Six Degrees of Alexander: Social Network Analysis as a Tool for Ancient History

Diane Harris Cline

Most academics are by now familiar with the concept of "six degrees of separation," otherwise known as the "small-world effect," popularized by Duncan Watts, Albert-Laszlo Barabasi, and Mark Buchanan.[1] The basic idea is that "almost any pair of people in the world can be connected to one another by a short chain of intermediate acquaintances, of typical length about six," as Mark Newman of the University of Michigan has put it in a recent review.[2]

Such degrees of separation come from the network of people in which an individual is embedded, ranging from their family to close friends to mere acquaintances. This type of social network is frequently discussed today in connection with Facebook, MySpace, and other recent phenomena associated with the Internet. The concept has also entered the domain of pop culture, as exemplified by the "Six Degrees of Kevin Bacon" game, in which participants attempt to link movie actors with Kevin Bacon based upon films in which each actor has appeared.[3]

Originally known as network theory or sometimes network analysis, Social Network Analysis (SNA), as it will be called here, began in part because of the ground-breaking study in 1967 by Stanley Milgram.[4] Networks are entities of any kind linked together in some way. Social networks are people, or groups of people, linked together through social interaction. SNA has been used and applied successfully in a number of different fields, including sociology and business, not to mention international security, for decades—since at least the 1970s in most cases—but few ancient historians have made use of it to date.

In brief, Social Network Analysis studies individuals ("vertices" or "nodes" or "actors") and the relations between those individuals ("edges" or "links" or "ties").[5] The flow of information, or material resources, or power, can be traced from node to node through the

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[1] D. Watts, *Six Degrees: The Science of a Connected Age*. New York: W.W. Norton, 2003; A. Barabasi, *Linked: How Everything Is Connected to Everything Else and What It Means for Business, Science, and Everyday Life.* Cambridge: Penguin, 2003; M. Buchanan*, Nexus: Small Worlds and the Groundbreaking Science of Networks*. New York and London: W. W. Norton, 2002.

[2] M.E.J. Newman, "Models of the Small World: A Review," *J. Stat. Phys.* 101 (2000) 819-841.

[3] See Newman's discussion of the game's invention by Brett Tjaden, in Newman (2000) 819, with a link to the online version of the game at: http://www.cs.virginia.edu/oracle/.

[4] S. Milgram, "The small world problem," *Psychology Today* **2** (1967) 60–67.

[5] M.E.J. Newman, *Networks, An Introduction*, 36. Oxford: Oxford University Press, 2010.

links. Pairs who know each other or relate in some way to each other are entered into a spreadsheet, which then is processed via a computer program in order to create graphs depicting the data visually. Such network graphs have established typologies with characteristics that can lead to political and sociological interpretation and which can be used for a variety of purposes, including finding cliques or clusters within the fabric of the network; visually displaying a network of individuals and their relationships; indicating gaps or "structural holes" where the network is weak; and identifying figures who act as "bridges" within the network.[6]

Using Social Network Analysis for Ancient History

For ancient history in particular, Social Network Analysis can be useful in numerous ways. One might, for instance, look at the network present during a period early in an emperor's rule and compare it to the network present during a period late in his reign, thereby possibly providing insight into how his power grew, how he expanded relations with other countries and peoples, or who else held power and had their own circle of relationships in addition to the sovereign.

While the past decade has seen a slight increase in the use of Social Network Analysis by ancient historians and archaeologists, it is surprising that it hadn't caught on and spread much earlier. Already in 1990, Michael Alexander and James Danowski of the University of Illinois at Chicago published an article entitled "Analysis of an ancient network: Personal communication and the study of social structure in a past society." However, their article appeared in a Dutch journal devoted to social networks and its publication went virtually unnoticed by ancient historians.[7] In 1993, one of the earliest and most intriguing studies was published by John Padgett and Christopher Ansell on the rise of the Medici family in the 15th century, although it too escaped notice of most historians, having been published in the *American Journal of Sociology*.[8] In 1996, Barry Wellman and Charles Wetherell suggested to historians that it would be useful to use "a social network analytic approach to studying communities and community-like social structures." Since it was published in the inaugural

[6] R.S. Burt, *Structural Holes: The Social Structure of Competition.* Cambridge: Harvard University Press, 1995.

[7] M.C. Alexander and J.A. Danowski, "Analysis of an Ancient Network: Personal Communication and the Study of Social Structure in a Past Society," *Social Networks* 12 (1990) 313-335.

[8] J.F. Padgett and C. K. Ansell, "Robust Action and the Rise of the Medici, 1400-1434." *American Journal of Sociology* 98/6 (1993) 1259–1319.

issue of a journal called *The History of the Family*, though, it also went essentially unnoticed and uncited by ancient historians.[9]

Most network analysis studies involving the ancient world to date have been done by archaeologists and have usually been concerned with artifacts, for those too have discernible networks, usually based on excavation context and association, but also involving areas of origin in the case of imported objects. Such scholars include Tom Brughmans on networks in archaeology;[10] Carl Knappett on material culture and Cyprian Broodbank on island interactions during the Aegean Bronze Age;[11] and Fiona Coward on ancient Near Eastern artifacts.[12] One of the most interesting studies is that by Shawn Graham, published in 2006, on Roman bricklayers in central Italy. Here, he studied 234 named brick manufacturers known from stamps, dating to the 1st through 3rd centuries AD, who formed a network based on family ties, industrial relationships, or co-location. By using SNA to analyze these names, he was able to reconstruct relationships between workshops and situate them along the Tiber River.[13]

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[9] B. Wellman and C. Wetherell, "Social Network Analysis of Historical Communities: Some Questions from the Present for the Past," *The History of the Family* 1/1 (1996) 97-121.

[10] T. Brughmans, "Facebooking the past: a critical social network analysis approach for archaeology." In *Thinking beyond the Tool: Archaeological Computing and the Interpretative Process*, A. Chrysanthi, M.P. Flores, and C. Papadopoulos (eds). Oxford: Archaeopress, forthcoming; see previously idem, "Connecting the Dots: Towards Archaeological Network Analysis," *Oxford Journal of Archaeology* 29/3 (2010) 277–303; idem, "Thinking through networks: a review of formal network methods in archaeology," *Journal of Archaeological Method and Theory* (20 April 2012; available online at: http://dx.doi.org/10.1007/s10816-012-9133-8).

[11] T. Evans, R. Rivers, and C. Knappett, "Physical and Relational Networks in the Aegean Bronze Age." In *European Conference of Complex Systems - ECCS '06*. 2006 (available online at: http://theory.imperial.ac.uk/~time/TSEpaper/AegeanECCS06.pdf); C. Knappett, *An archaeology of interaction: network perspectives on material culture and society*. New York: Oxford University Press, 2011; C. Broodbank, *An Island Archaeology of the Early Cyclades*. Cambridge, UK: Cambridge University Press, 2002.

[12] F. Coward, "Small Worlds, Material Culture and Ancient Near Eastern Social Networks." In *Social Brain, Distributed Mind*, Robin Dunbar, Clive Gamble, and John Gowlett (eds.), 449-479. Oxford University Press, 2010.

[13] S. Graham, *EX FIGLINIS: The network dynamics of the Tiber Valley brick industry in the hinterland of Rome*. Oxford: Archaeopress, 2006; see also idem, "The Space Between: The Geography of Social Networks in the Tiber Valley." In *Mercator Placidissimus. The Tiber Valley in Antiquity. New Research in the Upper and Middle River Valley*, Filippo Coarelli and Helen Patterson (eds.), 671-686. Rome: Edizioni Quasar, 2009; idem, "Converting 2-mode Networks to 1-mode Networks," Electric Archaeology (8 Feb 2012; available online at: http://electricarchaeologist.wordpress.com/2012/02/08/converting-2-mode-networks-to-1-mode-networks/).

Studies concerned specifically with texts and ancient history are fewer, but have been spearheaded in recent years by Irad Malkin of Tel Aviv University. He has published several books on relevant and related topics already, including *A Small Greek World: Networks in the Ancient Mediterranean* in 2011, as well as a co-edited volume in 2009 entitled *Greek and Roman Networks in the Mediterranean*, and an issue of the *Mediterranean Historical Review* in December 2007 that was devoted entirely to articles dealing with aspects of network analysis.[14] In addition, a new multi-media online project called the Berkeley Prosopography Service (BPS), which has received funding from the NEH, is applying these techniques to a corpus of 700 cuneiform tablets which documents the members and activities of a relatively small group of elite Mesopotamian citizens during the Hellenistic period (331-46 BCE) in the city of Uruk (located in what is now modern southern Iraq).[15]

Initial Steps towards Gathering and Inputting Data for Social Network Analysis: The "Old Guard" of Philip II of Macedon as an Example

One of the most effective uses of Social Network Analysis is the so-called ego-centered approach, which begins with a single key individual (or "actor") and the connections that s/he has to the people ("alters") with whom s/he has direct relations. This creates one degree of separation, for the actor and each alter are connected via a single link. The simplest initial graph generated from inputting this data looks like a hub with spokes, with the hub being the actor/key individual and the spokes radiating out to his or her connections/alters (see Fig. 1). However, it can also be made more complex, if the alters know each other as well as the actor and thus have links between each other as well as with him/her (see Fig. 2). Furthermore, once one proceeds to the next step and inputs the additional individuals with whom each of the alters has relations, the network becomes more complex, particularly if those alters also know each other (see Fig. 3). This is called two degrees of separation.

One can then continue on in this way, inputting additional individuals with links further and further from the primary key individual. As one might imagine, even small one-degree networks can grow quite large by the time they have reached three degrees and beyond (as anyone who has tried to create a genealogical chart for their family can attest, especially when they find themselves inputting information about their step-brother's wife's second cousins once removed).

[14] I. Malkin, C. Constantakopoulou, and K. Panagopoulou (eds.), *Greek and Roman Networks in the Mediterranean*. London: Routledge, 2009; I. Malkin, *A Small Greek World: Networks in the Ancient Mediterranean*. Oxford: Oxford University Press, 2011.

[15] http://berkeleyprosopography.org/

As an example, let us begin to create a Social Network Analysis involving Philip II of Macedon and his top generals, i.e., the so-called Old Guard—Antigonus Monophthalmus, Antipater, Attalus, Black Cleitus, Hegelochus, Hippostratus, Parmenion, and Philotas. Simply inputting the generals and their association with Philip II results in a very simple one-degree graph, with Philip as the dominant individual (Fig. 1) in a star pattern of nine nodes, which is called a "star graph" in SNA terms.[16]

However, all of the generals also knew and were in contact with each other as well as with Philip, and this must be depicted as well, thereby already increasing the complexity of the graph (Fig. 2). Note that since they all know each other, Philip II is no longer the dominant figure, at least structurally, since information can pass between all of the generals without him serving as an intermediary or filter. And yet, this is still a network based on one degree of separation and in network graph terms is called a "peer-to-peer network with supernodes."[17]

Once we enter more individuals tied to each of the original eight generals and Philip II, the graph gets even more complicated, for adding in everyone else whom the generals knew and with whom they interacted, including family, friends, and acquaintances, increases the size of the network immediately. While still part and parcel of the larger network, Philip's generals can now each be seen to also be the hub of their own ego-centric networks, for while they are still interconnected to each other and have Philip in common, they each also have their own ties to additional individuals with whom the other generals and Philip do not interact (Fig. 3). For the purposes of this experiment, the named individuals who were added at this stage all appear in Waldemar Heckel's chapter entitled the "Old Guard" in his book *The Marshals of Alexander's Empire*.[18] For Philip II, the named associates come from his entry in Heckel's *Who's Who in the Age of Alexander the Great*.[19] From the original eight generals plus Philip, the list of nodes or individuals in this two-degree chart now grows to 113 (adversaries in battle were excluded), with 232 links between them.

Interesting, and quite useful, is the fact that a variety of different algorithms may be applied to the data at this point, and alternative graph layouts can be generated with ease to depict the relationships, sometimes with surprising—or counter-intuitive—results. For example, when the Clauset-Newman-Moore cluster algorithm is applied, it identifies and displays six clusters (Fig. 4a). These are not necessarily the networks of the original eight generals plus Philip, but instead come from the structure of the interrelationships and ties

[16] Newman, *Networks* (*supra* n. 5) 543.

[17] Newman, *Networks* (*supra* n. 5) 712.

[18] W. Heckel, *The Marshals of Alexander's Empire*, 3-56. London and New York: Routledge, 1992.

[19] W. Heckel, *Who's Who in the Age of Alexander the Great: Prosopography of Alexander's Empire*, 208-211. Oxford: Wiley-Blackwell, 2006.

within the entire network. In three of the clusters, the central figure is still one of the original generals, i.e. Antipater, Antigonus Monophthalmus, and Philotas, but the central figures in the other three clusters are new: Alexander the Great, Cleander, and Dimnus (the latter is the chief conspirator in the so-called Philotas Affair, who in SNA terms is the central node of a tightly knit group of conspirators along with the participants involved in the revelation and punishment of same). In the graph shown in Figure 4a, these six clusters can be seen, with each shown in a different color; the thick red lines show the ties between Philip II and the original eight generals, who can now be seen within the texture of the larger social network.

The new clusters identified by the Clauset-Newman-Moore cluster algorithm can be made even clearer by using a "cluster-in-a-box" graph. Here, as seen in Figure 4b, the specified clusters are pulled out of the larger network and placed in a series of boxes, but still show the links and lines of interconnections with the other individuals in the overall network. Nothing has changed except the visual rendering, but that can make a world of difference. Changing the graph configurations allows the ancient historian to study the whole system at the same time as conducting analyses at the cluster level.

If we were to subsequently add in even more individuals and their links, by taking the data to three degrees of separation from Philip, one can imagine how complex the resulting graph would be. That assumes, of course, that we have additional sources which would accurately give us the friends and their families (degree 3) of the families and friends (degree 2) of Philip II's eight generals (degree 1). In order to generate this sort of detail, however, we would need to go back and mine the original sources, pulling every co-occurrence of named individuals, rather than simply using secondary compilations such as Heckel's prosopographical studies. Even with a two-degree graph, though, it is clear that we already have enough visual data to begin re-examining old established theories and hypotheses, with an eye towards confirming or rejecting them, as well as perhaps to come up with some new observations and suggestions which had not been previously apparent.

The Social Network of Pericles: A Brief Look

I began my own initial experiments with using Social Network Analysis in ancient history by taking Pericles and Alexander the Great as my first two case studies.[20] Looking at Pericles first, I began by simply entering the details from Plutarch's *Life of Pericles* into a social

[20] I am greatly indebted to Dr. Ben Schneiderman, a computer scientist at the University of Maryland, and to Cody Dunne, a data visualization specialist at the same university, for their input and feedback.

network analysis tool called NODEXL.[21] Within the database, I created pairs between Pericles (the actor) and the other named individuals (the alters) whom he knew—including Phidias; Thucydides, son of Milesias; Aspasia; and Cimon, to name only a few. When Plutarch mentioned relations between the alters, I included those as well; for example, Ictinus, the architect, was mentioned in relation to Phidias, but is not linked directly to Pericles. From Pericles to Ictinus, therefore, there are two degrees of separation, with Phidias serving as the connecting link or "bridge." Using just this one source, Plutarch's *Life of Pericles*, I was able to harvest 49 named individuals and 72 total pairs. These pairs were then run through algorithms which generated the network chart seen in Figure 5.

What observations can we make from the analysis? The network chart shows seven clusters of relationships; each cluster is shown in a different color within Figure 5. Pericles is at the center, of course, with his direct relationships shown in dark blue, but the four important alters at the center of their own clusters are Cimon (light blue); Pheidias (red); Ephialtes (yellow); and Cleandridas (orange/burnt sienna). The other two clusters shown are both groups. One includes Pericles' father, his own sons, and other family members (light green). The other is a group that includes Alcibiades, Socrates, and Pericles' mistress, Aspasia (dark green); we may note that this group is not isolated, but that Aspasia has one edge or link, via their illegitimate son, to Pericles' family cluster.

The size of the nodes are indicative of how many connections each individual has, so it is understandable that Pericles is shown as the largest, but it is already visually instructive to see that Pheidias, the Athenian sculptor, and Xanthippus (2), Pericles' son (as opposed to Xanthippus, Pericles' father), are the next largest, which is not necessarily intuitive and which one might not necessarily have suspected at first blush. Note also that the size of the node correlates to the number of interconnections between that node and others; thus, Pericles is the largest since it is his ego-centric network being analyzed, but Pheidias comes in a surprising second, because of the number of workmen under his command. Xanthippus (2), Pericles' son, is also large because of his position within Pericles' family.

While it might not ordinarily occur to someone to read Plutarch's *Life of Pericles* specifically to look at his relationships, family and otherwise, it is clear from the SNA graph that the data to do so is there. When the graph is viewed from a sociological perspective, we first see that there is a large family component, which is not surprising. We also notice that most of these related individuals are tied to Pericles and to no one else. This is, though, perhaps due to the nature of our single source, the *Life of Pericles*; had we access to other sources and been able to input additional individuals, with additional relationships spelled

[21] NODEXL is the "Network Overview, Discovery and Exploration for Excel" software available for download at http://nodexl.codeplex.com/ . See D. Hansen, B. Schneiderman, and M. A. Smith, *Analyzing Social Media Networks with NODEXL: Insights for a Connected World.* Burlington, MA: Morgan Kaufman, 2010.

out, thereby creating a graph with more examples of two- or even three degrees of separation, we might have a different picture.

As it stands, we also see that there is a hierarchical cluster of workmen under Pheidias' supervision, as noted. Another cluster is of potentially great interest, for it shows Cimon and Thucydides son of Milesias, i.e., Pericles' main rivals, and indicates that there are ties between those actors. In addition, a small "kite-like cluster" (so called because it resembles a modern toy kite) contained within Pericles' direct relationships is observable for his childhood teachers and tutors, including Anaxagoras, Zeno, Pythocleides, and Damon. Both Elpinice, Cimon's sister, and Pericles' unnamed wife, each shown in light blue, are good examples of individuals—women in this case—who appear to serve important intermediary roles by weaving and holding the network together. Pericles' mistress, Aspasia, also appears to serve in such a capacity. Their positions in the network are key, because if they were removed it would leave a number of members isolated and cut off from the core. These women are "bridges" in the network and their absence would result in "structural holes."[22] We have known, of course, how women interconnect families in ancient Greece, but by using Social Network Analysis we have the opportunity to actually see this in action.

Alexander the Great: A Larger Network

Looking at the social network of Alexander the Great is a larger and more ambitious project, because there are more sources and far more nodes (individuals) and links (vertices or edges). Here again I began by creating a database, this time entering individuals listed in Waldemar Heckel's prosopography, *Who's Who in the Age of Alexander the Great.*[23] I selected 404 individuals who either were family or friends, or served in Alexander's military, or were conquered and absorbed into his empire (see Fig. 6).

Note that I omitted individuals who were minor or peripheral, such as an actor or flute-player who happened to be named once for performing at a party and then disappears from history, as well as, for the purposes of this initial study, people who lived before or after Alexander's lifetime. A more comprehensive study is now underway, using the primary sources (Arrian, Diodorus Siculus Book XVII, Curtius Rufus, Plutarch's Life of Alexander, and Justin's Epitome of Pompeius Trogus) to flesh out the relationships and uncover more interrelationships than are mentioned in the brief biographies in Heckel's *Who's Who* which was used for this prototype.

One immediate caveat should be pointed out here; any Social Network Analysis, regardless of the topic, will of course be affected by gaps in the available data, even in

[22] Burt, *Structural Holes* (*supra* n. 6).

[23] Heckel, *Who's Who in the Age of Alexander the Great* (*supra* n. 19).

something as well-documented as the life and times of Alexander the Great. For instance, there were about 1,800 Companions and 30,000 troops under Alexander's command, but our sources do not give all of their names and relationships, obviously, and even Heckel's thorough prosopography has just over 800 known individuals, of whom my initial analysis considered only 404. Nevertheless, this is already a much larger sample than is available for Pericles.

I studied the entire network as well as individual groups or clusters in this brief examination. The results can be depicted in a multitude of ways, but in all cases, these visual network charts helped me to see and understand the accounts more clearly, and in ways that would not have occurred to me when simply reading the narratives. For instance, in addition to examining the relations between Alexander and his family and between Alexander and his officers, I looked specifically at the 26 different ethnicities of the individuals in my database. It has long been clear from the detailed sources that he and his army conquered and absorbed many different ethnic peoples as they marched through 12,000+ miles over the period from 334 to 323 BC. Therefore, as I added each of the 404 actors to the database, I included their ethnicity so that I could sort them later. I then used Social Network Analysis to see how interrelated the Macedonians were to the other ethnic groups with whom Alexander was associated, with some surprising results. In Figure 7, the Macedonians are the largest group (shown in blue), with Persians the next largest group, then Greeks, then Indians, and so on down the line.

When depicted in additional ways (see Fig. 8 as an example), Social Network Analysis reveals Alexander's wide-spread reach; his relationships with virtually every ethnicity within his far-flung empire are readily apparent. However, it also reveals, for instance, clusters of Spartans, tightly knit with Greeks and the people living on the coast of Turkey, but peripheral to Alexander's inner circle. Furthermore, it also shows a cluster of Persians tied to Darius III, the Great King of Persia, who stay connected after his death but also integrate into Alexander's army.

Perhaps most intriguingly, Social Network Analysis also indicates that many of the Macedonian officers who resisted Alexander's more liberal inclusive policies did not have any close relationships at all with the peoples they conquered. One such example is Coenus, a rebellion leader at the Hyphasis River, who only has relations with other Macedonians, as can be seen in Figure 9, where Coenus and his contacts are shown in red. Another example is Black Cleitus, who has an edge (link) to only one person outside his immediate Macedonian circle, namely Bessus, a Persian enemy combatant whom he helped capture, as seen in Figure 10.

In contrast, other Macedonian officers, including those who were left behind in garrisons, or administered satrapies, or led mercenary or foreign troops, were far more interconnected

with other ethnicities. This can be seen, for instance, in Figure 11, which depicts Hephaestion's social network. Cavalry commanders of foreign troops, or garrison commanders and satraps stationed in conquered territories working directly with local leaders appear in SNA graphs as interconnected with other ethnic groups to a larger extent than Macedonians who served Alexander inside a purely Macedonian regiment.

We might hypothesize that the more interconnected the Macedonian officers were to other ethnic groups, the less likely they were to have been participants in the mutiny on the Hyphasis River or the Opis mutiny. It is already clear from the sources that both of these events were protests against integrating "outsiders" into the Macedonian army units, but SNA further indicates that the instigators who expressed opposition to Alexander's policies, such as Coenus and Black Cleitus, were relatively insulated Macedonians who had not come into contact with other ethnicities except in battle and were thus far less tolerant than they might otherwise have been.

The mass marriages that Alexander arranged in 324 BC may have been an attempt to create inter-ethnic ties where there were really no organic ones, in order to help solve this critical problem, as we would be able to see if we had enough information (i.e. specific names of individuals) to create a SNA graph of every soldier and his bride. In Social Network Analysis terms, Alexander may have been attempting to fill structural holes, those key nodes in the network that link up clusters. Unfortunately, the intimacy that was created by these marriages between Macedonians and Persians or Sogdianians did not last beyond Alexander's death the following year, as we know, for the ties were so weak that neither the marriages nor the empire could hang together following his premature demise. Too little, too late, one might say.

Other Uses: SNA for Clarity

In addition, Social Network Analysis charts, graphs, and figures may be built for the purpose of making a specific episode or event clearer, or for the purpose of illustrating stories or incidents. For example, based on the narratives from Plutarch, Arrian, Curtius Rufus, Diodorus Siculus, and Justin, I created a database and then several different graphs for three events: the murder of Philip, the Philotas Affair, and the Conspiracy of the Pages (below, Figs. 12, 13, and 14).

In Figure 12, green edges connect nodes or individuals suspected of complicity in the plot; red edges connect people who participated in capturing and killing the murderer, Pausanias; and black edges are the actors involved in the grievance against Philip which led Pausanias to murder him. Interestingly, although this is a representation of the assassination of Philip, the focal point of the egocentric star graph is Pausanias, rather than the king. This may be simply a function of the way the story has been handed down to us, which emphasizes the

lurid details surrounding the circumstances leading to the assassination and rumors about the alleged instigators.

Although the stories are well known and there is understandably nothing radically new to be seen in the graphs, it still became clear that rendering the stories visually opens the possibility for discoveries. Furthermore, from a network perspective it can be argued that in the case of the Philotas Affair and the Conspiracy of the Pages, Alexander's harshness in putting down the plots and killing those involved was justified. As can be seen in Figure 15, the effect of the conspirators on the network was even deeper, more substantial, and threatening to his regime than it might seem, especially if one looks at the swath of red which indicates the influence or ties that the nodes (individuals) involved have to the rest of the network.

Summation and Final Thoughts

The brief review and introduction of Social Network Analysis presented here is meant only to show its applicability and potential usefulness in ancient history. Each of the above examples can and should be examined further and published as individual studies in their own right. Those interested in utilizing SNA may want to do quantitative analyses of ancient networks as well, in addition to the type of qualitative analyses presented above, by drilling down and examining the sociological and mathematical measures and metrics that quantify the closeness of nodes, their centrality, their betweenness, the clustering coefficients, and other mathematical functions that help us to rank influence and demonstrate paths for the flow of information or power inside the networks. When using NODEXL, these metrics are easily accessible at the click of a button.

It should also be noted that while SNA thrives on prosopographical studies, not every such study will be suitable. For example, consider the epigraphical records of manumissions which are inscribed on walls at Delphi. Other than visiting the same site, the named individuals do not have enough in common to be viewed as a network, since they didn't know each other. The literary evidence, whether it is inscriptions on stone, texts on clay tablets, or discussions in ancient sources, must name individuals who can be interpreted as a network; that is, they must be members of families, communities, or governments, or be co-workers or co-religionists, or otherwise related in some way, shape, or form. Suitable subjects for future Social Network Analyses range from the Amarna Letters of Amenhotep III and Akhenaten in the Egyptian New Kingdom and the Hittite archives at Hattusas in the Late Bronze Age down to and including the family of Augustus and the Julio-Claudians in Rome. Such analyses of relatively well-documented figures like Julius Caesar, Hadrian, or Marcus Aurelius can be readily conducted, and should be done soon.

The applicability of Social Network Analysis in other fields such as sociology, business, and international security has long been known. A few early adopters in archaeology and ancient history have begun to use it as well in the past few years, with some cutting-edge projects financially supported under the broad umbrella of Digital Humanities initiatives. It is now time for additional scholars in these fields to realize and begin to utilize its potential as well.

DIANE HARRIS CLINE
THE GEORGE WASHINGTON UNIVERSITY

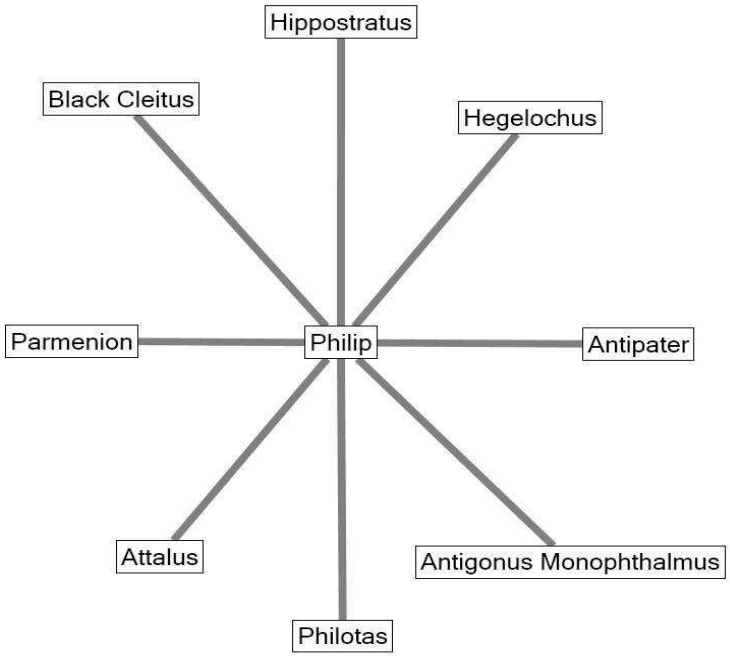

Figure 1. The Old Guard network of Philip II of Macedon as a one-degree graph, showing simple direct links between Philip and each of his generals.

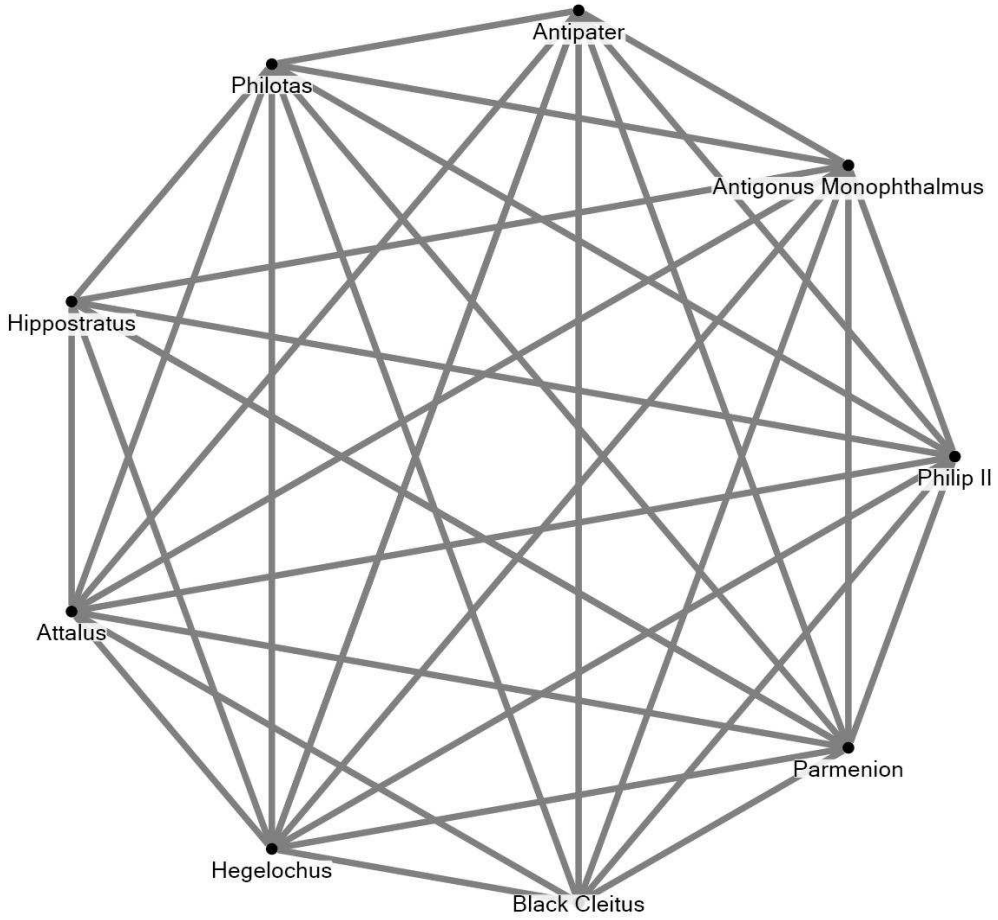

Figure 2. The Old Guard Network of Philip II of Macedon, still with one-degree of separation but now with additional links depicted in a peer-to-peer graph, showing each of the generals connected to each other as well as to Philip.

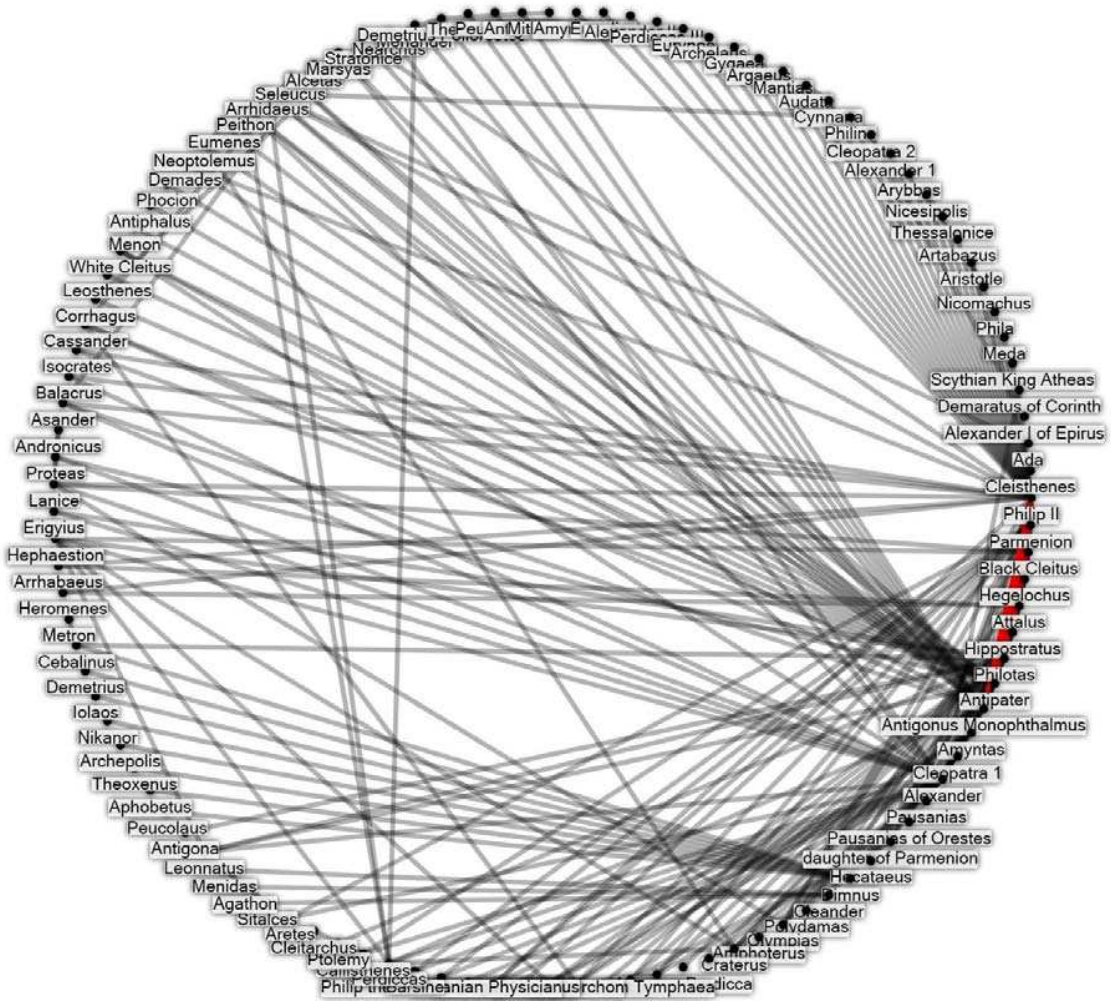

Figure 3. The two-degree whole network of Philip II of Macedon, his officers, and their associates.

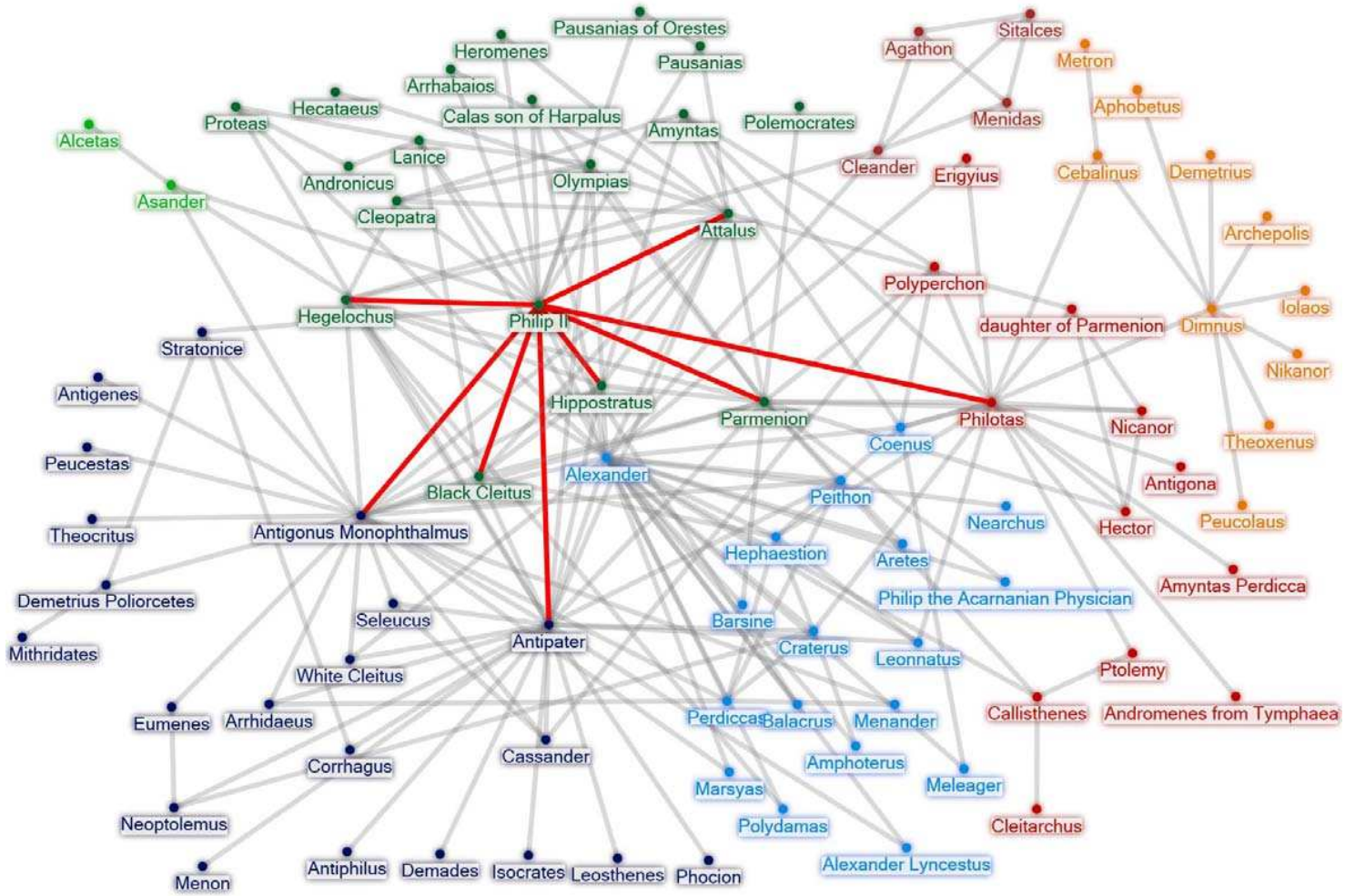

Figure 4a. The two-degree network of Philip II of Macedon and his generals, rendered with the Clauset-Newman-Moore cluster algorithm. The red lines connect Philip II with his eight original generals. Names of individuals sharing the same color belong to the same cluster as identified by the algorithm.

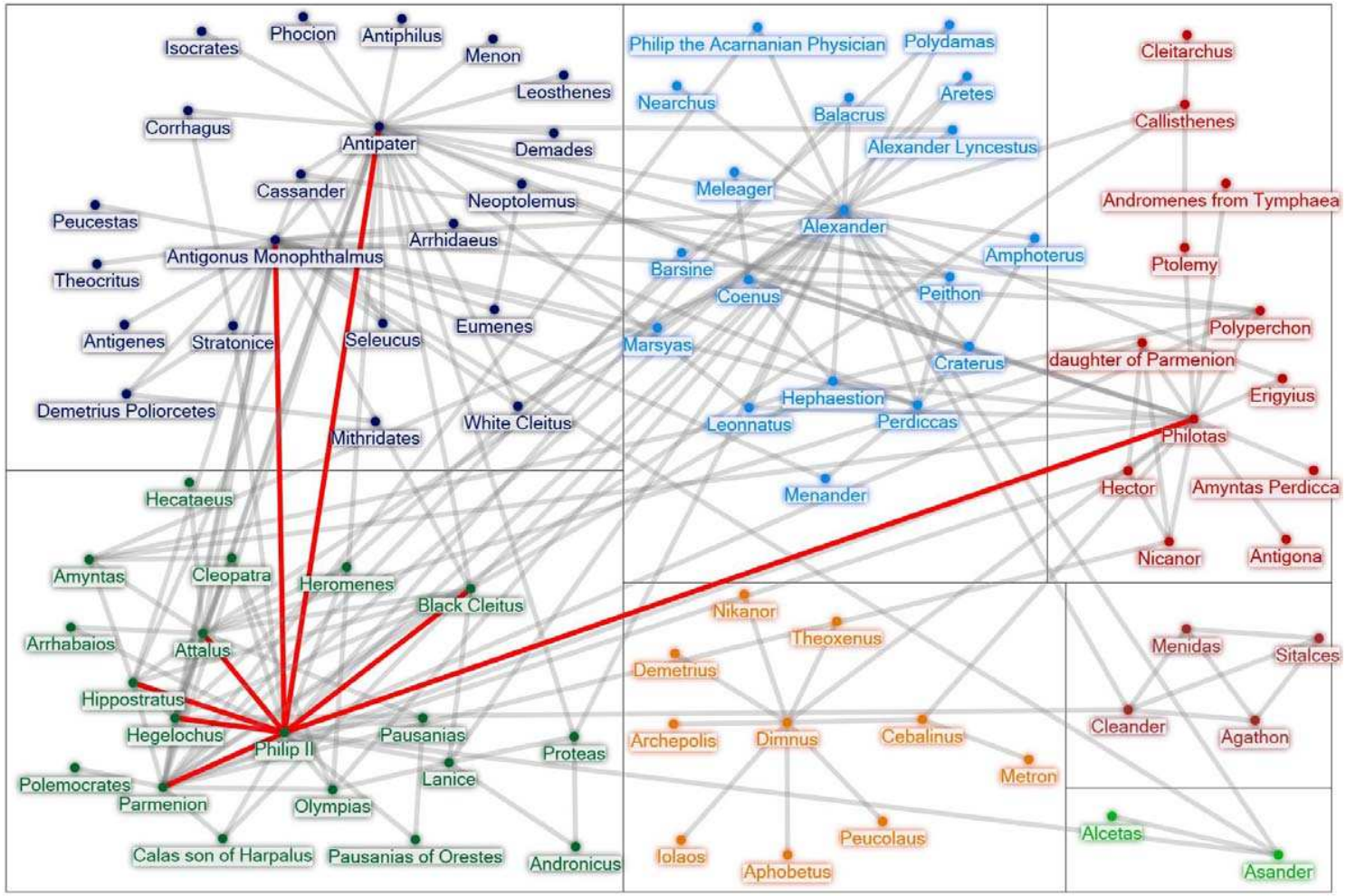

Figure 4b. The two-degree network of Philip II of Macedon and his generals, depicted according to the Clauset-Newman-Moore cluster algorithm, but using a “cluster-in-a-box” graph. Red lines connect Philip II to his Old Guard generals.

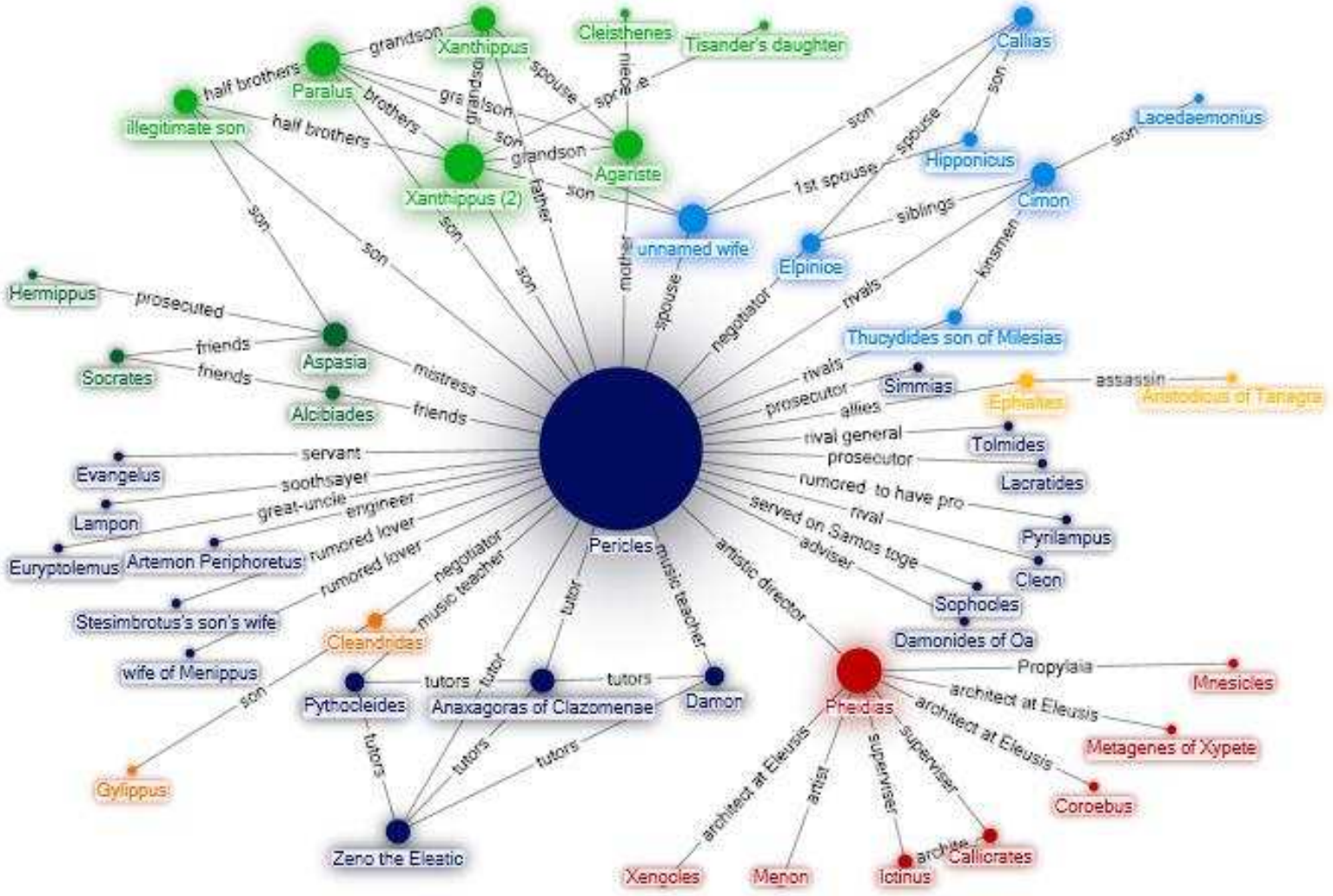

Figure 5. The social network of Pericles, based on data from Plutarch's *Life of Pericles*.

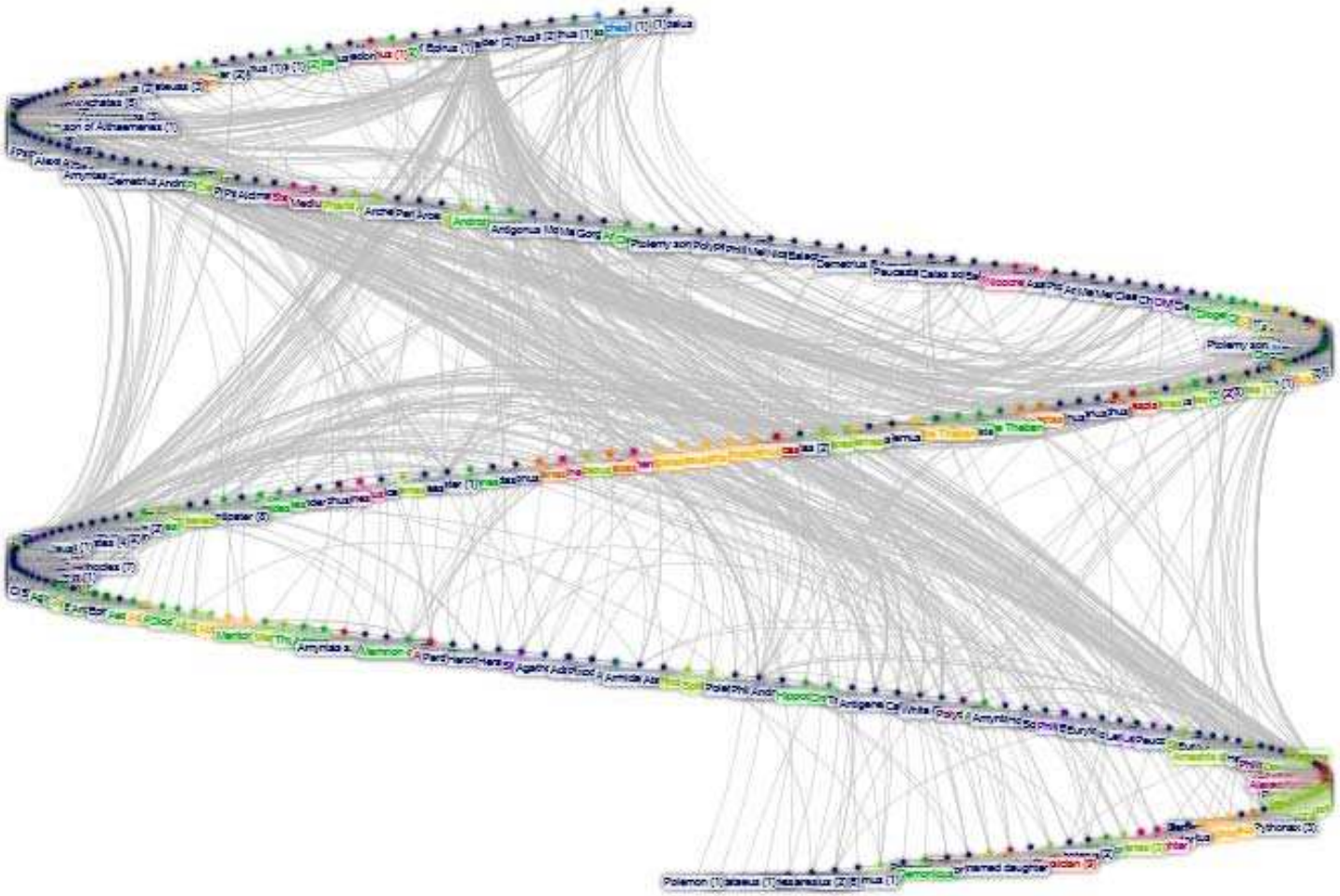

Figure 6. The entire social network of Alexander the Great, rendered as a sine wave.
The color of the nodes was assigned based on clusters.

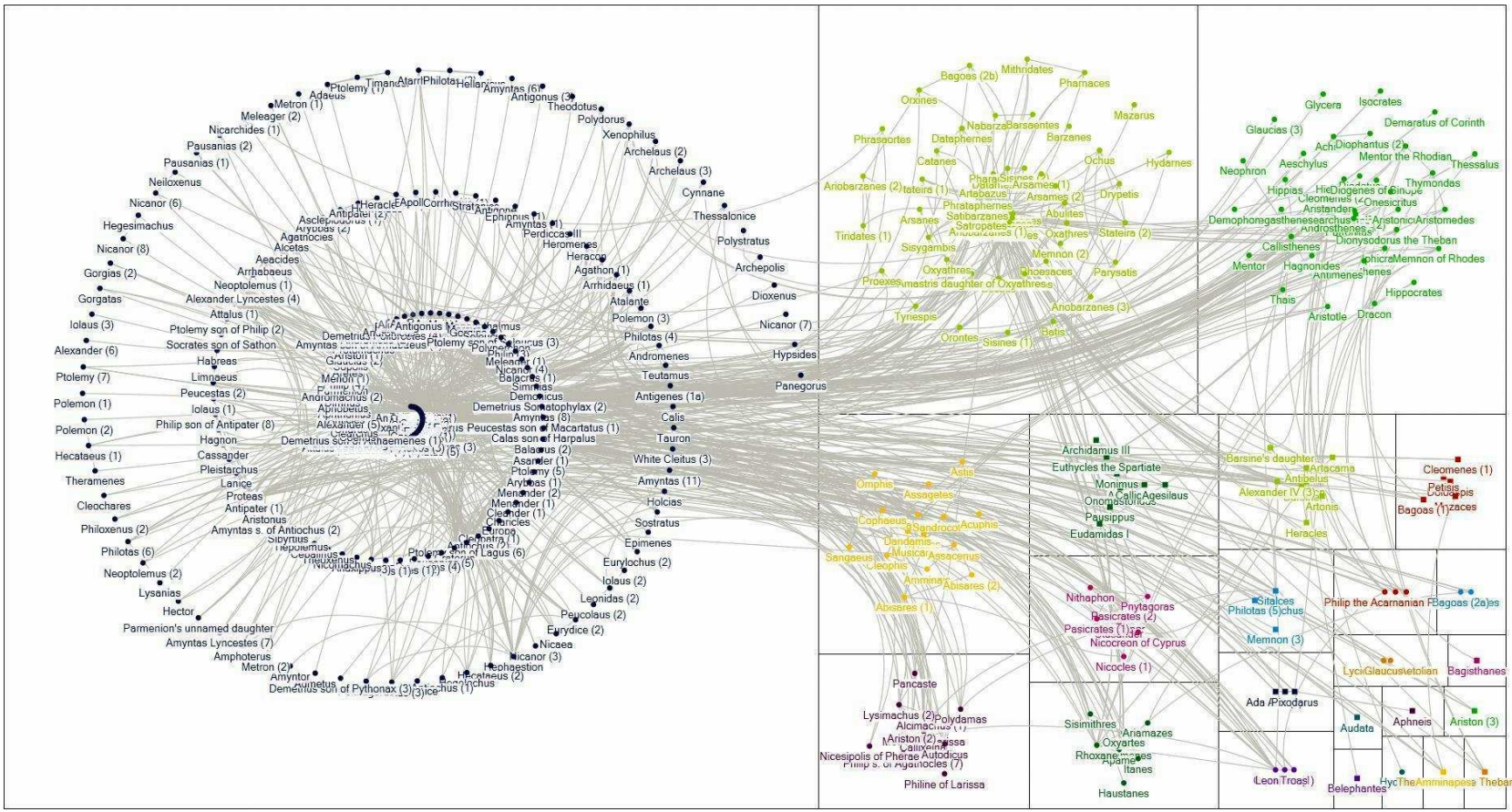

Figure 7. Ethnic groups, and the interaction between them, within Alexander the Great's social network.

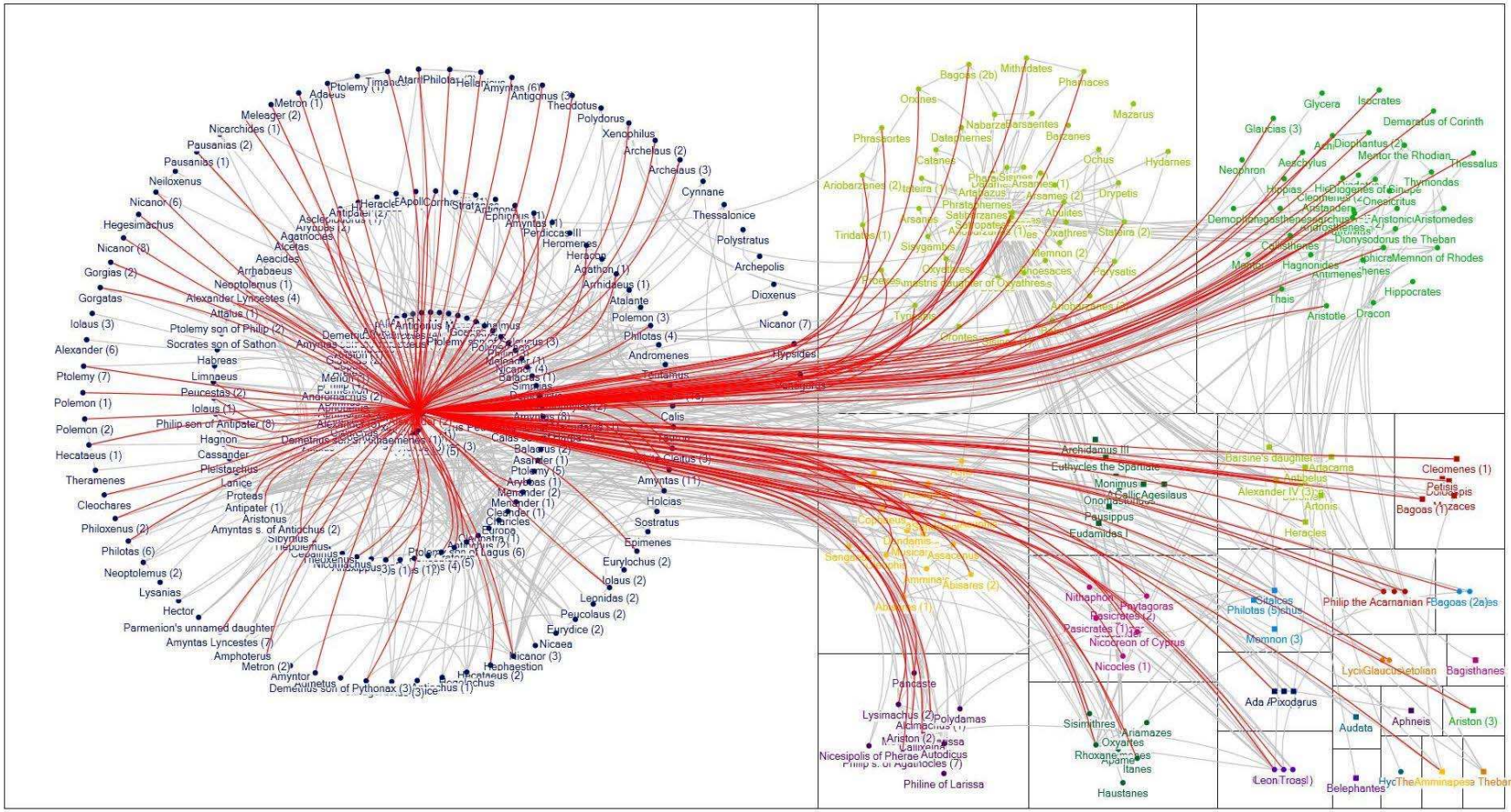

Figure 8. Alexander's reach, as indicated by his social network connections to other ethnicities throughout his empire.

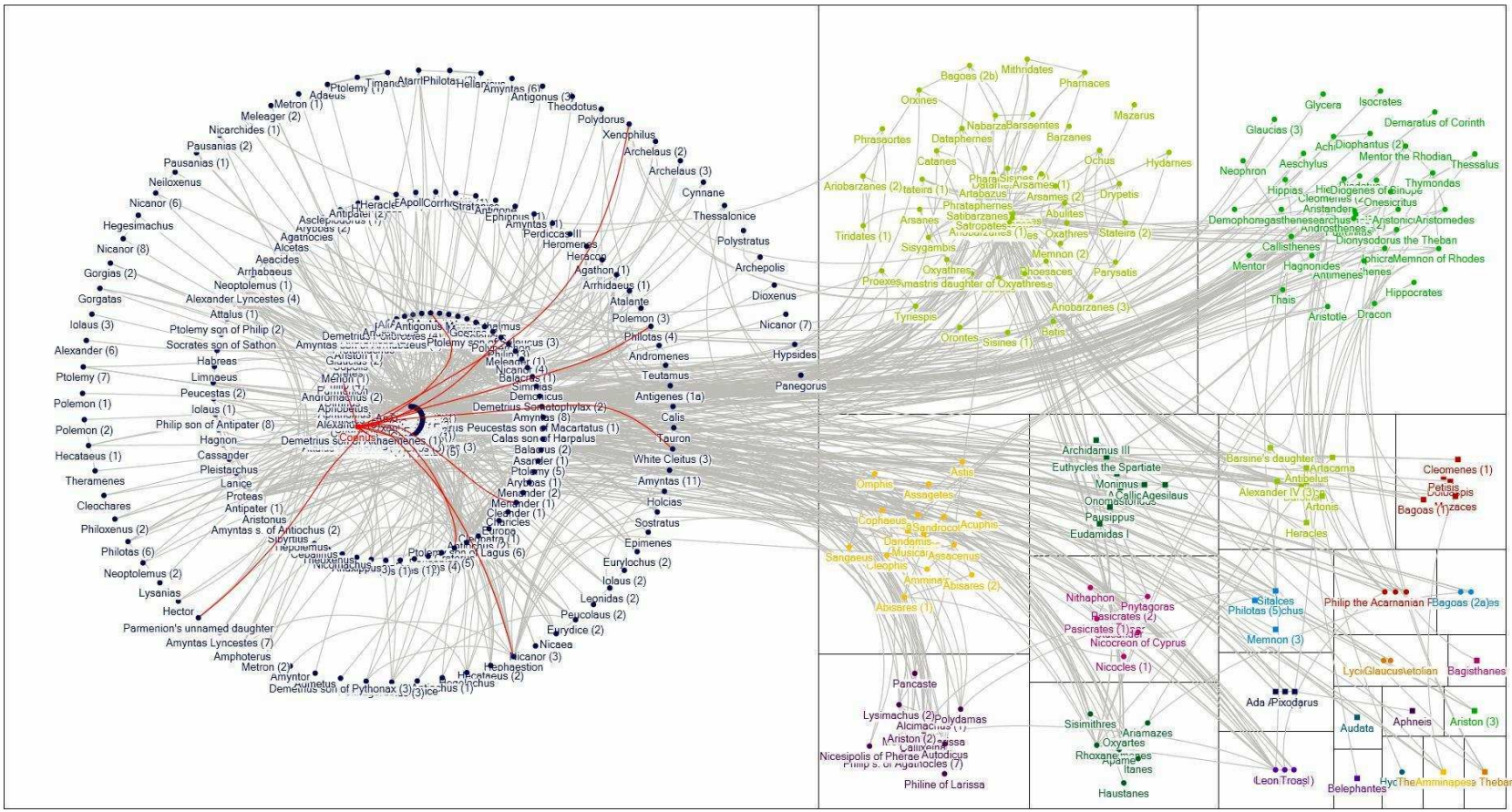

Figure 9. Coenus and his social network (shown in red).

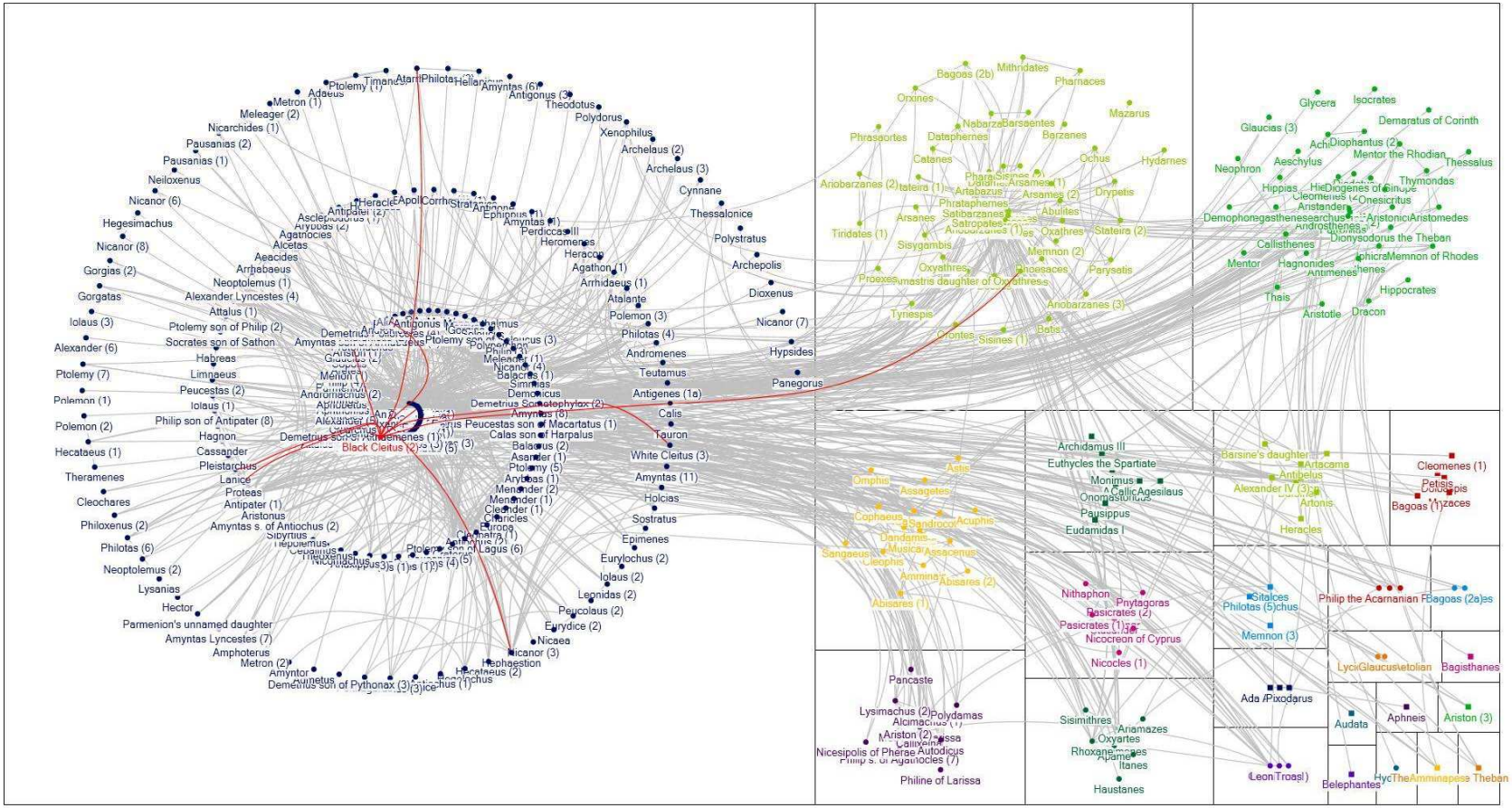

Figure 10. Black Cleitus and his social network (shown in red).

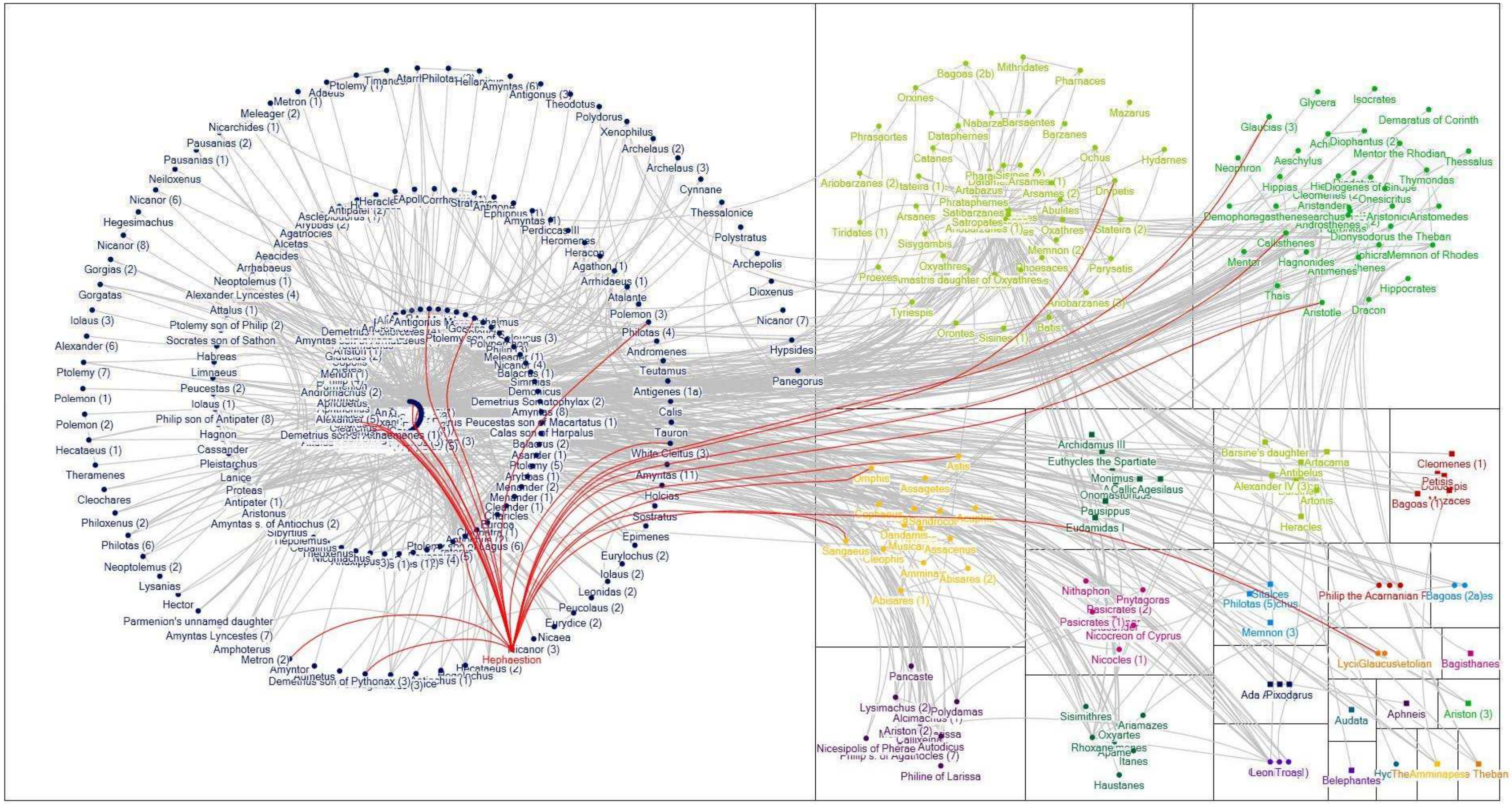

Figure 11. The social network of Hephaestion (shown in red), who shared Alexander's tolerant and liberal views on integrating the races.

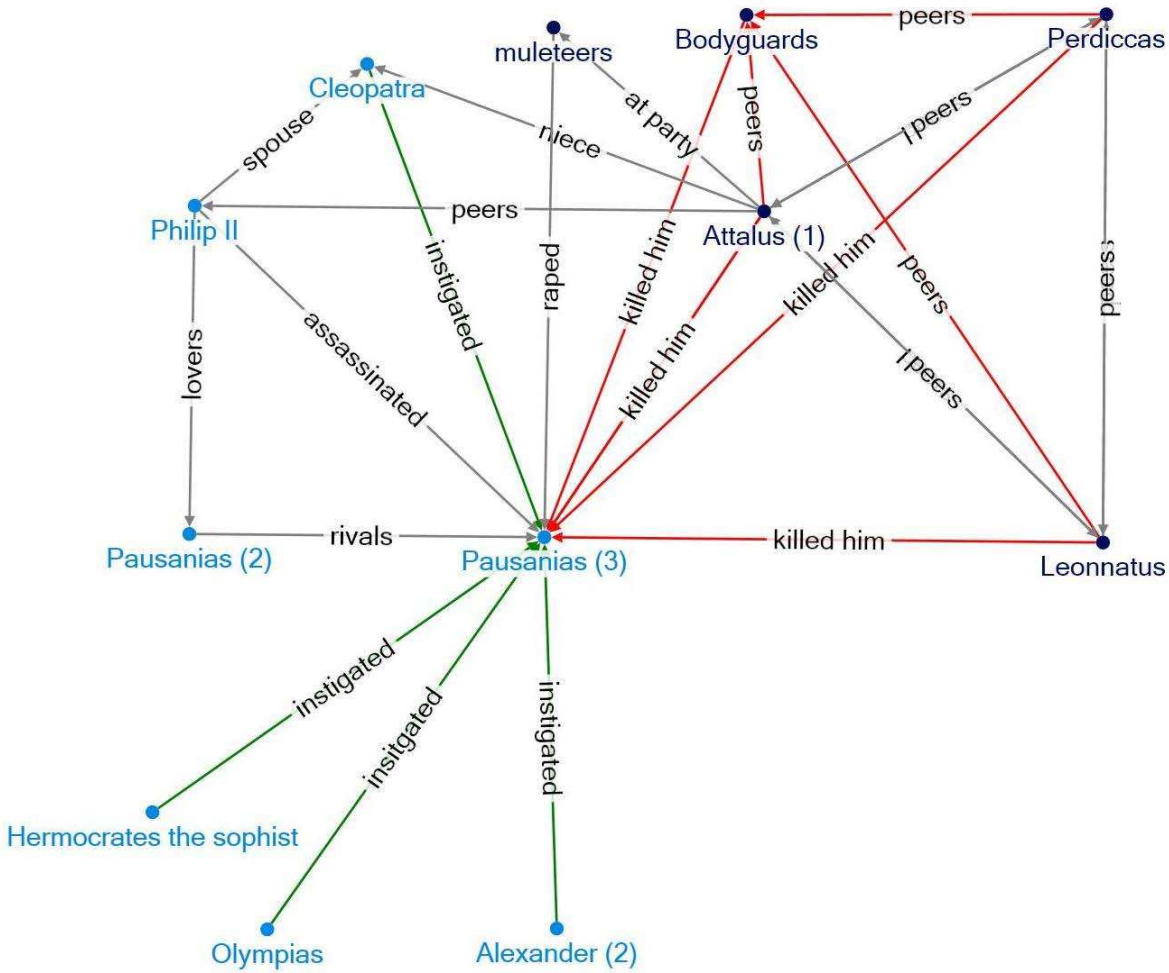

Figure 12. The network diagram for the murder of Philip II in 336 BC.

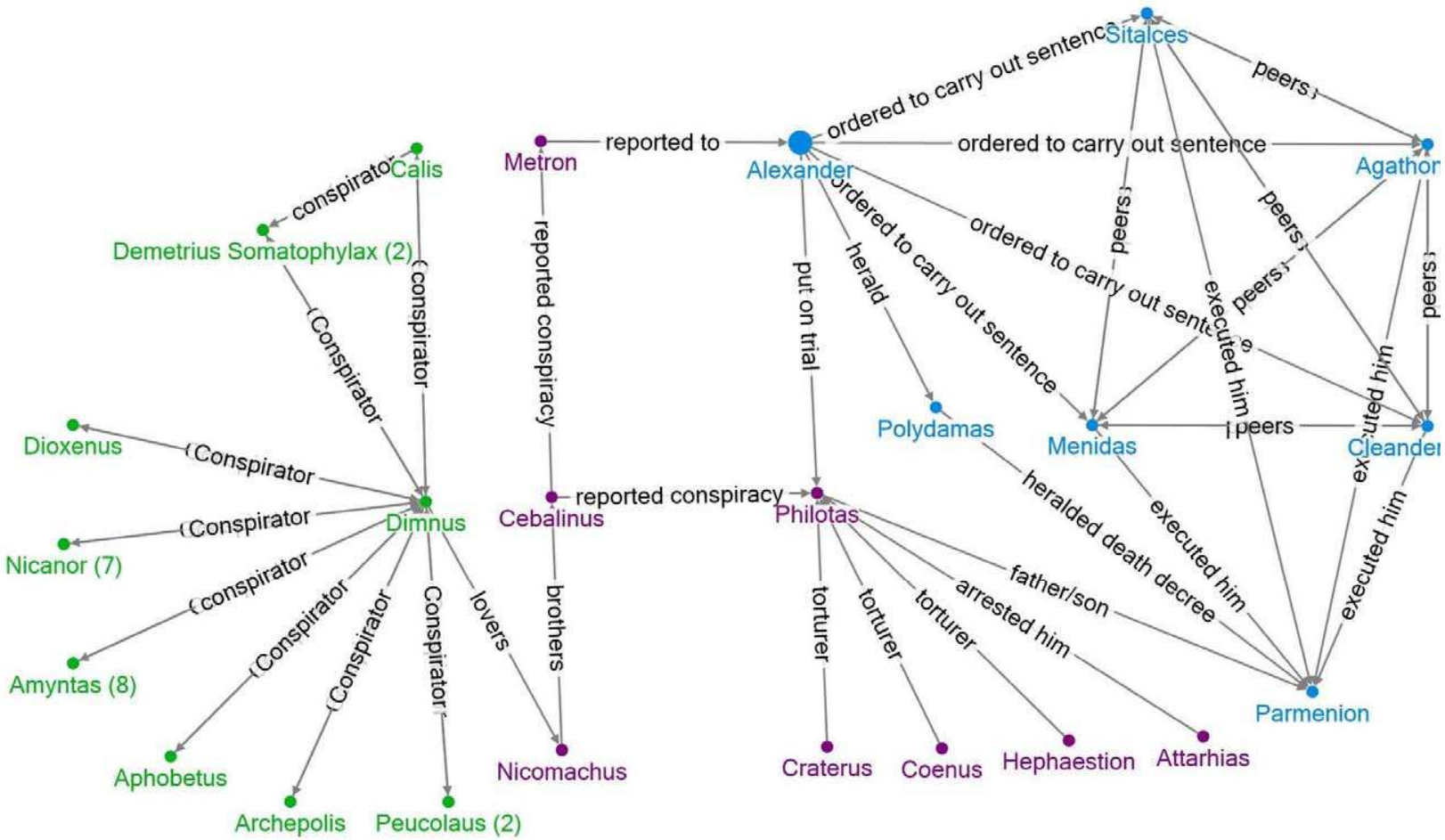

Figure 13. The network diagram for the conspiracy of Dimnus and the so-called Philotas Affair that resulted in the punishment and execution of Philotas and his father Parmenion.

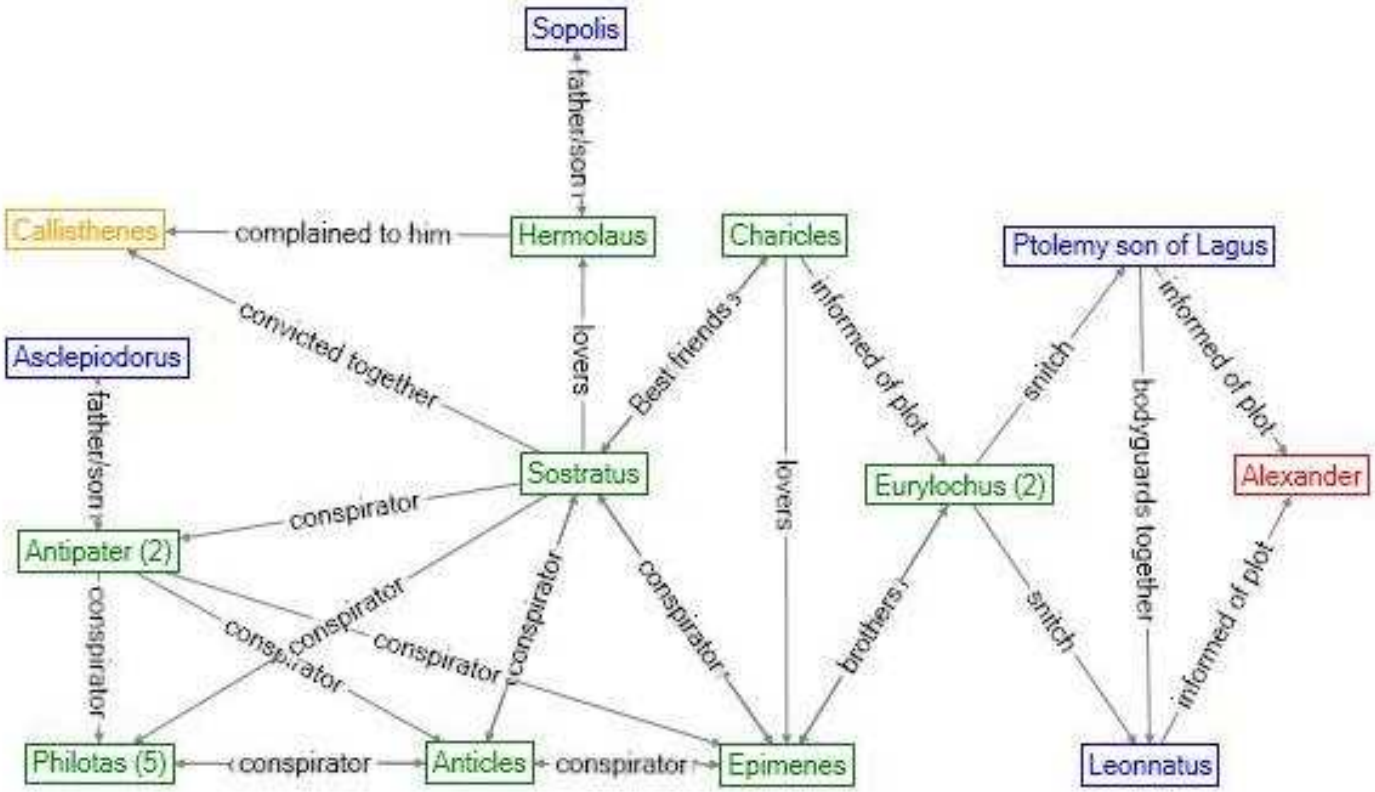

Figure 14. The network diagram for the so-called “Conspiracy of the Pages” that led to many executions, including the death of Callisthenes, Aristotle’s nephew.

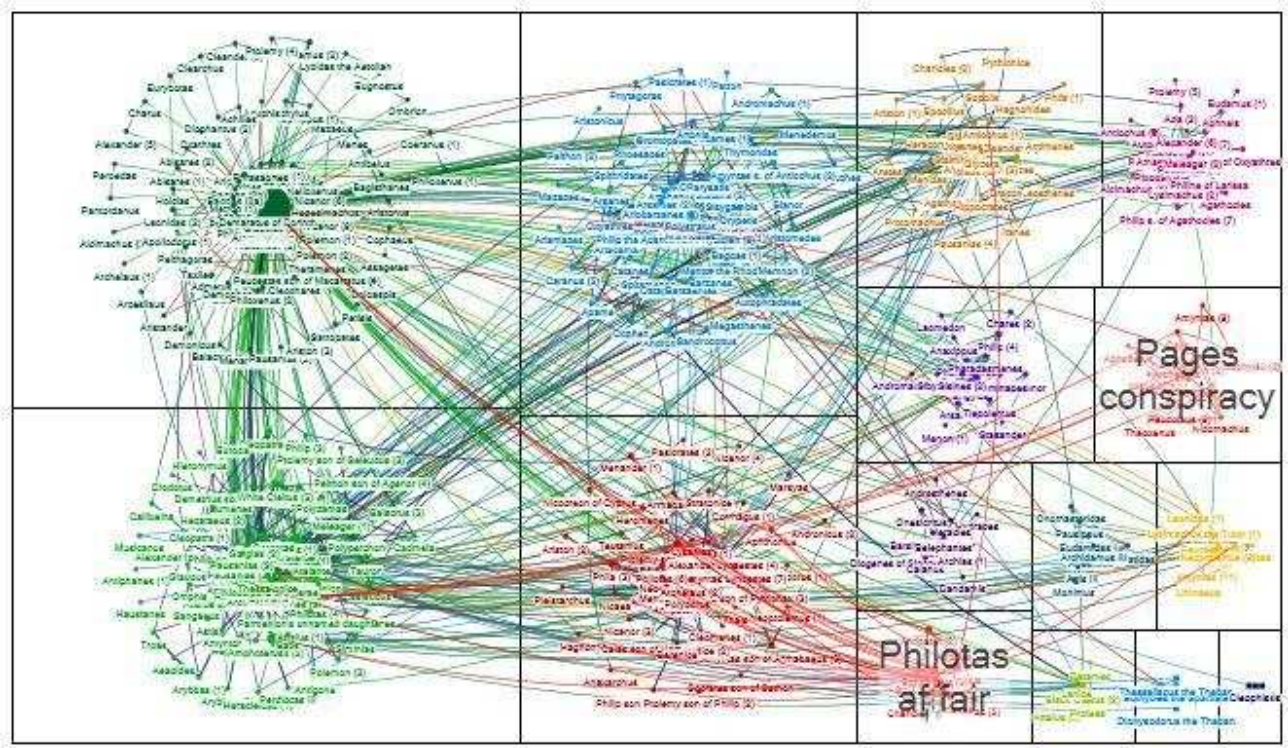

Figure 15. The effect on Alexander the Great's social network of the Philotas Affair and the Conspiracy of the Pages (both indicated in red).