ Phone call networks

Biology

→ Genetic regulation
→ Protein-protein interactions
→ Metabolic pathways
→ Food webs
→ Neuron networks

And more…

→ Airline routes
→ Word webs
→ Power grid

Networks in life

Society

→ Friendships, sex

→ Co-authors

→ Movie a

Communication

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Biolog

→ Genetic re

→ Protein-protei

→ Metabolic pathways

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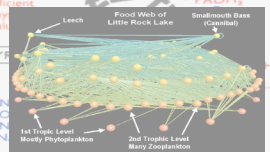
→ Neuron networks



Complexity

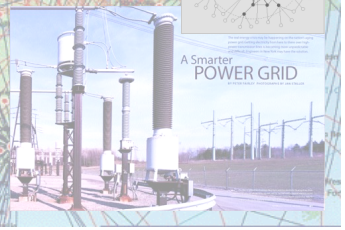
• topology of interactions

• time evolution of the structure

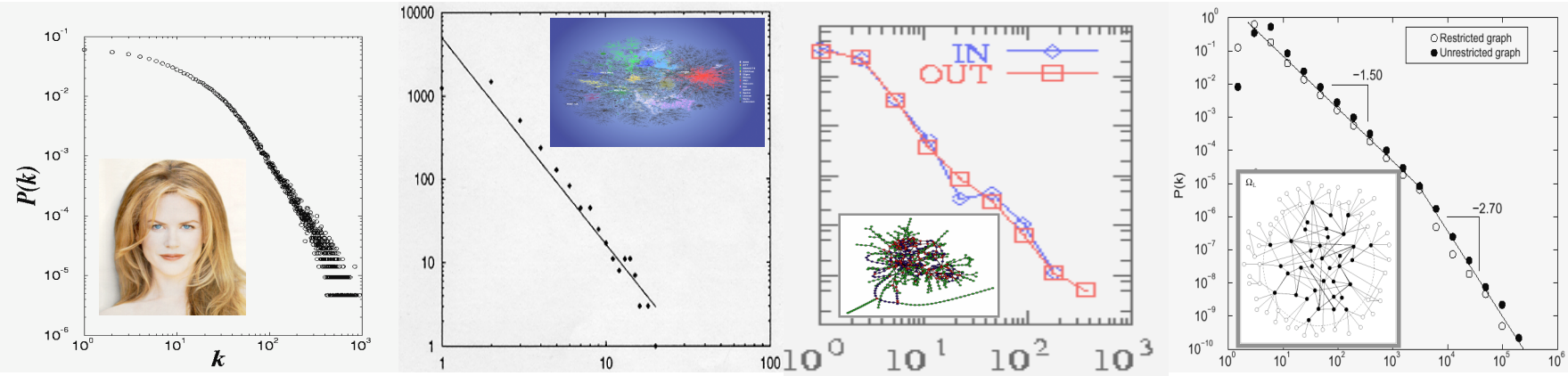
• dynamics on the structure

ebs

→ Power grid



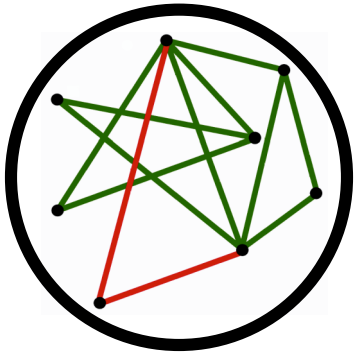
Similar topologies



POWER LAW DEGREE DISTRIBUTION

⇨ **Barabási-Albert model**

→ growth and preferential attachment



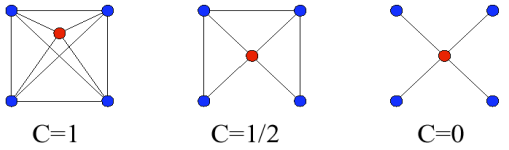
⇨ **preferential attachment as a consequence**

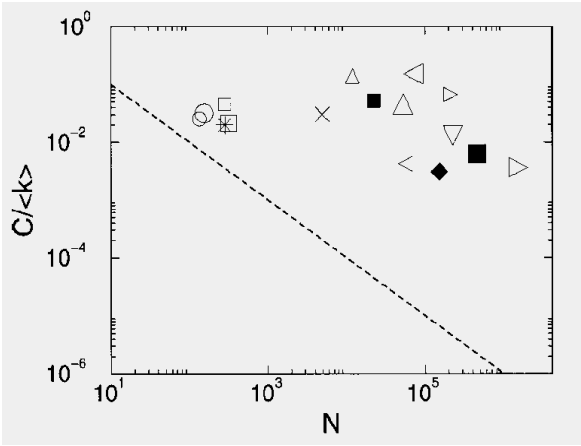
protein duplication
triad formation
finite memory of nodes

Clustering in networks

⇨ **Clustering coefficient**

→ high average in real networks





⇨ **Modular organization**

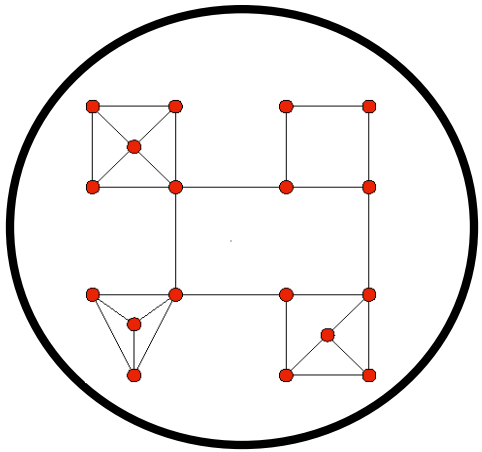
→ WWW communities

→ Research groups

→ Research areas

→ Circles of friends

→ Protein complexes



Clustering in networks

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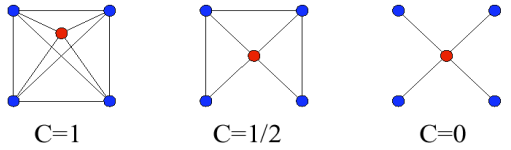

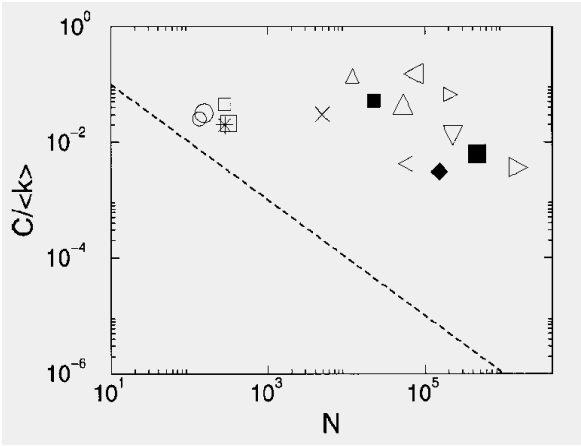

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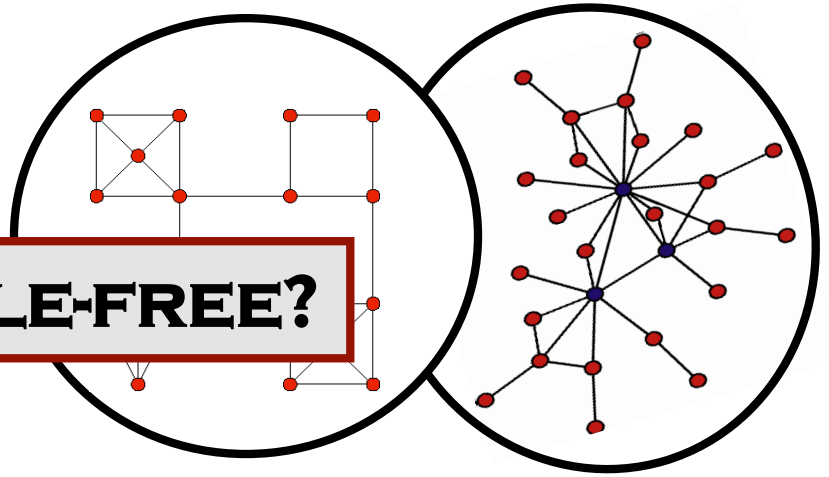
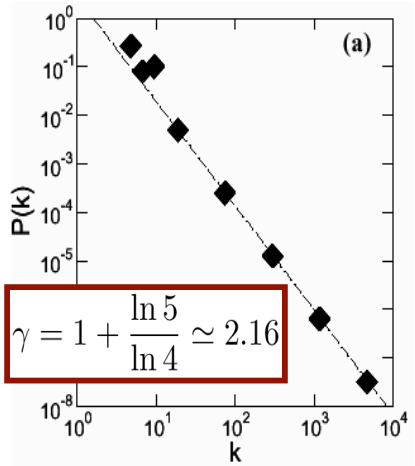
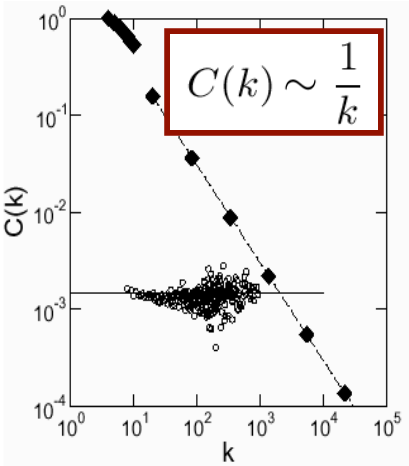


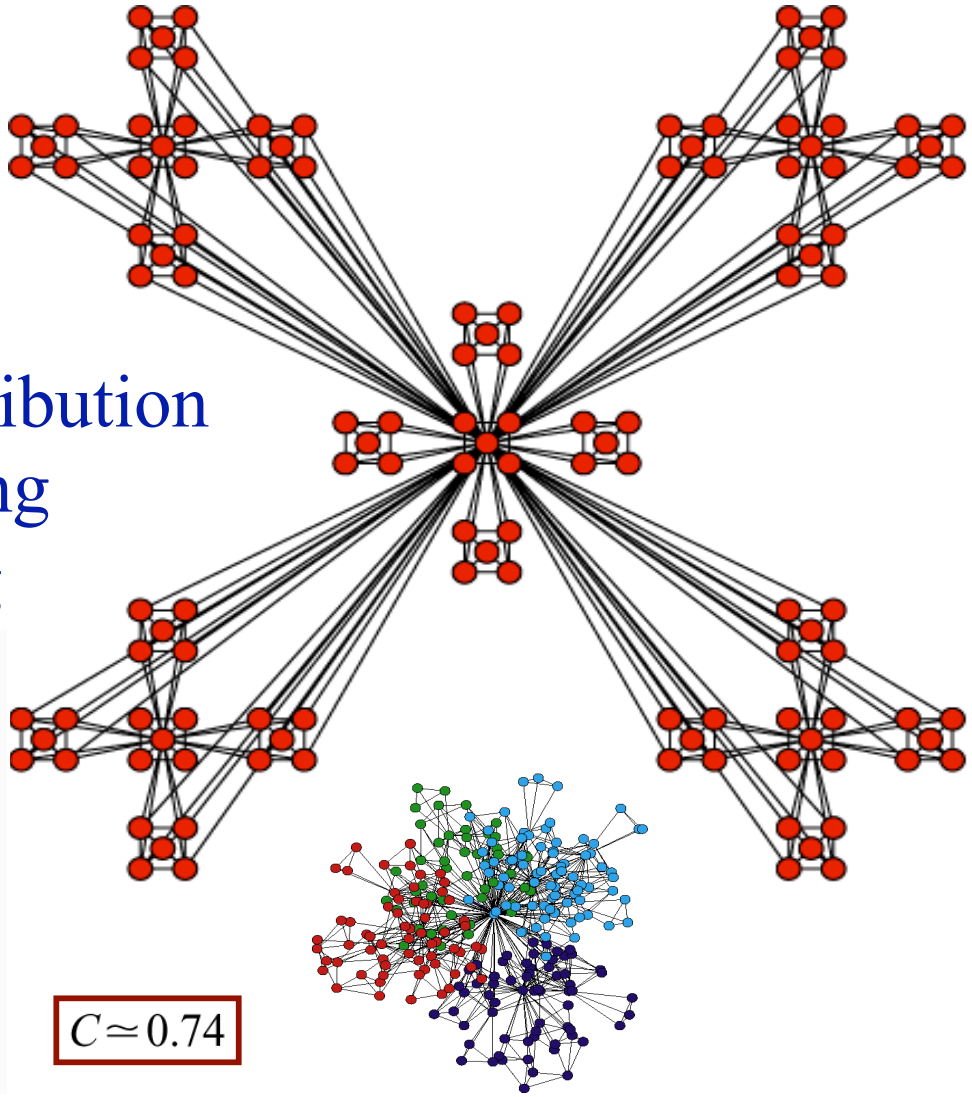
MODULAR AND SCALE-FREE?

Module hierarchy

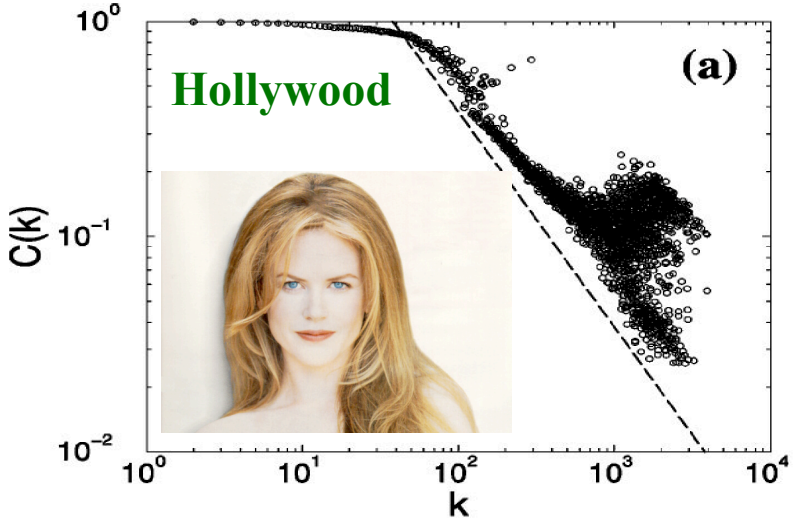
- **Hierarchical model**
  - → iterative construction
  - → nested modules
- **Topological properties**
  - → scale-free degree distribution
  - → large average clustering
  - → hierarchical clustering

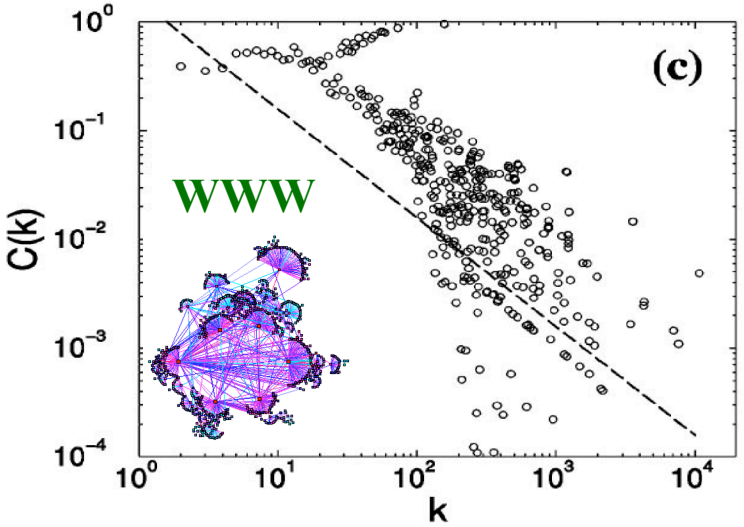


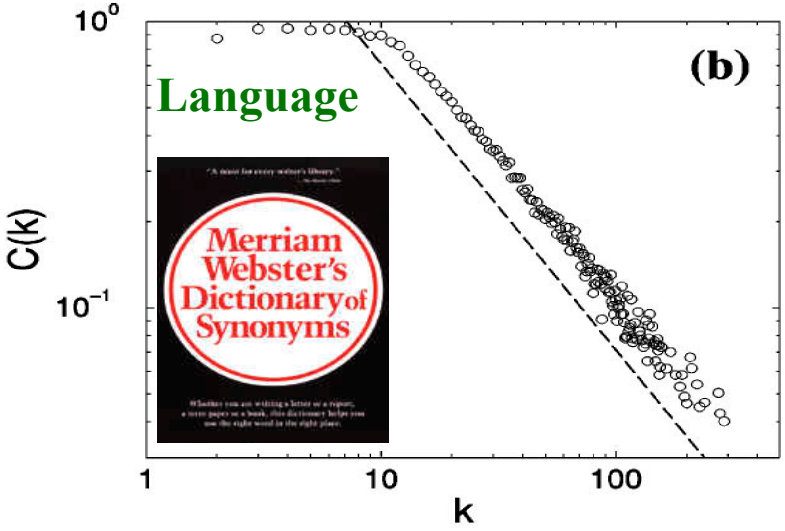


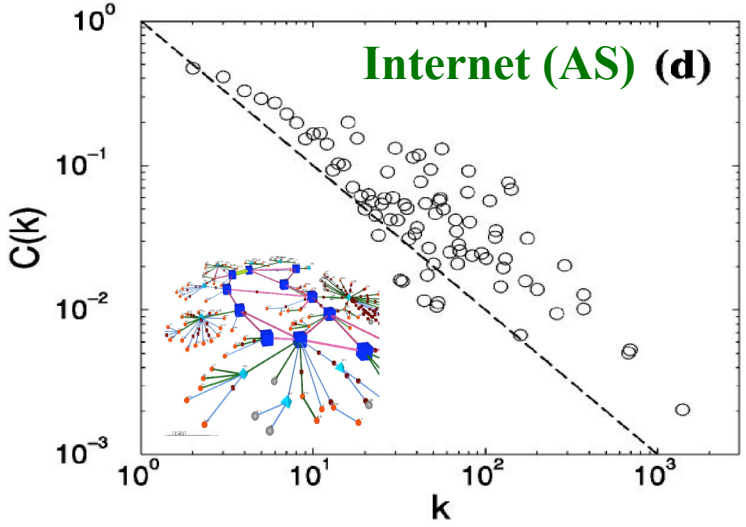


❖ Hierarchical networks ❖



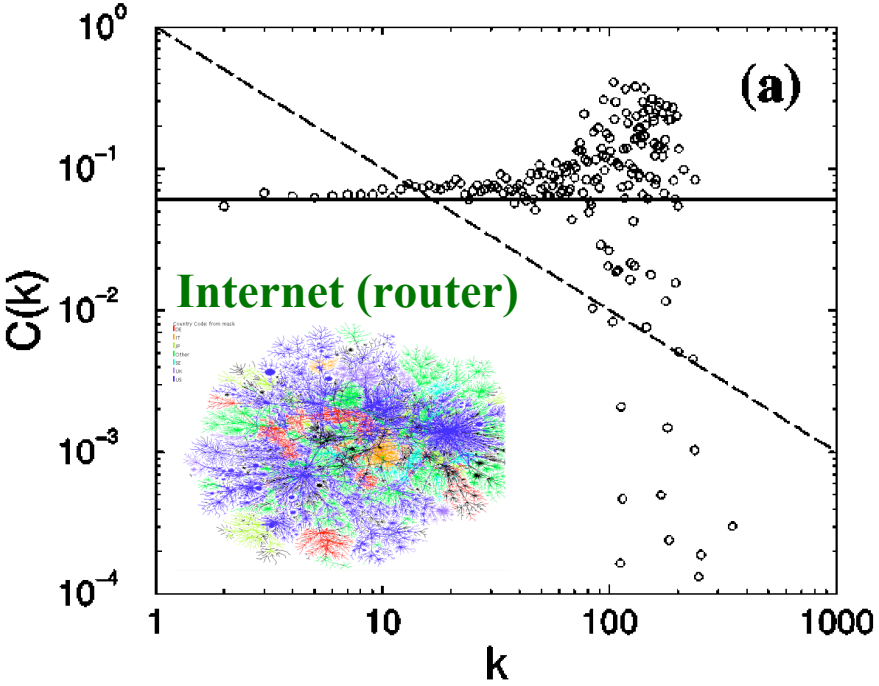


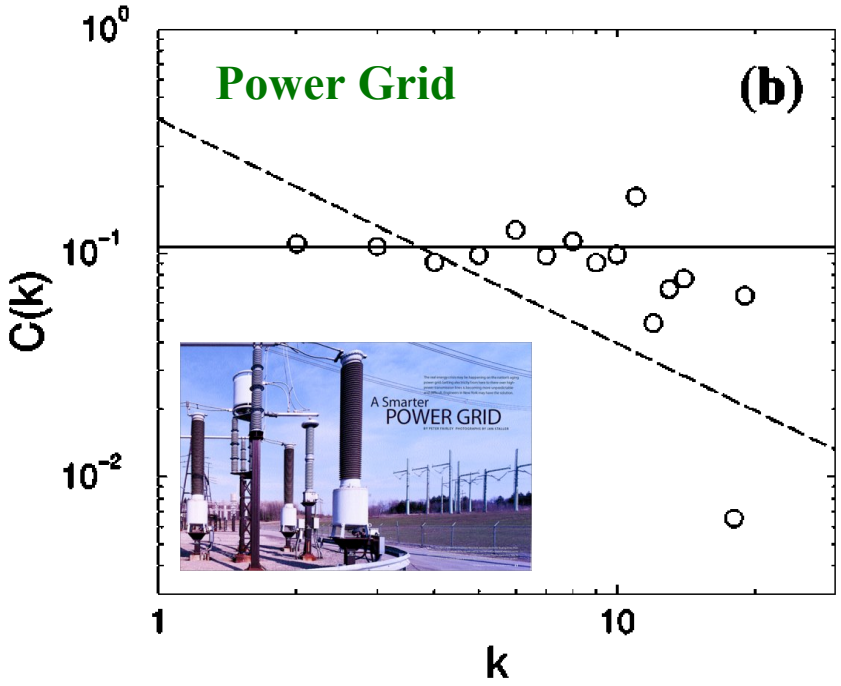




❖ Absence of hierarchy ❖

Geographically localized networks

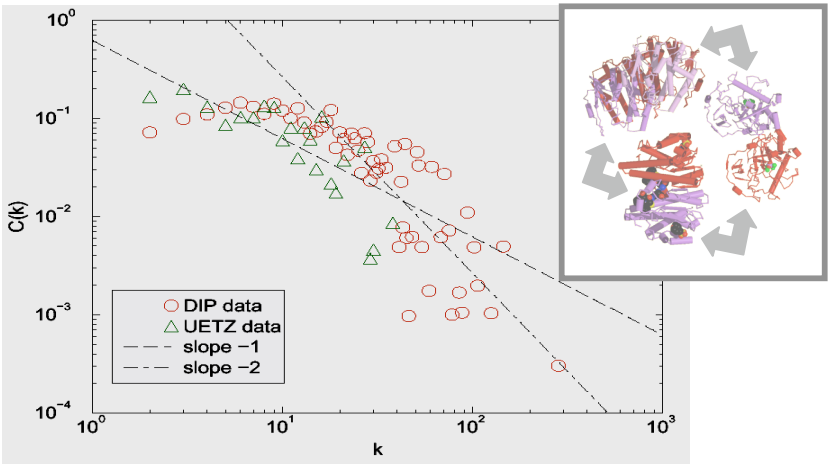




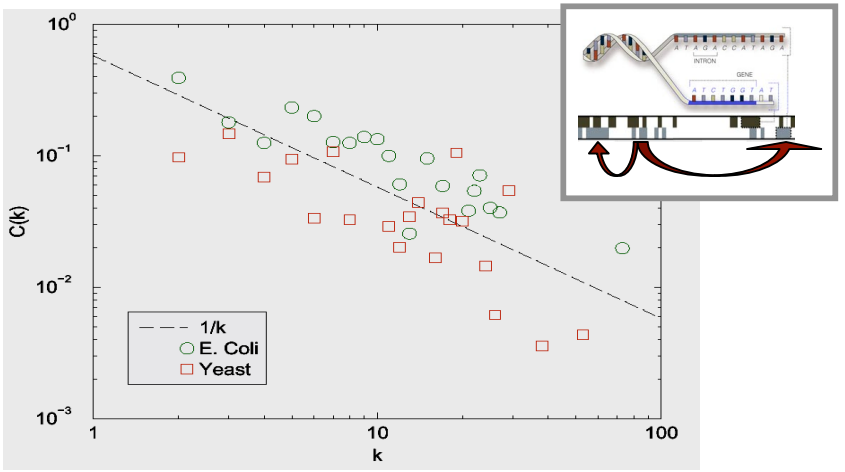
Economic pressure to minimize link lengths

Biological systems

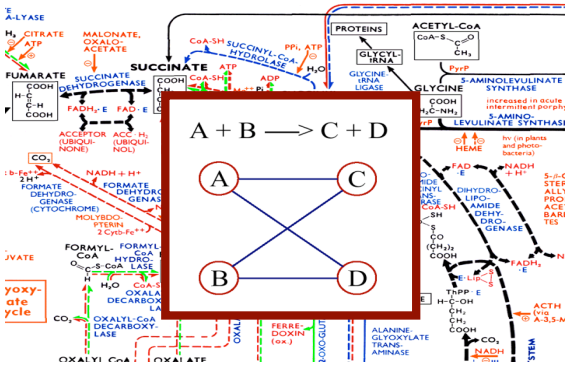
Protein-protein interaction

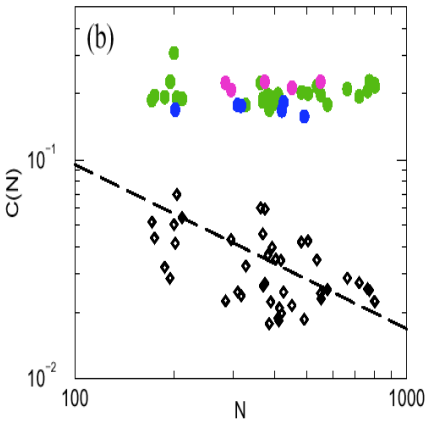


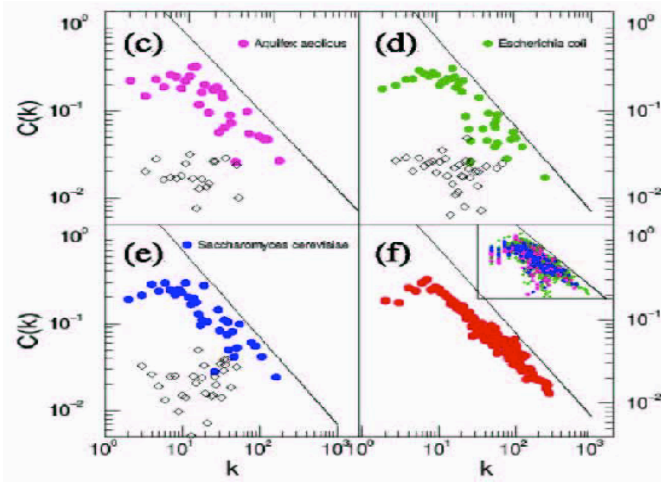
Regulatory networks



Metabolic networks

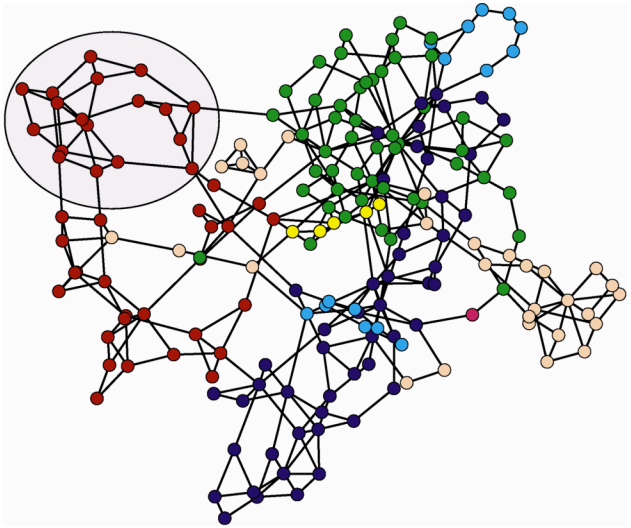






The metabolism of *E. Coli*

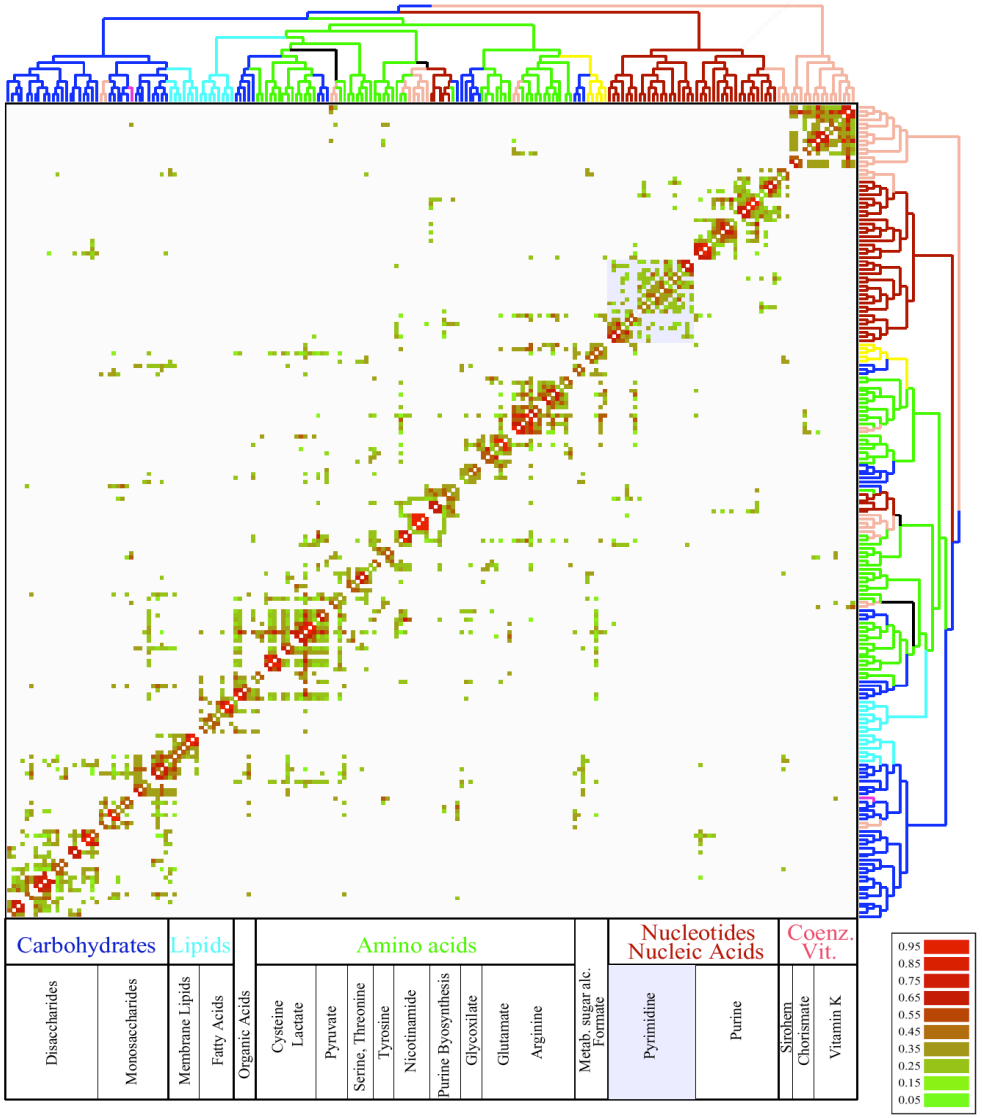
Biochemical and topological reduction



Hierarchical clustering

→ Similarity matrix

→ Average linkage clustering (UPGMA)



❖ Further thesis topics ❖

- Evolution of the scientific co-authorship network
- Lethality in the *E. Coli* metabolic network
- Modeling metabolic network topology

THANK YOU!