Network analysis begins with data that describes the set of relationships among the members of a system. The goal of analysis is to obtain from the low-level relational data a higher-level description of the structure of the system which identifies various kinds of patterns in the set of relationships. These patterns will be based on the way individuals are related to other individuals in the network. Some approaches to network analysis look for clusters of individuals who are tightly connected to one another; some look for sets of individuals who have similar patterns of relations to the rest of the network. Our work has emphasized the use of spectral methods for finding structure in social and other networks, a focus on graph theoretic rather than statistical methods, the development of a unified, coherent theoretical foundation which shows the connections to other fields, and the insistence on concepts and procedures that scale well to very large networks. Spectral methods construct a continuous multidimensional representation of the network in which the coordinates of the individuals can be further analysed to obtain a variety of kinds of information about them and their relation to the rest of the network.

Spectral methods (eigendecomposition) have been a part of graph theory for over a century. Network researchers have used spectral methods either implicitly or explicitly since the late 1960's, when computers became generally accessible in most universities. The eigenvalues of a network are intimately connected to important topological features such as maximum distance across the network (diameter), presence of cohesive clusters, long paths and bottlenecks, and how random the network is. The associated eigenvectors can be used as a natural coordinate system for graph visualization; they also provide methods for discovering clusters and other local features. Eigenvector coordinates may be analysed in combination with other node attributes either given as part of the data (e.g. sex) or derived from the network (e.g. degree) to find relationships in large, complex multivariate networks

In particular, the Normal spectrum has become the centre of our research and developmental efforts since its natural handling of bipartite graphs has allowed us to examine multi-modal networks, which we have recently used to address medical problems such as relationships among symptoms and exposures, and co-occurrences of types of cancers in families. The use of spectral methods allows *analytic visualization*. To extend this approach, we have developed methods that build upon spectral results, making it possible, for example, to bring node and link characteristics into the analysis. These are demonstrated in figure 1, which shows Normal spectral results for people, symptoms and exposures in which the locations of people on one eigenvector have been quantized into deciles. Figure 2a shows the relation between the decile people are in and the symptoms they report. Figure 2b shows the same deciles of people and the exposures they report. This clustering of types of symptoms and associated clustering of types of exposures is a new result.

Figure 3 shows two dimensions from the Normal spectrum of a 3-mode dataset describing 1440 families, their members, and co-occurrences of several types of cancer. Deciles based on this analysis reveal different patterns of co-occurrences in the bottom (Q1) and top (Q10) deciles of families – something not previously observed.

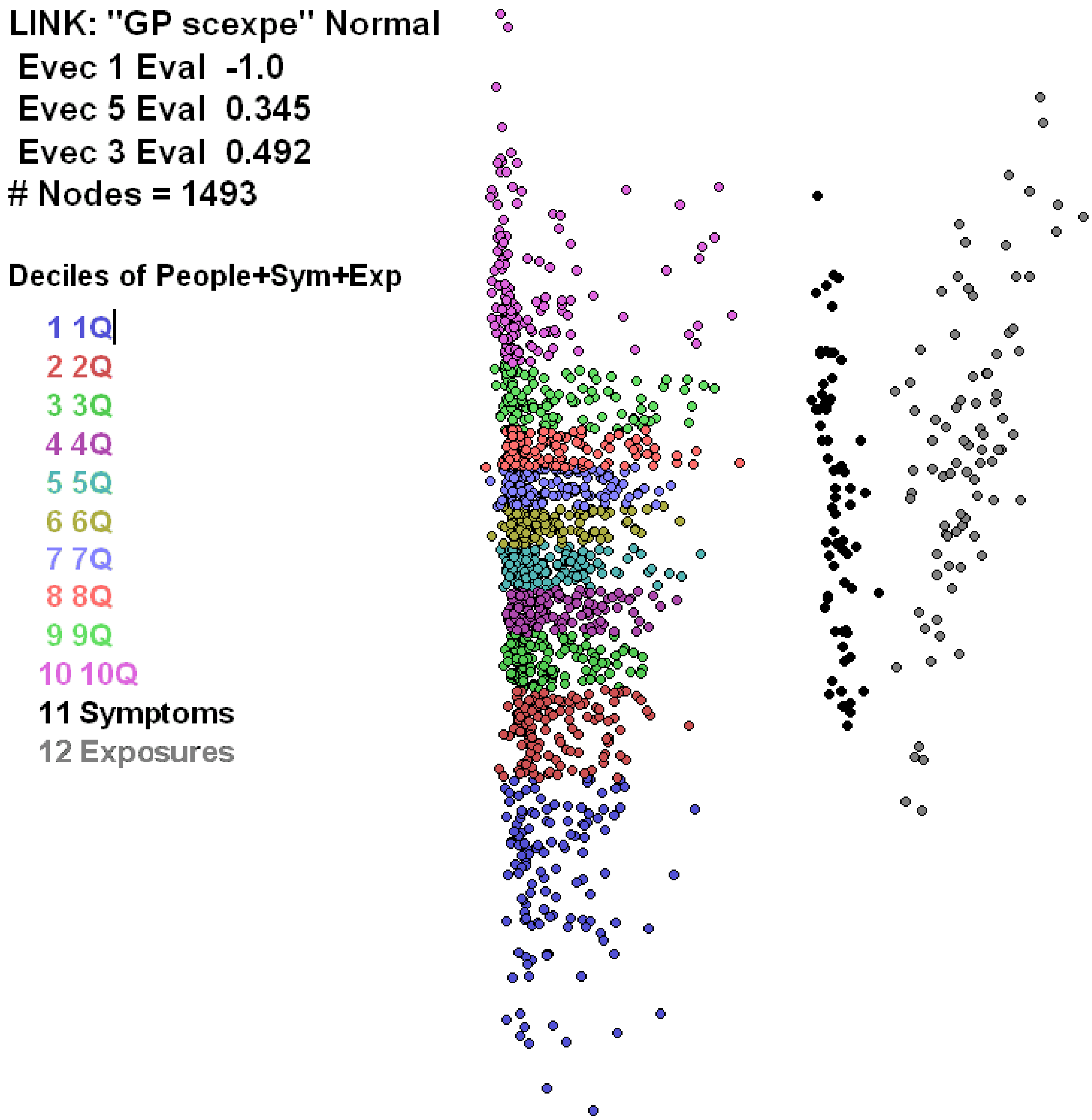
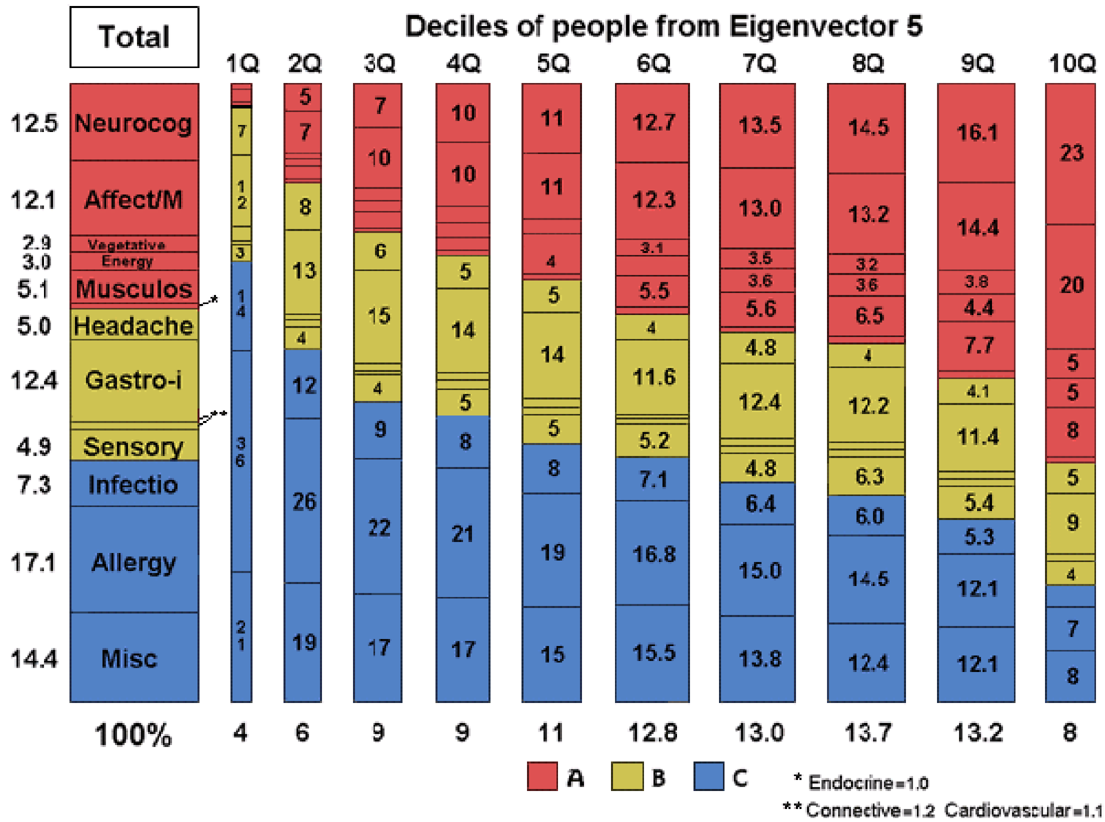
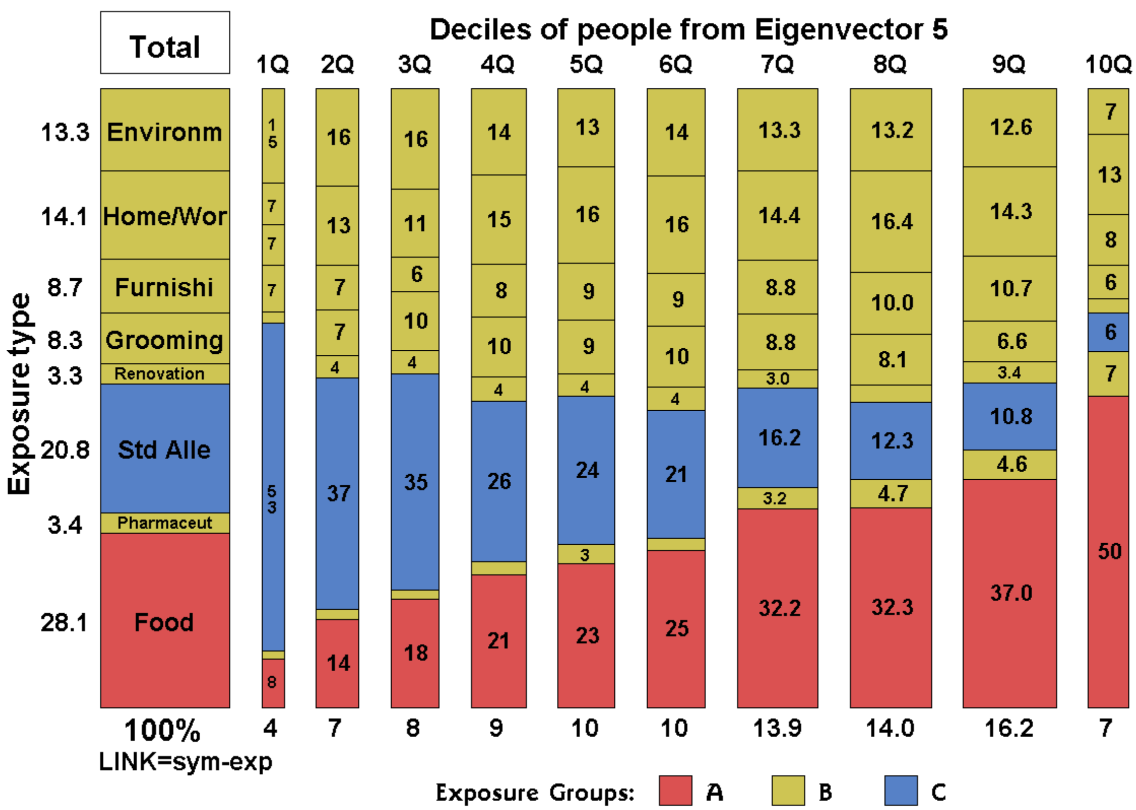

LINK: "GP scexpe" Normal
Evec 1 Eval -1.0
Evec 5 Eval 0.345
Evec 3 Eval 0.492
Nodes = 1493
Deciles of People+Sym+Exp
1 1Q
2 2Q
3 3Q
4 4Q
5 5Q
6 6Q
7 7Q
8 8Q
9 9Q
10 10Q
11 Symptoms
12 Exposures

Figure 1


Total
Deciles of people from Eigenvector 5
1Q 2Q 3Q 4Q 5Q 6Q 7Q 8Q 9Q 10Q
12.5 Neurocog
12.1 Affect/M
2.9 Vegetative
3.0 Energy
5.1 Musculos
5.0 Headache
12.4 Gastro-i
4.9 Sensory
7.3 Infectio
17.1 Allergy
14.4 Misc
100%
4 6 9 9 11 12.8 13.0 13.7 13.2 8
A B C
* Endocrine=1.0
** Connective=1.2 Cardiovascular=1.1


Total
Deciles of people from Eigenvector 5
1Q 2Q 3Q 4Q 5Q 6Q 7Q 8Q 9Q 10Q
Exposure type
13.3 Environm
14.1 Home/Wor
8.7 Furnishi
8.3 Grooming
3.3 Renovation
20.8 Std Alle
3.4 Pharmaceut
28.1 Food
100%
LINK=sym-exp
4 7 8 9 10 10 13.9 14.0 16.2 7
Exposure Groups: A B C

Figures 2a,b

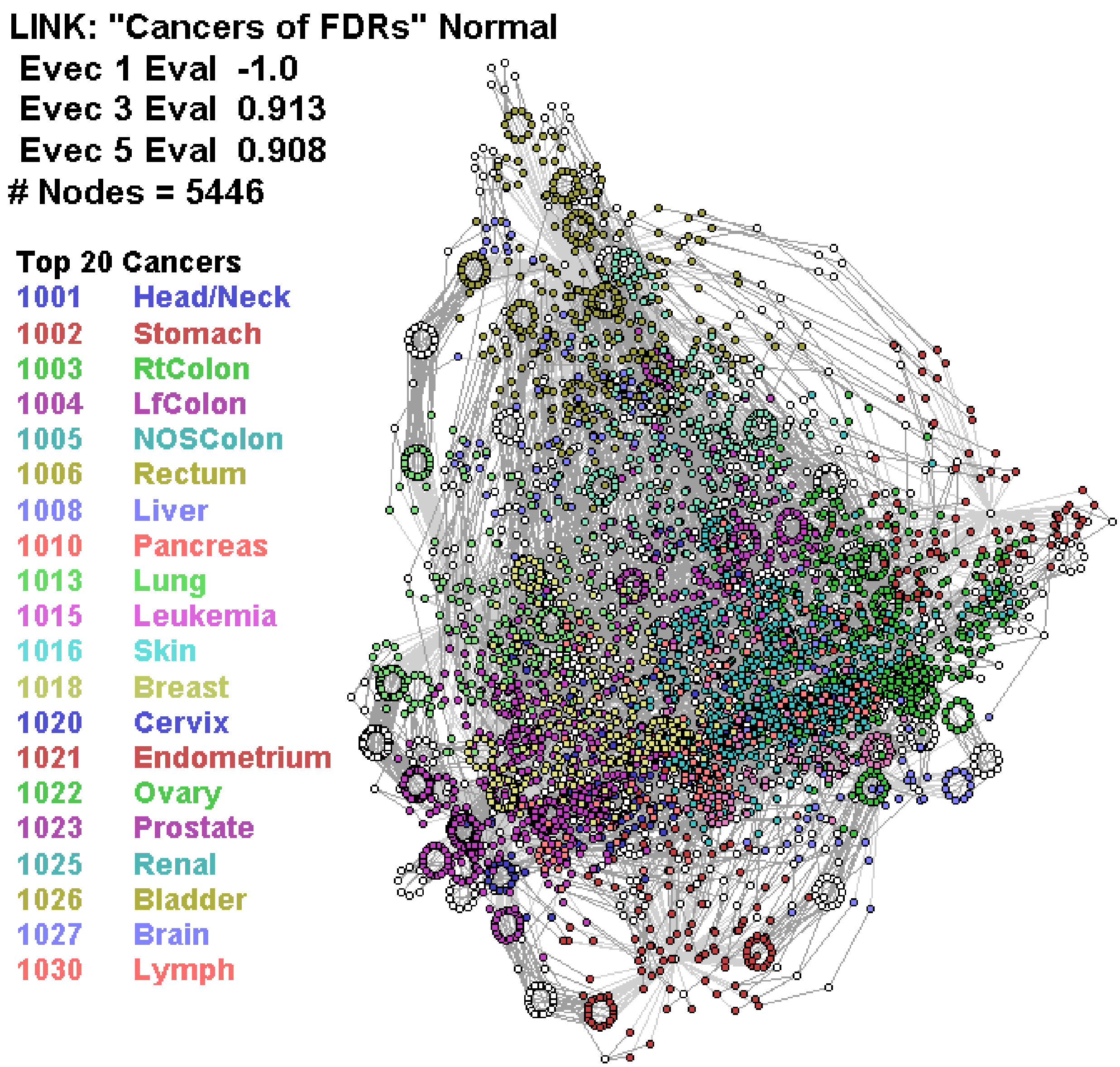

LINK: "Cancers of FDRs" Normal
Evec 1 Eval -1.0
Evec 3 Eval 0.913
Evec 5 Eval 0.908
Nodes = 5446
Top 20 Cancers
1001 Head/Neck
1002 Stomach
1003 RtColon
1004 LfColon
1005 NOSColon
1006 Rectum
1008 Liver
1010 Pancreas
1013 Lung
1015 Leukemia
1016 Skin
1018 Breast
1020 Cervix
1021 Endometrium
1022 Ovary
1023 Prostate
1025 Renal
1026 Bladder
1027 Brain
1030 Lymph

Figure 3