Glossary

The vocabularies we use derive from anthropology (kinship, social roles), sociology (social networks, norms), graph theory (graphs, networks), complexity theory (fractals, power laws), and hybrids (network concepts for kinship). References are provided to sources where methods and computer software are discussed, such as Pajek (Batagelj and Mrvar 1998) and UCINET (Borgatti, Everett, and Freeman 1995). Where software commands are possible to implement some of the operational terms, the commands are given in Glossary endnotes. Other terms that require illustration and conceptual understanding are given where needed in the text. We present the list of terms in the Glossary first to make it easier for the reader to find what he or she is looking for. The page on which a key term in bold is mentioned is also given in the index. While a number of terms in the graph theory and other sections are ordinary English words, they may have technical meanings or are associated with technical measurements. As a branch of mathematics, for example, graph theory is particularly powerful because simple intuitive terms are given technical meanings that allow formal measurements to be replicated and theorems to be proven. Other terms have technical meanings for kinship or other domains of the social sciences.

List of Terms in the Glossary

Ethnographic and Sociological Vocabulary:

- Behavior
  - Constraint (on behavior)
  - Preference
  - Emergent group, rule, role, process. See Network-Defined Concepts in Social Organization
- Norm
  - Statistical Norm
  - Ideal Norm
  - Prescription
- Marriage Behaviors
  - Marital relinking
  - Affinal relinking
  - Consanguineal relinking
- Role Relations
  - Avoidance
  - Authority
  - Respect
  - Informality
  - Joking
- Types of Kin

e.g., MBD, FZD, FB, FBD, MZ, MZD, HZ, BW, y, e
Consanguineal
Affinal
Kinship Terms

Graph Theory

Node
vertices
degree
Line
endpoints
incident
edge
arc
loop
multiple
Graph
signed graph
multigraph
digraph
simple graph
path
cycle
Relation
multiple relation
directed relation
simple relation
matrix

Networks Vocabulary:

Network
social network
subnetwork
maximal
Tie
simple tie
multiplex tie
reciprocal
transitive see triad

Structural Properties of Graphs and Networks:

Reciprocity
Curvature
topology
Balance, Clustering and Ranking
balanced graph
clustered graph
ranked
Transitivity
Properties of Triples
complete
triad census
reciprocity
balance
clustering
transitivity
ranking
Cohesion, Structural Cohesion
k-connectivity
multiconnectivity
k-components
embedded cohesive hierarchies
k-components
Exocohesion
Adhesion
Centrality
closeness
betweenness
Recursive centrality
Centralization
Edge Betweenness and Cohesion
Structural and Regular Equivalence and Blockmodeling
structurally equivalent
regularly equivalent
blockmodel

Methods of Graph and Network Analysis:

Hierarchical Clustering

Automatic drawing, spring embedding
- Energized graphs
- Energy commands
- spring embedders

Eigenvalue/Eigenvector analysis

Analytic Kinship Vocabulary:

Asset and Marriage Transfers:
- Wealth-asset
- Bridewealth
- Dowry

Descent Groups:
- Clan
- Lineage

Affinity and Descent:
- Agnatic
- Uterine
- Cognatic or Bilateral
- Unilineal
- Modes of reckoning descent
  - depth first search (DFS)
  - breadth first search (BFS)
  - sibling set depth first search
  - ahnentafel (inverse BFS)

Postmarital Residence:
- Patrilocal
- Matrilocal
- Neolocal

Network-Defined Concepts in Social Organization: for detail see Table 5.2
- Structural Endogamy
- Categorical Endogamy
- P-graph
- Emergents: See Complexity
- Emergent group
- Emergent rule
- Emergent role
- Emergent process

Complexity Theory:

Micro-macro linkages

Emergents and Emergence
- emergent
  - emergent group, rule, role, process: see *Network-Defined Concepts in Social Organization*
- nonlocal
- local emergents
- simulation
- complex adaptive systems (CAS)
- Emergence

Complexity

Tipping Point

Power-law growth or decay

Fractality

Exponential growth or decay

Ethnographic and Sociological Vocabulary:

Behavior. An observed regularity in a person's actions or pattern of similarity in the actions of members of a group.

Constraint (on behavior). One or more external circumstances that together limit the scope of an action or behavior.

Preference. A regularity in behavior that favors one alternative significantly above chance levels within a set of unconstrained alternatives and attributable to a valued choice rather than to constraints on behavior. Care must be taken in attributing preferences, and they are not always stable.

Emergent group, rule, role, process. See ***Network-Defined Concepts in Social Organization.***

Norm. A regularity in people's actions, as members of a group, either in practice or stated as an ideal.

Statistical Norm. A rule of behavior that applies to members of a group, usually including a hierarchy of exceptional subrules.

Ideal Norm. A cognized and culturally shared statement of how people should behave, not always corresponding to how people do behave.

Prescription. An ideal norm that purports to allow no deviation of actual behavior from a stated rule.

Types of Kin

Examples include **MBD, FZD, FB, FBD, MZ, MZD, HZ, BW, y, e.** These compounds are used to stand for types of relatives, where the individual letters stand for **mother (M), father (F), sister (Z), brother (B), wife (W), husband (H), daughter (D)** and **son (S), parent (P)** and **child (C)**; and for the relative age distinctions **elder (e)** and **younger (y)**. FeBD, for example, is father's elder brother's daughter.

Consanguineal. Two persons are consanguines if they have one or more common ancestors, for example, the reciprocal pair MBD/FZS is a consanguineal relationship.

Affinal. Two persons are affinals if a relation between them can be traced that includes a tie of marriage. **In-laws** include the consanguines of a spouse or the spouses of consanguines, but longer chains of relationship such as the spouse of a consanguineal of a spouse of a consanguineal (e.g., **HZHZ**) or a consanguineal of a spouse of a consanguineal (e.g., **BWB**) are affinals in the more extended sense of the term.

Marriage Behaviors.

Marital relinking is the term used by European ethnographers (Brudner and White 1997) to refer to marriages in which the families of bride and groom are already linked by kinship or marriage.

Affinal relinking refers to the case, common in European villages, in which the bride and groom are not blood relatives, but are linked by prior marriage between their families.

Consanguineal relinking refers to marriage between consanguineal relatives, and calls attention to the fact that their respective nuclear families are already linked by blood ties.

Role Relations. Observed social behaviors associated with norms stated by members of a group. The following are examples in the kinship domain that are relatively self-explanatory and widely used in ethnographies because they are easily observed and often comprehensibly verbalized:

Avoidance.
Authority.
Respect.
Informality.
Joking.

Kinship Terms. The linguistic terms used in reference or address for blood relatives and in-laws. For the Aydınlı some of the important terms used in this book are given below.[1] Terms are distinctive for each of the parents and parents' siblings, and for each type of cousin.

Boba –	F father
Ana –	M mother
Koca, herıf –	H husband
Avrat, horanta, aile –	W wife (*aile* also used for small family)
Kız –	D daughter
Oğul –	S son
Ağa –	eB elder brother (also term of respect)
Kardaş –	B, yB younger B (term of familiarity)
Abla –	eZ elder sister (also term of respect)
Bacı –	Z, yZ sister (also term of familiarity)
Emmi –	FB, FFB father's brother
Dayı –	MB mother's brother
Emmi oğlu, emminin oğlu –	FB father's brother
Hala –	FZ father's sister
Teyze –	MZ mother's sister
Dede –	PF, PPF grandfather
Ebe –	PM, PPM grandmother
Kardaşın oğul –	BS brother's son
Kardaşın kızı –	BD brother's daughter
Bacının oğul–	ZS sister's son

Bacının kızı –	ZD sister's daughter
Torun –	CC, CCC grandchild (both sexes)
Dayının oğlu –	MBS mother's brother's son
Halanın oğlu –	FZS father's sister's son
Teyzenın oğlu –	MZS mother's sister's son
Emmi oğlu, emminin kızı –	FBD father's brother's daughter
Dayının kızı –	MBD mother's brother's daughter
Halanın kızı –	FZD father's sister's daughter
Teyzenın kızı –	MZD mother's sister's daughter
Güvey –	bridegroom
Gelin –	SW daughter-in-law, bride, y married woman
Oğlan, damat –	DH son-in-law
Enişte –	WB, ZH brother-in-law, spouse's kin
Yenge –	WZ, BW sister-in-law
Kayın –	affinal of first ascending generation
Kayınbaba –	WF, HF father-in-law
Kayınana –	WM, HM mother-in-law

Graph Theory: A qualitative or relational branch of mathematics (Harary 1969) dealing with formal definitions that build on earlier ones or on primitives, and with deriving theorems from formal definitions. We mark such terms in bold when first introduced.

Node. Synonym: **vertex**. The elements represented in a graph are points or nodes, connected by lines (see below). The **degree** of a node is the number of lines that are attached to it.

Line. A relation between a pair of nodes. Its two defining **endpoints** (or endnodes) are **incident** with the line. A line may be directed or undirected. An undirected line is an **edge** and an undirected line an **arc**. A **loop** is a special type of a line that connects a node to itself. Lines may be **multiple** between the same pair of nodes.

Graph. A set of nodes and a set of lines between distinct pairs of nodes.[2] A **signed graph** is one with two types of edges, positive and negative. A **multigraph** has multiple lines between nodes. A **digraph** has arcs but no edges, although arcs may be bidirected and thus represented as edges.[3] A graph may have arcs and edges, but a **simple graph** has only edges.[4] A (directed) **path** in a graph is an alternating sequence of nodes and (directed) edges that connects two nodes without repeated nodes or edges. A (directed) **cycle** is the same as a path except that the endpoints are the same.

Relation. A graph with the addition of loops.[5] See **tie**. A **multiple relation** has multiple lines between nodes. A **directed relation** has arcs but no edges (although edges may be bidirected and thus represented as edges). A relation may have arcs and edges, but a **simple relation** has only edges. Graphs and relations may be equivalently represented by a **matrix** in which columns represent nodes, arcs, edges, or loops are represented by ones, and their absence is represented by zeros. Operations on the matrix will have corresponding operations defined on the graph or relation.

Networks Vocabulary:

Network. A graph or relation with additional information on its nodes or lines: e.g., a **social network** implies a correspondence between a graph that represents individuals as nodes and social relations as lines.[6] A **subnetwork** is a subset of the elements (nodes, e.g., representing individuals) in a network together with all the information pertaining to the nodes and the lines between them.[7] An object with a mathematical property is **maximal** with respect to this property in a given context, such as a subnetwork or graph, when there is no larger object within the context that contains it that has that property.

Tie. A set of relations between nodes in a network (e.g., a social network) that can be represented by lines in the graph of the network and for which there is additional information about the nodes and their relations. A **simple tie** is a single relation; a **multiplex tie** is one with multiple relations.[8] A tie between A and B in a social network is **reciprocal** when there is evidence that A gives to B and B gives to A, without an a priori constraint of symmetry. Ties in a subnetwork are **transitive** when, for each triple, A, B, and C, a tie from A to B and from B to C is always accompanied by one from A to C (see ***triad***).

Structural Properties of Graphs and Networks: Structural properties of graphs or networks are those that derive from patterns of relationships.

Reciprocity. A repetitive pattern in a network or graph in which ties are directed but many ties are reciprocal. This corresponds to the concept of reciprocal exchange, but at minimum, as used in defining the property of curvature, is a minimal indication of mutual recognition.

Curvature. For ties that are reciprocal between social units in a network, the local curvature of each unit A is the ratio of complete triples A, B, C to triples where A-B and A-C have reciprocal ties. Clusters of adjacent nodes with high curvature constitute a **topology** of a network (Eckmann and Moses 2002).

Balance, Clustering, and Ranking. These are properties of signed graphs and of digraphs in the special case in which reciprocated ties are the positive edges and unreciprocated ties the negative edges. A **balanced graph** has no cycles with an odd number of negative edges, and a **clustered graph** has no cycles with a single negative edge. Nodes in a balanced (or clustered) graph may be partitioned into two (or three or more) so that all positive edges are within the same partition and all negative edges between nodes in different partitions. A balanced or clustered digraph is **ranked** when the partitioned sets can be arranged in a partial order from lower to higher ranks so that arcs (directed lines) go from lower sets of nodes to higher ones.

Transitivity. A digraph or graph is **transitive** when for any subset of three nodes {A, B, C}, a pair of (directed) lines from A to B and B to C entails one from A to C.

Properties of Triples.[9] A subnetwork of three nodes in a network and their ties (edges, arcs). A triple is **complete** when each pair of its nodes are an arc or and edge, or, in a social network, a tie. There are 15 other possible patterns of ties in triples. A **triad census** of the frequencies of triples with different properties allows the degree of **reciprocity**, **balance, clustering, transitivity**, **ranking**, and other local structuration of a network to be estimated.

Cohesion, Structural Cohesion.[10] The cohesion of a network or subnetwork is measured by **k-connectivity** (White and Harary 2001): the minimum number k of nodes that must be removed to disconnect it. To say that a graph has connectivity k is equivalent to saying that every pair of nodes is connected by k or more completely distinct paths (Harary 1969:43). We refer to k-connectivity as **multiconnectivity** or node-connectivity and refer to levels of multiconnectivity as implying different numbers of node-independent paths. Pairwise connectivity is the number of node-independent paths between a given pair of endnodes, where two paths are node-independent if they have no nodes in common except for their endnodes. This way of conceiving of cohesion is a classical one in graph theory, but so time-consuming and complicated to compute that network analysis using this concept only began with Moody and White (2003); compare with Friedkin (1998).

k-components. A network can be decomposed into **embedded cohesive hierarchies** consisting of **k-components**: maximal subnetworks corresponding to each level of k-connectivity. Elaborations are given in the text. The **embeddedness** of a person in a subnetwork is the connectivity of the most cohesive k-component to which that person belongs.

Exocohesion. A set of nodes in a graph has an exocohesive level k if there are k node-independent paths between every pair of nodes in the set, but not all the intermediate connecting nodes on these paths need be in the exocohesive set but may lie outside it.

Adhesion. The adhesion of a network or subnetwork is measured by k-edge-connectivity (White and Harary 2002): the minimum number k of edges that must be removed to disconnect it.

Centrality.[11] A property of a node that depends on its relation to other nodes in a graph: **degree** centrality is the number of lines incident to a node; **closeness** centrality is a function of the number of lines in all the shortest paths needed to reach all the other nodes in a graph; and **betweenness** centrality (Freeman 1977, 1980) is a function of the number of pairs of other nodes in a graph weighted by the proportion of the shortest paths between each pair that pass through a given node. These are useful to measure the **activity** of a node in a network, the potential **influence** of a node over others, or the **control** a node has in mediating connections between others, respectively.

Recursive centrality.[12] The extent to which a node is connected to others that are central, **eigen** centrality, is measured by the first eigenvector in a principal components analysis of a network matrix (*eigen*=own, in German, connotes that every matrix has unique principal component vectors whose vector product sums reproduce the matrix).

Centralization.[13] A measure of the extent to which a graph has the greatest possible difference of centrality between the most central node and each of the other nodes. For each measure of the centralities of individual nodes, the centralization measure of the graph is standardized between 0 and 1, where 1 is the most centralized possible graph, a star. Centralization can be compared across different networks.

Edge Betweenness and Cohesion.[14] Edge betweenness is a centrality measure of the number of pairs of nodes in a graph weighted by the fraction of shortest paths between each pair that pass through a given edge. Girvan and Newman (2002) show that hierarchical clusters of edges with low betweenness identify **embedded cohesive hierarchies** with high accuracy.

Structural and Regular Equivalence and Blockmodeling. Nodes in a network are **structurally equivalent** if they are in the neighborhood of the same other nodes. They are **regularly equivalent** if they are in the neighborhood of the equivalent neighborhoods or by recursion, have equivalent relations with equivalent sets of others. In each case, an equivalence **blockmodel** maps equivalent nodes together into a network image of positions that are related by carrying over the ties between nodes into ties between positions.

Methods of Graph and Network Analysis: There are methods for analysis of each of the structural properties listed above, such as blockmodeling, cohesion, centrality triad census, and so forth. Students can consult a software manual by de Nooy, Mrvar, and Batagelj (2002) to replicate the graphical representations and network analyses used in this book. We use their terms except where they conflict with those of Harary (1969). The following methods are not structural properties of graphs but methods of representation.

Hierarchical clustering analysis (HCA).[15] A method for showing hierarchical subsets of elements in a matrix or network in which all pairs of elements in each subset have a minimum {average, maximum} value.

Automatic drawing, spring embedding.[16] Optimal layouts of graphs that minimize line length, in which more cohesive nodes tend to be more clustered, and hierarchical clustering of cohesive sets can be easily superimposed. **Energized graphs** drawn in the Pajek program implement these automated procedures:

> **Energy commands** move nodes to locations that minimize variation in line length. Imagine that the lines are springs which pull vertices together. The energy commands "pull" vertices to better positions until they are in a state of equilibrium. These procedures are known as **spring embedders (**de Nooy, Mrvar and Batagelj 2003).

Eigenvalue/eigenvector analysis. Because a network can be represented by a matrix, mathematical matrix methods can be used to reconstitute a matrix by a series of pairs of values and vectors that decompose how the cells in the original matrix are eigenvalue weighted sums of their corresponding vectors. If the first few eigenvalues are highly weighted, the original matrix or network can be reduced by close approximation to a linear combination of correspondingly few vectors.

Analytic Vocabulary for Kinship and Social Organization: See http://www.as.ua.edu/ant/Faculty/murphy/436/kinship.htm for a kinship glossary compiled by M. D. Murphy, and another by B. Schwimmer at: http://www.umanitoba.ca/anthropology/tutor/glossary.html. The glossary at http://www.iversonsoftware.com/anthropology/anthropology.htm has more general anthropological terminology that includes social organization.

Asset and Marriage Transfers:

Wealth-asset. Defined in the text. **Inheritance** is a binding transfer of wealth-assets or consumables to customary heirs after or anticipating a death. **Testamentary disposition** is the annulment of inheritance through substituting a written will left by the deceased.

Bridewealth. A transfer of wealth-assets from a husband's wealth-holding group to the wife's at and following marriage, in exchange for reproductive rights transferred from the wife's group (e.g., over their daughter's offspring) to the husband's (e.g., children are retained by the man's lineage). Bridewealth is typically paid in animals such as cattle that qualify as a wealth-asset. (Bride price is a term that can be used to contrast with bridewealth, when only consumables are transferred at marriage, but is out of date because of the association with purchase, which is an inappropriate term.) **Bride payment** is synonymous with bridewealth except that either wealth-assets or consumables may be transferred.

Dowry. A transfer of wealth-assets or consumables from the wife's group to the wife because of her marriage. Note the asymmetry with bridewealth: dowry transfers are usually not to the husband or husband's group.

Descent Groups:

Clan. A descent group or category whose members trace descent from a common putative ancestry, where genealogical links back to a single apical ancestor are not known.

Lineage. A corporate group whose members share a common ancestor, usually based on unilineal descent with members having rights to common wealth-assets, including inheritance, and statuses. An **ambilineage** is a lineage whose members share a common cognatic ancestor and affiliate through either their father or mother but not both. A **sib** is a single lineage distributed across multiple communities. We use the term **segmented lineage** for "a descent group in which minimal lineages are encompassed as segments of minor lineages, minor lineages as segments of major lineages, and so on" (Anthropology Explorer glossary) in preference to **segmentary lineage** that has other connotations such as spatially fixed segments that derive from Evans-Pritchard's (1940) description of the Nuer.

Affinity and Descent:

Agnatic. A relation between two descendants of the same ancestor traced only through males. Synonym: **Patrilineal.** A **patrilineage** is a corporate group whose members share agnatic descent.

Uterine. A relation between two descendants of the same ancestor traced only through females. Synonym: **Matrilineal.** A **matrilineage** is a corporate group whose members share uterine descent.

Cognatic or **Bilateral.** A relation between two descendants of the same ancestor. A **kindred** is an ego-centered group of bilateral kin who often assemble for celebrations or life events.

Unilineal. An agnatic or uterine descent principle. An **ambilineal** descent principle is operative in an ambilineage. **Bilateral** descent is reckoned by the cognatic principle, for example, through males and females.

Modes of reckoning descent. These are ways that descent is recounted orally. The **depth first search** (DFS) starts from the topmost ancestor and works down (often through the line of highest rank) to the bottom, then returns up this same line only to the point where there is another line to follow down, and so forth until all lines have been recounted. A **breadth first search** (BFS) starts from the topmost ancestor and takes up next the descendants in the following generation, then takes each in turn (often in order of highest rank) and their immediate descendants, repeating until all successive generations are exhausted. A **sibling set depth first search** imposes the recounting of sibling sets within the order of a DFS, that is, each time a lower node is taken the siblings of that node are taken up next (often in order of rank) before going on to the descendants of the initial node (Fox 1978:32). The **ahnentafel** recording system for ancestries uses a reverse BFS in which ancestors are successively numbered in generations using the powers of two (2 parents, 4 grandparents, 8 . . .) as the numbering system so that F is 1, FF is 3, FFF is 5, FFFF is 9, and numbers are standardized breadthwise to create an ancestry tree of bilateral ancestry where some names may known and others not.

Postmarital Residence:

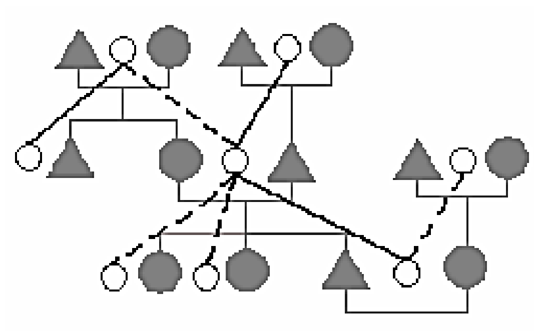
Patrilocal. A married couple goes to live in the household of the husband's parents. Synonym: **Virilocal**. In Murdock's (1967) variant, **patrilocal** entails residence with the husband's patrilineage.

Matrilocal. A married couple goes to live in the household of the husband's parents. Synonym: **Uxorilocal**. In Murdock's (1967) variant, **matrilocal** entails residence with the wife's matrilineage.

Neolocal. A married couple sets up their own household independent of either set of parents. There are many other alternatives than the three given here, each having many possible subtypes (and potential difficulties for classification of households!).

Network-Defined Concepts in Social Organization: for detail see Table 5.2

Structural Endogamy.[17] When a genealogical network contains a maximal subset of families of which each pair is linked through two or more completely distinct ties of affinity or descent, they are structurally endogamous. Derived from the more general concept of cohesion and the theory of graphs (White and Harary 2001) in such a way that the boundaries of structurally endogamous groups are emergent from the pattern of relationships in the network. Can be accurately identified as a bicomponent of a P-graph. **Categorical Endogamy**, in contrast, is marriage among a set of people characterized by their attributes, such as nationality, ethnicity, social class, region, or religion.



P-graph.[18]

In a genealogical network represented as a p-graph, couples or unmarried individuals are identified with the nodes, and lines are drawn between each node identified as a parent or parents and every other node identified with a corresponding daughter or son. Two types can be distinguished: one for daughters and one for sons. When a person has multiple marriages, each marriage has a line to that person's parent. If we consider the underlying graph, structurally endogamous subnetworks correspond to cohesive sets.

Emergents: See ***Complexity Theory***. Unlike emic concepts that field researchers derive from the concepts and linguistic usage of community members, emergent patterns in social networks are etic, and stated by the researchers, usually in the form of descriptive patterns or hypotheses. An emergent differs from descriptive statistics or **aggregate** patterns because it is a structural property that is hypothesized to influence further development of networks, and empirical tests of such hypotheses support such effects. Thus, an emergent has **configurational effects** elsewhere in the network, which is always a product of interaction, on nodes or relations.

Emergent group. A group without well-known elements of self-definition, such as a named group with known membership, but observable in network analysis. In network analysis, an emergent group is a cohesive component with clear-cut boundaries (see ***k-component***).

Emergent rule. A rule of behavior that is not explicitly stated by people, but can be stated by network analysis. In network analysis, an emergent rule is observable as a recurrent structure in a time frame or as a regularity that plays out in time. An example is **matrimonial sides** that derive from a marriage practice of marital relinking in which the cycles of ties that connect spouses avoid having an odd number of male links (**uxori-sides**) or an odd number of female ties (**viri-sides**) or both (**cross-cutting sides**). The balance theorem for signed graphs provides the micro-macro linkage (see next item below) between this practice and a relational model that approximates that of matrimonial moieties. Sides, while found in moieties, need not be named nor hereditary, but are a marriage rule that is emergent from behavior.

Emergent role. A social role that is not explicitly named or expressed but that can be identified by network analysis. In network analysis, **blockmodeling** social positions on the basis of **structural** or **regular equivalence** yields patterns of relationships among emergent roles as positions defined by patterns of relationship (see Structural Properties of Graphs or Networks).

Emergent process. A process that is not recognizable or named in everyday practice but can be identified by network analysis. Process models derived from network analysis can take many different forms.

Complexity Theory: Complex systems have embedded interiors with many interacting parts, networks, and fields. From the viewpoint of mechanics, emergent field processes often lead to "surprising" results that are not reducible to a mechanical or deterministic account. "Emergent" behaviors at one level are not determined by the embedded levels that produce them but are the result of complex interactions.

Micro-macro linkages. A micro property of a graph or network is one that can be expressed as a property of nodes, neighborhoods of nodes, or traversals and recursions from nodes and their neighborhoods, for example, through cycles that go out from a node or back. A macro property in this context is a global property of a graph, such as k-connectivity: the minimum number of nodes that along with their edges must be removed from a connected graph in order for it to become disconnected. A number of the basic findings in graph theory deal with micro-macro linkages between local properties including traversal and global structural properties such as connectivity.

Emergents and Emergence. For **emergent group**, **rule**, **role**, **process**: see: *Network-Defined Concepts in Social Organization*. An **emergent** or **emergent property** in the simplest sense is a structural property that has configurational effects, that is, measurable predictive consequences. Emergents may be classified as **nonlocal** when they have no known micro-macro linkages and as **local emergents** when the micro-macro linkages that produce them are know. One of the accomplishments of **simulation** research in complex interactive or **complex adaptive systems** (CAS) is to discover new nonlocal emergents, that is, ones that were not obvious from micro-macro linkages. **Emergence** is a term used in CAS and simulation studies for complex and unexpected outcomes from simple rules of interaction. A scientific definition that includes the surprise as an element, however, may soon be invalidated because the surprise may pass if micro-macro linkages are discovered that explain the phenomenon. Such discoveries are often of major importance, however, and do not occur easily, so this sense of emergence is useful to retain, as least for the present. For the moment it seems to express the wonderment of those working in the field of complexity.

Complexity. Interaction between a system and its changing environment is **complex** when system responses to changes are on longer time scales than the tempos of environmental change. A measure of complexity based on dynamics (from Arthur Iberall) is the ratio of response time to periodicities of changes in inputs. Complex systems can pack **memory** into their internal states.

Tipping Point. When tipping-point thresholds are passed in a network or field internal to a complex system, such as connectivity among the nodes, critical density, or alignment, the global properties of the network or field change qualitatively, and can pass on this "emergent" or structural change to a more aggregate level in the system of which the network or field is a component.

Power-Law growth or decay. For every doubling of the energy in an earthquake, the frequency is about four times less. If this α ratio of -4 to +2 (here α = -2) is invariant across a wide range of energy and spatial scales, the relationship is power law. Magnitudes of earthquakes measured on log scales (originally, the Richter scale) of powers of ten reflect the power law that the log of energy varies with the log of frequency (Buchanan 2000): as energy doubles, frequency is four times less. Power-law dynamics are fixed power exponents applied to a base of where you are at in a series or distribution (the x axis of a plot), with result $y = Ax^{\alpha}$ ($\log y = \log A + \alpha \log x$), where A is an initial value and α the power constant. A power-law process or distribution is **scale-free** in that changes or differences occur at the same rate whether high or how, early or late in the series. So they can be superimposed by linear changes in the two axes. In this sense a phenomena that follows a power law acts in the same way for a range of scales at which the power curve is constant. For example, for homogeneous fragmentable solids thrown against a wall—such as frozen skinned potatoes, chunks of gypsum, or soap-fragments double in size are six times less frequent (α = -3). Power-law exponents usually go no higher than 3 for growth or lower than -3 for decay.

That power-law relations are scale-free also means that a "special theory" might not be needed to account for large earthquakes as opposed to small ones, or large fragments as opposed to small ones in the throwing experiment. A special branch of a theory of segmentary lineages might not be needed to account for big segments as opposed to little ones. So a "special theory" to account for FBD marriage in a segmentary lineage system might not be needed if that system has fractal properties (see next item) governed by power-law processes.

Fractality. A **fractal** is a geometric structure with new details as well as similarities at any level of scale or magnification. Properties or behaviors that are fractal, like power laws, are self-similar at different spatial or temporal scales: the appearance of the 'edge of a coastline' at different resolutions, or of variation of stock prices at different time intervals are examples. Complex systems often have fractal properties. One hypothesis is that fractal processes that result from interaction of two levels (a complex system), such as earthquakes at one level and randomly distributed frictional stresses along potential fault lines at a lower level that affects the production of the earthquake, usually have the signature of a log-log power-law distribution that is fractal or scale invariant over a large range of spatial or temporal resolutions in which the logged magnitude varies linearly with the log of temporal frequency. Another two-level example is that while the growth of savings accounts according to fixed compound interest is not power law, the rich get richer faster than others by moving successively larger amounts of capital to new accounts that have increasingly higher interest rates. This dynamic is self-amplifying and produces the classical power-law Pareto distribution of the inequality of wealth.

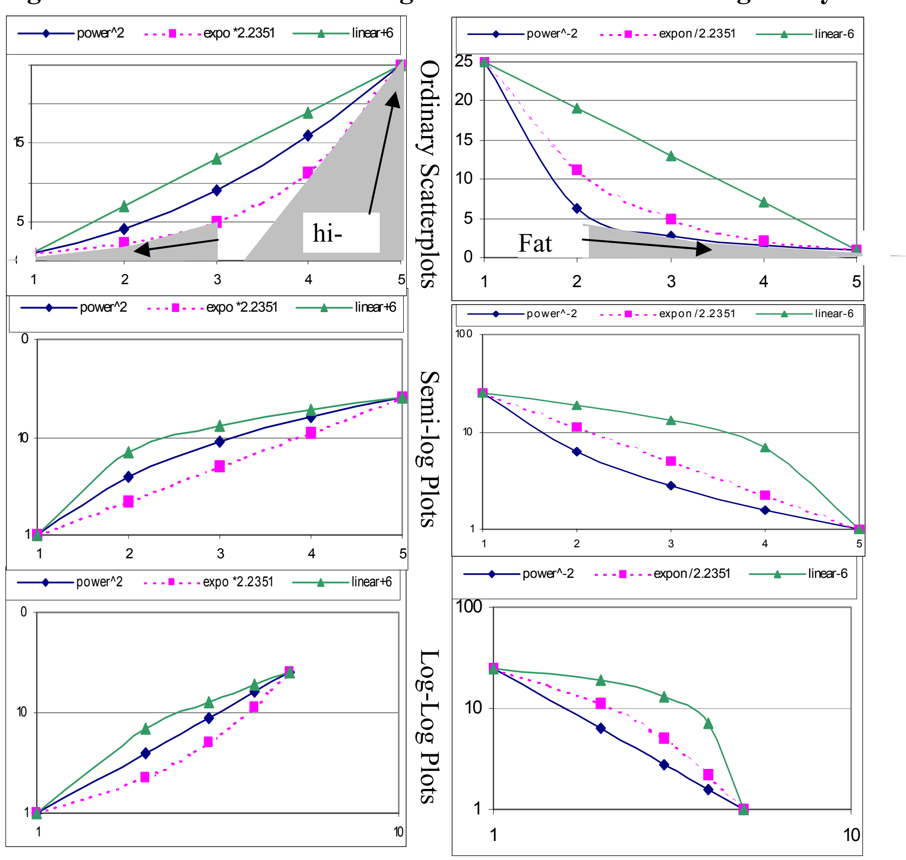
Exponential growth or decay. Applied to an initial value A, a fixed rate r of growth or decay is raised to successively higher powers (x), with result $y = A^{r\,x}$, so log y = log A + r x (the log of y varies with x). In the continuous case, $y = A\ e^{\ln(r)x}$ so $\ln y = \ln A + \beta\ x$), where e=2.718 is the base constant of the natural log and $\ln(r) = \beta$ is the natural log of r, the power to which e must be raised to get r. In the exponential the base (A or e) is constant while the exponent changes with x. Hence, the curve starts with slow growth and accelerates with x.

Many mechanical rules (e.g., growth of savings in an account with fixed interest) and random processes (e.g., distribution of the number of edges of nodes in a graph in which edges are added to new pairs of nodes that are chosen with uniform probabilities) have characteristic exponential distributions. To see how a savings account grows exponentially, let S be the initial balance, γ the growth rate (one plus interest), and t the number of years. Then the new balance $N(S) = S\ \gamma^{t}$. Plotting t and N(S) on semilog paper in which only one of the x,y axes is logged, because $\log N(S) = \log S + t \log \gamma$, we will see that log N(S), logged growth in savings, varies linearly with time (t). With a 6% interest rate there is not much growth the first few years, but after ten years it has doubled and is increasing at twice the rate of the first year. If you leave it for your grandchildren, thirty years, it is increasing at five times the rate. After a hundred years, it is increasing at thirty times the rate, with $32,000 in the account. Few people get to that stage, and successively fewer people have increasingly large accounts. Exponential dynamics do not follow a constant exponential power of where you are at, like the power law, but successive multiples of where you started from. The effect of successive multiples on a fixed base is exponentially increasing or decreasing. Nor is an exponential process or distribution scale-free because differences lower (early) or higher (late) in the series change at different rates. So they cannot be superimposed by linear changes in the two axes. Further, with exponential decay by a constant γ of the number N(S) of savings accounts of size S, for example, such that $N(S) = S\ e^{-\ln \gamma\ S}$, a limiting account size is reached after which no savings accounts are expected to appear. Savings accounts, then, exist only on a characteristic scale. Many natural processes, such as radioactivity, or elimination of drugs in the body, have exponential decay, so the feature of a “half-life” or characteristic scale can be a fortunate one. Because the resale price of a car decays exponentially, businessmen trade in their cars early, while others may experience in the longer term the characteristic of value loss.

Power laws, unlike savings accounts, often imply that the short-term past is no guide to the long-term future. In the saving account example, if the decay were a power law where $N(S) = A\ S^{-\beta}$, accounts will be observable on a much broader range of sizes. The relationship of wealth to wealthy is a dynamic that produces such differences because the rich get richer not at a constant rate but at an accelerating rate of increase proportional to existing wealth, that is, the rich get disproportionately richer.

Figure G.1 shows linear distributions (triangles, upper lines) as seen in ordinary unlogged scatterplots, exponential distributions (squares) that are linear (dotted lines) only in semi-log plots (second row of plots), and power-law distributions (diamonds) that are linear (dark lines) only in log-log plots (third row of plots). Two columns of plots are shown, one for growth, with positive constants (addition, multiplication, or positive powers), and one for decay, with negative constants (subtraction, division, or negative powers). In the power law curve $y = 1\ x^{2}$ and $y = 25\ x^{--2} = 25/x^{2}$, where A = 1, 25 and β = 2, -2, are the respective constants for $y = A\ x^{\beta}$. In the exponential curve, r = √5, y = 1 e.805 x and y = 25 e-.805 x = 25/e.805 x.

Figure G.1: Curves of Increasing Growth and of Decreasing Decay



The symmetries of these plots are created by operations that reverse one another, which are called *duals*: addition and subtraction by a constant are duals in linear distributions; multiplication and division by a constant are duals in exponentials; positive and negative exponentiation by a constant are duals in power laws. Positive exponents may be added, and negative subtracted.

The asymmetries of these plots are that exponentials are the lower curve in growth but the middle curve in decay, while power laws are the lower curve in decay but the middle in growth. The grey areas in the ordinary (top) scatterplots show the "fattest" distributions: they are the exponential slow-start and high-rise distributions for growth and the power law fast-drop and fat-tail distributions for decay. So exponential population growth is higher than power-law growth at later times: its high-rise occurs later.

Further Reading

Solé and Goodwin provide an excellent overview of theory and method, together with examples for the study of complex forms of organization in social and biological systems. Other references provide discussions of kinship analysis (Fox 1979; Keesing 1975), aspects of methodology (Freeman 1979, 1980; Eckmann and Moses 2002; Girvan and Newman 2002; Moody and White 2003), network methods (Degenne and Forsé 1997, Scott 1991, Wasserman and Faust 1994), or computer packages (Batagelj and Mrvar 1998, de Nooy, Mrvar and Batagelj 2003, Borgatti, Everett and Freeman 1995a,b). White and Houseman (2002) review the literature on small worlds, including the seminal work of Watts and Strogatz (1998) and navigability in small worlds (Watts, Dodds, and Newman 2002), on which our modeling of segmented lineage system, is based. They also present a summary, in more technical and theoretical terms, of the significance of the findings of the present study for understanding complex system dynamics in social organization.

Notes

[1] The Aydınlı kinship terms are in general accord with those used in the neighboring Yörük tribe studied by Bates (1973), although there are several important variants for that group:
ağa – father (title of respect to an older man)

ağabey - elder brother (*ağa* and *bey*, a compound formed of two words of social respect)
bacı – sister (also a title of respect to an older woman)
ai*l*e – wife (also used to mean small family)
[2] The exclusion of loops in this definition of graph is standard in graph theory (Harary 1969), and makes it easier intuitively to conceptualize some of the main theorems about the traversability of graphs.
[3] Pajek options [Main] Net>Transform>Arcs→Edges>Bidirected only.
[4] Harary's (1969) definition of graph is synonymous with simple graph, which he distinguishes from a digraph (directed graph) with directed edges (arcs).
[5] Network analysis packages (Pajek and UCINET, for example) are capable of analyzing relations (containing loops) and not just graphs and, of course, analyzing the attributes of nodes as well.
[6] See the previous footnote (4).
[7] Given a partition on the nodes of a network, or a cluster with selective numbers for a set of nodes, [Main] Operations>Extract from Network>Partition or >Cluster will extract a subnetwork according to the user's specification of the node set.
[8] [Main] Transform includes options to >Remove>Multiple lines in various ways that reduce them to simple lines and to convert >Arcs→Edges or >Edges→Arcs.
[9] [Main] Info>Network>Triadic Census.
[10] [Main] Net>Components>Bicomponents with default size set to 3 or more identifies sets of nodes with connectivity 2 or more. Tricomponents have yet to be implemented in current network packages (but see edge betweenness).
[11] [Main] Net>Partitions>Degree and Net>Vector>Centrality>Betweenness or >Closeness compute the centrality measures for nodes. Degree are computed by Pajek centralities for up to 1 million nodes and closeness and betweenness centralities for up to 10,000 nodes.

Flow centrality is another measure (Freeman, Borgatti, and White 1991), computed by UCINET. When we assume that each edge in a graph has a transport capacity of one unit, the flow centrality of a node u is the percentage of the total amount of flow between all pairs of nodes that is not reduced when node i is removed from the graph.
[12] Eigen centrality is computed in the UCINET program package.
[13] Automatically computed in both the UCINET and Pajek program packages when centrality scores are calculated.
[14] Edge betweenness is computed in the UCINET program package. Hierarchical clustering of dissimilarity scores may be applied to show cohesive groups.
[15] UCInet's Network>Cohesion>Maximum Flow or Point Connectivity options automatically perform a hierarchical clustering analysis of a matrix of pairwise connectivity values.
[16] [Main] Draw>Draw Partition, [Draw] Layout>Energy>Fruchterman-Reingold>2D or 3D, and [Draw] Layout>Energy>Kamada-Kawai>2D or 3D.

[17] [Main] Net>Components>Bicomponents with default size set to 3 or more identifies blocks of structurally endogamous marriages for a genealogical database in p-graph.

[18] Available at http://eclectic.ss.uci.edu/~drwhite/pgraph/pgraph.html, the pgraph program Ego2all.exe converts genealogical data from the text-file format described in Chapter 1 to formats for all the major types of kinship analysis software. Text-file formatted datasets on genealogical networks in over fifty societies are available at http://eclectic.ss.uci.edu/~drwhite/PDATASET.htm for use with the conversion program. This provides a comparative database for the strictly genealogical aspect of kinship networks. Pajek's [Main] File>Network> Read uses the p-graph format suitable for network analysis as the standard default for reading databases in *.GED formats used by commercial and freeware genealogical programs and produced as well by Pgraph software.